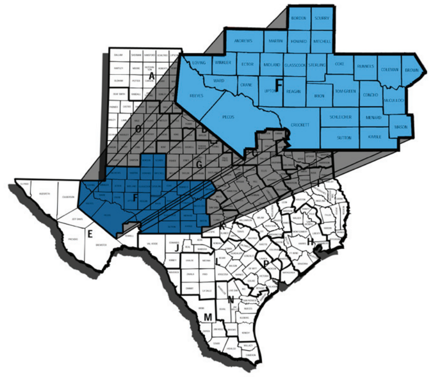
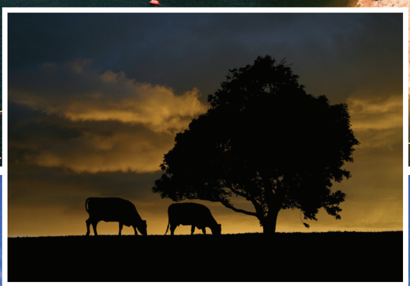
2011 Region F Water Plan

Volume I
Main Report

November 2010





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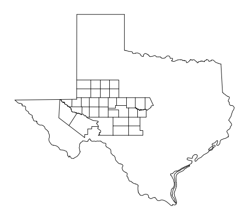
2011 Region F Water Plan

November 2010

Prepared for:

Region F Water Planning Group

Jon S. Albright, Hydrologist



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Prepared by:

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CMD07215

Volume I – Region F Water Plan Report

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Volume II – Appendices

List of Common Acronyms

Acronym	Name	Meaning
BCWID	Brown County Water Improvement District Number One	Owns and operates Lake Brownwood. Wholesale water provider in Brown and Coleman Counties.
CRMWD	Colorado River Municipal Water District	Water district that owns and operates 3 major reservoirs and several well fields. CRMWD is the largest water supplier in Region F and is the political subdivision for the Region F RWPG.
DFC	Desired Future Condition	Criteria for which is used to define the amount of available groundwater from an aquifer.
GAM	Groundwater Availability Model	Numerical groundwater flow model. GAMs are used to determine the aquifer response to pumping scenarios. These are the preferred models to assess groundwater availability.
GCD	Groundwater Conservation District	Generic term for all or individual state recognized Districts that oversee the groundwater resources within a specified political boundary.
GMA	Groundwater Management Area	Sixteen GMAs in Texas. Tasked by the Legislature to define the desired future conditions for major and minor aquifers within the GMA.
MAG	Managed Available Groundwater	The MAG is the amount of groundwater that can be permitted by a GCD on an annual basis. It is determined by the TWDB based on the DFC approved by the GMA. Once the MAG is established, this value must be used as the available groundwater in regional water planning.
RWPG	Regional Water Planning Group	The generic term for the planning groups that oversee the regional water plan development in each respective region in the State of Texas

Acronym	Name	Meaning
SB1	Senate Bill One	Legislation passed by the 75th Texas Legislature that is the basis for the current regional water planning process.
TCEQ	Texas Commission on Environmental Quality	Agency charged with oversight of Texas surface water rights and WAM program.
TWDB	Texas Water Development Board	Texas Agency charged with oversight of regional water plan development and oversight of GCDs
UCRA	Upper Colorado River Authority	Owner of water rights in O.C. Fisher Reservoir and Mountain Creek Lake. Designated WWP.
WAM	Water Availability Model	Computer model of a river watershed that evaluates surface water availability based on Texas water rights.
WMS	Water Management Strategy	Strategies available to RWPG to meet water needs identified in the regional water plan.
WUG	Water User Group	A group that uses water. Six major types of WUGs: municipal, manufacturing, mining, steam electric power, irrigation and livestock.
WWP	Wholesale Water Provider	Entity that has or is expected to have contracts to sell 1,000 ac-ft/yr or more of wholesale water.

EXECUTIVE SUMMARY

This report presents the *Region F Water Plan* developed in the third round of Senate Bill One regional water planning process. Region F includes all of 32 counties in West Texas, as shown in Figure ES-1. This report presents the results of a five-year planning effort to develop a plan for water supply for the region through 2060.

The *2011 Region F Water Plan* was developed under the direction of the 21-member Region F Water Planning Group and adopted by the planning group on October 25, 2010.

The Region F Plan includes the following chapters:

1. Description of Region
2. Current and Projected Population and Water Demand Data for the Region
3. Water Supply Analysis
4. Identification, Evaluation, and Selection of Water Management Strategies Based on Needs
5. Impacts of Water Management Strategies on Key Parameters of Water Quality and Impacts of Moving Water from Rural and Agricultural Areas
6. Water Conservation and Drought Management Recommendations
7. Description of How the Regional Water Plan is Consistent with Long-Term Protection of the State's Water Resources, Agricultural Resources, and Natural Resources
8. Unique Stream Segments/Reservoir Sites/Legislative Recommendations
9. Infrastructure Financing Recommendations
10. Plan Adoption and Public Participation

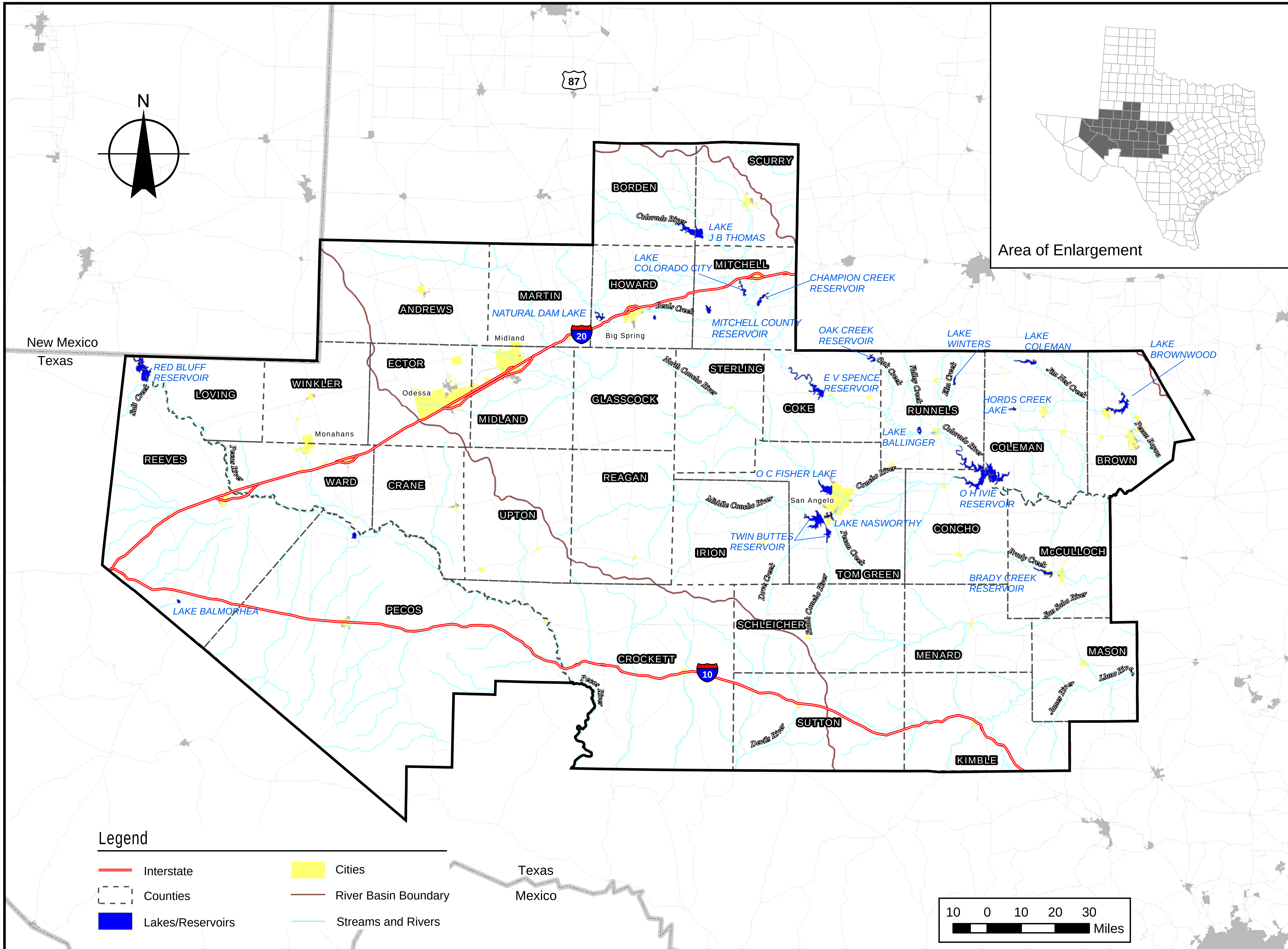

Figure ES - 1

Region F

General Location Map

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FILE	RegionF_Hillshade.mxd
DATE	April 2010
SCALE	1:1,750,000
DESIGNED	BME
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ES.1 Current Water Needs and Supplies in Region F

As of the 2000 census, the population of Region F was 578,814. The three most populous counties in Region F, Ector, Midland, and Tom Green, have 59 percent of the region's population. Six cities in Region F had a population of more than 10,000 people as of year 2000. These six cities included 57 percent of the population in Region F.

ES.1.1 Physical Setting

Most of Region F is located in the upper portion of the Colorado Basin and in the Pecos portion of the Rio Grande Basin. A small portion of the region is in the Brazos Basin. Figure ES-1 shows the major streams in Region F. Precipitation increases from west to east across the region, as does the average runoff. Evaporation increases from southeast to northwest. The patterns of rainfall, runoff, and evaporation result in more abundant water supplies in the eastern portion of the region.

Region F includes 17 major water supply reservoirs that provide most of the region's surface water supply. Four major aquifers and seven minor aquifers provide groundwater supplies to Region F.

ES.1.2 Water Use

In the year 2006, Region F used nearly 610,000 acre-feet of water. Approximately 69 percent of the current water use in Region F is for irrigated agriculture, followed by municipal, mining, steam-electric power generation, livestock watering, and manufacturing.

ES.1.3 Current Sources of Water

The Region F surface water supplies are associated primarily with major reservoirs. Region F does not import a significant amount of surface water from outside the region. However, Region F exports surface water to the cities of Sweetwater and Abilene, both in the Brazos G Region. The City of Sweetwater owns and operates Oak Creek Reservoir in Region F. The City of Abilene has a contract to purchase water out of O.H. Ivie Reservoir in Region F.

Approximately 65 to 70 percent of the water used in Region F is supplied by groundwater. Eleven aquifers provide groundwater supplies in Region F. Region F has 15 Underground Water Conservation Districts (GCDs) that oversee the use of water from the aquifers in the region. Ten of these GCDs formed an alliance known as the West Texas Regional Groundwater Alliance that promotes conservation, preservation, and beneficial use of water in Region F.

Region F has identified 13 "major springs" in the region that are important for water supply or other natural resources protection. These major springs include: San Solomon, Giffin, Sandia, Comanche, Diamond Y, Spring Creek, Dove Creek, Rocky Creek, Anson, Lipan, Kickapoo, Clear Creek, and San Saba Springs.

ES.1.4 Water Providers in Region F

Water providers in Region F include 202 water user groups and seven wholesale water providers. The wholesale water providers include the Colorado River Municipal Water District, Brown County Water Improvement District Number 1, Upper Colorado River Authority, the City of Odessa, the City of San Angelo, the Great Plains Water System, and University Lands.

ES.2 Projected Need for Water

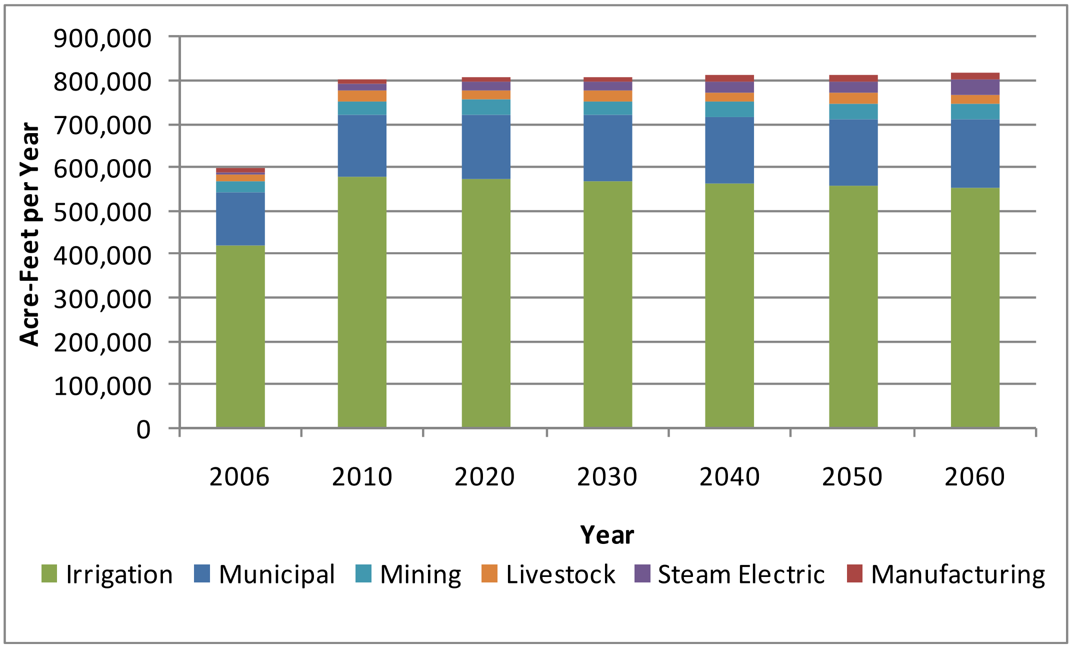
ES.2.1 Population Projections

The population of Region F is projected to grow from 578,814 in the year 2000 to 724,094 in 2060, an average growth rate of 0.37 percent per year. The population projections were developed by the Texas Water Development Board (TWDB). The relative distribution of population in Region F is expected to remain stable throughout the planning period. All but three of the counties are generally rural counties and are expected to remain so into the future. The distribution of the projected population by county and city is discussed in Chapter 2.

ES.2.2 Demand Projections

Figure ES-2 shows the projected demands for water by category of use in Region F. The total historical water use was about 600,000 acre-feet in the year 2006 and is projected to be as much as 803,376 acre-feet in 2010 and 814,991 in 2060. The significant increase in water use between the historical year 2006 data and the year 2010 projections is due to irrigation demands. Region F believes that recent historical water use for irrigation is not indicative of the potential for irrigation water use in the region. During the recent drought irrigation demand was suppressed because of low crop prices and reduced water supply. The adopted projections are an estimate of what the irrigation demand could have been with higher crop prices and sufficient water supplies. Irrigation water demands are projected to make up the majority of the water use in Region F.

Figure ES-2
Projected Water Demand in Region F by Use Category



ES.2.3 Water Supply Analysis

As required by TWDB rules, the available surface water supplies are derived from Water Availability Models (WAMs), Full Authorization Run (Run 3). The WAMs were developed by the Texas Commission on Environmental Quality (TCEQ). Three WAMs are available in Region F: (a) the Colorado WAM, which covers most of the central and eastern portions of the region, (b) the Rio Grande WAM, which covers the Pecos Basin, and (c) the Brazos WAM. The WAMs allocate water based on priority without regard to geographic location, agreements between water right holders, or type of use. As a result, the Colorado WAM significantly underestimates the total surface water supply in Region F.

Groundwater provides most of the irrigation water used in the region, as well as a significant portion of the water used for municipal and other purposes. Groundwater is primarily found in four major and seven minor aquifers that vary in quantity and quality (Figures 1.2-1 and 1.2-2). Total groundwater supply is determined using aquifer recharge plus a portion of the water in storage. The portion of groundwater supply from storage is based on either (1) management policies of the various groundwater conservation districts in the region, or (2) historical trends in areas with no groundwater conservation district. Supply for the Trinity aquifer in Brown County is based on the Managed Available Groundwater (MAG) value as determined by the TWDB. This is the only groundwater source in Region F that had an adopted Desired Future Condition and MAG by December 2009.

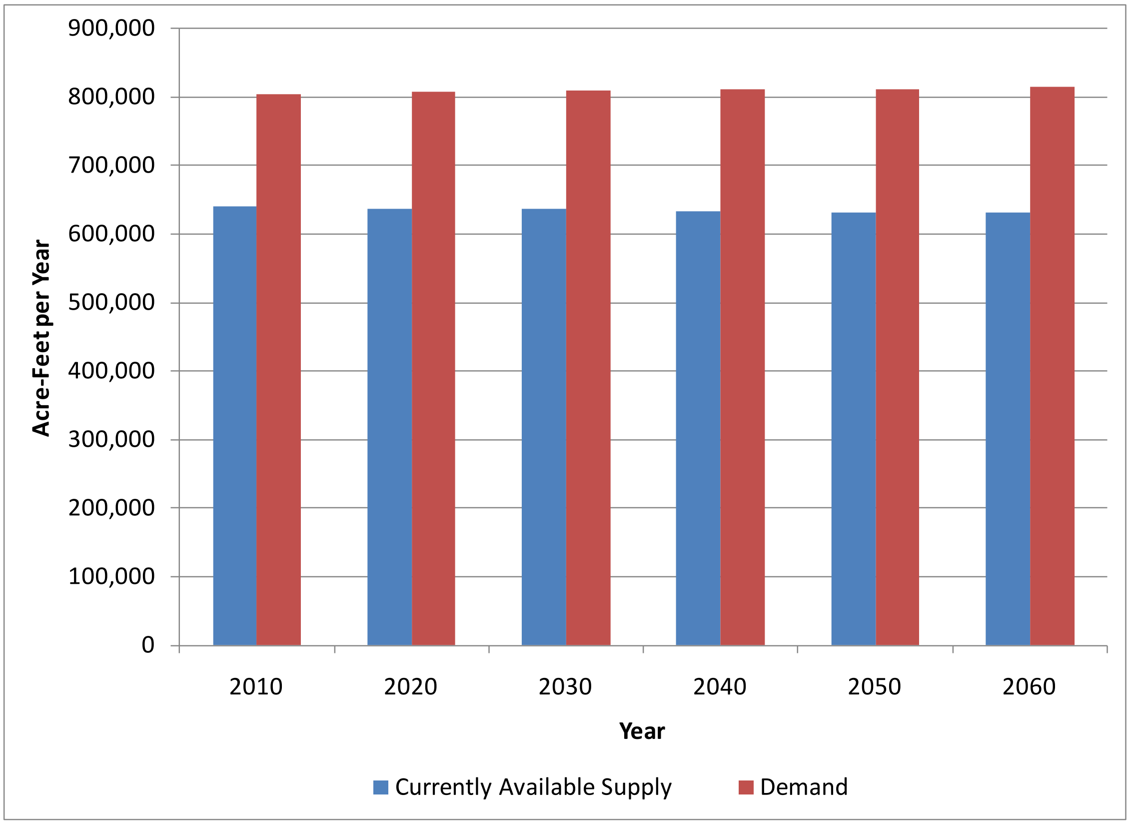
Not all of the water supplies in the region are currently available to users. Water supply may be limited by the yield of reservoirs, well field capacity, aquifer characteristics, water quality, water rights, permits, contracts, regulatory restrictions, raw water delivery infrastructure or water treatment capacity. Based on current limitations, in 2060 there will be about 632,000 acre-feet per year of available water supply in the region.

ES.2.4 Comparison of Supply and Demand

Figure ES-3 shows a comparison of the available water supply to Region F and projected demands. Surface water supplies are significantly reduced from the historical year 2000 use because of the assumptions used in the Colorado WAM (see Section 3.2). With a projected 2060 demand of 814,991 acre-feet per year, Region F has a projected regional shortage of about 183,000 acre-feet per year by 2060. Considering individual water user groups, the collective projected shortage is nearly 220,000 acre-feet per year.

Irrigation, municipal, and steam-electric demands have the largest shortages. Typically, the counties with the largest irrigation needs are those with large irrigation demands and limited groundwater supplies. Most of the municipal needs are a result of underestimation of available supply according to the Colorado WAM. Steam-electric generation needs are a result of projected growth in demands that exceeds the available supply, as well as the impacts on supply due to the Colorado WAM.

Figure ES-3
Comparison of Currently Available Supplies and Projected Demands



ES.2.5 Socio-Economic Impact of Not Meeting Projected Water Needs

According to the comparison of supply and demand, Region F could face significant shortages in water supply over the planning period for some water users. To assess the potential socio-economic impacts of these shortages, the TWDB conducted an evaluation of failing to meet the projected water needs in Region F. This analysis found that a one-year drought could result in substantial losses of jobs and income to the region (approximately 18 percent), resulting in a population loss of about 7 percent.

ES.3 Identification and Selection of Water Management Strategies

The Region F Water Planning Group identified and evaluated a wide variety of potentially feasible water management strategies in developing this plan. Water supply availability, costs and environmental impacts were determined for conservation and reuse efforts, the connection of existing supplies, and the development of new supplies.

As required by the TWDB regulations, the evaluation of water management strategies was an equitable comparison of all feasible strategies and considered the following factors:

- Evaluation of quantity, reliability, and cost of water diverted and treated
- Environmental factors
- Impacts on other water resources and on threats to agricultural and natural resources
- Significant issues affecting feasibility
- Consideration of other water management strategies affected

ES.3.1 Water Conservation and Reuse

The Region F Water Planning Group considered three major categories of water conservation: municipal, irrigation and steam-electric power generation. Overall, in Region F more than 82,500 acre-feet of water could be conserved by 2060.

The recommended water conservation activities for municipal water users in Region F are:

- Education and public awareness programs,
- Reduction of unaccounted for water through water audits and maintenance of water systems, and
- Water rate structures that discourage water waste.

Irrigation is the largest water user in Region F and the category with the largest needs. The irrigation conservation activities evaluated as part of this plan focus on efficient irrigation practices.

ES.3.2 Recommended Water Management Strategies

Table ES-1 lists the recommended water management strategies by type for Region F. In total, the Region F plan includes water management strategies to develop or use approximately 251,000 acre-feet per year of additional supplies by 2060, including new well fields, desalination, reuse and voluntary redistribution. The most significant strategy in the Region F plan is subordination of senior water rights. This strategy, which was developed in conjunction with the Lower Colorado Region (Region K) in the second round of regional planning, reserves over 72,000 acre-feet of surface water for use in Region F in 2060. Of this amount, approximately 34,000 acre-feet per year is used to meet projected water shortages. Nearly 23,000 acre-feet of existing and/or future supplies will be made available to other water users through voluntary redistribution of supplies, some of which is made available through subordination and other strategies. Overall, with all strategies in place, by 2060 the total available supply for Region F water user groups is approximately 829,000 acre-feet per year. Additional supply is available to wholesale water providers for future customers or use beyond this planning cycle.

Irrigation demands in some years for 16 counties are not met with this plan due to limited water existing supplies and lack of cost effective alternative sources of water. Steam-electric demands in three counties are not met because of lack of supplies in the demand location and uncertainty regarding how the steam-electric power industry will meet these demands.

Water quality is an important factor in Region F water supplies, particularly for municipal use. Communities in Region F are being pressured to expend limited public and private financial resources to meet water quality standards for arsenic, radionuclides, and secondary water constituents. Meeting these standards is particularly difficult for small communities in the region.

Figure ES-4 shows the comparison of surface water supply and demand for Region F with and without the subordination agreement. Figure ES-5 shows the makeup of the nearly 829,000 acre-feet per year of supplies proposed for water user groups in the region in 2060.

Table ES-1
Recommended Water Management Strategies by Type

Water Management Strategy	2060 Supply (Acre-Feet per Year)	Implementation Cost
Conservation	82,423	$68,650,668
Desalination [a]	16,050	$213,760,990
New Groundwater	33,960	$437,621,000
Infrastructure Improvements	2,440	$31,628,900
Reuse	12,490	$130,906,000
Subordination [b]	72,207	$0
Voluntary Redistribution [c]	22,866	$8,964,000
Other [d]	8,363	$23,023,000
Total	*250,799*	*$914,554,558*

a Includes 9,500 ac-ft of supply not assigned to a particular water user group.

b Includes all available water from Subordination Strategy, including supplies not assigned to a water user group.

c. This strategy uses existing supplies or water developed from other strategies.

d. Includes brush control and bottled water programs.

Figure ES-4
Comparison of Supplies and Demands in Region F
With and Without the Subordination Strategy

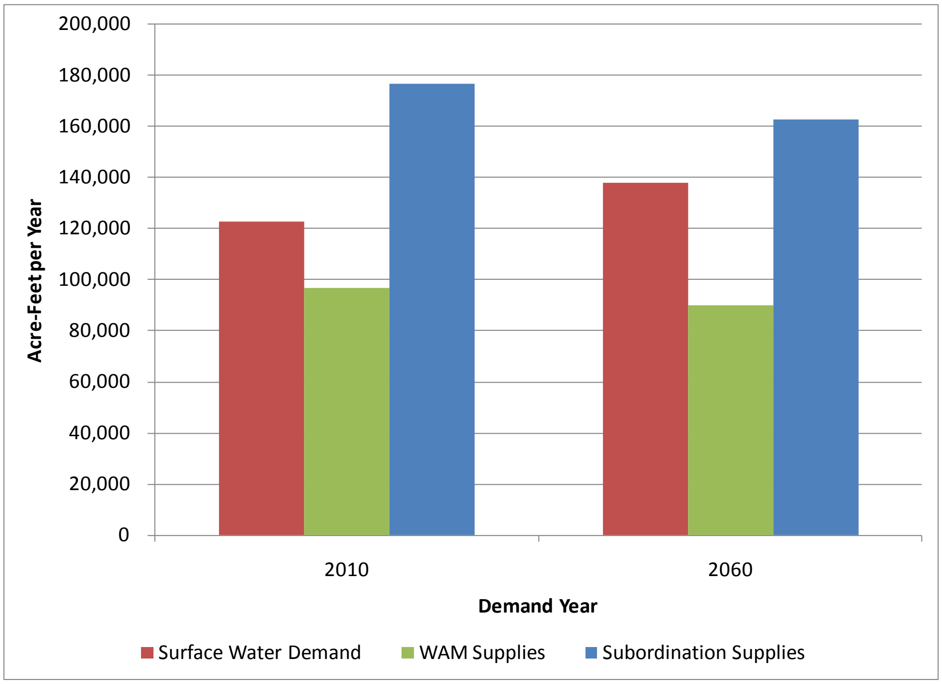
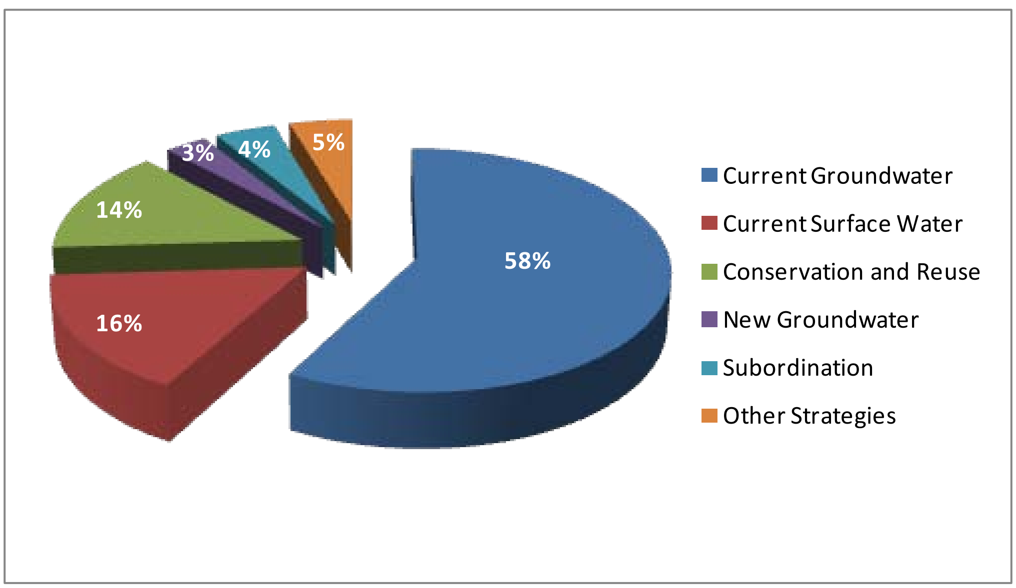


Figure ES-5
Current and Recommended Sources of Water Available to Region F
Water User Groups as of 2060



1. DESCRIPTION OF REGION

In 1997, the 75th Texas Legislature passed Senate Bill One (SB1), legislation designed to address Texas water issues. With the future passage of SB1, the legislature put in place a grass-roots regional planning process to plan for the future water needs of all Texans. To implement this planning process, the Texas Water Development Board (TWDB) created 16 regional water planning groups across the state and established regulations governing regional planning efforts. The first 16 Regional Water Plans developed as part of the SB1 planning process were submitted to the TWDB in 2001. The TWDB combined these regional plans into one statewide plan. SB1 calls for these plans to be updated every five years. Since 2001, the regional water plans were updated in 2006 and consolidated into the current state water plan, *Water for Texas 2007*.

The TWDB refers to the current round of regional planning as SB1, Third Round. This report is the update to the *2006 Region F Water Plan* and will become part of the basis for the next state water plan.

This chapter presents a description of Region F, one of the 16 regions created to implement SB1. Figure 1.1-1 is a map of Region F, which includes 32 counties in West Texas. The data presented in this regional water plan is a compilation of information from previous planning reports, on-going planning efforts and new data. A list of references is found at the end of this chapter, and a bibliography is included in Appendix 1A.

1.1 Introduction to Region F

Region F includes all of Borden, Scurry, Andrews, Martin, Howard, Mitchell, Loving, Winkler, Ector, Midland, Glasscock, Sterling, Coke, Runnels, Coleman, Brown, Reeves, Ward, Crane, Upton, Reagan, Irion, Tom Green, Concho, McCulloch, Pecos, Crockett, Schleicher, Menard, Sutton, Kimble and Mason Counties. Table 1.1-1 shows historical populations for these

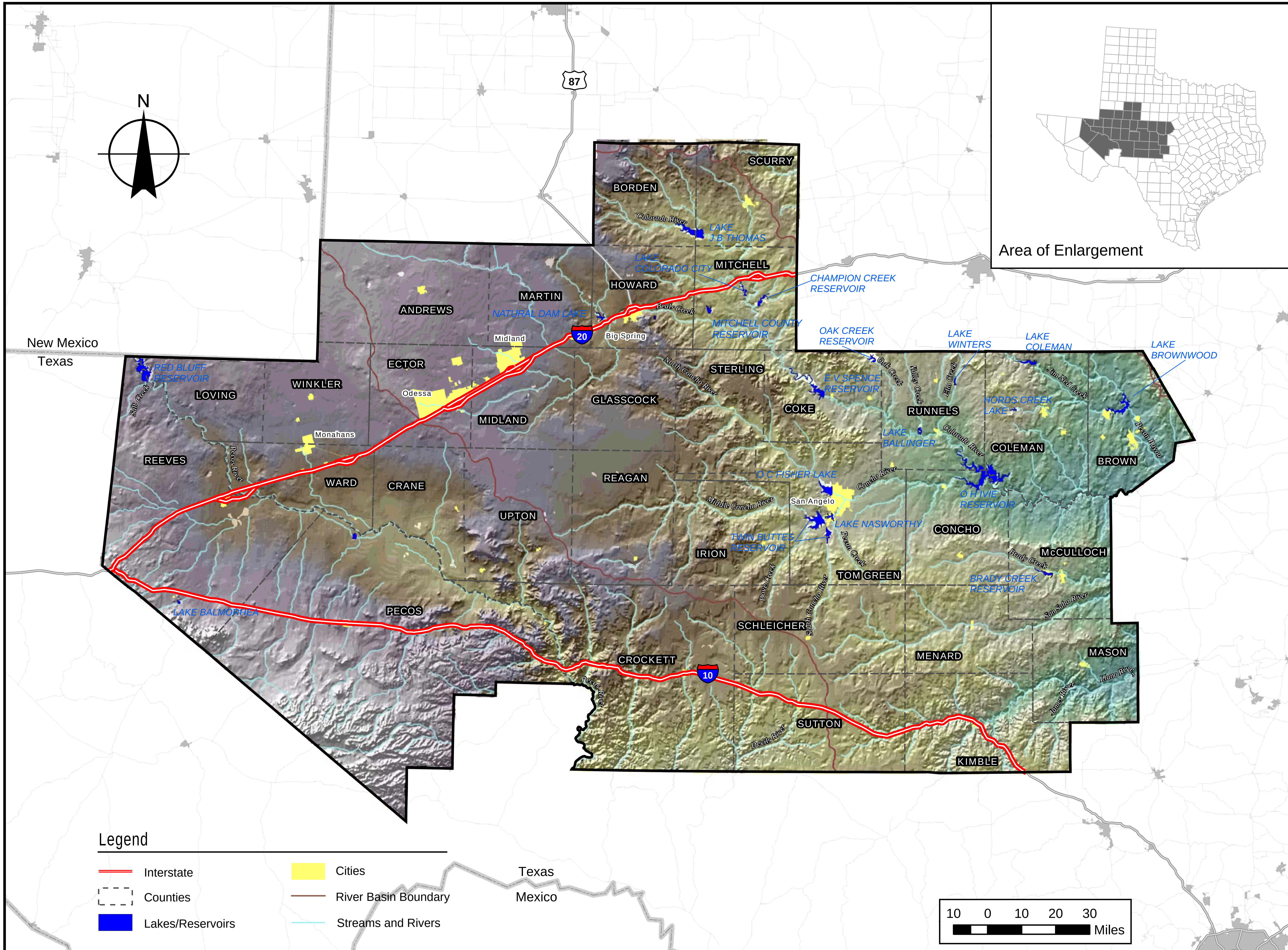


Figure 1.1-1

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Region F

General Location Map

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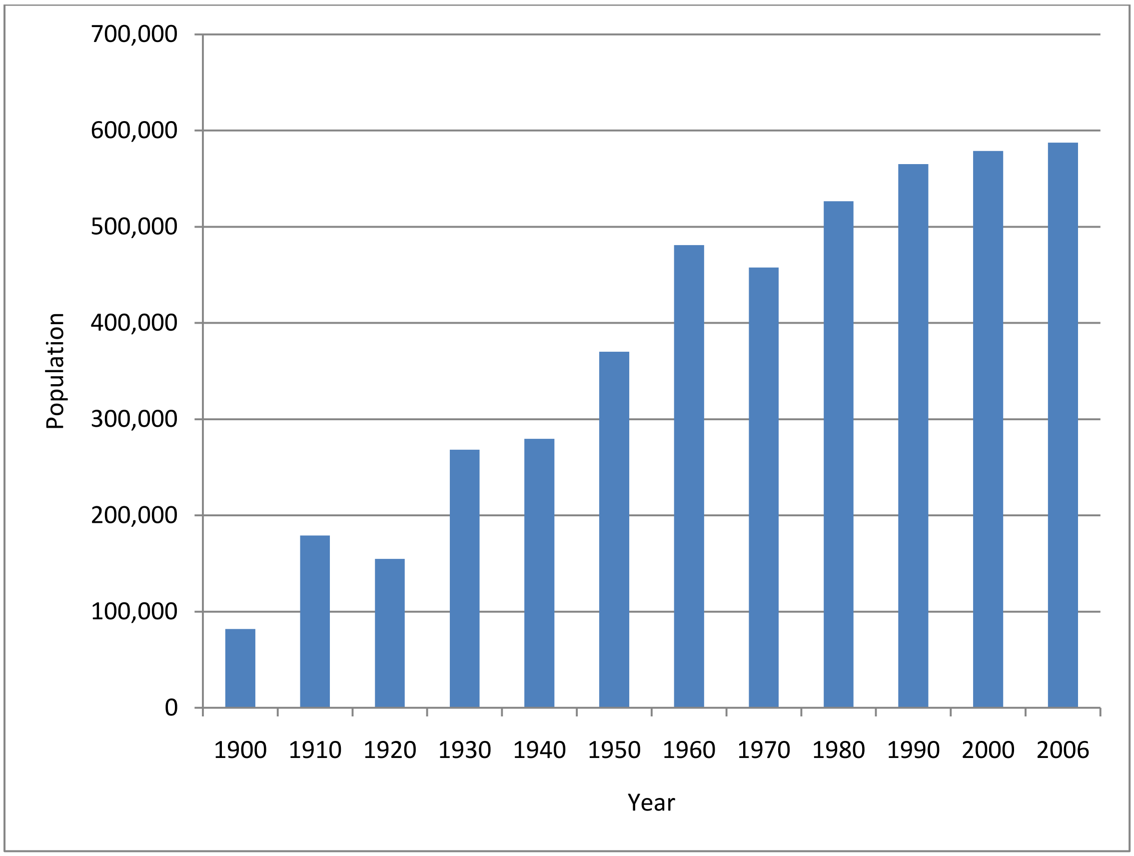
Table 1.1-1
Historical Population of Region F Counties

County	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2006
Andrews	87	975	350	736	1,277	5,002	13,450	10,372	13,323	14,338	13,004	13,154
Borden	776	1,386	965	1,505	1,396	1,106	1,076	888	859	799	729	710
Brown	16,019	22,935	21,682	26,382	25,924	28,607	24,728	25,877	33,057	34,371	37,674	38,617
Coke	3,430	6,412	4,557	5,253	4,590	4,045	3,589	3,087	3,196	3,424	3,864	3,897
Coleman	10,077	22,618	18,805	23,669	20,571	15,503	12,458	10,288	10,439	9,710	9,235	8,860
Concho	1,427	6,654	5,847	7,645	6,192	5,078	3,672	2,937	2,915	3,044	3,966	3,801
Crane	51	331	37	2,221	2,841	3,965	4,699	4,172	4,600	4,652	3,996	3,854
Crockett	1,591	1,296	1,500	2,590	2,809	3,981	4,209	3,885	4,608	4,078	4,099	3,986
Ector	381	1,178	760	3,958	15,051	42,102	90,995	91,805	115,374	118,934	121,123	127,212
Glasscock	286	1,143	555	1,263	1,193	1,089	1,118	1,155	1,304	1,447	1,406	1,241
Howard	2,528	8,881	6,962	22,888	20,990	26,722	40,139	37,796	33,142	32,343	33,627	32,918
Irion	848	1,283	1,610	2,049	1,963	1,590	1,183	1,070	1,386	1,629	1,771	1,748
Kimble	2,503	3,261	3,581	4,119	5,064	4,619	3,943	3,904	4,063	4,122	4,468	4,612
Loving	33	249	82	195	285	227	226	164	91	107	67	60
Martin	332	1,549	1,146	5,785	5,556	5,541	5,068	4,774	4,684	4,956	4,746	8,113
Mason	5,573	5,683	4,824	5,511	5,378	4,945	3,780	3,356	3,683	3,423	3,738	4,820
McCulloch	3,960	13,405	11,020	13,883	13,208	11,701	8,815	8,571	8,735	8,778	8,205	3,719
Menard	2,011	2,707	3,162	4,447	4,521	4,175	2,964	2,646	2,346	2,252	2,360	2,297
Midland	1,741	3,464	2,449	8,005	11,721	25,785	67,717	65,433	82,636	106,611	116,009	124,383
Mitchell	2,855	8,956	7,527	14,183	12,477	14,357	11,255	9,073	9,088	8,016	9,698	9,596
Pecos [c]	2,360	2,071	3,857	7,812	8,185	9,939	11,957	13,748	14,618	14,675	16,809	16,422
Reagan [b]		392	377	3,026	1,997	3,127	3,782	3,239	4,135	4,514	3,326	3,041
Reeves	1,847	4,392	4,457	6,407	8,006	11,745	17,644	16,526	15,801	15,852	13,137	11,606
Runnels	5,379	20,858	17,074	21,821	18,903	16,771	15,016	12,108	11,872	11,294	11,495	11,020
Schleicher	515	1,893	1,851	3,166	3,083	2,852	2,791	2,277	2,820	2,990	2,935	2,911
Scurry	4,158	10,924	9,003	12,188	11,545	22,779	20,369	15,760	18,192	18,634	16,361	15,895
Sterling	1,127	1,493	1,053	1,431	1,404	1,282	1,177	1,056	1,206	1,438	1,393	1,223
Sutton	1,727	1,569	1,598	2,807	3,977	3,746	3,738	3,175	5,130	4,135	4,077	4,205
Tom Green [b]	6,804	17,882	15,210	36,033	39,302	58,929	64,630	71,047	84,784	98,458	104,010	103,123
Upton	48	501	253	5,968	4,297	5,307	6,239	4,697	4,619	4,447	3,404	3,169
Ward	1,451	2,389	2,615	4,599	9,575	13,346	14,917	13,019	13,976	13,115	10,909	10,369
Winkler	60	442	81	6,784	6,141	10,064	13,652	9,640	9,944	8,626	7,173	6,805
Region F Total	***81,985***	***179,172***	***154,850***	***268,329***	***279,422***	***370,027***	***480,996***	***457,545***	***526,626***	***565,212***	***578,814***	***587,387***
% Change		*119%*	*-14%*	*73%*	*4%*	*32%*	*30%*	*-5%*	*15%*	*7%*	*2%*	*1%*

Notes:
a. Population data are from the U.S. Bureau of Census
b. Reagan County was formed from part of Tom Green County in 1903
c. Terrell County was formed from part of Pecos County in 1905.

counties from 1900 through 2006.[1] Figure 1.1-2 shows graphically the total population of the region. The population of Region F has increased from 81,985 in 1900 to 587,387 in 2006. Since 1940, the region's population has increased at a compounded rate of 1.1 percent per year.

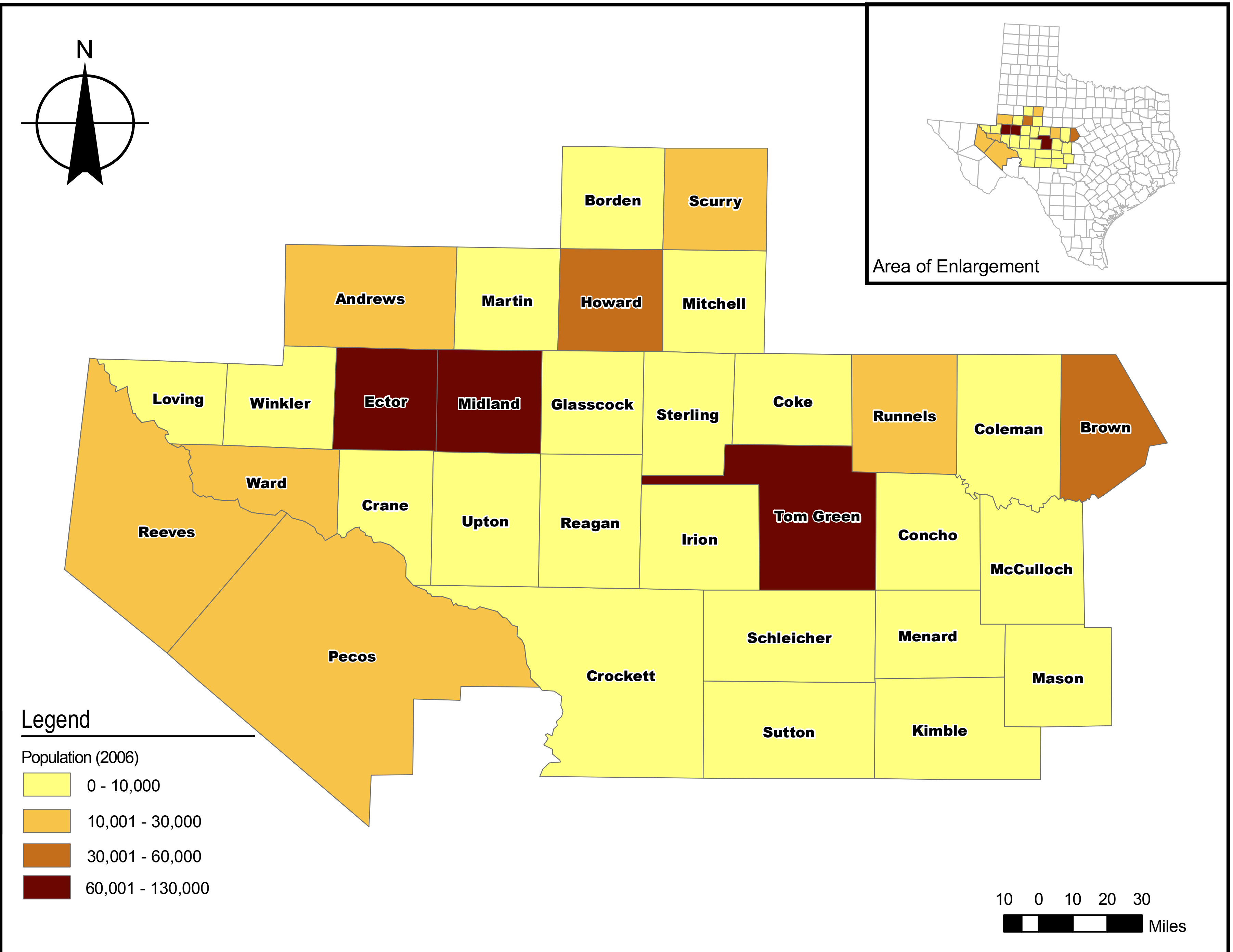
Figure 1.1-2
Historical Population of Region F



According to the 2000 census, Region F accounted for 3.0 percent of Texas' total population. Figure 1.1-3 shows the distribution of population in Region F counties based on the census data. Ector, Midland, and Tom Green were the three most populous counties in Region F, accounting for 59 percent of the region's population. Brown and Howard Counties were the next most populous counties with more than 30,000 people in each. Table 1.1-2 lists the six cities in Region F with a year 2006 population of more than 10,000. These cities included 57 percent of the population in Region F.

Population Distribution by County (2006)

Region F



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FILE	RegionF_Population.mxd
DATE	January 4, 2010
SCALE	1:2,421,500
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FIGURE 1.1-3

Table 1.1-2
Region F Cities with a Year 2006 Population Greater than 10,000

City	Year 2006 Population
Midland	100,193
Odessa	94,089
San Angelo	87,212
Big Spring	25,179
Brownwood	19,694
Snyder	10,493
Total	*336,860*

Data are from the State Date Center[9].

1.1.1 Economic Activity in Region F

Region F includes the Midland, Odessa, and San Angelo Metropolitan Statistical Areas (MSAs). The largest employment sector in the Midland MSA is the service industry, followed by wholesale and retail trade and the oil and gas industry. In the Odessa and San Angelo MSAs the largest employment sectors are wholesale and retail trade, services, and manufacturing.[2] Table 1.1-3 summarizes 2007 payroll data for Region F by county and economic sector. (Data for certain payroll categories are only available on a state-wide basis and are not broken down by counties.)

Figure 1.1-4 shows the geographic distribution of total payroll in Region F. This figure shows that Ector, Midland and Tom Green Counties are the primary centers of economic activity in the region. These three counties account for 78 percent of the payroll and 71 percent of the employment in the region. Other major centers of economic activity are located in Brown and Howard Counties. The largest business sectors in Region F in terms of payroll in 2007 are healthcare and social assistance, mining and manufacturing, which together account for 43 percent of the region's total payroll.

Table 1.1-3
2007 County Payroll by Category ($1000)

Category	Andrews	Borden	Brown	Coke	Coleman	Concho	Crane	Crockett
Forestry, Fishing, Hunting, and Agricultural Support	(N)	(N)	(D)	(D)	(D)	(N)	(N)	(D)
Mining	51,169	(N)	(D)	729	696	(D)	26,616	6,960
Utilities	(D)	(N)	3,392	(D)	(D)	(D)	(N)	D
Construction	14,972	(N)	20,825	586	(D)	160	1,873	3,345
Manufacturing	(D)	(N)	124,654	(D)	2,023	(D)	(D)	(D)
Wholesale Trade	7,259	(N)	11,718	(D)	1,765	256	847	957
Retail Trade	7,850	(D)	43,541	1,263	4,155	1,180	2,528	4,300
Transportation and Warehousing	7,790	(N)	6,361	(D)	778	(N)	4,405	992
Information	920	(N)	8,155	(D)	1,036	(D)	(N)	(D)
Finance and Insurance	7,046	(N)	14,005	906	3,333	(D)	345	(D)
Real Estate, Rental, and Leasing	5,425	(N)	2,641	(N)	423	(D)	(N)	(D)
Professional, Scientific and Technical Services	2,371	(D)	4,871	150	708	(D)	(D)	348
Management of Companies and Enterprises	(N)	(N)	3,139	(N)	(D)	(N)	(N)	(D)
Admin, Support, Waste Mgmt, Remediation Services	(D)	(N)	5,328	(D)	(D)	(D)	(D)	(D)
Educational Services	(D)	(D)	(D)	(N)	(D)	(N)	(D)	(N)
Health Care & Social Assistance	(D)	(N)	74,221	(N)	9,065	2,654	4,564	524
Arts, Entertainment, & Recreation	(D)	(N)	1,203	(D)	(D)	(D)	(D)	104
Accommodation & Food Services	3,273	(N)	13,871	275	1,377	865	211	1,908
Other Services	10,953	(N)	11,880	382	1,118	(D)	(D)	402
Total Payroll	*119,028*	*(D)*	*349,805*	*4,291*	*26,477*	*5,115*	*41,389*	*19,840*
Total Employees	*4,081*	*(N)*	*13,287*	*413*	*1,607*	*674*	*1,002*	*928*

Table 1.1-3 (cont.) 2007 County Payroll by Category ($1000)

Category	Ector	Glasscock	Howard	Irion	Kimble	Loving	Martin	Mason
Forestry, Fishing, Hunting, and Agricultural Support	(D)	880	(D)	(D)	(N)	(N)	(D)	(D)
Mining	256,212	(D)	38,893	939	(D)	(N)	5,333	(D)
Utilities	10,915	(N)	4,871	(N)	(D)	(N)	(N)	(D)
Construction	275,054	(D)	17,578	1,325	3,683	(N)	(D)	1,291
Manufacturing	217,893	(D)	46,569	(N)	7,116	(N)	(N)	(D)
Wholesale Trade	264,324	(D)	10,650	(D)	D	(N)	(D)	(D)
Retail Trade	175,007	(D)	29,034	(D)	4,613	(N)	2,833	2,285
Transportation and Warehousing	72,211	(N)	1,677	(D)	(D)	(N)	(D)	594
Information	(D)	(N)	3,560	(D)	213	(N)	(D)	(D)
Finance and Insurance	50,297	(D)	12,905	(D)	(D)	(N)	779	3,169
Real Estate, Rental, and Leasing	69,772	(N)	3,396	(N)	122	(N)	(N)	(D)
Professional, Scientific and Technical Services	91,438	(D)	10,741	174	369	(N)	(D)	860
Management of Companies and Enterprises	23,241	(N)	(D)	(D)	(D)	(N)	(N)	(N)
Admin, Support, Waste Mgmt, Remediation Services	62,906	(N)	(D)	(D)	(D)	(N)	94	112
Educational Services	3,032	(D)	(D)	(N)	(D)	(N)	D	(N)
Health Care & Social Assistance	255,162	(N)	92,601	(D)	(D)	(N)	4,651	2,925
Arts, Entertainment, & Recreation	5,886	(N)	782	(D)	65	(N)	(D)	(D)
Accommodation & Food Services	59,907	(N)	10,315	(D)	2,197	(D)	(D)	1,423
Other Services	75,584	(D)	8,469	(D)	835	(N)	809	643
Total Payroll	*1,968,841*	*880*	*292,041*	*2,438*	*19,213*	*(D)*	*14,499*	*13,302*
Total Employees	*50,942*	*118*	*9,705*	*398*	*1,177*	*(N)*	*931*	*844*

Table 1.1-3 (cont.) 2007 County Payroll by Category ($1000)

Category	McCulloch	Menard	Midland	Mitchell	Pecos	Reagan	Reeves	Runnels
Forestry, Fishing, Hunting, and Agricultural Support	(D)	(N)	(D)	463	(D)	(N)	(D)	(D)
Mining	(D)	(N)	756,637	2,820	13,538	19,767	12,207	3,600
Utilities	(D)	(D)	33,544	(D)	1,334	(D)	2,227	(D)
Construction	2,006	521	167,541	553	5,255	3,537	(D)	2,074
Manufacturing	(D)	D	90,954	D	(D)	(N)	365	22,714
Wholesale Trade	689	D	193,750	305	(D)	1,353	554	2,099
Retail Trade	8,854	807	185,485	4,890	13,073	1,713	10,282	11,797
Transportation and Warehousing	1,690	(N)	71,963	3,815	8,635	(D)	2,004	1,815
Information	(D)	(D)	47,567	409	D	(D)	1,015	371
Finance and Insurance	2,952	(D)	94,009	1,454	3,743	314	(D)	3,399
Real Estate, Rental, and Leasing	(D)	(D)	70,482	(D)	624	(D)	262	(D)
Professional, Scientific and Technical Services	2,395	(D)	181,036	699	3,538	98	635	(D)
Management of Companies and Enterprises	(D)	(D)	119,566	(N)	(N)	(N)	(D)	(D)
Admin, Support, Waste Mgmt, Remediation Services	573	(D)	72,422	(D)	(D)	(N)	(D)	498
Educational Services	(D)	(N)	15,620	(N)	(N)	(N)	(N)	(D)
Health Care & Social Assistance	7,786	(D)	231,068	(D)	13,687	(D)	(D)	8,024
Arts, Entertainment, & Recreation	(D)	(D)	18,265	(N)	239	(D)	(D)	70
Accommodation & Food Services	1,441	365	74,466	938	6,203	435	3,421	1,587
Other Services	1,403	117	80,968	889	3,587	1,054	854	2,046
Total Payroll	*29,789*	*1,810*	*2,505,343*	*17,235*	*73,456*	*28,271*	*33,826*	*60,094*
Total Employees	*2,126*	*247*	*62,373*	*1,227*	*3,102*	*810*	*1,909*	*2,509*

Table 1.1-3 (cont.) 2007 County Payroll by Category ($1000)

Category	Schleicher	Scurry	Sterling	Sutton	Tom Green	Upton	Ward	Winkler
Forestry, Fishing, Hunting, and Agricultural Support	(D)	(D)	(N)	(N)	1,530	(N)	(N)	(N)
Mining	6,472	43,367	3,492	12,339	24,756	16,825	58,909	25,769
Utilities	(D)	(D)	(D)	(D)	10,978	(D)	10,057	(D)
Construction	(D)	21,199	(D)	11,804	68,523	(D)	6,300	10,101
Manufacturing	(D)	7,562	(N)	(D)	120,060	(D)	(D)	(D)
Wholesale Trade	985	8,810	(D)	6,251	43,959	1,394	4,726	(D)
Retail Trade	917	14,668	297	3,090	134,488	1,329	5,873	3,476
Transportation and Warehousing	(D)	14,126	(D)	6,508	18,558	2,645	5,867	4,363
Information	(D)	(D)	(N)	(D)	80,093	(D)	(D)	(D)
Finance and Insurance	663	6,228	(D)	2,710	49,833	(D)	3,210	1,374
Real Estate, Rental, and Leasing	(N)	5,120	(N)	1,496	15,654	(D)	4,198	(D)
Professional, Scientific and Technical Services	127	4,717	(D)	596	53,239	134	1,268	292
Management of Companies and Enterprises	(N)	(D)	(N)	(N)	13,396	(N)	(D)	(N)
Admin, Support, Waste Mgmt, Remediation Services	(D)	(D)	(N)	(D)	54,058	(D)	(D)	(D)
Educational Services	(N)	(N)	(N)	(N)	3,222	(D)	(N)	(N)
Health Care & Social Assistance	2,154	13,841	91	(D)	259,683	3,965	7,070	3,565
Arts, Entertainment, & Recreation	(D)	418	(N)	(D)	6,957	(D)	(D)	(D)
Accommodation & Food Services	135	5,762	(D)	2,753	52,735	549	1,968	946
Other Services	308	7,123	112	862	37,410	91	2,798	3,896
Total Payroll	*11,761*	*152,941*	*3,992*	*48,409*	*1,049,132*	*26,932*	*112,244*	*53,782*
Total Employees	*593*	*5,049*	*163*	*1,426*	*37,196*	*892*	*3,617*	*1,533*

Notes: Data are from U.S. Census Bureau 2007 economic data[3]
D = Data withheld to avoid disclosing data for individual companies
N = Data not available

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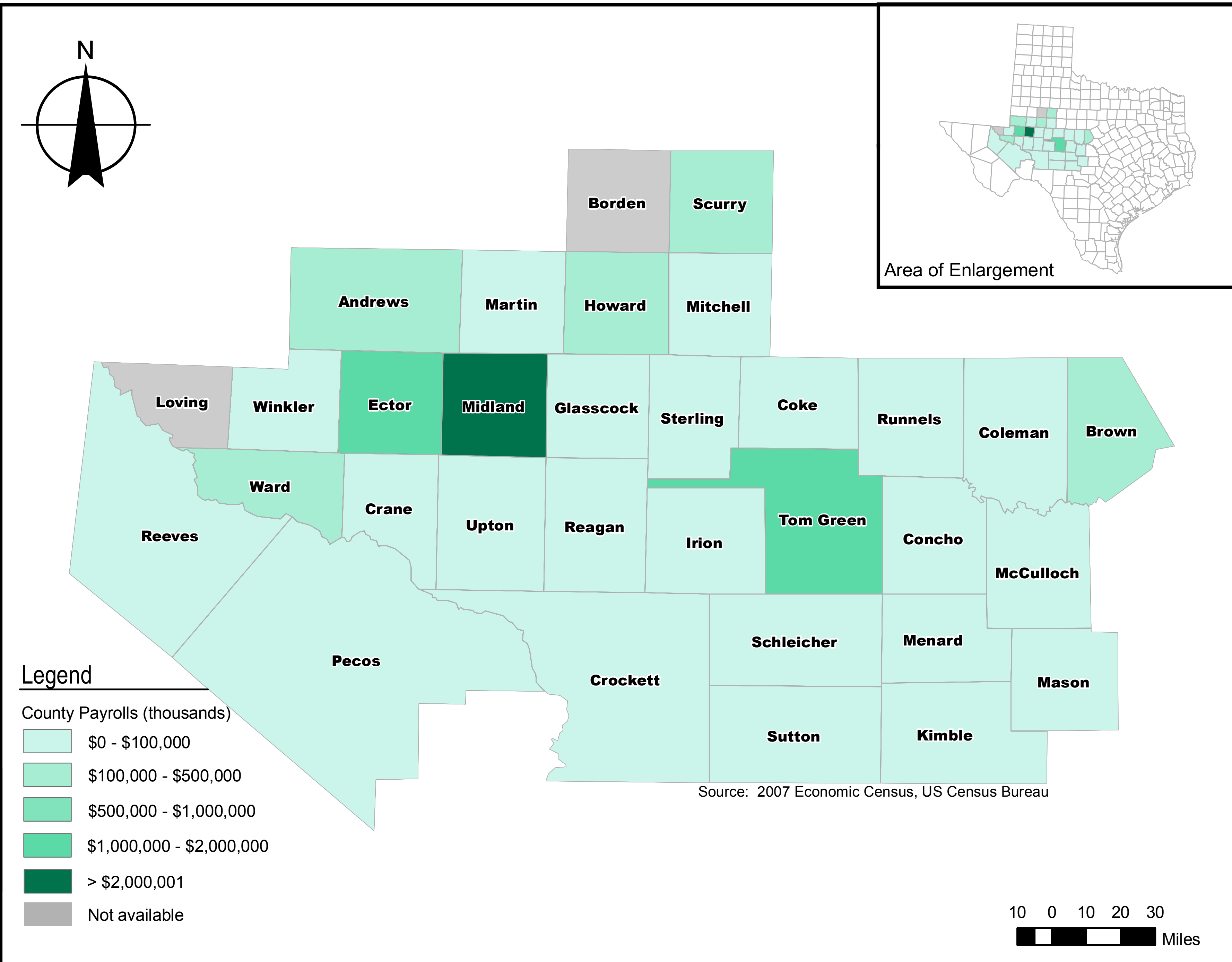
Region F
Total County Payrolls (2007)

FN JOB NO	FILE	DATE	SCALE	DESIGNED	DRAFTED
CMD07215	RegionFPayroll.mxd	January 4, 2010	1:2,446,400	BME	BME

FIGURE 1.1-4



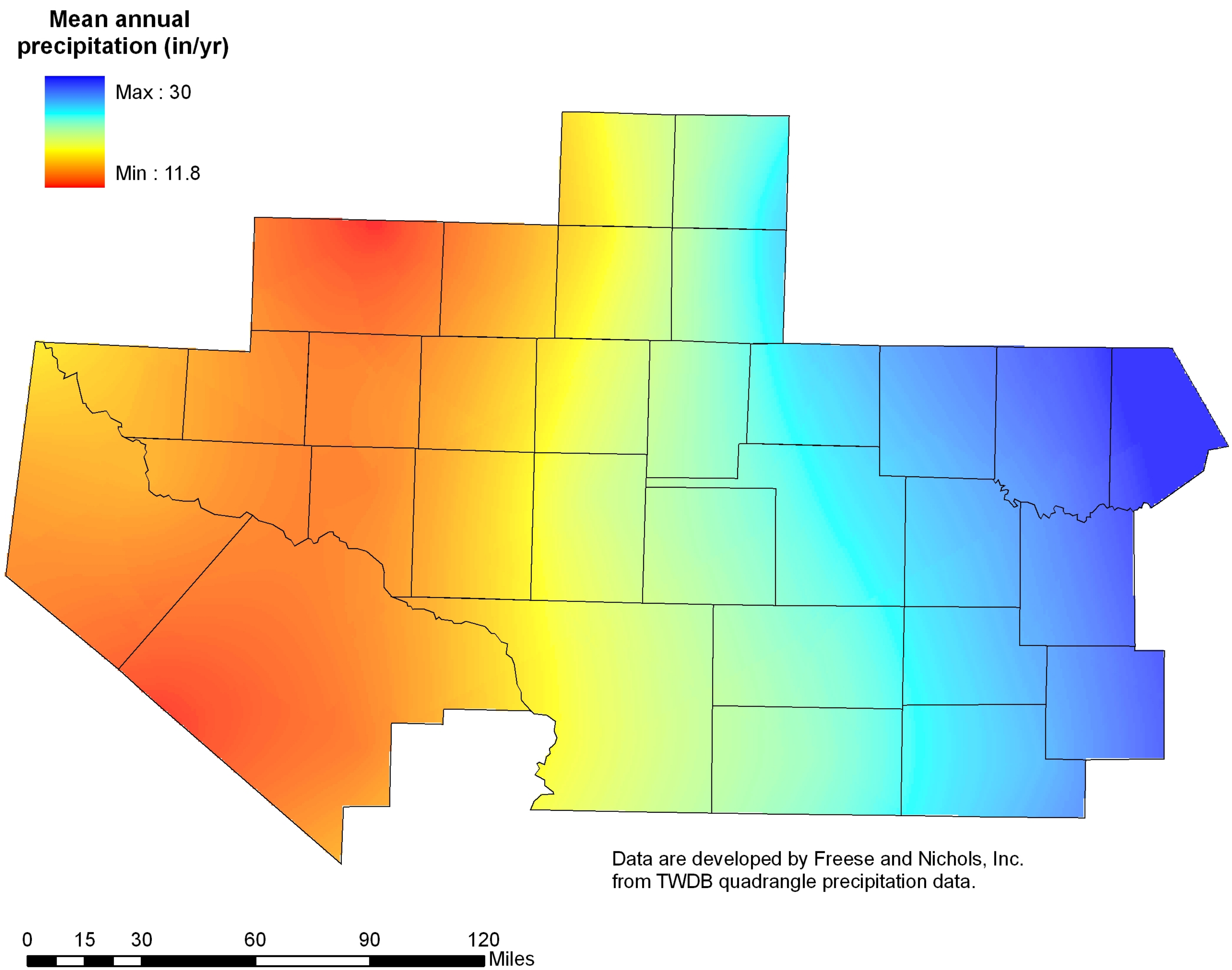
1.1.2 Water-Related Physical Features in Region F

Most of Region F is in the upper portion of the Colorado Basin and in the Pecos portion of the Rio Grande Basin. A small part of the region is in the Brazos Basin. Figure 1.1-1 shows the major streams in Region F, which include the Colorado River, Concho River, Pecan Bayou, San Saba River, Llano River and Pecos River.

Figure 1.1-5 shows the average annual precipitation in Texas. In Region F, precipitation increases from slightly more than 11 inches per year in western Reeves County to approximately 30 inches per year in Brown County. Figure 1.1-6 shows average annual runoff, which follows a similar pattern of increasing from the west to the east.[4] Figure 1.1-7 shows gross reservoir evaporation in Texas, which generally increases from northeast to southwest.[5] (Gross reservoir evaporation is the amount lost to evaporation from the surface of a reservoir.) Some of the highest evaporation rates in the state are in Region F, exceeding rainfall throughout the region. The patterns of rainfall, runoff, and evaporation result in more abundant water supplies in the eastern portion of Region F.

Figure 1.1-8 shows the variations in annual streamflow for seven U.S. Geological Survey (USGS) streamflow gages in Region F.[6] The five gages on tributaries have watersheds with limited development and show the natural variation in streamflows in this region. The Colorado gage near Winchell is the most downstream gage on the main stem of the Colorado River in Region F. Flows at the Pecos River gage near Girvin are largely controlled by releases from Red Bluff Reservoir. Figure 1.1-9 shows seasonal patterns of median streamflows for the same seven gages.

Table 1.1-4 lists the 17 major water supply reservoirs in Region F, all of which are shown in Figure 1.1-1. These reservoirs provide most of the region's surface water supply. Reservoirs are necessary to provide a reliable surface water supply in this part of the state because of the wide variations in natural streamflow. Reservoir storage serves to capture high flows when they are available and save them for use during times of normal or low flow.



Mean Annual Precipitation

Region F

FIGURE 1.1-5

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N W E S

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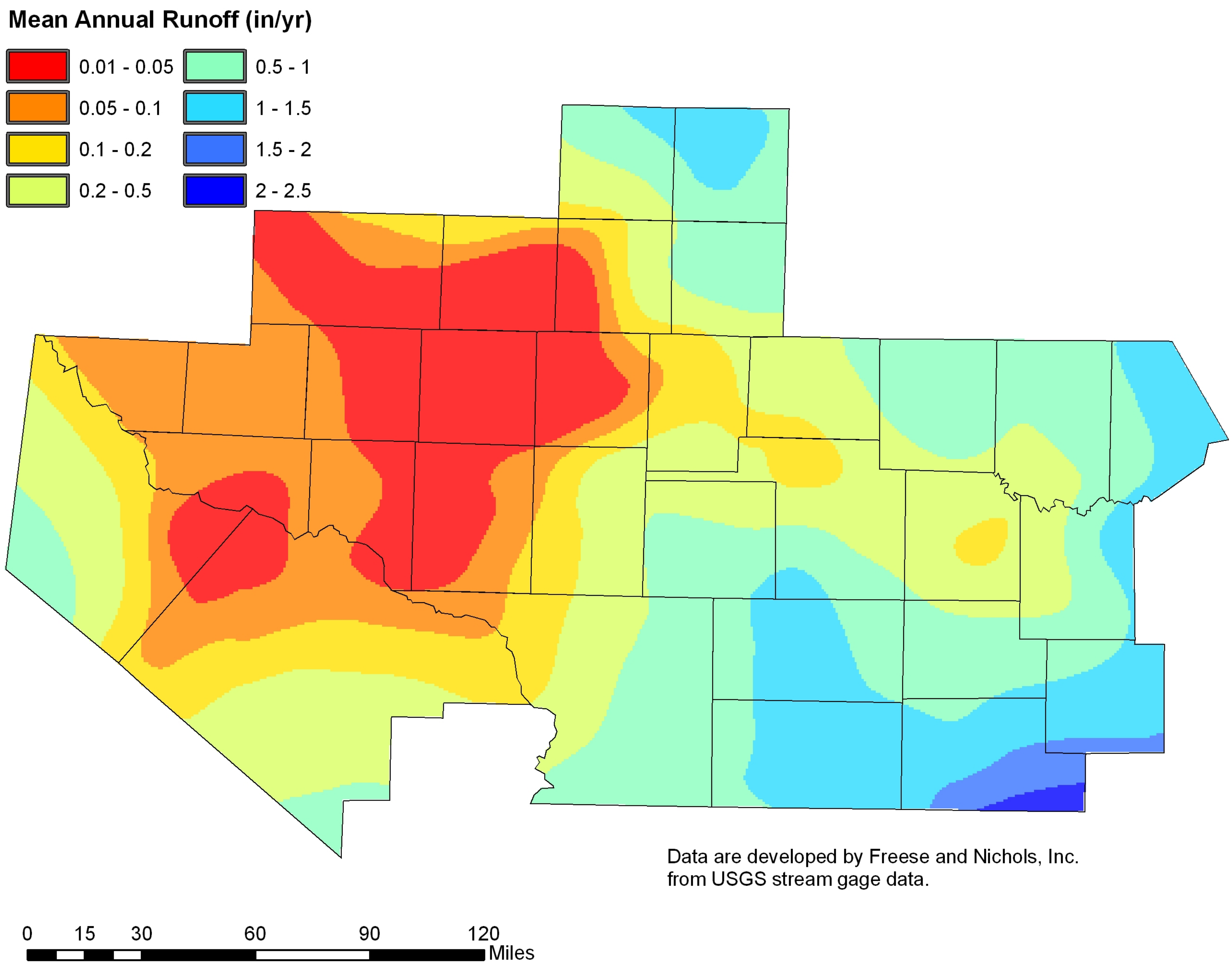

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Mean Annual Runoff

Region F

DRAFTED HEO
DESIGNED HEO
SCALE 1:2,400,000
DATE July, 2005
FILE 1-6 RegF_Runoff.mxd
FN JOB NO CMD01311

FIGURE 1.1-6

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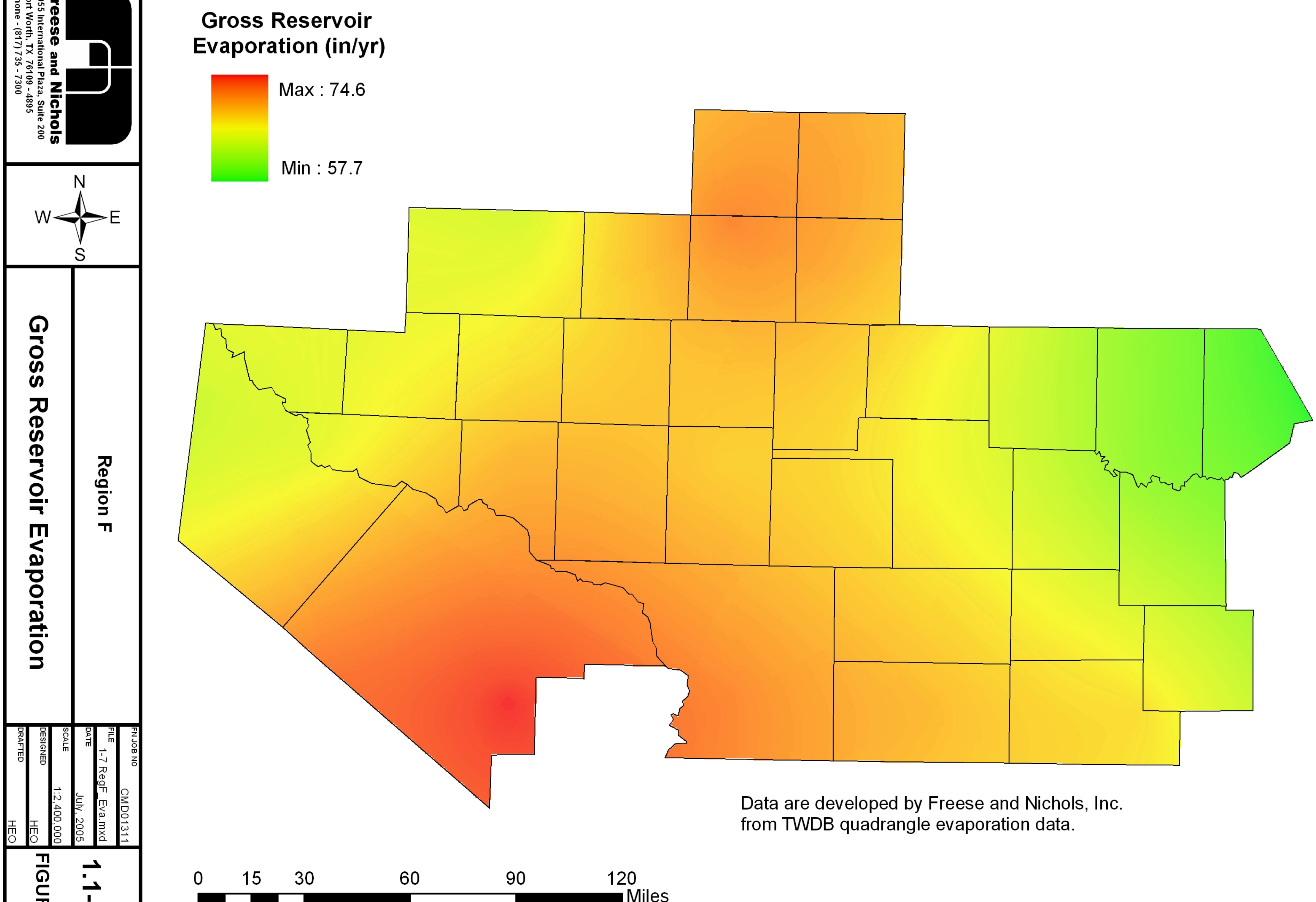


Gross Reservoir Evaporation

Region F

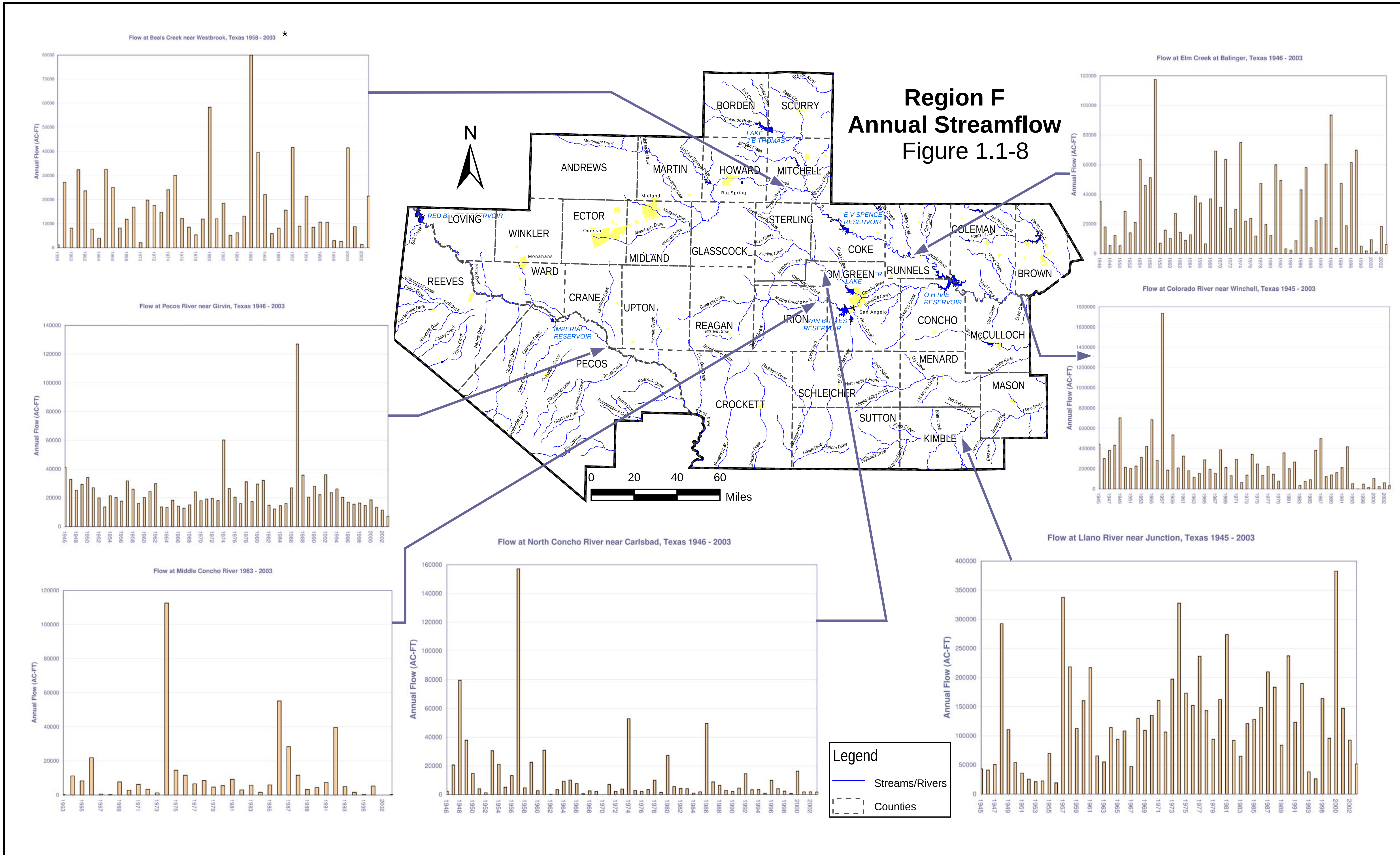
DRAFTED	DESIGNED	SCALE	DATE	FILE	FN JOB NO
HEO	HEO	1:2,400,000	July, 2005	1-7 RegF_Eva.mxd	CMD01311

FIGURE 1.1-7

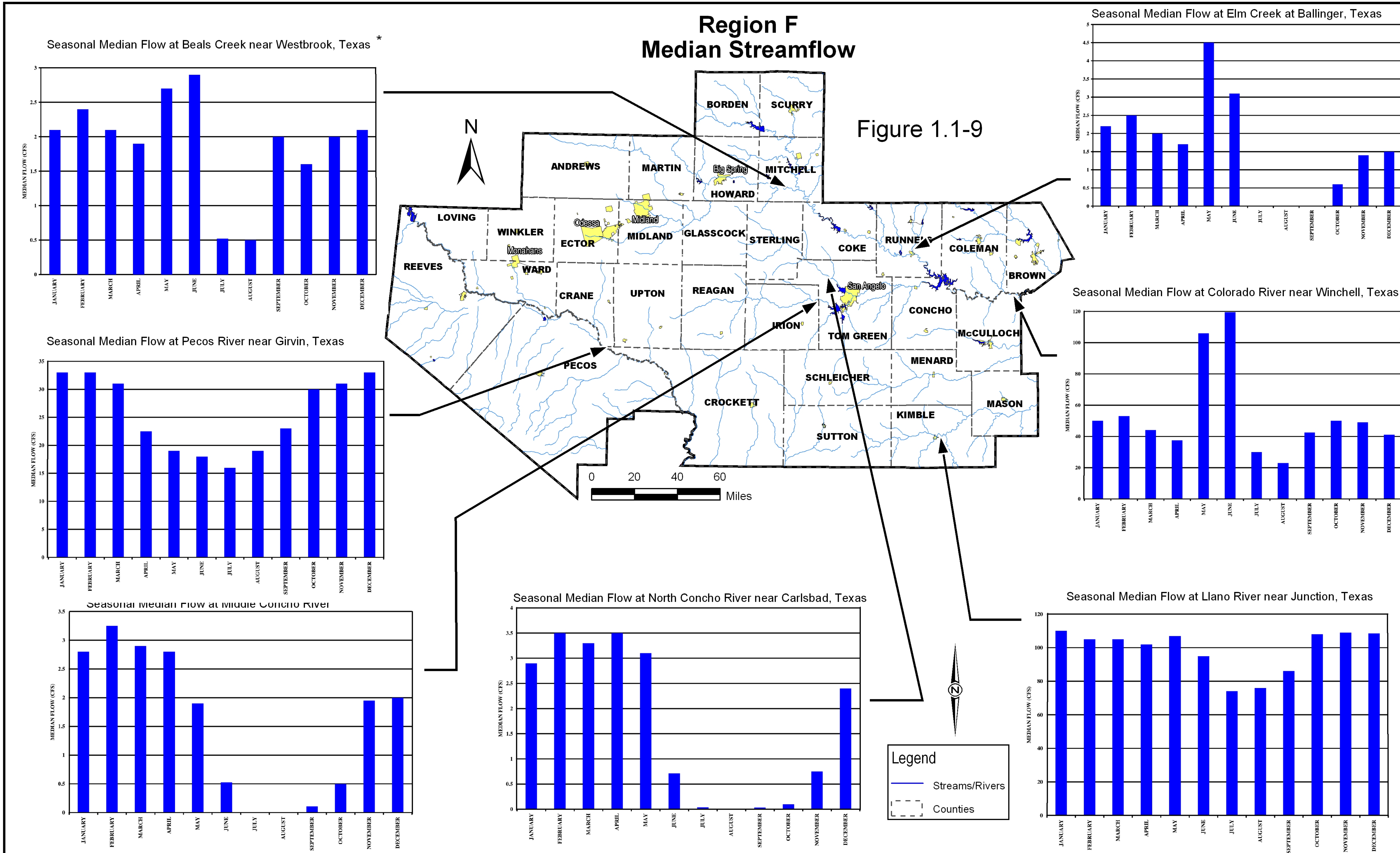
Table 1.1-4
Major Water Supply Reservoirs in Region F [a]

Reservoir Name	Basin	Stream	County(ies)	Water Right Number(s)	Priority Date	Permitted Conservation Storage (Acre-Feet)	Permitted Diversion (Acre-Feet per Year)	Year 2006 Use (Acre-Feet per Year)	Owner	Water Rights Holder(s)
Lake J B Thomas	Colorado	Colorado River	Borden and Scurry	CA-1002	08/05/1946	204,000	30,000 [c]	15,398	CRMWD	CRMWD
Lake Colorado City	Colorado	Morgan Creek	Mitchell	CA-1009	11/22/1948	29,934	5,500	38 [b]	TXU	TXU
Champion Creek Reservoir	Colorado	Champion Creek	Mitchell	CA-1009	04/08/1957	40,170	6,750		TXU	TXU
Oak Creek Reservoir	Colorado	Oak Creek	Coke	CA-1031	04/27/1949	30,000	10,000	95	City of Sweetwater	City of Sweetwater
Lake Coleman	Colorado	Jim Ned Creek	Coleman	CA-1702	08/25/1958	40,000	9,000	1,513	City of Coleman	City of Coleman
E V Spence Reservoir	Colorado	Colorado River	Coke	CA-1008	08/17/1964	488,760	50,000 [c]	14,048	CRMWD	CRMWD
Lake Winters	Colorado	Elm Creek	Runnels	CA-1095	12/18/1944	8,347	1,755	0	City of Winters	City of Winters
Lake Brownwood	Colorado	Pecan Bayou	Brown	CA-2454	09/29/1925	114,000	29,712	13,678	Brown Co. WID	Brown Co. WID
Hords Creek Lake	Colorado	Hords Creek	Coleman	CA-1705	03/23/1946	7,959	2,240	262	COE	City of Coleman
Lake Ballinger	Colorado	Valley Creek	Runnels	CA-1072	10/04/1946	6,850	1,000	197	City of Ballinger	City of Ballinger
O. H. Ivie Reservoir	Colorado	Colorado River	Coleman, Concho and Runnels	A-3866 P-3676	02/21/1978	554,340	113,000	42,954	CRMWD	CRMWD
O. C. Fisher Lake	Colorado	North Concho River	Tom Green	CA-1190	05/27/1949	80,400	80,400	NA	COE	Upper Colorado River Authority
Twin Buttes Reservoir	Colorado	South Concho River	Tom Green	CA-1318	05/06/1959	170,000	29,000	NA	U.S. Bureau of Reclamation	City of San Angelo
Lake Nasworthy	Colorado	South Concho River	Tom Green	CA-1319	03/11/1929	12,500	25,000	NA	City of San Angelo	City of San Angelo
Brady Creek Reservoir	Colorado	Brady Creek	McCulloch	CA-1849	09/02/1959	30,000	3,500	0	City of Brady	City of Brady
Red Bluff Reservoir	Rio Grande	Pecos River	Loving and Reeves	CA-5438	01/01/1980	300,000	292,500	9,194	Red Bluff Water Power Control District	Red Bluff Water Power Control District
Lake Balmorhea	Rio Grande	Toyah Creek	Reeves	A-0060 P-0057	10/05/1914	13,583	41,400	14,863	Reeves Co WID #1	Reeves Co WID #1
Total						*2,130,843*	*730,757*	*112,241*		

a Data are from TCEQ active water rights list, TCEQ water rights permits,[7] and TCEQ historical water use by water right.[8] Year 2006 use is consumptive.
b Use is total consumptive use from both Champion Creek Reservoir and Lake Colorado City.
c Total consumptive use for CA 1002 and CA 1008 limited to 73,000 ac-ft per year.
CA Certificate of Adjudication
A Application
P Permit
COE Corps of Engineers
NA – Data Not Available



* Natural Dam Lake, which is above the Beals Creek gage, spilled intermittantly during 1986 and 1987. Natural Dam has subsequently been improved so that spills from the lake will not reoccur.



* Natural Dam Lake, which is above the Beals Creek gage, spilled intermittantly during 1986 and 1987. Natural Dam has subsequently been improved so that spills from the lake will not reoccur.

Figure 1.2-1 shows major aquifers in Region F, and Figure 1.2-2 shows the minor aquifers. There are 11 aquifers that supply water to the 32 counties of Region F. The major aquifers are the Edwards-Trinity Plateau, Ogallala, Pecos Valley and a small portion of the Trinity. The minor aquifers are Dockum, Hickory, Lipan, Ellenberger-San Saba, Marble Falls, Rustler and the Capitan Reef Complex. A small portion of the Edwards-Trinity High Plains extends into Region F but is not a major source of water. More information on these aquifers may be found in Chapter 3.

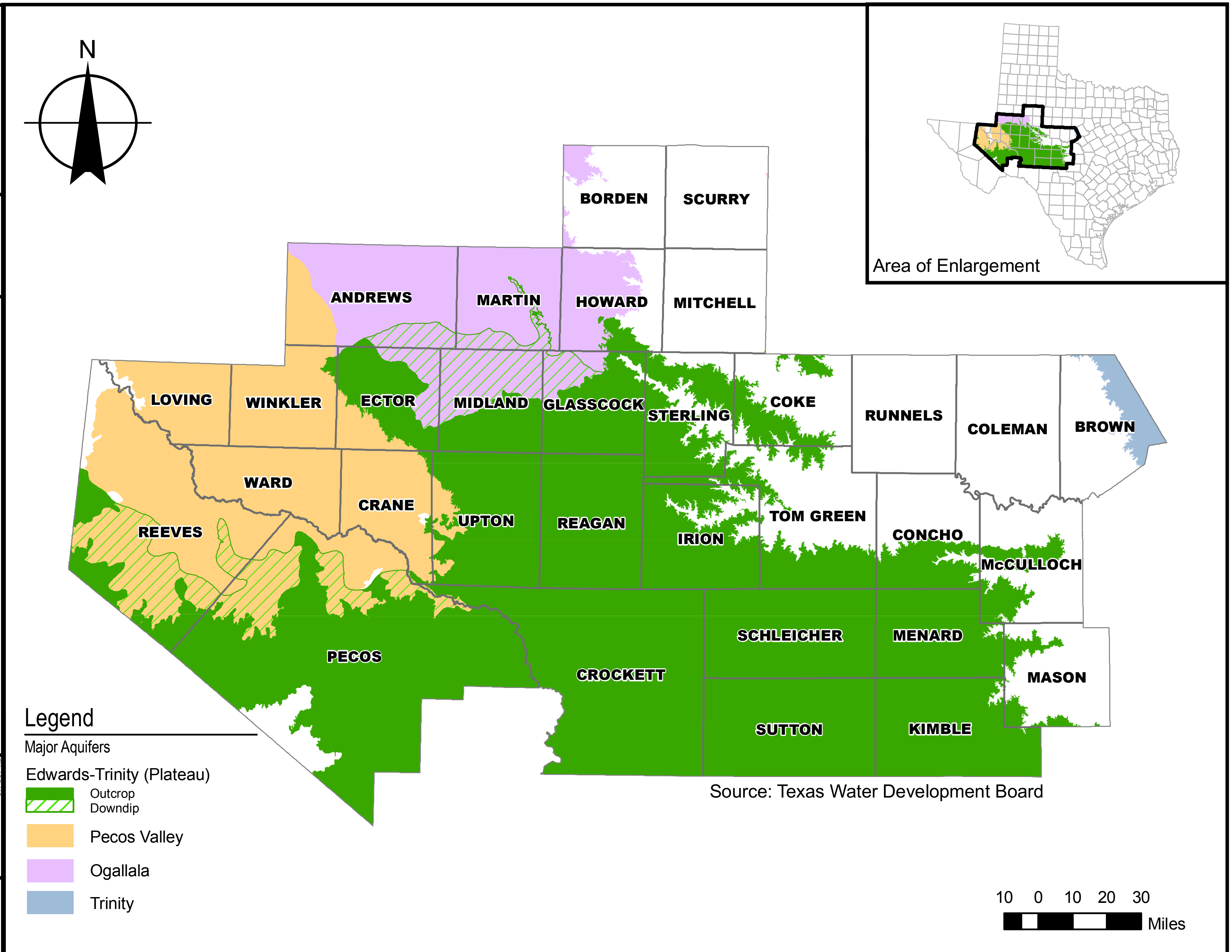
1.2 Current Water Uses and Demand Centers in Region F

Table 1.2-1 shows the total water use by county in Region F from 1997 through 2006. (Year 2006 data are the most recent available.)[9] Table 1.2-2 shows water use for the same period by TWDB use category and Figure 1.2-3 is a graph of the same data. Water use in Region F decreased somewhat between 1997 and 2003 and has increased in recent years. Most of these trends in water use are associated with irrigation. This may be attributed in part to changes by the TWDB in the reporting of irrigated agriculture water use after year 2000. Some of these changes include reporting of delivery losses associated with surface water irrigation systems, source of data for irrigated acreages (previous reporting was based on surveys by the Natural Resources Conservation Service and Texas Agricultural Statistics Service, while recent data is provided by the Farm Service Agency and local districts), and types of crops included for water use estimates. In addition to these factors, irrigated agriculture is subject to water use fluctuations due to availability of surface water, economic factors and government programs.

Table 1.2-3 shows water use by category and county in 2006, and Figure 1.2-4 shows the distribution of water use by county in the region. About 70 percent of the current water use in Region F is for irrigated agriculture. Municipal supply is the second largest category, followed by mining, steam electric power generation, livestock watering, and manufacturing.

The data in Table 1.2-3 and Figure 1.2-4 lead to the following observations about year 2006 water use in Region F:

- The areas with the highest water use are Reeves, Pecos, Tom Green, Midland and Glasscock Counties, accounting for over half of the total water used in the region.



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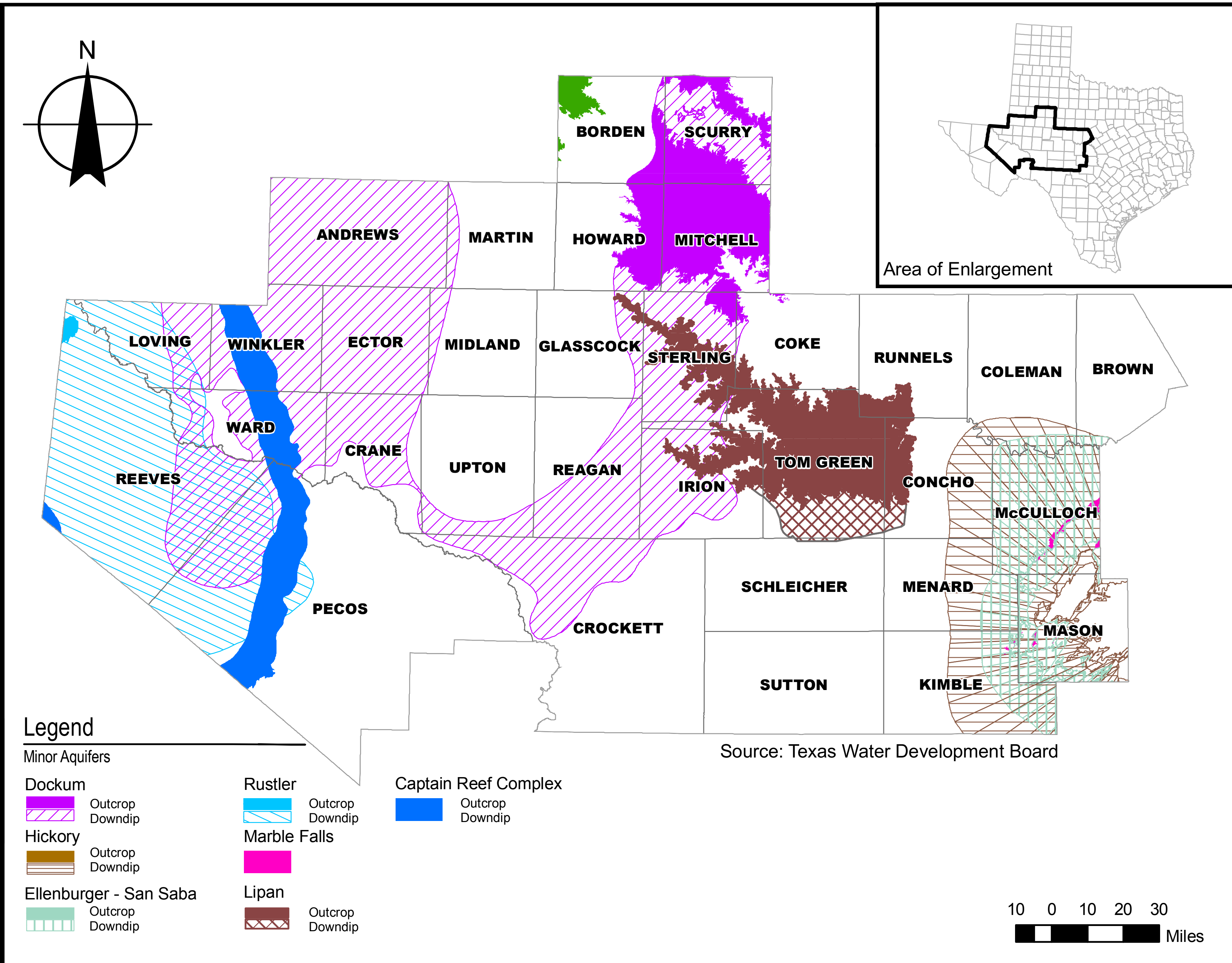
N W E S

Major Aquifer Map

Region F

FN JOB NO	FILE	DATE	SCALE	DESIGNED	DRAFTED
CMD07215	RegionF_MajAquifers.mxd	January 4, 2010	1:2,420,500	BME	BME

FIGURE 1.2-1



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N W E S

Minor Aquifer Map

Region F

FN JOB NO CMD07215
FILE RegionF_MinAquifers.mxd
DATE January 4, 2010
SCALE 1:2,420,500
DESIGNED BME
DRAFTED BME

FIGURE 1.2-2

Table 1.2-1
Historical Total Water Use by County in Region F
(Values in acre-feet)

County	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Andrews	23,139	18,901	17,633	24,187	34,446	34,197	38,924	33,419	35,943	35,219
Borden	11,071	4,096	3,547	3,187	3,202	3,491	3,357	3,604	3,895	3,488
Brown	23,456	27,286	26,161	21,374	19,660	18,851	16,013	14,312	16,162	19,165
Coke	2,347	3,434	2,525	2,846	2,863	2,674	1,984	2,562	2,499	1,965
Coleman	4,262	4,222	4,278	2,894	2,571	2,421	2,957	3,389	3,305	3,458
Concho	3,553	5,473	7,331	3,813	3,245	4,888	3,779	4,162	4,853	8,879
Crane	4,346	3,947	3,823	3,523	3,013	4,738	6,349	6,591	6,634	6,622
Crockett	6,058	4,929	4,761	3,863	3,565	3,208	2,928	2,903	3,069	2,498
Ector	39,242	32,072	32,258	61,697	45,246	30,539	31,709	29,318	32,520	32,915
Glasscock	52,825	62,642	24,920	35,828	26,126	26,758	45,427	44,641	44,612	46,924
Howard	14,923	16,129	17,399	15,716	14,478	13,323	16,464	14,275	17,630	13,785
Irion	3,558	2,493	2,285	2,724	2,244	2,279	3,006	2,140	1,991	1,247
Kimble	2,712	3,051	3,146	2,750	2,157	2,099	4,022	3,541	3,812	4,422
Loving	667	651	638	412	379	258	50	50	97	111
Martin	16,232	22,214	21,074	16,107	17,862	17,904	14,435	16,230	7,118	17,193
Mason	10,919	10,716	10,767	11,952	11,122	11,435	11,094	11,320	17,645	8,932
McCulloch	6,201	6,444	6,036	7,420	5,429	5,387	7,599	7,072	10,203	9,577
Menard	4,642	4,456	5,045	3,908	4,573	4,507	2,734	2,163	2,313	3,271
Midland	63,214	70,267	78,372	62,945	60,854	61,852	52,117	49,543	47,502	54,747
Mitchell	6,202	7,206	8,610	18,153	7,945	9,693	9,770	13,254	13,349	8,919
Pecos	85,785	87,948	89,417	80,436	72,170	68,314	43,271	47,793	52,352	74,653
Reagan	49,463	67,271	23,456	18,769	14,452	17,559	12,858	13,277	15,689	21,966
Reeves	115,958	113,892	128,338	79,453	81,792	68,776	38,797	94,104	98,122	94,581
Runnels	9,200	7,975	5,957	3,497	5,592	6,514	5,851	4,692	4,673	5,726
Schleicher	2,971	3,869	4,405	3,473	2,476	2,469	1,992	1,814	1,842	2,071
Scurry	8,150	7,513	9,791	9,094	7,193	8,200	8,952	9,790	10,588	10,289
Sterling	1,918	1,966	1,939	1,886	1,994	1,969	1,121	1,011	975	1,135
Sutton	4,273	2,170	4,276	3,483	3,163	3,087	2,031	1,813	3,103	3,265
Tom Green	133,483	75,645	63,786	53,396	62,970	61,759	57,857	71,030	66,285	70,681
Upton	19,462	29,166	10,804	16,139	11,328	11,643	11,274	10,631	11,598	12,079
Ward	19,391	22,558	19,318	23,171	19,484	12,537	8,911	9,600	10,042	10,871
Winkler	3,651	3,868	3,411	5,523	5,412	6,016	6,539	6,310	6,169	7,360
Total	*753,274*	*734,470*	*645,507*	*603,619*	*559,006*	*529,345*	*474,172*	*536,354*	*556,590*	598,014

Note: Data are from the Texas Water Development Board.
Data for Reeves County after 2003 includes all water released from the Red Bluff Reservoir. Approximately 25% of this water is delivered to customers in Pecos, Reeves, Ward and Loving Counties. The remaining 75% of the water is lost to evaporation and stream losses.

Table 1.2-2
Historical Water Use by Category in Region F
(Values in acre-feet)

Year	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining[a]	Livestock	Total
1997	121,510	7,581	556,928	15,405	31,892	19,958	753,274
1998	134,656	6,661	534,735	13,995	27,985	16,438	734,470
1999	131,308	6,429	448,573	13,772	27,985	17,440	645,507
2000	153,415	8,364	378,187	17,516	28,683	17,454	603,619
2001	131,104	10,861	365,952	11,089	23,477	16,523	559,006
2002	119,678	8,065	348,932	10,935	26,048	15,687	529,345
2003	129,580	7,017	289,196	9,272	25,962	13,145	474,172
2004	131,205	9,213	346,540	9,581	26,566	13,249	536,354
2005	128,464	9,951	367,682	9,593	26,905	13,995	556,590
2006	121,620	11,914	418,636	3,732	26,905	15,207	598,014
State Total in 2000	*4,047,661*	*1,559,912*	*10,228,528*	*561,394*	*278,624*	*300,441*	*16,976,560*
% of State Total in Region F	*3.17%*	*0.54%*	*3.86%*	*3.16%*	*10.54%*	*5.80%*	*3.51%*

Note: Data are from the Texas Water Development Board (TWDB).
a. Mining use data are from 2005.

Figure 1.2-3
Historical Water Use by Category in Region F

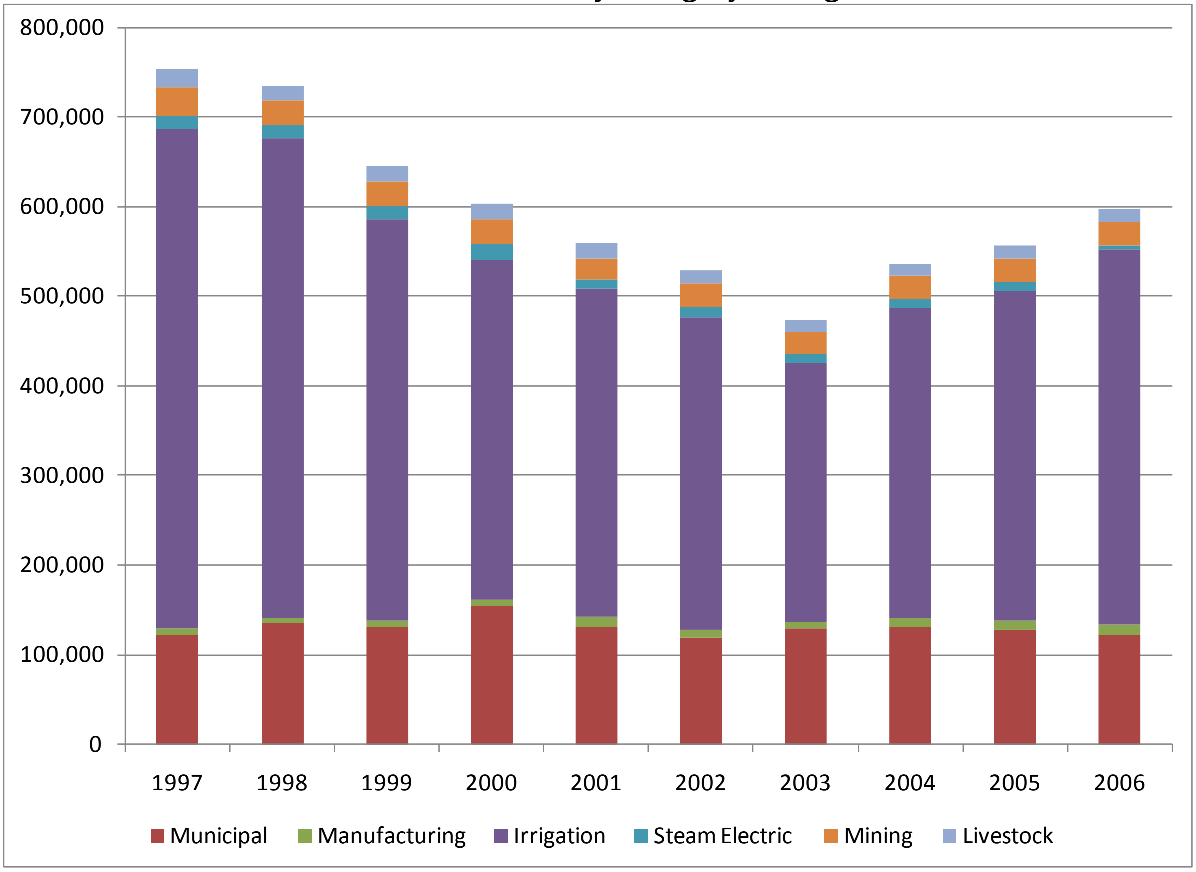


Table 1.2-3
Year 2006 Water Use by Category and County
(Values in acre-feet)

County	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining [a]	Livestock	Total
Andrews	2,736	47	30,459	0	1,702	275	35,219
Borden	144	0	2,322	0	806	216	3,488
Brown	6,747	422	9,467	0	1,227	1,302	19,165
Coke	389	0	965	0	293	318	1,965
Coleman	1,767	3	742	0	16	930	3,458
Concho	578	0	7,727	0	0	574	8,879
Crane	1,125	0	0	0	5,418	79	6,622
Crockett	1,267	41	485	0	24	681	2,498
Ector	24,749	2,185	1,450	0	4,283	248	32,915
Glasscock	145	0	46,579	0	7	193	46,924
Howard	5,785	2,233	3,155	604	1,793	215	13,785
Irion	198	0	700	0	125	224	1,247
Kimble	835	68	3,054	0	91	374	4,422
Loving	7	0	0	0	3	101	111
Martin	597	53	15,626	0	788	129	17,193
Mason	854	0	6,830	0	0	1,248	8,932
McCulloch	2,869	2,475	3,477	0	140	616	9,577
Menard	332	3	2,538	0	0	398	3,271
Midland	31,965	786	20,687	0	960	349	54,747
Mitchell	1,134	0	7,306	29	141	309	8,919
Pecos	4,220	88	69,056	0	356	933	74,653
Reagan	1,346	0	18,741	0	1,742	137	21,966
Reeves	3,264	1,433	88,925	0	97	862	94,581
Runnels	1,320	17	3,534	0	41	814	5,726
Schleicher	425	0	1,005	0	108	533	2,071
Scurry	1,918	8	5,707	0	2,152	504	10,289
Sterling	239	0	600	0	0	296	1,135
Sutton	1,110	0	1,677	0	108	370	3,265
Tom Green	17,853	1,940	49,140	0	59	1,689	70,681
Upton	770	4	7,301	0	3,885	119	12,079
Ward	3,042	0	4,469	3,099	189	72	10,871
Winkler	1,890	108	4,912	0	351	99	7,360
Total	*121,620*	*11,914*	*418,636*	*3,732*	*26,905*	*15,207*	*598,014*

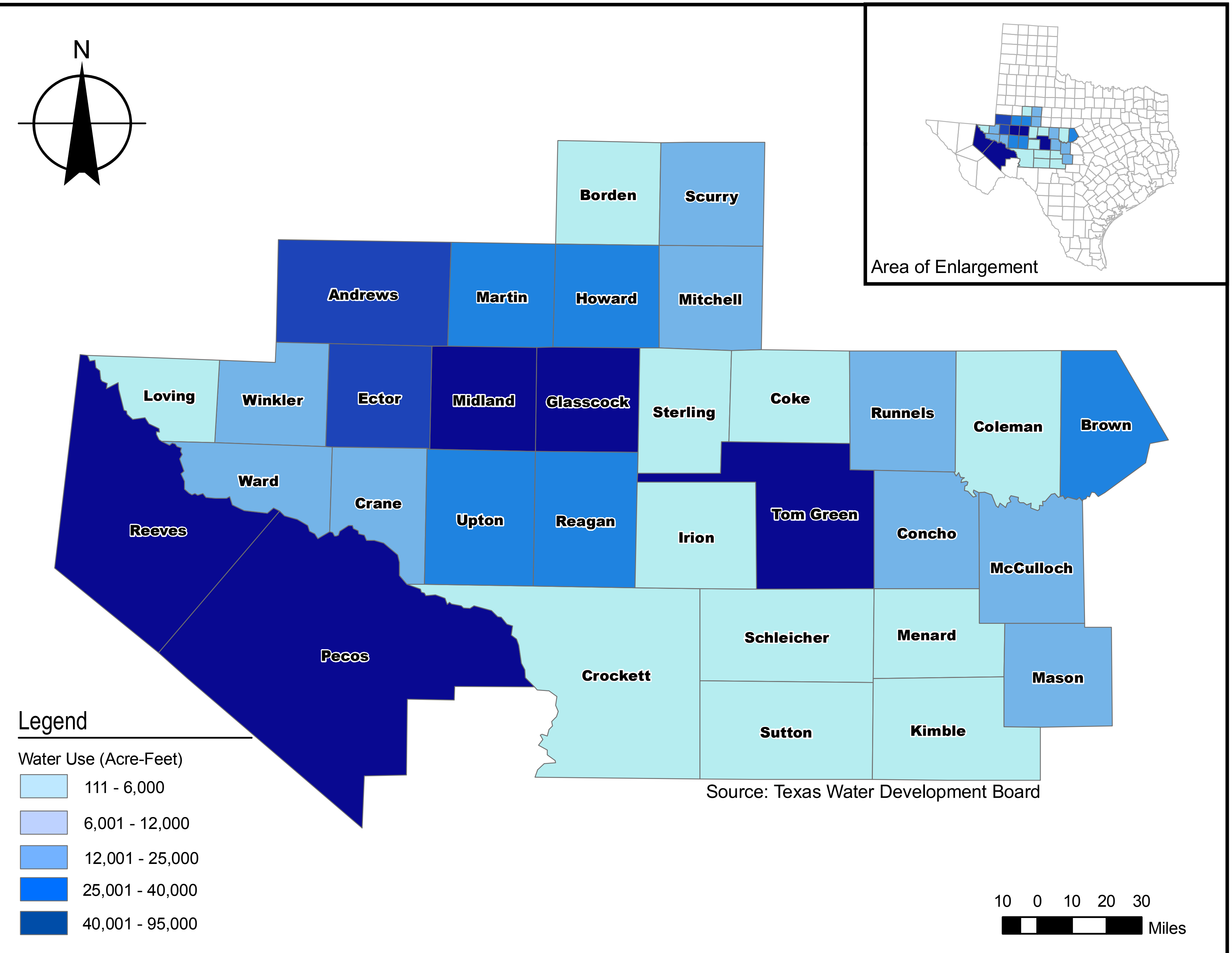
Note: Data are from the Texas Water Development Board.

a. Mining use data are from 2005.

b. Data for Reeves County includes all water released from the Red Bluff Reservoir. In accordance with TCEQ reports, 62,691 ac-ft of water was released. from Red Bluff Reservoir. Of this amount, 660 ac-ft was delivered for use in Reeves County and 8,533 ac-ft was delivered to customers in Pecos, Ward and Loving Counties. The remaining water was lost to evaporation and stream losses.

Region F

Water Use by County (2006)



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FN JOB NO	CMD07215
FILE	RegionFWaterUse.mxd
DATE	January 4, 2010
SCALE	1:2,401,000
DESIGNED	BME
DRAFTED	BME

FIGURE 1.2-4

- Most of the municipal water use occurred in Midland, Ector and Tom Green Counties, location of the cities of Midland, Odessa and San Angelo, respectively. In the year 2006 these counties accounted for almost 62 percent of the water use in this category. Other significant municipal demand centers include Brown County (Brownwood) and Howard County (Big Spring).
- Manufacturing water use is concentrated in Ector, Howard, Tom Green, McCulloch and Reeves Counties, accounting for 85 percent of the total use in this category.
- Reeves and Pecos Counties accounted for most of the reported irrigation water use in 2006, accounting for more than a third of the irrigation water use in the region. However, a large amount of the water reported for irrigation in Reeves County is associated with delivery losses from the Red Bluff Reservoir. The actual use of irrigation water in Reeves County is much less. Other significant demand centers for irrigation water include Glasscock, Andrews, Midland and Tom Green Counties.
- Steam-electric power generation water use occurred only in Ector, Howard, Mitchell, and Ward Counties. Facilities in other counties have temporarily or permanently ceased operations.
- Most of the water used for mining purposes occurred in Ector and Crane Counties, accounting for over 30 percent of the total use. Other significant areas of mining water use included Scurry, Upton, Brown, Andrews, Reagan, and Howard Counties. (Mining use data are from 2005. TWDB Data for 2006 are only self reported use which differs from previous estimates.)
- Most of the livestock water use occurred in Tom Green, Brown, and Mason Counties, accounting for slightly more than a quarter of the total use in this category in the year 2006.

In addition to the consumptive water uses discussed above, water-oriented recreation is important in Region F. Table 1.2-4 summarizes recreational opportunities at major reservoirs in the region. Smaller lakes and streams provide opportunities for fishing, boating, swimming, and other water-related recreational activities. Water in streams and lakes is also important to fish and wildlife in the region, providing a wide variety of habitats.

Table 1.2-4
Recreational Use of Reservoirs in Region F

Reservoir Name	County	Fishing	Boat Launch	Swimming Area	Marina	Picnic Area	Camping	Hiking Trails	Back-packing	Bicycle Trails	Equestrian Trails	Pavilion Area
Lake J. B. Thomas	Borden and Scurry	X	X			X	X					X
Lake Colorado City	Mitchell	X	X	X		X	X					
Champion Creek Reservoir	Mitchell											
Oak Creek Reservoir	Coke	X	X	X								
Lake Coleman	Coleman	X	X	X		X	X					
E. V. Spence Reservoir	Coke	X	X		X	X	X					X
Lake Winters/ New Lake Winters	Runnels	X	X	X	X	X	X	X				X
Lake Brownwood	Brown	X	X	X		X	X	X				
Hords Creek Lake	Coleman	X	X	X		X	X	X		X		
Lake Ballinger / Lake Moonen	Runnels	X	X	X		X	X		X			
O. H. Ivie Reservoir	Concho and Coleman	X	X		X	X	X	X				X
O. C. Fisher Lake	Tom Green	X	X	X		X	X	X		X	X	X
Twin Buttes Reservoir	Tom Green	X	X	X		X	X					
Lake Nasworthy	Tom Green	X	X	X	X	X	X			X		X
Brady Creek Reservoir	McCulloch	X	X	X	X	X	X	X	X		X	X
Mountain Creek	Coke											
Red Bluff Reservoir	Reeves and Loving											
Lake Balmorhea	Reeves			X		X	X					

Note: "X" indicates that the activity is available at the specified reservoir.

1.3 Current Sources of Water

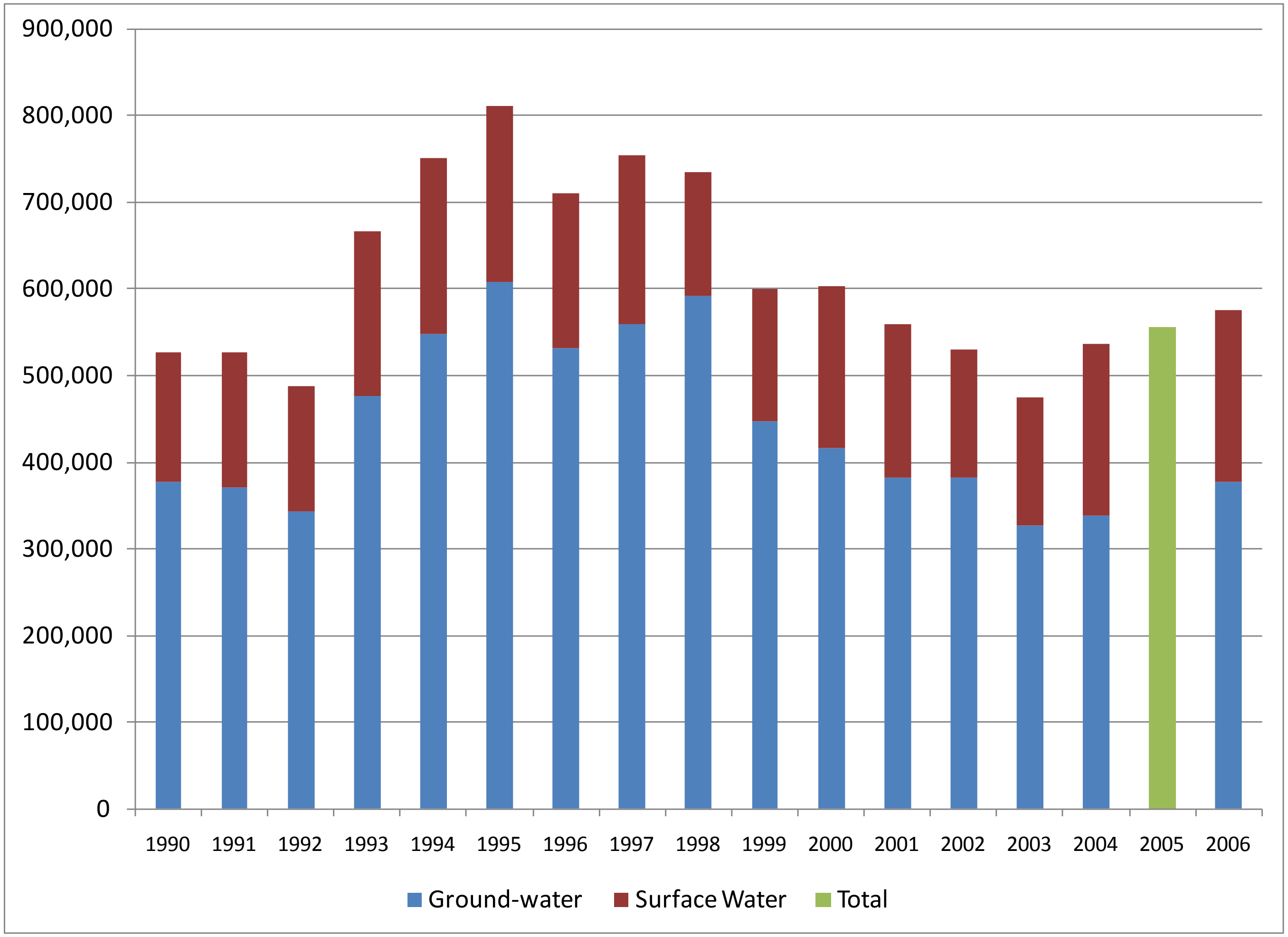
Table 1.3-1 summarizes the total surface water and groundwater use in Region F from 1990 through 2006, and Figure 1.3-1 graphically illustrates the same data. (2006 is the latest year for which the split between groundwater and surface water use is available.) Total historical water use peaked in 1995. Groundwater use has followed a similar trend ranging from 80 percent of total water use in 1998 to 66 percent in 2006. Total water use increased by 48,236 acre-feet (9.1 percent) between 1990 and 2006. Groundwater use increased by 1,162 acre feet (0.3 percent) and surface water use increased by 47,074 acre-feet (31.3 percent) over the same period. Total water use was significantly higher between 1993 and 1998 than the rest of the decade. The reduction in water use at the end of the decade was primarily due to unusually hot, dry weather associated with a significant drought, suppressing the amount of water available for irrigation. Table 1.3-2 shows the distribution of groundwater and surface water use by county and category for 2006, which is the most recent year for which data are available. Figure 1.3-2 shows the percentage of supply from groundwater for each county in the region in the same year.

Table 1.3-1
Historical Groundwater and Surface Water Use in Region F

Year	Water Use in Acre-Feet		
	Ground-water	Surface Water	Total
1990	376,891	150,339	527,230
1991	371,311	154,848	526,159
1992	343,522	143,559	487,081
1993	476,492	190,465	666,957
1994	547,948	202,740	750,688
1995	607,802	203,160	810,962
1996	531,956	177,836	709,792
1997	559,393	193,881	753,274
1998	591,390	143,123	734,513
1999	447,738	151,241	598,979
2000	417,179	186,681	603,860
2001	382,724	176,282	559,006
2002	382,087	147,258	529,345
2003	326,588	147,584	474,172
2004	338,316	198,038	536,354
2005			556,590*
2006	394,127	203887	598,014

Note: Data are from Texas Water Development Board. *2005 data were not broken by groundwater/surface water at the time of this plan.

Figure 1.3-1
Historical Groundwater and Surface Water Use in Region F



*2005 data were not broken by groundwater/surface water at the time of this plan.

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Region F

Supplies from Groundwater by County (2006)

FN JOB NO	CMD07215
FILE	RegionF_GWUse.mxd
DATE	January 4, 2010
SCALE	1:2,420,500
DESIGNED	BME
DRAFTED	BME

FIGURE 1.3-2

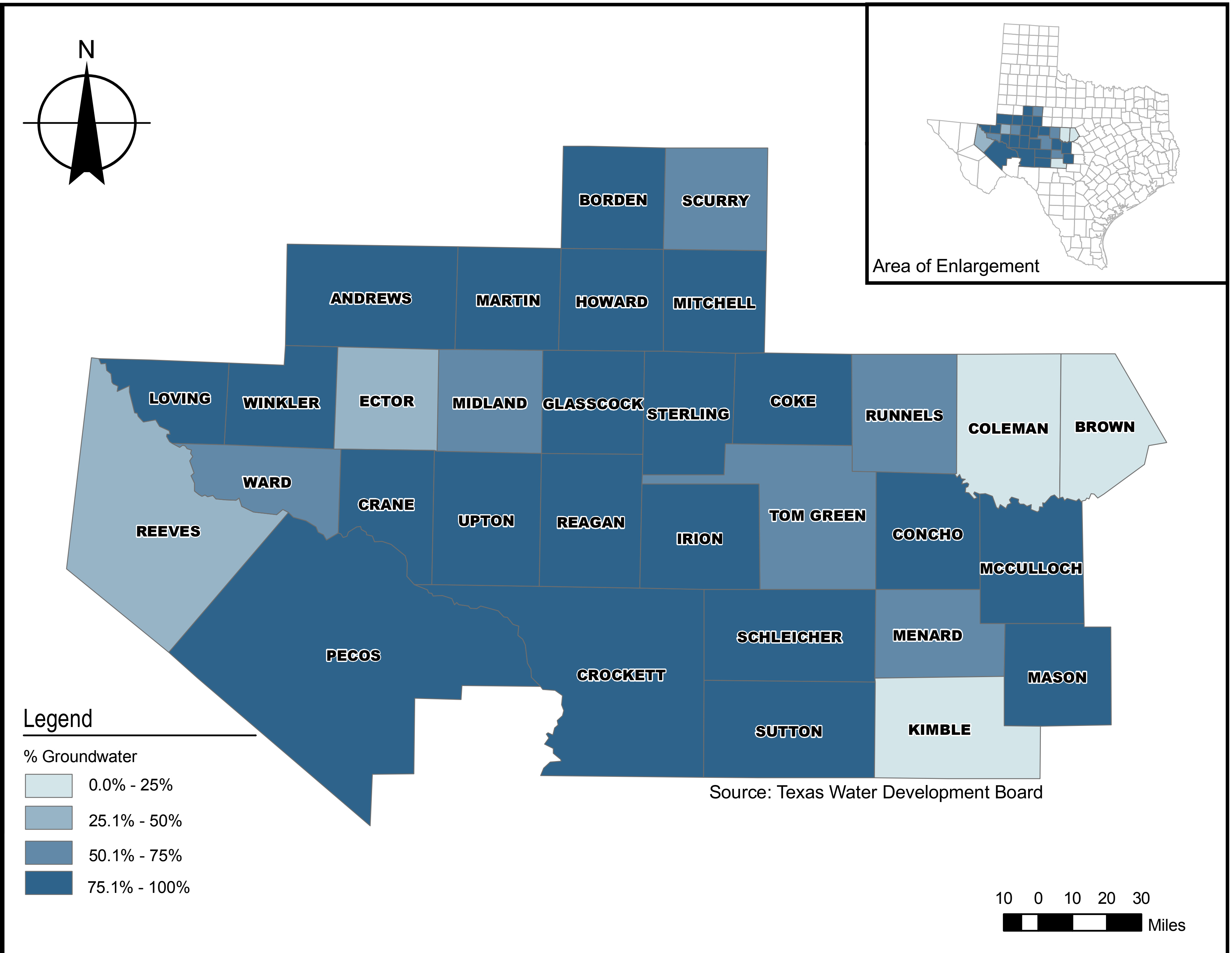


Table 1.3-2
Source of Supply by County and Category in 2006 for Region F
(Values in Acre-Feet)

County	Source of Water	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining[a]	Livestock	*Total*
Andrews	Ground	2,736	47	30,459	0	1,702	275	35,219
	Surface	0	0	0	0	0	0	0
	Total	2,736	47	30,459	0	1,702	275	35,219
Borden	Ground	144	0	2,322	0	806	65	3,337
	Surface	0	0	0	0	0	151	151
	Total	144	0	2,322	0	806	216	3,488
Brown	Ground	106	0	45	0	72	195	418
	Surface	6,641	422	9,422	0	1,155	1,107	18,747
	Total	6,747	422	9,467	0	1,227	1,302	19,165
Coke	Ground	173	0	937	0	178	248	1,536
	Surface	216	0	28	0	115	70	429
	Total	389	0	965	0	293	318	1,965
Coleman	Ground	0	3	0	0	16	28	47
	Surface	1,767	0	742	0	0	902	3,411
	Total	1,767	3	742	0	16	930	3,458
Concho	Ground	574	0	7,632	0	0	287	8,493
	Surface	4	0	95	0	0	287	386
	Total	578	0	7,727	0	0	574	8,879
Crane	Ground	1,125	0	0	0	2,712	75	3,912
	Surface	0	0	0	0	2,706	4	2,710
	Total	1,125	0	0	0	5,418	79	6,622
Crockett	Ground	1,267	41	485	0	4	647	2,444
	Surface	0	0	0	0	20	34	54
	Total	1,267	41	485	0	24	681	2,498
Ector	Ground	4,019	2,179	25	0	3,533	223	9,979
	Surface	20,730	6	1,425	0	750	25	22,936
	Total	24,749	2,185	1,450	0	4,283	248	32,915
Glasscock	Ground	145	0	46,579	0	7	154	46,885
	Surface	0	0	0	0	0	39	39
	Total	145	0	46,579	0	7	193	46,924
Howard	Ground	5,483	590	3,155	0	189	183	9,600
	Surface	302	1,643	0	604	1,604	32	4,185
	Total	5,785	2,233	3,155	604	1,793	215	13,785
Irion	Ground	198	0	700	0	125	179	1,202
	Surface	0	0	0	0	0	45	45
	Total	198	0	700	0	125	224	1,247
Kimble	Ground	211	2	24	0	91	262	590
	Surface	624	66	3,030	0	0	112	3,832
	Total	835	68	3,054	0	91	374	4,422
Loving	Ground	7	0	0	0	3	99	109
	Surface	0	0	0	0	0	2	2
	Total	*7*	*0*	*0*	*0*	*3*	*101*	*111*

Table 1.3-2 (cont.): Source of Supply by County and Category in 2006 for Region F

County	Source of Water	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining[a]	Livestock	*Total*
Martin	Ground	303	53	15,626	0	788	90	16,860
	Surface	294	0	0	0	0	39	333
	Total	*597*	*53*	*15,626*	*0*	*788*	*129*	*17,193*
Mason	Ground	854	0	6,775	0	0	936	8,565
	Surface	0	0	55	0	0	312	367
	Total	854	0	6,830	0	0	1,248	8,932
McCulloch	Ground	2,553	2,475	2,943	0	140	493	8,604
	Surface	316	0	534	0	0	123	973
	Total	*2,869*	*2,475*	*3,477*	*0*	*140*	*616*	*9,577*
Menard	Ground	332	3	1,559	0	0	338	2,232
	Surface[b]	0	0	979	0	0	60	1,039
	Total	*332*	*3*	*2,538*	*0*	*0*	*398*	*3,271*
Midland	Ground	7,363	786	20,687	0	960	346	30,142
	Surface	24,602	0	0	0	0	3	24,605
	Total	*31,965*	*786*	*20,687*	*0*	*960*	*349*	*54,747*
Mitchell	Ground	1,108	0	7,306	17	0	77	8,508
	Surface	26	0	0	12	141	232	411
	Total	1,134	0	7,306	29	141	309	8,919
Pecos	Ground	4,220	88	61,906	0	356	886	67,456
	Surface	0	0	7,150	0	0	47	7,197
	Total	4,220	88	69,056	0	356	933	74,653
Reagan	Ground	1,346	0	18,741	0	1,742	123	21,952
	Surface	0	0	0	0	0	14	14
	Total	1,346	0	18,741	0	1,742	137	21,966
Reeves	Ground	3,230	1,433	18,925	0	97	862	24,547
	Surface[c]	34	0	70,000	0	0	0	70,034
	Total	3,264	1,433	88,925	0	97	862	94,581
Runnels	Ground	129	0	2,663	0	41	407	3,240
	Surface	1,191	17	871	0	0	407	2,486
	Total	1,320	17	3,534	0	41	814	5,726
Schleicher	Ground	425	0	1,005	0	108	506	2,044
	Surface	0	0	0	0	0	27	27
	Total	425	0	1,005	0	108	533	2,071
Scurry	Ground	227	0	5,623	0	2,150	126	8,126
	Surface	1,691	8	84	0	2	378	2,163
	Total	1,918	8	5,707	0	2,152	504	10,289
Sterling	Ground	239	0	600	0	0	266	1,105
	Surface	0	0	0	0	0	30	30
	Total	239	0	600	0	0	296	1,135
Sutton	Ground	1,110	0	1,677	0	108	363	3,258
	Surface	0	0	0	0	0	7	7
	Total	1,110	0	1,677	0	108	370	3,265

Table 1.3-2 (cont.): Source of Supply by County and Category in 2006 for Region F

County	Source of Water	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining[a]	Livestock	*Total*
Tom Green	Ground	2,085	332	33,086	0	59	1,351	36,913
	Surface	15,768	1,608	16,054	0	0	338	33,768
	Total	*17,853*	*1,940*	*49,140*	*0*	*59*	*1,689*	*70,681*
Upton	Ground	770	4	7,301	0	3,885	119	12,079
	Surface	0	0	0	0	0	0	0
	Total	*770*	*4*	*7,301*	*0*	*3,885*	*119*	*12,079*
Ward	Ground	3,042	0	969	3,099	189	68	7,367
	Surface	0	0	3,500	0	0	4	3,504
	Total	*3,042*	*0*	*4,469*	*3,099*	*189*	*72*	*10,871*
Winkler	Ground	1,890	108	4,912	0	351	97	7,358
	Surface	0	0	0	0	0	2	2
	Total	*1,890*	*108*	*4,912*	*0*	*351*	*99*	*7,360*
Total	*Ground*	*47,414*	*8,144*	*304,667*	*3,116*	*20,412*	*10,374*	*394,127*
	Surface	*74,206*	*3,770*	*113,969*	*616*	*6,493*	*4,833*	*203,887*
	Total	*121,620*	*11,914*	*418,636*	*3,732*	*26,905*	*15,207*	*598,014*

Source: Data are based on draft report of year 2006 usage from the Texas Water Development Board.

a. Mining use shown is for 2005.

b. The City of Menard's water supply comes from several wells on the banks of the San Saba River. Historically, the city's water supply has been classified as surface water.

c. Reeves County surface water for irrigation includes all delivery losses associated with the Red Bluff Reservoir. Actual surface water use for irrigation is much less.

1.3.1 Surface Water Sources

Table 1.3-3 summarizes permitted surface water diversions by use category for each county in Region F. (These categories differ slightly from the demand categories used by TWDB for regional water planning.) Table 1.3-3 does not include non-consumptive use categories such as recreation. Figure 1.3-3 shows the distribution of permitted diversions by county. Most of the large surface water diversions in Region F are associated with major reservoirs. Table 1.1-4 in Section 1.1.2 lists the permitted diversions and the reported year 2006 water use from major water supply reservoirs in the region.

Region F does not import a significant amount of surface water from other regions. Region F exports a significant amount of water to two cities in Region G: Sweetwater and Abilene. The City of Sweetwater owns and operates Oak Creek Reservoir, a 30,000 acre-feet reservoir in Coke County. The City of Sweetwater used an average of 1,500 acre-feet per year from Oak Creek

Reservoir between 1980 and 2006. The West Central Texas Municipal Water District has a contract with the Colorado River Municipal Water District (CRMWD) for 15,000 acre-feet per year of water from O.H. Ivie Reservoir to supply the City of Abilene. Facilities to transfer water from Lake O.H. Ivie to Abilene became operational in September 2003. The pipeline has an initial peak capacity of 20 million gallons per day (MGD) with an ultimate capacity of 24 MGD. Currently Abilene is receiving an average of approximately 8 MGD (9,000 acre-feet per year) from O.H. Ivie. Small amounts of surface water are also supplied to the Cities of Lawn and Rotan, both of which are in Region G. Several rural water supply corporations also supply small amounts of surface water to neighboring regions.

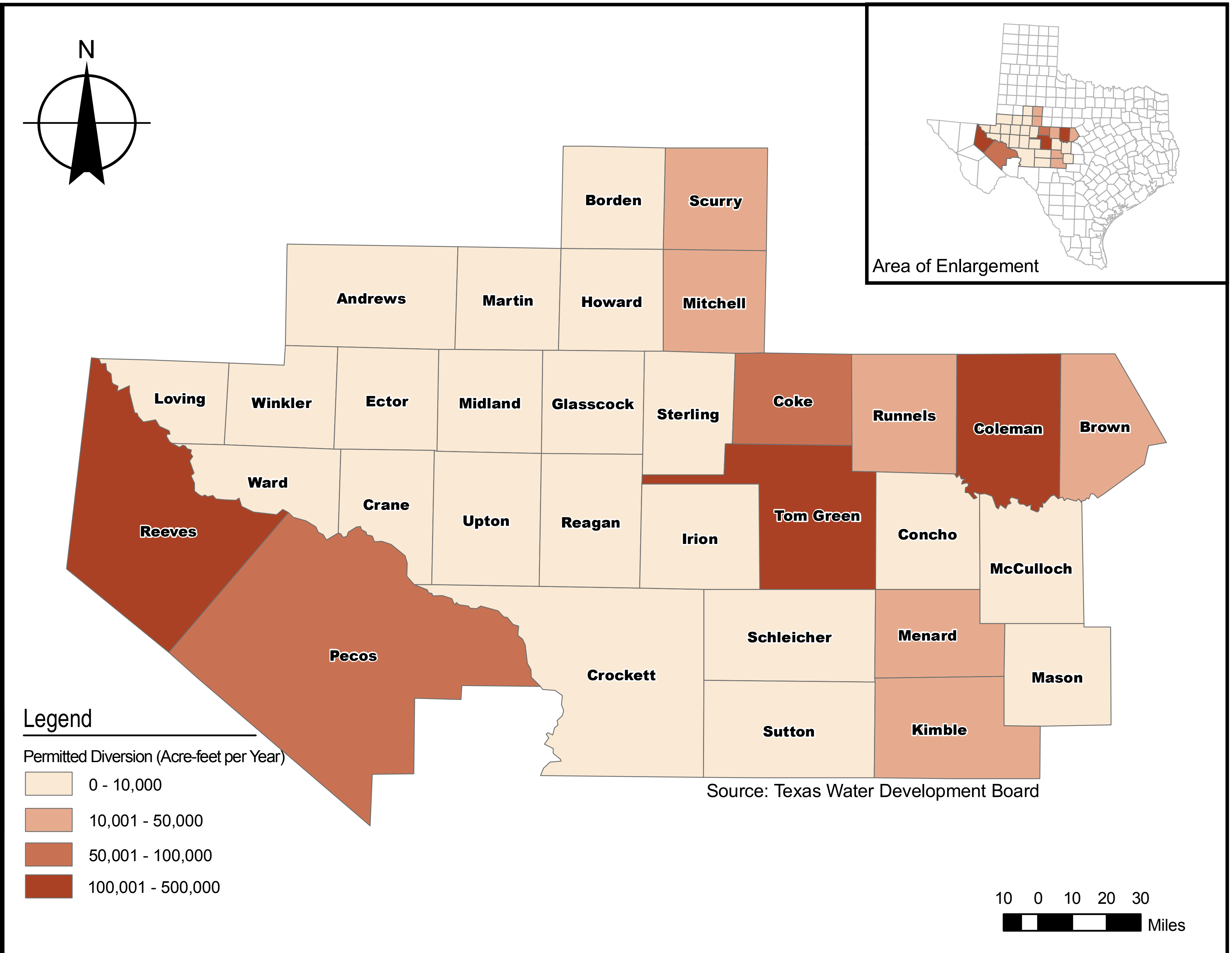
Table 1.3-3
Surface Water Rights by County and Category

County	Permitted Surface Water Diversions (Acre-Feet per Year)					
	Municipal	Industrial	Irrigation	Mining	Other	Total
Borden	200	0	63	0	0	263
Brown	31,360	0	8,859	0	0	40,219
Coke	47,865	6,135	869	9,634[a]	0	64,503
Coleman [b]	127,192	14,509	6,362	0	0	148,063
Concho	70	0	2,476	0	16	2,562
Ector	0	0	3,200	0	0	3,200
Howard	1,700	0	89	5,715	0	7,504
Irion	0	0	5,421	0	0	5,421
Kimble	1,000	2,466	8,486	60	0	12,012
Martin	0	2,500	0	0	0	2,500
Mason	0	0	356	0	0	356
McCulloch	3,500	0	2,152	0	0	5,652
Menard	1,016	0	10,597	3	0	11,616
Mitchell	8,200	4,050	123	0	0	12,373
Pecos	0	0	66,902	0	0	66,902
Reeves [c]	1,890	0	412,352	0	0	414,242
Runnels	2,919	0	7,024	70	0	10,013
Schleicher	0	0	38	3	0	41
Scurry [d]	30,050	0	503	0	0	30,553
Sterling	0	0	168	0	0	168
Sutton	0	0	99	3	0	102
Tom Green	138,434	15,002	41,019	0	0	194,462
Total	*395,396*	*44,662*	*577,158*	*15,488*	*16*	*1,032,720*

a Includes up to 6,000 acre-feet per year that can be diverted and used in Mitchell or Howard Counties
b Includes water rights for Ivie Reservoir, which is located in Coleman, Concho and Runnels Counties.
c Includes rights for Red Bluff Reservoir, which is located in Loving and Reeves Counties.
d Includes rights for Lake J.B. Thomas, which is located in Borden and Scurry Counties.
Note: Data are from TCEQ's active water rights list.[10] Other counties have no permitted water rights on the TCEQ list. Does not include recreation rights.

Region F

Total Permitted Surface Water Diversion by County



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N W E S

FN JOB NO: CMD07215
FILE: RegionF_Diversion.mxd
DATE: January 4, 2010
SCALE: 1:2,420,500
DESIGNED: BME
DRAFTED: BME

FIGURE 1.3-3

1.3.2 Groundwater Sources

There are eleven aquifers that supply water to the 32 counties of Region F: four major aquifers (Edwards-Trinity Plateau, Ogallala, Pecos Valley, and Trinity) and seven minor aquifers (Dockum, Hickory, Lipan, Ellenberger-San Saba, Marble Falls, Rustler and the Capitan Reef Complex). Figure 1.2-1 shows the major aquifers and Figure 1.2-2 shows the minor aquifers in Region F. The TWDB defines a major aquifer as an aquifer that supplies large quantities of water to large areas.[11] Minor aquifers supply large quantities of water to small areas, or relatively small quantities of water to large areas. The Trinity aquifer is considered a major aquifer by the TWDB because it supplies large quantities of water in other regions. However, the Trinity aquifer covers only a small portion of Region F in Brown County and supplies a relatively small amount of water in the region.

Table 1.3-4 shows the 2003 groundwater use by county and aquifer, the latest year for which these data are available. The Edwards-Trinity Plateau, Pecos Valley and Ogallala are the largest sources of groundwater in Region F, providing 36.0 percent, 24.7 percent and 16.7 percent of the total groundwater pumped in 2003, respectively. The Lipan aquifer provided almost 8 percent of the 2003 totals, with all remaining aquifers contributing 14.6 percent combined. Groundwater pumping is highest in Andrews, Reeves, Midland, Pecos, Glasscock, and Tom Green Counties. These six counties account for 63 percent of the region's total pumping.

Groundwater conservation districts are the preferred method for managing groundwater in the State of Texas. There are 15 Underground Water Conservation Districts (GCDs) in Region F. Figure 1.3-4 is a map of the jurisdictional boundaries of the Districts. These entities are required to develop and adopt comprehensive management plans, permit wells that are drilled, completed or equipped to produce more than 25,000 gallons per day, keep records of well completions, and make information available to state agencies. Other powers granted to GCDs are prevention of waste, conservation, recharge projects, research, distribution and sale of water, and making rules regarding transportation of groundwater outside of the district.[12]

Table 1.3-4
2003 Groundwater Pumping by County and Aquifer
(Values in Acre-Feet)

County	Edwards -Trinity Plateau	Ogallala	Pecos Valley	Lipan	Hickory	Dockum	Trinity	Ellen-berger-San Saba	Marble Falls	Edwards -Trinity High Plains	Rustler	Other	*Total*
Andrews	23	39,096	155	0	0	4	0	0	0	0	0	0	39,278
Borden	0	2,227	0	0	0	0	0	0	0	8	0	861	3,096
Brown	0	0	0	0	0	0	2,123	0	0	0	0	143	2,266
Coke	51	0	0	0	0	0	0	0	0	0	0	664	715
Coleman	0	0	0	0	0	0	13	0	0	0	0	39	52
Concho	92	0	0	1,495	506	0	0	0	0	0	0	265	2,358
Crane	0	0	3,011	0	0	13	0	0	0	0	64	0	3,088
Crockett	2,169	0	0	0	0	0	0	0	0	0	0	0	2,169
Ector	5,554	917	36	0	0	403	0	0	0	0	0	0	6,910
Glasscock	38,943	6,392	0	0	0	0	0	0	0	0	0	0	45,335
Howard	770	3,134	0	0	0	98	0	0	0	0	0	0	4,002
Irion	435	0	0	0	0	0	0	0	0	0	0	360	795
Kimble	590	0	0	0	0	0	0	0	0	0	0	0	590
Loving	0	0	36	0	0	7	0	0	0	0	0	0	43
Martin	0	14,740	0	0	0	0	0	0	0	0	0	0	14,740
Mason	0	0	0	0	10,415	0	0	207	199	0	0	0	10,821
McCulloch	11	0	0	0	6,404	0	0	242	10	0	0	128	6,795
Menard	558	0	0	0	0	0	0	8	0	0	0	38	604
Midland	9,323	14,744	0	0	0	0	0	0	0	0	0	0	24,067
Mitchell	0	0	0	0	0	6,950	0	0	0	0	0	5	6,955
Pecos	28,710	0	13,981	0	0	0	0	0	0	0	684	3	43,378
Reagan	12,481	0	0	0	0	103	0	0	0	0	0	0	12,584
Reeves	252	0	23,944	0	0	1,061	0	0	0	0	26	0	25,283
Runnels	0	0	0	0	0	0	0	0	0	0	0	2,335	2,335
Schleicher	1,970	0	0	0	0	0	0	0	0	0	0	0	1,970
Scurry	0	0	0	0	0	4,807	0	0	0	0	0	304	5,111
Sterling	309	0	0	0	0	0	0	0	0	0	0	795	1,104
Sutton	1,987	0	0	0	0	0	0	0	0	0	0	0	1,987
Tom Green	1,572	0	0	23,896	0	0	0	0	0	0	0	3,973	29,441
Upton	12,570	0	0	0	0	12	0	0	0	0	0	0	12,582
Ward	0	0	13,263	0	0	1,367	0	0	0	0	0	0	14,630
Winkler	0	0	504	0	0	3,014	0	0	0	0	0	0	3,518
Total	*118,370*	*81,250*	*54,930*	*25,391*	*17,325*	*17,839*	*2,136*	*457*	*209*	*8*	*774*	*9,913*	*328,602*

Note: Data are from the Texas Water Development Board. 2003 is the most recent year data were available by aquifer.

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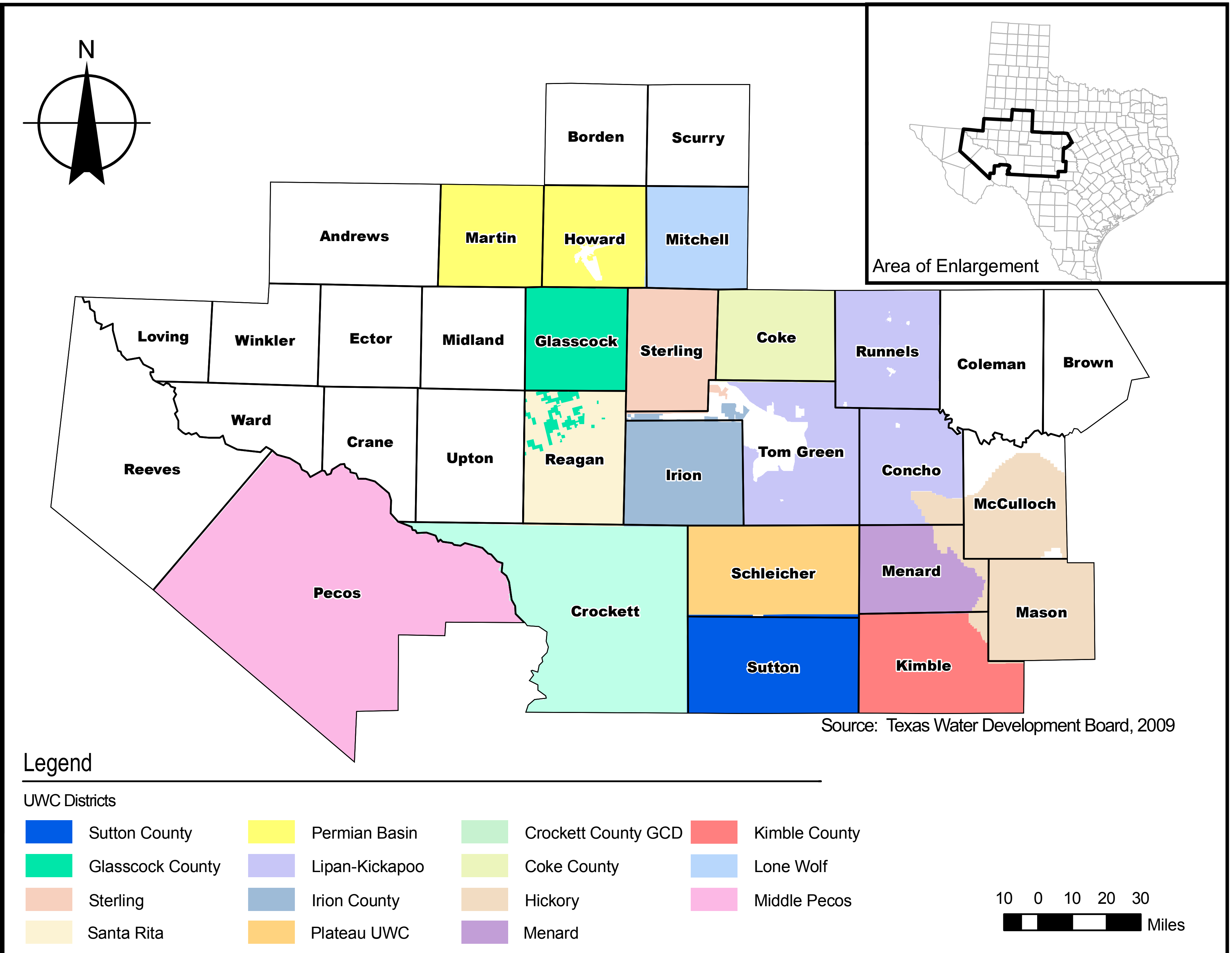
Region F

Underground Water Conservation Districts



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BME	BME	1:2,421,500	January 4, 2010	RegionF_UWCD.mxd	CMD07215

FIGURE 1.3-4

Ten of the GCDs in Region F form the West Texas Regional Groundwater Alliance, an organization that promotes the conservation, preservation and beneficial use of water and related resources in the region. Seven of the GCDs are also members of the West Texas Weather Modification Association, a group that performs rainfall enhancement activities in a seven county area.

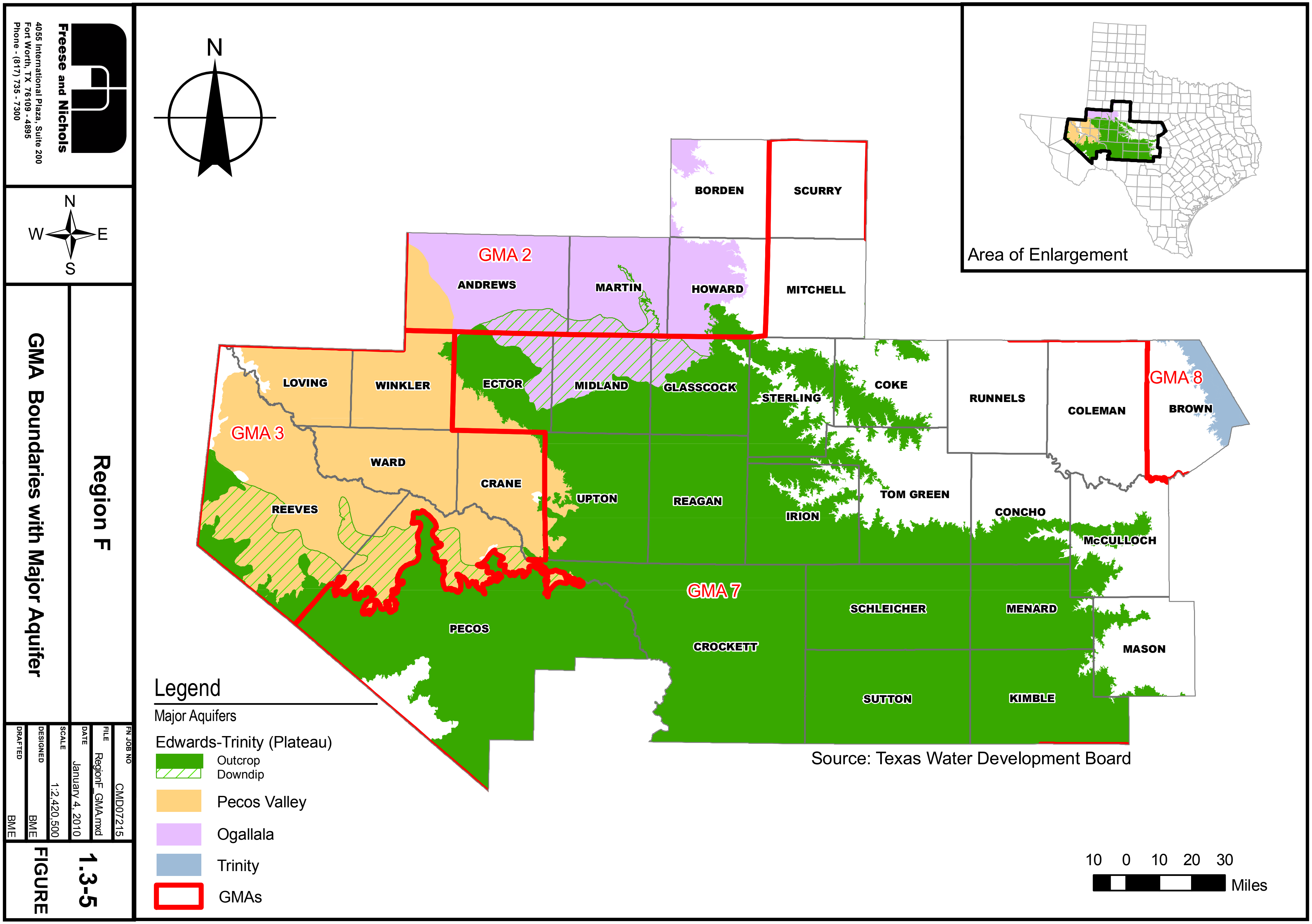
The GCDs also are participating in a joint planning initiative for groundwater through Groundwater Management Areas (GMAs). The State Legislature designated 16 GMAs to coincide with major aquifers in the State of Texas. Each GMA is tasked with determining Desired Future Conditions for the aquifers in the management area for planning purposes. There are four GMAs that include one or more counties in Region F: GMA-7, GMA-4, GMA-2, and GMA-8. The GMA coverage in Region F is shown in Figure 1.3-5. Additional information on the GMA process and groundwater availability is included in Chapter 3.

1.3.3 Springs in Region F

Springs in Region F have been important sources of water supply since prehistoric times and have had great influence on early transportation routes and patterns of settlement. However, groundwater development and the resulting water level declines have caused many springs to disappear over time and have greatly diminished the flow from many of those that remain. Even though springflows are declining throughout the region due to groundwater development, brush infestation, and climatic conditions, many still are important sources of water.

Several rivers in Region F have significant spring-fed flows, including tributary creeks to the Concho and the San Saba Rivers, which are directly or indirectly used for municipal and irrigation purposes in the region.

Many springs are also important to the region for natural resources purposes. The Diamond Y Springs in northern Pecos County and the Balmorhea spring complex in southern Reeves County flow continuously and are important habitat for endangered species. Also in Pecos County, the historically significant Comanche Springs flow occasionally during winter months when there is less stress on the underlying aquifer.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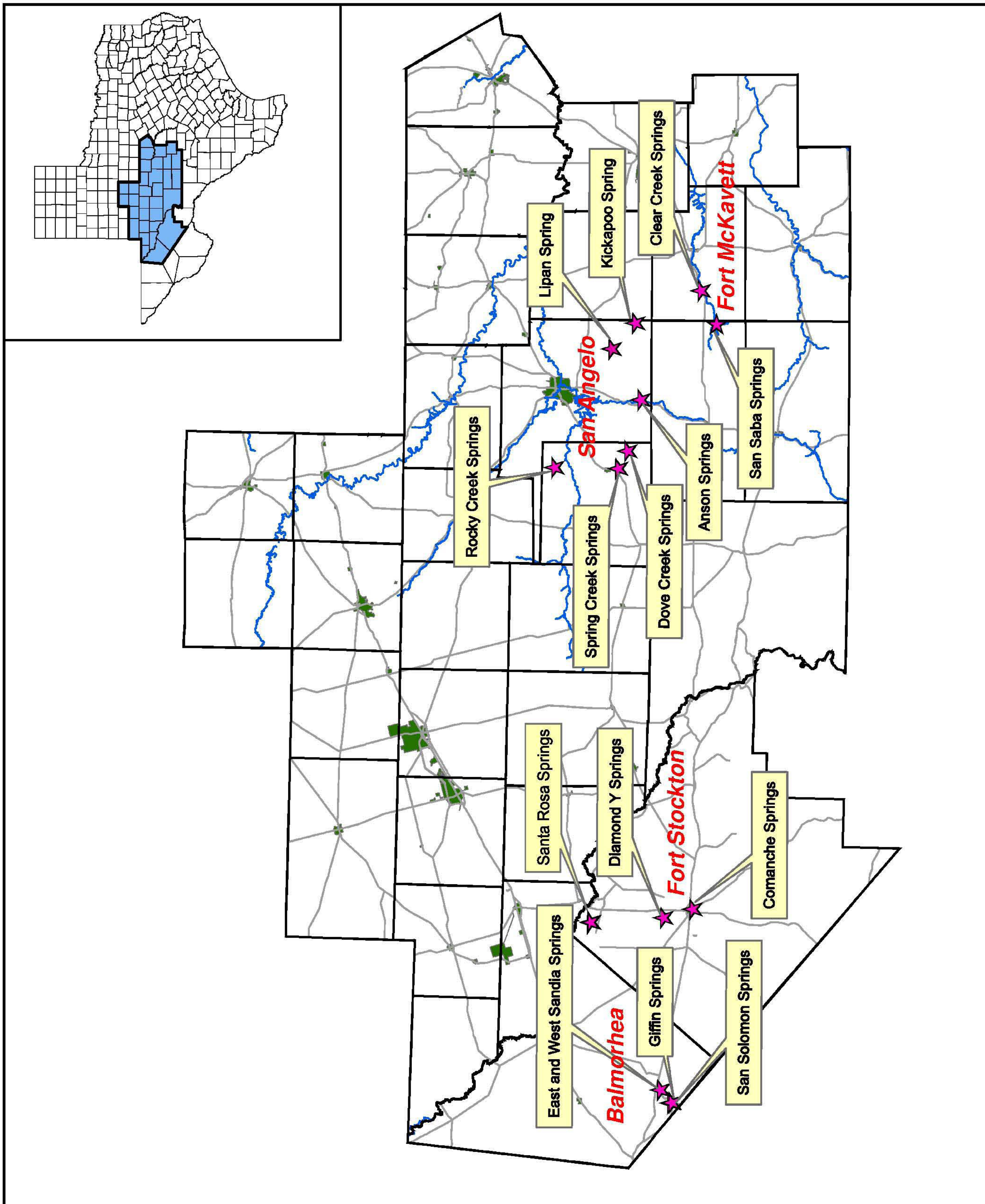
GMA Boundaries with Major Aquifer
Region F
DRAFTED BME
DESIGNED BME
SCALE 1:2,420,500
DATE January 4, 2010
FILE RegionF_GMA.mxd
FN JOB NO CMD07215
FIGURE 1.3-5
N
Area of Enlargement
GMA 2
GMA 3
GMA 7
GMA 8
BORDEN
SCURRY
ANDREWS
MARTIN
HOWARD
MITCHELL
LOVING
WINKLER
ECTOR
MIDLAND
GLASSCOCK
STERLING
COKE
RUNNELS
COLEMAN
BROWN
WARD
CRANE
UPTON
REAGAN
IRION
TOM GREEN
CONCHO
McCULLOCH
REEVES
PECOS
CROCKETT
SCHLEICHER
MENARD
MASON
SUTTON
KIMBLE
Legend
Major Aquifers
Edwards-Trinity (Plateau)
Outcrop
Downdip
Pecos Valley
Ogallala
Trinity
GMAs
Source: Texas Water Development Board
10 0 10 20 30
Miles

The Region F Planning Group has identified 14 major springs in the region that are important for water supply or natural resources protection (Figure 1.3-6). These major springs include: San Solomon, Giffin, and Sandia Springs in Reeves County; Comanche and Diamond Y Springs in Pecos County; Spring Creek Springs, Dove Creek Springs, and Rocky Creek Springs in Irion County; Anson Springs, Lipan Spring, and Kickapoo Spring in Tom Green County; Clear Creek Spring in Menard County; Santa Rosa in Pecos County and San Saba Spring in Schleicher County. For convenience, the following spring descriptions are grouped into related geographic areas. Discussions pertaining to the historical significance of these springs are taken from Gunner Brune.[13,14]

Balmorhea Area Springs

Springs in the Balmorhea area have supported agricultural cultures for centuries. Early native Americans dug acequias to divert spring-water to crops. In the nineteenth century several mills were powered by water from the springs. The Reeves County Water Control and Improvement District No. 1 was formed in 1915 and provides water, mostly from San Solomon Springs, to irrigated land in the area. The springs are also used for recreational purposes at the Balmorhea State Park, and are the home of rare and endangered species, including the Comanche Springs pupfish, which was transplanted here when flow in Comanche Springs at Fort Stockton became undependable. Three major springs are located in and around the community of Balmorhea: San Solomon Springs, Giffin Springs, and East and West Sandia Springs. A fourth spring, Phantom Spring, is located in Jeff Davis County (Region E) a short distance west of Balmorhea. Below average rainfall in the area over the past decade has resulted in diminishing flows from these springs.

San Solomon Springs are located in the large swimming pool in Balmorhea State Park and are the largest spring in Reeves County. The spring's importance begins with its recreational use in the pool, then its habitat for endangered species in the ditches leading from the pool,[15] and finally its irrigation use downstream, where water from these springs is used to irrigate approximately 10,000 acres of farmland. These springs, which were once known as Mescalero or Head Springs, issue from lower Cretaceous limestones that underlie surface gravels in the area. Spring flow is maintained by precipitation recharge in the nearby Davis Mountains to the south. Discharge from San Solomon Springs is typically between 25 cubic feet per second (cfs)



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Region F Water Plan

Identified Major Springs in Region F

FN JOB NO	
FILE	
DATE	July 18, 2005
SCALE	1" = 35 miles
DESIGNED	ACAD
DRAFTED	BJS

FIGURE 1.3-6

and 30 cfs. After strong rains, the springflow often increases rapidly and becomes somewhat turbid. These bursts in springflow are typically short-lived.

Giffin Springs are located across the highway from Balmorhea State Park, and are at the same elevation as San Solomon Springs. Giffin Springs are smaller than, but very similar to, San Solomon Springs. Water discharging from these springs is used for irrigation, and typically averages between three and four cubic feet per second. Discharge from Giffin Springs responds much more closely to precipitation than the other Balmorhea-area springs.

East and West Sandia Springs are located about one mile east of Balmorhea at an elevation slightly lower than San Solomon and Giffin Springs. Flow from this spring system was classified as a "stream segment with significant natural resources" in the first regional plan. They are ecologically significant due to the presence of the Pecos Gambusia and the Pecos Sunflower, and the only known naturally occurring populations of the Comanche Springs pupfish.[16] East Sandia Springs are about twice as large as the West Sandia Springs located approximately one mile farther up the valley. Together these two springs were called the Patterson Springs in 1915 by the U.S. Army Corps of Engineers. East and West Sandia Springs flow from alluvial sand and gravel, but the water is probably derived from the underlying Cretaceous Comanchean limestone. Discharge is typically between one and three cfs.

Fort Stockton Area Springs

Comanche Springs flows from a fault fracture in the Comanchean limestone. This complex of springs includes as many as five larger springs and eight smaller springs in and around Rooney Park. These springs were historically very important, serving as a major crossroads on early southwestern travel routes. It is because of their historical significance and their continued ecotourism importance to the city of Fort Stockton, that this spring system is considered a major spring. The development of irrigated farming in the Belding area 12 miles to the southwest has intercepted natural groundwater flow, and by the early 1960s Comanche Springs had ceased to flow continuously. However, since 1987, Comanche Springs has sporadically flowed, primarily during winter months.

Diamond Y Springs (or Deep Springs) is the largest spring system in Pecos County, and provides aquatic habitat for rare and endangered species. The springs are one of the largest and last remaining cienega (desert marshland) systems in West Texas. These springs are located north of Fort Stockton, and issue from a deep hole in Comanchean limestone, approximately sixty feet in diameter. The chemical quality of the spring water suggests that its origin may be from the deeper Rustler aquifer. This spring is one of the last places the Leon Springs pupfish can be found, and is also home for the Pecos Gambusia. The Texas Nature Conservancy maintains conservation management of the Diamond Y Springs.

Santa Rosa Spring is located in a cavern southwest of the City of Grandfalls. At one time this spring provided irrigation water. Spring flow ceased in the 1950s.

San Angelo Area Springs

Six springs/spring-fed creeks located within approximately twenty miles of San Angelo are identified as major springs. Four of these springs, including Dove Creek Springs, Spring Creek Springs, Rocky Creek Springs, and Anson Springs, form the primary tributaries that feed into Twin Buttes Reservoir, which is a water supply source for the City of San Angelo. Two other springs, Lipan Spring and Kickapoo Spring, do not feed into Twin Buttes, but instead flow into the Concho River downstream from San Angelo.

Dove Creek Springs are located at the head of Dove Creek in Irion County about eight miles southwest of Knickerbocker. The perennial springs flow an average of 9 cfs and contribute to surface flow destined for Twin Buttes Reservoir. The landowners of these springs have placed the river corridor surrounding the springs into a Conservation Reserve Program so as to protect aquatic and other wildlife as well as vegetation species.

Anson Springs, also known as the Head of the River Springs, are located on ranchland approximately five miles south of Christoval in Tom Green County. Perennial spring flow in the bed and banks of the South Concho River results in an average discharge of more than 20 cfs. This springflow sustains the South Concho River, which has major irrigation diversion permits dating back to the early 1900s. The environment surrounding the springs is a sensitive eco-system with diverse flora and fauna found only in this specific location. The landowners of the springs have placed the river corridor of their property where the springs are located into a Conservation Reserve Program to protect vegetation and aquatic life as well as other wildlife.

Spring Creek Springs (also known as Seven, Headwaters, or Good Springs) are located on Spring Creek in eastern Irion County approximately three miles south of the town of Mertzon.

Besides evidence of significant occupation by early American Indians, the U.S. Cavalry also used the springs in the late 1840s. This was the last fresh water spring on the route westward.

Rocky Creek Springs are located on West Rocky Creek in northeastern Irion County, four to five miles northwest of the town of Arden.

Lipan Spring is located approximately 15 miles southeast of San Angelo and was a stop on the old Chihuahua Road. This spring, which issues from Edwards limestone, has historically flowed at less than one cfs.

Kickapoo Spring also discharges from Edwards limestone, and is located approximately twelve miles south of Vancourt. This spring was used for irrigation in the early days of settlement and historically has flowed between 1 and 4 cfs.

Fort McKavett Area Springs

San Saba Springs (Government or Main Springs), located at the headwaters of the San Saba River, were on the Chihuahua Road from the Port of Indianola to Mexico and were the water supply for Fort McKavett, established in 1852.

Clear Creek Springs (Wilkinson Springs) forms the headwaters of Clear Creek, which contributes significant flow to the upper reaches of the San Saba River in Menard County. The old San Saba Mission was located near these springs from 1756 to 1758. The springs were also a stop on the Chihuahua Road.

1.4 Agricultural and Natural Resources in Region F

1.4.1 Endangered or Threatened Species

Table 1.4-1 is a compilation of federal and state threatened and endangered species found in Region F counties. Section 7 of the Federal Endangered Species Act requires federal agencies to consult with the U.S. Fish and Wildlife Services (USFWS) to ensure that action they authorize, fund, or carry out will not jeopardize listed species. Under Section 9 of the same act, it is unlawful for a person to “take” a listed species. Under the federal definition “take means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect or attempt to engage in any such conduct.” Included in the definition of harm are habitat modifications or degradation that actually kills or injures a species or impairs essential behavioral patterns such as breeding, feeding or sheltering.[17]

Table 1.4-1
Endangered and Threatened Species in Region F

Species		Status		County																															
Common Name	**Scientific Name**	**Federal**	**State**	**Andrews**	**Borden**	**Brown**	**Coke**	**Coleman**	**Concho**	**Crane**	**Crockett**	**Ector**	**Glasscock**	**Howard**	**Irion**	**Kimble**	**Loving**	**Martin**	**Mason**	**McCulloch**	**Menard**	**Midland**	**Mitchell**	**Pecos**	**Reagan**	**Reeves**	**Runnels**	**Schleicher**	**Scurry**	**Sterling**	**Sutton**	**Tom Green**	**Upton**	**Ward**	**Winkler**
Birds																																			
American Peregrine Falcon	*Falco peregrinus anatum*		T	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Bald Eagle	*Haliaeetus leucocephalus*		T	S	S	S	S	S	S	S		S	S	S	S	S	S	S	S	S	S	S	S		S		S	S	S	S		S	S	S	S
Black-capped Vireo	*Vireo atricapilla*	E	E			B	B	B	B		B				B	B			B	B	B	F		B	B		B	B		B	B	B	F		
Common Black-hawk	*Buteogallus anthracinus*		T																													S			
Golden-Cheeked Warbler	*Dendroica chrysoparia*	E	E			S		S	S							B			B	S	B														
Interior Least Tern	*Sterna antillarum*	E	E		S	S	S	S	S	S	S						S			S			S	S		S	S		S			B		S	
Northern Aplomado Falcon	*Falco femoralis septentrionalis*	E	E																					S		B									
Peregrine Falcon	*Falco peregrinus*		T	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Reddish Egret	*Egretta rufuscens*		T																					S		S									
Whooping Crane	*Grus americana*	E	E	S	S	B	S	B	S				S	S	S	S		B	B	B	S	S	S		S		S	S	S	S	S	S			
Zone-Tailed Hawk	*Buteo albonotatus*		T								S					S			S	S	S			S		S									
Fish																																			
Clear Creek Gambusia	*Gambusia hetochir*	E	E																		B														
Comanche Springs Pupfish	*Cyprinodon elegans*	E	E																					S		B									
Leon Springs Pupfish	*Cyprinodon bovinus*	E	E																					B											
Pecos Gambusia	*Gambusia nobilis*	E	E																					B		B									
Pecos Pupfish	*Cyprinodon pecosensis*		T							S	S						S							S		S								S	
Proserpine Shiner	*Cyprinella proserpina*		T								S													S											
Rio Grande Darter	*Etheostoma grahami*		T								S																								
Mammals																																			
Black Bear	*Ursus americanus*		T							S	S					S	S		S					S	S	S		S			S		S	S	
Gray Wolf	*Canis lupus*		E	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Ocelot	*Leopardus pardalis*		E								S																				S				
Palo Duro Mouse	*Peromyscus truei comanche*		T		S																														
Red Wolf	*Canis rufus*		E			S		S	S							S			S	S	S						S	S			S	S			
Reptiles																																			
Concho Water Snake	*Nerodia paucimaculata*	T				F	F	F	F						F					F			F				F					F			
Texas Horned Lizard	*Phrynosoma cornutum*		T		S		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Trans-Pecos Black-headed Snake	*Tantilla cucullata*		T	S		S					S													S											
Texas Tortoise	*Gopherus berlandiere*		T																												S				

Table 1.4-1 (Cont.)
Endangered and Threatened Species in Region F

Species		Status		County																															
Common Name	Scientific Name	Federal	State	Andrews	Borden	Brown	Coke	Coleman	Concho	Crane	Crockett	Ector	Glasscock	Howard	Irion	Kimble	Loving	Martin	Mason	McCulloch	Menard	Midland	Mitchell	Pecos	Reagan	Reeves	Runnels	Schleicher	Scurry	Sterling	Sutton	Tom Green	Upton	Ward	Winkler
Flowering Plants																																			
Texas Poppy-mallow	*Callirhoe scabriuscula*	E	E				B																B				B								
Texas Snowbells	*Styrax texanus*	E														F																			
Tobusch Fishhook Cactus	*Ancistrocactus tobuschii*	E	E													B																			
Pecos/Puzzle Sunflower	*Helianthus paradoxus*	T	T																					B		B									
Snails																																			
Pecos Assiminea Snail	*Assiminea pecos*	E	E																					B		B									
Mussels																																			
False Spike	*Quadrula mitchelli*		T			S		S	S	S	S					S	S		S	S	S			S		S						S		S	
Smooth Pimpleback	*Quadrula houstonensis*		T			S		S	S										S	S	S						S								
Texas Fatmucket	*Lampsilis bracteata*		T			S		S	S						S	S			S	S	S						S					S			
Texas Fawnsfoot	*Truncilla macrodon*		T			S		S	S							S			S	S	S						S					S			
Texas Hornshell	*Popenaias popeii*		T							S	S						S							S		S		S			S			S	

Status: ***Key:***

T - Threatened ***F - Federal listings only (US Fish and Wildlife Service. 2009. Ecological Services. Endangered Species List. http://www.fws.gov/southwest/es/EndangeredSpecies/lists/ListSpecies.cfm)***

E - Endangered ***S - State listings only (Texas parks and Wildlife Department. 2009. Annotated County Lists of Rare Species. http://gis.tpwd.state.tx.us/TpwEndangeredSpecies/DesktopDefault.aspx)***

B - Both Federal and State listings

The Texas Endangered Species Act gives the Texas Parks and Wildlife Department (TPWD) the authority to establish a list of fish and wildlife that are endangered or threatened with statewide extinction. As defined by the statute, "fish and wildlife" excludes all invertebrates except mollusks and crustaceans. No person may capture, trap, take, or kill or attempt to capture, trap, take, or kill listed fish and wildlife species without a permit. Plants are not protected by these provisions. Endangered, threatened or protected plants may not be taken from public land for commercial sale or taken from private land for commercial purposes without a permit. Laws and regulations pertaining to endangered or threatened animal species are contained in Chapters 67 and 68 of the Texas Parks and Wildlife (TPW) Code and Sections 65.171 - 65.184 of Title 31 of the Texas Administrative Code (T.A.C.). Laws and regulations pertaining to endangered or threatened plant species are contained in Chapter 88 of the TPW Code and Sections 69.01 - 69.14 of the T.A.C.

The Texas Endangered Species Act does not protect wildlife species from indirect take (e.g., destruction of habitat or unfavorable management practices). The TPWD has a Memorandum of Understanding with every state agency to conduct a thorough environmental review of state initiated and funded projects, such as highways, reservoirs, land acquisition, and building construction, to determine their potential impact on state endangered or threatened species.

1.4.2 Agriculture and Prime Farmland

Agriculture plays a significant role the economy of Region F. Table 1.4-2 provides basic data regarding agricultural production in Region F.[18] Region F includes approximately 22,300,000 acres in farms and over 2,800,000 acres of potential cropland. In 2007 the market value of agriculture products (crops and livestock) for Region F was over $738,000,000, with livestock and crops each accounting for approximately 50 percent of the total.

Figure 1.4-1 shows the distribution of prime farmland in Region F.[19] The National Resources Conservation Service (NRCS) defines prime farmland as "land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is also available for these uses". As part of the National Resources Inventory, the NRCS has identified prime farmland throughout the country. Each color in Figure 1.4-1 represents the percentage of the total acreage that is considered prime farmland of any kind.

Table 1.4-2
2007 U.S. Department of Agriculture County Census Data for Region F

Category	Andrews	Borden	Brown	Coke	Coleman	Concho	Crane	Crockett
Farms	175	116	1,726	430	1,003	418	37	183
Land in Farms (acres)								
- Crop Land[a]	62,247	93,814	95,342	45,927	188,432	105,973	15,252	18,637
- Pasture Land	(D)	(D)	384,656	427,659	458,635	430,504	(D)	1,573,739
- Other	(D)	(D)	80,067	17,625	52,385	14,894	(D)	10,109
- Total	808,474	435,166	560,065	491,211	699,452	551,371	375,177	1,602,485
Market Value ($1,000)								
- Crops	$11,362	$8,038	$5,896	$605	$5,444	$10,212	$7	(D)
- Livestock	$4,556	$5,196	$29,989	$13,034	$14,591	$10,980	$1,667	(D)
- Total	$15,919	$13,233	$35,885	$13,639	$20,035	$21,192	$1,674	$13,636

Category	Ector	Glasscock	Howard	Irion	Kimble	Loving	Martin	Mason
Farms	301	185	519	156	639	9	464	647
Land in Farms (acres)								
- Crop Land[a]	6,993	126,695	227,974	7,500	35,921	(D)	275,982	57,098
- Pasture Land	416,233	343,089	279,802	612,144	544,997	(D)	175,589	431,562
- Other	693	10,001	15,015	4,982	39,043	(D)	6,419	47,742
- Total	423,919	479,785	522,791	624,626	619,961	426,792	457,990	536,402
Market Value ($1,000)								
Crops	$979	$44,099	$33,274	$705	$1,346	-	$51,231	$1,837
Livestock	$2,580	$2,158	$7,578	$5,373	$7,086	$497	$1,669	$46,206
Total	$3,559	$46,258	$40,853	$6,078	$8,432	$497	$52,900	$48,044

a. Crop land is the land that is currently or recently cultivated for farming. Acreages in active farms may be less.

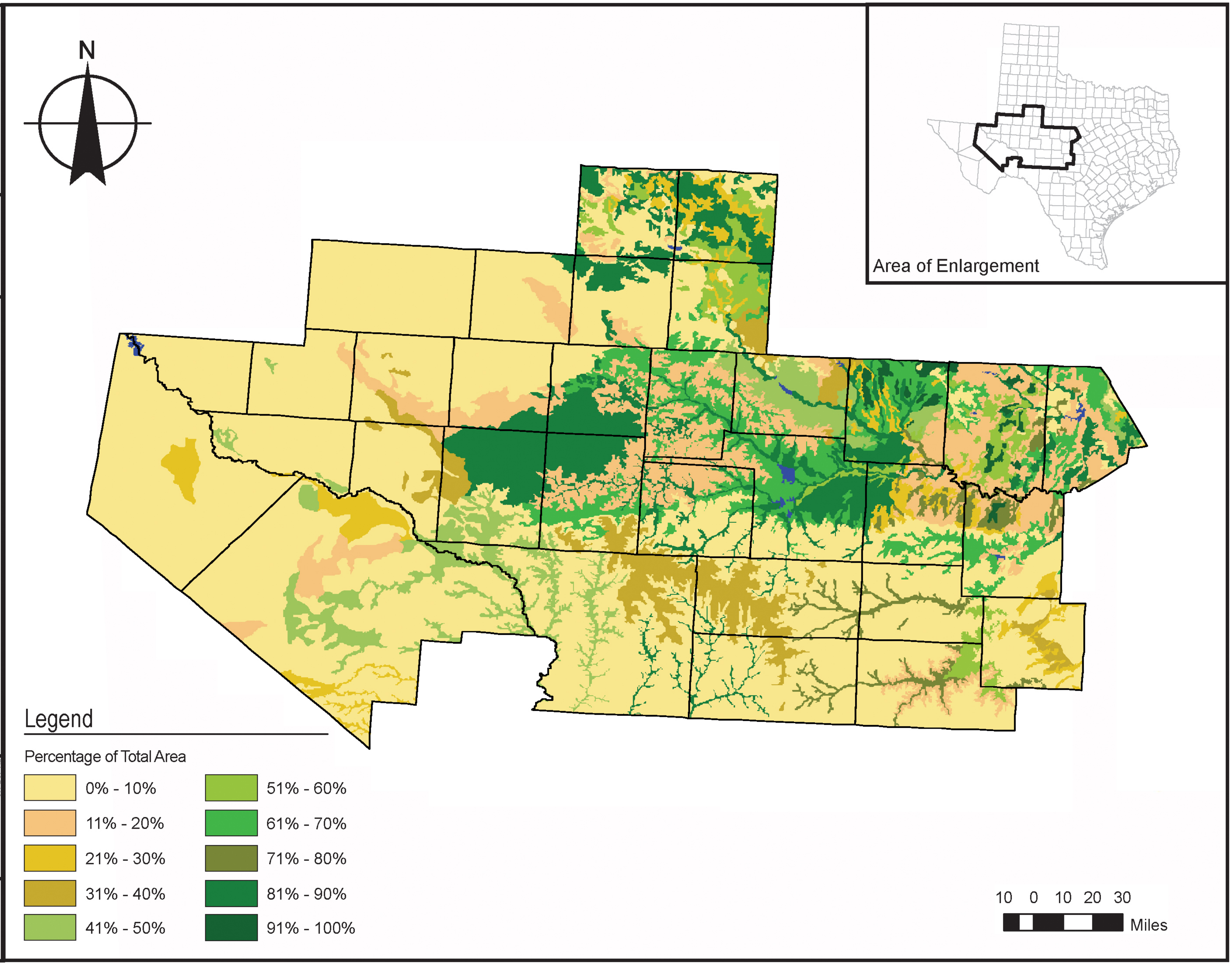
Table 1.4-2 (Cont'd)
2007 U.S. Department of Agriculture County Census Data for Region F

Category	McCulloch	Menard	Midland	Mitchell	Pecos	Reagan	Reeves	Runnels
Farms	694	356	601	519	287	137	221	953
Land in Farms (acres)								
- Crop Land[a]	108,473	22,731	90,046	163,760	101,383	57,947	136,698	264,780
- Pasture Land	473,422	450,964	353,336	398,577	2,778,691	590,941	890,289	355,293
- Other	30,732	17,598	13,251	12,658	27,891	34,926	13,357	36,131
- Total	612,627	491,293	456,633	574,995	2,907,965	683,814	1,040,344	656,204
Market Value ($1,000)								
Crops	$5,541	$611	$11,962	$17,400	$11,763	$12,393	$4,275	$30,814
Livestock	$12,559	$7,319	$3,436	$9,884	$15,781	$4,078	$12,904	$23,026
Total	$18,100	$7,930	$15,398	$27,284	$27,545	$16,471	$17,179	$53,840

Category	Schleicher	Scurry	Sterling	Sutton	Tom Green	Upton	Ward	Winkler	Total
Farms	332	681	74	234	1180	110	119	53	13,559
Land in Farms (acres)									
- Crop Land[a]	49,920	214,315	9,524	21,603	227,958	31,974	22,899	(D)	2,887,798
- Pasture Land	739,448	280,910	567,156	851,160	670,856	600,924	408,676	(D)	16,489,252
- Other	11,228	24,325	1,636	21,752	24,695	1,618	1,345	(D)	572,118
- Total	800,596	519,550	578,316	894,515	923,509	634,516	432,920	532,883	22,356,347
Market Value ($1,000)									
Crops	$3,270	$28,211	(D)	$333	$49,986	$6,231	$479	(D)	358,304
Livestock	$10,336	$15,223	(D)	$9,280	$83,005	$2,342	$1,050	(D)	363,383
Total	$13,606	$43,434	(D)	$9,613	$132,990	$8,573	$1,529	$3,262	738,588

a. Crop land is the land that is currently or recently cultivated for farming. Acreages in active farms may be less.

NOTES: (D) – Data withheld to avoid disclosing data for individual farms.
Total Market Value amounts include value of crops and livestock listed as (D) (data withheld). .
Source: Data are from the U.S. Department of Agriculture (USDA, 2007)



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N W E S

Region F

Prime Farmland
Percentage of Total Area

FN JOB NO: CMD01311
FILE: RegionF_Farm.mxd
DATE: January 17, 2005
SCALE: 1:2,795,000
DESIGNED: BME
DRAFTED: BME

FIGURE 1.4-1

Prime farmland has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is also available for these uses.

A number of counties in Region F have significant prime farmland acreage. Those with the largest acreage include Runnels, Glasscock, Upton, Tom Green, Scurry, and Reagan Counties. These six counties accounted for about 17 percent of the total land in farms and 41 percent of the total crop value for Region F in 2007.

It is interesting to note that major agricultural production also occurs in some counties with a relatively small amount of prime farmland. For example, Andrews, Martin, Pecos, and Reeves Counties have 10 percent or less acreage identified as prime farmland. However, these four counties combined accounted for approximately 23 percent of the total land in farms and 15 percent of the crop value for the region in 2007.

Shrimp farming is a relatively new business in West Texas. In 2008, 4 acres of ponds were located in Pecos County. Because the water used in this industry has a TDS range of 3,000 to 20,000 parts per million, it is not in direct competition with most other water uses.

1.4.3 Mineral Resources

Oil and natural gas fields are significant natural resources throughout Region F. Eleven of the top-producing oil fields and seven of the top-producing gas fields are located in Region F.[20] Other significant mineral resources in Region F include lignite resources in Brown and Coleman Counties, and stone, sand and gravel in various parts of the region.

1.5 Water Providers in Region F

Water providers in Region F include regional providers and retail suppliers. Regional water providers include river authorities and water districts. Retail water suppliers include cities and towns, water supply corporations, special utility districts, and private water companies.

1.5.1 Wholesale Water Providers

The TWDB defined the term wholesale water provider (WWP) as “any person or entity, including river authorities and irrigation districts, that has contracts to sell more than 1,000 acre-feet of water wholesale in any one year during the five years immediately preceding the adoption of the last Regional Water Plan. The Planning Groups shall include as wholesale water providers other persons and entities that enter or that the Planning Group expects to enter contracts to sell more than 1,000 acre-feet of water wholesale during the period covered by the plan."[21] Region F has identified seven entities that qualify as wholesale water providers:

- Colorado River Municipal Water District
- Brown County Water Improvement District Number One
- Upper Colorado River Authority
- Great Plains Water System, Inc.
- City of Odessa
- City of San Angelo
- University Lands

There are no implications of designation as a "wholesale water provider" except for the additional data required by TWDB. The wholesale water provider designation provides a different way of grouping water supply information.

Colorado River Municipal Water District (CRMWD). CRMWD is the largest water supplier in Region F. CRMWD member cities include Big Spring, Odessa and Snyder. CRMWD also supplies water to Midland, San Angelo and Abilene, as well as several smaller cities in Ward, Martin, Howard and Coke Counties. CRMWD owns and operates Lake J.B. Thomas, E.V. Spence Reservoir, and O.H. Ivie Reservoir, as well as several chloride control reservoirs. The district's water supply system also includes well fields in Ward, Scurry, Ector and Martin Counties. Table 1.5-1 is a list of fiscal year 2006 sales by the CRMWD, which totaled 78,069 acre-feet.

Brown County Water Improvement District Number One (BCWID). The 2006 sales by the BCWID totaled 13,230 acre-feet and are listed in Table 1.5-2. BCWID supplies raw water and treated water from Lake Brownwood to the Cities of Brownwood, Early, Bangs and Santa Anna, and rural areas of Brown and Coleman Counties, as well as irrigation water in Brown County.

Upper Colorado River Authority (UCRA). The UCRA is the owner of water rights in O.C. Fisher Reservoir in Tom Green County and Mountain Creek Lake in Coke County. O.C. Fisher supplies are used by the Cities of San Angelo and Miles. The City of Robert Lee uses water from Mountain Creek Lake. Table 1.5-3 is a list of year 2006 diversions from UCRA sources, which totaled 130 acre-feet.

Table 1.5-1
Fiscal Year 2006 Sales by the Colorado River Municipal Water District
(Values in Acre-Feet per Year)

Customer	Total Water Sales
Odessa	22,028
Big Spring	6,862
Snyder	2,326
Midland	24,382
Stanton	285
San Angelo	14,992
Robert Lee	178
Grandfalls	169
Pyote/West Tx State School	151
Ballinger	0
MDWSC	339
West Central Texas MWD	4,258
Non-Municipal Customers	2,099
Total	*78,069*

Data are from the Colorado River Municipal Water District[22]

Table 1.5-2
2006 Sales by the Brown County Water Improvement District Number One
(Values in Acre-Feet)

Customer	2006 Total Water Sales[a]
Bangs	330
Early	1,040
Brownwood	4,525
Brookesmith WSC	1,100
Santa Anna	(b)
Thunderbird Bay	90
Other	1,687
Irrigation	4,458
Total	13,230

a. Data are from the Brown County Water Improvement District No. 1 [23]

b. Santa Anna Served by Brookesmith WSC

Table 1.5-3
2006 Diversions from Upper Colorado River Authority Sources
(Values in Acre-Feet per Year)

Customer	2006 Diversions
San Angelo	0
Miles	90
Robert Lee	40
Total	130

Data are from UCRA. [24]

Great Plains Water System, Inc. The Great Plains Water System was initially developed to provide water to oil field operations in the Permian Basin. The System's source of water is the Ogallala aquifer in Andrews County in Region F and Gaines County in Region O. The System's largest customer is the recently established steam electric operation in Ector County. Great Plains has contracts to supply 6,096 acre-feet per year. The 2010 projected demand for steam electric operation in Ector County is 6,375 acre-feet, increasing to 17,637 acre-feet by 2060. The System also provides water to the City of Goldsmith (64 acre-feet in 2006).

City of Odessa. The City of Odessa is a CRMWD member city. The City of Odessa sells treated water to the Ector County Utility District and the Odessa County Club. In the year 2006, Odessa purchased 22,028 acre-feet from CRMWD.

City of San Angelo. The City of San Angelo's sources of supply are Lake O.C. Fisher (purchased from Upper Colorado River Authority), Twin Buttes Reservoir, Lake Nasworthy, local surface water rights, O.H. Ivie Reservoir (purchased from CRMWD), and E.V. Spence Reservoir (purchased from CRMWD). San Angelo supplies water to the power plant located on Lake Nasworthy. San Angelo also treats and delivers O.C. Fisher water to the City of Miles.

University Lands. University Lands manages property owned by the University of Texas System in West Texas. Although University Lands does not actively provide water, several major water well fields are located on property leased from University Lands, including fields operated by CRMWD, the City of Midland and the City of Andrews.

1.5.2 Retail Water Sales

Cities and towns provide most of the retail water service in Region F, and some cities also serve as retail water providers to connections outside of their city limits or as wholesale water suppliers by selling treated water to other water suppliers. Table 1.5-4 lists the cities in Region F that had outside sales in 2006.

Table 1.5-4
Water Supplied by Selected Cities in Region F

Supplier	County	Year 2006 Sales in Acre-Feet		
		Municipal Sales within City	Outside Sales	Total
Odessa	Ector	20,639	704	21,343
San Angelo	Tom Green	14,682	2,116	16,798
Big Spring	Howard	4,409	903	5,312
Brownwood	Brown	3,885	415	4,300
Snyder	Scurry	1,898	526	2,424
Pecos	Reeves	2,608	282	2,890
Andrews	Andrews	2,523	352	2,875
Coleman	Coleman	1,126	618	1,744
Colorado City	Mitchell	823	251	1,074
Crane	Crane	937	27	964
Ballinger	Runnels	494	183	677
Early	Brown	678	368	1,046
Winters	Runnels	457	9	466
Balmorhea	Reeves	52	29	81

Data are from the TWDB [9]

1.6 Existing Plans for Water Supply Development

Prior to SB1 regional water plans and water availability models, the most comprehensive study of water availability in the basin was published in 1978 by the Texas Department of Water Resources (TDWR). This study, titled *Present and Future Water Availability in the Colorado River Basin, Texas, Report LP-60*, was a detailed analysis of water availability and needs for the years 1980 and 2030.[25] According to this report, in 1980 there would be sufficient supplies in the basin to meet demands. By 2030, there would only be minor shortages in the upper basin provided that Ivie Reservoir was constructed. In the same period the middle and lower basins could experience significant shortages. The report recommended the construction of new reservoirs to meet needs in the lower basin.

In 2007, the Texas Water Development Board released the State Water Plan, *Water for Texas – 2007*, which was a compilation of the 16 regional water plans developed under SB1.[26] The Region F Water Planning Group published the *Region F Regional Water Plan* in January 2006. Some of the findings of the 2006 Region F plan included:

- Approximately 60 water user groups had projected water shortages over the planning period (through 2060). Many of these shortages were associated with WAM priority analysis of surface water supplies. Water management strategies were developed to address these needs.
- Sixteen counties had a collective irrigation need of over 167,000 acre-feet per year. No water supply is readily available to meet this need. Advanced water conservation irrigation technologies were recommended to reduce the irrigation demands. This strategy would significantly reduce the demands and eliminate projected shortages in several counties. However, some counties in Region F still had significant irrigation water needs.
- Major municipal needs occur with water user groups that rely on the Hickory aquifer. Needs are the result of water quality standards for radionuclides imposed by USEPA and TCEQ. Four water management strategies were developed for the users of Hickory aquifer:
    - Brady Creek Reservoir water treatment plant
    - Lake Ivie water treatment plant
    - New Ellenberger well field
    - New Hickory well field (in area with low radionuclides)
    - Advanced Treatment (Reverse Osmosis)
- General water management strategies recommended in the plan included: subordination, water conservation and drought response, brush control, weather modification, wastewater reuse, recharge enhancement, and desalination and chloride control.

The City of San Angelo completed their *Long-Range Water Supply Plan* in November of 2000.[27] Major recommendations from the plan include:

- *Improve delivery system from Fisher, Ivie and Spence.* At that time, the City was unable to receive water from both Lake Spence and Lake Ivie concurrently and was limited to a maximum delivery capacity of 18 mgd. The proposed improvements included a parallel pipeline and a new pump station, increasing the delivery capacity to 50 mgd. The new pipeline has been constructed.

- *Increase water treatment capacity*. The City's water treatment plant should have adequate capacity through about 2031. Expansion may be delayed by using water from the McCulloch County Well Field even during times when the local reservoirs are full (Groundwater from McCulloch County requires different level of treatment from surface water supplies, pending water quality).
- *Pursue trade of treated effluent for irrigation supplies.* The City can gain additional supply and reduce pumping costs by trading irrigation supply from Twin Buttes and Nasworthy for treated effluent from the City's wastewater plant. Effluent is available even during droughts and increases over time as municipal demands increase. To implement this option, additional wastewater storage ponds will be needed. Construction is recommended in the years 2002, 2015 and 2032 at a cost of $7 million per pond or expansion.
- *Add the McCulloch County well field to the system.* Two options were considered to bring McCulloch County water to the City:
    - Constructing a pipeline directly from the well field to San Angelo or
    - Constructing a pipeline to Ivie Reservoir and using CRMWD facilities to transport the water the remaining distance (San Angelo already has such a right by its contract with CRMWD to do so under specific circumstances).

Although the capital costs of the Ivie option are much lower, the direct option was recommended because:

- The operational savings of the direct pipeline offset most of the increased capital costs, and
- The Ivie option impacts other users of the CRMWD system by adding radionuclides to the Ivie pipeline.

The City of San Angelo is currently studying several water supply options, including desalination of brackish groundwater, reuse, alternative sources of groundwater and other options. Identified goals for the city include:

- Development of groundwater resources in the Edwards-Trinity south of San Angelo,
- Acquisition of additional surface water rights in the Concho watershed, and
- Continuation of brush control efforts on O.C. Fisher Reservoir and Twin Buttes Reservoir.

Several groundwater districts in Region F (including those located in Crockett, Schleicher, Sutton, Menard, and Kimble Counties) as well as the Real-Edwards district, Val Verde County, and the City of Del Rio collectively funded an independent water budget analysis to determine their respective Desired Future Conditions. Ronald Green, Ph.D., P.G. and Paul Bertelli, P.G. of the Southwest Research Institute are the primary investigators for the study, which is currently ongoing. Preliminary findings are presented in the following discussion. The study is in progress and therefore these finding are subject to revision.

The saturated thickness of the Edwards-Trinity across the eight county study area ranges from 200 to 300 feet in the northern counties and thickens up to 500 to 1000 feet in the southern counties. The potentiometric surface across the eight counties indicates that flow is predominantly toward the south and southwest.

Numerous springs occur in the western Edwards-Trinity (Plateau) where the base of the lower Edwards intersects topographic lows and discharge near streams. Major springs utilized in the water balance analysis for Val Verde County include Goodenough and San Felipe Springs.

The project study area encompasses seven river sub watersheds within three river basins: the Lower Pecos, Devils, Rio Grande Amistad, and Rio Grande Falcon watersheds within the Rio Grande River Basin; the Concho and Llano watersheds within the Colorado River Basin, and the Nueces River Basin (undivided). The watershed divide between the Colorado and Rio Grande/Nueces basins defines the primary surface water flow. In the Colorado River basin, flow is primarily to the north and east, whereas in the Rio Grande and Nueces basin, flow is typically to the east, south, and southwest. Green emphasizes that the groundwater catchment area is not the same as the surface water catchment.

For Schleicher, Menard, Kimble and Sutton counties, Green used a watershed analysis to calculate recharge. Green's results (including Val Verde County and historical estimates for comparison) are summarized in Table 1.6-1.

Table 1.6-1
Recharge Rates from Green's Water Budget Analysis

County	Recharge Rate (in/yr)	Recharge Rate (ac-ft/yr)
Estimates from Water Budget Analysis		
Schleicher	0.98 to 1.15	68,520 to 80,400
Menard	0.73	35,100
Kimble	1.45	96,700
Sutton	1.0	78,200
Val Verde (groundwater basin)	0.76	634,200
Val Verde (Devils River basin)	1.25	263,536
Historical Estimates from other Sources		
Edwards	1.3	150,000
Real	2.0	70,000

Key findings of the study include:

- Groundwater basins and surface water basins do not align and are not equivalent in area of catchment nor do they align with geopolitical entity boundaries
- Groundwater flow rates have less certainty that surface water flow rates
- The recharge rates derived by this water budget analysis are somewhat greater than previous investigations
- Downstream users are impacted significantly by upstream users

This is an ongoing project with preliminary results subject to revision. The primary remaining tasks include:

- Completion of technical literature review,
- Refinement of the conceptual model,
- Completion of surface water data review,
- Refinement of drought discharge/recharge estimates,
- Correction of Rio Grande budget gauging data for storm flow,
- Identification and assessment of additional factors impacting the water budget analysis,
- Comparison of recharge estimates to published values, and
- Presentation of a final comprehensive interpretation.

Several projects that have been envisioned by Dr. Green in order to complete a more precise evaluation in the future are as follows:

- Establishment of a controlled monitor well network,
- Refinement of exempt and non-exempt water well inventory,
- Installation of flow meters on select wells,
- Evaluation of water chemistry signatures and sources,
- Refinement of the water balance,
- Determination of baseline conditions,
- Performance of tracer tests to determine extent of groundwater basin, and
- Refinement of the Edwards-Trinity Aquifer GAM.

1.6.1 Conservation Planning in Region F

The Texas Water Code requires that certain entities develop, submit, and implement a water conservation plan (Texas Water Code § 11.1271). Those entities include holders of an existing permit, certified filing, or certificate of adjudication for the appropriation of surface water in the amount of 1,000 acre-feet per year or more for municipal, industrial, and other uses, as well as 10,000 acre-feet per year or more for irrigation uses. These plans must be consistent with the appropriate approved regional water plan(s). Water conservation plans must include specific, quantified 5-year and 10-year targets for water savings. Goals must be set for water loss programs and for municipal per capita water use. In 2007, § 13.146 of the Texas Water Code was amended requiring retail public suppliers with more than 3,300 connections to submit a water conservation plan by May 1, 2009 to the TWDB.

Many entities around the state have already developed conservation plans and/or drought contingency plans. These plans have improved the awareness of the need for water conservation in Texas. In its projections of water use the Texas Water Development Board has assumed reductions in per capita municipal use due to the implementation of the plumbing code requiring the use of low flow plumbing fixtures in all new development and renovation.

Many cities in Region F have developed water conservation plans. Water conservation education is stressed in most cities. These cities plan to provide educational brochures to new and existing customers. Other measures to conserve water include retrofit programs, leak detection and repair, recycling of wastewater, water conservation landscaping, and adoption of the plumbing code. As part this plan, model water conservation plans are included in Appendix 6A. These models can serve as templates for entities to develop or update their water conservation plan.

1.6.2 Assessment of Current Preparations for Drought in Region F

Drought is a fact of life in Region F. Periods of low rainfall are frequent and can extend for a long period of time. Most of the area has been in drought-of-record conditions since the mid 1990s. Many Region F water suppliers have already made or are currently making improvements to increase their capacity to deliver raw and treated water under drought conditions. Some smaller suppliers in Region F have faced a shortage of supplies within the last few years and have had to restrict water use.[28]

The Texas Water Code requires that wholesale and retail public water suppliers and irrigation districts develop drought contingency plans (Texas Water Code § 11.1272). These plans must also be consistent with the appropriate approved regional water plan(s). In addition, all drought contingency plans must include specific, quantified targets for water use reductions to be achieved during periods of water shortages and drought.

Most of the conservation plans that have been developed in response to state requirements also include a drought contingency plan. The purpose of the drought contingency plan is to address circumstances that could affect a water supplier's ability to supply water to the customer due to transmission line failures, water treatment plant failures, prolonged emergency demand, or acts of God. The drought contingency plans for each area have established trigger conditions that indicate when to take demand management measures. These trigger conditions range from mild to emergency. Model drought contingency plans are included in Appendix 6B. These models can serve as templates for entities to develop or update their drought contingency plan.

1.6.3 Other Water-Related Programs

In addition to the SB1 regional planning efforts, there are a number of other significant water-related programs that affect water supply in Region F. Perhaps the most significant are Texas Commission on Environmental Quality's water rights permitting, the Clean Rivers Program, the Clean Water Act, the Safe Drinking Water Act, the Texas Brush Control Plan, and precipitation enhancement programs.

Texas Commission on Environmental Quality (TCEQ) Water Rights Permitting. Surface water in Texas is a public resource, and the TCEQ is empowered to grant water rights that allow beneficial use of that resource. Any major new surface water supply source will require a water right permit. In recent years, TCEQ has increased its scrutiny of the environmental impacts of water supply projects, and permitting has become more difficult and complex. Among its many other provisions, SB1 set out formal criteria for the permitting of interbasin transfers for water supply.

Clean Rivers Program. The Texas Clean Rivers Program (CRP) is a state-fee funded water quality monitoring, assessment, and public outreach program. The CRP is a collaboration of 15 partner agencies and the TCEQ. The CRP provides the opportunity to approach water quality issues within a watershed or river basin at the local and regional level through coordinated efforts among diverse organizations. In Region F, the program is carried out by the Lower

Colorado River Authority, with assistance from CRMWD and UCRA, in the Colorado Basin, and by the International Boundary and Water Commission in the Rio Grande Basin.[29]

Clean Water Act. The Clean Water Act is a federal law designed to protect water quality. The Act does not directly address groundwater nor water quantity issues. The statute employs a variety of regulatory and non-regulatory tools to reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff. These tools are employed to achieve the broader goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters so that they can support "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water." [30]

The parts of the act which have the greatest impact on water supplies are the NPDES permitting process, which affects water quality, and the Section 404 permitting process for dredging and filling in the waters of the United States, which affects reservoir construction. In Texas, the state oversees the NPDES permitting system, which sets the operating requirements for wastewater treatment plants. The Section 404 permitting process is facilitated by the Corps of Engineers and is an important step in the development of a new reservoir.

The TCEQ administers a Total Maximum Daily Load (TMDL) Program for surface water bodies in the state of Texas. TMDL programs are a result of the Clean Water Act. In this program, water quality analyses are performed for water bodies to determine the maximum load of pollutants the water body can handle and still support its designated uses. The load is then allocated to potential sources of pollution in the watershed and implementation plans are developed which contain measures to reduce the pollutant loads. The Implementation Plan for Sulfate and Total Dissolved Solids (TDS) TMDLs in the E.V. Spence Reservoir (Segment 1411) was established in August 2001. The TCEQ has completed analyzing the Colorado River below E.V. Spence Reservoir (Segment 1426) for chloride, sulfate, and TDS concentrations.

Safe Drinking Water Act. The Safe Drinking Water Act (SDWA) was originally passed by Congress to protect public health by regulating the nation's public drinking water supply. The law requires many actions to protect drinking water and its sources – rivers, lakes, reservoirs, springs, and groundwater wells. To ensure that drinking water is safe, SDWA sets up multiple barriers against pollution including source water protection, treatment, distribution system integrity, and public information.[31] Some of the initiatives that will most likely have significant impacts in Region F are the reduction in allowable levels of trihalomethanes in treated water, the requirement for reduction of total organic carbon levels in raw water, and the reduction in the allowable level of arsenic and radionuclides in drinking water. The allowable limit on arsenic has been reduced from 50 micrograms per liter to 10 micrograms per liter.

Texas Brush Control Plan. The Texas Brush Control Plan was developed pursuant to Chapter 203 of the Texas Agricultural Code. There are seven Brush Control Projects currently underway in Region F, including the O.C. Fisher Project, Twin Buttes Reservoir/Lake Nasworthy Brush Control Projects, and the Lake Brownwood Project. These projects are discussed further in Chapter 4. In these programs, cost share funds are administered at the local level by soil and water conservation districts based on allocations made by the State Board. Acreages of land are treated to eliminate the amount of water being used by brush.

Precipitation Enhancement Programs. In Region F, there are several ongoing weather modification programs, including the West Texas Weather Modification Association (WTWMA) project, and the Trans Pecos Weather Modification Association (TPWMA) program. Another weather modification program, conducted by the West Central Texas Weather Modification Association (WCTWMA), was started in 2001, but due to budgetary issues, stopped cloud seeding after the 2003 season. The Southern Ogallala Aquifer Rain (SOAR) program is being conducted in Region O counties bordering Region F to the north. Precipitation enhancement is discussed in more detail in Chapter 4.

1.7 Summary of First Biennium Special Studies

As part of the 2011 regional water planning effort the Region F Water Planning Group conducted six special studies. The purpose of these special studies was to evaluate in greater detail important aspects of the *2006 Region F Water Plan*. An overview of each special study is provided including how the study is incorporated into the *2011 Region F Water Plan*. The complete studies were previously published and submitted to the TWDB.

1.7.1 Ground Water Study

Future water supplies for Region F will likely be developed from groundwater or wastewater reuse. This study identified several new sites that have groundwater development potential and focused on refining the groundwater quantity and quality estimates for Region F. The objective of this study was to refine groundwater supply estimates in selected areas and identify potential projects that may use fresh and brackish groundwater. As appropriate, the findings of this study are incorporated in the recommended water management strategies discussed in Chapter 4 of this plan.

Three potential groundwater areas were identified for further study. The three areas selected for further study were:

1. The Ogallala aquifer in the southeast portion of Andrews County,
2. Potential local groundwater sources for the City of Robert Lee in Coke County,
3. Region wide assessment using the TWDB database to assess areas containing multiple productive wells that might sustain long-term pumping.

Ogallala Aquifer – Andrews County

Based on the data obtained for this study and the methods employed, there are a few areas that may yield small volumes of fresh and brackish groundwater for municipal use in southeast Andrews County. However, the data indicate that there may be less groundwater available than previously estimated, depending on the assumptions used for the calculations. This results in greater uncertainty of the available supply from the Ogallala aquifer in Andrews County. More field investigations are required to confirm the quantity and quality of groundwater for development. At this time, it is not recommended to develop additional Ogallala supplies for the City of Andrews.

Local Groundwater – Coke County

Several potential areas/units were identified in Coke County that may merit further field investigation. These are (1) dual completion wells in the San Angelo Formation, Choza Formation, (2) Choza Formation/Merkel Dolomite Member in southeast Coke County, (3) Choza Formation/Merkel Dolomite Member/Alluvium in Runnels County, and (4) River Alluvium. Water quantity and quality were identified as a concern in some areas. The study recommended further investigations, including test well drilling north and east of Bronte in the San Angelo and Choza formations, structural and well capacity assessment of Merkel Dolomite in southeast Coke County, and water sampling of alluvial wells to determine water quality trends in alluvium. Development of groundwater is a considered strategy for the City of Robert Lee.

Regional Groundwater Supplies

The Regional Supply project evaluated the TWDB groundwater database to assess areas containing multiple productive wells that might sustain long-term pumping. The goal was to use the data to discern the long-term availability of groundwater from areas that have had high volume wells in the past. The assessment indicates that there are some areas with moderate to high production capacity. With the exception of the Pecos Valley Alluvium, most of the available groundwater in these areas is already being utilized. In most areas, groundwater would need to be transferred from an existing use to a new use.

The study also assessed the cost of co-developing groundwater from separate wellfields in the Pecos Valley Alluvium (Ward and Winkler County area) and transporting it to the Midland/Odessa area. The results indicate that unit costs of the joint project are slightly less than individual projects, but the initial capital costs are higher. This is because the joint project is developing and moving more water than the sum of the individual projects. Pending the timing of increased demands, it may not be cost effective to develop the joint project. At this time, a joint project is not recommended.

1.7.2 Irrigation Survey

Irrigation water use represents the largest demand category in Region F, and in the *2006 Region F Water Plan* there were significant unmet irrigation needs. Conservation was identified as the primary means to meet these needs but more information is needed to accurately quantify the projected water savings. The Irrigation Survey was conducted to better define historical irrigation data, identify data gaps in irrigation data that are needed to reasonably project future irrigation water use and identify means to collect the information needed to close those gaps. Six counties were selected for this survey: Glasscock, Midland, Reagan, Reeves, Pecos and Tom Green. These counties represent over 70 percent of the irrigation demand in the 32-county region, and 76 percent of the irrigation shortage.

Region F planning group members and interested members of the public actively participated in providing and reviewing the available data. Four sources provided quantifiable data on historical water use and crop types: Texas Water Development Board (TWDB), Farm Service Agency, National Agricultural Statistical Services and members of the Irrigation Work Group (these members also represent groundwater conservation districts). The Environmental Quality Incentives Program (EQIP) and the TWDB also provided some data on irrigation equipment.

Irrigation data reported by the different sources are generally consistent with a few notable exceptions. The largest differences are based on the reporting categories (variety and types of crops reported as irrigated). Counties with few major crops, such as Glasscock and Reagan Counties, have relatively small differences while counties with wide varieties of crops or non-major crops, have greater differences. The TWDB provides the most comprehensive data on irrigation. While these data represent the best available information it is at best an estimate of the irrigation water used in the study area. The data reported by these agencies are based on application practices and crop types rather than metered water use. Actual water use may differ significantly from one irrigator to the next.

The percentage of irrigated acres using high-efficiency irrigation methods are increasing in the six counties. The data indicate over 90 percent of the irrigated acres in Glasscock County currently use either sprinkler or drip irrigation, which is up from 45 percent in 2000. In Reagan County 75 percent of the crops are irrigated using either sprinkler or drip. These percentages are considerably higher than the assumed adoption rate in the *2006 Region F Water Plan*. However, there were limited data on type of equipment in other counties.

Based on the findings of this study the Region F Planning Group chose not to change the irrigation water use projections for the *2011 Region F Water Plan*, but rather continue to collect and monitor historical irrigation water use data to adequately plan for agricultural water needs in subsequent plans. As appropriate, conservation savings for irrigation were refined for the *2011 Region F Water Plan* to reflect current conservation equipment adoption rates.

1.7.3 Municipal Conservation Survey

Water conservation has been identified throughout the state's regional water planning process as an important strategy for meeting future water needs. While important, the methods to achieve water conservation and the costs and effectiveness of conservation strategies remain uncertain. In an effort to gain more information regarding those uncertainties, Region F authorized a study to document current conservation practices used by municipalities in Region

F and the costs and water savings associated with them. This study was also intended to identify municipal conservation practices that may be appropriate for Region F.

Thirteen cities were surveyed regarding their conservation efforts, and selected cities were interviewed to obtain further information on their conservation practices. The results from the surveys were compiled and analyzed along with rainfall data and TWDB historical water use data. Costs of implementing conservation strategies were also collected and analyzed.

The results of this survey and analysis show that most cities are implementing one or more conservation strategies, but funding is key to continued and increased conservation efforts in the region. Several cities expressed interest in wastewater reuse for municipal or industrial purposes. Cities have great difficulty in tracking water savings from conservation practices. Only specific projects, such as pipe replacement programs and reuse, had quantified savings. Reuse and System Water Audit and Water Loss are two practices that show the greatest overall savings. (System Water Audit and Water Loss include repair and replacement of pipelines.) These findings were incorporated in the recommended conservation strategies for the respective entities.

1.7.4 Evaluation of Supplies in the Pecan Bayou Watershed

This study presents the results the analyses of potential operating scenarios for four reservoirs in the Pecan Bayou watershed: Lake Brownwood, Lake Coleman, Hords Creek Reservoir and Lake Clyde. The *2006 Region F Water Plan* assumed that Lake Brownwood, which is the senior water rights holder in the watershed, would not make priority calls on Lake Coleman, Hords Creek Reservoir and Lake Clyde. This assumption is consistent with the operations of other major reservoirs in the region, but may not be appropriate for the Pecan Bayou watershed during times of drought. If Lake Brownwood fully exercises its senior priority right, the three upstream reservoirs have no reliable supply. However, under drought conditions it is possible that Lake Brownwood would call on inflows from the three upstream junior reservoirs. This study examined six different operational scenarios for regional water planning purposes, varying assumptions for when water is passed through the upper reservoirs to meet priority calls from Lake Brownwood.

The modeling indicated that passing only high flows or flows when Lake Brownwood was below 50 percent of its capacity would result in sufficient supply to meet projected demands from the three upstream reservoirs. Lake Brownwood has sufficient supplies to meet its projected demands in all scenarios.

Scenario 3, *Priority call when Lake Brownwood storage is below 50%*, was the preferred strategy for regional water planning, and is incorporated in the *2011 Region F Water Plan* Subordination Strategy for the water users in Pecan Bayou watershed. This assumption is for planning purposes only and does not imply any restrictions on the ability of Brown County WID No. 1 to exercise its full permitted water rights.

1.7.5 Economics of Rural Water Distribution and Integrated Water Supply Study

The *Economics of Rural Water Distribution and Integrated Water Supply Study* addresses several concerns for rural water providers that were raised during the development of the *2006 Region F Water Plan*:

- Reliability problems
- Water quality problems, and
- High costs of strategies to address problems.

The study concentrated on rural water providers in a seven-county area in the eastern portion of Region F (Brown, Coke, Coleman, Concho, Runnels, Tom Green and McCulloch Counties). The objective of this study was to examine the factors that impact costs of rural water systems and how those factors might affect the ability of these systems to function as part of regional solutions.

Key findings of the study include:

- The primary factors that affect the economics of rural water systems in the study area are a limited economic base, lack of water supply alternatives, extensive infrastructure for small populations, and difficulties in meeting regulatory requirements.
- If regionalization or integration strategies are pursued, water providers in the study area will most likely need to rely on volunteer construction of water lines to reduce costs.

- Attractive alternatives to regionalization or integration strategies include rainwater harvesting, point-of-use or point-of-entry treatment, and bottled water programs.

One of the most important factors in the capability of rural systems to initiate new strategies appears to be population density and the expectation for growth. Systems such as the Brookesmith Special Utility District were designed with larger water lines that anticipate additional water use. The near term water quality problems associated with oversized lines is expected to be offset by future growth and flexibility in operation. On the other hand, systems in areas with lower population densities and less expectation of growth were, by necessity, built with smaller lines. Although appropriate for these systems, the smaller lines mean that additional growth may require new infrastructure. These systems may not have the flexibility to add new sources of water or add emergency connections without construction of new infrastructure. Therefore regionalization or other integration strategies are unlikely to be cost-effective for these systems.

1.7.6 Region K Coordination

The coordination with Region K included attending meetings with the Region K water Planning Group and evaluating the differences between the adopted Region K "cutoff" model and the model currently used by the Region F for the Subordination Strategy (discussed in Chapter 4).

- The Region K cutoff model shows that less water is passed from Region F to Region K than the Region F model used in the 2006 plan.
- The Region K model does not include Brady Creek Lake or the City of Junction water right. However the total amount of flow retained in Region F is more than the impact of these two rights. Therefore the overall water balance between the two regions should not be impacted.
- Region F does not intend to change its water availability analysis for the *2011 Region F Water Plan*, and intends to retain the Subordination Strategy initially developed in the *2006 Region F Water Plan*, including water provider agreements and system operations. This approach should not have an impact to the supplies in Region K as determined by the new Region K "cutoff" model.

- While there are some differences between the models, the use of the two models in this round of planning should not impact the overall balance of water between the two regions. However future water availability analyses should address the Brady Creek Lake and the City of Junction water rights. This is further discussed in Chapter 4 under the Subordination Strategy.

1.8 Summary of Threats and Constraints to Water Supply in Region F

1.8.1 Threats to Water Supply

Threats to water supply in Region F include:

- Use of the TCEQ Water Availability Model (WAM) Run 3 for regional water planning;
- Water quality concerns in several areas of the region; and
- The impact of drought.

Surface water quality concerns identified by the TWDB, TCEQ, TPWD, EPA and others (River Authorities, etc.) within Region F are summarized in Table 1.8-1.

Use of TCEQ WAM Run 3 for Regional Water Planning

The TWDB requires the use of the TCEQ Water Availability Models (WAM) Run 3 as the definition of water availability for regional water planning. WAM Run 3 has the following major assumptions:

- Full use of permitted diversion and storage
- 100 percent reuse of return flows (except return flows specified within the water right permit)
- Allocation of water according to priority date regardless of geographic location or type of use

The Colorado WAM Run 3 has significantly different results than previous assessments of water availability in the basin. Previous studies by the State of Texas and others showed sufficient reliable supplies from reservoirs in Region F to meet current and projected demands, including the 1978 Report LP-60, the 1990 state water plan,[32] the 1997 state water plan,[33] and the 2002 state water plan. Recent experience of critical drought conditions in the upper basin show that supplies are available from the region's reservoirs under drought-of-record conditions.

Table 1.8-1
Summary of Identified Surface Water Quality Problems in Region F

Segment ID	Segment Name	Concern Location	Water Quality Concern	Status
1412	Colorado River Below J.B Thomas	From the confluence of Beals Creek upstream to the dam below Barber Reservoir pump station	bacteria	Additional data and information will be collected before a TMDL is scheduled.
1413	Lake J. B. Thomas	Entire water body	chloride	Additional data and information will be collected before a TMDL is scheduled.
1416	San Saba River	From the confluence with the Colorado River in San Saba County upstream to the US 190	bacteria	Additional data and information will be collected before a TMDL is scheduled.
1416 A	Brady Creek (unclassified water body)	From FM 714 upstream to Brady Lake dam	depressed dissolved oxygen	Additional data and information will be collected before a TMDL is scheduled.
1421	Concho River	From the dam near Vines Road upstream to the confluence of the North Concho River and the South Concho River	impaired macrobenthic community	Additional data and information will be collected before a TMDL is scheduled.
		North Concho River, from the confluence with the South Concho River upstream to O.C. Fisher dam	bacteria	Additional data and information will be collected before a TMDL is scheduled.
			depressed dissolved oxygen	Additional data and information will be collected before a TMDL is scheduled.
1425	O.C. Fisher	Entire reservoir	chloride	Additional data and information will be collected before a TMDL is scheduled.
1431	Mid Pecan Bayou	Entire water body	bacteria	Additional data and information will be collected before a TMDL is scheduled.
2311	Upper Pecos River	US 80 (Bus 20) to FM 1776	depressed dissolved oxygen	Additional data and information will be collected before a TMDL is scheduled.
		FM 1776 to US 67	depressed dissolved oxygen	Additional data and information will be collected before a TMDL is scheduled.

Source: Data from 2008 Draft 303(d) list (March 19, 2008) [34]

However, the Colorado WAM indicates that almost all of the major reservoirs in Region F have little or no reliable supply. This result is contrary to previous water plans and recent historical experience.

The WAM was developed by TCEQ to process new water rights and amendments to existing water rights. The WAM operates in a theoretical legal space that is different from the way that the Colorado Basin has historically been operated. The WAM generally does not include return flows, which can be a significant source of water in many areas. Many run-of-the-river irrigation rights depend on these return flows for reliable supplies. Until such time as return flows are claimed for reuse, water rights holders can legally make use of these return flows. The WAM also assumes that storage in a reservoir has the same weight as diversion. A downstream reservoir with a senior priority date can appropriate all of the available water just to fill storage, often leaving upstream junior water rights with no available water for use.

WAMs are a relatively new tool available to state agencies for planning, permitting and making policy decisions. Care must be used when using these models without modifications to set state water policies for existing and future water users. In some cases, modifications to the assumptions used in TCEQ WAM Run 3 would make these models more appropriate for other purposes. As presently used, the WAM adversely impacts water availability in Region F.

The development of water supplies in the Colorado Basin has a long history of conflict and resolution over the impact upstream development may have on downstream water rights. Requiring the use of the WAM for planning purposes without modification has reopened these issues and thus poses a policy threat to existing water rights in Region F. It also forces an overestimation of water needs within Region F, and a corresponding underestimation of the future water needs downstream in Region K.

Rio Grande Basin Water Quality

The high levels of chlorides, sulfates and TDS present in the Pecos River below Red Bluff Reservoir appear to originate from geologic formations and oil and gas production activities. The cause of the toxic algae blooms is unknown. However, their occurrence has been linked to salinity and nutrient concentrations. The elevated levels of arsenic have been attributed to agricultural activities. Red Bluff Reservoir contains elevated levels of mercury. The heavy metals present in the surface water in this region represent the most serious public health concern. The high chloride and TDS levels in the surface water preclude most agricultural uses. Instead, agricultural water users rely heavily on the groundwater supply.

Colorado River Basin Water Quality

The high levels of chlorides, sulfates and TDS present in the Upper Colorado River above O.H. Ivie Reservoir (including E.V. Spence Reservoir) are thought to originate from geologic formations and oil and gas production.[35] In August 2000, a Total Maximum Daily Load (TMDL) study was completed at E.V. Spence Reservoir. This TMDL study was approved by the Environmental Protection Agency (EPA) in May 2003. As a result of the TMDL study, a Watershed Action Plan was developed which provides a comprehensive strategy for restoring and maintaining water quality in the area. Continued monitoring of the area should show improving water quality as the Action Plan is implemented.

Infrequent low dissolved oxygen levels have been reported by the TCEQ within the lower 25 miles of Pecan Bayou above Lake Brownwood. There are no known point sources of water pollution within the segment that could be responsible for the problem. Low oxygen levels may be due to natural conditions and/or agricultural non-point source pollution. The TCEQ has not given this a priority ranking on the 303(d) list, instead stating that more data will be collected before a TMDL is scheduled. No impairment to water use as a result of the water quality has been reported.

The high nitrate levels present in the Concho River east of San Angelo and the groundwater water in Runnels, Concho and Tom Green Counties appear to be from a combination of natural conditions, general agricultural activities (particularly as related to wide spread and intense crop production), and locally from confined animal feeding operations and/or industrial activities. Surface waters in the Concho River near Paint Rock have consistently demonstrated nitrate levels above drinking water limits during winter months. This condition has caused compliance problems for the city of Paint Rock, which uses water from the Concho River. It has been determined through studies funded by the Texas Clean Rivers Program that the elevated nitrates in the Concho River result from dewatering of the Lipan aquifer through springs and seeps to the river.[36]

The North Fork of the Concho River from O.C. Fisher Reservoir Dam to Bell Street in San Angelo is heavily impacted with non-point source urban runoff, which leads to oxygen depletion and a general water quality deterioration. Numerous fish kills have occurred along this 4.75 mile stretch of the Concho River since the late 1960's. In addition, toxics have been reported by the TCEQ within the same stream segment. Both of these problems are believed to result from non-point source water pollution. Since 1994, the Upper Colorado River Authority and the City of San Angelo have been involved in a comprehensive effort to mitigate these problems through the Federal Clean Water Act (CWA) 319(h) program. This program provides grant funds to implement Best Management Practices (BMPs) designed to mitigate non-point source water quality problems. The EPA 319(h) program is administered in Texas through the TCEQ.

Hickory Aquifer

Radionuclides present in the Hickory aquifer originate from geologic formations. Several of the public water systems that rely on this aquifer sometimes exceed the TCEQ's radionuclide limits, including limits on radon. Some users are blending water from other sources with Hickory supplies to reduce radionuclide concentrations. According to local representatives of Hickory aquifer users on the Region F Water Planning Group, water from the Hickory aquifer has been used for decades with no known or identified health risk or problems. Since the radioactive contaminants are similar chemically to water hardness minerals (with the exception of radon), removal techniques are well known within the water industry. Problems that have yet to be resolved in utilizing these techniques are the storage and disposal of the removed radioactive materials left over from the water treatment process, and the funding of treatment improvements for small, rural communities. Removal techniques for radon are well known and should not present any major problems to suppliers in implementation. Generally, agricultural use is not impaired by the presence of the radionuclides.

Other Groundwater Quality Issues

Other groundwater quality issues in Region F include elevated levels of fluoride, nitrate, arsenic and perchlorate. Table 1.8-2 shows the percentage of water wells sampled by the TWDB that exceed drinking water standards for fluoride, nitrate and arsenic. The largest percentage of wells with excessive fluoride can be found in Andrews and Martin Counties. Elevated nitrate levels can be found throughout Region F, with a high percentage of wells exceeding standards in Ector, Midland, Runnels and Upton Counties. The highest percentages of wells exceeding arsenic standards are found in Borden, Midland and Martin Counties. Perchlorate is a growing water quality concern for water from the Ogallala aquifer in west Texas. Preliminary research found perchlorate levels exceeding drinking water standards in 35 percent of the public drinking water wells.[37]

Table 1.8-2
Percentage of Sampled Water Wells Exceeding Drinking Water Standards for Fluoride, Nitrate and Arsenic (2008)

County	Fluoride	Nitrate	Arsenic
Andrews	27%	54%	36%
Borden	13%	44%	40%
Brown	2%	36%	0%
Coke	1%	39%	0%
Coleman	1%	41%	0%
Concho	1%	56%	0%
Crane	7%	38%	30%
Crockett	0%	15%	0%
Ector	2%	81%	26%
Glasscock	3%	72%	11%
Howard	20%	61%	28%
Irion	0%	22%	0%
Kimble	0%	26%	0%
Loving	0%	41%	5%
Martin	46%	76%	72%
Mason	0%	52%	0%
McCulloch	1%	26%	0%
Menard	0%	19%	0%
Midland	11%	85%	42%
Mitchell	6%	37%	0%
Pecos	2%	31%	5%
Reagan	3%	67%	10%
Reeves	1%	30%	1%
Runnels	10%	94%	0%
Schleicher	0%	22%	0%
Scurry	3%	34%	6%
Sterling	0%	29%	0%
Sutton	0%	18%	0%
Tom Green	0%	52%	0%
Upton	0%	80%	3%
Ward	1%	25%	8%
Winkler	2%	13%	14%

Data are from the Texas Water Development Board 12-2008[38]

Current and Proposed TMDL Studies in Region F

The TCEQ publishes *The State of Texas Water Quality Inventory* every two years. The Water Quality inventories indicate whether public water supply use is supported in the stream segments designated for public water supply in Region F. The TCEQ has also established a list of stream segments for which it intends to develop Total Maximum Daily Load (TMDL) evaluations to address water quality concerns.[39] Two TMDLs exist in Region F: one for E.V. Spence Reservoir and one for the Colorado River downstream of E.V. Spence Reservoir. Monitoring of these reaches is conducted by TCEQ.

Regional Drought

Most of Region F has experience drought-of-record conditions since the mid 1990s. Although extensive rains in 2004 and 2007 brought some relief to the drought conditions, there remains a large volume of empty reservoir storage in the region. Over the last few years, reservoir storage has generally continued to remain low. In March 2010, the capacities of Lake J.B. Thomas, E.V. Spence Reservoir, and O.C. Fisher Lake were less than 10 percent. Twin Buttes, Champion Creek, Hords Creek Lake and Red Bluff reservoirs reported storage amounts at less than or equal to 25 percent of capacity. O.H. Ivie was at 43 percent of capacity. Aquifers generally respond more slowly to drought conditions than surface water supplies. However, without significant rainfall, little recharge will be available to replace water currently being pumped from these aquifers.

Drought conditions also have a negative impact on water quality. As water levels decline, reservoirs tend to concentrate dissolved materials. Without significant fresh water inflows the water quality in a reservoir degrades. The lack of recharge to aquifers has a similar effect on groundwater.

1.8.2 Constraints

A major constraint to enhancing water supply in Region F is a lack of appropriate locations for new surface water supply development and lack of available water for new surface water supply projects. There are few sites in the region that have sufficient runoff to justify the cost of developing a new reservoir without having a major impact on downstream water supplies. Generally, the few locations that do have promise are located far from the areas with the greatest needs for additional water. In addition, the Colorado and Rio Grande WAMs show very little available surface water for new appropriations in Region F. There is very little water available that has not already been allocated to existing water rights.

Much of the surface water and groundwater in the region contains high concentrations of dissolved solids, originating from natural and man-made sources. It is possible to make use of these resources, but the cost to treat this water can be high. Much of the region is economically distressed due to downturns in the petroleum industry and agriculture. Therefore, advanced treatment, system improvements or long distance transportation of water may not be economically feasible. Also, many of these smaller communities have experienced declining populations in recent years. More than one-half of the counties in the region have a population less than 5,000 people. These smaller counties lost 2.2 percent of their population between 1990 and 2000. Thus they are ill equipped to afford the high cost of advanced water treatment techniques, given their declining revenue base.

Finally, many of the municipal water supply needs in Region F are relatively small and are in locations that are far away from reliable water supplies of good quality. Transporting small quantities of water over large distances is seldom cost-effective. Desalination and reuse are good options for these communities. However, the high cost of developing and permitting these types of supplies is a significant constraint on water development. Also, finding a suitable means of disposing the reject concentrate from a desalination project may limit the feasibility of such projects in many locations.

1.9 Water-Related Threats to Agricultural and Natural Resources in Region F

Water-related threats to agricultural resources in Region F include water quality concerns and insufficient groundwater supplies. Water-related threats to natural resources include changes to natural flow conditions and water quality concerns.

1.9.1 Water Related Threats to Agriculture

Water quality concerns for agriculture are largely limited to salt water pollution, both from natural and man-made sources. In some cases, improperly abandoned oil and gas wells have served as a conduit for brines originating deep within the earth to contaminate the shallow groundwater supplies. Prior to 1977, the brines associated with oil and gas production were commonly disposed in open, unlined pits. In some cases these disposal pits have not been remediated and remain as sources of salt contamination. Current brine disposal practices involve repressurizing hydrocarbon-producing formations or disposing through deep well injection. These practices lead to the possibility of leaks into water supply aquifers since the hydraulic pressure of the injected water routinely exceeds the pressure needed to raise the water to the ground's surface. In other aquifers, excessive pumping may cause naturally occurring poor quality water to migrate into fresh water zones.

Most of Region F depends on groundwater for irrigation. According to the *2006 Region F Water Plan,*[40] agricultural demand exceeds the available groundwater supply in several counties. Parts of three counties (Midland, Reagan and Upton) have already been declared a Priority Groundwater Management Area by the TCEQ in response to excessive drawdown in the aquifer.

1.9.2 Water Related Threats to Natural Resources

Reservoir development and invasion by brush have altered natural stream flow patterns in Region F. Spring flows in Region F have greatly diminished. Many springs have dried up because of groundwater development, the spread of high water use plant species such as mesquite and salt cedar, or the loss of native grasses and other plant cover. High water use plant species have reduced reliable flows for many tributary streams. Reservoir development also changes natural hydrology by diminishing flood flows and capturing low flows. It is unlikely that future changes to flow conditions in Region F will be as dramatic as those that have already occurred. If additional reservoirs are developed, they will be required to make low flow releases to maintain downstream stream conditions.

1.10 Water Loss Audit

Retail public water utilities are required to complete and submit a water loss audit form to the Texas Water Development Board every five years. The first water loss audit reports were submitted to the TWDB by March 31, 2006. The data from these reports were compiled by Alan Plummer Associates Inc. through a research and planning fund grant from TWDB.[41] The water audit reporting requirements follow the International Water Association (IWA) and American Water Works Association (AWWA) Water Loss Control Committee methodology.[42]

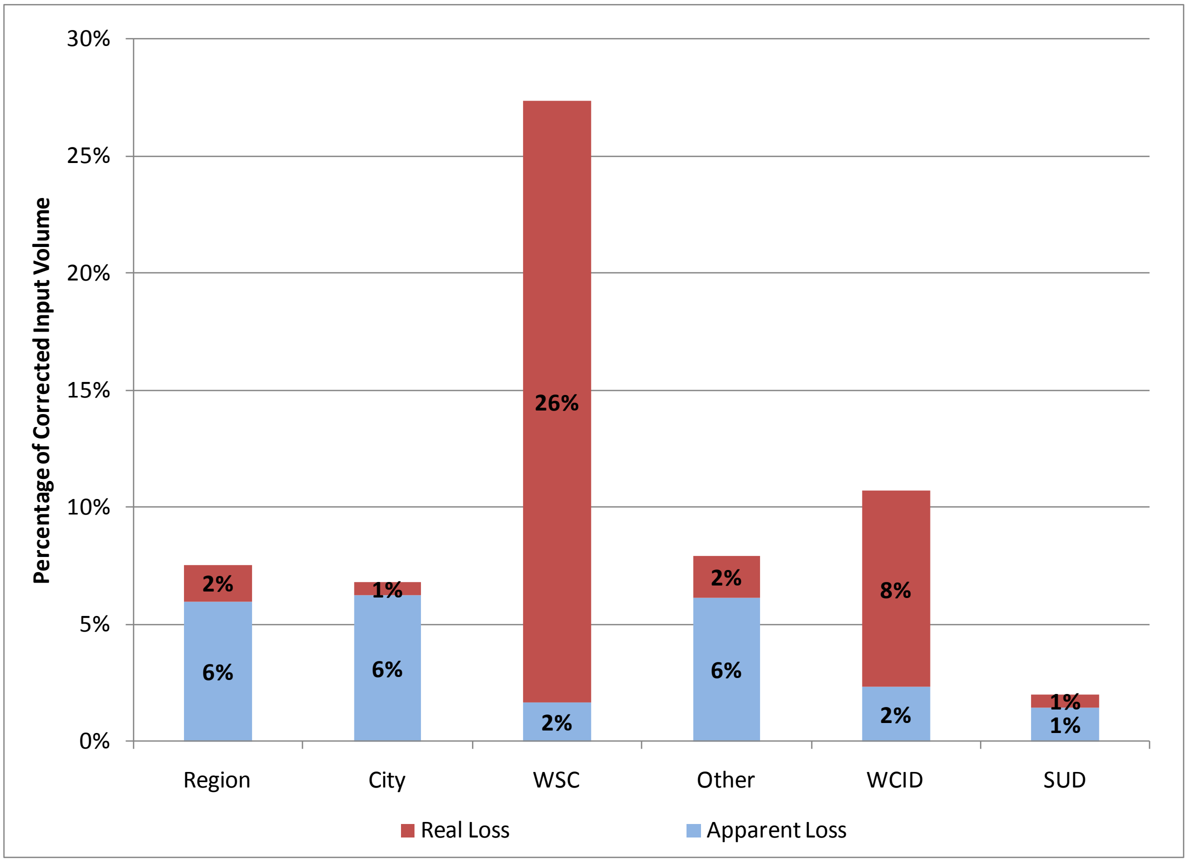
The primary purposes of a water loss audit are to account for all of the water being used and to identify potential areas where water can be saved. Water losses are classified as either as apparent loss or real loss. Apparent loss is the water that has been used but has not been tracked. It includes losses associated with inaccurate meters, billing adjustment and waivers, and unauthorized consumption. Real loss is the actual water loss of water from the system, and includes main breaks and leaks, customer service line breaks and leaks, and storage overflows. The sum of the apparent loss and the real loss make up the total water loss for a utility.

In the Region F planning area, 56 public water suppliers submitted a water loss audit to TWDB. These suppliers include 31 cities, 16 water supply corporations, five other water suppliers, three water conservation and improvement districts and one special utility district. Figure 1.10-1 shows the percentage of total water loss for the region, cities, water supply corporations, other utilities, water conservation and improvement districts and the special utility district.

The average total water loss for Region F is 8 percent. The percentage of total water loss for cities, other suppliers, water conservation and improvement districts and the special utility district are within the range of acceptable water loss (less than or equal to 12 percent). The water loss for water supply corporations is much higher. One explanation for this may be the large areas with low population densities served by rural water suppliers. This makes it difficult for these entities to identify and repair leaks.

The amount of real losses in Region F from the 56 public water suppliers totaled 454 million gallons in 2006. This represents 1.1 percent of the total estimated municipal water demand for the region. Based on these findings, the region is adequately addressing municipal water loss. Measures that are currently in place to control water loss should continue. For the water suppliers that fall under WSC category, there may be few cost effective options in reducing water loss. However, these providers may consider more efficient leak detection and reducing the time required to repair a leak after it is identified.

Figure 1.10-1: Water Loss in Region F



1.11 Navigation in Region F

The U.S. Army Corps of Engineers has published a list of the navigable portions of the rivers in Texas.[43] The Colorado River is considered navigable from the Bastrop-Fayette County line to Longhorn Dam in Travis County. The Rio Grande is considered navigable from the Zapata-Webb County line to the point of intersection of the Texas-New Mexico state line and Mexico. All of these areas are outside of the boundaries of Region F. The Pecos River segment is not specifically included.

1.12 List of References

[1] U.S. Bureau of Census: Population Estimates for Texas Counties 1900 to 2006, available on-line at http://www.cpa.state.tx.us/ecodata/popdata/popfiles.html

[2] Dallas Morning News: *2008-09 The Texas Almanac*, Dallas, 2008.

[3] U.S. Census Bureau, Texas Quick Facts, available on-line at http://quickfacts.census.gov/qfd/states/48/48085.html, downloaded November 2009.

[4] Precipitation and runoff data developed by Freese and Nichols, Inc. from National Climatic Data Center Weather Data and runoff from http://www.ce.utexas.edu/prof/maidment/gishyd97/library/wbtexas/wbtexas.htm.

[5] Developed by Freese and Nichols, Inc. from Texas Water Development Board Quadrangle Evaporation Data, available on-line at ftp://rio.twdb.state.tx.us.evap_data/.

[6] U.S. Geological Survey: Streamflow gage Records, available on line at http://waterdata.usgs.gov/tx/nwis.

[7] Texas Commission on Environmental Quality: Certificates of Adjudication, various dates.

[8] Texas Commission on Environmental Quality: Historical water use database, electronic files, 2009.

[9] Texas Water Development Board: Historical and Projected Population and Water Use Data, electronic files, Austin, 2004.

[10] Texas Commission on Environmental Quality: *Active Water Rights Database*, electronic files, Austin, 2009.

[11] Ashworth, J.B. and Hopkins, J. *Aquifers in Texas*, Texas Water Development Board Report 345, 1995.

[12] Texas Agricultural Extension Service (TAES): Managing Texas' Groundwater Resources Through Underground Water Conservation Districts, College Station, 1996.

[13] Brune, Gunnar: *Major and Historical Springs of Texas,* Texas Water Development Board Report 189, 1975.

[14] Brune, Gunnar: *Springs of Texas,* Volume I, Branch-Smith, Inc., Fort Worth, 1981.

[15] Texas Parks and Wildlife Department: *Evaluation of Selected Natural Resources in Parts of Loving, Pecos, Reeves, Ward and Winkler Counties, Texas,* Austin, 1998.

[16] Texas Nature Conservancy. Sandia Springs Preserve. Available on-line at http://nature.org/wherewework/northamerica/states/texas/preserves/art6622.html, 2004.

[17] U.S. Fish and Wildlife Service (USFWS). 2004. ESA Basics, 30 Years of Protecting Endangered Species. [Online] (November 2004). Available URL: http://endangered.fws.gov

[18] United States Department of Agriculture, National Agricultural Statistics Service: *2007 Census of Agriculture, Texas State and County Profiles*, [online], at URL: http://www.agcensus.usda.gov/Publications/2007/index.asp

[19] National Resources Conservation Service, State Soil Geographic (STATSGO) Database, URL http://www.ftw.nrcs.usda.gov/stat_data.html

[20] Texas Railroad Commission: Map of Top 25 Producing Oil and Gas Fields, Based on 1999 Production, [Online], (November 2003), Available URL: http://www.rrc.state.tx.us/divisions/og/activity/top251999.html

[21] Texas Water Development Board: *Exhibit B Guidance for Developing Regional Water Plans*, February 2008.

[22] Colorado River Municipal Water District: Wholesale Water Provider Survey data, March 2009.

[23] Brown County Water Improvement District Number One: Wholesale Water Provider Survey data, April 2009.

[24] Upper Colorado River Authority: Wholesale water Provider Survey data, April 2009.

[25] Texas Department of Water Resources: *Present and Future Water Availability in the Colorado River Basin, Texas, Report LP-60*, 1978.

[26] Texas Water Development Board: *Water for Texas – 2002*, Austin, 2002.

[27] Freese and Nichols, Inc.: *Long-Range Water Supply Plan*, prepared for the City of San Angelo, November 2000.

[28] Texas Water Development Board: Rainfall and Runoff Data, [online], (May 1999), at URL: rainfall http://www.ocs.orst.edu/prism_new.html and runoff http://www.ce.utexas.edu/prof/maidment/gishyd97/library/wbtexas/wbtexas.htm

[29] Texas Commission on Environmental Quality. 2000. The Texas Clean Rivers Program. [Online] (November 2004). Available URL: http://www.tnrcc.state.tx.us/water/quality/data/wmt

[30] Environmental Protection Agency (EPA). 2003. Introduction to the Clean Water Act. [Online] (November 2004). Available URL: www.epa.gov/watertrain/cwa/rightindex.htm

[31] Environmental Protection Agency (EPA). 1999. Understanding the Safe Water Drinking Act. [Online] (November 2004). Available URL: http://www.epa.gov/safewater/sdwa/index.html

[32] Texas Water Development Board: *Water for Texas Today and Tomorrow – 1990*, December 1990.

[33] Texas Water Development Board: *Water for Texas*, August 1997.

[34] Texas Commission on Environmental Quality (TCEQ). Draft 2008 Water Quality Inventory Summary of Water Bodies with Water Quality Concerns. [Online] (May 19, 2008). Available URL: http://www.tceq.state.tx.us/assets/public/compliance/monops/water/08twqi/2008_303d.pdf

[35] Texas Clean Rivers Program, 2004 Colorado River Basin Highlights Report, 2004. Available URL: http://www.lcra.org/crp/crpreports.html

[36] Upper Colorado River Authority: *North Concho River Watershed Brush Control Planning, Assessment and Feasibility Study*, September 1999.

[37] "Perchlorate Mystery Surfaces in Texas", Environmental Science and Technology Online, October 2, 2003. Available URL http://pubs.acs.org/subscribe/journals/esthag-w/2003/oct/science/kc_perchlorate.html

[38] Texas Water Development Board groundwater database. Available URL http://www.twdb.state.tx.us/publications/reports/GroundWaterReports/GWDatabaseReports

[39] Texas Commission on Environmental Quality (TCEQ). 2008. Draft 2008 Water Quality Assessments for Individual Water Bodies. [Online] (May 2008). Available URL:

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/08twqi/2008_303d.pdf

[40] Freese and Nichols, Inc., *Region F Regional Water Plan*, Fort Worth, January 2001.

[41]Alan Plummer Associates, Inc. Water prospecting and Rsource Consulting, LLC. Final Report: An Analysis of Water Loss as Reported by Public Water Suppliers in Texas. Austin: TWDB, January 24, 2007.

[42] AWWA Water Loss Control Committee, *Water Audits and Loss Control Programs, Near Final Draft for Water Loss Control Committee Review*, AWWA M36 Publication Rewrite, 2006.

[43] U.S. Army Corps of Engineers, Fort Worth District: *Navigable Waters of the United States in the Fort Worth, Albuquerque, and Tulsa Districts Within the State of Texas*, March 20, 1999.

2 CURRENT AND PROJECTED POPULATION AND WATER DEMAND DATA FOR THE REGION

2.1 Introduction

In November 2003,[1] the Texas Water Development Board (TWDB) approved population and water demand projections for Region F for use in the 2006 regional water plan. As part of the 2010 regional water plan update, these projections were reviewed by the region and revised as needed. There are no recommended revisions to population projections. The region decided to wait until after the 2010 U.S. Population Census to adjust populations if needed. The only recommended revision to water demands is for steam electric power in Mitchell County, which was reduced from 9,100 to 5,023 acre-feet in 2010 and 14,730 to 4,140 acre-feet in 2060.

The TWDB distributes its population and demand projections into Water User Groups (WUGs). A WUG is defined as one of the following:

- Cities with population of 500 or more,
- Individual utilities providing more than 0.25 million gallons per day (MGD) for municipal use,
- Rural/unincorporated areas of municipal water use, known as County Other (aggregated on a county/basin basis),
- Manufacturing (aggregated on a county/basin basis),
- Steam electric power (aggregated on a county/basin basis),
- Mining (aggregated on a county/basin basis),
- Irrigation (aggregated on a county/basin basis), or
- Livestock (aggregated on a county/basin basis).

Each WUG has an associated water demand. Only municipal WUGs have population projections.

To simplify the presentation of these data all projections in this chapter are aggregated by county. Projections divided by WUG, county and basin may be found in Appendix 2A.

The projections were developed by decade and cover the period from 2010 to 2060.

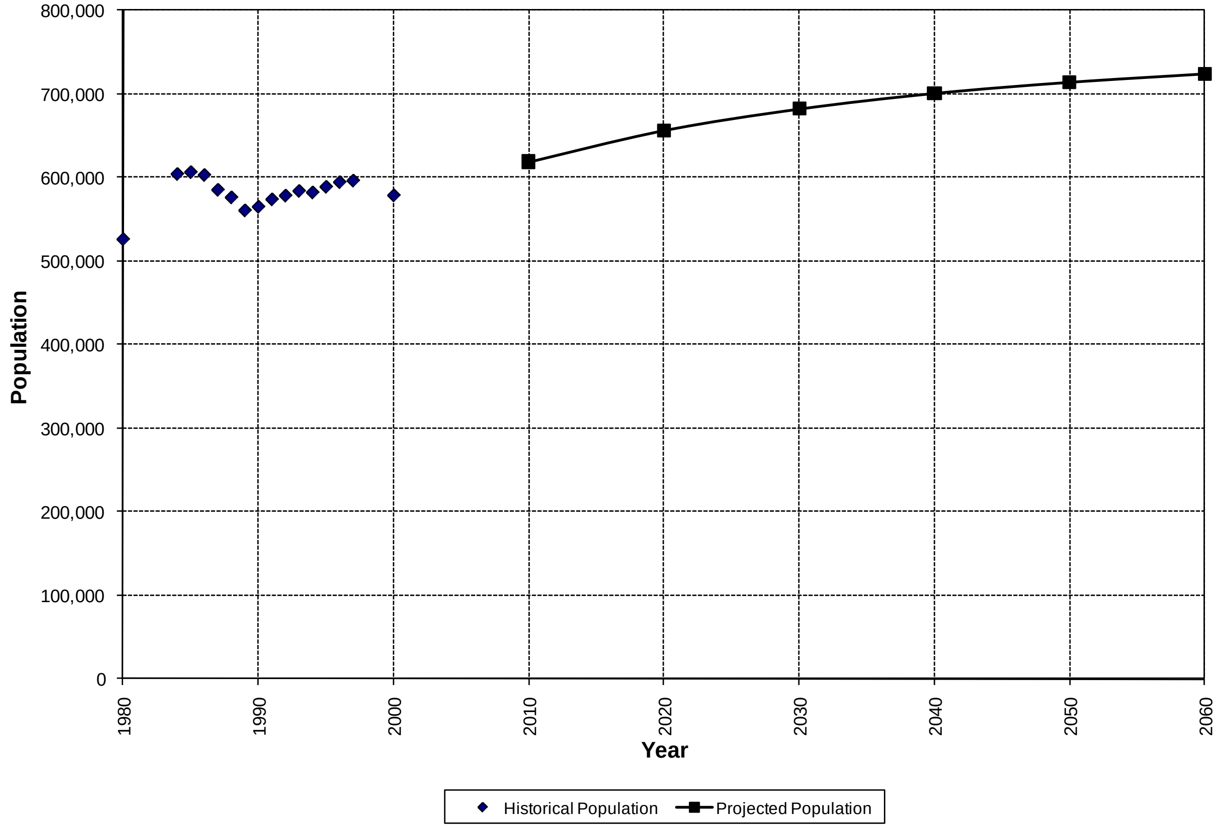
2.2 Population Projections

Table 2.2-1 presents the historical year 2000 and projected populations for the counties in Region F. Figure 2.2-1 compares the region's historical population between 1980 and 2000 and the projected population through 2060. Figure 2.2-2 shows the geographical distribution of the population projections for the years 2000 and 2060. Population projections divided by WUG, county and basin are in Table 2A-1 of Appendix 2A.

Table 2.2-1
Historical and Projected Population by County

County	Historical	Projected					
	2000	2010	2020	2030	2040	2050	2060
Andrews	13,004	14,131	15,078	15,737	16,358	16,645	16,968
Borden	729	792	820	782	693	644	582
Brown	37,674	39,324	40,602	40,959	40,959	40,959	40,959
Coke	3,864	3,748	3,750	3,750	3,750	3,750	3,750
Coleman	9,235	9,141	9,149	9,149	9,149	9,149	9,149
Concho	3,966	4,467	4,628	4,628	4,628	4,628	4,628
Crane	3,996	4,469	4,990	5,272	5,487	5,718	5,961
Crockett	4,099	4,482	4,840	4,966	5,022	5,139	5,244
Ector	121,123	132,759	144,073	154,160	163,141	170,307	177,026
Glasscock	1,406	1,582	1,783	1,891	1,921	1,915	1,954
Howard	33,627	34,574	35,438	35,719	35,719	35,719	35,719
Irion	1,771	1,888	1,938	1,892	1,774	1,680	1,606
Kimble	4,468	4,660	4,702	4,702	4,702	4,702	4,702
Loving	67	67	67	67	67	67	67
McCulloch	8,205	8,235	8,377	8,377	8,377	8,377	8,377
Martin	4,746	5,203	5,696	5,935	6,082	5,934	5,633
Mason	3,738	3,817	3,856	3,876	3,886	3,891	3,896
Menard	2,360	2,493	2,528	2,528	2,528	2,528	2,528
Midland	116,009	124,710	134,022	140,659	145,595	148,720	151,664
Mitchell	9,698	9,736	9,714	9,545	9,332	9,069	8,521
Pecos	16,809	17,850	18,780	19,300	19,580	19,630	19,246
Reagan	3,326	3,791	4,182	4,381	4,367	4,213	4,010
Reeves	13,137	14,281	15,451	16,417	17,219	17,949	18,527
Runnels	11,495	11,610	12,025	12,339	12,686	12,956	13,298
Schleicher	2,935	3,159	3,387	3,491	3,533	3,594	3,658
Scurry	16,361	16,998	17,602	17,923	18,092	18,203	18,203
Sterling	1,393	1,529	1,680	1,744	1,766	1,717	1,739
Sutton	4,077	4,479	4,737	4,780	4,762	4,773	4,725
Tom Green	104,010	112,138	118,851	123,109	125,466	127,333	127,752
Upton	3,404	3,757	4,068	4,185	4,278	4,400	4,518
Ward	10,909	11,416	11,710	11,846	11,846	11,846	11,846
Winkler	7,173	7,603	7,956	8,023	8,041	7,890	7,638
Total	*578,814*	*618,889*	*656,480*	*682,132*	*700,806*	*714,045*	*724,094*

Figure 2.2-1
Historical and Projected Population of Region F



1. Historical data provided by the Texas Water Development Board.[2] Data from 1981 to 1983 are not available. Projected population was approved by TWDB for the second round of regional water planning and adopted for this plan.

The population projections for each county are derived from the 2000 U.S. Census. The projections use a standard methodology known as the *cohort-component method*. This method is based upon historical birth and survival rates of the region's population. More information on the methodology used for the population projections may be found in the TWDB publication *Water for Texas – Today and Tomorrow: A 1996 Consensus-Based Update to the Texas Water Plan Vol. III, Water Use Planning Data Appendix.*[3]

TWDB projects the region's total population to increase from 578,814 in 2000 to 724,094 in 2060, an average growth rate of 0.37 percent per year. TWDB projects the total population for Texas to increase from 20,851,790 in 2000 to 46,323,826 in 2060, a growth rate of 1.3 percent per year.

The relative distribution of population in Region F is expected to remain stable throughout the 50-year planning period. Almost 80 percent of the people in Region F live in urban areas or small to moderate sized rural communities. Three counties, Midland, Ector and Tom Green, account for nearly half of the region's population. These counties contain the cities of Midland, Odessa and San Angelo, respectively. Each of these cities had a year 2000 population between 85,000 and 95,000.

Twenty-nine of the thirty-two counties that comprise Region F are generally rural. Twenty-one counties have populations of less than 10,000. Two of these counties, Loving and Borden, have populations of less than 1,000. These twenty-nine counties are expected to remain primarily rural throughout the planning period. Some counties, particularly those in the eastern portion of Region F, are beginning to see an influx of weekend, recreational and other non-resident population from other parts of the state. Because this population is counted by the census as residing in another region, this population growth and the resulting water demand are not reflected in the TWDB-approved projections.

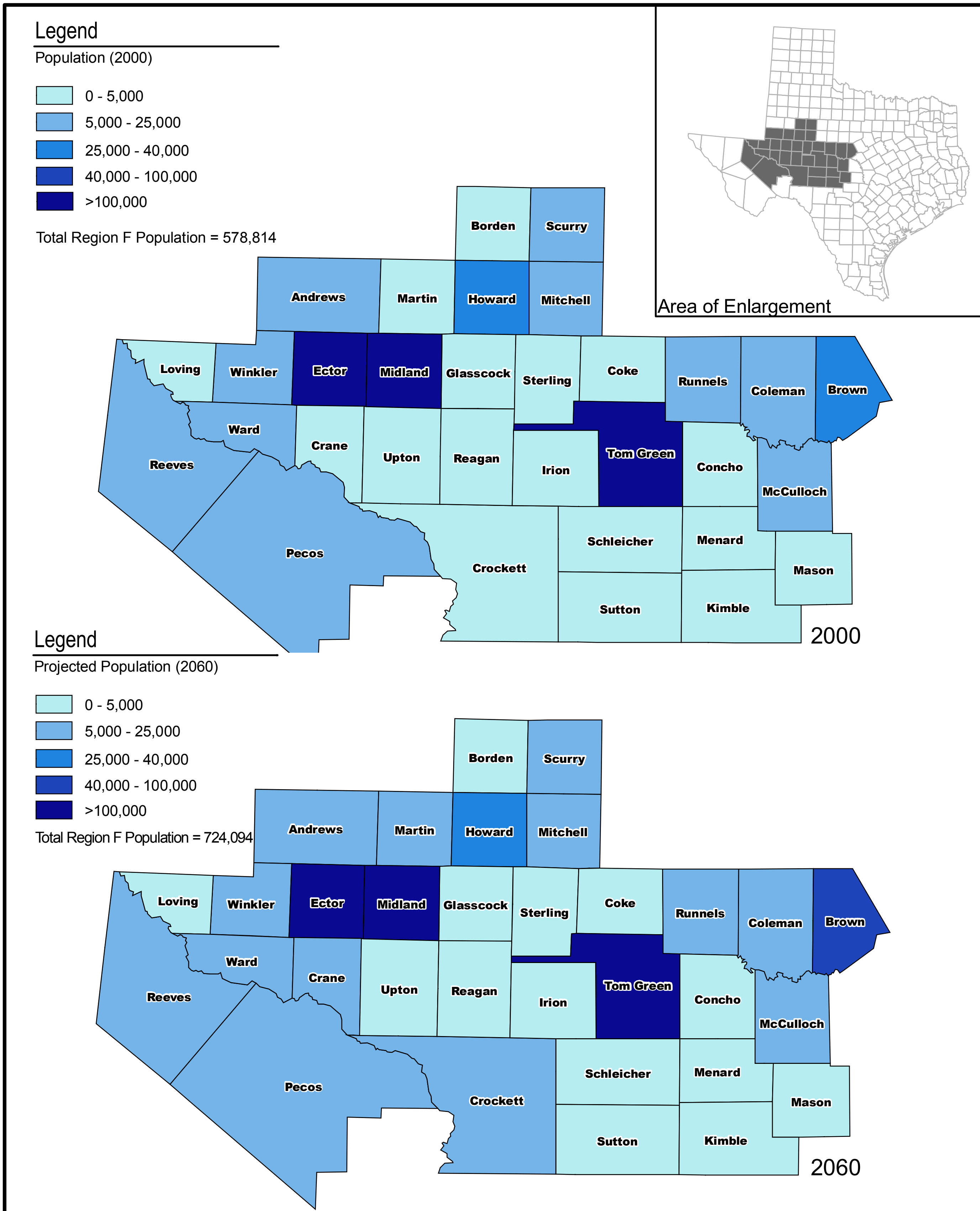
2.3 Historical and Projected Water Demands

TWDB divides its water demand projections into six water use categories:

- *Municipal* – residential and commercial uses, including landscape irrigation,
- *Manufacturing* – various types of heavy industrial use,
- *Irrigation* - irrigated commercial agriculture,
- *Steam Electric Power Generation* – water consumed in the production of electricity,
- *Livestock Watering* – water used in commercial livestock production, and
- *Mining* – water used in the commercial production of various minerals, as well as water used in the production of oil and gas.

Municipal water use is the only category subdivided into individual entities such as cities and other water providers. All other categories are aggregated into county/basin units.

Each category has annual water demand projections for the years 2010, 2020, 2030, 2040, 2050, and 2060. These projections are not the same as the average day and peak-day projections used in planning for municipal water supply distribution systems.



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Region F

Population Distribution by County 2000-2060

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FIGURE

The average day projection is the amount of water expected to be delivered during a normal day. A peak-day projection is the maximum amount of water expected to be delivered during the highest demand day, typically expressed in million gallons per day (MGD). The TWDB water demand projections are the volume of water expected to be used during a dry year and are usually expressed in acre-feet (one acre-foot equals 325,851 gallons).

The water demand projections for the 2006 water plan were developed in conjunction with the TWDB and regional stakeholders. The Region F Water Planning Group solicited input from selected cities, water providers, county judges, and steam electric power generators. The projections were then compared to historical data and other projections and evaluated for anomalies such as recent water use exceeding future predictions, changes in trends in per capita water use since 1990, etc. The final recommended demands were approved by the region and the TWDB for the 2006 Region F Water Plan. These projections are the basis for the water demands in the updated 2011 Region F Water Plan.

Subsequent to the completion of the 2006 regional water plans, the TWDB contracted with the Bureau of Economic Geology (BEG) to develop water demand projections for power generation in Texas.[4] The region reviewed the data in the report and it was recommended that Region F adopt the projections developed for the 2006 Region F Water Plan for all counties with a reduction in demand in Mitchell County. For Mitchell County, it was recommended that the projected demands be limited to the currently available supply in the county for this use. The review and recommendations for steam electric power are further discussed in Section 2.3.4.

Table 2.3-1 and Figure 2.3-1 present the TWDB-approved total water demand projections for the region by water-use type through 2060. Table 2.3-2 summarizes the historical year 2006 use and the projected water use by county. Figure 2.3-2 shows the geographical distribution of the year 2006 historical water use and year 2060 total water demand projections by county. A discussion of the demand projections by each use type is presented in Sections 2.3.1 through 2.3.6.

The significant increase in total water use between the historical year 2006 data and the year 2010 projections is mainly due to irrigation demands. Region F feels that historical year 2006 water use for irrigation is not indicative of the potential for irrigation water use in the region. More information on the region’s projected irrigation demands may be found in Section 2.3.3.

Steam electric projects are also higher than the historical 2006 use. Several power generation facilities in Region F have recently ceased operation. The future use of these facilities is uncertain.

Table 2.3-1
Water Demand Projections for Region F by Use Category
(Values in Acre-Feet per Year)

Use Category	Historical	Projected					
	2006[a]	2010	2020	2030	2040	2050	2060
Municipal	121,620	141,965	147,828	151,280	153,206	155,340	157,632
Manufacturing	11,914	9,757	10,595	11,294	11,960	12,524	13,313
Irrigation	418,636	578,606	573,227	567,846	562,461	557,080	551,774
Steam Electric	3,732	18,138	19,995	22,380	25,324	28,954	33,418
Mining	26,905	31,850	33,097	33,795	34,479	35,154	35,794
Livestock	15,207	23,060	23,060	23,060	23,060	23,060	23,060
Total	598,014	*803,376*	*807,802*	*809,655*	*810,490*	*812,112*	*814,991*

a. Data are from the TWDB.

b. Historical mining data are from 2005. The mining data for 2006 includes only self-reported usage, which is not representative of all mining use in the region.

Figure 2.3-1
Projected Water Demand in Region F by Use Category

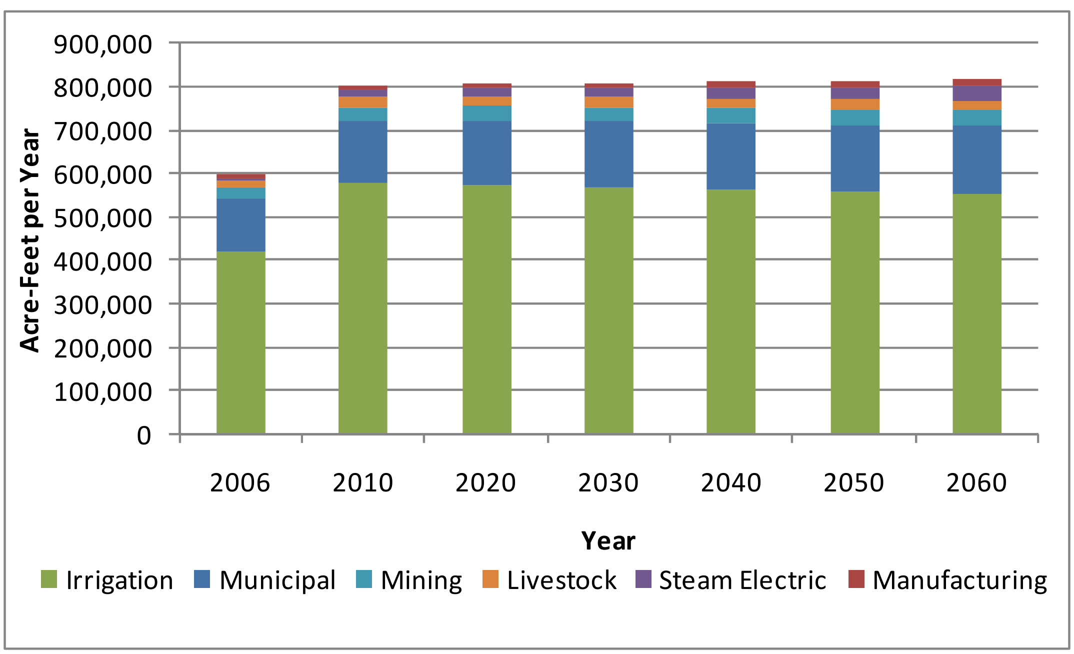
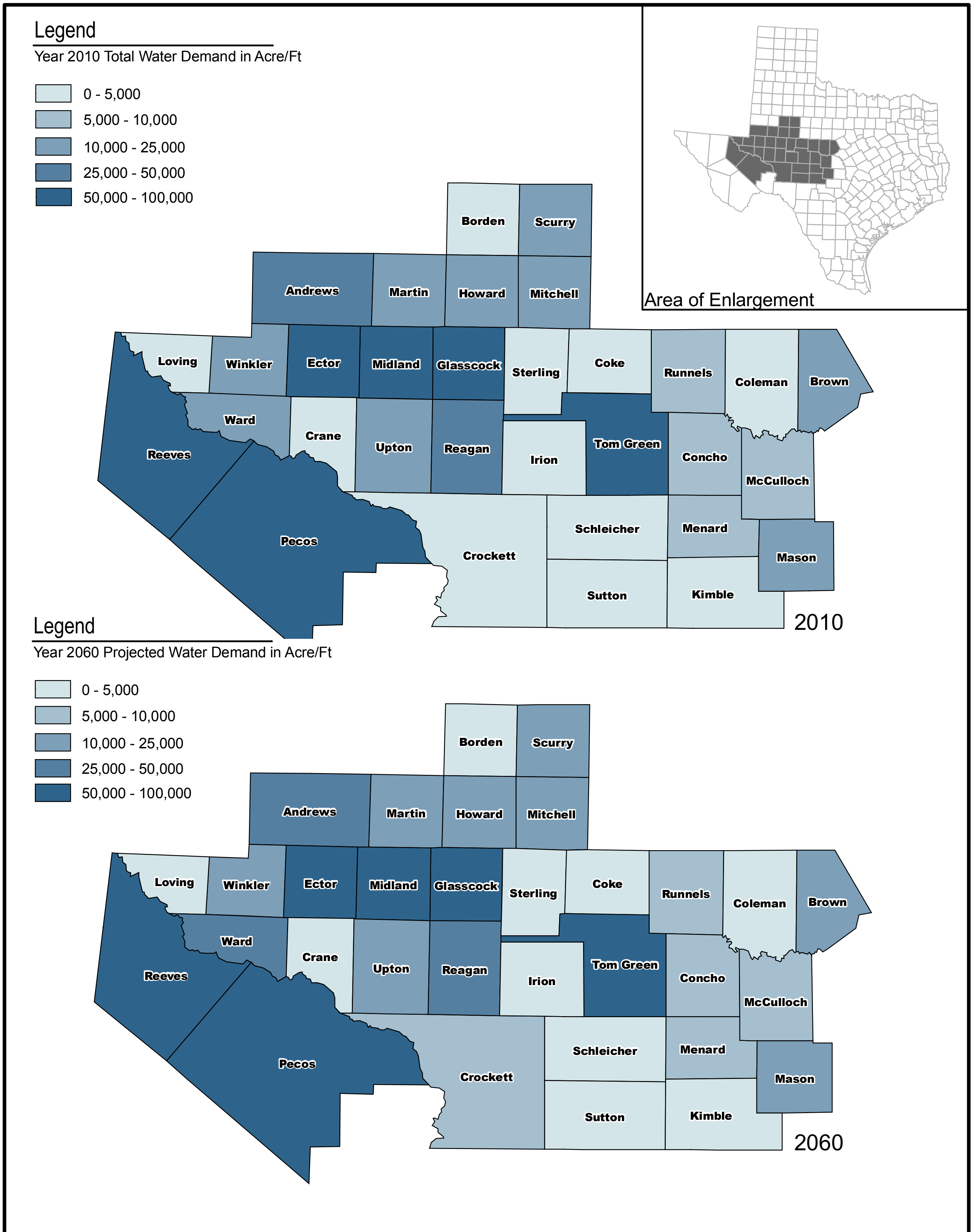


Table 2.3-2
Total Historical and Projected Water Demand by County
(Values in Acre-Feet per Year)

County	Historical	Projected					
	2006 [a]	2010	2020	2030	2040	2050	2060
Andrews	35,219	38,579	38,550	38,413	38,261	38,059	37,892
Borden	3,488	3,836	3,805	3,778	3,744	3,717	3,689
Brown	19,165	24,119	24,221	24,173	24,053	24,011	24,040
Coke	1,965	3,098	3,070	3,121	3,179	3,257	3,354
Coleman	3,458	4,536	4,509	4,477	4,447	4,429	4,429
Concho	8,879	5,945	5,947	5,921	5,890	5,869	5,853
Crane	6,622	3,969	4,097	4,159	4,201	4,258	4,323
Crockett	2,498	4,604	4,543	4,708	4,873	5,110	5,387
Ector	32,915	53,556	59,000	62,670	66,493	70,656	75,320
Glasscock	46,924	52,690	52,287	51,878	51,458	51,037	50,628
Howard	13,785	15,904	16,118	16,122	16,064	16,064	16,184
Irion	1,247	3,623	3,563	3,491	3,411	3,337	3,268
Kimble	4,422	3,574	3,592	3,598	3,601	3,606	3,641
Loving	111	664	663	658	657	655	654
McCulloch	17,193	7,101	7,167	7,183	7,190	7,205	7,270
Martin	8,932	16,098	15,875	15,629	15,371	15,085	14,787
Mason	9,577	12,053	11,904	11,750	11,595	11,445	11,305
Menard	3,271	7,161	7,138	7,110	7,083	7,058	7,039
Midland	54,747	75,806	77,236	78,097	78,534	78,836	79,259
Mitchell	8,919	12,824	12,584	12,327	12,060	11,796	11,500
Pecos	74,653	85,897	84,826	83,661	82,434	81,178	79,854
Reagan	21,966	39,940	39,550	39,059	38,502	37,919	37,336
Reeves	94,581	110,088	109,479	108,809	108,090	107,382	106,701
Runnels	5,726	8,059	8,102	8,123	8,143	8,172	8,229
Schleicher	2,071	3,743	3,763	3,745	3,707	3,681	3,662
Scurry	10,289	10,217	10,393	10,393	10,357	10,346	10,373
Sterling	1,135	2,090	2,101	2,090	2,068	2,034	2,020
Sutton	3,265	4,159	4,195	4,160	4,105	4,068	4,020
Tom Green	70,681	132,935	133,952	134,464	134,624	134,938	135,230
Upton	12,079	20,575	20,420	20,208	19,986	19,780	19,584
Ward	10,871	22,477	21,656	22,202	22,863	23,743	24,870
Winkler	7,360	13,456	13,496	13,478	13,446	13,381	13,290
Total	*598,014*	*803,376*	*807,802*	*809,655*	*810,490*	*812,112*	*814,991*

a. Data are from the TWDB. Historical mining data are from 2005.



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N W E S

Region F

Total Water Demand by County 2010-2060

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FIGURE

2.3.1 Municipal Water Demand Projections

Municipal water demand consists of both residential and commercial use, including water used for landscape irrigation. Residential use includes water used in single and multi-family households. Commercial use includes business establishments, public spaces and institutions, but does not include most industrial water use. Industrial water demand projections are included in the manufacturing category.

Municipal projections were developed for each city of more than 500 people and water utilities that provide 0.25 MGD or more. TWDB aggregates rural populations and towns of less than 500 people into the County Other classification. The municipal projections are the only projections developed for individual water providers such as cities and other water providers. TWDB aggregates all other demand categories by county and river basin.

TWDB used a three-step process to calculate municipal water demands. First, population projections were developed for each municipal WUG. Second, per capita water use projections were developed. (Population projections are discussed in Section 2.2.) Finally, the per capita water demand projections were multiplied by the population projections to determine the annual municipal water demand for each WUG.

Per Capita Water Use Projections

Future water use is calculated by multiplying the population of a region, county or city by a calculated per capita water use. *Per capita water use,* expressed in gallons per capita per day (gpcd), is the average daily municipal water use divided by the population of the area. It includes the amount of water used by each person in their daily activities, water used for commercial purposes, and landscape watering. This definition of per capita water use does not include water used for manufacturing or other non-municipal purposes (if it can be distinguished from other uses), or water sold to another entity. (This definition of per capita use is not the same as the definition adopted by the Water Conservation Implementation Task Force. The Task Force definition does not differentiate between municipal use and non-municipal use or outside sales[5].)

The TWDB based the per capita water demand projections on year 2000 annual municipal water use divided by the 2000 population. In some cases, the projections were adjusted if the year 2000 water use was not indicative of historical water use by a WUG. In Region F, several WUGs were under water use restrictions in 2000 and their per capita water use was adjusted upward.

The TWDB assumes that per capita water use will show a downward trend over the planning period as a result of the State Water-Efficiency Plumbing Act. Among other things, the Plumbing Act requires that only water-saving plumbing fixtures may be sold in Texas. The TWDB determined the per capita water demand savings based upon the expected rate of replacement of old plumbing fixtures with water-conserving models and the number of new housing units expected in the region. The actual amount of estimated savings can vary somewhat depending upon the age of housing units in a WUG's service area.

Table 2.3-3 shows the average per capita water use for each decade in Region F and compares these values to average values for the state. Average per capita water use for Region F is expected to decline from 205 gpcd in 2010 to 194 gpcd in 2060, a reduction of 5 percent. This compares to the statewide average of 171 gpcd for the year 2010 declining to 162 gpcd by 2060.

Table 2.3-3
Comparison of Per Capita Water Use and Municipal Conservation Trends

Region F	**Base***	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Per Capita Use (gpcd)	206	205	201	198	195	194	194
Decline from Year 2000		1	5	8	11	12	12
% Decline from Year 2000		1%	3%	4%	5%	6%	6%
Statewide	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Per Capita Use (gpcd)	173	171	168	166	164	162	162
Decline from Year 2000		2	5	7	10	11	11
% Decline from Year 2000		1.5%	3%	4%	5%	6%	6%

Source: Data are from TWDB[6].

* In most cases per capita demand projections are based on year 2000 water use. However, in Region F other years may have been used that are more indicative of historical water demand trends, particularly for water users under restrictions in the year 2000. This results in a base per capita water use of 206 gpcd. In Region F, the actual year 2000 per capita water use was 198 gpcd.

Municipal Water Demand

The TWDB calculated the municipal water demand projections by multiplying the population projections by the average per capita water use projections. As shown in Table 2.3-4, the total municipal water demand for Region F is expected to increase from 141,965 acre-feet per year in 2010 to 157,632 acre-feet per year in 2060, an increase of 11 percent over the planning period. This compares to an expected 73 percent increase in municipal demand statewide.

Table 2.3-4
Municipal Water Demand Projections for Region F Counties
(Values in Acre-Feet Per Year)

	Historical	**Projected**					
County	**2006** [a]	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Andrews	2,736	3,625	3,821	3,937	4,041	4,093	4,173
Borden	144	175	179	169	148	136	123
Brown	6,812	7,106	7,173	7,111	6,978	6,932	6,932
Coke	389	771	766	755	742	737	737
Coleman	1,767	1,874	1,846	1,814	1,784	1,766	1,766
Concho	578	873	892	884	870	865	865
Crane	1,125	1,256	1,389	1,453	1,497	1,556	1,623
Crockett	1,267	1,707	1,831	1,865	1,870	1,909	1,949
Ector	26,553	28,708	30,634	32,271	33,757	35,208	36,725
Glasscock	145	181	196	203	200	197	201
Howard	5,787	7,308	7,372	7,310	7,190	7,140	7,140
Irion	198	238	239	227	208	194	185
Kimble	835	1,148	1,142	1,129	1,113	1,104	1,104
Loving	7	11	11	10	10	10	10
McCulloch	2,388	2,252	2,263	2,236	2,205	2,190	2,190
Martin	597	788	843	858	860	832	789
Mason	854	932	926	916	905	898	900
Menard	332	458	455	446	438	435	435
Midland	31,965	32,568	34,202	35,301	35,976	36,517	37,180
Mitchell	1,390	1,703	1,671	1,621	1,559	1,499	1,409
Pecos	4,220	4,816	4,991	5,071	5,090	5,079	4,980
Reagan	1346	1,035	1,123	1,167	1,148	1,103	1,049
Reeves	3,264	3,834	4,082	4,272	4,416	4,571	4,713
Runnels	1,320	2,091	2,140	2,174	2,207	2,250	2,319
Schleicher	425	723	775	795	794	806	824
Scurry	1,918	3,666	3,714	3,721	3,695	3,696	3,696
Sterling	239	349	377	387	386	373	379
Sutton	1,110	1,472	1,540	1,539	1,517	1,514	1,499
Tom Green	17,846	23,494	24,257	24,648	24,664	24,833	24,888
Upton	808	942	1,007	1,024	1,033	1,059	1,088
Ward	3,041	3,484	3,521	3,522	3,482	3,469	3,469
Winkler	1,890	2,377	2,450	2,444	2,423	2,369	2,292
Total	*123,296*	*141,965*	*147,828*	*151,280*	*153,206*	*155,340*	*157,632*

a. Data are from the Texas Water Development Board

The total estimated water savings associated with the implementation of the State Water-Efficiency Plumbing Act by county is presented in Table 2.3-5. Water-saving plumbing fixtures are expected to save almost 10,700 acre-feet per year by 2060.

Table 2.3-5
Expected Savings from Implementation of Plumbing Code for Region F Counties
(Values in Acre-Feet Per Year)

County	2010	2020	2030	2040	2050	2060
Andrews	67	123	181	243	266	271
Borden	4	6	9	9	10	9
Brown	135	304	430	564	610	610
Coke	10	24	35	47	53	53
Coleman	27	58	89	120	137	137
Concho	17	30	39	53	58	58
Crane	21	42	61	80	90	93
Crockett	25	43	61	78	86	88
Ector	382	807	1,329	1,824	2,048	2,147
Glasscock	7	16	21	28	30	31
Howard	116	238	360	480	530	530
Irion	7	14	19	23	25	23
Kimble	21	37	50	66	75	75
Loving	0	1	1	1	1	1
Martin	23	45	66	89	93	88
Mason	13	26	39	52	59	59
McCulloch	31	59	87	118	133	133
Menard	11	21	29	38	40	40
Midland	557	1,166	1,667	2,180	2,392	2,438
Mitchell	32	59	80	104	117	110
Pecos	55	132	195	253	276	271
Reagan	18	38	50	64	67	63
Reeves	75	133	197	264	299	309
Runnels	37	86	130	179	203	208
Schleicher	13	28	38	51	57	58
Scurry	76	158	221	284	306	306
Sterling	7	13	18	24	25	26
Sutton	24	41	57	73	79	78
Tom Green	399	939	1,368	1,798	1,978	1,984
Upton	16	34	47	62	69	71
Ward	51	105	146	186	199	199
Winkler	26	62	90	117	124	120
Total	*2,303*	*4,888*	*7,210*	*9,552*	*10,535*	*10,687*

Data are from the Texas Water Development Board

2.3.2 Manufacturing Projections

Manufacturing use is the water used by industries in producing various products. In Region F much of the manufacturing water use is associated with the generation of products from sand and gravel operations and the energy industry. In recent years the water use for these industries in McCulloch, Midland and Reeves Counties have shown substantial increases over the year 2000 water use. The year 2000 was the basis year in developing manufacturing water use projections, and as a result the manufacturing projections in these counties are lower than the water use reported in 2006. Since this change in water use is recent and may not reflect long-term trends Region F will continue to monitor the manufacturing water use in these counties to determine if revisions are warranted for the 2016 plan. No revisions were made to the manufacturing water use projections for this water plan update.

To produce the projections used for the 2006 regional water plans, the TWDB developed relationships between water use and unit production of a product. TWDB then calculated the water demand projections based on expected statewide growth in unit production of each type of product. TWDB then distributed the growth in demand to each county. It was assumed that the types of industry located in a particular county would remain the same throughout the planning period.

Manufacturing water demand accounts for only one percent of the region's total water use and is concentrated in a few counties. Ector, Howard and Tom Green Counties are expected to have the largest manufacturing demands for the region with a combined total use of over 9,000 acre-feet per year by 2060. Total manufacturing water use is expected to increase from 9,757 acre-feet in 2010 to 13,313 acre-feet by 2060, an increase of 3,556 acre-feet (see Table 2.3-6). Although TWDB projects a 36 percent increase in manufacturing demands from 2010 to 2060, manufacturing is expected to remain a relatively small amount of the region's total demands. Statewide, manufacturing demand is expected to increase by 67 percent over the same period.

Table 2.3-6
Manufacturing Water Demand Projections for Region F Counties
(Values in Acre-Feet Per Year)

County	Historical	Projected					
	2006 [a]	2010	2020	2030	2040	2050	2060
Andrews	47	0	0	0	0	0	0
Borden	0	0	0	0	0	0	0
Brown	422	577	636	686	734	775	837
Coke	0	0	0	0	0	0	0
Coleman	3	6	6	6	6	6	6
Concho	0	0	0	0	0	0	0
Crane	0	0	0	0	0	0	0
Crockett	41	0	0	0	0	0	0
Ector	1,982	2,759	2,963	3,125	3,267	3,376	3,491
Glasscock	0	0	0	0	0	0	0
Howard	2,233	1,648	1,753	1,832	1,910	1,976	2,099
Irion	0	0	0	0	0	0	0
Kimble	68	702	767	823	880	932	1,002
Loving	0	0	0	0	0	0	0
McCulloch	2,475	844	929	1,004	1,075	1,137	1,233
Martin	53	39	41	42	43	44	47
Mason	0	0	0	0	0	0	0
Menard	3	0	0	0	0	0	0
Midland	786	164	182	198	213	226	245
Mitchell	0	0	0	0	0	0	0
Pecos	88	2	2	2	2	2	2
Reagan	0	0	0	0	0	0	0
Reeves	1,433	720	741	756	770	781	825
Runnels	17	63	70	76	82	87	94
Schleicher	0	0	0	0	0	0	0
Scurry	8	0	0	0	0	0	0
Sterling	0	0	0	0	0	0	0
Sutton	0	0	0	0	0	0	0
Tom Green	1,906	2,226	2,498	2,737	2,971	3,175	3,425
Upton	4	0	0	0	0	0	0
Ward	0	7	7	7	7	7	7
Winkler	108	0	0	0	0	0	0
Total	*11,677*	*9,757*	*10,595*	*11,294*	*11,960*	*12,524*	*13,313*

a. Data are from the TWDB.

2.3.3 Irrigation Projections

Irrigated agriculture is the largest user of water in Region F. Irrigation use can vary substantially from year to year depending on the number of irrigated acres, weather, crop prices, government programs and other factors. These projections are for dry-year conditions and represent the maximum demand expected during the planning period. During most of the planning period, irrigation demand will probably be less than predicted.

An irrigation study conducted during this planning cycle reviewed the historical irrigation water use for six counties in Region F: Glasscock, Midland, Reagan, Reeves, Pecos and Tom Green. These counties represent over 70 percent of the irrigation demand in the region and 76 percent of the projected irrigation shortage. Data were collected from multiple sources on the historical water use, irrigated acreages and adoption of irrigation equipment. The study found that while there are some differences in reported irrigation use, the data provided by the TWDB was the most comprehensive. The biggest differences in data occur in counties with a wide variety of crops or non-major crops (such as fruit). The study did find that the use of more efficient irrigation methods is increasing in the six counties. In Glasscock and Reagan Counties most of the crops are currently being irrigated with either sprinkler or drip.

This study was conducted with considerable input from Region F planning group members and the public. Based on the findings of the study, it was recommended that the region continue to monitor irrigation water use data and collect available information on irrigation conservation efforts across the region. It was also recommended that region retain the projected irrigation demands developed for the 2006 Region F Water Plan with the understanding that a more complete review of the irrigation demands will be conducted for the 2016 regional water plan. Based on the data collected on conservation equipment, it was recommended that the adoption rates for conservation equipment be reviewed as part of the irrigation conservation strategies discussed in Chapter 4 of this plan. A copy of the study is included in Volume II.

The irrigation projections adopted for Region F for 2010 are based on the historical reported irrigation water use in each county. These projections are considerably higher than the historical water use in the year 2006. This is mostly associated with the limited availability of surface water for irrigation in Menard, Pecos, Reeves, Tom Green, and Ward Counties. The projections adopted by Region F are more indicative of potential irrigation demand with stable cotton prices and unrestricted surface water supplies.

Table 2.3-8 shows the irrigation water demands by county in Region F. The projected annual water use for irrigation was reduced from the 2010 estimates by the expected savings associated with the implementation of more efficient irrigation practices due to replacement of irrigation equipment with more efficient models. These reductions were determined by TWDB. Table 2.3-7 summarizes the reduction in irrigation demand for the region for each decade and compares these reductions to statewide totals. Figure 2.3-3 compares historical irrigation water use data to the Region F irrigation projections.

Table 2.3-7
Comparison of Region F Irrigation Demand Projections to Statewide Projections

Region F	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Irrigation (ac-ft)	578,606	573,227	567,846	562,461	557,080	551,774
Decline from Year 2010	0	5,379	10,760	16,145	21,526	26,832
% Decline	0%	1%	2%	3%	4%	5%
Statewide						
Irrigation (ac-ft)	10,061,165	9,626,239	9,282,167	9,007,934	8,680,985	8,354,329
Decline from Year 2010	0	434,926	778,998	1,053,231	1,380,180	1,706,836
% Decline	0%	4%	8%	10%	14%	17%

Note: Data are from the TWDB

Agricultural use accounted for 72 percent of Region F's total water use in 2006. By 2060, irrigation is expected to continue to be a major water use and could be as much as 68 percent of the region's total water demand. Statewide irrigation demand is projected to be 56 percent of total demand in the year 2010 and 38 percent of statewide demand in 2060. The counties with the largest irrigation water use are Tom Green, Reeves, Pecos, Glasscock, Midland, Reagan and Andrews Counties. These counties are expected to account for 78 percent of the region's irrigation demand in 2060.

Figure 2.3-3
Comparison of Historical Water Use to Projected Irrigation Water Demand for Region F

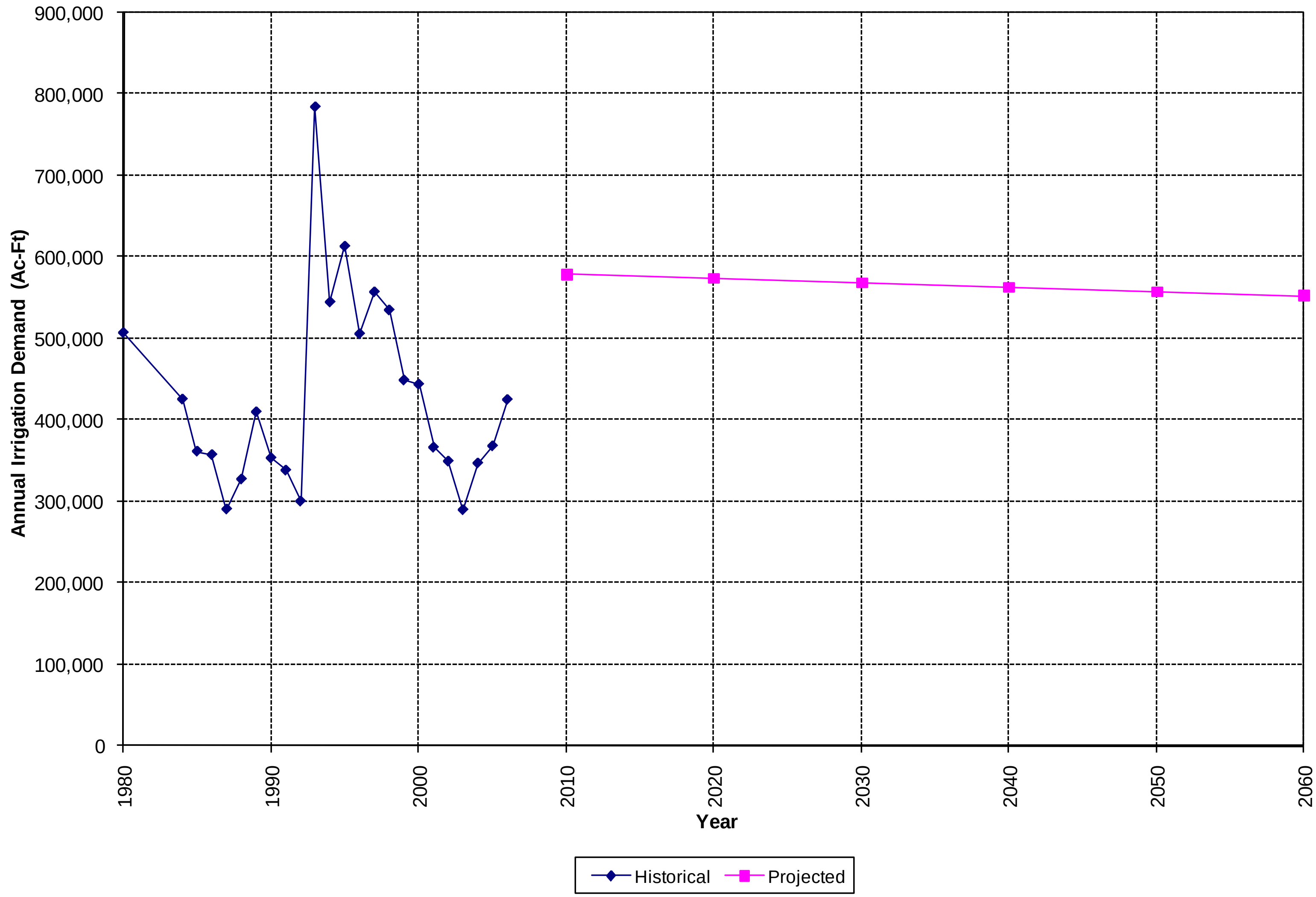


Table 2.3-8
Irrigation Water Demand Projections for Region F Counties
(Values in Acre-Feet per Year)

	Historical	Projected					
County	**2006** [a]	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Andrews	30,459	32,608	32,334	32,062	31,788	31,516	31,245
Borden	2,322	2,690	2,687	2,682	2,680	2,675	2,673
Brown	9,467	12,313	12,272	12,230	12,189	12,146	12,105
Coke	965	936	936	934	933	933	933
Coleman	742	1,379	1,379	1,379	1,379	1,379	1,379
Concho	7,727	4,297	4,280	4,262	4,245	4,229	4,213
Crane	0	337	337	337	337	337	337
Crockett	485	525	518	508	498	492	482
Ector	1,450	5,533	5,466	5,402	5,335	5,271	5,204
Glasscock	46,579	52,272	51,854	51,438	51,021	50,603	50,190
Howard	3,155	4,799	4,744	4,690	4,635	4,581	4,527
Irion	700	2,803	2,742	2,682	2,621	2,561	2,501
Kimble	3,054	985	948	913	877	841	807
Loving	0	581	580	576	575	573	572
McCulloch	3,477	2,824	2,789	2,754	2,718	2,683	2,649
Martin	15,726	14,324	14,073	13,822	13,571	13,321	13,075
Mason	6,830	10,079	9,936	9,792	9,648	9,505	9,363
Menard	2,578	6,061	6,041	6,022	6,003	5,981	5,962
Midland	24,687	41,493	41,170	40,848	40,526	40,203	39,884
Mitchell	7,306	5,534	5,507	5,479	5,452	5,425	5,398
Pecos	70,194	79,681	78,436	77,191	75,945	74,700	73,475
Reagan	18,741	36,597	35,990	35,385	34,779	34,174	33,579
Reeves	88,925	103,069	102,196	101,323	100,448	99,575	98,710
Runnels	3,834	4,331	4,317	4,298	4,279	4,260	4,241
Schleicher	1,005	2,108	2,067	2,024	1,982	1,939	1,897
Scurry	5,763	2,815	2,723	2,630	2,537	2,444	2,355
Sterling	656	648	621	595	569	543	518
Sutton	1,677	1,811	1,777	1,742	1,708	1,673	1,639
Tom Green	49,140	104,621	104,362	104,107	103,852	103,593	103,338
Upton	7,301	16,759	16,521	16,285	16,047	15,809	15,576
Ward	4,736	13,793	13,624	13,454	13,284	13,115	12,947
Winkler	4,912	10,000	10,000	10,000	10,000	10,000	10,000
Total	*424,593*	*578,606*	*573,227*	*567,846*	*562,461*	*557,080*	*551,774*

a. Data are from the Texas Water Development Board

2.3.4 Steam Electric Power Generation

The steam electric power generation water demand projections for the 2006 Region F Water Plan were developed by a TWDB-sponsored study by a consortium representing the Texas power industry[7]. The study, conducted in 2003, developed water demands for steam electric based on state-wide projections of power usage. The water demands needed to produce the projected power were distributed to each county based on existing facilities and information from the 2001 state water plan.

Since the initial 2003 study was completed, there have been tremendous changes in the energy industry. Several facilities located within Region F have been mothballed or retired. These include power generation facilities in Coke, Tom Green, Mitchell, Pecos and Crockett Counties. In response to these changes and other statewide trends, the TWDB contracted with the Bureau of Economic Geology (BEG) to update water demand projections for power generation in Texas. This report provided a comprehensive review of existing and planned power needs for Texas.

With the current uncertainty in the power industry, it is nearly impossible to accurately predict the location and need for future water demands for steam electric power. The recent closings of power facilities may represent a shift in demand locations or an opportunity for future development. The projections developed by the BEG were reviewed and considered by the region. Based on the possibilities for future power development, it was recommended that Region F retain the projections developed for the 2006 Region F Water Plan for all counties except Mitchell County. For Mitchell County, it was recommended that the reliable supply from the Champion Creek/Colorado City reservoir system be used as the water demand. This is because the available water for power use is limited from these sources, and it is assumed that additional electric generating facilities beyond what can be readily supplied by the region's water sources will likely be cooled through alternative technology.

Based on the adopted projections, steam electric water demand in Region F is expected to almost double, increasing from 18,138 acre-feet per year in 2010 to 33,418 acre-feet per year in 2060. Table 2.3-9 summarizes the projections for steam electric demands. Statewide, steam electric demand is expected to increase from 733,179 acre-feet per year in 2010 to 1,620,411 acre-feet per year in 2060 .

2.3.5 Mining Projections

The mining category includes water used in both the production of minerals and the production of oil and gas. (Water used in the processing of minerals or oil and gas into a finished product is considered under the manufacturing use category.) The TWDB mining water demand projections are based on water-use survey data for various types of mineral production. TWDB used historical data to calculate factors relating output to water use. These factors were applied to projections of future output for each commodity. It was assumed that the geographical location of production would remain constant throughout the 50-year planning period. Future water conservation measures are not built into the projections.

The oil and gas industry has played an important role in the development of West Texas and still accounts for a large percentage of its total payroll. Over the past five years there have been considerable changes in the oil and gas industry with rapidly fluctuating energy prices and improved production technologies. This has resulted in an apparent increase in mining activities associated with the oil and gas industry across the state, including some parts of Region F. Other mining activities, such as sand, gravel and stone production, represent a small portion of the region's economy and water demands.

To assess the potential impacts of recent oil and gas activities on the water use, a review was conducted of the Railroad Commission of Texas (RRC) data. According to the Railroad Commission of Texas (RRC), the primary use of freshwater in oil and gas production is for enhanced recovery (i.e. water flooding). The second highest use is for drilling and completion activities, which includes well fracing. The data available from the RRC indicate that the percentage of freshwater used for enhanced recovery is only about 3 percent of the total water used for this purpose. Saline water accounts for most of the water used for enhanced recovery. Based on 2007 estimates, injection for enhanced recovery within Region F is greatest in Andrews, Crockett, Ector, Pecos and Sutton Counties. New drilling permits were the highest in Andrews, Crockett, Ector, Midland, Pecos, Sutton and Upton Counties (greater than 250 new permits per year over the past nine years), so these counties have the greatest potential for (increased or continued) water use for drilling activities.

The RRC data were used to estimate water use by the three major types of usage: 1) enhanced recovery, 2) drilling, and 3) well fracing. It was assumed that three percent of total injected fluids used for enhanced recovery was fresh water. Water required for drilling was estimated from new drilling permits between 2000 and 2008. Water used for well fracing purposes was based on the number of fracing events in horizontal and vertical wells. In Region F, the volumes used for fracing are relatively small compared to the volumes required for enhanced recovery and drilling.

Comparison of total mining demand estimated by TWDB for 2005 (26,905 acre-feet) with the estimate for oil and gas use with the RRC data (21,533 acre-feet) indicate that the estimates are similar for Region F as a whole. Individual county comparisons yield mixed results with the RRC-based use higher for some counties and the TWDB demands higher in others. Counties with potentially higher water use than shown in the current mining projections include Pecos and Sutton and Crockett Counties (differences are greater than 1,000 acre-feet per year).

For the 2006 water plan the TWDB expected water demand for oil and gas production to increase slightly over the 50-year planning period. This assumption may still be valid and the recent increases in mining activities in Region F may be in response to short-term price increases of oil and gas rather than long-term trends. To better characterize the mining activities across the state the TWDB has contracted with the Bureau of Economic Geology to assess the water use for mining. This study will not be available for this plan update, but should be available for the 2016 regional water plans. In the interim, Region F will continue to monitor the oil and gas activities in the region to determine if revisions are warranted for the 2016 plan. For the 2011 water plan update, no revisions were made to the mining water use projections.

The mining demands for Region F are projected to increase from 31,850 acre-feet in 2010 to 35,794 acre-feet in 2060. This water use represents about 4 percent of the total water demand in Region F. Statewide mining use is expected to account for less than 2 percent of the state’s water demands. Table 2.3-10 compares Region F’s mining projections to statewide projections. A summary of the projected mining demands by county is presented in Table 2.3-11.

Table 2.3-9
Steam Electric Water Demand Projections for Region F Counties
(Values in Acre-Feet per Year)

County	Historical 2006 [a]	Projected 2010	2020	2030	2040	2050	2060
Andrews	0	0	0	0	0	0	0
Borden	0	0	0	0	0	0	0
Brown	0	0	0	0	0	0	0
Coke	0	310	247	289	339	401	477
Coleman	0	0	0	0	0	0	0
Concho	0	0	0	0	0	0	0
Crane	0	0	0	0	0	0	0
Crockett	0	973	776	907	1,067	1,262	1,500
Ector	3,875	6,375	9,125	10,668	12,549	14,842	17,637
Glasscock	0	0	0	0	0	0	0
Howard	604	0	0	0	0	0	0
Irion	0	0	0	0	0	0	0
Kimble	0	0	0	0	0	0	0
Loving	0	0	0	0	0	0	0
Martin	0	0	0	0	0	0	0
Mason	0	0	0	0	0	0	0
McCulloch	0	0	0	0	0	0	0
Menard	0	0	0	0	0	0	0
Midland	0	0	0	0	0	0	0
Mitchell	29	5,023	4,847	4,670	4,493	4,317	4,140
Pecos	0	0	0	0	0	0	0
Reagan	0	0	0	0	0	0	0
Reeves	0	0	0	0	0	0	0
Runnels	0	0	0	0	0	0	0
Schleicher	0	0	0	0	0	0	0
Scurry	0	0	0	0	0	0	0
Sterling	0	0	0	0	0	0	0
Sutton	0	0	0	0	0	0	0
Tom Green	0	543	777	909	1,069	1,264	1,502
Upton	0	0	0	0	0	0	0
Ward	3,099	4,914	4,223	4,937	5,807	6,868	8,162
Winkler	0	0	0	0	0	0	0
Total	*7,607*	*18,138*	*19,995*	*22,380*	*25,324*	*28,954*	*33,418*

a. Data are from the Texas Water Development Board

Table 2.3-10
Comparison of Region F Mining Projections to Statewide Totals

Region F	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Mining (ac-ft)	31,850	33,097	33,795	34,479	35,154	35,794
Change from Yr 2010	0	1,247	1,945	2,629	3,304	3,944
% Increase	0%	3.9%	6.1%	8.3%	10.4%	12.4%
Statewide [a]	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Mining (ac-ft)	296,106	313,302	296,347	284,877	284,515	292,169
Change from Yr 2010	0	17,196	241	-11,229	-11,591	-3,937
% Change	0%	6%	0%	-4%	-4%	-1%

a. Source: Data are from the TWDB[(6)].

2.3.6 Livestock Watering

Livestock watering accounted for slightly more than 2 percent of the water use in Region F in 2006. The livestock projections relate the water needs per head for each type of livestock and each type of livestock operation. The number of head in each county was estimated from information provided by the Texas Agricultural Statistics Service. Total water use for each county was calculated by multiplying the number of head by the estimated water demand per head of livestock. Livestock water use was considered to be constant after the year 2010. Projections are only available for counties and are not available for specific livestock operations.

Livestock demand in Region F is expected to remain constant at 23,060 acre-feet per year throughout the planning period (see Table 2.3-12). Statewide livestock demand is expected to be 371,923 acre-feet per year in 2060.

Table 2.3-11
Mining Water Demand Projections for Region F Counties
(Values in Acre-Feet per Year)

County	Historical	Projected					
	2005 [a]	2010	2020	2030	2040	2050	2060
Andrews	1,702	1,908	1,957	1,976	1,994	2,012	2,036
Borden	806	690	658	646	635	625	612
Brown	1,227	2,487	2,504	2,510	2,516	2,522	2,530
Coke	293	488	528	550	572	593	614
Coleman	16	18	19	19	19	19	19
Concho	0	0	0	0	0	0	0
Crane	5,418	2,221	2,216	2,214	2,212	2,210	2,208
Crockett	24	402	421	431	441	450	459
Ector	4,283	9,888	10,519	10,911	11,292	11,666	11,970
Glasscock	7	5	5	5	5	5	5
Howard	1,793	1,783	1,883	1,924	1,963	2,001	2,052
Irion	125	122	122	122	122	122	122
Kimble	91	71	67	65	63	61	60
Loving	3	2	2	2	2	2	2
McCulloch	140	154	159	162	165	168	171
Martin	788	674	645	634	624	615	603
Mason	0	6	6	6	6	6	6
Menard	0	0	0	0	0	0	0
Midland	960	677	778	846	915	986	1,046
Mitchell	141	115	110	108	107	106	104
Pecos	356	159	158	158	158	158	158
Reagan	1,742	2,036	2,165	2,235	2,303	2,370	2,436
Reeves	97	182	177	175	173	172	170
Runnels	41	44	45	45	45	45	45
Schleicher	108	125	134	139	144	149	154
Scurry	2,152	3,107	3,327	3,413	3,496	3,577	3,693
Sterling	0	590	600	605	610	615	620
Sutton	108	80	82	83	84	85	86
Tom Green	59	73	80	85	90	95	99
Upton	3,885	2,662	2,680	2,687	2,694	2,700	2,708
Ward	189	153	155	156	157	158	159
Winkler	351	928	895	883	872	861	847
Total	*26,905*	*31,850*	*33,097*	*33,795*	*34,479*	*35,154*	*35,794*

a. Source: Data are from the Texas Water Development Board

Historical data for mining are reported for 2005. In 2006, the TWDB changed the methodology of reporting mining use to include only data provided to the TWDB through the annual survey and other mining use that can be confirmed. This resulted in significantly lower estimates of mining water use across the state.

Table 2.3-12
Livestock Water Demand Projections for Region F Counties
(Values in Acre-Feet per Year)

County	Historical	Projected					
	2006[a]	2010	2020	2030	2040	2050	2060
Andrews	275	438	438	438	438	438	438
Borden	216	281	281	281	281	281	281
Brown	1,302	1,636	1,636	1,636	1,636	1,636	1,636
Coke	318	593	593	593	593	593	593
Coleman	930	1,259	1,259	1,259	1,259	1,259	1,259
Concho	574	775	775	775	775	775	775
Crane	79	155	155	155	155	155	155
Crockett	681	997	997	997	997	997	997
Ector	248	293	293	293	293	293	293
Glasscock	193	232	232	232	232	232	232
Howard	215	366	366	366	366	366	366
Irion	223	460	460	460	460	460	460
Kimble	375	668	668	668	668	668	668
Loving	101	70	70	70	70	70	70
McCulloch	616	1,027	1,027	1,027	1,027	1,027	1,027
Martin	128	273	273	273	273	273	273
Mason	1,248	1,036	1,036	1,036	1,036	1,036	1,036
Menard	398	642	642	642	642	642	642
Midland	349	904	904	904	904	904	904
Mitchell	309	449	449	449	449	449	449
Pecos	932	1,239	1,239	1,239	1,239	1,239	1,239
Reagan	137	272	272	272	272	272	272
Reeves	862	2,283	2,283	2,283	2,283	2,283	2,283
Runnels	813	1,530	1,530	1,530	1,530	1,530	1,530
Schleicher	532	787	787	787	787	787	787
Scurry	504	629	629	629	629	629	629
Sterling	296	503	503	503	503	503	503
Sutton	371	796	796	796	796	796	796
Tom Green	1,688	1,978	1,978	1,978	1,978	1,978	1,978
Upton	119	212	212	212	212	212	212
Ward	72	126	126	126	126	126	126
Winkler	99	151	151	151	151	151	151
Total	*15,203*	*23,060*	*23,060*	*23,060*	*23,060*	*23,060*	*23,060*

a. Source: Data are from the Texas Water Development Board

2.4 Wholesale Water Providers

As part of the development of the regional water plan, demands were identified for the wholesale water providers in Region F. A wholesale water provider has wholesale water contracts for 1,000 acre-feet per year or is expected to contract for 1,000 acre-feet per year or more over the planning period. The wholesale water providers in Region F are the Colorado River Municipal Water District (CRMWD), Brown County Water Improvement District Number 1 (BCWID), Upper Colorado River Authority (UCRA), the City of Odessa, the City of San Angelo, the Great Plains Water System, and University Lands.

2.4.1 Colorado River Municipal Water District (CRMWD)

CRMWD provides raw surface and groundwater to both its member cities and to others through various contracts. CRMWD provides all of the water used by its member cities: Odessa, Big Spring and Snyder. The City of Odessa also uses reuse water for non-potable uses. Midland, San Angelo, Robert Lee, Abilene and Millersview-Doole WSC have other sources of water and rely on CRMWD for part of their supply. The remaining municipal contract holders rely entirely on CRMWD for water. Manufacturing water is provided through municipal users. Most mining contracts are for water from CRMWD's chloride control projects. Table 2.4-1 shows the projected water demands for current CRMWD customers. New CRWMD customers are discussed in Chapter 4.

2.4.2 Brown County Water Improvement District No. 1 (BCWID)

BCWID provides both raw and treated water for municipal, manufacturing and irrigation purposes. Most BCWID customers are located in Brown County. The District provides treated water to the Cities of Brownwood and Bangs and Brookesmith SUD. The District provides water to the City of Santa Anna in Coleman County, Coleman County WSC and to users in Coleman and Mills Counties through Brookesmith SUD. Coleman County WSC has customers in Coleman, Brown, Runnels, Callahan and Taylor Counties. For the purposes of this plan, it is assumed that half of the demand for Coleman County WSC will be met by supplies from the District. The District also currently provides raw water to the City of Early, industries and irrigation. By 2010, it is expected that BCWID will provide treated water to the City of Early and its customers (Zephyr WSC).

Table 2.4-1
Expected Demands for the Colorado River Municipal Water District[a]
(Values in Acre-Feet per Year)

Member City	County(ies)	Basin	2010	2020	2030	2040	2050	2060
Odessa	Ector & Midland	Colorado	20,427	21,187	21,850	22,645	23,722	24,984
Ector County UD	Ector	Colorado	1,480	1,847	2,177	2,473	2,706	2,932
Manufacturing	Ector	Colorado	1,243	1,296	1,307	1,298	1,257	1,221
Big Spring	Howard	Colorado	6,016	6,077	6,035	5,945	5,915	5,915
Manufacturing	Howard	Colorado	989	1,052	1,099	1,161	1,227	1,350
Snyder	Scurry	Colorado	2,792	2,834	2,844	2,829	2,832	2,832
County-Other	Scurry	Colorado	200	200	200	200	200	200
Rotan	Fisher	Brazos	278	271	249	231	222	203
		Member Cities Total	*33,425*	*34,764*	*35,761*	*36,782*	*38,081*	*39,637*
Customer	**County(ies)**		**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Robert Lee	Coke	Colorado	351	346	342	338	336	336
County Other	Coke	Colorado	105	97	95	92	91	91
Coahoma	Howard	Colorado	183	185	183	180	177	177
Stanton[b]	Martin	Colorado	0	0	0	0	0	0
Midland 1966 Contract[c]	Midland	Colorado	16,624	18,257	0	0	0	0
Midland Ivie Contract	Midland	Colorado	10,925	10,699	10,473	10,246	10,021	9,795
County Other	Midland	Colorado	21	21	21	21	21	21
Manufacturing	Midland	Colorado	28	31	34	37	39	42
Abilene	Taylor	Brazos	10,974	10,751	10,528	10,304	10,081	9,858
San Angelo	Tom Green	Colorado	13,282	13,046	12,809	12,571	12,335	12,098
Millersview-Doole WSC[d]	Concho, McCulloch, Runnels & Tom Green	Colorado	500	500	500	500	0	0
Ballinger	Runnels	Colorado	600	600	600	600	0	0
County Other	Ward	Rio Grande	400	400	400	400	400	400
Mining	Howard	Colorado	1,476	1,576	1,617	1,656	1,694	1,745
Mining	Coke	Colorado	318	358	380	402	423	444
		Customer Total	*55,787*	*56,867*	*37,982*	*37,347*	*35,618*	*35,007*
		CRMWD Total	***89,212***	***91,631***	***73,743***	***74,129***	***73,699***	***74,644***

a Does not include potential new customers identified in the planning process or contract renewals.
b Stanton contract expires in December 2009.
c Midland 1966 contract expires in December 2029.
d Millersview-Doole WSC contract expires in October 2041.

The demands in table 2.4-2 are for current BCWID customers. It is likely that BCWID will acquire new customers in the future. Potential new customers are discussed in Chapter 4.

Table 2.4-2
Expected Demands for the Brown County Water Improvement District No. 1 [a]
(Values in Acre-Feet per Year)

Customer	County	Basin	2010	2020	2030	2040	2050	2060
Brownwood	Brown	Colorado	3,896	3,927	3,889	3,816	3,792	3,792
County Other	Brown	Colorado	385	385	379	370	367	367
Manufacturing	Brown	Colorado	577	636	686	734	775	837
Bangs	Brown	Colorado	265	266	262	256	254	254
Santa Anna	Coleman	Colorado	200	197	193	190	187	187
Brookesmith SUD	Brown, Coleman & Mills	Colorado	1,394	1,412	1,404	1,377	1,368	1,367
Zephyr WSC	Brown	Colorado	399	404	399	391	387	387
Coleman County WSC	Brown & Coleman	Colorado	200	200	200	200	200	205
Early	Brown	Colorado	799	812	810	801	797	797
Irrigation	Brown	Colorado	6,970	6,970	6,970	6,970	6,970	6,970
BCWID Total			*15,085*	*15,209*	*15,192*	*15,105*	*15,097*	*15,163*

a. Does not include potential new customers identified in the planning process

2.4.3 The Upper Colorado River Authority (UCRA)

UCRA owns the water rights in O.C. Fisher Reservoir and Mountain Creek Reservoir. Water from O.C. Fisher is contracted to the Cities of San Angelo and Miles. Mountain Creek Reservoir is used exclusively by the City of Robert Lee. The projected demands presented in Table 2.4-3 are the estimated drought-year supplies available from these sources. Mountain Creek has no reliable supply under these conditions. During normal to wet years, more water may be used from these sources than is indicated in Table 2.4-3.

Table 2.4-3
Expected Demands for the Upper Colorado River Authority
(Values in Acre-Feet per Year)

Customer	County	Basin	Contract Amount	2010	2020	2030	2040	2050	2060
San Angelo	Tom Green	Colorado	80,400	3,637	3,518	3,400	3,282	3,163	3,045
Miles	Runnels	Colorado	200	200	200	200	200	200	200
Robert Lee	Coke	Colorado	250	0	0	0	0	0	0
Paint Rock	Concho	Colorado	50	25	25	25	25	25	25
UCRA Total			*80,900*	3,862	3,743	3,625	3,507	3,388	3,270

2.4.4 The Great Plains Water Supply System

Table 2.4-4 shows the expected demands for the Great Plains Water Supply System. Historically, Great Plains provided water for oil field operations in Gaines, Andrews and Ector Counties, as well as a small amount of municipal water in Ector County. A new power generation facility near Odessa is now a major customer. Supplies for steam electric generation in Ector County have been fixed at the current use levels until a strategy to provide the additional supply is developed. No additional supply is available in either Gaines or Andrews Counties because the Ogallala aquifer has been fully allocated in those counties.

Table 2.4-4
Expected Demands for the Great Plains Water Supply System
(Values in Acre-Feet per Year)

Customer	County	Basin	2010	2020	2030	2040	2050	2060
County Other	Ector	Colorado	64	64	64	64	64	64
Steam-Electric	Ector	Colorado	5,156	5,156	5,156	5,156	5,156	5,156
Great Plains WSC Total			*5,220*	*5,220*	*5,220*	*5,220*	*5,220*	*5,220*

2.4.5 The City of Odessa

Table 2.4-5 shows the expected demands for the City of Odessa. The City of Odessa is a CRMWD member city. Odessa sells treated water to the Ector County Utility District. The city also provides water for manufacturing in Ector County. A portion of the manufacturing demand is met by treated effluent from the city.

Table 2.4-5
Expected Demands for the City of Odessa
(Values in Acre-Feet per Year)

Water User Group	County(ies)	Basin	2010	2020	2030	2040	2050	2060
Odessa	Ector & Midland	Colorado	21,927	22,687	23,350	24,145	25,222	26,484
Ector County UD	Ector	Colorado	1,480	1,847	2,177	2,473	2,706	2,932
Manufacturing	Ector	Colorado	2,743	2,946	3,107	3,248	3,357	3,471
City of Odessa Total			*26,150*	*27,480*	*28,634*	*29,866*	*31,285*	*32,887*

2.4.6 The City of San Angelo

Table 2.4-6 shows the expected demands for current customers of the City of San Angelo. The city provides treated water to Millersview-Doole WSC, the City of Miles and a few rural customers outside the city limits. Most of the water used for manufacturing in Tom Green County is also provided by the city. The city has contracted a portion of the supply from Lake Nasworthy to a power generation facility located on the lake. At this time, this facility is shut down, and it is uncertain when it will be restarted. The demands shown for Tom Green County irrigation are associated with water for Tom Green County WCID #1. Water is provided to the irrigation district from Twin Buttes Reservoir and the city's wastewater treatment plant.

Table 2.4-6
Expected Demands for the City of San Angelo
(Values in Acre-Feet per Year)

Water User Group	County	Basin	2010	2020	2030	2040	2050	2060
San Angelo	Tom Green	Colorado	20,800	21,418	21,734	21,744	21,907	21,969
County Other & Millersview-Doole WSC	Tom Green	Colorado	250	250	250	250	250	250
Miles	Runnels	Colorado	200	200	200	200	200	200
Manufacturing	Tom Green	Colorado	2,226	2,498	2,737	2,971	3,175	3,425
Steam-Electric	Tom Green	Colorado	543	777	909	1,021	1,021	1,021
Irrigation	Tom Green	Colorado	26,500	26,500	26,500	26,500	26,500	26,500
San Angelo Total			*50,519*	*51,643*	*52,330*	*52,686*	*53,053*	*53,365*

2.4.7 University Lands

University Lands manages the University of Texas System Permanent University Fund lands in West Texas. Several well fields in Region F are located on properties managed by University Lands, including the CRMWD Ward County Well Field (contract expires in 2019), the City of Midland's Paul Davis Well Field in Andrews and Martin Counties (contract expires in 2033) and the City of Andrews' well field (contract expires in 2035).

Table 2.4-7 summarizes the expected demands from leases with University Lands. These demands assume that contracts with University Lands will be renewed for the remainder of the planning period.

Table 2.4-7
Expected Demands from University Lands [a]
(Values in Acre-Feet per Year)

Recipient	Source County	Basin	2010	2020	2030	2040	2050	2060
CRMWD [b]	Ward	Rio Grande	5,200	5,200	5,200	5,200	5,200	5,200
Andrews [c]	Andrews	Colorado	671	708	730	750	760	773
Midland [d]	Andrews	Colorado	1,237	1,237	1,237	0	0	0
	Martin	Colorado	3,485	3,485	3,485	0	0	0
University Lands Total			*10,593*	*10,630*	*10,652*	*5,950*	*5,960*	*5,973*

a Demands assume that contracts with University Lands will be renewed for the duration of the planning period.
b The contract between CRMWD and University Lands will expire in 2019.
c The contract between Andrews and University Lands will expire in 2035. Andrews obtains approximately 20 percent of supply from University Lands.
d The contract between Midland and University Lands will expire in 2033. The City of Midland expects its well field on University Lands will be depleted by 2035. No supply is assumed after this time.

2.5 List of References

[1] Texas Water Development Board: *Final Historical and Projected Water Use Data for Region F*, November 5, 2003.

[2] Texas Water Development Board: Historical Water Use Summary Data for Region F, available at www.twdb.state.tx.us, downloaded June 2009.

[3] Texas Water Development Board: *Water for Texas – Today and Tomorrow: A 1996 Consensus-Based Update to the Texas Water Plan, Volume III*, Water Use Planning Data Appendix, Austin, 1996.

[4] Bureau of Economic Geology. *Water Demand Projections for Power Generation in Texas*, prepared for the Texas Water Development Board, January 2009.

[5] Texas Water Development Board: Water Conservation Implementation Task Force Report to the 79th Legislature, November 2004.

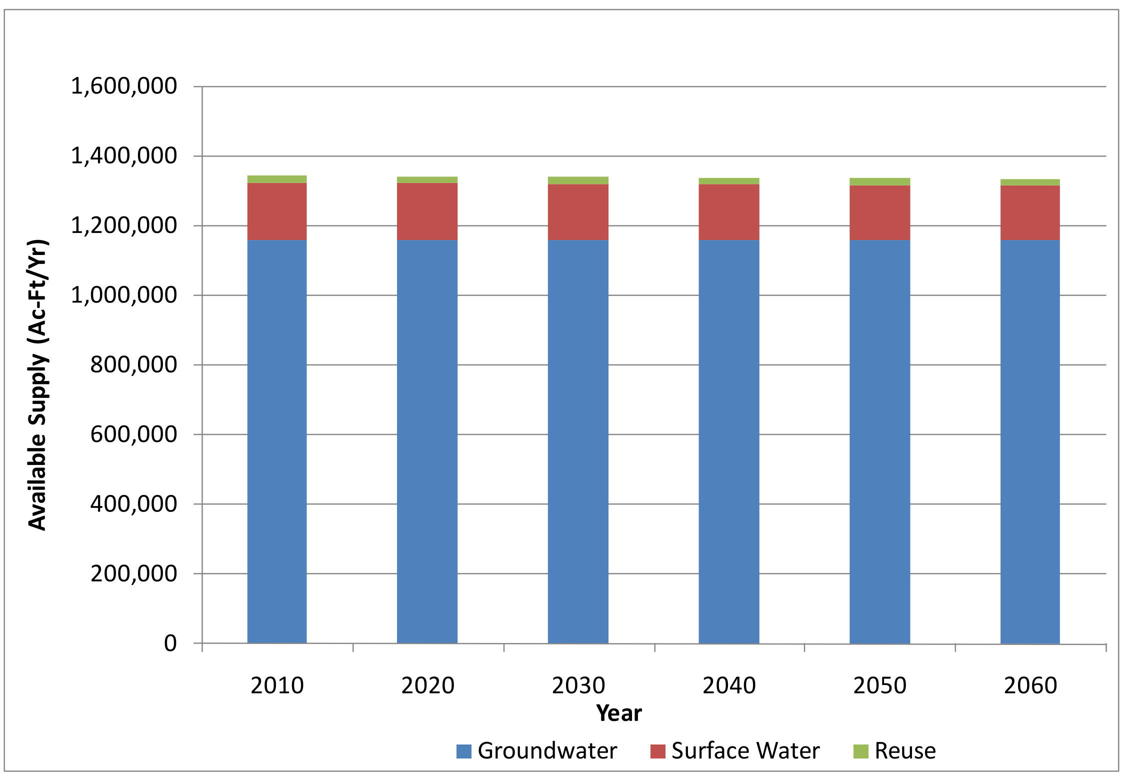
[6] Texas Water Development Board, DB12 database, March 2010.

[7] Representatives of Investor-Owned Utilities of Texas: *Power Generation Water Use in Texas for the Years 2000 through 2060 Final Report*, prepared for the Texas Water Development Board, January 2003.

3 WATER SUPPLY ANALYSIS

In Region F, water comes from surface water sources such as run-of-the-river supplies and reservoirs, groundwater from individual wells or well fields, and from alternative sources such as reuse or desalination. Figure 3.1-1 shows the amount of water within Region F that is available for use. This supply generally does not include infrastructure or contract limitations, but does represent the amount of reliable supply that is currently available. Groundwater is the largest source of water supply available in Region F. Surface water supplies in Figure 3.1-1 are significantly reduced because of the assumptions used in the Colorado River Basin Water Availability Model (WAM) (see Section 3.2). A small amount of reuse is currently being used in the region.

Figure 3.1-1
Water Availability by Source Type



3.1 Existing Groundwater Supplies

Texas is in the midst of a Joint Planning initiative for groundwater. The state has been divided into sixteen (16) Ground Water Management Areas (GMAs). Joint Planning is conducted by the Groundwater Conservation Districts (GCDs) in each GMA and is sometimes referred to as GMA planning. Region F falls in GMA-7, GMA-4, GMA-2, and GMA-8. The boundaries of these GMAs may be found in Figure 1.3-5. The Joint Planning effort in each GMA determines the Desired Future Conditions (DFC) for each aquifer. TWDB then determines the Managed Available Groundwater (MAG) based on the DFC. The Texas Water Code now requires that RWPGs rely on the MAG estimates to determine groundwater supplies. Since the last planning cycle, the GCDs have been meeting in their respective GMAs to discuss approaches for determining DFCs and MAGs, and the TWDB has assisted the GMAs by running several model runs with the Ground Water Availability Models (GAMs) to help estimate the supply from potential DFCs. However, at this time, the only MAG developed in Region F is for the Trinity Aquifer in Brown County. Therefore, the only groundwater supply that has been modified since the *2006 Region F Water Plan* is for the Trinity Aquifer in Brown County.

In 2006, groundwater sources supplied 378,000 acre feet of water, accounting for 66 percent of all water used in the region. Groundwater provides most of the irrigation water used in the region, as well as a significant portion of the water used for municipal and other purposes. Groundwater is primarily found in four major and seven minor aquifers that vary in quantity and quality (Figures 1.2-1 and 1.2-2). The following discussion describes each of these aquifers, including their current use and potential availability. Section 3.1.12 discusses the supply of brackish groundwater potentially available for desalination treatment.

In the absence of MAG supplies, groundwater supply should be defined based on locally accepted water use and management policy considerations. These management policy decisions are expressed in the rules and management plans of the various groundwater conservation districts in the region. Some districts consider recharge only, while other districts may consider recharge and an acceptable level of aquifer depletion over time. In some cases, groundwater supply may be limited by water quality. Only the fresh to moderately saline portions of the aquifer are included in the supply volume. For those counties in the region that are not governed by a groundwater conservation district, aquifer supply is based on historical use trends. Figure 1.3-4 shows the counties currently governed by groundwater conservation districts.

Groundwater supply by aquifer and river basin within each county is listed in Table 3.1-1. As discussed above, the supply volumes listed in this table represent an acceptable level of aquifer withdrawal in each county based on policy decisions determined by GCDs (Figure 3.1-2). Also of consideration in much of the region is the desire to maintain aquifers such that springflow and associated base flow to rivers and streams are protected. It is, however, recognized that in times of severe drought, reduction in springflow and surface water flow will likely occur regardless of management policies.

With the exception of Brown County (Trinity Aquifer), for which groundwater availability was determined by the TWDB, the quantification of groundwater supply considers both aquifer recharge and water held in storage in the aquifer matrix. For planning purposes, groundwater supply for designated major and minor aquifers is defined by the following formula:

Supply = Drought Year Recharge + Annual Volume from Storage

The volume of water from storage may be zero (no water from storage, limiting supply to recharge only), 75 percent of the recoverable volume in storage divided by 50 years, or 75 percent of the recoverable volume in storage divided by 100 years (see Figure 3.1-2).

For the *2006 Region F Water Plan*, the draft Edwards-Trinity (Plateau) Groundwater Availability Model (ETPGAM) was used as a source to estimate recharge estimates for counties in Region F. At that time, the drought-of-record (DOR) for supply purposes was assumed to be one-half of the average annual recharge in the draft ETPGAM. Since the *2006 Region F Water Plan* was completed, the ETPGAM has been finalized. Therefore, the final recharge estimates from the ETPGAM were extracted from the model for each county and compared to the draft recharge estimates that were used in the last round of planning. The DOR recharge for the Edwards-Trinity (Plateau) aquifer for all of Region F that was estimated from the final ETPGAM was 290,000 af/yr, which is 60,920 af/yr less than the 350,920 af/yr calculated from the draft ETPGAM. The final DOR recharge equates to 83 percent of the DOR recharge that was estimated in the previous round of planning.

Table 3.1-1
Groundwater Supplies in Region F
(Values in Acre-Feet per Year)

County	Aquifer	Basin	Annual Recharge During Drought [a]	Annual Volume from Storage	Annual Supply
Andrews	Pecos Valley	Rio Grande	685	504	1,189
	Dockum	Colorado	0	905	905
		Rio Grande	0	5,792	5,792
	Ogallala	Colorado	22,427	8,852	31,279
		Rio Grande	3,293	1,040	4,333
	Edwards-Trinity	Colorado	4,205	435	4,640
Borden	Dockum	Colorado	0	117	117
	Ogallala	Brazos	0	108	108
		Colorado	300	482	782
Brown	Ellenburger-San Saba	Colorado	0	0	0
	Hickory	Colorado	0	0	0
	Trinity	Brazos	na	na	59
	Trinity	Colorado	na	na	2,017
Coke	Dockum	Colorado	12	0	12
	Edwards-Trinity	Colorado	3,242	0	3,242
Coleman	Ellenburger-San Saba	Colorado	0	0	0
	Hickory	Colorado	0	0	0
Concho	Edwards-Trinity	Colorado	11,869	409	12,278
	Hickory	Colorado	0	14,299	14,299
	Lipan	Colorado	5,984	529	6,513
Crane	Pecos Valley	Rio Grande	2,537	0	2,537
	Dockum	Rio Grande	0	0	0
	Edwards-Trinity	Rio Grande	115	0	115
Crockett	Dockum	Rio Grande	0	0	0
	Edwards-Trinity	Colorado	636	0	636
		Rio Grande	24,824	0	24,824
Ector	Pecos Valley	Rio Grande	1,059	1,845	2,904
	Dockum	Colorado	0	2,498	2,498
		Rio Grande	0	3,479	3,479
	Edwards-Trinity	Colorado	9,027	1,103	10,130
		Rio Grande	1,059	135	1,194
	Ogallala	Colorado	4,850	999	5,849
Glasscock	Dockum	Colorado	0	140	140
	Ogallala	Colorado	940	2,988	3,928
	Edwards-Trinity	Colorado	17,420	3,518	20,938

Table 3.1-1: Groundwater Supplies in Region F (continued)

County	Aquifer	Basin	Annual Recharge During Drought [a]	Annual Volume from Storage	Annual Supply
Howard	Dockum	Colorado	0	900	900
	Edwards-Trinity	Colorado	1,606	94	1,700
	Ogallala	Colorado	2,610	7,799	10,409
Irion	Dockum	Colorado	0	0	0
	Edwards-Trinity	Colorado	9,445	0	9,445
Kimble	Edwards-Trinity	Colorado	23,965	0	23,965
	Ellenburger-San Saba	Colorado	216	0	216
	Hickory	Colorado	0	0	0
Loving	Pecos Valley	Rio Grande	457	3,906	4,363
	Dockum	Rio Grande	0	860	860
Martin	Ogallala	Colorado	7,760	11,642	19,402
	Edwards-Trinity	Colorado	2,895	503	3,398
Mason	Edwards-Trinity	Colorado	3,205	623	3,828
	Ellenburger-San Saba	Colorado	3,537	1,113	4,650
	Hickory	Colorado	21,521	54,971	76,492
McCulloch	Edwards-Trinity	Colorado	7,735	514	8,249
	Ellenburger-San Saba	Colorado	3,596	12,926	16,522
	Hickory	Colorado	3,419	122,726	126,145
Menard [b]	Edwards-Trinity	Colorado	-	-	19,000
	Ellenburger-San Saba	Colorado	-	-	159
	Hickory	Colorado	-	-	34,000
Midland	Dockum	Colorado	0	45	45
	Ogallala	Colorado	3,270	1,397	4,667
	Edwards-Trinity	Colorado	18,082	1,313	19,395
Mitchell	Dockum	Colorado	8,744	5,274	14,018
Pecos	Dockum	Rio Grande	0	1,089	1,089
	Pecos Valley	Rio Grande	50,050	8,528	58,578
	Edwards-Trinity	Rio Grande	91,014	23,835	114,849
	Capitan Reef	Rio Grande	0	34,000	34,000
Reagan	Dockum	Rio Grande	0	54	54
	Edwards-Trinity	Colorado	19,522	9,364	28,886
		Rio Grande	1,629	720	2,349
Reeves	Dockum	Rio Grande	0	3,065	3,065
	Pecos Valley	Rio Grande	40,099	20,421	60,520
	Edwards-Trinity	Rio Grande	11,909	41,936	53,845
Runnels	Lipan	Colorado	4,536	0	4,536
Schleicher	Edwards-Trinity	Colorado	12,204	0	12,204
		Rio Grande	3,960	0	3,960

Table 3.1-1: Groundwater Supplies in Region F (continued)

County	Aquifer	Basin	Annual Recharge During Drought [a]	Annual Volume from Storage	Annual Supply
Scurry	Dockum	Brazos	7,898	1,940	9,838
		Colorado	3,226	3,159	6,385
Sterling	Dockum	Colorado	0	0	0
	Edwards-Trinity	Colorado	5,168	0	5,168
Sutton	Edwards-Trinity	Colorado	9,349	0	9,349
		Rio Grande	11,426	0	11,426
Tom Green	Dockum	Colorado	0	54	54
	Edwards-Trinity	Colorado	14,373	664	15,037
	Lipan	Colorado	24,916	12,570	37,486
Upton	Pecos Valley	Rio Grande	803	275	1,078
	Dockum	Rio Grande	0	797	797
	Edwards-Trinity	Colorado	6,745	1,303	8,048
		Rio Grande	8,511	1,292	9,803
Ward	Pecos Valley	Rio Grande	5,984	11,304	17,288
	Dockum	Rio Grande	0	2,340	2,340
	Capitan Reef	Rio Grande	0	12,000	12,000
Winkler	Pecos Valley	Rio Grande	3,727	48,267	51,994
	Dockum	Rio Grande	0	10,746	10,746
		Colorado	0	2	2
	Edwards-Trinity	Colorado	423	94	517
	Capitan Reef	Rio Grande	0	15,000	15,000
Total			*574,019*	*541,602*	*1,170,856*

a. Drought recharge was assumed to be equal to one half of average annual recharge.
b. Supplies for Menard County are from the Menard County Underground Water District management plan. Annual recharge and storage volumes are not shown for this county.

Crane, Reeves, Sterling and Winkler counties have higher recharge in the final ETPGAM than in the draft ETPGAM and the remaining counties have a lower recharge. Because the Joint Planning process is still underway for all the GMAs in Region F that manage the Edwards-Trinity (Plateau) aquifer and because MAGs have not been determined across the region, the groundwater availability estimates for the Edwards-Trinity (Plateau) aquifer were not modified from the *2006 Region F Water Plan*.

Recharge for other aquifers in the region, along with water in storage estimates, were retained from the *2006 Region F Water Plan*. These recharge estimates were from previous studies by TWDB.

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Groundwater Availability Determination

Region F Water Plan

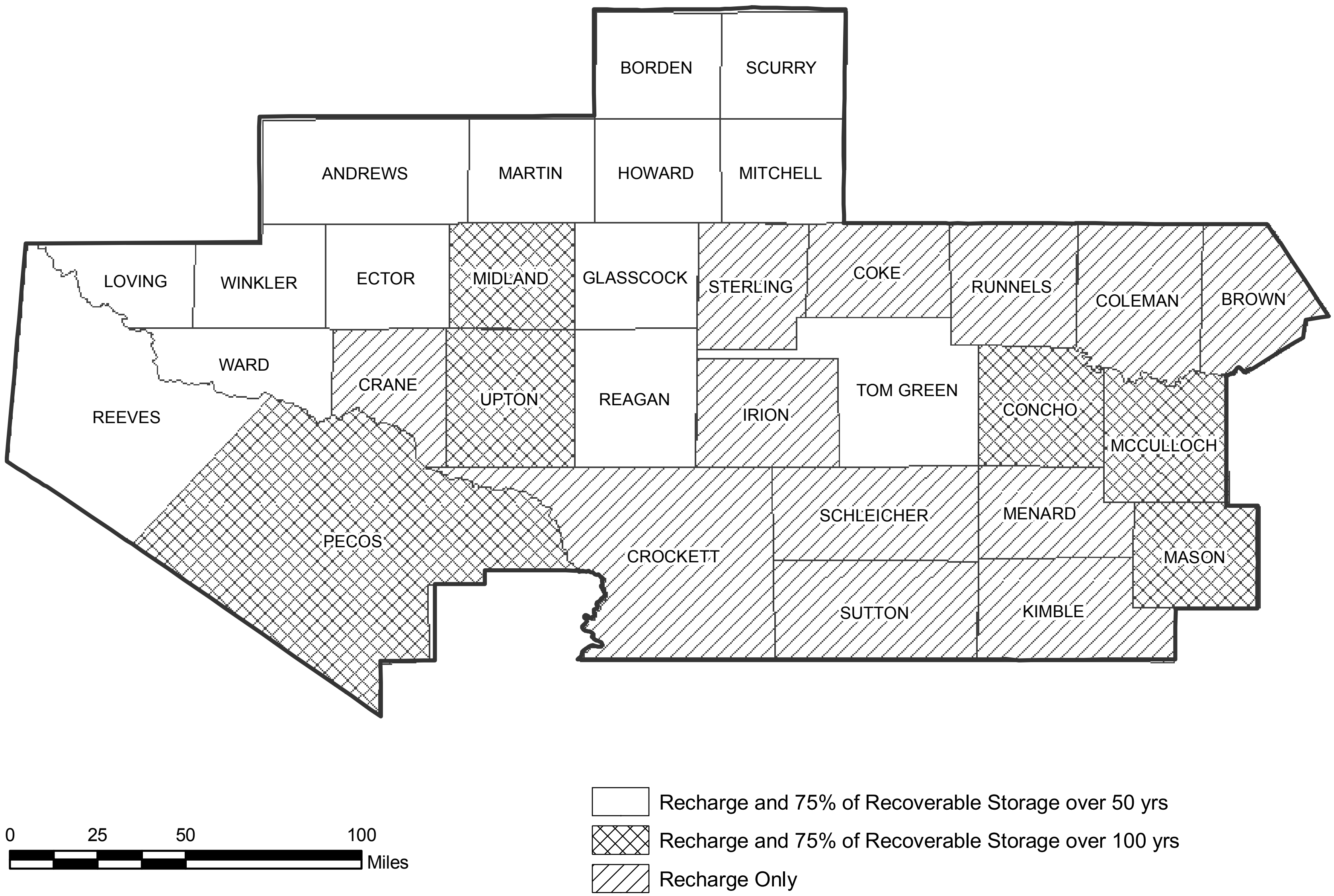

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FIGURE 3.1-2

Estimates of groundwater availability from local alluvium and aquifers that are not listed in Table 3.1-1 were based on historical use estimates provided by the TWDB or other local studies. The supply estimates for these groundwater sources are shown in Table 3.1-2.

Table 3.1-2
Groundwater Supplies from Other Aquifers

County	Aquifer Name	Basin	Annual Availability
Borden	Other Aquifer	Brazos	0
		Colorado	1,118
Brown	Other Aquifer	Brazos	0
		Colorado	131
Coke	Other Aquifer	Colorado	1,007
Coleman	Other Aquifer	Colorado	179
Concho	Other Aquifer	Colorado	490
Crane	Other Aquifer	Rio Grande	81
Irion	Other Aquifer	Colorado	928
Mason	Marble Falls Aquifer	Colorado	134
McCulloch	Marble Falls Aquifer	Colorado	15
	Other Aquifer	Colorado	104
Menard	Other Aquifer	Colorado	47
Mitchell	Other Aquifer	Colorado	2
Pecos	Other Aquifer	Rio Grande	5
	Rustler Aquifer	Rio Grande	1,389
Reeves	Rustler Aquifer	Rio Grande	103
Runnels	Other Aquifer	Colorado	2,656
Scurry	Other Aquifer	Brazos	51
		Colorado	263
Sterling	Other Aquifer	Colorado	1,002
Tom Green	Other Aquifer	Colorado	10,670

3.1.1 Edwards-Trinity (Plateau) Aquifer

Extending from the Hill Country of Central Texas to the Trans-Pecos region of West Texas, the Edwards-Trinity (Plateau) aquifer is the largest aquifer in areal extent in Region F, occurring in 21 of the 32 Region F counties (Figure 3.1-3). This aquifer is comprised of water-bearing portions of the Edwards Formation and underlying formations of the Trinity Group, and is one of the largest contiguous karst regions in the United States. Regionally, this aquifer is categorized by the TWDB as one aquifer. However, in other parts of the state the Edwards and Trinity components are not hydrologically connected and are considered separate aquifers. The Trinity aquifer is also present as an individual aquifer in Eastern Brown County within Region F. More groundwater is produced from the Edwards-Trinity (Plateau) aquifer (approximately 34 percent) than any other aquifer in the region, three-fourths of which is used for irrigation and livestock watering. Many communities in the region use the aquifer for their public drinking-water supply as well.

The Edwards-Trinity (Plateau) aquifer is comprised of lower Cretaceous formations of the Trinity Group and limestone and dolomite formations of the overlying Edwards, Comanche Peak, and Georgetown formations. These strata are relatively flat lying, and located atop relatively impermeable pre-Cretaceous rocks. The saturated thickness of the entire aquifer is generally less than 400 feet, although the maximum thickness can exceed 1,500 feet. Recharge is primarily through the infiltration of precipitation on the outcrop, in particular where the limestone formations outcrop. Discharge is to wells and to rivers in the region. Groundwater flow in the aquifer generally flows in a south-southeasterly direction, but may vary locally. The hydraulic gradient averages about 10 feet/mile.

Long-term water-level declines have been observed in areas of heavy pumping, most notably in the Saint Lawrence irrigation district in Glasscock, Reagan, Upton, and Midland Counties, in the Midland-Odessa area in Ector County, and in the Belding Farm area in Pecos County. Figures 3.1-4, 3.1-5 and 3.1-6 show selected hydrographs for the Edwards-Trinity (Plateau) aquifer in Region F. As noted above, some areas have shown consistent water-level declines, as shown in Figure 3.1-4. In some cases, these declines have stopped due to cessation or reduction in pumpage, and are currently recovering. Figure 3.1-5 shows selected wells showing increases in water levels over time.

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Edwards-Trinity Aquifer

Region F Water Plan

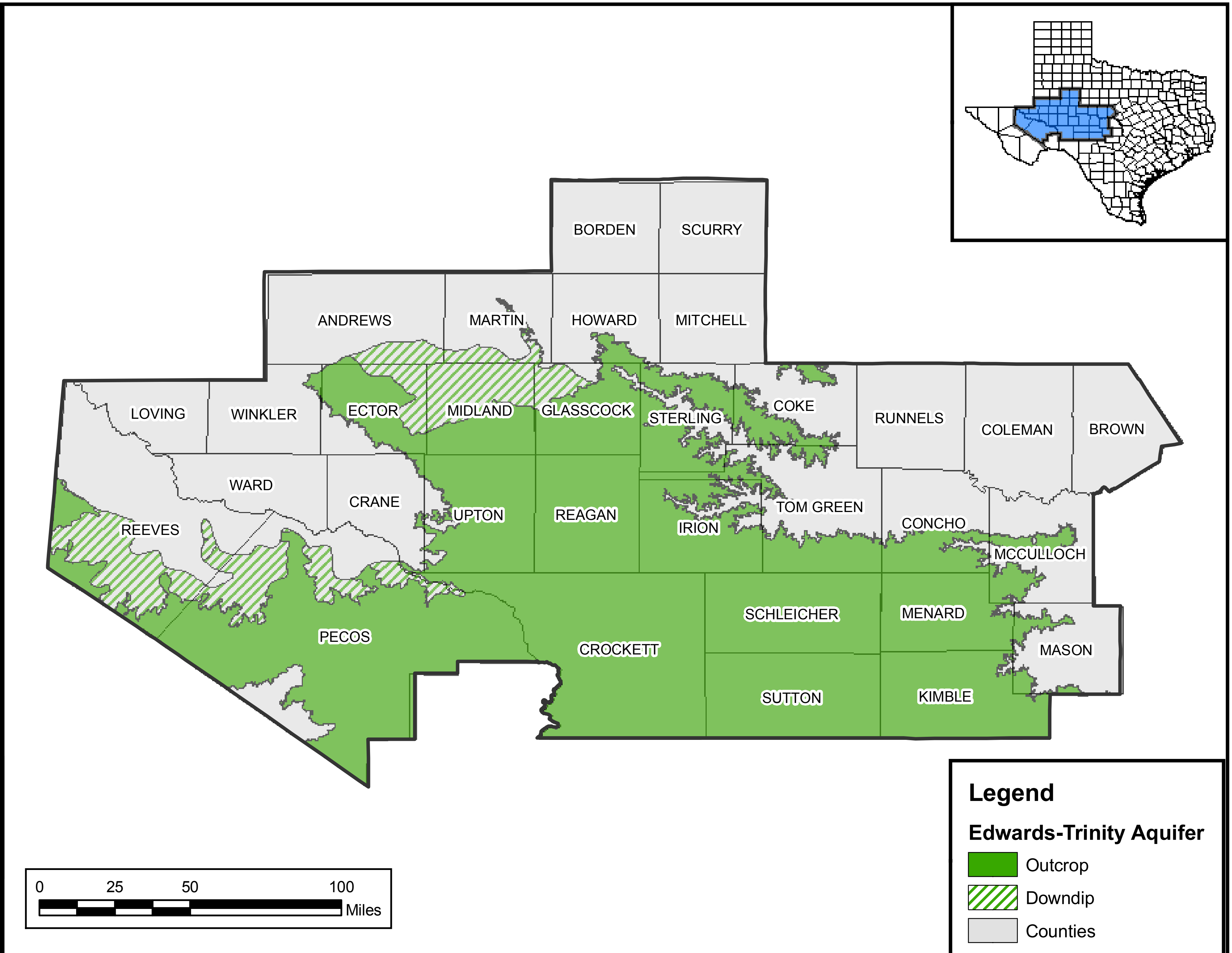

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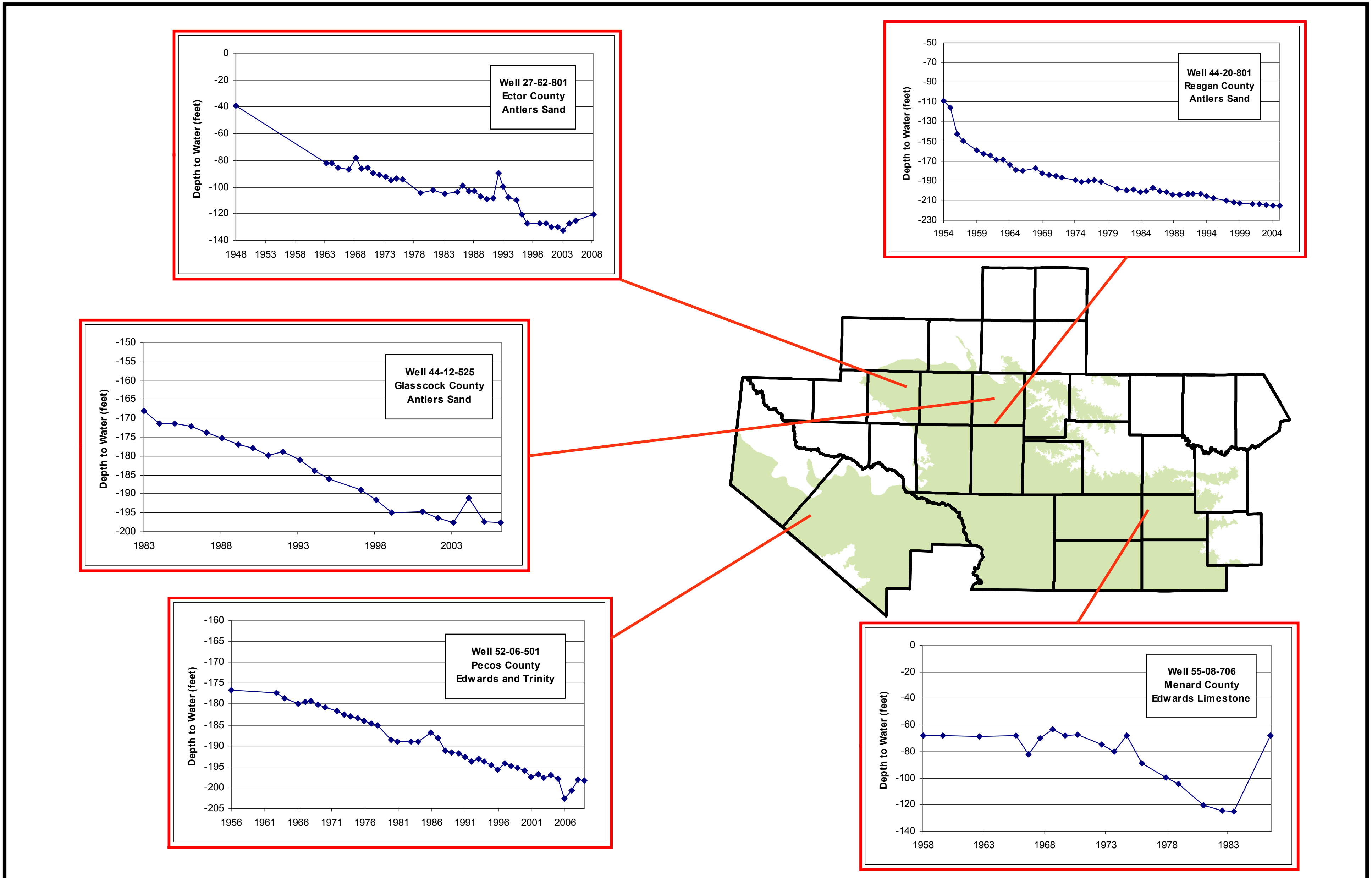
FIGURE 3.1-3



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Region F Water Plan

Selected Hydrographs from the Edwards-Trinity (Plateau) Aquifer Showing Declining Water Levels

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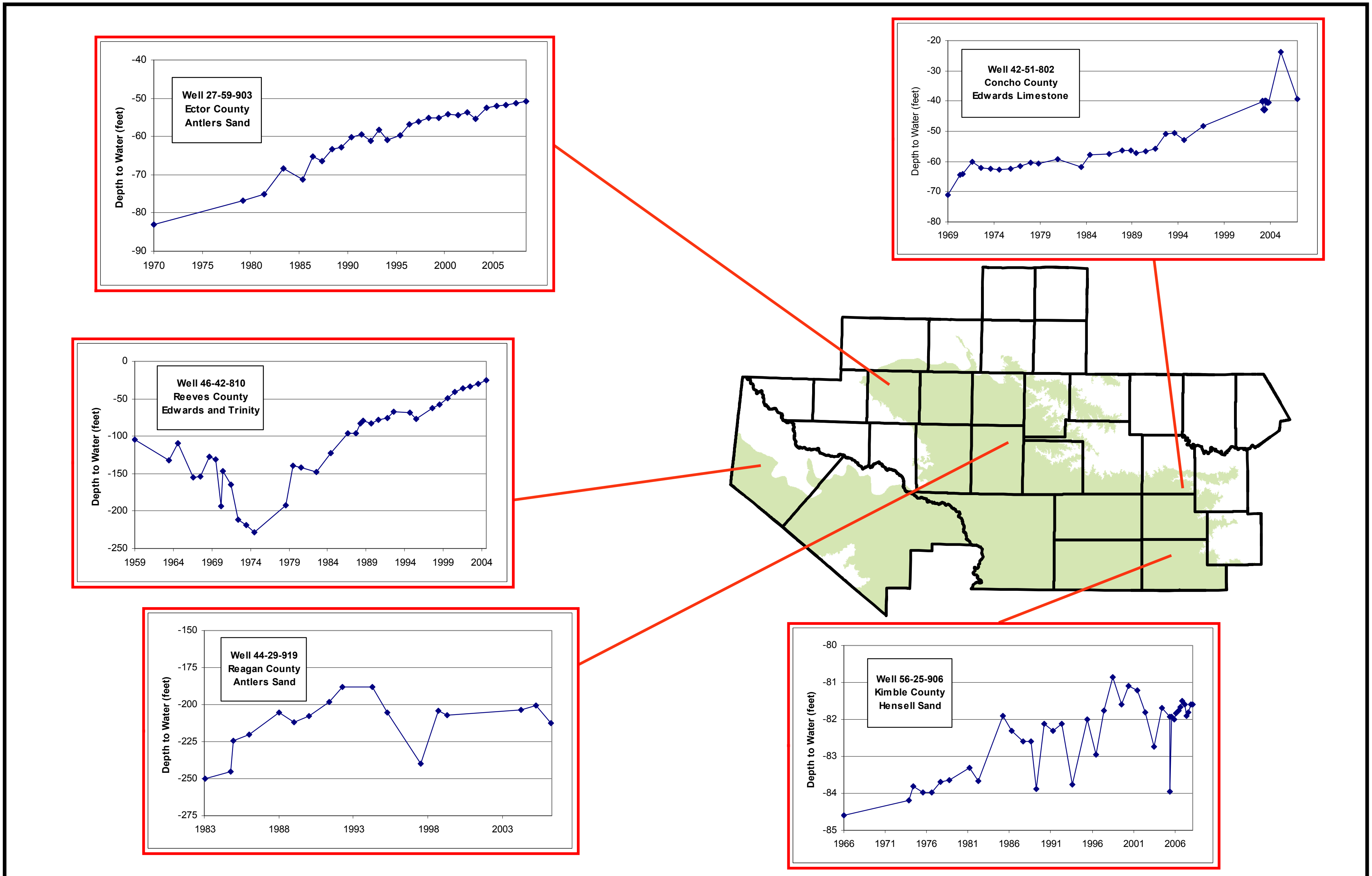
3.1-4

FIGURE



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Selected Hydrographs from the Edwards-Trinity (Plateau) Aquifer Showing Rising Water Levels

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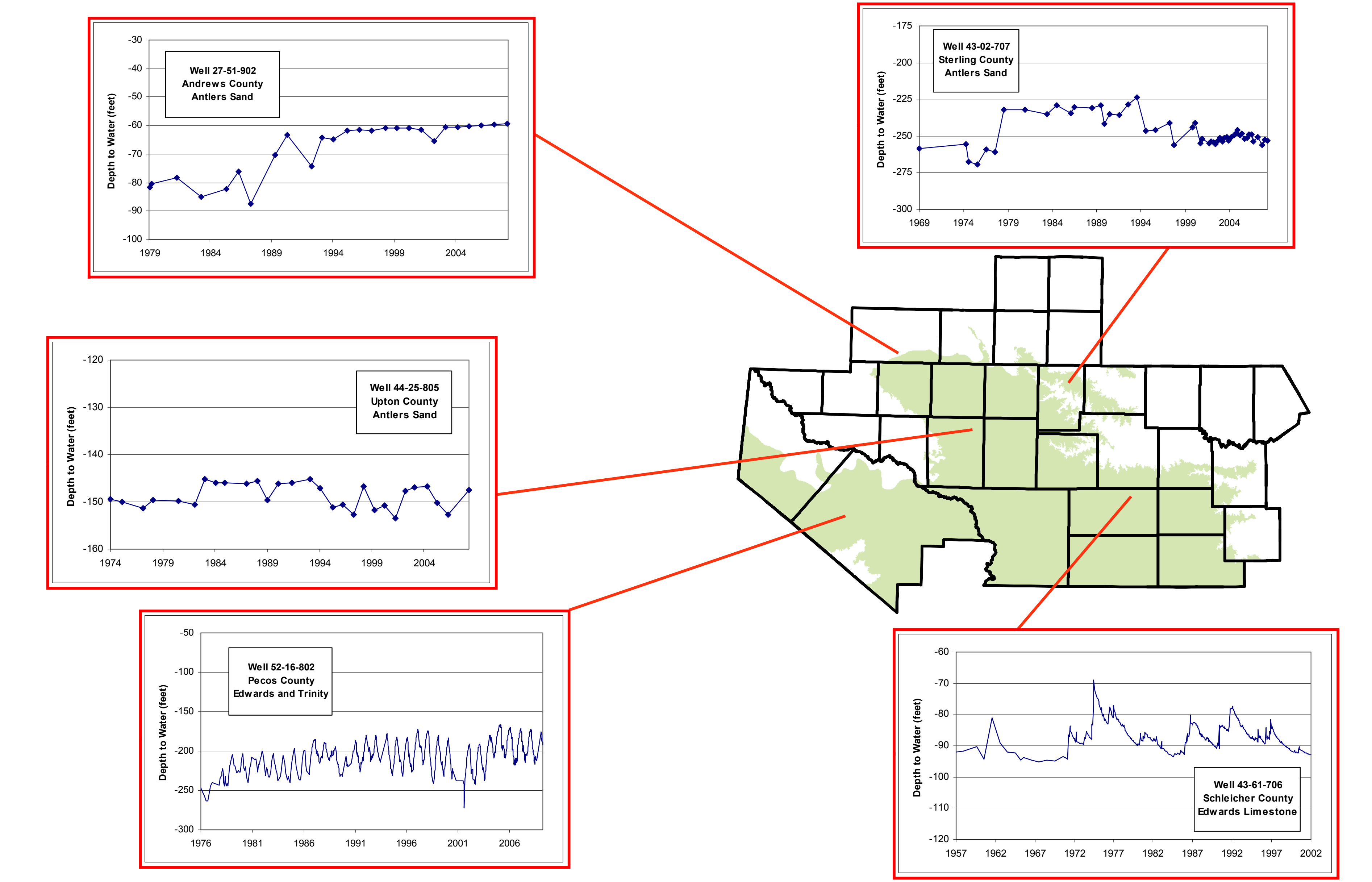
3.1-5

FIGURE



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Selected Hydrographs from the Edwards-Trinity (Plateau) Aquifer Showing Stable Water Levels

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3.1-6

FIGURE

However, most Edwards-Trinity (Plateau) wells in the region show fairly stable water levels, or are slightly declining, as shown by the hydrographs in Figure 3.1-6. Well 52-16-802 in Pecos County (Figure 3.1-6) shows the water level variations throughout the year as pumpage increases in the summer and stops in the winter.

Edwards Formation

Groundwater is produced from the Edwards Formations portion of the Edwards-Trinity (Plateau) aquifer in a majority of the region. Groundwater in the Edwards and associated limestones occurs primarily in solution cavities that have developed along faults, fractures, and joints in the limestone. These formations are the main water-producing units in about two-thirds of the aquifer extent. The largest single area of pumpage from the Edwards portion of the aquifer in Region F is in the Belding Farms area of Pecos County.

Due to the nature of groundwater flow in the Edwards, it is very difficult to estimate aquifer properties for this portion of the Edwards-Trinity (Plateau) aquifer. However, based on aquifer characteristics of the Edwards elsewhere, wells producing from the Edwards portion of the Edwards-Trinity (Plateau) aquifer are expected to be much more productive than from the Trinity portion of the aquifer.

The chemical quality of the Edwards and associated limestones is generally better than that in the underlying Trinity aquifer. Groundwater from the Edwards and associated limestones is fairly uniform in quality, with water being a very hard, calcium bicarbonate type, usually containing less than 500 mg/l total dissolved solids (TDS), although in some areas the TDS can exceed 1,000 mg/l.

Trinity Group

Water-bearing units of the Trinity Group are used primarily in the northern third and on the southeastern edge of the aquifer. In most of the region, the Trinity is seldom used due to the presence of the Edwards above it, which produces better quality water at generally higher rates. In the southeast portion, the Trinity consists of, in ascending order, the Hosston, Sligo, Cow Creek, Hensell and Glen Rose Formations. In the north where the Glen Rose pinches out, all of the Trinity Group is referred to collectively as the Antlers Sand. The greatest withdrawal from the Trinity (Antlers) portion of the aquifer is in the Saint Lawrence irrigation area in Glasscock, Reagan, Upton and Midland Counties.

Reported well yields from the Trinity portion of the Edwards-Trinity (Plateau) aquifer commonly range from less than 50 gallons per minute (gpm) from the thinnest saturated section to as much as 1,000 gpm. Higher yields occur in locations where wells are completed in jointed or cavernous limestone. Specific capacities of wells range from less than 1 to greater than 20 gpm/ft.

The water quality in the Trinity tends to be poorer than in the Edwards. Water from the Antlers is of the calcium bicarbonate/sulfate type and very hard, with salinity increasing towards the west. Salinities in the Antlers typically range from 500 to 1,000 mg/l TDS, although groundwater with greater than 1,000 mg/l TDS is common.

Edwards-Trinity (Plateau) Aquifer Recharge

Accurate recharge estimates are a key factor in estimating long-term groundwater availability in an aquifer system. The Edwards-Trinity (Plateau) aquifer covers all or parts of 21 of the 32 counties in Region F and provides water for many WUGs in the region. Therefore, in support of the aquifer availability analysis, a three-year study of the groundwater recharge in the Edwards portion of the aquifer was conducted. The goal of the study was to better understand the nature and timing of recharge events and to consider alternative methods of estimating recharge. This study entailed:

1. Design of monitoring well and rain gage networks in the study area,
2. Collection and evaluation of new and historical data to help estimate recharge characteristics,
3. Development of a rainfall-runoff model for the South Concho watershed in Tom Green and Schleicher Counties,
4. Documentation and discussion of data collection, recharge evaluation, statistical analyses, model development and results, and conclusions.

Monthly and (in some cases) daily water level and precipitation data were collected during 2003 and 2004, and in a few areas into 2005. Fifteen wells were monitored daily with transducers and about 100 wells were measured manually on a monthly basis. Precipitation data were assimilated from nine National Weather Service gages and over 60 volunteer-monitored gages. The project was performed within the boundaries of and with the assistance of seven groundwater conservation districts:

- Glasscock Groundwater Conservation District
- Sterling County Underground Water Conservation District
- Irion County Water Conservation District
- Lipan-Kickapoo Water Conservation District (Tom Green, Concho, and Runnels Counties)
- Emerald Underground Water Conservation District (Crockett County)
- Plateau Underground Water Control and Supply District (Schleicher County)
- Sutton County Underground Water Conservation District

These districts assisted in establishing the monitor well and rain gage networks, and collected and recorded the data used in the study. A full discussion of the study and the results are contained in the report *Evaluation of Edwards-Trinity (Plateau) Aquifer Recharge in a Portion of the Region F Planning Area*. Summary conclusions from the study include:

- Based on measured precipitation and groundwater levels, recharge of the Edwards-Trinity (Plateau) is highly variable both geographically and in time.
- Statistical evaluation of observed rainfall and water level data indicate that, because of the numerous factors that affect groundwater recharge, including temporal changes in precipitation, evapotranspiration, and geographic variations in hydrogeology and soils, a unique regional linear correlation between rainfall and recharge does not exist.
- Long periods of wet conditions in winter months tend to result in more recharge than similar periods in the summer due to the increased evapotranspiration and drier soil conditions in the summer.
- A South Concho watershed rainfall-runoff model developed for this study reproduced measured streamflow conditions relatively well and was helpful in identifying conditions that were conducive to increased groundwater recharge.
- Because the rainfall-runoff model accounts for temporal changes in precipitation, evapotranspiration and to some degree, geographic variations in hydrogeology and soils, model results were used to develop a relationship between annual precipitation and recharge for the South Concho watershed. The relationship can be used to estimate a "threshold" annual precipitation that results in groundwater recharge for the South

Concho watershed. Due to the variability of factors impacting recharge potential, it is recommended that similar models be developed for individual watersheds in the area.

3.1.2 Ogallala Aquifer

The Ogallala is one of the largest sources of groundwater in the United States, extending from South Dakota to the Southern High Plains of the Texas Panhandle. In Region F, the aquifer occurs in seven counties in the northwestern part of the region including Andrews, Borden, Ector, Howard, Glasscock, Martin and Midland Counties (Figure 3.1-7). The aquifer provides approximately 20 percent of all groundwater used in the region. The formation is hydrologically connected to the underlying Edwards-Trinity (Plateau) aquifer in southern Andrews and Martin Counties, and northern Ector, Midland and Glasscock Counties.

In Region F, agricultural irrigation and livestock consumption account for approximately two-thirds of the total use of Ogallala groundwater. Municipal use accounts for approximately 20 percent. Most of the withdrawals from the aquifer occur in Midland, Martin, and Andrews Counties.

The Ogallala is composed of coarse to medium grained sand and gravel in the lower strata grading upward into fine clay, silt and sand. Recharge occurs principally by infiltration of precipitation on the surface and to a lesser extent by upward leakage from underlying formations. Highest recharge infiltration rates occur in areas overlain by sandy soils and in some playa lake basins. Groundwater in the aquifer generally moves slowly in a southeastwardly direction. Water quality of the Ogallala in the Southern High Plains ranges from fresh to moderately saline, with dissolved solids averaging approximately 1,500 mg/l.

3.1.3 Pecos Valley Aquifer

The Pecos Valley aquifer is located in the upper part of the Pecos River Valley of West Texas in Andrews, Crane, Crockett, Ector, Loving, Pecos, Reeves, Upton, Ward and Winkler Counties (Figure 3.1-8). Consisting of up to 1,500 feet of alluvial fill, the Pecos Valley occupies two hydrologically separate basins: the Pecos Trough in the west and the Monument Draw Trough in the east. The aquifer is hydrologically connected to underlying water-bearing strata, including the Edwards-Trinity in Pecos and Reeves Counties, the Triassic Dockum in Ward and Winkler Counties, and the Rustler in Reeves County.

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Ogallala Aquifer

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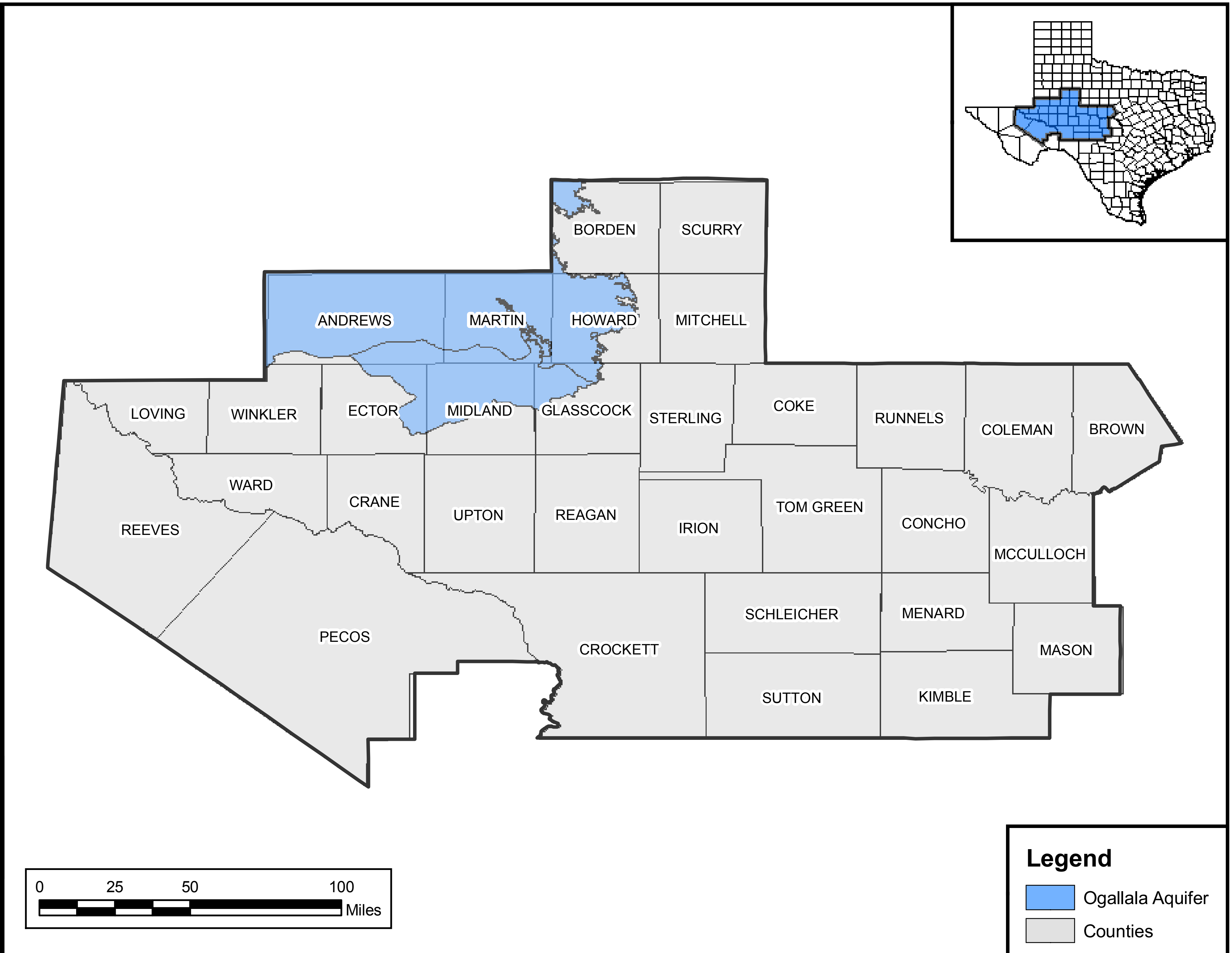
FIGURE 3.1-7



Pecos Valley Aquifer

Region F Water Plan

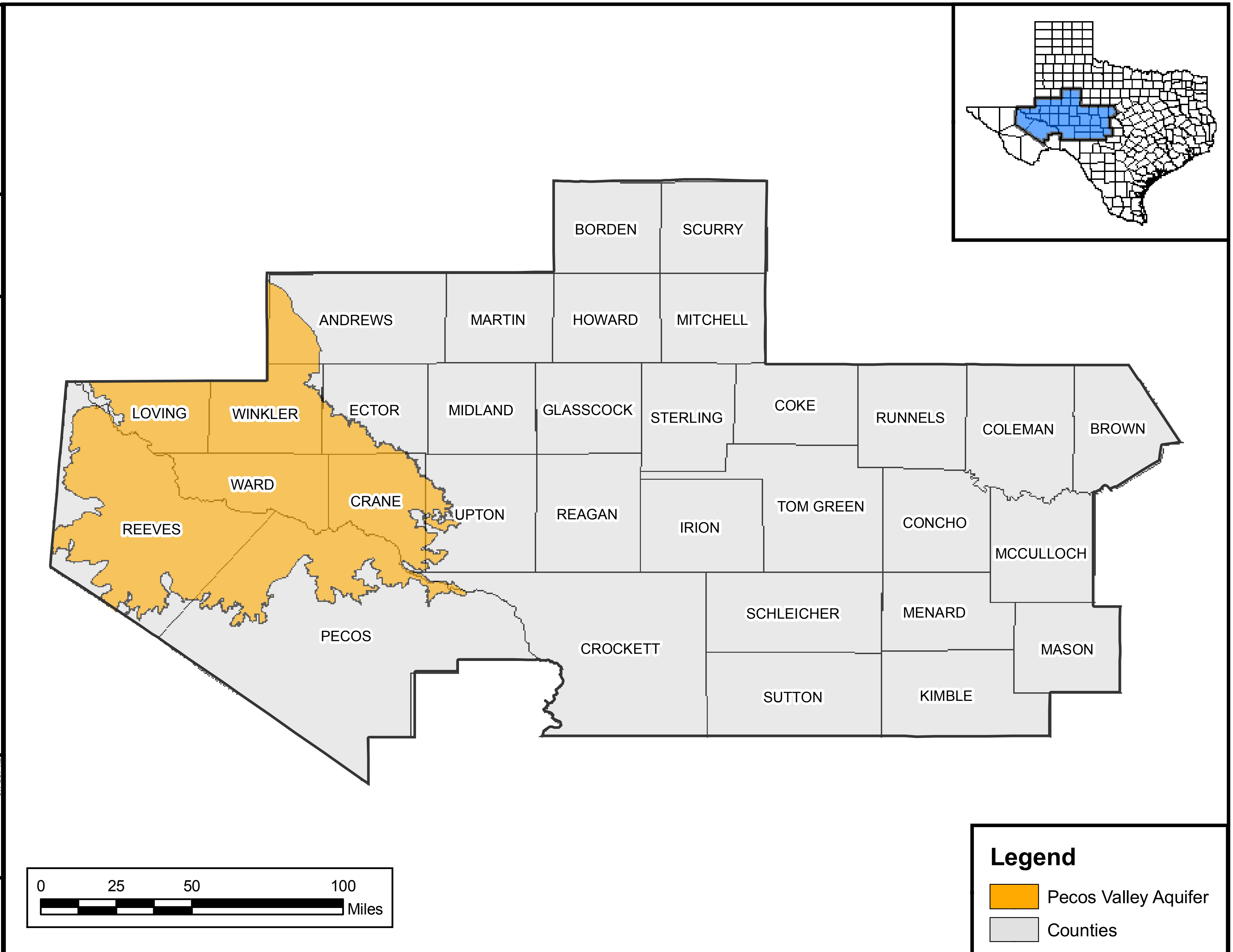


FIGURE 3.1-8

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The western basin (Pecos Trough) contains poorer quality water and is used most extensively for irrigation of salt-tolerant crops. The eastern basin (Monument Draw Trough) contains relatively good quality water that is used for a variety of purposes, including industrial use, power generation, and public water supply.

The Pecos Valley is the second most used aquifer in the region, representing approximately 31 percent of total groundwater use. Agricultural related consumption (irrigation and livestock) accounts for approximately 80 percent of the total, while municipal consumption and power generation account for about 15 percent of aquifer use. Lateral subsurface flow from the Rustler aquifer into the Pecos Valley has significantly affected the chemical quality of groundwater in the overlying western Pecos Trough aquifer. Most of this basin contains water with greater than 1,000 mg/l TDS, and a significant portion is above 3,000 mg/l TDS. The eastern Monument Draw Trough is underlain by the Dockum aquifer but is not as significantly affected by its quality difference. Water levels in the past fifty years have generally been stable. However, in Reeves and Pecos Counties water levels have dropped an average of 80 feet.

3.1.4 Trinity Aquifer

The Trinity aquifer is a primary groundwater source for eastern Brown County (Figure 3.1-9). Small isolated outcrops of Trinity Age rocks also occur in south central Brown County and northwest Coleman County. However, these two areas are not classified as the contiguous Trinity aquifer by the TWDB and the TWDB did not estimate a groundwater availability for the Trinity Aquifer in Coleman County. Agricultural related consumption (irrigation and livestock) accounts for approximately 80 percent of the total withdrawal from the aquifer.

The Trinity was deposited during the Cretaceous Period and is comprised of (from bottom to top) the Twin Mountains, Glen Rose and Paluxy Formations. In western Brown and Coleman Counties, the Glen Rose is thin or missing and the Paluxy and Twin Mountains coalesce to form the Antlers Sand. The Paluxy consists of sand and shale and is capable of producing small quantities of fresh to slightly saline water. The Twin Mountains formation is composed of sand, gravel, shale, clay and occasional conglomerate, sandstone and limestone beds. It is the principal aquifer and yields moderate to large quantities of fresh to slightly saline water. Maximum thickness of the Trinity aquifer is approximately 200 feet in this area.

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Trinity Aquifer

Region F Water Plan

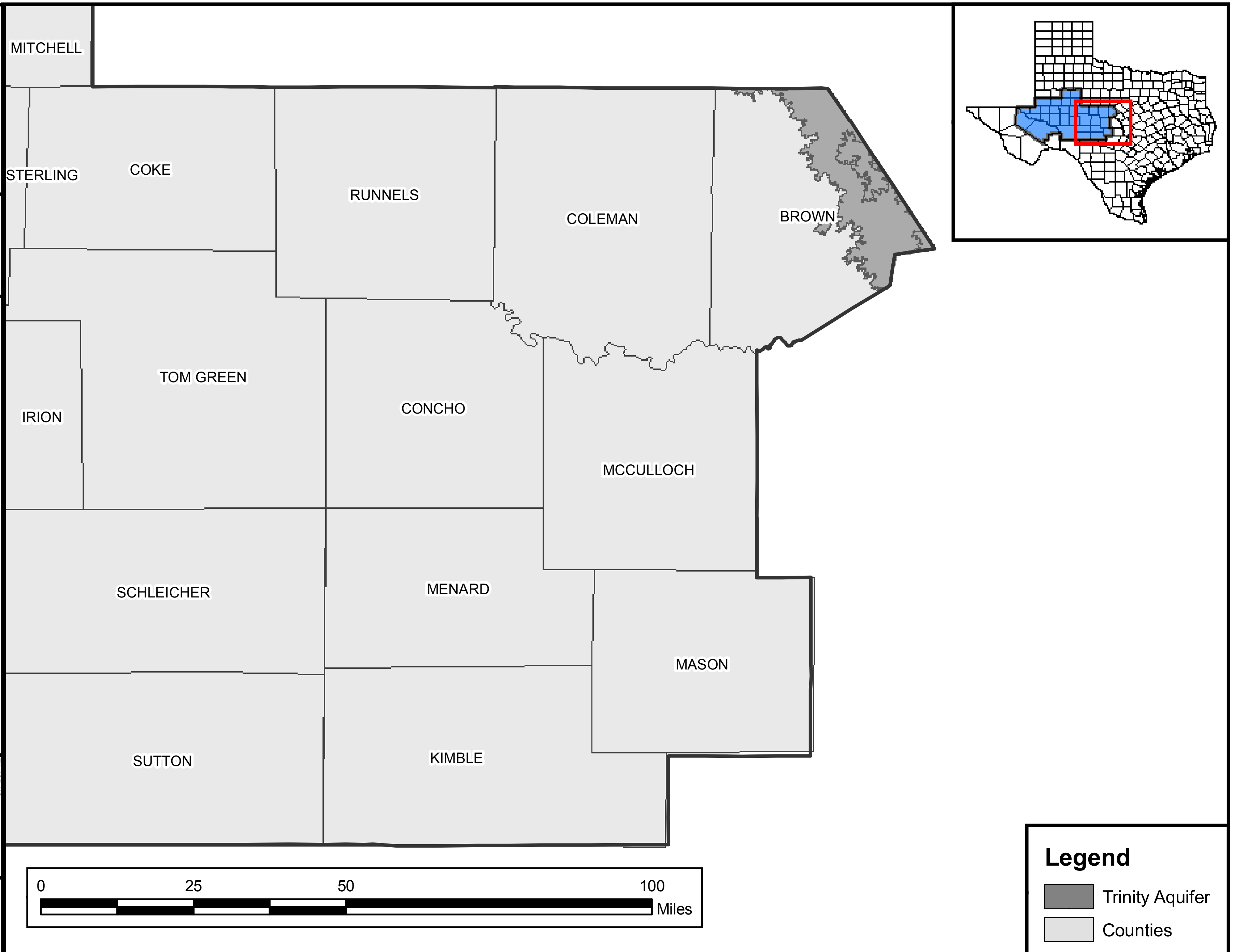

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FIGURE 3.1-9

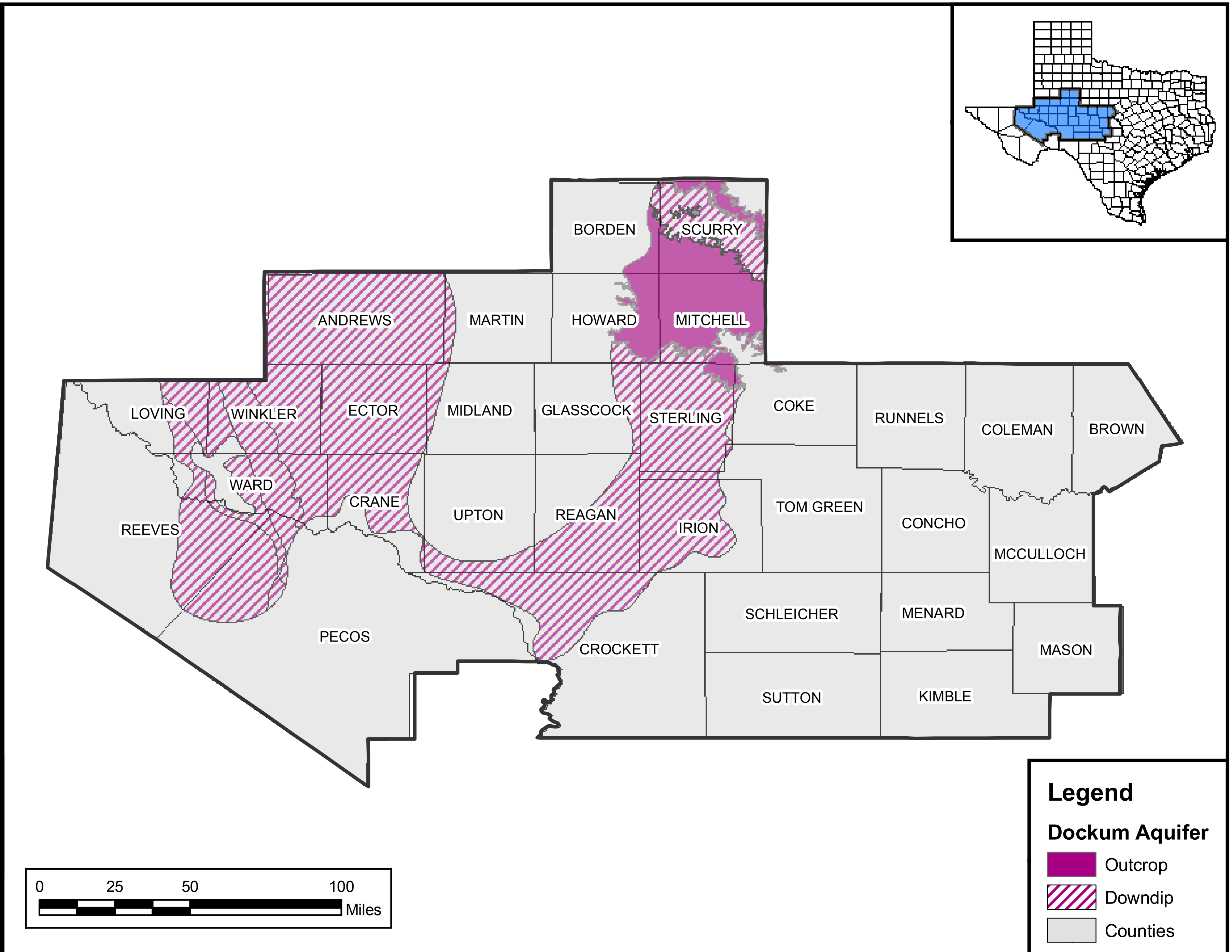
Trinity aquifer water quality is acceptable for most municipal, industrial, and irrigation purposes. Dissolved solids range from approximately 150 to over 7,000 mg/l in Brown County; however, most wells have dissolved solids concentrations of less than 1,000 mg/l. The potential for updip movement of poor quality water exists where large and ongoing water level declines have reversed the natural water level gradient and have allowed water of elevated salinity to migrate back updip toward pumpage centers.

3.1.5 Dockum Aquifer

The Dockum aquifer is used for water supply in 12 counties in Region F, including Andrews, Crane, Ector, Howard, Loving, Mitchell, Reagan, Reeves, Scurry, Upton, Ward and Winkler Counties (Figure 3.1-10). The Dockum outcrops in Scurry and Mitchell Counties, and elsewhere underlies rock formations comprising the Ogallala, Edwards-Trinity, and Pecos Valley aquifers. Although the Dockum aquifer underlies much of the region, its low water yield and generally poor quality results in its classification as a minor aquifer.

Most Dockum water used for irrigation is withdrawn in Mitchell and Scurry Counties, while public supply use of Dockum water occurs mostly in Reeves and Winkler Counties. Elsewhere, the aquifer is used extensively for oil field water flooding operations.

The primary water-bearing zone in the Dockum Group, commonly called the “Santa Rosa”, consists of up to 700 feet of sand and conglomerate interbedded with layers of silt and shale. The Santa Rosa abuts the overlying Trinity aquifer along a corridor that traverses Sterling, Irion, Reagan and Crockett Counties. Within this corridor, the Trinity and Dockum are hydrologically connected, thus forming a thicker aquifer section. A similar hydrologic relationship occurs in Ward and Winkler Counties, where the Santa Rosa unit of the Dockum is in direct contact with the overlying Pecos Valley aquifer. Local groundwater reports use the term “Allurosa” aquifer in reference to this combined section of water-bearing sands.



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Dockum Aquifer

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FIGURE 3.1-10

Recharge to the Dockum primarily occurs in Scurry and Mitchell Counties where the formation outcrops at the land surface. Recharge potential also occurs where water-bearing units of the Trinity and Pecos Valley directly overlie the Santa Rosa portion of the Dockum. Elsewhere, the Dockum is buried deep below the land surface, is finer grained, and receives very limited lateral recharge. Groundwater pumped from the aquifer in these areas will come directly from storage and will result in water level declines.

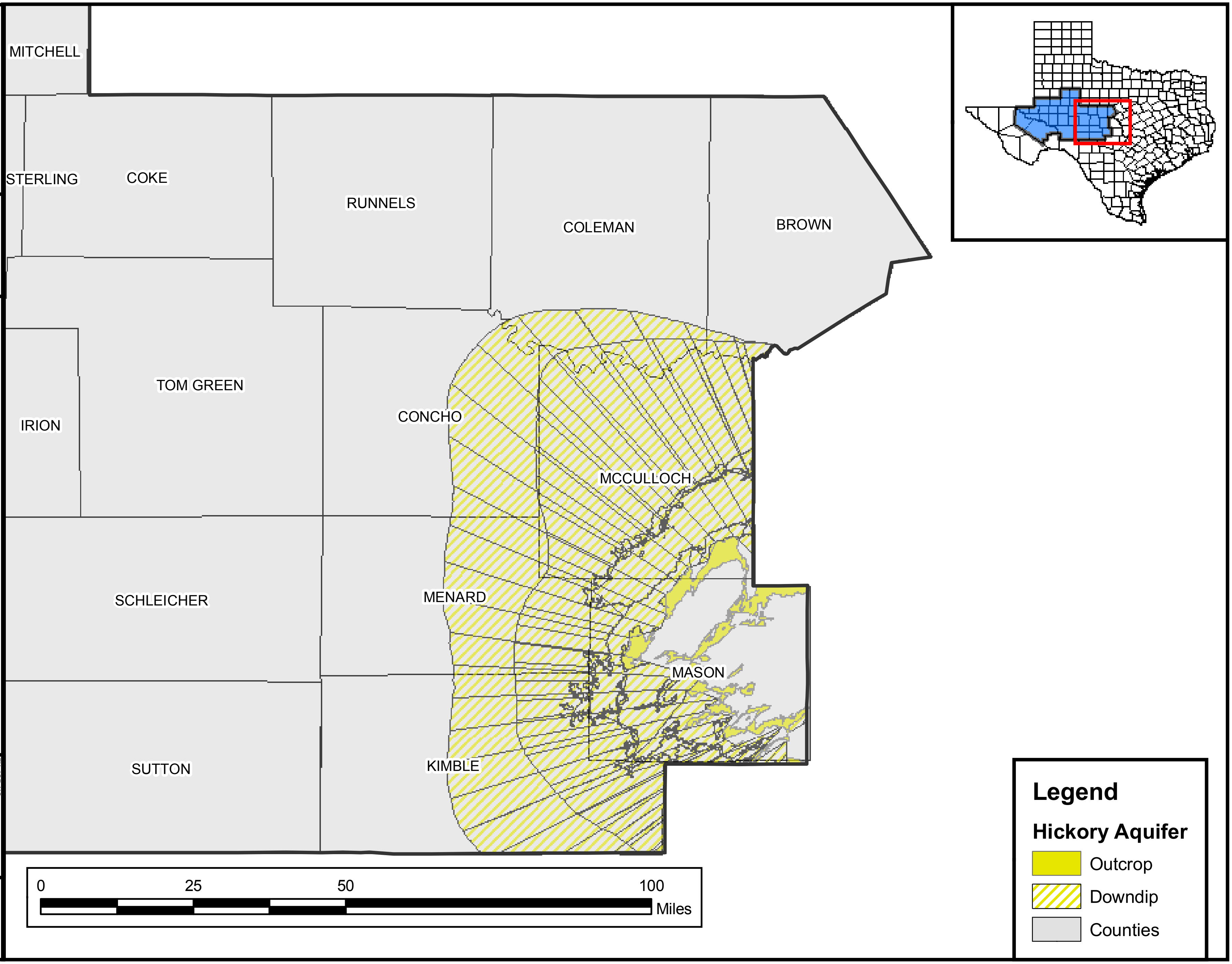
The chemical quality of water from the Dockum aquifer ranges from fresh in outcrop areas to very saline in the deeper central basin area. Groundwater pumped from the aquifer in Region F has average dissolved solids ranging from 558 mg/l in Winkler County to over 2,500 mg/l in Andrews, Crane, Ector, Howard, Reagan and Upton Counties.

3.1.6 Hickory Aquifer

The Hickory aquifer is located in the eastern portion of Region F and outcrops in Mason and McCulloch Counties (Figure 3.1-11). Besides these two counties, this aquifer also supplies groundwater to Concho and Menard Counties. The Hickory Sandstone Member of the Cambrian Riley Formation is composed of some of the oldest sedimentary rocks in Texas. Irrigation and livestock account for approximately 80 percent of the total pumpage, while municipal water use accounts for approximately 18 percent. Mason County uses the greatest amount of water from the Hickory aquifer, most of which is used for irrigation.

In most northern and western portions of the aquifer, the Hickory Sandstone Member can be differentiated into lower, middle and upper units, which reach a maximum thickness of 480 feet in southwestern McCulloch County. Block faulting has compartmentalized the Hickory aquifer, which locally limits the occurrence, movement, productivity, and quality of groundwater within the aquifer.

Hickory aquifer water is generally fresh, with dissolved solids concentrations ranging from 300 to 500 mg/l. Much of the water from the Hickory aquifer exceeds drinking water standards for alpha particles, beta particles and radium particles in the downdip portion of the aquifer. The middle Hickory unit is believed to be the source of alpha, beta and radium concentrations in excess of drinking water standards. The water may also contain radon gas. The upper unit of the



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Hickory Aquifer

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FIGURE 3.1-11

Hickory aquifer produces groundwater containing concentrations of iron in excess of drinking water standards. Wells in the shallow Hickory and the outcrop areas have local concentrations of nitrate in excess of drinking water standards.

Yields of large-capacity wells usually range between 200 and 500 gpm. Some wells have yields in excess of 1,000 gpm. Highest well yields are typically found northwest of the Llano Uplift, where the aquifer has the greatest saturated thickness.

3.1.7 Lipan Aquifer

The Lipan aquifer occurs in Concho, Runnels and Tom Green Counties (Figure 3.1-12). The aquifer is principally used for irrigation, with limited rural domestic and livestock use. The Lipan aquifer is comprised of saturated alluvial deposits of the Leona Formation and the updip portions of the underlying Permian-age Choza Formation, Bullwagon Dolomite, and Standpipe Limestone that are hydrologically connected to the Leona. Total thickness of the Leona alluvium ranges from a few feet to about 125 feet. However, most of the groundwater is contained within the underlying Permian units.

Typical irrigation practice in the area is to withdraw water held in storage in the aquifer during the growing season with expectation of recharge recovery during the winter months. The Lipan-Kickapoo Water Conservation District controls overuse by limiting well density.

Groundwater in the Leona Formation ranges from fresh to slightly saline and is very hard, while water in the underlying updip portions of the Choza, Bullwagon and Standpipe tends to be slightly saline. The chemical quality of groundwater in the Lipan aquifer generally does not meet drinking water standards but is suitable for irrigation. In some cases Lipan water has TDS concentrations in excess of drinking water standards due to influx of water from lower formations. In other cases the Lipan has excessive nitrates because of agricultural activities in the area. Well yields generally range from 20 to 500 gpm with the average well yielding approximately 200 gpm.

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Lipan Aquifer

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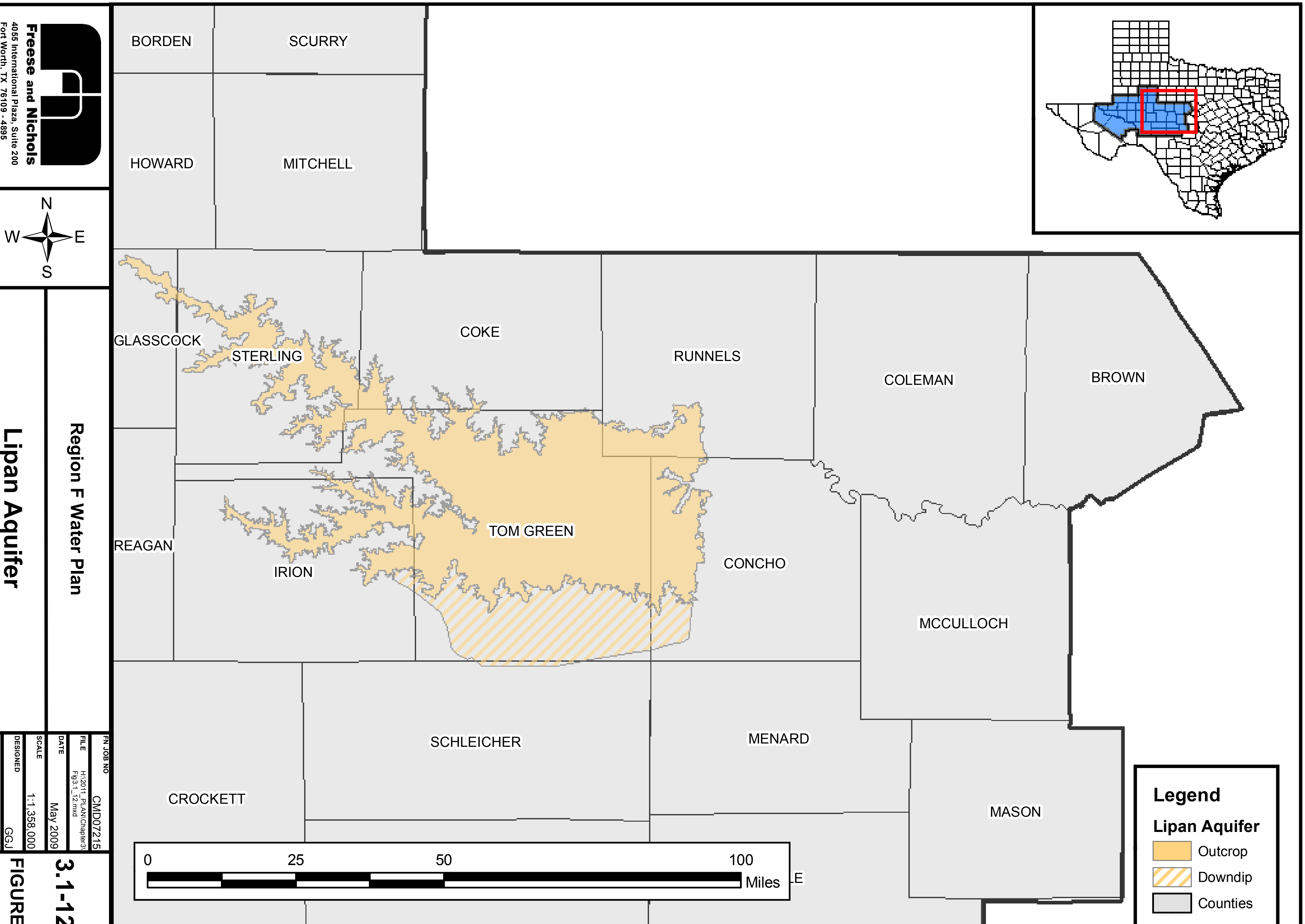
FIGURE 3.1-12



Most of the water in the Lipan aquifer is brackish due to the dissolution of gypsum and other minerals from the aquifer matrix. Additionally, irrigation return flow has concentrated minerals in the water through evaporation and the leaching of natural salts from the unsaturated zone.

3.1.8 Ellenburger-San Saba Aquifer

Including the downdip boundary as designated by the TWDB, the Ellenburger-San Saba aquifer occurs in Brown, Coleman, Kimble, Mason, McCulloch and Menard Counties within Region F (Figure 3.1-13). Currently, most pumpage from the aquifer occurs in McCulloch County. The aquifer is present in only the extreme southern parts of Brown and Coleman counties, and most of the aquifer in this area contains water in excess of 1,000 mg/l TDS. The downdip boundary of the aquifer, which represents the extent of water with less than 3,000 mg/l TDS, is roughly estimated due to lack of data.

The Ellenburger-San Saba aquifer is comprised of the Cambrian-age San Saba member of the Wilberns Formation and the Ordovician-age Ellenburger Group, which includes the Tanyard, Gorman and Honeycut Formations. Discontinuous outcrops of the aquifer generally encircle older rocks in the core of the Llano Uplift. The maximum thickness of the aquifer is about 1,100 feet. In some areas, where the overlying beds are thin or absent, the Ellenburger-San Saba aquifer may be hydrologically connected to the Marble Falls aquifer. Local and regional block faulting has significantly compartmentalized the Ellenburger-San Saba, which locally limits the occurrence, movement, productivity, and quality of groundwater within the aquifer.

Water produced from the aquifer has a range in dissolved solids between 200 and 3,000 mg/l, but is usually less than 1,000 mg/l. The quality of water deteriorates rapidly away from outcrop areas. Approximately 20 miles or more downdip from the outcrop, water is typically unsuitable for most uses. All the groundwater produced from the aquifer is inherently hard.

Principal use from the aquifer is for livestock supply in Mason and McCulloch Counties, and a minor amount in Menard County. Maximum yields of large-capacity wells generally range between 200 and 600 gpm, most other wells typically yield less than 100 gpm.

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Ellenburger-San Saba Aquifer

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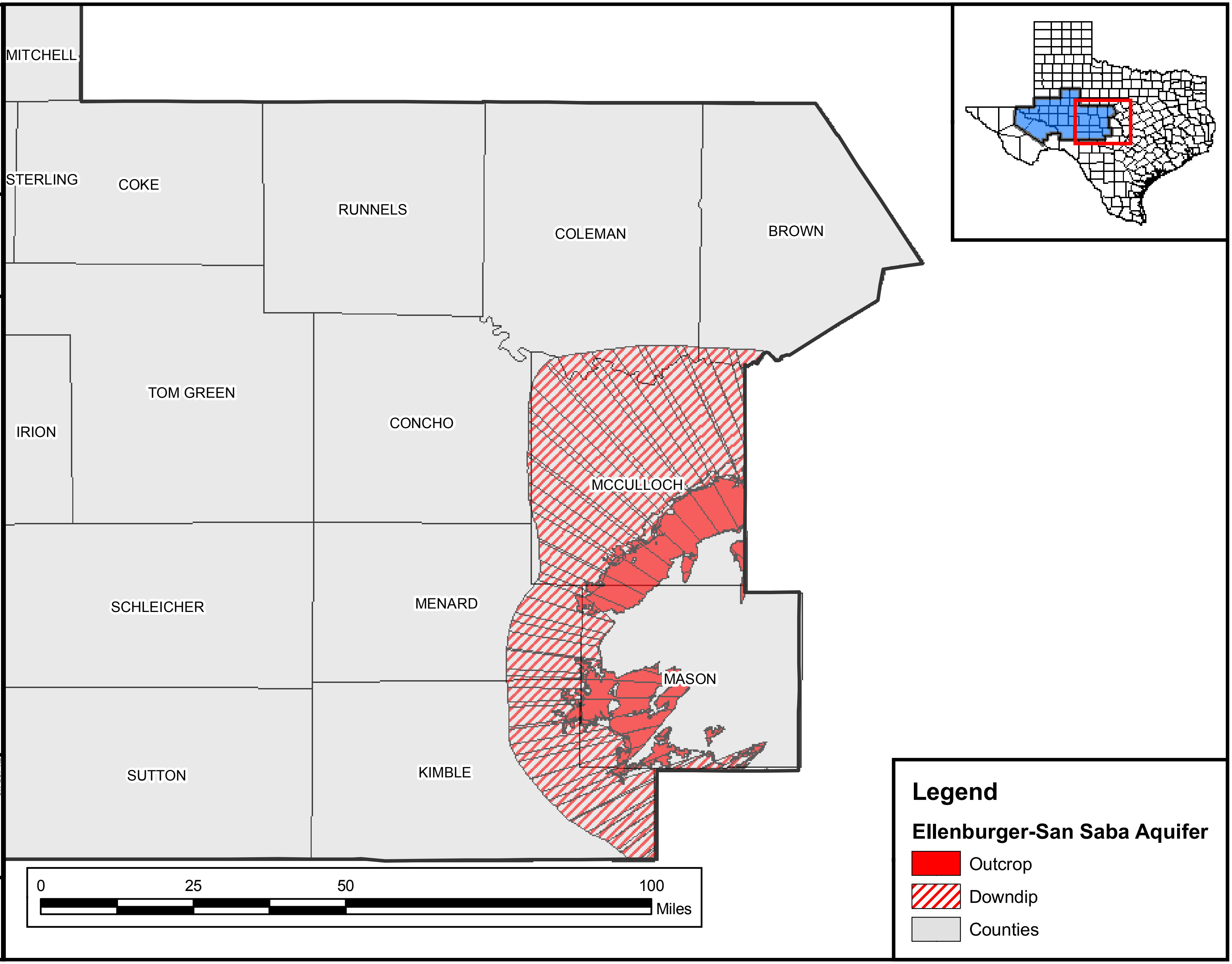
FIGURE 3.1-13



3.1.9 Marble Falls Aquifer

The Marble Falls is the smallest aquifer in the region, occurring in very limited outcrop areas in Kimble, Mason and McCulloch Counties (Figure 3.1-14). Groundwater in the aquifer occurs in fractures, solution cavities, and channels in the limestones of the Marble Falls Formation of the Pennsylvanian-age Bend Group. Where underlying beds are thin or absent, the Marble Falls and Ellenburger-San Saba aquifers may be hydrologically connected.

A limited amount of well data suggests that water quality is acceptable for most uses only in wells located on the outcrop and in wells that are less than 300-feet deep in the downdip portion of the aquifer. The downdip artesian portion of the aquifer is not extensive, and water becomes significantly mineralized within a relatively short distance downdip from the outcrop area. Most water produced from the aquifer occurs in Mason County, with lesser amounts in McCulloch County.

3.1.10 Rustler Aquifer

The Rustler Formation outcrops outside of Region F in Culberson County, but the majority of its downdip extent occurs in Loving, Pecos, Reeves and Ward Counties (Figure 3.1-15). The Rustler Formation consists of 200 to 500 feet of anhydrite and dolomite with a basal zone of sandstone and shale deposited in the ancestral Permian-age Delaware Basin. Water is produced primarily from highly permeable solution channels, caverns and collapsed breccia zones.

Groundwater from the Rustler Formation may locally migrate upward, impacting water quality in the overlying Edwards-Trinity and Pecos Valley aquifers. The Rustler is primarily used for livestock watering and a minor amount of irrigation, mostly in Pecos County.

Throughout most of its extent, the Rustler is relatively deep below the land surface, and generally contains water with dissolved constituents (TDS) well in excess of 3,000 mg/l. Only in western Pecos, eastern Loving and southeastern Reeves Counties has water been identified that contains less than 3,000 mg/l TDS. The dissolved-solids concentrations increase down gradient, eastward into the basin, with a shift from sulfate to chloride as the predominant anion. No groundwater from the Rustler aquifer has been located that meets drinking water standards.

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Marble Falls Aquifer

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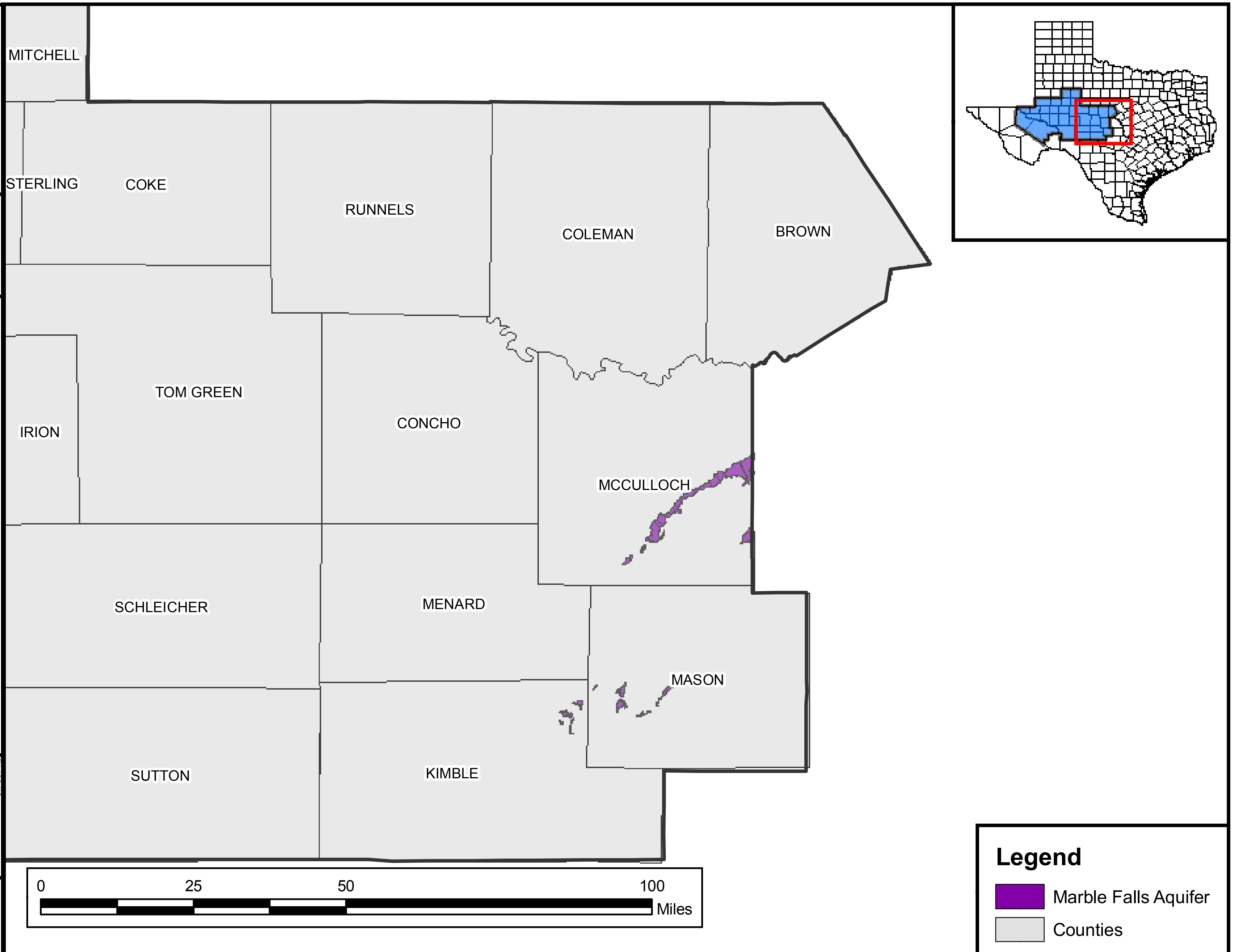
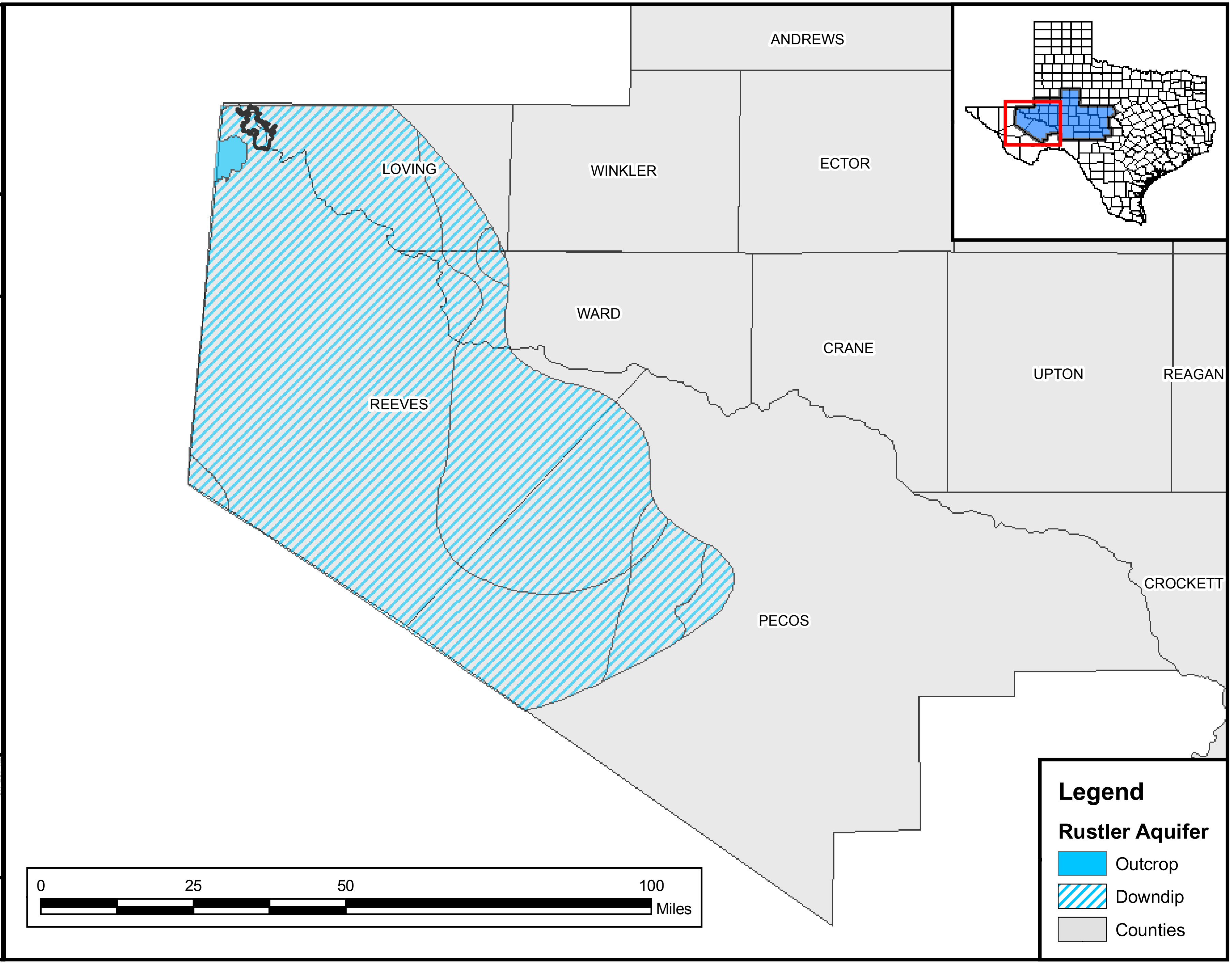
FIGURE 3.1-14





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Rustler Aquifer

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FIGURE 3.1-15

3.1.11 Capitan Reef Aquifer

The Capitan Reef formed along the margins of the ancestral Delaware Basin, an embayment covered by a shallow sea in Permian time. In Texas, the reef parallels the western and eastern edges of the basin in two arcuate strips 10 to 14 miles wide and is exposed in the Guadalupe, Apache and Glass Mountains. From its exposure in the Glass Mountains in Brewster and southern Pecos Counties, the reef plunges underground to a maximum depth of 4,000 feet in northern Pecos County. The reef trends northward into New Mexico where it is a major source of water in the Carlsbad area.

The aquifer is composed of up to 2,000 feet of massive, vuggy to cavernous dolomite, limestone and reef talus. Water-bearing formations associated with the aquifer system include the Capitan Limestone, Goat Sheep Limestone, and most of the Carlsbad facies of the Artesia Group, which includes the Grayburg, Queen, Seven Rivers, Yates and Tansill Formations. The Capitan Reef aquifer underlies the Pecos Valley, Edwards-Trinity (Plateau), Dockum and Rustler aquifers in Pecos, Ward and Winkler Counties (Figure 3.1-16).

The aquifer generally contains water of marginal quality, with TDS concentrations ranging between 3,000 and 22,000 mg/l. High salt concentrations in some areas are probably caused by migration of brine waters injected for secondary oil recovery. The freshest water is located near areas of recharge where the reef is exposed at the surface. Yields of wells commonly range from 400 to 1,000 gpm.

Most of the groundwater pumped from the aquifer has historically been used for oil reservoir water-flooding operations in Ward and Winkler Counties. A few irrigation wells have also tapped the aquifer in Pecos County. Otherwise, very little reliance has been placed on this aquifer due to its depth, limited extent, and marginal quality. The Capitan Reef aquifer may be a potential brackish water supply for desalination.

Capitan Reef Aquifer

Region F Water Plan

FIGURE 3.1-16

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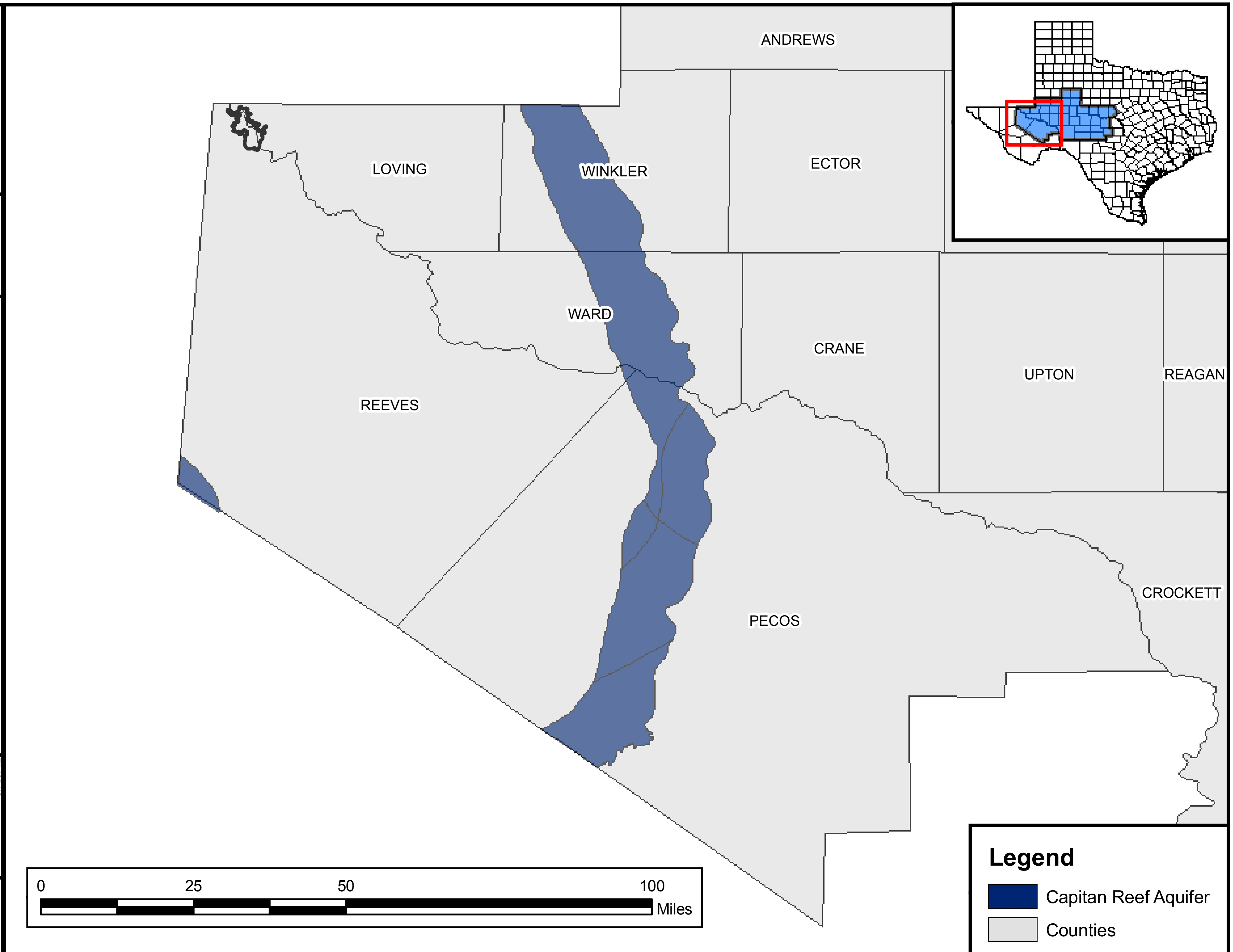

3.1.12 Brackish Groundwater Availability

Additional supplies of water in Region F may be obtained from the desalination of existing brackish or saline water sources. Desalination technology is improving, and costs are continuing to decrease, meaning more brackish groundwater supplies may become economically feasible to use as a water supply to meet regional water demands.

Many of the major and minor aquifers in Region F contain significant quantities of groundwater with TDS concentrations ranging between 1,000 and 5,000 mg/l. While some of this water is currently being used for agricultural and industrial purposes, much of it remains unused.

It is unlikely that desalination will be sufficiently economical to be a significant supply for end uses such as irrigated agriculture.

Although extensive brackish and saline water occurs in the deep, typically hydrocarbon-producing formations throughout Region F, for the most part these formations are not practical water supplies for meeting regional water demands. Many of these formations typically produce groundwater with very high salinities and are found at depths too great to be economically feasible as a water supply. It should be noted that most of the deeper, hydrocarbon-producing formations have some potential to produce brackish groundwater at reasonable rates in and near where they outcrop. The outcrops for many of these units are in the eastern third of the region. Additional data will be required to evaluate the outcrops of these formations for water supply purposes.

More information on brackish water supplies may be found in Appendix 3A in the *2006 Region F Water Plan*.

3.2 Existing Surface Water Supplies

In the year 2004, approximately 198,000 acre-feet of surface water was used in Region F, supplying 37 percent of the water supply in the region. Surface water from reservoirs provides most of the municipal water supply in Region F. Run-of-the-river water rights are used primarily for irrigation. Table 3.2-1 shows information regarding the 17 major reservoirs in Region F. Figure 3.2-1 shows the location of these reservoirs.

Table 3.2-1
Major Reservoirs in Region F[a]

Reservoir Name	Basin	Stream	County(ies)	Water Right Number(s)	Priority Date	Permitted Conservation Storage (Acre-Feet)	Permitted Diversion (Acre-Feet per Year)	Owner	Water Rights Holder(s)
Lake J. B. Thomas	Colorado	Colorado River	Borden and Scurry	CA-1002	08/05/1946	204,000	30,000[b]	CRMWD	CRMWD
Lake Colorado City	Colorado	Morgan Creek	Mitchell	CA-1009	11/22/1948	29,934	5,500	TXU	TXU
Champion Creek Reservoir	Colorado	Champion Creek	Mitchell	CA-1009	04/08/1957	40,170	6,750	TXU	TXU
Oak Creek Reservoir	Colorado	Oak Creek	Coke	CA-1031	04/27/1949	30,000	10,000	City of Sweetwater	City of Sweetwater
Lake Coleman	Colorado	Jim Ned Creek	Coleman	CA-1702	08/25/1958	40,000	9,000	City of Coleman	City of Coleman
E. V. Spence Reservoir	Colorado	Colorado River	Coke	CA-1008	08/17/1964	488,760	43,000[b]	CRMWD	CRMWD
Lake Winters	Colorado	Elm Creek	Runnels	CA-1095	12/18/1944	8,347	1,755	City of Winters	City of Winters
Lake Brownwood	Colorado	Pecan Bayou	Brown	CA-2454	09/29/1925	114,000	29,712	Brown Co. WID	Brown Co. WID
Hords Creek Lake	Colorado	Hords Creek	Coleman	CA-1705	03/23/1946	7,959	2,240	COE	City of Coleman
Lake Ballinger / Lake Moonen	Colorado	Valley Creek	Runnels	CA-1072	10/04/1946	6,850	1,000	City of Ballinger	City of Ballinger
O. H. Ivie Reservoir	Colorado	Colorado River	Coleman, Concho and Runnels	A-3866 P-3676	02/21/1978	554,340	113,000	CRMWD	CRMWD
O. C. Fisher Lake	Colorado	North Concho River	Tom Green	CA-1190	05/27/1949	80,400[c]	80,400	COE	Upper Colorado River Authority
Twin Buttes Reservoir	Colorado	South Concho River	Tom Green	CA-1318	05/06/1959	170,000	29,000	U.S. Bureau of Reclamation	City of San Angelo
Lake Nasworthy	Colorado	South Concho River	Tom Green	CA-1319	03/11/1929	12,500	25,000	City of San Angelo	City of San Angelo
Brady Creek Reservoir	Colorado	Brady Creek	McCulloch	CA-1849	09/02/1959	30,000	3,500	City of Brady	City of Brady
Red Bluff Reservoir	Rio Grande	Pecos River	Loving and Reeves	CA-5438	01/01/1980	300,000	292,500	Red Bluff WCD	Red Bluff WCD
Lake Balmorhea	Rio Grande	Toyah Creek	Reeves	A-0060 P-0057	10/05/1914	13,583	41,400	Reeves Co WID #1	Reeves Co WID #1
Total						*2,130,843*	*723,757*		

a. A major reservoir has more than 5,000 acre-feet of storage.
b. Total diversions under CA 1002 and CA 1008 limited to 73,000 acre-feet per year. CA 1008 allows up to 50,000 acre-feet per year of diversion. For purposes of this table, the limitation is placed on CA 1008.
c. Permitted storage reported is for water conservation storage. UCRA has permission to use water from the sediment pool.

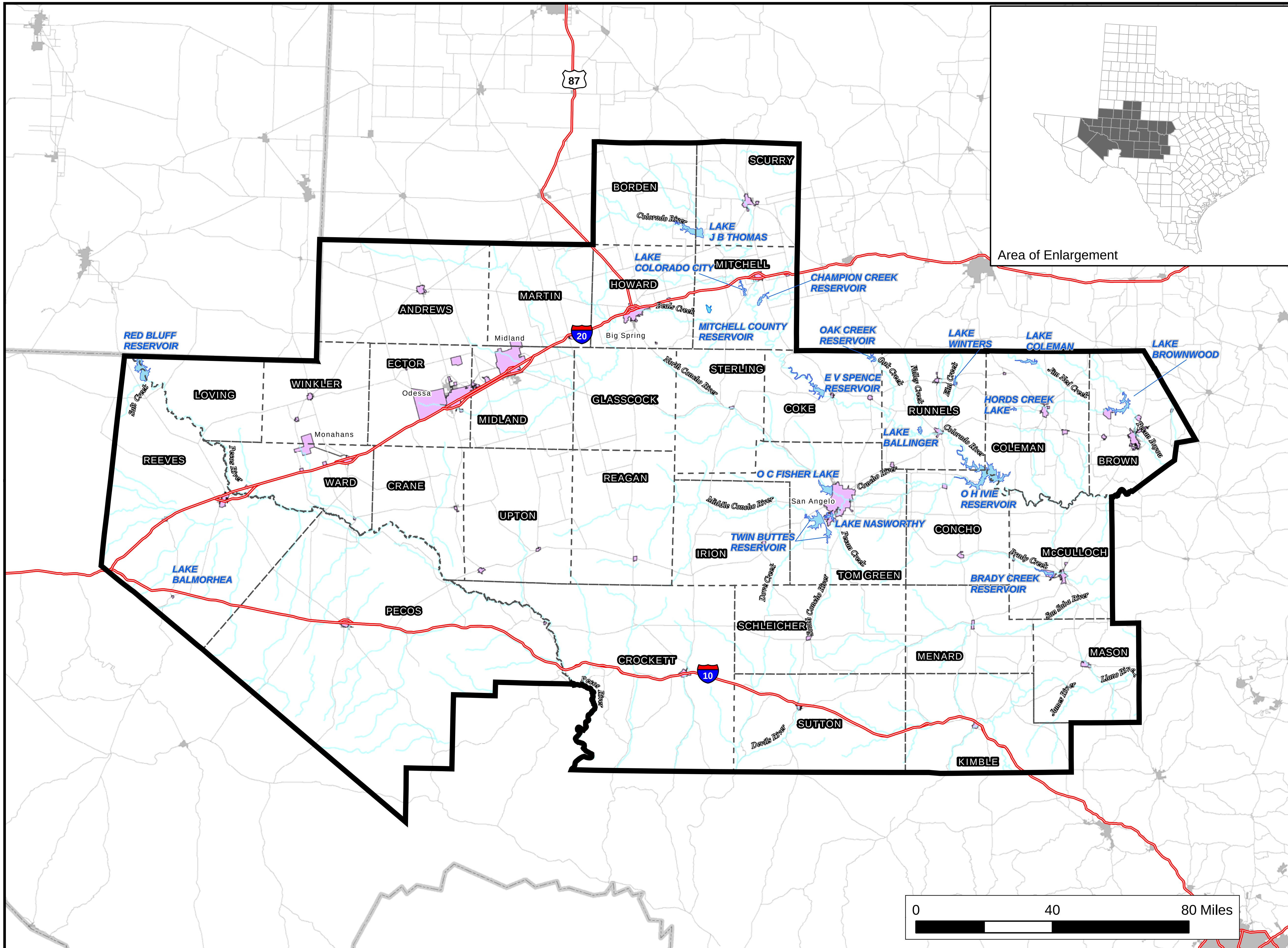

Figure 3.2-1

Region F

Major Reservoirs

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Additional information regarding water rights and historical water use may be found in Chapter 1.

3.2.1 Description of Major Reservoirs

Fifteen of the 17 major reservoirs in Region F are located in the Colorado River Basin. Two are located in the Pecos River Basin, which is part of the Rio Grande River Basin. A brief description of these reservoirs and/or systems is presented below.

Colorado River Municipal Water District Surface Water System

The Colorado River Municipal Water District (CRMWD) owns and operates three major reservoirs, Lake J.B. Thomas, E.V. Spence Reservoir and O.H. Ivie Reservoir, for water supply. CRMWD also operates several impoundments for salt water control. The CRMWD reservoirs are located in the Upper Colorado River Basin, with Lake J.B. Thomas at the upstream end of the system in Scurry and Borden Counties and O.H. Ivie at the downstream end in Concho and Coleman Counties. E.V. Spence Reservoir is located in Coke County near the City of Robert Lee. Water from the reservoir system is supplemented with groundwater from several well fields and used to supply three member cities and other customers. Collectively, the three reservoirs are permitted for 1,247,100 acre-feet of storage and 186,000 acre-feet per year of diversions. Recent droughts have left the two upper reservoirs (J.B. Thomas and E.V. Spence) at storage levels less than 10 percent of conservation capacity. O.H. Ivie is currently at less than 50 percent capacity.

Lake Colorado City/ Champion Creek Reservoir System

Lake Colorado City and Champion Creek Reservoir are located in Mitchell County, south of Colorado City. Lake Colorado City was built in 1949 on Morgan Creek to supply cooling water for the Morgan Creek Power Plant and municipal supply to Colorado City. Colorado City no longer receives water from these lakes. Lake Colorado City is permitted to store 29,934 acre-feet and divert 5,500 acre-feet per year for municipal, industrial and steam electric power use. Champion Creek Reservoir was constructed 10 years later in 1959 to supplement supplies from Lake Colorado City. A 30-inch pipeline is used to transfer water from Champion Creek Reservoir to Lake Colorado City when the lake's water levels are low. Champion Creek Reservoir is permitted to store 40,170 acre-feet and divert 6,750 acre-feet per year.

Twin Buttes Reservoir

Twin Buttes Reservoir is located on the Middle Concho River, Spring Creek and the South Concho River southwest of San Angelo in Tom Green County. The reservoir is owned by the Bureau of Reclamation. The dam was completed in 1963. The reservoir has permitted conservation storage of 170,000 acre-feet and permitted diversion of 29,000 acre-feet per year for municipal and irrigation use. Twin Buttes reservoir is operated with Lake Nasworthy to provide municipal water to San Angelo through the San Angelo Water Supply Corporation. Irrigation water is released directly from the reservoir to a canal system for irrigation use in Tom Green County. Due to recent droughts, little supply has been available for irrigation purposes in recent years.

Lake Nasworthy

Lake Nasworthy is located on the South Concho River, approximately 6 miles southwest of San Angelo in Tom Green County. Lake Nasworthy was completed in 1930 to provide municipal, industrial and irrigation water to the City of San Angelo. The lake is permitted to store 12,500 acre-feet and divert 25,000 acre-feet per year of water for municipal and industrial purposes. This permitted diversion amount includes water diverted by San Angelo from the Twin Buttes Reservoir for municipal purposes. Lake Nasworthy is operated as a system with Twin Buttes Reservoir.

O.C. Fisher Reservoir

O.C. Fisher reservoir is on the North Concho River, located northwest of San Angelo in Tom Green County. The reservoir was constructed by the U.S. Army Corps of Engineers for flood control and water supply. The project was fully operational in 1952. The Upper Colorado River Authority (UCRA) holds water rights to impound 80,400 acre-feet and divert 80,400 acre-feet per year for water for municipal, industrial and mining use. The Cities of San Angelo and Miles have contracts for water from this source.

Oak Creek Reservoir

Oak Creek Reservoir is located on Oak Creek in northeastern Coke County. The reservoir was completed in 1953, and is permitted to store 30,000 acre-feet and divert 10,000 acre-feet per year for municipal and industrial use. The reservoir is owned by the City of Sweetwater, which is located in the Brazos G Region. Municipal water from the lake supplies the Cities of Sweetwater, Blackwell and Bronte Village. Until recently the reservoir also provided cooling water for the Oak Creek Power Plant. That facility is currently mothballed, but could be restarted in the future.

Lake Coleman

Lake Coleman is constructed on Jim Ned Creek in Coleman County, approximately 14 miles north of the City of Coleman. It is located in the Pecan Bayou watershed of the Colorado River Basin, upstream of Lake Brownwood. The lake was completed in 1966 and has a permitted conservation capacity of 40,000 acre-feet. The City of Coleman holds water rights to use 9,000 acre-feet per year for municipal and industrial purposes.

Lake Brownwood

Lake Brownwood is located on Pecan Bayou, north of the City of Brownwood in Brown County. The lake is owned and operated by the Brown County Water Improvement District #1. Construction was completed on Lake Brownwood in 1933. It is permitted to store 114,000 acre-feet of water and divert 29,712 acre-feet per year for municipal, industrial and irrigation purposes.

Hords Creek Lake

Hords Creek Lake is located on Hords Creek in western Coleman County. Construction of the dam was completed in 1948 and impoundment of water began. The lake has a permitted conservation capacity of 7,959 acre-feet and a permitted diversion of 2,240 acre-feet per year. The lake is jointly owned by the City of Coleman and the U.S. Army Corps of Engineers, and is used for flood control and as a municipal water supply.

Lake Winters

Lake Winters/ New Lake Winters is on Elm Creek, about five miles east of the City of Winters in northeast Runnels County. The City of Winters owns and operates the lake for municipal water supply. The original lake was constructed in 1944 and expanded in 1983. The lake is permitted to store 8,347 acre-feet of water and divert up to 1,755 acre-feet per year.

Lake Ballinger/Lake Moonen

Lake Ballinger is located on Valley Creek in Runnels County. The lake is owned and operated by the City of Ballinger for municipal water supply. The original dam was completed in 1947 (Lake Ballinger). A larger dam was constructed downstream of Lake Ballinger in 1985 (Lake Moonen). The two lakes are permitted to impound 6,850 acre-feet and divert 1,000 acre-feet per year.

Brady Creek Reservoir

Brady Creek Reservoir is located on Brady Creek in central McCulloch County. The lake is owned and operated by the City of Brady for municipal and industrial water supply. Construction of the dam was completed and impoundment of water began in 1963. The reservoir has a permitted conservation storage capacity of 30,000 acre-feet and a permitted diversion of 3,500 acre-feet per year.

Red Bluff Reservoir

Red Bluff Reservoir is located on the Pecos River in Reeves and Loving counties, approximately 45 miles north of the City of Pecos, and extends into Eddy County, New Mexico. The reservoir is owned and operated by the Red Bluff Water Control District. Construction of the dam was completed in 1936 and water use started in 1937. The reservoir is permitted to store 300,000 acre-feet and divert 292,500 acre-feet per year for irrigation purposes.

Seven water districts form the Red Bluff Water Control District, which supplies irrigation water to Loving, Pecos, Reeves and Ward Counties. Hydropower is no longer generated at the dam. With much of the drainage area of the reservoir in New Mexico, water is released from New Mexico to Red Bluff Reservoir in accordance with the Pecos River Compact. At this time, New Mexico has a credit towards its Texas deliveries, which could substantially reduce water supplies to Red Bluff Reservoir during drought.

Water is released from Red Bluff to irrigation users through the bed and banks of the Pecos River and canal systems. Due to high evaporative rates and infiltration, approximately 75 percent of the water released is lost during transport. Naturally occurring salt springs above the reservoir and high evaporative losses contribute to high concentrations of total dissolved solids and chlorides in the water. Irrigation water with total dissolved solids concentrations greater than

1,500 mg/l impacts agricultural production and concentrations greater than 4,500 mg/l damages the land and is not suitable for irrigation. The salinity in Red Bluff Reservoir can exceed these thresholds during dry years, making the available water unusable for its intended purpose. Imperial Lake, which is located in Pecos County and considered part of the Red Bluff system, currently has total dissolved solids concentrations greater than 10,000 mg/l .[1] Other water quality concerns include low dissolved oxygen and golden algae.

Lake Balmorhea

Lake Balmorhea is located on Sandia Creek in the Pecos River Basin in southern Reeves County, southeast of the City of Balmorhea. The Reeves County Water Improvement District No. 1 owns and operates the lake. Construction began on the earthfill dam in 1916 and was completed in 1917. The lake is permitted to store 13,583 acre-feet of water and divert 41,400 acre-feet per year for irrigation purposes. The lake is predominantly spring fed. In addition to water from Sandia Creek, Lake Balmorhea receives water from Kountz Draw from the south and Toyah Creek, which receives water from Solomon Springs, through Madera Diversion Dam and its canals. Surplus water from Phantom Lake Canal, which is supplied by several springs, is also stored in Lake Balmorhea until it is needed for irrigation.

3.2.2 Available Surface Water Supply

All surface water supplies in this chapter are derived from Water Availability Models (WAMs) developed by the Texas Commission on Environmental Quality (TCEQ). The TWDB requires the use of the Full Authorization Run (Run 3) of the approved TCEQ WAM for each basin as the basis for water availability in regional water planning[2]. Three WAM models are available in Region F: (a) the Colorado WAM, which covers most of the central and eastern portions of the region, (b) the Rio Grande WAM, which covers the Pecos Basin, and (c) the Brazos WAM. There are approximately 493,000 acre-feet of permitted diversions in the Colorado Basin in Region F, more than half of the permitted diversions in the region. There are 416,158 acre-feet of permitted diversions in the Rio Grande Basin. There is one water right in the Brazos Basin in Region F with a permitted diversion of 63 acre-feet per year.

Table 3.2-2 compares the firm yields of the 17 major reservoirs in Region F developed prior to the WAMs to the yields from the TCEQ WAM.[3] Table 3.2-3 provides a similar comparison for the run-of-the river supplies. The supplies derived using the WAMs are very different from the older estimates. Total supplies from reservoirs are about 75 percent of that determined by methods prior to the WAMs. Total run-of-the-river supplies are about one third of the supplies in the previous planning. Nearly all of the supply reductions are associated with sources in the Colorado Basin.

Table 3.2-2
Comparison of WAM Firm Yields of Region F Reservoirs under Different Planning Assumptions
(Values in Acre-Feet per Year)

Reservoir Name	Basin	Firm Yield Prior to WAM [a]	WAM Firm Yield [b]	WAM Safe Yield
Lake J. B. Thomas	Colorado	9,900	20	0
E. V. Spence Reservoir	Colorado	38,776	6,170	560
O. H. Ivie Reservoir	Colorado	96,169	85,150	67,700
Lake Colorado City	Colorado	4,550	0	0
Champion Creek Reservoir	Colorado	4,081	10	0
Oak Creek Reservoir	Colorado	5,684	5	0
Lake Coleman	Colorado	8,822	5	0
Lake Winters/ New Lake Winters	Colorado	1,407	0	0
Lake Brownwood	Colorado	41,800	47,200 [c]	33,500 [c]
Hords Creek Lake	Colorado	1,425	0	0
Lake Ballinger / Lake Moonen	Colorado	3,566	30	0
O. C. Fisher Lake	Colorado	2,973	0	0
Twin Buttes Reservoir	Colorado	8,900	10 [c]	0
Lake Nasworthy	Colorado	7,900		
Brady Creek Reservoir	Colorado	2,252	0	0
Red Bluff Reservoir	Rio Grande	31,000	41,725 [c]	33,600 [c]
Lake Balmorhea	Rio Grande	182	21,844 [d]	21,844 [d]
Total		*269,387*	*202,169*	*157,204*

a Firm Yield Prior to WAM is from the 2001 Water Plan are for year 2000 sediment conditions
b WAM yields are for original sediment conditions except where noted.
c WAM yield using year 2000 sediment conditions at reservoir
d The yield from Lake Balmorhea is assumed to be the minimum annual supply from the springs that feed the reservoir

The reason for this change is that previous studies made significantly different assumptions about the availability of water supplies in the Colorado Basin. The WAMs assume that priority of diversion and storage determines water availability regardless of geographic location, the type of right, or purpose of use. Previous water analyses generally assumed that municipal reservoir supplies in the Colorado Basin were not subject to priority calls by senior water rights. If any water was passed to senior downstream water rights holders it was only for diversions and not to maintain permitted storage.

Table 3.2-3
Comparison of Run-of-the-River Supplies under Different Planning Assumptions[a]
(Values in Acre-Feet per Year)

County	Previous Planning Supplies[b]	WAM Firm Supplies	Increase (Decrease) in Yield
Andrews	125	0	(125)
Borden	145	0	(145)
Brown	3,256	778	(2,478)
Coke	275	48	(227)
Coleman	2,326	31	(2,295)
Concho	727	263	(464)
Crane	1,434	0	(1,434)
Crockett	361	0	(361)
Ector	1,800	23	(1,777)
Howard	24	0	(24)
Irion	1,980	580	(1,400)
Kimble	3,502	1,488	(2,014)
Loving	0	0	0
Martin	550	0	(550)
Mason	0	0	0
McCulloch	550	128	(422)
Menard	3,792	3,238	(554)
Midland	1,400	0	(1,400)
Mitchell	235	15	(220)
Pecos	0	4,444	4,444
Reagan	0	0	0
Reeves	182	0	(182)
Runnels	5,500	771	(4,729)
Schleicher	0	0	0
Scurry	1,170	69	(1,101)
Sterling	0	48	48
Sutton	475	8	(467)
Tom Green	15,839	3,454	(12,385)
Upton	0	0	0
Ward	0	0	0
Winkler	0	0	0
Total	*45,648*	*15,386*	*(30,262)*

a Does not include unpermitted supplies for livestock or diverted water from CRMWD chloride projects

b. Previous planning values are taken from the 1997 and 2001 State Water Plans

TWDB requires the use of the TCEQ WAM for regional water planning even though the Colorado WAM uses many assumptions that are very different than the way that the basin has historically been operated. More detailed information about these assumptions may be found in Appendix 3C of the *2006 Region F Water Plan*. It is the opinion of the Region F Water Planning Group that the Colorado WAM does not give a realistic assessment of water supplies for planning purposes because it ignores the historical operation of the basin and previous agreements among water right holders. Using the WAM for water supply planning tends to overestimate available supplies in the lower Colorado River Basin, while underestimating available supplies in the upper basin.

In order to address these water supply issues, a joint modeling effort was conducted with the Lower Colorado Regional Water Planning Group (Region K) as part of the development of the 2006 regional water plans. This modeling effort analyzed the impact of subordination of major senior water rights in the lower Colorado Basin to major water rights in Region F, as well as subordination of major Region F water rights to each other. The subordination strategy and the results of the subordination modeling are described in Chapter 4.

For this plan update, Region K refined the modeling efforts in the Lower Colorado River Basin for use in the 2011 Region K regional water plan. As a special study, Region F monitored the Region K modeling and provided input (see Volume II). The special study found that the Region K model assumes that less water is passed from Region F to Region K than shown in the subordination model used for the 2006 water plans. This results in showing more water available in Region F. Region F decided to retain the water availability analyses and subordination strategy used in the 2006 water plan, including water provider agreements and system operations. This includes subordination of lower basin water rights to water rights held by the Cities of Junction and Brady. This approach should not have an impact to the supplies in Region K as determined by the new Region K "cutoff" model. Since overall supplies in Region F would likely be higher if assumptions similar to the Region K model were used, the water availability analysis performed for the *2006 Region F Water Plan* should be conservative. While there are some differences between the models, the use of the two models in this round of planning should not impact the overall balance of water between the two regions. Therefore supplies from the *2006 Region F Water Plan* were retained.

3.3 Alternative Water Supplies

This section highlights sources of water that have not traditionally been used for water supply, but which could potentially be a significant resource for consideration in future water planning. In Region F, these sources include desalination of brackish water (groundwater and surface water) and reclaimed water.

This section provides information about the current status of alternative water supplies in Region F. Information on brackish groundwater sources may be found in Section 3.1.12. Potential strategies using brackish water or reuse may be found in Chapter 4.

3.3.1 Desalination

Desalination processes are used to treat water for use as a public water supply, or for non-potable uses sensitive to the salt content of the water. Desalination can be defined as any process that removes salts from water.[4] The Texas secondary drinking water standard for chloride is 300 mg/l. Consumers can generally detect a salty taste in water that has chloride concentration above about 250 mg/l. However, because chloride is only one component of the dissolved solids typically present in water, the specific taste threshold for TDS is difficult to pinpoint.[5] The Texas secondary drinking water standard for TDS is 1,000 mg/l. Although secondary standards are recommended limits and not required limits, TWDB will not fund a municipal project that uses a water source with TDS greater than 1,000 mg/l unless desalination is part of the planned treatment process, greatly increasing the cost of new water supplies. Region F believes that this policy should be revised allowing for local conditions such as the economy, availability of water, community concerns for the aesthetic of water, and technologies such as point-of use treatment on a voluntary basis.

Water is considered brackish if the total dissolved solids (TDS) range from 1,000 mg/l to 10,000 mg/l. Brackish waters have historically not been considered a water supply source except in limited applications. Until recently desalination of brackish waters was too expensive to be a feasible option for most public water suppliers. However, the costs associated with desalination technology have declined significantly in recent years, making it more affordable for communities to implement. If an available source of brackish water is nearby, desalination can be as cost-effective as transporting better quality water a large distance. In some areas, there is less competition for water from brackish sources because very little brackish water is currently used for other purposes, making it easier to develop new brackish sources.

Two factors significantly impact the cost-effectiveness of desalination: water quality and concentrate disposal. Treatment costs are directly correlated to the quality of the source water and can vary significantly depending on the constituents in the water. Use of brackish waters with higher ranges of TDS may not be cost-effective. The presence of other constituents, such as calcium sulfate, may also impact the cost-effectiveness of desalination. The disposal of brine waste from the desalination process can be a significant portion of the costs of a project. The least expensive option is discharge to a receiving body of water or land application. However, a suitable receiving body with acceptable impacts to the environment may not be available.

Disposal of concentrate by deep well injection could be a practical and cost-effective method for large-scale desalination projects in Region F. If the native water quality in the injection zone is 10,000 mg/l or less, then the underground reservoir is classified as an Underground Source of Drinking Water (USDW) and will likely require a Class V Authorization supplemented with portions of a Class I application. Therefore the time and cost for permitting can be substantial. However, the disposal of water from oil field operations, which is similar or worse in quality to the reject from desalination, requires a Class II permit from the Railroad Commission of Texas, which has a less intensive permitting process. Non-hazardous desalination concentrate can be injected into a Class II well without any additional permitting if it is also used for secondary recovery. Non-hazardous desalination concentrate can also be injected into a Class I well under a general permit. The TCEQ is currently working to implement a more streamlined permitting process for desalination concentrate. TWDB Report 366, *Please Pass the Salt: Using Oil Fields for the Disposal of Concentrate from Desalination*, provides detail regarding the potential for injecting desalination concentrate into oil fields.[6]

TWDB through a contract with the Bureau of Economic Geology developed a database of the desalination facilities operating in Texas in 2005. The information in the database was obtained through surveys and correspondence with the plant operators. Facilities placed in operation after 2005 are not included in the database. According to the data posted on the TWDB website, a total of about 6.6 million gallons of water per day (MGD) is desalinated on a regular basis in Region F by municipal, commercial and industrial facilities.[7] It should be noted that not all of the source water for the desalination activities is considered brackish water, and some desalination facilities are used to treat the water for other constituents such as radionuclides. The current TWDB list of desalination facilities does not distinguish between brackish source waters and source waters classified as fresh water.

A major treatment facility for brackish water currently operating in Region F is at Fort Stockton. Fort Stockton draws water from the Edwards-Trinity Aquifer that must be treated to reduce TDS to acceptable levels. The Fort Stockton plant consists of microfiltration (MF) and ultraviolet (UV) disinfection pretreatment, followed by RO and chlorination. Feed water with a TDS concentration of approximately 1,400 mg/l is blended with RO permeate at a ratio of 60:40. The maximum capacity of the RO permeate stream is approximately 3.8 MGD. Currently, the Fort Stockton facility produces approximately 7.0 MGD blended water, at 800 mg/l TDS. Concentrate streams are disposed of using evaporation ponds. Future plans for the Fort Stockton facility include the possible installation of a dedicated treatment train for the city's industrial customers.[8,9]

Other current users of desalination facilities include the City of Brady, Midland Country Club and Water Runner, Inc in Midland. In addition, the Millersview-Doole Water Supply Corporation (MDWSC) is building a RO desalination plant with an initial capacity of approximately 1.5 MGD. The MDWSC will use O.H. Ivie Reservoir as a water source, which has TDS levels ranging from 1,100 to 1,500 mg/l. Ultimately, the City of Brady and MDWSC plants plan to expand to 3.0 MGD each.[10,11]

Other industrial and commercial users in the region also desalinate water for various uses. However, the TWDB database does not report any user with a treatment facility smaller than 0.025 million gallons per day. At this time, it is not feasible to estimate how much of the industrial and commercial desalination utilizes a brackish water source.

3.3.2 Use of Reclaimed Water

Reclaimed water can be defined as any water that has already been used for some purpose, and is used again for another purpose instead of being discharged or otherwise disposed. Although water initially used for agricultural and industrial purposes can be reclaimed, this discussion will focus on reuse of treated municipal wastewater effluent. In Region F, reclaimed water has been used for agricultural irrigation and some industrial purposes for many years. The use of reclaimed water for other purposes has gained a level of public acceptance that allows water managers to implement other reuse strategies. Although there is still public resistance to the direct reuse of wastewater effluent for potable water supply, there is increasingly widespread use of reclaimed water for irrigation of parks and landscaping. The use of reclaimed water requires development of the infrastructure necessary to transport the treated effluent to secondary users. For some uses, the wastewater may be difficult to treat to the required standard.

The TWDB notes three important advantages of the use of reclaimed water:

- Effluent from municipal wastewater plants is a drought-proof supply.
- Treated effluent is the *only* source of water that automatically increases as economic and population growth occurs in the community.
- The source of treated effluent is usually located near the intended use, not at some yet-to-be developed, distant reservoir or well field.[12]

The use of reclaimed water can occur directly or indirectly. Direct use is typically defined as use of the effluent before it is discharged, under arrangements set up by the generator of the wastewater. Indirect reuse occurs when the effluent is discharged to a stream or reservoir and later diverted from the stream for some purpose, such as municipal, agricultural or industrial supply. Indirect reuse is sometimes difficult to quantify because the effluent becomes mixed with the waters of the receiving body. A water rights permit may be needed to enable the diversion of the effluent from the stream.

A number of communities in Region F have direct wastewater reuse programs in place, utilizing municipal wastewater effluent for landscape irrigation or for industrial or agricultural purposes. The major municipal reuse programs in Region F are listed in Table 3.3-1. Smaller programs (less than 0.1 MGD) are also reported in Concho, Howard, Irion, Martin, and Reagan counties.

One of the Region F special studies completed in 2008 was the Municipal Conservation Survey. This survey offered detail on the conservation practices, including water reuse of select cities in Region F. The cities of Andrews, Eden, and Odessa reported using wastewater effluent for municipal irrigation and/or industrial purposes. Midland and San Angelo currently reuse their effluent for irrigated agriculture. Two cities, Odessa and San Angelo, provided more recent reuse data. This data is summarized in Table 3.3-2.

Table 3.3-1
Recent Reuse Quantities in Region F

City	County	Use	Year 2000 (MGD)	Year 2000 (Ac-Ft/Yr)	Year 2001 (MGD)	Year 2001 (Ac-Ft/Yr)	Year 2002 (MGD)	Year 2002 (Ac-Ft/Yr)
Midland	Midland	Irrigation	10.7	12,000	11.3	12,700	11.3	12,700
San Angelo	Tom Green	Irrigation	7.6	8,500	8.2	9,200	7.6	8,500
Odessa	Ector	Industrial Irrigation	3.2	3,600	3.4	2,800	3.3	3,700
Monahans	Ward	Irrigation	no data	no data	0.6	670	0.6	670
Andrews	Andrews	Irrigation	0.5	560	no data	no data	no data	no data
Winters	Runnels	Irrigation	0.2	220	0.2	220	0.2	220
Snyder	Scurry	Irrigation	no data	no data	0.1	110	0.1	110
TOTAL			*22.2*	*24,880*	*23.8*	*25,700*	*23.1*	*25,900*

Source of Data: TWDB reuse database [13]

Teleconferences with several cities provided insight into current and future plans to expand water reuse. The City of Menard is currently trying to fund a wastewater treatment plant that would provide wastewater reuse for golf course irrigation. In addition to current reuse practices, Midland wants to provide Midland College with 100,000 gallons per day of reuse water for landscape irrigation by constructing an interceptor unit. The City of Odessa already provides reuse water for industrial, irrigation and residential irrigation users. The city is exploring options to offer reuse water for irrigation to additional facilities which are in the vicinity of existing reuse pipelines. San Angelo has historically used reuse water to irrigate city-owned farms or has sold the effluent to other irrigators. The City of Eden used an average of about 80 acre-feet per year to irrigate a golf course. The city plans to increase treatment capacity and storage to provide up to 224 acre-feet of water for this purpose.

Table 3.3-2
Reuse Water Sales in Region F

City	County	Use	Year 2005 (MGD)	Year 2005 (Ac-Ft/Yr)	Year 2006 (MGD)	Year 2006 (Ac-Ft/Yr)	Year 2007 (MGD)	Year 2007 (Ac-Ft/Yr)
San Angelo	Tom Green	Irrigation	8.2	9,181	7.0	7,798	8.2	9,215
Odessa	Ector	Industrial Irrigation	2.9	3,228	3.0	3,332	2.4	2,741

a. The amount of reuse water provided for industrial purposes is approximately 47% of the total amount reported. The City has a contract to provide 3 MGD of reuse water for industrial purposes.
b. The reported MGD is average daily use.

For planning purposes only the reuse for Midland, San Angelo and Odessa will be considered as a current supply for purposes of assessing needs. This is because it is uncertain whether the TWDB considered reuse projects that are used to irrigate city properties and park facilities when developing demands for the cities. To be conservative, it will be assumed that the demands for the cities in Region F do not include the existing municipal irrigation demands for reuse supplies. Reuse supplies developed beyond what is currently being used may be considered as a water management strategy. A summary of the current reuse supplies for Region F is presented in Table 3.3-3.

Table 3.3-3
Reuse Water Supply in Region F
(Values in Acre-Feet per Year)

County	Basin	2010	2020	2030	2040	2050	2060
Andrews	Colorado	560	560	560	560	560	560
Concho	Colorado	80	224	224	224	224	224
Ector	Colorado	3,000	3,150	3,300	3,450	3,600	3,750
Midland	Colorado	5,987	5,987	5,987	5,987	5,987	5,987
Runnels	Colorado	218	218	218	218	218	218
Scurry	Colorado	110	110	110	110	110	110
Tom Green	Colorado	8,500	8,500	8,500	8,500	8,500	8,500
Ward	Rio Grande	670	670	670	670	670	670

3.4 Currently Available Supplies for Water User Groups

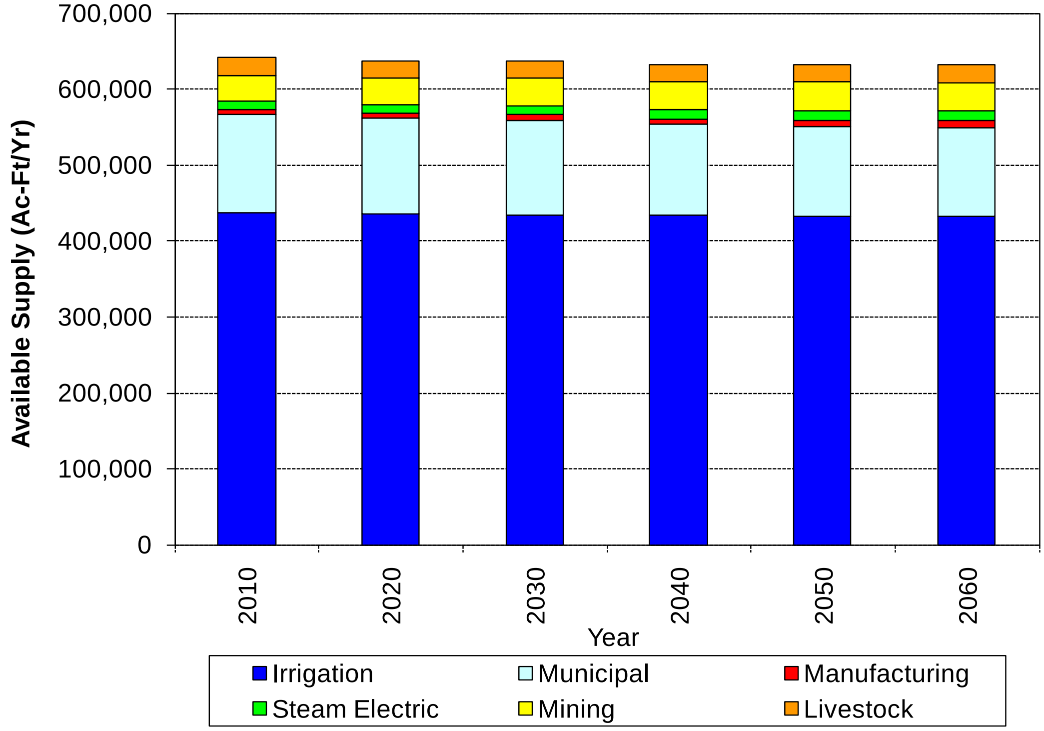
Currently available supplies in each county are shown in Table 3.4-1. The total of the currently available supply by use type is shown in Figure 3.4-1. Unlike the overall water availability figures in Sections 3.1 and 3.2, currently available supplies are limited by the ability to deliver and/or use water. These limitations may include firm yield of reservoirs, well field capacity, aquifer characteristics, water quality, water rights, permits, contracts, regulatory restrictions, raw water delivery infrastructure and water treatment capacities where appropriate. Summary tables in Appendix 3A present the currently available water available for each water user group (WUG), arranged by county. (Water user groups are cities with populations greater than 500, water suppliers who serve an average of at least 0.25 million gallons per day (MGD) annually, "county other" municipal uses, and countywide manufacturing, irrigation, mining, livestock, and steam electric uses.)

Table 3.4-1
Summary of Currently Available Supply to Water Users by County[a]
(Values in Acre-Feet per Year)

County	Year 2010	Year 2020	Year 2030	Year 2040	Year 2050	Year 2060
Andrews	25,761	25,761	25,761	26,249	26,239	26,226
Borden	2,316	2,317	2,316	2,316	2,316	2,316
Brown	21,750	21,840	21,843	21,808	21,820	21,877
Coke	2,228	2,181	2,446	2,401	2,372	2,327
Coleman	2,806	2,791	2,788	2,786	2,785	2,781
Concho	7,035	7,172	7,191	7,185	7,129	7,129
Crane	3,969	4,097	4,159	4,201	4,258	4,323
Crockett	5,980	5,997	6,006	6,014	6,022	6,030
Ector	48,065	44,694	53,214	54,096	55,127	55,472
Glasscock	24,906	24,906	24,906	24,906	24,906	24,906
Howard	14,040	13,722	16,332	15,897	15,646	15,294
Irion	2,331	2,331	2,325	2,316	2,309	2,305
Kimble	2,749	2,746	2,746	2,746	2,746	2,746
Loving	667	667	666	666	666	666
Martin	14,949	14,949	14,949	15,022	14,760	14,496
Mason	18,097	18,096	18,097	18,097	18,097	18,097
McCulloch	9,449	9,530	9,645	9,708	9,665	9,764
Menard	4,650	4,647	4,646	4,646	4,646	4,646
Midland	58,331	58,133	45,989	41,081	40,880	40,660
Mitchell	7,882	7,872	7,858	7,838	7,821	7,793
Pecos	91,772	91,792	91,801	91,800	91,796	91,782
Reagan	28,950	28,950	28,950	28,950	28,950	28,950
Reeves	95,847	96,092	96,282	96,427	96,580	96,716
Runnels	4,953	4,948	5,102	5,090	4,701	4,732
Schleicher	4,921	4,910	4,903	4,898	4,894	4,897
Scurry	11,139	11,019	11,697	11,538	11,451	11,324
Sterling	2,187	2,225	2,240	2,244	2,236	2,247
Sutton	4,884	4,879	4,879	4,874	4,873	4,872
Tom Green	74,429	74,207	74,041	73,822	73,449	73,226
Upton	10,543	10,547	10,549	10,551	10,552	10,554
Ward	16,950	16,283	16,081	15,924	15,759	15,609
Winkler	16,768	16,768	16,768	16,768	16,768	16,768
Total	*641,304*	*637,069*	*637,176*	*632,865*	*632,219*	*631,531*

a. Currently available supply reflects the most limiting factor affecting water availability to users in the region. These limitations include firm yield of reservoirs, well field capacity, aquifer characteristics, water quality, water rights, permits, contracts, regulatory restrictions, raw water delivery infrastructure and water treatment capacities

Figure 3.4-1
Supplies Currently Available to Water User Groups by Type of Use



Historical water use from TWDB provides the basis for livestock water availability. Surface water supplies for livestock in Region F come primarily from private stock ponds, most of which are exempt under §11.142 of the Texas Water Code and do not require a water right. In addition, a significant portion of the mining demand in Brown and Crane Counties appears to be based on recirculated surface water from exempt sources. Therefore, a supply to meet the demand is assumed to come from exempt sources to prevent an unwarranted shortage.

3.5 Currently Available Supplies for Wholesale Water Providers

There are seven designated wholesale water providers in Region F. A wholesale water provider has wholesale water contracts for 1,000 acre-feet per year or more, or is expected to contract for 1,000 acre-feet per year or more over the planning period. Similar to the currently available supply for water user groups, the currently available supply for each wholesale water provider is limited by the ability to deliver water to end-users. These limitations include firm yield of reservoirs, well field capacity, aquifer characteristics, water quality, water rights, permits, contracts, regulatory restrictions and infrastructure. A summary of currently available supplies for each wholesale water provider is included in Table 3.5-1 and Appendix 3B. Brief descriptions of the supply sources are presented below.

Table 3.5-1
Currently Available Supplies for Wholesale Water Providers
(Values in Acre-Feet per Year)

Water Provider	Source	2010	2020	2030	2040	2050	2060
BCWID	Lake Brownwood [a]	29,712	29,712	29,712	29,712	29,712	29,712
CRMWD	Lake Ivie [b]	66,350	65,000	63,650	62,300	60,950	59,600
	Spence Reservoir [b]	560	560	560	560	560	560
	Thomas Reservoir [b]	0	0	0	0	0	0
	Ward Co. Well Field [c]	5,200	0	0	0	0	0
	Martin Co. Well Field	1,035	1,035	1,035	1,035	1,035	1,035
	Ector Co. Well Field	440	440	440	440	440	440
	Scurry Co. Well Field	900	900	900	900	900	900
Great Plains Water System	Andrews and Gaines Counties Well Fields [d]	5,220	5,220	5,220	5,220	5,220	5,220
City of Odessa	CRMWD System [b]	13,366	13,098	20,632	20,613	21,015	20,894
	Ector Co. Well Field (CRMWD)	440	440	440	440	440	440
	Ward Co. Well Field (CRMWD)	4,800	0	0	0	0	0
	Direct Reuse	3,000	3,150	3,300	3,450	3,600	3,750
UCRA	O.C. Fisher Reservoir [b]	0	0	0	0	0	0
	Mountain Creek Reservoir [b]	0	0	0	0	0	0
City of San Angelo	Twin Buttes/ Nasworthy [b]	0	0	0	0	0	0
	O.C. Fisher Reservoir [b]	0	0	0	0	0	0
	Spence Reservoir [e]	0	0	0	0	0	0
	Lake Ivie [f]	10,974	10,751	10,528	10,304	10,081	9,858
	Concho River	642	642	642	642	642	642
	Direct Reuse - Irrigation	8,500	8,500	8,500	8,500	8,500	8,500

Table 3.5-1 (Continued)

Water Provider	Source	2010	2020	2030	2040	2050	2060
University Lands	CRMWD Ward Co Well Field [c]	5,200	0	0	0	0	0
	Midland Paul Davis Well Field [g]	4,722	4,722	4,722	0	0	0
	City of Andrews Well Field [h]	671	708	730	0	0	0
Total Wholesale Providers		*161,732*	*144,878*	*151,011*	*144,116*	*143,095*	*141,551*

a Yield of Lake Brownwood limited by water right.
b Safe yield from the Colorado WAM. See subordination strategy for actual supply used in planning.
c Contract between CRMWD and University Lands expires in 2019.
d Region F supplies only.
e Supplies from Spence Reservoir currently not available to the City of San Angelo pending rehabilitation of Spence pipeline.
f For planning purposes supplies limited to 16.54 percent of the safe yield of Ivie Reservoir.
g Contract between University Lands and the City of Midland expires in 2035. Current supplies estimated at 4,722 acre-feet per year.
h Contract between University Lands and the City of Andrews expires in 2033. Current supplies estimated at 20% of the city's demands.

Colorado River Municipal Water District (CRMWD). CRMWD supplies raw water from Lake J.B. Thomas, E.V. Spence Reservoir, and O.H. Ivie Reservoir, and well fields in Ward, Martin, Scurry and Ector Counties. Water for oil and gas production, which is classified as a mining use, is supplied from several chloride control projects. CRMWD owns and operates more than 600 miles of 18-inch to 60-inch water transmission lines to provide water to its member cities and customers.[14]

Brown County Water Improvement District Number One (BCWID). BCWID owns and operates Lake Brownwood, as well as raw water transmission lines that supply the District's water treatment facilities, irrigation customers and the City of Early. BCWID operates two water treatment facilities in the City of Brownwood which together have a combined capacity of 16 mgd.[15] Other customers divert water directly from the lake.

Upper Colorado River Authority (UCRA). The UCRA owns water rights in O.C. Fisher Reservoir in Tom Green County and Mountain Creek Lake in Coke County. O.C. Fisher supplies are contracted to the Cities of San Angelo and Miles, and Mountain Creek Lake supplies are contracted to the City of Robert Lee.

Great Plains Water Supply System, Ltd. The Great Plains Water Supply System (Great Plains) provides water to customers in Region F from the Ogallala Aquifer in Andrews County in Region F and Gaines County in Region O. Great Plains owns an extensive pipeline system that has historically provided water primarily for oil and gas operations, although a small amount of municipal water has been supplied to rural Ector County as well. The provider's largest customer is a steam electric operation in Ector County.

City of Odessa. The City of Odessa is a CRMWD member city. As a member city, all of Odessa's water supplies will be provided from CRMWD sources. The City of Odessa sells treated water to the Ector County Utility District, and treated effluent to industrial users and municipal irrigation users.

City of San Angelo. The City of San Angelo's sources of supply are Lake O.C. Fisher (purchased from Upper Colorado River Authority), Twin Buttes Reservoir, Lake Nasworthy, local surface water rights, O.H. Ivie Reservoir (purchased from CRMWD), and E.V. Spence Reservoir (purchased from CRMWD). The city also owns several run-of-the river water rights on the Concho River. San Angelo owns and operates a raw water transmission line from Spence Reservoir (currently in need of rehabilitation) and a 5-mile water transmission line from a pump station on the CRMWD Ivie pipeline just north of the city. The city also owns an undeveloped well field in McCulloch County. San Angelo supplies raw water to the power plant located on Lake Nasworthy. The city provides treated water to the City of Miles and to rural customers in Tom Green County. Treated wastewater from the city is currently used for irrigation.

University Lands. University Lands manages properties belonging to the University of Texas System in West Texas. University Lands does not directly supply water; CRMWD, the City of Midland and the City of Andrews have developed water well fields on property managed by University Lands. The well fields produce water from the Pecos Valley aquifer in Ward County and the Ogallala aquifer in Martin and Andrews Counties.

3.6 Impact of Drought on Region F

During the past century, recurring drought has been a natural part of Texas' varying climate, especially in the arid and semi-arid regions of the state. An old saying about droughts in west Texas is that "droughts are continual with short intermittent periods of rainfall."[16] Droughts, due to their complex nature, are difficult to define and understand, especially in a context that is useful for communities that must plan and prepare for drought. Drought directly impacts the availability of ground and surface water supplies for agricultural, industrial, municipal, recreational, and designated aquatic life uses. The location, duration, and severity of drought determine the extent to which the natural environment, human activities, and economic factors are impacted.

Geography, geology and climate vary significantly from east to west in Region F. Ecoregions within Region F vary from the Edwards Plateau to the east, Central Great and Western High Plains in the central and northern portions of the region, and Chihuahuan Deserts to the west. Annual rainfall in Region F ranges from an average of more than 28 inches in the east to slightly more than 10 inches in the west. Likewise, the annual gross reservoir evaporation rate ranges from 60 inches in the east to approximately 75 inches in the western portion of the region. Extended periods of drought are common in the region, with severe to extreme droughts having occurred in the 1950s, 1990s, and early 2000s.

3.6.1 Drought Conditions

Numerous definitions of drought have been developed to describe drought conditions based on various factors and potential consequences. In the simplest of terms, drought can be defined as "a prolonged period of below-normal rainfall." However, the *State Drought Preparedness Plan*[17] provides more specific and detailed definitions:

- *Meteorological Drought.* A period of substantially diminished precipitation duration and/or intensity that persists long enough to produce a significant hydrologic imbalance.
- *Agricultural Drought.* Inadequate precipitation and/or soil moisture to sustain crop or forage production systems. The water deficit results in serious damage and economic loss to plant and animal agriculture. Agricultural drought usually begins after meteorological drought but before hydrological drought and can also affect livestock and other agricultural operations.
- *Hydrological Drought.* Refers to deficiencies in surface and subsurface water supplies. It is measured as streamflow, and as lake, reservoir, and groundwater levels. There is usually a lack of rain or snow and less measurable water in streams, lakes, and reservoirs, making hydrological measurements not the earliest indicators of drought.
- *Socioeconomic Drought.* Occurs when physical water shortages start to affect the health, well-being, and quality of life of the people, or when the drought starts to affect the supply and demand of an economic product.

These definitions are not mutually exclusive, and provide valuable insight into the complexity of droughts and their impacts. They also help to identify factors to be considered in the development of appropriate and effective drought preparation and contingency measures.

Droughts have often been described as "insidious by nature." This is mainly due to several factors:

- Droughts cannot be accurately characterized by well-defined beginning or end points.
- Severity of drought-related impacts is dependent on antecedent conditions, as well as ambient conditions such as temperature, wind, and cloud cover.
- Droughts, depending on their severity, may have significant impacts on human activities; and human activities during periods of drought may exacerbate the drought conditions through increased water usage and demand.

Furthermore, the impact of a drought may extend well past the time when normal or above-normal precipitation returns.

Various indices have been developed in an attempt to quantify drought severity for assessment and comparative purposes. One numerical measure of drought severity that is frequently used by many federal and state government agencies is the Palmer Drought Severity Index (PDSI). It is an estimate of soil moisture that is calculated based on precipitation and temperature. The PDSI ranges from +6.0 for the wettest conditions to –6.0 for the driest conditions. A PDSI of –3.99 to –3.0 is termed "severe drought" and a PDSI of –6.0 to –4.0 is described as "extreme drought". The Texas Water Development Board (TWDB) uses the PDSI to monitor wet/dry conditions in Texas. In 2000, all counties of Region F experienced at least some periods of severe or extreme drought. However, the PDSI is an indicator of an agricultural drought only. It has little relationship with a hydrological drought.

3.6.2 Drought of Record and Recent Droughts in Region F

In general, the drought of record is defined as the worst drought to occur in a region during the entire period of meteorological record keeping. For most of Texas, the drought of record occurred from 1950 to 1957. During the 1950s drought, many wells, springs, streams, and rivers went dry and some cities had to rely on water trucked in from other areas to meet drinking water demands. By the end of 1956, 244 of the 254 Texas counties were classified as disaster areas due to the drought, including all of the counties in Region F.

During the past decade, most regions of Texas have experienced droughts resulting in diminished water supplies for agricultural and municipal use, decreased flows in streams and reservoirs, and significant economic loss. Droughts of moderate to extreme conditions occurred in 1996, 1998, and 2000 in various regions of the state, including Region F. The worst year during the recent drought was 2000, when most Region F counties experienced extreme drought for the entire growing season.

Meteorological Drought in Region F

Meteorological drought is characterized by below-normal precipitation for an extended period of time. Figures 3.6-1 and 3.6-3 show the historical annual precipitation totals for Midland and San Angelo for the period from 1951 to 2007. As is typical in Texas, the average annual precipitation in Region F increases from west to east. Midland is further west, and averages about 14 inches a year over the period shown. San Angelo averages about 19 inches of precipitation per year. The patterns of wet and dry years have some general correlation, but can vary significantly. Figures 3.6-2 and 3.6-4 show the rainfall variation from the annual average for the two locations. For both the 1950’s drought and the recent drought, annual rainfall is significantly below average for an extended number of years. The current drought appears more severe than the 1950’s drought. Ten of the last fifteen years show rainfall less than the historic average. This occurred at no other time in the period of record.

Hydrological Drought in Region F

Available water supplies for municipal and agricultural use have been a major concern in the region since the end of the 19th century. During the past 80 years, seventeen major reservoirs have been constructed for water storage, recreation and flood control throughout Region F. Table 3.2-1 summarizes pertinent data for these reservoirs, including conservation storage capacities. The locations of these reservoirs are shown on Figure 3.2-1.

Figure 3.6-1
Annual Precipitation at Midland, Texas from 1951 to 2007

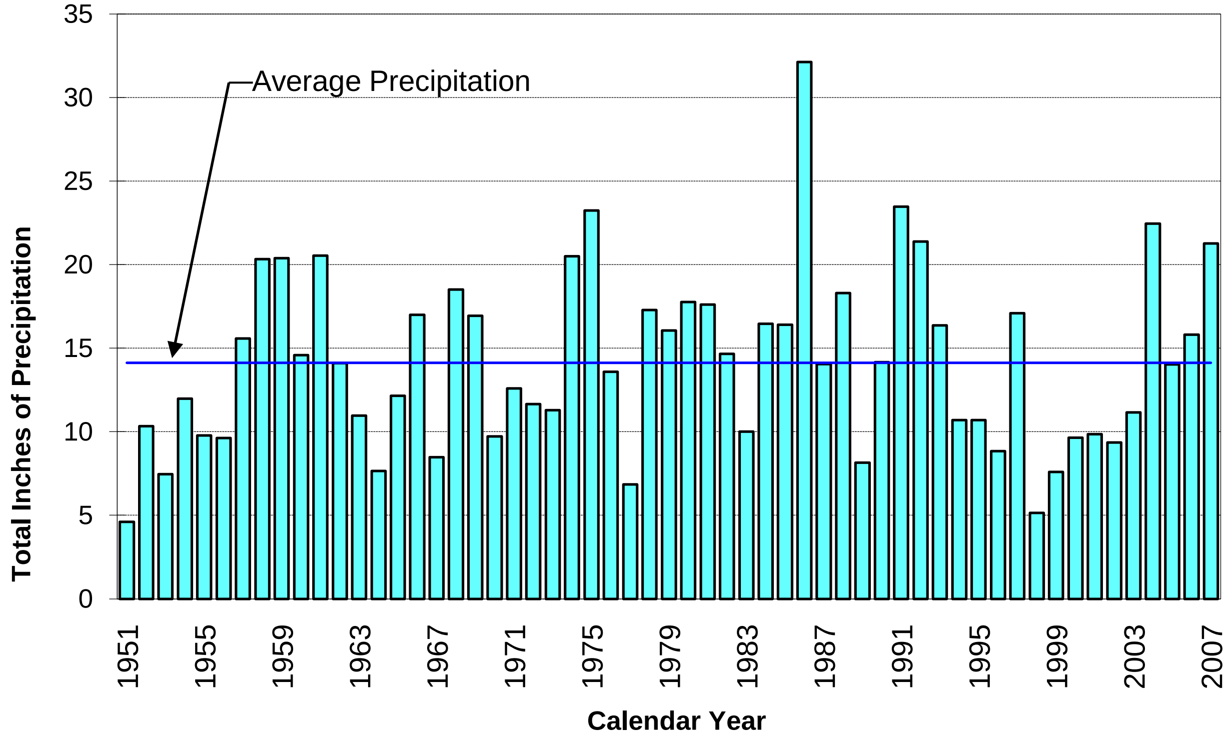
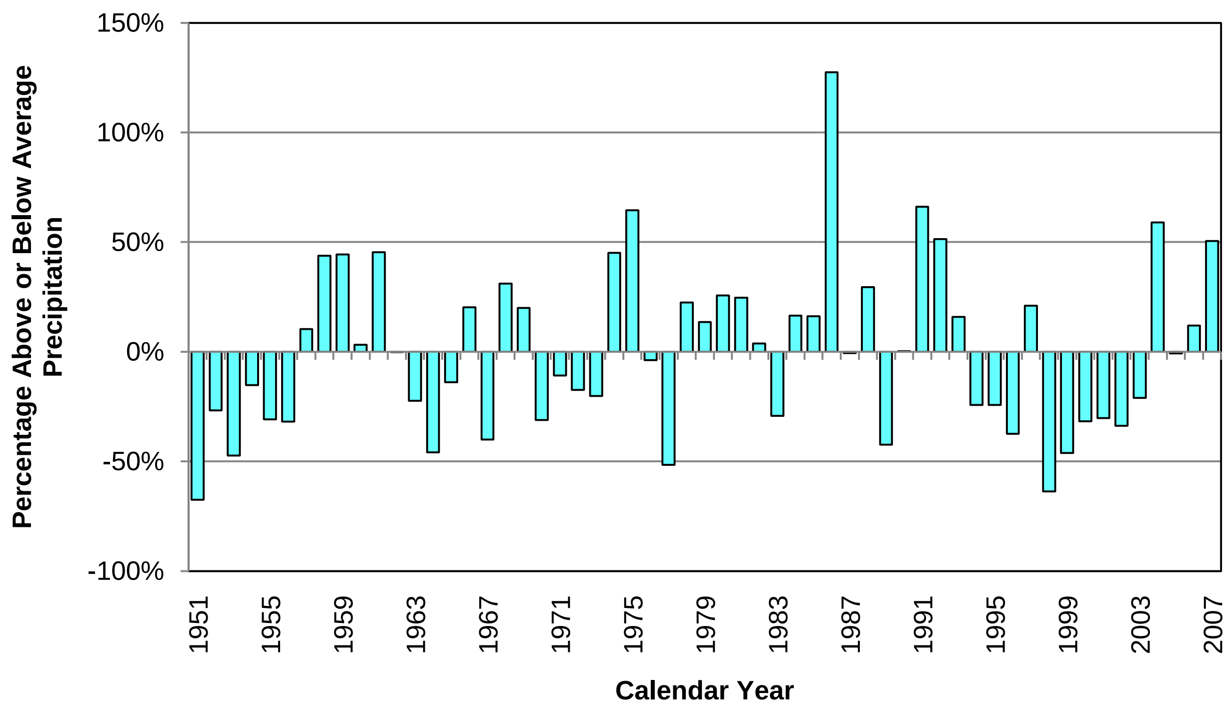


Figure 3.6-2
Precipitation Variation from Average at Midland, Texas from 1951 to 2007



Data for Figures 3.6-1 and 3.6-2 are from the National Climate Data Center, Station ID #5890

Figure 3.6-3
Annual Precipitation at San Angelo, Texas from 1951 to 2007

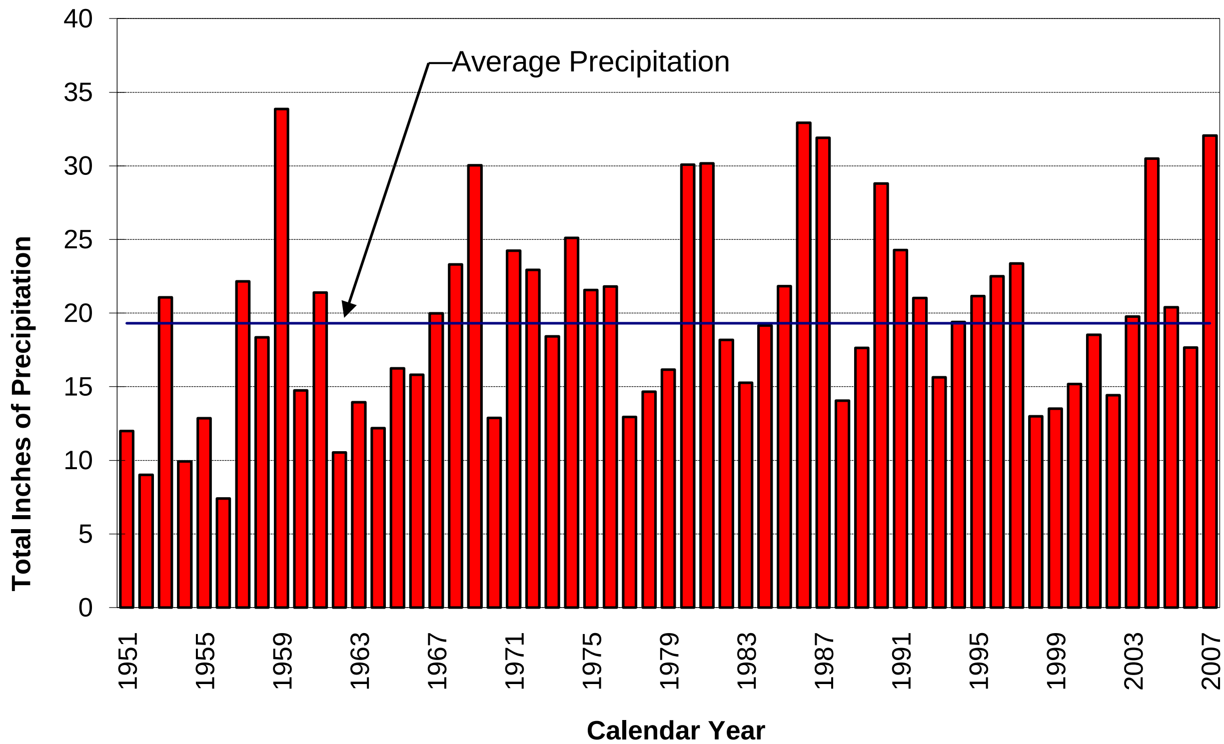
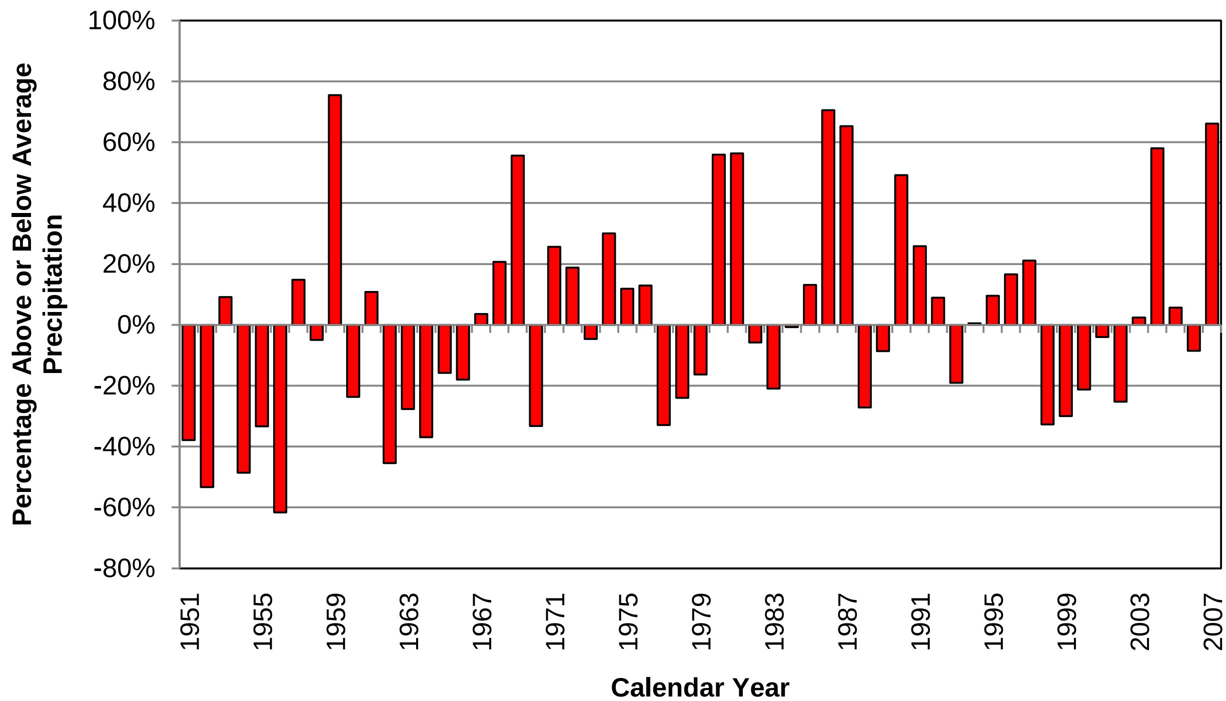


Figure 3.6-4
Precipitation Variation from Average at San Angelo, Texas from 1951 to 2007



Data for Figures 3.6-3 and 3.6-4 are from the National Climate Data Center, Station ID #5890

Frequent and extended hydrological droughts have occurred in almost every decade since 1940. The most severe droughts occurred in the 1950s, 1960s, 1980s and the late 1990s through early 2000. The most recent drought is quite possibly the worst hydrologic drought experienced in that period.

According to TWDB records, reservoir levels in Region F have generally decreased over the past ten to fifteen years. For some reservoirs the recent above average rainfall has had little impact to reservoir storage. A summary of major reservoirs in the region follows:

- O.H. Ivie Reservoir experienced a sharp decrease in storage in 1996, recovered in 1997 and then experienced a steady decline until hitting a low of about 30% capacity in 2004. The reservoir began to recover late in 2004 with additional rainfall in the watershed. The highest storage in 2005 was about 55% with the level declining to about 40% by the beginning of 2007. The reservoir recovered quickly in 2007 but in May 2009 was only 50% full.
- Levels at E.V. Spence Reservoir began a general decline in 1992 and hit a low of less than 10% capacity in 2002. By January 2005, the reservoir levels rose to 18% of capacity. However, by May 2009 the reservoir level reached its lowest point of 8.6% capacity.
- Levels at O.C. Fisher and Twin Buttes Reservoirs also declined in the past 10 years, both hitting critically low levels. In January 2005, levels at O.C. Fisher and Twin Buttes were only at 6% of storage capacity. By the end of 2005 the level in O.C. Fisher had increased to 15% but since then the storage has steadily been declining. From the January 2005 low, the Twin Buttes Reservoir had increased to 25% by May 2009.
- Lake Brownwood, in the northeastern corner of Region F, suffered two to three years of declining water levels in the late 1990's. It hit a low of about 50% in 2000, but recovered by late 2002 to levels above 90%. In 2005 the level started to decline and reached a low of 60% by 2007. By May 2009 the reservoir level had increased to 74% capacity.
- Red Bluff Reservoir, on the Pecos River at the western edge of Region F, dropped from a high of about 50% capacity in 1992 to a low of about 10% in 2001, but had recovered to a 39% level by 2005. In May 2009 the reservoir had declined to 25%.

These data indicate the degree of drought in Region F during the past 10 to 15 years and the percent recovery in five of the region's major reservoirs. By the end of the 1990's, many Region F reservoirs were at their lowest recorded levels. However, for the same period, the TWDB reported the statewide reservoir storage level at approximately 90 percent of capacity. The reported statewide reservoir storage level in the late 1990's indicates that many reservoirs in other regions of the state were at or near 100 percent of capacity and drought conditions were not occurring in these regions.

Agricultural Drought in Region F

Because a substantial portion of water used in Region F is for agriculture, a drought can result in serious economic losses to farmers and ranchers. During the 1950's drought, many Texas ranchers and farmers incurred increased levels of debt or were forced to abandon their operations. Some ranchers singed the spines off of prickly pear cactus so their cattle would have something to eat. Ranch debt reached a high of $3 billion and 143 rural counties statewide experienced a population decline during the drought.[18] In Region F, the population declined in 18 of the region's 32 counties between 1950 and 1960.

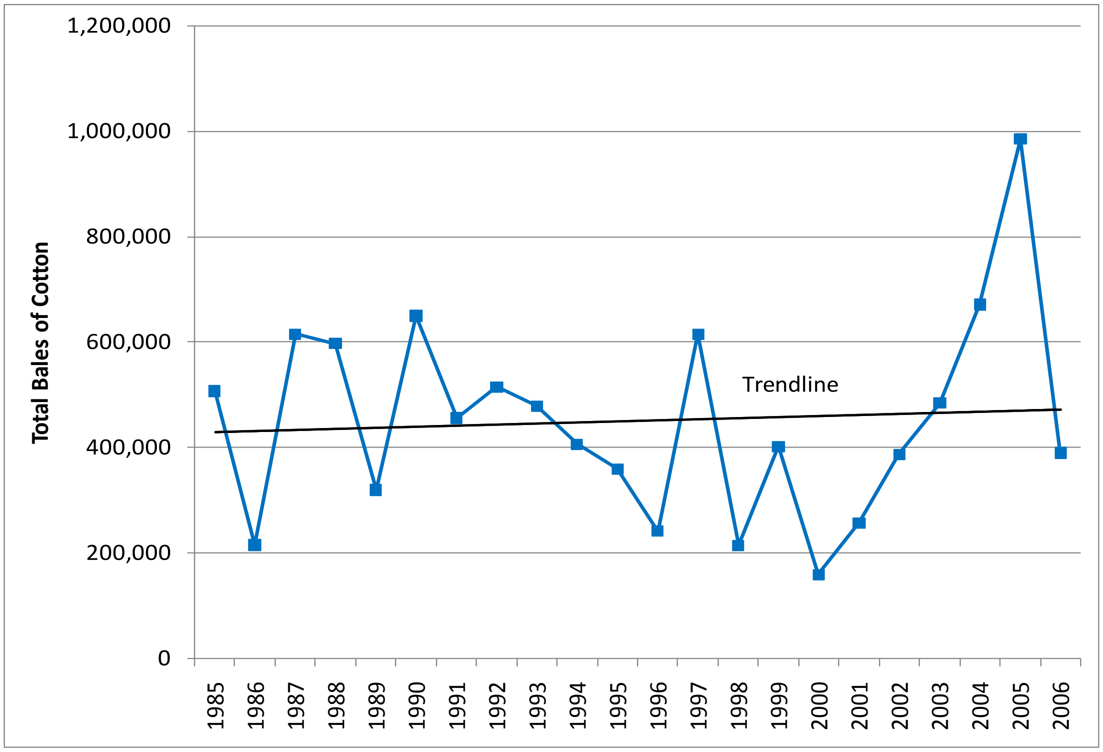
Agricultural drought can occur even when calendar-year precipitation totals are not abnormally low, especially if the rainfall is inadequate during the growing season. Researchers at the Texas A&M University Sonora Experiment Station report that the precipitation during the growing season averaged only about 7 inches per year during the 1990's, compared to a long-term average of 15 inches. Researchers also calculated the PDSI for the Sonora station and noted that the period from August 1999 through September 2000 had the lowest continuous PDSI values for any 12-month or greater time period since the 1950's drought.

Annual production of agricultural crops can be used as an indicator of impacts due to droughts. Various factors, such as market demand and production costs, can also play a significant role with respect to the number of acres planted and harvested for specific crops. However, a decline in crop production over a prolonged period may indicate an impact of drought.

In general, cotton is a good indicator of agricultural drought impacts in Region F because it is the major agricultural crop in the region and it can be grown with or without irrigation. Between 1951 and 1958, the number of acres planted in cotton statewide declined by 57 percent and the number of acres harvested declined by 55 percent. More recently crop productions have fluctuated considerably, with a low of less than 200,000 bales of cotton produced in 2000 to a high of nearly 1 million bales in 2005. Figure 3.6-5 shows a graph of annual Region F cotton production from 1985 to 2006.

During this period, winter wheat crops in Region F were not as seriously impacted by the drought, because the precipitation deficits were more pronounced during the warmer months. Livestock production was also impacted by the drought. During the hot, dry summer of 2000,

Figure 3.6-5
Annual Cotton Production in Region F from 1985 to 2006



large grass die-offs occurred in parts of west Texas. The drought was severe enough to even cause some live oak trees to die.[19]

Socio-Economic Drought in Region F

As presented previously, drought can have a significant and prolonged impact on the economy and social fabric within a region. Region F is not an exception to this fact. The drought of record in the 1950's produced drastic decreases in the annual production values for agriculture and livestock. At the same time, census data indicate that thousands of rural residents in Region F migrated from rural county areas to the main metropolitan centers in the region. This type of migration can have a significant impact on the demographics, health, and social needs in both rural and municipal settings.

Much of the economic activity in Region F has historically been associated with the oil and gas industry. In the past few years that industry has experienced volatile ups and downs with changing markets. Cities in Region F have been actively seeking new industries to balance the uncertainty in the oil and gas sector, but the recent drought and its impacts on water supplies has hindered that process. Rural communities need new business and industries to replace the agricultural sector and population losses. The Governor's Office, Texas Department of Agriculture, and the U.S. Department of Agriculture are trying to promote and assist rural areas. These efforts are hindered due to availability of water and the cost of securing and producing water that meets water quality standards.

3.6.3 Potential Environmental Impacts of Drought in Region F

Increasing water demand for municipal and agricultural uses, the encroachment of invasive brush (e.g., mesquite, Ashe juniper, and salt cedar), and extended drought conditions during the 1990's, have resulted in a net decrease in water supplies available to sustain designated aquatic life uses in areas of the region. Combined with reservoir construction on the Concho and Colorado Rivers, the quantity of water available to maintain instream flows has declined. However, the Texas Parks and Wildlife Department (TPWD) and U.S. Fish and Wildlife Service (USFWS) are collaborating to determine instream flow levels necessary to maintain designated aquatic life uses.

In December 2004, the USFWS issued a revised Biological Opinion[20] concerning the status of threatened aquatic species. The Biological Opinion changes the magnitude of required releases from the E.V. Spence and O.H. Ivie Reservoirs under certain conditions. These changes will result in a decrease in the volume of mandatory releases from the two reservoirs, especially during periods of extended drought and low reservoir levels.

These reduced flows and the elimination of mandatory water releases during periods of no inflow to the reservoirs will provide relief to the water suppliers and their users, especially during periods of low rainfall or extended drought. In the Biological Opinion, USFWS has determined that these reduced flows are not likely to jeopardize the continued existence of threatened species, nor likely to destroy or adversely impact designated critical habitat for the species.

3.6.4 Impacts of Recent Drought on Water Supply

The Colorado WAM uses naturalized flows from 1940 through 1998. As a result, the WAM does not include most of a major drought in Region F. Indications are that for many reservoirs the recent drought may be more severe than previous droughts, potentially lowering the available supply from the reservoirs.

To assess the potential impact of the recent drought on water supplies in Region F, historical gauge flows at key locations in Region F were developed covering the period from 1999 through 2004. These flows were incorporated into a special simplified version of the Colorado WAM (MiniWAM). The MiniWAM includes only major reservoirs in Region F and the City of Junction's run-of-the-river right. Flows from 1940 through 1998 are based on the modeled flows available to these water rights. Impacts of the new drought on reservoir yields in Region F using WAM Run 3 (no subordination) are negligible due to the low yields of the reservoirs. Impacts are more readily seen with the subordination strategy, which is discussed in Section 4.2.3. With subordination, the analysis showed that most of the Colorado Basin Reservoirs in Region F have experienced new drought-of-record conditions as a result of the current drought. More detailed information on the impact of drought may be found in Appendix 4E in the *2006 Region F Water Plan*.

3.7 List of References

[1] Telephone conversation with Alan Zeman, Dr. Michael McCulloch and Mr. Bryant, March 22, 2010.

[2] Texas Water Development Board: General Guidelines for Regional Water Plan Development, September 2008.

[3] R.J. Brandes Company et al.: Water Availability Modeling for the Colorado/Brazos-Colorado Basin, prepared for the Texas Natural Resources Conservation Commission, December 2001.

[4] Krishna, Hari J., Introduction to Desalination Technologies, included in Chapter 2 of The Future of Desalination in Texas, Volume 2: Technical Papers, Case Studies, and Desalination Technology Resources, TWDB, available at http://www.twdb.state.tx.us/desalination/desal/Volume2Main.asp and accessed on 2/28/2005.

[5] Viessman, Warren, Jr. and Hammer, Mark J., Water Supply and Pollution Control, Fourth Edition, Harper & Row, New York, 1985, pg. 230.

[6] TWDB. Report 366, *Please Pass the Salt: Using Oil Fields for the Disposal of Concentrate from Desalination,* April 2006.

[7] TWDB Desalination Database, available at http://www.twdb.state.tx.us/iwtdesaldb/dbStart.aspx

[8] Mickley, Michael C., Membrane Concentrate Disposal: Practices and Regulations, report prepared for the U.S. Department of Interior, Bureau of Reclamation, September 2001.

[9] Phone conversation with Cindy Hollander, City of Fort Stockton, 2/22/05.

[10] Phone conversation with Derrick Turner of Jacoby Martin, design engineer for the Brady and MDWSC treatment plants, January 2005.

[11] Phone conversation with Rufus Beam, City of Brady, 1/21/2005.

[12] Krishna, Hari J., "Water Reuse in Texas", TWDB, available at http://www.twdb.state.tx.us/assistance/conservation/Municipal/Reuse/ReuseArticle.asp and accessed 2/21/05.

[13] TWDB reuse database, available at http://www.twdb.state.tx.us/assistance/conservation/Municipal/Reuse/Reuse.asp and accessed 2/23/05.

[14] Colorado River Municipal Water District: *District Operations.* Available online at www.crmwd.org/op.htm.

[15] Brown County Water Improvement District No. 1: *About the Brown County WID #1*. Available online at http://www.bcwid.org/About/Facilities/Treatment.cfm.

[16] Word, Jim, quoted by Hamilton, Cliff, in "Is the drought over? Experts won't know until late summer", Odessa American, January 12, 2005.

[17] Drought Preparedness Council: *State Drought Preparedness Plan*, January 2001.

[18] Votteler, Todd H., Ph.D., "Texas Water", Texas Water Foundation, article accessed at http://www.texaswater.org/water/drought/drought2.htm, March 2005.

[19] Personal communication from Butch Taylor, Sonora Experiment Station, Texas A&M Agricultural Extension Service, Feb. 11, 2005.

[20] United States Department of the Interior Fish and Wildlife Service, Biological Opinion (2-15-F-2004-0242) to U.S. Army Corps of Engineers, Fort Worth District, regarding the Concho water snake, Austin, December 3, 2004.

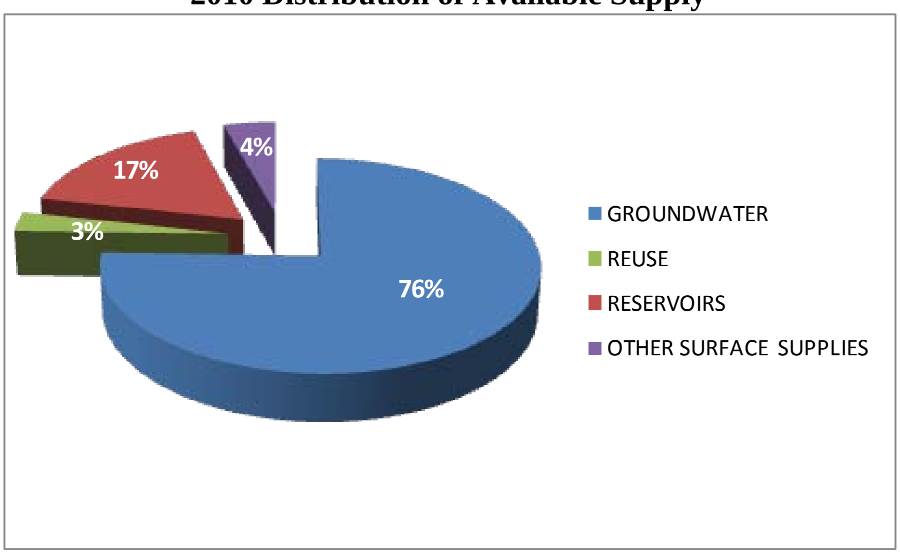
4 IDENTIFICATION, EVALUATION, AND SELECTION OF WATER MANAGEMENT STRATEGIES BASED ON NEEDS

4.1 Comparison of Current Supplies and Demand

4.1.1 Current Supply

The current supply in Region F consists of groundwater, surface water from in-region reservoirs, local supplies and wastewater reuse. There is a small amount of groundwater that comes from outside the region (Regions G and O). Based on the assessment of currently available supplies (Chapter 3), groundwater is the largest source of water in Region F, accounting for 78 percent of the total supply. Reservoirs are the second largest source of water, with 14 percent of the supply. Run-of-the-river supplies and alternative sources such as desalination and wastewater reuse provide the remainder of the region's supply. (Reservoir and run-of-the-river supplies are based on the Colorado WAM, which underestimates the amount of water available from reservoirs in Region F.) The total currently available water supply for Region F is approximately 641,000 acre-feet per year. The distribution of this supply by source type in the year 2010 is shown in Figure 4.1-1.

Figure 4.1-1
2010 Distribution of Available Supply



Surface water supplies are based on the Colorado WAM.

4.1.2 Regional Demands

Regional demands were developed by city, county and category, and are discussed in Chapter 2. In summary, the total demands for the region are projected to increase from 803,376 in 2010 to 814,991 acre-feet per year in 2060. The largest water demand category is irrigation, which accounts for about 72 percent of the total demand in the region. Municipal is the next largest water user in the Region F. Manufacturing, mining, steam electric power and livestock demands combined account for only about 10 percent of the total water demands. Over the planning period, irrigation demand is expected to decrease, while municipal, manufacturing, mining and steam electric are projected to increase. Livestock demands are projected to remain the same through 2060. The projected increases in demands are expected to occur near the larger municipalities and to a lesser extent in the rural areas.

Irrigation demands for 2010 through 2060 are higher than the historical irrigation use in the year 2006. Irrigation demands in Region F in 2006 were lower than they could have been due to reduced surface water supplies. Baseline irrigation demands are based upon full availability of surface water supplies. More information on irrigation demands may be found in Section 2.3.3.

4.1.3 Comparison of Demand to Currently Available Supplies

This comparison of supply to demand is based on the projected demands developed in Chapter 2 and the currently available supplies developed in Chapter 3. As discussed in Chapter 3, currently available supplies are based on the most restrictive of current water rights, contracts and available yields for surface water and historical use and/or groundwater availability for groundwater. There may be supplies not included in this comparison that can meet a need with changes to existing infrastructure or contractual agreements. Surface water supplies in the Colorado Basin are based on the Colorado WAM, which substantially underestimates the actual supply available to Region F.

Figure 4.1-2 compares the overall supply allocation for projected supplies and demands from 2010 through 2060. On a regional basis the demand exceeds the currently available supply by about 162,000 acre-feet per year in the year 2010, increasing to over 183,000 acre-feet per year by 2060. On a water user group basis, the sum of the shortages is about 191,000 acre-feet per year in 2010, and increases to nearly 220,000 acre-feet per year by 2060. Figures 4.1-3 through 4.1-5 compare supply and demand for the three largest water use categories: irrigation, municipal and steam-electric. Irrigation demand exceeds available supply by about 142,000 acre-feet per year in the year 2010, decreasing to 120,000 acre-feet per year by the year 2060. Municipal demand exceeds currently available supplies by over 12,000 acre-feet per year in the year 2010, increasing to nearly 40,000 acre-feet per year by 2060. Steam-electric demand is expected to exceed supply by approximately 6,500 acre-feet per year in 2010, increasing to almost 21,000 acre-feet per year by 2060.

Tables 4.1-1 to 4.1-3 compare the current available supply to demand by county, divided into use categories, for years 2010, 2030 and 2060. Based on this analysis, there are significant irrigation, municipal and steam-electric generation needs throughout the 50-year planning period. Typically the counties with the largest irrigation needs are those with large irrigation demands and limited groundwater supplies. Most of the municipal needs are the result of underestimation of available supply based on the Colorado WAM (the Colorado WAM is discussed in section 3.2). Steam-electric generation needs are largely associated with growth in demand that exceeds the available supply, although this demand category is significantly impacted by the Colorado WAM as well. Specific needs by user group are included in Appendix 4A.

4.1.4 Identified Needs for Wholesale Water Providers

Table 4.1-4 is a summary of the needs for the seven Wholesale Water Providers in Region F. Needs for CRMWD, San Angelo, Odessa and UCRA are primarily the result of using the Colorado WAM for water availability. Needs for University Lands are the result of contract expiration. More information on contracts with University Lands may be found in Section 3.5. A summary of the supply and demand comparison for each designated wholesale provider is included in Appendix 4A.

Figure 4.1-2
Comparison of Total Region F Supplies and Demands

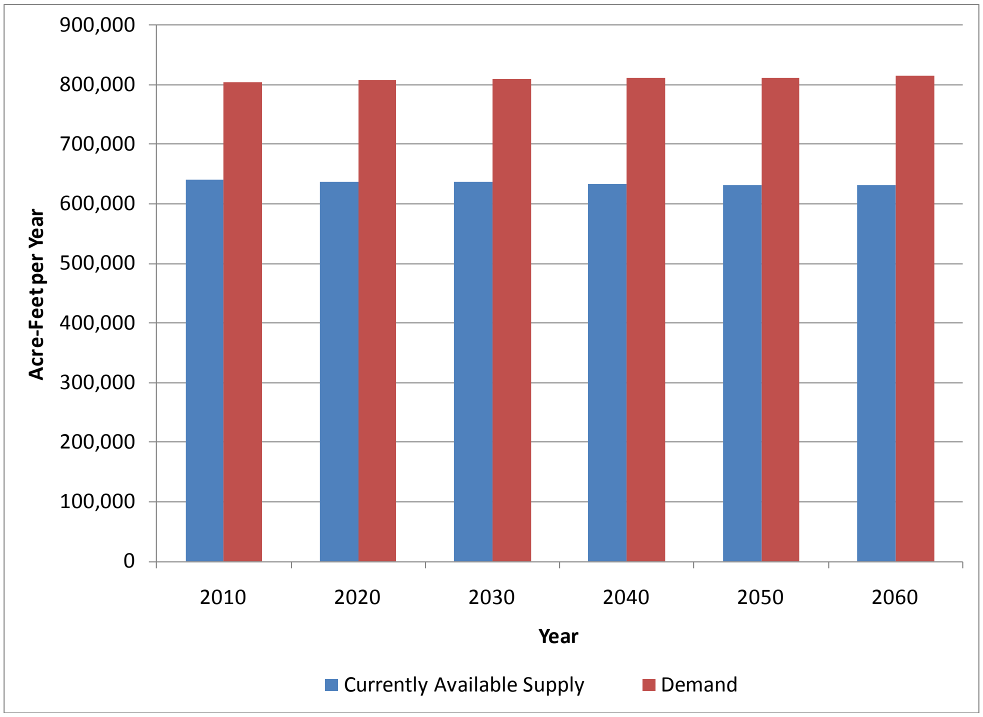
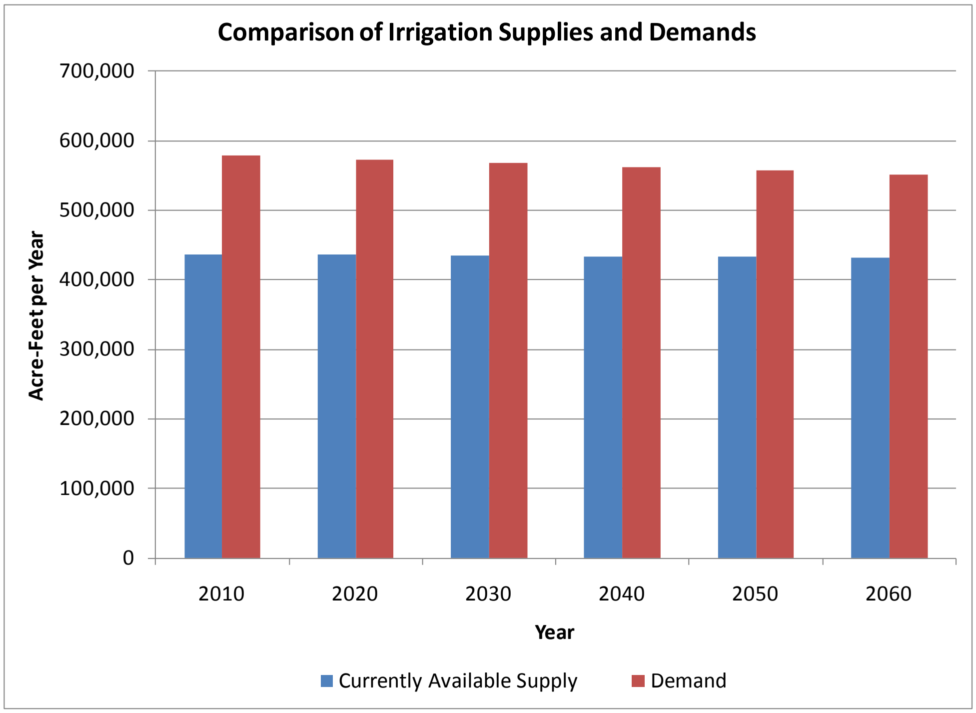


Figure 4.1-3
Comparison of Irrigation Supplies and Demands



Historical water demand data and projections are from the Texas Water Development Board.

Figure 4.1-4
Comparison of Municipal Supplies and Demands

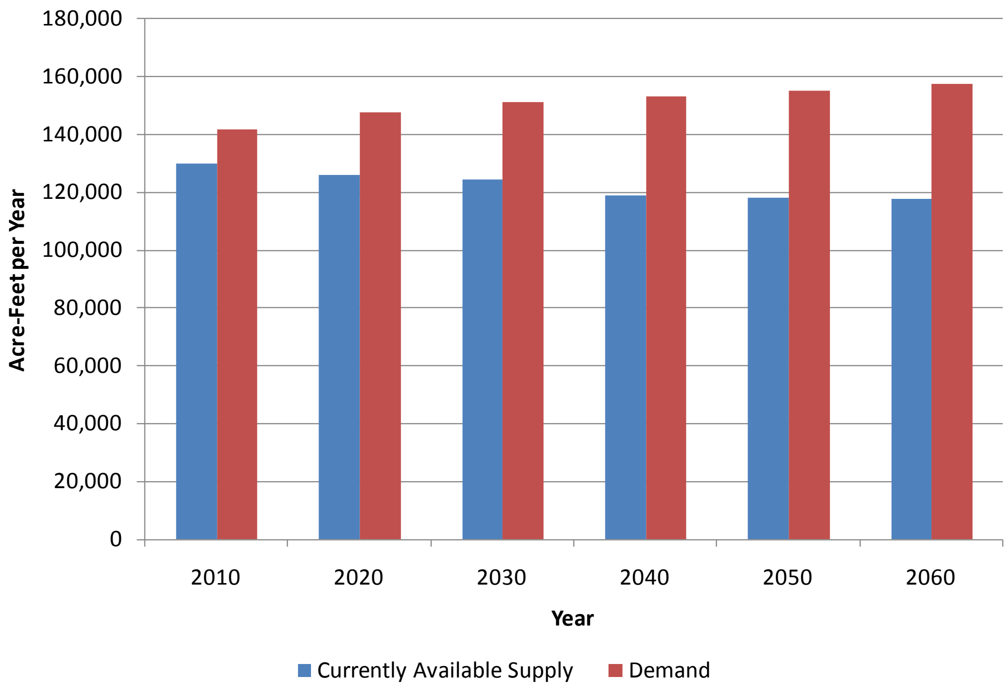
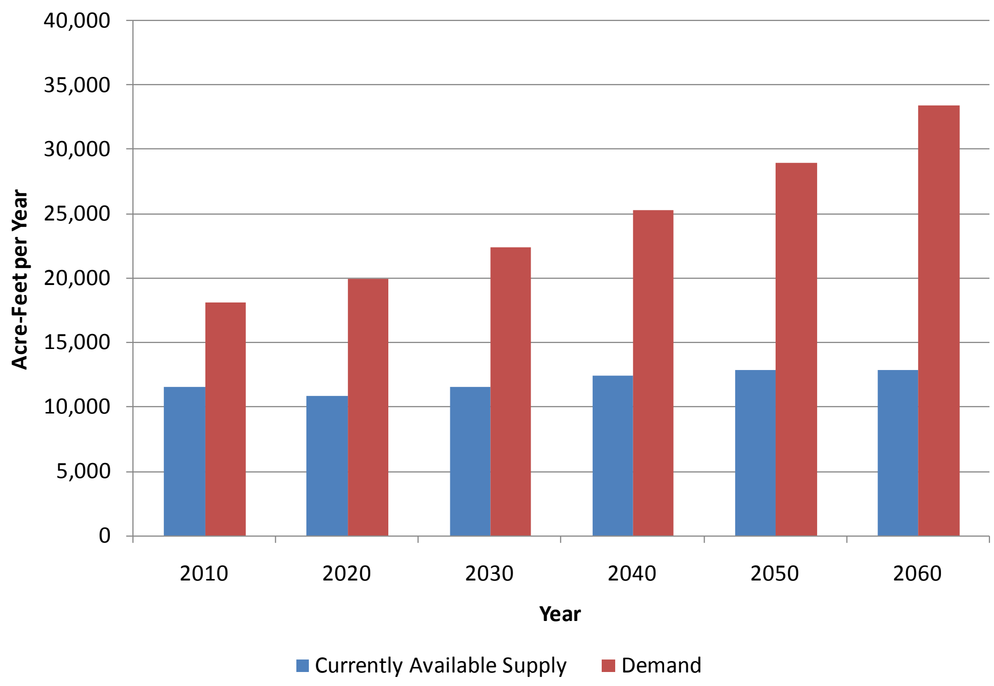


Figure 4.1-5
Comparison of Steam Electric Supplies and Demands



Historical water demand data and projections are from the Texas Water Development Board.

Table 4.1-1
Comparison of Currently Available Supply to Projected Demands by County and Category
Year 2010

County[1]	Irrigation			Manufacturing			Mining			Municipal			Steam Electric Power			Livestock			Total		
	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)
Andrews	19,733	32,608	(12,875)	0	0	0	1,965	1,908	57	3,625	3,625	0	0	0	0	438	438	0	25,761	38,579	(12,818)
Borden	843	2,690	(1,847)	0	0	0	1,014	690	324	178	175	3	0	0	0	281	281	0	2,316	3,836	(1,520)
Brown	9,307	12,313	(3,006)	577	577	0	2,487	2,487	0	7,743	7,106	637	0	0	0	1,636	1,636	0	21,750	24,119	(2,369)
Coke	573	936	(363)	0	0	0	402	488	(86)	660	771	(111)	0	310	(310)	593	593	0	2,228	3,098	(870)
Coleman	31	1,379	(1,348)	0	6	(6)	1	18	(17)	1,515	1,874	(359)	0	0	0	1,259	1,259	0	2,806	4,536	(1,730)
Concho	5,265	4,297	968	0	0	0	0	0	0	995	873	122	0	0	0	775	775	0	7,035	5,945	1,090
Crane	337	337	0	0	0	0	2,221	2,221	0	1,256	1,256	0	0	0	0	155	155	0	3,969	3,969	0
Crockett	535	525	10	0	0	0	402	402	0	2,546	1,707	839	1,500	973	527	997	997	0	5,980	4,604	1,376
Ector	5,533	5,533	0	2,393	2,759	(366)	10,074	9,888	186	24,616	28,708	(4,092)	5,156	6,375	(1,219)	293	293	0	48,065	53,556	(5,491)
Glasscock	24,488	52,272	(27,784)	0	0	0	5	5	0	181	181	0	0	0	0	232	232	0	24,906	52,690	(27,784)
Howard	4,862	4,799	63	1,471	1,648	(177)	1,383	1,783	(400)	5,958	7,308	(1,350)	0	0	0	366	366	0	14,040	15,904	(1,864)
Irion	1,501	2,803	(1,302)	0	0	0	122	122	0	248	238	10	0	0	0	460	460	0	2,331	3,623	(1,292)
Kimble	1,771	985	786	3	702	(699)	104	71	33	203	1,148	(945)	0	0	0	668	668	0	2,749	3,574	(825)
Loving	583	581	2	0	0	0	3	2	1	11	11	0	0	0	0	70	70	0	667	664	3
Martin	13,536	14,324	(788)	39	39	0	705	674	31	396	788	(392)	0	0	0	273	273	0	14,949	16,098	(1,149)
Mason	16,099	10,079	6,020	0	0	0	6	6	0	956	932	24	0	0	0	1,036	1,036	0	18,097	12,053	6,044
McCulloch	6,103	2,824	3,279	844	844	0	154	154	0	1,321	2,252	(931)	0	0	0	1,027	1,027	0	9,449	7,101	2,348
Menard	3,620	6,061	(2,441)	0	0	0	0	0	0	388	458	(70)	0	0	0	642	642	0	4,650	7,161	(2,511)
Midland	25,260	41,493	(16,233)	164	164	0	677	677	0	31,326	32,568	(1,242)	0	0	0	904	904	0	58,331	75,806	(17,475)
Mitchell	5,564	5,534	30	0	0	0	141	115	26	1,728	1,703	25	0	5,023	(5,023)	449	449	0	7,882	12,824	(4,942)
Pecos	82,583	79,681	2,902	3	2	1	286	159	127	7,660	4,816	2,844	0	0	0	1,240	1,239	1	91,772	85,897	5,875
Reagan	25,600	36,597	(10,997)	0	0	0	2,036	2,036	0	1,035	1,035	0	0	0	0	279	272	7	28,950	39,940	(10,990)
Reeves	88,816	103,069	(14,253)	720	720	0	182	182	0	3,846	3,834	12	0	0	0	2,283	2,283	0	95,847	110,088	(14,241)
Runnels	2,973	4,331	(1,358)	0	63	(63)	44	44	0	406	2,091	(1,685)	0	0	0	1,530	1,530	0	4,953	8,059	(3,106)
Schleicher	3,132	2,108	1,024	0	0	0	150	125	25	852	723	129	0	0	0	787	787	0	4,921	3,743	1,178
Scurry	3,529	2,815	714	0	0	0	3,880	3,107	773	3,101	3,666	(565)	0	0	0	629	629	0	11,139	10,217	922
Sterling	745	648	97	0	0	0	590	590	0	349	349	0	0	0	0	503	503	0	2,187	2,090	97
Sutton	1,812	1,811	1	0	0	0	80	80	0	2,196	1,472	724	0	0	0	796	796	0	4,884	4,159	725
Tom Green	57,531	104,621	(47,090)	0	2,226	(2,226)	150	73	77	14,770	23,494	(8,724)	0	543	(543)	1,978	1,978	0	74,429	132,935	(58,506)
Upton	6,119	16,759	(10,640)	0	0	0	2,662	2,662	0	1,550	942	608	0	0	0	212	212	0	10,543	20,575	(10,032)
Ward	8,266	13,793	(5,527)	7	7	0	153	153	0	3,484	3,484	0	4,914	4,914	0	126	126	0	16,950	22,477	(5,527)
Winkler	10,000	10,000	0	0	0	0	1,878	928	950	4,721	2,377	2,344	0	0	0	169	151	18	16,768	13,456	3,312
Total	436,650	578,606	(141,956)	6,221	9,757	(3,536)	33,957	31,850	2,107	129,820	141,965	(12,145)	11,570	18,138	(6,568)	23,086	23,060	26	641,304	803,376	(162,072)

1. County shown is the county where the supply is used. The actual supply may come from a different county.

2. Surplus and need are calculated on a county basis. The surplus and needs for individual water users are included in Appendix 4A.

Table 4.1-2
Comparison of Currently Available Supply to Projected Demands by County and Category
Year 2030

County[1]	Irrigation			Manufacturing			Mining			Municipal			Steam Electric Power			Livestock			Total		
	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)
Andrews	19,355	32,062	(12,707)	0	0	0	2,031	1,976	55	3,937	3,937	0	0	0	0	438	438	0	25,761	38,413	(12,652)
Borden	843	2,682	(1,839)	0	0	0	1,014	646	368	178	169	9	0	0	0	281	281	0	2,316	3,778	(1,462)
Brown	9,284	12,230	(2,946)	686	686	0	2,510	2,510	0	7,727	7,111	616	0	0	0	1,636	1,636	0	21,843	24,173	(2,330)
Coke	573	934	(361)	0	0	0	548	550	(2)	732	755	(23)	0	289	(289)	593	593	0	2,446	3,121	(675)
Coleman	31	1,379	(1,348)	0	6	(6)	1	19	(18)	1,497	1,814	(317)	0	0	0	1,259	1,259	0	2,788	4,477	(1,689)
Concho	5,265	4,262	1,003	0	0	0	0	0	0	1,151	884	267	0	0	0	775	775	0	7,191	5,921	1,270
Crane	337	337	0	0	0	0	2,214	2,214	0	1,453	1,453	0	0	0	0	155	155	0	4,159	4,159	0
Crockett	535	508	27	0	0	0	431	431	0	2,543	1,865	678	1,500	907	593	997	997	0	6,006	4,708	1,298
Ector	5,402	5,402	0	3,017	3,125	(108)	11,078	10,911	167	28,268	32,271	(4,003)	5,156	10,668	(5,512)	293	293	0	53,214	62,670	(9,456)
Glasscock	24,466	51,438	(26,972)	0	0	0	5	5	0	203	203	0	0	0	0	232	232	0	24,906	51,878	(26,972)
Howard	4,862	4,690	172	1,843	1,832	11	1,915	1,924	(9)	7,346	7,310	36	0	0	0	366	366	0	16,332	16,122	210
Irion	1,501	2,682	(1,181)	0	0	0	122	122	0	242	227	15	0	0	0	460	460	0	2,325	3,491	(1,166)
Kimble	1,771	913	858	3	823	(820)	104	65	39	200	1,129	(929)	0	0	0	668	668	0	2,746	3,598	(852)
Loving	583	576	7	0	0	0	3	2	1	10	10	0	0	0	0	70	70	0	666	658	8
Martin	13,500	13,822	(322)	42	42	0	705	634	71	429	858	(429)	0	0	0	273	273	0	14,949	15,629	(680)
Mason	16,099	9,792	6,307	0	0	0	6	6	0	956	916	40	0	0	0	1,036	1,036	0	18,097	11,750	6,347
McCulloch	6,103	2,754	3,349	1,004	1,004	0	162	162	0	1,349	2,236	(887)	0	0	0	1,027	1,027	0	9,645	7,183	2,462
Menard	3,620	6,022	(2,402)	0	0	0	0	0	0	384	446	(62)	0	0	0	642	642	0	4,646	7,110	(2,464)
Midland	24,500	40,848	(16,348)	198	198	0	846	846	0	19,541	35,301	(15,760)	0	0	0	904	904	0	45,989	78,097	(32,108)
Mitchell	5,564	5,479	85	0	0	0	141	108	33	1,704	1,621	83	0	4,670	(4,670)	449	449	0	7,858	12,327	(4,469)
Pecos	82,583	77,191	5,392	3	2	1	286	158	128	7,689	5,071	2,618	0	0	0	1,240	1,239	1	91,801	83,661	8,140
Reagan	25,269	35,385	(10,116)	0	0	0	2,235	2,235	0	1,167	1,167	0	0	0	0	279	272	7	28,950	39,059	(10,109)
Reeves	88,780	101,323	(12,543)	756	756	0	175	175	0	4,288	4,272	16	0	0	0	2,283	2,283	0	96,282	108,809	(12,527)
Runnels	2,973	4,298	(1,325)	0	76	(76)	45	45	0	554	2,174	(1,620)	0	0	0	1,530	1,530	0	5,102	8,123	(3,021)
Schleicher	3,132	2,024	1,108	0	0	0	150	139	11	834	795	39	0	0	0	787	787	0	4,903	3,745	1,158
Scurry	3,477	2,630	847	0	0	0	3,880	3,413	467	3,711	3,721	(10)	0	0	0	629	629	0	11,697	10,393	1,304
Sterling	745	595	150	0	0	0	605	605	0	387	387	0	0	0	0	503	503	0	2,240	2,090	150
Sutton	1,794	1,742	52	0	0	0	83	83	0	2,206	1,539	667	0	0	0	796	796	0	4,879	4,160	719
Tom Green	57,531	104,107	(46,576)	0	2,737	(2,737)	150	85	65	14,382	24,648	(10,266)	0	909	(909)	1,978	1,978	0	74,041	134,464	(60,423)
Upton	6,099	16,285	(10,186)	0	0	0	2,687	2,687	0	1,551	1,024	527	0	0	0	212	212	0	10,549	20,208	(9,659)
Ward	7,733	13,454	(5,721)	7	7	0	156	156	0	3,122	3,522	(400)	4,937	4,937	0	126	126	0	16,081	22,202	(6,121)
Winkler	10,000	10,000	0	0	0	0	1,878	883	995	4,721	2,444	2,277	0	0	0	169	151	18	16,768	13,478	3,290
Total	434,310	567,846	(133,536)	7,559	11,294	(3,735)	36,166	33,795	2,371	124,462	151,280	(26,818)	11,593	22,380	(10,787)	23,086	23,060	26	637,176	809,655	(172,479)

1. County shown is the county where the supply is used. The actual supply may come from a different county.

2. Surplus and need are calculated on a county basis. The surplus and needs for individual water users are included in Appendix 4A.

Table 4.1-3
Comparison of Currently Available Supply to Projected Demands by County and Category
Year 2060

County[1]	Irrigation			Manufacturing			Mining			Municipal			Steam Electric Power			Livestock			Total		
	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)	Supply	Demand	Surplus[2] (Need)
Andrews	20,299	31,245	(10,946)	0	0	0	2,089	2,036	53	3,400	4,173	(773)	0	0	0	438	438	0	26,226	37,892	(11,666)
Borden	847	2,673	(1,826)	0	0	0	1,014	612	402	174	123	51	0	0	0	281	281	0	2,316	3,689	(1,373)
Brown	9,264	12,105	(2,841)	837	837	0	2,530	2,530	0	7,610	6,932	678	0	0	0	1,636	1,636	0	21,877	24,040	(2,163)
Coke	573	933	(360)	0	0	0	542	614	(72)	619	737	(118)	0	477	(477)	593	593	0	2,327	3,354	(1,027)
Coleman	31	1,379	(1,348)	0	6	(6)	1	19	(18)	1,490	1,766	(276)	0	0	0	1,259	1,259	0	2,781	4,429	(1,648)
Concho	5,265	4,213	1,052	0	0	0	0	0	0	1,089	865	224	0	0	0	775	775	0	7,129	5,853	1,276
Crane	337	337	0	0	0	0	2,208	2,208	0	1,623	1,623	0	0	0	0	155	155	0	4,323	4,323	0
Crockett	535	482	53	0	0	0	459	459	0	2,539	1,949	590	1,500	1,500	0	997	997	0	6,030	5,387	643
Ector	5,204	5,204	0	3,083	3,491	(408)	12,117	11,970	147	29,619	36,725	(7,106)	5,156	17,637	(12,481)	293	293	0	55,472	75,320	(19,848)
Glasscock	24,468	50,190	(25,722)	0	0	0	5	5	0	201	201	0	0	0	0	232	232	0	24,906	50,628	(25,722)
Howard	4,862	4,527	335	1,879	2,099	(220)	1,767	2,052	(285)	6,420	7,140	(720)	0	0	0	366	366	0	15,294	16,184	(890)
Irion	1,501	2,501	(1,000)	0	0	0	122	122	0	222	185	37	0	0	0	460	460	0	2,305	3,268	(963)
Kimble	1,771	807	964	3	1,002	(999)	104	60	44	200	1,104	(904)	0	0	0	668	668	0	2,746	3,641	(895)
Loving	583	572	11	0	0	0	3	2	1	10	10	0	0	0	0	70	70	0	666	654	12
Martin	13,075	13,075	0	47	47	0	705	603	102	396	789	(393)	0	0	0	273	273	0	14,496	14,787	(291)
Mason	16,099	9,363	6,736	0	0	0	6	6	0	956	900	56	0	0	0	1,036	1,036	0	18,097	11,305	6,792
McCulloch	6,103	2,649	3,454	1,233	1,233	0	171	171	0	1,230	2,190	(960)	0	0	0	1,027	1,027	0	9,764	7,270	2,494
Menard	3,620	5,962	(2,342)	0	0	0	0	0	0	384	435	(51)	0	0	0	642	642	0	4,646	7,039	(2,393)
Midland	23,891	39,884	(15,993)	245	245	0	1,046	1,046	0	14,574	37,180	(22,606)	0	0	0	904	904	0	40,660	79,259	(38,599)
Mitchell	5,564	5,398	166	0	0	0	141	104	37	1,639	1,409	230	0	4,140	(4,140)	449	449	0	7,793	11,500	(3,707)
Pecos	82,583	73,475	9,108	3	2	1	286	158	128	7,670	4,980	2,690	0	0	0	1,240	1,239	1	91,782	79,854	11,928
Reagan	25,186	33,579	(8,393)	0	0	0	2,436	2,436	0	1,049	1,049	0	0	0	0	279	272	7	28,950	37,336	(8,386)
Reeves	88,707	98,710	(10,003)	825	825	0	170	170	0	4,731	4,713	18	0	0	0	2,283	2,283	0	96,716	106,701	(9,985)
Runnels	2,973	4,241	(1,268)	0	94	(94)	45	45	0	184	2,319	(2,135)	0	0	0	1,530	1,530	0	4,732	8,229	(3,497)
Schleicher	3,132	1,897	1,235	0	0	0	154	154	0	824	824	0	0	0	0	787	787	0	4,897	3,662	1,235
Scurry	3,400	2,355	1,045	0	0	0	3,947	3,693	254	3,348	3,696	(348)	0	0	0	629	629	0	11,324	10,373	951
Sterling	745	518	227	0	0	0	620	620	0	379	379	0	0	0	0	503	503	0	2,247	2,020	227
Sutton	1,794	1,639	155	0	0	0	86	86	0	2,196	1,499	697	0	0	0	796	796	0	4,872	4,020	852
Tom Green	57,531	103,338	(45,807)	0	3,425	(3,425)	150	99	51	13,567	24,888	(11,321)	0	1,502	(1,502)	1,978	1,978	0	73,226	135,230	(62,004)
Upton	6,081	15,576	(9,495)	0	0	0	2,708	2,708	0	1,553	1,088	465	0	0	0	212	212	0	10,554	19,584	(9,030)
Ward	6,059	12,947	(6,888)	7	7	0	159	159	0	3,069	3,469	(400)	6,189	8,162	(1,973)	126	126	0	15,609	24,870	(9,261)
Winkler	10,000	10,000	0	0	0	0	1,878	847	1,031	4,721	2,292	2,429	0	0	0	169	151	18	16,768	13,290	3,478
Total	432,083	551,774	(119,691)	8,162	13,313	(5,151)	37,669	35,794	1,875	117,686	157,632	(39,946)	12,845	33,418	(20,573)	23,086	23,060	26	631,531	814,991	(183,460)

1. County shown is the county where the supply is used. The actual supply may come from a different county.

2. Surplus and need are calculated on a county basis. The surplus and needs for individual water users are included in Appendix 4A.

Table 4.1-4
Comparison of Supplies and Demands for Wholesale Water Providers
(Values in Acre-Feet per Year)

Wholesale Water Provider	Category	2010	2020	2030	2040	2050	2060
BCWID	Supply	29,712	29,712	29,712	29,712	29,712	29,712
	Demand	15,085	15,209	15,192	15,105	15,097	15,163
	Surplus (Need)	*14,627*	*14,503*	*14,520*	*14,607*	*14,615*	*14,549*
CRMWD	Supply	74,485	67,935	66,585	65,235	63,885	62,535
	Demand	89,212	91,631	73,743	74,129	73,699	74,644
	Surplus (Need)	*(14,727)*	*(23,696)*	*(7,158)*	*(8,894)*	*(9,814)*	*(12,109)*
City of Odessa	Supply	21,606	16,688	24,372	24,503	25,055	25,084
	Demand	26,150	27,480	28,634	29,866	31,285	32,887
	Surplus (Need)	*(4,544)*	*(10,792)*	*(4,262)*	*(5,363)*	*(6,230)*	*(7,803)*
City of San Angelo	Supply	*20,116*	*19,893*	*19,670*	*19,446*	*19,223*	*19,000*
	Demand	50,519	51,643	52,330	52,686	53,053	53,365
	Surplus (Need)	*(30,403)*	*(31,750)*	*(32,660)*	*(33,240)*	*(33,830)*	*(34,365)*
Great Plains Water	Supply	5,220	5,220	5,220	5,220	5,220	5,220
System	Demand	5,220	5,220	5,220	5,220	5,220	5,220
	Surplus (Need)	*0*	*0*	*0*	*0*	*0*	*0*
UCRA	Supply	0	0	0	0	0	0
	Demand	3,862	3,743	3,625	3,507	3,388	3,270
	Surplus (Need)	*(3,862)*	*(3,743)*	*(3,625)*	*(3,507)*	*(3,388)*	*(3,270)*
University Lands	Supply	10,593	5,430	5,452	0	0	0
	Demand	10,593	10,630	10,652	5,950	5,960	5,973
	Surplus (Need)	*0*	*(5,200)*	*(5,200)*	*(5,950)*	*(5,960)*	*(5,973)*

Note: The demands on San Angelo include irrigation demands (26,500 ac-ft/year).

4.1.5 Socio-Economic Impacts of Not Meeting Projected Shortages

Based on the above analysis, Region F will face substantial shortages in water supply over the planning period. The TWDB provided technical assistance to regional water planning groups in the development of specific information on the socio-economic impacts of failing to meet projected water needs.[1]

The TWDB's analysis calculated the impacts of a severe drought occurring in a single year at each decadal period in Region F. It was assumed that all of the projected shortage was attributed to drought. Under these assumptions, the TWDB's findings are shown on Table 4.1-5 and can be summarized as follows:

- With the projected shortages, the region's projected 2060 population would be reduced by 49,236, which is approximately 7 percent.
- Without any additional supplies, the projected water needs would reduce the region's projected 2060 employment by 40,877 jobs (18 percent reduction). Most of this reduction occurs in the municipal and manufacturing sectors.
- Without any additional supplies, the projected water needs would reduce the region's projected annual income and taxes in 2060 by $3.9 billion. This represents about 19 percent of the region's current income and business taxes.

Table 4.1-5
Socio-Economic Impacts in Region F for a Single Year Extreme Drought without Implementation of Water Management Strategies

Year	Lost Income ($ millions)	Lost State and Local Taxes ($ millions)	Lost Jobs
2010	$1,444	$145	19,225
2020	$1,715	$176	21,784
2030	$2,195	$236	26,293
2040	$2,729	$288	34,853
2050	$3,061	$330	37,661
2060	$3,470	$380	40,877

4.2 Identification and Evaluation of Water Management Strategies

4.2.1 Evaluation Procedures

In accordance with TWDB rules, the Region F Water Planning Group has adopted a standard procedure for identifying potentially feasible strategies. This procedure classifies strategies using the TWDB's standard categories developed for regional water planning. These strategies categories include:

- Water Conservation
- Drought Management Measures
- Wastewater Reuse
- Expanded Use of Existing Supplies
  - System Operation
  - Conjunctive Use of Groundwater and Surface Water
  - Reallocation of Reservoir Storage
  - Voluntary Redistribution of Water Resources
  - Voluntary Subordination of Existing Water Rights
  - Yield Enhancement
  - Water Quality Improvement
- New Supply Development
  - Surface Water Resources
  - Groundwater Resources
  - Brush Control
  - Precipitation Enhancement
  - Desalination
  - Water Right Cancellation
  - Aquifer Storage And Recovery (ASR)
- Interbasin Transfers

The Region F Water Planning Group did not consider water right cancellation to be a feasible strategy. Instead, Region F recommends that a water right holder consider selling water under their existing water right to the willing buyer.

Appendix 4C contains the procedures used to evaluate strategies and the results of the strategy evaluations.

4.2.2 Strategy Development

Water management strategies were developed for water user groups to meet projected needs in the context of their current supply sources, previous supply studies and available supply within the region. Much of the water supply in Region F is from groundwater, and several of the identified needs could be met by development of new groundwater supplies. Where site-specific data were available, this information was used. When specific well fields could not be identified, assumptions regarding well capacity, depth of well and associated costs were developed based on county and aquifer. In most cases new surface water supplies are not feasible because of the lack of unappropriated water in the upper Colorado Basin.

Water transmission lines were assumed to take the shortest route, following existing highways or roads where possible. Profiles were developed using USGS topographic maps. Pipes were sized to deliver peak-day flows within reasonable pressure and velocity ranges.

Municipal and manufacturing strategies were developed to provide water of sufficient quantity and quality that is acceptable for its end use. Water quality issues affect water use options and treatment requirements. For the evaluations of the strategies, it was assumed that the final water product would meet existing state water quality requirements for the specified use. For example, a strategy that provided water for municipal supply would meet existing drinking water standards, while water used for mining may have a lower quality.

In addition to the development of specific strategies to meet needs, there are other water management strategies that are general and could potentially increase water for all user groups. These include weather modification and brush control. A brief discussion of each of these general strategies and its applicability to Region F is included in Section 4.9.

In accordance with TWDB guidance, costs are reported using September 2008 prices and debt service is set at a 6 percent annual interest rate over 20 years except for reservoirs, which assumed a 6 percent annual interest rate over a period of 40 years. Cost estimates for region F strategies may be found in Appendices 4Dand 4E. Appendix 4F includes a Strategy Evaluation Matrix and Quantified Environmental Impact Matrix.

4.2.3 Subordination of Downstream Senior Water Rights

The TWDB requires the use of the TCEQ Water Availability Models (WAM) for regional water planning. Most of the water rights in Region F are in the Colorado River Basin. Chapter 3 discusses the use of the WAM models for water supply estimates and the impacts to the available supplies in the upper Colorado River Basin. Table 3.2-2 in Chapter 3 shows that the Colorado WAM gives a very different assessment of water availability for many reservoirs in Region F than reported in previous studies. The primary difference between the supply analysis used in previous plans and the Colorado WAM is that previous plans did not assume that senior lower basin water rights would continuously make priority calls on Region F water rights. Other differences include a shorter period of hydrologic analysis, assumptions about channel losses, reservoir operation and the use of return flows.

Although the Colorado WAM does not give an accurate assessment of water supplies based on the way the basin has historically been operated, TWDB requires the regional water planning groups to use the WAM to determine supplies. Therefore several sources in Region F have no supply by definition, even though in practice their supply may be greater than indicated by the WAM. According to the WAM, the cities of Ballinger, Coleman, Junction, and Winters and their customers have no water supply. The Morgan Creek power plant has no supply to generate power. The cities of Big Spring, Bronte, Coahoma, Midland, Miles, Odessa, Robert Lee, San Angelo, Snyder and Stanton do not have sufficient water to meet current demands. The City of Brady, which recently built a new water treatment plant on Brady Creek Reservoir because its groundwater supplies exceed drinking water standards for radium, has no supply from that reservoir. Overall, the Colorado WAM shows shortages that are the result of modeling assumptions and regional water planning rules rather than the historical operation of the Colorado Basin. This would indicate Region F needs to immediately spend significant funds on new water supplies, when in reality the indicated water shortages are not justified. Conversely, the WAM model shows more water in Region K (Lower Colorado Basin) than may actually be available.

One way for the planning process to reserve water supplies for these communities and their customers is to assume that downstream senior water rights do not make priority calls on major

Region F municipal water rights, a process referred to as *subordination*. This assumption is similar to the methodology used to evaluate water supplies in previous water plans.

Because this strategy impacts water supplies outside of Region F, a joint modeling effort was conducted with the Lower Colorado Regional Water Planning Group (Region K) during the development of the 2006 regional water plans. The joint modeling had two major assumptions: 1) water rights in Region K do not make priority calls on specific upper basin water rights located in Regions F and Brazos G, and 2) these upper basin water rights do not make priority calls on each other. Only selected Region K water rights with a priority date before May 8, 1938, major reservoirs in Region F, and the City of Junction run-of-the-river right were subject to subordination. Table 4.2-1 contains a list of the water rights assumed to be participating in the subordination strategy. All other water rights were assumed to operate as originally modeled in the Colorado WAM. A detailed description of the joint modeling approach may be found in Appendix 4D of the *2006 Region F Water Plan*.

Refinements to the subordination modeling were conducted for the Pecan Bayou watershed in 2009 as part of a special study conducted for Region F. A copy of the study is included in Volume II. As discussed above the assumption that upper basin water rights do not make calls on each other is consistent with general operations in the basin, but it may not be appropriate for determining water supplies during drought in the Pecan Bayou watershed. The special study evaluated six different operating scenarios in the Pecan Bayou watershed, which includes Lake Brownwood, Lake Coleman, Hords Creek Reservoir and Lake Clyde. In addition, refinements to the naturalized flows in the Colorado WAM were made for Lake Coleman, Hords Creek Reservoir and Lake Clyde to better correlate with historical data.

Based on the findings of the special study for Pecan Bayou, all but one of the operating scenarios would provide sufficient supplies to meet the demands of the water rights holders. For planning purposes, Scenario 3 is selected for estimating the available supply from the Subordination Strategy. Scenario 3 assumes that the upstream reservoirs hold inflows that would have been passed to Lake Brownwood under strict priority analysis if Lake Brownwood is above 50 percent of the conservation capacity. This scenario provides additional supplies in the upper watershed while allowing Lake Brownwood to make priority calls at certain times during drought.

Since many of the reservoirs in the Colorado River Basin are experiencing significant drought conditions, a study was conducted as part of the *2006 Region F Water Plan* to evaluate the impacts of recent drought on reservoir yields by extending hydrology through 2004. The yields presented in this section are the result of the findings of this study and have been adjusted to account for reduced yield due to drought conditions that have occurred since 1998, the last year simulated in the Colorado WAM. Many of the reservoirs are in drought of record conditions and new firm yields cannot be determined. The yields for the reservoirs in the Pecan Bayou watershed are based on the findings of the Pecan Bayou study.

Two reservoirs providing water to the Brazos G planning region were included in the subordination analysis. Lake Clyde is located in Callahan County and provides water to the City of Clyde. Oak Creek Reservoir is located in Region F and supplies a small amount of water to water user groups within the region. Oak Creek Reservoir is owned and operated by the City of Sweetwater, which is in the Brazos G Region. Both Clyde and Sweetwater have other sources of water in addition to the supplies in the Colorado Basin.

The subordination strategy modeling was conducted for regional water planning purposes only. By adopting this strategy, the Region F Water Planning Group does not imply that the water rights holders in Table 4.2-1 have agreed to relinquish the ability to make priority calls on junior water rights. The Region F Water Planning Group does not have the authority to create or enforce subordination agreements. Such agreements must be developed by the water rights holders themselves. Region F recommends and supports ongoing discussions on water rights issues in the Colorado Basin that may eventually lead to formal agreements that reserve water for Region F water rights.

The subordination analysis presented in this plan is only one possible scenario; others may need to be developed before implementation of this strategy.

Quantity, Reliability and Cost of Subordination

The subordination strategy shows additional supplies of 80,130 in 2010 and 72,830 in 2060. Figure 4.2-1 compares overall Region F surface water supplies and demands in the years 2010 and 2060, with and without the subordination strategy.

Table 4.2-1
Major Water Rights Included in Subordination Analysis

Water Right Number	Region	Name of Water Right	Priority Date(s)
CA 1002	F	Lake Thomas	5/08/1946
CA 1009	F	Champion Creek Reservoir	4/08/1957
		Lake Colorado City	11/22/1948
CA 1008	F	Spence Reservoir	8/17/1964
CA 1031	F/G*	Oak Creek Reservoir	4/27/1949
CA 1072	F	Lake Ballinger	10/04/1946 4/7/1980
CA 1095	F	Lake Winters	12/18/1944
CA 1190	F	Fisher Reservoir	5/27/1949
CA 1318	F	Twin Buttes Reservoir	5/06/1959
CA 1319	F	Lake Nasworthy	3/11/1929
A 3866/P 3676	F	Ivie Reservoir	2/21/1978
CA 1705	F	Hords Creek Lake	3/23/1946
CA 1702	F	Lake Coleman	8/25/1958
CA 1660	G	Lake Clyde	2/02/1965
CA 1849	F	Brady Creek Reservoir	9/02/1959
CA 1570	F	Run-of-the river right City of Junction	5/17/1931 11/23/1964
CA 2454	F	Lake Brownwood	9/29/1925
CA 5434	K	Garwood	11/1/1900
CA 5476	K	Gulf Coast	12/1/1900
CA 5475	K	Lakeside	1/4/1901 9/2/1907
CA 5477	K	Pierce Ranch	9/1/1907
CA 5478	K	Lake Buchanan	3/29/1926 12/31/1929 3/7/1938
CA 5480	K	Lake LBJ	3/29/1926
CA 5479	K	Inks Lake	3/29/1926
CA 5482	K	Lake Travis	3/29/1926 03/07/1938
CA 5471	K	Lake Austin, Town Lake, Decker Lake et al.	6/30/1913 6/27/1914 12/31/1928

CA Certificate of Adjudication number
P Permit number
A Application number

* Oak Creek Reservoir is located in Region F but the supplies are primarily used in Brazos G.

Table 4.2-2 compares the 2010 and 2060 supplies for Region F water supply sources with and without the subordination strategy. Without the subordination strategy, in 2010 demand exceeds supply by 25,967 acre-feet per. With subordination, the region has a surplus supply of 54,163 acre-feet per year that can be used to meet other needs. By 2060, without subordination demand exceeds supply by 47,870 acre-feet per year. With subordination, the region has a surplus supply of 24,960 acre-feet per year that can be used to meet other needs. Much of this supply is associated with wholesale water providers and associated reservoirs. A list of the water user groups that could potentially benefit from subordination and the amounts assumed for planning are shown in Table 4.2-4.

Figure 4.2-1
Comparison of Supplies and Demands in Region F
With and Without the Subordination Strategy

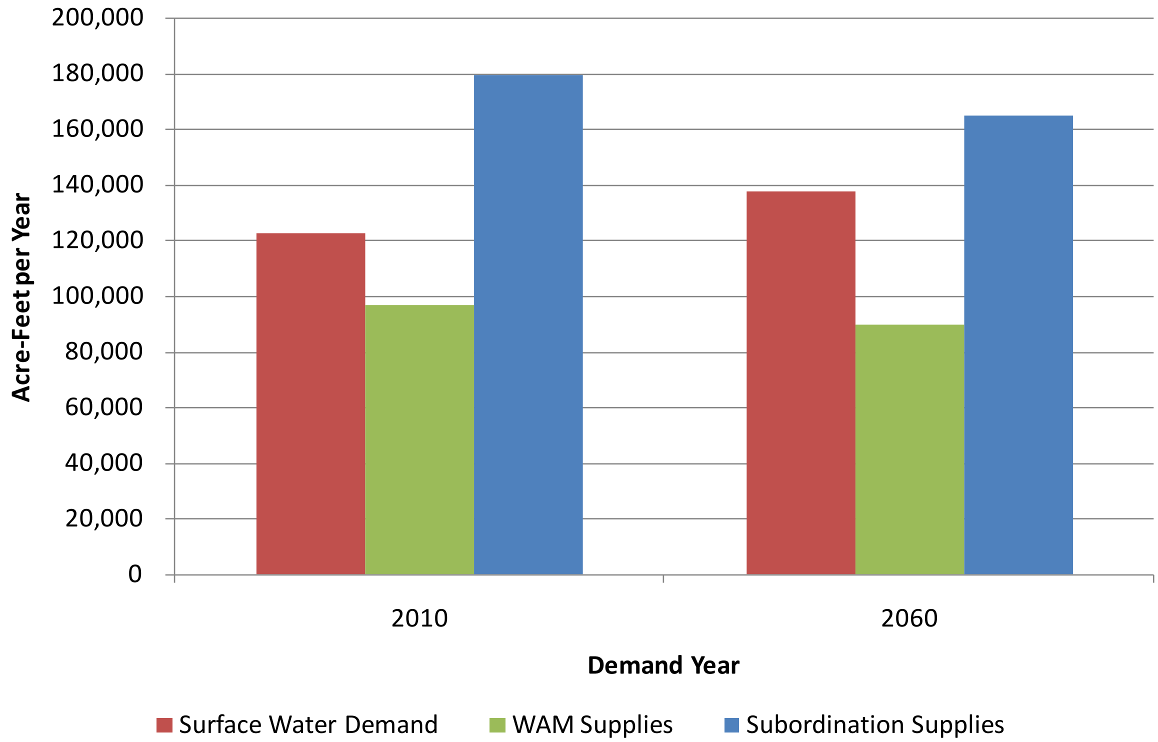


Table 4.2-2
Comparison of Colorado Basin Region F Water Supplies with and without Subordination
(Values in Acre-feet per Year)

Supply Source	2010 Supply WAM Run 3	2010 Supply Subord-ination	2060 Supply WAM Run 3	2060 Supply Subord-ination	Comments
Lake Colorado City	0	2,686	0	1,920	
Champion Creek Reservoir	0	2,337	0	2,220	
Colorado City/Champion System	*0*	*5,023*	*0*	*4,140*	
Oak Creek Reservoir	0	2,118	0	1,760	
Lake Ballinger	0	940	0	890	
Lake Winters	0	720	0	670	
Twin Buttes Reservoir/Lake Nasworthy	0	12,310	0	11,360	
O.C. Fisher Reservoir	0	3,862	0	3,270	
San Angelo System	*0*	*16,172*	*0*	*14,630*	
Hords Creek Reservoir[1]	0	380	0	380	
Lake Coleman[1]	0	3,580	0	3,580	
Coleman System	*0*	*3,960*	*0*	*3,960*	
Brady Creek Reservoir	0	2,170	0	2,220	
Lake Thomas	0	10,013	0	10,130	
Spence Reservoir (CRMWD system portion)	526	36,164	526	35,090	
Spence Reservoir (Non-system portion)	34	2,308	34	2,240	6% of safe yield
Spence Reservoir Total	*560*	*38,472*	*560*	*37,330*	
Ivie Reservoir (CRMWD system portion)	33,428	33,479	30,026	28,345	
Ivie Reservoir (Non-system portion)	32,922	32,973	29,574	27,915	49.62% of safe yield
Ivie Reservoir Total	*66,350*	*66,452*	*59,600*	*56,260*	
CRMWD Grand Total (Thomas, Spence & Ivie)	*66,910*	*114,937*	*60,160*	*103,720*	
Lake Brownwood[2]	29,712	29,712	29,712	29,712	
City of Junction	0	1,000	0	1,000	
TOTAL	*96,622*	*176,752*	*89,872*	*162,702*	

1. Reservoir supplies based on safe yields.
2. Subordination values are based on Scenario 3 of the Pecan Bayou Study (Volume II).

Table 4.2-3
Recommended Supplies from Subordination Strategy for Water User Groups

Water User Group Name	County	Source Name	Strategy Supply for 2010	Strategy Supply for 2020	Strategy Supply for 2030	Strategy Supply for 2040	Strategy Supply for 2050	Strategy Supply for 2060
City of Bronte	Coke	Oak Creek Reservoir	129	129	129	129	129	129
City of Robert Lee	Coke	Colorado River MWD System	95	115	2	21	34	55
County-Other	Coke	Colorado River MWD System	28	32	0	6	9	15
Mining	Coke	Colorado River MWD System	86	119	2	24	43	72
Steam Electric Power	Coke	Oak Creek Reservoir	310	247	289	339	401	477
City of Coleman	Coleman	Lake Coleman	1,650	1,651	1,647	1,645	1,639	1,631
City of Coleman	Coleman	Hords Creek Reservoir	380	380	380	380	380	380
Coleman County WSC	Coleman	Lake Coleman	126	114	109	103	101	99
County-Other	Coleman	Lake Coleman	20	19	19	18	18	18
Irrigation	Coleman	Lake Coleman	1,348	1,348	1,348	1,348	1,348	1,348
Manufacturing	Coleman	Lake Coleman	6	6	6	6	6	6
Mining	Coleman	Lake Coleman	17	18	18	18	18	18
County-Other	Concho	OC Fisher Reservoir	25	25	25	25	25	25
Millersview-Doole WSC	Concho	Colorado River MWD System	34	42	1	7	0	0
Ector County UD	Ector	Colorado River MWD System	400	613	11	151	272	478
Manufacturing	Ector	Colorado River MWD System	366	149	3	46	86	158
City of Odessa	Ector	Colorado River MWD System	4,019	5,611	59	1,085	1,913	3,314
City of Big Spring	Howard	Colorado River MWD System	1,345	1,672	24	299	491	796
City of Coahoma	Howard	Colorado River MWD System	49	61	1	11	18	29
Manufacturing	Howard	Colorado River MWD System	267	349	5	71	124	220
Mining	Howard	Colorado River MWD System	400	523	9	101	171	285
City of Junction	Kimble	Llano River	991	991	991	991	991	991
County-Other	Kimble	Llano River	9	9	9	9	9	9
Manufacturing	Kimble	Llano River	1,000	1,000	1,000	1,000	1,000	1,000
City of Brady	McCulloch	Brady Creek Reservoir	2,170	2,170	2,170	2,170	2,170	2,170
Millersview-Doole WSC	McCulloch	Colorado River MWD System	67	81	1	14	0	0

Table 4.2-3 (Continued)

Water User Group Name	County	Source Name	Strategy Supply for 2010	Strategy Supply for 2020	Strategy Supply for 2030	Strategy Supply for 2040	Strategy Supply for 2050	Strategy Supply for 2060
City of Midland	Midland	Colorado River MWD System	4,488	6,152	211	324	438	553
City of Midland	Midland	O.H. Ivie Reservoir	17	(97)	(211)	(324)	(438)	(553)
City of Odessa	Midland	Colorado River MWD System	186	176	28	66	97	150
Steam Electric Power	Mitchell	Colorado City/Champion Creek	5,023	4,847	4,670	4,493	4,317	4,140
City of Ballinger	Runnels	Lake Ballinger	917	930	920	910	900	890
City of Ballinger and customers	Runnels	Colorado River MWD System	343	356	227	243	0	0
Coleman County WSC	Runnels	Lake Coleman	18	30	39	48	56	66
County-Other	Runnels	Lake Ballinger	23	0	0	0	0	0
County-Other	Runnels	Lake Winters	114	89	69	49	31	0
Manufacturing	Runnels	Lake Winters	54	60	65	70	74	79
City of Miles	Runnels	OC Fisher Reservoir	200	200	200	200	200	200
Millersview-Doole WSC	Runnels	Colorado River MWD System	25	31	0	6	0	0
City of Winters	Runnels	Lake Winters	552	561	566	571	575	591
County-Other	Scurry	Colorado River MWD System	54	66	1	12	20	33
City of Snyder	Scurry	Colorado River MWD System	511	641	9	117	194	315
County-Other	Tom Green	Nasworthy/Twin Buttes	250	250	250	250	250	250
Irrigation	Tom Green	Nasworthy/Twin Buttes	3,377	3,273	3,170	3,066	2,693	2,860
Manufacturing	Tom Green	Nasworthy/Twin Buttes	2,226	2,498	2,737	2,971	3,175	3,425
Millersview-Doole WSC	Tom Green	Colorado River MWD System	64	87	1	19	0	0
City of San Angelo	Tom Green	Nasworthy/Twin Buttes	5,436	5,078	4,752	4,431	4,141	3,804
City of San Angelo	Tom Green	OC Fisher Reservoir	3,637	3,518	3,400	3,282	3,163	3,045
City of San Angelo	Tom Green	OH Ivie Reservoir	17	(97)	(211)	(324)	(438)	(553)
City of San Angelo	Tom Green	Spence (non-system)	2,274	2,261	2,247	2,233	2,220	2,206
Steam Electric Power	Tom Green	Nasworthy/Twin Buttes	1,021	1,021	1,021	1,021	1,021	1,021
		TOTAL	*46,164*	*49,405*	*32,419*	*33,751*	*34,085*	*36,245*

The reliability of this strategy is considered to be medium based on the uncertainty of implementing this strategy. The subordination strategy defined for the Region F Water Plan is for planning purposes. If an entity chooses to enter into a subordination agreement with a senior downstream water right holder, the details of the agreement (including costs, if any) will be between the participating parties. Therefore strategy costs will not be determined for the subordination strategy. For planning purposes, capital and annual costs for the subordination strategy are assumed to be $0.

Environmental Issues Associated with Subordination

The WAM models assume a perfect application of the prior appropriations doctrine. A significant assumption in the model is that junior water rights routinely bypass water to meet the demands of downstream senior water rights and fill senior reservoir storage. If a downstream senior reservoir is less than full, all junior upstream rights are assumed to cease diverting and storing water until that reservoir is full, even if that reservoir does not need to be filled for that water right to meet its diversion targets. Currently in the Region F portion of the Colorado Basin, water rights divert and store inflows until downstream senior water rights make a priority call on upstream junior water rights. Many other assumptions are made in the Colorado WAM model that may be contrary to historical operation of the Colorado Basin in Region F.

Because many of the assumptions in the Colorado WAM are contrary to the actual operation of the upper portion of the basin, the model does not give a realistic assessment of stream flows in Region F. In the WAM a substantial amount of water is passed downstream to senior water rights that would not be passed based on historical operation. The subordination analysis better represents the actual operation of the basin. Therefore a comparison of flows with and without subordination is meaningless as an assessment of impacts on streamflow in the upper basin.

Environmental impacts should be based on an assessment of the actual conditions, not a simulation of a theoretical legal framework such as the WAM. Impacts should also be assessed for a change in actions. The subordination modeling approaches the actual operation of the upper basin. There is no change in operation or distinct action taken under this strategy. The actual impacts of implementing this strategy could occur during extreme drought when a downstream senior water right may elect to make a priority call on upstream junior water rights. Flows from priority releases could be used beneficially for environmental purposes in the intervening stream reaches before the water is diverted by the senior water right. Priority calls are largely based on the decision of individual water rights holders, making it difficult to quantify impacts. However, the potential environmental impacts are considered to be low to medium because this strategy, as modeled, assumes that operations in the basin continue as currently implemented. Existing species and habitats are established for current conditions, which will not change under this strategy.

Agricultural and Rural Issues Associated with Subordination

The water user groups impacted the most by the Colorado WAM are small rural towns such as Ballinger, Winters and Coleman, and the rural water supply corporations supplied by these towns. These towns have developed surface water supplies because groundwater supplies of sufficient quality and quantity are not available. This strategy reserves water for these rural communities.

Three Region F reservoirs included in the subordination strategy provide a significant amount of water for irrigation: the Twin Buttes Reservoir/Lake Nasworthy system and Lake Brownwood. Twin Buttes Reservoir uses a pool accounting system to divide water between the City of San Angelo and irrigation users. As long as water is in the irrigation pool, water is available for irrigation. Due to drought, no water has been in the irrigation pool since 1998. The total authorized diversion for the Twin Buttes/Nasworthy system is 54,000 acre-feet per year. The two reservoirs have no firm or safe yield in the Colorado WAM. With the subordination analysis the current safe yield of the Twin Buttes/Nasworthy system is 12,500 acre-feet per year. Historical water use from the reservoir has been as high as 40,000 acre-feet per year. The average recent use from the reservoir when irrigation supplies were available has been 29,000 acre-feet per year.[2] Therefore even with subordination there may not be sufficient water to meet both the needs of the City of San Angelo and irrigation demands.

The reliable supply from Lake Brownwood is the same with and without subordination. However, with subordination there is less water in storage during extreme drought. This implies that there is less unpermitted yield available in the reservoir. The occurrence of drought conditions more severe than those encountered during the historical modeling period could impact supplies from this source.

Other Natural Resource Issues Associated with Subordination

None identified.

Significant Issues Affecting Feasibility of Subordination

Water supply in the Colorado Basin involves many complex legal and technical issues, as well as a variety of perspectives on these issues. There is also a long history associated with water supply development in the Colorado Basin. It is likely that a substantial study evaluating multiple subordination scenarios will be required before a full assessment of the feasibility of this strategy can be made. Legal opinions regarding the implementation of subordination agreements under Texas water law will be a large part of assessing the feasibility of the strategy.

Before assigning costs for this strategy a definitive assessment of the impacts on senior water right holders and the benefits to junior water rights holders must be determined. This assessment should take into account the existing agreements and the historical development of water supply in the basin. The analysis presented in this plan is not sufficient to make that determination.

Other Water Management Strategies Directly Affected by Subordination

All other strategies for this plan are based on water supplies with the subordination strategy in place. Table 4.2-4 is a partial list of Region F strategies potentially impacted by the subordination strategy. The amount of water needed from most of these strategies may be higher without the subordination strategy and/or the timing for implementation may need to be sooner. Other strategies may be indirectly impacted. Changes to the assumptions made in the subordination strategy may have a significant impact on the amount of water needed from these strategies.

Table 4.2-4
Partial List of Region F Water Management Strategies Potentially Impacted by the Subordination Strategy

Water User Group	County	Category	Description
Bronte	Coke	Other	Rehabilitate Oak Creek pipeline
Robert Lee	Coke	Desalination	Lake Spence RO
Robert Lee	Coke	Other	Expand WTP
Manufacturing	Kimble	New groundwater	Edwards-Trinity
Manufacturing	Kimble	Voluntary redistribution	Purchase or lease water rights
Midland	Midland	New groundwater	T-Bar Well Field
Midland	Midland	Voluntary redistribution	CRMWD
Ballinger	Runnels	Voluntary redistribution	Hords Creek Reservoir
Ballinger	Runnels	Voluntary redistribution	Obtain water from CRMWD system
San Angelo	Tom Green	New groundwater	McCulloch Well Field
San Angelo	Tom Green	Reuse	Municipal reuse
CRMWD	Various	New Groundwater	Winkler well field
CRMWD	Various	Reuse	Big Spring reuse
CRMWD	Various	Reuse	Midland/Odessa reuse
CRMWD	Various	Reuse	Snyder reuse

4.3 Municipal Needs

Implementation of the subordination strategy eliminates many of the needs shown in Tables 4.1-1, 4.1-2 and 4.1-3. However, there are seven municipal water user groups (WUGs) that do not have sufficient supplies even with the subordination strategy: Cities of Andrews, Ballinger, Bronte, Midland, Menard, San Angelo and Robert Lee. Other municipal needs in Concho and McCulloch County are associated with the use of water from the Hickory aquifer, which exceeds drinking water standards for radionuclides in some areas. Several municipal water users are interested in developing additional water supplies or improved infrastructure to improve the overall reliability of their water supply. Section 4.8 discusses needs for Wholesale Water Providers, including the City of San Angelo and CRMWD.

Over the planning period there may be additional water users that will need to upgrade their water supply systems or develop new supplies, but are not specifically identified in this plan. It is the intent of this plan to include all water systems that may demonstrate a need for water supply. This includes established water providers and new water supply corporations formed by individual users that may need to band together to provide a reliable water supply. In addition, Region F considers water supply projects that do not impact other water users but are needed to meet demands to meet regulatory requirements for consistency with the regional plan even though not specifically recommended in the plan.

4.3.1 City of Andrews

The City of Andrews obtains its water from city well fields in the Ogallala aquifer and purchased groundwater from University Lands. The City's contract with University Lands expires in 2035. It is assumed that the City will renew this contract for supplies through the planning period and this is a recommended strategy for the City of Andrews. Water from both the University Lands and the city well fields may provide sufficient supplies for the City of Andrews, but there are insufficient supplies to meet all demands within Andrews County. As a result there is competition for this water supply among other users. Also, the special study conducted for Region F on potential groundwater sources (Volume II) indicated that the available supply from the Ogallala in southeast Andrews County may be less than estimated in this regional water plan. Only additional field data will be able to better define the available groundwater supplies in Andrews County. In addition to the quantity concerns, the city's supply exceeds drinking water standards for fluoride. The city is interested in desalination as a long-term strategy to improve the reliability and quality of their water supply.

Potentially Feasible Water Management Strategies for the City of Andrews

The following strategies have been identified as potentially feasible for the City of Andrews:

- Renew existing contract with University Lands for water from the Ogallala aquifer in Andrews County
- Develop and desalinate water from the Dockum aquifer in Andrews County
- Implement municipal water conservation

Desalination – Dockum Aquifer

The City of Andrews has identified the Dockum aquifer as a potential long-term source of water for the city. Use of this water would most likely require desalination to meet secondary drinking water standards. The project proposed by the city includes development of new wells into the Dockum located near the city's existing well field in northern Andrews County. This well field is located near an existing oil and gas field. Therefore, co-disposal of brine reject from the treatment process could help make this project more cost-effective. The proposed project could be developed in conjunction with the City of Seminole in Gaines County (Region O).

Additional information on the Dockum aquifer may be found in Chapter 3.

Quantity, Reliability and Cost of Desalination

For the purposes of this plan it is assumed that a 1 mgd desalination plant delivering up to 950 acre-feet of water per year would be constructed in northern Andrews County near the city's existing well field. Delivery to the city would be through the existing pipeline from the city's well field. Disposal of brine reject would be through co-disposal with oil field brines at a near-by oil field. Because of the uncertainty involved with development of this source for municipal water use, the reliability of this source is considered to be moderate. Table 4.3-1 summarizes the expected costs for the project.

Table 4.3-1
Dockum Brackish Water Desalination Project for the City of Andrews

Supply from Strategy	**950 acre-feet per year**
Total Capital Costs (2008 Prices)	$ 6,717,000
Annual Costs	$ 1,105,000
Unit costs (during amortization)	$ 1,163 per acre-foot
	$ 3.57 per 1,000 gallons
Unit Costs (after amortization)	$ 546 per acre-foot
	$ 1.68 per 1,000 gallons

Environmental Issues Associated with Desalination

There is no surface expression of water from the Dockum aquifer in Andrews County. Therefore, it is unlikely that pumping from the Dockum will result in any alteration of terrestrial habitats. The conceptual design for the project uses existing deep well injection facilities for brine disposal. A properly designed and maintained facility should have minimal environmental impact. Well field development and construction of the treatment facility should have minimal environmental impact.

Agricultural and Rural Issues of Desalination

According to TWDB records, only a very small amount of water from the Dockum aquifer is used for mining and livestock in Andrews County. No competition is expected with municipal or irrigated agricultural water users. Therefore, agricultural and rural impacts are expected to be minimal.

Other Natural Resource Issues Associated with Desalination

None identified.

Significant Issues Affecting Feasibility

Additional studies will be required to determine the suitability of this source for municipal water supply.

Other Water Management Strategies Directly Affected by Desalination

None identified.

Water Conservation Savings by the City of Andrews

A review of the city's water losses indicate the total loss is about 13 percent, of which most is attributed to paper losses (under recording by meters, unauthorized use, etc.) Based on the city's per capita water use, water conservation is a potential strategy for the City of Andrews. Table 4.3-2 compares projected demands for the City of Andrews with no conservation, with the expected conservation due to plumbing code (the default projections used in regional water planning), and using Region F water conservation criteria (see Appendix 4G). Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. These water conservation practices are intended to be guidelines. Water conservation strategies determined and implemented by the City of Andrews supersede the recommendations in this plan and are considered to meet regulatory requirements for consistency with this plan.

Quantity, Reliability and Cost of Water Conservation

The Region F recommended conservation strategies reduce the demand of the City of Andrews by 310 acre-feet per year by 2060, about 8 percent of the expected demand without conservation. The reliability of this supply is considered to be medium because of the uncertainty involved in the potential for savings and the degree to which public participation is needed to realize savings. Site specific data regarding residential, commercial, industrial and other types of use would give a better estimate of the reliable supply from this strategy. Costs range from $628 per acre foot in 2010 to $185 per acre-foot in 2060.

Environmental Issues Associated with Water Conservation

There are no identified environmental issues associated with this strategy. This strategy may have a positive impact on the environment by reducing the quantity of water needed by the city to meet future demands.

Table 4.3-2
Estimated Water Conservation Savings for the City of Andrews[a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	266	266	266	266	266	266	266
Plumbing Code	Projections	266	262	259	256	253	252	252
	Savings	0	4	7	10	13	14	14
Region F Estimate	Projections	266	255	244	238	234	231	230
	Savings (Region F practices)	0	7	15	18	20	21	22
	Savings (Total)	0	11	22	28	32	35	36
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	2,876	3,134	3,351	3,502	3,645	3,710	3,784
Plumbing Code	Projections	2,876	3,087	3,263	3,371	3,467	3,515	3,585
	Savings	0	47	88	131	178	195	199
Region F Estimate	Projections	2,876	3,003	3,072	3,131	3,202	3,228	3,275
	Savings (Region F practices)	0	84	191	240	265	287	310
	Savings (Total)	0	131	279	371	443	482	509
Costs								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Annual Costs			$52,743	$59,855	$59,813	$59,494	$57,936	$57,385
Cost per Acre-Foot [b]			$628	$313	$249	$225	$202	$185
Cost per 1,000 Gal [b]			$1.93	$0.96	$0.76	$0.69	$0.62	$0.57

a. Costs and savings based on information from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.
b Costs for implementing recommended practices. Plumbing code savings not included in unit cost calculations.

Agricultural and Rural Issues Associated with Water Conservation

Due to the limited availability of water from the Ogallala aquifer in Andrews County, the City of Andrews competes with agriculture for water. Reducing the demand on the limited Ogallala resources in the county could have positive impacts on water availability for agriculture.

Other Natural Resource Issues Associated with Water Conservation

None identified.

Significant Issues Affecting Feasibility of with Water Conservation

This strategy is based on generic procedures and may not accurately reflect the actual costs or water savings that can be achieved by the City of Andrews. Site-specific data will be required for a better assessment of the potential for water conservation by the city. Technical and financial assistance by the state may be required to implement this strategy.

Other Water Management Strategies Directly Affected by Water Conservation

This may reduce the demand for water from other water management strategies.

4.3.2 City of Ballinger

Table 4.3-3 compares the current supply and projected demand for the City of Ballinger. Demands for the city (including sales) are 1,142 acre-feet per year in 2010, increasing to 1,329 acre-feet in 2060. The city's primary sources of water are Lake Ballinger and Lake Moonen. These lakes have been heavily impacted by the recent drought. In 2003 the city completed a connection to the City of Abilene's pipeline from Ivie Reservoir and has a contract for emergency supplies from that source. This contract expired in 2008 and was not renewed. The City of Ballinger has since entered into a subcontract agreement with Millersview-Doole Water Supply Corporation (MDWSC) for water from CRMWD. This contract expires when the MDWSC contract expires in 2041. The city has also drilled several wells into a local unclassified aquifer, but has not been able to obtain a significant quantity of water from this source.

TWDB requires use of the TCEQ water availability models (WAM) to determine supplies in regional water planning.[3] Because these models are based on a perfect application of the prior appropriation system, the Colorado WAM shows essentially no yield for Lake Ballinger and Lake Moonen.[4] The reduced supplies are presented in Table 4.3-3. With implementation of a subordination strategy the current safe yield of Lakes Ballinger and Moonen is estimated to be 950 acre-feet per year in year 2000. By 2060, the yield of the reservoir would decline to 890 acre-feet per year due to sedimentation. (Supplies from the subordination strategy are discussed in Section 4.2.3.) Current supplies from the CRMWD system are estimated between 244 and

373 acre-feet per year. Using the subordination strategy supplies, needs for the City of Ballinger are 439 acre-feet per year in 2060, or about 33 percent of total demand.

Potentially Feasible Water Management Strategies for the City of Ballinger

The following strategies have been identified as potentially feasible for the City of Ballinger:

- Subordination of downstream senior water rights
- Voluntary redistribution from Hords Creek Reservoir
- Voluntary redistribution from the CRMWD system (Spence and Ivie Reservoirs)
- Reuse
- Water Conservation

Table 4.3-3
Comparison of Supply and Demand for the City of Ballinger
(Values in Acre-Feet per Year)

Supply	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
Lake Ballinger/Moonen	0	0	0	0	0	0	WAM safe yield *
Ivie Reservoir	257	244	373	357	0	0	New contract through Millerview-Doole
Other aquifer	0	0	0	0	0	0	Assuming no reliable supply
Total	*257*	*244*	*373*	*357*	*0*	*0*	
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
City of Ballinger	917	998	1,057	1,121	1,178	1,237	
Municipal sales	216	177	148	116	94	77	Rowena & N. Runnels WSC
Industrial Sales	9	10	11	12	13	15	
Total	*1,142*	*1,185*	*1,216*	*1,249*	*1,285*	*1,329*	
Subordination–Ballinger/Moonen	*940*	*930*	*920*	*910*	*900*	*890*	
Subordination - CRMWD system	*343*	*356*	*227*	*243*	*0*	*0*	
Surplus (Need)	*398*	*345*	*304*	*261*	*(385)*	*(439)*	

* Supplies from the Colorado WAM. With implementation of a subordination strategy, the 2010 supply from Lake Ballinger is estimated to be 940 acre-feet per year in 2010, declining to 890 acre-feet per year in 2060.

Although several strategies are technically feasible, the small quantity of water used by the city, the distance to other water sources, and the limited economic resources available to the community limit the number of strategies that can be implemented by the city.

Subordination of Downstream Senior Water Rights for the City of Ballinger

As previously discussed, TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, any water right in Region F with a priority date after 1926 has no firm supply. The priority dates for Lake Ballinger and Moonen are December 4, 1946 and April 7, 1980 respectively, so according to the WAM this reservoir has no reliable yield. The subordination strategy evaluates water supplies assuming the lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights holders in Region F do not make priority calls on each other. The subordination strategy is discussed in detail in Section 4.2.3. Table 4.3-4 is a summary of the supply made available from Lakes Ballinger and Moonen from the subordination strategy.

Table 4.3-4
Impact of Subordination Strategy on Lakes Ballinger and Moonen [a]
(Values in acre-feet per year)

Reservoir	Priority Date	Permitted Diversion	2010 Supply WAM Run 3	2010 Supply with Subord-ination	2060 Supply WAM Run 3	2060 Supply with Subord-ination
Lake Ballinger/Moonen	10/04/1946 4/7/1980	1,000	0	940	0	890

a Water supply is defined as the safe yield of the reservoir. Safe yield reserves one year of supply in the reservoir.

In addition, the water supply from the CRMWD system that the city of Ballinger has contracted through Millersview-Doole is assumed to be made whole through the subordination strategy (600 acre-feet per year).

The modeling for the subordination strategy was developed for planning purposes only. By adopting this strategy, neither Region F nor the Lower Colorado Region (Region K) stipulates that water rights holders will not make priority calls on junior water rights. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including the City of Ballinger and any other surface water sources considered by the city. Impacts of the subordination strategy are discussed in Section 4.2.3.

Voluntary Redistribution – Hords Creek Reservoir to Ballinger

The City of Coleman holds the water right for Hords Creek Reservoir, an 8,000 acre-foot reservoir in Coleman County. The reservoir is owned and operated by the Corps of Engineers. The City of Coleman has Certificate of Adjudication 14-1705A, authorizing storage of 7,959 acre-feet of water and diversion of 2,240 acre-feet of water per year for municipal and domestic purposes. The priority date of this right is March 23, 1946.

The City of Ballinger has discussed purchasing water from the City of Coleman and has completed a preliminary engineering feasibility report for this strategy. The proposed transmission line from Hords Creek would consist of 21 miles of 10-inch and 12-inch HDPE raw water transmission line, a pump station and a ground storage tank. The transmission line would tie into the City of Ballinger's existing 10-inch raw water line from the City of Abilene's Ivie pipeline to the city's treatment plant. The system is designed to deliver up to 800 acre-feet per year.[5] If implemented, the timing of this strategy would likely occur after the contract with MDWSC expires.

Quantity, Reliability and Cost for the Hords Creek Strategy

According to the Pecan Bayou study, Hords Creek Reservoir would have a safe yield of 380 acre-feet per year. Historical use from the reservoir averaged 750 acre-feet per year between 1956 and 1975, with significant reductions in diversions from the City of Coleman since 1975 (see Figure 4.3-1). During the last significant drought from 1997 through 2004, the City of Coleman diverted an average of 221 acre-feet per year. In 2003 water levels in the lake declined to a little more than one foot above the city's inlet structure at elevation 1878 feet msl. This indicates that the long-term reliable safe yield of Hords Creek Reservoir may be less than the 380 acre-feet per year estimated with the WAM.

Another factor impacting the reliability of Hords Creek Reservoir is the potential for a call by downstream water rights. According to the Colorado WAM, if the Colorado Basin is operated on a strict priority basis, Hords Creek Reservoir has no yield. Lake Brownwood, the first major reservoir downstream of Hords Creek, has a priority date of 1925. Other downstream senior water rights can make a priority call as well. Priority calls could significantly impact the yield of Hords Creek Reservoir.

Figure 4.3-1
Historical Water Use from Hords Creek Reservoir

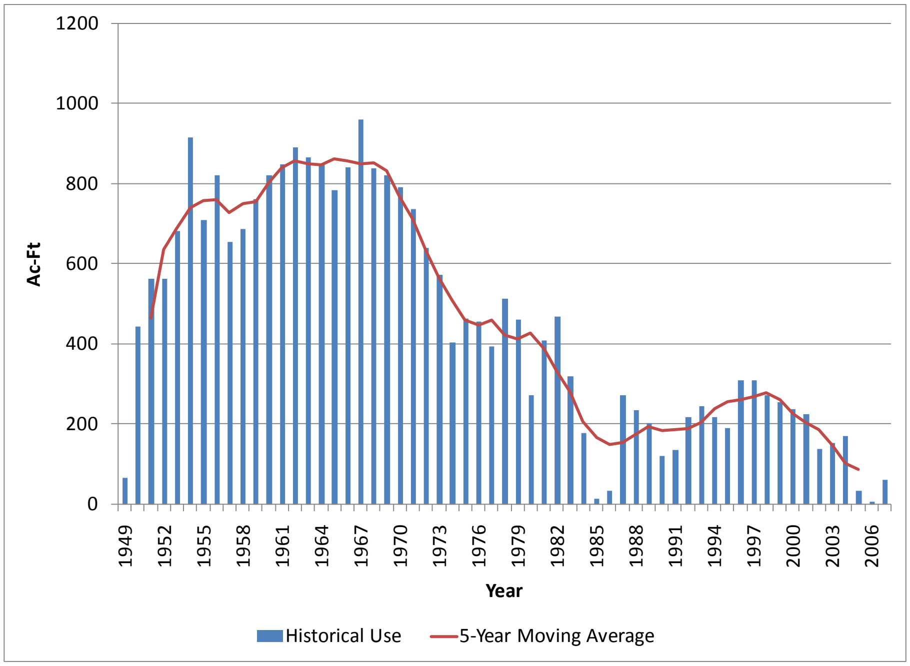
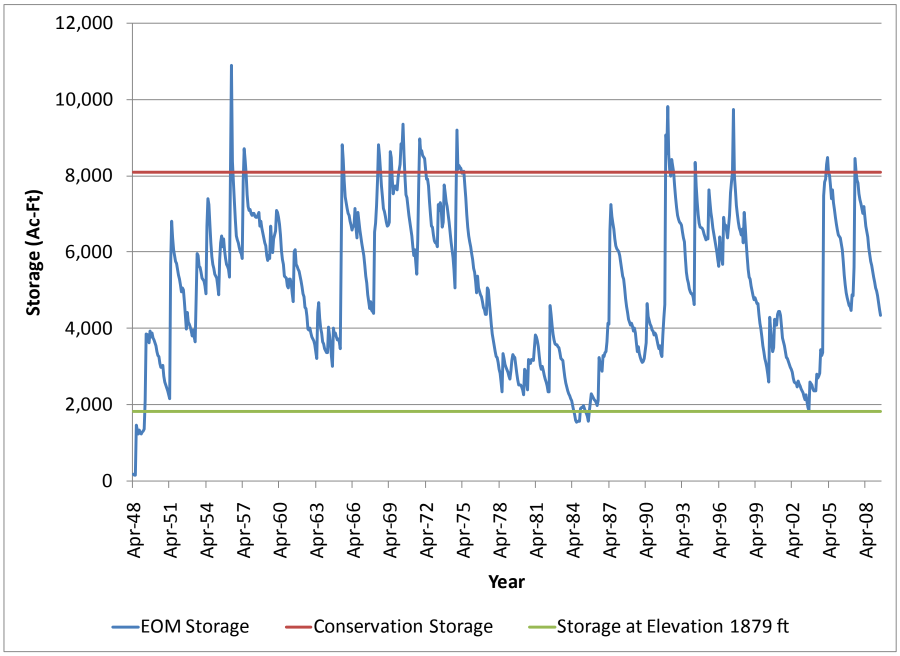


Figure 4.3-2
Historical Storage in Hords Creek Reservoir



The uncertainty regarding the reliable supply from the reservoir indicates that the reliability of this source may be low.

Total costs for this project may be found in Table 4.3-5. Detailed cost estimates may be found in Appendix 4D.

Table 4.3-5
Costs for Hords Creek Reservoir to Ballinger Pipeline

Supply from Strategy	220 acre-feet per year
Total Capital Costs (2008 Prices)	$ 6,795,000
Annual Costs	$ 739,500
Unit Costs (during amortization)	$ 3,361 per acre-foot
	$ 10.32 per 1,000 gallons
Unit Costs (after amortization)	$ 670 per acre-foot
	$ 2.06 per 1,000 gallons

Environmental Issues Associated with the Hords Creek Strategy

The proposed route is almost entirely along existing highway right-of-way, so the environmental impacts should be minimal. It can be assumed that the pipeline could be routed around sensitive environmental areas if needed.

Agricultural and Rural Issues Associated with the Hords Creek Strategy

The City of Ballinger supplies a large portion of the drinking water for rural Runnels County. Since the proposed project will make the city's water supply more reliable, it should have a positive impact on rural and agricultural interests in the area. Hords Creek Reservoir is used exclusively for drinking water, so the project will not be in conflict with existing agricultural water needs.

The City of Ballinger is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially negating the positive impacts of a more reliable water supply.

Other Natural Resource Issues Associated with the Hords Creek Strategy

None identified.

Significant Issues Affecting Feasibility of the Hords Creek Strategy

There are several significant factors that impact the feasibility of this strategy:

- A subordination or some other form of agreement from downstream senior water rights holders may be necessary to ensure a reliable supply from this source.

- A contract must be negotiated with the City of Coleman to use the water.
- A new intake structure may be required if the City of Ballinger desires to withdraw more than 200 acre-feet per year during a drought period.
- An agreement may be necessary with the Corps of Engineers, particularly if the City of Ballinger desires to access storage below the existing City of Coleman intake structure.

Other Water Management Strategies Directly Affected by the Hords Creek Strategy

Other Ballinger strategies.

Voluntary Redistribution – Purchase Water from CRMWD System

In 2003, the City of Ballinger completed a 10-mile pipeline to the West Central Texas Municipal Water District (WCTMWD) pipeline from Ivie Reservoir to the City of Abilene. Ballinger and Abilene executed an emergency supply agreement to obtain water from this source when Lake Ballinger reaches approximately 13.7 percent of capacity. The contract expired in 2008 and was not renewed. Instead the City of Ballinger has subcontracted with Millersview-Doole Water Supply Corporation (MDWSC) for 600 acre-feet per year of water of the MDWSC contract with CRMWD for water from Lake Ivie. The MDWSC contract is for 1,100 acre-feet per year from the CRMWD system and expires in 2041. After the MDWSC contract expires, it is assumed that the city will contract directly with CRMWD for enough water to prevent shortages. Water will continue to be delivered through the Abilene pipeline.

Quantity, Reliability and Cost of Water from the CRMWD System

For the purposes of this plan, it was assumed that the city would directly contract with CRMWD upon expiration of the contract with MDWSC for 600 acre-feet per year. Actual amounts will depend upon the city's projected needs and negotiations with CRMWD. The reliability of the water is considered to be high because sufficient reliable supplies are available from the Ivie Reservoir.

The cost of water is estimated to be $2.02 per 1,000 gallons, or $658 per acre-foot. The cost includes $1.47 per 1,000 gallons from the CRMWD system plus $0.55 per 1,000 gallons to cover the cost of pumping using the WCTMWD pipeline. Actual costs would be negotiated between the contracting parties.

Environmental Issues Associated with Water from the CRMWD System

This strategy calls for water from an existing source using existing infrastructure which results in minimal impacts.

Agricultural and Rural Issues Associated with Water from the CRMWD System

The City of Ballinger supplies a large portion of the drinking water for rural Runnels County. Since this strategy will make the city's water supply more reliable, it should have a positive impact on rural and agricultural interests in the area.

Other Natural Resource Issues Associated with Water from the CRMWD System

None identified.

Significant Issues Affecting Feasibility of Water from the CRMWD System

This strategy depends on the success of the city negotiating agreements with CRMWD, WCTMWD and the City of Abilene. Actual quantities and costs will be determined through these negotiations.

This strategy relies on the WCTMWD pipeline from Ivie Reservoir to the City of Abilene to deliver water to Ballinger's tie-in to the water line. Therefore, obtaining water from this source may depend on whether the City of Abilene is currently using the pipeline for its own needs.

Other Water Management Strategies Directly Affected by Water from the CRMWD System

Other strategies for the City of Ballinger.

Reuse

Reuse has been identified as a feasible strategy for the City of Ballinger. The city currently holds a wastewater discharge permit for 0.48 MGD. This evaluation is based on a generalized direct reuse strategy developed for the Region F plan. This strategy assumes that a portion of the wastewater stream will be sent through membrane filtration and reverse osmosis (RO). The treated water will then be blended with raw water prior to treatment at the city's existing water treatment plant. It is assumed that the waste stream from the reuse facility will be permitted for discharge into a local stream. If this strategy is pursued, additional site-specific studies will be required to determine actual quantities of water available, costs and potential impacts.

Quantity, Reliability and Cost of Reuse

For the City of Ballinger, it is estimated that reuse could provide as much as 200,000 gallons per day of additional supply, or 220 acre-feet per year. This supply would be very reliable. Table 4.3-6 summarizes the costs for this strategy.

Table 4.3-6
Costs of Direct Reuse of Treated Effluent by the City of Ballinger

Supply from Strategy	220 acre-feet per year
Total Capital Costs (2008 Prices)	$ 2,567,000
Annual Costs	$ 324,000
Unit Costs (during amortization)	$ 1,473 per acre-foot
	$ 4.52 per 1,000 gallons
Unit Costs (after amortization)	$ 455 per acre-foot
	$ 1.39 per 1,000 gallons

Environmental Issues Associated with Reuse

The City of Ballinger currently discharges its wastewater, and it is assumed that the waste stream from the treatment facility will be combined with unused treated effluent and discharged in a similar manner. The potential impacts of this discharge on the receiving stream will need to be evaluated prior to implementation of this strategy. If the impacts are unacceptable, an alternative method of disposal may be required. Alternative disposal methods may significantly increase the cost of the project.

Reuse would result in a reduction in the quantity of water discharged by the city. An analysis of the impacts on the receiving stream will be required in the permitting process. However, because of the relatively small amount of flow reduction associated with this reuse project, the impact is not expected to be significant.

Agricultural and Rural Issues Associated with Reuse

The City of Ballinger supplies a large portion of the drinking water for rural Runnels County. Since the proposed project will make the city’s water supply more reliable, it should have a positive impact on rural and agricultural interests in the area.

The City of Ballinger is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially negating the positive impacts of a more reliable water supply.

Other Natural Resource Issues Associated with Reuse

None identified.

Significant Issues Affecting Feasibility of Reuse

Although direct reuse for potable consumption is technically feasible, at this time there are no operating facilities within the State of Texas. Adequate monitoring and oversight will be required to protect public health and safety. There may be public resistance to direct reuse of water.

The infrastructure associated with reuse requires on-going use of water from this source to make the project cost-effective. Reuse water should not be used on an as-needed basis.

The reuse strategy assumes that both the subordination and voluntary redistribution strategies have been implemented.

Other Water Management Strategies Directly Affected by Reuse

Other strategies for the City of Ballinger.

Water Conservation Savings by the City of Ballinger

Recent drought has severely impacted the City of Ballinger. As a result, the city has actively promoted water conservation and drought management. Table 4.3-7 compares projected demands for the City of Ballinger with no conservation, with the expected conservation due to plumbing code (the default projections used in regional water planning), and using Region F water conservation criteria (see Appendix 4G). Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. These water conservation practices are intended to be guidelines. Water conservation strategies determined and implemented by the City of Ballinger supersede the recommendations in this plan and are considered to meet regulatory requirements for consistency with this plan.

Table 4.3-7
Estimated Water Conservation Saving for the City of Ballinger [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	190	190	190	190	190	190	190
Plumbing Code	Projections	190	187	183	180	177	176	176
	Savings	0	3	7	10	13	14	14
Region F Estimate	Projections	190	180	167	162	158	156	155
	Savings (Region F practices)	0	7	16	18	19	20	21
	Savings (Total)	0	10	23	28	32	34	35
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	903	932	1,037	1,116	1,203	1,271	1,335
Plumbing Code	Projections	903	917	998	1,057	1,121	1,178	1,237
	Savings	0	15	39	59	82	93	98
Region F Estimate	Projections	903	884	910	950	1,002	1,047	1,093
	Savings (Region F practices)	0	33	88	107	119	131	144
	Savings (Total)	0	48	127	166	201	224	242
Costs								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Annual Costs		$0	$21,957	$27,891	$28,586	$29,326	$29,534	$30,018
Cost per Acre-Foot [b]		$0	$665	$317	$267	$246	$225	$208
Cost per 1,000 Gal [b]		$0	$2.04	$0.97	$0.82	$0.76	$0.69	$0.64

a Costs and savings based on information from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.
b Costs for implementing recommended practices. Plumbing code savings not included in unit cost calculations.

Quantity, Reliability and Cost of Water Conservation

The Region F recommended conservation strategies reduce the demand of the City of Ballinger by 242 acre-feet per year by 2060, about 18 percent of the expected demand without conservation. Actual experience during the recent drought indicates that the potential to save water may be even greater. The reliability of this supply is considered to be medium because of the uncertainty involved in the potential for savings and the degree to which public participation is needed to realize savings. Site specific data regarding residential, commercial, industrial and other types of use would give a better estimate of the reliable supply from this strategy. Costs range from $665 per acre foot in 2010 to $208 per acre-foot in 2060.

Environmental Issues Associated with Water Conservation

There are no identified environmental issues associated with this strategy. This strategy may have a positive impact on the environment by reducing the quantity of water needed by the city to meet future demands.

Agricultural and Rural Issues Associated with Water Conservation

The City of Ballinger is not in direct competition with agriculture for water, so there are no identified agricultural issues associated with this strategy.

The City of Ballinger is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area. However, other less costly conservation strategies may be identified by the city that achieve similar results.

Other Natural Resource Issues Associated with Water Conservation

None identified.

Significant Issues Affecting Feasibility of with Water Conservation

This strategy is based on generic procedures and may not accurately reflect the actual costs or water savings that can be achieved by the City of Ballinger. Site-specific data will be required for a better assessment of the potential for water conservation by the city. Technical and financial assistance by the state may be required to implement this strategy.

The water conservation strategy assumes that both the subordination and voluntary redistribution strategies have been implemented.

Other Water Management Strategies Directly Affected by Water Conservation

Other Ballinger strategies may be impacted.

Drought Management

Region F has not identified drought strategies for the City of Ballinger other than those included in the city's water conservation and drought management plans.

Recommended Water Management Strategies for the City of Ballinger

The recommended strategies for the City of Ballinger are:

- Subordination of downstream water rights,
- Voluntary redistribution of water from Ivie Reservoir, and
- Water conservation.

Alternate strategies for the City of Ballinger include reuse and water form Hord's Creek Reservoir.Table 4.3-8 compares expected demands for the City of Ballinger and its customers to water supplies with the strategies in place. Table 4.3-9 summarizes the annual costs of the recommended strategies.

4.3.3 City of Winters

Table 4.3-10 compares the supply and demand for the City of Winters. The maximum expected demand for the city (including outside sales) is 720 acre-feet per year in 2010. Although demand for the city is expected to grow over time, outside sales are expected to diminish as rural residents are annexed into the city, sales to Runnels County WSC are shifted to the City of Ballinger, and water conservation reduces per capita demand. The city's primary source of water is Lake Winters. Lake Winters has been heavily impacted by the recent drought. Without subordination to downstream water rights, the Colorado WAM shows no yield for the reservoir.

Potentially Feasible Water Management Strategies for the City of Winters

The following strategies have been identified as potentially feasible for the City of Winters:

- Subordination of downstream senior water rights
- Reuse
- Water conservation
- Drought management

Table 4.3-8
Recommended Water Management Strategies for the City of Ballinger
(Values in Acre-Feet per Year)

Supplies	2010	2020	2030	2040	2050	2060
Lake Ballinger	0	0	0	0	0	0
CRMWD System	257	244	373	357	0	0
Subordination of downstream water rights to Lake Ballinger	940	930	920	910	900	890
Subordination of downstream rights to CRMWD System	343	356	227	243	0	0
Voluntary redistribution - new contract for water from O.H. Ivie	0	0	0	0	600	600
Total	*1,540*	*1,530*	*1,520*	*1,510*	*1,500*	*1,490*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential savings*	33	88	107	119	131	144
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Ballinger	917	998	1,057	1,121	1,178	1,237
Municipal sales	216	177	148	116	94	77
Industrial Sales	9	10	11	12	13	15
Total	*1,142*	*1,185*	*1,216*	*1,249*	*1,285*	*1,329*
Surplus (Need) without conservation	*398*	*345*	*304*	*261*	*215*	*161*
Surplus (Need) with conservation	*431*	*433*	*411*	*380*	*346*	*305*

* Does not include plumbing code savings, which are already included in the water demand projections.

Table 4.3-9
Costs of Recommended Water Management Strategies for the City of Ballinger

Strategy	Capital Costs	Annual Costs					
		2010	2020	2030	2040	2050	2060
Voluntary redistribution – new contract for water from Ivie Reservoir	$0	$0	$0	$0	$0	$394,800	$394,800
Water Conservation	$0	$21,957	$27,891	$28,586	$29,326	$29,934	$30,018
Total	*$0*	*$21,957*	*$27,891*	*$28,586*	*$29,326*	*$424,334*	*$424,818*

Note: The subordination strategy will be developed by CRMWD.

Table 4.3-10
Comparison of Supply and Demand for the City of Winters
(Values in Acre-Feet per Year)

Supply	2010	2020	2030	2040	2050	2060	Comments
Lake Winters	0	0	0	0	0	0	WAM yield *
Total	*0*	*0*	*0*	*0*	*0*	*0*	
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
City of Winters	552	561	566	571	575	591	
Municipal sales	114	89	69	49	31	0	N. Runnels WSC, etc.
Industrial Sales	54	60	65	70	74	79	
Total	*720*	*710*	*700*	*690*	*680*	*670*	
Surplus (Need)	*(720)*	*(710)*	*(700)*	*(690)*	*(680)*	*(670)*	

* Supplies from the Colorado WAM. With implementation of a subordination strategy, the supply from Lake Winters is estimated to be 720 acre-feet per year in 2010, declining to 670 acre-feet per year in 2060.

Although several strategies are technically feasible, the small quantity of water used by the city, the distance to other water sources, and the limited economic resources available to the community limit the number of strategies that can be implemented by the city.

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, most reservoirs in Region F with a priority date after 1926 do not have a firm or safe yield. The priority date of Lake Winters is December 18, 1944, so the WAM shows no yield for the reservoir. This result is largely due to the assumptions used in the Colorado WAM.

In order to address water availability issues resulting from the Colorado WAM model, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights in Region F do not make priority calls on each other. The subordination strategy is discussed in Section 4.2.3. Table 4.3-11 is a summary of the impacts of the subordination strategy on Lake Winters.

The joint modeling between the two regions was conducted for planning purposes only. Neither Region F nor the Lower Colorado Region mandates the adoption of this strategy by individual water right holders. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including the City of Winters.

Table 4.3-11
Impact of Subordination Strategy on Lake Winters [a]
(Values in acre-feet per year)

Reservoir	Priority Date	Permitted Diversion	2010 Supply WAM Run 3	2010 Supply with Subord-ination	2060 Supply WAM Run 3	2060 Supply with Subord-ination
Lake Winters	12/18/1944	1,360	0	720	0	670

a Water supply is defined as the safe yield of the reservoir. Safe yield reserves one year of supply in the reservoir.

Impacts of the subordination strategy are discussed in Section 4.2.3.

Reuse

Reuse has been identified as a feasible strategy for the City of Winters. The city currently holds a wastewater discharge permit for 0.49 MGD. Treated effluent is also authorized for irrigation. This evaluation is based on a generalized direct reuse strategy developed for the Region F plan. This strategy assumes that a portion of the wastewater stream will be sent through membrane filtration and reverse osmosis (RO). The treated water will then be blended with raw water prior to treatment at the city's existing water treatment plant. It is assumed that the waste stream from the reuse facility will be combined with the remaining treated effluent and discharge into a local stream or disposed of using land application. If this strategy is pursued, additional site-specific studies will be required to determine actual quantities of water available, costs and potential impacts.

Quantity, Reliability and Cost of Reuse by the City of Winters

For the City of Winters, it is estimated that reuse could provide as much as 100,000 gallons per day of additional supply, or 110 acre-feet per year. This supply would be very reliable. Table 4.3-12 summarizes the costs for this strategy.

Table 4.3-12
Direct Reuse of Treated Effluent by the City of Winters

Supply from Strategy	**110 acre-feet per year**
Total Capital Costs (2008 Prices)	$ 2,158,000
Annual Costs	$ 258,000
Unit Costs (during amortization)	$ 2,345 per acre-foot
	$ 7.20 per 1,000 gallons
Unit Costs (after amortization)	$ 636 per acre-foot
	$ 1.95 per 1,000 gallons

Environmental Issues Associated with Reuse by the City of Winters

The City of Winters currently discharges to a receiving stream and irrigates with its treated wastewater. This strategy assumes that reject from advanced treatment will be blended with the treated effluent that is not reused and disposed of in a similar manner. The potential impacts of this discharge on the receiving stream will need to be evaluated prior to implementation of this strategy. If the impacts are unacceptable, an alternative method of disposal may be required. Alternative disposal methods may significantly increase the cost of the project.

Agricultural and Rural Issues Associated with Reuse by the City of Winters

Reuse may make less water available for irrigation by diverting part of the treated effluent currently use for irrigation.

The City of Winters supplies a large portion of the drinking water for rural Runnels County. Since the proposed project will make the city's water supply more reliable, it should have a positive impact on rural and agricultural interests in the area

The City of Winters is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially offsetting the positive impacts of a more reliable water supply.

Other Natural Resource Issues Associated with Reuse by the City of Winters

None identified.

Significant Issues Affecting Feasibility of Reuse by the City of Winters

Although direct reuse for potable consumption is technically feasible, at this time there are no operating facilities within the State of Texas. Adequate monitoring and oversight will be required to protect public health and safety. There may be public resistance to direct reuse of water.

The infrastructure associated with reuse requires on-going use of water from this source to make the project cost-effective. Reuse water should not be used on an as-needed basis.

Other Water Management Strategies Directly Affected by Reuse

Other strategies for the City of Winters may be impacted.

Water Conservation

Using the Region F suite of water conservation practices, it is estimated that the City of Winters can reduce water demand by as much as 20 percent. Additional information on Region F recommended water conservation practices may be found in Appendix 4G.

Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. The water conservation practices in this plan are guidelines. Region F considers water conservation strategies determined and implemented by the City of Winters to supersede the recommendations in this plan and meet regulatory requirements for consistency with this plan.

Quantity, Reliability and Cost of Water Conservation

Table 4.3-13 summarizes the estimated water savings and costs associated with the recommended Region F water conservation practices. Based on this evaluation, by 2060 up to 129 acre-feet of water per year could be saved, a reduction of almost 20 percent. The city's experience during the recent drought indicates that more water could potentially be saved. In 2006, the most recent year for which per capita water use data are available, the city had a per capita demand of 147 gpcd. The estimated per capita water demand in 2060 using the Region F criteria is 136 gpcd. The reliability of water conservation is considered to be medium due to the uncertainty of the long-term savings due to implementation of water conservation strategies.

Table 4.3-13
Estimated Water Conservation Savings for the City of Winters [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	102	170	170	170	170	170	170
Plumbing Code	Projections	102	167	164	161	158	156	156
	Savings	0	3	6	9	12	14	14
Region F Estimate	Projections	170 [b]	161	148	143	139	137	136
	Savings (Region F Practices)	0	6	16	18	19	19	20
	Savings (Total)	0	9	22	27	31	33	34
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	548	562	582	597	614	627	644
Plumbing Code	Projections	548	552	561	566	571	575	591
	Savings	0	10	21	31	43	52	53
Region F Estimate	Projections	548	531	506	503	504	504	515
	Savings (Region F Practices)	0	21	55	63	67	71	76
	Savings (Total)	0	31	76	94	110	123	129
Costs [c]								
Annual Costs			$14,796	$19,808	$19,527	$19,265	$18,900	$18,843
Cost per Acre-Foot			$705	$360	$310	$288	$266	$248
Cost per 1,000 Gal			$2.16	$1.11	$0.95	$0.88	$0.82	$0.76

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.
b The City of Winters was under water use restriction in 2000. Base year 2000 demands were extrapolated from historical water use from 1995 to 1997.
c Costs for implementing Region F recommended practices. Costs of implementing plumbing code not included.

Environmental Issues Associated with Water Conservation

Most of the water used by the City of Winters is expected to come from Lake Winters. Conserved water will remain in the reservoir, so there will be little if any impact on instream flows and over-banking flows.

Agricultural and Rural Issues Associated with Water Conservation

Water conservation by the City of Winters will not make more water available for agriculture.

The City of Winters is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially offsetting the positive impacts of water conservation.

Other Natural Resource Issues Associated with Water Conservation

None identified.

Significant Issues Affecting Feasibility of Water Conservation

This strategy is based on a generalized assessment of water conservation practices and may not accurately reflect the actual costs or water savings that can be achieved by the City of Winters. Site-specific data will be required for a better assessment of the potential for water conservation by the city. Technical assistance and funding by the state may be required to implement this strategy.

Other Water Management Strategies Directly Affected by Water Conservation

None identified.

Drought Management

The City of Winters has effectively used drought management to control demand during times of drought. Strategies are specified in the city's water conservation and drought contingency plan. Region F has not identified additional drought management strategies for the City of Winters.

Recommended Strategies for the City of Winters

Although subordination of downstream water rights will make sufficient supplies available to meet projected needs, the City of Winters may want to consider another strategy to increase the reliability of their water supply. While several strategies are feasible, all of the alternatives are costly and would strain the financial resources of the community. Region F recommends that the city consider reuse and water conservation as long-term alternatives to increase the reliability of the city's water supply. Table 4.3-14 is a comparison of supply to demand with the recommended strategies in place. Table 4.3-15 summarizes the expected costs for these strategies.

Table 4.3-14
Recommended Water Management Strategies for the City of Winters
(Values in Acre-Feet per Year)

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Lake Winters	0	0	0	0	0	0
Subordination of downstream water rights to Lake Winters	720	710	700	690	680	670
Direct Reuse	0	0	0	110	110	110
Total	*720*	*710*	*700*	*800*	*790*	*780*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential savings*	21	55	63	67	71	76
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Winters	552	561	566	571	575	591
Municipal sales	114	89	69	49	31	0
Industrial Sales	54	60	65	70	74	79
Total	720	710	700	690	680	670
Surplus (Need) without conservation	*0*	*0*	*0*	*110*	*110*	*110*
Surplus (Need) with conservation	*21*	*55*	*63*	*177*	*181*	*186*

* Does not include plumbing code savings, which are already included in the water demand projections.

Table 4.3-15
Costs of Recommended Water Management Strategies for the City of Winters

Strategy	**Capital Costs**	**Annual Costs**					
		2010	**2020**	**2030**	**2040**	**2050**	**2060**
Direct Reuse	$2,158,000	$0	$0	$0	$258,000	$258,000	$69,960
Water Conservation		$14,796	$19,808	$19,527	$19,265	$18,900	$18,843
Total	$2,158,000	$14,796	$19,808	$19,527	$277,265	$276,900	$88,803

Note: There are no costs developed for the subordination strategy.

4.3.4 City of Bronte

Table 4.3-16 compares the supply and demand for the City of Bronte. The city of Bronte is expected to have a maximum projected demand of about 258 acre-feet per year. The population of the city is expected to remain relatively stable over the next 50 years. Water demand projections decline over time due to conservation.

In the past the city relied exclusively on water from Oak Creek Reservoir, which was heavily impacted by the recent drought. As a result, the city developed a groundwater supply from ten wells in the vicinity of Oak Creek Reservoir. The groundwater is delivered to the city in the Oak Creek pipeline. The groundwater supply is from an unclassified aquifer and the reliability of the source is not well known. Collectively, the well field has a capacity of about 0.7 million gallons per day (MGD). For the purposes of this plan, it was assumed that this aquifer could produce up to 250 acre-feet per year in 2010 with 5 percent reductions each following decade.

Table 4.3-16
Comparison of Supply and Demand for the City of Bronte
(Values in Acre-Feet per Year)

Supply	2010	2020	2030	2040	2050	2060	Comments
Oak Creek Reservoir	0	0	0	0	0	0	WAM shows no yield
Other aquifer	250	238	226	215	204	194	
Total	*250*	*238*	*226*	*215*	*204*	*194*	
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
City of Bronte	245	258	254	250	249	249	No outside sales
Total	*245*	*258*	*254*	*250*	*249*	*249*	
Surplus (Need)	*5*	*(20)*	*(28)*	*(35)*	*(45)*	*(55)*	

Without subordination to downstream water rights, Oak Creek Reservoir has no yield. Groundwater wells are sufficient for the near-term, but the long-term reliability of this source is unknown. While the city is currently using the infrastructure from Oak Creek Reservoir to move groundwater, the pipeline needs rehabilitation to more efficiently transport the water and reduce losses. The City is also planning to provide residential water service to residents around Oak Creek Reservoir and possibly develop joint water supply projects with Robert Lee and Coke County Rural water System. The demands of the residents around Oak Creek Reservoir would be in addition to the projected need shown in Table 4.3-16.

Potentially Feasible Water Management Strategies

To meet the projected need for the City of Bronte and potential additional customers, the city is exploring an array of water management strategies. The following potentially feasible strategies have been identified for the City of Bronte:

- Subordination of downstream water rights
- Reuse
- Rehabilitation of Oak Creek pipeline
- Develop additional groundwater around Oak Creek Reservoir
- Develop groundwater southeast of town
- Water Conservation
- Drought Management

Brush control and precipitation enhancement are discussed in Section 4.9.

The City of Bronte is currently conducting a water supply study in conjunction with the City of Robert Lee and Coke County Rural Water System. This study was initiated in September 2010 and was not available for inclusion for this plan. Other water management strategies that will be evaluated as part of this study include purchasing treated water from San Angelo, increasing the amount of water taken from Oak Creek Reservoir, purchasing water from Lake Brownwood, and developing joint treatment and distribution to serve the participants. Although several of these strategies were evaluated for the 2006 Region F Water Plan, the small quantity of water used by the city, the distance to other water sources and the limited economic resources available to the community limit the strategies that can be implemented. This cooperative study may identify more cost-effective strategies to meet the needs in Coke County.

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, any water right in Region F with a priority date after 1926 has no firm supply. The priority date for Oak Creek Reservoir is April 27, 1949, so according to the WAM Oak Creek Reservoir has no yield. In order to address water availability issues in the Colorado Basin, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights holders in Region F do not make priority calls on each other. The subordination strategy is discussed in detail in Section 4.2.2.

The joint modeling between the two regions was conducted for planning purposes only. By adopting this strategy, neither Region F nor the Lower Colorado Region stipulates that water rights will not make priority calls on junior water rights. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves. Oak Creek Reservoir is owned by the City of Sweetwater. For the purposes of this plan, it will be assumed that, with subordination, the City of Bronte will be able to obtain 129 acre-feet per year during drought from the reservoir.

Impacts of the subordination strategy are discussed in Section 4.2.3.

Reuse

Reuse has been identified as a feasible strategy for the City of Bronte. The city currently uses land application for disposal of treated effluent. This evaluation is based on a generalized direct reuse strategy developed for the Region F plan. This strategy assumes that a portion of the wastewater stream will be sent through membrane filtration and reverse osmosis (RO). The treated water will then be blended with raw water prior to treatment at the city's existing water treatment plant. It is assumed that the waste stream from the reuse facility will be combined with unused treated effluent and discharged into a local stream or use existing land application facilities. If this strategy is pursued, additional site-specific studies will be required to determine actual quantities of water available, costs and potential impacts.

Quantity, Reliability and Cost of Reuse

For the City of Bronte, it is estimated that reuse could provide as much as 100,000 gallons per day of additional supply, or 110 acre-feet per year. This supply would be very reliable. Table 4.3-17 summarizes the costs for this strategy.

Table 4.3-17
Direct Reuse of Treated Effluent by the City of Bronte

Supply from Strategy	110 acre-feet per year
Total Capital Costs (2008 Prices)	$ 2,158,000
Annual Costs	$ 258,000
Unit Costs (during amortization)	$ 2,345 per acre-foot
	$ 7.20 per 1,000 gallons
Unit Costs (after amortization)	$ 636 per acre-foot
	$ 1.95 per 1,000 gallons

Environmental Issues Associated with Reuse

The City of Bronte currently uses land application to dispose of treated effluent. This strategy assumes that the waste stream from the treatment facility will be blended with unused treated effluent and disposed of in a similar fashion. The potential impacts of land application may need to be evaluated prior to implementation of this strategy. If the impacts are unacceptable, an alternative method of disposal may be required. Alternative disposal methods may significantly increase the cost of the project.

Agricultural and Rural Issues Associated with Reuse

Less treated wastewater may be available for irrigation with implementation of this strategy.

The City of Bronte is a rural community. Like other water supply strategies, the high cost of this strategy may have an adverse impact on the limited financial resources of the city and the surrounding rural community.

Other Natural Resource Issues Associated with Reuse

None identified.

Significant Issues Affecting Feasibility of Reuse

Although direct reuse for potable consumption is technically feasible, at this time there are no such operating facilities within the State of Texas. Adequate monitoring and oversight will be required to protect public health and safety. There may be public resistance to direct reuse of water for municipal purposes.

The infrastructure associated with reuse requires on-going use of water from this source to make the project cost-effective. Reuse water should not be used on an as-needed basis.

Other Water Management Strategies Directly Affected by Reuse

Other strategies for the City of Bronte.

Rehabilitation of Oak Creek Pipeline

The City of Bronte has a 13-mile 8-inch and 10-inch pipeline to Oak Creek Reservoir. This pipeline is approximately 55 years old and in need of rehabilitation. All but approximately five miles of the pipeline has been replaced or rehabilitated. The remaining five miles of pipe need to be replaced. The proposed strategy includes a new 50,000 gallon raw water ground storage tank.

Quantity, Reliability and Cost of Pipeline Rehabilitation

The pipeline has a capacity of 0.5 mgd and can deliver the city's projected demands. Table 4.3-18 is a summary of the expected costs of the project. To facilitate comparison with other strategies, the costs presented in this plan assume that the city will finance the entire project at one time. The city may elect to spread out the costs of the project over a longer period of time. Routine operation and maintenance costs are not included in the costs after the amortization period because these will not be new costs for the city.

Table 4.3-18
Rehabilitation of Pipeline from Oak Creek Reservoir to Bronte

Supply from Strategy	**0 acre-feet per year**
Total Capital Costs (2008 Prices)	$ 1,364,900
Annual Costs	$ 23,800
Unit Costs	Not applicable

Environmental Issues Associated with Pipeline Rehabilitation

Environmental impacts are expected to be minimal because this is rehabilitation of an existing project.

Agricultural and Rural Issues Associated with Pipeline Rehabilitation

Rehabilitation may temporarily impact agricultural activities.

Other Natural Resource Issues Associated with Pipeline Rehabilitation

None identified.

Significant Issues Affecting Feasibility of Pipeline Rehabilitation

The most significant factor affecting rehabilitation of the pipeline is funding of the project. The city plans to use block grants to implement this strategy.

Other Water Management Strategies Directly Affected by Pipeline Rehabilitation

None identified.

New Water Wells located Southeast of Bronte

The city is evaluating potential alluvium groundwater located southeast of the city for future water supplies. This source is currently used for agricultural purposes and may require advanced treatment for municipal use. To provide approximately 300 acre-feet per year, three new wells would need to be drilled. These wells would produce water from an unclassified aquifer approximately 200 feet below the surface.

Quantity, Reliability and Cost of New Water Wells

The quantity and reliability of water from this source is not well known. Historical agricultural use indicates that the alluvium may be a viable source but high sulfides will require advanced treatment. For this plan, the three new wells are assumed to supply an additional 300 acre-feet per year. The reliability of the supply is considered to be medium because of the potential competing demands. Table 4.3-19 summarizes the expected costs for the city.

Table 4.3-19
Costs for New Water Wells for the City of Bronte

Supply from Strategy	350 acre-feet per year
Total Capital Costs (2008 Prices)	$5,723,000
Annual Costs	$609,000
Unit Costs (before amortization)	$1,740 per acre-foot
	$5.34 per 1,000 gallons
Unit Costs (after amortization)	$314 per acre-foot
	$0.96 per 1,000 gallons

Environmental Issues Associated with New Water Wells

The aquifer is a proven groundwater source for agricultural purposes. However, the long-term water quality is unknown. At this time, it is assumed that the discharge from the advanced treatment facility can be discharged to the City's wastewater treatment plant or land applied. If these options are not available to Bronte, then additional facilities will be needed for the treatment plant discharge. Environmental issues associated with the treatment facility would be addressed during permitting.

Agricultural and Rural Issues Associated with New Water Wells

This source is currently used for agricultural purposes. This strategy would reduce the amount of water currently available to agricultural users. It is assumed that the transfer of water rights will be between a willing buyer and willing seller, and there would be minimal impacts to agricultural users.

The City of Bronte is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially offsetting the positive impacts of a more reliable water supply.

Other Natural Resource Issues Associated with New Water Wells

None identified.

Significant Issues Affecting Feasibility of New Water Wells

Because the long-term reliability and quality of this supply is unknown, the city may need to develop other alternatives to meet long-term needs. Funding construction of these new wells will be a significant strain on the financial resources of the city.

Other Water Management Strategies Directly Affected by New Water Wells

Other strategies for the City of Bronte may be impacted.

New Water Wells at Oak Creek Reservoir and Water Service to Local Residents

The city is considering providing water service to resident around Oak Creek Reservoir. This would include developing new groundwater wells near the lake and developing a distributions system to serve approximately 300 homes. The most likely location for the new wells would be near the city's existing wells near Oak Creek Reservoir. These wells produce water from an unclassified aquifer approximately 275 to 300 feet below the surface.

For the purposes of this plan, it is assumed that three new wells and approximately three miles of 6-inch transmission pipeline would be needed. Additional distribution pipelines will likely be needed to serve the local community. This is considered part of the service distribution system and is not included in this plan.

Quantity, Reliability and Cost of Water Service at Oak Creek Reservoir

The quantity and reliability of water from this source is not well known. The city has only recently begun intensive use of the aquifer. For this plan, the three new wells are assumed to supply an additional 150 acre-feet per year. The reliability of the supply is considered to be medium to low because the source has not been in use for an extended period of time and the reliability is unknown. Table 4.3-20 summarizes the expected costs for the city.

Table 4.3-20
Costs for Water Service at Oak Creek Reservoir for the City of Bronte

Supply from Strategy	150 acre-feet per year
Total Capital Costs (2002 Prices)	$2,970,000
Annual Costs	$309,000
Unit Costs (before amortization)	$2,060 per acre-foot
	$6.32 per 1,000 gallons
Unit Costs (after amortization)	$333 per acre-foot
	$1.02 per 1,000 gallons

Environmental Issues Associated with Water Service at Oak Creek Reservoir

There are no significant environmental issues associated with this strategy. Water quality is adequate for municipal use. There are no subsidence districts in Region F, and it is unlikely that water production for local residents will result in subsidence.

Agricultural and Rural Issues Associated with Water Service at Oak Creek Reservoir

No direct agricultural impacts have been identified for this strategy.

Other Natural Resource Issues Associated with Water Service at Oak Creek Reservoir

None identified.

Significant Issues Affecting Feasibility of Water Service at Oak Creek Reservoir

Because the reliability of this supply is unknown, the city may need to develop other alternatives to meet long-term needs. Funding construction of these new wells will be a significant strain on the financial resources of the city and/or local residents around the lake.

Other Water Management Strategies Directly Affected by Water Service at Oak Creek Reservoir

Long-term supply for the City of Bronte from existing wells may be impacted as more demand is placed on the aquifer.

Water Conservation

The City of Bronte has actively promoted water conservation and drought management during the recent drought. Peak demands have been reduced from as much as 760,000 gallons per day to about 600,000 gallons per day. The city uses mail outs, newspaper articles, public education and word-of-mouth to distribute information on water conservation. Several sample xeriscape projects have been implemented in the city with assistance from Texas A&M University. School education programs targeting grades 5 and 6 are used as well.

Table 4.3-21 compares projected demands for the City of Bronte with no conservation, with the expected conservation due to plumbing code (the default projections used in regional water planning), and using Region F water conservation criteria (see Appendix 4G).

Quantity, Reliability and Cost of Water Conservation

Using the Region F criteria, conservation can reduce the demand for the City of Bronte by 68 acre-feet per year, about 25 percent of the expected demand for the city without conservation. The reliability of this supply is considered to be medium because of the uncertainty involved in the analysis used to calculate the savings. Site specific data regarding residential, commercial, industrial and other types of use would give a better estimate of the reliable supply from this strategy. Table 4.3-21 summarizes the estimated costs of implementing the Region F conservation practices. Costs range from over $334 per acre foot in 2010 to $188 per acre-foot in 2060.

Environmental Issues Associated with Water Conservation

There are no identified environmental issues associated with this strategy. This strategy may have a positive impact on the environment by reducing the quantity of water needed by the city to meet future demands.

Table 4.3-21
Estimated Water Conservation Savings for the City of Bronte [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	192	208	208	208	208	208	208
Plumbing Code	Projections	192	205	202	199	196	195	195
	Savings	0	3	6	9	12	13	13
Region F Estimate	Projections	208 [b]	192	167	161	158	156	155
	Savings (Region F practices)	0	13	35	38	38	39	40
	Savings (Total)	0	16	41	47	50	52	53
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	251	248	266	266	266	266	266
Plumbing Code	Projections	251	245	258	254	250	249	249
	Savings	0	3	8	12	16	17	17
Region F Estimate	Projections	251	229	213	206	202	199	198
	Savings (Region F practices)	0	16	45	48	48	50	51
	Savings (Total)	0	19	53	60	64	67	68
Costs [c]								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Annual Costs			$5,340	$10,440	$10,196	$9,958	$9,725	$9,580
Cost per Acre-Foot			$334	$232	$212	$207	$195	$188
Cost per 1,000 Gal			$1.03	$0.71	$0.65	$0.64	$0.60	$0.58

a Costs and savings based on information from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.

b The City of Bronte was under restrictions in 2000. Base year 2000 demands were extrapolated from historical water use between 1997 and 1999.

c Costs for implementing recommended practices. Costs of implementing plumbing code savings not included in cost calculations.

Agricultural and Rural Issues Associated with Water Conservation

The City of Bronte is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources. However, the city may identify other less costly conservation strategies that achieve similar results.

Other Natural Resource Issues Associated With Water Conservation

None identified.

Significant Issues Affecting Feasibility of Water Conservation

This strategy is based on generic procedures and may not accurately reflect the actual costs or water savings that can be achieved by the City of Bronte. Site-specific data will be required for a better assessment of the potential for water conservation by the city. Technical and financial assistance by the state may be required to implement this strategy.

Other Water Management Strategies Directly Affected by Water Conservation

If water conservation is successful in reducing water demand, other water management strategies may be delayed or become unnecessary.

Drought Management

Region F has not identified specific drought management strategies for the City of Bronte. Drought management will be conducted through the city's drought contingency plan.

Recommended Strategies for the City of Bronte

The recommended strategies for the City of Bronte are: 1) subordination of downstream water rights, 2) rehabilitation of the Oak Creek pipeline, and 3) water conservation. The recommended alternate strategies include: 1) new wells near Oak Creek reservoir and water service to local residents and 2) new wells southeast of Bronte with advanced treatment. Other water management strategies will continue to be evaluated by Bronte and its consultants. Should these strategies prove to be cost effective and reliable, the city may chose to undertake additional strategies to provide for its customers and other water users in Coke County. Table 4.3-22 compares expected demands for the City of Bronte to water supplies with the strategies in place. Table 4.3-23 summarizes the annual costs of the recommended strategies.

Table 4.3-22
Recommended Water Management Strategies for the City of Bronte
(Values in Acre-Feet per Year)

Supplies	2010	2020	2030	2040	2050	2060
Oak Creek Reservoir	0	0	0	0	0	0
Subordination/Pipeline Rehab	129	129	129	129	129	129
Existing Water Wells	250	238	226	215	204	194
Total	*379*	*367*	*355*	*344*	*333*	*323*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential savings*	16	45	48	48	50	51
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Bronte	245	258	254	250	249	249
Surplus (Need) without conservation	*134*	*109*	*101*	*94*	*84*	*74*
Surplus (Need) with conservation	*150*	*154*	*149*	*142*	*134*	*125*

* Does not include plumbing code savings, which are already included in the water demand projections.

Table 4.3-23
Costs of Recommended Water Management Strategies for the City of Bronte

Strategy *	Capital Costs	Annual Costs					
		2010	2020	2030	2040	2050	2060
Rehabilitation of the Oak Creek pipeline	$1,364,900	$23,800	$23,800	$ 0	$ 0	$ 0	$ 0
Water Conservation	$ 0	$5,340	$10,440	$10,196	$9,958	$9,725	$9,580
Total	*$1,364,900*	*$29,140*	*$34,240*	*$10,196*	*$9,958*	*$9,725*	*$9,580*

* The subordination strategy will be implemented by the City of Sweetwater

4.3.5 City of Robert Lee

Table 4.3-24 compares the supply and demand for the City of Robert Lee. The City of Robert Lee is expected to have a maximum projected demand of about 450 acre-feet per year, including municipal sales. The city has three sources of water: E.V. Spence Reservoir (owned and operated by CRMWD), Mountain Creek Reservoir (owned by the Upper Colorado River Authority and operated by the city) and a small run-of-the-river right on the Colorado River. Although Spence Reservoir has adequate supplies for the city, the water has historically been high in chlorides, dissolved solids and sulfates. Mountain Creek Reservoir, which is a very small reservoir, is an important supply source for Robert Lee when supplies are available because it has better water quality. The WAM shows a small reliable supply from the city's run-of-the-river right, but in practice this supply is not reliable and is used infrequently.

The city uses a floating pump in Spence Reservoir and a pump and intake structure in Mountain Creek Reservoir. The intake in Mountain Creek Reservoir limits the ability of the city to obtain water when the reservoir is low. In addition, due to operational constraints of the water treatment plant, the city's water treatment plant is near capacity. An additional 0.5 mgd of capacity would be desirable to prevent overloading of the treatment plant.

Table 4.3-24
Comparison of Supply and Demand for the City of Robert Lee
(Values in Acre-Feet per Year)

Supply	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
Colorado River	7	7	7	7	7	7	Underflow right
Mountain Creek Reservoir	0	0	0	0	0	0	No WAM yield
Spence Reservoir	333	296	435	403	384	357	Supply changes as other CRMWD contracts expire
Total	*340*	*303*	*442*	*410*	*391*	*364*	
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
City of Robert Lee	351	346	342	338	336	336	
Municipal Sales	105	97	95	92	91	91	Coke Co WSC et al.
Total	*456*	*443*	*437*	*430*	*427*	*427*	
Surplus (Need)	*(116)*	*(140)*	*5*	*(20)*	*(36)*	*(63)*	

Potentially Feasible Water Management Strategies

The City of Robert Lee is participating in a water supply with the City of Bronte and Coke County Rural water System. This study will be evaluating potential cooperative strategies to provide reliable supplies to water users in Coke County. At this time, this study was not available for inclusion in the regional water plan. Based on previous planning studies and local input, the following potentially feasible water management strategies have been identified for the City of Robert Lee:

- Subordination of downstream water rights
- Reuse
- Desalination of Spence Reservoir water
- New floating pump in Mountain Creek Reservoir
- Expansion of water treatment plant and storage facilities
- New groundwater from the local alluvium aquifer
- Purchase water from San Angelo using rehabilitated Spence pipeline
- Water Conservation
- Drought Management

Brush control and precipitation enhancement are discussed in Section 4.9.

Although several other strategies are technically feasible, the small quantity of water used by the city, the distance to other water sources, and the limited economic resources available to the community limit the number of strategies that can be implemented by the city.

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, any water right in Region F with a priority date after 1926 has little or no firm supply. The priority date of Mountain Creek Reservoir is December 16, 1949 and the priority date of Spence Reservoir is August 17, 1964. According to the WAM, Mountain Creek Reservoir has no yield and Spence Reservoir has a safe yield of 560 acre-feet per year.

In order to address water availability issues in the Colorado Basin, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights holders in Region F do not make priority calls on each other. The subordination strategy is discussed in detail in Section 4.2.3.

The joint modeling between the two regions was conducted for planning purposes only. By adopting this strategy, neither Region F nor the Lower Colorado Region stipulates that water rights will not make priority calls on junior water rights. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves. Mountain Creek Reservoir is owned by the

Upper Colorado River Authority, and Spence Reservoir is owned by CRMWD. For the purposes of this plan, it will be assumed that Mountain Creek Reservoir will be overdrafted during normal to wet years and will have no supply during drought. With subordination, the City of Robert Lee should be able to obtain sufficient water from Spence Reservoir to meet projected demands.

Impacts of the subordination strategy are discussed in Section 4.2.3.

Reuse

Reuse has been identified as a feasible strategy for the City of Robert Lee. The city is currently authorized to both discharge and irrigate with treated effluent. This evaluation is based on a generalized direct reuse strategy developed for the Region F plan. This strategy assumes that a portion of the wastewater stream will be sent through membrane filtration and reverse osmosis (RO). The treated water will then be blended with raw water from either Spence Reservoir or Mountain Creek Reservoir prior to treatment at the city's existing water treatment plant. It is assumed that the waste stream from the reuse facility will be permitted for discharge along with unused treated effluent into a local stream or for land application. If this strategy is pursued, additional site-specific studies will be required to determine actual quantities of water available, costs and potential impacts.

Quantity, Reliability and Cost of Reuse

For the City of Robert Lee, it is estimated that reuse could provide as much as 100,000 gallons per day of additional supply, which is about 25 percent of the maximum expected demand for the city and its customers. This supply is considered very reliable. Table 4.3-25 summarizes of the costs for this strategy.

Environmental Issues Associated with Reuse

This strategy assumes that the City of Robert Lee will discharge the waste stream from treatment along with the remaining treated effluent or use existing land application facilities. The potential impacts of discharge will need to be evaluated prior to implementation of this strategy. If the impacts are unacceptable, an alternative method of disposal may be required, which may significantly increase the cost of the project.

Because of the relatively small amount of treated effluent currently discharged by the city, the strategy is not expected to have a significant impact on the volume of instream flows or over-bank flows. The strategy will have no impact on the Colorado estuary or Matagorda Bay.

Table 4.3-25
Direct Reuse of Treated Effluent for the City of Robert Lee

Supply from Strategy	110 acre-feet per year
Total Capital Costs (2008 Prices)	$ 2,158,000
Annual Costs	$ 258,000
Unit Costs (during amortization)	$ 2,345 per acre-foot
	$ 7.20 per 1,000 gallons
Unit Costs (after amortization)	$ 636 per acre-foot
	$ 1.95 per 1,000 gallons

Agricultural and Rural Issues Associated with Reuse

Reuse of treated wastewater currently used for land application may make less water available for irrigated agriculture.

The City of Robert Lee is a rural community. Like other water supply strategies, the high cost of this strategy may have an adverse impact on the limited financial resources of the city and the surrounding rural community.

Other Natural Resource Issues Associated with Reuse

None identified.

Significant Issues Affecting Feasibility of Reuse

Although direct reuse for potable consumption is technically feasible, at this time there are no operating facilities within the State of Texas. Adequate monitoring and oversight will be required to protect public health and safety. There may be public resistance to direct reuse of water.

Another significant issue is the on-going use of water from this strategy. The operating costs of the project are relatively high. On-going maintenance and operation of the plant are necessary for the project to be cost-effective. If this project is implemented, it should be considered an integral part of the city’s supply and not used on an as-needed basis.

Other Water Management Strategies Directly Affected by Reuse

Other strategies for the City of Robert Lee.

Desalination of Spence Reservoir Water

The city currently obtains 75 percent or more of its water from Spence Reservoir. Historically, water from Spence Reservoir has been high in chlorides, sulfates and dissolved solids. Although water quality has improved with recent inflows, the city may need to consider advanced treatment of Spence water to improve the water quality available to its citizens.

Quantity, Reliability and Cost of Spence Reservoir Desalination

For the purposes of this plan, this strategy assumes that the city would construct an intake structure in Lake Spence to replace its existing floating pump and a reverse osmosis (RO) facility capable of producing up to 1.0 mgd of treated water. This would give the city sufficient capacity to meet most of its projected demand from Spence Reservoir. The reliability of the water is considered to be high. Table 4.3-26 contains a cost summary for this strategy.

Table 4.3-26
Desalination of Spence Reservoir Water by the City of Robert Lee

Supply from Strategy	500 acre-feet per year
Total Capital Costs (2008 Prices)	$ 8,771,000
Annual Costs	$ 939,500
Unit Costs (during amortization)	$ 1,879 per acre-foot
	$ 5.77 per 1,000 gallons
Unit Costs (after amortization)	$ 349 per acre-foot
	$ 1.07 per 1,000 gallons

Environmental Issues Associated with Spence Reservoir Desalination

Many surface water sources in this portion of the Colorado Basin have high dissolved solids and most aquatic communities are adapted to these conditions. This strategy assumes that the reject from the RO process will be discharged into Spence Reservoir, the Colorado River or disposed using land application. If this strategy is pursued, additional studies may be required to evaluate potential impacts of reject disposal. If other methods of disposal are required, costs may be significantly higher.

Spence Reservoir has never spilled, so this project is not expected to have significant impacts on instream flows or over-bank flows. There will be no impact on bays and estuaries.

Agricultural and Rural Issues Associated with Spence Reservoir Desalination

No agricultural issues have been identified for this strategy.

The City of Robert Lee is a rural community. Like other water supply strategies, the high cost of this strategy may have an adverse impact on the limited financial resources of the city and the surrounding rural community.

Other Natural Resource Issues Associated with Spence Reservoir Desalination

None identified.

Significant Issues Affecting Feasibility of Spence Reservoir Desalination

The costs for implementing this strategy will be significant, and financing the project will be an issue for the City of Robert Lee.

Feasibility is also dependent upon the city's ability to dispose of brine reject by discharge or land application. If deep well injection or other methods are required, the costs of the project could be significantly higher. If this option is pursued, additional studies may be required to address the disposal issue.

Other Water Management Strategies Directly Affected by Spence Reservoir Desalination

Other strategies for the City of Robert Lee.

Floating Pump in Mountain Creek Reservoir

The existing intake structure in Mountain Creek Reservoir makes it difficult for the city to take water when the reservoir is 10 to 15 feet below conservation. A new floating pump could allow the city access to more water during dry periods.

Quantity, Reliability and Cost of Floating Pump

For the purposes of this plan, this strategy assumes that the city would install a new floating pump with a capacity of 1.0 mgd and 1,000 feet of 12-inch piping. This would give the city sufficient capacity to meet most of its demand from Mountain Creek Reservoir when water is available. The reliability of the water is low because supplies from this source are typically unavailable during drought. However, the water quality of this source is typically better than

Spence Reservoir. The city uses Mountain Creek Reservoir to supply about 25 percent of its water. Table 4.3-27 contains a cost summary for this strategy. Although the intake has more capacity than shown, the actual amount of reliable supply made available is low, increasing the unit cost of the project.

Table 4.3-27
New Floating Pump in Mountain Creek Reservoir for the City of Robert Lee

Supply from Strategy	50 acre-feet per year
Total Capital Costs (2008 Prices)	$528,000
Annual Costs	$ 56,600
Unit Costs (during amortization)	$ 1,132 per acre-foot
	$ 3.47 per 1,000 gallons
Unit Costs (after amortization)	$ 212 per acre-foot
	$ 0.65 per 1,000 gallons

Environmental Issues Associated with Floating Pump

The impact of this strategy is expected to be minimal.

Agricultural and Rural Issues Associated with Floating Pump

The City of Robert Lee is a rural community. Like other water supply strategies, the high cost of this strategy may have an adverse impact on the community's limited financial resources.

Other Natural Resource Issues Associated with Floating Pump

None identified.

Significant Issues Affecting Feasibility of Floating Pump

The most significant issues associated with this project are financing for the new facilities.

Another issue is the available supply from the project. Although the project will allow additional water to be used from the reservoir, there are less than 200 acre-feet of storage that the city cannot access. The supply from this storage is not reliable and may not be sufficient to justify the cost of the project.

Other Water Management Strategies Directly Affected by Floating Pump

Lake Spence RO project, other strategies for Robert Lee.

Infrastructure Expansion - Water Treatment Plant and Storage Facility

Infrastructure improvements include a 0.5 mgd expansion of the city's water treatment plant, a new 100,000 gallon treated water storage tank for the city, and improvements to allow the city to simultaneously treat water from both Spence and Mountain Creek Reservoirs.

Quantity, Reliability and Cost of Infrastructure Expansion

The expansions would increase the reliability of existing supplies and make approximately 200 acre-feet per year of additional average production available to the city. Table 4.3-28 shows the estimated costs for these improvements.

Table 4.3-28
0.5 MGD Water Treatment Plant Expansion for the City of Robert Lee

Supply from Strategy	200 acre-feet per year
Total Capital Costs (2008 Prices)	$ 2,436,000
Annual Costs	$ 265,600
Unit Costs (during amortization)	$ 1,328 per acre-foot
	$ 4.08 per 1,000 gallons
Unit Costs (after amortization)	$ 268 per acre-foot
	$ 0.82 per 1,000 gallons

Improvements to existing infrastructure are not evaluated for impacts. Although this strategy will increase the reliability of the Robert Lee water system, it may not sufficiently reduce chlorides and TDS to meet secondary drinking water standards (see Desalination of Spence Reservoir Water).

New Groundwater

As part of the Groundwater Special Study conducted for this plan, potential groundwater sources were identified in Coke and Runnels Counties. The study identified four different formations and/or locations that could potential provide groundwater to Robert Lee to supplement the city's surface water supplies. Based on location and available data on water quality, the local alluvium aquifer is selected as the preferred source for this plan. However, additional studies and water testing is needed to confirm the quantity and quality of this source. If this source proves to be unsuitable either due to quantity or quality concerns, alternative sources include the San Angelo Formation, Choza Formation and Merkel Dolomite Member in Coke or Runnels Counties.

Quantity, Reliability and Cost of New Groundwater Wells

For the purposes of this plan, this strategy assumes that the city would install new groundwater wells in the local alluvium within 5 miles from the city. The strategy would provide 150 acre-feet per year of groundwater supply and includes two wells (130 gpm), pump station and a 6-inch pipeline to the city. Water from the groundwater system would be blended with the city's surface water before distribution. The reliability of the strategy is moderate because supplies from the alluvium may be susceptible to drought. Based on available data, the water quality of this source is generally good, but there is quite a bit of variability across the formation. Also, the impact of recharge zone proximity on water quality is not clear given the limited availability of data. Table 4.3-29 contains a cost summary for this strategy.

Environmental Issues Associated with New Wells

Depending on the connection between the river alluvium and local streams, this strategy could impact stream flows. Reduced stream flows could have impacts to water quality and aquatic habitats.

Table 4.3-29
New Groundwater Wells for the City of Robert Lee

Supply from Strategy	150 acre-feet per year
Total Capital Costs (2008 Prices)	$ 1,502,000
Annual Costs	$ 157,000
Unit Costs (during amortization)	$ 1,047 per acre-foot
	$ 3.21 per 1,000 gallons
Unit Costs (after amortization)	$ 173 per acre-foot
	$ 0.53 per 1,000 gallons

Agricultural and Rural Issues Associated with New Wells

It is assumed that the new groundwater rights will be purchased from a willing buyer so that this strategy will have minimal impacts to agricultural lands. The City of Robert Lee is a rural community. Like other water supply strategies, the initial cost of this strategy may have an adverse impact on the community's limited financial resources.

Other Natural Resource Issues Associated with New Wells

None identified.

Significant Issues Affecting Feasibility of New Wells

The most significant issues associated with this project are financing for the new facilities.

Other Water Management Strategies Directly Affected by New Wells

Lake Spence RO project, other strategies for Robert Lee.

Purchase Treated Water from San Angelo using Rehabilitated Spence Pipeline

The City of San Angelo is considering rehabilitating its pipeline from Spence Reservoir to the city. This pipeline was designed with the capabilities of pumping water in either direction (i.e., from Spence to San Angelo or from San Angelo to Spence). As a possible source of water for Robert Lee, San Angelo could pump treated water to Robert Lee using the Spence pipeline. A new pump station would be required, in addition to the improvements identified to rehabilitate the pipeline.

Quantity, Reliability and Cost of Treated Water from San Angelo

This strategy assumes that the existing Spence pipeline to San Angelo would be rehabilitated to the extent necessary to transport treated water to Robert Lee. The costs associated with this infrastructure improvement are listed in Table 4.3-30, with the discussion for San Angelo. The additional cost needed to move water to Robert Lee is approximately $778,000 to install a new pump station. It is assumed that Robert Lee would purchase up to 400 acre-feet per year from San Angelo. This water is available through the development of new strategies by San Angelo. The reliability of the strategy is high to moderate pending San Angelo's selected strategies. Table 4.3-27 contains a cost summary for this strategy. The cost of the purchased water would be negotiated between San Angelo and Robert Lee.

Table 4.3-30
Treated Water from San Angelo for the City of Robert Lee

Supply from Strategy	400 acre-feet per year
Total Capital Costs (2008 Prices)	$ 778,000
Annual Costs	$ 467,000
Unit Costs (during amortization)	$ 1,168 per acre-foot
	$ 3.58 per 1,000 gallons
Unit Costs (after amortization)	$ 998 per acre-foot
	$ 3.06 per 1,000 gallons

Environmental Issues Associated with Treated Water from San Angelo

There are no known environmental issues with this strategy.

Agricultural and Rural Issues Associated with Treated Water from San Angelo

There are no known agricultural or rural issues with this strategy.

Other Natural Resource Issues Associated with Treated Water from San Angelo

None identified.

Significant Issues Affecting Feasibility of Treated Water from San Angelo

The most significant issues associated with this project are financing for the new facilities.

Other Water Management Strategies Directly Affected by Treated Water from San Angelo

This project would directly impact the ability of San Angelo to use the Spence pipeline for water supplies from Spence Reservoir. Further study is needed to determine whether water can be transported in both directions under certain conditions. Other projects impacted include the Lake Spence RO project and other strategies for Robert Lee.

Water Conservation

In recent years the City of Robert Lee has been under water use restrictions primarily due to infrastructure limitations. Table 4.3-31Table 4.3-31 compares projected demands for the city without conservation, with the expected conservation due to the implementation of the plumbing code (the default projections used in regional water planning), and with Region F water conservation criteria (see Appendix 4G).

Quantity, Reliability and Cost of Water Conservation

Using the Region F criteria, conservation can reduce the demand for the City of Robert Lee by 66 acre-feet per year, about 19 percent of the expected demand for the city without conservation. The reliability of this supply is considered to be medium because of the uncertainty involved in the analysis used to calculate the savings. Site specific data would give a better estimate of the reliable supply from this strategy. Costs range from $356 per acre-foot in 2010 to $199 per acre-foot in 2060.

Table 4.3-31
Estimated Water Conservation for the City of Robert Lee [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	278	278	278	278	278	278	278
Plumbing Code	Projections	278	276	272	269	266	264	264
	Savings	0	2	6	9	12	14	14
Region F Estimate	Projections	278	263	240	232	228	225	224
	Savings (Region F practices)	0	13	32	37	38	39	40
	Savings (Total)	0	15	38	46	50	53	54
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	365	354	354	354	354	354	354
Plumbing Code	Projections	365	351	346	342	338	336	336
	Savings	0	3	8	12	16	18	18
Region F Estimate	Projections	365	335	306	298	293	290	288
	Savings (Region F practices)	0	16	40	44	45	46	48
	Savings (Total)	0	19	48	56	61	64	66
Costs [b]								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Annual Costs			$5,696	$10,422	$10,177	$9,940	$9,708	$9,565
Cost per Acre-Foot			$356	$261	$231	$221	$211	$199
Cost per 1,000 Gal			$1.09	$0.80	$0.71	$0.68	$0.65	$0.61

a Costs and savings based on information from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.

b Costs for implementing recommended practices. Costs of implementing plumbing code savings not included in cost calculations.

Drought Management

The City of Robert Lee has a water conservation and drought contingency plan. Region F has not identified any additional drought management strategies for the city.

Recommended Strategies for the City of Robert Lee

The recommended strategies for the City of Robert Lee are:

- Subordination of downstream water rights
- Expansion of water treatment plant and storage facilities
- Water Conservation

Table 4.3-32 is a comparison of supplies to demands with strategies in place, and Table 4.3-33 summarizes the costs of the strategies.

The recommended strategies may not sufficiently address treated water quality for the city. As an alternative or supplement to the water treatment plant expansion, the city may wish to consider RO treatment of Spence Reservoir water and/or develop new groundwater in the nearby river alluvium. Region F considers these strategies to meet regulatory requirements for consistency with this plan. The RO treatment plant is not recommended because of the cost of the project and the uncertainty involved with disposal of the brine reject. New groundwater wells are not recommended at this time due to the uncertainty of quantity and quality of this source.

Recommended Alternative Strategies for the City of Robert Lee

The recommended alternative strategies for the City of Robert Lee are:

- New groundwater in river alluvium
- Desalination of Spence Reservoir water

Table 4.3-32
Recommended Water Management Strategies for the City of Robert Lee
(Values in Acre-Feet per Year)

Supplies	2010	2020	2030	2040	2050	2060
Colorado River	7	7	7	7	7	7
Mountain Creek Reservoir	0	0	0	0	0	0
Spence Reservoir	333	296	435	403	384	357
Infrastructure Expansion [a]	0	0	0	0	0	0
Subordination	123	147	2	27	43	70
Total	*463*	*450*	*444*	*437*	*434*	*434*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential savings [b]	16	40	44	45	46	48
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Robert Lee	351	346	342	338	336	336
Municipal Sales	105	97	95	92	91	91
Total	*456*	*443*	*437*	*430*	*427*	*427*
Surplus (Need) without conservation	*7*	*7*	*7*	*7*	*7*	*7*
Surplus (Need) with conservation	*23*	*47*	*51*	*52*	*53*	*55*

a The infrastructure expansion increases the reliability of existing supplies but does not make additional water available.

b Does not include plumbing code savings, which are already included in the water demand projections.

Table 4.3-33
Costs of Recommended Water Management Strategies for the City of Robert Lee

Strategy	Capital Costs	Annual Costs					
		2010	2020	2030	2040	2050	2060
Infrastructure expansion	$2,436,000	$265,600	$265,600	$53,600	$53,600	$53,600	$53,600
Water Conservation		$5,696	$10,422	$10,177	$9,940	$9,708	$9,565
Total	*$2,436,000*	*$271,296*	*$276,022*	*$63,777*	*$63,540*	*$63,308*	*$63,165*

Note: The subordination strategy will be implemented by CRWMD.

4.3.6 City of Menard

The city of Menard has several wells near the banks of the San Saba River that produce water from the San Saba River Alluvium. Reduced flows in the San Saba River during a severe drought have the potential to reduce the city's available supply.

Under drought-of-record conditions Menard may experience small shortages. For the purposes of this plan, supplies for the City of Menard are considered to be surface water. However, recent actions by state agencies have re-classified the city's supply as groundwater.

Table 4.3-34 compares the supply and demand for the city. (Supplies are based on the Colorado WAM, which may not give an accurate picture of the city's particular method of obtaining water supply. Based on historical data, the Colorado WAM supply appears to be somewhat conservative and more water may actually be available to the city.) The projected population of the city is expected to remain fairly stable over the planning period, so demands are expected to decline over time due to conservation. The projected need for Menard is 70 acre-feet per year in 2010, decreasing to 54 acre-feet per year by 2060. During the recent drought the city relied on water conservation and drought management to prevent shortages. Although this strategy proved successful, the city desires to increase the reliability of its supplies by developing a groundwater source. The city is currently considering developing a well in the Hickory aquifer. In addition the city is interested in developing a direct reuse project for irrigation of a municipal golf course.

Table 4.3-34
Comparison of Supply and Demand for the City of Menard
(Values in Acre-Feet per Year)

Supply	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
San Saba River	304	304	304	304	304	304
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Menard	354	353	347	341	339	339
Municipal sales	20	21	20	20	19	19
Total	*374*	*374*	*367*	*361*	*358*	*358*
Surplus (Need)	*(70)*	*(70)*	*(63)*	*(57)*	*(54)*	*(54)*

Potentially Feasible Strategies

Potentially feasible strategies for the City of Menard include:

- Water conservation
- Drought management
- New groundwater development
- Aquifer storage and recovery.
- Voluntary redistribution – San Saba Off-Channel Reservoir

Although several other strategies are technically feasible, the small quantity of water used by the city, the distance from other water supply sources, and the limited economic resources available to the community limits the number of strategies that could be implemented by the city.

Water Conservation

Using the Region F suite of water conservation practices, it is estimated that the City of Menard can reduce water demand by as much as 17 percent. Additional information on Region F recommended water conservation practices may be found in Appendix 4G.

Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. The water conservation practices in this plan are guidelines. Region F considers water conservation strategies determined and implemented by the City of Menard to supersede the recommendations in this plan and to meet regulatory requirements for consistency with this plan.

Quantity, Reliability and Cost of Water Conservation

Table 4.3-36 summarizes the estimated water savings and costs associated with the recommended Region F water conservation practices. Based on this evaluation, by 2060 up to 61 acre-feet of water per year could be saved, a reduction of almost 17 percent. The estimated reductions compare favorably with actual reductions in demand experienced by the city during the recent drought. The estimated per capita water demand in 2030 using the Region F criteria is 161 gpcd. In 2002, the most recent year for which per capita water use data are available, the city had a per capita demand of 161 gpcd. The reliability of water conservation is considered to be medium due to the uncertainty of the long-term savings from implementation of water conservation strategies.

Environmental Issues Associated with Water Conservation

Water conserved by the City of Menard will most likely be made available for irrigation or livestock purposes in the area. Some of the saved water may contribute to environmental flow needs. Other impacts are expected to be minimal.

Agricultural and Rural Issues Associated with Water Conservation

Water from the San Saba River is also used for irrigation purposes. Some of the conserved water may become available for irrigation needs.

The City of Menard is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources.

Other Natural Resource Issues Associated with Water Conservation

None identified.

Significant Issues Affecting Feasibility of Water Conservation

This strategy is based on a generalized assessment of water conservation practices and may not accurately reflect the actual costs or water savings that can be achieved by the City of Menard. Site-specific data will be required for a better assessment of the potential for water conservation by the city. Technical assistance and funding by the state may be required to implement this strategy.

Table 4.3-35
Estimated Water Conservation Savings for the City of Menard [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	185	185	185	185	185	185	185
Plumbing Code	Projections	185	181	178	175	172	171	171
	Savings	0	4	7	10	13	14	14
Region F Estimate	Projections	185	176	166	161	157	155	154
	Savings (Region F Practices)	0	5	12	14	15	16	17
	Savings (Total)	0	9	19	24	28	30	31
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	343	362	367	367	367	367	367
Plumbing Code	Projections	343	354	353	347	341	339	339
	Savings	0	8	14	20	26	28	28
Region F Estimate	Projections	343	344	329	319	311	307	306
	Savings (Region F Practices)	0	10	24	28	30	32	33
	Savings (Total)	0	18	38	48	56	60	61
Costs [b]								
Annual Costs			$8,755	$13,526	$13,146	$12,776	$12,414	$12,190
Cost per Acre-Foot			$876	$564	$470	$426	$388	$369
Cost per 1,000 Gal			$2.69	$1.73	$1.44	$1.31	$1.19	$1.13

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide,* November 2004.
b Costs for implementing Region F recommended practices. Costs of implementing plumbing code not included.

Other Water Management Strategies Directly Affected by Water Conservation

None identified.

Drought Management

The City of Menard has effectively used drought management to control demand during times of drought. Strategies are specified in the city's water conservation and drought contingency plan. Region F has not identified additional drought management strategies for the City of Menard.

New Groundwater Development - Hickory Aquifer

The City of Menard has been actively seeking a groundwater source to back up its current supplies. Yields from the Edwards-Trinity Plateau aquifer tend to be low in Menard County and the city has been unsuccessful in locating an adequate supply from that source. An alternative is the Hickory aquifer, which underlies the city at a depth of approximately 3,500 ft. The city is planning to drill a well near its existing storage tanks. In this portion of the aquifer, dissolved solids may be above 1,000 mg/l. Also, much of the water from the Hickory aquifer exceeds drinking water standards for radionuclides. For the purposes of this plan, this strategy assumes that water from the Hickory can meet primary drinking water standards if blended with the city's existing water supply. However, advanced treatment may be required to meet standards, significantly increasing the cost of this strategy.

Quantity, Reliability and Cost of Hickory Aquifer Well

The proposed well will produce water from the down-dip portion of the Hickory aquifer. Faulting may have caused this portion of the aquifer to be compartmentalized and isolated from the recharge zone. Therefore, most of the supply is expected to come from water in storage. The total thickness of the Hickory formation is approximately 500 feet. Although no wells are available in the immediate area of the city, based on other users of the aquifer, such as the City of Brady, there should be sufficient supplies to meet the city's long-term water supply needs. Reliability is medium because water quality may impact the usefulness of the supply. Table 4.3-36 summarizes the estimated costs of the project.

Table 4.3-36
Costs for New Hickory Water Well for the City of Menard

Supply from Strategy	160 acre-feet per year
Total Capital Costs (2008 Prices)	$ 1,684,000
Annual Costs	$ 233,000
Unit Costs (during amortization)	$ 1,456 per acre-foot
	$ 4.47 per 1,000 gallons
Unit Costs (after amortization)	$ 538 per acre-foot
	$ 1.65 per 1,000 gallons

Environmental Issues Associated with Hickory Aquifer Well

The proposed well will produce water from the down-dip portion of the Hickory aquifer. Because of the over 3,000 feet of overburden, there is no connection with the land surface and, therefore, there would be no impact on springs or surface water sources. Subsidence would also not be a factor due to the depth of the source and the competency of the overburden. Therefore environmental impacts are expected to be minimal unless the water requires advanced treatment. If advanced treatment is required to use the aquifer, impacts may be higher depending on the method used to dispose of the reject from the treatment process.

Based on the available data, it is unlikely that pumping limits other than those already imposed by the Hickory Underground Water Conservation District will be required to protect the environment.

Agricultural and Rural Issues Associated with Hickory Aquifer Well

Currently, only a very small amount of water from the Hickory is used for irrigation in Menard County. Because of the relatively small amount of water from this strategy, there are no expected impacts on irrigated agriculture.

The City of Menard is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources.

Other Natural Resource Issues Associated with Hickory Aquifer Well

None identified.

Significant Issues Affecting Feasibility of Hickory Aquifer Well

Much of the water from the Hickory aquifer has radium levels that exceed the maximum contaminant level (MCL) for drinking water. Water in this portion of the Hickory aquifer may be high in dissolved solids as well. The water may require special treatment, blending or some other process to meet standards. A test well will be required to determine if water quality will limit the use of this source. Both financing the test program and development of the well will be an issue for the City of Menard.

Other Water Management Strategies Directly Affected by Hickory Aquifer Well

Aquifer storage and recovery by the City of Menard.

Aquifer Storage and Recovery

Aquifer storage and recovery (ASR) may work well with development of a Hickory aquifer well. It is possible that the Hickory aquifer can be used to store water during the winter months for use during peak summer months. Additional supplies may be held longer for use during times of drought. During extreme droughts, the native water in the Hickory formation may be used to supplement the stored water. This strategy may mitigate any water quality issues associated with the Hickory.

Quantity, Reliability and Cost of ASR

Treated surface water would be injected into the Hickory aquifer during winter months at approximately the same rate that groundwater can be withdrawn from the aquifer. Because of the depth of this aquifer, there are no other Hickory wells in the area. Therefore, water placed in this reservoir would be relatively protected from unauthorized withdrawals. Assuming that the water would be withdrawn within the following few months, a return of approximately 80 to 90 percent can be anticipated. The cost of modifying an existing water well into an ASR injection and retrieval well is slight. The major cost is incorporated into the drilling and construction of the well (see New Groundwater Development - Hickory aquifer above). Additional cost will be required in the permitting phase of the project.

Since more water is made available by this strategy than the Hickory well by itself, the unit costs of the strategy are lower. Table 4.3-37 is a summary of the expected costs of the project.

Table 4.3-37
Costs for Aquifer Storage and Recovery by the City of Menard

Supply from Strategy	240 acre-feet per year
Total Capital Costs (2008 Prices)	$ 1,752,000
Annual Costs	$ 305,000
Unit Costs (during amortization)	$ 1,271 per acre-foot
	$ 3.90 per 1,000 gallons
Unit Costs (after amortization)	$ 633 per acre-foot
	$ 1.94 per 1,000 gallons

Environmental Issues Associated with ASR

This strategy relies on using diversions made under an existing water right and does not represent a significant variation in diversions on an annual basis. Seasonally, this strategy will most likely result in slightly higher diversions in the winter, potentially reducing diversions during the summer. As a result, this strategy should have a positive impact on water quality and environmental water needs because of reduced diversions during the summer months. Therefore instream bypass, diversion limits and other operational factors should not be needed. This strategy should have little or no impact on over-banking flows.

Agricultural and Rural Issues Associated with ASR

Menard is a rural community, and implementation of this and other strategies represents a significant financial drain on the community.

The potential to reduce diversions during the summer may have a positive impact on irrigated agriculture in the Menard area.

Other Natural Resource Issues Associated with ASR

None identified.

Significant Issues Affecting Feasibility of ASR

The suitability of the Hickory aquifer in this area for ASR has not been firmly established. Further studies will be required to evaluate aquifer characteristics. Injection of water into the subsurface will likely require a Class V permit from TCEQ. Also as stated above, the project could have a significant financial impact on the rural community. The price to extract injected water from the proposed Hickory ASR project could be costly given the 3,500 foot well depth and possible deep static water level.

Other Water Management Strategies Directly Affected by ASR

New well in the Hickory aquifer.

San Saba Off-Channel Reservoir

Previous studies have evaluated an off-channel reservoir on the San Saba River in McCulloch County. For this plan, the off-channel reservoir would be located near the City of Menard with a yield of approximately 500 acre-feet per year. The conceptual design for the project includes a channel weir and pump station, an off channel reservoir with 1,550 acre-feet of storage, a new water treatment plant, and a pipeline from the reservoir to the treatment plant.

There is little unappropriated water available in the San Saba River. If constructed, the reservoir would most likely need to be permitted under the existing City of Menard water right or as an upstream diversion under the Lower Colorado River Authority water rights for the Highland Lakes, or both.

Quantity, Reliability and Cost of Off-Channel Reservoir

The project has been designed to yield 500 acre-feet per year. Water was stored in the reservoir at a 1926 priority date, the same priority date as the Highland Lakes, limited by bypass requirements based on the Consensus Method. The reliability of the project is expected to be high. Table 4.3-38 summarizes the costs for this strategy.

Environmental Issues Associated with Off-Channel Reservoir

A specific location for the off-channel reservoir has not been determined. Before this strategy could be pursued, a site selection study would need to be performed, in addition to other studies to identify and quantify potential environmental impacts associated with the project. For the purposes of this analysis, it is assumed that a site could be selected that would have acceptable impacts. It can be assumed that the impacts of reservoir construction would be greater than the other feasible strategies for the City of Menard.

In accordance with TWDB guidelines, this analysis assumes that the consensus environmental bypass apply to diversions from the San Saba River. Other bypass requirements may change the yield and cost of the project.

Table 4.3-38
San Saba Off-Channel Reservoir - City of Menard

Supply from Strategy	500 acre-feet per year
Total Capital Costs (2008 Prices)	$ 25,273,000
Annual Costs	$ 2,215,000
Unit Costs (during amortization)	$ 4,430 per acre-foot
	$ 13.60 per 1,000 gallons
Unit Costs (after amortization)	$ 758 per acre-foot
	$ 2.33 per 1,000 gallons

Agricultural and Rural Issues Associated with Off-Channel Reservoir

Menard is a rural community, and implementation of this and other strategies represents a significant financial drain on the community.

Other Natural Resource Issues Associated with Off-Channel Reservoir

None identified.

Significant Issues Affecting Feasibility of Off-Channel Reservoir

There is not enough unappropriated water in this reach for a new water right. One possibility for implementation of this project would be as an upstream diversion of the Lower Colorado River Authority water rights in the Highland Lakes. The existing City of Menard water right may be used as well. An agreement with LCRA would be necessary to implement this project. Diversion with a priority date junior to 1926 could significantly impact the feasibility of this project.

The analyses presented in this plan were developed for screening purposes only. Additional studies will be required if this strategy is pursued. The cost and feasibility of this project may change significantly based upon a more detailed analysis.

Other Water Management Strategies Directly Affected by Off-Channel Reservoir

Other City of Menard strategies.

Recommended Strategies for the City of Menard

Region F recommends the following strategies for the City of Menard:

- New groundwater development from the Hickory aquifer
- Water conservation

Recommended Alternative Strategies for the City of Menard

Region F recommends the following alternative strategy for the City of Menard:

- ASR with new well in the Hickory aquifer

If possible, the city should explore the possibility of using the Hickory aquifer for ASR when developing the Hickory well. If the city elects to pursue ASR, Region F will consider this option to meet regulatory requirements for consistency with this plan. Table 4.3-39 compares supply to demand with the recommended strategies. Table 4.3-40 summarizes the capital and annual costs associated with these strategies.

Table 4.3-39
Comparison of Supply and Demand with Recommended Water Management Strategies City of Menard
(Values in Acre-Feet per Year)

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
San Saba River	304	304	304	304	304	304
New Hickory well	160	160	160	160	160	160
Total	*464*	*464*	*464*	*464*	*464*	*464*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential savings	10	24	28	30	32	33
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Menard	354	353	347	341	339	339
Municipal Sales	20	21	20	20	19	19
Total	*374*	*374*	*367*	*361*	*358*	*358*
Surplus (Need) without Conservation	*90*	*90*	*97*	*103*	*106*	*106*
Surplus (Need) with Conservation	*100*	*114*	*125*	*133*	*138*	*139*

Table 4.3-40
Costs of Recommended Strategies for the City of Menard

Strategy	**Capital Costs**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
New Hickory well	$1,684,000	$233,000	$233,000	$86,000	$86,000	$86,000	$86,000
Water Conservation *	$0	$8,755	$13,526	$13,146	$12,776	$12,414	$12,190
Total	*$1,684,000*	*$241,755*	*$246,526*	*$99,146*	*$98,776*	*$98,414*	*$98,190*

* Costs for water conservation are for Region F practices only. Costs of implementing plumbing code savings not included.

4.3.7 City of Midland

The City of Midland currently uses three sources of water:

- The 1966 Contract with CRMWD, which can provide water from any source in the CRMWD system (Ivie, Spence, Thomas or groundwater sources). The amount of water from this contract increases from 16,624 acre-feet per year in 2010 to 18,257 acre-feet per year in 2020. The contract will expire in 2026.
- The CRMWD Ivie Contract for water from Ivie Reservoir. The contract is currently set at 15,000 acre-feet per year. The contract also has a clause allowing the contract to be

reduced to 16.54 percent of the safe yield of the reservoir. For the purposes of this analysis, we have assumed that the amount of water available to Midland over the planning period will be limited to 16.54 percent of the safe yield of Ivie Reservoir based on the Region F assessment of water availability.

- Paul Davis Well Field in Martin and Andrews Counties, which provides an average of 4,722 acre-feet per year from the Ogallala aquifer. The city expects the well field to be depleted by about 2035.

The city also owns an undeveloped well field in Winkler County, known as the T-Bar Ranch. The McMillan Well Field in Midland County was used for aquifer storage and recovery for many years, but has remained idle recently due to elevated concentrations of perchlorate in the water.

TWDB requires use of the TCEQ water availability models (WAM) to determine supplies in regional water planning. Because these models are based on a perfect application of the prior appropriation system, the Colorado WAM[6] shows substantially less water for Region F than previous assessments of water availability. As a result, supplies from CRMWD have been uniformly decreased for all users. The reduced supplies for the City of Midland are presented in Table 4.3-41.

Table 4.3-41 compares the available supplies to the projected demands for the City of Midland and its current customers. The city provides a small amount of water to industrial users and to municipal customers outside of the city. Demands for the city are expected to increase from about 29,000 acre-feet per year in 2010 to over 32,000 acre-feet per year by 2060.

Based on the Region F analysis, the city may experience short-term needs by 2010. These needs are the result of the water supply analysis using the Colorado WAM and can be met by CRMWD supplies, assuming subordination of downstream senior water rights. Beginning in 2030 the city may experience significant needs if supplies from the 1966 Contract are no longer available. Needs increase in 2040 when water from the Paul Davis Well Field is no longer available.

Potentially Feasible Water Management Strategies for the City of Midland

Three potentially feasible strategies have been identified for the city:

- *New Groundwater* - development of the T-Bar Well Field in Winkler county
- *Voluntary Redistribution* - purchase water from the CRMWD system
- *Water Conservation* – implementation of water conservation management practices to reduce demand

Region F has identified several other feasible strategies for the City of Midland, including subordination of downstream senior water rights, reuse, co-development of groundwater in the Pecos Valley aquifer with CRMWD's Winkler well field, desalination and aquifer storage and recovery. For the purposes of this plan it was assumed that these strategies would be implemented by CRMWD or in conjunction with CRMWD. These strategies are discussed in Section 4.8.1 regarding strategies for CRMWD. Other feasible strategies are considered less likely to be implemented over the planning period.

Table 4.3-41
Comparison of Current Supplies to Projected Demands for the City of Midland
(Values in Acre-Feet per Year)

Supplies	2010	2020	2030	2040	2050	2060
CRMWD 1966 Contract [a,b]	12,136	12,202	0	0	0	0
Ivie Contract [c]	10,925	10,669	10,473	10,246	10,021	9,795
Paul Davis Well Field [d]	4,722	4,722	4,722	0	0	0
Total Supplies	*27,783*	*27,593*	*15,195*	*10,246*	*10,021*	*9,795*
Demands	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Midland	28,939	30,056	30,804	31,246	31,631	32,112
Outside Sales	49	52	55	58	60	63
Total Demand	*28,988*	*30,108*	*30,859*	*31,304*	*31,691*	*32,175*
Surplus (Need)	*(1,205)*	*(2,515)*	*(15,664)*	*(21,058)*	*(21,670)*	*(22,380)*

a Actual contract amounts for the 1966 Contract are 16,624 acre-feet per year in 2010 and 18,257 acre-feet per year in 2020. Surface water supplies for all CRMWD customers have been reduced to reflect lower supplies from the CRMWD system from the Colorado WAM. With implementation of the subordination strategy, supplies from the 1966 Contract will be increased to current levels because of the additional supply available from the system.

b The 1966 Contract will expire in 2026.

c The Ivie Contract amount has been reduced to 16.54 percent of the safe yield of the reservoir using the Colorado WAM. Currently, the contract is set at 15,000 acre-feet per year. CRMWD has the option to reduce this contract if the safe yield of Ivie Reservoir has been reduced because of sedimentation, drought or other conditions.

d The Paul Davis Well Field is expected to be depleted by 2035.

T-Bar Well Field

In 1965 the city of Midland purchased the T-Bar Well Field, which consists of approximately 20,230 acres in northwestern Winkler County and northeastern Loving County. Based on previous studies, the City of Midland estimates that there is approximately 650,000 acre-feet of available water in storage in the Pecos Valley aquifer from this field. The city expects the well field to have a life of approximately 60 years. The recharge is estimated at approximately 6,600 acre-feet per year. The city is planning to use this well field during high demand periods. The proposed design capacity is 20 MGD.[7] To develop this well field, it is assumed that 43 wells will be installed and a 70-mile transmission line will be constructed. Costs are based on a draft study re-evaluating supplies from this source.[8] It is possible that this well field could be developed in conjunction with CRMWD resources in Winkler County.

Quantity, Reliability and Cost of T-Bar Well Field

The T-Bar Well Field could provide as much as 40 percent of the city's demand in 2060. The reliability is high over the planning period, since there is available supply from storage in the Pecos Valley aquifer in Winkler County and annual recharge is approximately half of the proposed annual supply. Expected costs for the project may be found in Table 4.3-42. More detailed cost estimates may be found in Appendix 4D.

Table 4.3-42
Costs for T-Bar Well Field - City of Midland

Supply from Strategy	13,600 acre-feet per year
Total Capital Costs (2008 Prices)	$ 168,507,000
Annual Costs	$ 19,339,500
Unit costs (during amortization)	$ 1,422 per acre-foot
	$ 4.36 per 1,000 gallons
Unit Costs (after amortization)	$ 342 per acre-foot
	$ 1.05 per 1,000 gallons

Environmental Issues Associated with T-Bar Well Field

There is no flowing surface water in Winkler County, so development of the T-Bar Well Field is expected to have no impact on environmental water needs. Development of the well field and construction of the 70-mile pipeline are expected to have minimal impact on wildlife habitats or cultural resources. It is assumed that the 70-mile pipeline can be routed to minimize or eliminate impact on potentially sensitive areas if needed. Once the pipeline route has been chosen, the potential for environmental impacts will need further investigation.

No subsidence or bay and estuary impacts are expected with well field development.

Agricultural and Rural Issues Associated with T-Bar Well Field

This strategy should have minimal effects on agriculture since the water rights are already owned by the city and there is little agriculture in the area. The right of way for the transmission line may temporarily affect a small amount of agricultural acreage during construction.

Other Natural Resource Issues Associated with T-Bar Well Field

There is adequate supply in the Pecos Valley aquifer in Winkler County to support the proposed well field. Since the proposed well field is located in a geological trough, pumping of groundwater should have minimal impacts on the aquifer outside of the well field.

Significant Issues Affecting Feasibility of T-Bar Well Field

The most significant obstacle for implementation of this strategy will be financing the project. The cost of the project represents a significant financial commitment by the city. Other issues include possible water quality concerns, including the potential for perchlorate and arsenic concentrations that may exceed drinking water standards. Additional treatment of the water may be required if standards cannot be met by blending with other sources. Also, elevated chloride and TDS levels may be present in some or all of the future wells.

Other Water Management Strategies Directly Affected by T-Bar Well Field

There are no other identified management strategies that will be affected.

Voluntary Redistribution – Purchase Water from CRMWD

Additional water should be available from the CRMWD system to meet potential long-term needs for the city. Sources of water include existing CRMWD reservoirs and groundwater sources, as well as future sources such as reuse, desalination, aquifer storage and recovery or new groundwater sources. Actual sources of water, quantity and costs will be determined by negotiation between the two parties.

Quantity, Reliability and Cost of Purchasing Water from CRMWD

For the purposes of this plan, it will be assumed that Midland will renew its 1966 Contract at 8.45 percent of the total yield of the existing CRMWD system. Supplies are set at 10,000 acre-feet per year in 2030, declining to 9,400 acre-feet per year in 2060. Costs are assumed to be $479 per acre-foot ($1.47 per 1,000 gallons), the current CRMWD system rate. The actual amount and cost of water depends on negotiations between the two parties. The reliability is considered to be high due to the multiple sources in the CRMWD system. No new infrastructure will be required to implement this strategy.

Impacts of Purchasing Water from CRMWD

Contract renewal strategies are not evaluated for environmental impacts. Because this is a renewal of an existing contract, all impacts are expected to be low. This strategy should not affect any other water management strategies.

Water Conservation

The City of Midland has developed and is currently implementing a comprehensive water conservation program, including public education on indoor and outdoor water conservation. The city has completed a demonstration project at a city park that includes water conserving landscaping and irrigation practices. The City of Midland is currently focusing on their largest water user, the Midland Independent School District. The city is subsidizing the cost to install sprinkler systems at the schools with centralized control for each of the systems. Projected savings from this project is 369,000 gallons per day in the summer months. Midland also is investigating the feasibility of using reuse water for landscape irrigation to a local college. In addition, the city's wastewater may be used in a proposed reuse project sponsored by CRMWD.

Quantity, Reliability and Cost of Water Conservation

Since most of the city's water conservation effort begun after 2000 (basis year for water demands), the default Region F suite of water conservation practices and the city's irrigation strategy were used to evaluate the potential water savings and costs of implementation. Table 4.3-43 compares projected demands for the City of Midland with no conservation, with the expected conservation due to plumbing code (the default projections used in regional water planning), and using Region F water conservation criteria (see Appendix 4G).

The reliability of this supply is considered to be medium because of the uncertainty involved in the analysis used to calculate the savings.

Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. These water conservation practices are intended only as guidelines. Region F considers water conservation strategies determined and implemented by the City of Midland to supersede the recommendations in this plan and to meet regulatory requirements for consistency with this plan.

Table 4.3-43
Estimated Water Conservation Savings by the City of Midland [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	262	262	262	262	262	262	262
Plumbing Code	Projections	262	258	254	251	248	247	247
	Savings	0	4	8	11	14	15	15
Region F Estimate [a]	Projections	262	246	232	226	222	220	219
	Savings	0	16	30	36	40	42	43
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	27,879	29,388	31,003	32,154	33,010	33,552	34,062
Plumbing Code	Projections	27,879	28,939	30,056	30,804	31,246	31,631	32,112
	Savings	0	449	947	1,350	1,764	1,921	1,950
Region F Estimate	Projections	27,879	27,595	27,440	27,743	27,985	28,174	28,449
	Savings (Region F practices)	0	1,344	2,616	3,061	3,261	3,457	3,663
	Savings (Total)	0	1,793	3,563	4,411	5,025	5,378	5,613
Costs								
Annual Costs			$602,091	$521,355	$517,031	$507,177	$492,061	$484,787
Cost per Acre-Foot [b]			$448	$199	$169	$156	$142	$132
Cost per 1,000 Gal [b]			$1.37	$0.61	$0.52	$0.48	$0.44	$0.41

a Costs and savings based on information from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004 and communication with Midland..

b Costs for implementing recommended Region F practices. Plumbing code savings not included in unit cost calculations.

Environmental Issues Associated with Water Conservation

There are no identified environmental issues associated with this strategy. This strategy may have a positive impact on the environment by reducing the quantity of water needed by the city to meet future demands.

Agricultural and Rural Issues Associated with Water Conservation

The City of Midland is not in direct competition with agriculture for water, so there are no identified agricultural issues associated with this strategy.

Other Natural Resource Issues Associated with Water Conservation

None identified.

Significant Issues Affecting Feasibility of Water Conservation

This strategy is based on a generic assessment of water conservation practices and may not accurately reflect the actual costs or water savings that can be achieved by the City of Midland. Site-specific data will be required for a better assessment of the potential for water conservation by the city. Technical assistance by the state may be required to implement this strategy.

Other Water Management Strategies Directly Affected by Water Conservation

The timing and quantity of other recommended strategies for the City of Midland could be impacted by successful implementation of water conservation.

Drought Management

The current Midland Drought Contingency Plan, the CRMWD Drought Contingency Plan and subsequent revisions of these plans determine drought management for the City of Midland. No other drought management strategies have been identified.

Recommended Strategies for the City of Midland

Table 4.3-44 compares demands to the supplies from the recommended water management strategies for the City of Midland. These include:

- Subordination,
- New groundwater development of the T-Bar Well Field,
- Voluntary redistribution from the CRMWD system and
- Municipal water conservation

Although Table 4.3-49 includes adjustments to supplies from subordination, the strategy would be implemented by CRMWD. A discussion of this strategy is included in Section 4.2.3. Note that water conservation may delay implementation or reduce the amount of water needed from other strategies. Because both the renewal of the 1966 Contract and the T-Bar Well Field are long-term strategies, the city can monitor demand reductions due to conservation and adjust the timing and supply from each project as needed before implementation of those strategies. Table 4.3-45 is a breakdown of expected costs for these strategies. Costs for subordination, which will be implemented by CRMWD, are not included in Table 4.3-45**.**

Table 4.3-44
Recommended Water Management Strategies for the City of Midland
(Values in Acre-Feet per Year)

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
CRMWD 1966 Contract	12,136	12,202	0	0	0	0
Ivie Contract	10,925	10,669	10,473	10,246	10,021	9,795
Subordination Strategy [a]	4,656	6,113	-156	-266	-378	-490
Paul Davis Well Field	4,722	4,722	4,722	0	0	0
T-Bar Well Field	0	0	13,600	13,600	13,600	13,600
Voluntary Redistribution (purchase from CRMWD)	0	0	10,000	9,800	9,600	9,400
Total Supplies	32,439	33,706	38,639	33,380	32,843	32,305
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential Savings [b]	1,344	2,616	3,061	3,261	3,457	3,663
Demands	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Midland	28,939	30,056	30,804	31,246	31,631	32,112
Outside Sales	49	52	55	58	60	63
Total Demand	*28,988*	*30,108*	*30,859*	*31,304*	*31,691*	*32,175*
Surplus (Need) without Conservation	*3,451*	*3,598*	*7,780*	*2,076*	*1,152*	*130*
Surplus (Need) with Conservation	*4,795*	*6,214*	*10,841*	*5,337*	*4,609*	*3,793*

a With implementation of the subordination strategy, near-term supplies are increased. Subordination decreases long-term supplies because of the reduced yield in Ivie Reservoir.

b Does not include plumbing code savings, which are already included in the water demand projections.

Table 4.3-45
Costs of Water Management Strategies for the City of Midland

Strategy	Capital Cost	Annual Costs					
		2010	2020	2030	2040	2050	2060
T-Bar Well Field	$168,507,000			$19,339,500	$19,339,500	$4,648,500	$4,648,500
Voluntary Redistribution				$4,790,000	$4,694,200	$4,598,400	$4,502,600
Conservation		$602,091	$521,355	$517,031	$507,177	$492,061	$484,787
Total	*$168,507,000*	*$602,091*	*$521,355*	*$24,646,531*	*$24,570,877*	*$9,738,961*	*$9,635,997*

Note: Subordination strategy will be implemented by CRMWD.

4.3.8 City of Coleman

Table 4.3-46 compares the supply and demand for the City of Coleman. The maximum expected demand for the city (including outside sales) is 1,542 acre-feet per year in 2010. Demand declines to 1,474 acre-feet in 2060 due to water conservation. Lake Coleman is the city's primary source of water. The city also obtains a small amount of supply from Hords Creek Reservoir. Without subordination to downstream water rights, the Colorado WAM shows no yield for either reservoir. .

Table 4.3-46
Comparison of Supply and Demand for the City of Coleman
(Values in Acre-Feet per Year)

Supply	2010	2020	2030	2040	2050	2060	Comments
Lake Coleman	0	0	0	0	0	0	WAM yield *
Hords Creek Reservoir	0	0	0	0	0	0	WAM yield *
Total	*0*	*0*	*0*	*0*	*0*	*0*	
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
City of Coleman	1,285	1,269	1,252	1,235	1,223	1,223	
Municipal sales	251	253	250	244	243	245	Coleman Co WSC, etc.
Manufacturing Sales	6	6	6	6	6	6	
Total	*1,542*	*1,528*	*1,508*	*1,485*	*1,472*	*1,474*	
Surplus (Need)	*(1,542)*	*(1,528)*	*(1,508)*	*(1,485)*	*(1,472)*	*(1,474)*	

* Supplies from the Colorado WAM. With implementation of a subordination strategy, the combined supply from Lake Coleman and Hords Creek Reservoir is estimated to be 3,960 acre-feet per year .

Potentially Feasible Water Management Strategies

With subordination of downstream water rights, the City of Coleman has sufficient supply. Therefore other water management strategies, except for water conservation, are not necessary.

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, most reservoirs in Region F with a priority date after 1926 do not have a firm or safe yield. The priority dates of Lake Coleman and Hords Creek Reservoir are August 25, 1958 and March 23, 1946, respectively, so the reservoirs have no yield. This result is largely due to the assumptions used in the Colorado WAM.

In order to address water availability issues resulting from the Colorado WAM model, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights in Region F do not make priority calls on each other. Subsequent to the joint modeling effort, Region F conducted a study on the Pecan Bayou watershed to identify possible operating scenarios in this watershed. (A copy of this study is included in Volume II.) One scenario was selected for planning purposes, which is the basis of the water supplies for the subordination scenario in the Pecan Bayou watershed. The subordination strategy is described in Section 4.2.3. Table 4.3-47 is a summary of the impacts of the subordination strategy on the city's raw water supplies. Available supplies are limited by the city's existing infrastructure to 2,200 acre-feet per year.

Table 4.3-47
Impact of Subordination Strategy on City of Coleman Water Supplies [a]
(Values in acre-feet per year)

Reservoir	Priority Date	Permitted Diversion	2010 Supply WAM Run 3	2010 Supply with Subord-ination	2060 Supply WAM Run 3	2060 Supply with Subord-ination
Lake Coleman	8/25/1958	9,000	0	3,580	0	3,580
Hords Creek Reservoir	3/23/1946	2,240	0	380	0	380
Total [b]		*11,240*	*0*	*3,960*	*0*	*3,960*

a Water supply is defined as the safe yield of the reservoir.
b Actual supplies are limited to 2,200 acre-feet per year by treatment plant and delivery capacity.

The subordination modeling was conducted for planning purposes only. Neither Region F nor the Lower Colorado Region mandates the adoption of this strategy by individual water right holders. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including the City of Coleman and Brown County WID.

Impacts of the subordination strategy are discussed in Section 4.2.3.

Water Conservation

Using the Region F suite of water conservation practices, it is estimated that the City of Coleman can reduce water demand by as much as 14 percent. Additional information on Region F recommended water conservation practices may be found in Appendix 4G

Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. The water conservation practices in this plan are guidelines. Region F considers water conservation strategies determined and implemented by the City of Coleman to supersede the recommendations in this plan and to meet regulatory requirements for consistency with this plan.

Quantity, Reliability and Cost of Water Conservation

Table 4.3-48 summarizes the estimated water savings and costs associated with the recommended Region F water conservation practices. Based on this evaluation, by 2060 up to 187 acre-feet of water per year could be saved, a reduction of more than 14 percent. Experience during the recent drought indicates that there may be even more opportunity for savings. The city has been under restrictions for much of the period since the year 2000 because of low lake levels. In 2006, the most recent year for which per capita water use data are available, the city had a per capita demand of 203 gpcd. The estimated per capita water demand in 2060 using the Region F criteria is 196 gpcd. The reliability of water conservation is considered to be medium due to the uncertainty of the long-term savings due to implementation of water conservation strategies.

Environmental Issues Associated with Water Conservation

Water conserved by the City of Coleman will most likely remain in Lake Coleman and Hords Creek Reservoir. Because these reservoirs spill infrequently, it is unlikely that conservation will contribute to environmental flow needs or increase over-bank flows. Other impacts are expected to be minimal.

Agricultural and Rural Issues Associated with Water Conservation

No agricultural issues have been identified for this strategy.

The City of Coleman is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources.

Other Natural Resource Issues Associated with Water Conservation

None identified.

Significant Issues Affecting Feasibility of Water Conservation

This strategy is based on a generalized assessment of water conservation practices and may not accurately reflect the actual costs or water savings that can be achieved by the City of Coleman. Site-specific data will be required for a better assessment of the potential for water conservation by the city. Technical assistance and funding by the state may be required to implement this strategy.

Other Water Management Strategies Directly Affected by Water Conservation

None identified.

Drought Management

The City of Coleman has effectively used drought management to control demand during times of drought. Strategies are specified in the city's water conservation and drought contingency plan. Region F has not identified additional drought management strategies for the City of Coleman.

Recommended Strategies for the City of Coleman

Region F recommends water conservation and subordination of downstream water rights for the City of Coleman. Table 4.3-49 is a comparison of supply to demand with the recommended strategies in place. Table 4.3-50 summarizes the expected costs for these strategies.

Table 4.3-48
Estimated Water Conservation Savings by the City of Coleman [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	177	229	229	229	229	229	229
Plumbing Code	Projections	177	226	223	220	217	215	215
	Savings	0	3	6	9	12	14	14
Region F Estimate	Projections	229 [b]	220	210	204	200	197	196
	Savings (Region F Practices)	0	6	13	16	17	18	19
	Savings (Total)	0	9	19	25	29	32	33
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	1,315	1,302	1,303	1,303	1,303	1,303	1,303
Plumbing Code	Projections	1,315	1,285	1,269	1,252	1,235	1,223	1,223
	Savings	0	17	34	51	68	80	80
Region F Estimate	Projections	1,315	1,252	1,194	1,162	1,140	1,122	1,116
	Savings (Region F Practices)	0	33	75	90	95	101	107
	Savings (Total)	0	50	109	141	163	181	187
Costs [c]								
Annual Costs		$0.00	$6,345	$11,035	$10,963	$10,932	$10,872	$10,843
Cost per Acre-Foot		$0.00	$192	$147	$122	$115	$108	$101
Cost per 1,000 Gal		$0.00	$0.59	$0.45	$0.37	$0.35	$0.33	$0.31

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.
b The City of Coleman was under water use restriction in 2000. Base year 2000 demands were extrapolated from historical water use between 1995 and 1999.
c Costs for implementing Region F recommended practices. Costs of implementing plumbing code not included.

Table 4.3-49
Recommended Water Management Strategies for the City of Coleman
(Values in Acre-Feet per Year)

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Lake Coleman	0	0	0	0	0	0
Hords Creek Reservoir	0	0	0	0	0	0
Subordination of downstream water rights [a]	2,200	2,200	2,200	2,200	2,200	2,200
Total	*2,200*	*2,200*	*2,200*	*2,200*	*2,200*	*2,200*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential savings [b]	33	75	90	95	101	107
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Coleman	1,285	1,269	1,252	1,235	1,223	1,223
Municipal sales	251	253	250	244	243	245
Manufacturing Sales	6	6	6	6	6	6
Total	*1,542*	*1,528*	*1,508*	*1,485*	*1,472*	*1,474*
Surplus (Need) without conservation	*658*	*672*	*692*	*715*	*728*	*726*
Surplus (Need) with conservation	*691*	*747*	*782*	*810*	*829*	*833*

a Limited by treatment and delivery capacity. The combined supply from Lake Coleman and Hords Creek Reservoir is estimated to be 3,960 acre-feet per year.
b Does not include plumbing code savings, which are already included in the water demand projections.

Table 4.3-50
Costs of Recommended Water Management Strategies for the City of Coleman

Strategy	**Capital Costs**	**Annual Costs**					
		2010	**2020**	**2030**	**2040**	**2050**	**2060**
Water Conservation		$6,345	$11,035	$10,963	$10,932	$10,872	$10,843
Total	*$0*	*$6,345*	*$11,035*	*$10,963*	*$10,932*	*$10,872*	*$10,843*

4.3.9 City of Brady

Table 4.3-51 compares the supply and demand for the City of Brady. The maximum expected demand for the city (including outside sales) is 2,108 acre-feet per year in 2020. Demand declines to 1,967 acre-feet in 2060 due to water conservation. The city obtains water from groundwater wells in the Hickory aquifer and surface water from Brady Creek Reservoir. To address water quality concerns, the city has constructed a 3.0 MGD filtration treatment plant for water from Brady Creek Reservoir. For purposes of this plan it is assumed that the City of

Brady obtains about 60 percent of its water from Brady Creek Reservoir and the remainder from groundwater. However, without subordination to downstream water rights, the Colorado WAM shows no yield for Brady Creek Reservoir, leaving the city with an unmet need.

Table 4.3-51
Comparison of Supply and Demand for the City of Brady
(Values in Acre-Feet per Year)

Supply	2010	2020	2030	2040	2050	2060	Comments
Brady Creek Reservoir	0	0	0	0	0	0	WAM yield *
Hickory aquifer	1,009	1,009	1,009	1,009	1,009	1,009	Half of maximum demand
Total	*1,009*	*1,009*	*1,009*	*1,009*	*1,009*	*1,009*	
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
City of Brady	1,879	1,893	1,874	1,854	1,842	1,842	
Manufacturing Sales	125	125	125	125	125	125	
Total	*2,004*	*2,018*	*1,999*	*1,979*	*1,967*	*1,967*	
Surplus (Need)	*(995)*	*(1,009)*	*(990)*	*(970)*	*(958)*	*(958)*	

* Supplies from the Colorado WAM. With implementation of a subordination strategy, the supply from Brady Creek Reservoir is 2,170 acre-feet per year.

Potentially Feasible Water Management Strategies for the City of Brady

With subordination of downstream water rights, the City of Brady has excess supply. Therefore other water management strategies, except for water conservation, are not necessary.

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, most reservoirs in Region F with a priority date after 1926 do not have a firm or safe yield. The priority date of Brady Creek Reservoir is September 2, 1959, so the reservoir has no yield. This result is largely due to the assumptions used in the Colorado WAM.

In order to address water availability issues resulting from the Colorado WAM model, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights in Region F do not make priority calls on each other. The subordination strategy is discussed in Section 4.2.3. Table 4.3-52 is a summary of the impacts of the subordination strategy on the city's raw water supplies. The actual supply from the reservoir will be limited by the capacity of the new water treatment plant. For the purposes of this plan, the amount of water available from the reservoir is assumed to be 1,350 acre-feet per year.

Table 4.3-52
Impact of Subordination Strategy on City of Brady Water Supplies [a]
(Values in acre-feet per year)

Reservoir	Priority Date	Permitted Diversion	2010 Supply WAM Run 3	2010 Supply with Subord-ination	2060 Supply WAM Run 3	2060 Supply with Subord-ination
Brady Creek Reservoir	9/02/1959	3,500	0	2,170	0	2,170 [b]

a Water supply is defined as the safe yield of the reservoir. Actual supply to Brady is limited by treatment capacity.
b Although capacity of the reservoir is somewhat less in 2060, the safe yield is the same because fewer downstream senior water rights call on water from the reservoir.

The joint modeling between the two regions was conducted for planning purposes only. Neither Region F nor the Lower Colorado Region mandates the adoption of the subordination strategy by individual water right holders. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including the City of Brady.

Impacts of the subordination strategy are discussed in Section 4.2.3.

Water Conservation

Using the Region F suite of water conservation practices, it is estimated that the City of Brady can reduce water demand by as much as 17 percent. Additional information on Region F recommended water conservation practices may be found in Appendix 4G.

Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. The water conservation practices in this plan are guidelines. Region F considers water conservation strategies determined and implemented by the City of Brady to supersede the recommendations in this plan and to meet regulatory requirements for consistency with this plan.

Quantity, Reliability and Cost of Water Conservation

Table 4.3-53 summarizes the estimated water savings and costs associated with the recommended Region F water conservation practices. Based on this evaluation, by 2060 up to 328 acre-feet of water per year could be saved, a reduction of almost 17 percent. The city's experience during the recent drought indicates that more water could potentially be saved. In 2006, the most recent year for which per capita water use data are available, the city had a per capita demand of 236 gpcd. The estimated per capita water demand in 2060 using the Region F criteria is 251 gpcd. The reliability of water conservation is considered to be medium due to the uncertainty of the long-term savings due to implementation of water conservation strategies.

Environmental Issues Associated with Water Conservation

Most of the water used by the City of Brady is expected to come from Brady Creek Reservoir. Conserved water will remain in the reservoir, so there will be little if any impact on instream flows and over-banking flows.

Agricultural and Rural Issues Associated with Water Conservation

No agricultural issues have been identified for this strategy.

The City of Brady is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources.

Other Natural Resource Issues Associated with Water Conservation

None identified.

Significant Issues Affecting Feasibility of Water Conservation

This strategy is based on a generalized assessment of water conservation practices and may not accurately reflect the actual costs or water savings that can be achieved by the City of Brady. Site-specific data will be required for a better assessment of the potential for water conservation by the city. Technical assistance and funding by the state may be required to implement this strategy.

Table 4.3-53
Estimated Water Conservation Savings by the City of Brady [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	303	303	303	303	303	303	303
Plumbing Code	Projections	303	300	297	294	291	289	289
	Savings	0	3	6	9	12	14	14
Region F Estimate	Projections	303	287	267	260	256	253	251
	Savings (Region F Practices)	0	13	30	34	35	36	38
	Savings (Total)	0	16	36	43	47	50	52
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	1,875	1,898	1,931	1,931	1,931	1,931	1,931
Plumbing Code	Projections	1,875	1,879	1,893	1,874	1,854	1,842	1,842
	Savings	0	19	38	57	77	89	89
Region F Estimate	Projections	1,875	1,802	1,701	1,660	1,632	1,612	1,603
	Savings (Region F Practices)	0	77	192	214	222	230	239
	Savings (Total)	0	96	230	271	299	319	328
Costs [c]								
Annual Costs			$26,992	$31,776	$31,695	$31,660	$31,593	$31,561
Cost per Acre-Foot			$351	$166	$148	$143	$137	$132
Cost per 1,000 Gal			$1.08	$0.51	$0.45	$0.44	$0.42	$0.41

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide,* November 2004.
b The City of Brady was under water use restriction in 2000. Base year 2000 demands were extrapolated from historical water use from 1997 to 1999.
c Costs for implementing Region F recommended practices. Costs of implementing plumbing code not included.

Other Water Management Strategies Directly Affected by Water Conservation

None identified.

Drought Management

The City of Brady has effectively used drought management to control demand during times of drought. Strategies are specified in the city's water conservation and drought contingency plan. Region F has not identified additional drought management strategies for the City of Brady.

Recommended Strategies for the City of Brady

Region F recommends water conservation and subordination of downstream water rights for the City of Brady. Since the new treatment plant is under construction, a strategy is not necessary. Table 4.3-54 is a comparison of supply to demand with the recommended strategies in place. Table 4.3-55 summarizes the expected costs for these strategies.

Table 4.3-54
Recommended Water Management Strategies for the City of Brady
(Values in Acre-Feet per Year)

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Brady Creek Reservoir	0	0	0	0	0	0
Hickory aquifer	1,009	1,009	1,009	1,009	1,009	1,009
Subordination of downstream water rights [a]	1,350	1,350	1,350	1,350	1,350	1,350
Total	*2,359*	*2,359*	*2,359*	*2,359*	*2,359*	*2,359*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential savings [b]	77	192	214	222	230	239
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Brady	1,879	1,893	1,874	1,854	1,842	1,842
Manufacturing Sales	125	125	125	125	125	125
Total	*2,004*	*2,018*	*1,999*	*1,979*	*1,967*	*1,967*
Surplus (Need) without conservation	*355*	*341*	*360*	*380*	*392*	*392*
Surplus (Need) with conservation	*432*	*533*	*574*	*602*	*622*	*631*

a Limited by treatment and delivery capacity of the water treatment plant.
b Does not include plumbing code savings, which are already included in the water demand projections.

Table 4.3-55
Costs of Recommended Water Management Strategies for the City of Brady

Strategy	**Capital Costs**	**Annual Costs**					
		2010	**2020**	**2030**	**2040**	**2050**	**2060**
Water Conservation		$26,992	$31,776	$31,695	$31,660	$31,593	$31,561
Total	*$0*	*$26,992*	*$31,776*	*$31,695*	*$31,660*	*$31,593*	*$31,561*

4.3.10 City of Colorado City

The City of Colorado City currently obtains its water supply from a well field in the Dockum aquifer. In the summer 2010, the City of Colorado City in Mitchell County experienced groundwater supply problems from their Dockum aquifer municipal well field. The production level could not keep up with demand and emergency supply options were considered and additional supply is needed by 2011. The Economic Development Board for Mitchell County is currently conducting a feasibility study to assess brackish groundwater desalination using wind energy. This project will supply all necessary supply to Colorado City and other rural communities throughout the county. The proposed project for the regional plan in Mitchell County will draw freshwater and brackish supplies from the Dockum aquifer to supply municipal needs. The project is expected to yield approximately 2,200 acre feet per year.

New Water Wells located near Colorado City

The economic development board, Lone Wolf GCD, and city are evaluating potential Dockum aquifer groundwater around the city for future water supplies, including desalination of brackish supplies. This source is currently used for municipal and agricultural purposes and may require advanced treatment for municipal use. To provide approximately 2,200 acre-feet per year, six to eight new wells would need to be drilled. These wells would produce water from the Dockum aquifer approximately 200 to 800 feet below the surface.

Quantity, Reliability and Cost of New Water Wells

The quantity and reliability of water from this source is expected to be less than 500 gpm. Historical municipal and agricultural use indicates that the Dockum may be a viable source but high TDS will require advanced treatment. For this plan, the new wells are assumed to supply an additional 2,200 acre-feet per year. The reliability of the supply is considered to be medium because of aquifer and water quality properties. Table 4.3-56 summarizes the expected costs for the county.

Table 4.3-56
Costs for New Water Wells for Mitchell County

Supply from Strategy	2,200 acre-feet per year
Total Capital Costs (2010 Prices)	$17,855,000
Annual Costs	$2,536,000
Unit Costs (before amortization)	$1,153 per acre-foot
	$3.54 per 1,000 gallons
Unit Costs (after amortization)	$445 per acre-foot
	$1.37 per 1,000 gallons

Environmental Issues Associated with New Water Wells

The aquifer is a proven groundwater source for municipal, industrial, and agricultural purposes. However, the long-term water quality is unknown. At this time, it is assumed that the discharge from the advanced treatment facility can be discharged to the City's wastewater treatment plant, evaporation ponds, or land applied. In addition, the discharge could be used in the local oil industry. Environmental issues associated with the treatment facility would be addressed during permitting.

Agricultural and Rural Issues Associated with New Water Wells

This source is currently used for agricultural purposes. It is assumed that the transfer of water rights will be between a willing buyer and willing seller, and there would be minimal impacts to agricultural users.

The City of Colorado City is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially offsetting the positive impacts of a more reliable water supply.

Other Natural Resource Issues Associated with New Water Wells

None identified at this time

Significant Issues Affecting Feasibility of New Water Wells

Because the long-term reliability and quality of this supply is unknown, the city and county are currently pursuing a feasibility study for a brackish desalination facility in the vicinity of Colorado City. Funding the construction of these new wells will be a significant strain on the financial resources of the city and county.

Other Water Management Strategies Directly Affected by New Water Wells

No other water management strategies will be impacted.

4.3.11 Strategies for Hickory Aquifer Users

Among the needs identified in previous regional water plans was a water shortage resulting from new EPA regulations limiting the permissible amount of radionuclides in drinking water. Some of the Hickory aquifer wells produce water with radionuclide concentrations that exceed the maximum concentration limits (MCLs) for drinking water. Water suppliers currently relying on these wells will need to implement water management strategies that will allow them to continue to serve their customers. The following sections describe these water suppliers, the regulatory framework, and the potential water management strategies.

In the 2001 Region F Plan, water management strategies were evaluated for public water suppliers that were using the Hickory aquifer as a major or as a sole water source. This included public water supplies in McCulloch and Concho Counties, and in portions of Runnels and Tom Green Counties. Treatment to remove radionuclides was considered infeasible due to a lack of options for disposal of treatment residuals. In the 2001 Region F plan, the lack of treatment alternatives effectively eliminated the consideration of the Hickory aquifer as a primary drinking water source after the year 2010. A regional approach to obtaining alternative water supplies was considered in the 2001 Region F plan, but all of the identified strategies were expensive and the smaller communities affected by the radionuclides rule did not opt for a regional strategy.

Further evaluation of water management strategies for Hickory aquifer users was undertaken for the 2006 *Region F Regional Water Plan*. Each of the affected public water suppliers was contacted in order to update the status of each regarding Hickory aquifer usage. Since the 2001 plan, TCEQ has implemented a regular testing program of Hickory aquifer users, providing additional water quality data for each system. The current status of drinking water and waste disposal regulations as related to radionuclides were investigated. For selected water suppliers, specific water management strategies were identified and evaluated.

These strategies were reviewed and updated based on current activities of Hickory water users and updates to the regulations. This section presents these findings. A description of the Hickory aquifer may be found in Chapter 3 of this plan.

Hickory Aquifer Water User Groups

The municipal wells in Region F with radionuclide levels exceeding drinking water limits are located in Concho and McCulloch Counties. Nine public water suppliers currently rely on the Hickory aquifer as a supply source. The demands for City of Brady, the Millersview-Doole Water Supply Corporation (MDWSC), the City of Eden and the Richland Special Utility District (Richland SUD) are listed in Table 4.3-57. These four entities are classified as Water User Groups (WUGs). The remaining Hickory water suppliers are Rochelle WSC, Lakeland Services, Inc., the City of Melvin, Lohn WSC and Live Oak Hills Subdivision. The demands for these small water suppliers are aggregated as McCulloch County Other. The demand for this category is underestimated because the approved TWDB population projections for the County Other category are low. In addition there are other potential future users of the Hickory aquifer, including the City of Menard.

Table 4.3-57
Hickory Water Suppliers

Public Water System	**Average Annual Demand** (acre-feet per year)
City of Brady	1,000
Millersview-Doole WSC	524
City of Eden	572
Richland SUD	207 [a]
McCulloch County Other	12 [b]

a TWDB approved projections are 113 acre-feet per year. However, TWDB projections do not include water used for livestock or other purposes. Richland SUD expects demands to be closer to 207 acre-feet per year.
b Demands for McCulloch County Other are underestimated because TWDB approved population projections for this category are low.

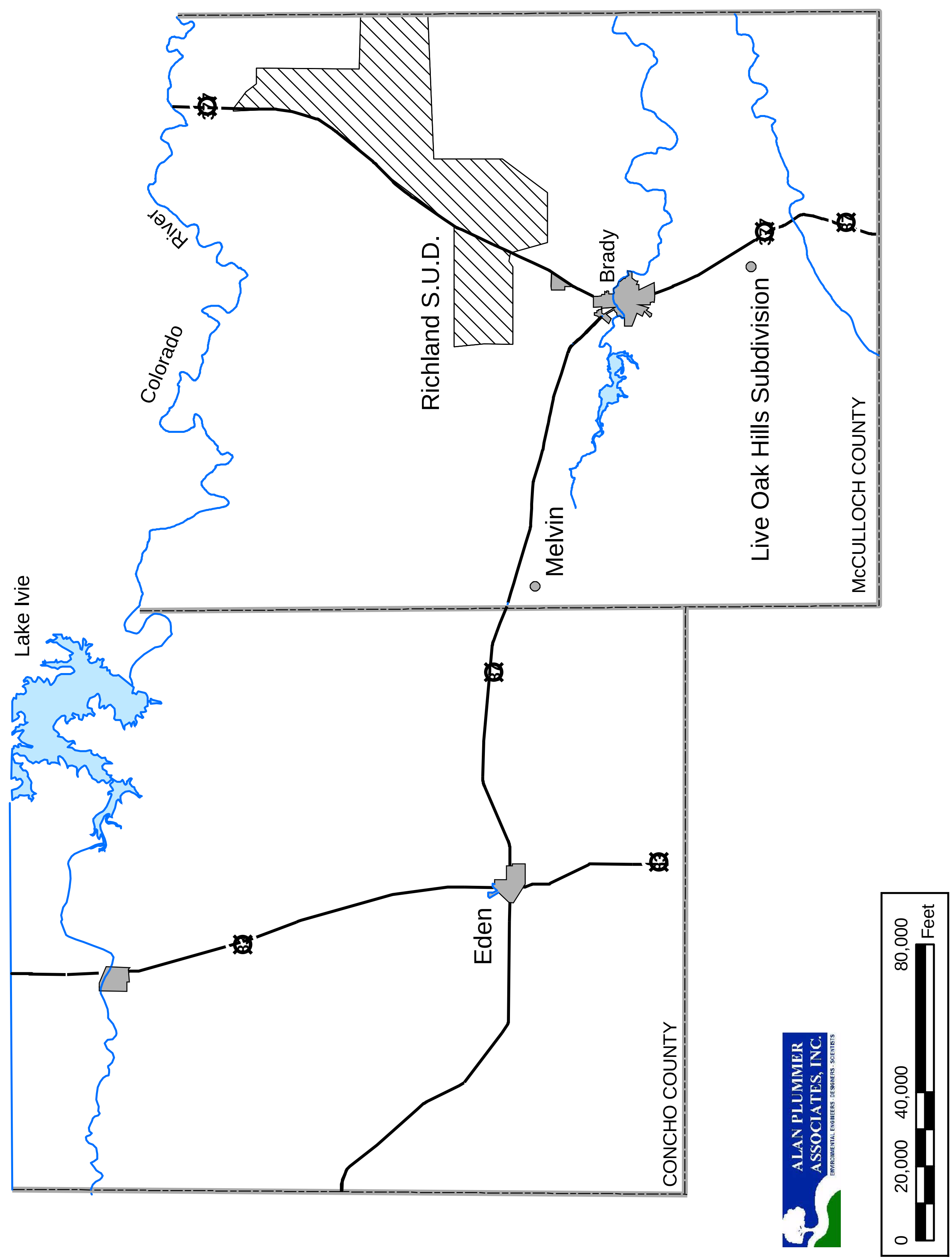
Three of the larger Hickory water suppliers, the City of Brady, MDWSC and Richland SUD, have recently implemented strategies that enable them to reduce their reliance on Hickory water and comply with the MCLs for radionuclides. The City of Brady has constructed a 3.0 MGD plant utilizing microfiltration and reverse osmosis (RO) to treat water from the Brady Creek Reservoir and blend it with groundwater from the Hickory aquifer so that the MCLs for radionuclides are not exceeded. The plant will initially operate at 1.5 MGD.[9] Lakeland Services, Inc. is supplied by the City of Brady.[10] MDWSC is constructing a 3.0 MGD plant that will treat water from Lake Ivie, using treatment processes similar to those at the Brady plant and will blend treated surface water with Hickory groundwater. The construction of the Lake Ivie treatment plant should be complete and operational by 2010. Richland SUD has drilled a new well in the Ellenburger Aquifer in San Saba County and is planning to connect this source to its McCulloch County distribution system. The SUD will blend Hickory Aquifer water with the low radium Ellenburger supply. The City of Eden is in the process of developing a plan to replace a well, construct a reverse osmosis water treatment facility to treat Hickory Aquifer water, and add additional storage. Funding will follow the plan. The treated water will comply with the MCL for radionuclides.

Several of the water suppliers expect to be able to comply with the radionuclides rule without having to treat the Hickory groundwater. Rochelle WSC recently began utilizing a new Hickory well that does not have levels of radionuclides that exceed the drinking water limits. They expect to rely on the new well and reduce or eliminate use of the older well. Lohn WSC also reports radionuclides levels that are under the drinking water standard.[11]

The other communities that will continue to utilize the Hickory aquifer as a sole or major source of water serve a combined population of less than 1,000 persons. These communities include the City of Melvin and Live Oak Hills Subdivision. Due to the long transmission distances required, these communities have not opted to join with a larger service provider. Figure 4.3-3 shows the locations of these water suppliers.

Radionuclides and the Hickory Aquifer Users

Communities that continue to rely on Hickory aquifer water wells where radionuclide concentrations exceed the drinking water standards will soon be required to comply with the EPA/TCEQ rules. EPA is concerned that the radionuclides pose a health threat when routinely ingested over a long period of time. The original rules implementing the Safe Water Drinking Act contained maximum concentration limits (MCLs) for radionuclides, but, until recently, the limits were not enforced and water suppliers were not required to treat for radionuclides. In December 2000, EPA published the Radionuclides Rule, retaining the MCLs for combined radium-226 and radium-228, gross alpha particle radioactivity, and beta particle and photon activity. The rule also regulates uranium for the first time.[12] In December 2004, TCEQ amended its rules to implement the EPA radionuclides rule as part of the state's drinking water program



	Area of Evaluation for Hickory Users	FN JOB NO	**FIGURE**
		FILE	
		DATE July 22, 2005	**4.3-3**
		SCALE	
		DESIGNED CCL	
		DRAFTED	

(TAC Rule §290.108).[13] The federal and state MCLs for radionuclides are listed in Table 4.3-58. Compliance determinations are based on a running average annual MCL. In some areas, Hickory aquifer water contains radium and gross alpha particle activity. Neither beta/photon emitters nor uranium have been shown to be a problem in the Hickory aquifer.

Table 4.3-58
MCLs for Regulated Radionuclide Contaminants

Contaminant	MCL
Beta/photon emitters	4 mrem/yr
Gross alpha particle activity	15 pCi/L
Combined radium-226/228	5 pCi/L
Uranium	30 μg/L

EPA expects the implementation of the radionuclides rule to reduce the risk of cancer for affected citizens. Many of the Hickory aquifer users in Region F, however, question the assertion that their drinking water increases cancer risk. Anecdotally, residents compare themselves to populations in other areas and see no cause for alarm, in spite of having used Hickory groundwater for their entire lives. A cluster cancer investigation was conducted by the Texas Cancer Registry of the Texas Department of Health (TDH), analyzing incidence and mortality data from the early 1990's through 2001 over a four-county area of Hickory groundwater consumption.[14] The study showed that cancer incidence and mortality in the area were within ranges comparable to the rest of the state. The Texas Radiation Advisory Board has also expressed concern that the EPA rules are unwarranted and unsupported by epidemiological public health data. They describe the rules as relying on models of health impacts which have not been validated.[15]

The affected communities in Region F are also greatly concerned about the costs of compliance with the radionuclides rule. EPA estimates that the 795 water systems nationwide affected by the radionuclides rule will incur a combined annual cost of $81 million to comply with the rules, an average of about $100,000 per system.[16] TCEQ also included cost estimates in the publication of its rules, estimating that large water systems would face increases of less than $3 per household per month, while typical small water systems, serving less than 10,000 persons, would have to charge customers between $4 and $9 extra per month to comply with the radionuclide standard.[17] TCEQ is continuing to study the potential economic impacts on small communities struggling to comply with the December 2004 TCEQ drinking water amendments, and is funding a comprehensive study of drinking water compliance issues and costs for small communities.[18]

Potentially Feasible Water Management Strategies

As previously described, two water suppliers in Region F currently have no expectation of being able to develop a water source where the radionuclide levels are under the drinking water MCLs. The City of Melvin has a population of 155 on 127 meter connections. Live Oak Hills Subdivision serves a population of 75 and has 33 connections.

The City of Melvin and the Live Oak Hills Subdivision are both very small communities that do not have the financial resources or staffing to implement water treatment systems. Annual income for water services at Live Oak Hills Subdivision is only about $5,000 per year.[19] These communities also do not operate wastewater collection and treatment systems. Thus, disposal of liquid residuals from water treatment processes would require considerable expense and permitting effort.

Water management strategies have been identified and evaluated for each of these water suppliers and the City of Eden and Richland SUD that are currently pursing alternatives for compliance. Other communities who may later find that their source water exceeds the MCLs for radionuclides should be able to implement similar strategies. The strategies that were evaluated include well replacement, advanced treatment processes, specialty media treatment options, treatment at point-of-entry or point-of-use, several configurations of bottled water options, and a no-action alternative. The well replacement strategy is necessary to sustain the water supply currently provided by a well that is beyond its service life. The other types of strategies identified for the Hickory aquifer users represent very different responses to the EPA/TCEQ radionuclides rule. The first type of strategy is to comply by treating all of the water supply for the water supplier (advanced treatment alternatives). The second option involves treating all or a portion of the water supply at the point where water reaches the customer (point-of-entry/point-of-use alternative). In the third strategy, the water supplier treats only the portion of its water supply that is used for human consumption or imports enough water to ensure a sufficient drinking water supply (bottled water alternative). The last strategy would include a decision by the water supplier to simply not comply with the radionuclides rule (no-action alternative). These alternatives are described in further detail in the following sections.

Well Replacement

The first recommended strategy is replacement of existing Hickory wells owned by the City of Eden and Richland SUD. The City of Eden needs to replace the city's older Hickory wells and add additional ground storage to ensure a continued adequate supply for the city. (The cost of the additional storage is included with the advanced treatment strategy described later in this section.) The proposed well is estimated at a depth of 4,200 feet, with an estimated maximum production of 300 gpm and an average of 200 gpm. Operation and maintenance costs are based on average production rates. It is assumed that this well will not provide additional water supplies, but rather replace supplies from Eden's existing wells.

Richland SUD has been investigating areas of the Hickory aquifer that may have lower radionuclide concentrations. If a low-radium location can be found, Richland SUD may convert most of its supply to the replacement well.

Quantity, Reliability and Cost of Well Replacement

A replacement Hickory aquifer well could provide up to 323 acre-feet of water per year. This source is considered very reliable. Table 4.3-59 summarizes the expected costs for the City of Eden and table 4.3-60 summarizes the expected costs for Richland SUD.

Table 4.3-59
Costs for Replacement Hickory Well for the City of Eden

Supply from Strategy	323 acre-feet per year*
Total Capital Costs	$ 1,800,000
Annual Costs	$ 359,000
Additional Unit Costs (during amortization)	$ 1,113 per acre-foot
	$ 3.42 per 1,000 gallons
Additional Unit Costs (after amortization)	$ 626 per acre-foot
	$ 1.92 per 1,000 gallons

*This supply is not new supplies, but replaces water from existing wells.

Table 4.3-60
Costs for Replacement Hickory Well for Richland SUD

Supply from Strategy	113 acre-feet per year
Total Capital Costs	$ 1,700,979
Annual Costs	$ 224,000
Additional Unit Costs (during amortization)	$ 1,982 per acre-foot
	$ 6.08 per 1,000 gallons
Additional Unit Costs (after amortization)	$ 673 per acre-foot
	$ 2.06 per 1,000 gallons

Environmental Issues Associated with Well Replacement

The proposed wells will produce water from the down-dip portion of the Hickory aquifer. Because of the over 4,000 feet of overburden, there is no connection with the land surface and, therefore, there would be no impact on springs or surface water sources. Subsidence would also not be a factor due to the depth of the source and the competency of the overburden. Therefore environmental impacts are expected to be minimal.

Based on the available data, it is unlikely that pumping limits other than those already imposed by the Hickory Underground Water Conservation District will be required to protect the environment.

Agricultural and Rural Issues Associated with Well Replacement

Currently, no water from the Hickory aquifer is used for irrigation in Concho County. The new well will allow the City of Eden to continue furnishing financial, educational, medical, public safety, and agricultural services. Without these services, agriculture will suffer an increase in cost of doing business, a decrease in productivity, and loss of services that contribute to its overall well-being and safety. As a rural community, drilling a new well represents a significant burden on the public and private economic resources.

Although the Hickory aquifer is used for irrigation in McCulloch County, it is likely that the replacement well for Richland SUD will be located in an area downdip of the agricultural users. Richland SUD provides drinking water to rural residents in McCulloch County, as well as much of the water used for livestock in the area. Therefore, this strategy should have a positive impact on the rural areas of the county.

Other Natural Resource Issues Associated with Well Replacement

Because these wells will replace existing wells, aquifer withdrawals are not expected to significantly exceed current levels.

Significant Issues Affecting Feasibility of Well Replacement

The primary issue affecting feasibility is funding of the replacement wells. As small communities, the City of Eden and Richland SUD have limited resources available for infrastructure improvements. Furthermore, in order to receive funding the City of Eden may need to agree to treat the water to remove radionuclides. The combined costs of advanced treatment plus new wells could raise the average monthly bill per household in the City of Eden to as much as $65.00 per month. To fund both the well and treatment facility will expend public and private money needed for other services such as education, community health, public safety, streets, wastewater treatment, and recreation. The city is classified as economically disadvantaged.

Other Water Management Strategies Directly Affected by Well Replacement

Other strategies for the City of Eden and Richland SUD will be dependent on the production levels and the radium concentrations in the new wells.

Connection to Existing System

Richland SUD serves customers in both San Saba and McCulloch Counties. Presently the San Saba system and McCulloch system are separate. As previously discussed, the SUD has recently completed a new well in the Ellenburger Aquifer in San Saba County. Richland SUD is planning to connect the two systems with a 10-inch pipeline and blend Ellenburger water with Hickory water to meet the radionuclides standards. The San Saba well field can produce approximately 400 acre-feet per year. It is assumed that 200 acre-feet will be used in McCulloch County.

Quantity, Reliability and Cost of Well Replacement

Supply from the San Saba well field could provide up to 200 acre-feet of water per year to McCulloch County. This source is considered reliable. Table 4.3-61 summarizes the expected costs for Richland SUD to interconnect the two systems. It was assumed that the connection would include a 10-mile pipeline, pump station and ground storage.

Table 4.3-61
Costs for Richland SUD Connection to San Saba Well Field

Supply from Strategy	200 acre-feet per year
Total Capital Costs	$ 5,148,000
Annual Costs	$ 523,000
Additional Unit Costs (during amortization)	$ 2,615 per acre-foot
	$ 8.03 per 1,000 gallons
Additional Unit Costs (after amortization)	$ 370 per acre-foot
	$ 1.14 per 1,000 gallons

Environmental Issues Associated with System Connection

There are no known environmental issues associated with strategy. The pipeline crossing of environmentally sensitive areas could be avoided or minimized if needed.

Agricultural and Rural Issues Associated with System Connection

Currently, no water from the Ellenburger Aquifer is used for irrigation in San Saba County. This interconnection will allow Richland SUD to continue furnishing water to rural residents and livestock and should have a positive impact on the rural areas of the county.

Other Natural Resource Issues Associated with System Connection

There is sufficient supply to provide this water to McCulloch County. Aquifer drawdown is not expected to significantly exceed current levels.

Significant Issues Affecting Feasibility of System Connection

Cost may be a factor in implementing this strategy. The SUD has sought funding from the TWDB for this project. There are no other significant issues affecting the feasibility.

Other Water Management Strategies Directly Affected by System Connection

Other strategies for the Richland SUD may be delayed pending the need for water..

Advanced Treatment Alternatives

Several treatment technologies effectively remove radionuclides from water. Radium and gross alpha particle activity are the two radionuclide contaminants that are of concern in the Hickory aquifer wells. Gross alpha particle activity is an indirect measure for radionuclides, measuring the alpha radiation generated by source contaminants. EPA recommends cation exchange (CAX), reverse osmosis (RO), and specialty media as effective technologies for radium removal for small communities. For removal of gross alpha particle activity, the recommended EPA "best available technology" is limited to RO. However, one EPA expert has stated that if radium is the generator of the gross alpha particle activity, then effective radium removal will also reduce the gross alpha particle activity.[20] For well sources where gross alpha particle activity exceeds the MCL, pilot tests would have to be conducted to assess the effectiveness of treatment processes other than RO.

CAX and RO are both considered advanced treatment processes, beyond what has been historically required to enable a water supplier to produce water that complies with the MCLs. CAX is commonly used to remove the hardness minerals, calcium and magnesium, but will also effectively remove radium. RO involves forcing the water under pressure through very fine membranes that prevent passage of contaminants. Both processes produce a brine waste stream, though their characteristics vary. RO typically produces a continuous waste stream consisting of about 15-25 percent of the influent flow quantity. CAX resins must be periodically regenerated, and therefore the waste stream is typically both saline and highly concentrated. The waste stream typically constitutes approximately 5-15 percent of the influent flow. It should also be noted that radium adsorption sites on the CAX resins are not easily regenerated, reducing the ion exchange capacity of the media over time, and ultimately increasing the frequency of resin replacement. However, because radium concentrations are typically very small (10^{-8} mg/L or less) in terms of the amount of mass present, this effect is not pronounced.

Brine with radium concentrations exceeding 60 pCi/L of either radium-226 or radium-228 may require handling as a low-level radioactive waste and may not be discharged to the environment.[21] Therefore, CAX and RO treatment are only cost-effective in situations where there is a waste stream that the brine can be blended into, such that radium concentrations do not exceed the stated discharge limits. Discharges to a sanitary sewer system may not have radium concentrations exceeding 600 pCi/L and must not adversely affect the ability of the wastewater treatment plant to meet its effluent limits.

The City of Eden is pursuing the development of a RO water treatment facility to treat water from the new Hickory aquifer well. The finished water will be a blend of 60 percent treated water with 40 percent well water. The RO facility is assumed to be sized for 0.7 mgd, with a total finished water capacity of 1.2 mgd. The reject water will likely be discharged to the city's wastewater treatment plant, assuming it meets the state's discharge limits. This strategy includes a replacement ground storage tank, sized at 750,000 gallons. The estimated cost for this strategy, including the RO facility and ground storage tank, is shown in Table 4.3-62.

Table 4.3-62
Reverse Osmosis Treatment System for City of Eden

Supply from Strategy	392 acre-feet per year*
Total Capital Costs	$2,582,000
Annual Costs	$321,000
Unit Costs before Amortization	$819 per acre-foot
	$2.51 per 1,000 gallons
Unit Costs after Amortization	$245 per acre-foot
	$0.75 per 1,000 gallons

* This strategy will not create new supplies. It will treat existing supplies and/or supplies from the replacement well. The quantity is based on the average treatment capacity.

Specialty Media Treatment Systems

Specialty media are designed to preferentially remove particular contaminants. Media that specifically target radium are not as sensitive to competing contaminants as standard media, thus enabling longer use before replacement is required. The disadvantage of a longer life cycle is that radium may build up to high concentration levels before the media replacement is needed, requiring operational precautions for workers who routinely inspect and maintain the water supply system. Specialty media are much more expensive than standard filtration or CAX media. A spent medium typically must be disposed as a low-level radioactive waste.

One specialty media considered for implementation in Region F has been developed and licensed by Water Remediation Technologies, LLC (WRT). The WRT system has been shown to effectively reduce both radium and gross alpha particle activity by capturing the radium on the media. TWDB funded a pilot test of the WRT system for Richland SUD from December 2003 to April 2004. From this study, Richland SUD concluded that the WRT system will successfully treat the water from Richland's well to EPA drinking water standards.[14] WRT would maintain ownership of its system and would be responsible for media replacement and disposal. The company is currently seeking to license an injection well in west Texas, where they would be able to dispose of the spent media in a slurried form.[22]

Quantity, Reliability and Cost of Specialty Media Systems

WRT has provided a proposal to Richland SUD to treat water at a cost of $0.78 per 1,000 gallons. Costs for other specialty media systems are assumed to be similar. At a cost of $0.85 per 1000 gallons, Richland SUD would need to charge about $1.25 per 1000 gallons sold, because of the high transmission losses. In addition to the WRT fees, Richland SUD would be required to provide a facility to house the WRT equipment, connection of the treatment facility Richland SUD's distribution system, and the electricity required to power the equipment.[23] The proposed WRT system would be sized to provide radium removal for all of the water pumped from Richland SUD's existing well. The projected costs are shown in Table 4.3-63.

Table 4.3-63
Specialty Media Treatment System for Richland SUD

Supply from Strategy	113 acre-feet per year
Total Capital Costs	$78,000
Annual Costs for Treatment	$75,000
Unit Costs to be added to Water Rates	$664 per acre-foot
	$2.04 per 1,000 gallons

WRT could also be implemented at Melvin's well, but the per-unit cost is likely to be higher than at Richland because there are a number of fixed costs associated with the system that would not scale down for the lower production at Melvin. The City of Melvin has only about 10 percent of the demand at Richland SUD. Based on an assumption that the per-unit cost would be twice as high for Melvin as compared to Richland SUD, the annual cost for Melvin to implement a specialized media technology is $35,000, or about $24 per residential connection per month.

Environmental Issues Associated with Specialty Media Systems

This treatment technology results in a build-up of radium concentrations in the media over the course of its useful life. Accidental release of the highly concentrated radium to the environment is possible if security systems fail or if there is an accident during transport of the spent media to a regulated disposal site.

Agricultural and Rural Issues Associated with Specialty Media Systems

Richland SUD and the City of Melvin are located in a rural area and their customers include ranchers and seasonal hunters. The expense of specialty media treatment may cause some customers to revert to the use of stock ponds or shallow wells for household and livestock water increasing the potential for human and livestock diseases.

Other Natural Resource Issues Associated with Specialty Media Systems

None identified.

Significant Issues Affecting Feasibility of Specialty Media Systems

Suppliers of specialty media, such as WRT, typically require a long-term contract and a minimum guaranteed payment from communities. For rural areas that do not anticipate significant growth in the future, the communities could be legally obligated to pay for more water treatment than they need. Loss of revenues as users conserve water because of high water costs is another concern. Additionally, communities are concerned about the feasibility of providing adequate security and worker safety for the treatment system. The increased costs to customers may result in a decrease in water sales, potentially causing financial difficulties for the community's water system.

Other Water Management Strategies Directly Affected by Specialty Media Systems

The long-term contracts required for implementation of specialty media could inhibit the flexibility of communities to implement more cost-effective strategies that may become available in the future.

Point-of-Entry/Point-of-Use Alternatives

Because of the expense of advanced treatment, EPA allows an option for small community water suppliers to implement point-of-entry or point-of-use treatment for its customers. Point-of-entry (POE) refers to treatment of the water supply for a residence or business at the point where the water enters the building. The most typical example of this is home water softeners. Point-of-use (POU) devices are most often installed under a kitchen sink and treat only the water at the kitchen tap. EPA rules require that the water supplier own, maintain, inspect and test all of the POE/POU devices within its system. One hundred percent customer participation is required.[24] The POE/POU strategy has several pitfalls. The most obvious obstacle to a POU/POE strategy is the private property access required for a water supplier to fulfill the EPA requirements. Maintenance and testing at levels acceptable to the EPA and TCEQ represent a significant investment in time and personnel for small systems. TCEQ has indicated that each home needs to be tested at least once every three years.[12] The TDH Laboratory lists the current fees for drinking water 226 and 228 radium tests at $66 and $94 respectively.[25]

Quantity, Reliability and Cost of POE/POU

EPA has strict guidelines for implementation of POE/POU options, aimed at ensuring reliable treatment of drinking water for all customers. POE/POU strategies do not affect the reliability of the quantity of water, but these systems may not provide the reliability of water quality that an advanced treatment system provides.

For Richland SUD, the City of Melvin and Live Oak Hills Subdivision, POE/POU options are potential strategies for complying with the radionuclides rule. POE/POU treatment provides an acceptable means of handling treatment residuals because single-family septic systems are exempt from the regulations applicable to disposal of radionuclide waste products.

The EPA has developed a small system cost calculator[26] with their report using standard costs developed from the case studies included in *Point-of-Use or Point-of-Entry Treatment Options for Small Drinking Water Systems.*[27] The calculator can be set to reflect the size of a system, the treatment type, and the contaminant of interest. Technologies in this calculator are limited to those identified by EPA for treatment of the contaminant by small systems.

One of the issues facing rural systems in Region F is the treatment of radionuclides. Treatment options for radium 226 and radium 228 include ion exchange, reverse osmosis and lime softening. However, the EPA cost calculator only has options for reverse osmosis for POU applications and cation exchange for POE applications. Three entities facing radium compliance issues, Richland SUD, the City of Melvin, and Live Oak Hills, were selected as examples using the EPA cost calculator.

The costs for POU treatment were estimated using the EPA created small system cost calculator for Richland SUD, the City of Melvin, and Live Oak Hills subdivision. Table 4.3-64 shows results for RO POU for these three entities, and Table 4.3-65 shows the same information for POE treatment using cation exchange. Each table shows the number of connections for each system, the cost per connection, total capital costs, the annual operation and maintenance costs and the total annual costs including the capital costs annualized over 10 years.

Table 4.3-64
Total Costs for POU Treatment using Reverse Osmosis

Entity	# Connections	$/Connection	$/1,000 gal	Total Capital Costs	Annual O&M Costs	Total Annual Costs
Richland SUD	382	$378.64	$4.56	$379,757	$90,571	$144,640
City of Melvin	127	$381.26	$4.59	$126,676	$30,385	$48,420
Live Oak Hills Subdivision	33	$402.40	$4.85	$34,928	$8,306	$13,279

Table 4.3-65
Total Costs for POE Treatment

Entity	# Connections	$/Connection	$/1,000 gal	Total Capital Costs	Annual O&M Costs	Annual Costs
Richland SUD	382	$403.45	$4.86	$595,684	$69,307	$154,119
City of Melvin	127	$239.25	$4.89	$198,463	$23,315	$51,572
Live Oak Hills Subdivision	33	$428.48	$5.16	$53,876	$6,469	$14,140

POE costs are higher than the cost of POU treatment. This is because POE treatment treats all water used in a building, while POU focuses primarily on water used for human consumption.

Table 4.3-66 compares the operation and maintenance costs for POU RO treatment to the annual budget for treatment provided by these entities in the Rural Systems Study survey. (The Rural Systems Study may be found in Volume III of this report.) In every case the current budget is significantly less than the estimated costs for POE/POU treatment.

Table 4.3-66
Cost Comparison of Current Treatment to POU

Entity	Current Annual Costs	Annual O&M Costs (POU)
Richland SUD	$10,489	$90,571
City of Melvin	$5,000	$30,385
Live Oak Hills Subdivision	$300	$8,306

In its response to the Rural Systems Study survey, Richland SUD indicated the potential of using the Water Remediation Technology (WRT) removal system, a centralized system for treating Radium 226 and 228 at the water treatment facility. The WRT removal system will cost about $0.78/1000 gallons per year or $39,000 per year. The WRT treatment strategy is half the cost for operating and maintaining a POU system.

Environmental Issues Associated with POE/POU

The potential groundwater impacts of long-term disposal of naturally occurring radionuclides through septic systems have not been studied.

Agricultural and Rural Issues Associated with POE/POU

POE/POU systems that would require periodic access to private property are unlikely to be acceptable to residents in rural areas such as are served by Richland SUD, the City of Melvin and Live Oak Hills Subdivision. The high costs associated with POE/POU systems would impose an economic burden on these rural communities.

Other Natural Resource Issues Associated with POE/POU

None Identified

Significant Issues Affecting Feasibility of POE/POU

POU/POE options cannot be recommended as a strategy because of access, cost, and liability uncertainties. The strategy requires full participation by all customers of a water system. National Rural Water Association (NRWA) is recommending that EPA modify the regulations for POE/POU to make the implementation of these strategies more economical for small communities.[22]

Other Water Management Strategies Directly Affected by POE/POU

The implementation of POE/POU strategies requires a large initial investment that would likely preclude adoption of an advanced treatment or bottled water strategy.

Bottled Water Alternatives

Another water management strategy considered for Region F Hickory aquifer users is bottled water. Although not presently allowed by EPA as a compliance option, bottled water is allowed on a temporary basis to avoid "unreasonable health risks". Some cities in Texas have provided bottled water in cases where the water supply concentrations of fluoride or nitrates exceed levels considered safe for certain segments of the population. These systems have been set up under bilateral compliance agreements, meaning that the water suppliers are not considered to be in compliance with regulations, but have implemented a temporarily acceptable alternative strategy. Regulators from several states are currently lobbying EPA for inclusion of a bottled water compliance option. This option may be limited to home delivery of bottled water.[12]

A different approach to provision of bottled water is supplying drinking water at a central location for customer self-bottling. The City of Andrews has used a bottled water strategy for the past 12 years to supply customers with drinking water that has been treated to remove fluorides. The treatment equipment is installed in a building, with an external tap that is always accessible to customers. Citizens bring their own 1- to 5-gallon containers to refill and are allowed up to 10 gallons per day. Andrews supplies an average of 1,000 gpd of bottled water to its customers.[28] Water suppliers lacking the personnel or expertise to set up treatment facilities could contract for water brought by truck or distributed at commercial water kiosks.

Bottled water strategies would be implemented only as a temporary option, pending the following future developments:

- More definitive rules regarding disposal options for radionuclide treatment residuals. The EPA and TCEQ regulations and guidance for disposal of residuals from radionuclide drinking water treatment processes remains unclear. An EPA guidance document published in 2006 provides recommendations for disposal.
- Development of less expensive technologies for radium removal

- Further study by EPA and TCEQ of treatment options and associated costs for small community compliance with the drinking water standards. TCEQ currently has a study underway addressing these issues.
- Possible modification of the EPA rules regarding POE/POU and/or bottled water options, as has been suggested by the NRWA.

Hopefully, these future changes will enable small communities to move forward with more certainty in making the large investments that are likely to be required to enable long-term compliance with the drinking water standards.

Quantity, Reliability and Costs of Bottled Water Alternative for Eden

Because of the expense involved in treating to remove radium and the potential impacts of full-scale treatment systems on the City of Eden's wastewater plant and discharge permit, the recommended water management strategy is for the city to treat only the volume of water necessary to provide adequate supply for drinking and cooking. This strategy involves treating about 1200 gpd, approximately ½ gallon per person per day, with two separate distribution points. The first would be at a central location where citizens could obtain self-serve bottled water, and a second within the prison. It is expected that citizens would fill several 3- to 5-gallons containers on each trip, while inmates would frequently refill a personal drinking water bottle. Prison representatives have tentatively approved the implementation of this type of system.[29] Although a second treatment system is not specifically required because treated water could be piped to the two distribution points, a second system would provide redundancy to help ensure a continuous supply of low-radium water. Some cost savings may be expected if only one 1200-gpd system is implemented.

The bottled water program could provide up to 1.3 acre-feet of bottled water per year. The reliability of the supply is high. A 600 gpd treatment facility is comparable to one used by a business or a small industrial facility. The capital cost estimate is based on information provided by a local supplier of CAX and RO commercial/residential equipment. The estimate also includes $39,500 for small buildings to house the equipment at each location. If the treatment equipment can be housed within a prison building and/or within a city building, the costs incurred would be less. The amortization period for the system is estimated at 10 years, since it is assumed that smaller systems generally require more frequent replacement than larger municipal equipment. Operation and maintenance costs are estimated at $0.02 per gallon of water served. Table 4.3-67 summarizes the costs for this strategy. It is estimated that $0.14 per 1,000 gallons would need to be added to residential customers' water rates to cover the costs associated with the non-prison bottled water supply.

Table 4.3-67
Bottled Water Costs for City of Eden

Supply from Strategy	1.3 acre-feet per year
Total Capital Costs	$176,000
Annual Costs for Treatment	$33,000
Unit Costs	$24,552 per acre-foot
	$75 per 1,000 gallons

Quantity, Reliability and Costs of Bottled Water Alternative for Richland SUD, Melvin and Live Oak Hills

Because of the high costs and uncertain regulatory implications of alternative strategies, the recommended temporary strategy for Richland SUD, along with the City of Melvin, and Live Oak Hills Subdivision, is to set up a self-service bottled water supply point within the City of Brady where customers of these utilities can obtain tap water that meets the MCLs. Each supplier would decide whether or not to implement this strategy, but costs can be reduced by implementing a cooperative system. The customers of these three utilities typically make trips to Brady at least weekly for shopping or other business and could obtain water during those trips. One possible location for delivery is the office of the Hickory Underground Water Conservation District No. 1 (HUWCD). It is also possible that an arrangement could be made for citizens to obtain water at other locations in Brady. The estimated costs associated with this strategy include $13,000 in annual administrative costs, plus $1,200 per year for purchase of water from the City of Brady. Some initial expenses for plumbing reconfiguration may also be incurred. Combined expenses for the system would be distributed among the three utilities relative to the expected water usage. The estimated system costs are summarized in Table 4.3-68.

Table 4.3-68
Bottled Water System Costs for Richland SUD, Melvin and Live Oak Hills

Supply from Strategy	0.5 acre-feet per year
Annual Costs	$14,200
Unit Costs to be added to Water Rates	$28,800 per acre-foot
	$88 per 1,000 gallons

Environmental Issues of Bottled Water Alternatives

Impacts of small scale bottled water treatment systems are expected to be minimal.

Agricultural and Rural Issues Associated with Bottled Water Alternatives

Self-serve bottled water will not be as convenient for rural customers as for urban customers. However, as rural communities that serve the area, the low cost of implementation could reserve public and private funds for other uses such as improving educational and medical facilities, providing public safety such as fire protection, and promoting economic development leading to an increase of products and services needed in agriculture and rural communities..

Other Natural Resource Issues Associated with Bottled Water Alternatives

None identified.

Significant Issues Affecting Feasibility of Bottled Water Alternatives

The TCEQ regulatory procedures for setting up a bottled water system as a means of providing low-radium water to customers have not yet been established. The specific requirements for this type of system remain uncertain.

Other Water Management Strategies Directly Affected by Bottled Water Alternatives

Bottled water systems would be set up as a temporary strategy, allowing water suppliers to remain flexible regarding future options. Technology developments, regulatory changes, and availability of funding may change in future years to make other strategies more feasible for these small water suppliers.

No-Action Alternative

Another approach considered for the Hickory aquifer users is a “no action” alternative. This alternative does not bring the water supplier into compliance with TCEQ drinking water rules. However, representatives of some of the supplier utilizing the Hickory aquifer have expressed concern that the questionable health benefits of compliance with the radionuclides rule do not justify the high costs that their customers will be forced to bear. In fact, some have argued that the significant increase in water cost resulting from the implementation of any alternative to reduce radionuclides may force some of their customers to revert to using stock ponds or shallow wells that have a greater likelihood of containing pollutants that pose a serious health risk.

A cluster cancer investigation was conducted by the Texas Cancer Registry of the Texas Department of Health and found that the cancer incidence and mortality in the area were within ranges comparable to the rest of the state.[30] The Texas Radiation Advisory Board also expressed concern that the EPA rules are unsupported by epidemiological public health data.[31]

Environmental Issues of No Action Alternative

The no-action alternative would have no environmental impacts that differ from current practices. Furthermore, any environmental consequences of disposal of concentrated brine reject will be eliminated.

Agricultural and Rural Issues Associated with No Action Alternative

The lack of compliance with drinking water regulations could have negative impacts on the economic development in this area. It may be difficult for the area to attract new industries if the water supply does not meet drinking water standards. On the other hand, the adverse impact of the high cost of advanced treatment will tie up the area’s limited financial resources that could be used for other purposes such as improving educational and medical facilities, providing public safety such as fire protection, and promoting economic development leading to an increase of products and services needed in agriculture and rural communities..

Other Natural Resources Issues Associated with No Action Alternative

None identified.

Significant Issues Affecting Feasibility of No Action Alternative

Water suppliers choosing a no-action alternative could face fines or penalties, or other legal action. Private-action lawsuits are also possible. There could be repercussions for funding of state or federal projects.

Other Water Management Strategies Affected by No Action Alternative

The no-action alternative is only a response to the radionuclides rule and does not impact water management strategies that may be necessary to increase or to ensure water supplies.

Hickory Strategy Summary

Potential water management strategies considered for Hickory aquifer users are listed in Table 4.3-69. Table 4.3-72 provides a summary of the issues associated with each type of strategy.

Table 4.3-69
Strategy Evaluation Matrix for Hickory Aquifer Users

Strategy	City of Eden	Richland SUD	Melvin	Live Oak Hills
Well replacement	X	X		
System Connection		X		
Cation Exchange (CAX)				
Reverse Osmosis (RO)	X			
Specialized Media (e.g. WRT)		X	X	
POE/POU (CAX or RO)		X	X	X
Bottled Water – Central Location	X	X	X	X
No Action		X	X	X

Recommended Strategies for Hickory Aquifer Users

For each of these four water suppliers, the potential water management strategies involve significant uncertainties regarding costs and regulations. Regulatory uncertainty about disposal options for treatment residuals and the potential economic impact of treatment on rural Texas continue to inhibit implementation of compliance strategies. The more innovative options of POE/POU do not yet have clearly defined requirements for operation, maintenance and testing. These strategies are also expensive to implement and are the most intrusive for customers. Although EPA is being lobbied to include bottled water as a compliance strategy, this option has not yet been defined in that manner. The current regulatory environment is not conducive to the implementation of strategies that would allow these small community water systems to comply with the radionuclides rule. Thus, the bottled water strategies are recommended as a temporary measure until conditions improve such that other options become more economically feasible and involve less regulatory uncertainty.

Table 4.3-70 summarizes the costs of the recommended strategies for each Hickory aquifer user. Table 4.3-71 shows the alternate strategies. In addition to the recommended strategies in Table 4.3-70 the Bottled Water Alternative for the City of Eden is recommended if the city is unable to obtain sufficient funding to implement the RO water treatment plant. The Specialty Media strategy is an alternate strategy for Richland SUD should the SUD not be able to develop a low radium well.

Table 4.3-70
Costs of Recommended Strategies for Hickory Aquifer Users

City of Eden

Strategy	Capital Costs	2010	2020	2030	2040	2050	2060
RO water treatment plant	$2,582,000	$321,000	$321,000	$96,000	$96,000	$96,000	$96,000
Replacement well	$1,800,000	$359,000	$359,000	$202,000	$202,000	$202,000	$202,000
Total	*$4,382,000*	*$680,000*	*$680,000*	*$298,000*	*$298,000*	*$298,000*	*$298,000*

Richland SUD

Strategy	Capital Costs	2010	2020	2030	2040	2050	2060
System connection	$5,148,000	$0	$523,000	$523,000	$74,000	$74,000	$74,000
Bottled water* system	$3,000	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400
Low Radium well	$1,701,000	$0	$0	$224,000	$224,000	$76,050	$76,050
Total	*$6,852,000*	*$10,400*	*$533,400*	*$757,400*	*$308,400*	*$160,450*	*$160,450*

City of Melvin

Strategy	Capital Costs	2010	2020	2030	2040	2050	2060
Bottled water* system	$0	$2,400	$2,400	$2,400	$2,400	$2,400	$2,400

Live Oak Hills Subdivision

Strategy	Capital Costs	2010	2020	2030	2040	2050	2060
Bottled water* system	$0	$1,400	$1,400	$1,400	$1,400	$1,400	$1,400

* Capital costs are assigned to Richland SUD for the purposes of this plan. Actual costs will be shared by program participants.

Table 4.3-71
Costs of Alternate Strategies for Hickory Aquifer Users

Strategy	Capital Costs	2010	2020	2030	2040	2050	2060
Specialty Media – Richland SUD	$78,000	$75,000	$75,000	$75,000	$75,000	$75,000	$75,000

Table 4.3-72
Potential Strategies for Hickory Aquifer Users

Type of WMS	Primary Advantages	Primary Disadvantages	Disposal Issues	Other Regulatory Issues
Cation Exchange (CAX)	Provides high level of treatment for radium.	System requires regular backwashing/regeneration. Sodium supply is a constant expense. Ion exchange media must also periodically be replaced.	Brine could be considered low-level radioactive waste unless there is a waste stream to blend the brine into. Potential long-term liability risks.	State needs to address low-level radioactive waste rules to accommodate disposal of treatment residuals in Texas.
Reverse Osmosis (RO)	Provides high level of treatment for radium and gross alpha.	Membranes have to be monitored and periodically cleaned or replaced and 15-25% of water is wasted as brine. High level of operator training is required to properly operate and maintain the system.	Brine could be considered low-level radioactive waste unless there is a waste stream to blend the brine into. Potential long-term liability risks.	State needs to address low-level radioactive waste rules to accommodate disposal of treatment residuals in Texas.
Specialized Media (e.g. WRT Z-88)	No liquid residual requiring disposal, requires little operation/maintenance from the water supplier.	Water supplier is reliant on commercial supplier to maintain and operate. Radium concentrations in the media require precautions regarding worker safety and could also expose water supplier to liability risks.	There is no viable disposal option within Texas at this time. WRT is seeking to permit an injection well within Texas. Disposal costs will be higher if the well can't be permitted.	State needs to address low-level radioactive waste rules to accommodate disposal of treatment residuals in Texas.
POE (CAX)	Smaller CAX systems are simpler to operate and maintain than central systems. Water supplier operators could maintain systems that are located in accessible areas outside the customers' homes.	The water supplier must own the system and 100% of customers must agree to participate. Property access by the water supplier operator is required for maintenance and inspection. A contract must be set up between the water supplier and the homeowner to allow the necessary access. Each system has to be tested once every 3 years.	Single-family septic systems are exempt from rules regarding disposal of radionuclides.	Maintenance and inspection intervals have not yet been determined by TCEQ. Radium testing cost would be prohibitive; no adequate substitute test has yet been approved by TCEQ.
POU (RO)	Only a portion of the water supply has to be treated. Home RO systems are less expensive and easier to install and maintain than POE CAX.	Water supplier must own the system and 100% of customers must agree to participate. Access to interior of customers' homes for maintenance and inspection is required. A contract must be set up between the water supplier and the homeowner to allow the necessary access. Each system has to be tested once every 3 years.	Single-family septic systems are exempt from rules regarding disposal of radionuclides.	Maintenance and inspection intervals have not yet been determined by TCEQ. Radium testing costs would be prohibitive; no adequate substitute test has yet been approved by TCEQ.
Bottled Water (delivered)	Convenient supply of drinking water for customers.	Delivery is extremely expensive and typically requires use of 3- to 5-gallon containers that may be too heavy for some customers to handle. Water supplier would be dependent on a commercial water supplier or would have to implement treatment, bottling and delivery themselves.	None if imported by a commercial supplier. Septic system could possibly accommodate disposal of residuals from CAX or RO processes, if there is a sufficient waste stream to blend the brine into.	EPA has not approved bottled water as a compliance option, but TCEQ believes delivery might be viewed the same as POU from a regulatory standpoint. A water supplier that is bottling water for delivery will have to comply with the regulations that govern the bottled water industry.
Bottled Water (central location)	Provides customers a drinking water supply, without the added expense of home delivery or the maintenance access issues of POE or POU.	Customers bear the inconvenience of obtaining drinking water from a central location. Abuse is possible from non-customers taking water or from customers taking too much water. Round-the-clock accessibility to bottled water may be required.	Water suppliers have to dispose of brine residuals in a sanitary sewer system or a septic system. Septic system could possibly accommodate disposal of residuals from CAX or RO processes, if there is a sufficient waste stream to blend the brine into. Drinking water supply could be tanked in from a nearby city.	EPA has not approved bottled water as a compliance option. This option has only been allowed under bilateral compliance agreements.
No Action	Avoids high costs of compliance that could impose an economic hardship on customers. Avoids liability issues of concentrating radium via treatment process.	Customers continue to be supplied with drinking water that exceeds EPA standards. Water supplier could potentially bear liability if health concerns are later validated.	None	Water supplier would face fines and penalties, or other legal action. Private-action lawsuits are also possible. There could be potential repercussions for funding of state or federal projects.

4.4 Manufacturing Needs

Table 4.4-1 summarizes the manufacturing needs for Region F. There are six counties showing manufacturing needs over the planning period: Coleman, Ector, Howard, Kimble, Runnels and Tom Green Counties. Manufacturing needs in Coleman, Ector, Howard, Runnels and Tom Green Counties are associated with needs for the cities of Coleman, Odessa, Big Spring, Ballinger and San Angelo, respectively, and will be met by strategies developed for these cities. Needs for the City of Coleman are met exclusively with the subordination strategy described in Sections 4.2.3 and 4.2.4. Needs for Odessa and Big Spring are met by strategies discussed with Colorado River Municipal Water District strategies in Section 4.8.1. Strategies for San Angelo are found in Section 4.8.3. Only manufacturing needs in Kimble County cannot be met with a municipal strategy and require a stand-alone analysis.

4.4.1 Kimble County

Kimble County has three of the largest cedar processing operations in the world.[32] These operations account for most of the manufacturing water in Kimble County. According to data from the Texas Water Development Board, manufacturing water use in Kimble County has declined significantly from a high of 2,100 acre-feet per year in 1993 to 14 acre-feet per year in 2007. An average of 20 acre-feet of surface water and 1 acre-feet of groundwater were used for manufacturing purposes in Kimble County between 2001 and 2007, excluding 2005. (Historical groundwater and surface water use are not available from TWDB for the year 2005.) The current water use is significantly less than the projections for Kimble County, which range from 702 acre-feet per year in 2010 to 1,002 acre-feet per year in 2060.

The City of Junction is the major user of surface water in Kimble County. However, TWDB records show no industrial sales by the city. There are only two water rights in Kimble County authorized for manufacturing use, with a total authorized diversion of 2,466 acre-feet per year. However, only 51 acre-feet per year are authorized for consumption by these water rights, which is about two percent of the total diversion. The remainder must be returned to the stream. It also appears that a significant part of the historical reported surface water use includes water that is not consumed. Recently the reported water use has changed from total diverted water to consumed water.[33]

Table 4.4-1
Manufacturing Needs in Region F
(Values in Acre-Feet per Year)

Source	2010	2020	2030	2040	2050	2060	Comments
Coleman County							
Lake Coleman	*0*	*0*	*0*	*0*	*0*	*0*	Coleman sales, no supply in WAM
Demand	*6*	*6*	*6*	*6*	*6*	*6*	
Surplus (Need)	*(6)*	*(6)*	*(6)*	*(6)*	*(6)*	*(6)*	
Ector County							
CRMWD system	877	797	1199	902	871	813	Odessa sales
Reuse	1500	1650	1800	1950	2100	2250	Odessa reuse
Edwards-Trinity Plateau	16	17	18	19	19	20	
Total Supply	*2393*	*2464*	*3017*	*2871*	*2990*	*3083*	
Demand	*2759*	*2963*	*3125*	*3267*	*3376*	*3491*	
Surplus (Need)	*(366)*	*(499)*	*(108)*	*(396)*	*(386)*	*(408)*	
Howard County							
CRMWD system	722	703	1,094	1,090	1,103	1,130	Big Spring sales
Edwards-Trinity Plateau	288	288	288	288	288	288	
Ogallala	461	461	461	461	461	461	
Total Supply	1,471	1,452	1,843	1,839	1,852	1,879	
Demand	1,648	1,753	1,832	1,910	1,976	2,099	
Surplus (Need)	(177)	(301)	11	(71)	(124)	(220)	
Kimble County							
Edwards-Trinity Plateau	3	3	3	3	3	3	
Johnson Fork	0	0	0	0	0	0	Self-supplied, no supply in WAM
Total Supply	3	3	3	3	3	3	
Demand	702	767	823	880	932	1,002	
Surplus (Need)	(699)	(764)	(820)	(877)	(929)	(999)	
Runnels County							
Lake Ballinger	0	0	0	0	0	0	Ballinger sales, no supply in WAM
Lake Winters	0	0	0	0	0	0	Winters sales, no supply in WAM
Total Supply	0	0	0	0	0	0	
Demand	63	70	76	82	87	94	
Surplus (Need)	(63)	(70)	(76)	(82)	(87)	(94)	
Tom Green County							
San Angelo System	0	0	0	0	0	0	San Angelo sales, no supply in WAM
Demand	2,226	2,498	2,737	2,971	3,175	3,425	
Surplus (Need)	(2,226)	(2,498)	(2,737)	(2,971)	(3,175)	(3,425)	
Total For Counties with Needs							
Total Need	(3,537)	(4,138)	(3,736)	(4,403)	(4,707)	(5,152)	

Three potential water management strategies have been identified for Kimble County Manufacturing:

- Subordination of downstream senior water rights
- Voluntary redistribution through purchase or lease of existing surface water rights
- New groundwater development from the Edwards-Trinity Plateau aquifer

Region F does not evaluate water conservation for manufacturing because of the relatively small amount of water used and a lack of specific data on manufacturing processes.

Subordination of Senior Water Rights

The two Kimble County manufacturing water rights were not included in the larger subordination analysis associated with the major water rights in the Colorado Basin. As a result the WAM shows that they do not have a reliable supply. As a surrogate for a more thorough analysis, the availability for these water rights was determined running the Colorado WAM in natural order. Natural order ignores the priority of water rights and meets demands from upstream to downstream. In natural order, the combined reliable supply from these two rights is 20 acre-feet per year.

Quantity, Reliability and Cost

Assuming that this diversion represents the two percent of water that is actually consumed, the total recirculated use for these rights would be 1,000 acre-feet per year, which is sufficient to meet demands. However, this supply may not be entirely reliable because diversions may not be available when needed during drought. The cost of this strategy depends on negotiations between the water rights holders. No costs have been developed for the subordination strategy (see Section 4.2.3).

Environmental Issues

Implementation of this strategy is expected to have minimal impacts on environmental flows, over-banking flows, or habitats because of the small consumptive use authorized by these two water rights.

Agricultural and Rural Issues

There are no agricultural or rural issues associated with this project.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

The natural order simulation assumes that no downstream water rights make priority calls on these two water rights. In practice, it would be extremely difficult to enter subordination agreements with all senior downstream rights. Normally only water rights with large diversions enter into subordination agreements. However, these agreements may not prevent smaller rights from making priority calls. Given the relatively small consumptive use associated with these rights, even a priority call by a small water right could impact availability.

Other Water Management Strategies Directly Affected

Voluntary redistribution to meet Kimble County manufacturing needs may be affected.

Voluntary Redistribution through Lease or Purchase of Existing Water Rights

Voluntary redistribution through purchase or lease of existing water rights is a feasible strategy that is complementary to subordination. The leased or purchased water rights must have priority dates senior to the two manufacturing rights for this strategy to be effective. Diversions for these rights could be moved upstream, or the rights could simply not be exercised, eliminating the possibility of a priority call. For example, according to the Colorado WAM there are 1,475 acre-feet per year of reliable irrigation diversions in Kimble County. However, Kimble County irrigation has a surplus of 786 acre-feet per year in 2010, increasing to 964 acre-feet per year by 2060. This implies that at least some irrigation rights may be available for purchase or lease.

Region F has not identified specific rights for purchase, so no quantity, costs or impacts can be developed at this time. These transactions would be made between private corporations and individuals and valuating these transactions is not appropriate for regional water planning.

New Groundwater Development from the Edwards-Trinity Plateau Aquifer

There are undeveloped groundwater supplies in the Edwards-Trinity Plateau aquifer in Kimble County. Water from this source is not widely used because of low well yields in most areas. Some areas have poor water quality as well. However, there appears to be some areas within the county that have sufficient well yields to meet manufacturing water needs. This strategy assumes that 5 new wells with an average transmission distance of 15 miles could be constructed to supply manufacturing water.

Quantity, Reliability and Cost

This strategy could be implemented if the Kimble County manufacturing water needs are for consumptive use and not for recirculated water. This strategy assumes that up to 1,000 acre-feet of water per year could be produced from the Edwards-Trinity (Plateau) aquifer. Reliability would be moderate to high, depending on well capacity. The cost of water would be approximately $1,080 per acre-foot ($3.31/1,000 gallons). Table 4.4-2 summarizes the costs for this strategy.

Table 4.4-2
New Water Wells in the Edwards-Trinity (Plateau) Aquifer
Kimble County Manufacturing

Supply from Strategy	**1,000 acre-feet per year**
Total Capital Costs (2008 Prices)	$ 9,080,000
Annual Costs	$ 1,080,000
Unit costs (during amortization)	$ 1,080 per acre-foot
	$ 3.31 per 1,000 gallons
Unit Costs (after amortization)	$ 288 per acre-foot
	$ 0.88 per 1,000 gallons

Environmental Issues

A specific drilling location for this strategy has not been identified. Many areas of good well production in the Edwards-Trinity Plateau aquifer are associated with surface water discharge from springs. Groundwater development from this source should be evaluated for potential impacts on spring flows and base flows of area rivers. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Issues

There are no agricultural or rural issues associated with this project.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

The most significant challenge for this strategy is locating areas with sufficient well production and low potential for impacts on spring flows. There is also uncertainty regarding the amount of water actually needed to meet consumptive manufacturing needs in Kimble County. It is quite likely that the actual amount of water needed is overstated in the projections.

Other Water Management Strategies Directly Affected

Other Kimble County manufacturing strategies.

Recommended Strategies for Kimble County Manufacturing

Since it appears that the manufacturing demands for Kimble County include a significant amount of recirculated water, the most likely strategy to meet future manufacturing needs is subordination of downstream water rights. Voluntary redistribution by purchase or lease of other water rights could be effective as well, depending on which water rights are available for purchase. Drilling of water wells by manufacturing interests in Kimble County is recommended as an alternate strategy for manufacturing needs.

Table 4.4-3 summarizes the recommended strategies for Kimble County manufacturing. Costs for this strategy have not been developed because of the uncertainty regarding the implementation of these strategies.

Table 4.4-3
Recommended Strategies for Kimble County Manufacturing
(Values in Acre-Feet per Year)

	2010	2020	2030	2040	2050	2060
Existing Supplies	3	3	3	3	3	3
Subordination, voluntary redistribution & recirculation	1,000	1,000	1,000	1,000	1,000	1,000
Total Supplies	*1,003*	*1,003*	*1,003*	*1,003*	*1,003*	*1,003*
Demand	*702*	*767*	*823*	*880*	*932*	*1,002*
Surplus (Need)	*301*	*236*	*180*	*123*	*71*	*1*

4.5 Steam-Electric Power Needs

By 2060 the region has water needs for Steam-Electric Power Generation of almost 20,600 acre-feet. These shortages are the result of three factors:

- Little or no yield in reservoirs using Colorado WAM Run 3, which is required for use in the regional water plans by the TWDB,
- Limited groundwater supplies in Ward and Andrews Counties, and
- Increased demands that cannot be met with existing supplies, particularly in Ector County.

Table 4.5-1 compares region-wide demands to existing available supplies. In areas where there are insufficient supplies, steam-electric power generation has been limited to the maximum recent historical use.

The projections for growth in steam-electric power water use in Region F are based on state-wide projections for new generation capacity and do not necessarily reflect site-specific water needs.[34] In Region F, the projected growth in water demand exceeds the water supply currently available to existing generation facilities. Because growth in demand is not site-specific, strategies may include movement of demand to other locations as well as new supply development.

Potentially Feasible Strategies

Because of an overall lack of available new water supplies at existing generation facilities, Region F has limited water use for steam-electric power generation to current use. The expected growth in water demand reflects the expected need for additional electrical generation capacity in Texas, and that additional capacity can be met through a variety of approaches. Therefore meeting these shortages is not limited to water management strategies.

Strategies to meet steam-electric needs include:

- Moving the power generation need to another existing facility outside of Region F with sufficient water supplies;
- Construction of a new generation facility in an area where there are sufficient water supplies to meet projected demands, either inside or outside of Region F;
- Using an alternative source of water, including brackish water (either groundwater or surface water from chloride control projects such as Mitchell County Reservoir) or treated wastewater, either inside or outside of Region F;
- Voluntary redistribution of water supplies already dedicated to another use, including purchase of existing irrigation supplies; and
- Use of alternative cooling technologies that use less water.

Table 4.5-1
Comparison of Region F Steam-Electric Water Demand Projections to Currently Available Supplies

	Name	County	2010	2020	2030	2040	2050	2060	Comments
Currently Available Supply	Oak Creek Reservoir	Coke	0	0	0	0	0	0	No supply in priority order WAM
Demand	AEP Oak Creek	Coke	310	247	289	339	401	477	
Surplus (Need)			*(310)*	*(247)*	*(289)*	*(339)*	*(401)*	*(477)*	
Currently Available Supply	Edwards-Trinity Plateau aquifer	Pecos	1,500	1,500	1,500	1,500	1,500	1,500	Supply based on recent use
Demand	AEP Rio Pecos	Crockett	973	776	907	1,067	1,262	1,500	Source in Pecos County
Surplus (Need)			*527*	*724*	*593*	*433*	*238*	*0*	
Currently Available Supply	Ogallala aquifer	Andrews	5,156	5,156	5,156	5,156	5,156	5,156	Supply limited to recent use
Demand	Panda Odessa-Ector	Ector	6,375	9,125	10,668	12,549	14,842	17,637	Source in Andrews County
Surplus (Need)			*(1,219)*	*(3,969)*	*(5,512)*	*(7,393)*	*(9,686)*	*(12,481)*	
Currently Available Supply	Champion/Colorado City System	Mitchell	0	0	0	0	0	0	No supply in priority order WAM
Demand	TXU Morgan Creek	Mitchell	5,023	4,847	4,670	4,493	4,317	4,140	
Surplus (Need)			*(5,023)*	*(4,847)*	*(4,670)*	*(4,493)*	*(4,317)*	*(4,140)*	
Currently Available Supply	Twin Buttes/Nasworthy	Tom Green	0	0	0	0	0	0	No supply in priority order WAM
Demand	AEP San Angelo	Tom Green	543	777	909	1,069	1,264	1,502	
Surplus (Need)			*(543)*	*(777)*	*(909)*	*(1,069)*	*(1,264)*	*(1,502)*	
Currently Available Supply	Pecos Valley	Ward	4,914	4,223	4,937	5,807	6,189	6,189	Supply limited to recent use
Demand	TXU Permian Basin	Ward	4,914	4,223	4,937	5,807	6,868	8,162	
Surplus (Need)			*0*	*0*	*0*	*0*	*(679)*	*(1,973)*	
	Total Currently Available Supply		*11,570*	*10,879*	*11,593*	*12,463*	*12,845*	*12,845*	
	Total Demand		*18,138*	*19,995*	*22,380*	*25,324*	*28,954*	*33,418*	
	Total Surplus (Need)		*(6,568)*	*(9,116)*	*(10,787)*	*(12,861)*	*(16,109)*	*(20,573)*	

Region F has identified only subordination of downstream water rights as a recommended strategy. Other strategies may be employed in Region F, including the voluntary redistribution of existing water supplies, moving demand to another location, desalination and use of alternative cooling technologies. However, the actual strategies are largely a business decision on the part of the power industry. An analysis of the potential costs of alternative cooling technologies is included in this plan. The other strategies have a large degree of uncertainty that makes it difficult to perform a meaningful analysis in the context of regional planning. Therefore, analyses of these strategies are not included in this plan.

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, most reservoirs in Region F with a priority date after 1926 do not have a firm or safe yield. This result is largely due to the assumptions used in the Colorado WAM. Four reservoirs in Region F provide water for steam-electric power generation:

- Oak Creek Reservoir, which is owned by the City of Sweetwater;
- Champion Creek Reservoir and Lake Colorado City, which are owned by Luminant and operated as system; and
- Lake Nasworthy, which is owned by the City of San Angelo.

All of these reservoirs have priority dates after 1926, so these reservoirs have no yield.

In order to address water availability issues associated with the Colorado WAM model, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights in Region F do not make priority calls on each other. The subordination strategy is discussed in Section 4.2.3.

Table 4.5-2 is a summary of the impacts of the subordination strategy on supplies used for steam-electric power generation.

The joint modeling between the two regions was conducted for planning purposes only. Neither Region F nor the Lower Colorado Region mandates the adoption of this strategy by individual water right holders. A subordination agreement is not within the authority of the

Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including steam-electric power generators.

Table 4.5-2
Impact of Subordination Strategy on Steam-Electric Water Supplies [a]
(Values in acre-feet per year)

Reservoir	Priority Date	Permitted Diversion	2010 Supply WAM Run 3	2010 Supply with Subord-ination	2060 Supply WAM Run 3	2060 Supply with Subord-ination
Oak Creek Reservoir	4/27/1949	10,000 [b]	0	2,118	0	1,760
Champion Creek Reservoir	4/08/1957	6,750 [c]	0	2,337	0	2,220
Lake Colorado City	11/22/1948	5,500	0	2,686	0	1,920
Lake Nasworthy [d]	3/11/1929	25,000 [e]	0	12,310 [f]	0	11,360 [f]
Total		*47,250*	*0*	*19,451*	*0*	*17,260*

a Water supply is defined as the safe yield of the reservoir.

b 4,000 acre-feet per year for industrial purposes and 6,000 acre-feet per year for municipal purposes, making the total authorized diversion from Oak Creek Reservoir 10,000 acre-feet per year. Steam-electric power generation is considered an industrial use.

c 2,700 acre-feet per year of the authorized diversions can be used for municipal purposes. However, at this time there is no municipal use from the reservoir, so the entire 6,750 acre-feet per year can be used for power generation.

d Diversions from Lake Nasworthy are backed up by storage in Twin Buttes Reservoir, which has a priority date of 5/06/1959.

e 7,000 acre-feet per year for industrial, 17,000 acre-feet per year for municipal and 1,000 acre-feet per year for irrigation, making the total authorized diversions from Lake Nasworthy 25,000 acre-feet per year.

f Yield from Twin Buttes Reservoir and Lake Nasworthy operating as a system.

Impacts of the subordination strategy are discussed in Section 4.2.3.

Alternative Cooling Technologies

Region F considers alternative cooling technologies on new power generation projects a likely method for developing new generation capacity within Region F. This technology, which uses air for cooling instead of water, can be utilized on any steam cycle based power generation project, for an incremental cost. This cost, calculated on a dollar per installed megawatt basis, would be above the cost of conventional cooling.

Quantity, Reliability and Cost

Table 4.5-3 shows the results of this analysis. Using the suggested technology up to 15,000 acre-feet per year of unmet needs can be met by 2060. This technology is currently in use and is very reliable. Capital costs, which are based on the incremental difference between more conventional cooling technologies and the alternative technology, are approximately $50.25 million in 2010, increasing to $201 million by 2060. These costs are based on the development of incremental capacities in units of 500 MW. Actual electric generating capacities will be determined on a facility basis.

Agricultural and Rural Issues

There are no agricultural or rural issues associated with this project.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

The implementation of this strategy is dependent upon a distribution of state-wide generation needs that may not represent the actual needs for generation within Region F. Location of new generation facilities within Region F is largely an economic issue that will be made by the power industry. Other technologies or strategies may be more attractive for meeting the need for new generation capacity.

Other Water Management Strategies Directly Affected

No other water management strategies are impacted by this project.

Recommended Water Management Strategies for Steam Electric Power Generation

Table 4.5-4 is a summary of supply and demand for steam-electric power generation with subordination of downstream water rights, the only recommended strategy in this plan. There are significant needs remaining. It is likely that other strategies may be implemented by the steam-electric power industry to meet these demands, including moving demand to other locations, use of alternative water sources such as desalination, and use of alternative generation technologies.

Table 4.5-3
Needed Generation Capacity on Incremental Cost of ACC Technology

	2010[a]	2020	2030	2040	2050	2060
Steam Electric Needs [b] (Ac-Ft)	1,219	3,969	5,512	7,441	10,608	14,935
Equivalent needs (GWh)	-	2,332	3,387	4,880	7,419	11,104
MW Capacity Needed (MW)	-	389	565	813	1,236	1,851
Incremental Capacity Installed (MW)	-	500	500	0	500	500
Total Capacity Installed (MW)	-	500	1,000	1,000	1,500	2,000
Capacity Factor of New Capacity (%)	-	53%	39%	56%	56%	63%
Incremental cost of ACC (million $)	-	$50.25	$50.25	$0.00	$50.25	$50.25
Total Capital Cost *(million $)*	-	$50.25	$100.50	$100.50	$150.75	$201.00
Debt Service (million $)	-	$4.38	$8.76	$4.38	$4.38	$8.76
O&M (million $) [c]	-	$1.26	$2.51	$2.51	$3.77	$5.03
Total Annual Cost *(million $)*	-	$5.64	$11.27	$6.89	$8.15	$13.79
Amount of Water Saved (af/y)		5,000	8,000	9,000	12,000	16,000
Cost/Ac-Ft	-	$1,127	$1,409	$766	$679	$862
Cost/1,000 Gal	-	$3.46	$4.32	$2.35	$2.08	$2.65

[a] Strategy assumed to be implemented after 2010.

[b] Does not include surplus supplies at other locations.

[c] Assuming 2.5 percent of construction for O&M.

Table 4.5-4
Recommended Strategies for Steam-Electric Power Generation

Category	Name	County	2010	2020	2030	2040	2050	2060
Supply	Oak Creek Reservoir	Coke	0	0	0	0	0	0
	Subordination		310	247	289	339	401	477
	Total		310	247	289	339	401	477
Demand	AEP Oak Creek	Coke	310	247	289	339	401	477
Surplus (Need)			0	0	0	0	0	0
Supply	Edwards-Trinity Plateau aquifer	Pecos	1,500	1,500	1,500	1,500	1,500	1,500
Demand	AEP Rio Pecos	Crockett	973	776	907	1,067	1,262	1,500
Surplus (Need)			527	724	593	433	238	0
Supply	Ogallala aquifer	Andrews	5,156	5,156	5,156	5,156	5,156	5,156
Demand	Panda Odessa-Ector	Ector	6,375	9,125	10,668	12,549	14,842	17,637
Surplus (Need)			(1,219)	(3,969)	(5,512)	(7,393)	(9,686)	(12,481)
Supply	Champion/Colorado City System	Mitchell	0	0	0	0	0	0
	Subordination		5,023	4,847	4,670	4,493	4,317	4,140
	Total		5,023	4,847	4,670	4,493	4,317	4,140
Demand	TXU Morgan Creek	Mitchell	5,023	4,847	4,670	4,493	4,317	4,140
Surplus (Need)			0	0	0	0	0	0
Supply	Twin Buttes/Nasworthy	Tom Green	0	0	0	0	0	0
	Subordination		1,021	1,021	1,021	1,021	1,021	1,021
	Total		1,021	1,021	1,021	1,021	1,021	1,021
Demand	AEP San Angelo	Tom Green	543	777	909	1,069	1,264	1,502
Surplus (Need)			478	244	112	(48)	(243)	(481)
Supply	Pecos Valley	Ward	4,914	4,223	4,937	5,807	6,189	6,189
Demand	TXU Permian Basin	Ward	4,914	4,223	4,937	5,807	6,868	8,162
Surplus (Need)			0	0	0	0	(679)	(1,973)
Total Supply			*17,924*	*16,994*	*17,573*	*18,316*	*18,584*	*18,483*
Total Demand			*18,138*	*19,995*	*22,380*	*25,324*	*28,954*	*33,418*
Total Surplus (Need)			*(214)*	*(3,001)*	*(4,807)*	*(7,008)*	*(10,370)*	*(14,935)*

4.6 Irrigation Needs

Sixteen of the thirty-two counties in Region F have identified irrigation needs. However, the adoption of advanced conservation technologies throughout the region will help preserve existing water resources for continued agricultural use and provide for other demands. Therefore, this analysis presents water savings for all counties in Region F. The counties with identified irrigation needs are listed in Table 4.6-1.

Table 4.6-1
Counties with Projected Irrigation Needs
(Values in Acre-Feet per Year)

County	Projected Irrigation Needs					
	2010	2020	2030	2040	2050	2060
Andrews	12,875	12,845	12,707	11,317	11,114	10,946
Borden	1,847	1,844	1,839	1,835	1,829	1,826
Brown	3,006	2,982	2,946	2,905	2,868	2,841
Coke	363	363	361	360	360	360
Coleman	1,348	1,348	1,348	1,348	1,348	1,348
Glasscock	27,784	27,381	26,972	26,552	26,131	25,722
Irion	1,302	1,241	1,181	1,120	1,060	1,000
Martin	788	564	322	-	-	-
Menard	2,441	2,421	2,402	2,383	2,361	2,342
Midland	16,233	16,359	16,348	16,254	16,112	15,993
Reagan	10,997	10,607	10,116	9,559	8,976	8,393
Reeves	14,253	13,401	12,543	11,681	10,820	10,003
Runnels	1,358	1,344	1,325	1,306	1,287	1,268
Tom Green	47,090	46,831	46,576	46,321	46,062	45,807
Upton	10,672	10,451	10,223	9,992	9,762	9,539
Ward	5,527	4,973	5,721	6,539	6,905	6,888
Total	*157,884*	*154,955*	*152,930*	*149,472*	*146,995*	*144,276*

Region F recommends improvements in the efficiency of irrigation equipment as the most effective water conservation strategy for irrigation within the region. The analysis presented in this plan is an update of the analysis performed for the 2001 *Region F Regional Water Plan.*[35] For this plan a review of the current irrigation practices was conducted through a special study for selected counties in Region F (see Volume II). The special study found that in two counties, Glasscock and Reagan Counties, the adoption rate of highly efficient irrigation equipment is greater than assumed in the 2006 plan. This means that the potential for incremental increases in irrigation conservation savings in these counties may be small. There was not sufficient data on the other counties to warrant changing the distribution of irrigation technologies. It was determined to retain the approach used in the *2006 Region F Water Plan* for irrigation conservation since the demands were developed prior to this observed increase in use of efficient irrigation equipment. Irrigation demands and adoption rates of irrigation equipment will be updated for the 2016 Region F Water Plan.

Six alternative irrigation systems were evaluated based on assumed use in Region F or the potential to improve water use efficiency. The alternative irrigation systems analyzed included furrow flood (FF), surge flow (SF), mid-elevation sprinkler application (MESA), low elevation spray application (LESA), low energy precision application (LEPA) and subsurface drip irrigation (drip). This analysis assumed an irrigation system was installed on a square quarter section of land (160 acres). Terrain and soil types were assumed to not limit the feasibility of adopting an irrigation system. Application efficiencies for the various irrigation technologies were assumed as follows:

- Furrow irrigation (FF) – 60 percent,
- Surge flow (SF) – 75 percent,
- MESA – 78 percent,
- LESA – 88 percent,
- LEPA – 95 percent, and
- Drip irrigation – 97 percent[36].

The system with the higher efficiency rating is considered more efficient because it uses less water.

Table 4.6-2 contains data on irrigated acreage by crop type from the Texas Water Development Board (TWDB). As shown in Table 4.6-2, there were 226,444 irrigated acres within Region F in 2006.[37] Cotton was the most significant irrigated crop with 50 percent of the irrigated acreage. Wheat and hay-pasture represented 11 percent and 8 percent, respectively, of the irrigated acreage. Seven counties (Andrews, Glasscock, Martin, Midland, Pecos, Reeves, and Tom Green) account for 71 percent of the region's irrigated acreage.

The procedure used to evaluate potential savings is dependent upon data regarding the current irrigation equipment types used in the region, which are summarized in Table 4.6-3. These data were from the 2006 Region F Plan and were not updated in this round of planning.

Based on this methodology, 42 percent of the region's irrigated crop production used some form of advanced irrigation technology (surge, sprinkler or drip) in 2002. Accelerated adoption of advanced irrigation technologies, and in particular, adoption of the most feasible advanced technologies could potentially reduce irrigation demands while maintaining the highest level of irrigated acreage possible. To examine the impact of an aggressive rate of water-conserving technology implementation, one half of the necessary adoption of advanced irrigation technologies was assumed to take place by the year 2020, with 100 percent adoption by the year 2030.

The selection of the most feasible advanced irrigation technology for each crop within a county was based on several assumptions and constraints relating to crop type, water source, and water quality considerations. The following guidelines were used:

- Furrow and surge acres were moved to drip or sprinkler whenever feasible.
- Existing sprinkler acres were moved to the most efficient sprinkler technology whenever feasible.
- Surface water supplies were assumed to remain as furrow or flood due to problems associated with the use of sprinkler or drip technologies with surface supplies. While there may be ways to make more efficient use of surface water supplies, this would involve a county by county assessment, which was beyond the scope of this analysis.
- The shift of furrow to drip was considered feasible for cotton and grain sorghum.
- Other crops such as wheat, alfalfa, peanuts, forage crops, and hay-pasture were shifted from furrow to the most feasible sprinkler technology.
- Orchard and vineyard crops currently using flood irrigation were not changed to alternative technologies.
- The application efficiency of drip and LEPA in Reeves, Ward, Loving, and Pecos counties was reduced to 93 percent and 91 percent, respectively, to allow for a flood irrigation at least once every 3 years to flush any buildup of salts in the upper soil profile.
- No additional sprinkler acreage was included in Glasscock, Midland, Upton, and Reagan counties due to the low water well yields in those counties. This strategy would involve using multiple wells per system and was deemed unlikely.

Table 4.6-2
Irrigated Acreage by Crop Type in 2006
(Values in Acres)

County/Crop	Cotton	Grain Sorghum	Wheat	Alfalfa	Forage Crops	Hay Pasture	Veg Deep	Veg Shallow	Peanuts	Pecans	Vineyards	Corn	Other	County Total
Andrews	10,460	0	6,094	0	0	158	20	0	2,170	20	0	0	2,016	*20,938*
Borden	1,135	0	202	50	100	9	0	0	0	12	0	0	200	*1,708*
Brown	0	0	259	136	172	1,385	39	0	0	2,250	0	623	155	*5,019*
Coke	138	0	0	10	250	18	0	0	0	0	0	0	111	*527*
Coleman	0	0	0	0	50	350	0	0	0	0	0	0	0	*400*
Concho	2,030	394	1,479	400	535	306	0	0	0	0	0	315	76	*5,535*
Crane	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
Crockett	0	0	231	69	0	0	0	0	0	0	0	0	0	*300*
Ector	0	0	0	0	0	300	0	0	0	200	0	0	0	*500*
Glasscock	24,033	359	764	56	0	153	114	0	0	422	0	68	262	*26,231*
Howard	2,498	0	250	82	22	50	0	0	0	28	0	0	50	*2,980*
Irion	0	0	100	0	400	100	0	0	0	0	0	0	0	*600*
Kimble	0	0	250	18	108	2,000	0	0	0	44	0	0	0	*2,420*
Loving	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
McCulloch	0	0	0	0	150	2,500	0	0	0	0	6	0	150	*2,806*
Martin	11,541	0	1,144	800	27	549	50	0	0	0	0	0	827	*14,938*
Mason	0	58	783	600	751	1,530	256	0	0	10	34	22	392	*4,436*
Menard	98	0	243	0	202	750	0	0	0	158	200	0	164	*1,815*
Midland	5,644	0	535	1,058	150	2,500	353	0	0	127	28	0	2,000	*12,395*
Mitchell	3,386	14	1,535	129	0	48	27	0	0	17	3	36	100	*5,295*
Pecos	5,561	568	886	6,000	778	2,000	1,500	1,500	0	3,000	1,000	0	1,662	*24,455*
Reagan	10,000	0	72	38	317	9	0	0	0	94	0	473	43	*11,046*
Reeves	2,673	0	2,000	2,491	1,750	1,145	1,000	500	0	375	0	0	11,347	*23,281*
Runnels	1,158	66	231	0	221	300	0	0	0	62	0	109	236	*2,383*
Schleicher	0	0	170	0	0	300	0	0	0	50	0	0	0	*520*
Scurry	2,173	0	400	347	1,500	500	0	0	52	0	0	0	63	*5,035*
Sterling	0	0	500	0	100	100	0	0	0	0	0	0	25	*725*
Sutton	0	0	551	0	100	90	0	0	0	154	0	0	127	*1,022*
Tom Green	24,189	2,585	5,089	230	1,597	469	100	106	0	100	0	3,170	1,494	*39,129*
Upton	4,980	0	50	0	0	0	184	0	0	100	0	212	100	*5,626*
Ward	677	0	0	0	0	1,000	0	0	0	0	0	0	80	*1,757*
Winkler	608	0	735	20	0	150	109	0	0	0	0	0	1,000	*2,622*
Crop Totals	*112,982*	*4,044*	*24,553*	*12,534*	*9,280*	*18,769*	*3,752*	*2,106*	*2,222*	*7,223*	*1,271*	*5,028*	*22,680*	*226,444*

Irrigated crops as reported by the TWDB in 2006. Acreages and/or crop types may have changed since 2006, but such changes are not reflected in this table.

Table 4.6-3
Estimated Distribution of Irrigation Equipment in 2002

County	Irrigated Acres	Acres by Equipment Type						Percentage of Acreage		
		Furrow	Surge	MESA	LESA	LEPA	Drip	% Furrow & Surge	% Sprinkler	% Drip
Andrews	20,326	12,183	177	0	5,046	2,800	120	60.8	38.6	0.6
Borden	2,149	861	0	640	648	0	0	40.1	59.9	0.0
Brown	7,642	6,012	0	691	909	0	31	78.7	20.9	0.4
Coke	564	289	0	224	51	0	0	51.2	48.9	0.0
Coleman	188	188	0	0	0	0	0	100.0	0.0	0.0
Concho	4,478	3,937	0	212	329	0	0	87.9	12.1	0.0
Crane	0	0	0	0	0	0	0	0.0	0.0	0.0
Crockett	96	9	0	23	64	0	0	9.2	90.5	0.0
Ector	1,632	1,052	0	0	402	0	179	64.4	24.6	11.0
Glasscock	26,598	16,650	41	80	80	1,190	8,555	62.8	5.1	32.2
Howard	2,315	1,308	0	36	272	628	72	56.5	40.4	3.1
Irion	1,245	884	0	361	0	0	0	71.0	29.0	0.0
Kimble	922	548	0	39	335	0	0	59.4	40.6	0.0
Loving	100	100	0	0	0	0	0	100.0	0.0	0.0
McCulloch	2,258	310	0	1,821	102	0	25	13.7	85.2	1.1
Martin	14,502	5,574	0	1,509	2,090	4,845	486	38.4	58.2	3.4
Mason	6,610	1,606	0	4,230	704	0	68	24.3	74.6	1.0
Menard	3,188	2,567	0	360	49	0	212	80.5	12.8	6.6
Midland	15,954	5,832	0	3,067	6,476	0	579	36.6	59.8	3.6
Mitchell	4,837	4,061	150	213	394	0	20	87.1	12.5	0.4
Pecos	23,848	8,800	10,165	0	2,447	57	2,379	79.5	10.5	10.0
Reagan	10,716	9,480	2	68	46	85	1,035	88.5	1.9	9.7
Reeves	22,078	5,843	12,726	0	2,021	20	1,467	84.1	9.2	6.6
Runnels	3,646	3,298	161	0	186	0	1	94.9	5.1	0.0
Schleicher	820	757	0	62	1	0	0	92.3	7.7	0.0
Scurry	3,490	2,929	42	72	432	0	15	85.1	14.4	0.4
Sterling	647	187	0	460	0	0	0	28.9	71.1	0.0
Sutton	851	776	0	10	67	0	0	91.1	9.0	0.0
Tom Green	30,820	25,004	1,567	261	3,419	0	568	86.2	11.9	1.8
Upton	6,301	5,029	0	0	0	0	1,272	79.8	0.0	20.2
Ward	1,426	1,414	0	12	0	0	0	99.1	0.9	0.0
Winkler	1,029	409	375	47	11	0	188	76.2	5.6	18.2
Crop Totals	*221,276*	*127,896*	*25,405*	*14,497*	*26,581*	*9,624*	*17,272*	*69.3*	*22.9*	*7.8*

Estimated irrigated crops in 2002 are from the 2006 Region F plan. Recent information provided by the GCDs indicate the distributions in some counties may be different than shown here.

Utilizing these assumptions, the projected percentages of use for different irrigation equipment are shown in Table 4.6-4.

The methodology for calculating annual water savings in acre-feet was to shift acreages of furrow irrigated crops to LEPA or drip, from Surge to LEPA or drip, from MESA to LEPA and from LESA to LEPA when an advanced technology was considered feasible. The gross irrigation application rate per acre for each crop in a given county using a furrow system was used as the base water application rate. This base rate was then compared to the required equivalent irrigation application rate with advanced irrigation technology. The difference in application rates was the assumed water savings. For example, the total per acre applied irrigation water for cotton using a furrow system was 16 acre-inches in Glasscock County. Using the 60 percent application efficiency for furrow resulted in an effective application rate of 9.6 acre-inches. If a drip system were used with an application efficiency of 97 percent, the resulting total application rate would be 9.9 acre-inches. Therefore, the potential water savings for a shift from furrow to drip would be 6.1 acre-inches.

Quantity, Reliability and Cost of Irrigation Conservation

Table 4.6-5 presents the estimates of water savings by decade from accelerated adoption of water-efficient technology for all counties in Region F. With partial adoption (50%) completed by 2020, the annual water savings for the region is 40,470 acre-feet. Following full adoption in 2030, these annual water savings increase to 81,112 acre-feet. For the counties with irrigation needs, 22 percent of the initial deficit was recovered by 2020 and 44 percent was recovered by 2030. As shown on Table 4.6-5, all of the projected irrigation need can be met by advanced conservation for Brown and Martin Counties. The large irrigation counties, including Andrews, Glasscock, Midland, Reeves and Tom Green, still have considerable unmet irrigation demands. No specific alternative strategies were identified for these needs. It is anticipated that in the counties with unmet irrigation demands, some portion of the irrigated acreage will shift to non-irrigated crop production or to other uses. While it is difficult to predict what crops will likely be removed from production, the crops with the lower relative value of water will most likely be removed first. Table 4.6-6 presents the revised projected irrigation needs after accounting for advanced irrigation technologies. Also shown are estimates of the number of irrigated acres that

Table 4.6-4
Estimated Percentage of Projected Adoption of Advanced Irrigation Technology in Region F

County	Irrigated Acres	2002 (current)			2020			2030 - 2060		
		% Furrow & Surge	% Sprinkler	% Drip	% Furrow & Surge	% Sprinkler	% Drip	% Furrow & Surge	% Sprinkler	% Drip
Andrews	20,326	60.8	38.6	0.6	37.9	54.5	7.6	15.0	70.4	14.6
Borden	2,149	40.1	59.9	0.0	22.1	70.4	7.4	4.2	80.9	14.9
Brown	7,642	78.7	20.9	0.4	78.7	20.9	0.4	78.7	20.9	0.4
Coke	564	51.2	48.9	0.0	51.2	48.9	0.0	51.2	48.9	0.0
Coleman	188	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0
Concho	4,478	87.9	12.1	0.0	47.2	39.4	13.4	6.5	66.7	26.8
Crane	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crockett	96	9.2	90.5	0.0	9.2	90.5	0.0	9.2	90.5	0.0
Ector	1,632	64.4	24.6	11.0	40.1	48.9	11.0	15.8	73.2	11.0
Glasscock	26,598	62.8	5.1	32.2	35.9	5.1	59.0	9.1	5.1	85.8
Howard	2,315	56.5	40.4	3.1	33.2	51.5	15.3	9.8	62.7	27.5
Irion	1,245	71.0	29.0	0.0	71.0	29.0	0.0	71.0	29.0	0.0
Kimble	922	59.4	40.6	0.0	40.1	59.9	0.0	20.8	79.2	0.0
Loving	100	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0
McCulloch	2,258	13.7	85.2	1.1	9.8	89.1	1.1	5.8	93.1	1.1
Martin	14,502	38.4	58.2	3.4	19.9	61.7	18.4	1.4	65.2	33.4
Mason	6,610	24.3	74.6	1.0	14.8	84.1	1.0	5.4	93.5	1.0
Menard	3,188	80.5	12.8	6.6	80.5	12.8	6.6	80.5	12.8	6.6
Midland	15,954	36.6	59.8	3.6	25.3	59.8	14.9	14.1	59.8	26.1
Mitchell	4,837	87.1	12.5	0.4	47.0	26.2	26.8	7.0	39.8	53.1
Pecos	23,848	79.5	10.5	10.0	46.3	31.4	22.3	13.1	52.3	34.5
Reagan	10,716	88.5	1.9	9.7	51.9	1.9	46.3	15.3	1.9	82.9
Reeves	22,078	84.1	9.2	6.6	45.9	36.4	17.7	7.7	63.6	28.7
Runnels	3,646	94.9	5.1	0.0	94.9	5.1	0.0	94.9	5.1	0.0
Schleicher	820	92.3	7.7	0.0	63.9	36.1	0.0	35.5	64.5	0.0
Scurry	3,490	85.1	14.4	0.4	47.3	42.6	10.1	9.5	70.8	19.7
Sterling	647	28.9	71.1	0.0	28.9	71.1	0.0	28.9	71.1	0.0
Sutton	851	91.1	9.0	0.0	61.0	39.1	0.0	30.8	69.3	0.0
Tom Green	30,820	86.2	11.9	1.8	58.8	25.9	15.3	30.5	40.2	29.2
Upton	6,301	79.8	0.0	20.2	50.6	0.0	49.4	21.4	0.0	78.6
Ward	1,426	99.1	0.9	0.0	58.7	41.3	0.0	18.3	81.7	0.0
Winkler	1,029	76.2	5.6	18.2	50.1	31.7	18.2	23.9	57.8	18.2
System Totals	*221,276*	*69.3*	*22.9*	*7.8*	*44.2*	*34.2*	*21.6*	*19.0*	*45.6*	*35.4*

would need to be converted to dryland farming or taken out of production to remain within the available supplies in each decade.

The actual amount of water saved by using advanced irrigation conservation is dependent upon a large number of factors, including weather, crop prices, funding, technical assistance, and individual preference. Therefore the reliability of this strategy is expected to be medium because of the uncertainty involved in the actual savings associated with this strategy.

Table 4.6-5
Projected Water Savings with Advanced Irrigation Technologies

County	Irrigation Need	Projected Water Savings (acre-feet/year)		% Reduction of 2010 Need	
	2010	2020	2030-2060	2020	2030-2060
Andrews	12,875	2,727	5,455	21.2%	42.4%
Borden	1,847	230	460	12.5%	24.9%
Brown	3,006	93	185	3.1%	6.2%
Coke	363	0	0	0.0%	0.0%
Coleman	1,348	0	0	0.0%	0.0%
Concho		748	1,496		
Crane		0	0	0.0%	0.0%
Crockett		0	0		
Ector		245	490		
Glasscock	27,784	3,631	7,262	13.1%	26.1%
Howard		327	653		
Irion	1,302	37	73	2.8%	5.6%
Kimble		74	147		
Loving		0	0		
McCulloch		197	394		
Martin	788	1,751	3,502	100%	100%
Mason		746	1,491		
Menard	2,441	23	46	0.9%	1.9%
Midland	16,233	1,800	3,600	11.1%	22.2%
Mitchell		865	1,729		
Pecos		6,300	12,600		
Reagan	10,997	1,968	3,936	17.9%	35.8%
Reeves	14,253	5,824	11,648	40.9%	81.7%
Runnels	1,358	0	0	0.0%	0.0%
Schleicher		107	214		
Scurry		571	1,143		
Sterling		45	89		
Sutton		142	284		
Tom Green	47,090	5,774	11,548	12.1%	24.5%
Upton	10,672	920	1,840	8.6%	17.2%
Ward	5,527	785	1,570	14.2%	28.4%
Winkler		195	389		
Total	*157,884*	*36,125*	*72,244*	*22.9%*	*45.8%*

Table 4.6-6
Revised Irrigation Needs Incorporating Advanced Irrigation Technologies

County	Projected Irrigation Need (ac-ft/yr)						Projected Irrigation Need with Conservation (ac-ft/yr)					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Andrews	12,875	12,845	12,707	11,317	11,114	10,946	12,875	10,118	7,252	5,862	5,659	5,491
Borden	1,847	1,844	1,839	1,835	1,829	1,826	1,847	1,614	1,379	1,375	1,369	1,366
Brown	3,006	2,982	2,946	2,905	2,868	2,841	3,006	2,889	2,761	2,720	2,683	2,656
Coke	363	363	361	360	360	360	363	363	361	360	360	360
Coleman	1,348	1,348	1,348	1,348	1,348	1,348	1,348	1,348	1,348	1,348	1,348	1,348
Glasscock	27,784	27,381	26,972	26,552	26,131	25,722	27,784	23,750	19,710	19,290	18,869	18,460
Irion	1,302	1,241	1,181	1,120	1,060	1,000	1,302	914	528	467	407	347
Martin	788	564	322	0	0	0	788	0	0	0	0	0
Midland	2,441	2,421	2,402	2,383	2,361	2,342	2,441	2,398	2,356	2,337	2,315	2,296
Midland	16,233	16,359	16,348	16,254	16,112	15,993	16,233	14,559	12,748	12,654	12,512	12,393
Reagan	10,997	10,607	10,116	9,559	8,976	8,393	10,997	8,639	6,180	5,623	5,040	4,457
Reeves	14,253	13,401	12,543	11,681	10,820	10,003	14,253	7,577	895	33	0	0
Runnels	1,358	1,344	1,325	1,306	1,287	1,268	1,358	1,344	1,325	1,306	1,287	1,268
Tom Green	47,090	46,831	46,576	46,321	46,062	45,807	47,090	41,057	35,028	34,773	34,514	34,259
Upton	10,672	10,451	10,223	9,992	9,762	9,539	10,672	9,531	8,383	8,152	7,922	7,699
Ward	5,527	4,973	5,721	6,539	6,905	6,888	5,527	4,188	4,151	4,969	5,335	5,318
Totals	*157,884*	*154,955*	*152,930*	*149,472*	*146,995*	*144,276*	*157,884*	*130,289*	*104,405*	*101,269*	*99,620*	*97,718*

* Values are for each decade and do not represent incremental reductions in irrigated acreage.

Estimated costs for implementing this strategy are based on the analysis performed in the 2001 Region F plan. Assuming a static pumping lift of 350 feet, the cost of implementing a furrow flood system is $557/acre, a surge flow system $581/acre, MESA system $876/acre, LESA system $920/acre, LEPA system $936/acre and drip system $1,354/acre.

The costs of implementing advanced irrigation technologies in Region F are presented in Appendix 4E. The additional investment for converting a furrow irrigation system to LEPA and drip is $380 and $800 per acre respectively; from Surge to LEPA and drip is $360 and $780 per acre respectively; from MESA to LEPA and from LESA to LEPA is $60 and $20 per acre respectively. The corresponding annualized cost per acre for each strategy amortized over 30 years at 6 percent interest is $27.61, $58.12, $26.15, $56.67, $4.36 and $1.45, respectively.

The estimated per acre water savings achieved with shifts from one irrigation technology to another varies by county. Therefore, the costs to adopt alternative irrigation systems are given by county. In general, the highest cost per acre-foot of water savings is for shifts from furrow or surge to drip. However, this represents only capital costs associated with equipment changes. Cost savings associated with reduced labor requirements for the more advanced irrigation technologies (sprinkler and drip) are not included in this analysis. To fully assess the economic feasibility of a strategy, a more complete economic evaluation is required.

Environmental Issues Associated with Irrigation Conservation

This strategy is expected to have minimal impact on the environment, either positive or negative. Most of the areas in Region F with significant irrigation needs rely on groundwater for irrigation, and most of the conservation strategies developed in this analysis are specifically for groundwater-based irrigation. In areas where conserved groundwater is discharged as springs or base flow, conservation will have a positive impact. However, in many cases projected irrigation demand exceeds available supply even with implementation of advanced irrigation technologies.

Agricultural and Rural Issues Associated with Irrigation Conservation

Irrigated agriculture is vital to the economy and culture of Region F. Implementation of water-conserving irrigation practices may be necessary to retain the economic viability of many areas that show significant water supply needs throughout the planning period.

Other Natural Resource Issues Associated with Irrigation Conservation

None identified.

Significant Issues Affecting Feasibility of Irrigation Conservation

The most significant issue associated with implementation of this strategy is the lack of a clear sponsor for the strategy. Although the TWDB and other state and federal agencies sponsor many excellent irrigation conservation programs, the actual implementation is the responsibility of individual irrigators. Because this strategy relies largely on individual behavior, it is difficult to quantify the actual savings that can be achieved.

Another significant factor is the lack of detailed data on both irrigation equipment in use and the quantity of water used for individual crops. The conservation calculations included in this analysis were hampered by a lack of current data for these two items.

Other Water Management Strategies Directly Affected by Irrigation Conservation

None identified.

4.7 Mining Needs

There are four counties in Region F with mining needs: Coke, Coleman and Howard Counties. Table 4.7-1 compares supplies to demands for these counties. These mining needs are the result of using the Colorado WAM for water supplies and can be met by the implementation of a subordination strategy.

Potentially Feasible Strategies

Region F has identified subordination of downstream water rights and use of non-potable water to meet mining needs. Most of the water used for mining purposes in Region F is for enhanced oil and gas production. According to §27.0511 of the Texas Water Code, the oil and gas industry is required by law to use non-potable supplies whenever possible for enhanced production.[38] As a result, it is unclear to what extent the water demand projections for the region actually represent direct competition with other types of use that require better water quality. The actual amount of mining needs may be considerably less than indicated.

Table 4.7-1
Mining Needs in Region F
(Values in Acre-Feet per Year)

	Source	2010	2020	2030	2040	2050	2060
Coke County							
Supply	CRMWD diverted water	232	239	378	378	380	372
	Other aquifer	170	170	170	170	170	170
	Total	*402*	*409*	*548*	*548*	*550*	*542*
Demand	*Mining*	*488*	*528*	*550*	*572*	*593*	*614*
Surplus (Need)		*(86)*	*(119)*	*(2)*	*(24)*	*(43)*	*(72)*
Coleman County							
Supply	Lake Coleman	0	0	0	0	0	0
	Other aquifer	1	1	1	1	1	1
	Total	*1*	*1*	*1*	*1*	*1*	*1*
Demand	*Mining*	*18*	*19*	*19*	*19*	*19*	*19*
Surplus (Need)		*(17)*	*(18)*	*(18)*	*(18)*	*(18)*	*(18)*
Howard County							
Supply	Edwards-Trinity Plateau	82	82	82	82	82	82
	Ogallala	119	119	119	119	119	119
	Dockum	106	106	106	106	106	106
	CRMWD diverted water	1,076	1,053	1,608	1,555	1,523	1,460
	Total	*1,383*	*1,360*	*1,915*	*1,862*	*1,830*	*1,767*
Demand	*Mining*	*1,783*	*1,883*	*1,924*	*1,963*	*2,001*	*2,052*
Surplus (Need)		*(400)*	*(523)*	*(9)*	*(101)*	*(171)*	*(285)*
Total Needs		*(503)*	*(660)*	*(29)*	*(143)*	*(232)*	*(375)*

Subordination of Downstream Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, most reservoirs in Region F with a priority date after 1926 do not have a firm or safe yield. This result is largely due to the assumptions used in the Colorado WAM. Mining water in Coke and Howard Counties is from the CRMWD system. Mining water in Coleman County comes from Lake Coleman. All of these sources have reduced supplies because of the WAM.

In order to address water availability issues resulting from the Colorado WAM model, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights in Region F do not make priority calls on each other. The subordination strategy is discussed in Section 4.2.3. With implementation of the subordination strategy there are sufficient supplies in these counties to meet demands.

The joint modeling between the two regions was conducted for planning purposes only. Neither Region F nor the Lower Colorado Region mandates the adoption of this strategy by individual water right holders. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including CRMWD and the City of Coleman. Impacts of the subordination strategy are discussed in Section 4.2.3.

Recommended Strategies

Table 4.7-2 is a summary of the recommended strategies to meet mining needs in Coke, Coleman, and Howard Counties. Meaningful costs for these strategies are difficult to develop because of the uncertainty regarding the magnitude of the shortages and the actual way that these strategies will be implemented.

Table 4.7-2
Strategies to Meet Mining Needs
(Values in Acre-Feet per Year)

Category	2010	2020	2030	2040	2050	2060
Coke County						
Existing supplies	402	409	548	548	550	542
Subordination	86	119	2	24	43	72
Total Supply	*488*	*528*	*550*	*572*	*593*	*614*
Demand	*488*	*528*	*550*	*572*	*593*	*614*
Surplus (need)	*0*	*0*	*0*	*0*	*0*	*0*
Coleman County						
Existing supplies	1	1	1	1	1	1
Subordination	17	18	18	18	18	18
Total Supply	*18*	*19*	*19*	*19*	*19*	*19*
Demand	*18*	*19*	*19*	*19*	*19*	*19*
Surplus (need)	*0*	*0*	*0*	*0*	*0*	*0*
Howard County						
Existing Supplies	1,383	1,360	1,915	1,862	1,830	1,767
Subordination	400	523	9	101	171	285
Total Supply	*1,783*	*1,883*	*1,924*	*1,963*	*2,001*	*2,052*
Demand	*1,783*	*1,883*	*1,924*	*1,963*	*2,001*	*2,052*
Surplus (need)	*0*	*0*	*0*	*0*	*0*	*0*

Note: The subordination strategy will be implemented by CRMWD and the City of Coleman.

4.8 Strategies for Wholesale Water Providers

Strategies have been developed for the Colorado River Municipal Water District and the City of San Angelo. For the purposes of this plan, contracts between University Lands and CRMWD, the City of Andrews and the City of Midland are expected to be renewed when they expire. If these contracts are not renewed, the timing of recommended strategies for the City of Midland and CRMWD may be impacted. The City of Andrews may not have sufficient supplies even with the contract renewal and may require a new source of water.

4.8.1 Colorado River Municipal Water District

The Colorado River Municipal Water District (CRMWD), the largest water supplier in Region F, provides raw water from both groundwater and surface water sources. CRMWD owns and operates three major reservoirs, Lake J.B. Thomas, E.V. Spence Reservoir, and O.H. Ivie Reservoir, as well as several chloride control reservoirs. Groundwater sources include well fields in Ward, Scurry and Martin Counties. CRMWD member cities include Big Spring, Odessa and Snyder. CRMWD also supplies water to Midland, San Angelo and Abilene (through West Central Texas MWD) as well as several smaller cities in Ward, Martin, Howard and Coke Counties.

Table 4.8-1 compares supplies to projected demands for CRMWD customers. As shown in Table 4.8-1, CRMWD has needs throughout the planning period. These needs are the result of the use of the Colorado WAM as the basis for water availability.

Potentially Feasible Strategies for CRMWD

The following potentially feasible strategies have been identified for CRMWD:

- Subordination of downstream senior water rights
- Water conservation
- Drought management
- Reuse

Table 4.8-1
Comparison of Supply and Demand for CRMWD
(Values in Acre-Feet per Year)

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Thomas	0	0	0	0	0	0
Spence	560	560	560	560	560	560
Ivie	66,350	65,000	63,650	62,300	60,950	59,600
Ward County Well Field (Pecos Valley) *	5200	0	0	0	0	0
Scurry County Well Field (Dockum)	900	900	900	900	900	900
Ector County Well Field (Edwards-Trinity)	440	440	440	440	440	440
Martin County Well Field (Ogallala)	1,035	1,035	1,035	1,035	1,035	1,035
Total	*74,485*	*67,935*	*66,585*	*65,235*	*63,885*	*62,535*
Demands	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Member Cities	33,425	34,764	35,761	36,782	38,081	39,637
Others	55,787	56,867	37,982	37,347	35,618	35,007
Total	*89,212*	*91,631*	*73,743*	*74,129*	*73,699*	*74,644*
Surplus (Need)	*-14,727*	*-23,696*	*-7,158*	*-8,894*	*-9,814*	*-12,109*

* The contract with University Lands for the Ward County Well Field expires in 2019.

- Voluntary redistribution
  - Roberts County groundwater
  - Renew contract with University Lands for groundwater in Ward County, including replacement of lost capacity
  - New contracts to provide water
- New groundwater
  - Winkler County Well Field
  - Groundwater from southwestern Pecos County
- Groundwater Desalination

Precipitation enhancement and brush control are discussed in Section 4.9.

With subordination agreements CRMWD will have sufficient water to meet projected demands throughout the planning period. However, new supplies are needed to increase the reliability of the CRMWD system and to improve water quality. Water quality considerations often prevent CRMWD from operating its system at full capacity. The total dissolved solids (TDS) concentration of water varies among CRMWD's sources of water, ranging from less than 500 mg/l in Lake Thomas to up to 4,000 mg/l in Lake Spence. The CRMWD system is operated so that all of its customers receive water of approximately the same quality. To fully utilize the yield of Spence Reservoir and maintain water quality, additional low TDS water is needed.

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, most reservoirs in Region F with a priority date after 1926 do not have a firm or safe yield. This result is largely due to the assumptions used in the Colorado WAM. The priority dates for CRMWD reservoirs are 1946 for Lake Thomas, 1964 for Spence Reservoir and 1978 for Ivie Reservoir. However, TCEQ modeled the Ivie Reservoir so that it can impound water at a 1926 priority date to represent the subordination with the Highland Lakes included in the water rights for those sources. As a result, Thomas and Spence have little or no yield, while Lake Ivie has a safe yield of over 66,000 acre-feet.

In order to address water availability issues resulting from the Colorado WAM model, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights in Region F do not make priority calls on each other. The subordination strategy is discussed in Section 4.2.3. Table 4.8-2 is a summary of the impacts of the subordination strategy on CRMWD supplies.

Table 4.8-2
Impact of Subordination Strategy on CRMWD Water Supplies [a]
(Values in acre-feet per year)

Reservoir	Priority Date	Permitted Diversion	2010 Supply WAM Run 3	2010 Supply with Subord-ination	2060 Supply WAM Run 3	2060 Supply with Subord-ination
Lake Thomas	5/08/1946	23,000	0	10,013	0	10,130
Spence Reservoir	8/17/1964	41,573	560	38,472	560	37,330
Ivie Reservoir	2/21/1978 [b]	113,000	66,350	66,452	59,600	56,260
Total		*177,573*	*66,910*	*114,937*	*60,160*	*103,720*

a Water supply is defined as the safe yield of the reservoir.

b Although Ivie Reservoir has a junior priority date, in the Colorado WAM TCEQ assumed that the reservoir could store water at a 1926 priority date because of the subordination of Ivie to the Highland Lakes.

The joint modeling between the two regions was conducted for planning purposes only. Neither Region F nor the Lower Colorado Region mandates the adoption of this strategy by individual water right holders. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including CRMWD.

Impacts of the subordination strategy are discussed in Section 4.2.3.

CRMWD Reclamation Project

Wastewater reuse is becoming an increasingly important source of water across the state, especially in West Texas where there are few new water sources. Reuse provides a reliable source that remains available in a drought. The quantity of available reuse increases as water demands increase. This strategy also represents an effective means of conserving existing water sources, which can defer development of new water sources.

CRMWD serves several large municipal areas that could potentially benefit from wastewater reuse, reducing the demand for water from CRMWD's existing sources. To evaluate a regional reclamation project, three reuse projects were studied to serve the District's primary customers: Snyder, Big Spring and Odessa-Midland. Each of these projects could be implemented independently or collectively as a regional wastewater reuse plan for the District. A discussion of each proposed reuse project is presented in the following sections. Additional information on these projects may be found in the report *Regional Water Reclamation Project Feasibility Study.*[39]

Snyder Reuse Project

The City of Snyder is a CRMWD member city and obtains most of its water from Lake J.B. Thomas. During times of drought and low water levels in the lake CRMWD moves water from its other sources through Lake Thomas to serve Snyder. This operation is less than desirable due to increased water losses and higher TDS concentrations of the transferred water. The proposed Snyder Reclamation Project would provide additional water to the city and minimize the transfer of water from other sources.

The proposed Snyder Reclamation Project would blend the city's treated effluent, which is currently discharged to Deep Creek, with raw water from Lake Thomas. Approximately 0.9 MGD of wastewater effluent would be subjected to advanced treatment using membrane filtration, reverse osmosis and ultraviolet oxidation, and then blended with raw surface water in a new 15 million gallon terminal storage facility.

Treated effluent that is not needed during wet seasons or periods of low demand would be stored underground at a suitable site with an aquifer storage and recovery (ASR) system. An 8-inch transmission pipeline would be constructed to move the treated effluent to and from the ASR facility. Two new wells would be used for injection and extraction of the water.

Quantity, Reliability and Cost of Snyder Reuse Project

This strategy would provide approximately 726 acre-feet per year of additional supply to Snyder, or about 22 percent of the maximum expected demand for the city and its customers during the planning period. The reliability of this water source is high. Table 4.8-3 is a summary of the costs of the project. Capital costs are estimated at $9.6 million, with a unit cost of $4.67 per 1,000 gallons of reclaimed water.

Table 4.8-3
Snyder Reuse Project

Supply from Strategy	**726 acre-feet per year**
Total Capital Costs (2008 Prices)	$ 9,643,000
Annual Costs	$ 1,104,000
Unit costs (during amortization)	$ 1,521 per acre-foot
	$ 4.67 per 1,000 gallons
Unit Costs (after amortization)	$ 362 per acre-foot
	$ 1.11 per 1,000 gallons

Environmental Issues Associated with Snyder Reuse Project

Wastewater reuse will reduce low flows in Deep Creek and, to a much lesser extent, flows in the Colorado River below Lake Thomas. The advanced treatment will produce a reject stream that will be blended with other wastewater effluent and discharged to Deep Creek, which may increase TDS levels. However, TDS levels in Deep Creek and this portion of the Colorado River are already very high, and downstream impacts will be mitigated by diversion of high TDS water at the existing chloride control project near Colorado City and stored in Barber Reservoir.

Because of the relatively small volume of effluent currently discharged, the impact on overbanking flows is expected to be minimal. There is no impact on bays and estuaries because all of the current discharge is lost, impounded or used before reaching the Colorado estuary or Matagorda Bay.

This strategy should have a positive impact on water quality in Lake Thomas because the need to pass water from other sources through the reservoir during drought will be reduced or eliminated.

The project does not require a bed-and-banks permit because the reuse occurs prior to discharge.

Agricultural and Rural Issues Associated with Snyder Reuse Project

There are no agricultural or rural issues associated with this project.

Other Natural Resource Issues Associated with Snyder Reuse Project

This strategy will provide an alternative source of water for Snyder, which will conserve water from CRMWD sources that otherwise would be needed to meet Snyder's water needs.

Significant Issues Affecting Feasibility of Snyder Reuse Project

Public acceptability of wastewater reuse for municipal use may affect the feasibility of this project.

Other Water Management Strategies Directly Affected by Snyder Reuse Project

No other water management strategies are impacted by this project.

Big Spring Reuse Project

Similar to the Snyder Reclamation Project, the Big Spring Reclamation Project would blend treated wastewater effluent from Big Spring with raw water from Spence Reservoir. This project proposes to treat 2.3 MGD of wastewater effluent with advanced treatment (membrane filtration, reverse osmosis and UV oxidation) and blend the treated water directly with raw water in the District's Spence Pipeline that runs along the northeast side of Big Spring. The raw water/effluent blend would then be treated at the city's water treatment plant for municipal and industrial use. Pilot testing of the project was initiated in 2008 and is on-going (2009). Based on the findings of this study the project could be on-line within the next several years. Water from Spence Reservoir has historically been high in TDS and the reclaimed water should improve the quality of the water from this source.

The reject water from the reverse osmosis treatment would be discharged to Beals Creek and subsequently re-diverted at the existing Beals Creek chloride control project and stored in Red Draw Reservoir.

An alternative to the proposed project is to use all or a portion of the reclaimed water for industrial purposes. The industrial water will require less treatment.

Quantity, Reliability and Cost of the Big Spring Reuse Project

The annual yield of the project is estimated at 1,855 acre-feet per year, which is approximately 25 percent of the maximum projected municipal demand for the city and its customers. The reliability of the water source is high. Capital costs are estimated at $9.9 million, with unit costs for the reclaimed water at $2.53 per 1,000 gallons. Table 4.8-4 summarizes the costs for the project.

Table 4.8-4
Big Spring Reuse Project

Supply from Strategy	**1,855 acre-feet per year**
Total Capital Costs (2008 Prices)	$ 9,911,000
Annual Costs	$ 1,529,000
Unit costs (during amortization)	$ 824 per acre-foot
	$ 2.53 per 1,000 gallons
Unit Costs (after amortization)	$ 358 per acre-foot
	$ 1.10 per 1,000 gallons

Environmental Issues Associated with the Big Spring Reuse Project

Currently almost all of the treated wastewater discharge from the City of Big Spring is re-diverted at the Beals Creek chloride control project, and this operation is not expected to change with the proposed project. Except for the short reach between the existing discharge point and the diversion project, there should be little impact on instream flows. The water quality of this stream reach is already high in TDS and the discharge is expected to have little impact on water quality. The existing chloride control project will mitigate any impacts on downstream water quality.

Because of the relatively small volume of effluent currently discharged, the impact on overbanking flows is expected to be minimal. There will be no impact on bays and estuaries because all of the water currently discharged is lost, diverted or stored in reservoirs before reaching the Colorado estuary or Matagorda Bay. The project does not require a bed-and-banks permit because the reuse occurs prior to discharge.

Agricultural and Rural Issues Associated with the Big Spring Reuse Project

There are no agricultural or rural issues associated with this project.

Other Natural Resource Issues Associated with the Big Spring Reuse Project

This strategy will provide an alternative source of water for Big Spring, which will conserve water from CRMWD sources that would be needed to meet the city's water needs.

Significant Issues Affecting Feasibility of the Big Spring Reuse Project

Public acceptability of wastewater reuse for municipal use may affect the feasibility of this project.

Other Water Management Strategies Directly Affected by the Big Spring Reuse Project

No other water management strategies are impacted by this project.

Odessa-Midland Reuse Project

The proposed Odessa-Midland Reuse Project would utilize wastewaters from both cities and reclaim approximately 10.8 MGD of treated wastewater. The effluent would undergo advanced treatment at a Regional Reclamation Facility prior to blending with raw water at the District's 100 million gallon terminal storage reservoir between the two cities. The City of Odessa already has an extensive water reclamation system which could be used as part of this project. Treatment will consist of membrane filtration, reverse osmosis and ultraviolet oxidation. This strategy includes ASR using the City of Midland's abandoned McMillan well field for underground storage.

Handling and disposal of the brine reject from the treatment process is a large part of the cost of this project. The disposal process includes a combination of disposal wells, storage and evaporation reservoirs, and transfers to oil operations at the Mabee Oil Field. The strategy also calls for construction of secondary treatment facilities at the City of Midland's existing treatment plant.

Quantity, Reliability and Cost of the Odessa/Midland Reuse Project

The annual yield of the project is estimated at 9,799 acre-feet per year, or about 17 percent of the combined demand for the cities of Odessa and Midland and their municipal customers.

The reliability of the water source is high. Capital costs are estimated at $109 million, with unit costs for the reclaimed water at $4.16 per 1,000 gallons. Table 4.8-5 summarizes the costs for the project.

Table 4.8-5
Odessa-Midland Reuse Project

Supply from Strategy	**9,799 acre-feet per year**
Total Capital Costs (2008 Prices)	$ 109,194,000
Annual Costs	$ 13,272,000
Unit costs (during amortization)	$ 1,354 per acre-foot
	$ 4.16 per 1,000 gallons
Unit Costs (after amortization)	$ 383 per acre-foot
	$ 1.18 per 1,000 gallons

Environmental Issues Associated with the Odessa/Midland Reuse Project

Currently the City of Midland disposes of treated effluent using land application; none of the treated effluent is discharged. The City of Odessa also uses a large part of its treated effluent for irrigation, with some water contracted for industrial use. Unused treated wastewater is discharged into Monahans Draw. Almost all of the flow in Monahans Draw is treated wastewater, and during the summer very little treated wastewater is discharged. Although reuse will reduce current flows in Monahans Draw, most of the current discharge is lost due to evapotranspiration and infiltration before reaching Beals Creek just above Big Spring. Therefore downstream impacts will be negligible.

Reuse is expected to have minimal impacts on overbank flows and no impact on bays and estuaries.

The proposed project does not call for discharge of the waste stream from treatment, so implementation will not cause a degradation of water quality because of the waste stream. The project does not require a bed-and-banks permit.

Agricultural and Rural Issues Associated with the Odessa/Midland Reuse Project

The City of Midland currently irrigates with treated effluent. Therefore, this project may make less water available for irrigation in Midland County.

Other Natural Resource Issues Associated with the Odessa/Midland Reuse Project

This strategy will provide an alternative source of water for the cities of Odessa and Midland, which will conserve water from CRMWD sources.

Significant Issues Affecting Feasibility of the Odessa/Midland Reuse Project

Public acceptability of wastewater reuse for municipal use may affect the feasibility of this project.

Other Water Management Strategies Directly Affected by the Odessa/Midland Reuse Project

CRMWD Winkler County Well Field project.

New Groundwater Development - Winkler Well Field

CRMWD owns groundwater rights to an undeveloped well field in southern Winkler County. The well field will produce water from the Pecos Valley aquifer. For the purposes of this plan it has been assumed that water from the well field would be pumped approximately 43 miles directly to the City of Odessa. At Odessa the water could be blended with other sources and distributed to CRMWD's customers.

For this plan, it is assumed that the CRMWD Winkler well field will be developed as a stand-alone project. However, the CRMWD Winkler well field is near the City of Midland's undeveloped T-Bar Well Field. As an alternative, these two projects could use the same transmission facilities. This project could also be developed in conjunction with other supply projects from the Pecos Valley or other fresh or brackish groundwater sources. Region F considers co-development of these projects to be consistent with this plan. A discussion of potential co-development of supply from the Pecos Valley with the CRMWD Winkler well field and the Midland T-Bar project may be found in *Special Study No. 1: Refinement of Groundwater Supplies and Identification of Potential Projects* in Volume II. This study found that although there is some potential cost savings by developing these projects together, the initial capital costs are much higher. Cost savings due to co-development depend on the timing of the need for the water. If all of the water is needed in a short time period there may be some savings from co-development. However, if the projects will be phased over time then cost savings may not be realized from co-development.

Quantity, Reliability and Cost of Winkler County Well Field

CRMWD estimates that the Winkler County Well Field could provide 6,000 acre-feet per year. Water from this source is considered to be very reliable. Table 4.8-6 summarizes the expected costs of developing the well field.

Table 4.8-6
Costs for CRMWD Winkler County Well Field

Supply from Strategy	**6,000 acre-feet per year**
Total Capital Costs (2008 Prices)	$ 76,268,000
Annual Costs	$ 8,666,000
Unit costs (during amortization)	$ 1,444 per acre-foot
	$ 4.43 per 1,000 gallons
Unit Costs (after amortization)	$ 336 per acre-foot
	$ 1.03 per 1,000 gallons

Environmental Issues Associated with Winkler County Well Field

Winkler County has no flowing water. Therefore development of this source has very little potential of impacting springflow, baseflow in rivers, or habitats. Based on the available data, it is unlikely that pumping limits will be needed to prevent impacts on aquatic or terrestrial ecosystems. It is not anticipated that groundwater development will cause subsidence.

Agricultural and Rural Issues Associated with Winkler County Well Field

The Region F water supply analysis shows sufficient water supply in Winkler County to meet local agricultural and municipal needs and support well field development by CRMWD and the City of Midland. Therefore, this strategy should have minimal effects on agriculture and rural areas. The right of way for the transmission line may temporarily affect a small amount of agricultural acreage during construction.

Other Natural Resource Issues Associated with Winkler County Well Field

None identified.

Significant Issues Affecting Feasibility of Winkler County Well Field

None identified.

Other Water Management Strategies Directly Affected by Winkler County Well Field

Odessa-Midland Reuse project.

Water Marketing – Water from Southwestern Pecos County

A group of landowners in southwestern Pecos County has proposed selling groundwater from an unclassified aquifer in southwestern Pecos County. Initial estimates indicate that this area can produce a large quantity of water of acceptable quality.

Quantity, Reliability and Cost of Water from Pecos County

The sustainable quantity of water from Southwestern Pecos County has not been established, although preliminary estimates indicate that 50,000 to 100,000 acre-feet per year could be available from this source. This strategy assumes that CRMWD would take up to 15,000 acre-feet per year from this source. Because of the uncertainty associated with the sustained availability of water from this source, the reliability of supply is medium. Table 4.8-7 shows the estimated costs associated with this strategy.

Table 4.8-7
Costs for Water from Southwestern Pecos County

Supply from Strategy	**15,000 acre-feet per year**
Total Capital Costs (2008 Prices)	$ 183,321,000
Annual Costs	$ 22,279,000
Unit costs (during amortization)	$ 1,485 per acre-foot
	$ 4.56 per 1,000 gallons
Unit Costs (after amortization)	$ 420 per acre-foot
	$ 1.29 per 1,000 gallons

Environmental Issues Associated with Water from Pecos County

Information provided by the sponsors of this project indicates possible impacts on flow in the Pecos River from development of this strategy,[40] which should be investigated if this strategy is pursued. If linkage between groundwater development and flows in the Pecos River can be established, the local groundwater conservation district may wish to impose pumping limits if needed to protect endangered and threatened species and environmental flows. It is unlikely that development of water from this source will cause subsidence.

Agricultural and Rural Issues Associated with Water from Pecos County

According to information provided by the developers of this project, the supply in the immediate area is primarily used for cattle ranching and development of the project will have minimal impact on existing uses. However, it is possible that large-scale production from this source could impact irrigation supplies in the Belding Farms area. Additional studies may be needed to quantify this impact.

Other Natural Resource Issues Associated with Water from Pecos County

None identified.

Significant Issues Affecting Feasibility of Water from Pecos County

The most significant issue facing this project is the lack of site-specific studies regarding supplies from this source and the potential impacts of large-scale groundwater development. These studies will be needed before this source can be recommended as a strategy. Also, the source is located more than 100 miles from the nearest potential user and will require a significant investment in infrastructure to make the water available.

Other Water Management Strategies Directly Affected by Water from Pecos County

Winkler Well Field, Odessa-Midland Reuse.

Water Marketing – Water from Roberts County

In the year 2000, Mesa Water, Inc., published a study that included an evaluation of delivery of Ogallala aquifer water from Roberts County in the Texas Panhandle to CRMWD and other users in Texas.[41] Delivery of water from this source requires construction of over 300 miles of pipeline. Since the initial study, Mesa Water has acquired water rights in four counties in the Panhandle (referenced as Roberts County Area for this plan).

Quantity, Reliability and Cost of Water from Roberts County Area

According to previous studies, there is a substantial amount of water available in Roberts County Area and this supply is very reliable.[42] For the purposes of this plan, this strategy assumes that CRMWD would take up to 25,000 acre-feet per year from this source. Table 4.8-8 shows the estimated costs associated with this strategy. Capital costs include the estimated development fee for this project. Costs are dependent upon the amount of water assumed to be used from this project. If other entities would participate in the project, costs could be lower.

Table 4.8-8
Costs for Water from Roberts County Area

Supply from Strategy	25,000 acre-feet per year
Total Capital Costs (2008 Prices)	$ 775,401,000
Annual Costs	$ 82,982,000
Unit costs (during amortization)	$ 3,319 per acre-foot
	$ 10.19 per 1,000 gallons
Unit Costs (after amortization)	$ 615 per acre-foot
	$ 1.89 per 1,000 gallons

Environmental Issues Associated with Water from Roberts County

There is some concern that large-scale groundwater use from the Roberts County Area could impact baseflow of the Canadian River, potentially impacting habitat of the Arkansas River Shiner, a threatened species. If this strategy is implemented, mitigation may be required. It is unlikely that development of water from this source will cause subsidence.

Agricultural and Rural Issues Associated with Water from Roberts County

According to previous studies, only a small amount of water from this portion of Roberts County Area is currently being used for local purposes. There is little irrigated agriculture in the area.

Other Natural Resource Issues Associated with Water from Roberts County

None identified.

Significant Issues Affecting Feasibility of Water from Roberts County

The most significant issue facing this project is the significant investment in infrastructure needed to deliver water from the Roberts County Area. Without the participation of other large water users it may not be cost-effective to deliver water from Roberts County to Region F.

Other Water Management Strategies Directly Affected by Water from Roberts County

Other CRMWD strategies.

Water Conservation

Potential water savings due to implementation of the recommended Region F conservation practices has been evaluated for the CRMWD member cities: Big Spring, Odessa and Snyder. Water conservation savings for the cities of Midland and San Angelo may be found in the

Section 4.3.6 and 4.8.3, respectively. Water conservation for smaller customer cities which have needs that are met through subordination and contract renewal have not been evaluated because of the small quantity of water used by these entities.

Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. The water conservation practices in this plan are guidelines. Region F considers water conservation strategies determined and implemented by the CRMWD, the CRMWD member cities and CRMWD customers to supersede the recommendations in this plan and to meet regulatory requirements for consistency with this plan.

Quantity, Reliability and Cost

Table 4.8-9, Table 4.8-10 and Table 4.8-11 show potential water conservation savings and costs of water conservation programs for the cities of Snyder, Big Spring and Odessa, respectively. Potential savings range from approximately 14 percent to 18 percent of the demand with no conservation. The reliability of this supply is classified as medium because of the uncertainty involved in the analysis used to calculate the savings. Site specific data regarding residential, commercial, industrial and other types of use would give a better estimate of the reliable supply from this strategy.

Environmental Issues

Most of the CRMWD's water supply comes from reservoirs which spill infrequently. Therefore water conservation could result in more water remaining in reservoir storage, and will have minimal impact on downstream flows. Much of the conserved water in storage will be used for other purposes or lost to evaporation. The additional water in storage may result in a minimal positive impact on recreation use and environmental water needs associated with those reservoirs.

Much of the new water supply development for CRMWD is driven by water quality concerns. CRMWD needs additional high-quality water sources to blend with existing water of lesser quality. As a result, water conservation may not delay or eliminate the need for new water supply development.

Table 4.8-9
Potential Water Conservation Summary for the City of Snyder [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	194	227	227	227	227	227	227
Plumbing Code	Projections	227 [b]	223	219	216	213	212	212
	Savings	0	4	8	11	14	15	15
Region F Estimate	Projections	227 [b]	217	207	201	197	195	194
	Savings (Region F practices)	0	6	12	15	16	17	18
	Savings (Total)	0	10	20	26	30	32	33
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	2,343	2,843	2,938	2,988	3,015	3,033	3,033
Plumbing Code	Projections	2,742	2,792	2,834	2,844	2,829	2,832	2,832
	Savings	0	51	104	144	186	201	201
Region F Estimate	Projections	2,742	2,722	2,680	2,653	2,624	2,612	2,598
	Savings (Region F practices)	0	70	154	191	205	220	234
	Savings (Total)	0	121	258	335	391	421	435
Costs								
Annual Costs			$56,052	$61,357	$59,809	$57,823	$55,694	$54,185
Cost per Acre-Foot [c]			$801	$398	$313	$282	$253	$232
Cost per 1,000 Gal [c]			$2.46	$1.22	$0.96	$0.87	$0.78	$0.71

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.

b Year 2000 water use is based on a per capita water use of 227 gpcd. Actual year 2000 use was 2,343 acre-feet, equivalent to a per capita water demand of 194 gpcd.

c Costs for implementing recommended practices. Costs of implementing plumbing code savings not included in unit cost calculations.

Table 4.8-10
Potential Water Conservation Summary for the City of Big Spring [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	198	210	210	210	210	210	210
Plumbing Code	Projections	210	207	204	201	198	197	197
	Savings	0	3	6	9	12	13	13
Region F Estimate	Projections	210	199	184	178	175	173	172
	Savings (Region F practices)	0	8	20	23	23	24	25
	Savings (Total)	0	11	26	32	35	37	38
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	5,596	6,103	6,255	6,305	6,305	6,305	6,305
Plumbing Code	Projections	5,936	6,016	6,077	6,035	5,945	5,915	5,915
	Savings	0	87	178	270	360	390	390
Region F Estimate	Projections	5,936	5,775	5,474	5,359	5,247	5,190	5,161
	Savings (Region F practices)	0	241	603	676	698	725	754
	Savings (Total)	0	328	781	946	1,058	1,115	1,144
Costs								
Annual Costs			$130,084	$134,880	$130,163	$124,565	$119,088	$115,696
Cost per Acre-Foot [c]			$540	$224	$193	$178	$164	$153
Cost per 1,000 Gal [c]			$1.66	$0.69	$0.59	$0.55	$0.50	$0.47

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.

b Year 2000 water use is based on a per capita water use of 210 gpcd. Actual year 2000 use was 5,596 acre-feet, equivalent to a per capita water demand of 198 gpcd.

c Costs for implementing recommended practices. Costs of implementing plumbing code savings not included in unit cost calculations.

Table 4.8-11
Potential Water Conservation Summary for the City of Odessa [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	208	208	208	208	208	208	208
Plumbing Code	Projections	208	205	202	198	195	194	194
	Savings	0	3	6	10	13	14	14
Region F Estimate	Projections	208	200	191	185	181	179	178
	Savings (Region F practices)	0	5	11	13	14	15	16
	Savings (Total)	0	8	17	23	27	29	30
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	21,189	22,248	23,361	24,528	25,755	27,043	28,394
Plumbing Code	Projections	21,189	21,927	22,687	23,350	24,145	25,222	26,484
	Savings	0	321	674	1,178	1,610	1,821	1,910
Region F Estimate	Projections	21,189	21,376	21,487	21,814	22,430	23,302	24,335
	Savings (Region F practices)	0	551	1,200	1,536	1,715	1,920	2,149
	Savings (Total)	0	872	1,874	2,714	3,325	3,741	4,059
Costs								
Annual Costs			$478,790	$497,510	$499,438	$500,957	$501,922	$511,229
Cost per Acre-Foot [c]			$869	$415	$325	$292	$261	$238
Cost per 1,000 Gal [c]			$2.67	$1.27	$1.00	$0.90	$0.80	$0.73

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.
b Year 2000 water use is based on a per capita water use of 208 gpcd, which is the actual per capita water use in that year.
c Costs for implementing recommended practices. Costs of implementing plumbing code savings not included in unit cost calculations.

Agricultural and Rural Issues

None identified.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

This strategy is based on a generalized assessment of water conservation practices and may not accurately reflect the actual costs or water savings that can be achieved by the CRMWD and its member cities. Site-specific data will be required for a better assessment of the potential for water conservation by the city. Technical assistance and funding by the state may be required to implement this strategy.

Other Water Management Strategies Directly Affected

Timing and quantity from other CRMWD strategies.

Drought Management

Drought management strategies are designed to temporarily reduce water demand during extreme drought periods. The CRMWD Drought Contingency Plan (May 2009), drought contingency plans developed by CRMWD customers, and subsequent revisions of these plans determine drought management strategies for CRMWD and its customers. Region F has not identified additional drought management strategies.

Voluntary Redistribution – Renew Contract with University Lands

CRMWD's Ward County Well Field is leased from University Lands, the managing agency for properties belonging to the University of Texas System. The contract expires in 2019. For the purposes of this plan it is assumed that CRMWD and University Lands will renew the contract without change in the quantity of water available from the source. Actual quantities and costs will be determined at the time of renewal. To maintain the same amount of groundwater supplies from Ward County, CRMWD will need to develop replacement wells and/or acquire additional water rights. CRMWD has recently received funding to acquire additional water rights and drill 14 additional water wells to maintain the long-term capacity of the Ward County well field. Rehabilitation and replacement of existing wells will be on-going for this well field and other CRMWD groundwater sources. Generic costs for replacement wells are discussed in another subsection of this chapter.

It is assumed that the supply from the additional wells will simply replace the contract amount with University Lands. Renewals of existing contracts for the same quantity of water are not evaluated for impacts. An estimate of the capital cost for constructing the 14 new wells is shown below. Actual costs will be determined during design.

Supply from Strategy	**5,200 acre-feet per year***
Total Capital Costs (2008 Prices)	$ 8,964,000
Annual Costs	$ 847,000
Unit costs (during amortization)	Not Applicable
Unit Costs (after amortization)	Not applicable

* This supply is for the same amount as the current contract.

Voluntary Redistribution – New Contracts to Provide Water

The planning process has identified several new CRMWD contracts to provide water, which are shown in Table 4.8-12. All of these contracts are the result of expiration of existing customer contracts. The amounts shown in Table 4.8-12 are for planning purposes. The actual amount of water and cost for the water will be negotiated between the contracting parties.

Other CRMWD contracts do not expire during the planning period.

Table 4.8-12
New CRMWD Contracts to Supply Water

Water User	Amount (Acre-Feet per Year)						Comments
	2010	2020	2030	2040	2050	2060	
Midland			10,000	9,800	9,600	9,400	8.45 percent of system yield
Stanton	392	422	429	430	415	393	Set to demands
Millersview-Doole WSC					500	500	
Ballinger					600	600	Set to existing amt
Total	*392*	*422*	*10,429*	*10,230*	*11,115*	*10,893*	

Groundwater Desalination

CRMWD intends to develop supplies from brackish groundwater. The Capitan Reef aquifer has been identified as a potential source. In Region F, the Capitan Reef aquifer extends from the New Mexico border in Winkler County, through Ward County and into Pecos County. The Region F water supply analysis shows about 27,000 acre-feet of water per year available from this source. Development of this aquifer could occur concurrently with development of the CRMWD well field in Winkler County, the City of Midland T-Bar well field or supplies from other sources. Brackish water production from the Dockum or Pecos Valley aquifer could also be developed as an alternative to or in conjunction with brackish water from the Capitan Reef aquifer. Additional information on the Capitan Reef aquifer may be found in Section 3.1.11.

Quantity, Reliability and Cost of Capitan Reef Desalination Project

For the purposes of this plan it is assumed that a 10 MGD desalination plant delivering up to 9,500 acre-feet of water per year would be constructed in Winkler County near the proposed Winkler County Well Field. A parallel pipeline would be constructed to deliver the water to CRWMD customers. Disposal of brine reject would be through deep well injection. Because of the uncertainty involved with development of this source for municipal water use, the reliability of this source is considered to be moderate. Table 4.8-13 summarized the expected costs for the project.

Table 4.8-13
CRMWD Brackish Water Desalination Project

Supply from Strategy	**9,500 acre-feet per year**
Total Capital Costs (2008 Prices)	$ 131,603,990,000
Annual Costs	$ 17,814,378
Unit costs (during amortization)	$ 1,875 per acre-foot
	$ 5.75 per 1,000 gallons
Unit Costs (after amortization)	$ 667 per acre-foot
	$ 2.05 per 1,000 gallons

Environmental Issues Associated with CRMWD Desalination Project

This strategy relies on brackish groundwater from formations which have no surface outflow in the vicinity of the proposed project. It is unlikely that pumping from these formations will result in any alteration of terrestrial habitats. The conceptual design for the project uses deep well injection for brine disposal. A properly designed and maintained facility should have minimal environmental impact. Well field development and construction of the treatment facility should have minimal environmental impact as well.

Agricultural and Rural Issues of CRMWD Desalination Project

Water from the Capitan Reef aquifer is currently used only for oil field flooding. No competition is expected with municipal or agricultural water users. Therefore agricultural and rural impacts are expected to be minimal.

Other Natural Resource Issues Associated with CRMWD Desalination Project

None identified.

Significant Issues Affecting Feasibility

Because this source of water is only used for oil field flooding, very little is known about the suitability of this source for municipal water supply. Additional studies will be required to evaluate the merit of this source.

Other Water Management Strategies Directly Affected by CRMWD Desalination Project

Winkler County Well Field.

Supplemental Wells

The CRMWD operates groundwater systems for four existing well fields located in Ward, Scurry, Ector and Martin Counties. The supplies from each of these well fields are expected to produce a total of 7,558 acre-feet per year through 2060 (assuming renewal of the University Lands contract). In order to maintain this level of production, it is likely that new wells will be needed to replace diminished capacities of existing wells. These supplemental wells will be needed over time to ensure a continued adequate supply for CRMWD. The depth and capacity of each supplemental well will need to be determined on a case by case basis. For this plan, a typical cost was developed based on average well depths and productions capacities.

Since the supplemental wells do not provide additional water supplies but rather replace existing supplies, this strategy is not evaluated for impacts.

Table 4.8-14
Generic Cost for Supplemental Well

Supply from Strategy	**0 acre-feet per year**
Total Capital Costs (2008 Prices)	$522,000
Annual Costs	$ 50,000
Unit costs (during amortization)	Not Applicable
Unit Costs (after amortization)	Not applicable

Recommended Strategies for CRMWD

Recommended strategies for CRMWD include:

- Subordination of downstream senior water rights
- New groundwater – Winkler Well Field
- Reuse – CRMWD Reclamation Project
- Renew contract with University Lands and maintain capacities of Ward County well field
- Groundwater Desalination
- Water conservation
- Supplemental Wells

Table 4.8-15 compares the supply from the strategies to demands with these strategies in place, and Table 4.8-16 summarizes the capital costs for the recommended strategies. For the purposes of this plan, it has been assumed that water conservation activities will be financed by the member cities, so costs for water conservation do not appear in Table 4.8-16.

Table 4.8-15
Recommended Water Management Strategies for CRMWD
(Values in Acre-Feet per Year)

Supplies	2010	2020	2030	2040	2050	2060
Existing Supplies	*74,485*	*67,935*	*66,585*	*65,235*	*63,885*	*62,535*
Subordination	48,027	47,134	46,240	45,347	44,453	43,560
Winkler County Well Field	0	0	6,000	6,000	6,000	6,000
CRMWD Reclamation Project	0	12,380	12,380	12,380	12,380	12,380
Renew Contract with University Lands and Maintain Capacity	0	5,200	5,200	5,200	5,200	5,200
Desalination				9,500	9,500	9,500
Supplemental Wells		0	0	0	0	0
Total Supplies	*122,512*	*132,649*	*136,405*	*143,662*	*141,418*	*139,175*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential Savings [a]	862	1,957	2,403	2,618	2,865	3,137
Demands	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Existing customers	89,212	91,631	73,743	74,129	73,699	74,644
New Contracts	392	422	10,429	10,230	11,115	10,893
Total Demand	89,604	92,053	84,172	84,359	84,814	85,537
Surplus (Need) without Conservation	*32,908*	*40,596*	*52,233*	*59,303*	*56,604*	*53,638*
Surplus (Need) with Conservation	*33,770*	*42,553*	*54,636*	*61,921*	*59,469*	*56,775*

a Savings for member cities only, and does not include plumbing code savings, which are already included in the water demand projections.

Table 4.8-16
Capital Costs for Recommended Strategies [a]

Strategy	Capital Costs	Annual Costs					
		2010	2020	2030	2040	2050	2060
Winkler County Well Field	$76,268,000	$-	$-	$8,666,000	$8,666,000	$2,017,000	$2,017,000
CRMWD Reclamation Project	$128,748,000	$-	$15,905,000	$15,905,000	$4,680,000	$4,680,000	$4,680,000
Subordination [b]	$-	$-	$-	$-	$-	$-	$-
University Lands Contract	$8,964,000	$-	$847,000	$847,000	$65,000	$65,000	$65,000
Desalination	$131,603,990	$-	$-	$-	$17,814,378	$17,814,378	$6,340,378
Supplemental Wells [c]	$10,440,000	$-	$200,000	$400,000	$416,000	$432,000	$448,000
Total	*$356,023,990*	*$0*	*$16,952,000*	*$25,818,000*	*$31,641,378*	*$25,008,378*	*$13,550,378*

a. Water conservation would be implemented by individual member cities and would not be a CRMWD cost.
b. Costs were not determined for the subordination strategy.
c. It is assumed that 4 wells per decade would be replaced. The actual number and cost will be based on operations and specific well fields.

4.8.2 City of San Angelo

The City of San Angelo is located in Tom Green County near the center of Region F. As one of the largest cities in the region, it is a major center of employment, trade and cultural activities in the region. The city receives water from six sources: Lake Nasworthy, Twin Buttes Reservoir, the Concho River, O.C. Fisher Reservoir, Ivie Reservoir, and Spence Reservoir. The water rights for Lake Nasworthy, Twin Buttes Reservoir and the Concho River are owned by the city. The rights for O.C. Fisher are owned by the Upper Colorado River Authority (UCRA). Ivie and Spence Reservoirs are owned by the Colorado River Municipal Water District (CRMWD). The city also owns an undeveloped groundwater well field in McCulloch County.

Table 4.8-17 is a comparison of the Region F supply and demand for the City of San Angelo for municipal and industrial use. For this analysis it is assumed that the city will provide all of the water for the City of San Angelo, approximately 250 acre-feet per year to connections outside of the city (County-Other), all of the manufacturing demand in Tom Green County, and up to 1,021 acre-feet of raw water for steam electric power generation. Steam-electric demand is limited to recent historical use. According to historical data from the TWDB, 1,021 acre-feet of water was used for steam-electric generation in Tom Green County in 1999. More recent use has been less. The city also supplies treated O.C. Fisher water to the City of Miles through an agreement with UCRA.

Table 4.8-17 contains the Region F supplies for the City of San Angelo based on the TCEQ Colorado WAM.[43] TWDB requires use of the Colorado WAM Run 3 in regional water planning. In this model, all of San Angelo's local reservoir supplies and Spence Reservoir have little or no firm yield. Ivie Reservoir is the only significant source of water with a reliable yield. The model shows a small reliable supply from three of the city's run-of-the-river permits, namely CA 1325 (Lone Wolf), CA 1333 and CA 1337. (Note: CA 1357 was not included in the version of the Colorado WAM used for this analysis). Using these supplies, the City of San Angelo has needs for over 12,000 acre-feet of water in 2010 which increases to over 16,000 acre-feet by 2060.

Table 4.8-17
Comparison of Supply and Demand for the City of San Angelo
(Values in Acre-Feet per Year)

Supplies	2010	2020	2030	2040	2050	2060	Comment
Twin Buttes/Nasworthy	0	0	0	0	0	0	WAM supply
O.C. Fisher	0	0	0	0	0	0	WAM supply
Concho River	642	642	642	642	642	642	WAM supply
Spence Contract	0	0	0	0	0	0	Currently not available
Ivie Contract	10,974	10,751	10,528	10,304	10,081	9,858	Supply limited to 16.54 % of safe yield
Total	*11,616*	*11,393*	*11,170*	*10,946*	*10,723*	*10,500*	
Demand	**2,010**	**2,020**	**2,030**	**2,040**	**2,050**	**2,060**	**Comment**
City of San Angelo	20,800	21,418	21,734	21,744	21,907	21,969	
City of Miles	200	200	200	200	200	200	
Municipal Sales	250	250	250	250	250	250	Assumed
Manufacturing	2,226	2,498	2,737	2,971	3,175	3,425	100% of demand
Steam-Electric	543	777	909	1,021	1,021	1,021	Limited to recent use
Total	*24,019*	*25,143*	*25,830*	*26,186*	*26,553*	*26,865*	
Surplus (Need)	*(12,403)*	*(13,750)*	*(14,660)*	*(15,240)*	*(15,830)*	*(16,365)*	

Note: San Angelo also provides 8,500 ac-ft/yr of treated wastewater for irrigation in exchange for supplies from Twin Buttes Reservoir. This table does not include irrigation demands on Twin Buttes Reservoir.

The supplies from CRMWD reservoirs (Spence and Ivie) have been adjusted to reflect yields determined with the Colorado WAM. The city's contracts with CRMWD are currently set at 3,000 acre-feet per year from Spence Reservoir and 15,000 acre-feet per year from Ivie

Reservoir. These contracts also specify that, at the option of CRMWD, the contracted amount from these reservoirs can be reduced to 6 percent of the safe yield of Spence Reservoir and 16.54 percent of the safe yield of Ivie Reservoir. For the purposes of this plan, it was assumed that CRMWD will reduce available supplies to San Angelo based on the Region F safe yield of each source. Also, the city's pipeline to Spence Reservoir is not usable at this time and requires extensive rehabilitation. Therefore supplies from Spence Reservoir are considered to be unavailable until the pipeline has been repaired. This plan includes the repair of the pipeline as a water management strategy.

Potentially Feasible Strategies

In accordance with TWDB rules, the Region F Water Planning Group has adopted a standard procedure for identifying potentially feasible strategies. This procedure classifies strategies using the TWDB's standard categories developed for regional water planning.

In addition to the Region F analysis, the city used an extensive public process to evaluate potential strategies to meet the City's future needs. In February of 2004, the San Angelo City Council, the Citizen's Water Advisory Board, and the City Staff published the results of this process in the report *San Angelo Water Preparing for the Next 50 Years.*[44] In this report five preferred strategies were identified:

- Develop and communicate public and private conservation and drought management programs
- Develop reclamation, reuse and water storage alternatives
- Protect and enhance existing surface water resources
- Expand cooperative efforts and agreements to increase water availability for both urban and rural areas
- Identify and develop fresh and brackish groundwater alternatives

Combining these strategies with standard categories results in the following list of potentially feasible strategies for the City of San Angelo:

- Water conservation
- Drought management
- Subordination of downstream senior water rights
- Desalination of brackish groundwater
- New groundwater – development of the McCulloch County well field

- New groundwater – water from Edwards-Trinity aquifer
- Reuse
- System Optimization through system operation and conjunctive use
- Voluntary redistribution through purchase of additional water rights or contracts for additional supplies
- Other – Rehabilitation of the Spence pipeline

Precipitation enhancement and brush control are discussed in Section 4.9.

Water Conservation

During the recent drought the City of San Angelo succeeded in significantly reducing per capita water demand. Between 1980 and 2000, the average per capita water demand for the city was 196 gallons per person per day (gpcd). In 2006, the latest year for which data are available, the per capita water demand was 149 gpcd.[45] Some of this reduction is the result of implementation of water use restrictions and other drought management strategies. Water conservation activities conducted by the city include public awareness and education programs, inclining rate structure to discourage high water use, outdoor watering restrictions and infrastructure improvements to reduce water loss.

Quantity, Reliability and Cost

Municipal conservation activities that the City of San Angelo has implemented are consistent with the recommended strategies for Region F. The water use restrictions that the city has implemented are considered part of the drought management strategies. These restrictions were put into place in response to the current drought and it is uncertain whether they will remain in place during non-drought periods. Therefore, for this plan, the potential water savings associated with municipal water conservation is based on the Region F package of water conservation practices.

Table 4.8-18 compares projected demands for the City of San Angelo with no conservation, with the expected conservation due to plumbing code (the default projections used in regional water planning), and with Region F water conservation criteria (see the Appendix 4G).

Based on these data, savings due to conservation could be about 1,000 acre-feet per year in 2010, increasing to about 4,000 acre-feet per year by 2060. The reliability of these supplies has been determined to be medium due to the lack of site-specific data regarding the long-term savings associated with implementing these strategies. Costs range from $565 per acre-foot in 2010 to $158 per acre-foot in 2060.

Table 4.8-18
Potential Water Conservation Summary for the City of San Angelo [a]

		2000	2010	2020	2030	2040	2050	2060
Per Capita Demand (gpcd)								
No Conservation	Projections	162	200	200	200	200	200	200
Plumbing Code	Projections	162	197	193	190	187	186	186
	Savings	0	3	7	10	13	14	14
Region F Estimate [b]	Projections	200 [c]	190	178	172	169	167	166
	Savings (Region F Practices)	0	7	15	18	18	19	20
	Savings (total)	0	10	22	28	31	33	34
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	19,813	21,117	22,195	22,878	23,256	23,556	23,623
Plumbing Code	Projections	19,813	20,800	21,418	21,734	21,744	21,907	21,969
	Savings	0	317	777	1,144	1,512	1,649	1,654
Region F Estimate [b]	Projections	19,813	20,099	19,713	19,725	19,617	19,652	19,598
	Savings (Region F Practices)	0	701	1,705	2,009	2,127	2,255	2,371
	Savings (total)	0	1,018	2,482	3,153	3,639	3,904	4,025
Costs								
Annual Costs			$230,014	$250,370	$256,256	$259,652	$261,609	$261,721
Cost per Acre-Foot [d]			$328	$147	$128	$122	$116	$110
Cost per 1,000 Gal [d]			$1.01	$0.45	$0.39	$0.37	$0.36	$0.34

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide,* November 2004, and data provided by the City of San Angelo, 2008.
b Includes plumbing code savings.
c Year 2000 water use is based on a per capita water use of 200 gpcd. Actual year 2000 use was 16,048 acre-feet, equivalent to a per capita water demand of 162 gpcd.
d Costs for implementing recommended practices. Plumbing code savings not included in unit cost calculations.

Recent experience in the City of San Angelo has shown that per capita water demand can be even lower than estimated using these techniques. There are several possible explanations for this:

- The base per capita demand of 200 gpcd used to develop the projections may be high
- Replacement of old 2-inch pipes and other leak reduction and water accounting activities implemented by the city
- Drought contingency measures implemented by the city (these measures are assumed to be temporary and water demand would increase as these restrictions are removed)
- Public awareness of the city's water supply problems, creating a 'culture of conservation'

Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. The water conservation practices in this plan are guidelines. Region F considers water conservation strategies determined and implemented by the City of San Angelo to supersede the recommendations in this plan and to meet regulatory requirements for consistency with this plan.

Environmental Issues

Most of the City of San Angelo's water supply comes from reservoirs which spill infrequently. Therefore water conservation could result in more water remaining in reservoir storage, and will have minimal impact on downstream flows. Much of the conserved water in storage will be used for other purposes or lost to evaporation. The additional water in storage may result in a minimal positive impact on recreation use and environmental water needs associated with those reservoirs.

Agricultural and Rural Issues

Conservation is expected to have a small positive impact on agricultural resources because some of the conserved water may be available for irrigation.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

This strategy is based on a generalized assessment of water conservation practices and may not accurately reflect the actual costs or water savings that can be achieved by the City of San Angelo. Site-specific data will be required for a better assessment of the potential for water conservation by the city. Technical assistance and funding by the state may be required to implement this strategy.

Other Water Management Strategies Directly Affected

None identified.

Drought Management

Drought management strategies are designed to temporarily reduce water demand during drought periods. The San Angelo Drought Contingency Plan, the CRMWD Drought Contingency Plan and subsequent revisions of these plans determine drought management for the City of San Angelo. Some of the recent reduction in water demand by the city may be attributable to practices that result in temporary reductions in water use. Examples include landscape watering or car washing restrictions that may be discontinued once the area is out of critical drought conditions. Until additional data are available after these restrictions have been lifted, it is uncertain how much water has been saved by implementation of these practices.

During the current drought, use of Lake Nasworthy water for power generation was reduced. No irrigation water has been used from Twin Buttes Reservoir because the irrigation pool is empty. During part of the drought Twin Buttes ceased impounding water in order to pass water for downstream senior water rights. All of these activities could be considered drought management strategies.

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, reservoirs in Region F with a priority date after 1926 do not have a firm or safe yield. This result is largely due to the assumptions used in the Colorado WAM. In order to address water availability issues in the Colorado Basin associated with the WAM model, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights in Region F do not make priority calls on each other. The subordination strategy is discussed in detail in Section 4.2.3. Table 4.8-19 is a summary of the impacts of the subordination strategy on supplies for the city.

The joint modeling between the two regions was conducted for planning purposes only. Neither Region F nor the Lower Colorado Region mandates the adoption of this strategy by individual water right holders. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including the City of San Angelo and CRMWD.

Impacts of the subordination strategy are discussed in Section 4.2.3.

Table 4.8-19
Impact of Subordination Strategy on San Angelo Water Supplies
(Values in acre-feet per year)

Reservoir	Priority Date	Permitted Diversion	2010 Supply WAM Run 3	2010 Supply Subord-ination	2060 Supply WAM Run 3	2060 Supply Subord-ination	Comments
San Angelo System							
Twin Buttes Reservoir	5/6/1959	29,000	0	12,310	0	11,360	
Lake Nasworthy	3/11/1929	25,000					
O.C. Fisher Reservoir	5/27/1949	80,400	0	3,862	0	3,270	
San Angelo System Total		*134,400*	*0*	*16,172*	*0*	*14,630*	
Spence Reservoir	8/17/1964	41,573					
CRMWD system portion			526	36,164	526	35,090	
San Angelo contract			34	2,308	34	2,240	6% of safe yield
Spence Reservoir Total			*560*	*38,472*	*560*	*37,330*	
Ivie Reservoir	2/21/1978	113,000					
CRMWD, Midland, Abilene			55,376	55,461	49,742	46,955	
San Angelo contract			10,974	10,991	9,858	9,305	16.54% of safe yield
Ivie Reservoir Total			*66,350*	*66,452*	*59,600*	*56,260*	

Voluntary Redistribution through Lease or Purchase of Existing Water Rights

Voluntary redistribution through purchase or lease of existing water rights is a feasible strategy that is complementary to subordination. The City of San Angelo has already purchased several water rights in the vicinity, and will continue to consider purchase of other water rights on a willing-buyer willing-seller basis. Diversions for these rights could be moved to one of San Angelo’s existing diversion points, or the rights could simply not be exercised, eliminating the possibility of a priority call.

Region F has not identified specific rights for purchase, so no quantity, costs or impacts can be developed at this time.

Reuse

The City of San Angelo has historically disposed of its treated effluent through land application. In the past few years the city has sold treated effluent to the local irrigation district as a substitute for Twin Buttes water. The city has recently initiated a reuse study to investigate alternative uses for its treated effluent. The results of this study are not available at this time.

Potential reuse strategies include:

- In-city landscape irrigation (parks, cemeteries, golf courses, Angelo State University, air base, etc.)
- Manufacturing purposes
- Steam-electric power generation
- Blending with other sources of water for indirect reuse
- Aquifer storage and recovery (ASR) in conjunction with one or more of the above strategies

Under current rules, ASR would require treatment of wastewater to drinking water standards before injection. This strategy would most likely use reverse osmosis or a similar membrane process.

An analysis of quantity and impacts will be completed once specific strategies have been identified in the reuse study.

Desalination

The Region F Water Planning Group, in association with the City of San Angelo and UCRA, has identified several potential brackish groundwater sources north and west of the city. An initial investigation into one of these sources, the Whitehorse formation, did not yield water of sufficient quality or quantity and has been dropped from consideration. A test of the Clear Fork formation was more promising and merits additional investigation.[46] The city plans to continue investigating sources of saline water for future water supplies. For the purposes of this plan, a conceptual design was developed for phased development of a facility with an initial capacity of 5 MGD and an ultimate capacity of 10 MGD. The most likely location for desalination facility is on the northwest side of the city. The conceptual design for this strategy calls for disposal of brine reject through deep-well injection.

Quantity, Reliability and Cost

Since a specific source for this strategy has not been identified, at this time the amount of water available from the formation and the quality of the water is largely unknown. For the purposes of this plan, it will be assumed that sufficient water is available from these sources to provide up to 11,200 acre-feet of water per year and that a source of water will be located within 30 miles of the city. The reliability of this source is considered to be medium due to the uncertainty associated with the available water from the source. Table 4.8-20 is a summary of costs for the project. It is assumed that the facilities will be built with an initial capacity of 5 MGD and upgraded to 10 MGD at a later date.

Environmental Issues

This strategy relies on brackish groundwater for its source. These formations have no surface outflow in the vicinity of the proposed project. It is unlikely that pumping from these formations will result in any alteration of terrestrial habitats. The conceptual design for the project uses deep well injection for brine disposal. A properly designed and maintained facility should have minimal environmental impact. Well field development and construction of the treatment facility should have minimal environmental impact as well.

Table 4.8-20
Desalination Facility for San Angelo

Initial Capacity (5 MGD)	
Supply from Strategy	5,600 acre-feet per year
Total Capital Costs (2008 Prices)	$ 75,440,000
Annual Costs	$ 9,223,930
Unit costs (during amortization)	$ 1,647 per acre-foot
	$ 5.05 per 1,000 gallons
Unit Costs (after amortization)	$ 473 per acre-foot
	$ 1.45 per 1,000 gallons
Ultimate Capacity (10 MGD)	
Supply from Strategy	11,200 acre-feet per year
Total Expansion Capital Costs (2008 Prices)	$ 40,424,000
Annual Costs	$ 12,047,500
Unit costs (during amortization)	$ 1,076 per acre-foot
	$ 3.30 per 1,000 gallons
Unit Costs (after amortization)	$ 445 per acre-foot
	$ 1.37 per 1,000 gallons

Agricultural and Rural Issues

One of the most productive agricultural areas in the region is located east of the City of San Angelo. Some of this area is irrigated with surface water from Twin Buttes Reservoir and the Concho River, resulting in direct competition for water during dry periods. One of the chief benefits of this strategy is that there is no competition for this source of water with other interests; at present water from these formations is not used for any beneficial purpose.

Therefore this strategy has a positive impact on agricultural interests by reducing the competition for water supplies.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

The most significant factor affecting feasibility is the lack of data on water quality and quantity from these formations. It has been demonstrated that there is water in these formations and geophysical logs indicate favorable formation conditions. However, specific data on chemistry and quantity of water are not available at this time. Water chemistry could have a significant impact on the cost and feasibility of this project.

Other Water Management Strategies Directly Affected

Other San Angelo strategies

New Groundwater Development - McCulloch County Well Field

The City of San Angelo owns an undeveloped well field on the border of McCulloch and Concho Counties. This well field produces water from the Hickory aquifer. Water from this well field may not meet current drinking water standards for radium. The city is currently conducting a study evaluating the water quality of the aquifer, options to meet drinking water standards for radionuclides, well field layout and alternatives to deliver the water to the city.

The results of the study are not complete and are not available for this plan update. Preliminary cost estimates provided by the City of San Angelo from the current study show the total estimated capital cost, including treatment using ion exchange, at $173 million.[47] The schedule shows the initial new supply to be on line by 2014, with subsequent expansions in 2026 and 2036.

Quantity, Reliability and Cost

The quantity of water available from the McCulloch well field is limited by an agreement with the Hickory Underground Water Conservation District to 6,700 acre-feet per year when the well field is brought on line in about 2014, increasing to 10,000 acre-feet in 2026. By 2036, the maximum amount of water available will be 12,000 acre-feet per year. The reliability of water from the well field is high. Table 4.8-21 shows the costs associated with this strategy.

Table 4.8-21
Costs for the McCulloch County Well Field

Supply from Strategy	**12,000 acre-feet per year**
Total Capital Costs (2008 Prices)	$173,307,000
Annual Costs*	$18,215,000
Unit costs (during amortization)	$ 2,719 per acre-foot
	$ 8.34 per 1,000 gallons
Unit Costs (after amortization)	$ 1,083 per acre-foot
	$ 3.32 per 1,000 gallons

* Annual costs vary with the different phases. The annual and unit costs reported in this table are for Phase 1.

Environmental Issues

Previous studies of the McCulloch County Well Field have not assessed the potential for impacts on springflows.[48, 49] The well field will produce water from the down-dip portion of the Hickory aquifer. Faulting may have caused portions of the well field to be cut off from the recharge zone of the aquifer, and most of the supply is expected to come from water in storage. Based on this information, it is unlikely that development of this well field will have a significant impact on springflow and streamflows, or cause subsidence. Therefore environmental impacts are expected to be minimal.

Based on the available data, it is unlikely that pumping limits other than those already imposed by the Hickory Underground Water Conservation District will be required to protect the environment. There are no subsidence districts in Region F.

Agricultural and Rural Issues

The Hickory aquifer is used extensively for irrigation and for municipal water supply in the area. There is concern that other users of the Hickory aquifer, particularly the cities of Eden, Brady and Melvin, may be affected by lowering of the water table caused by pumping for San Angelo. It is recommended that additional investigations be performed prior to implementation of this strategy to assess the impacts on other users.

This strategy should have minimal impacts on agriculture since most of the irrigated acreage using the Hickory aquifer is located upgradient of the well field in the recharge zone or shallower areas of the aquifer. San Angelo’s holdings are in the deeper portion of the aquifer. The right of way for the transmission line may affect a small amount of agricultural acreage that will need to be determined once the pipeline route has been finalized.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

Much of the water from the Hickory aquifer has radium levels that exceed the maximum contaminant level (MCL) for drinking water. It is assumed that the water from the McCulloch County well field will be treated using ion exchange.

Other Water Management Strategies Directly Affected

Other San Angelo strategies.

System Optimization

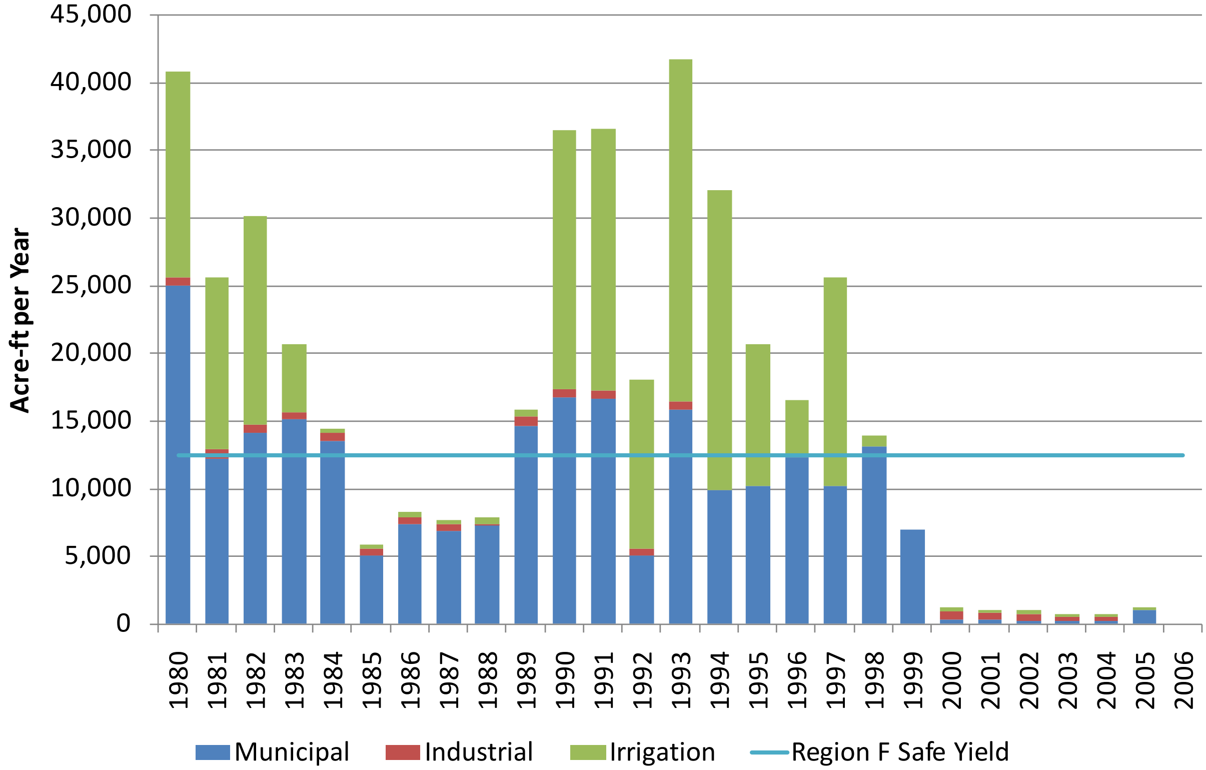
The City of San Angelo uses multiple sources of water. Previous studies have shown some increased yield from operating these sources in a coordinated fashion. In the first round of planning, it was estimated that an additional 2,100 acre-feet of water could be generated by operating Twin Buttes, Lake Nasworthy and O.C. Fisher in a coordinated fashion. If other existing and potential sources are added, additional supplies may be generated.

As part of system optimization, the city is pursuing changes to its water rights in O.C. Fisher Reservoir to allow storage of water pumped from Ivie Reservoir, Spence Reservoir or other sources in the reservoir. Water from these sources could be stored in the reservoir during lower-demand winter months for use later in the year.

Another issue associated with system optimization is the overdrafting of Twin Buttes Reservoir and Lake Nasworthy. The contract between the city and the Tom Green County Water Control and Improvement District (Tom Green County WCID) specifies a pool accounting system that reserves the lower 50,000 acre-feet of storage in the reservoir for municipal use. The remaining storage may be used for irrigation supplies. The amount of water in each storage pool is tracked over time based on an accounting system defined in the contract. During an extended drought, the reservoir may drop below 50,000 acre-feet of storage and no water from the irrigation pool will be available.

Figure 4.8-1 shows historical water use from the two reservoirs between 1980 and 2006. Between 1980 and 2000 as much as 41,000 acre-feet of water has been used from the two reservoirs, which greatly exceeds the safe supply of the two reservoirs of 12,400 acre-feet per year. Recent use has been considerably less than the safe supply.

Figure 4.8-1
Historical Water Use from the Twin Buttes Reservoir/Lake Nasworthy System



Quantity, Reliability and Cost

The 2001 Region F plan estimated that an additional 2,100 acre-feet of water could be made available by operating Twin Buttes, Nasworthy and O.C. Fisher as a coordinated system. However, the 2001 Region F plan did not consider the impact of this type of operation on senior water rights. Also, with the current drought the reliable supply cannot be determined. Additional studies will be required to determine potential supplies taking into account priority of other water rights, subordination of major water rights, additional sources of water and the impact of recent drought. Until further studies have been performed, no water should be considered available from this strategy.

Impacts

Impacts cannot be determined until the amount of water available from this strategy has been defined.

Rehabilitation of the Spence Pipeline

Currently the city's pipeline from Spence Reservoir is not operational. Rehabilitation of the pipeline will be required for the city to access this source.

Quantity, Reliability and Cost

For the purposes of this plan it was assumed that the supply from Spence Reservoir is limited to 6 percent of the safe yield. With subordination, the 2010 supply is 2,308 acre-feet per year and the 2060 supply is 2,240 acre-feet per year. The reliability of this source is medium because of the water rights issues associated with subordination. Table 4.8-22 shows the expected costs of this strategy.

Table 4.8-22
Costs for Rehabilitation of the Spence Pipeline *

Supply from Strategy	**2,300 acre-feet per year**
Total Capital Costs (2008 Prices)	$6,157,000
Annual Costs *	$716,000
Unit costs (during amortization)	$ 311 per acre-foot
	$ 0.96 per 1,000 gallons
Unit Costs (after amortization)	$ 78 per acre-foot
	$ 0.24 per 1,000 gallons

* Costs do not include purchase of water from CRMWD

Impacts

Because this is an existing source for the City of San Angelo, an impact analysis was not conducted.

Water Marketing – Water from Southwestern Pecos County

A group of landowners in southwestern Pecos County has proposed selling groundwater from the Edwards-Trinity (Plateau) aquifer in southwestern Pecos County. Initial estimates indicate that this area can produce a large quantity of water of reasonable quality.

Quantity, Reliability and Cost

The sustainable quantity of water from Southwestern Pecos County has not been established, although preliminary estimates indicate that 50,000 to 100,000 acre-feet per year could be provided from this source. For this analysis, we are assuming that the City of San Angelo could take up to 12,000 acre-feet per year from Pecos County. Because of the uncertainty associated with this source, the reliability of the supply is medium. Table 4.8-23 shows the costs associated with this strategy.

Table 4.8-23
Costs for water from Southwestern Pecos County
City of San Angelo

Supply from Strategy	**12,000 acre-feet per year**
Total Capital Costs (2008 Prices)	$ 277,730,000
Annual Costs	$ 31,725,000
Unit costs (during amortization)	$ 2,644 per acre-foot
	$ 8.11 per 1,000 gallons
Unit Costs (after amortization)	$ 626 per acre-foot
	$ 1.92 per 1,000 gallons

Environmental Issues

Information provided by the sponsors of this project indicates possible impacts on flow in the Pecos River from development of this strategy,[50] which should be investigated if this strategy is pursued. If linkage between groundwater development and flows in the Pecos River can be established, the local groundwater conservation district may wish to impose pumping limits. There are no subsidence districts in Region F.

Agricultural and Rural Issues

According to information provided by the developers of this project, the supply in the immediate area is primarily used for cattle ranching and development of the project will have minimal impact on existing uses. However, it is possible that large-scale production from this source could impact irrigation supplies in the Belding Farms area. Additional studies may be needed to quantify this impact.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

The most significant issue facing this project is the lack of funds to perform studies to verify the potential supplies from this source. Also, the source is located over 175 miles from the City of San Angelo.

Other Water Management Strategies Directly Affected

Other San Angelo strategies.

New Groundwater – Water from the Edwards-Trinity (Plateau) Aquifer

In 1985 the City of San Angelo investigated the possibility of developing a water supply from the Edwards-Trinity (Plateau) aquifer in northern Schleicher County.[51] This study concluded the following:

- Water from the Edwards limestones was of good quality. The water quality of the Trinity sands was somewhat poorer in quality.
- Water production from the Edwards limestones appears to be from cavernous porosity and could provide sufficient water for municipal supply. The Trinity sand is poorly developed, contains a high percentage of clay and is less attractive for large-scale water development.
- Drought conditions from 1962 to 1967 caused water levels in the Edwards to drop by 15 to 20 feet.
- Models of production from a proposed well field near Hulldale had a significant impact on the Anson springs. These springs provide much of the base flow of the South Concho River, which flows into Twin Buttes Reservoir.

Other areas in the Edwards-Trinity (Plateau) aquifer south of the city may provide water in sufficient quantities for municipal supplies. However, the quantity of water can vary greatly depending on the presence of porosity in the Edwards limestones. An exploration program would be required to find other suitable areas for municipal development.

Quantity, Reliability and Cost

According to the Region F water supply analysis, over 62,000 acre-feet of water per year are available from the Edwards-Trinity in Crockett, Schleicher and Sutton Counties. However, most of the water is contained in caverns or fractures in the Edwards limestone. This type of porosity tends to be highly localized, making it difficult to find areas with sufficient production for municipal supplies. Studies have also indicated that production from the aquifer may be significantly impacted by drought. Therefore the reliability of the supply has been classified as medium.

The 1985 San Angelo study proposed construction of a 30-mile 30-inch pipeline with a capacity of 15 MGD. The proposed well field had 10 wells. Table 4.8-24 is a cost estimate based on this study. If this strategy is pursued, additional engineering studies will be required to refine these estimates.

Table 4.8-24
Costs for Water from Edwards-Trinity (Plateau) Aquifer
City of San Angelo

Supply from Strategy	**12,000 acre-feet per year**
Total Capital Costs (2008 Prices)	$47,982,000
Annual Costs	$7,920,500
Unit costs (during amortization)	$ 660 per acre-foot
	$ 2.02 per 1,000 gallons
Unit Costs (after amortization)	$ 311 per acre-foot
	$ 0.96 per 1,000 gallons

Environmental Issues

Previous studies have indicated that groundwater development from the Edwards-Trinity aquifer may significantly impact springflow. If this strategy is pursued, a detailed study of the potential impacts of groundwater development should be conducted. If necessary, pumping limits in addition to those already imposed by the local groundwater conservation districts may be necessary to protect the environment. Development of water from this source is unlikely to cause subsidence.

Agricultural and Rural Issues

Springflows from the Edwards-Trinity supply much of the base flow of the South Concho and other flowing streams in the area. Many of these streams are used extensively for irrigation. Wells provide water for ranching, domestic and municipal supplies throughout the area. Studies will be required to evaluate potential impacts on the area.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

Local groundwater district rules in the area discourage the large-scale development of groundwater. Rule changes may be necessary for development of water from these counties.

Other Water Management Strategies Directly Affected

Other San Angelo strategies.

Recommended Strategies for the City of San Angelo

The recommended strategies for the City of San Angelo include:

- Subordination of downstream senior water rights
- Voluntary Redistribution through lease or purchase of existing water rights
- Rehabilitation of the Spence pipeline
- Development of the McCulloch County Well Field by 2020
- Development of a 5 MGD brackish groundwater desalination facility by 2040
- Water Conservation

Table 4.8-25 compares the supply from recommended strategies to projected demands for the City of San Angelo. Alternative strategies such as reuse and other water sources may be required if studies currently being conducted by the City of San Angelo prove that one or more of these strategies is more costly, produces less water or has greater impacts than determined in this analysis.

Table 4.8-25
Recommended Water Management Strategies for the City of San Angelo

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Existing Supplies	11,616	11,393	11,170	10,946	10,723	10,500
Subordination – municipal and industrial only	12,787	12,468	12,149	11,831	11,512	11,192
Lease or Purchase of Existing Water Rights [a]	0	0	0	0	0	0
Rehabilitation of Spence Pipeline	0	0	2,281	2,267	2,254	2,240
Desalination Facility	0	5,600	5,600	5,600	5,600	5,600
McCulloch County Well Field	0	0	5,000	12,000	12,000	12,000
Total Supplies	*24,403*	*29,461*	*36,200*	*42,644*	*42,089*	*41,532*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential Savings [b]	701	1,705	2,009	2,127	2,255	2,371
Demands	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of San Angelo	20,800	21,418	21,734	21,744	21,907	21,969
Outside Sales	3,219	3,725	4,096	4,442	4,646	4,896
Total Demand	24,019	25,143	25,830	26,186	26,553	26,865
Surplus (Need) without Conservation	384	4,318	10,370	16,458	15,536	14,667
Surplus (Need) with Conservation	1,085	6,023	12,379	18,585	17,791	17,038

a A specific quantity of water has not been identified for this strategy.
b Does not include plumbing code savings, which are already included in the water demand projections.

Recommended Alternative Strategies for the City of San Angelo

The recommended alternative strategies include for the City of San Angelo include:

- Wastewater reuse
- Development of alternative groundwater sources

4.9 Other Strategies

4.9.1 Weather Modification

Weather modification is a water management strategy currently used in Texas to increase precipitation released from clouds over a specified area typically during the dry summer months. The most common form of weather modification or rainfall enhancement is cloud seeding. Early forms of weather modification began in Texas in the 1880s by firing cannons to induce convective cloud formation. Current cloud seeding techniques are used to enhance the natural process for the formation of precipitation in a select group of convective clouds.

Convective clouds, also known as cumulus clouds, are responsible for producing the bulk of rainfall during any given year in Texas.[52] The cloud seeding process increases the availability of ice crystals, which bond with moisture in the atmosphere to form raindrops, by injecting a target cloud with artificial crystals, such as silver iodide. Specially equipped aircraft release the seeding crystals into clouds as flares that are rich in supercooled droplets. The silver iodide crystals form water droplets from available moisture in the air. Droplets then collide with droplets transforming the ice crystal into a raindrop.

Weather modification is most often utilized as a water management strategy during the dry summers in West Texas. The water produced by weather modification augments existing surface and groundwater supplies. It also reduces the reliance on other supplies for irrigation during times of normal and slightly below normal rainfall. However, not all of this water is available for water demands. Some of this precipitation is lost to evaporation, evapotranspiration, and local ponds. During drought years the amount of additional rainfall produced by weather modification may not be significant.

The amount of water made available to a specific entity from this strategy is difficult to quantify, yet there are regional benefits. Three major benefits associated with weather modification include:

- Improved rangeland and agriculture due to increased precipitation
- Greater runoff to streams and rivers due to higher soil moisture
- Groundwater recharge

Weather Modification Programs in Region F

In Region F, there are two ongoing weather modification programs: the West Texas Weather Modification Association (WTWMA) project and the Trans Pecos Weather Modification Association (TPWMA) program.

West Texas Weather Modification Association (WTWMA) Project

The WTWMA began weather modification efforts in 1995. The intent of the rainfall enhancement program was to increase ground water recharge, spring flow, and runoff resulting in increased agricultural productivity and reduction in ground water withdrawals. WTWMA operates in eight counties covering an area of 10 thousand square miles. The City of San Angelo, Emerald Underground Water Conservation District (UWCD), Glasscock County UWCD, Irion County Water Conservation District (WCD), Plateau Underground Water Conservation and Supply District (UWC & SD), Santa Rita UWCD, Sterling County UWCD and Sutton County UWCD are the current participants in the rainfall enhancement effort. In 2008, a total of 77 clouds were seeded as part of WTWMA's rain enhancement efforts in 38 operational days. WTWMA's estimates a 20-percent increase in rainfall in the target area because of their operations.[53]

Table 4.9-1 shows a breakdown by county of the estimated increase in rainfall for the year 2008 from the annual report of the Texas Weather Modification Association.[54]

Table 4.9-1
Estimated Precipitation Increase for the Year 2008 due to WTWMA Activities

County	Inches (Increase)	Rain Gage (season value)	% Increase
Glasscock	0.99	9.55	10.4
Sterling	3.12	13.75	22.7
Reagan	3.94	11.1	35.5
Irion	2.96	11.69	25.3
Tom Green	3.11	12.24	25.4
Crockett	1.92	12.93	15.0
Schleicher	2.71	12.06	22.5
Sutton	0.68	13.29	5.1
Total	19.43	96.61	20.1

Data are from the Texas Weather Modification Association

Trans Pecos Weather Modification Association (TPWMA) Program

The TPWMA began operation in 2003. The TPWMA consists of the Ward County Irrigation District and other political entities from a 4-county area, including Culberson, Loving, Reeves, and Ward counties. The program's target area covers over 5.1 million acres along and to the west of the Pecos River from El Paso to Midland. The program is currently funded by local ranchers, farmers, and landowners, Loving County, the Ward County Irrigation District, and a grant from the Texas Department of Agriculture. In 2008, TPWMA had 17 seeding days.[55]

Quantity, Reliability and Cost

Benefits of the weather modification programs are widespread and are difficult to quantify in the context of regional water planning. To precisely estimate the benefit of weather modification requires an estimate of how much precipitation would have occurred naturally without weather modification, and an estimate of how much of the increase in precipitation becomes directly available to a water user. Research indicates that rainfall can increase by 15 percent or more in areas participating in weather modification. Some locations have shown rainfall increases of as much as 27 percent. Other methods of measuring the effects of rainfall enhancement have shown positive benefits of weather modification. Dry land farm production, a common measurement, has increased in regions participating in rainfall enhancement. However, because there is no direct method to quantify the benefits to individual water user groups, no specific quantity will be assigned by Region F for this planning cycle.

The reliability of water supplies from precipitation enhancement is considered to be low for two reasons. First, it is uncertain how much water is made directly available per water user. Second, during drought conditions precipitation enhancement may not result in a significant increase in water supply. (The guidelines for regional water planning in TAC §357.5(a) specifies that regional water planning evaluate supplies from water management strategies during critical drought conditions.) Cloud formations suitable for seeding may not occur frequently during drought, so benefits during drought may be negligible.

The cost of operating the weather modification program is approximately nine to ten cents per acre. Additional data collection may be vital in determining if weather modification could be used as a long-term water management strategy in the region.

Environmental Issues

Weather modification should have a positive impact on the environment due to the increased rainfall from storms. The chemicals used in weather modification should be sufficiently diluted to minimize any threat of contamination.

Agricultural and Rural Issues

Weather modification has a positive impact on agriculture and ranching by increasing productivity. Another benefit of weather modification is hail suppression, which helps minimize damage from severe weather.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

The most significant issue facing existing weather modification programs is funding. In many cases these programs rely on the cooperation of several entities and the availability of outside funding to continue operations. In addition, local opposition to weather modification programs has caused some programs to be discontinued.

Other Water Management Strategies Directly Affected

None identified.

4.9.2 Brush Control

Brush control has been identified as a potentially feasible water management strategy for Region F. It has the potential to create additional water supply that could be used for some of the unmet needs in the Region as well as enhance the existing supply from the Region's reservoirs.

Background

Prior to settlement, most of Texas was grassland. Along with settlement came grazing animals which, for a number of reasons, created an environment that favored shrubs and trees (brush) rather than grasslands. Brush not only increases the costs of land management and decreases the livestock carrying capacity of the land, but as shown in Table 4.9-2, certain species of brush can drastically reduce water yield in a watershed. For these reasons, an effort was bought forth to control this brush and convert land back to grasslands.

In 1985, the Texas Legislature authorized the Texas State Soil and Water Conservation Board (TSSWCB) to conduct a program for the "selective control, removal, or reduction of … brush species that consume water to a degree that is detrimental to water conservation." In 1999 the TSSWCB began the Brush Control Program. This is a voluntary program in which landowners may contract with the state for cost-share assistance. Working through local soil and water conservation districts, landowners develop resource management plans addressing brush control, soil erosion, water quality, wildlife habitat and other natural resource issues.

Table 4.9-2
Plant Water Use Rates

Plant	Water Loss (in/yr)	Water Loss (ac-ft/ac/yr)
Cottonwood	43.5 – 64.5	3.63 – 5.38[56, 57]
Crops	30.8 – 37.0	2.57 – 3.08[58]
Fourwing Saltbush	28.5 – 68.8	2.38 – 5.73[59]
Grass	6.0	0.50[60]
Honey Mesquite	13.7 – 25.4	1.14 – 2.12[61]
Juniper	23.3 – 25.0	1.94 – 2.08[62]
Mesquite	19.2 – 26.3	1.60 – 2.19
Salt cedar	27.3 – 234	2.28 – 19.52[56,63,64,65]
Salt grass	11.9 – 44.8	0.99 – 3.73[66]

The TSSWCB has designated areas of critical need in the State in which to implement the Brush Control Program. Currently four watersheds have been designated as critical areas based on water needs and the results of the completed feasibility studies. Three of those four critical watersheds lie within Region F. They are the North Concho River Watershed, Twin Buttes Reservoir Watershed, and the Upper Colorado River Watershed.

Methods of Brush Control

A number of methods can be employed to control brush. They include: mechanical, chemical, prescribed burning, bio-control, and range management. Mechanical brush control methods can range from selective cutting with a hand axe and chain saw to large bulldozers. Moderate to heavy mesquite or cedar can be grubbed or plowed for $100 to $165/acre.[67]

Several herbicides are approved for chemical brush control. The herbicides may be applied from aircraft, from booms on tractor-pulled spray rigs, or from hand tanks. Some herbicides are also available in pellet form. The herbicides Triclopyr (Remedy®) and Clopyralid methyl (Reclaim®) are approved herbicides for on-going TSSWCB brush programs. Arsenal is the herbicide typically used for removal of salt cedar. These chemical were shown to achieve about 70 percent root kill in studies around the state and in adjacent states. Specific soil temperature and foliage conditions must be met in order for chemical brush control to be effective. Aerial spraying of brush such as mesquite costs the same regardless of the plant density or canopy cover, about $25 per acre.[67]

Prescribed burning is also used to control brush. Burning is conducted under prescribed conditions to specifically target desired effects. Prescribed burning is estimated at $15 per acre for the TSSWCB programs. There are some limitations however. Burning rarely affects moderate to heavy stands of mature mesquite. Burning only topkills the smooth-bark mesquite plants and they re-sprout profusely. In addition, for mesquite, fire only gives short-term suppression and it stimulates the development of heavier canopy cover than was present pre-burn. Fire is not usually an applicable tool in moderate to heavy cedar (juniper) because these stands suppress production of an adequate amount of grass for fine fuel. Fire can be excellent for controlling junipers over 4 feet tall, if done correctly. Prescribed burning is often not recommended for initial clearing of some heavy brush due to the concern that the fire could become too hot and sterilize the soil. Burning is often used for maintenance of brush removal that has been initially performed through some other method.

Bio-control of salt cedar is a relatively new technique to be used in Texas. It has been studied for nearly 20 years, and there have been pilot studies in the Lake Meredith watershed and most recently in the Colorado River Basin.[68] Research has shown that the Asian leaf beetle can consume substantial quantities of salt cedar in a relatively short time period, and generally does not consume other plants. Different subspecies of the Asian beetle appear to be sensitive to varying climatic conditions, and there is on-going research on appropriate subspecies for Texas. It is recommended that this control method be integrated with chemical and mechanical removal to best control re-growth. The cost per acre is unknown.

Range or grazing management should follow any type of upland brush control. It allows the regrowth of desirable grasses, maintaining good groundcover that hinders establishment of woody plant seedlings. Continued maintenance of brush is necessary to ensure the benefits of brush control.

Brush Control in Region F

Brush control is a potential water management strategy that could possibly create additional water supply within Region F. Predicting the amount of water that would be made available by implementing a brush control program is difficult, but some estimates have been made through ongoing pilot projects. Feasibility studies were conducted in many areas, and based on those feasibility studies, a number of brush control projects were initiated in Region F. Currently active projects sponsored by the Texas State Soil and Water Conservation Board (TSSWCB) include: O.C. Fisher Project, Twin Buttes Reservoir/Lake Nasworthy Projects, and the Lake Brownwood Project.[69]

O. C. Fisher Project

In 1999, the Legislature authorized the North Concho River Pilot Brush Control Project for the purpose of enhancing the amount of water flowing from the North Concho River watershed into O.C. Fisher Reservoir. O.C. Fisher Reservoir serves as a water supply source for the City of San Angelo. This project is a follow-on to the North Concho project, further enhancing potential watershed yield by removal of water-loving exotic species on approximately 15,860 acres owned by the Corps of Engineers above the existing lake level. The project area includes lake habitat, riverine habitat, intermittent riverine habitat and bottomland hardwoods. As of 2008 1,255 acres had been treated.

Twin Buttes Reservoir/Lake Nasworthy Brush Control Projects

In September 2002, brush control projects were initiated to enhance the amount of water flowing into the Twin Buttes Reservoir/Lake Nasworthy complex. Twin Buttes Reservoir is used to maintain sufficient water levels in Lake Nasworthy, which serves as a water supply for the City of San Angelo. TSSWCB has allocated $10.8 million for brush control cost-share in this watershed. As of December 2008, over 252,729 acres have already been treated using state funds. TSSWCB estimates that this project could increase water yield by approximately 198,000 acre-feet over the life of the project. Additional allocation of funds will be needed to complete the treatment of the more than 555,000 acres of eligible brush in the Twin Buttes Subbasin.

Lake Brownwood Project

In March 2008, the TSSWCB funded efforts to treat mesquite and juniper in the Lake Brownwood watershed. The program is being administered by the Pecan Bayou Soil and Water Conservation District. Lake Brownwood provides municipal, industrial and agricultural water supply to Brown County and surrounding areas. As of the end of 2008, TSSWCB $200,000 to the project and contracted to treat 701 acres. TSSWCB estimates an increase in water yield of approximately 1,900 acre-feet over the life of the project.

Quantity, Reliability and Cost

Although many studies have illustrated the benefits of brush control, until recently it has been difficult to quantify the benefits in the context of regional water planning. This quantification is very important because in most areas that the program is currently being implemented, hydrologic records indicate long term declines in reservoir watershed yields (some as much as 80%). Region F has been in critical drought conditions during most of the time that the current brush removal programs have been in place, so the monitoring programs associated with these projects may not have shown significant gains due to the lack of rainfall events. Also, the benefits from brush control are long term; it takes time for aquifers to recharge and for watersheds to return to pre-brush conditions. This fact was recognized by the various scientists during the initial planning for the Texas Brush Control Program and the preparation of numerous feasibility studies. Measuring success and hydrologic responses to brush control projects is going to be a long-term process, even under ideal conditions. Until recently, the projects have been implemented under less than ideal conditions due to the record drought. While the relatively short period of time these programs have been in place may not be indicative of the long term gains of the programs, evidence is beginning to manifest that should serve to offer some indications.

Considering the above facts as a point of reference, the measured hydrologic responses and ongoing research findings to date have been nothing short of spectacular. Some of the indications of water production successes observed to date are as follows:

- Following modest surface water inflows in November 2004, unprecedented base flows into Twin Buttes Reservoir essentially doubled reservoir capacity (to 47,500 acre feet by mid June) and is effectively mitigating summer evaporation losses from the reservoir. The Twin Buttes watershed has been the recent recipient of a major brush removal effort on targeted and high priority sub-basins.
- Base flows on Pecan Creek (a long dormant perennial tributary to Lake Nasworthy and the subject of a special brush control project) provided so much base flow to Lake Nasworthy that water had to be released downstream on several occasions during the winter and spring of 2004-2005. This condition has been unprecedented in recent history.
- Long dormant tributary springs throughout the region have begun to flow following brush removal. Most of these became active during the drought and without benefit of any rainfall.
- The East Fork of Grape Creek, which is a portion of a major tributary to O.C. Fisher Reservoir, has received extensive brush removal (approximately 70 percent of targeted brush in the sub-basin). This tributary has been measured to have produced hundreds of acre feet of water in base flows since November, 2004. A similarly sized adjacent watershed (West Fork

of Grape Creek) that has not received brush removal produced no downstream water base flows. Hydrologic calculations of data from the East Fork indicate that this watershed is producing in excess of 1.0 acre inch of water per year in base flows. Prior to brush removal, the hydrologic characteristics of this watershed were similar to that of the West Fork. An August, 2005 runoff event on both watersheds revealed a dramatic difference in the flood hydrographs from each stream. The untreated watershed produced a rapid short flow event, while the treated watershed produced a longer and sustained flow.

- For the first time since the mid 20th century, the North Concho River has experienced perennial base flows for an extended period of the year throughout the stream reach. As a result of this saturated stream condition, the watershed yield from an August, 2005 storm runoff event was undoubtedly increased.
- Regional groundwater monitoring within the North Concho watershed during the last 48 months is indicating a significant trend in increasing ground water levels. Much of this data has been collected during a period of record drought.
- Preliminary evapotranspiration data from on-going paired watershed studies conducted by the Texas Institute for Applied Environmental Research (TIAER) at Tarleton State University for the Upper Colorado River Authority (UCRA) is indicating a significant difference in water use between treated and untreated mesquite infested sites. This data, which is due to be published by TIAER by early 2006, will likely confirm existing watershed model predictions and other ongoing research and monitoring initiatives.

Based on anecdotal accounts and observations, almost everyone in the area from participating landowners to water supply and elected officials are recognizing the water producing value of the program. It would appear from preliminary observations and findings that brush control as a water producing strategy is viable and should be incorporated into water supply planning. Since the region appears to be moving out of the drought period of the last few years and reliable experimental data is emerging from monitoring efforts, accurate quantification of the hydrological effects of brush control may soon be possible. This quantification will likely be based on existing modeling output found in a completed watershed feasibility study and confirmation or adjustment of that modeling prediction. Also, since the program is based on voluntary participation by landowners, an analysis of the completed brush control work as to the extent within each sub-basin, location of each sub-basin in relationship to the overall watershed and anticipated water production from each sub-basin should be performed. The feasibility studies and models assume removal of all of the targeted brush, which will not often happen. A summary of each sub-basin within the Upper Colorado watershed by production and costs was published by the Upper Colorado River Authority (UCRA) in 2002 and is available for use in performing an analysis.

The UCRA document referenced above is also a good source of information regarding the cost of water produced through brush control. In consideration of the entire upper Colorado River basin, there is tremendous variability in sub-basin water yields and therefore tremendous variability in costs per acre-feet of water produced. According to existing feasibility studies, treating the entire upper Colorado River basin (nine reservoir watersheds) would result in a composite cost of slightly over $70 per acre foot of water produced. Treating only the most productive sub-basins, however, could produce a high percentage of the modeled water production and reduce the composite costs to less than $50 per acre foot. This (priority sub-basin) approach has been utilized in allocating initial funding available for brush control in the region. An assumption of water yields (from feasibility studies) based on 50 percent of high priority brush removal and 65 percent of modeled water yield will result in 191,817 acre feet of water being produced in ten (10) upper basin reservoirs, including 30,000 acre feet in the O.C. Fisher watershed and 49,856 acre feet in the Twin Buttes/Nasworthy watershed.

In order to be an effective and reliable long term water production strategy, areas of brush once removed, must be maintained. Follow –up treatment is essential to the program and has been built into the TSSWCB landowner contracts. During the 10-year contract period landowners must perform any needed follow- up treatment if state funding is available. Toward this end, the NRCS has made funding available for landowners in the O.C. Fisher and Twin Buttes watersheds for follow-up treatment through the EQIP program.

In 2003 the cost of the existing brush control program in Region F was $26,000,000. Near-term funding for brush control in the region would be at similar levels.

Environmental Issues

The Texas Parks and Wildlife Department (TPWD) list the potential environmental impacts of brush control as alteration of terrestrial habitat, increased sediment runoff and erosion, impacts from chemical control measures, potential for increase groundwater recharge, impacts to aquatic and terrestrial communities and ecosystem process, and influence on energy and nutrient inputs and processing[70]. Region F suggests coordinating with TPWD and other state and federal agencies regarding any brush control program.

Agricultural and Rural Issues

Invasive brush has altered the landscape of Region F and the rest of West Texas. Restoration of much of the landscape to natural grassland conditions will benefit the ranching economy of the region as well as enhance water supplies.

Other Natural Resource Issues

Although invasive brush has impacted water supplies and altered the natural landscape of the region and reduced runoff, in some cases the brush has provided habitat for wildlife. In addition to the environmental benefits of this habitat, some of this habitat is suitable for deer and other game. Hunting is an important part of the economy of Region F. Therefore it may be desirable to leave portions of a watershed with brush to maintain habitat.

Significant Issues Affecting Feasibility

The most significant factor regarding the feasibility of this strategy is on-going funding for brush control projects. Brush control is an on-going process that must be constantly maintained for the project to be successful. Existing programs provide funding for the initial clearing of brush but generally do not provide funding for on-going maintenance and monitoring. Without maintenance and monitoring, brush control will not be effective as either a range management or water management strategy.

Like other similar activities, brush control is dependent upon the on-going cooperation and financial contributions of individual landowners. Therefore each program should be tailored to local conditions.

Other Water Management Strategies Directly Affected

If the findings of the existing upper basin feasibility studies are verified and/or adjusted, and if the program is adequately implemented and maintained, brush control could delay or eliminate the need for new water supply projects. Currently, the major on-going brush removal projects are located above O.C. Fisher and the Twin Buttes/Nasworthy reservoirs. Both of these reservoirs are a part of the San Angelo water supply system. To date, approximately 300,000 acres have been completed on the O.C. Fisher watershed and 200,000 acres completed on the Twin Buttes/Nasworthy watershed. Neither of the projects are currently complete with an additional 10,000 acres targeted on the O.C. Fisher watershed and 25,000 acres targeted on the Twin Buttes/Nasworthy watershed during the FY 2006-2007 biennium. However, hydrologic observations and response monitoring on these watersheds previously reported herein, indicates a trend toward watershed restoration and partial return to pre-brush conditions. While this process is not complete, it is apparent that an improvement in watershed yields is occurring and should be recognized in planning.

With an intention of being prudent and in consideration of relevant factors, it is recommended that during the current planning period, an additional 8,362 acre feet of water per year should be recognized as available to San Angelo from local sources due to brush control. This estimate is based on the short term availability of approximately 20 percent of the ultimate increased watershed yield based on the current status of the brush removal program.

4.10 Summary of Needs and Strategies by County

Table 4.10-1 is a summary of the recommended water management strategies for water user groups in Region F grouped by county, as well as a summary by strategy type. Table 4.10-2 shows additional strategies whose capital costs are associated with wholesale water providers. (There is some overlap for the supplies in these two tables, but no overlap in capital costs.) Only three counties, Crane, Crockett, and Loving, do not have water management strategies. The largest single category of water management strategies is conservation, totaling over 82,000 acre-feet per year in 2060. The largest contribution to this strategy comes from irrigation conservation, which contributes about 88 percent of the total. Other significant strategies include subordination, new groundwater sources, and voluntary redistribution. Altogether, these strategies result in nearly 195,000 acre-feet of water becoming available to water user groups by 2060, with an overall capital cost of about $897 million (includes costs developed by wholesale water providers).

Table 4.10-3 shows the unmet needs in Region F. All of these needs are for irrigation and steam-electric power generation. Unmet irrigation needs are the result of either insufficient groundwater supplies to meet projected demand or limited surface water availability for run-of-the-river irrigation rights from the Colorado WAM (any run-of-the-river right with a priority date after 1926 will have no supply by definition). In most cases conservation is the only cost-effective method to reduce irrigation needs. In every county except Martin County conservation was insufficient to prevent unmet needs.

In this plan, the default method to allocate groundwater was to first meet municipal, manufacturing, livestock, mining and steam-electric demands. (Steam-electric demands were limited to current use. Any growth in steam-electric demand was given last priority). In most cases, irrigation was allocated water last, resulting in a need if insufficient supplies were available to meet all demands. For most of the aquifers in counties with irrigation shortages, irrigation represents from 70 to 99 percent of the demand from these aquifers in 2010, so it is appropriate to assign water supply needs to irrigation demands. An exception is Ward County, where irrigation accounts for only 34 percent of the 2010 demand from the Pecos Valley aquifer. In Ward County there are significant demands for municipal, mining and steam-electric use. For the purposes of this plan, it was assumed that these demand categories would have priority over irrigation demand.

Unmet irrigation needs for surface water supplies are primarily the result of the priority of the water rights in each county as allocated by the Colorado and Rio Grande WAMs. In the Colorado Basin, any run-of-the-river water right with a priority date after 1926 will have no reliable supply. Water rights with priority dates senior to 1926 may not have sufficient supplies in all years. (Run-of-the-river irrigation rights were not part of the subordination analysis performed with Region K.) Although historical surface water use from these sources may be greater than indicated, the shortage may be appropriate if it is assumed that senior downstream rights make priority calls on these irrigation rights.

In most cases steam-electric power generation demands are the result of the projections exceeding available supplies at existing generation facilities. Although it is likely that the steam-electric power generation industry will meet these demands, there is a great deal of uncertainty regarding the type of strategy or the location of future generation facilities used to meet the needs. Therefore these demands have been left as unmet needs.

Table 4.10 -1 Strategy Summary by County (Volume in Acre-Feet per Year)

Water User Group Name	County	Basin Name	Water Management Strategy Name	Source Name	Strategy Supply for 2010	Strategy Supply for 2020	Strategy Supply for 2030	Strategy Supply for 2040	Strategy Supplyfor 2050	Strategy Supply for 2060	Capital Cost
City of Andrews	Andrews	Colorado	Voluntary Redistribution	Ogallala aquifer	0	0	0	750	760	773	$0
City of Andrews	Andrews	Colorado	Desalination	Dockum aquifer	0	950	950	950	950	950	$6,717,000
City of Andrews	Andrews	Colorado	Conservation		84	191	240	265	287	310	$0
Irrigation	Andrews	Colorado	Conservation		0	2,727	5,455	5,455	5,455	5,455	$4,822,904
Andrews County Total					*84*	*3,868*	*6,645*	*7,420*	*7,452*	*7,488*	*$11,539,904*
Irrigation	Borden	Brazos	Conservation		0	94	189	189	189	189	$196,062
Irrigation	Borden	Colorado	Conservation		0	136	271	271	271	271	$282,138
Borden County Total					*0*	*230*	*460*	*460*	*460*	*460*	*$478,200*
Irrigation	Brown	Colorado	Conservation		0	93	185	185	185	185	$54,917
Brown County Total					*0*	*93*	*185*	*185*	*185*	*185*	*$54,917*
City of Bronte	Coke	Colorado	Subordination	Oak Creek Reservoir	129	129	129	129	129	129	$0
City of Bronte	Coke	Colorado	Infrastructure Improvements	Oak Creek Reservoir	0	0	0	0	0	0	$1,364,900
City of Bronte	Coke	Colorado	Conservation		16	45	48	48	50	51	$0
City of Robert Lee	Coke	Colorado	Conservation		16	40	44	45	46	48	$0
City of Robert Lee	Coke	Colorado	Infrastructure Improvements	Spence Reservoir	0	0	0	0	0	0	$2,436,000
City of Robert Lee	Coke	Colorado	Subordination	Colorado River MWD System	95	115	2	21	34	55	$0
County-Other	Coke	Colorado	Subordination	Colorado River MWD System	28	32	0	6	9	15	$0
Mining	Coke	Colorado	Subordination	Colorado River MWD System	86	119	2	24	43	72	$0
Steam Electric Power	Coke	Colorado	Subordination	Oak Creek Reservoir	310	247	289	339	401	477	$0
Coke County Total					*680*	*727*	*514*	*612*	*712*	*847*	*$3,800,900*
City of Coleman	Coleman	Colorado	Subordination	Lake Coleman	1,650	1,651	1,647	1,645	1,639	1,631	$0
City of Coleman	Coleman	Colorado	Subordination	Hords Creek Reservoir	380	380	380	380	380	380	$0
City of Coleman	Coleman	Colorado	Conservation		33	75	90	95	101	107	$0
Coleman County WSC	Coleman	Colorado	Subordination	Lake Coleman	126	114	109	103	101	99	$0
County-Other	Coleman	Colorado	Subordination	Lake Coleman	20	19	19	18	18	18	$0
Irrigation	Coleman	Colorado	Subordination	Lake Coleman	1,348	1,348	1,348	1,348	1,348	1,348	$0
Manufacturing	Coleman	Colorado	Subordination	Lake Coleman	6	6	6	6	6	6	$0
Mining	Coleman	Colorado	Subordination	Lake Coleman	17	18	18	18	18	18	$0
Coleman County Total					*3,580*	*3,611*	*3,617*	*3,613*	*3,611*	*3,607*	*$0*
City of Eden	Concho	Colorado	New well *	Hickory aquifer	0	0	0	0	0	0	$1,800,000
City of Eden	Concho	Colorado	Advanced treatment *	Hickory aquifer	0	0	0	0	0	0	$2,582,000
County-Other	Concho	Colorado	Subordination	OC Fisher Reservoir	25	25	25	25	25	25	
Irrigation	Concho	Colorado	Conservation		0	748	1,496	1,496	1,496	1,496	$1,895,367
Millersview-Doole WSC	Concho	Colorado	Subordination	Colorado River MWD System	34	42	1	7	0	0	$0
Millersview-Doole WSC	Concho	Colorado	Voluntary Redistribution	Colorado River MWD System	0	0	0	0	74	74	$0
Concho County Total					*59*	*815*	*1,522*	*1,528*	*1,595*	*1,595*	*$4,477,367*

Table 4.10 -1 Strategy Summary by County (Volume in Acre-Feet per Year)

Water User Group Name	County	Basin Name	Water Management Strategy Name	Source Name	Strategy Supply for 2010	Strategy Supply for 2020	Strategy Supply for 2030	Strategy Supply for 2040	Strategy Supplyfor 2050	Strategy Supply for 2060	Capital Cost
Ector County UD	Ector	Colorado	Subordination	Colorado River MWD System	400	613	11	151	272	478	$0
Irrigation	Ector	Colorado	Conservation		0	243	485	485	485	485	$301,633
Irrigation	Ector	Rio Grande	Conservation		0	2	5	5	5	5	$3,047
Manufacturing	Ector	Colorado	Subordination	Colorado River MWD System	366	149	3	46	86	158	$0
Manufacturing	Ector	Colorado	Reuse	Direct Reuse	0	350	105	350	300	250	
City of Odessa	Ector	Colorado	Conservation		540	1,168	1,488	1,657	1,854	2,074	$0
City of Odessa	Ector	Colorado	Voluntary Redistribution	Pecos Valley aquifer	0	4,708	4,708	10,507	10,502	10,498	$0
City of Odessa	Ector	Colorado	Reuse		0	3,943	4,168	3,912	3,958	4,006	$0
City of Odessa	Ector	Colorado	Subordination	Colorado River MWD System	4,019	5,611	59	1,085	1,913	3,314	$0
Ector County Total					*5,325*	*16,787*	*11,032*	*18,198*	*19,375*	*21,268*	*$304,680*
Irrigation	Glasscock	Colorado	Conservation		0	3,631	7,262	7,262	7,262	7,262	$11,422,560
City of Big Spring	Howard	Colorado	Conservation		241	603	676	698	725	754	$0
City of Big Spring	Howard	Colorado	Reuse		0	1,855	1,855	1,855	1,855	1,855	$0
City of Big Spring	Howard	Colorado	Subordination	Colorado River MWD System	1,345	1,672	24	299	491	796	$0
City of Coahoma	Howard	Colorado	Subordination	Colorado River MWD System	49	61	1	11	18	29	$0
Irrigation	Howard	Colorado	Conservation		0	327	653	653	653	653	$647,652
Manufacturing	Howard	Colorado	Subordination	Colorado River MWD System	267	349	5	71	124	220	$0
Mining	Howard	Colorado	Subordination	Colorado River MWD System	400	523	9	101	171	285	$0
Howard County Total					*2,302*	*5,390*	*3,223*	*3,688*	*4,037*	*4,592*	*$647,652*
Irrigation	Irion	Colorado	Conservation		0	37	73	73	73	73	$21,137
Irrigation	Irion	Colorado	Weather Modification		0	0	0	0	0	0	$0
Irion County Total					*0*	*37*	*73*	*73*	*73*	*73*	*$21,137*
City of Junction	Kimble	Colorado	Subordination	Llano River	991	991	991	991	991	991	$0
County-Other	Kimble	Colorado	Subordination	Llano River	9	9	9	9	9	9	$0
Irrigation	Kimble	Colorado	Conservation		0	74	147	147	147	147	$141,658
Manufacturing	Kimble	Colorado	Subordination	Llano River	1,000	1,000	1,000	1,000	1,000	1,000	$0
Kimble County Total					*2,000*	*2,074*	*2,147*	*2,147*	*2,147*	*2,147*	*$141,658*
City of Stanton	Martin	Colorado	Voluntary Redistribution	Colorado River MWD System	392	422	429	430	415	393	$0
Irrigation	Martin	Colorado	Conservation		0	1,751	3,502	3,502	3,502	3,502	$4,001,621
Martin County Total					*392*	*2,173*	*3,931*	*3,932*	*3,917*	*$3,895*	*$4,001,621*
Irrigation	Mason	Colorado	Conservation		0	746	1,491	1,491	1,491	1,491	$713,460

Table 4.10 -1 Strategy Summary by County (Volume in Acre-Feet per Year)

Water User Group Name	County	Basin Name	Water Management Strategy Name	Source Name	Strategy Supply for 2010	Strategy Supply for 2020	Strategy Supply for 2030	Strategy Supply for 2040	Strategy Supplyfor 2050	Strategy Supply for 2060	Capital Cost
City of Brady	McCulloch	Colorado	Conservation		77	192	214	222	230	239	$0
City of Brady	McCulloch	Colorado	Subordination	Brady Creek Reservoir	2,170	2,170	2,170	2,170	2,170	2,170	$0
County-Other	McCulloch	Colorado	Bottled Water Program	Hickory aquifer	0	0	0	0	0	0	$0
Irrigation	McCulloch	Colorado	Conservation		0	197	394	394	394	394	$166,844
Millersview-Doole WSC	McCulloch	Colorado	Subordination	Colorado River MWD System	67	81	1	14	0	0	$0
Millersview-Doole WSC	McCulloch	Colorado	Voluntary Redistribution	Colorado River MWD System	0	0	0	0	143	143	$0
Richland SUD	McCulloch	Colorado	Bottled Water Program	Hickory aquifer	1	1	1	1	1	1	$3,000
Richland SUD	McCulloch	Colorado	Infrastructure Improvements	Ellenburger aquifer	0	200	200	200	200	200	$5,148,000
Richland SUD	McCulloch	Colorado	Infrastructure Improvements	Hickory aquifer	0	0	0	0	0	0	$1,700,979
McCulloch County Total					*2,315*	*2,841*	*2,980*	*3,001*	*3,138*	*3,147*	*$7,018,823*
City of Menard	Menard	Colorado	New Groundwater	Hickory aquifer	140	139	140	140	141	141	$1,684,000
City of Menard	Menard	Colorado	Conservation		10	24	28	30	32	33	$0
County-Other	Menard	Colorado	New Groundwater	Hickory aquifer	20	21	20	20	19	19	$0
Irrigation	Menard	Colorado	Conservation		0	23	46	46	46	46	$16,029
Menard County Total					*170*	*207*	*234*	*236*	*238*	*239*	*$1,700,029*
City of Midland	Midland	Colorado	Conservation		1,344	2,616	3,061	3,261	3,457	3,663	$0
City of Midland	Midland	Colorado	Reuse		0	5,389	5,389	5,389	5,389	5,389	$0
City of Midland	Midland	Colorado	Subordination	Colorado River MWD System	4,488	6,152	211	324	438	553	$0
City of Midland	Midland	Colorado	Voluntary Redistribution	Colorado River MWD System	0	0	10,000	9,800	9,600	9,400	$0
City of Midland	Midland	Colorado	Subordination	O.H. Ivie Reservoir	17	(97)	(211)	(324)	(438)	(553)	$0
City of Midland	Midland	Colorado	New Groundwater	Pecos Valley aquifer	0	0	13,600	13,600	13,600	13,600	$168,507,000
Irrigation	Midland	Colorado	Conservation		0	1,800	3,600	3,600	3,600	3,600	$3,169,471
City of Odessa	Midland	Colorado	Subordination	Colorado River MWD System	186	176	28	66	97	150	$0
City of Odessa	Midland	Colorado	Conservation		11	32	48	58	66	75	$0
City of Odessa	Midland	Colorado	Voluntary Redistribution	Pecos Valley aquifer	0	0	0	201	206	210	$0
City of Odessa	Midland	Colorado	Reuse		0	117	137	148	152	154	$0
City of Odessa	Midland	Colorado	Voluntary Redistribution	Pecos Valley aquifer	0	92	92	92	92	92	$0
Midland County Total					*6,046*	*16,277*	*35,955*	*36,215*	*36,259*	*36,333*	*$171,676,471*
Colorado City	Mitchell	Colorado	New Groundwater	Dockum aquifer	0	2,200	2,200	2,200	2,200	2,200	$17,855,000
Irrigation	Mitchell	Colorado	Conservation		0	865	1,729	1,729	1,729	1,729	$2,548,056
Irrigation	Mitchell	Colorado	Weather Modification		0	0	0	0	0	0	$0
Steam Electric Power	Mitchell	Colorado	Subordination	Colorado City/Champion Creek	5,023	4,847	4,670	4,493	4,317	4,140	$0
Mitchell County Total					*5,023*	*7,912*	*8,599*	*8,422*	*8,246*	*8,069*	*$20,403,056*
Irrigation	Pecos	Rio Grande	Conservation		0	6,300	12,600	12,600	12,600	12,600	$8,329,226
Irrigation	Reagan	Colorado	Conservation		0	1,968	3,936	3,936	3,936	3,936	$6,275,976

Table 4.10 -1 Strategy Summary by County (Volume in Acre-Feet per Year)

Water User Group Name	County	Basin Name	Water Management Strategy Name	Source Name	Strategy Supply for 2010	Strategy Supply for 2020	Strategy Supply for 2030	Strategy Supply for 2040	Strategy Supplyfor 2050	Strategy Supply for 2060	Capital Cost
Irrigation	Reeves	Rio Grande	Conservation		0	5,824	11,648	11,648	11,648	11,648	$8,253,318
City of Ballinger	Runnels	Colorado	Conservation		33	88	107	119	131	144	$0
City of Ballinger	Runnels	Colorado	Subordination	Lake Ballinger	917	930	920	910	900	890	$0
City of Ballinger	Runnels	Colorado	Subordination	Colorado River MWD System	141	169	68	115	0	0	$0
City of Ballinger and customers	Runnels	Colorado	Voluntary Redistribution	Colorado River MWD System	0	0	0	0	493	508	$0
Coleman County WSC	Runnels	Colorado	Subordination	Lake Coleman	18	30	39	48	56	66	$0
County-Other	Runnels	Colorado	Subordination	Lake Ballinger	23	0	0	0	0	0	$0
County-Other	Runnels	Colorado	Subordination	Lake Winters	114	89	69	49	31	0	$0
County-Other	Runnels	Colorado	Subordination	Colorado River MWD System	193	177	148	116	0	0	$0
County-Other	Runnels	Colorado	Voluntary Redistribution	Colorado River MWD System	0	0	0	0	94	77	$0
Manufacturing	Runnels	Colorado	Subordination	Lake Winters	54	60	65	70	74	79	$0
Manufacturing	Runnels	Colorado	Subordination	Colorado River MWD System	9	10	11	12	0	0	$0
Manufacturing	Runnels	Colorado	Voluntary Redistribution	Colorado River MWD System	0	0	0	0	13	15	$0
City of Miles	Runnels	Colorado	Subordination	OC Fisher Reservoir	200	200	200	200	200	200	$0
Millersview-Doole WSC	Runnels	Colorado	Subordination	Colorado River MWD System	25	31	0	6	0	0	$0
Millersview-Doole WSC	Runnels	Colorado	Voluntary Redistribution	Colorado River MWD System	0	0	0	0	58	58	$0
City of Winters	Runnels	Colorado	Conservation		21	55	63	67	71	76	$0
City of Winters	Runnels	Colorado	Reuse		0	0	0	110	110	110	$2,158,000
City of Winters	Runnels	Colorado	Subordination	Lake Winters	552	561	566	571	575	591	$0
Runnels County Total					*2,300*	*2,400*	*2,256*	*2,393*	*2,806*	*2,814*	*$2,158,000*
Irrigation	Schleicher	Colorado	Conservation		0	89	178	178	178	178	$146,895
Irrigation	Schleicher	Rio Grande	Conservation		0	18	36	36	36	36	$30,087
Schleicher County Total					*0*	*107*	*214*	*214*	*214*	*214*	*$176,982*
County-Other	Scurry	Colorado	Subordination	Colorado River MWD System	54	66	1	12	20	33	$0
Irrigation	Scurry	Brazos	Conservation		0	160	320	320	320	320	$361,342
Irrigation	Scurry	Colorado	Conservation		0	411	823	823	823	823	$929,166
City of Snyder	Scurry	Colorado	Conservation		70	154	191	205	220	234	$0
City of Snyder	Scurry	Colorado	Reuse		0	726	726	726	726	726	$0
City of Snyder	Scurry	Colorado	Subordination	Colorado River MWD System	511	641	9	117	194	315	$0
Scurry County Total					*635*	*2,158*	*2,070*	*2,203*	*2,303*	*2,451*	*$1,290,509*
Irrigation	Sterling	Colorado	Conservation		0	45	89	89	89	89	$25,860
Irrigation	Sutton	Colorado	Conservation		0	44	88	88	88	88	$60,431
Irrigation	Sutton	Rio Grande	Conservation		0	98	196	196	196	196	$134,509
Sutton County Total					*0*	*142*	*284*	*284*	*284*	*284*	*$194,940*

Table 4.10 -1 Strategy Summary by County (Volume in Acre-Feet per Year)

Water User Group Name	County	Basin Name	Water Management Strategy Name	Source Name	Strategy Supply for 2010	Strategy Supply for 2020	Strategy Supply for 2030	Strategy Supply for 2040	Strategy Supplyfor 2050	Strategy Supply for 2060	Capital Cost
County-Other	Tom Green	Colorado	Subordination	Nasworthy/Twin Buttes	250	250	250	250	250	250	$0
Irrigation	Tom Green	Colorado	Conservation		0	5,774	11,548	11,548	11,548	11,548	$10,120,488
Irrigation	Tom Green	Colorado	Subordination	Nasworthy/Twin Buttes	3,377	3,273	3,170	3,066	2,693	2,860	$0
Manufacturing	Tom Green	Colorado	Subordination	Nasworthy/Twin Buttes	2,226	2,498	2,737	2,971	3,175	3,425	$0
Millersview-Doole WSC	Tom Green	Colorado	Subordination	Colorado River MWD System	64	87	1	19	0	0	$0
Millersview-Doole WSC	Tom Green	Colorado	Voluntary Redistribution	Colorado River MWD System	0	0	0	0	225	225	$0
City of San Angelo	Tom Green	Colorado	Desalination	Other aquifer	0	0	0	5,600	5,600	5,600	See WWP
City of San Angelo	Tom Green	Colorado	New Groundwater	Hickory aquifer	0	6,700	10,000	12,000	12,000	12,000	See WWP
City of San Angelo	Tom Green	Colorado	Conservation		701	1,705	2,009	2,127	2,255	2,371	$0
City of San Angelo	Tom Green	Colorado	Infrastructure Improvements	Spence Reservoir	0	0	2,281	2,267	2,254	2,240	See WWP
City of San Angelo	Tom Green	Colorado	Subordination	Nasworthy/Twin Buttes	5,436	5,078	4,752	4,431	4,141	3,804	$0
City of San Angelo	Tom Green	Colorado	Subordination	OC Fisher Reservoir	3,637	3,518	3,400	3,282	3,163	3,045	$0
City of San Angelo	Tom Green	Colorado	Subordination	OH Ivie Reservoir	17	(97)	(211)	(324)	(438)	(553)	$0
City of San Angelo	Tom Green	Colorado	Brush Control		8,362	8,362	8,362	8,362	8,362	8,362	See WWP
Steam Electric Power	Tom Green	Colorado	Subordination	Nasworthy/Twin Buttes	1,021	1,021	1,021	1,021	1,021	1,021	$0
Tom Green County Total					*25,091*	*38,169*	*49,320*	*56,620*	*56,249*	*56,198*	*$10,120,488*
Irrigation	Upton	Colorado	Conservation		0	911	1,822	1,822	1,822	1,822	$2,885,269
Irrigation	Upton	Rio Grande	Conservation		0	9	18	18	18	18	$58,883
Upton County Total					*0*	*920*	*1,840*	*1,840*	*1,840*	*1,840*	*$2,944,152*
County-Other	Ward	Rio Grande	Voluntary Redistribution	Pecos Valley aquifer	0	400	400	400	400	400	$0
Irrigation	Ward	Rio Grande	Conservation		0	785	1,570	1,570	1,570	1,570	$437,760
Irrigation	Ward	Rio Grande	Weather Modification		0	0	0	0	0	0	$0
Ward County Total					*0*	*1,185*	*1,970*	*1,970*	*1,970*	*1,970*	*$437,760*
Irrigation	Winkler	Rio Grande	Conservation		0	195	389	389	389	389	$196,902
			Conservation		3,197	43,113	80,551	81,141	81,769	82,423	$68,650,668
			Desalination		0	950	950	6,550	6,550	6,550	$6,717,000
			New Groundwater		160	9,060	25,960	27,960	27,960	27,960	$188,046,000
			Infrastructure Improvements		0	200	2,481	2,467	2,454	2,440	$15,031,879
			Reuse		0	12,380	12,380	12,490	12,490	12,490	$2,158,000
			Bottled Water Program		1	1	1	1	1	1	$3,000
			Brush Control		8,362	8,362	8,362	8,362	8,362	8,362	$0
			Subordination		43,890	47,144	30,172	31,518	31,865	34,039	$0
			Voluntary Redistribution		392	5,622	15,629	22,180	23,075	22,866	$0
			Weather Modification		0	0	0	0	0	0	$0
			Total for All Strategies		*56,002*	*126,832*	*176,486*	*192,669*	*194,526*	*197,131*	*$280,606,547*

Table 4.10-2 Strategy Summary by Wholesale Water Provider

Wholesale Water Provider	Water Management Strategy Name	Source Name	Strategy Supply for 2010	Strategy Supply for 2020	Strategy Supply for 2030	Strategy Supply for 2040	Strategy Supplyfor 2050	Strategy Supply for 2060	Capital Cost
CRMWD	Reuse		0	12,380	12,380	12,380	12,380	12,380	$128,748,000
	Subordination	CRMWD System	48,027	47,133	46,240	45,347	44,453	43,560	$0
	Renew contract with University Lands	Ogallala aquifer		5,200	5,200	5,200	5,200	5,200	$8,964,000
	Supplemental wells	Pecos Valley, Ogallala aquifers	0	0	0	0	0	0	$10,440,000
	New Groundwater	Pecos Valley aquifer	0	0	6,000	6,000	6,000	6,000	$76,268,000
	Desalination	Capitan Reef aquifer	0	0		9,500	9,500	9,500	$131,603,990
CRMWD Total			*48,027*	*64,713*	*69,820*	*78,427*	*77,533*	*76,640*	*$356,023,990*
San Angelo	Subordination	San Angelo system	16,147	15,838	15,530	15,221	14,643	14,605	$0
	Rehabilitation of Spence pipeline	Spence reservoir (non-system)	0	0	2,281	2,267	2,254	2,240	$6,157,000
	Desalination	Other aquifer	0	0	0	5,600	5,600	5,600	$75,440,000
	New Groundwater	Hickory aquifer	0	6,700	10,000	12,000	12,000	12,000	$173,307,000
	Brush Control	San Angelo system	8,362	8,362	8,362	8,362	8,362	8,362	$23,020,000
San Angelo Total			*24,509*	*22,538*	*27,811*	*35,088*	*34,497*	*34,445*	*$254,904,000*
UCRA	Subordination	OC Fisher Reservoir	3,862	3,743	3,625	3,507	3,388	3,270	$0
University Lands	Renew contract with CRMWD	Ogallala aquifer	0	5,200	5,200	5,200	5,200	5,200	$0
	Renew contract with Andrews	Ogallala aquifer	0	0	0	750	760	773	$0
	Reuse		0	12,380	12,380	12,380	12,380	12,380	$128,748,000
	Subordination		64,174	62,971	61,770	60,568	59,096	58,165	$0
	Infrastructure Improvements		0	0	2,281	2,267	2,254	2,240	$16,597,000
	New Groundwater		0	6,700	16,000	18,000	18,000	18,000	$249,575,000
	Voluntary Distribution		0	5,200	5,200	5,950	5,960	5,973	$8,964,000
	Desalination		0	0	0	15,100	15,100	15,100	$207,043,990
	Brush Control		8,362	8,362	8,362	8,362	8,362	8,362	$23,020,000
	Total for All Strategies		*72,536*	*95,613*	*105,993*	*122,627*	*121,152*	*120,220*	*$633,947,990*

Table 4.10-3
Unmet Needs in Region F
(Values in Acre-Feet per Year)

Water User Group	County	Basin	Source(s)	2010	2020	2030	2040	2050	2060
Irrigation	Andrews	Colorado	Ogallala aquifer	(12,875)	(10,118)	(7,252)	(5,862)	(5,659)	(5,491)
Irrigation	Borden	Brazos	Ogallala aquifer	(1,019)	(924)	(827)	824	(821)	(819)
Irrigation	Borden	Colorado	Ogallala aquifer	(828)	(690)	(552)	(551)	(548)	(547)
Irrigation	Brown	Colorado	Trinity aquifer, run-of-river	(3,006)	(2,889)	(2,761)	(2,720)	(2,683)	(2,656)
Irrigation	Coke	Colorado	Other aquifer, run-of-river	(363)	(363)	(361)	(360)	(360)	(360)
Irrigation	Glasscock	Colorado	Edwards-Trinity aquifer, Ogallala aquifer	(27,784)	(23,750)	(19,710)	(19,290)	(18,869)	(18,460)
Steam-Electric Power	Ector	Colorado	Ogallala aquifer	(1,219)	(3,969)	(5,512)	(7,393)	(9,686)	(12,481)
Irrigation	Irion	Colorado	Run-of-river	(1,302)	(1,204)	(1,108)	(1,047)	(987)	(927)
Irrigation	Martin	Colorado	Ogallala aquifer	(788)	0	0	0	0	0
Irrigation	Menard	Colorado	Run-of-river	(2,441)	(2,398)	(2,356)	(2,337)	(2,315)	(2,296)
Irrigation	Midland	Colorado	Edwards-Trinity aquifer, Ogallala aquifer	(16,233)	(14,559)	(12,748)	(12,654)	(12,512)	(12,393)
Irrigation	Reeves	Rio Grande	Pecos Valley aquifer	(14,253)	(7,577)	(895)	(33)	0	0
Irrigation	Runnels	Colorado	Run-of-river	(1,358)	(1,344)	(1,325)	(1,306)	(1,287)	(1,268)
Irrigation	Tom Green	Colorado	Lipan aquifer, run-of-river	(43,713)	(37,784)	(31,858)	(31,707)	(31,821)	(31,399)
Steam-Electric Power	Tom Green	Colorado	Twin Buttes/Nasworthy System	0	0	0	(48)	(243)	(481)
Irrigation	Upton	Colorado	Edwards-Trinity aquifer	(10,672)	(9,540)	(8,401)	(8,170)	(7,940)	(7,717)
Irrigation	Ward	Rio Grande	Pecos Valley aquifer	(5,527)	(4,188)	(4,151)	(4,969)	(5,335)	(5,318)
Steam-Electric Power	Ward	Rio Grande	Pecos Valley aquifer	0	0	0	0	(679)	(1,973)
Total				*(154,378)*	*(129,936)*	*(105,997)*	*(103,246)*	*(106,785)*	*(109,043)*

4.11 List of References

[1] Norvell, Stuart: Economic Impacts of Projected Water Shortages for the Region F Regional Water Planning Area, prepared for the Texas Water Development Board, October 5, 2010.

[2] Historical water use data from TCEQ database.

[3] Texas Water Development Board: Exhibit B Guidelines for Regional Water Plan Development, July 2002.

[4] November 2004 version of the Colorado and Brazos Colorado WAM, full authorization run. Obtained from Kathy Alexander of TCEQ in November 2004.

[5] Hibbs & Todd, Inc.: *Preliminary Engineering Report for a New Water Transmission Line*, prepared for the City of Ballinger, April 2004.

[6] November 2004 version of the Colorado and Brazos Colorado WAM, Full Authorization Run (Run 3). Obtained from Kathy Alexander of TCEQ on November 12, 2004.

[7] Kay Snyder, City of Midland. Personal communication.

[8] PSC draft report. Reference needed.

[9] Phone conversation with Rufus Beam, City of Brady, 1/21/05.

[10] Phone conversation with Aubrey Bierman, President of Lakeland Services, Inc., 6/6/05.

[11] Verbal information provided at Regional Planning Meeting, 2/05.

[12] US Environmental Protection Agency Radionuclides Rule, 66 FR 76708-76753, Volume 65, No. 236, December 7, 2000.

[13] Texas Commission on Environmental Quality, Chapter 290 – Public Drinking Water, Rule Project No. 2004-038-290-WT, adopted December 1, 2004.

[14] Summary of Investigation Into the Occurrence of Cancer; Concho, McCulloch, San Saba, and Tom Green Counties, Texas, 1990-1998, prepared by Texas Department of Health, December 15, 2000.

[15] Letter to Robert J. Huston, Chairman of Texas Natural Resource Conservation Commission, from Michael Ford, C.H.P., Vice Chair of the Texas Radiation Advisory Board, dated May 6, 2002.

[16] US Environmental Protection Agency Radionuclides Rule: A Quick Reference Guide, EPA 816-F-01-003, June 2001.

[17] Texas Commission on Environmental Quality, Chapter 290 – Public Drinking Water, Rule Project No. 2004-038-290-WT, Response to Comments.

[18] Meeting with Tony Bennett, Water Supply Division, Texas Commission on Environmental Quality, 02/04/05.

[19] Personal communication with Bill Wootan, representative for Live Oak Hills water utility, March 2005.

[20] Phone conversation with Thomas Sorg, US Environmental Protection Agency, Cincinnati, OH, on 02/05/05.

[21] Standards for Protection Against Radiation from Radioactive Materials, TAC §289.202, administered by Texas Department of Health.

[22] Phone conversation with Ron Dollar of Water Remediation Technology, LLC on 1/20/05.

[23] WRT Proposal letter to Mr. August Pope, Richland Springs SUD, dated July 8, 2004.

[24] US Environmental Protection Agency, Office of Ground Water and Drinking Water, "Radionuclides in Drinking Water: A Small Entity Compliance Guide", February 2002.

[25] Texas Department of State Health Services, Environmental Sciences Branch, Fee List sent by fax on 6/17/2005.

[26] Environmental Protection Agency: Small System Cost Calculator, available on-line at http://www.epa.gov/OGWDW/smallsystems/compliancehelp.html

[27] United States Environmental Protection Agency: *Point-of-Use or Point-of-Entry Treatment Options for Small Drinking Water Systems*, EPA 815-R-06-010, April 2006

[28] Phone conversation with David Sanders, Director of Utilities, City of Andrews, 1/31/05.

[29] Phone conversation with Wendell Moody, City of Eden, 6/14/2005.

[30] Texas Department of Health: *Summary of an Investigation into the Occurrence of Cancer Concho, McCulloch, San Saba, and Tom Green Counties, Texas 1990-1998*, December 15, 2000.

[31] Michael Ford, Vice Chair of the Texas Radiation Advisory Board, letter to Robert J. Huston, Chairman, Texas Natural Resource Conservation commission, May 6, 2002.

[32] Charles Haygood, Kimble County representative to Region F, personal communication.

[33] Kevin Kluge, Texas Water Development Board, personal communication.

[34] Investor-Owned Utility Companies of Texas: Power Generation Water Use in Texas for the Years 2000 to 2060, prepared for the Texas Water Development Board, January 2003.

[35] Freese and Nichols, Inc. et al.: Region F Regional Water Plan, prepared for the Region F Water Planning Group, January 2001.

[36] New, L.L. 1999. Personal Communication. Texas Agricultural Extension Service, Amarillo, Texas.

[37] Texas Water Development Board. Available on-line at http://www.twdb.state.tx.us/assistance/conservation/ASPApps/survey.asp

[38] Texas Water Code. Available on-line at http://www.capitol.state.tx.us/statutes/wa.toc.htm.

[39] Freese and Nichols, Inc., Regional Water Reclamation Project Feasibility Study, prepared for the Colorado River Municipal Water District, March 29, 2005.

[40] Layne Water Development Corporation, presentation on the Hovey Trough, September 2002.

[41] Mesa Water, Inc.: Water Supply Study Providing Groundwater from the Texas Panhandle to Communities Throughout the State of Texas, 2000.

[42] R.W. Hardin & Associates, Inc.: Groundwater Availability Evaluation Hemphill, Lipscomb, Ochiltree, and Roberts Counties, prepared for Mesa Water, Inc., December 2002.

[43] November 2004 version of the Colorado WAM.

[44] City of San Angelo et al.: San Angelo Water Preparing for the Next 50 Years, February 2004.

[45] TWDB historical per capita data.

[46] LBG-Guyton Associates: Report on Brackish Source Water Exploration in the San Angelo Area, prepared for the Upper Colorado River Authority and the Texas Water Development Board, April 2008.

[47] John Kelley, P.E., Parkhill, Smith and Cooper, personal communication, May 26, 2005.

[48] Ed L. Reed and Associates: Development of the Menard-McCulloch County Well Field, prepared for the City of San Angelo, June 1975.

[49] Ed L. Reed and Associates: Evaluation of Six Pumping Tests in the City of San Angelo McCulloch County Well Field, McCulloch County, Texas, prepared for the City of San Angelo, September, 1980.

[50] Layne Water Development Corporation, presentation on the Hovey Trough, September 2002.

[51] Ed L. Reed & Associates: Ground Water Resources Investigation Schleicher County, Texas, prepared for the City of San Angelo, May 1985.

[52] Texas Department of Licensing and Regulation website. November 11, 2004. http://www.license.
state.tx.us/weather/weathermod.htm.

[53] West Texas Weather Modification Association. 2008. 2008 Annual Report for West Texas Weather Modification Association.

[54] Arquimedes Ruiz Columbie, Active Influence & Scientific Management, 2008, Annual Evaluation Report 2008 State of Texas, prepared for the Texas Weather Modificatoin Association. Available on-line at http://www.texasweathermodification.com.

[55] Texas Weather Modification Courrier, Vol. 3 Issue 1, February 2009, Available on-line at http://www.texasweathermodification.com

[56] Gatewood, J. S., Robinson, T. W., Colby, B. R., Hem, J. D., and Halpenny, L. C., 1950, Use of water by bottom-land vegetation in lower Safford Valley, Arizona. U.S. Geological Survey, Water Supply Paper 1103.

[57] Mogg, J. L., Schoff, S. L., and Reed, E. W., 1960, Ground water resources of Canadian County, Oklahoma. Oklahoma Geological Survey, Bull. 87.

[58] Borrelli, J., Fedler, C.B., and Gregory, J. M., 1998, Mean crop consumptive use and free-water evaporation for Texas. Texas Water Development Board Grant No. 95-483-137.

[59] McDonald, C. C., and Hughes, G. H., 1968, Studies of consumptive use of water by phreatophytes and hydrophytes near Yuma, Arizona. U.S. Geological Survey, Prof. Paper 486-F.

[60] Hines, L. B., 1992, Quantification of natural ground-water evapotranspiration in Smith Creek Valley, Lander County, Nevada, U.S. Geological Survey, Water Supply Paper 2340.

[61] Ansley, R. J., Trevino, B. A., and Jacoby, P. W., 1998, Intraspecific competition in honey mesquite: Leaf and whole plant responses. Jour. Range Mgt., v. 51, p. 345-352.

[62] Dugas, W. A., and Hicks, R. A., 1998, Effect of removal of Juniper ashe on evapotranspiration and runoff in the Seco Creek watershed. Water Resources Research, v. 34, no. 6, p. 1499-1506.

[63] Van Hylckama, T. E. A., 1970, Water use by salt cedar. Water Resources Research, v. 6, no. 3, p. 728-735.

[64] Sala, A., Smith, S. D., and Devitt, D. A., 1996, Water use by Tamarix ramosissima and associated phreatophytes in a Mojave Desert floodplain. Jour. Applied Ecology, v. 6, no. 3, p. 888-898.

[65] Weeks, E. P., Weaver, H. L., Campbell, G. S., and Tanner, B. D., 1987, Water use by salt cedar and by replacement vegetation in the Pecos River floodplain between Acme and Artesia, New Mexico. U.S. Geological Survey, Prof. Paper 491-G.

[66] Duell, L. F. W., 1990, Estimates of evapotranspiration in alkaline scrub and meadow communities of Owens Valley, California, using the Bowen-ratio, eddy-correlation, and Penman-combination methods. U.S. Geological Survey, Water Supply Paper 2370.

[67] Freese and Nichols, Inc. and HDR, Inc., Draft Memorandum on Brush Control - Region G, September 7, 2004)

[68] Colorado River Municipal Water District, Annual Report, 2003.

[69] Texas State Soils and Water Conservation Board (TSSWCB), Brush Control Program, 2008 Annual Report, available on-line at http://www.tsswcb.state.tx.us/en/reports

[70] Robert L. Cook, Executive Director of Texas Parks and Wildlife: Letter to Kevin Ward, Executive Director of the Texas Water Development Board, May 5, 2004.

5 IMPACTS OF WATER MANAGEMENT STRATEGIES ON KEY PARAMETERS OF WATER QUALITY AND IMPACTS OF MOVING WATER FROM RURAL AND AGRICULTURAL AREAS

5.1 Introduction

The regulations that describe the content and process for the development of regional water plans state that the plan include "a description of the major impacts of recommended water management strategies on key parameters of water quality identified by the regional water planning group . . ." [30 TAC 357.7(a)(12)].

This chapter presents an assessment of the water quality parameters that could be affected by the implementation of water management strategies (WMS) for Region F. Based on this assessment, the key water quality parameters for each type of WMS are identified. From this determination, the specific water management strategies selected for Region F were evaluated with respect to potential impacts to the key water quality parameters.

In addition, this chapter discusses the potential impacts of moving water from rural areas to urban uses.

5.2 Potential Impacts of Water Management Strategies on Key Water Quality Parameters

The key water quality parameters to be evaluated are dependent on the WMS being proposed. Table 5.2-1 summarizes the most pertinent water quality parameters for the types of WMS proposed in this plan.

The implementation of specific WMS can potentially impact both the physical and chemical characteristics of water resources in the region. The following is an assessment of the characteristics of each WMS type that may affect water quality and an identification of the specific water quality parameters that could be affected based on those characteristics.

Table 5.2-1
Key Water Quality Parameters by Water Management Strategy Type [a]

Water Quality Parameter	Voluntary Redistribution	Reuse	New or Expanded Use of Groundwater	Water Conservation	Desalination (Reverse Osmosis)
Total dissolved solids (TDS)	+ / -	+ / -		+	-
Alkalinity				+	
Hardness				+	
Dissolved Oxygen (DO)	+ / -	+ / -		+	
Nitrogen	+ / -	+ / -		+	-
Phosphorus	+ / -	+ / -		+	
Radionuclides			-		
Metals [b]	- [b]	+	- [b]		- [b]

a Water management strategies with no potential impacts to water quality are not shown in this table.
b Only for specific metals where there are significant discharges of the metal.
\+ Positive Impact
\- Negative Impact

5.2.1 Expanded Use of Surface Water Resources

The *Region F Water Plan* does not recommend the expanded use of surface water sources as water management strategies. The plan does recommend the subordination of downstream senior water rights holders to major reservoirs in Region F. This reflects the current operation of the basin, so there are no expected changes in water quality associated with this strategy.

5.2.2 Voluntary Redistribution

If surface waters are transferred from one area of the region to another, there can be a decrease in instream flows below the location of the diversion. The water quality parameters potentially impacted by that action as shown in Table 5.2-1 are possible increases in total dissolved solids (TDS), nutrients, and in some cases, metals, and potential decreases in dissolved oxygen (DO) in stream flows below the diversion.

For users of surface water downstream of voluntary redistribution diversion, changes in alkalinity, hardness, or turbidity due to higher TDS loading can impact water users that require treatment processes that produce high quality waters (for example boiler feed) and water treatment plants. Water treatment processes are tailored to the quality of the water being treated. If the quality of the feed water changes, the treatment process may have to be changed as well.

Changes in nutrient concentrations or water clarity can affect the extent of algal growth or aquatic vegetation in a stream. The same concentration of nutrients can produce different levels of algal growth in different water bodies depending on factors such as water clarity, shading, stream configuration, or other chemical constituents in the waters.

With respect to water clarity, there are also aesthetic considerations. It is generally not desirable to introduce waters with higher turbidity, or color, into high clarity waters.

Voluntary redistribution of groundwater sources will have minimal impacts on water quality parameters assuming there is no relative change in the amount of groundwater pumped. Impacts on key water quality parameters for large increases in groundwater pumpage to meet contractual sales are discussed in Section 5.2.4 (New and/or Expanded Use of Groundwater Resources).

Pending the location and use of the water under voluntary redistribution, changes in locations of return flows (if applicable) could impact flows in receiving streams. Such impacts would be site specific and could be positive or negative, pending the changes.

Generally, these impacts are relative to the quantities of water that are diverted or redistributed. Small quantities are likely to have minimal to no impacts, while large quantities may have measured impacts. In Region F no large surface water volume transfers are expected.

5.2.3 Reuse of Treated Wastewaters

In general, there are three possible water quality effects associated with the reuse of treated wastewaters:

- There can be a reduction in instream flow if treated wastewaters are not returned to the stream, which could affect TDS, nutrients, and DO concentrations of the receiving stream.

- Conversely, in some cases, reducing the volume of treated wastewater discharged to a stream could have a positive effect and improve levels of TDS, nutrients, DO, and possibly metals in the receiving stream.
- Reusing water multiple times and then discharging it can significantly increase the TDS concentration in the effluent and in the immediate vicinity of the discharge in the receiving stream. Total loading to the stream (i.e. the amount of dissolved material in the waste stream) should not change significantly.

These impacts will vary depending on the quality and quantity of treated wastewater that has historically been discharged to the stream and the existing quality and quantity of the receiving stream.

5.2.4 New and/or Expanded Use of Groundwater Resources

Increased use of groundwater can decrease instream flows if the base flow is supported by spring flow. This is not expected to be a concern for the recommended water management strategies in Region F. Most new groundwater development is in areas that have no flowing surface water, such as Winkler County, or from relatively deep portions of aquifers that most likely do not have significant impact on surface flows, such as McCulloch County.

Increased use of groundwater has the potential to increase TDS concentrations in area streams if the groundwater sources have higher concentrations of TDS or hardness than local surface water and are discharged as treated effluent. This is not the case in most areas in Region F. Naturally occurring salt seeps and high TDS waters are common in Region F. The development of new supplies from brackish groundwater is discussed under desalination.

New development of groundwater from the Hickory aquifer could potentially introduce radionuclides to surface water if wastewaters are discharged to local streams. The net concentrations in the receiving streams are expected to be low and should not impact water use from the stream.

5.2.5 Water Conservation

The water conservation measure with the greatest potential for water savings to be implemented in Region F is improvements in the efficiency of irrigation equipment (advanced irrigation technologies). These recommended strategies are not expected to affect water quality adversely. The results should be beneficial because the demand on surface and groundwater resources will be decreased.

5.2.6 Desalination

Desalination of brackish groundwater is a recommended strategy for CRMWD and the Cities of San Angelo and Andrews. With new technologies, desalination has become a potentially viable option for the treatment of brackish and high nitrate source waters. However, these systems produce a waste stream that may adversely impact waters if discharged to surface waters. Key water quality parameters that may be affected include TDS, nutrients, and metals.

5.3 Impacts of Region F Water Management Strategies on Key Water Quality Parameters

The Region F water plan recommends six major water management strategies:

- Conservation or Drought Management
- Subordination
- Voluntary Redistribution
- New or Expanded Groundwater
- Reuse
- Desalination

Of these, conservation and subordination of downstream water rights do not have any potential impacts to key water quality parameters. A description of each of the other strategies and the potential impacts follows.

5.3.1 Voluntary Redistribution

Voluntary redistribution in Region F involves the sales of water from a source to a water user group or wholesale water provider. None of the recommended strategies listed below involve placing water from one source into another source. The amount of water proposed to be transferred should not significantly impact source reservoir or stream quantities beyond current commitments. Impacts to key water quality parameters are expected to be minimal.

Voluntary Redistribution Strategies:

- City of Midland - renew contract with CRMWD
- City of Ballinger - purchase water from Millersview-Doole WSC and CRMWD
- City of Stanton - renew contract with CRMWD
- CRMWD, City of Midland and City of Andrews - renewal of contracts with University Lands
- Millersview-Doole WSC - renew contract with CRMWD

5.3.2 New or Expanded Groundwater

Much of the groundwater supplies in Region F are fully developed and used for irrigation and local water needs. There is available groundwater from the Pecos Valley, Dockum and Hickory aquifers, which are proposed to meet specific needs in the region. Additional use of these aquifers is not expected to impact stream flows, and water quality is comparable or better than area surface water. Wastewater discharges from new users of the Hickory aquifer may contain radionuclides above the drinking water standards but should not impact the current water uses in the receiving streams. The proposed treatment strategies for Hickory aquifer water will improve water quality from this source. The proposed quantities of new or expanded groundwater use are within the sustainable amount for the respective aquifer and should not impact key water quality parameters within the aquifer formation.

New or Expanded Groundwater Strategies:

- City of Eden – new Hickory aquifer well (replacement well)
- City of Colorado City – new wells in Dockum aquifer (brackish)
- City of Menard – new Hickory aquifer well
- City of Midland – T-Bar Well Field (Pecos Valley aquifer)
- CRMWD – Winkler County Well Field (Pecos Valley aquifer)
- San Angelo – McCulloch County Well Field (Hickory aquifer)

5.3.3 Reuse

Wastewater reuse is a proposed strategy for the City of Winters and CRMWD. The CRMWD project proposes to reuse a portion of the treated wastewater from the cities of Big Spring, Odessa, Midland, and Snyder. The first phase of this project will likely involve Big Spring wastewater. Currently this wastewater is discharged to Beals Creek and diverted downstream at the Beals Creek chloride control facility. The natural water quality of the receiving stream is high in TDS and salts. Because most of the reject from the treatment process and the remaining treated wastewater is diverted at the chloride control project, this strategy is expected to have little if any impact on key water quality parameters below the Beals Creek diversion. The reuse project will produce high-quality water that will be blended with high TDS water from Spence Reservoir, improving the overall water quality available from that source.

The recommended reuse strategy for the City of Winters calls for reuse of about 25 to 35 percent of the city's treated effluent. The reject from the advanced treatment of the effluent will be blended with the remaining effluent and either discharged or disposed of using land application. The small quantity of water involved in the strategy should have acceptable impacts on water quality. However, site-specific studies will be needed to verify water quality impacts.

5.3.4 Desalination

There are four recommended desalination water management strategies: City of San Angelo, City of Andrews, City of Colorado City and CRMWD. These strategies propose to desalinate brackish groundwater and dispose of the waste stream through deep well injection or evaporation ponds. The proposed treatment process will treat local brackish groundwater and make it suitable for municipal use. The finished water will be of comparable or higher quality than existing supplies and will have no impacts to area surface water.

5.4 Impacts of Moving Water from Rural and Agricultural Areas

Three recommended water management strategies involve taking water from primarily rural areas for use in primarily urban areas all of which already own water rights:

- CRMWD Winkler County Well Field
- City of Midland T-Bar Well Field
- City of San Angelo McCulloch County Well Field

Although all of these well fields are located in rural areas, these strategies are not expected to have significant impact on those areas. The CRMWD and Midland well fields are located in areas where very little groundwater is used for other purposes. The San Angelo well field may impact wells in rural communities that also depend on the Hickory aquifer. However, pumping and well spacing limits set by the Hickory Underground Water Conservation District may minimize the potential impacts. Further studies may be required to determine the potential impacts of the San Angelo well field.

Another strategy that involves moving water from rural to urban areas is the CRMWD brackish groundwater strategy. This strategy proposes to use water that is not currently usable for rural and agricultural purposes. This strategy would have little to no impacts on rural communities.

6 WATER CONSERVATION AND DROUGHT MANAGEMENT RECOMMENDATIONS

Water conservation is a potentially feasible water savings strategy that can be used to preserve the supplies of existing water resources. For municipalities and manufacturers, advanced drought planning and conservation can be used to protect their water supplies and increase reliability during drought conditions. Some of the demand projections developed for SB1 Planning incorporate an expected level of conservation to be implemented over the planning period. For municipal use, the assumed reductions in per capita water use are the result of the implementation of the State Water-Efficiency Plumbing Act. Among other things, the Plumbing Act specifies that only water-efficient fixtures can be sold in the State of Texas. Savings occur because all new construction must use water-efficient fixtures, and other fixtures will be replaced at a fairly steady rate. On a regional basis, the Plumbing Act results in about a seven percent reduction in municipal water use (10,688 acre-feet per year) by year 2060. Additional municipal water savings can be expected from the Federal mandate for energy efficient clothes washing machines that went into effect in 2007.

TWDB also included conservation savings in the steam electric power demands and irrigation demands. Demands for steam electric power were developed on a state-wide basis and these demands assume that long-term power needs will be met with high water efficient facilities. The estimated water savings associated with the higher efficient power plants is nearly 27 percent of the total demands or 12,300 acre-feet per year in Region F. Based on factors developed by the TWDB, irrigation demands are expected to decline approximately 4.6 percent over the planning period (2010 to 2060), primarily due to conservation. Reductions in demands due to conservation were not quantified by the TWDB for manufacturing, mining and livestock needs.

SB1 requires each region’s water plan to address drought management and conservation for each supply source within the region. This includes both groundwater and surface water. Frequent recurring drought is a fact of life in Region F. Droughts have occurred in almost every decade since the 1940s. Recent experience with critical drought conditions attests to the effectiveness of water conservation and drought management in the region. The City of San Angelo reduced its municipal water use from approximately 19,000 acre-feet per year in 1997 to less than 16,000 acre-feet per year in 2005. Other cities in Region F have reported similar reductions in demand in response to drought. These reductions are at least partially due to the implementation of drought response activities included in the municipality's drought plan. However, according to city officials, the most significant factor in reducing water consumption is public awareness of drought conditions and voluntary reductions in water use. Other cities, such as Midland, are pursuing aggressive water conservation programs that include using xeriscaping and efficient irrigation practices for public properties such as parks and buildings, and reuse of treated effluent for municipal and manufacturing supplies.

A municipal water conservation survey was conducted in Region F as part of this water plan update to determine municipal water conservation strategies being implemented in Region F, and the costs and water savings associated with the strategies. Thirteen cities were surveyed regarding their conservation efforts, and selected cities were interviewed to obtain further information on their conservation practices. The thirteen cities selected represent a range of locations and sizes in Region F. They included Andrews, Ballinger, Big Spring, Bronte, Eden, Fort Stockton, Junction, Menard, Midland, Odessa, Pecos, San Angelo, and Snyder. Four cities which returned surveys and demonstrated active conservation programs were interviewed via teleconference: Menard, Midland, Odessa, and San Angelo. The results of this survey and analysis show that most cities are implementing one or more conservation strategies, but funding is key to continued success and increased conservation efforts. Several cities expressed interest in wastewater reuse for municipal and industrial purposes. Cities have great difficulty tracking water saving from most conservation practices. Quantified savings are available only from specific projects such as pipeline replacement or reuse projects. Reuse and System Water Audit and Water Loss are two conservation best management practices that showed the greatest overall savings. For the complete Municipal Conservation Survey study see Volume II.

As part of the assessment of conservation opportunities in Region F, the results of water loss audit reports for water suppliers in Region F were reviewed. TAC §358.6, requiring retail public water utilities to complete and submit a water loss audit form to the Texas Water Development Board every five years, with the first report submitted in March 31, 2006. The data from these reports for Region F water providers are discussed in more detail in Section 1.9 of this plan.

Fifty-four water providers in Region F submitted water loss audits. Based on these reports, the percentage of total water loss for Region F is slightly greater than seven percent, which is within the accepted range of water loss (less than or equal to twelve percent). When evaluated by types of water provider (cities, water supply corporations, water conservation and improvement districts and the special utility districts), only water supply corporations reported water losses higher than 12 percent. One possible explanation for this is the large service areas with low population densities characteristic of rural water supply corporations. For the water suppliers that fall under the water supply corporation category, there may be few cost effective options in reducing water loss. The amount of real losses in Region F from the 54 public water suppliers totaled 454 million gallons in 2006. This represents 1.1 percent of the total estimated municipal water demand for the region. Based on these findings, the region is adequately addressing municipal water loss. Measures that are currently in place to control water loss should continue.

Although water conservation is part of the culture of the region, the challenge for future water conservation activities in Region F will be the development water conservation programs that are cost-effective, meet state mandates, and result in permanent real reductions in water use. Development of water conservation programs will be a particular challenge for smaller communities which lack the financial and technical resources needed to develop and implement the programs. Any water conservation activities should take into account the potential adverse impacts of lost revenues from water sales and the ability of communities to find alternative sources for those revenues. State financial and technical assistance will be required to meet state mandates for these communities.

Irrigation conservation can potentially save the most water of any water conservation method. However, without technical and financial assistance it is unlikely that aggressive irrigation conservation programs will be implemented.

Although water conservation and drought management have proven to be effective strategies in Region F, the Region F Water Planning Group believes that water conservation should not be relied upon exclusively for meeting future needs. The region will need to develop additional surface water, groundwater and alternative supplies to meet future needs. However, each entity that is considering development of a new water supply should monitor on-going conservation activities to determine if conservation can delay or eliminate the need for a new water supply project.

The Region F Water Planning Group recognizes that it has no authority to implement, enforce or regulate water conservation and drought management practices. The water conservation and drought management practices described in this chapter and elsewhere in this plan are intended only as guidelines. Water conservation and drought management strategies determined and implemented by municipalities, water providers, industries or other water users supersede the recommendations in this plan and are considered to be consistent with this plan.

6.1 Water Conservation Plans

The TCEQ defines water conservation as "a strategy or combination of strategies for reducing the volume of water withdrawn from a water supply source, for reducing the loss or waste of water, for maintaining or improving the efficiency in the use of water, for increasing the recycling and reuse of water, and for preventing the pollution of water."[1]

The State of Texas in §11.1271 of the Texas Water Code requires water conservation plans for all municipal and industrial water users with surface water rights of 1,000 acre-feet per year or more and irrigation water users with surface water rights of 10,000 acre-feet per year or more. Water conservation plans are also required for all water users applying for a state water right, and may also be required for entities seeking state funding for water supply projects. Recent legislation passed in 2003 requires all conservation plans to specify quantifiable 5-year and 10-year conservation goals. While achieving these goals is not mandatory, the goals must be identified. In 2007, § 13.146 of the Texas Water Code was amended requiring retail public suppliers with more than 3,300 connections to submit a water conservation plan to the TWDB.

Table 6.1-1
Municipal, Industrial and Irrigation Water Users in Region F
Required to Submit Water Conservation Plans

Municipal/Industrial Water Rights Holders		
Brown County WID #1	City of Menard	Texas Parks and Wildlife Department
City of Ballinger	City of San Angelo[1]	Murpaks INC
City of Big Spring[1]	City of Sweetwater[2]	San Angelo Water Supply Corporation
City of Brady	City of Winters	Luminant Generation Company
City of Coleman	CRMWD	Upper Colorado River Authority
City of Junction		
Retail Public Suppliers		
City of Andrews	City of Midland	City of Pecos
City of Brownwood	City of Odessa	City of Snyder
Irrigation Water Rights Holders		
Pecos County WCID #1	San Angelo Water Supply Corporation	Red Bluff Water Power Control District
Reeves County WID #1	Wayne Moore & W H Gilmore	

Notes:
1. These entities are also required to develop a conservation plan as a retail public provider.
2. City of Sweetwater is located in the Brazos G region but holds water rights in Region F.

In the Region F area, 16 entities hold municipal or industrial rights in excess of 1,000 acre-feet per year and five entities have irrigation water rights greater than 10,000 acre-feet per year. Each of these entities is required to develop and submit to the TCEQ a water conservation plan. In addition, six retail public suppliers are required to submit conservation plans to the TWDB. A list of the users in Region F which are required to submit water conservation plans is shown in Table 6.1-1. Many more water users have contracts with regional water providers for 1,000 acre-feet per year or more. Presently, these water users are not required to develop water conservation plans unless the user is seeking state funding. However, TCEQ rules require that a wholesale water provider include contract language requiring water conservation plans or other conservation activities from its customers to assist in meeting the goals of the wholesale water provider's plan.

To assist entities in the Region F area with developing water conservation plans, model plans for municipal water users (wholesale or retail public water suppliers), industrial users and irrigation districts are included in Appendix 6A. Each of these model plans address the 2008 TCEQ requirements and is intended to be modified by each user to best reflect the activities appropriate to the entity.

6.2 Evaluation of Potential Savings from Water Conservation

Regional F recommendations that municipal water suppliers consider the following conservation practices:

- Education and public awareness programs,
- Reduction of unaccounted for water through water audits and maintenance of water systems,
- Water rate structures that discourage water waste, and
- Reuse.

These practices were used to evaluate the potential for water conservation for municipal water users with needs. Savings for passive implementation of water-efficient clothes washers was included as well. Implementing these practices could save over 10,000 acre-feet of water by 2060.

Irrigation is the largest water user in Region F and the category with the largest needs. The irrigation conservation activities evaluated in Section 4.2.7 of this plan focus on efficient irrigation practices. In addition to these practices, the region encourages research into development of drought-tolerant crops, implementation of a region-wide evapo-transpiration and soil moisture monitoring network, and, where applicable, water-saving improvements to water transmission systems. Implementation of irrigation conservation activities could save over 72,000 acre-feet of water by 2060.

Manufacturing water use is a minor demand in Region F, accounting for less than 2 percent of the water use in the region. From a regional perspective, savings due to implementation of manufacturing water conservation practices would not be significant. Most manufacturing needs are associated with water supply needs for municipalities. For regional planning purposes, water conservation strategies were developed for municipalities with needs, not for the manufacturers who purchase water from those municipalities. The region recommends that manufacturing water users be encouraged to develop and implement site-specific water conservation practices through their contracts with the municipalities, as required by TCEQ. (TCEQ requires that all contracts for water from municipal and wholesale water providers include language requiring water conservation plans or other water conservation measures.)[2]

Most of the mining water use in Region F is used in oil and gas production. In accordance with §27.0511 of the Texas Water Code, Region F encourages the use of alternatives to fresh water for oil and gas production whenever it is economically and technically feasible to do so. Furthermore, Region F recognizes the regulatory authority of the Railroad Commission and the TCEQ to determine alternatives to fresh water use in the permitting process. Because oil and gas production is already a regulated industry, Region F does not feel that additional conservation measures are needed.

Most of the livestock demand in Region F is for free-range livestock. Region F encourages individual ranchers to adopt practices that prevent the waste of water for livestock. However, the savings from these practices will be small and difficult to quantify. Therefore, livestock water conservation will not be considered in the planning process.

Steam-electric demands in Region F almost double over the planning period. However, there are insufficient supplies at most existing generation facilities to support the expected growth in demand. As an alternative to using water, Region F in consultation with representatives of the power generators in the area has developed an analysis of alternative cooling technologies that use little or no water. A description of these technologies can be found in Section 4.5. Because these technologies reduce the amount of water needed for power generation, using these technologies can be considered a water conservation strategy. Implementing this strategy could save over 24,000 acre-feet of water by 2060. These strategies are implemented by industry and are considered alternative strategies in the Region F Plan. Rising water costs and limited additional supplies will require increased water efficiency in industrial processes.

Estimates of water conservation savings for Region F in this plan are shown in Table 6.1-2. This table shows the amount of conservation that is estimated in the water demands (as a demand reduction) and the amount of additional water savings that are estimated through conservation water management strategies. The demands used in regional water planning already assume some conservation, and these are shown under the heading Savings in Demand in Table 6.1-2. Municipal reductions are the results of implementation of plumbing codes requiring more water efficient fixtures. Irrigation demands include a reduction in expected demand due to the passive implementation of more efficient irrigation practices (this is upgrades to irrigation equipment due to natural replacements). Steam electric power demands developed for the 2006 regional water plans assumed that new facilities would utilize more efficient cooling technologies and reduce water usage per kilowatt-hour generated. The amounts under the heading Savings in Recommended Water Management Strategies in Table 6.1-2 are the additional savings that could be realized by implementation of the water conservation management strategies mentioned at the beginning of this section. Figure 6.1-1 shows the projected conservation savings over the planning period.

Some of the savings in the recommended strategies may have been realized, but are included in the total strategy savings because the projected demands do not account for these savings. This is the case of irrigation conservation in some counties. Data gathered as part of the Irrigation Survey Special Study found that the adoption rates advanced irrigation equipment are much higher in Reagan and Glasscock Counties than assumed for the irrigation conservation strategy.

Figure 6.1-1
Projected Conservation Savings in Region F

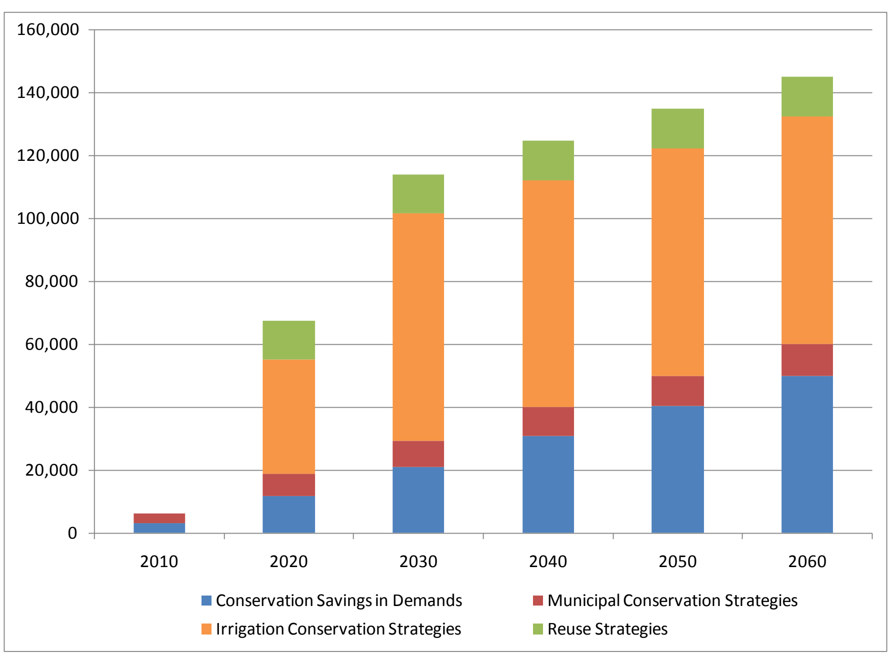


Table 6.2-1
Water Conservation Savings in Region F
-Values in Acre-feet per Year-

	2010	2020	2030	2040	2050	2060
Savings in Demands						
Municipal Conservation	2,302	4,887	7,210	9,553	10,533	10,688
Irrigation	0	5,379	10,760	16,145	21,526	26,832
Steam Electric	828	1,636	2,945	5,258	8,330	12,330
Total Conservation Saving from Demands	*3,130*	*11,902*	*20,915*	*30,956*	*40,389*	*49,850*
Savings in Recommended Water Management Strategies						
Municipal Conservation	3,214	7,022	8,358	8,965	9,605	10,259
Irrigation Conservation	0	36,125	72,244	72,245	72,246	72,247
Reuse	0	12,380	12,380	12,490	12,490	12,490
Total Conservation Saving from Strategies	*3,214*	*55,527*	*92,982*	*93,700*	*94,341*	*94,996*
Total Conservation Savings	**6,344**	**67,429**	**113,897**	**124,656**	**134,730**	**144,846**

Adjusting the adoption rates without adjusting the projected demands would not accurately represent the projected need for irrigation water. This may also apply to some cities that have successfully implemented conservation programs and lowered per capita water use. These adjustments to demands and conservation savings will be made for the 2016 regional water plan.

6.3 Drought Contingency Plans

Drought management is a temporary strategy to conserve available water supplies during times of drought or emergencies. This strategy is not recommended to meet long-term growth in demands, but rather acts as a means to minimize the potential for adverse impacts or water supply shortages during drought. The TCEQ requires drought contingency plans for wholesale and retail public water suppliers and irrigation districts. A drought contingency plan may also be required for entities seeking state funding for water projects.

Drought contingency plans typically identify different stages of drought and specific triggers and response for each stage. In addition, the plan must specify quantifiable targets for water use reductions for each stage, and a means and method for enforcement. As with the water conservation plans, drought contingency plans are to be updated and submitted to the TCEQ by May 1, 2009.

Model drought contingency plans were developed for Region F and are included in Appendix 6B. Each plan identifies four drought stages: mild, moderate, severe and emergency. The recommended responses range from notification of drought conditions and voluntary reductions in the "mild" stage to mandatory restrictions during an "emergency" stage. Entities using the model plan can select the trigger conditions for the different stages and appropriate responses for each stage.

6.4 Drought Response by Source

As required by TAC §357.5(e)(7), each region's water plan must include "factors specific to each source of water supply to be considered in determining whether to initiate a drought response, and actions to be taken as part of the response." This includes both groundwater and surface water sources. Where possible, existing drought management plans have been reviewed to develop consistent drought trigger conditions and management actions for each source. Specific information on drought trigger conditions may be found in Appendix 6C.

6.5 List of References

[1] TAC 30 §288.1

[2] TAC 30 §288.2(a)(2)(C) and TAC §288.5(a)(1)(G)

7 DESCRIPTION OF HOW THE REGIONAL WATER PLAN IS CONSISTENT WITH LONG-TERM PROTECTION OF THE STATE'S WATER RESOURCES, AGRICULTURAL RESOURCES, AND NATURAL RESOURCES

7.1 Introduction

The development of viable strategies to meet the demand for water is the primary focus of regional water planning. However, another important goal of water planning is the long-term protection of resources that contribute to water availability, and to the quality of life in the state. The purpose of this chapter is to describe how the 2011 update to the Region F Water Plan is consistent with the long-term protection of the state's water resources, agricultural resources, and natural resources. The requirement to evaluate the consistency of the regional water plan with protection of resources is found in 31 TAC Chapter 357.14(2)(C),[1] which states, in part:

> "The regional water plan is consistent with the guidance principles if it is developed in accordance with §358.3 of this title (relating to Guidelines), §357.5 of this title (relating to Guidelines for Development of Regional Water Plans), §357.7 of this title (relating to Regional Water Plan Development), §357.8 of this title (relating to Ecologically Unique River and Stream Segments), and §357.9 of this title (relating to Unique Sites for Reservoir Construction)."

Chapter 7 addresses this issue by providing general descriptions of how the plan is consistent with protection of water resources, agricultural resources, and natural resources. Additionally, the chapter will specifically address consistency of the 2011 Region F Water Plan with the state's water planning requirements. To demonstrate compliance with the state's requirements, a matrix has been developed and will be addressed in this chapter.

7.2 Consistency with the Protection of Water Resources

The water resources in Region F include three river basins providing surface water, and 11 aquifers providing groundwater. Most of Region F is located in the upper portion of the Colorado River basin and in the Pecos portion of the Rio Grande River basin. A small portion of the region is located in the Brazos River basin. Figure 1.1-1 shows the major streams in Region F, including the Colorado River, Concho River, Pecan Bayou, San Saba River, Llano River, and Pecos River.

Figure 1.2-1 shows the major aquifers in Region F, and Figure 1.2-2 shows the minor aquifers. There are a total of 11 aquifers that supply water to the 32 counties in Region F. The major aquifers are the Edwards-Trinity Plateau, Ogallala, Pecos Valley, and a small portion of the Trinity. The minor aquifers are Dockum, Hickory, Lipan, Ellenburger-San Saba, Marble Falls, Rustler, and the Capitan Reef Complex. The Edwards-Trinity High Plains is used only on a limited basis. More detailed information on these aquifers is presented in Chapter 3.

The source of most of the region's surface water supply is the upper Colorado River basin and the Pecos portion of the Rio Grande basin, which supply much of the municipal, industrial, mining and irrigation needs in the region. Major reservoirs in Region F include Red Bluff Reservoir, Lake J.B. Thomas, E.V. Spence Reservoir, O.C. Fisher Lake, Twin Buttes Reservoir, O.H. Ivie Reservoir, and Lake Brownwood.

Springs are an important water resource in Region F. They supplement surface water sources and provide water for aquatic and riparian habitat. Region F identified 14 major springs, which are shown on Figure 1.3-6. Lake Balmorhea, Twin Buttes Reservoir, Concho River and San Saba River are just some of the important water supply sources in Region F that rely on spring-fed stream flow.

The Edwards-Trinity Plateau, Pecos Valley, and Ogallala aquifers are the largest sources of groundwater in Region F, providing 36 percent, 25 percent, and 17 percent of the total groundwater pumped in 2003, respectively. The Lipan aquifer provided almost 8 percent of the 2003 totals, with all other aquifers contributing less than 15 percent. (Note: 2003 is the last year that the TWDB provided data on pumpage by aquifer.)

To be consistent with the long-term protection of water resources, the plan must recommend strategies that minimize threats to the region's sources of water over the planning period. The water management strategies identified in Chapter 4 were evaluated for threats to water resources. The recommended strategies represent a comprehensive plan for meeting the needs of the region while effectively minimizing threats to water resources. Descriptions of the major strategies and the ways in which they minimize threats include the following:

- *Subordination of Downstream Water Rights.* The Colorado WAM makes many assumptions that are contrary to the way the Colorado Basin has historically operated, showing that most surface water sources in the region have no supply. In conjunction with the Lower Colorado Region (Region K), a subordination strategy was developed that protects the supply of Region F water rights and the water resources in Region F. This strategy is described in Chapter 4.

- *Water Conservation*. Strategies for water conservation have been recommended that will reduce the demand for water, thereby reducing the impact on the region's groundwater and surface water sources. Water conservation practices are expected to save approximately 3,200 acre-feet of water annually by 2010, reducing impacts on both groundwater and surface water resources. By 2060, the recommended conservation strategies savings (excluding wastewater reuse) total 82,506 acre-feet per year. These savings are in addition to the water savings assumed in the demands. The total projected water savings from conservation for Region F by 2060 (excluding wastewater reuse) is 132,350 acre-feet per year.

- *Wastewater Reuse.* This strategy will provide high quality treated wastewater effluent for municipal water needs in the region. This strategy will decrease the future demands on surface and groundwater sources and will not have a major impact on key water quality parameters.

- *New or Expanded Use of Groundwater.* This strategy is recommended for entities with limited alternative sources and sufficient groundwater supplies to meet needs. Groundwater availability reported in the plan is the long-term sustainability of each aquifer, and is based on aquifer recharge capacity. Large transfers of groundwater may have potential impacts to local surface water and springs. Such impacts were considered during the evaluation of the strategies. Where possible, strategies were selected that minimized impacts to surface water.

- *Voluntary Redistribution.* Under this strategy, surface and ground water rights holders with surplus water supplies will provide water to areas with current or projected needs. This strategy is proposed for users in Andrews, Concho, Ector, Martin, McCulloch, Midland, Runnels, Tom Green and Ward Counties. As proposed, this strategy will only use water that is available on a sustainable basis and will not significantly impact key water quality parameters.
- *Desalination.* The City of San Angelo, City of Andrews and CRMWD have recommended long-term strategies to desalinate brackish groundwater. Desalination represents an important additional source of water that could be used to augment existing freshwater sources.

The Region F Plan does not have an impact on navigation.

The Region F plan protects existing water contracts and option agreements by reserving the contracted amount for included in those agreements where those amounts were known. In some cases there were insufficient supplies to meet existing contracts. In those cases, water was reduced proportionately for each contract holder.

A special water resource is a major water supply source that is committed to provide water outside of the Region. TWDB has designated two special water resources in Region F: (1) Oak Creek Reservoir, which supplies water to the City of Sweetwater in Brazos G, and (2) Ivie Reservoir, which supplies water to the City of Abilene in Brazos G. Supplies to these entities are included in the Region F plan.

7.3 Consistency with Protection of Agricultural Resources

Agriculture is an important economic and cultural cornerstone in Region F. Given the relatively low rainfall rates, irrigation is a critical aspect of agriculture for the region. The RWPG is recommending advanced irrigation technologies as a strategy to maximize the efficient use of available water supplies and protect current and future agricultural resources in the region. Currently, it is estimated that 42 percent of the region’s irrigated crop production uses some form of advanced irrigation technology. The proposed strategy is to increase the adoption of advanced irrigation technologies to 50 percent by 2020, and 100 percent by 2030.

In addition to irrigated agriculture, dry land agriculture and the ranching industry are important economically and culturally to the region. All agricultural enterprises depend on the survival of small rural communities and their assurance of a reliable, affordable water supply. These communities increase the local area's tax base and provide government services, health services, fire protection, education facilities, and businesses where agriculture obtains fuels, crop processing and storage, banking, and general products and supplies. If small rural communities do not have an affordable water supply to sustain themselves and provide for economic stability, agriculture will suffer an increase in the cost of doing business and the loss of services that contribute to its overall well being and safety. The Governor's Office, the Texas Department of Agriculture and U.S. Department of Agriculture are working to enhance the validity and sustainability of Texas agriculture and small rural communities.

7.4 Consistency with Protection of Natural Resources

Region F contains many natural resources that must be considered in water planning. Natural resources include threatened or endangered species; local, state, and federal parks and public land; and energy/mineral reserves. The Region F Water Plan is consistent with the long-term protection of these resources. Following is a brief discussion of consistency of the plan with protection of natural resources.

Threatened/Endangered Species

A list of threatened or endangered species located within Region F is contained in Table 1.4-1, in Chapter 1. Included are eleven species of birds, five mammals, four reptiles, seven fishes and six mussels. None of the recommended water management strategies in this plan inherently impact the listed species. However, some strategies may require site-specific studies to verify that threatened or endangered species will not be impacted.

Parks and Public Lands

Seven state parks (Lake Brownwood, Big Spring, Lake Colorado City, Monahans Sandhills, San Angelo, Balmorhea and South Llano River) and one state wildlife management area (Mason Mountain) are located in Region F. The state parks and wildlife management area are not expected to be impacted by the recommended strategies. The Subordination Strategy simply continues the current operations in the basin and will not change lake or stream operations. There are no new surface water strategies to impact stream flows.

In addition to the state parks, there are a number of city parks, recreational facilities, and public lands located throughout the region. None of the recommended water management strategies evaluated for the Region F Water Plan is expected to adversely impact these facilities or public land.

Energy Reserves

Thousands of producing oil and gas wells are located within Region F, representing an important economic base for the region. None of the recommended water management strategies are expected to significantly impact oil or gas production in the region.

7.5 Consistency with State Water Planning Guidelines

To be considered consistent with long-term protection of the State's water, agricultural, and natural resources, the Region F Water Plan must be determined to be in compliance with the following regulations:

- 31 TAC Chapter 358.3
- 31 TAC Chapter 357.5
- 31 TAC Chapter 357.7
- 31 TAC Chapter 357.8
- 31 TAC Chapter 357.9

The information, data, evaluation, and recommendations included in Chapters 1 through 6 and Chapter 8 of the Region F Water Plan collectively comply with these regulations. To assist with demonstrating compliance, Region F has developed a matrix addressing the specific recommendations contained in the above referenced regulations.

The matrix is a checklist highlighting each pertinent paragraph of the regulations. The content of the Region F Water Plan has been evaluated against this matrix. Appendix 7A contains a completed matrix.

7.6 List of References

[1] Texas Administrative Code, available on-line at http://www.sos.state.tx.us/tac/, downloaded May 2005.

8 UNIQUE STREAM SEGMENTS/RESERVOIR SITES/LEGISLATIVE RECOMMENDATIONS

The Texas Water Development Board (TWDB) regional water planning guidelines require that a regional water plan include recommendations for regulatory, administrative, and legislative changes that will facilitate water resources development and management:

> "357.7(a) Regional water plan development shall include the following… regulatory, administrative, or legislative recommendations that the regional water planning group believes are needed and desirable to: facilitate the orderly development, management, and conservation of water resources and preparation for and response to drought conditions in order that sufficient water will be available at a reasonable cost to ensure public health, safety, and welfare; further economic development; and protect the agricultural and natural resources of the state and regional water planning area. The regional water planning group may develop information as to the potential impact once proposed changes in law are enacted."[1]

The guidelines also call for regional water planning groups to make recommendations on the designation of ecologically unique river and stream sites and unique sites for reservoir development. This section also presents the regulatory, administrative, legislative, and other recommendations of the Region F Water Planning Group and the reasons for the recommendations.

8.1 Recommendations for Ecologically Unique River and Stream Segments

For each planning region, the Texas Parks and Wildlife Department [2] (TPWD) developed a list of river and stream segments that meet one or more of the criteria for being considered ecologically significant. In Region F, TPWD identified 20 segments as listed in Table 8.1-1 and shown in red on Figure 8.1-1 as ecologically significant.

Table 8.1-1
Texas Parks and Wildlife Department Ecologically Significant River and Stream Segments

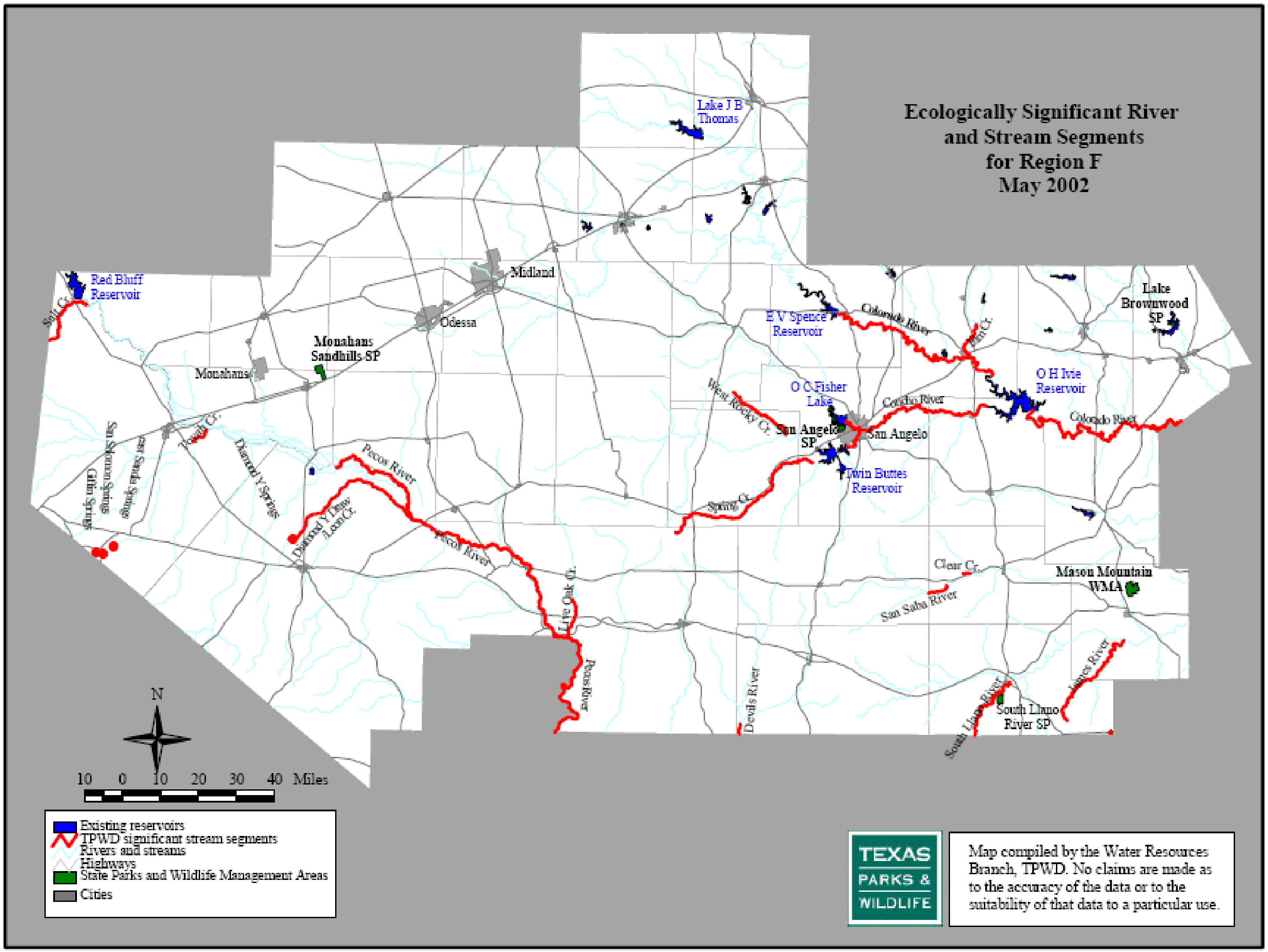
River or Stream Segment	Description	Basin	County	TPWD Reasons for Designation[(a)]				
				Biological Function	Hydrologic Function	Riparian Conservation Area	Water Quality/ Aesthetic Value	Endangered Species/ Unique Communities
Clear Creek	Impounded headwater springs	Colorado	Menard					X
Colorado River	Regional boundary upstream to E.V. Spence Reservoir dam, excluding O.H. Ivie Reservoir	Colorado	Multiple	X			X	X
Concho River	Above O.H. Ivie Reservoir to San Angelo Dam on North Concho River and Nasworthy Dam on South Concho River	Colorado	Concho, Tom Green				X	X
Devils River	Sutton/Val Verde County line upstream to Dry Devils River	Rio Grande	Sutton				X	X
Diamond Y Springs	Headwaters to confluence with Leon Creek	Rio Grande	Pecos					X
East Sandia Springs	Springs in Reeves County	Rio Grande	Reeves					X
Elm Creek	Elm Creek Park Lake to FM 2647 bridge	Colorado	Runnels				X	X
Giffen Springs	Springs in Reeves County	Rio Grande	Reeves					X
James River	Headwaters to confluence with Llano River	Colorado	Mason, Kimble				X	
Diamond Y Draw	Headwaters to confluence with Pecos River	Colorado	Pecos					X
Live Oak Creek	Headwaters to confluence with Pecos River	Colorado	Crockett				X	X
Pecos River	Val Verde/Crockett County line upstream to FM 11 bridge on Pecos/Crane County line	Rio Grande	Multiple	X			X	X
Pedernales River	Kimble/Gillespie County line upstream to FM 385	Colorado	Kimble	X			X	

Table 8.1-1 (Continued)

River or Stream Segment	Description	Basin	County	TPWD Reasons for Designation[a]				
				Biological Function	Hydrologic Function	Riparian Conservation Area	Water Quality/ Aesthetic Value	Endangered Species/ Unique Communities
Salt Creek	Confluence with Pecos River upstream to Reeves/ Culberson County line	Rio Grande	Reeves					X
San Saba River	From FM 864 upstream to Fort McKavett	Colorado	Menard			X		X
San Solomon Springs	Spring in Reeves County	Rio Grande	Reeves			X		X
South Llano River	Confluence with North Llano River upstream to Kimble/ Edwards County line	Colorado	Kimble			X	X	X
Spring Creek	Headwaters to FM 2335 crossing in Tom Green County	Colorado	Crockett, Orion, Tom Green				X	X
Toyah Creek	Confluence with Pecos River upstream to FM 1450	Rio Grande	Reeves					X
West Rocky Creek	Headwaters to confluence with Middle Concho River	Colorado	Irion, Tom Green, Sterling				X	X

[a] The criteria listed are from Texas Administration Code Section 357.8. The Texas Parks and Wildlife Department feels that their recommended stream reaches meet those criteria marked with an X.

Figure 8.1-1
Texas Parks and Wildlife Department Ecologically Significant River and Stream Segments



In previous planning cycles, the Region F Water Planning Group decided not to recommend any river or stream segments as ecologically unique because of unresolved concerns regarding the implications of such a designation. The Texas legislature has since clarified that the only intended effect of the designation of a unique stream segment was to prevent the development of a reservoir on the designated segment by a political subdivision of the state. However, the TWDB regulations governing regional water planning require analysis of the impact of water management strategies on unique stream segments, which implies some level of protection beyond the mere prevention of reservoir development.

Considering the remaining uncertainty for designation and the regional consensus that there are no new reservoirs recommended for development, the Region F Water Planning Group is not recommending the designation of any river or stream segment as ecologically unique at this time.

The Region F Water Planning Group recognizes the ecological benefits of major springs, which are discussed in Chapter 1, and the benefits of possible protection for these important resources. Several of the potential ecologically significant streams identified by TPWD are springs or spring-fed streams. The list includes springs that provide water to water supply reservoirs and/or ecologically sensitive species. The South Llano River in Kimble County, which is spring-fed, is an important water supply source for the City of Junction and Kimble County water users and may warrant additional protections. Other important stream segments include the South Concho River and Dove Creek. Both are spring-fed streams that flow into Twin Buttes Reservoir, which is a major water source for the City of San Angelo. The Region F Water Planning Group will reconsider the possible designation of unique streams for the 2016 water plan.

8.2 Recommendations for Unique Sites for Reservoir Construction

Section 357.9 of the Texas Water Development Board regional water planning guidelines allows a regional water planning group to recommend unique stream sites for reservoir construction:

> **357.9. Unique Sites for Reservoir Construction.** A regional water planning group may recommend sites of unique value for construction of reservoirs by including descriptions of the sites, reasons for the unique designation and expected beneficiaries of the water supply to be developed at the site.

Evaluations of available water supply in the Upper Colorado River Basin show limited availability for new surface water supplies. At this time, the Region F Water Planning Group does not recommend any unique sites for new reservoir development.

8.3 Policy and Legislative Recommendations

The Region F Water Planning Group established several committees with different interests to review and recommend water policy topics to include in the water plan. The following is a synopsis of the recommendations presented by the committees.

8.3.1 Surface Water Policies

In Region F approximately 70 percent of the population (440,000 people) depends on surface water from the upper Colorado River basin for all or part of their municipal water needs. Making sure that this water remains a dependable part of Region F's existing supplies is crucial.

The Colorado River basin is over appropriated and became that way in about 1938. This was well before there was any substantial population in Region F. All of the "senior water rights" are in the lower Colorado Basin. The majority of these water rights are held by the Lower Colorado River Authority, City of Austin and City of Corpus Christi. It is imperative that any changes to water rights, such as a change in use, change in point of diversion, transfers of water or transfer of water rights out of the Colorado Basin do not impair existing water rights even if they are junior in priority.

Surface water policy recommendations include:

- Require that any time a request is made to amend a water right, if the change involves an increase in the quantity, a change in the purpose of use or a change in the place of use, all water rights holders in the basin must be notified.
- Oppose any legislation that would repeal or modify the "junior priority provision" for interbasin transfers (Water Code 11.085 (s) and (t)) until the state has reviewed the results from the water availability models that were required in SB 1 in 1997 and the regional water plans to determine where the transfer of water from a basin would not be detrimental to the basin of origin.

- Review the state's surface water policy of prior appropriation to see if this is a policy that will work in Texas over the next 50 years.
- Recommends that state water law be amended to incorporate river basin subordinations as set forth in regional water plans.

8.3.2 Groundwater Policies

Groundwater policy recommendations include:

- That groundwater supply available to implement regional water supply strategies within the boundaries of the region's groundwater conservation districts will be projected groundwater supply based on the districts' management goals and regulatory requirements.
- To support retention of the Rule of Capture while encouraging fair treatment of all stakeholders, and the state's policy that groundwater districts are the preferred method for managing Texas' groundwater resources.
- To support local control and management of groundwater through confirmed groundwater conservation districts, while providing encouragement and incentives for cooperation among the groundwater conservation districts within the region.
- That no strategy for export of groundwater from a groundwater conservation district or from the region will be adopted until a comprehensive plan is in place to assure retention of adequate supplies of water within the district or region to protect existing economic enterprises including agriculture and support the foreseeable population growth and economic development so long as the groundwater conservation district or region applies the same rules and conditions, including fee structure, to both the proposed water exporter and all groundwater users residing within the borders of said district or region.
- That all persons or entities seeking to export a significant amount of water from a groundwater district must submit notice of their plan to the affected GWD and the Regional Water Planning Group.

- All state agencies with land within groundwater conservation districts must be subject to groundwater district rules and production limits, and must submit plans for withdrawal of groundwater to the relevant Regional Water Planning Group for consideration.

8.3.3 Environmental Policies

Region F believes in good stewardship of the region's water and natural resources. Environmental policy recommendations include:

- That brush control and desalination are Region F priority strategies for protecting environmental values while developing new water supply for municipal and other economic purposes.
- That because of the very limited water resources in this region there must be a carefully managed balance in the development, allocation and protection of water supplies, between supporting population growth and economic enterprise and maintaining environmental values. Consequently, while recognizing the need for, and importance of, reservations of adequate water resources for environmental purposes, the RWPG will not designate any special stream segments until the Texas Parks and Wildlife Department, working in cooperation with local entities such as groundwater districts, county soil and water conservation districts, local conservation groups and landowners, completes comprehensive studies identifying and quantifying priority environmental values to be protected within the region and the quantification of minimum stream flows necessary to maintain those environmental values.
    - To support legislative funding and diversion of TPWD resources, for undertaking the studies described above; and
    - To support the creation of cooperative local stakeholder groups to assist the TPWD in studies described above.
- There are insufficient water supplies within Region F to meet projected municipal, agricultural and environmental needs through 2060; therefore Region F RWPG opposes the export of surface water outside of the region except for existing contracts for such export, and will give priority consideration to needs within the region,

including protection of environmental values, in evaluating any future proposed contracts for export.

- Land (range and cropland) conservation and management practices (including brush management and proper follow-up grazing and burn management) are priority strategies to provide optimum conditions for most efficient utilization of the region's limited rainfall. These practices should receive top priority for funding from the Texas legislature and state agencies charged with protecting and developing our water resources. Whereas Texas is a leading user of compost, utilizing soil biology to conserve the infiltration of water.

8.3.4 Instream Flows

Region F is located in an arid area with much of the rainfall occurring in short bursts. This results in widely varying stream flows with many streams being intermittent, having water only part of the year. During drought, stream flows can be very low, but this is a natural occurrence and the ecological environment in Region F has developed under these conditions. State agencies have been engaged in studies of the requirements for instream flows since the late 1960s, particularly with regard to freshwater inflows to bays and estuaries. Some cities and municipalities are concerned that a significant portion of their water supply could be reallocated to meet instream flow demands. Region F recognizes that future flow conditions in Texas' rivers and streams must be sufficient to support a sound ecological environment that is appropriate for the area. However, Region F believes it is imperative that existing water rights are protected.

8.3.5 Interbasin Transfers

The State of Texas has 23 river basins that provide surface water to users in 16 regions. The current statutes require any new water right diverted from one river basin to another to become "junior" in priority to other rights in that basin. Also as part of the water rights application, an economic impact analysis is required for both basins involved in the transfer. These requirements are aimed at protecting the basin of origin while allowing transfers of water to entities with needs. The Region F Water Planning Group:

- Supports retention of the junior water rights provision (Water Code 11.085(s) and (t)).
- Urges the legislature and TCEQ to study and develop mechanisms to protect current water rights holders.

8.3.6 Uncommitted Water

The Texas Water Code currently allows the Texas Commission on Environmental Quality to cancel any water right, in whole or in part, for ten consecutive years of non-use.[3] This rule inhibits long-term water supply planning. Water supplies are often developed for ultimate capacity to meet needs far into the future. Some entities enter into contracts for supply that will be needed long after the first ten years. Many times, only part of the supply is used in the first ten years of operation.

The regional water plans identify water supply projects to meet water needs over a 50-year use period. In some cases, there are water supplies that are not currently fully utilized or new management strategies that are projected to be used beyond the 50-year planning period. To support adequate supply for future needs and encourage reliable water supply planning policy recommendations include

- Opposed to cancellation of uncommitted water contracts/rights.
- Supports long term contracts that are required for future projects and drought periods.
- Supports shorter term “interruptible” water contracts as a way to meet short term needs before long-term water rights are fully utilized.

8.3.7 Brush Control

Brush control is recognized as an important tool in the management and maintenance of healthy rangelands that can allow for more efficient circulation of rainfall into the soil profile. This in turn can add to the effectiveness of aquifer recharge and restoration of streams and springs.

Region F supports brush control where it has the greatest effect on rivers, streams, and spring flow such as riparian zones, areas of the region with the highest rainfall per year. Region F recognizes that the key to water restoration is managing the land to promote a healthy and vigorous soil and vegetative condition, of which brush control can play an important part.

Region F supports legislative efforts to promote funding for brush control activities for the purpose of river, stream, and spring enhancement in those areas that allow for the greatest success.

Region F Water Planning Group recommends the Texas legislature continue to support the State Brush Control Program through:

- Completion of the final phase of the North Concho River Brush Control project,
- Continued funding until completion of the Twin Buttes Project,
- Funding for other West Texas reservoirs in the region which include Ballinger, Oak Creek, Champion Creek, and Brady Creek Reservoirs,and
- Continued cooperation with federal agencies to secure funds for brush control projects that will improve water quality.

8.3.8 Desalination

There are significant reserves of brackish groundwater in Region F. Region F Planning Group recommends the Texas Legislature continue to provide funds to assist local governments in the implementation of development of these water resources.

8.3.9 Weather Modification

There are currently two operational weather modification programs in the region and one program's evaluation indicated an increase of 10.7 percent (1.98 inches) in additional rainfall for the April to October 2004 seeding season (the statewide program average is 10.2 percent). Weather modification is one of the region's recommended strategies, together with brush control and desalination, for augmenting water supply. Recommendations include:

- Support legislative funding for operational programs, research, and evaluation of impact on rainfall.
- Support the creation of additional programs.

8.3.10 Water Quality

Recommendations include:

- TCEQ authorize small, rural water suppliers who currently cannot afford the necessary capital improvements to their existing water systems and who have no reasonable available alternate water source to utilize bottled water options to the fullest extent possible and apart from the threat of TCEQ enforcement. The alternative is for the water supplier to receive grants, not loans, to construct, operate, and maintain a treatment system to reduce drinking water constituents that exceed the established MCLs of the federal drinking water standard level.
- TCEQ develop rules for the disposal of constituent residuals that result from water treatment processes for radionuclides. Without such rules, the accurate cost of water treatment cannot be computed, viable treatment options cannot be assessed, and water suppliers cannot be assured that their water system meets the standards.
- The State of Texas sponsor an oral ingestion study to determine the epidemiology of radium in potable water before enforcing minimum MCLs for radium. Region F is concerned about enforcement of state and federal regulations for radium in drinking water. A cluster cancer investigation was conducted by the Texas Cancer Registry of the Texas Department of Health and found that the cancer incidence and mortality in the area were within ranges comparable to the rest of the state[4] (see Appendix 8B). The Texas Radiation Advisory Board also expressed concern the EPA rules are "unwarranted and unsupported by public health information (specifically epidemiological data)"[5] (see Appendix 8C).
- TCEQ develop rules for disposal wells which would allow for the disposal of reject water from a membrane treatment plant through a well that is not classified as a "Hazardous Disposal Well".
- TCEQ revise its policy on requiring the use of secondary water standards, particularly TDS, when granting permits. Meeting secondary water standards should be the option of local water suppliers who must consider local conditions such as the

economy, availability of water, community concerns for the aesthetics of water, and the volunteer use of technologies such as point-of-use.

8.3.11 Municipal Conservation

The Region F Water Planning Group recognizes the importance of water conservation as a means to prolong existing water supplies that have shown to be vulnerable under drought conditions. The Water Conservation Task Force recently presented to the Texas legislature a summary of conservation recommendations, including state-wide municipal conservation goals. The Task Force indicated that these goals are voluntary, and recognized that a statewide per capita water use value is not appropriate for the State of Texas, with its wide variation in rainfall, economic development, and other factors. Considering the drought-prone nature of Region F and the recommendations of the Water Conservation Task Force, the Region F Water Planning Group:

- Supports the Water Conservation Task Force decision that the targets included in their report should be voluntary rather than mandatory goals.
- Recommends state participation in water conservation be increased by providing monetary incentives in the form of grants or low interest loans to municipal, industrial and agricultural interest for the implementation of advanced conservation technologies.
- Recommends the state encourage conservation by providing technical assistance to water users and not force conservation through mandatory targets and goals for water use.
- Recommends the state continue participation in research and demonstration projects for the development of new conservation ideas and technologies.
- Supports the development of a state-wide public information and education program to promote water conservation. Water conservation can only be successful with the willing support of the general public.

8.3.12 Reuse

Reuse of water is a major source of "new water" especially in Region F. Reclaimed or new water developed from a demineralization or reclamation project can be stored for use in aquifers that have been depleted. Region F Water Planning Group recognizes the importance of reuse for the region and state, and recommendations include:

- Support legislation that will encourage and allow the reuse of water in a safe and economical manner.
- Work with the state's congressional delegation and federal agencies to develop procedures that will allow reject water from demineralization and reclamation projects to be disposed of in a safe and economical manner.
- Support legislation that will encourage and allow aquifer storage and recovery projects to be developed and managed in an economical manner.
- Support legislation at both the state and federal levels to provide funding for demineralization, reclamation and aquifer storage and recovery pilot projects.
- Recommends consideration of inverted block rates, base rates and excess use rates such as water budget rates, and seasonal rates that encourage water conservation, and recognition of water conservation as an appropriate goal in determining water rates.

8.3.13 Conjunctive Use

The definition of conjunctive use must include "surface water, groundwater, water education and conservation, demineralization, reclaimed treated wastewater effluent, aquifer storage and recovery, land management, blending water from different sources and quality, regulatory impacts (state and federal) on water supplies and environmental needs".

8.3.14 Groundwater Conservation Districts

There are 15 established groundwater conservation districts in Region F that oversee groundwater production in more than half of the region. Region F recognizes and supports the state's preferred method of managing groundwater resources through locally controlled groundwater districts. In areas where groundwater management is needed, existing districts could be expanded or new districts could be created taking into consideration hydrological units (aquifers), sociological conditions, and political boundaries. Recommendations include:

- Legislation developed for managing the beneficial use and conservation of groundwater must be fair for all users.
- Rules and regulations must respect property rights and protect the right of the landowners to capture and market water within or outside of district boundaries.
- The region does not support the use of historical use limits in granting permits.
- The region does not support the use of groundwater fees for wells used exclusively for dewatering purposes.
- The legislature should support the collection of groundwater data that would be used to carry out the intent of regional water planning.

The region also recognizes that the state has groundwater resources associated with state lands that may or may not be governed by local groundwater districts. Region F encourages the state to review its groundwater resources on all state owned land and how those resources should be managed to the benefit of all of Texas.

8.3.15 Oil and Gas Operations

Protection of the quality of the region's limited groundwater resources is very important within Region F. Prevention of groundwater contamination from oil and gas well operations requires constant vigilance on the part of the Railroad Commission rules. Orphan oil and gas wells that need proper plugging have become a problem and a liability for the state, the oil and gas industry as a whole, and the Texas Railroad Commission. In response to this problem, the state initiated a well plugging program that is directed by the Railroad Commission. This program enables a large number of abandoned wells to be properly plugged each year, and has accomplished much by preventing water pollution.

In light of the importance of local groundwater supplies to users in Region F and the vulnerability of these supplies to contamination, the Region F Water Planning Group recommends:

- Stringent enforcement of the oil and gas operations rules and supports the levy of fines by the Commission against operators who violate the rules.
- Continuing support for the industry funded, Commission supported abandoned well and plugging program.
- The Legislative Budget Board and the Texas Legislature provide adequate personnel and funding to the Railroad Commission to carry out its mandated responsibility to protect water supplies affected by oil and gas industry activities.
- The Texas Legislature restore funds to the industry-initiated and industry-funded well plugging account, which were transferred to the general revenue following the 2003 budget crisis. The well plugging fund is not tax money but industry funds contributed for a specific purpose.
- The clean-up and remediation of all contamination related to the processing and transportation of oil and gas. This includes operational or abandoned gas processing plants, oil refineries, and product pipelines.

8.3.16 Electric Generation Industry

The steam electric power water demands in Region F account for 10 percent of the current non-agricultural demands in the region and are projected to more than double over the planning period. The planning group has concerns of how the statewide demand for steam electric generation was allocated to Region F given the current drought situation in our region. Water supply is essential to the reliable generation of electricity, and is generally obtained in the form of water contracts or water rights. Prior to the construction of an electric generation station water contracts/rights are secured at a level to ensure a reliable water source during future drought periods.

Electric utilities have a duty to plan for the long-term needs of our customers, and the utilities have made substantial investments to secure water contracts/rights and groundwater resources in advance of actual use. All of these water contracts/rights and groundwater resources have been or are held for a substantial period of time in advance of actual use – not only for future generating units but also during drought periods for existing power plants. In order for the electric utility industry to effectively provide service to existing and future customers, the industry opposes:

- Any attempt to cancel uncommitted water contracts/rights.
- Establishing historical use limits for groundwater.

Region F encourages the use of higher TDS or inferior waters for electric generation when possible to maximize available fresh water sources within the region.

8.3.17 Funding

The Region F Water Planning Group recognizes that the ability to implement the water plan will depend in part on the ability to fund the recommended projects. The TWDB and Texas Legislature have responded to this concern by providing different funding vehicles for water projects. However, due to the intense competition for the limited funds, many entities are still struggling with financing water projects. The Region F Water Planning Groups recommends:

- The state provides increased appropriations to the water infrastructure fund for implementation of strategies in the regional water plans.

8.4 Regional Planning Process

Planning Schedule

The current 5-year schedule for joint groundwater planning is not synchronized very well with the 5-year schedule for developing the State Water Plan. The *managed available groundwater* (MAG) volumes determined in the GMA process for each aquifer are to be incorporated into groundwater conservation district management plans, and will be required in the regional water planning process for assessing water supply availability during the next regional planning period (2011-2016). By modifying the due dates in the GMA process, MAG data can be better integrated into the overall state water planning program. The following table provides a suggested timeline for coordinating the interrelated water planning functions that will provide a more synchronized and orderly development of planning information.

Table 8.4-1 - Proposed Planning Schedule

Planning Process	Current Due Dates	Next Planning Cycle Due Dates	**Proposed Due Dates**
GMAs set DFC	2010	2015	**2013**
TWDB establishes MAG	2011	2016	**2014**
GCD Management Plans	Various*	2017	**2015**
Regional Water Plans	2011	2016	**2016**
State Water Plans	2012	2017	**2017**

* Currently local plans are submitted on staggered 5-year intervals; because the MAGs will be issued in 2011 most GCDs will be resubmitting their plans in 2012

In addition to the coordination of the different components of the planning process, the Region F Water Planning Group questions the need and expense for planning updates every five years. In Region F, there are few options for new water supply, and the region is not experiencing rapid grow or changes in population or demands. As a result, few changes are expected for future water supply plans. Region F requests that the TWDB review the frequency for plan updates and allow the regions the option to adopt an existing water plan to meet the legislative requirements for 5-year updates if there are no significant changes to the region's recommended water management strategies.

Allow Waivers of Plan Amendments for Entities with Small Strategies

Region F recommends that the Texas Water Development Board allow waivers for consistency issues for plan amendments that involve projects resulting in small amounts of additional supply.

Coordination between TWDB and TCEQ Regarding Use of the WAMs for Planning

The TWDB requires that the Water Availability Models (WAMs) developed under the direction of TCEQ to be used in determining available surface water supplies. The models were developed for the purpose of evaluating new water rights permit applications and are not appropriate for water supply planning. The TWDB and TCEQ should coordinate their efforts to determine the appropriate data and tools available through the WAM program for use in regional water planning. The TWDB should allow the regional water planning groups some flexibility in applying the models made available for planning purposes.

8.5 Summary of Recommendations

The following is a summary of the region's policy and legislative recommendations as agreed to by the Region F Regional Water Planning Group. The region:

1. Does not recommend the designation of any ecologically unique stream segments or unique reservoir sites.
2. Support recognition of the importance of springs and spring-fed streams.
3. Supports protection of existing water rights and encourages review and study of mechanisms to protect rights, including potential modification of the prior appropriation doctrine.
4. Supports the protection of environmental values and developing water supply using brush control and desalination.
5. Supports state funding for environmental studies with local stakeholder input.
6. Supports protection of existing water rights when considering instream flows.
7. Recommends that state water law be amended to incorporate river basin subordinations as set forth in regional water plans.
8. Opposes export of surface water from the region (above current contracts) and export of groundwater from the region until a comprehensive plan is in place to reserve adequate supplies within the region.
9. Supports state funding of land management activities to promote conservation of the region's natural resources.
10. Supports a requirement for notification of all water rights holders in a basin any time a request is made to amend a water right if the change involves an increase in the quantity, a change in the purpose of use or a change in the place of use.
11. Opposes any legislation that would repeal or modify the "junior priority provision" for interbasin transfers (Water Code 11.085 (s) and (t)) until the state has reviewed the results from the water availability models that were required in SB 1 in 1997 and the regional water plans to determine where the transfer of water from a basin would not be detrimental to the basin of origin.

12. Opposes cancellation of uncommitted or unused water contracts or water rights.

13. Supports long-term contracts as a means for reliable water supply planning and shorter-term "interruptible" water contracts as a way to meet short term needs before long-term water rights are fully utilized.

14. Recommends modification of the planning cycles as related to the timing of due dates in the Groundwater Management Area (GMA) process, groundwater conservation district management plans, and regional and state water plans.

15. Recommends the State allow the regions to adopt an existing water plan to meet the Legislative requirements for 5-year updates if there are no significant changes to the region's recommended water management strategies.

16. Supports continued and future funding of the State Brush Control Program, including but not limited to:

    a. Completion of the final phase of the North Concho River Brush Control project,

    b. Continued funding until completion of the Twin Buttes Project,

    c. Funding for other West Texas reservoirs in the region which include Ballinger, Oak Creek and Champion Creek Reservoirs, and

    d. Continued cooperation with federal agencies to secure funds for project brush control projects that will improve water quality such as salt cedar control.

17. Supports State funding for desalination projects of brackish groundwater.

18. Recommends the state provide increased appropriations to the water infrastructure fund for implementation of strategies in the regional water plans.

19. Recommends TCEQ develop rules for disposal wells that would facilitate the disposal of reject water from a membrane treatment plant, including desalination plants.

20. Supports State funding for existing weather modification programs and the creation of new programs.

21. Recommends that the TCEQ consider alternative programs (such as bottled water) to meet water quality standards for radionuclides and other constituents that are very costly to treat.

22. Recommends that TCEQ develop rules for the disposal of constituent residuals from the treatment of radionuclides.

23. Recommends the State of Texas sponsor an oral ingestion study to determine the epidemiology of radium in potable water before enforcing minimum MCLs for radium.

24. Recommends that TCEQ revise its policy on requiring the use of secondary water standards, particularly TDS, when granting permits.

25. Recommends state participation in water conservation through technical assistance to water users and monetary incentives to entities that implement advanced conservation.

26. Opposes mandatory targets and goals for water use.

27. Supports continued State participation in research and demonstration projects for conservation.

28. Supports the development of a state-wide public information and education program to promote water conservation.

29. Supports the use of water conservation pricing and recognition of water conservation as an appropriate goal when setting rates.

30. Supports legislation that would allow the reuse of water in a safe and economical manner.

31. Supports the development of procedures for disposal of waste streams from desalination and reclamation projects in a safe and economical manner.

32. Supports legislation that will encourage and allow aquifer storage and recovery projects to be developed in an economical manner.

33. Supports state funding of pilot projects for desalination, reclamation and aquifer storage and recovery projects.

34. Recommends a definition of conjunctive use that includes surface water, groundwater, water education and conservation, desalination, reuse, aquifer storage and recovery, land

management, blending of water supplies, regulatory impacts on water supplies and environmental needs.

35. Supports the use of groundwater conservation districts to manage groundwater resources, and recommends that:

    a. The legislation for managing the beneficial use and conservation of groundwater must be fair for all users.

    b. Rules and regulations must respect property rights and protect the right of the landowners to capture and market water within or outside of district boundaries.

    c. Historical use limits should not be used in granting permits.

    d. Groundwater fees should not be applied to wells used exclusively for dewatering purposes.

    e. Encouragement and incentives for cooperation among groundwater conservation districts be provided.

    f. All state lands within a groundwater conservation district be subject to that district's rules.

36. Supports retention of the Rule of Capture while encouraging fair treatment of all stakeholders.

37. Recommends that the legislature continue to support the principal of basing groundwater supplies used for regional water planning on the governing water conservation districts' management goals and regulatory requirements.

38. Supports a requirement for notification of Regional Water Planning Groups and GCDs whenever a significant amount of water is being exported from a groundwater conservation district.

39. Supports the collection of groundwater data that would be used to carry out the intent of Regional Water Planning and Joint Planning for Groundwater.

40. Encourages the state to review its groundwater resources on all state owned land and determine how those resources should be managed.

41. Supports the protection of groundwater resources through the current oil and gas operation rules and the state-initiated well plugging program.

42. Encourages the legislature to adequately fund and staff the Railroad Commission to carry out its mandated responsibility to protect water supplies affected by oil and gas operations.

43. Recommends the legislature restore funds to the well plugging account, which were transferred to the general revenue fund in 2003.

44. Recommends the clean-up and remediation of all contamination related to the processing and transportation of oil and gas.

45. Encourages the use of higher TDS water for stream-electric generation.

46. Recommends the following changes to the Regional Water Planning process:

    a. Clarification of the roles of the TWDB and the Regional Water Planning Groups in regards to data collection and quality control of data,

    b. Simplification of rules governing the regional water planning process,

    c. Provision of clear guidance on resolving consistency issues,

    d. Waivers of the requirement to amend the regional water plan for small entities, and

    e. Coordination between TWDB and TCEQ regarding the use of WAMs for regional water planning.

8.6 List of References

[1] Texas Water Development Board, *Chapter 357, Regional Water Planning Guidelines*, Austin, October 1999, amended July 11, 2001.

[2] Texas Parks and Wildlife Department, List of Potential Ecologically Unique Stream Segments for Region F, http://www.tpwd.state.tx.us/texaswater/sb1/rivers/unique/regions_text/regions_list/region_f.phtml, September 13, 2004.

[4] Texas Department of Health: *Summary of an Investigation into the Occurrence of Cancer Concho, McCulloch, San Saba, and Tom Green Counties, Texas 1990-1998*, December 15, 2000.

[5] Michael Ford, Vice Chair of the Texas Radiation Advisory Board, letter to Robert J. Huston, Chairman, Texas Natural Resource Conservation commission, May 6, 2002.

9 INFRASTRUCTURE FINANCING RECOMMENDATIONS

The Region F Water Planning Group surveyed nine wholesale water providers or water suppliers. Each entity has a projected water supply deficit and recommended strategies to meet that need, or they have an identified need for a water supply infrastructure project that might be eligible for state financial assistance. Three of the nine entity surveyed submitted responses. Survey responses summarized here include those for Colorado River Municipal Water District and the City of San Angelo. The City of Midland did respond to the survey but indicated that they would not be seeking financial assistance from the state.

The entities were surveyed to determine their proposed method(s) for financing the estimated capital costs involved in implementing the water supply strategies recommended in the *2011 Region F Water Plan*. Unlike infrastructure financing surveys conducted for previous regional water plans, questions during this planning cycle focused on projected needs for financial assistance from five programs administered by the TWDB. The TWDB will aggregate the projected requests for funding from these programs from the 16 water planning regions to provide estimates of long-term funding needs.

9.1 State Water Planning Funding

The TWDB offers financial assistance for the planning, design and construction of projects identified in the regional water plans or State Water Plan. Programs available include the State Participation Fund (SP), the Water Infrastructure Fund (WIF) and the Economically Distressed Areas Program (EDAP). In order to be eligible to apply for funding from any of these sources, the applicant must be a political subdivision of the state, or in some cases a water supply corporation, and the proposed project must be a recommended water management strategy in the most recent approved regional plan or State Water Plan.

In 2007 the 80th Texas Legislature appropriated funding to enable the issuance of $812 million in bonds for water plan projects, an amount estimated to meet water supply needs identified in the 2007 State Water Plan through 2020. The results of the current surveys carried out by each of the planning regions will be used to identify the amount of additional funds that will be needed for water supply projects through the end of the 2060 planning horizon.

9.1.1 Water Infrastructure Fund (WIF)

The Water Infrastructure Fund (WIF) provides subsidized interest rate loans for planning, design and construction. For projects that have a long lead time for development costs, a portion of the WIF is available specifically for planning, design, permitting and other costs associated with state or federal regulatory activities. This WIF-Deferred fund offers the option of deferring all interest and principal payments for up to 10 years or until the end of project construction.

9.1.2 State Participation Fund (SP)

The State Participation Fund (SP) is geared towards large projects which are regional in scope and meant to capitalize on economies of scale in design and construction, but where the local project sponsors are unable to assume the debt for an optimally sized facility. The TWDB assumes a temporary ownership interest in the project, and the local sponsor repays the cost of the funding through purchase payments on a deferred schedule. The goal of the program is to build a project that will be the right size for future needs, even if that results in the short term in building excess capacity, rather than constructing one or more smaller projects now. On new water supply projects, the TWDB can fund up to 80 percent of the costs, provided that the applicant can fund the other 20 percent through an alternate source and that at least 20 percent of the total capacity of the project serves current needs.

9.1.3 Rural and Economically Distressed Areas (EDAP)

Both grants and 0% interest loans for planning, design and construction costs are offered through these programs, which are available to eligible small, low-income communities. Rural and economically distressed areas that meet population, income and other criteria are eligible to apply for these funds. EDAP funding eligibility also requires adoption of the Texas Model Subdivision Rules by the applicant planning entities.

9.2 Infrastructure Financing Survey

The surveys were conducted online, with a unique URL address supplied to each surveyed entity. Each survey was prefaced with an explanation of its purpose in identifying the need for financial assistance programs offered by the State of Texas and administered by the TWDB. The available funding programs (WIF, SP and EDAP) were summarized, and the survey participant was asked to identify the amounts they would like to receive from each funding source for each identified project or strategy.

The surveys listed each recommended strategy and its total capital cost. Following this basic data, the water user group or wholesale water provider was asked: 1) the amount to be requested from each TWDB funding source; and 2) the earliest date the funds would be needed, by fund type. The Region F Planning Group did not add any additional, region-specific questions to the survey during this planning cycle.

Political subdivisions of the state whose water supply strategies were noted in the regional plan as having zero capital costs were not surveyed. Where a water user group with needs and strategies to meet those needs have multiple water management strategies, some of which have capital costs and others that have no capital costs, those water user groups were only surveyed for the strategies with a capital cost. Surveys were delivered in the first week of August received until October 6, 2010.

Table 9-1 summarizes the total capital costs for all recommended strategies in Region F. Each entity was asked to provide estimates of how much of this funding would be sought from state funding programs. Table 9-2 summarizes the individual project cost and the projected earliest date of implementation.

Table 9-1. Summary of Total Capital Costs by Entity

Entity	Total Capital Cost for Recommended Strategies
City of Andrews	$6,717,000
City of Bronte Village	$1,364,900
Colorado River Municipal Water District	$347,059,990
City of Eden	$4,382,000
City of Menard	$1,684,000
City of Midland	$168,507,000
City of Robert Lee	$2,436,000
City of San Angelo	$254,904,000
City of Winters	$2,158,000
TOTAL	**$789,212,890**

Table 9-2 Summary of Capital Costs by Entity and Project

Entity	Project Name	Earliest Date of Implementation	Sum of Capital Costs
City of Andrews	Desalination	2020	$6,717,000
City of Bronte Village	Rehabilitation Of Pipeline	2010	$1,364,900
CRMWD	Desalination	2040	$131,603,990
CRMWD	Develop Cenozoic Aquifer Supplies	2030	$76,268,000
CRMWD	Replacement Well	2010	$10,440,000
CRMWD	Reuse	2020	$128,748,000
City of Eden	Advanced Treatment	2010	$2,582,000
City of Eden	Replacement Well	2010	$1,800,000
City of Menard	Develop Hickory Aquifer Supplies	2010	$1,684,000
City of Midland	Develop Cenozoic Aquifer Supplies	2030	$168,507,000
City of Robert Lee	New WTP And Storage Facilities	2010	$2,436,000
City of San Angelo	Desalination	2040	$75,440,000
City of San Angelo	Develop Hickory Aquifer Supplies	2010	$173,307,000
City of San Angelo	Rehabilitation Of Pipeline	2030	$6,157,000
City of Winters	Reuse	2020	$2,158,000
TOTAL			**$789,212,890**

9.3 Summary of Responses to Surveys

Three of the nine entities surveyed responded. Those entities were CRMWD, the City of San Angelo, and the City of Midland. The City of Midland responded that they would not be seeking state funding for their project. The City of San Angelo and CRMWD both responded that they plan to seek state assistance for 100 percent of their projects. The total funding required for these two entities would be $601,963,990, which is about 76 percent of the total costs ($789,212,890) for recommended strategies in Region F.

10 PLAN ADOPTION AND PUBLIC PARTICIPATION

This section describes the plan approval process for the Region F Water Plan and the efforts made to encourage public participation in the planning process. During the development of the regional water plan special efforts were made to inform the general public, water suppliers, and others with special interest in the planning process and to seek their input.

10.1 Regional Water Planning Group

As part of SB1 regional water planning groups were formed to guide the planning process. These groups were comprised of local representatives of eleven specific interests:

- General public
- Counties
- Municipalities
- Industrial
- Agricultural
- Environmental
- Small businesses
- Electric generating utilities
- River authorities
- Water districts
- Water utilities

Table 10.1-1 lists the voting members of the Region F Water Planning Group, the interests they represent, and their counties. The Region F Water Planning Group also has non-voting members to represent counties that are not otherwise represented by voting members. Table 10.1-2 lists the non-voting members. The Region F Water Planning Group held regular meetings during the development of the plan, receiving information from the region’s consultants and making decisions on planning efforts. These meetings were open to the public, and proper notice was made under SB1 guidelines.

Table 10.1-1
Voting Members of the Region F Water Planning Group

Name	Interest	County
Len Wilson	Public	Andrews
Wendell Moody	Public	Concho
Jerry Bearden (Ret)	Counties	Mason
Robert Moore	Counties	Runnels
Will Wilde	Municipalities	Tom Green
Merle Taylor	Municipalities	Scurry
John Shepard	Municipalities	Winkler
Buddy Sipes (Ret) Ben Shepperd	Industries	Midland
Kenneth Dierschke	Agricultural	Tom Green
Terry Scott	Agricultural	Coleman
Woody Anderson	Agricultural	Mitchell
Steven C. Hofer (Ret)	Environmental	Midland
Caroline Runge	Environmental	Menard
Stuart Coleman(Ret) Charles Hagood	Small Business	Brown Kimble
Tim Warren	Elec. Gen. Util.	Mitchell
Stephen Brown	River Authorities	Tom Green
John Grant	Water Districts	Howard
Scott Holland	Water Districts	Irion
Paul Weatherby	Water Districts	Pecos
Larry Turnbough	Water Districts	Reeves
Richard Gist	Water Utilities	Brown

(Ret) – Retired during this planning cycle.

Table 10.1-2
Non-Voting Members of the Region F Water Planning Group

Name	County
Winton Milliff	Coke
Tom Hoysa	Coleman
Gordon Hooper	Crane
Debbie McReynolds	Ector
Rick Harston	Glasscock
Todd Darden	Howard
Billy Hopper	Loving
Ken Carver (Ret)	Martin
Don Daniel	Mason
Jill Reed	Midland
Sue Young	Mitchell
Michael McCulloch	Pecos
Cindy Weatherby	Reagan
Gary Foster	Sterling
Joe David Ross	Sutton
Lynn Halfmann John Evridge	Upton

(Ret) – Retired during this planning cycle.

10.2 Outreach to Water Suppliers, Water User Groups and Adjacent Regions

The Region F Water Planning Group made special efforts to contact municipalities, water districts, and rural water supply corporations and others in the region and obtain their input in the planning process. Much of this outreach was conducted as part of the development of the special studies during the first biennium of the planning cycle. Outreach included both questionnaires and meetings with selected water user groups and wholesale water providers. The questionnaires sought information on water use projections, current sources of water and supplies, drought planning, water quality issues, water management strategies, and other water supply issues. Particular emphasis was placed on receiving input from water user groups with water supply needs.

Region F continued to coordinate with Region K regarding water supply in the Colorado River Basin and coordinated with water users in adjacent basins that receive water from Region F.

10.3 Outreach to the Public

The public were given opportunities to participate throughout the regional water planning process, including the following:

- Regional water planning group meetings held throughout the planning process presented opportunities for dissemination of information to the public and receiving public comments. Notices for the meetings were posted in accordance with TWDB rules.
- A website specific to Region F was developed to provide information on the planning process to the public and planning group members.
- During the special study interim period the special study workgroups held meetings open to the public
- Scope of Work, meeting minutes and other information were available on the Region F and TWDB websites.

10.4 Public Meetings and Public Hearings

As required by SB1 rules, the Region F Water Planning Group held an initial public hearing to discuss the planning process and the scope of work for the region on April 28, 2008. Presentations were made on the planning process and input was solicited from participants. Public meetings were held approximately every quarter throughout the planning process.

On May 26, 2010 copies of the *Initially Prepared Region F Water Plan* were mailed to Region F county courthouses and libraries for public review. Copies of the Initially Prepared plan were also posted on the Region F website. Notices of the upcoming public meetings were sent to the Secretary of State, county clerks, county judges, regional legislators, groundwater and irrigation districts, and regional newspapers along with a description of how to obtain copies of the draft plan for review.

On June 28, 2010, the Region F Water Planning Group held a public hearing in Big Spring to present the draft *Initially Prepared Region F Water Plan* and seek public input. Oral comments were received following the presentation and written comments were accepted through August 28, 2010. There were no oral comments at the public hearing. Public comments received during the comment period are documented in Appendix 10A. Where appropriate, modifications to the plan were made and incorporated into the adopted *Regional Water Plan*. Responses to the public comments are also included in Appendix 10A.

10.5 Comments from State and Federal Agencies

Appendix 10B contains comments on the *Initially Prepared Region F Water Plan* from the Texas Water Development Board and the Texas Parks and Wildlife Department. No other comments were received from other state or federal agencies. Responses to agency comments are documented in Appendix 10B. Where appropriate, modifications to the plan were made and incorporated into the adopted *Region F Water Plan*.

10.6 Plan Implementation Issues

Implementation issues identified for the Region F *Regional Water Plan* include: 1) financial issues associated with paying for the proposed capital improvements, 2) additional studies associated with subordination of Colorado Basin water rights, and 3) implementation of conservation measures that were assumed in this plan.

10.6.1 Financial Issues

It is assumed that the entities for which strategies were developed will utilize existing financial resources, incur debt through bond sales and/or receive state-supported financial assistance. Most likely the funding of identified strategies will increase the cost of water to the customers. The economic feasibility to implement the strategies will depend on the cost increases the customer base can assume. Some strategies may not be able to be implemented without state assistance.

10.6.2 Additional Water Rights Studies in the Colorado Basin

The subordination strategy described in Section 4.2.3 is intended as an interim solution to water rights issues associated with use of the TCEQ Colorado WAM for regional water planning. The results are for planning purposes only. Additional studies will be required to clarify water rights issues in the Colorado Basin.

10.6.3 Water Conservation

Water conservation practices evaluated in this plan are based on rule-of-thumb information, primarily based on the experience in other states. Data collected as part of the special study on municipal conservation found that cities in Region F are implementing conservation measures, but it is difficult to quantify savings. Savings associated with irrigation conservation are based on estimated conversion rates that must be implemented by the irrigator. There is no confirmation that irrigation water saved will be available for future use. Experience during the recent droughts has demonstrated that significant savings can be made through water conservation and drought management. However, without specific data, it is difficult to quantify the potential long-term savings for water conservation activities and rely on these savings to meet future needs.