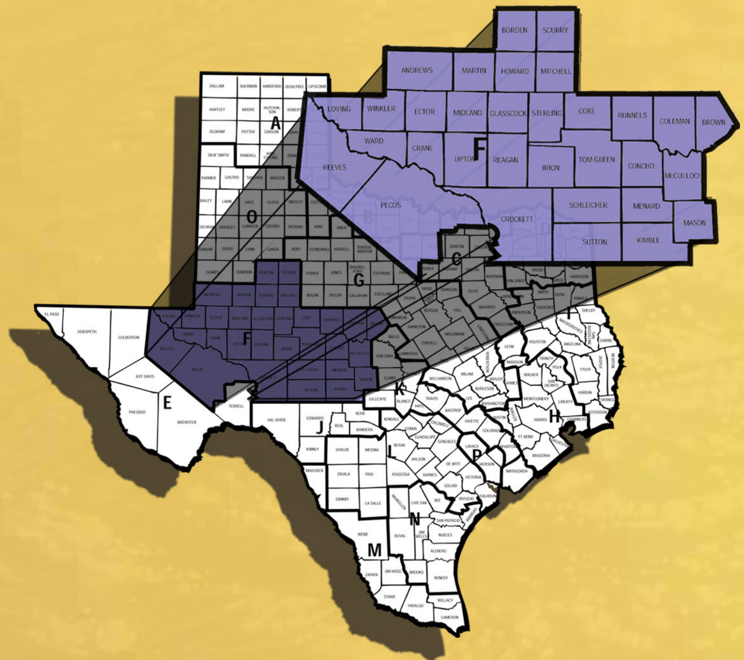
Region F
Regional Water Plan - Main Report



Freese and Nichols, Inc.
Alan Plummer Associates, Inc.
LBG - Guyton Associates, Inc.

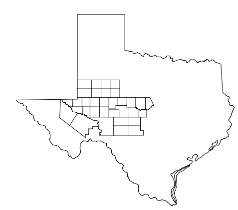
January 2006

Region F Water Plan

January 2006

Prepared for:

Region F Water Planning Group



Jon S. Albright

Prepared by:

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CMD01311

Region F Water Planning Group

Chair	John Grant	At-Large	Richard Gist
Vice-Chair	Steven C. Hofer	At-Large	Stephen Brown

Voting Membership

Interest Group	Member	Representing
Agriculture	Kenneth Dierschke	Tom Green County
	Terry Scott	Coleman County
	Lowell Woodward	Pecos County
Counties	Marilyn Egan	Runnels County
	Johnny Jones	Crockett County
Electric Generating Utilities	Andrew Valencia	Texas Utilities
Environmental	Steven C. Hofer	Midland County
	Caroline Runge	Menard County
Industries	Buddy Sipes	Midland County
Municipalities	Will Wilde	San Angelo Utilities
Public	Len Wilson	Andrews County
	Wendell Moody	Concho County
River Authority	Stephen Brown	Upper Colorado River Authority
	John Grant	Colorado River MWD
Small Business	Stuart Coleman	Coleman Distributing
Water Districts	Cindy Cawley	Plateau UWCD
	Larry Turnbough	Reeves County
	Scott Holland	Irion County WCD
Water Utilities	Richard Gist	Zephyr WSC

Non-Voting Membership

Don Daniel	Mason County	Winton Milliff	Coke County
Gordon Hooper	Crane County	Joe David Ross	Sutton County
Gary Foster	Sterling County	John Sheppard	Winkler County
Rick Harston	Glasscock County	Cindy Weatherby	Reagan County
Billy Hopper	Loving County	Ken Carver	Martin Count
	Sue Young	Mitchell County	

Harvey Everheart	Region O	Kathy Webster	Region G
Bob Stovell	Region E		
Ruben Cantu	Texas Parks & Wildlife Department	Kit Owens	Texas Commission on Environmental Quality
Mark Henkhaus	Texas Railroad Commission	Sherry Cordry	Texas Water Development Board

REGION F WATER PLAN

January 5, 2005

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Appendices

EXECUTIVE SUMMARY

This report presents the *Region F Water Plan* developed in the second 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 Region F water plan was developed under the direction of the 21-member Region F Water Planning Group. An initially prepared plan was presented for review by the public and state and federal agencies. Following a public hearing and comment period, the plan was amended based on comments received from the public and state agencies. The final plan was adopted by the Region F Water Planning Group on November 28, 2005 and submitted to the Texas Water Development Board in early January 2006.

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

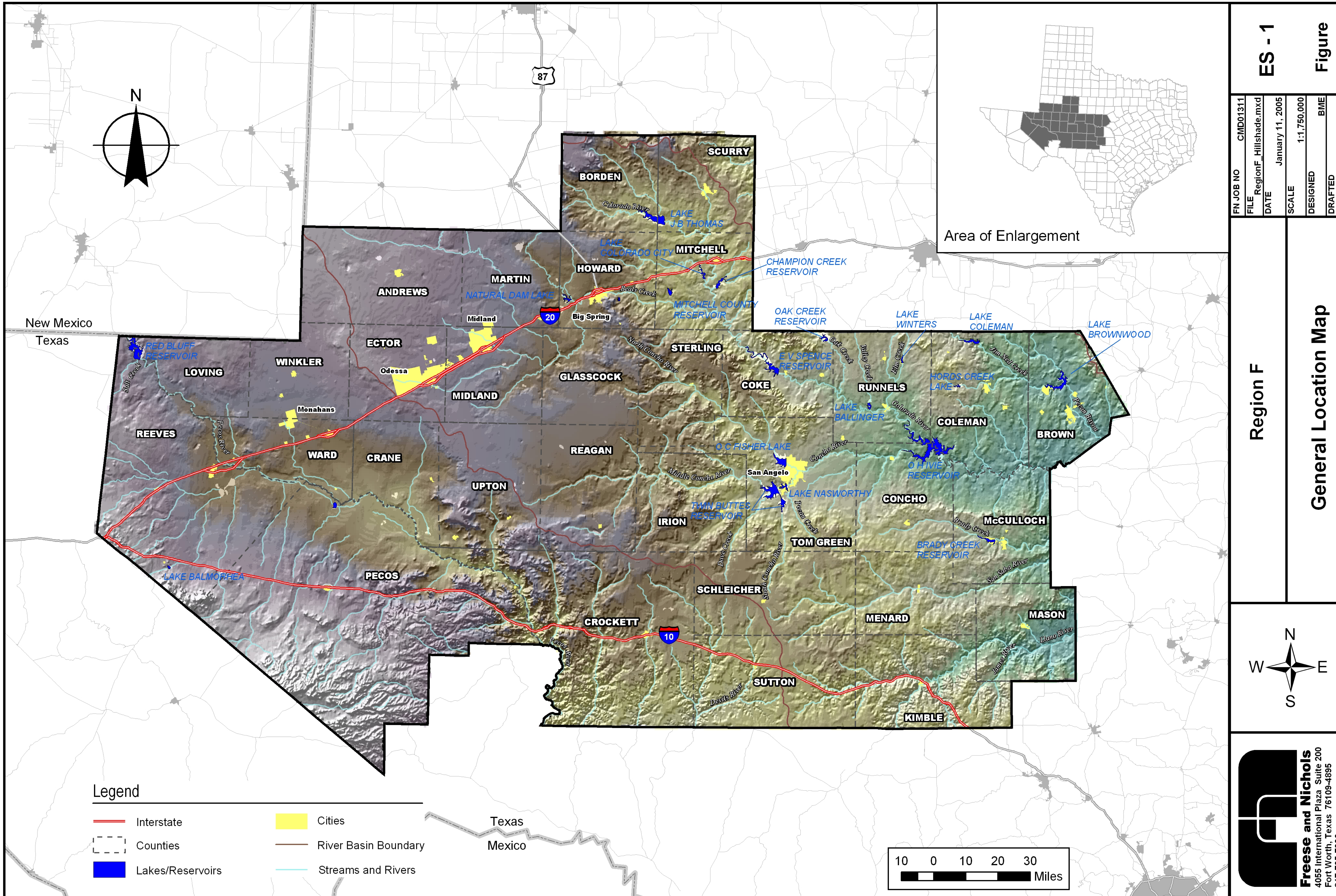


Figure
ES - 1
FN JOB NO CMD01311
FILE RegionF_Hillshade.mxd
DATE January 11, 2005
SCALE 1:1,750,000
DESIGNED BME
DRAFTED BME
Region F
General Location Map
Freese and Nichols
4055 International Plaza Suite 200
Fort Worth, Texas 76109-4895
817-735-7300
Area of Enlargement
N
New Mexico
Texas
Mexico
87
20
10
SCURRY
BORDEN
MITCHELL
HOWARD
MARTIN
ANDREWS
ECTOR
WINKLER
LOVING
MIDLAND
GLASSCOCK
STERLING
COKE
RUNNELS
COLEMAN
BROWN
REEVES
WARD
CRANE
UPTON
REAGAN
IRION
TOM GREEN
CONCHO
McCULLOCH
PECOS
SCHLEICHER
CROCKETT
MENARD
MASON
SUTTON
KIMBLE
Big Spring
Midland
Odessa
Monahans
San Angelo
LAKE J B THOMAS
LAKE COLORADO CITY
CHAMPION CREEK RESERVOIR
NATURAL DAM LAKE
MITCHELL COUNTY RESERVOIR
OAK CREEK RESERVOIR
LAKE WINTERS
LAKE COLEMAN
LAKE BROWNWOOD
RED BLUFF RESERVOIR
E V SPENCE RESERVOIR
HORDS CREEK LAKE
LAKE BALLINGER
O C FISHER LAKE
O H IVIE RESERVOIR
LAKE NASWORTHY
TWIN BUTTES RESERVOIR
BRADY CREEK RESERVOIR
LAKE BALMORHEA
Colorado River
Pecos River
North Concho River
Middle Concho River
Concho River
Devils River
Llano River
San Saba River
Legend
Interstate
Counties
Lakes/Reservoirs
Cities
River Basin Boundary
Streams and Rivers
10 0 10 20 30
Miles
N
W
E
S

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 Grand Basin. A small portion of the region is in the Brazos Basin. Figure ES-1 shows the major streams in Region F. The 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 18 major water supply reservoirs that provide most of the regions' surface water supply. Four major aquifers and seven minor aquifers provide groundwater supplies to Region F.

ES.1.2 Water Use

Water use in Region F increased significantly between 1990 and 1995, primarily due to increases in irrigated agriculture. The total water use has decreased some since 1995. However, the year 2000 use was still 15 percent higher than the amount of water used in 1990. In the year 2000, Region F used 595,696 acre-feet of water. Approximately 66 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 the major reservoirs. Region F does not import a significant amount of surface water. However, Region F exports a significant amount of surface water to 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 70 percent of the water use 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

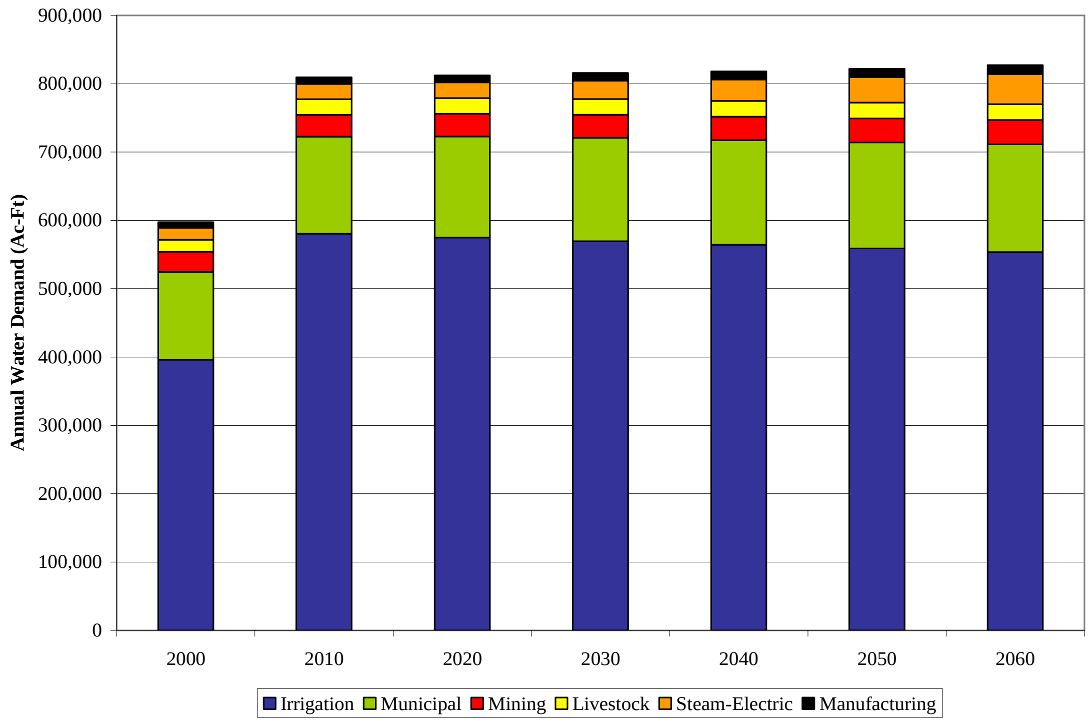
ES.2.1 Population Projections

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 included 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 595,696 acre-feet in the year 2000 and is projected to be 807,453 acre-feet in 2010 and 825,581 in 2060. The significant increase in water use between the historical year 2000 data and the year 2010 projections is due to irrigation demands. Region F believes that historical year 2000 water use for irrigation is not indicative of the potential for irrigation water use in the region. During the recent drought demand was suppressed because of low prices and reduced water supply. The adopted projections are an estimate of what the irrigation demand would 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, all surface water supplies in this chapter 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 allocates water based strictly 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 amount of water available 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). Groundwater availability is based on recharge plus a portion of the water in storage. The portion of groundwater available from storage is based on either management policies of the various groundwater conservation districts in the region, or on historical trends in areas with no groundwater conservation district.

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 609,000 acre-feet per year of water available to water users in the Region.

ES.2.4 Comparison of Supply and Demand

Figure ES-3 shows a comparison of supplies currently available 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 825,581 acre-feet per year, Region F has a shortage of almost 217,000 acre-feet per year by 2060.

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

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 supply, as well as the impacts on supply due to the Colorado WAM.

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

According to the comparison of supply and demand, Region F will face substantial shortages in water supply over the planning period. The Texas Water Development Board developed information on the potential socio-economic impacts of failing to meet projected water needs. The full report may be found in Appendix 4B. The TWDB's findings can be summarized as follows:

- Without implementing any water management strategies, the currently available supplies in Region F meet only 72 percent of the projected 2010 demand, decreasing to 69 percent by 2060.
- Without any water management strategies, the projected water needs would reduce the region's projected 2060 employment by 15,855 jobs, a reduction of 4.7 percent.
- Without any water management strategies, the projected water needs would reduce the region's projected annual income in 2060 by $962.72 million, a reduction of 4.9 percent.

Many of the shortages in supply are the results of the assumptions used in the Colorado WAM, which are explained in detail in Appendix 3D of this report. With implementation of the subordination strategy impacts of water shortages for municipal and manufacturing demands are reduced substantially. Assuming subordination has been implemented has the following potential impacts:

- The currently available supplies in Region F meet 77 percent of the projected 2010 demand, decreasing to 73 percent by 2060.
- The projected 2060 employment loss is reduced from 15,855 jobs to 4,563 jobs because of subordination.
- The 2060 income loss is reduced from $962.72 million to $331.65 million because of subordination.

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. Almost every strategy suggested to the region during the planning process was analyzed.

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 106,000 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 in as part of this plan focus on efficient irrigation practices.

Much of the water conservation proposed for Region F is associated with steam-electric power generation. Region F identified alternative cooling technology that uses very little water as a means of reaching power generation goals. Alternative cooling technology is a water conservation strategy because it replaces a high water use technology, conventional steam-electric power generation, with a very low water use technology. Therefore this strategy is included in the total water conservation savings for the region.

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 approximately 38,000 acre-feet per year of new supplies by 2060, including new well fields, desalination and reuse. 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), reserves over 39,000 acre-feet of water for use in Region F. Over 20,000 acre-feet of existing supplies will be made available to other water users through voluntary redistribution of existing supplies. Overall, with all strategies in place, by 2060 the total available supply for Region F is approximately 846,500 acre-feet per year. Irrigation demands in 16 counties are not met with this plan due to limited water supplies and lack of cost effective strategies.

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 846,500 acre-feet per year of supplies proposed for 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	82,057	$43,152,601
Alternative Cooling Technology	24,306	$626,502,088
Desalination	16,221	$131,451,830
New Groundwater	31,860	$249,031,400
Infrastructure Improvements	2,406	$11,378,820
Reuse	12,710	$100,889,000
Subordination	39,106	$16,110,200
Voluntary Redistribution	20,484	$35,668,000
Other*	8,362	$24,157,784
Total	*237,512*	*$1,238,341,723*

* Includes brush control and bottled water programs

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

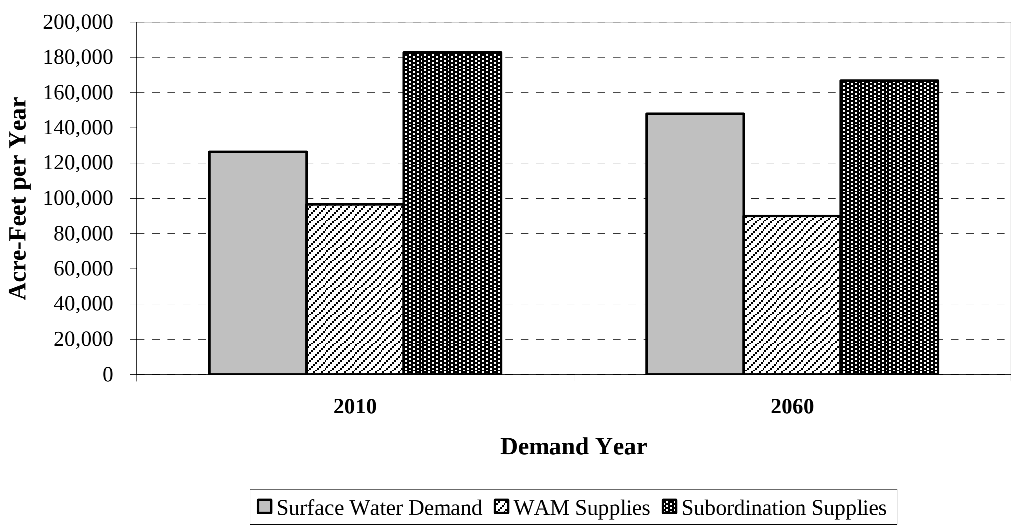
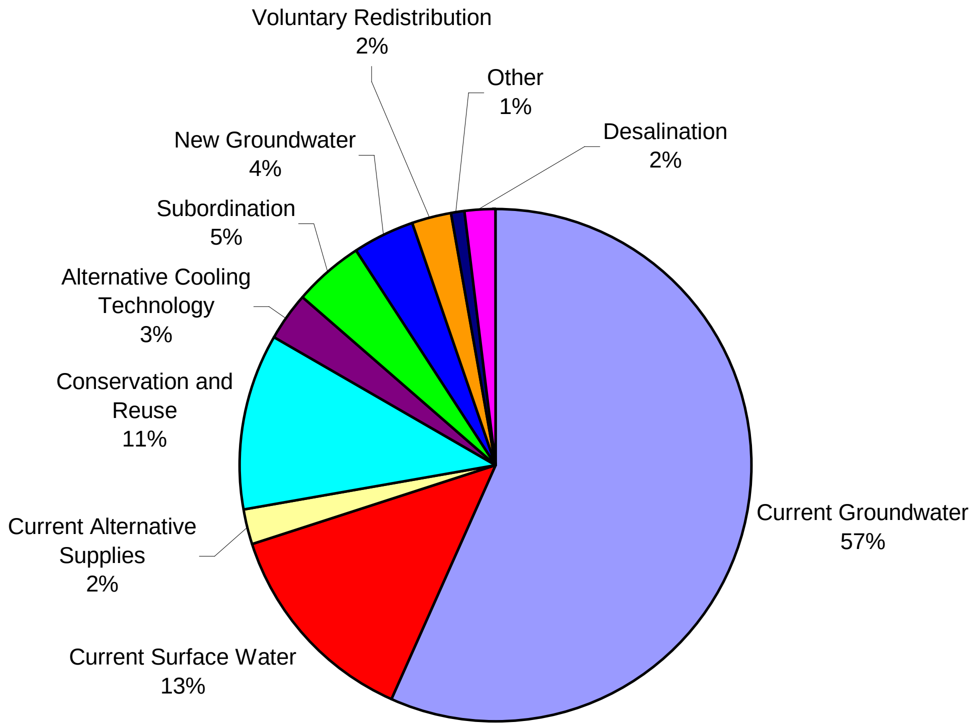


Figure ES-5
Current and Recommended Sources of Water Available to Region F as of 2060



1 DESCRIPTION OF REGION

In 1997, the 75th Texas Legislature passed Senate Bill One (SB1), legislation designed to address Texas water issues. With the passage of SB1, the legislature put in place a grass-roots regional planning process to plan for the water needs of all Texans in the next century. 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 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, *Water for Texas* 2002. SB1 calls for these plans to be updated every five years.

In 2001, the 77th Texas Legislature passed Senate Bill Two, which included the funding for the first update to the regional water plans. The TWDB refers to the current round of regional planning as SB1, Second Round. This report is the update to the 2002 Region F Plan and will become part of the basis for the next state water plan.

This section of the report is a description of Region F, one of the 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 section, 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

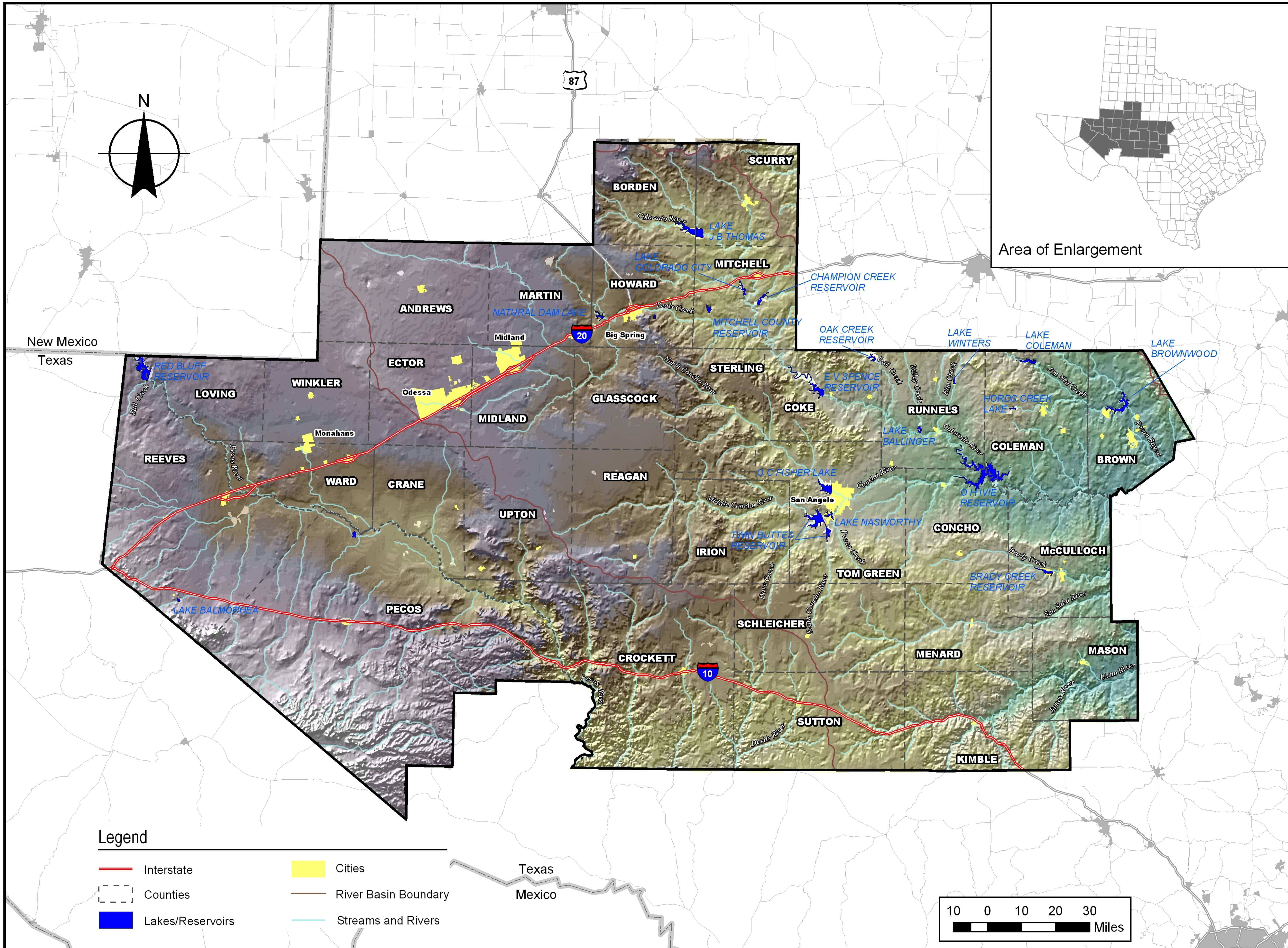


Figure 1.1-1

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DATE	January 11, 2005
SCALE	1:1,750,000
DESIGNED	BME
DRAFTED	BME

Region F

General Location Map

N W E S

Freese and Nichols
4055 International Plaza Suite 200
Fort Worth, Texas 76109-4895
817-735-7300

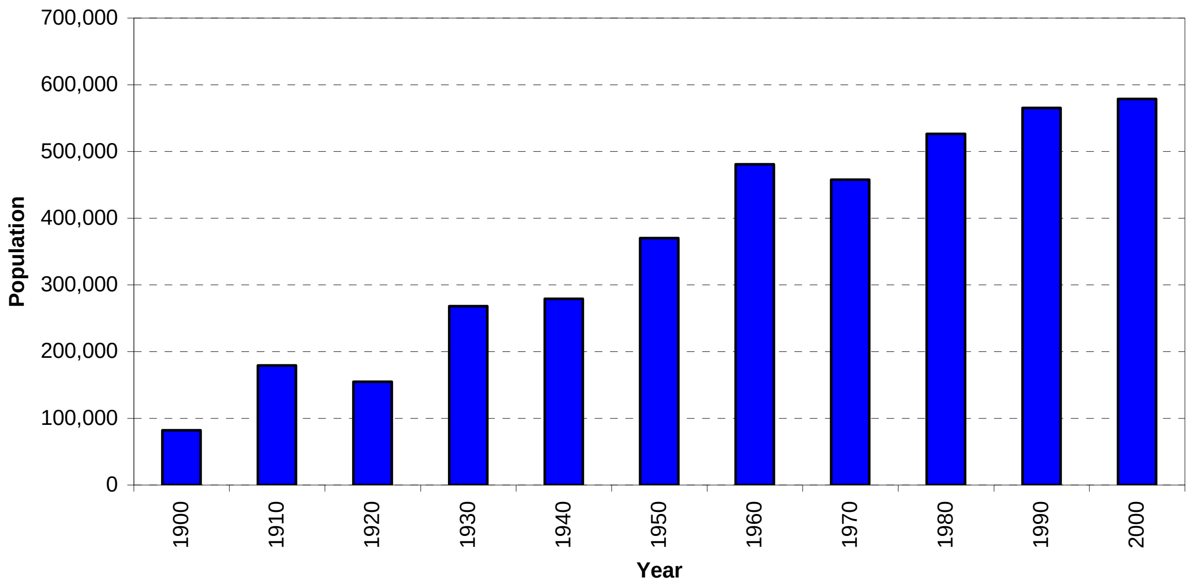
Table 1.1-1
Historical Population of Region F Counties

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

Notes:
a. Population data are from the U.S. Bureau of Census[1]
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 2000[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 578,814 in 2000. Since 1940, the region's population has increased at a compounded rate of 1.2 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 2000 population of more than 10,000. These cities included 57 percent of the population in Region F.

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Region F

Population Distribution by County (2000)

FN JOB NO	FILE	DATE	SCALE	DESIGNED	DRAFTED
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FIGURE 1.1-3

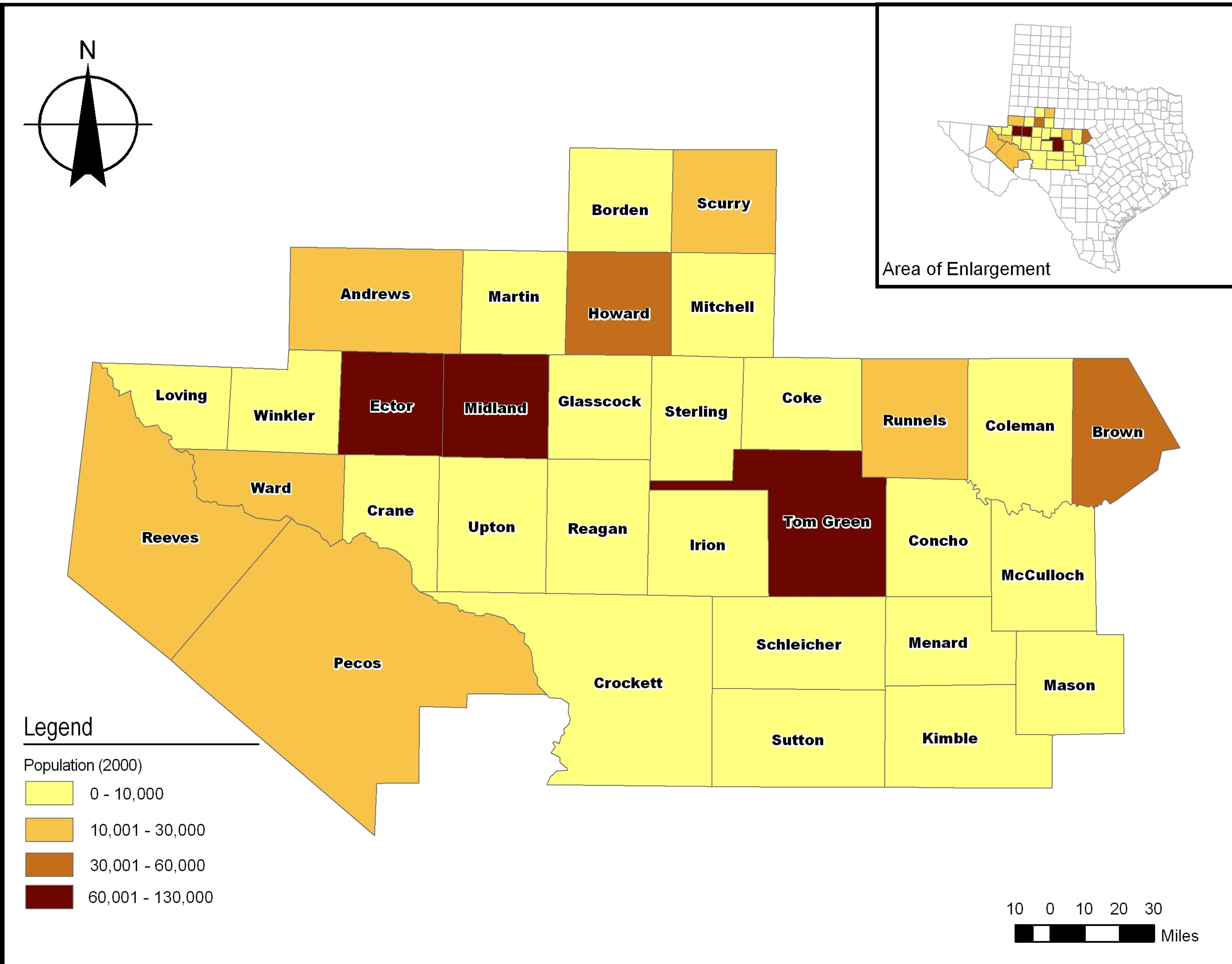

Table 1.1-2
Region F Cities with a Year 2000 Population Greater than 10,000

City	Year 2000 Population
Midland	94,996
Odessa	90,943
San Angelo	88,439
Big Spring	25,233
Brownwood	18,813
Snyder	10,783
Total	*329,207*

Data are from the TWDB[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 2002 payroll data for Region F by county and economic sector. Data for certain payroll information are only available on a state-wide basis and are not broken down by counties. One of these categories is mining, which includes the oil and gas industries, a significant economic sector in Region F.

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 75 percent of the payroll and 70 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 2002 are healthcare and social assistance, mining and manufacturing, which together account for 41 percent of the region's total payroll.

Table 1.1-3
2002 County Payroll by Category ($1000)

Category	Andrews	Borden	Brown	Coke	Coleman	Concho	Crane	Crockett
Forestry, Fishing, Hunting, and Agricultural Support	(N)	(N)	(D)	(N)	183	(N)	(N)	(N)
Mining	19,984	(D)	1,710	(D)	(D)	281	18,669	4,899
Utilities	601	(N)	3,392	(D)	1,455	(D)	(D)	459
Construction	5,048	(N)	11,038	398	2,280	(D)	1,339	2,327
Manufacturing	9,039	(N)	103,921	(D)	995	(D)	(D)	(N)
Wholesale Trade	2,081	(N)	12,027	(D)	1,024	(D)	389	492
Retail Trade	6,245	(D)	35,902	1,716	3,646	879	1,996	6,465
Transportation and Warehousing	2,270	(N)	1,321	(D)	1,307	(D)	694	982
Information	374	(N)	6,090	127	1,037	(D)	(D)	279
Finance and Insurance	3,338	(N)	10,681	1,108	4,001	1,051	340	(D)
Real Estate, Rental, and Leasing	270	(N)	1,417	(D)	297	(N)	(D)	(D)
Professional, Scientific and Technical Services	(D)	(N)	3,244	(D)	(D)	(D)	(D)	(D)
Management of Companies and Enterprises	(D)	(N)	(D)	(N)	(D)	(N)	(N)	(D)
Admin, Support, Waste Mgmt, Remediation Services	4,845	(N)	5,327	(D)	(D)	(D)	(D)	(N)
Educational Services	177	(D)	(D)	(D)	(D)	(D)	(D)	(D)
Health Care & Social Assistance	12,036	(N)	64,763	(D)	6,583	3,362	3,258	458
Arts, Entertainment, & Recreation	(D)	(N)	599	135	104	(D)	(N)	(D)
Accommodation & Food Services	1,842	(N)	10,595	188	1,362	549	297	1,621
Other Services	5,856	(N)	9,923	255	1,068	(D)	311	215
Total Payroll	*74,006*	*(D)*	*281,950*	*3,927*	*25,342*	*6,122*	*27,293*	*18,197*
Total Employees	*2,876*	*(N)*	*11,842*	*556*	*1,428*	*649*	*878*	*1,017*

Table 1.1-3 (cont.) 2002 County Payroll by Category ($1000)

Category	Ector	Glasscock	Howard	Irion	Kimble	Loving	Martin	Mason
Forestry, Fishing, Hunting, and Agricultural Support	(D)	(D)	(D)	(N)	(N)	(N)	(D)	(D)
Mining	68,491	(D)	16,103	2,836	(D)	(N)	(D)	(D)
Utilities	10,267	(N)	4,353	(D)	(D)	(N)	(D)	(D)
Construction	145,499	(D)	19,619	604	1,823	(N)	(D)	728
Manufacturing	154,211	(N)	39,486	(D)	9,532	(N)	(N)	(D)
Wholesale Trade	136,204	(D)	5,548	910	(D)	(N)	1,652	(D)
Retail Trade	138,317	(D)	27,513	(D)	3,663	(N)	2,789	1,187
Transportation and Warehousing	30,054	(N)	2,107	1,802	354	(N)	(D)	408
Information	23,391	(N)	4,557	(N)	(D)	(N)	(D)	(D)
Finance and Insurance	34,604	(D)	8,678	(D)	1,150	(N)	(D)	(D)
Real Estate, Rental, and Leasing	34,258	(N)	2,532	(D)	(D)	(N)	(N)	24
Professional, Scientific and Technical Services	40,741	(D)	2,807	(D)	(D)	(D)	(D)	(D)
Management of Companies and Enterprises	16,700	(N)	(D)	(N)	(D)	(N)	(D)	(N)
Admin, Support, Waste Mgmt, Remediation Services	37,513	(N)	18,151	(D)	(D)	(N)	(D)	(D)
Educational Services	5,062	(D)	(N)	(D)	(D)	(N)	(D)	(N)
Health Care & Social Assistance	171,575	(N)	82,966	(D)	1,251	(N)	3,905	1,794
Arts, Entertainment, & Recreation	5,531	(N)	586	(D)	(D)	(N)	(D)	(N)
Accommodation & Food Services	43,769	(N)	7,551	(D)	2,155	(N)	(D)	1,222
Other Services	48,528	(D)	7,486	91	1,276	(N)	499	646
Total Payroll	*1,144,715*	*(D)*	*250,043*	*6,243*	*21,204*	*(D)*	*8,845*	*6,009*
Total Employees	*41,306*	*120*	*9,926*	*262*	*1,148*	*(N)*	*575*	*580*

Table 1.1-3 (cont.) 2002 County Payroll by Category ($1000)

Category	McCulloch	Menard	Midland	Mitchell	Pecos	Reagan	Reeves	Runnels
Forestry, Fishing, Hunting, and Agricultural Support	(D)	(D)	293	440	(D)	(N)	(D)	(D)
Mining	(D)	(N)	293,099	(D)	9,899	9,009	3,328	1,272
Utilities	(D)	(D)	23,305	(D)	2,908	(D)	1,456	1,469
Construction	1,011	555	59,979	2,061	2,221	610	985	1,208
Manufacturing	7,138	(D)	46,971	(D)	1,964	(D)	(D)	27,807
Wholesale Trade	(D)	(D)	102,688	530	2,382	529	462	3,003
Retail Trade	6,621	751	120,690	4,114	10,435	1,553	11,116	5,949
Transportation and Warehousing	2,218	(N)	37,432	1,930	3,418	(D)	5,151	1,311
Information	444	(D)	31,220	376	1,326	(D)	873	371
Finance and Insurance	2,364	566	67,685	1,271	3,372	495	1,928	2,792
Real Estate, Rental, and Leasing	1,059	(D)	17,314	(D)	210	(D)	151	120
Professional, Scientific and Technical Services	1,606	(D)	98,245	(D)	(D)	(D)	1,999	1,115
Management of Companies and Enterprises	(N)	(N)	143,404	(N)	(N)	(N)	(N)	(D)
Admin, Support, Waste Mgmt, Remediation Services	182	(N)	46,950	(D)	(D)	(D)	(D)	559
Educational Services	(N)	(D)	12,051	(N)	(D)	(D)	(N)	(D)
Health Care & Social Assistance	6,000	(D)	183,708	7,365	10,564	(D)	5,697	7,511
Arts, Entertainment, & Recreation	(D)	(D)	12,951	(N)	(D)	(D)	237	64
Accommodation & Food Services	1,896	498	50,065	872	3,544	414	2,798	908
Other Services	1,172	58	51,957	780	3,611	673	858	1,626
Total Payroll	*31,711*	*2,428*	*1,400,007*	*19,739*	*55,854*	*13,283*	*37,039*	*57,085*
Total Employees	*1,837*	*254*	*46,328*	*1,129*	*2,824*	*695*	*2,650*	*2,735*

Table 1-3 (cont.) 2002 County Payroll by Category ($1000)

Category	Schleicher	Scurry	Sterling	Sutton	Tom Green	Upton	Ward	Winkler
Forestry, Fishing, Hunting, and Agricultural Support	(N)	(D)	(N)	(N)	1,187	(N)	(N)	(N)
Mining	6,738	25,442	2,511	17,208	19,255	8,186	13,800	7,684
Utilities	1,263	(D)	(D)	(D)	12,008	(D)	6,671	(D)
Construction	(D)	9,510	(D)	4,241	52,927	(D)	2,351	1,339
Manufacturing	(D)	4,224	(N)	(D)	136,195	(N)	351	(N)
Wholesale Trade	(D)	6,027	364	2,053	40,728	944	2,819	721
Retail Trade	918	11,354	(D)	2,933	108,477	1,429	5,037	2,885
Transportation and Warehousing	(D)	5,563	(D)	2,471	11,646	(D)	4,150	3,259
Information	(D)	1,582	(N)	105	115,103	(D)	591	246
Finance and Insurance	(D)	4,863	(D)	594	46,276	445	2,824	901
Real Estate, Rental, and Leasing	(D)	3,934	(D)	712	10,396	(N)	2,095	1,266
Professional, Scientific and Technical Services	(D)	(D)	(D)	(D)	42,050	(D)	1,934	(D)
Management of Companies and Enterprises	(N)	(D)	(N)	(D)	12,594	(N)	(D)	(D)
Admin, Support, Waste Mgmt, Remediation Services	(N)	452	(N)	102	35,397	(D)	(D)	(D)
Educational Services	(D)	(N)	(D)	(D)	3,649	(D)	(D)	(N)
Health Care & Social Assistance	(D)	13,276	290	1,124	200,763	2,827	4,994	3,585
Arts, Entertainment, & Recreation	(D)	292	(N)	412	4,976	(D)	(D)	(D)
Accommodation & Food Services	122	3,286	(D)	1,515	37,488	(D)	1,710	638
Other Services	327	5,283	134	(D)	31,250	92	1,811	1,830
Total Payroll	*9,368*	*95,088*	*3,299*	*33,470*	*922,365*	*13,923*	*51,138*	*24,354*
Total Employees	*605*	*4,215*	*214*	*1,196*	*35,429*	*658*	*2,019*	*1,102*

Notes: Data are from U.S. Census Bureau 2002 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 (2002)

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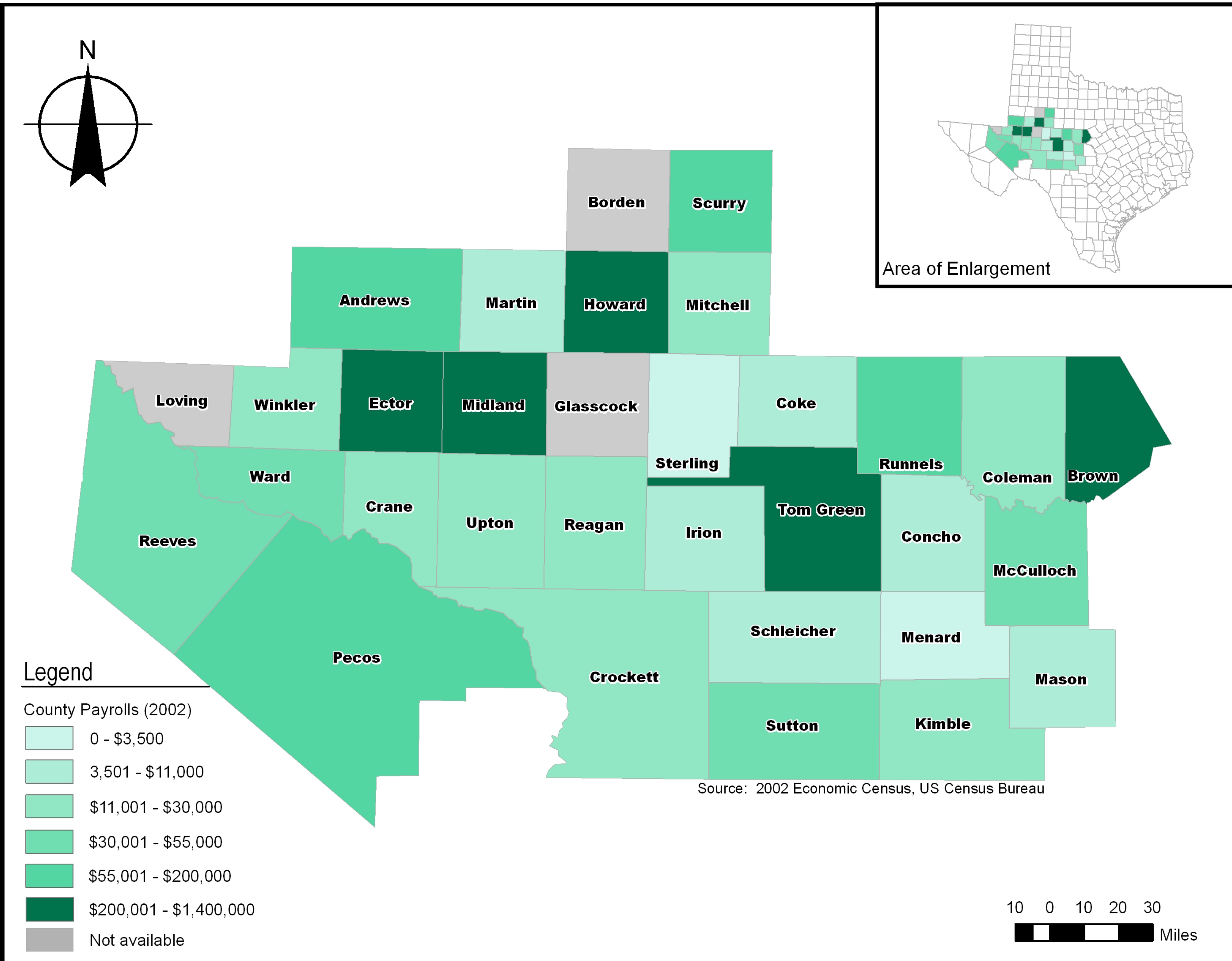
DATE	January 13, 2005
SCALE	1:2,446,400
DESIGNED	BME
DRAFTED	BME

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 west to east from slightly more than 10 inches per year in western Reeves County to more than 28 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 southeast to northwest[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 six gages[6].

Table 1.1-4 lists the 18 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.

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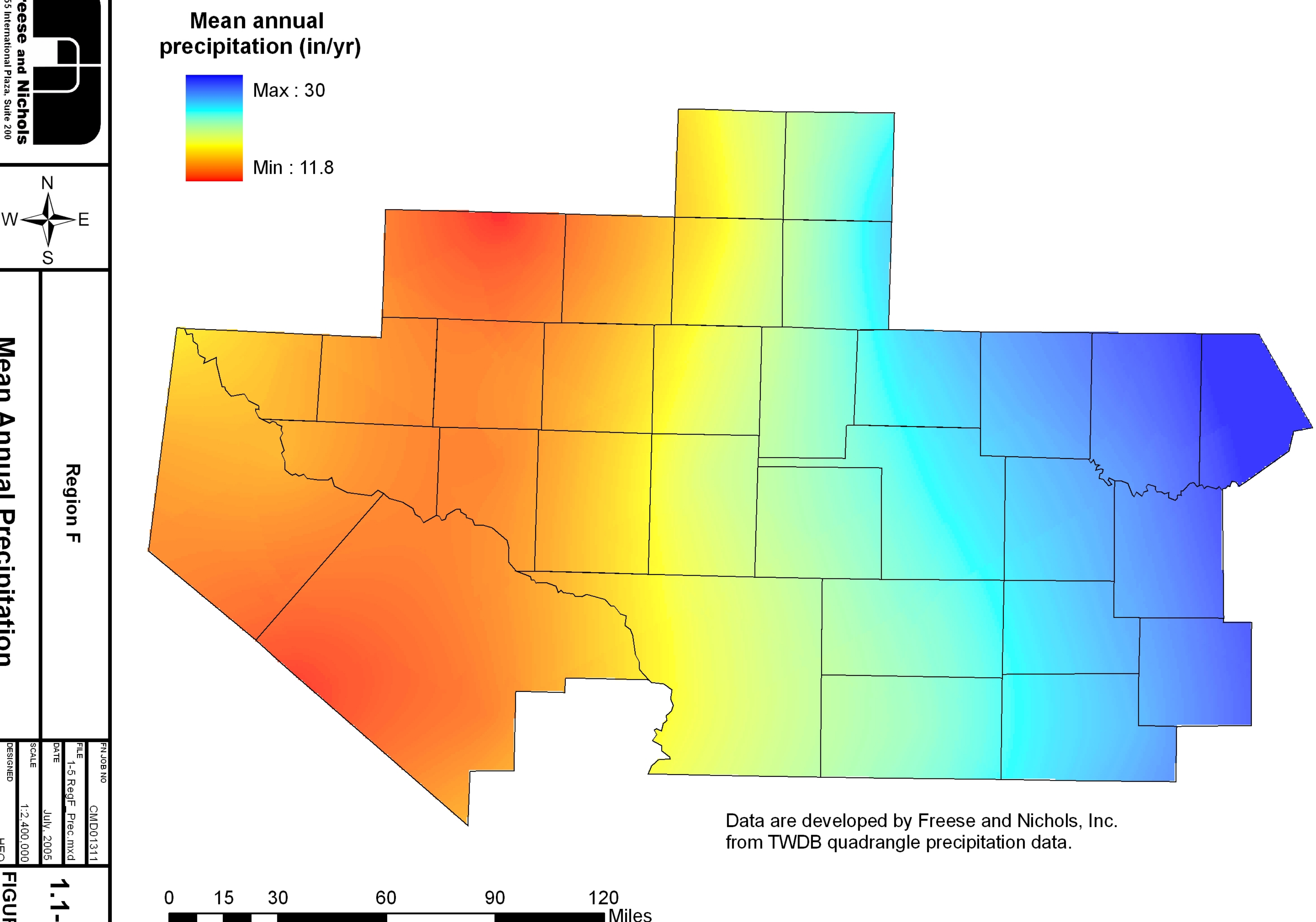
Mean Annual Precipitation

Region F



Data are developed by Freese and Nichols, Inc.
from TWDB quadrangle precipitation data.

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DESIGNED	HEO
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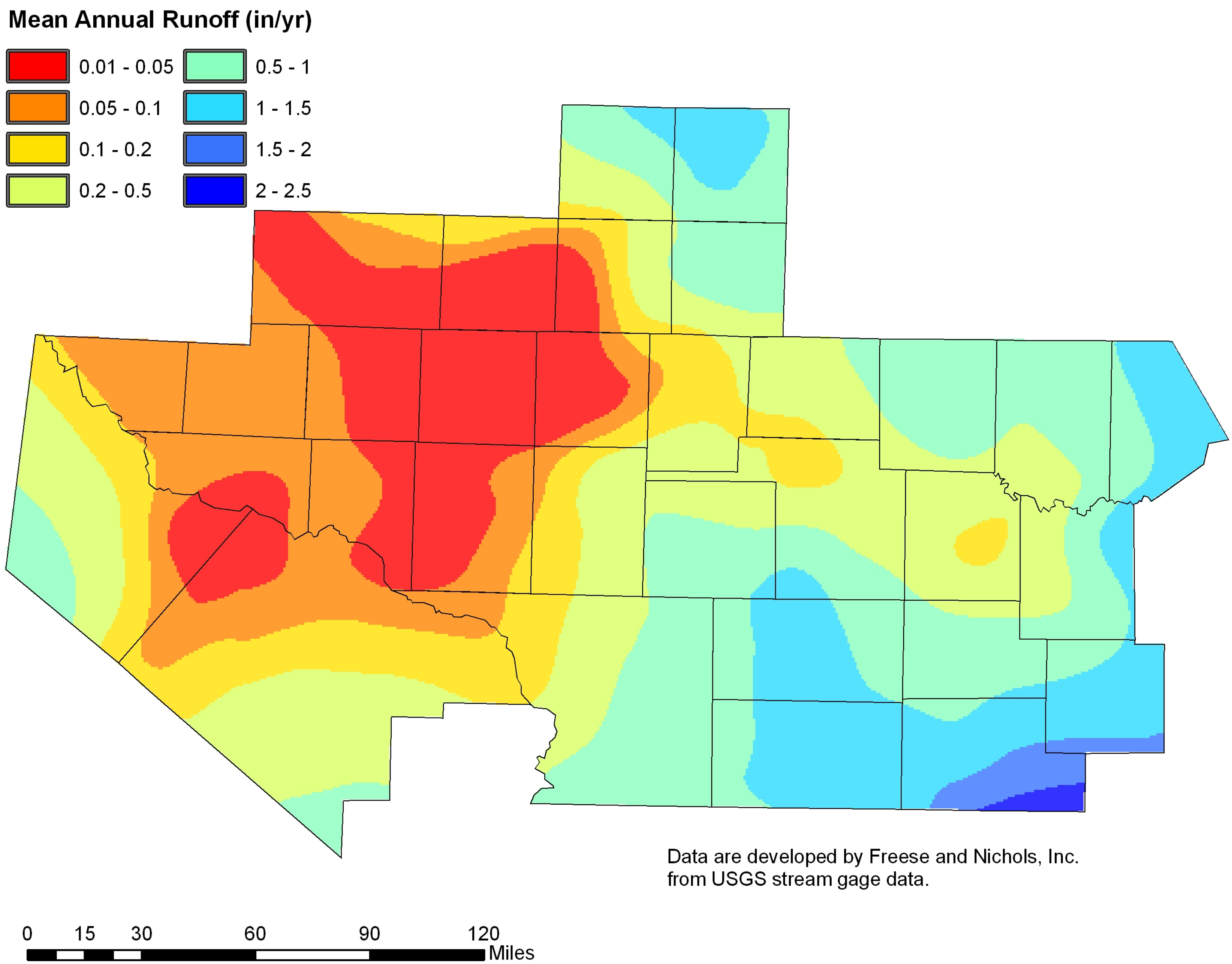
FILE	1-5 RegF_Prec.mxd
FN JOB NO	CMD01311

FIGURE 1.1-5



Data are developed by Freese and Nichols, Inc. from USGS stream gage data.

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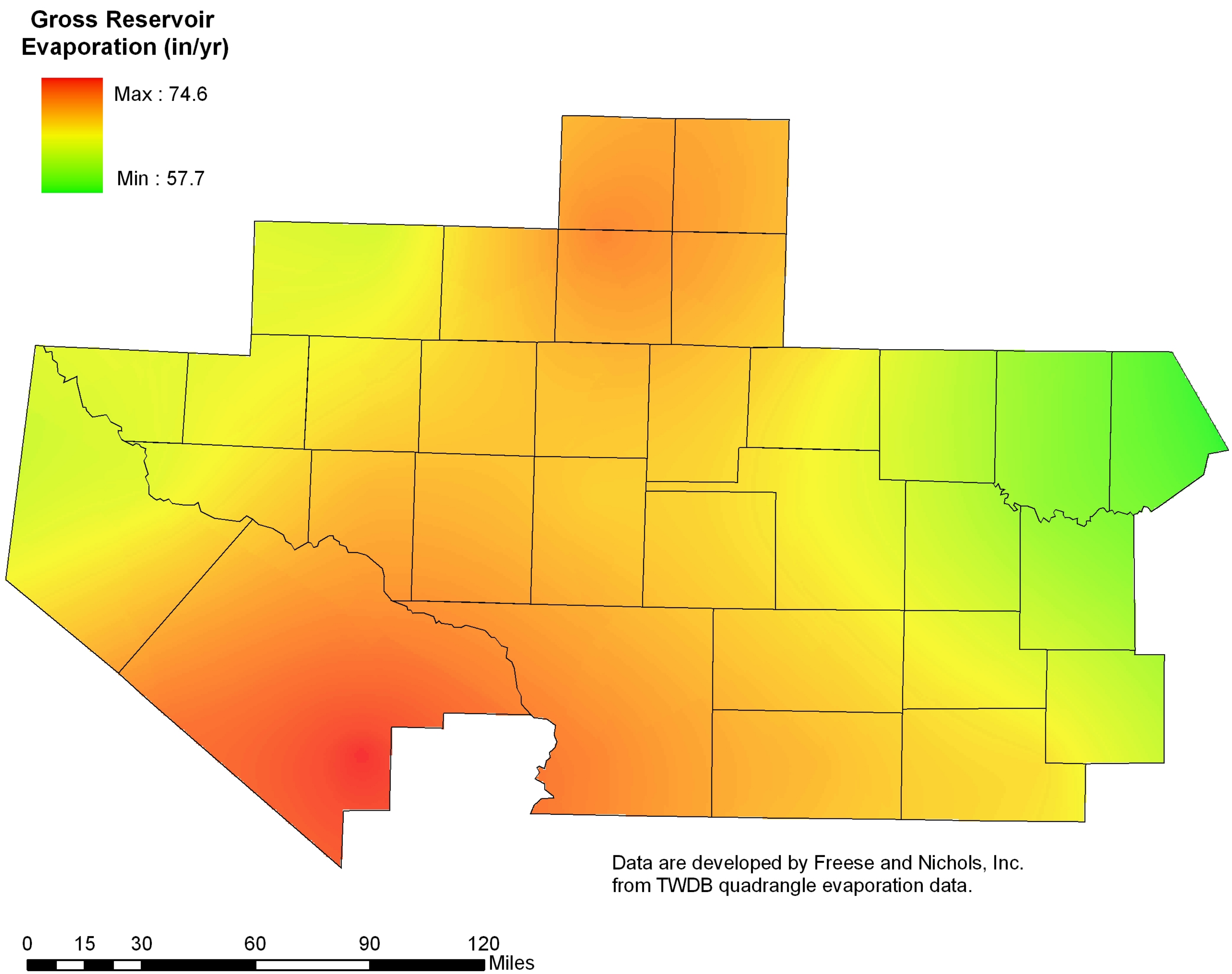
N
W E
S

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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N
W
E
S

Gross Reservoir Evaporation

Region F

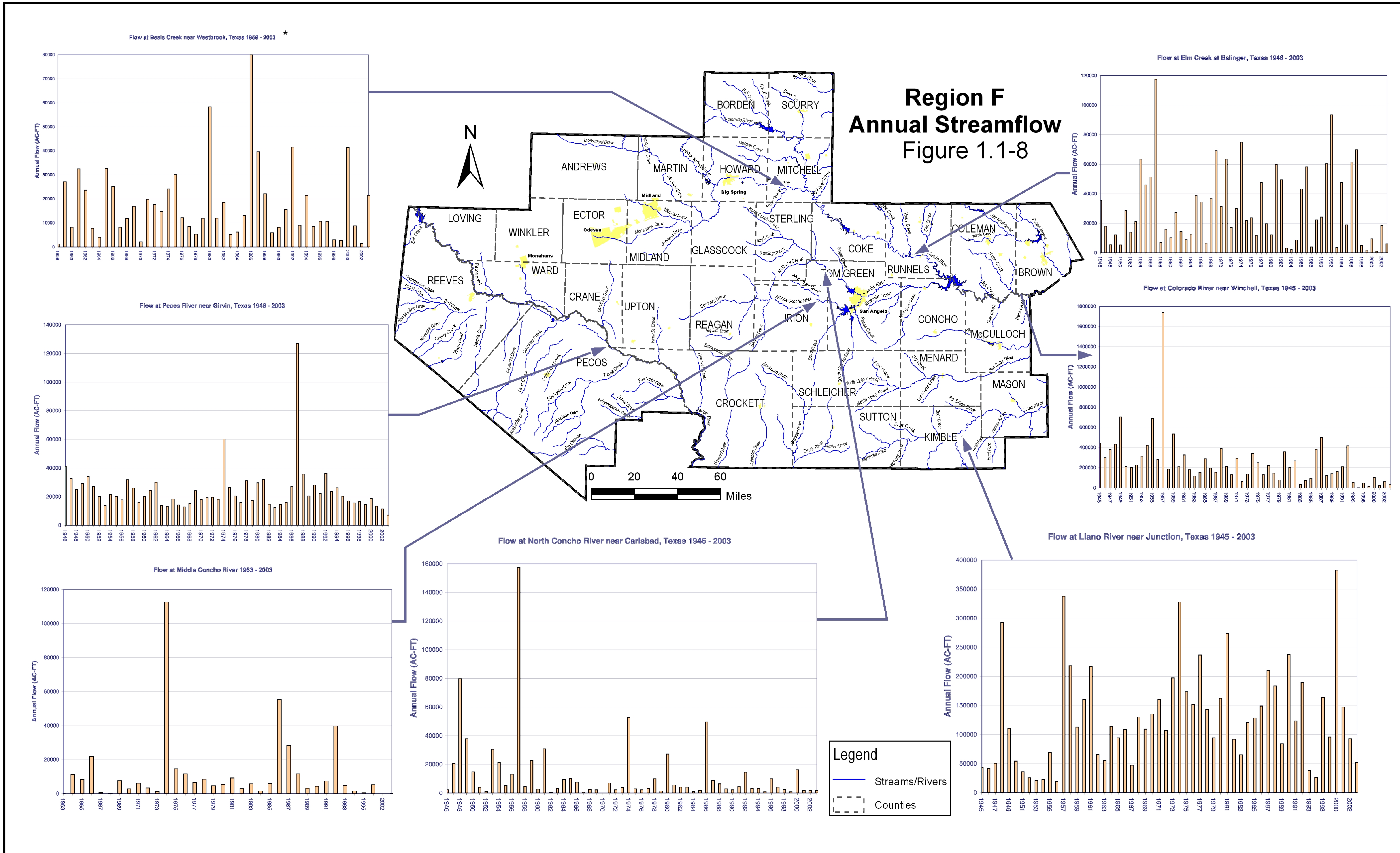
DRAFTED	DESIGNED	SCALE	DATE	FILE	FN JOB NO
HEO	HEO	1:2,400,000	July, 2005	1-7 RegF_Eva.mxd	CMD01311

FIGURE 1.1-7

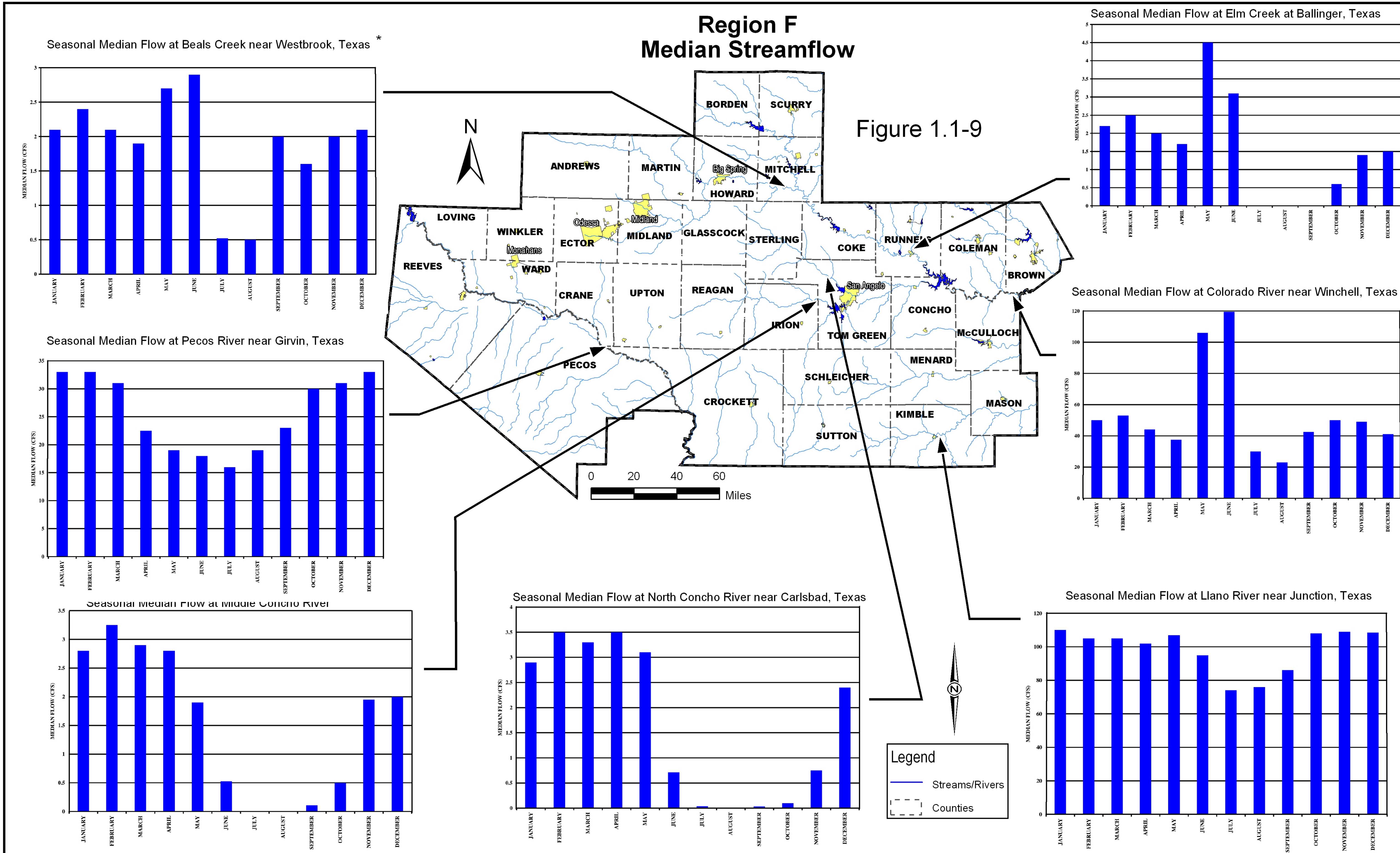
Table 1.1-4
Major Water Supply Reservoirs in Region F [a]

Reservoir Name	Basin	Stream	County(ies)	Water Right Number(s)	Priority Date	Permitted Conservation Storage (Acre-Feet)	Permitted Diversion (Acre-Feet per Year)	Year 2000 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]	13,560	CRMWD	CRMWD
Lake Colorado City	Colorado	Morgan Creek	Mitchell	CA-1009	11/22/1948	29,934	5,500	3,690 [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	4,309	City of Sweetwater	City of Sweetwater
Lake Coleman	Colorado	Jim Ned Creek	Coleman	CA-1702	08/25/1958	40,000	9,000	1,651	City of Coleman	City of Coleman
E V Spence Reservoir	Colorado	Colorado River	Coke	CA-1008	08/17/1964	488,760	50,000 [c]	10,932	CRMWD	CRMWD
Mitchell County Reservoir	Colorado	Off-Channel	Mitchell		02/14/1990	27,266				
Lake Winters	Colorado	Elm Creek	Runnels	CA-1095	12/18/1944	8,347	1,755	407	City of Winters	City of Winters
Lake Brownwood	Colorado	Pecan Bayou	Brown	CA-2454	09/29/1925	114,000	29,712	14,113	Brown Co. WID	Brown Co. WID
Hords Creek Lake	Colorado	Hords Creek	Coleman	CA-1705	03/23/1946	7,959	2,260	366	COE	City of Coleman
Lake Ballinger	Colorado	Valley Creek	Runnels	CA-1072	10/04/1946	6,850	1,000	842	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	47,837	CRMWD	CRMWD
O. C. Fisher Lake	Colorado	North Concho River	Tom Green	CA-1190	05/27/1949	119,000	80,400	2,201	COE	Upper Colorado River Authority
Twin Buttes Reservoir	Colorado	South Concho River	Tom Green	CA-1318	05/06/1959	186,000	29,000	NR	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	1,195	City of San Angelo	City of San Angelo
Brady Creek Reservoir	Colorado	Brady Creek	McCulloch	CA-1849	09/02/1959	30,000	3,500	272	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	69,743	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	9,677	Reeves Co WID #1	Reeves Co WID #1
Total						*2,185,443*	*692,400*	*180,429*		

a Data are from TCEQ active water rights list[10], TCEQ water rights permits[7], and TCEQ historical water use by water right[8]. Year 2000 Use is Consumptive Use.
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



* 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 1.2-1shows 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, Cenozoic Pecos Alluvium 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 1990 through 2000. (Year 2000 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 increased significantly between 1990 and 1995, primarily due to increases in irrigated agriculture. Total water use has decreased somewhat since the peak in 1995. However, year 2000 water use is still almost 13 percent higher than water use in 1990. Table 1.2-3 shows water use by category and county in 2000, and Figure 1.2-4 shows the distribution of water use by county in the region. About 66 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 2000 water use in Region F:

- The areas with the highest water use are Reeves, Pecos, Tom Green, Midland and Ector Counties, accounting for over half of the total water used in the region.
- 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 2000 these counties accounted for almost 60 percent of the water use in this category. Other significant municipal demand centers include Brown County (Brownwood) and Howard County (Big Spring).

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Major Aquifer Map

Region F

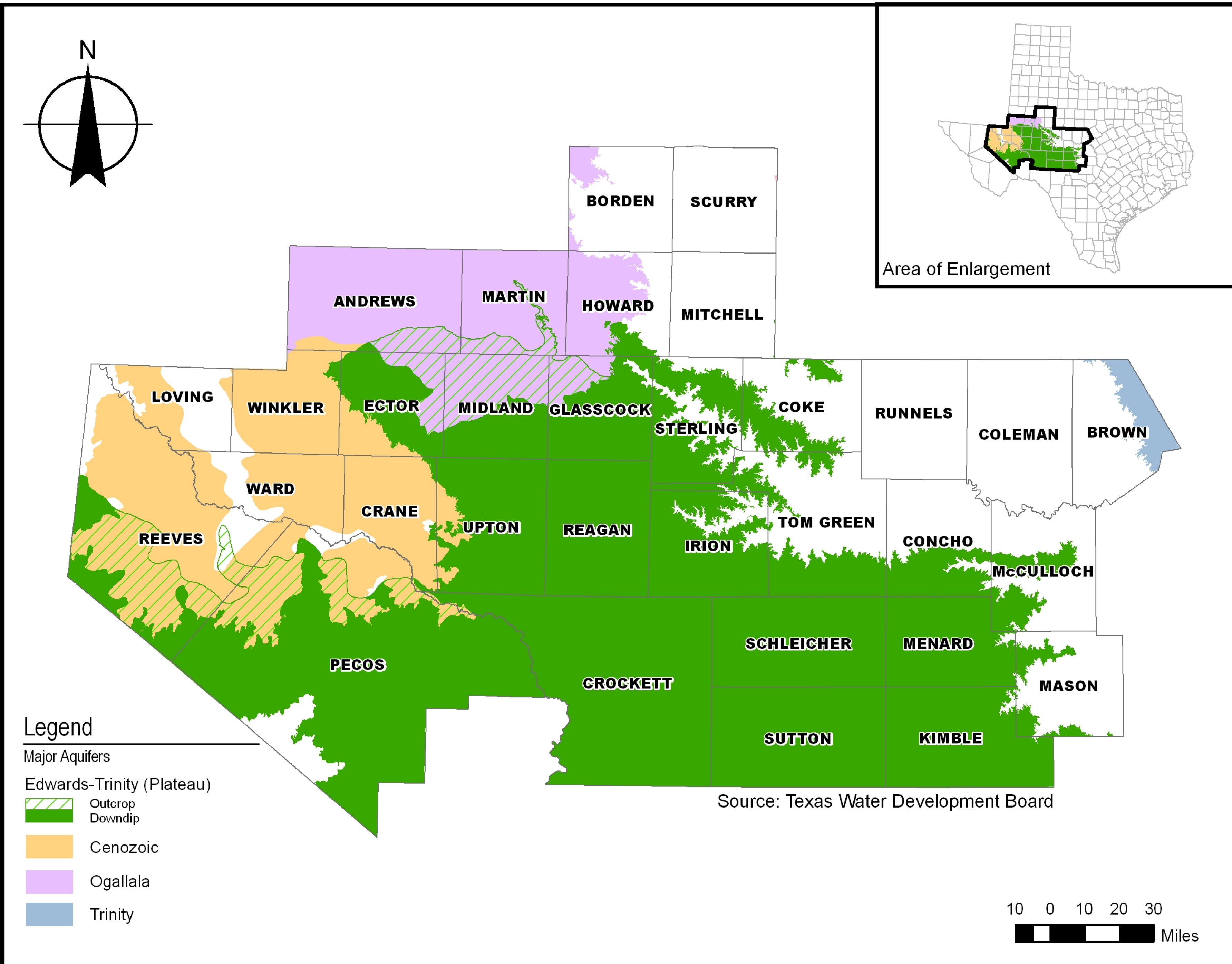

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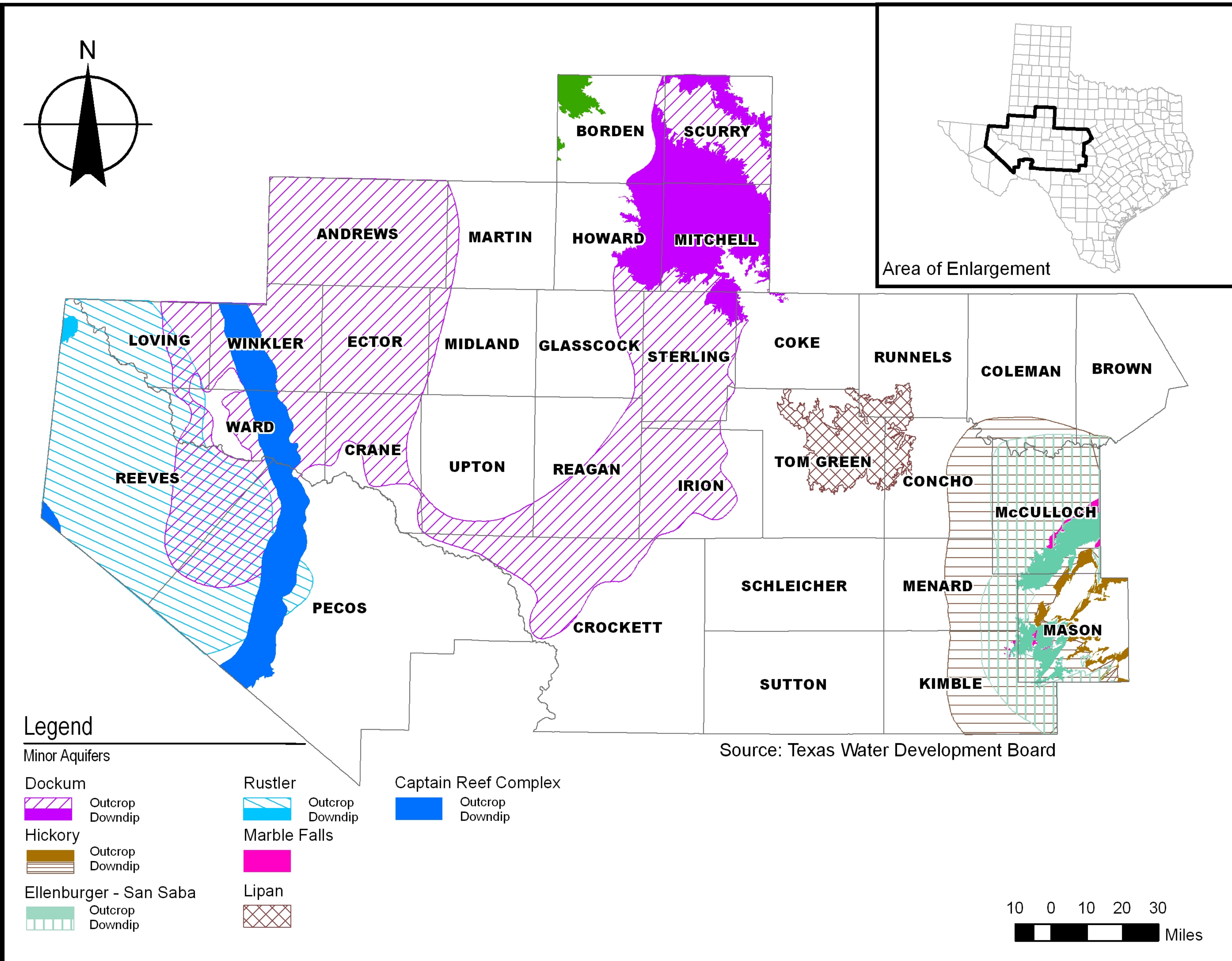
FIGURE 1.2-1



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Region F

Minor Aquifer Map

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DATE	June 27, 2005
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	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Andrews	15,177	15,098	16,163	18,350	26,971	22,424	20,988	23,139	18,901	17,633	38,356
Borden	1,153	1,866	1,913	2,307	2,543	3,095	6,505	11,071	4,096	3,547	3,187
Brown	11,053	10,923	10,949	20,722	21,320	24,350	23,121	23,456	27,286	26,161	21,375
Coke	2,333	2,216	2,226	2,799	2,545	2,610	2,788	2,347	3,434	2,525	2,845
Coleman	3,680	3,633	3,779	4,318	4,147	4,016	5,085	4,262	4,222	4,278	2,783
Concho	3,867	4,668	5,033	8,677	5,698	7,757	6,054	3,553	5,473	7,331	3,815
Crane	2,683	3,849	3,651	3,840	4,016	3,828	3,756	4,346	3,947	3,823	3,859
Crockett	4,760	4,801	4,526	4,864	4,820	4,718	4,424	4,032	4,929	4,761	4,032
Ector	35,275	41,673	37,882	40,200	41,659	40,207	42,034	39,242	32,072	32,258	40,501
Glasscock	27,545	36,116	25,139	39,885	58,429	69,096	55,551	52,825	62,642	24,920	35,828
Howard	12,826	14,153	14,068	13,764	15,477	15,706	12,906	14,923	16,129	17,467	15,035
Irion	3,528	3,559	3,544	3,921	3,915	2,836	3,630	3,558	2,493	2,285	2,724
Kimble	4,084	3,970	3,844	5,102	3,354	3,367	3,025	2,712	3,051	3,146	2,754
Loving	151	154	71	652	669	668	652	667	651	638	412
Martin	14,297	7,637	15,101	11,001	9,427	13,535	14,497	16,232	22,214	21,074	16,950
Mason	19,458	19,184	14,312	15,219	14,237	13,238	12,267	10,919	10,716	10,767	11,652
McCulloch	6,203	5,935	5,948	7,241	7,156	6,924	6,021	6,201	6,444	6,036	6,848
Menard	1,635	1,834	2,382	6,898	7,080	5,780	5,048	4,642	4,456	5,045	3,988
Midland	50,921	39,653	45,035	53,948	71,756	95,360	84,290	63,214	70,267	78,372	62, 155
Mitchell	7,459	7,289	6,376	6,720	6,323	5,648	7,386	6,202	7,206	8,610	18,156
Pecos	73,636	66,154	65,246	80,026	78,478	88,947	82,444	85,785	87,948	89,417	79,953
Reagan	39,945	35,153	27,315	26,946	34,080	46,120	46,866	49,463	67,271	23,456	18,769
Reeves	56,705	49,911	50,822	79,080	109,623	113,331	107,007	115,958	113,892	128,338	80,770
Runnels	5,665	8,114	5,570	8,370	6,924	7,986	11,427	9,200	7,975	5,957	3,499
Schleicher	2,233	2,345	2,556	2,836	3,222	2,794	3,010	2,971	3,869	4,405	3,474
Scurry	7,120	10,708	8,151	9,223	8,773	7,374	8,642	8,150	7,513	9,791	9,248
Sterling	1,886	2,139	2,225	1,906	1,958	1,894	1,880	1,918	1,966	1,939	1,886
Sutton	3,067	3,171	2,933	3,449	3,537	3,542	4,227	4,273	2,170	4,276	3,460
Tom Green	66,522	78,821	58,843	131,381	134,530	147,964	79,299	133,483	75,645	63,786	52,750
Upton	16,340	20,434	19,585	18,051	22,488	23,821	22,402	19,462	29,166	10,804	16,138
Ward	22,847	15,212	16,130	30,831	31,108	18,152	18,764	19,391	22,558	19,318	22,971
Winkler	3,176	5,786	5,763	4,430	4,425	3,874	3,796	3,651	3,868	3,411	5,523
Total	*527,230*	*526,159*	*487,081*	*666,957*	*750,688*	*810,962*	*709,792*	*751,248*	*734,470*	*645,575*	*595,696*

Note: Data are from the Texas Water Development Board[9].

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

Year	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining	Livestock	Total
1990	116,551	7,725	352,901	12,075	21,372	16,606	527,230
1991	118,390	7,205	337,813	13,309	32,331	17,111	526,159
1992	113,933	8,329	299,722	12,417	32,256	20,424	487,081
1993	118,009	8,386	471,551	13,933	34,799	20,279	666,957
1994	127,488	7,918	544,511	13,723	36,945	20,103	750,688
1995	125,566	8,241	613,020	12,593	31,410	20,132	810,962
1996	130,198	7,790	505,474	13,243	31,685	21,402	709,792
1997	121,510	7,581	556,928	13,379	31,892	19,958	751,248
1998	134,656	6,661	534,735	13,995	27,985	16,438	734,470
1999	131,308	6,429	448,573	13,840	27,985	17,440	645,575
2000	128,410	8,365	394,362	17,749	29,379	17,431	595,696
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[9]).

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

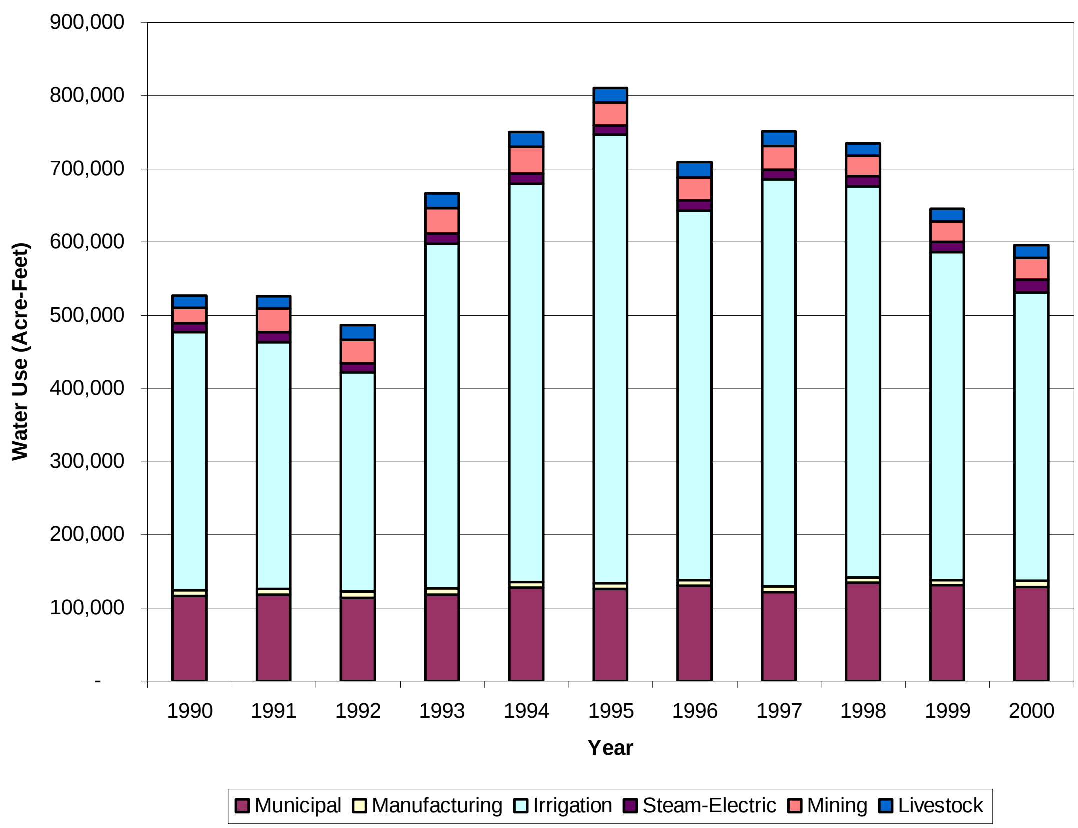
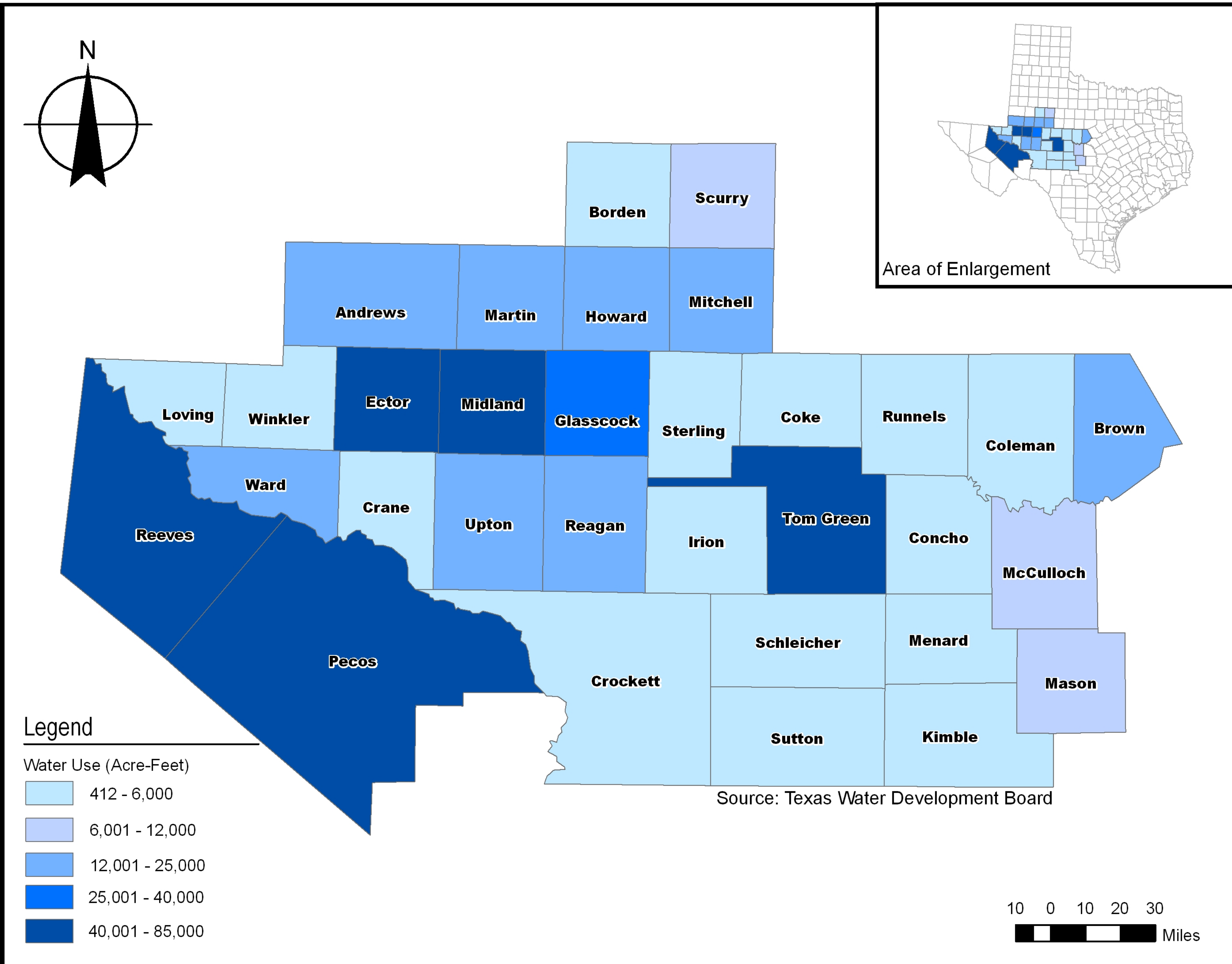


Table 1.2-3
Year 2000 Water Use by Category and County
(Values in acre-feet)

County	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining	Livestock	Total
Andrews	3,394	0	32,882	0	1,761	319	38,356
Borden	165	0	1,879	0	883	260	3,187
Brown	6,886	479	10,112	0	2,427	1,471	21,375
Coke	757	0	937	372	405	374	2,845
Coleman	1,623	5	0	0	16	1,139	2,783
Concho	699	0	2,574	0	0	542	3,815
Crane	1,138	0	337	0	2,240	144	3,859
Crockett	1,579	0	160	1,171	355	767	4,032
Ector	26,692	2,432	2,694	0	8,481	202	40,501
Glasscock	167	0	35,456	0	7	198	35,828
Howard	6,881	1,453	4,853	0	1,536	312	15,035
Irion	178	0	2,105	0	123	318	2,724
Kimble	972	582	637	0	91	472	2,754
Loving	11	0	358	0	3	40	412
Martin	645	34	14,575	0	845	851	16,950
Mason	889	0	10,223	0	6	534	11,652
McCulloch	2,266	680	2,859	0	140	903	6,848
Menard	427	0	3,143	0	0	418	3,988
Midland	30,627	135	30,483	0	515	395	62,155
Mitchell	1,728	0	5,564	10,280	141	443	18,156
Pecos	4,571	2	74,236	0	163	981	79,953
Reagan	923	0	15,879	0	1,742	225	18,769
Reeves	3,608	644	75,477	0	203	838	80,770
Runnels	1,550	52	920	0	41	936	3,499
Schleicher	671	0	2,150	0	105	548	3,474
Scurry	3,206	0	2,908	0	2,606	528	9,248
Sterling	324	0	637	0	560	365	1,886
Sutton	1,361	0	1,473	0	75	551	3,460
Tom Green	17,963	1,861	30,415	566	59	1,886	52,750
Upton	865	0	12,471	0	2,599	203	16,138
Ward	3,378	6	13,963	5,360	147	117	22,971
Winkler	2,268	0	2,002	0	1,104	149	5,523
Total	*128,412*	*8,365*	*394,362*	*17,749*	*29,379*	*17,429*	*595,696*

Note: Data are from the Texas Water Development Board[9].



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Region F

Water Use by County
(2000)

DRAFTED BME
DESIGNED BME
SCALE 1:2,401,000
DATE January 13, 2005
FILE RegionFWaterUse.mxd
FN JOB NO CMD01311

FIGURE 1.2-4

- Manufacturing water use is concentrated in Ector, Tom Green and Howard Counties, accounting for almost 70 percent of the total use in this category.
- Reeves and Pecos Counties accounted for most of the irrigation water use in 2000, accounting for more than a third of the irrigation water use in the region. Other significant demand centers for irrigation water include Glasscock, Andrews, Midland and Tom Green Counties.
- Steam-electric power generation water use occurred only in Mitchell, Ward, Crockett, Tom Green and Coke Counties.
- Most of the water used for mining purposes occurred in Ector County, accounting for almost 30 percent of the total use. Other significant areas of mining water use included Scurry, Upton, Brown, Crane, Andrews, Reagan, Howard and Winkler Counties.
- Most of the livestock water use occurred in Tom Green, Brown and Coleman Counties, accounting for slightly more than a quarter of the total use in this category in the year 2000.

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.

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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

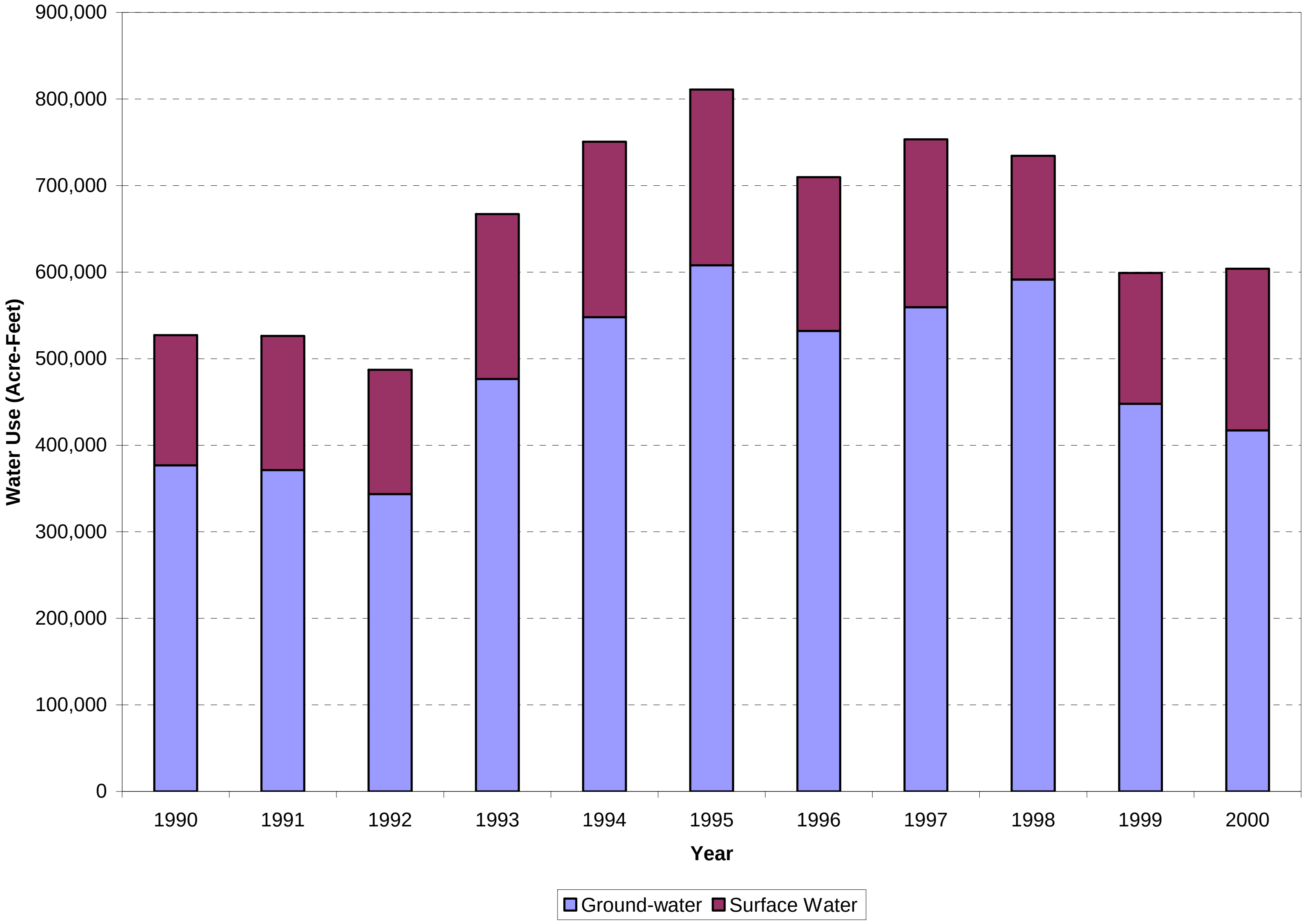
Table 1.3-1 summarizes the total surface water and groundwater use in Region F from 1990 through 2000[9], and Figure 1.3-1 graphically illustrates the same data. Total water use increased by 76,630 acre-feet (14.5 percent) between 1990 and 2000. Groundwater use increased by 40,288 acre feet (10.7 percent) and surface water use increased by 36,342 acre-feet (24 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 experienced with the current 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 2000, which is the most recent year for which data are available[9]. Figure 1.3-2 shows the percentage of supply from groundwater for each county in the region in the same year.

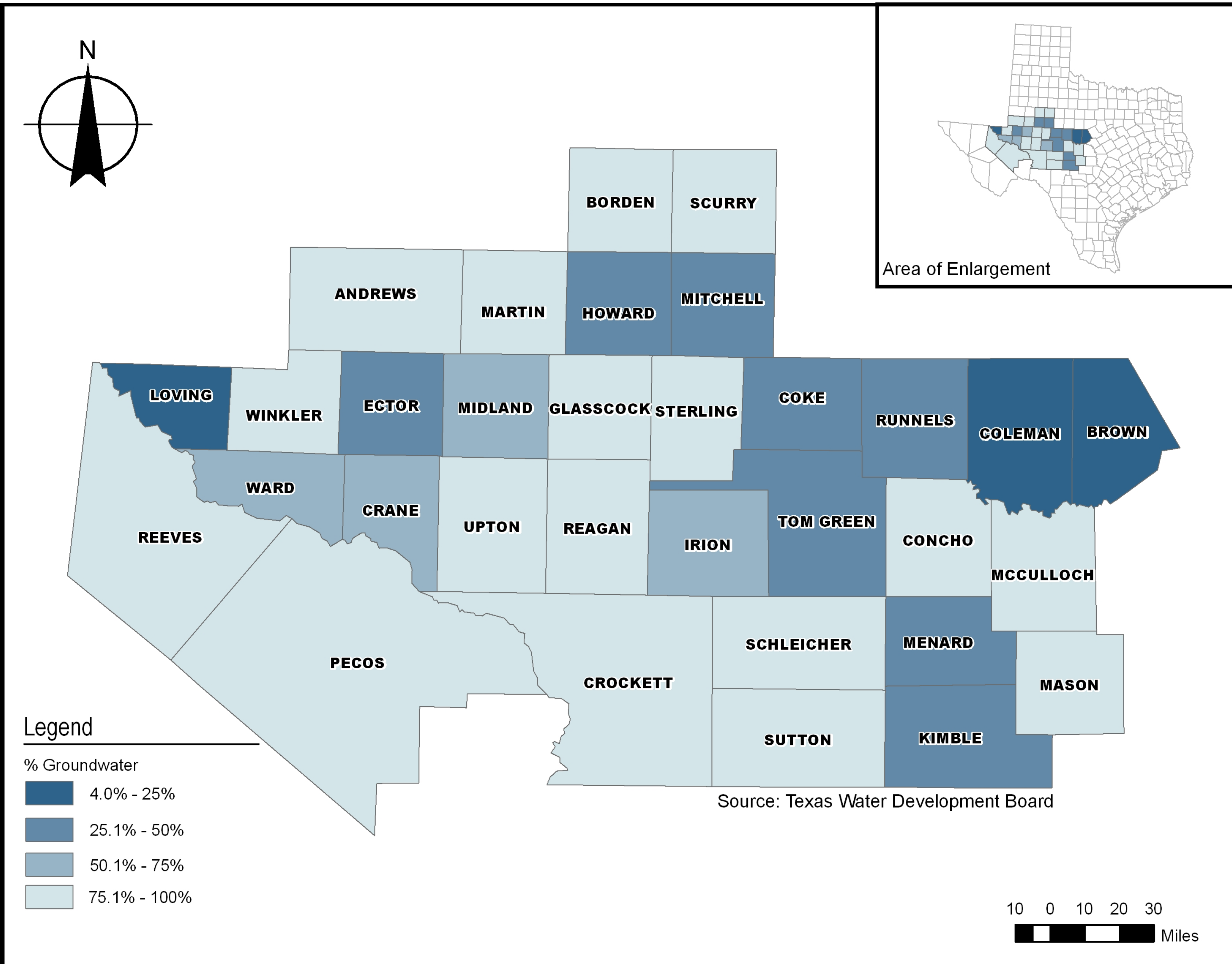
Table 1.3-1
Historical Groundwater and Surface Water Use in Region F

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

Note: Data are from Texas Water Development Board. Year 2000 water use for groundwater and surface water based on draft TWDB reported usage and does not match final water use in other tables.[9]

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





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N W E S

Region F

Supplies from Groundwater by County (2000)

FN JOB NO CMD01311
FILE RegionF_GWUse.mxd
DATE January 13, 2005
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 2000 for Region F
(Values in Acre-Feet)

County	Source of Water	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining	Livestock	*Total*
Andrews	Ground	3,625	0	18,482	0	1,761	255	*24,123*
	Surface	0	0	0	0	0	64	*64*
	Total	*3,625*	*0*	*18,482*	*0*	*1,761*	*319*	*24,187*
Borden	Ground	163	0	1,879	0	883	26	*2,951*
	Surface	2	0	0	0	0	234	*236*
	Total	*165*	*0*	*1,879*	*0*	*883*	*260*	*3,187*
Brown	Ground	168	0	2,320	0	153	147	*2,788*
	Surface	6,717	479	7,792	0	2,274	1,324	*18,586*
	Total	*6,885*	*479*	*10,112*	*0*	*2,427*	*1,471*	*21,374*
Coke	Ground	60	0	803	0	170	37	*1,070*
	Surface	698	0	134	372	235	337	*1,776*
	Total	*758*	*0*	*937*	*372*	*405*	*374*	*2,846*
Coleman	Ground	0	0	0	0	1	114	*115*
	Surface	1,734	5	0	0	15	1,025	*2,779*
	Total	*1,734*	*5*	*0*	*0*	*16*	*1,139*	*2,894*
Concho	Ground	632	0	2,408	0	0	433	*3,473*
	Surface	66	0	166	0	0	108	*340*
	Total	*698*	*0*	*2,574*	*0*	*0*	*541*	*3,813*
Crane	Ground	1,139	0	0	0	805	137	*2,081*
	Surface	0	0	0	0	1,435	7	*1,442*
	Total	*1,139*	*0*	*0*	*0*	*2,240*	*144*	*3,523*
Crockett	Ground	1,643	0	160	938	21	614	*3,376*
	Surface	0	0	0	0	334	153	*487*
	Total	*1,643*	*0*	*160*	*938*	*355*	*767*	*3,863*
Ector	Ground	4,704	1,545	2,694	0	8,411	192	*17,546*
	Surface	43,184	887	0	0	70	10	*44,151*
	Total	*47,888*	*2,432*	*2,694*	*0*	*8,481*	*202*	*61,697*
Glasscock	Ground	167	0	35,456	0	7	158	*35,788*
	Surface	0	0	0	0	0	40	*40*
	Total	*167*	*0*	*35,456*	*0*	*7*	*198*	*35,828*
Howard	Ground	680	155	4,834	0	184	250	*6,103*
	Surface	6,882	1,298	19	0	1,352	62	*9,613*
	Total	*7,562*	*1,453*	*4,853*	*0*	*1,536*	*312*	*15,716*
Irion	Ground	178	0	987	0	123	254	*1,542*
	Surface	0	0	1,118	0	0	64	*1,182*
	Total	*178*	*0*	*2,105*	*0*	*123*	*318*	*2,724*
Kimble	Ground	189	2	48	0	91	377	*707*
	Surface	780	580	589	0	0	94	*2,043*
	Total	*969*	*582*	*637*	*0*	*91*	*471*	*2,750*
Loving	Ground	11	0	0	0	3	32	*46*
	Surface	0	0	358	0	0	8	*366*
	Total	11	0	358	0	3	40	*412*

Table 1.3-2 (cont.): Source of Supply by County and Category in 2000 for Region F

County	Source of Water	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining	Livestock	*Total*
Martin	Ground	408	34	14,575	0	132	544	*15,693*
	Surface	278	0	0	0	8	136	*422*
	Total	*686*	*34*	*14,575*	*0*	*140*	*680*	*16,115*
Mason	Ground	889	0	10,223	0	140	350	*11,602*
	Surface	0	0	0	0	0	350	*350*
	Total	*889*	*0*	*10,223*	*0*	*140*	*700*	*11,952*
McCulloch	Ground	2,896	680	2,790	0	23	748	*7,137*
	Surface	27	0	69	0	0	187	*283*
	Total	*2,923*	*680*	*2,859*	*0*	*23*	*935*	*7,420*
Menard	Ground	80	0	370	0	0	335	*1,132*
	Surface*	347	0	2,773	0	0	84	*2,857*
	Total	*427*	*0*	*3,143*	*0*	*0*	*419*	*3,989*
Midland	Ground	7,501	117	24,496	0	515	316	*32,945*
	Surface	23,916	18	5,987	0	0	79	*30,000*
	Total	*31,417*	*135*	*30,483*	*0*	*515*	*395*	*62,945*
Mitchell	Ground	1,369	0	5,549	0	141	44	*7,103*
	Surface	356	0	15	10,280	0	399	*11,050*
	Total	*1,725*	*0*	*5,564*	*10,280*	*141*	*443*	*18,153*
Pecos	Ground	5,054	2	72,412	0	163	932	*78,563*
	Surface	0	0	1,824	0	0	49	*1,873*
	Total	*5,054*	*2*	*74,236*	*0*	*163*	*981*	*80,436*
Reagan	Ground	923	0	15,879	0	1,742	180	*18,724*
	Surface	0	0	0	0	0	45	*45*
	Total	*923*	*0*	*15,879*	*0*	*1,742*	*225*	*18,769*
Reeves	Ground	3,414	644	63,228	0	203	796	*68,285*
	Surface	315	0	10,811	0	0	42	*11,168*
	Total	*3,729*	*644*	*74,039*	*0*	*203*	*838*	*79,453*
Runnels	Ground	357	1	480	0	41	94	*973*
	Surface	1,192	51	440	0	0	842	*2,525*
	Total	*1,549*	*52*	*920*	*0*	*41*	*936*	*3,498*
Schleicher	Ground	671	0	2,150	0	105	438	*3,364*
	Surface	0	0	0	0	0	109	*109*
	Total	*671*	*0*	*2,150*	*0*	*105*	*547*	*3,473*
Scurry	Ground	3,057	0	2,660	0	2,606	53	*8,376*
	Surface	145	0	248	0	0	476	*869*
	Total	*3,202*	*0*	*2,908*	*0*	*2,606*	*529*	*9,245*
Sterling	Ground	324	0	637	0	560	292	*1,813*
	Surface	0	0	0	0	0	73	*73*
	Total	*324*	*0*	*637*	*0*	*560*	*365*	*1,886*
Sutton	Ground	1,385	0	1,473	0	75	440	*3,373*
	Surface	0	0	0	0	0	110	*110*
	Total	1,385	0	1,473	0	75	550	*3,483*

Table 1.3-2 (cont.): Source of Supply by County and Category in 2000 for Region F

County	Source of Water	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining	Livestock	*Total*
Tom Green	Ground	1,839	0	20,522	0	59	189	*22,609*
	Surface	16,770	1,861	9,893	566	0	1,697	*30,787*
	Total	*18,609*	*1,861*	*30,415*	*566*	*59*	*1,886*	*53,396*
Upton	Ground	866	0	12,471	0	2,599	162	*16,098*
	Surface	0	0	0	0	0	41	*41*
	Total	*866*	*0*	*12,471*	*0*	*2,599*	*203*	*16,139*
Ward	Ground	3,578	6	2,962	5,360	147	111	*12,164*
	Surface	0	0	11,001	0	0	6	*11,007*
	Total	*3,578*	*6*	*13,963*	*5,360*	*147*	*117*	*23,171*
Winkler	Ground	2,268	0	2,002	0	1,104	142	*5,516*
	Surface	0	0	0	0	0	7	*7*
	Total	*2,268*	*0*	*2,002*	*0*	*1,104*	*149*	*5,523*
Total	*Ground*	*50,585*	*3,186*	*324,950*	*6,298*	*22,968*	*9,192*	*417,179*
	Surface	*103,062*	*5,179*	*53,237*	*11,218*	*5,723*	*8,262*	*186,681*
	Total	*153,647*	*8,365*	*378,187*	*17,516*	*28,691*	*17,454*	*603,860*

* 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.

Data are based on draft report of year 2000 usage from the Texas Water Development Board[9]. Final breakdown by groundwater and surface water are not available at the time of this report.

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 the 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 2000 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 3,000 acre-feet per year from Oak Creek Reservoir between 1980 and 2000. 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	15,996	5,004	17,481	0	0	38,481
Coke	44,865	6,000	969	9,534 [a]	0	61,368
Coleman [c]	110,930	14,509	6,245	0	0	131,684
Concho	35	0	2,511	0	16	2,562
Ector	0	0	3,200	0	0	3,200
Howard	1,700	0	89	5,515	0	7,304
Irion	0	0	5,449	0	0	5,449
Kimble	1,000	2,466	8,490	100	0	12,056
Martin	0	0	2,500	0	0	2,500
Mason	0	0	465	0	0	465
McCulloch	3,000	500	2,229	0	0	5,729
Menard	1,016	0	8,935	3	0	9,954
Mitchell	2,700	9,550 [b]	123	0	0	12,373
Pecos	0	0	66,902	0	0	66,902
Reeves [d]	1,890	0	412,352	0	0	414,242
Runnels	2,919	0	6,924	70	0	9,913
Schleicher	0	0	38	3	0	41
Scurry [e]	30,000	0	503	0	0	30,503
Sterling	0	0	168	0	0	168
Sutton	0	0	99	3	0	102
Tom Green	107,934	8,002	41,019	0	0	156,955
Total	*324,185*	*46,031*	*586,754*	*15,228*	*16*	*972,214*

a Includes up to 6,000 acre-feet per year that can be diverted and used in Mitchell or Howard Counties

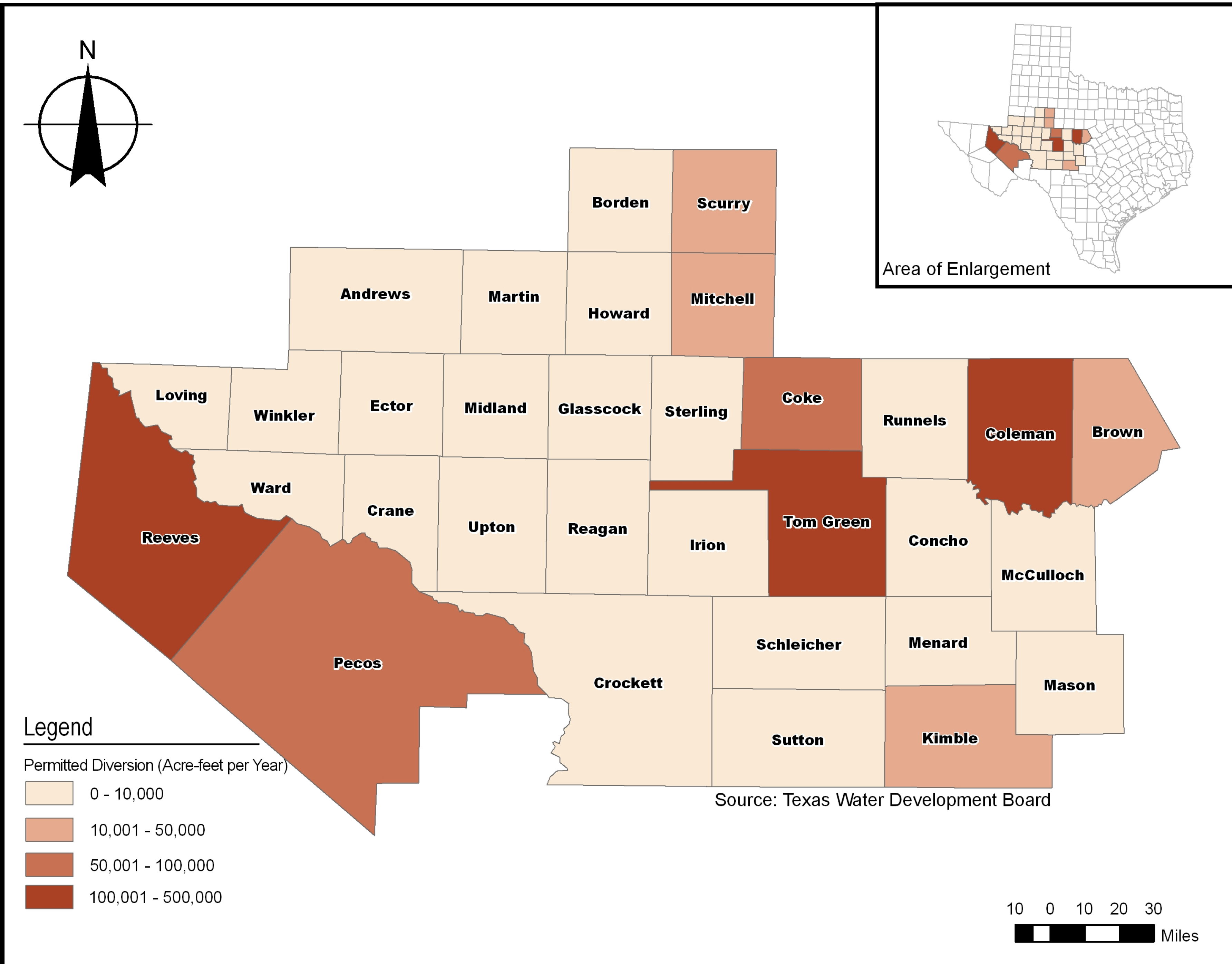
b 5,500 acre-feet per year of this amount is permitted for multiple uses. It is currently being used primarily for steam electric power generation.

c Includes water rights for Ivie Reservoir, which is located in Coleman, Concho and Runnels Counties.

d Includes rights for Red Bluff Reservoir, which is located in Loving and Reeves Counties.

e 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.



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4055 International Plaza, Suite 200
Fort Worth, TX 76109 - 4895
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N W E S

Region F

Total Permitted Surface Water Diversion by County

FN JOB NO CMD01311
FILE RegionF_Diversion.mxd
DATE January 13, 2005
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, Cenozoic Pecos Alluvium, 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.

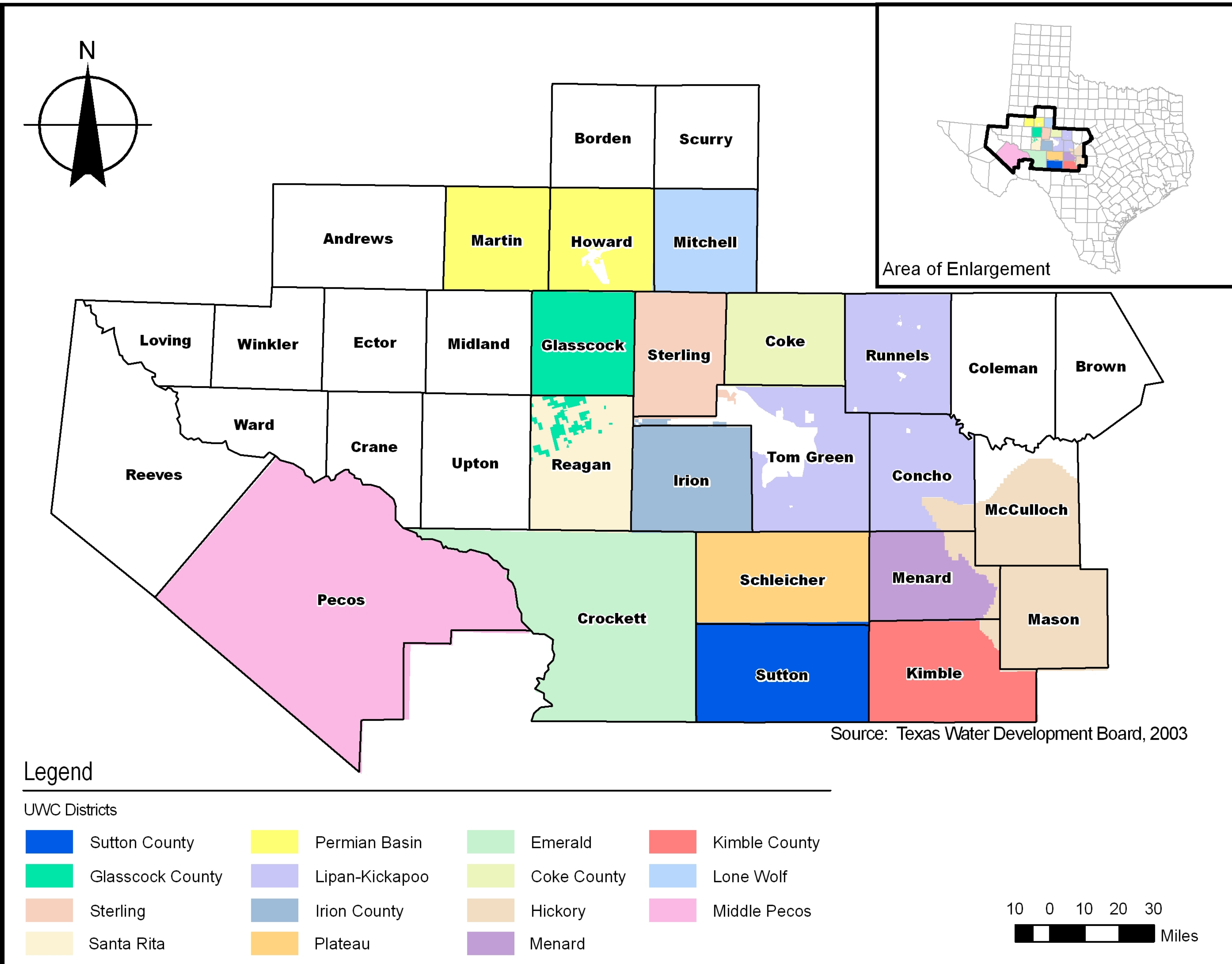
Table 1.3-4 shows the 1999 pumping by county and aquifer, the latest year for which these data are available[9]. The Edwards-Trinity Plateau, Cenozoic Pecos Alluvium and Ogallala are the largest sources of groundwater in Region F, providing 34 percent, 31 percent and 19 percent of the total groundwater pumped in 1999, respectively. The Lipan aquifer provided almost 6 percent of the 1999 totals, with all remaining aquifers contributing 10 percent combined. Groundwater pumping is highest in Reeves, Mitchell, Pecos, Glasscock, Tom Green, and Martin Counties. These six counties account for 68 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
1999 Groundwater Pumping by County and Aquifer
(Values in Acre-Feet)

County	Edwards -Trinity Plateau	Ogallala	Cenozoic Pecos Alluvium	Lipan	Hickory	Dockum	Trinity	Ellen-berger-San Saba	Marble Falls	Edwards -Trinity High Plains	Rustler	Other	*Total*
Andrews	7	17,957	170	0	0	7	0	0	0	0	0	0	*18,141*
Borden	0	2,262	0	0	0	0	0	0	0	4	0	1,021	*3,287*
Brown	0	0	0	0	0	0	3,809	0	0	0	0	69	*3,878*
Coke	26	0	0	0	0	0	0	0	0	0	0	675	*701*
Coleman	0	0	0	0	0	0	29	0	0	0	0	86	*115*
Concho	209	0	0	4,705	523	0	0	0	0	0	0	467	*5,904*
Crane	0	0	2,985	0	0	21	0	0	0	0	52	0	*3,058*
Crockett	3,243	0	0	0	0	0	0	0	0	0	0	0	*3,243*
Ector	10,290	5,687	343	0	0	785	0	0	0	0	0	0	*17,105*
Glasscock	21,342	3,494	0	0	0	0	0	0	0	0	0	0	*24,836*
Howard	819	5,637	0	0	0	125	0	0	0	0	0	0	*6,581*
Irion	569	0	0	0	0	0	0	0	0	0	0	551	*1,120*
Kimble	909	0	0	0	0	0	0	0	0	0	0	0	*909*
Loving	0	0	34	0	0	7	0	0	0	0	0	0	*41*
Martin	0	23,456	0	0	0	0	0	0	0	0	0	0	*23,456*
Mason	0	0	0	0	10,007	0	0	136	130	0	0	0	*10,273*
McCulloch	14	0	0	0	5,254	0	0	301	12	0	0	165	*5,746*
Menard	992	0	0	0	0	0	0	5	0	0	0	30	*1,027*
Midland	18,186	27,394	0	0	0	0	0	0	0	0	0	0	*45,580*
Mitchell	0	0	0	0	0	3,179	0	0	0	0	0	2	*3,181*
Pecos	54,727	0	28,473	0	0	0	0	0	0	0	1,408	5	*84,613*
Reagan	23,184	0	0	0	0	202	0	0	0	0	0	0	*23,386*
Reeves	351	0	95,821	0	0	1,057	0	0	0	0	41	0	*97,270*
Runnels	0	0	0	0	0	0	0	0	0	0	0	1,829	*1,829*
Schleicher	4,301	0	0	0	0	0	0	0	0	0	0	0	*4,301*
Scurry	0	0	0	0	0	6,461	0	0	0	0	0	279	*6,740*
Sterling	937	0	0	0	0	0	0	0	0	0	0	929	*1,866*
Sutton	3,695	0	0	0	0	0	0	0	0	0	0	0	*3,695*
Tom Green	701	0	0	21,076	0	0	0	0	0	0	0	3,698	*25,475*
Upton	10,798	0	0	0	0	16	0	0	0	0	0	0	*10,814*
Ward	0	0	15,197	0	0	204	0	0	0	0	0	0	*15,401*
Winkler	0	0	588	0	0	2,816	0	0	0	0	0	0	*3,404*
Total	*155,300*	*85,887*	*143,611*	*25,781*	*15,784*	*14,880*	*3,838*	*442*	*142*	*4*	*1,501*	*9,806*	*456,976*

Note: Data are from the Texas Water Development Board[9]. Year 2000 Groundwater pumpage was not available.



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N
W E
S

Underground Water Conservation Districts

Region F

DRAFTED	BME
DESIGNED	BME
SCALE	1:2,421,500
DATE	January 13, 2005
FILE	RegionF_UWCD.mxd
FN JOB NO	CMD01311

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. GCDs perform an important role in managing Region F's water supply. 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.

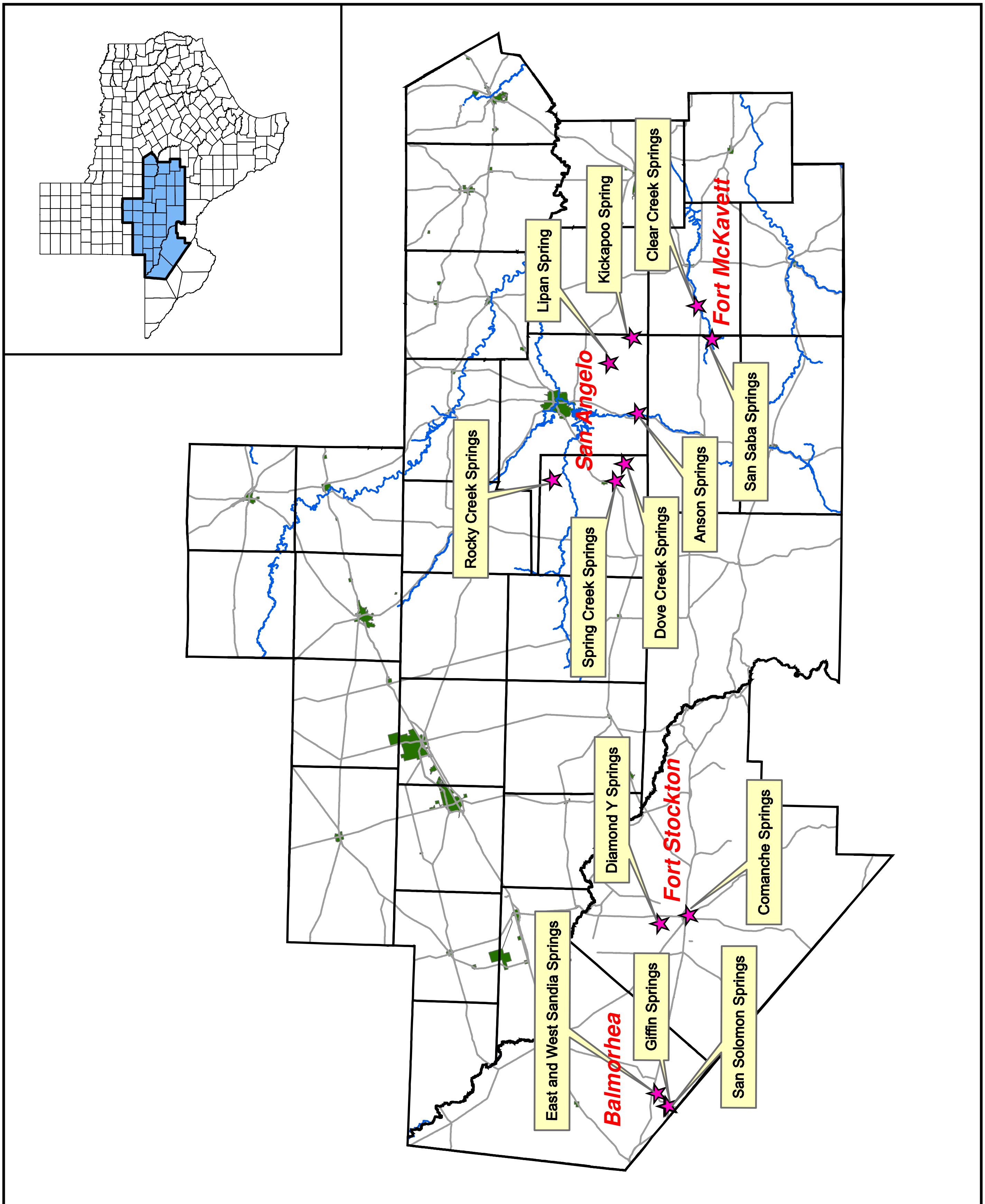
1.3.3 Springs in Region F

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.

The Region F Planning Group has identified 13 major springs in the region that are important for water supply or natural resources protection (Figure 1.3-5). 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; 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].



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Phone - (512) 327 - 9640

N E S W

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

1.3-5
FIGURE

Balmorhea Area Springs

Springs in the Balmorhea area have supported agricultural cultures for centuries. Early original 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) 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 Salomon 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.

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 1-13 is a compilation of federal and state threatened and endangered species found in Region F counties. Table 1-13 also includes species that are designated as rare or "species of concern" by the Texas Parks and Wildlife Department (TPWD). Unless designated as threatened or endangered by either TPWD or the U. S. Fish and Wildlife Service (USFWS), species of concern are not afforded any legal protection.

Section 7 of the Federal Endangered Species Act requires federal agencies to consult with the 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].

The Texas Endangered Species Act gives the Texas Parks and Wildlife Department 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

Table 1.4-1
Species of Special Concern in Region F

Species	Fed. Status	State Status	County																															
			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*
AMPHIBIANS																																		
Cascade Caverns Salamander	ND	T													✓																			
Edwards Plateau Spring Salamanders	ND	ND													✓																			
BIRDS																																		
American Peregrine Falcon	DL	E	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Arctic Peregrine Falcon	DL	T	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Baird's Sparrow	ND	ND	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Bald Eagle	LT-PDL	T	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Black-capped Vireo	LE	E			✓	✓	✓	✓		✓				✓	✓			✓	✓	✓			✓	✓		✓	✓			✓	✓			
Common Black Hawk	ND	T																													✓			
Ferruginous Hawk	ND	ND	✓	✓		✓			✓		✓	✓	✓	✓		✓	✓				✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Golden-cheeked Warbler	LE	E			✓		✓								✓			✓		✓														
Henslow's Sparrow	ND	ND																✓																
Interior Least Tern	LE	E			✓		✓	✓		✓				✓	✓			✓	✓	✓				✓			✓			✓	✓	✓		
Lesser Prairie Chicken	C1	ND	✓	✓		✓			✓		✓	✓	✓	✓		✓	✓				✓	✓		✓				✓	✓		✓	✓	✓	✓
Mexican Spotted Owl	LT	T																					✓		✓									
Montezuma Quail	ND	ND								✓													✓		✓									
Mountain Plover	ND	ND	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Northern Aplomado Falcon	LE	E																					✓		✓									
Prairie Falcon	ND	ND																					✓		✓									
Snowy Plover	ND	ND	✓	✓					✓		✓	✓	✓	✓		✓	✓				✓	✓		✓				✓	✓		✓	✓	✓	✓
Southwestern Willow Flycatcher	LE	E								✓													✓		✓									
Western Burrowing Owl	ND	ND	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Whooping Crane	LE	E	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Wood Stork	ND	T						✓																										
Yellow-billed Cuckoo	C1;NL	ND																					✓		✓									
Zone-tailed Hawk	ND	T				✓		✓		✓					✓			✓		✓			✓	✓	✓	✓	✓			✓	✓			

Table 1.4-1 (Cont.)
Species of Special Concern in Region F

Species	Fed. Status	State Status	County																															
			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*
CRUSTACEANS																																		
Clear Creek Amphipod	ND	ND																		✓														
Pecos Amphipod	ND	ND																					✓											
FISHES																																		
Chihuahua Catfish	ND	ND																					✓		✓									
Clear Creek Gambusia	LE	E																		✓														
Comanche Springs Pupfish	LE	E																					✓		✓									
Guadalupe Bass	ND	ND			✓	✓	✓	✓						✓	✓			✓	✓	✓						✓	✓				✓			
Headwater Catfish	ND	ND						✓		✓										✓														
Leon Springs Pupfish	LE	E																					✓											
Pecos Gambusia	LE	E																					✓		✓									
Pecos Pupfish	ND	T							✓	✓						✓							✓		✓								✓	
Prosperpine Shiner	ND	T								✓																								
Rio Grande Darter	ND	T								✓																								
Rio Grande Shiner	ND	ND								✓																								
Sharpnose Shiner	C1	ND			✓		✓																											
INSECTS																																		
Balmorhea Damselfly	ND	ND																							✓									
Balmorhea Saddle-case Caddis fly	ND	ND																							✓									
Leon River Winter Stonefly	C1	ND					✓																											
MAMMALS																																		
Big Free-tailed Bat	ND	ND								✓					✓								✓		✓									
Black Bear	T/SA; NL	T							✓	✓					✓	✓		✓		✓			✓	✓	✓		✓			✓		✓	✓	
Black-footed Ferret	LE	E	✓	✓					✓	✓	✓	✓	✓			✓	✓				✓	✓	✓	✓	✓			✓	✓			✓	✓	✓
Black-tailed Prairie Dog	ND	ND	✓	✓		✓			✓	✓	✓	✓	✓	✓		✓	✓				✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Cave Myotis Bat	ND	ND	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Davis Mountains Cottontail	ND	ND																					✓		✓									
Fringed Myotis Bat	ND	ND																					✓		✓									
Ghost-faced Bat	ND	ND								✓					✓								✓											
Gray Wolf	LE	E			✓		✓		✓	✓				✓	✓	✓		✓	✓	✓			✓	✓	✓	✓					✓	✓	✓	✓
Jones' Pocket Gopher	ND	ND	✓					✓	✓		✓					✓	✓				✓												✓	✓

Table 1.4-1 (Cont.)
Species of Special Concern in Region F

Species	Fed. Status	State Status	County																															
			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*
Limpia Creek Pocket Gopher	ND	ND																					✓											
Limpia Southern Pocket Gopher	ND	ND																					✓											
Llano Pocket Gopher	ND	ND													✓			✓	✓	✓														
Pale Townsend's Big-eared Bat	ND	ND								✓					✓								✓		✓									
Pecos River Muskrat	ND	ND								✓													✓		✓									
Plains Spotted Skunk	ND	ND			✓		✓											✓	✓															
Red Wolf	LE	E			✓		✓								✓			✓	✓	✓			✓		✓		✓							
Swift Fox	ND	ND	✓	✓				✓	✓	✓	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓				✓	✓		✓	✓	✓	✓
White-nosed Coati	ND	T																					✓											
Yuma Myotis Bat	ND	ND								✓													✓		✓									
MOLLUSKS																																		
Diamond Y Spring Snail	C1	ND																					✓											
Gonzalez Spring Snail	C1	ND																					✓											
Pecos Assiminea Snail	PE	ND																					✓		✓									
Phantom Cave Snail	C1	ND																							✓									
Phantom Cave Spring Tryonia	C1	ND																							✓									
Stockton Plateau Threeband	ND	ND																					✓											
Texas Hornshell	C1	ND																													✓		✓	
REPTILES																																		
Big Bend Blackhead Slider	ND	ND																					✓		✓									
Chihuahuan Desert Lyre Snake	ND	T																					✓		✓									
Chihuahuan Mud Turtle	ND	T								✓													✓		✓									
Concho Water Snake	LT	ND			✓	✓	✓	✓						✓					✓							✓					✓			
Dunes Sagebrush Lizard	C1	ND	✓						✓	✓						✓																	✓	✓
Reticulated Gecko	ND	T																					✓		✓									
Spot-tailed Earless Lizard	ND	ND	✓			✓		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓
Texas Garter Snake	ND	ND			✓		✓	✓										✓	✓	✓		✓												
Texas Horned Lizard	ND	T	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Texas Tortoise	ND	T							✓														✓		✓									
Trans-Pecos Blackheaded Snake	ND	T							✓														✓		✓									
VASCULAR PLANTS																																		
Alkali Spurge	ND	ND																					✓											
Basin bellflower	ND	ND																✓																

Table 1.4-1 (Cont.)
Species of Special Concern in Region F

Species	Fed. Status	State Status	County																															
			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*
Broadpod Rushpea	ND	ND								✓																				✓				
Bushy Wild-Buckwheat	ND	ND																					✓											
Correll's Green Pitaya	ND	ND				✓																	✓											
Desert Night-blooming Cereus	ND	ND																					✓		✓									
Dune Umbrella-sedge	ND	ND																															✓	✓
Dwarf Broomspurge	ND	ND																			✓	✓											
Enquist's sandmint	ND	ND															✓																
Granite Spiderwort	ND	ND															✓																
Grayleaf Rock-daisy	ND	ND																				✓		✓									
Gyp Locoweed	ND	ND																						✓									
Hester's Cory Cactus	ND	ND																				✓											
Hill Country Wild-Mercury	ND	ND			✓										✓					✓											✓			
Irion Country Wild-buckwheat	ND	ND				✓							✓	✓									✓	✓		✓			✓					
Leoncita false foxglove	ND	ND																				✓											
Longstock heimia	ND	ND																				✓											
Mexican mud-plantain	ND	ND																					✓										
Neglected Sunflower	ND	ND									✓					✓																	✓	✓
Pecos Sunflower	LT	T																				✓		✓									
Rock Quillwort	ND	ND															✓																
Texas Poppy-mallow	LE	E				✓															✓				✓								
Tharp's Blue-star	ND	ND																				✓											
Tobusch Fishhook Cactus	LE	E												✓																			
Two-Bristle Rock-daisy	ND	ND																				✓											
White Column Cactus	ND	ND																				✓											
Wright's Trumpets	ND	ND																				✓		✓									
Wright's Water-willow	ND	ND																				✓											

Status Key:
LE, LT – Federally Listed Endangered/Threatened
PE, PT – Federally Proposed Endangered/Threatened
E/SA, T/SA – Federally Listed Endangered/Threatened by Similarity of Appearance
C1 – Federal Candidate for Listing, Category 1; information supports proposing to list as endangered/threatened
DL, PDL – Federally Delisted/Proposed for Delisting
E, T – State Listed Endangered/Threatened
ND – Rare, but with no regulatory listing status

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 21,800,000 acres in farms and over 2,800,000 acres of cropland. The market value of agriculture products (crops and livestock), for 2002 for Region F was over $478,000,000, with livestock accounting for about 66 percent and crops accounting for the remaining 34 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.

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 39 percent of the total crop value for Region F in 2002.

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

Table 1.4-2
2002 U.S. Department of Agriculture County Census Data for Region F

Category	Andrews	Borden	Brown	Coke	Coleman	Concho	Crane	Crockett
Farms	169	132	1,347	335	829	411	44	198
Land in Farms (acres)								
- Crop Land	102,488	71,426	131,375	58,729	187,982	142,138	710	1,499
- Pasture Land	654,010	407,875	295,477	416,433	411,024	392,547	(D)	1,724,426
- Other	47,500	714	55,084	10,235	43,257	9,627	(D)	9,551
- Total	803,998	480,015	481,936	485,397	642,263	544,312	(D)	1,735,476
Market Value ($1,000)								
- Crops	$2,240	$3,876	$3,478	$576	$3,432	$6,865	$3	(D)
- Livestock	$6,432	$3,961	$22,251	$12,168	$12,305	$7,444	$1,299	(D)
- Total	$8,672	$7,837	$25,729	$12,744	$15,737	$14,309	$1,302	$10,238

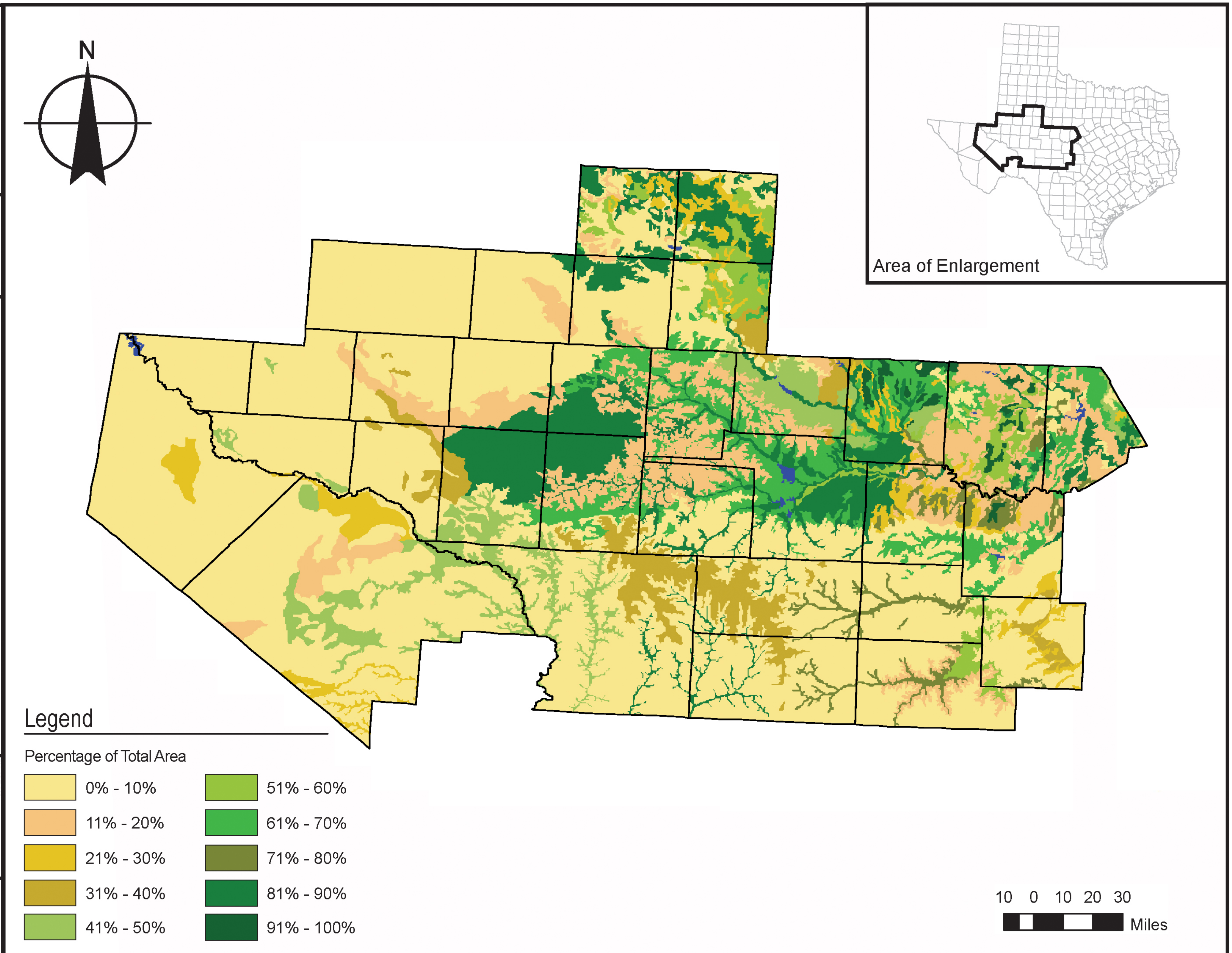
Category	Ector	Glasscock	Howard	Irion	Kimble	Loving	Martin	Mason
Farms	287	199	466	151	528	14	379	633
Land in Farms (acres)								
- Crop Land	4,062	169,845	248,202	10,321	31,180	909	280,977	67,411
- Pasture Land	492,345	317,487	258,722	522,408	535,440	514,207	210,461	445,189
- Other	7,374	5,607	11,445	3,563	48,881	76	34,569	42,997
- Total	503,781	492,939	518,369	536,292	615,501	515,192	526,007	555,597
Market Value ($1,000)								
Crops	$279	$11,412	$11,762	$116	$655	$0	$12,902	$2,367
Livestock	$1,594	$2,225	$3,344	$3,372	$6,702	$523	$1,172	$42,431
Total	$1,873	$13,637	$15,106	$3,488	$7,357	$523	$14,074	$44,798

Table 1.4-2 (Cont'd)
2002 U.S. Department of Agriculture County Census Data for Region F

Category	McCulloch	Menard	Midland	Mitchell	Pecos	Reagan	Reeves	Runnels
Farms	621	336	477	451	270	123	166	897
Land in Farms (acres)								
- Crop Land	144,750	24,771	72,892	171,053	110,235	67,347	89,336	299,223
- Pasture Land	384,025	506,798	279,851	304,714	2,801,801	(D)	915,900	264,813
- Other	17,518	17,269	8,815	12,155	4,034	(D)	4,641	20,842
- Total	546,293	548,838	361,558	487,922	2,916,070	538,285	1,009,877	584,878
Market Value ($1,000)								
Crops	$2,918	$777	$3,994	$7,062	$23,633	$4,398	$7,330	$14,811
Livestock	$10,047	$6,648	$3,407	$5,283	$14,585	$2,170	$11,233	$12,583
Total	$12,965	$7,425	$7,401	$12,345	$38,218	$6,568	$18,563	$27,394

Category	Schleicher	Scurry	Sterling	Sutton	Tom Green	Upton	Ward	Winkler	Total
Farms	307	674	66	191	1,024	83	86	44	11,938
Land in Farms (acres)									
- Crop Land	41,195	240,153	11,227	9,015	212,464	36,282	10,180	1,057	3,050,434
- Pasture Land	725,763	316,818	616,181	868,553	613,446	682,284	445,918	(D)	17,324,916
- Other	11,314	7,842	5,599	2,221	18,785	4,880	9,541	(D)	475,936
- Total	778,272	564,813	633,007	879,789	844,695	723,446	465,639	491,718	21,812,175
Market Value ($1,000)									
Crops	$908	$9,100	$58	$239	$18,851	$2,783	(D)	(D)	$156,825
Livestock	$8,309	$13,926	$5,730	$6,178	$78,372	$2,030	(D)	(D)	$307,724
Total	$9,217	$23,026	$5,788	$6,417	$97,223	$4,813	$1,681	$1,926	$478,394

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). Data are from the U.S. Department of Agriculture (USDA, 2002).



Freese and Nichols
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Phone - (817) 735 - 7300

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.

counties combined accounted for approximately 24 percent of the total land in farms and 29 percent of the crop value for the region in 2002.

Shrimp farming is a relatively new business in West Texas. Presently, 150 acres of ponds are located in Pecos and Ward Counties with plans to expand at a rate of 12 to 15 percent per year. Estimated water usage is 3,300 acre-feet per year of salt water from the Cenozoic Pecos Alluvium. 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 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 wholesale water providers and retail suppliers. Wholesale 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 2003 sales by the CRMWD, which totaled 72,896 acre-feet.

Brown County Water Improvement District Number One (BCWID). The 2000 sales by the BCWID totaled 13,274 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 2000 diversions from UCRA sources, which totaled 2,254 acre-feet.

Table 1.5-1
Fiscal Year 2003 Sales by the Colorado River Municipal Water District
(Values in Acre-Feet per Year)

Customer	Total Water Sales
Odessa	21,381
Big Spring	6,317
Snyder	2,416
Midland	24,150
Stanton	184
San Angelo	14,004
Robert Lee	63
Grandfalls	150
Pyote/West Tx State School	201
Ballinger	51
West Central Texas MWD	191
Non-Municipal Customers	3,788
Total	*72,896*

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

Table 1.5-2
2000 Sales by the Brown County Water Improvement District Number One
(Values in Acre-Feet)

Customer	2000 Treated Water Sales	2000 Raw Water Sales
Bangs	326 [a]	-
Early	-	1,176 [b]
Brownwood	4,324 [a]	-
Brooksmith WSC	924 [a]	
Santa Anna	-	37 [b]
Thunderbird Bay	-	
Other	-	1,766 [a]
Irrigation	-	4,721 [a]
Total	*5,574*	*7,700*

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

Table 1.5-3
2000 Diversions from Upper Colorado River Authority Sources
(Values in Acre-Feet per Year)

Customer	2000 Diversions
San Angelo	2,201
Miles*	-
Robert Lee	53
Total	*2,254*

Data are from the Texas Commission on Environmental Quality. [24]
* UCRA did not begin providing water to Miles until 2004.

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. The 2010 projected demand for this 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 (53 acre-feet in 2000) and the Notrees Water Company (2 acre-feet in 2001).

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 2000, Odessa purchased 24,768 acre-feet from CRMWD. In that same year, Odessa sold 1,098 acre-feet to Ector County Utility District and 405 acre-feet to the Odessa County Club.

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 as well as to Millersview-Doole WSC. 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 by 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 significant outside sales in 2000.

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

Supplier	County	Year 2000 Sales in Acre-Feet		
		Municipal Sales within City	Outside Sales	Total
Odessa	Ector	21,189	3,579	24,768
San Angelo	Tom Green	16,048	1,861	17,909
Big Spring	Howard	5,596	645	6,241
Brownwood	Brown	3,604	2,574	6,178
Snyder	Scurry	2,343	484	2,827
Fort Stockton	Pecos	3,102	415	3,517
Pecos	Reeves	2,575	315	2,890
Andrews	Andrews	2,876	365	3,141
Coleman	Coleman	1,017	658	1,675
Sonora	Sutton	1,104	129	1,233
Colorado City	Mitchell	1,012	83	1,095
Crane	Crane	886	294	1,180
Ballinger	Runnels	713	270	983
Early	Brown	774	379	1,153
Winters	Runnels	329	78	407
Balmorhea	Reeves	96	324	420

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 2002, the Texas Water Development Board released the State Water Plan, *Water for Texas – 2002*, 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 2001. Some of the findings of the 2001 Region F plan included:

- Approximately 40 water user groups had projected water shortages over the planning period (through 2050). Water management strategies were developed to address these needs.
- Ten counties had a collective irrigation need of over 200,000 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)
- General water management strategies recommended in the plan included: 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 does not require the level of treatment as surface water supplies).
- *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 brush control efforts on O.C. Fisher Reservoir and Twin Buttes Reservoir.

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). Additional requirements effective May 1, 2005 state that 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.

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 for SB1 Second Round, 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 compiled water conservation plans to ensure that they will be able to meet the future water demands of their constituents. 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 of SB1 Second Round, model water conservation plans have been developed and 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. As part of SB1 Second Round, model drought contingency plans have been developed and 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. 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 deal directly with groundwater nor with water quantity issues. The statute employs a variety of regulatory and non-regulatory tools to sharply 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 has recently taken over the NPDES permitting system, which sets the operating requirements for wastewater treatment plants. The Section 404 permitting process is handled 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, and the TCEQ is currently analyzing the Colorado River below E.V. Spence Reservoir (Segment 1426) for chloride, sulfate, and TDS concentrations. Additional information may be found in Section 1.7.

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 dinking 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.

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 North Concho River Pilot Brush Control Project, Twin Buttes Reservoir/Lake Nasworthy Brush Control Projects, Lake Ballinger Brush Control Project, Mountain Creek Reservoir Brush Control Project, Oak Creek Reservoir Brush Control Project, Pecos River/Upper Colorado River Salt Cedar Project, and Champion Creek Reservoir Brush Control 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 Colorado River Municipal Water District (CRMWD) rain enhancement project, 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.

Partial funding for weather modification programs was provided by the Texas Department of Licensing and Regulation, and its predecessor agencies for many years. This funding ended in October, 2004.

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

1.7.1 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 on-going drought.

Water quality problems identified by the TWDB, TCEQ, TPWD, EPA and others (River Authorities, etc.) within Region F are summarized in Table 1-19.

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[21]. 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[25], the 1990 state water plan[32], the 1997 state water plan[33], and the 2002 state water plan[26]. 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. However, because of its assumptions 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.

Table 1.7-1
Summary of Identified Surface Water Quality Problems in Region F

Segment ID	Segment Name	Concern Location	Water Quality Concern	Status
1416A	Brady Creek (unclassified water body)	From FM 714 upstream to Brady Lake dam	depressed dissolved oxygen	Additional information needed before a TMDL is scheduled
1420	Pecan Bayou Above Lake Brownwood	Lower 25 miles	depressed dissolved oxygen	Additional information needed before a TMDL is scheduled
1420	Concho River	Loop 306 to end of segment, including both North and South forks	impaired macrobenthos community	Additional information needed before a TMDL is scheduled
1425	O. C. Fisher Lake	Entire reservoir	chloride	Additional information needed before a TMDL is scheduled
			total dissolved solids	Additional information needed before a TMDL is scheduled
1426	Colorado River Below E. V. Spence Reservoir	Coke County line to SH 208	chloride	TMDL underway
			total dissolved solids	TMDL underway
		Country Club Lake to Coke County line	chloride	TMDL underway
			total dissolved solids	TMDL underway
		Lower end of segment to Country Club Lake	chloride	TMDL underway
			total dissolved solids	TMDL underway
		SH 208 to dam	chloride	TMDL underway
			total dissolved solids	TMDL underway

Data from 2004 Draft 303(d) list (May 13, 2005) [34]

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 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 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 regularly exceed the TCEQ's radionuclide limits, including limits on radon. Treatment of this water by water supply providers in this area has not been attempted to date. 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 1.7-2 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, Howard 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 1.7-2
Percentage of Sampled Water Wells Exceeding Drinking Water Standards for Fluoride, Nitrate and Arsenic

County	Fluoride	Nitrate	Arsenic
Andrews	27%	54%	3%
Borden	13%	44%	10%
Brown	2%	36%	0%
Coke	1%	39%	0%
Coleman	1%	41%	0%
Concho	1%	56%	0%
Crane	7%	38%	0%
Crockett	0%	15%	0%
Ector	2%	80%	3%
Glasscock	3%	71%	2%
Howard	20%	61%	25%
Irion	0%	22%	0%
Kimble	0%	26%	0%
Loving	0%	41%	0%
Martin	45%	75%	10%
Mason	0%	52%	0%
McCulloch	1%	25%	0%
Menard	0%	19%	0%
Midland	11%	85%	0%
Mitchell	6%	37%	0%
Pecos	2%	31%	0%
Reagan	3%	67%	3%
Reeves	0%	30%	0%
Runnels	3%	94%	0%
Schleicher	0%	23%	0%
Scurry	3%	35%	0%
Sterling	0%	29%	0%
Sutton	0%	18%	0%
Tom Green	0%	51%	0%
Upton	0%	80%	0%
Ward	1%	25%	0%
Winkler	2%	13%	0%

Data are from the Texas Water Development Board[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], which is summarized in Table 1.7-1. Two

TMDLs have been proposed for Region F: one for E.V. Spence Reservoir and one for the Colorado River downstream of E.V. Spence Reservoir. The E.V. Spence TMDL was adopted by TCEQ in June 2002 and approved by the EPA in May 2003. The Colorado River TMDL is currently underway. In December 2003, the TCEQ presented the results of the 2003 monitoring effort for the Colorado River TMDL to project stakeholders. Monitoring is scheduled to run through December 2004. The projected completion date for the Colorado River TMDL is March 2007.

Regional Drought

Most of Region F has experience drought-of-record conditions since the mid 1990s. Although extensive rains at the end of 2004 brought some relief to the drought conditions, there remains a large volume of empty reservoir storage in the region. In October 2004, the capacity of Lake J.B. Thomas, Champion Creek Reservoir, E.V. Spence Reservoir, and O.C. Fisher Lake was less than 15 percent. O.H. Ivie was at 30 percent of capacity. Hords Creek Lake had less than 50 percent of its capacity. In June 2004, Twin Buttes Reservoir was only at 3 percent of capacity. Red Bluff Reservoir was the only major reservoir in Region F that is almost full, at 95 percent of capacity in October 2004. 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.

1.7.2 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 water 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.

1.8 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 water supplies. Water-related threats to natural resources include changes to natural flow conditions and water quality concerns. In most cases, groundwater water supplies in Region F associated with irrigated agriculture have little impact on natural resources.

1.8.1 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 many 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 water for irrigation. According to the 2001 *Region F Regional Water Plan*[40], agricultural demand may exceed the available groundwater water supply. Parts of three counties (Midland, Reagan and Upton) have already been declared Priority Groundwater Water Management Area by the TCEQ in response to excessive drawdown in the aquifer.

1.8.2 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. Such 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.

1.9 Navigation in Region F

The U.S. Army Corps of Engineers has published a list of the navigable portions of the rivers in Texas[41]. 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.

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

2.1 Introduction

In 2002 and 2003, the Texas Water Development Board (TWDB) developed population and water demand projections for Region F for use in the 2006 regional water plan[1,2,3]. As part of the regional water planning process, these projections were reviewed by the regions and revised as needed based on input from cities, counties and water user groups. The Region F Regional Water Planning Group (RWPG) requested revisions to the population projections in December of 2002 and the demand projections in October of 2003. The TWDB approved the final projections in November 2003[4].

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,
- 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.

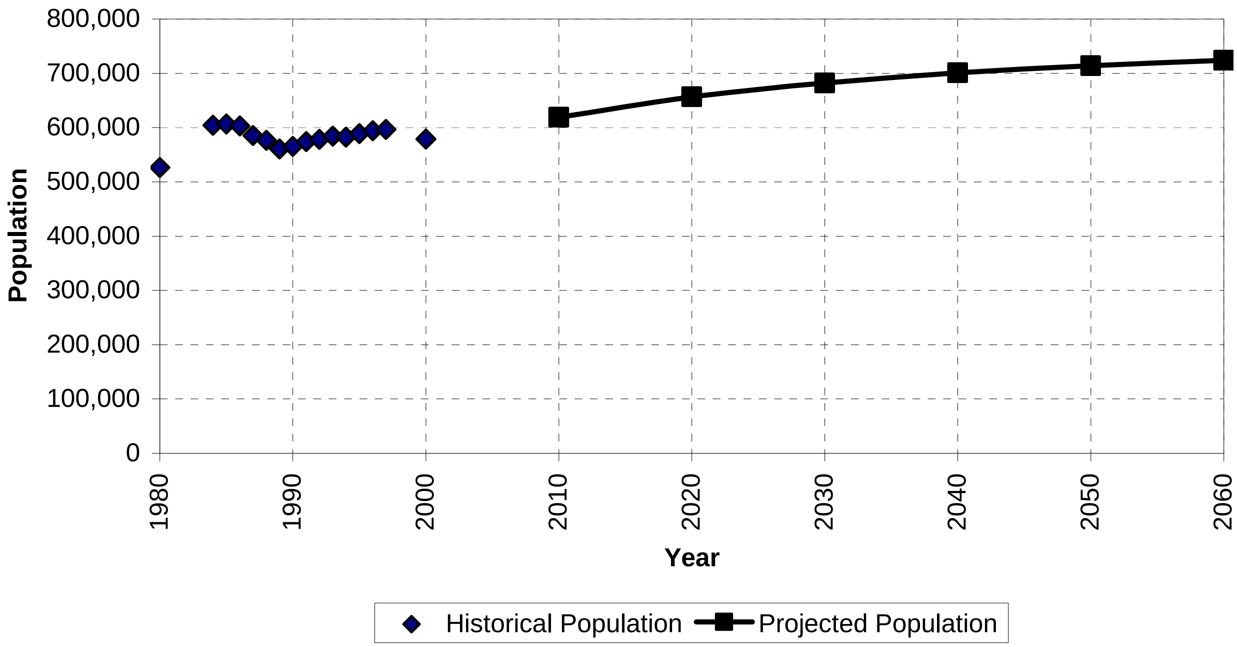
2.2 Population Projections

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. 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*

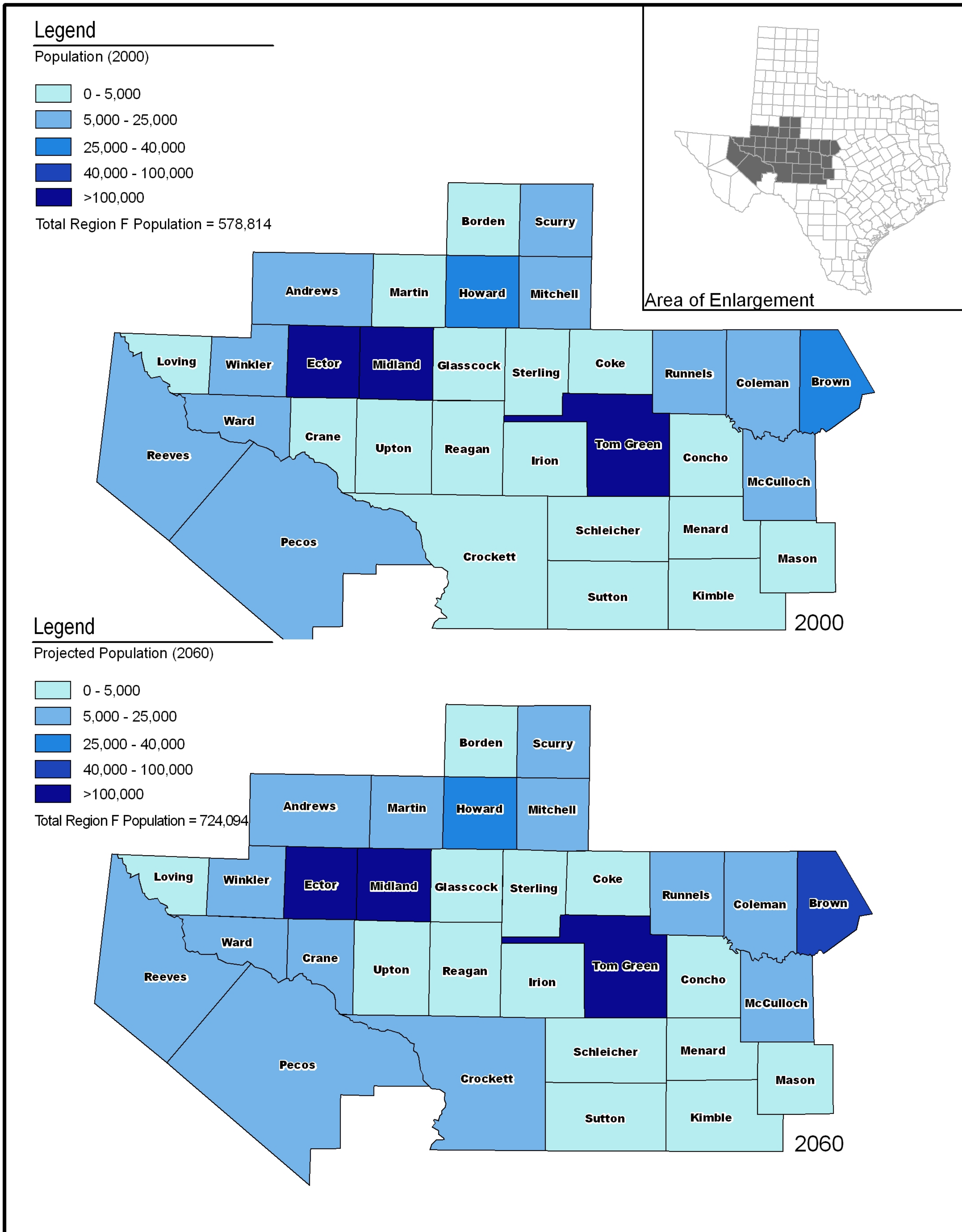
Figure 2.2-1
Historical and Projected Population of Region F



Historical data provided by the Texas Water Development Board[5]. Data from 1981 to 1983 are not available. Projected population approved by TWDB for the second round of regional water planning.

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*[6]. Information regarding the review and revision of the population projections by the Region F may be found in the December 2002 *Proposed Population Projections Revisions for Region F*[7].

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 45,533,734 in 2060, a growth rate of 1.3 percent per year.



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N W E S

Region F

Population Distribution by County 2000-2060

FN JOB NO	FTW94158C
FILE	H:/Census8511.mxd
DATE	January, 2005
SCALE	1:3,500,000
DESIGNED	BME
DRAFTED	BME

2.2-2

FIGURE

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. 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 Region F Water Planning Group reviewed the water demand projections for municipal, manufacturing, steam electric power generation and mining using a three-step process:

- A survey was sent to selected cities, water providers, county judges, and steam electric power generators. These surveys asked each entity to evaluate their TWDB projections. The consultant team compiled the survey data and responded to requests for revision.
- The projections were 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. If any of the anomalies indicated that the projections should be revised, the consultants contacted the affected entities for further review.
- A report was prepared summarizing the results of the survey and evaluations, noting any projections that merited revision. The report was sent to the members of the RWPG for review and comment. This report was then submitted to the TWDB for consideration of suggested water demand adjustments.

The results of this process are summarized in the October 2003 report *Proposed Revisions to Region F Water Demands*[8].

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 2000 use and the projected water use by county. Figure 2.3-2 shows the geographical distribution of the year 2000 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 2000 data and the year 2010 projections is due to irrigation demands. Region F feels that historical year 2000 water use for irrigation is not indicative of the potential for irrigation water use in the region. More information may be found in Section 2.3.3.

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

Use Category	Historical	Projected					
	2000	2010	2020	2030	2040	2050	2060
Municipal	128,410	141,965	147,828	151,280	153,206	155,340	157,632
Manufacturing	8,365	9,757	10,595	11,294	11,960	12,524	13,313
Irrigation	394,362	578,606	573,227	567,846	562,461	557,080	551,774
Steam Electric	17,749	22,215	22,769	26,620	31,312	37,033	44,008
Mining	29,379	31,850	33,097	33,795	34,479	35,154	35,794
Livestock	17,431	23,060	23,060	23,060	23,060	23,060	23,060
Total	595,696	807,453	810,576	813,895	816,478	820,191	825,581

Data are from the TWDB[4].

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

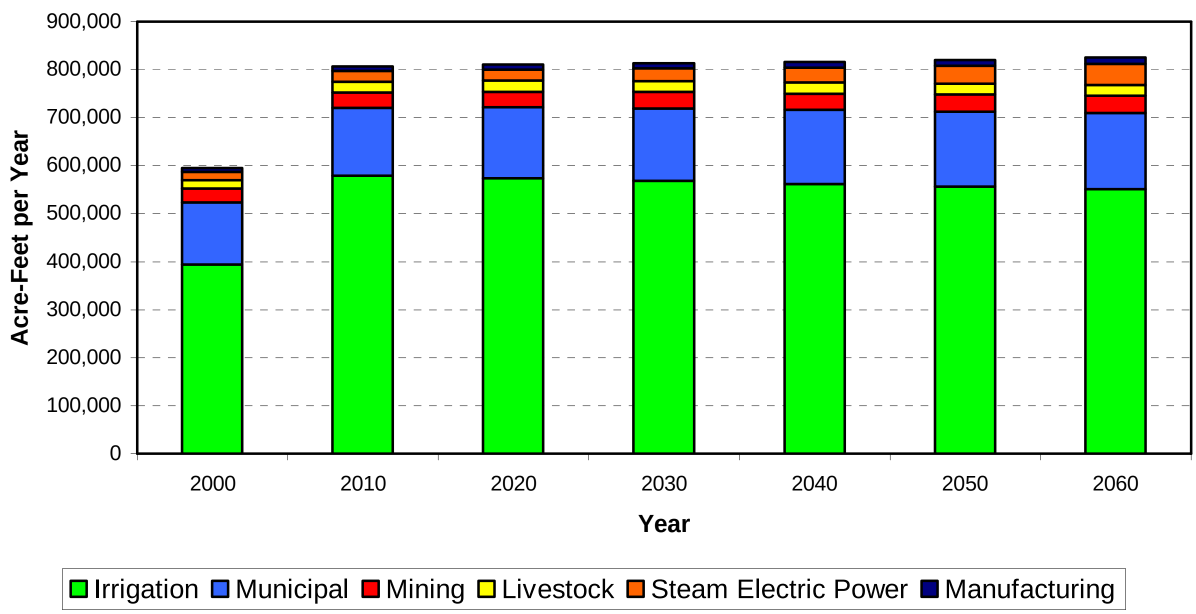
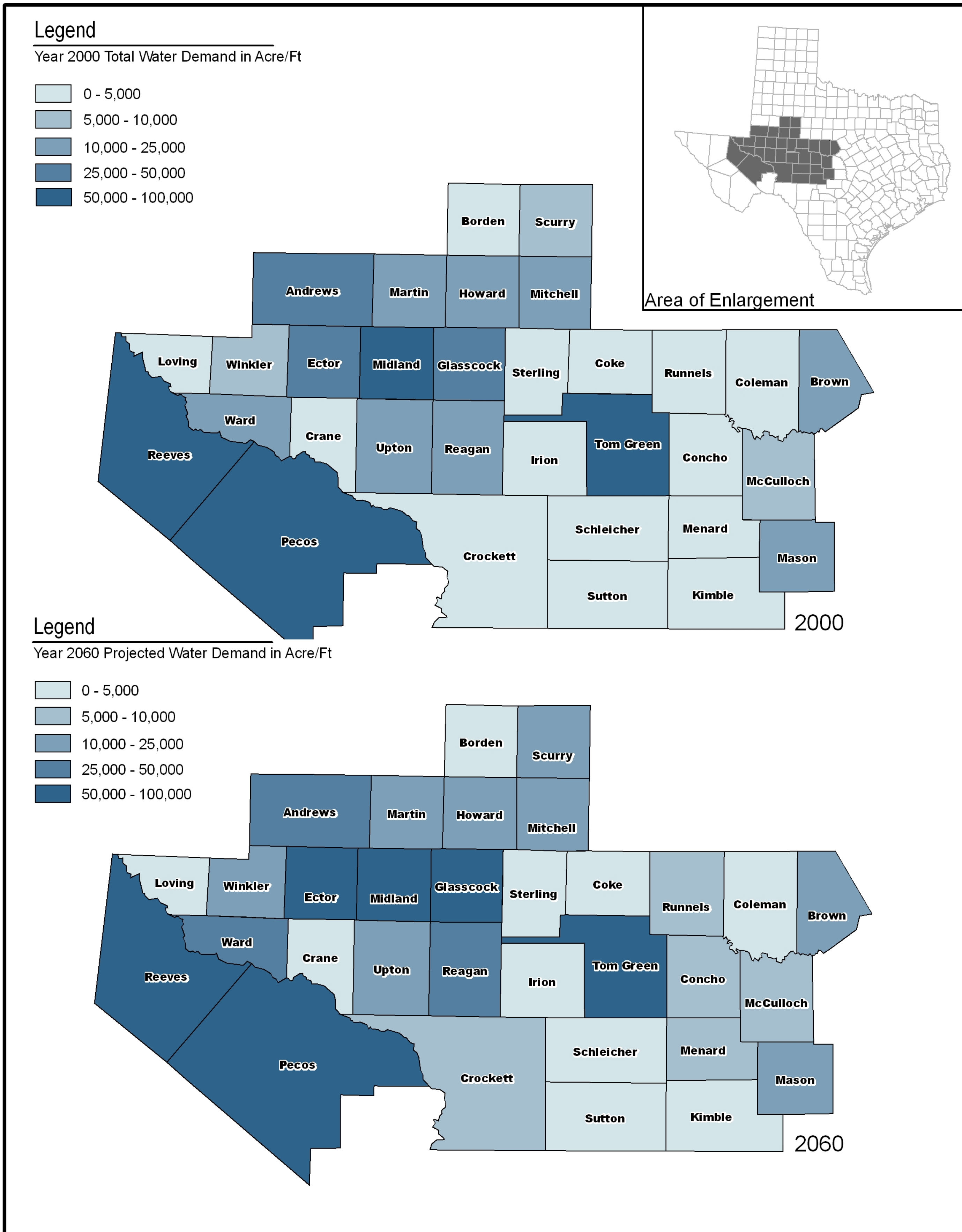


Table 2.3-2
Total Historical and Projected Water Demand by County
(Values in Acre-Feet per Year)

County	Historical	Projected					
	2000	2010	2020	2030	2040	2050	2060
Andrews	38,356	38,579	38,550	38,413	38,261	38,059	37,892
Borden	3,187	3,836	3,805	3,778	3,744	3,717	3,689
Brown	21,375	24,119	24,221	24,173	24,053	24,011	24,040
Coke	2,845	3,098	3,070	3,121	3,179	3,257	3,354
Coleman	2,783	4,536	4,509	4,477	4,447	4,429	4,429
Concho	3,815	5,945	5,947	5,921	5,890	5,869	5,853
Crane	3,859	3,969	4,097	4,159	4,201	4,258	4,323
Crockett	4,032	4,604	4,543	4,708	4,873	5,110	5,387
Ector	40,501	53,556	59,000	62,670	66,493	70,656	75,320
Glasscock	35,828	52,690	52,287	51,878	51,458	51,037	50,628
Howard	15,035	15,904	16,118	16,122	16,064	16,064	16,184
Irion	2,724	3,623	3,563	3,491	3,411	3,337	3,268
Kimble	2,754	3,574	3,592	3,598	3,601	3,606	3,641
Loving	412	664	663	658	657	655	654
McCulloch	6,848	7,101	7,167	7,183	7,190	7,205	7,270
Martin	16,950	16,098	15,875	15,629	15,371	15,085	14,787
Mason	11,652	12,053	11,904	11,750	11,595	11,445	11,305
Menard	3,988	7,161	7,138	7,110	7,083	7,058	7,039
Midland	62,155	75,806	77,236	78,097	78,534	78,836	79,259
Mitchell	18,156	16,901	15,358	16,567	18,048	19,875	22,090
Pecos	79,953	85,897	84,826	83,661	82,434	81,178	79,854
Reagan	18,769	39,940	39,550	39,059	38,502	37,919	37,336
Reeves	80,770	110,088	109,479	108,809	108,090	107,382	106,701
Runnels	3,499	8,059	8,102	8,123	8,143	8,172	8,229
Schleicher	3,474	3,743	3,763	3,745	3,707	3,681	3,662
Scurry	9,248	10,217	10,393	10,393	10,357	10,346	10,373
Sterling	1,886	2,090	2,101	2,090	2,068	2,034	2,020
Sutton	3,460	4,159	4,195	4,160	4,105	4,068	4,020
Tom Green	52,750	132,935	133,952	134,464	134,624	134,938	135,230
Upton	16,138	20,575	20,420	20,208	19,986	19,780	19,584
Ward	22,971	22,477	21,656	22,202	22,863	23,743	24,870
Winkler	5,523	13,456	13,496	13,478	13,446	13,381	13,290
Total	595,696	807,453	810,576	813,895	816,478	820,191	825,581

Data are from the TWDB[4].



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Region F

Total Water Demand by County 2000-2060

FN JOB NO	CMD01311
FILE	ProjectedWaterUse.mxd
DATE	January, 2005
SCALE	1:3,500,000
DESIGNED	BME
DRAFTED	BME

2.3-2

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 recently adopted by the Water Conservation Implementation Task Force (Task Force). The Task Force definition does not differentiate between municipal use and non-municipal use or outside sales[9].)

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 as a whole. 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	165	163	162	162
Decline from Year 2000		3	5	8	10	12	12
% Decline from Year 2000		2%	3%	5%	6%	7%	7%

Notes: Data are from TWDB[10].

* 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	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Andrews	3,394	3,625	3,821	3,937	4,041	4,093	4,173
Borden	165	175	179	169	148	136	123
Brown	6,886	7,106	7,173	7,111	6,978	6,932	6,932
Coke	757	771	766	755	742	737	737
Coleman	1,623	1,874	1,846	1,814	1,784	1,766	1,766
Concho	699	873	892	884	870	865	865
Crane	1,138	1,256	1,389	1,453	1,497	1,556	1,623
Crockett	1,579	1,707	1,831	1,865	1,870	1,909	1,949
Ector	26,692	28,708	30,634	32,271	33,757	35,208	36,725
Glasscock	167	181	196	203	200	197	201
Howard	6,881	7,308	7,372	7,310	7,190	7,140	7,140
Irion	178	238	239	227	208	194	185
Kimble	972	1,148	1,142	1,129	1,113	1,104	1,104
Loving	11	11	11	10	10	10	10
McCulloch	2,266	2,252	2,263	2,236	2,205	2,190	2,190
Martin	645	788	843	858	860	832	789
Mason	889	932	926	916	905	898	900
Menard	427	458	455	446	438	435	435
Midland	30,627	32,568	34,202	35,301	35,976	36,517	37,180
Mitchell	1,728	1,703	1,671	1,621	1,559	1,499	1,409
Pecos	4,571	4,816	4,991	5,071	5,090	5,079	4,980
Reagan	923	1,035	1,123	1,167	1,148	1,103	1,049
Reeves	3,608	3,834	4,082	4,272	4,416	4,571	4,713
Runnels	1,550	2,091	2,140	2,174	2,207	2,250	2,319
Schleicher	671	723	775	795	794	806	824
Scurry	3,206	3,666	3,714	3,721	3,695	3,696	3,696
Sterling	324	349	377	387	386	373	379
Sutton	1,361	1,472	1,540	1,539	1,517	1,514	1,499
Tom Green	17,963	23,494	24,257	24,648	24,664	24,833	24,888
Upton	865	942	1,007	1,024	1,033	1,059	1,088
Ward	3,378	3,484	3,521	3,522	3,482	3,469	3,469
Winkler	2,266	2,377	2,450	2,444	2,423	2,369	2,292
Total	*128,410*	*141,965*	*147,828*	*151,280*	*153,206*	*155,340*	*157,632*

Data are from the Texas Water Development Board[4]

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[4]

2.3.2 Manufacturing Projections

Manufacturing use is the water used by industries in producing various products. To produce the projections, 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[6].

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 41 percent over the same period.

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.

The irrigation projections adopted for Region F are substantially different from the 2002 TWDB projections developed by the TWDB and are considerably higher than historical water use in the year 2000. The Region F Water Planning Group feels that the number of irrigated acres in the year 2000 was suppressed because of low cotton prices, changes to farm programs, and lack of available surface water for irrigation in Brown, Menard, Pecos, Sutton, Tom Green, and Ward Counties. The projections adopted by Region F are more indicative of potential irrigation demand with stable cotton prices and surface water supplies.

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

County	Historical	Projected					
	2000	2010	2020	2030	2040	2050	2060
Andrews	0	0	0	0	0	0	0
Borden	0	0	0	0	0	0	0
Brown	479	577	636	686	734	775	837
Coke	0	0	0	0	0	0	0
Coleman	5	6	6	6	6	6	6
Concho	0	0	0	0	0	0	0
Crane	0	0	0	0	0	0	0
Crockett	0	0	0	0	0	0	0
Ector	2,432	2,759	2,963	3,125	3,267	3,376	3,491
Glasscock	0	0	0	0	0	0	0
Howard	1,453	1,648	1,753	1,832	1,910	1,976	2,099
Irion	0	0	0	0	0	0	0
Kimble	582	702	767	823	880	932	1,002
Loving	0	0	0	0	0	0	0
McCulloch	680	844	929	1,004	1,075	1,137	1,233
Martin	34	39	41	42	43	44	47
Mason	0	0	0	0	0	0	0
Menard	0	0	0	0	0	0	0
Midland	135	164	182	198	213	226	245
Mitchell	0	0	0	0	0	0	0
Pecos	2	2	2	2	2	2	2
Reagan	0	0	0	0	0	0	0
Reeves	644	720	741	756	770	781	825
Runnels	52	63	70	76	82	87	94
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	1,861	2,226	2,498	2,737	2,971	3,175	3,425
Upton	0	0	0	0	0	0	0
Ward	6	7	7	7	7	7	7
Winkler	0	0	0	0	0	0	0
Total	*8,365*	*9,757*	*10,595*	*11294*	*11,960*	*12,524*	*13,313*

Texas Water Development Board, 2003 [4]

The irrigation projections are based on the moving average of reported irrigation water use in each county in recent years. From this starting point, the annual water use for irrigation was reduced by the expected savings due to implementation of more efficient irrigation practices. 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. Additional information may be found in the October 2003 *Proposed Revisions to Region F Water Demands*[8].

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)	10,341,131	9,976,301	9,581,833	9,202,620	8,839,094	8,552,224
Decline from Year 2010	0	364,830	759,298	1,138,511	1,502,037	1,788,907
% Decline	0%	4%	7%	11%	15%	17%

Note: Data are from the TWDB[10].

Agricultural use accounted for 66 percent of Region F's total water use in 2000 and is projected to be 72 percent of the region's demand in the year 2010. By 2060, irrigation could be as much as 67 percent of the region's water demand by 2060 (see Table 2.3-8). Statewide irrigation demand is projected to be 56 percent of total demand in the year 2010 and 39 percent of statewide demand in 2060. The counties with the largest irrigation water demands are Tom Green, Reeves, Pecos, Glasscock, Midland and Andrews Counties. These counties are expected to account for 72 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

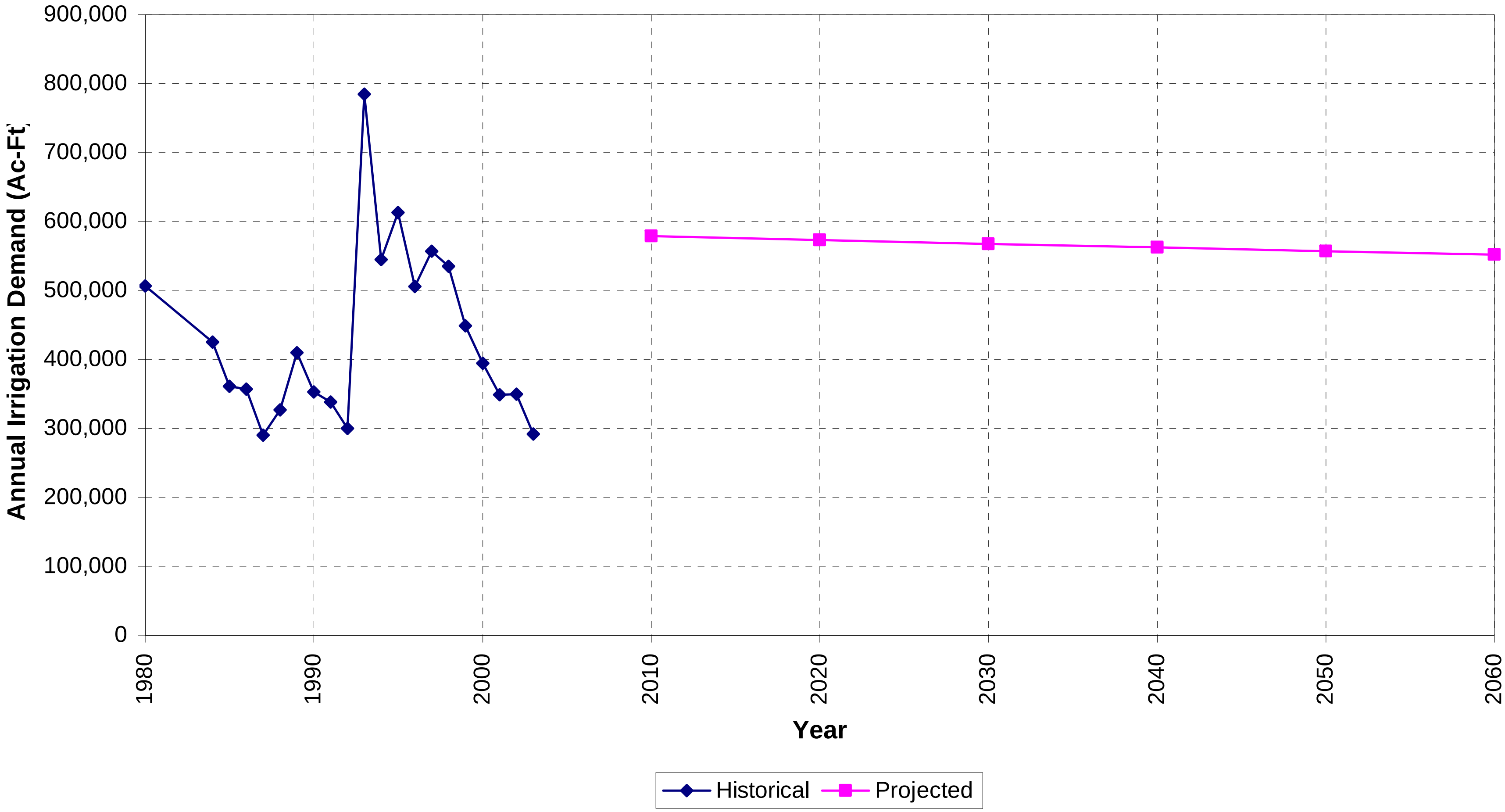


Table 2.3-8
Irrigation Water Demand Projections for Region F Counties
(Values in Acre-Feet per Year)

	Historical	**Projected**					
County	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Andrews	32,882	32,608	32,334	32,062	31,788	31,516	31,245
Borden	1,879	2,690	2,687	2,682	2,680	2,675	2,673
Brown	10,112	12,313	12,272	12,230	12,189	12,146	12,105
Coke	937	936	936	934	933	933	933
Coleman	0	1,379	1,379	1,379	1,379	1,379	1,379
Concho	2,574	4,297	4,280	4,262	4,245	4,229	4,213
Crane	337	337	337	337	337	337	337
Crockett	160	525	518	508	498	492	482
Ector	2,694	5,533	5,466	5,402	5,335	5,271	5,204
Glasscock	35,456	52,272	51,854	51,438	51,021	50,603	50,190
Howard	4,853	4,799	4,744	4,690	4,635	4,581	4,527
Irion	2,105	2,803	2,742	2,682	2,621	2,561	2,501
Kimble	637	985	948	913	877	841	807
Loving	358	581	580	576	575	573	572
McCulloch	2,859	2,824	2,789	2,754	2,718	2,683	2,649
Martin	14,575	14,324	14,073	13,822	13,571	13,321	13,075
Mason	10,223	10,079	9,936	9,792	9,648	9,505	9,363
Menard	3,143	6,061	6,041	6,022	6,003	5,981	5,962
Midland	30,483	41,493	41,170	40,848	40,526	40,203	39,884
Mitchell	5,564	5,534	5,507	5,479	5,452	5,425	5,398
Pecos	74,236	79,681	78,436	77,191	75,945	74,700	73,475
Reagan	15,879	36,597	35,990	35,385	34,779	34,174	33,579
Reeves	75,477	103,069	102,196	101,323	100,448	99,575	98,710
Runnels	920	4,331	4,317	4,298	4,279	4,260	4,241
Schleicher	2,150	2,108	2,067	2,024	1,982	1,939	1,897
Scurry	2,908	2,815	2,723	2,630	2,537	2,444	2,355
Sterling	637	648	621	595	569	543	518
Sutton	1,473	1,811	1,777	1,742	1,708	1,673	1,639
Tom Green	30,415	104,621	104,362	104,107	103,852	103,593	103,338
Upton	12,471	16,759	16,521	16,285	16,047	15,809	15,576
Ward	13,963	13,793	13,624	13,454	13,284	13,115	12,947
Winkler	2,002	10,000	10,000	10,000	10,000	10,000	10,000
Total	*394,362*	*578,606*	*573,227*	*567,846*	*562,461*	*557,080*	*551,774*

Texas Water Development Board, 2003 [4]

2.3.4 Steam Electric Power Generation

The steam electric power generation water demand projections were developed by TWDB-sponsored study by a consortium representing the Texas power industry[11]. The study 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. With the uncertainty in the power industry following deregulation, it is nearly impossible to accurately predict the location and need for future water demands. While the projections may not accurately reflect current activities, it is assumed that they represent the projected needs on a regional and state-wide basis. Based on the TWDB projections, steam electric water demand in Region F is expected to almost double, increasing from 22,215 acre-feet per year in 2010 to 44,008 acre-feet per year in 2060. This increase will make steam electric demands the third largest water use category in the region by 2060, behind agricultural irrigation and municipal. Table 2.3-9 summarizes the projections for steam electric demands. Statewide, steam electric demand is expected to increase from 755,170 acre-feet per year in 2010 to 1,533,556 acre-feet per year in 2060 [10].

2.3.5 Mining Projections

The mining category includes water used in both the production of minerals and the production of oil and gas. 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 analysis[6]. Table 2.3-10 compares Region F's mining projections to statewide 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. However, oil field flooding in Region F, the primary water use associated with production of oil and gas, has declined in recent years. Other mining activities, such as sand, gravel and stone production, represent a small portion of the region's economy and water demands. The TWDB expects that water demand for oil and

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

	Historical	Projected					
County	**2000**	**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	372	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	1,171	973	776	907	1,067	1,262	1,500
Ector	0	6,375	9,125	10,668	12,549	14,842	17,637
Glasscock	0	0	0	0	0	0	0
Howard	0	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	10,280	9,100	7,621	8,910	10,481	12,396	14,730
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	566	543	777	909	1,069	1,264	1,502
Upton	0	0	0	0	0	0	0
Ward	5,360	4,914	4,223	4,937	5,807	6,868	8,162
Winkler	0	0	0	0	0	0	0
Total	*17,749*	*22,215*	*22,769*	*26,620*	*31,312*	*37,033*	*44,008*

Texas Water Development Board, 2003 [4]

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	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Mining (ac-ft)	255,455	265,423	271,308	272,619	275,446	284,088
Change from Yr 2010	0	9,968	15,853	17,164	19,991	28,633
% Increase	0%	4%	6%	7%	8%	11%

Note: Data are from the TWDB [4].

gas production will increase somewhat over the planning period, resulting in a net increase in demand of 3,944 acre-feet per year by 2060. Mining 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 water use. A summary of the projected mining demands by county is presented in Table 2.3-11.

2.3.6 Livestock Watering

Livestock watering accounted for slightly less than 2 percent of the water use in Texas in 2000. The projections use information developed by the Texas A&M Agricultural Extension Service to 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.

The Region F RWPG increased the TWDB projections for the region by 32 percent to account for revised water use for different livestock categories and water use for wildlife associated with the hunting industry in the region. 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 404,397 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					
	2000	2010	2020	2030	2040	2050	2060
Andrews	1,761	1,908	1,957	1,976	1,994	2,012	2,036
Borden	883	690	658	646	635	625	612
Brown	2,427	2,487	2,504	2,510	2,516	2,522	2,530
Coke	405	488	528	550	572	593	614
Coleman	16	18	19	19	19	19	19
Concho	0	0	0	0	0	0	0
Crane	2,240	2,221	2,216	2,214	2,212	2,210	2,208
Crockett	355	402	421	431	441	450	459
Ector	8,481	9,888	10,519	10,911	11,292	11,666	11,970
Glasscock	7	5	5	5	5	5	5
Howard	1,536	1,783	1,883	1,924	1,963	2,001	2,052
Irion	123	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	845	674	645	634	624	615	603
Mason	6	6	6	6	6	6	6
Menard	0	0	0	0	0	0	0
Midland	515	677	778	846	915	986	1,046
Mitchell	141	115	110	108	107	106	104
Pecos	163	159	158	158	158	158	158
Reagan	1,742	2,036	2,165	2,235	2,303	2,370	2,436
Reeves	203	182	177	175	173	172	170
Runnels	41	44	45	45	45	45	45
Schleicher	105	125	134	139	144	149	154
Scurry	2,606	3,107	3,327	3,413	3,496	3,577	3,693
Sterling	560	590	600	605	610	615	620
Sutton	75	80	82	83	84	85	86
Tom Green	59	73	80	85	90	95	99
Upton	2,599	2,662	2,680	2,687	2,694	2,700	2,708
Ward	147	153	155	156	157	158	159
Winkler	1,104	928	895	883	872	861	847
Total	*29,379*	*31,850*	*33,097*	*33,795*	*34,479*	*35,154*	*35,794*

Texas Water Development Board, 2003 [4]

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

County	Historical	Projected					
	2000	2010	2020	2030	2040	2050	2060
Andrews	319	438	438	438	438	438	438
Borden	260	281	281	281	281	281	281
Brown	1,471	1,636	1,636	1,636	1,636	1,636	1,636
Coke	374	593	593	593	593	593	593
Coleman	1,139	1,259	1,259	1,259	1,259	1,259	1,259
Concho	542	775	775	775	775	775	775
Crane	144	155	155	155	155	155	155
Crockett	767	997	997	997	997	997	997
Ector	202	293	293	293	293	293	293
Glasscock	198	232	232	232	232	232	232
Howard	312	366	366	366	366	366	366
Irion	318	460	460	460	460	460	460
Kimble	472	668	668	668	668	668	668
Loving	40	70	70	70	70	70	70
McCulloch	903	1,027	1,027	1,027	1,027	1,027	1,027
Martin	851	273	273	273	273	273	273
Mason	534	1,036	1,036	1,036	1,036	1,036	1,036
Menard	418	642	642	642	642	642	642
Midland	395	904	904	904	904	904	904
Mitchell	443	449	449	449	449	449	449
Pecos	981	1,239	1,239	1,239	1,239	1,239	1,239
Reagan	225	272	272	272	272	272	272
Reeves	838	2,283	2,283	2,283	2,283	2,283	2,283
Runnels	936	1,530	1,530	1,530	1,530	1,530	1,530
Schleicher	548	787	787	787	787	787	787
Scurry	528	629	629	629	629	629	629
Sterling	365	503	503	503	503	503	503
Sutton	551	796	796	796	796	796	796
Tom Green	1,886	1,978	1,978	1,978	1,978	1,978	1,978
Upton	203	212	212	212	212	212	212
Ward	117	126	126	126	126	126	126
Winkler	151	151	151	151	151	151	151
Total	*17,431*	*23,060*	*23,060*	*23,060*	*23,060*	*23,060*	*23,060*

Texas Water Development Board, 2003 [4]

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. The wholesale water providers: 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 are described in Chapter 1.

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. Midland, San Angelo, Robert Lee, Abilene and Millersview-Doole WSC have other sources of water and only 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 water to the City of Santa Anna in Coleman County and to users in Coleman and Mills Counties through Brooksmith SUD. BCWID will soon provide water to Coleman County WSC to supplement water from Lake Coleman. Coleman County WSC has customers in Coleman, Brown, Runnels, Callahan and Taylor Counties. For the purposes of this plan, it is assumed that all of the BCWID water provided to Coleman County WSC will be used in Brown and Coleman Counties.

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

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	21,927	22,687	23,350	24,145	25,222	26,484
Big Spring	Howard	Colorado	6,016	6,077	6,035	5,945	5,915	5,915
Snyder	Scurry	Colorado	2,792	2,834	2,844	2,829	2,832	2,832
Member Cities Total			*30,735*	*31,598*	*32,229*	*32,919*	*33,969*	*35,231*
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
Ector County UD	Ector	Colorado	1,480	1,847	2,177	2,473	2,706	2,932
Manufacturing	Ector	Colorado	243	446	607	748	857	971
Coahoma	Howard	Colorado	183	185	183	180	177	177
Manufacturing	Howard	Colorado	989	1,052	1,099	1,161	1,227	1,350
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	14,951	14,948	14,945	14,942	14,940	14,937
County Other	Midland	Colorado	21	21	21	21	21	21
Manufacturing	Midland	Colorado	28	31	34	37	39	42
County-Other	Scurry	Colorado	200	200	200	200	200	200
Rotan	Fisher	Brazos	278	271	249	231	222	203
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	706	728	747	759	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			*62,609*	*64,560*	*46,433*	*46,515*	*45,749*	*45,805*
CRMWD Total			*93,344*	*96,158*	*78,662*	*79,434*	*79,718*	*81,036*

a Does not include potential new customers identified in the planning process or contract renewals.
b Stanton contract expires in 2010.
c Midland 1966 contract expires in 2026.
d Millersview-Doole WSC contract expires in 2044.

Table 2.4-2
Expected Demands for the Brown County Water Improvement District No. 1*
(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	229	229	223	214	211	211
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	231	234	230	226	225	227
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			*14,960*	*15,087*	*15,066*	*14,997*	*14,966*	*15,029*

* 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 what 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	2010	2020	2030	2040	2050	2060
San Angelo	Tom Green	Colorado	3,762	3,643	3,525	3,407	3,288	3,170
Miles	Runnels	Colorado	100	100	100	100	100	100
Robert Lee	Coke	Colorado	250	250	250	250	250	250
UCRA Total			4,112	3,993	3,875	3,757	3,638	3,520

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 2010 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. Great Plains is assumed to supply all of the water from the Ogallala aquifer used for mining purposes in Andrews County.

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	351	351	351	351	351	351
Steam-Electric	Ector	Colorado	6,375	6,375	6,375	6,375	6,375	6,375
Great Plains WSC Total			*6,726*	*6,726*	*6,726*	*6,726*	*6,726*	*6,726*

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. For this plan, power generation demands from Lake Nasworthy have been limited to 1,021 acre-feet per year, the maximum amount of water used for steam electric generation in 1999.

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

WUG Name	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	100	100	100	100	100	100
Manufacturing	Tom Green	Colorado	2,226	2,498	2,737	2,971	3,175	3,425
Steam-Electric	Tom Green	Colorado	543	777	909	1,069	1,264	1,502
Irrigation	Tom Green	Colorado	26,500	26,500	26,500	26,500	26,500	26,500
	Total		*50,419*	*51,543*	*52,230*	*52,634*	*53,196*	*53,746*

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 2008) and the City of Andrews' well field (contract expires in 2010). 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
	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 2010. Andrews obtains approximately 20 percent of supply from University Lands.
d The contract between Midland and University Lands will expire in 2008. The City of Midland expects its well field on University Lands will be depleted by 2035.

2.5 List of References

[1] Texas Water Development Board: *Draft Historical and Projected Population Data for Regional Planning Groups*, August 23, 2002.

[2] Texas Water Development Board: *Draft Historical and Projected Water Use Data for Regional Planning Groups*, December 20, 2002.

[3] Texas Water Development Board: *Revised Draft Historical and Projected Water Use Data for Region F*, May 2, 2003.

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

[5] Texas Water Development Board: Historical summary data for Region F, April 1999.

[6] 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.

[7] Freese and Nichols, Inc.: *Proposed Population Projections Revisions for Region F*, December 2002.

[8] Freese and Nichols, Inc.: *Proposed Revisions to Region F Water Demands*, October 2003.

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

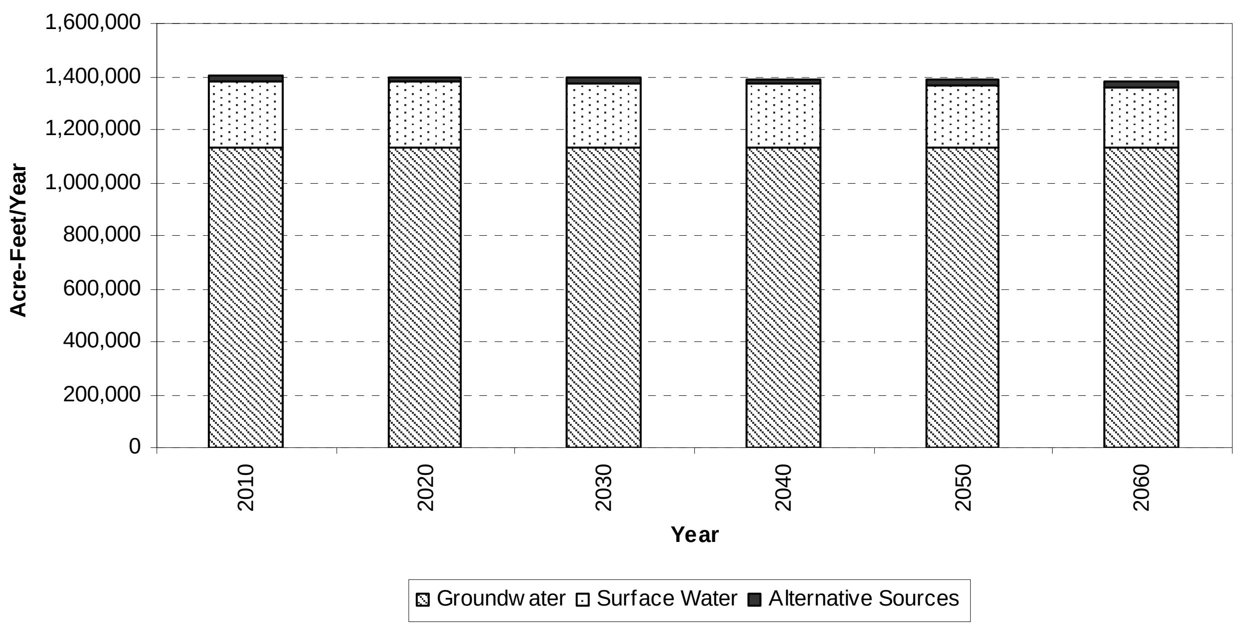
[10] Texas Water Development Board, DB07 database, June 2005.

[11] 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 baseline water availability for Water User Groups (WUGs) in Region F. 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)

Figure 3.1-1
Water Availability by Source Type



3.1 Existing Groundwater Supplies

In 2000, groundwater sources supplied 414,000 acre feet of water, accounting for 69 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.

From a planning perspective, groundwater availability 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 availability may be limited by the economics of water treatment. For those counties in the region that are not governed by a groundwater conservation district, aquifer availability is based on historical use trends. Figure 1.3-4 shows the counties currently governed by groundwater conservation districts.

Groundwater availability by aquifer and river basin within each county is listed in Table 3.1-1. As discussed above, the availability volumes listed in this table represent an acceptable level of aquifer withdrawal in each county based on policy decisions that attempt to maintain water levels in the aquifers at desired levels (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.

The quantification of groundwater availability considers both aquifer recharge and water held in storage in the aquifer matrix. Groundwater availability is defined by the following formula:

Availability = Drought Year Recharge + Annual Supply from Storage

The amount of water available from storage may be either 0 (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).

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

County	Aquifer	Basin	Annual Recharge During Drought [a]	Annual Supply from Storage	Annual Availability
Andrews	Cenozoic Pecos Alluvium	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	Colorado	2,026	0	2,026
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	Cenozoic Pecos Alluvium	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	Cenozoic Pecos Alluvium	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 Supply from Storage	Annual Availability
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	Cenozoic Pecos Alluvium	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	15,357	0	19,000
	Ellenburger-San Saba	Colorado	159	0	159
	Hickory	Colorado	0	0	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
	Cenozoic Pecos Alluvium	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
	Cenozoic Pecos Alluvium	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 Supply from Storage	Annual Availability
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	Cenozoic Pecos Alluvium	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	Cenozoic Pecos Alluvium	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	Cenozoic Pecos Alluvium	Rio Grande	3,727	48,267	51,994
	Dockum	Rio Grande	0	10,746	10,746
	Edwards-Trinity	Colorado	423	94	517
	Capitan Reef	Rio Grande	0	15,000	15,000
Total			*591,561*	*541,600*	*1,170,804*

a Drought recharge equals one half of average annual recharge.

b Supplies for Menard County are from the Menard County Underground Water District management plan.

The Edwards-Trinity (Plateau) Groundwater Availability Model (GAM) was not completed in time for its full use during this planning period. Therefore, only key input factors (recharge) from draft versions of the GAM were used. Recharge estimates for the Edwards-Trinity aquifer are one half of average annual recharge as provided in the Edwards-Trinity (Plateau) GAM. No data were available from other GAMs. Recharge for other aquifers in the region, along with water in storage estimates, were retained from the 2001 *Region F Water Plan*. These recharge estimates were from previous studies by TWDB.

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Groundwater Availability Determination

Region F Water Plan

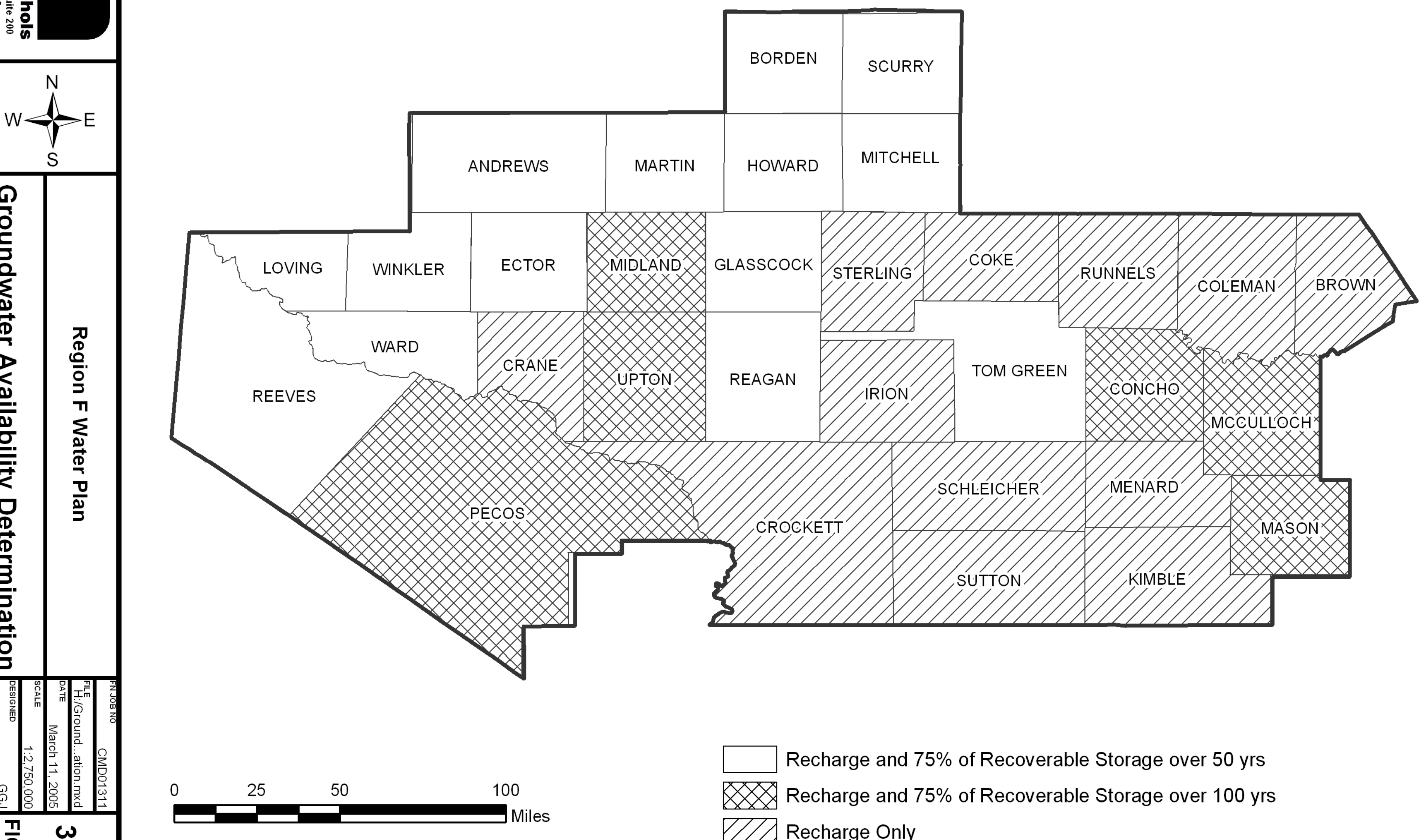

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FIGURE 3.1-2

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. 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 in pumpage, and are currently recovering. Figure 3.1-5 shows selected wells showing increases in water

Edwards-Trinity Aquifer

Region F Water Plan

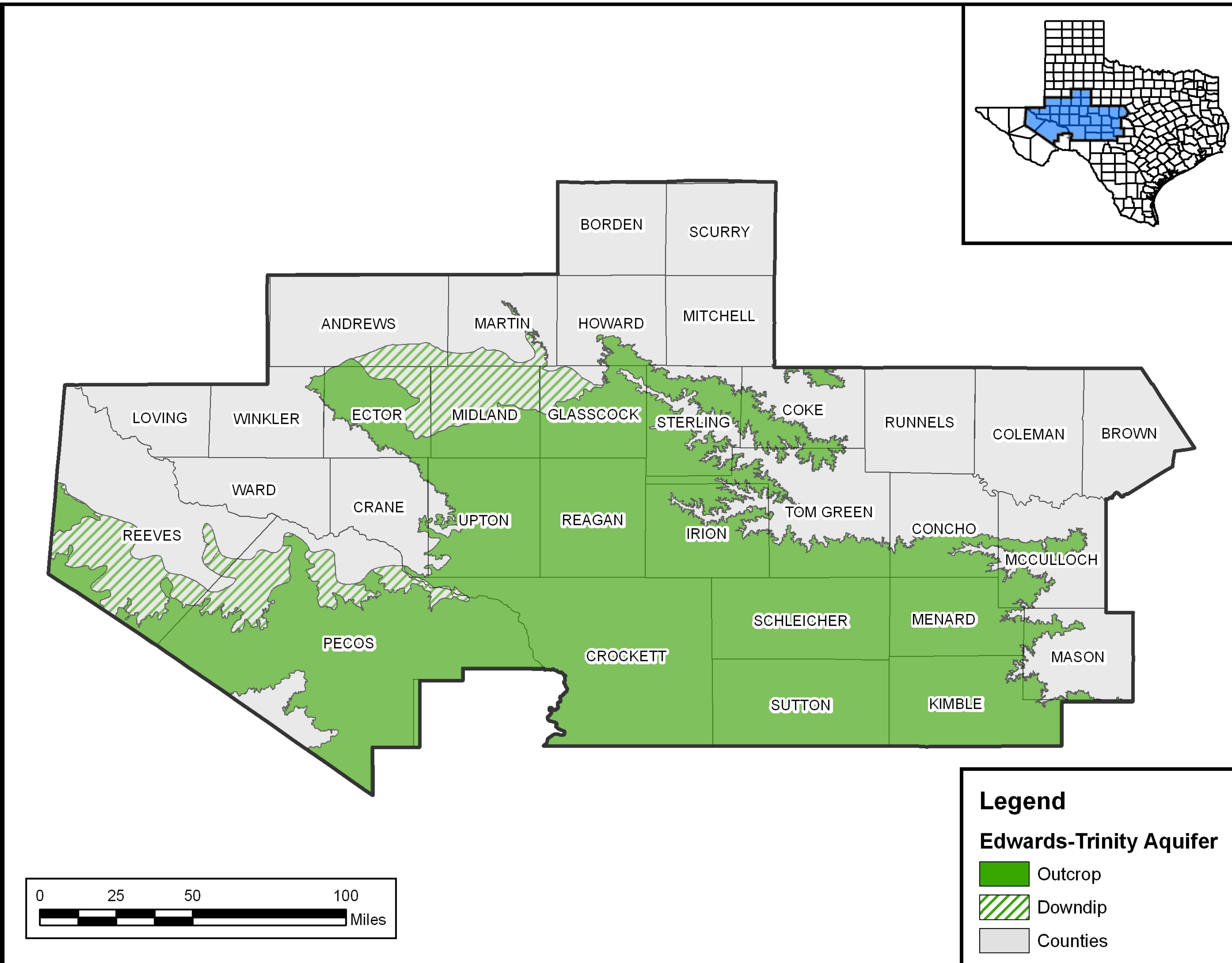

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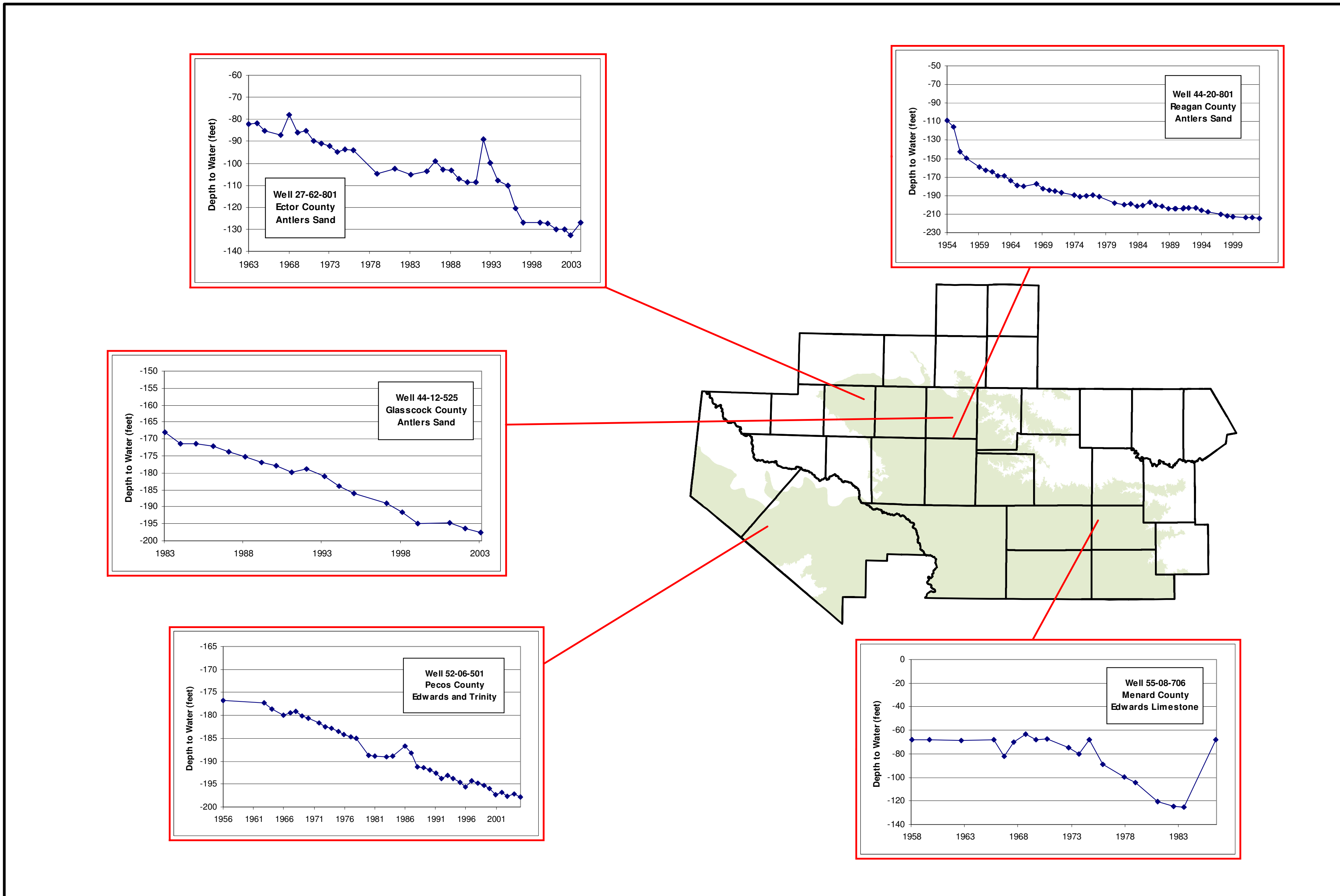
FIGURE 3.1-3



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Region F Water Plan

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

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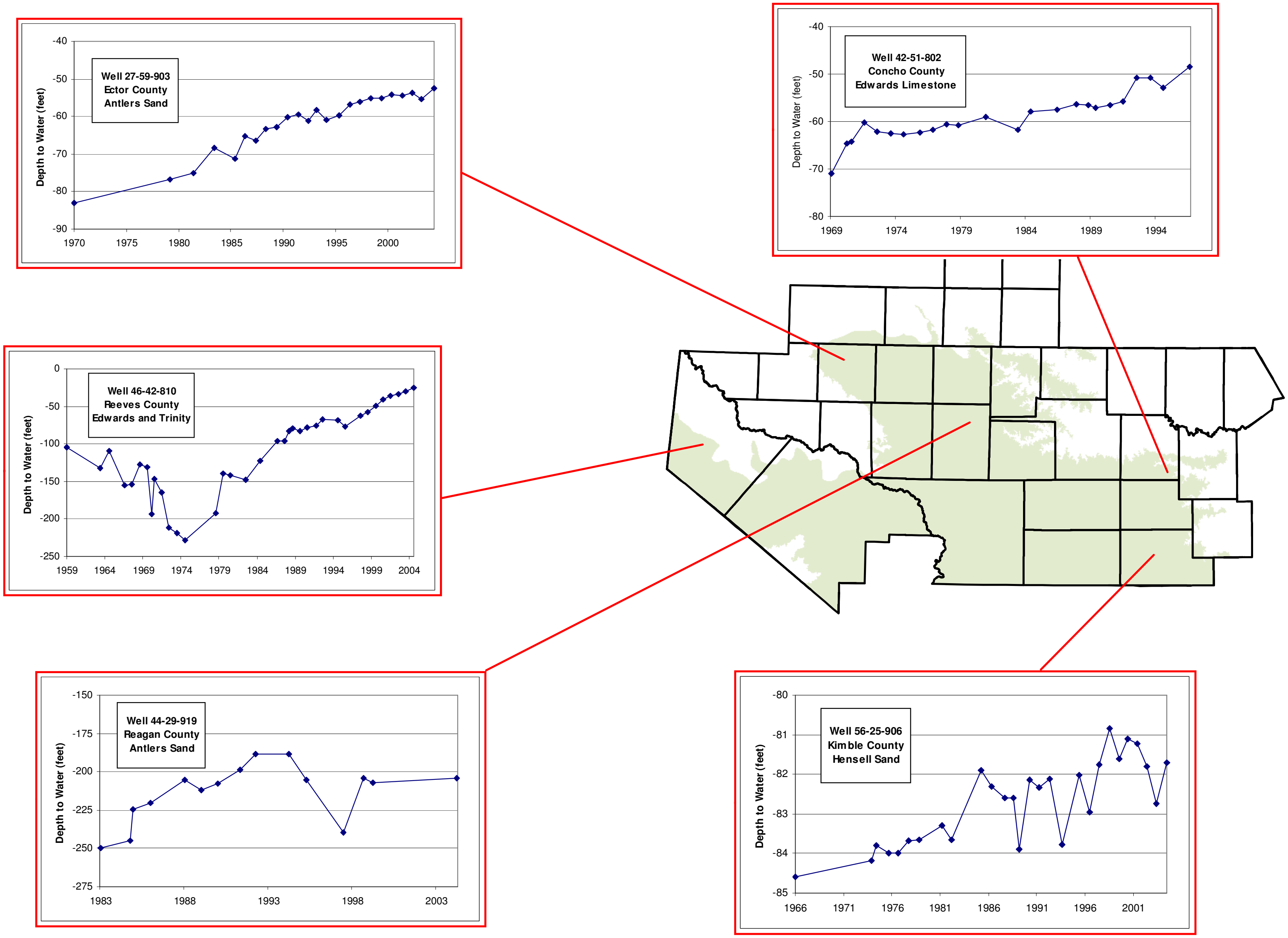
3.1-4

FIGURE



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Region F Water Plan

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

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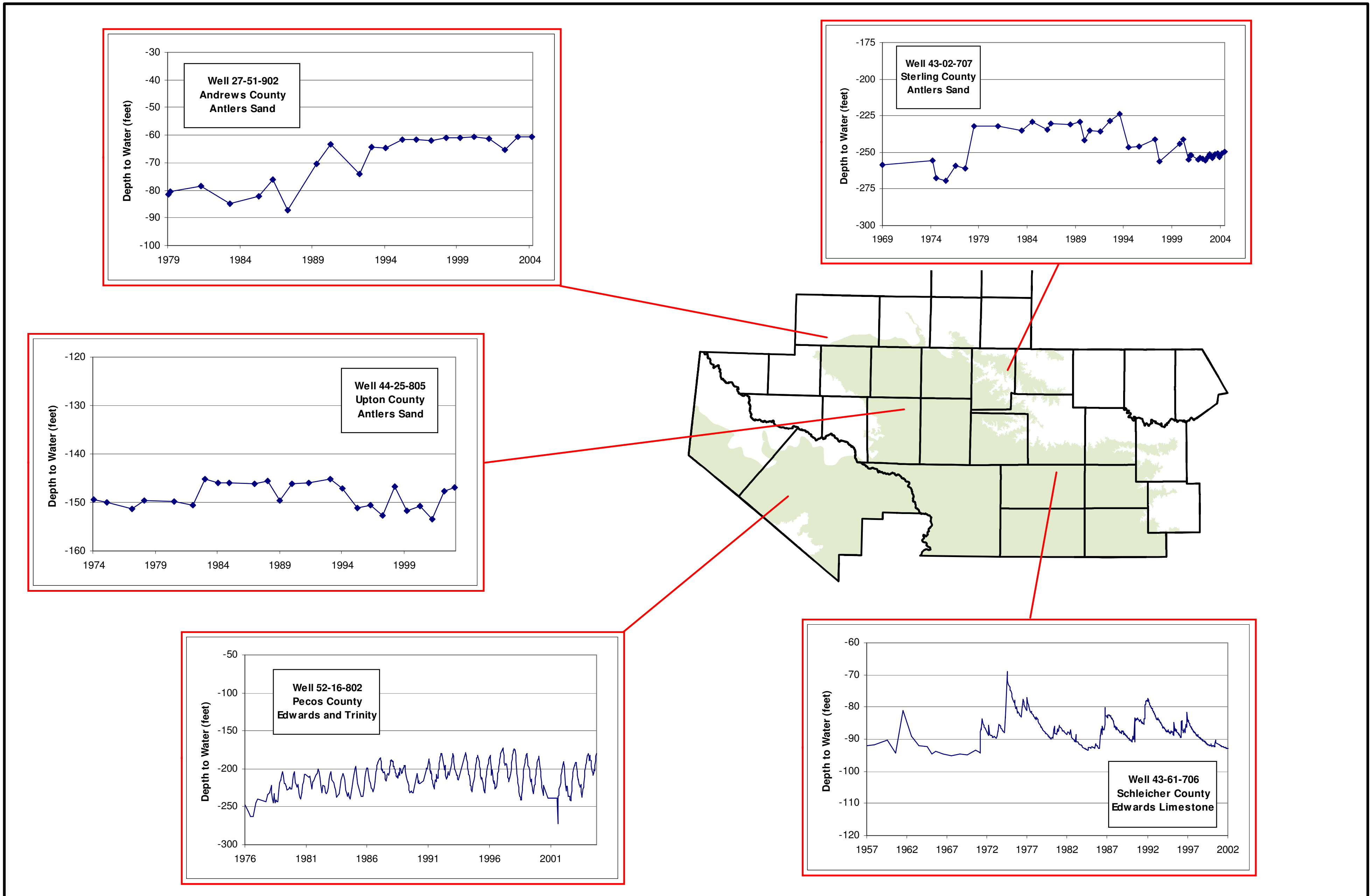
3.1-5
FIGURE



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Region F Water Plan

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

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3.1-6
FIGURE

levels over time. 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 rarely as much as 1,000 gpm, although 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 groundwater conservation districts. Seven districts assisted in establishing the monitor well and rain gage networks, and collected and recorded the data used in the study:

- 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

A full discussion of the study and the results are contained in a separately bound document titled *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.

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 Cenozoic Pecos Alluvium Aquifer

The Cenozoic Pecos Alluvium 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 Cenozoic Pecos Alluvium 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.

FIGURE 3.1-7

Ogallala Aquifer

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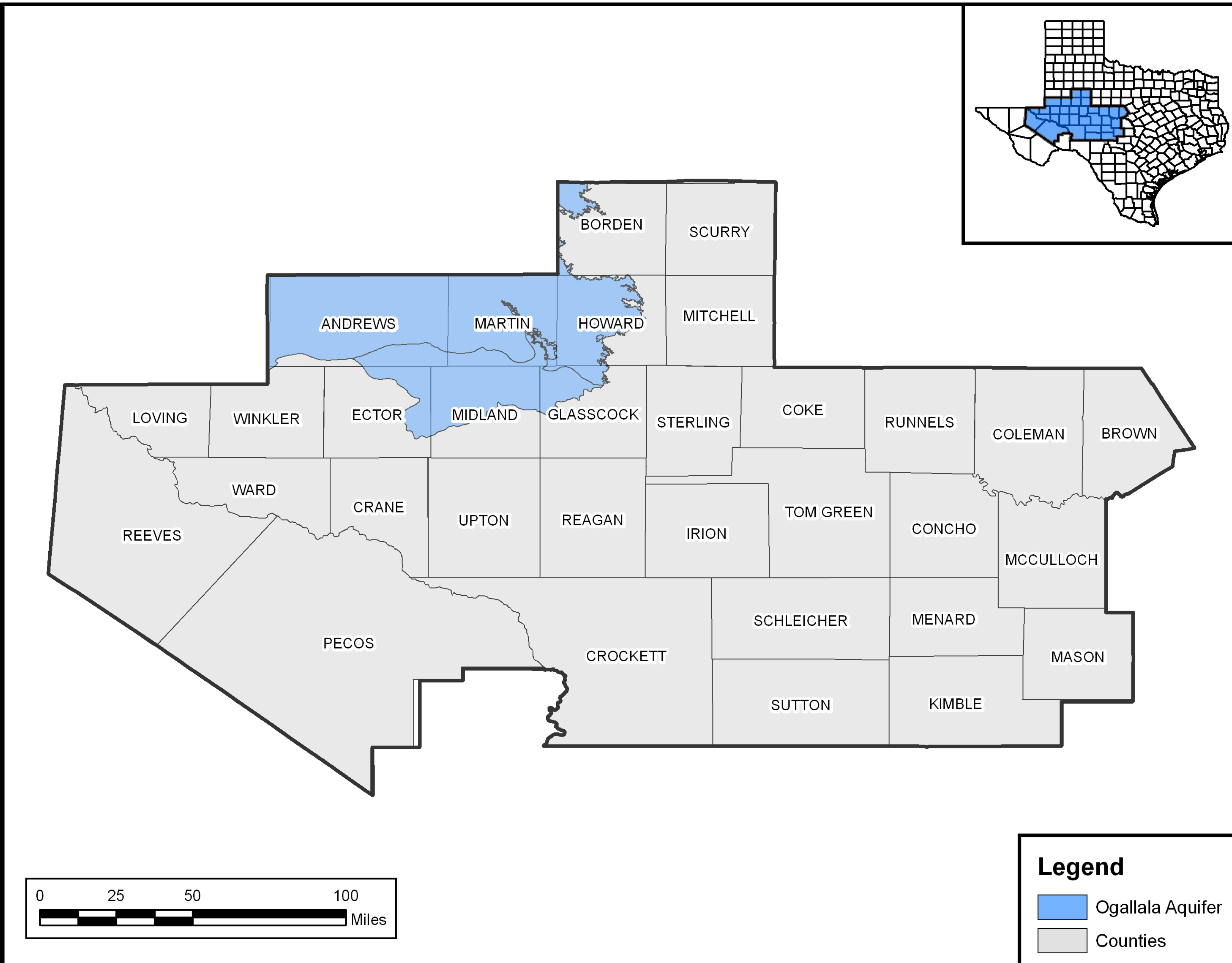

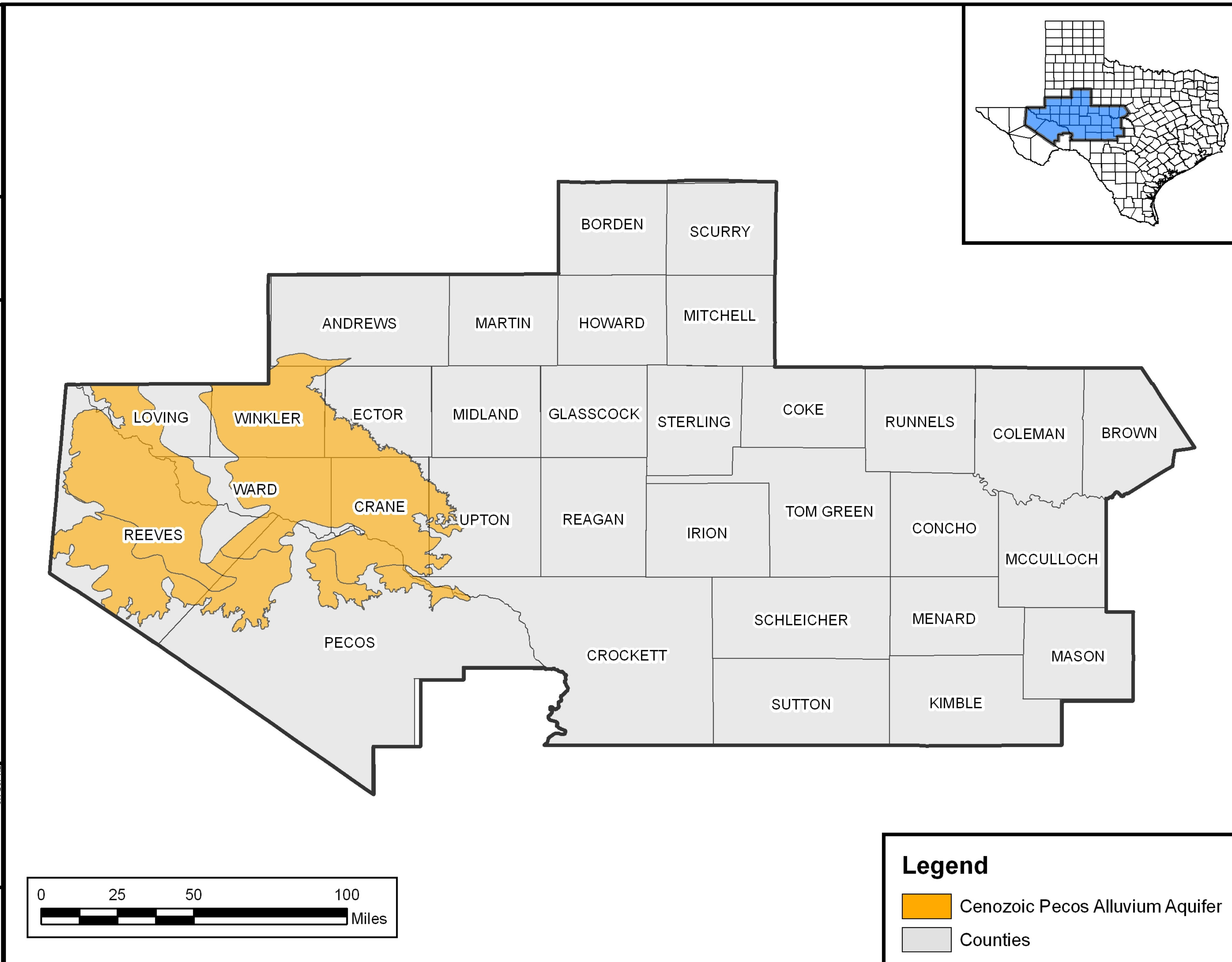

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Cenozoic Pecos Alluvium Aquifer

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FIGURE 3.1-8

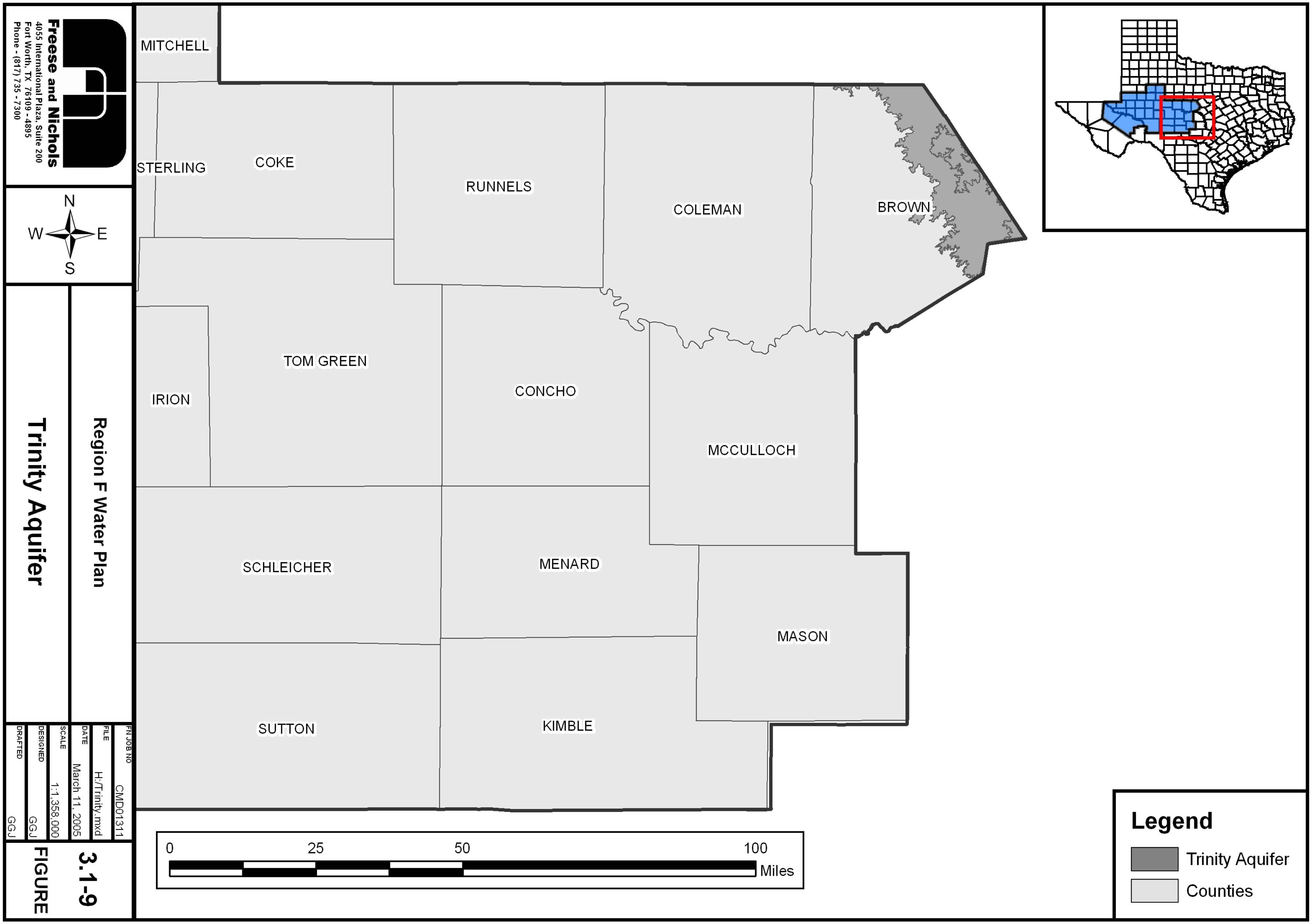
The western basin (Pecos Trough) contains poorer quality water and is used most extensively for irrigation of salt-tolerant crops. The eastern basin (Monument Draw Trough) contains relatively good quality water that is used for a variety of purposes, including industrial use, power generation, and public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

The Cenozoic Pecos Alluvium 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 Cenozoic Pecos Alluvium 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. 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
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FIGURE 3.1-9
MITCHELL
STERLING
COKE
RUNNELS
COLEMAN
BROWN
IRION
TOM GREEN
CONCHO
MCCULLOCH
SCHLEICHER
MENARD
MASON
SUTTON
KIMBLE
0
25
50
100
Miles
Legend
Trinity Aquifer
Counties

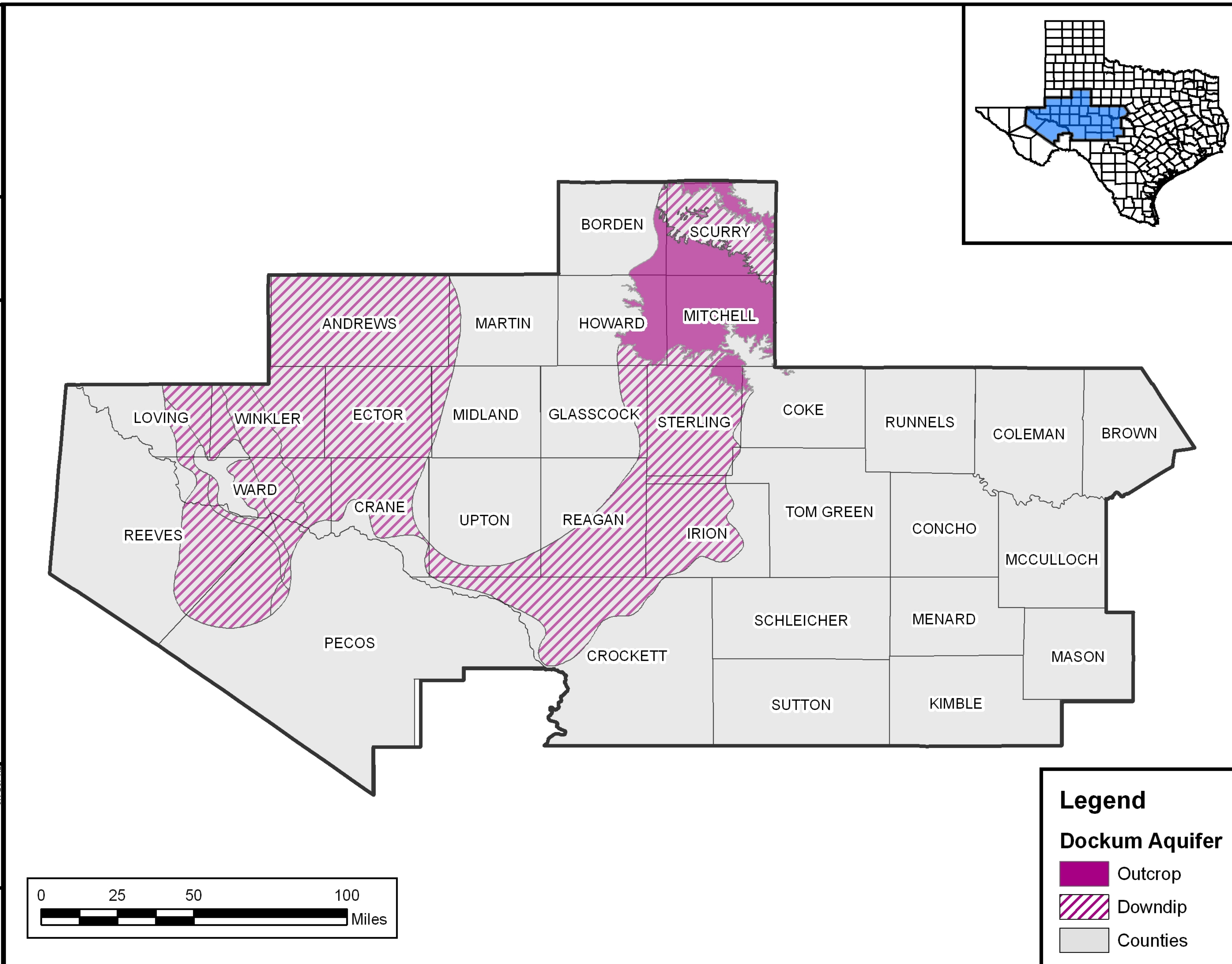
Trinity aquifer water quality is acceptable for most municipal, industrial, and irrigation purposes. Dissolved solids range from approximately 150 to over 7,000 mg/l in Brown County; however, most wells have dissolved solids concentrations of less than 1,000 mg/l. The potential for updip movement of 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 Cenozoic Pecos Alluvium. Although the Dockum aquifer underlies much of the region, its low water-yielding potential 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 defined 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 Cenozoic Pecos Alluvium 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. As discussed in the previous paragraph, recharge potential also occurs where water-bearing units of the Trinity and Cenozoic Pecos Alluvium 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.

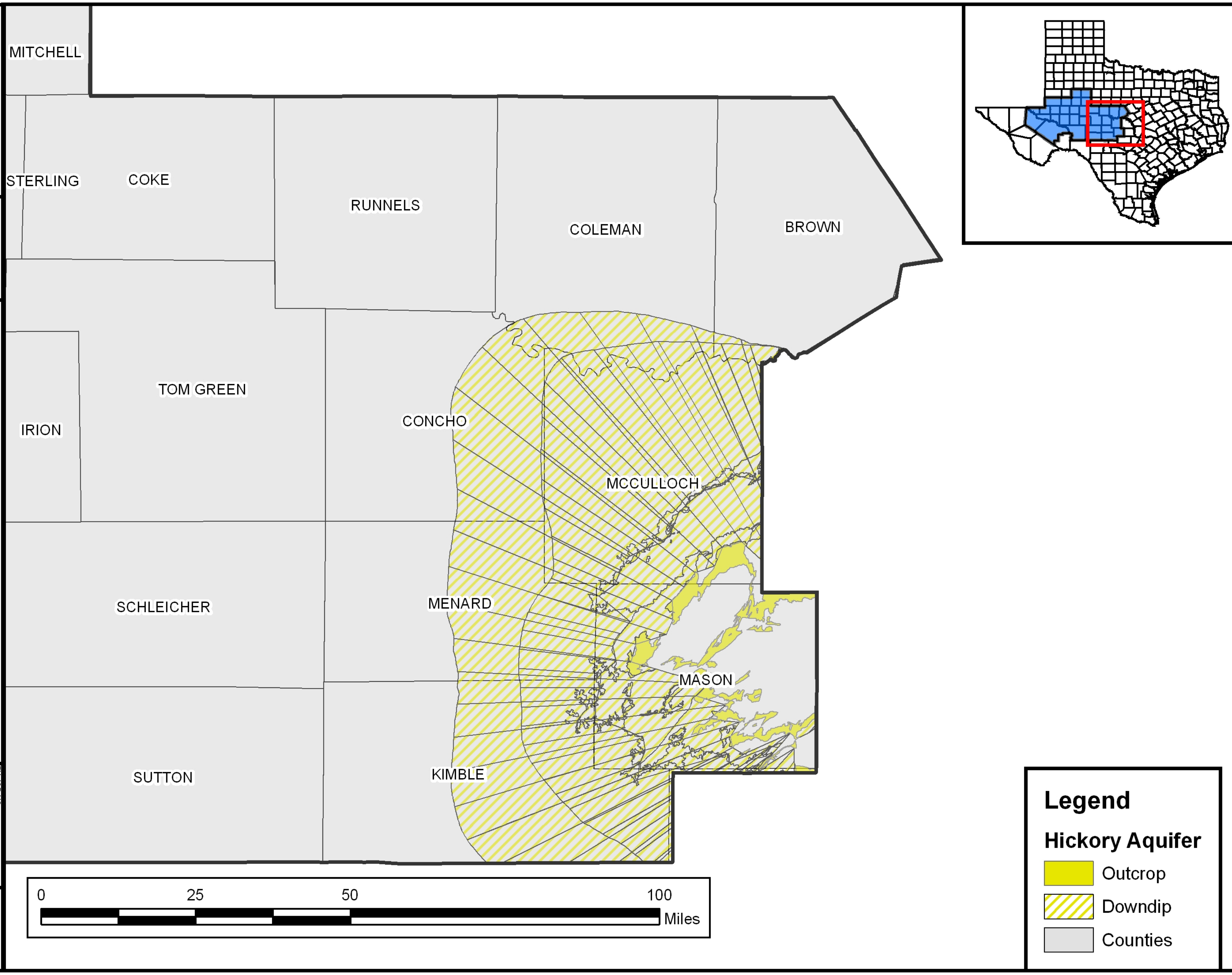
The chemical quality of water from the Dockum aquifer ranges from fresh in outcrop areas to very saline in the deeper central basin area. Groundwater pumped from the aquifer in Region F has average dissolved solids ranging from 558 mg/l in Winkler County to over 2,500 mg/l in Andrews, Crane, Ector, Howard,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



Hickory Aquifer

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FIGURE 3.1-11

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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.

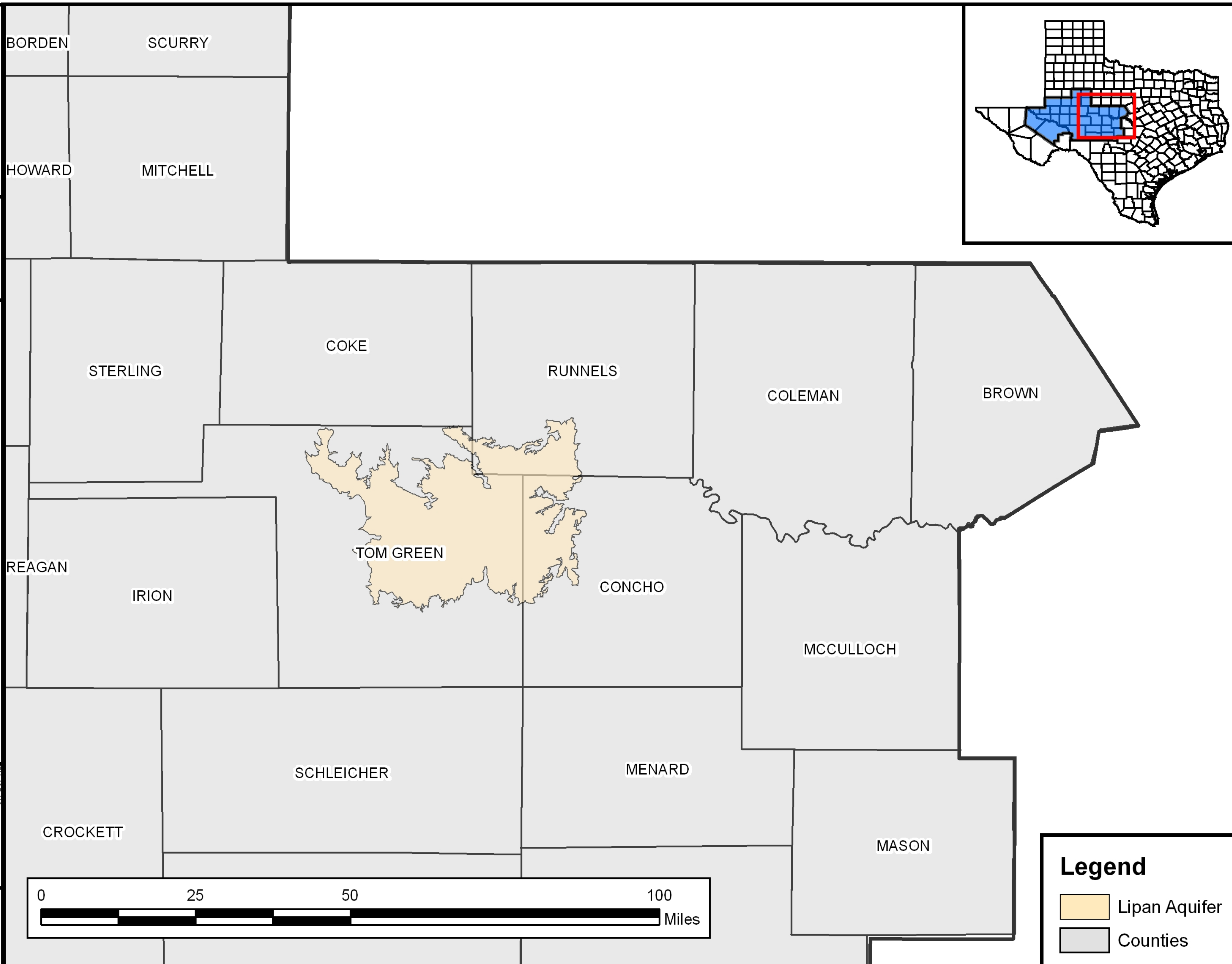
Yields of large-capacity wells usually range between 200 and 500 gpm. Some wells have yields in excess of 1,000 gpm. Highest well yields are typically found northwest of the Llano Uplift, where the aquifer has the greatest saturated thickness.

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 Choza Formation, Bullwagon Dolomite, and Standpipe Limestone of Permian-age 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

Oil field activities and irrigation practices have affected the quality of the groundwater in the Lipan aquifer. Leaking, abandoned oil wells have allowed brine to infiltrate into fresh-water zones in local areas. Seasonal heavy irrigation pumpage has encouraged the upward migration of poorer quality water from deeper zones. 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. In Brown and Coleman Counties, the aquifer is present in only the extreme southern part, 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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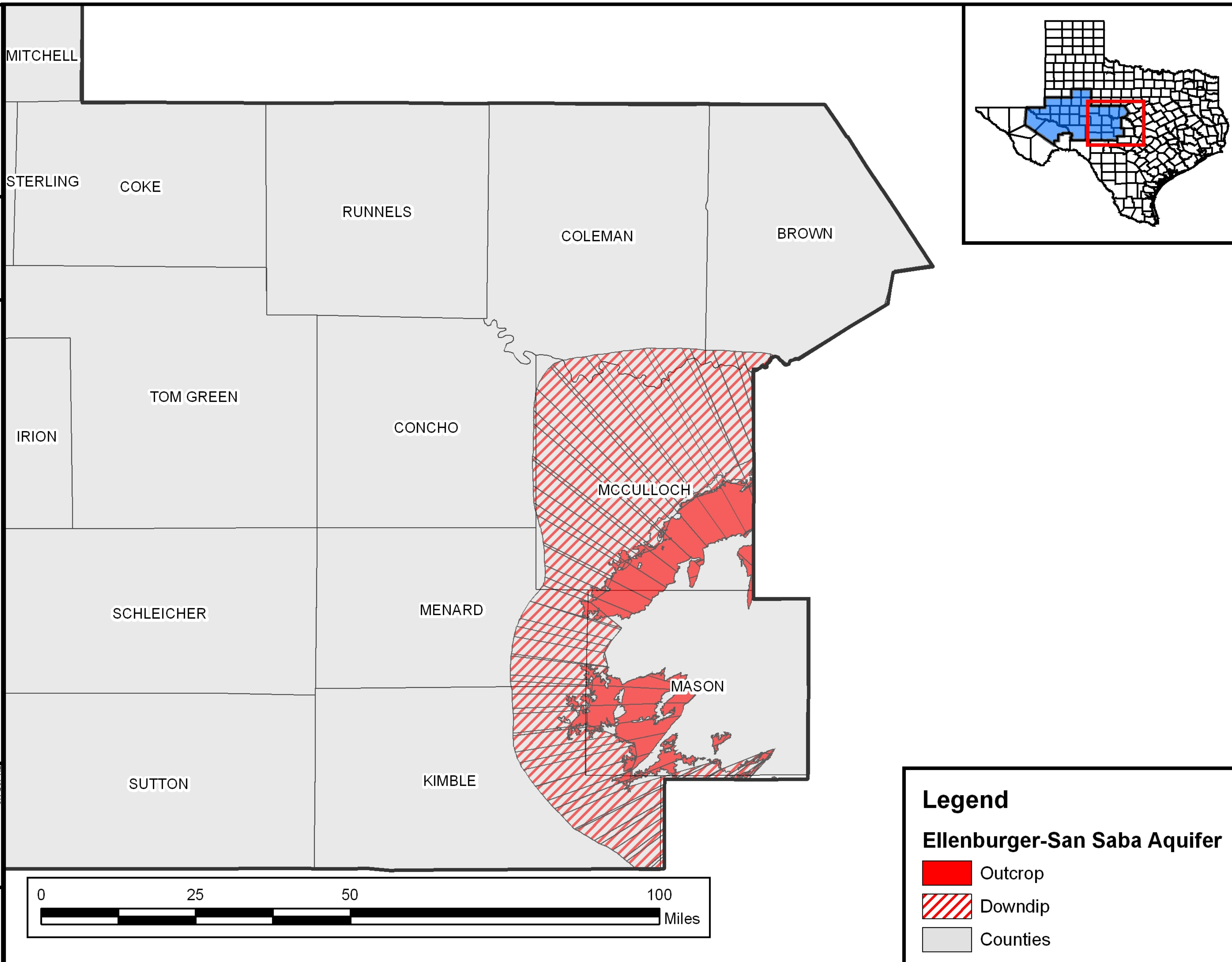
FIGURE 3.1-13



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 Cenozoic Pecos Alluvium 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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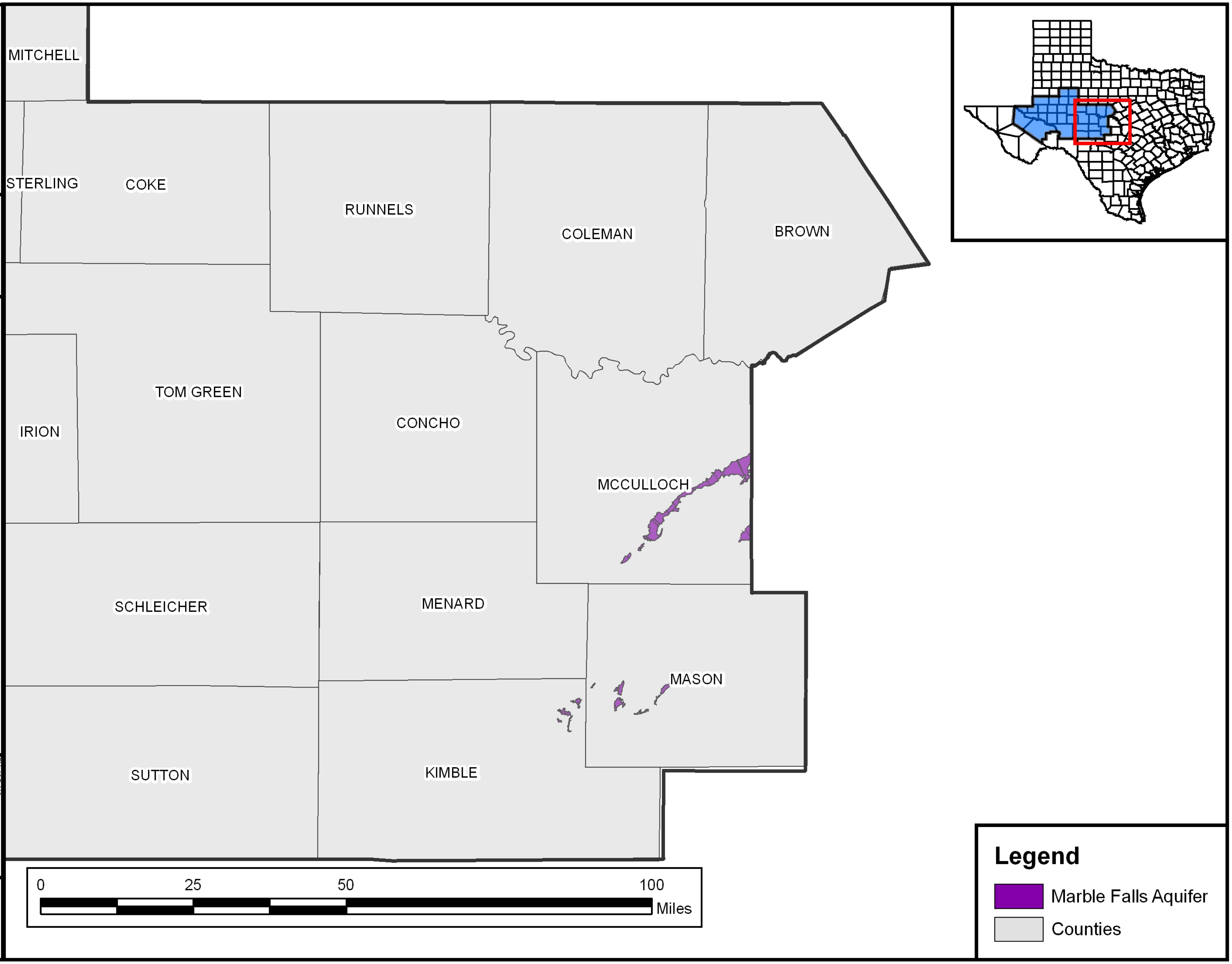
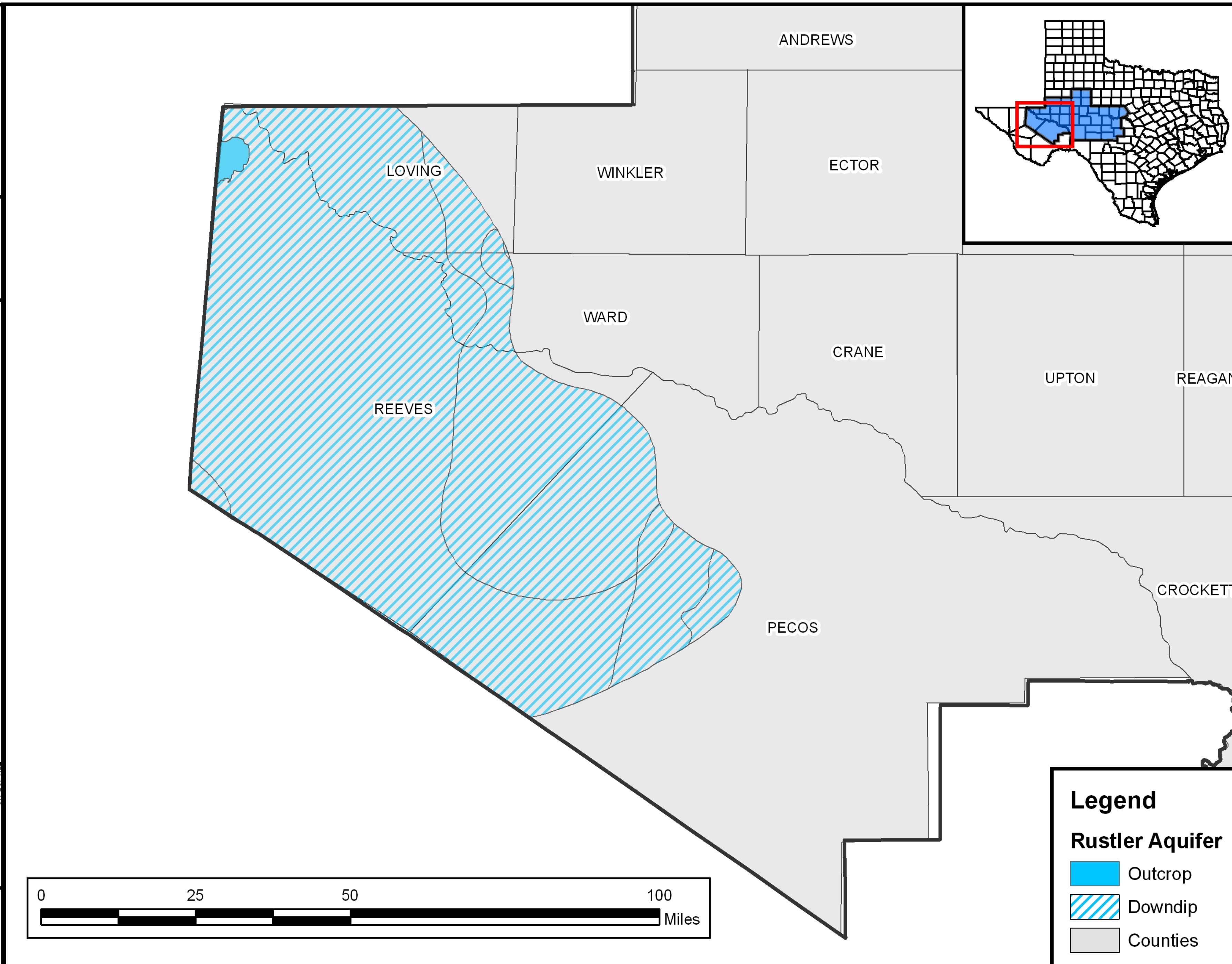
FIGURE 3.1-14





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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 Cenozoic Pecos Alluvium, 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 of brackish water supply for desalination treatment.

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Capitan Reef Aquifer

Region F Water Plan

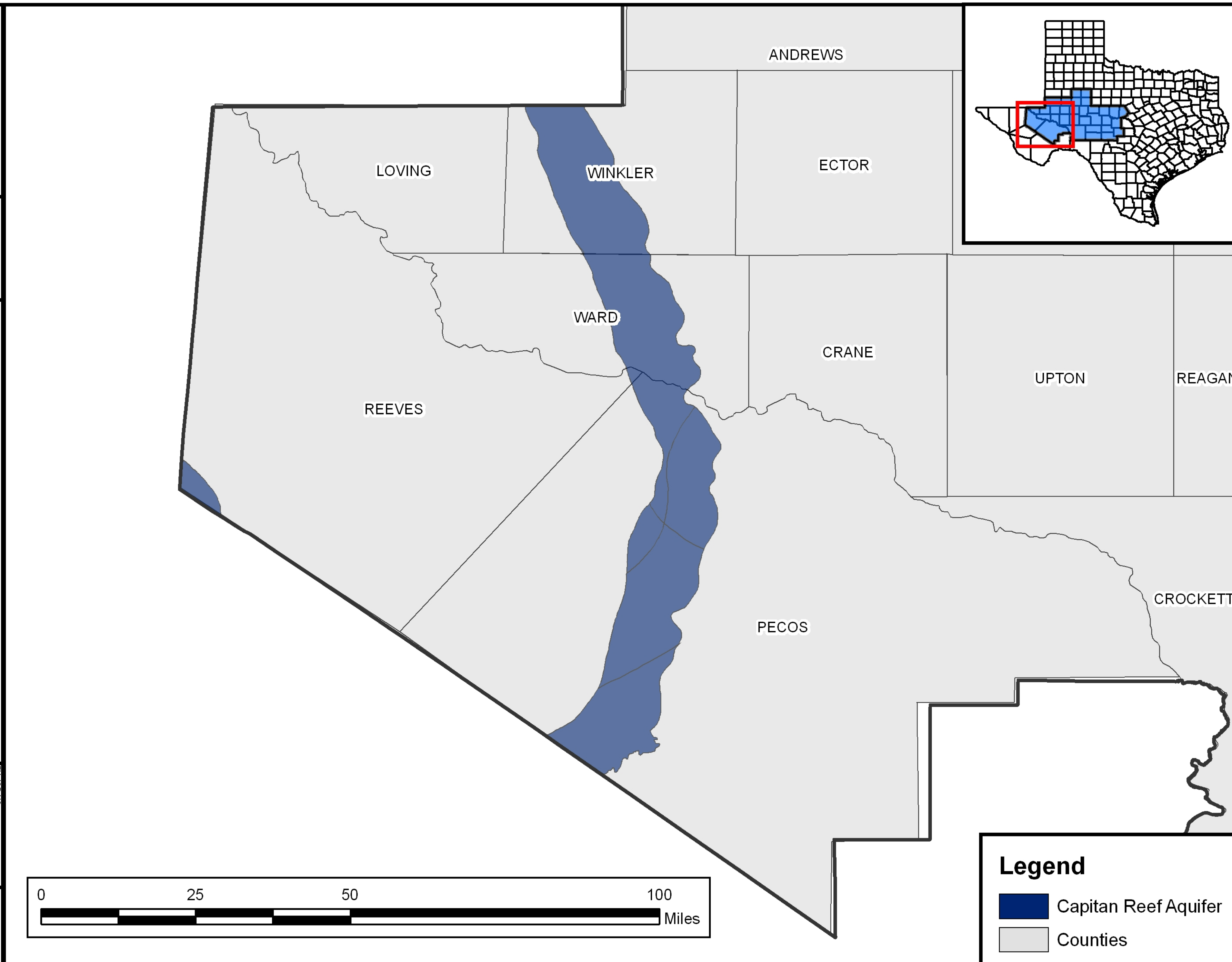

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FIGURE 3.1-16

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 are not effective 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 do have some potential to produce brackish groundwater at reasonable rates from shallower depths in and near where they outcrop, which for many of these units is in the eastern third of the region. If areas in or near the outcrop area of any of these deeper units are to be targeted, additional data and study on a site-specific basis will be required.

Additional information on brackish water supplies may be found in Appendix 3A.

3.2 Existing Surface Water Supplies

In the year 2000, approximately 187,000 acre-feet of surface water was used in Region F, supplying 31 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 18 major reservoirs in Region F. Figure 3.2-1 shows the location of these reservoirs. Additional information regarding water rights and historical water use may be found in Chapter 1. A comprehensive list of Region F water rights may be found in Appendix 3B.

Table 3.2-1
Major Reservoirs in Region F

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 *	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 *	CRMWD	CRMWD
Mitchell County Reservoir	Colorado	Off-channel	Mitchell		2/14/1990	27,266			
Lake Winters/ New 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	2,260	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	119,000	80,400	COE	Upper Colorado River Authority
Twin Buttes Reservoir	Colorado	South Concho River	Tom Green	CA-1318	05/06/1959	186,000	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 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	Reeves Co WID #1	Reeves Co WID #1
Total						*2,212,709*	*723,777*		

Note: A major reservoir has more than 5,000 acre-feet of storage.

* Total diversions under CA 1002 and CA 1008 limited to 73,000 acre-feet per year. 7,000 ac-ft per year can be diverted at either Thomas or Spence.

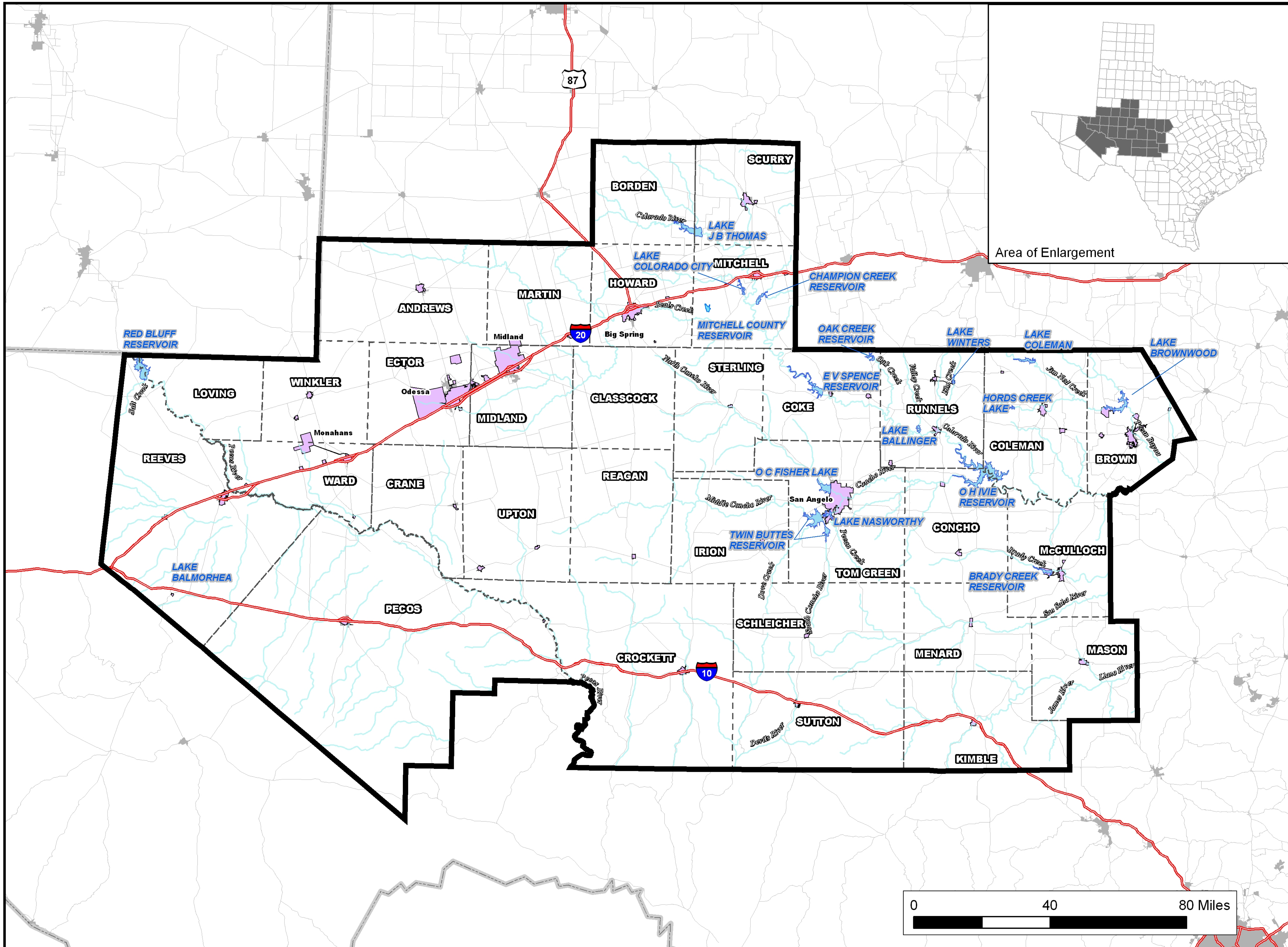

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Figure 3.2-1

Region F Major Reservoirs

N E S W

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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[1]. 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 492,000 acre-feet of permitted diversions in the Colorado Basin in Region F, slightly more than half of the permitted diversions in the region. There are 481,144 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 yield of the 17 major reservoirs in Region F used in the 1997 State Water Plan[2], the 2001 Region F Plan[3], and from the TCEQ WAM[4] (Mitchell County Reservoir was not included in the 1997 or 2001 water plans). Table 3.2-3 compares run-of-the river supplies from the 2001 Region F Plan to the supplies from the TCEQ WAM. (In most cases, the run-of-the-river supplies from the 2001 Region F Plan are identical to those used in the 1997 State Water Plan.) The supplies derived using the WAM are very different from those assumed in previous plans. Total supplies from reservoirs are about 75 percent of that assumed in the 2001 Region F Plan. Total run-of-the-river supplies are about one third of the supplies in the previous plan. Nearly all of the supply reductions are associated with sources in the Colorado Basin.

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 plans assumed that municipal reservoir supplies in the Colorado Basin were not subject to priority calls by senior water rights. The methodology used to develop run-of-the-river supplies in the previous state water plans is not well documented. (Run-of-the-river supplies from the 1997 plan were adopted for the 2001 Region F Plan.) It is unclear why the WAM shows less run-of-the-river supplies in the Colorado Basin.

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

Table 3.2-2
Comparison of Firm Yields of Region F Reservoirs from the 1997 State Water Plan, the 2001 Region F Plan, and the TCEQ Water Availability Model
(Values in Acre-Feet per Year)

Reservoir Name	Basin	Yield from 1997 State Water Plan [a]	Yield from 2001 Region F Plan [a]	WAM Firm Yield [b]
Lake J. B. Thomas	Colorado	151,800 [c]	9,900	100 [d]
E. V. Spence Reservoir	Colorado		38,776	
O. H. Ivie Reservoir	Colorado		96,169	113,000
Lake Colorado City	Colorado	5,500	4,550	0
Champion Creek Reservoir	Colorado	5,000	4,081	10
Oak Creek Reservoir	Colorado	4,800	5,684	5
Lake Coleman	Colorado	7,090	8,822	5
Lake Winters/ New Lake Winters	Colorado	1,160	1,407	0
Lake Brownwood	Colorado	31,400	41,800	47,200 [e]
Hords Creek Lake	Colorado	1,200	1,425	0
Lake Ballinger / Lake Moonen	Colorado	1,600	3,566	30
O. C. Fisher Lake	Colorado	13,200	2,973	0
Twin Buttes Reservoir	Colorado	31,400	8,900	10 [d]
Lake Nasworthy	Colorado	500	7,900	
Brady Creek Reservoir	Colorado	3,100	2,252	0
Red Bluff Reservoir	Rio Grande	32,000	31,000	41,725 [e]
Lake Balmorhea	Rio Grande	1,000	182	0
Total		*290,750*	*269,387*	*202,085*

a 1997 and 2001 Water Plan yields are for year 2000 sediment conditions
b WAM yields are for original sediment conditions except where noted
c Individual yields not reported for Thomas, Spence or Ivie in the 1997 State Water Plan
d Individual yields not computed in the Colorado WAM report
e WAM yield using year 2000 sediment conditions at reservoir

historically been operated. More detailed information about these assumptions may be found in Appendix 3C. 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. Requiring use of the Colorado WAM for regional planning is a significant policy shift by the State of Texas that overturns years of water planning in the Colorado Basin, including the 1997

Table 3.2-3
Comparison of Run-of-the-River Supplies from Previous State Water Plans to Supplies from the Water Availability Models [a]
(Values in Acre-Feet per Year)

County	1997 and 2001 Plan Supplies	WAM 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 and 2001 State Water Plans, and ignores many existing agreements among water rights holders in the basin. 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). 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.

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.[5] 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.[6] 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 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. There is also little competition for water from brackish sources because very little brackish water is currently used for other purposes, making it easier to develop brackish sources.

Two factors significantly impact the cost-effectiveness of desalination: water quality and disposal options. Treatment costs are directly correlated to the quality of the source 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 by deep well injection is the most likely practical and cost-effective method of disposal for large-scale desalination projects in Region F. However, current permitting policy for deep-well injection treats the brine waste from desalination the same as a hazardous chemical waste, requiring a Class I or V permit depending on the native water quality of the injection zone and the quality of the injected brine. 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. A streamlined permitting process would greatly increase the economic feasibility of large-scale desalination projects in West Texas.

TWDB is currently developing a database of the desalination facilities operating in Texas. The starting point for development of the database is a list from the Texas Commission on Environmental Quality (TCEQ) of all Texas facilities utilizing treatment processes for removal of salts, irrespective of the TDS concentrations in the source waters. Thus, any reverse osmosis (RO) treatment facility providing a public water supply is included in the database, including production of polished water for various industrial processes that would be negatively affected by using tap water. These facilities are being surveyed to obtain information about the source water quality, the treatment processes, and the production volumes. According to the unconfirmed data, a total of about 8.4 million gallons of water per day (MGD) is desalinated on a regular basis in Region F by municipal, commercial and industrial facilities.[7] However, the consultant preparing the database has indicated that many of the production estimates in the TCEQ list appear to be overstated.[8] Also, much of the source water for the desalination activities would not be considered brackish water. 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 an average of approximately 6.0 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.[9,10]

Two water suppliers in the region will soon begin treating high-TDS surface waters to replace or supplement their use of groundwater. The City of Brady and the Millersview-Doole Water Supply Corporation (MDWSC) are both planning to build RO desalination plants, each with an initial capacity of approximately 1.5 MGD. The City of Brady will be using water from the Brady Creek Reservoir and the MDWSC will use Lake Ivie as a water source. Lake Ivie TDS levels range from 1,100 to 1,500 mg/l and the levels at the Brady Creek Reservoir are similar. These facilities will produce finished water with a TDS level under 1,000 mg/l. Ultimately, both plants plan to expand to 3.0 MGD each.[11,12]

Industrial and commercial users in the region also desalinate water for various uses. Several energy companies, as well as the Midland Country Club, convenience stores, commercial water suppliers, and other smaller businesses utilize RO processes to desalinate groundwater or to tailor the quality of another source water to their use. Until the TWDB database is complete, 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. Reclaimed water has been used for agricultural irrigation and some industrial purposes for many years. Additionally its use has recently gained a level of public acceptance that allows water managers to readily implement other reuse strategies. Although there is still public resistance to the notion of the reuse of wastewater effluent for potable water supply, there is increasingly widespread use of reclaimed water for agricultural and industrial purposes and 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.[13]

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 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 Howard, Irion, Martin, and Reagan counties. The City of Midland's reuse program ranks Midland County among the top five counties in Texas for municipal reuse. San Angelo is considering options for expanding its use of reclaimed water. Industrial reuse is described by TWDB as being under-reported, but Ector County is listed as having 2.09 MGD of industrial reuse, ranking the county among the top five in Texas for that category.

Table 3.3-1
Recent Reuse Quantities in Region F

City	County	Use	Year 2000		Year 2001		Year 2002	
			(MGD)	(Ac-Ft/Yr)	(MGD)	(Ac-Ft/Yr)	(MGD)	(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*	*26,700*	*23.1*	*25,900*

Source of Data: TWDB reuse database [14]

For planning purposes only the reuse for Midland, San Angelo and Odessa will be considered as a current supply. It is uncertain whether the TWDB considered the other reuse projects as a source when developing demands for the cities of Monahans, Andrews, Winters and Snyder. To be conservative, it will be assumed that the demand for these cities does not include the demands for reuse supplies. The supplies are small and should not have a significant impact on the development of the plan.

3.4 Currently Available Supplies for Water User Groups

Summary tables in Appendix 3D 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.) 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. Currently available supplies in each county are shown in Table 3.5-1. The total of the currently available supply by use type is shown in Figure 3.5-1.

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

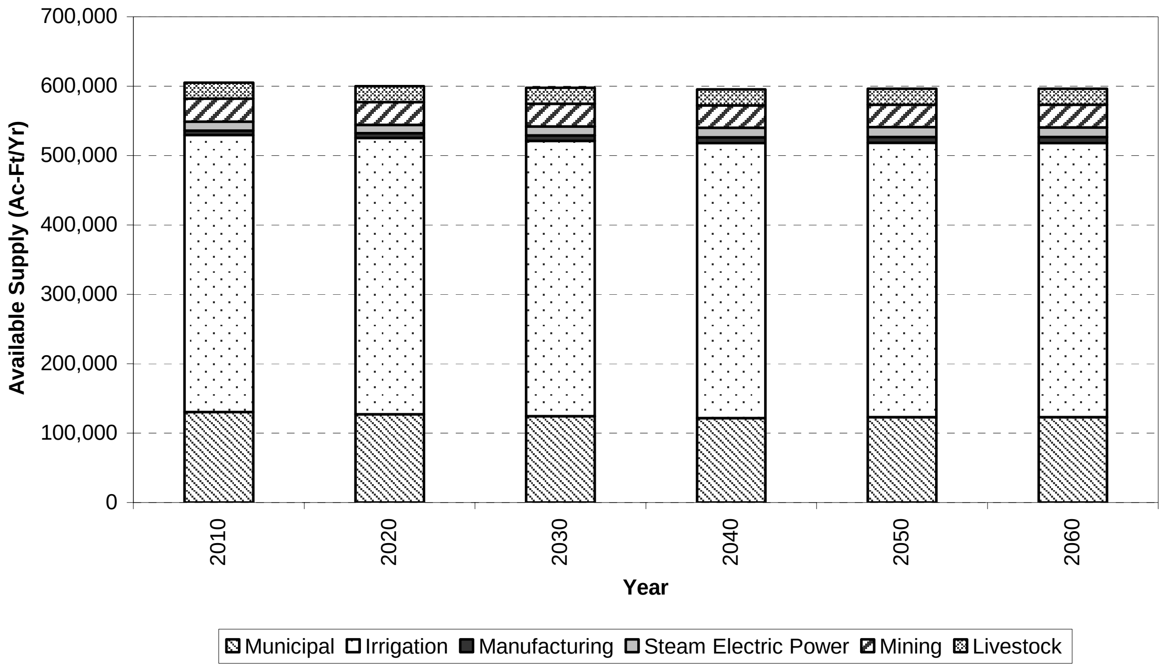
There are seven designated wholesale water providers in Region F. A wholesale water provider has wholesale water contracts for 1,000 acre-feet per year or is expected to contract for 1,000 acre-feet per year or more over the planning period. Similar to the currently available supply for water user groups, 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 3.5-2. Brief descriptions of the supply sources are presented below.

Table 3.5-1
Summary of Currently Available Supply to Water Users by County
(Values in Acre-Feet per Year)

County	Year 2010	Year 2020	Year 2030	Year 2040	Year 2050	Year 2060
Andrews	24,542	24,542	24,542	25,780	25,780	25,780
Borden	2,316	2,317	2,316	2,316	2,316	2,316
Brown	21,694	21,784	21,787	21,752	21,764	21,821
Coke	2,115	2,105	2,349	2,358	2,366	2,345
Coleman	1,823	1,826	1,821	1,818	1,817	1,819
Concho	7,005	6,999	7,033	7,028	7,026	7,020
Crane	2,872	2,899	2,911	2,920	2,931	2,945
Crockett	5,980	5,997	6,006	6,014	6,022	6,030
Ector	44,137	39,262	45,886	47,042	48,181	48,569
Glasscock	24,906	24,906	24,906	24,906	24,906	24,906
Howard	14,258	14,038	16,371	16,379	16,368	16,156
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	12,356	12,355	12,356	12,356	12,356	12,356
McCulloch	6,486	6,562	6,705	6,770	6,831	6,919
Menard	4,650	4,647	4,646	4,646	4,646	4,646
Midland	59,310	59,746	47,107	42,471	42,519	42,533
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	74,003	74,248	74,438	74,583	74,736	74,674
Runnels	4,838	4,833	4,860	4,857	4,860	4,878
Schleicher	4,921	4,910	4,903	4,898	4,894	4,897
Scurry	11,199	11,104	11,707	11,667	11,643	11,550
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	75,044	75,049	75,154	75,182	75,218	75,248
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	*605,087*	*600,138*	*597,616*	*595,442*	*596,416*	*596,196*

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 3.5-1
Supplies Currently Available to Water User Groups by Type of Use



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[15].

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[16]. Other customers divert water directly from the lake.

Table 3.5-2
Currently Available Supplies for Wholesale Water Providers
(Values in Acre-Feet per Year)

Major Water Provider	Source	Basin	2010	2020	2030	2040	2050	2060
BCWID	Lake Brownwood [a]	Colorado	29,712	29,712	29,712	29,712	29,712	29,712
CRMWD	Lake Ivie [b]	Colorado	66,350	65,000	63,650	62,300	60,950	59,600
	Spence Reservoir [b]	Colorado	560	560	560	560	560	560
	Thomas Reservoir [b]	Colorado	0	0	0	0	0	0
	Ward County Well Field [c]	Rio Grande	5,200	0	0	0	0	0
	Martin County Well Field	Colorado	1,035	1,035	1,035	1,035	1,035	1,035
	Ector County Well Field	Colorado	440	440	440	440	440	440
	Scurry County Well Field	Colorado	900	900	900	900	900	900
Great Plains Water System	Andrews County Well Field [d]	Colorado	6,456	6,456	6,456	6,456	6,456	6,456
City of Odessa	CRMWD System [b]	Colorado & Rio Grande	4,063	4,434	5,990	6,285	6,485	6,541
UCRA	O.C. Fisher Reservoir [b]	Colorado	0	0	0	0	0	0
	Mountain Creek Reservoir [b]	Colorado	0	0	0	0	0	0
City of San Angelo	Twin Buttes/Nasworthy [b]	Colorado	0	0	0	0	0	0
	O.C. Fisher Reservoir [b]	Colorado	0	0	0	0	0	0
	Spence Reservoir [e]	Colorado	0	0	0	0	0	0
	Lake Ivie [f]	Colorado	10,974	10,751	10,528	10,304	10,081	9,858
University Lands	CRMWD Ward Co Well Field [c]	Rio Grande	5,200	0	0	0	0	0
	Midland Paul Davis Well Field [g]	Colorado	0	0	0	0	0	0
	City of Andrews Well Field [h]	Colorado	0	0	0	0	0	0
	Total		*119,916*	*108,537*	*108,743*	*107,688*	*106,538*	*115,102*

a Yield of Lake Brownwood limited by water right.
b 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 2008. Current supplies estimated at 4,722 acre-feet per year.
h Contract between University Lands and the City of Andrews expires in 2010. Current supplies estimated at 3,353 acre-feet per year.

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 System, Inc. The Great Plains Water System provides water from the Ogallala Aquifer in Andrews County in Region F and Gaines County in Region O. The System 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 System's largest customer is the recently established 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 future needs will be provided from CRMWD sources. The City of Odessa sells treated water to the Ector County Utility District and the Odessa Country Club, and treated effluent to industrial 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 owns several run-of-the river water rights on the Concho River which enable the city to make use of uncontrolled supplies from the Concho River. San Angelo owns and operates a raw water transmission line from Spence Reservoir 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 Cenozoic Pecos Alluvium 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 a continual thing that are interrupted by short periods of rainfall."[17] 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 and 1990s.

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*[18] 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 2003. 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. Nine of the ten years during the current drought 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, eighteen 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 2003

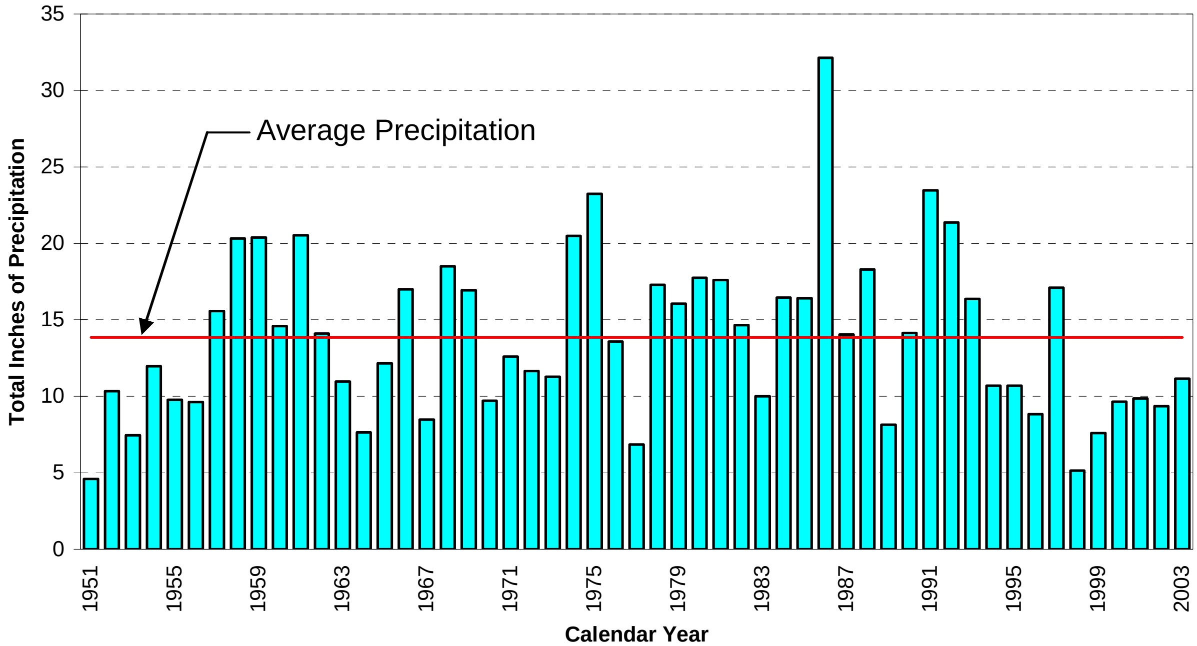
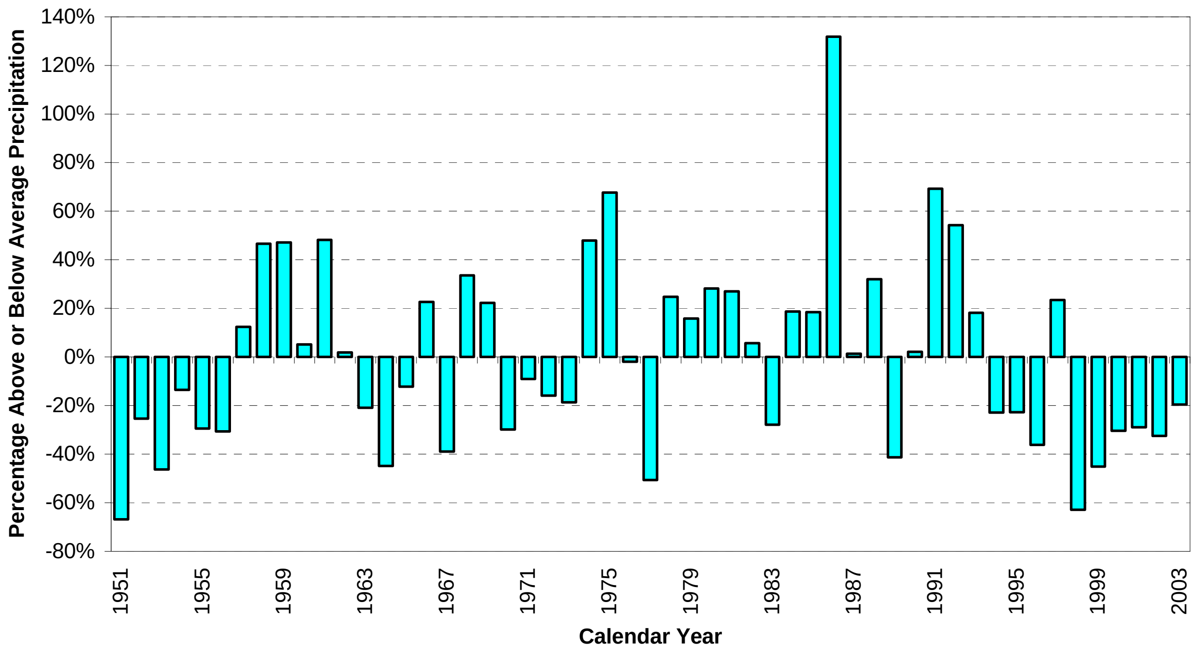


Figure 3.6-2
Precipitation Variation from Average at Midland, Texas from 1951 to 2003



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 2003

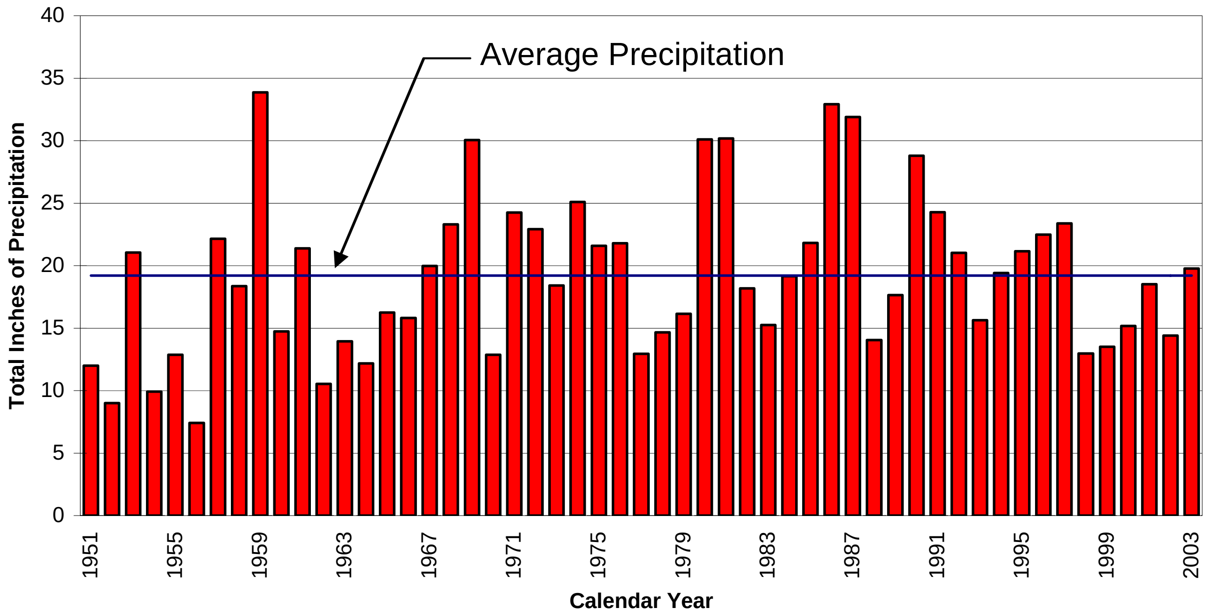
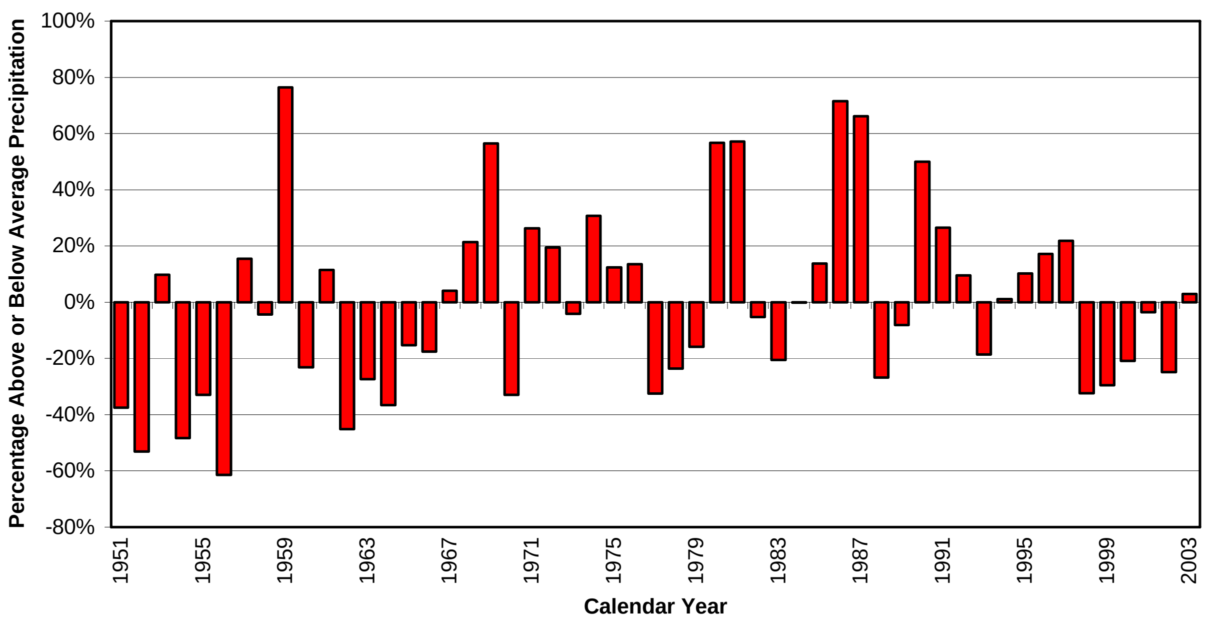


Figure 3.6-4
Precipitation Variation from Average at San Angelo, Texas from 1951 to 2003



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, and most have only begun to recover in recent months. 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 January 2005 levels were about 40% of capacity.
- Levels at E.V. Spence Reservoir began a general decline in 1992 and hit a low of less than 10% capacity in 2002. As of January 2005, reservoir levels had risen to 18% of 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.
- 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%.
- 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 January 2005.

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.[19] 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.

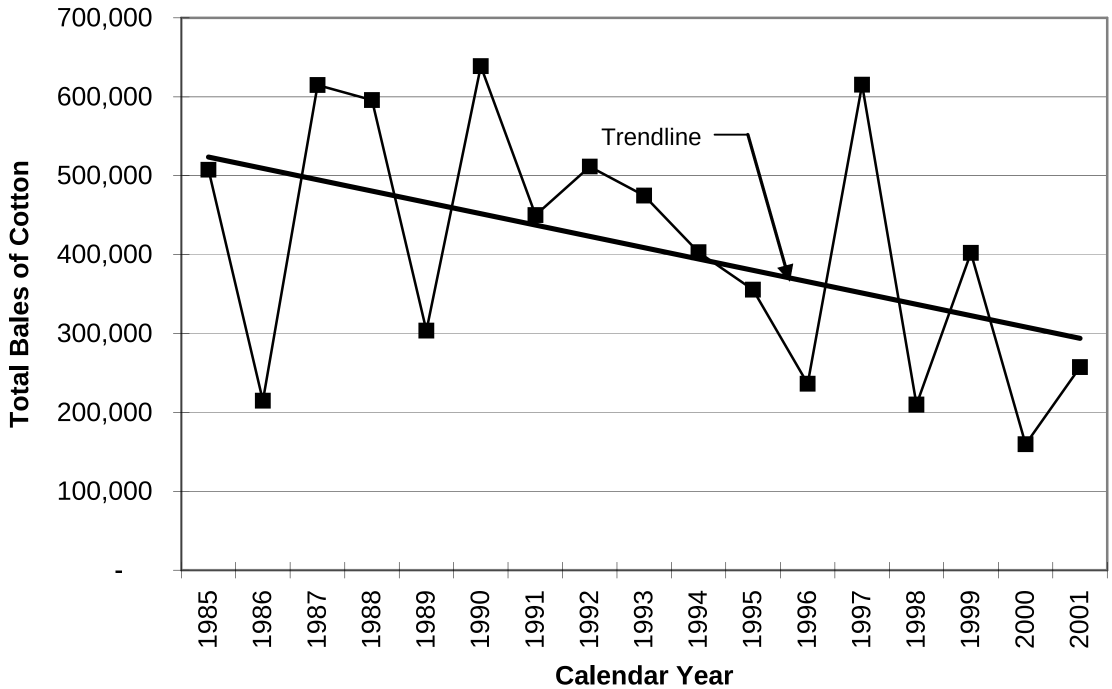
Annual production of agricultural crops can be used as an indicator of impacts due to droughts. Various factors, such as market demand and production costs, can also play a significant role with respect to the number of acres planted and harvested for specific crops. However, a decline in crop production 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. Agricultural production of cotton in Region F counties also declined significantly due to the prolonged drought. Figure 3.6-5 shows a graph of annual Region F cotton production from 1985 to 2001.

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, large grass die-offs occurred in parts of west Texas. The drought was severe enough to even cause some live oak trees to die.[20]

In 2001, Brian Chandler, a Midland farmer, testified before the US Senate Agriculture Committee on behalf of the National Farmers Union urging Congress to provide federal assistance for farmers and ranchers who had suffered drought-related production losses in 2001.

Figure 3.6-5
Annual Cotton Production in Region F from 1985 to 2001



He stated that, due to the drought conditions, his dry-land crops were decimated in 2001. The limited crop that was produced was sold at depressed prices. His livestock operation was severely curtailed due to the lack of small-grain crops and an 80 percent loss in his hay production. Ranchers were forced to sell their cattle at less-than-optimal weight because of the limited ability to sustain their herds as a direct result of the drought conditions. The flooded markets resulted in lower prices per pound at auction[21].

In 1997, a wet year sandwiched between two dry years, agricultural production for Region F totaled over $621,000,000. In 2002, not having yet recovered from the sustained drought, production was 24 percent less than in 1997. A few counties, however, saw increased production levels for livestock from 1997 to 2002 as ranchers thinned out herds down to levels that could be sustained through the dry conditions. Tom Green County, which accounted for about 20 percent of agricultural production in the region in 2002, reported a 31 percent decline in crop production from 1997, but a 29 percent increase in livestock production. Since May 15, 2003 through the fall of 2005 above average rainfall has resulted in improved conditions for Region F agriculture. However, runoff remains below normal.

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 much of that industry has declined, with many oil-related employers closing or moving their operations elsewhere. Cities in Region F have been actively seeking new industries to replace the loss in the oil and gas sector, but the recent drought and uncertainty about 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 being hindered be the 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 supply 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[22] 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.

3.7 List of References

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

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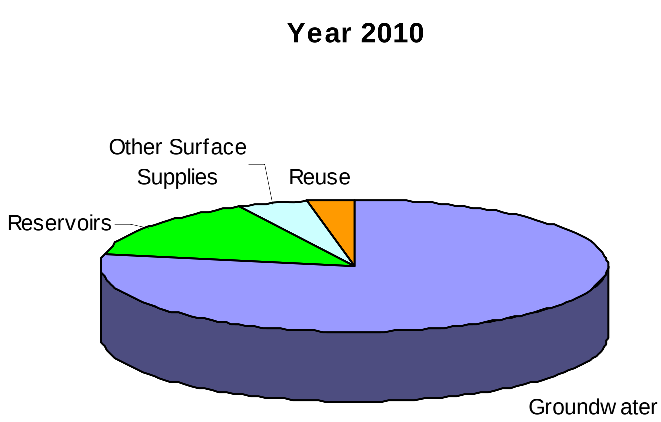
4 IDENTIFICATION, EVALUATION, AND SELECTION OF WATER MANAGEMENT STRATEGIES BASED ON NEEDS

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 E). 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 15 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 605,000 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
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 809,478 in 2010 to 827,397 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 together account for only about 11 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 significantly higher than the historical irrigation use in the year 2000. Irrigation demands in Region F in 2000 were somewhat lower than they could have been due to reduced surface water supplies and depressed cotton prices. Baseline irrigation demands are based upon full availability of surface water supplies and a recovery of cotton prices. 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. A discussion of water supplies in the Colorado WAM may be found in Appendix 3C.

Figure 4.1-2 compares the overall supply allocation for historical year 2000 and projected supplies and demands through 2060. The demand exceeds the available supply by about 202,000 acre-feet per year in the year 2010, increasing to over 229,000 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 180,000 acre-feet per year in the year 2010, decreasing to 157,000 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 over 34,000 acre-feet per year by 2060. Steam-electric demand is expected to exceed supply by over 9,400 acre-feet per year in 2010, increasing to almost 30,000 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. (More information on water supplies in the Colorado WAM may be found in Appendix 3D.) Needs for University Lands are the result of contract expiration. More information on contracts with University Lands may be found in Section 3.5.

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 Texas Water Development Board 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. This section is a summary of the TWDB's socio-economic report[1]. The full report may be found in Appendix 4B.

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

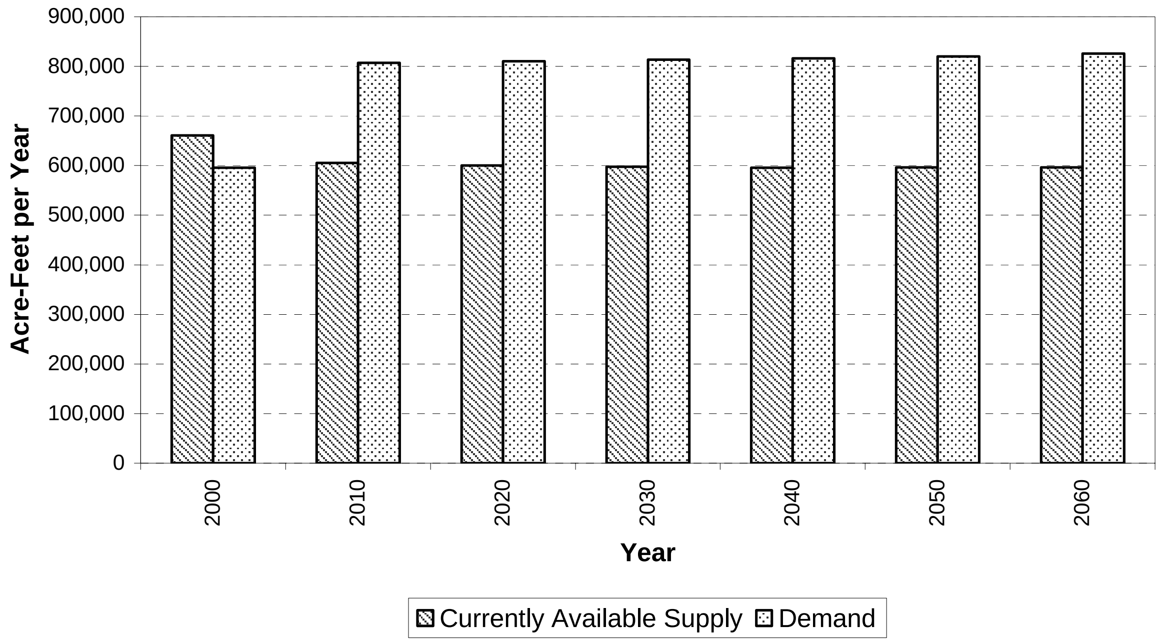
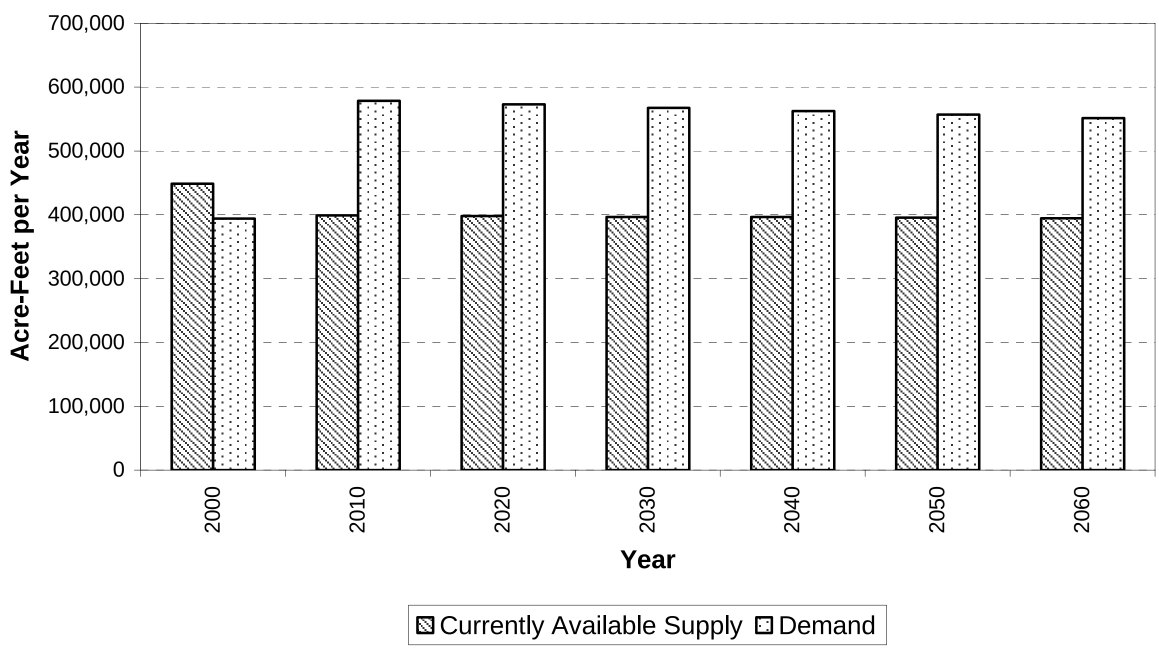


Figure 4.1-3
Comparison of Irrigation Supplies and Demands



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

Figure 4.1-4
Comparison of Municipal Supplies and Demands

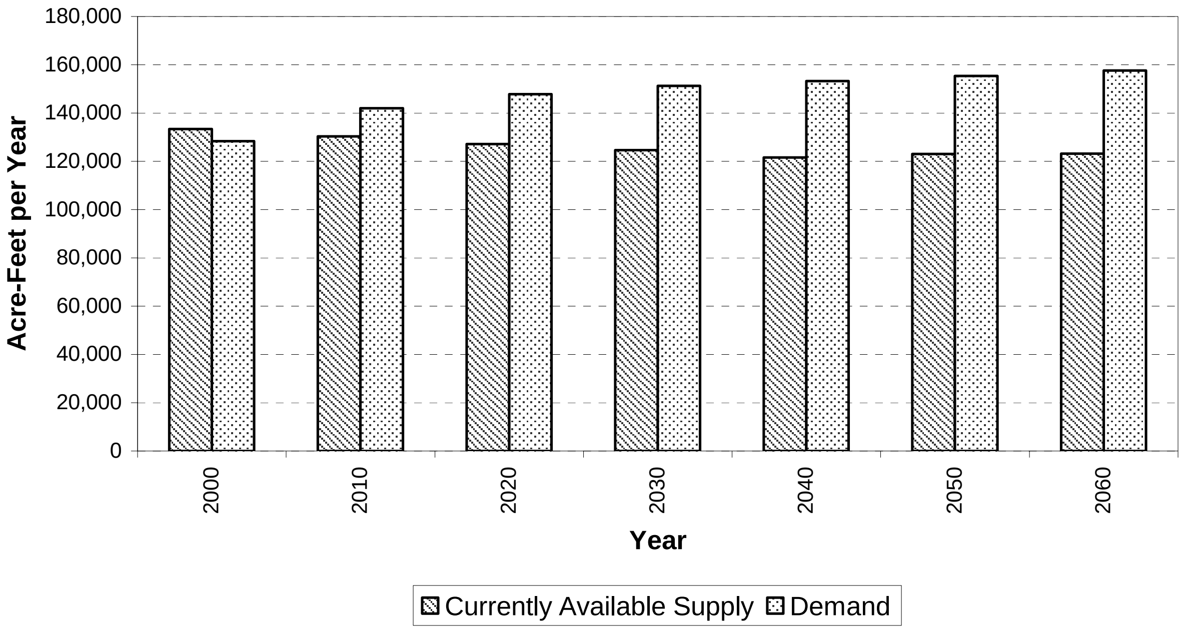
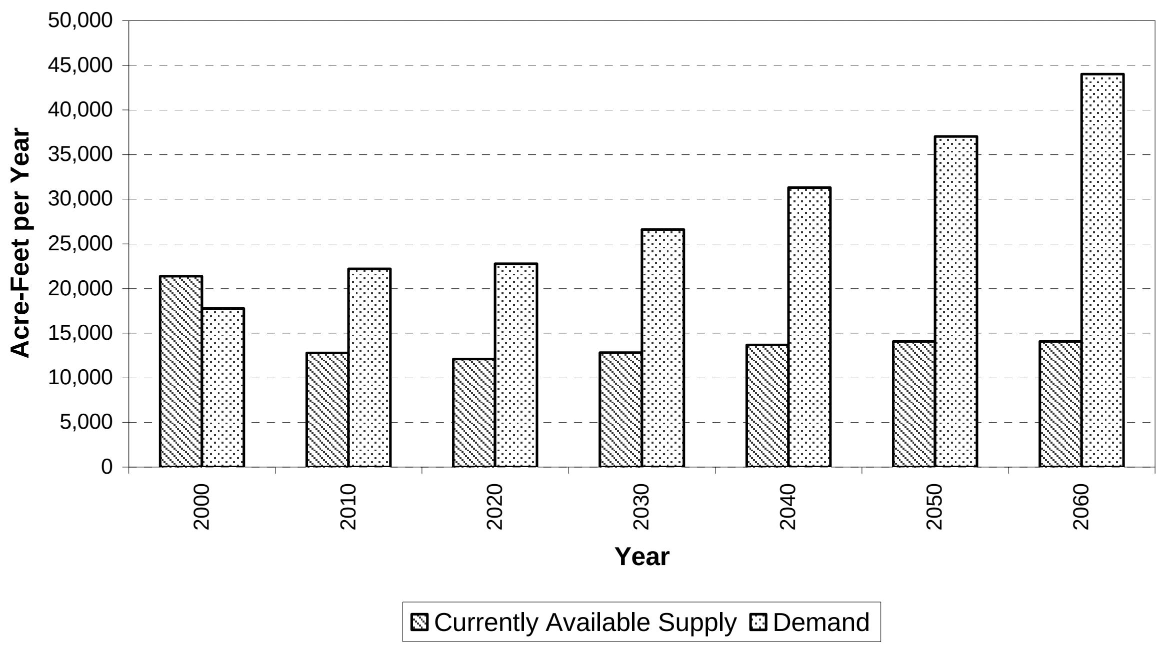


Figure 4.1-5
Comparison of Steam Electric Supplies and Demands



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*	Irrigation			Manufacturing			Mining			Municipal			Steam Electric Power			Livestock			Total		
	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)
Andrews	18,514	32,608	(14,094)	0	0	0	1,965	1,908	57	3,625	3,625	0	0	0	0	438	438	0	24,542	38,579	(14,037)
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	7,687	7,106	581	0	0	0	1,636	1,636	0	21,694	24,119	(2,425)
Coke	573	936	(363)	0	0	0	410	488	(78)	539	771	(232)	0	310	(310)	593	593	0	2,115	3,098	(983)
Coleman	31	1,379	(1,348)	0	6	(6)	1	18	(17)	532	1,874	(1,342)	0	0	0	1,259	1,259	0	1,823	4,536	(2,713)
Concho	5,265	4,297	968	0	0	0	0	0	0	965	873	92	0	0	0	775	775	0	7,005	5,945	1,060
Crane	0	337	(337)	0	0	0	1,461	2,221	(760)	1,256	1,256	0	0	0	0	155	155	0	2,872	3,969	(1,097)
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	274	5,533	(5,259)	2,699	2,759	(60)	10,074	9,888	186	24,422	28,708	(4,286)	6,375	6,375	0	293	293	0	44,137	53,556	(9,419)
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	1,499	1,648	(149)	1,426	1,783	(357)	6,105	7,308	(1,203)	0	0	0	366	366	0	14,258	15,904	(1,646)
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	10,358	10,079	279	0	0	0	6	6	0	956	932	24	0	0	0	1,036	1,036	0	12,356	12,053	303
McCulloch	2,918	2,824	94	844	844	0	154	154	0	1,543	2,252	(709)	0	0	0	1,027	1,027	0	6,486	7,101	(615)
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	32,305	32,568	(263)	0	0	0	904	904	0	59,310	75,806	(16,496)
Mitchell	5,564	5,534	30	0	0	0	141	115	26	1,728	1,703	25	0	9,100	(9,100)	449	449	0	7,882	16,901	(9,019)
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	66,972	103,069	(36,097)	720	720	0	182	182	0	3,846	3,834	12	0	0	0	2,283	2,283	0	74,003	110,088	(36,085)
Runnels	2,973	4,331	(1,358)	0	63	(63)	44	44	0	291	2,091	(1,800)	0	0	0	1,530	1,530	0	4,838	8,059	(3,221)
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	3,161	3,666	(505)	0	0	0	629	629	0	11,199	10,217	982
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	15,385	23,494	(8,109)	0	543	(543)	1,978	1,978	0	75,044	132,935	(57,891)
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	*399,065*	*578,606*	*(179,541)*	*6,555*	*9,757*	*(3,202)*	*33,248*	*31,850*	*1,398*	*130,344*	*141,965*	*(11,621)*	*12,789*	*22,215*	*(9,426)*	*23,086*	*23,060*	*26*	*605,087*	*807,453*	*(202,366)*

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

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

County*	Irrigation			Manufacturing			Mining			Municipal			Steam Electric Power			Livestock			Total		
	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)
Andrews	18,136	32,062	(13,926)	0	0	0	2,031	1,976	55	3,937	3,937	0	0	0	0	438	438	0	24,542	38,413	(13,871)
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	7,671	7,111	560	0	0	0	1,636	1,636	0	21,787	24,173	(2,386)
Coke	573	934	(361)	0	0	0	550	550	0	633	755	(122)	0	289	(289)	593	593	0	2,349	3,121	(772)
Coleman	31	1,379	(1,348)	0	6	(6)	1	19	(18)	530	1,814	(1,284)	0	0	0	1,259	1,259	0	1,821	4,477	(2,656)
Concho	5,265	4,262	1,003	0	0	0	0	0	0	993	884	109	0	0	0	775	775	0	7,033	5,921	1,112
Crane	0	337	(337)	0	0	0	1,303	2,214	(911)	1,453	1,453	0	0	0	0	155	155	0	2,911	4,159	(1,248)
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	77	5,402	(5,325)	3,125	3,125	0	8,545	10,911	(2,366)	27,471	32,271	(4,800)	6,375	10,668	(4,293)	293	293	0	45,886	62,670	(16,784)
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	1,848	1,832	16	1,924	1,924	0	7,371	7,310	61	0	0	0	366	366	0	16,371	16,122	249
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	10,358	9,792	566	0	0	0	6	6	0	956	916	40	0	0	0	1,036	1,036	0	12,356	11,750	606
McCulloch	2,918	2,754	164	1,004	1,004	0	162	162	0	1,594	2,236	(642)	0	0	0	1,027	1,027	0	6,705	7,183	(478)
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	20,659	35,301	(14,642)	0	0	0	904	904	0	47,107	78,097	(30,990)
Mitchell	5,564	5,479	85	0	0	0	141	108	33	1,704	1,621	83	0	8,910	(8,910)	449	449	0	7,858	16,567	(8,709)
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	66,936	101,323	(34,387)	756	756	0	175	175	0	4,288	4,272	16	0	0	0	2,283	2,283	0	74,438	108,809	(34,371)
Runnels	2,973	4,298	(1,325)	0	76	(76)	45	45	0	312	2,174	(1,862)	0	0	0	1,530	1,530	0	4,860	8,123	(3,263)
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	3,721	3,721	0	0	0	0	629	629	0	11,707	10,393	1,314
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	15,495	24,648	(9,153)	0	909	(909)	1,978	1,978	0	75,154	134,464	(59,310)
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	*396,659*	*567,846*	*(171,187)*	*7,672*	*11,294*	*(3,622)*	*32,733*	*33,795*	*(1,062)*	*124,654*	*151,280*	*(26,626)*	*12,812*	*26,620*	*(13,808)*	*23,086*	*23,060*	*26*	*597,616*	*813,895*	*(216,279)*

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

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

County*	Irrigation			Manufacturing			Mining			Municipal			Steam Electric Power			Livestock			Total		
	Supply	**Demand**	**Surplus (Need)**	**Supply**	**Demand**	**Surplus (Need)**	**Supply**	**Demand**	**Surplus (Need)**	**Supply**	**Demand**	**Surplus (Need)**	**Supply**	**Demand**	**Surplus (Need)**	**Supply**	**Demand**	**Surplus (Need)**	**Supply**	**Demand**	**Surplus (Need)**
Andrews	19,080	31,245	(12,165)	0	0	0	2,089	2,036	53	4,173	4,173	0	0	0	0	438	438	0	25,780	37,892	(12,112)
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	7,554	6,932	622	0	0	0	1,636	1,636	0	21,821	24,040	(2,219)
Coke	573	933	(360)	0	0	0	588	614	(26)	591	737	(146)	0	477	(477)	593	593	0	2,345	3,354	(1,009)
Coleman	31	1,379	(1,348)	0	6	(6)	1	19	(18)	528	1,766	(1,238)	0	0	0	1,259	1,259	0	1,819	4,429	(2,610)
Concho	5,265	4,213	1,052	0	0	0	0	0	0	980	865	115	0	0	0	775	775	0	7,020	5,853	1,167
Crane	0	337	(337)	0	0	0	1,167	2,208	(1,041)	1,623	1,623	0	0	0	0	155	155	0	2,945	4,323	(1,378)
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	75	5,204	(5,129)	3,435	3,491	(56)	7,804	11,970	(4,166)	30,587	36,725	(6,138)	6,375	17,637	(11,262)	293	293	0	48,569	75,320	(26,751)
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	2,021	2,099	(78)	1,952	2,052	(100)	6,955	7,140	(185)	0	0	0	366	366	0	16,156	16,184	(28)
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	10,358	9,363	995	0	0	0	6	6	0	956	900	56	0	0	0	1,036	1,036	0	12,356	11,305	1,051
McCulloch	2,918	2,649	269	1,233	1,233	0	171	171	0	1,570	2,190	(620)	0	0	0	1,027	1,027	0	6,919	7,270	(351)
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	16,447	37,180	(20,733)	0	0	0	904	904	0	42,533	79,259	(36,726)
Mitchell	5,564	5,398	166	0	0	0	141	104	37	1,639	1,409	230	0	14,730	(14,730)	449	449	0	7,793	22,090	(14,297)
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	66,863	98,710	(31,847)	825	825	0	170	170	0	4,533	4,713	(180)	0	0	0	2,283	2,283	0	74,674	106,701	(32,027)
Runnels	2,973	4,241	(1,268)	0	94	(94)	45	45	0	330	2,319	(1,989)	0	0	0	1,530	1,530	0	4,878	8,229	(3,351)
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	3,574	3,696	(122)	0	0	0	629	629	0	11,550	10,373	1,177
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	15,589	24,888	(9,299)	0	1,502	(1,502)	1,978	1,978	0	75,248	135,230	(59,982)
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	*394,628*	*551,774*	*(157,146)*	*8,656*	*13,313*	*(4,657)*	*32,546*	*35,794*	*(3,248)*	*123,216*	*157,632*	*(34,416)*	*14,064*	*44,008*	*(29,944)*	*23,086*	*23,060*	*26*	*596,196*	*825,581*	*(229,385)*

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

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	29,563	29,067	28,570
	Demand	14,960	15,087	15,066	14,975	14,966	15,029
	Surplus (Need)	*14,752*	*14,625*	*14,646*	*14,588*	*14,101*	*13,541*
CRMWD [a]	Supply	74,485	67,935	66,585	65,235	63,885	62,535
	Demand	93,344	96,158	78,662	79,434	79,718	81,036
	Surplus (Need)	*(18,859)*	*(28,223)*	*(12,077)*	*(14,199)*	*(15,833)*	*(18,501)*
City of Odessa	Supply	21,179	16,131	23,733	23,718	24,117	23,987
	Demand	26,150	27,480	28,634	29,866	31,285	32,887
	Surplus (Need)	*(4,971)*	*(11,349)*	*(4,901)*	*(6,148)*	*(7,168)*	*(8,900)*
City of San Angelo	Supply	*20,116*	*19,893*	*19,670*	*19,446*	*19,223*	*19,000*
	Demand	50,419	51,543	52,230	52,634	53,196	53,746
	Surplus (Need)	*(30,303)*	*(31,650)*	*(32,560)*	*(33,188)*	*(33,973)*	*(34,746)*
Great Plains Water	Supply	6,726	6,726	6,726	6,726	6,726	6,726
System	Demand	6,726	6,726	6,726	6,726	6,726	6,726
	Surplus (Need)	*0*	*0*	*0*	*0*	*0*	*0*
UCRA [b]	Supply	0	0	0	0	0	0
	Demand	4,112	3,993	3,875	3,757	3,638	3,520
	Surplus (Need)	*(4,112)*	*(3,993)*	*(3,875)*	*(3,757)*	*(3,638)*	*(3,520)*
University Lands [c]	Supply	5,200	0	0	0	0	0
	Demand	10,593	10,630	10,652	5,950	5,960	5,973
	Surplus (Need)	*(5,393)*	*(10,630)*	*(10,652)*	*(5,950)*	*(5,960)*	*(5,973)*

a Demands for CRMWD include all of the demands for the City of Odessa and water contracted to the City of San Angelo.
b Demands for UCRA include water supplied to the City of San Angelo.
c Demands for University Lands include water supplied to CRMWD and the City of Odessa.

The TWDB analysis of socio-economic impacts is based on information on potential shortages in Region F from the TWDB planning database. Table 4.1-5 and Figures 4.1-6 and 4.1-7 summarize the TWDB's analysis of 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 can be summarized as follows:

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

Year	Sales ($ millions)	Income ($ millions)	State and Local Taxes ($ millions)	Jobs
2010	$1,133.61	$474.96	$34.83	8,185
2020	$1,324.81	$573.60	$42.52	9,335
2030	$1,437.43	$636.60	$48.20	10,175
2040	$1,739.89	$797.11	$64.37	13,430
2050	$1,909.06	$877.55	$73.45	14,570
2060	$2,090.54	$962.72	$82.19	15,855

Note: These impacts are based on data provided by the TWDB[1].

- Without implementing any water management strategies, the currently available supplies in Region F meet only 72 percent of the projected 2010 demand, decreasing to 69 percent by 2060.
- Without any water management strategies, the projected water needs would reduce the region's projected 2060 employment by 15,855 jobs, a reduction of 4.7 percent.
- Without any water management strategies, the projected water needs would reduce the region's projected annual income in 2060 by $962.72 million, a reduction of 4.9 percent.

Subsequent analyses by the TWDB evaluated the impacts of water shortages with implementation of the subordination strategy described in Section 4.2.3. The results of this analysis may be found in Table 4.1-6. With implementation of the subordination strategy

Figure 4.1-6
Number of Jobs Lost in Region F Due to Water Shortages with and without Subordination Strategy

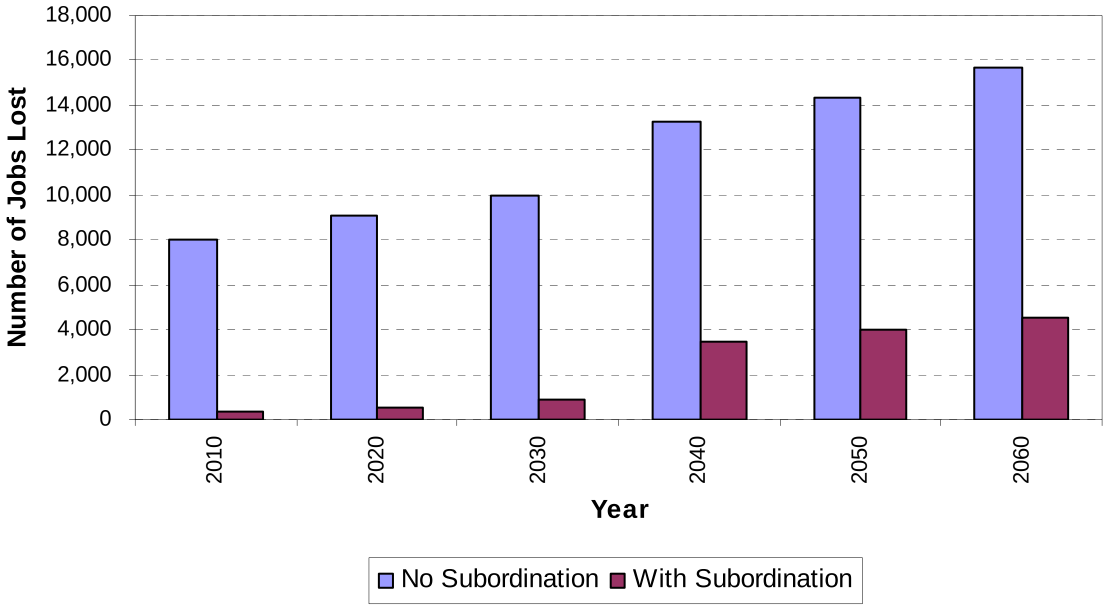
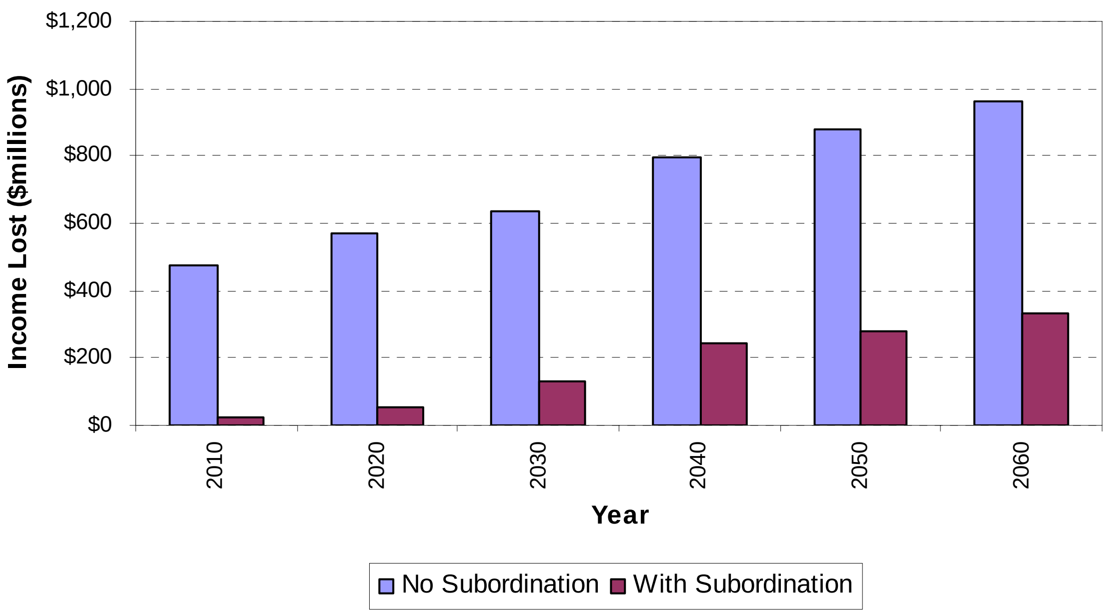


Figure 4.1-7
Income Lost in Region F Due to Water Shortages with and without Subordination Strategy



Note: These impacts are based on shortage data provided by the TWDB[1].

impacts of water shortages for municipal and manufacturing demands are reduced substantially. Assuming subordination has been implemented has the following potential impacts:

- The currently available supplies in Region F meet 77 percent of the projected 2010 demand, decreasing to 73 percent by 2060.
- The projected 2060 employment loss is reduced from 15,855 jobs to 4,563 jobs because of subordination.
- The 2060 income loss is reduced from $962.72 million to $331.65 million because of subordination.

The TWDB analysis assumes that the impacts of a drought occur in a single year in each decade, and that there are no cumulative impacts of drought. Droughts in Region F are frequent, severe and can last several years. It may take the region many years after a severe drought to recover, and it is possible that some communities may not recover at all. Therefore the TWDB socioeconomic analysis may underestimate the potential impact of water shortages in the region.

Table 4.1-6
Socio-Economic Impacts in Region F for a Single Year Extreme Drought with Subordination Strategy in Place

Year	Sales ($ millions)	Income ($ millions)	State and Local Taxes ($ millions)	Jobs
2010	$37.87	$21.70	$1.53	352
% Difference from Analysis without Subordination	- 96%	- 96%	- 95%	- 96%
2020	$76.38	$56.12	$3.47	521
% Difference from Analysis without Subordination	- 94%	- 90%	- 92%	- 94%
2030	$139.32	$128.34	$6.64	897
% Difference from Analysis without Subordination	-90%	-80%	-86%	-91%
2040	$330.02	$245.30	$19.29	3,441
% Difference from Analysis without Subordination	- 81%	- 69%	- 70%	- 74%
2050	$385.18	$281.61	$24.07	4,041
% Difference from Analysis without Subordination	- 80%	- 68%	- 67%	- 72%
2060	$459.48	$331.65	$31.36	4,563
% Difference from Analysis w/out Subordination	- 78%	- 65%	- 71%	- 60%

Note: These impacts are based on data provided by the TWDB[1].

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 second quarter 2002 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 30 years. Cost estimates may be found in Appendix 4F.

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. Table 4.2-1 compares the supplies for the Region F water rights using the Colorado WAM to those used in previous state water plans. As Table 4.2-1 shows, the Colorado WAM gives a very different assessment of water availability for many reservoirs in Region F than assumed in previous plans. 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, and the use of return flows. Appendix 3C contains more information regarding the assumptions used in the Colorado WAM and their impact on water supplies.

Some of the reservoirs and water rights in Table 4.2-1 are the sole source of water for several Region F water user groups and there are no other cost-effective alternative supplies. For example, Lake Ballinger, Lake Winters, Lake Coleman and Hords Creek Reservoir are the only sources of water for the communities of Ballinger, Winters and Coleman. These reservoirs have little or no yield based on the WAM. Other reservoirs are not operated according to the way that they are modeled in the WAM. For example, CRMWD does not pass water from Lake Thomas and Spence Reservoir downstream to Ivie Reservoir. There are many other examples of how the WAM model differs from the historical operation of the Colorado Basin. These differences are discussed in more detail in Appendix 3C. As a result, the WAM may not be an accurate assessment of actual water supplies available for use in the basin.

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 these 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

Table 4.2-1
Comparison of Supplies from Major Region F Water Rights from the 1997 State Water Plan, the 2001 Region F Plan, and the Colorado Water Availability Model
(Values in Acre-Feet per Year)

Reservoir Name	Yield from 1997 State Water Plan [a]	Firm Yield from 2001 Region F Plan [a]	Firm Yield from WAM Run 3 [b]
Lake J. B. Thomas	151,800 [c]	9,900	780 [d]
E. V. Spence Reservoir		38,776	
O. H. Ivie Reservoir		96,169	86,110 [e]
Lake Colorado City	5,500	4,550	0
Champion Creek Reservoir	5,000	4,081	0
Oak Creek Reservoir	4,800	5,684	0
Lake Coleman	7,090	8,822	30
Lake Winters/ New Lake Winters	1,160	1,407	0
Lake Brownwood	31,400	41,800	40,612 [e]
Hords Creek Lake	1,200	1,425	0
Lake Ballinger / Lake Moonen	1,600	3,566	40
O. C. Fisher Lake	13,200	2,973	0
Twin Buttes Reservoir	31,400	8,900	50 [d]
Lake Nasworthy	500	7,900	
Brady Creek Reservoir	3,100	2,252	10
Junction Run-of-River	814	873	0
Total	*258,564*	*239,078*	*127,632*

a 1997 and 2001 Water Plan yields are for year 2000 sediment conditions
b WAM supplies are for original sediment conditions except where noted
c Individual yields not reported for Thomas, Spence or Ivie in the 1997 State Water Plan
d Individual yields not computed in the Colorado WAM report
e WAM yield using year 2000 sediment conditions at reservoir

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 initiated with the Lower Colorado Regional Water Planning Group (Region K). 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 4.2-2 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 modeling approach may be found in Appendix 4D.

All of the yields presented in this section 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. Appendix 4E contains information on the impact of new drought-of-record conditions on water supplies in Region F.

Two reservoirs providing water to the Brazos G planning region were included in the 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. However 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 joint 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 4.2-2 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.

Table 4.2-2
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

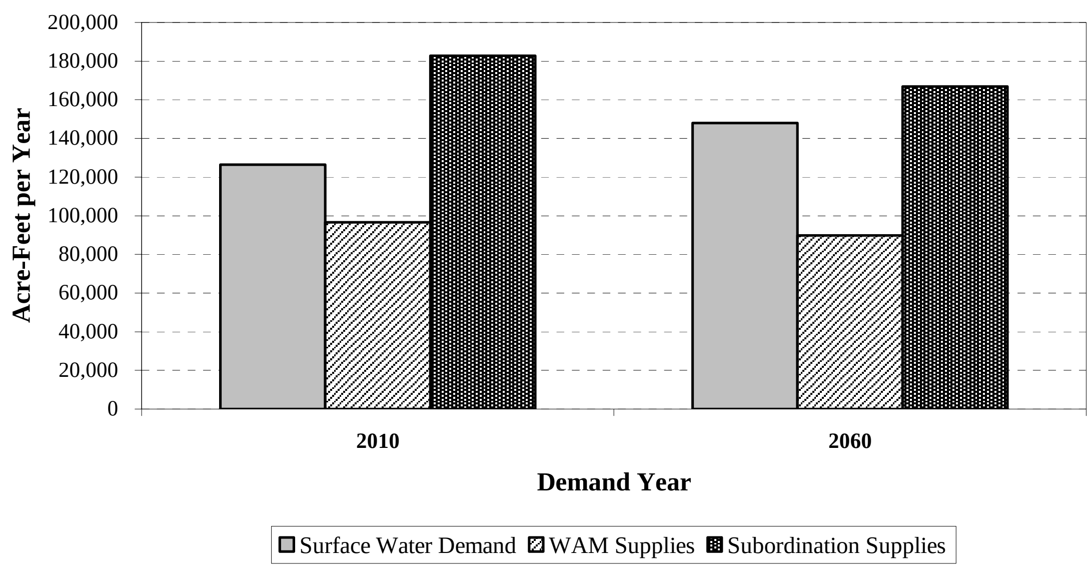
* Oak Creek Reservoir is located in Region F but the supplies are primarily used in Brazos G.

The subordination analysis presented in this plan is only one possible scenario; others may need to be developed before implementation of this strategy. At this time the available modeling tools for the Colorado WAM are inadequate to efficiently assess multiple subordination scenarios. Additional modeling capabilities may be required for further analysis.

Quantity, Reliability and Cost of Subordination

The subordination strategy shows additional supplies of 86,067 in 2010 and 76,958 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 4.2-3 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 29,797 acre-feet per. With subordination, the region has a surplus supply of 56,270 acre-feet per year that can be used to meet other needs. By 2060, without subordination demand exceeds supply by 58,100 acre-feet per year. With subordination, the region has a surplus supply of 18,848 acre-feet per year that can be used to meet other needs. Detailed comparisons of supplies and demands may be found in Appendix 4A.

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



The reliability of this strategy is considered to be medium based on the uncertainty of implementing this strategy. Also, the final forms of subordination agreements have not been determined, making it difficult to estimate the cost of implementing this scenario. One way to estimating the cost of subordination would be to estimate potential costs based on the experience of other states where water transfers are more common. These costs are sometimes referred to as

"Policy Induced Transaction Costs" or PITCs. These costs may include attorney's fees, engineering and hydrologic studies, court costs, and fees paid to state agencies. A study by B.C. Colby et al. (1990)[2] found that PITCs averaged $91 per acre-foot. PITCs averaged $187 per acre-foot in Colorado, $54 in New Mexico, and $66 in Utah.

Table 4.2-3
Comparison of Region F Water Supplies with and Without Subordination
(Values in Acre-feet per Year)

Reservoir	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	0	1,390	0	1,240	
Lake Coleman	0	8,507	0	7,990	
Coleman System	*0*	*9,897*	*0*	*9,230*	
Brady Creek Reservoir	0	2,170	0	2,220	
Lake Thomas	0	10,013	0	10,130	
Spence Reservoir (CRMWD system portion)	34	36,164	34	35,090	
Spence Reservoir (Non-system portion)	526	2,308	526	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	29,712	29,712	29,712	28,570	
City of Junction	0	1,000	0	1,000	

It may be reasonable to assume that the subordination strategy will be at the upper end of these costs. Therefore a cost of approximately $200 per acre-foot of supply may be appropriate for estimating Region F costs. It is assumed that this cost would be a one-time cost in the year 2010, with no costs in subsequent decades. Using these assumptions, the total estimated cost of the subordination strategy is a little over $17.2 million.

Note that these costs are strictly administrative costs and do not include the cost for purchase of water or other costs associated with impacts on downstream water rights. For the purposes of this plan, it can be assumed that most of the compensation associated with the impact on downstream water rights holders has already taken place in the past and need not be included in the current cost estimates.

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. These assumptions are discussed in detail in Appendix 3C.

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.

The same assessment may not be true of the lower portion of the basin. In the lower basin water supply is governed by the LCRA Water Management Plan. The Water Management Plan is incorporated into the Colorado WAM model, and the model does a reasonably good job of simulating the actual operation of the lower basin below the Highland Lakes. Comparison of flows in the lower basin may give a meaningful assessment of the impact of subordination on streamflows. This assessment is being performed by Region K and their consultants.

Environmental impacts should be based on an assessment of the actual conditions, not a simulation of a theoretical legal framework such as the WAM. The subordination modeling approaches the actual operation of the upper basin. 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 medium because this strategy, as modeled, assumes that priority calls are not made by major water rights during times of drought, potentially reducing streamflow in some reaches during drought.

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[3]. 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, there is less water in storage with subordination which 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 4.3-1 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. 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.

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, including the cities of Ballinger, Bronte, Midland, Menard, San Angelo and Robert Lee, as well as rural municipal supplies in Brown County (Brown County Other). 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. The City of Andrews is interested in developing additional water supplies to improve the overall reliability of their water supply. There are insufficient supplies from the Ogallala aquifer to meet all needs in Andrews County. Section 4.8 discusses needs for Wholesale Water Providers, including the City of San Angelo and CRMWD.

Table 4.3-1
Partial List of Region F Water Management Strategies Potentially Impacted by the Subordination Strategy

Water User Group	County	Category	Description
County-Other	Brown	Voluntary redistribution	Purchase treated water from BCWID
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	Brownwood regional system
Ballinger	Runnels	Voluntary redistribution	Obtain water from CRMWD system
San Angelo	Tom Green	New groundwater	McCulloch Well Field
San Angelo	Tom Green	Desalination	Regional desalination facility
San Angelo	Tom Green	Reuse	Municipal reuse
CRMWD	Various	New Groundwater	Winkler well field
CRMWD	Various	Voluntary redistribution	Lake Alan Henry
CRMWD	Various	Reuse	Big Spring reuse
CRMWD	Various	Reuse	Midland/Odessa reuse
CRMWD	Various	Reuse	Snyder reuse

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 the Ogallala aquifer. Although sufficient supplies may be available from this source for the City of Andrews, there are insufficient supplies to meet all needs within Andrews County. The city's supply also 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.

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 concentrate 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 Section 3.1.5.

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. 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 4.3-2 summarizes the expected costs for the project.

Table 4.3-2
Dockum Brackish Water Desalination Project for the City of Andrews

Supply from Strategy	950 acre-feet per year
Total Capital Costs (2002 Prices)	$ 4,678,300
Annual Costs	$ 796,000
Unit costs (before amortization)	$ 838 per acre-foot
	$ 2.57 per 1,000 gallons
Unit Costs (after amortization)	$ 408 per acre-foot
	$ 1.25 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 currently 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.

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 municipal sales) are 1,068 acre-feet per year in 2010, increasing to 1,337 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 will expire in 2008. In the past the city purchased emergency supplies from Spence Reservoir when the city's lakes have been low. 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[4]. 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[5]. The reduced supplies are presented in Table 4-8. With implementation of a subordination strategy the current safe yield of Lakes Ballinger and Moonen is estimated to be 950 acre-feet per year. By 2060, the yield of the reservoir would decline to 890 acre-feet per year due to sedimentation. (Supplies from the Colorado WAM and the subordination strategy are discussed in Section 4.2.3 and Appendices 3C, 4D and 4E.) Using the subordination strategy supplies, needs for the City of Ballinger are 202 acre-feet per year in 2010 increasing to 439 acre-feet per year in 2060, or about 18 percent and 33 percent of total demand, respectively.

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 yield *
Ivie Reservoir	0	0	0	0	0	0	Contract expires in 2008
Other aquifer	0	0	0	0	0	0	Assuming no reliable supply
Total	*0*	*0*	*0*	*0*	*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*	
Surplus (Need)	*(1,142)*	*(1,185)*	*(1,216)*	*(1,249)*	*(1,285)*	*(1,329)*	

* 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.

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 a proposed regional system from Lake Brownwood
- Voluntary redistribution from the CRMWD system (Spence and Ivie Reservoirs)
- Voluntary redistribution and desalination from the proposed San Angelo desalination project
- Reuse
- Water Conservation

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

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, so according to the WAM this reservoir has no reliable yield. According to the WAM Ballinger's lakes have 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 4.2.3. Table 4.3-4 is a summary of the supply made available from Lakes Ballinger and Moonen from the subordination strategy.

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 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.

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.

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 12 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.[6]

Quantity, Reliability and Cost for the Hords Creek Strategy

According to the Region F subordination analysis, Hords Creek Reservoir should have a safe yield of 1,400 acre-feet per year. However, the historical behavior of the reservoir indicates that this yield may be overstated. Figure 4.3-1 shows the historical annual diversions from Hords Creek Reservoir, and Figure 4.3-2 shows the historical storage in the reservoir. Although the City of Coleman used an average of 750 acre-feet per year between 1956 and 1975, the

Figure 4.3-1
Historical Water Use from Hords Creek Reservoir

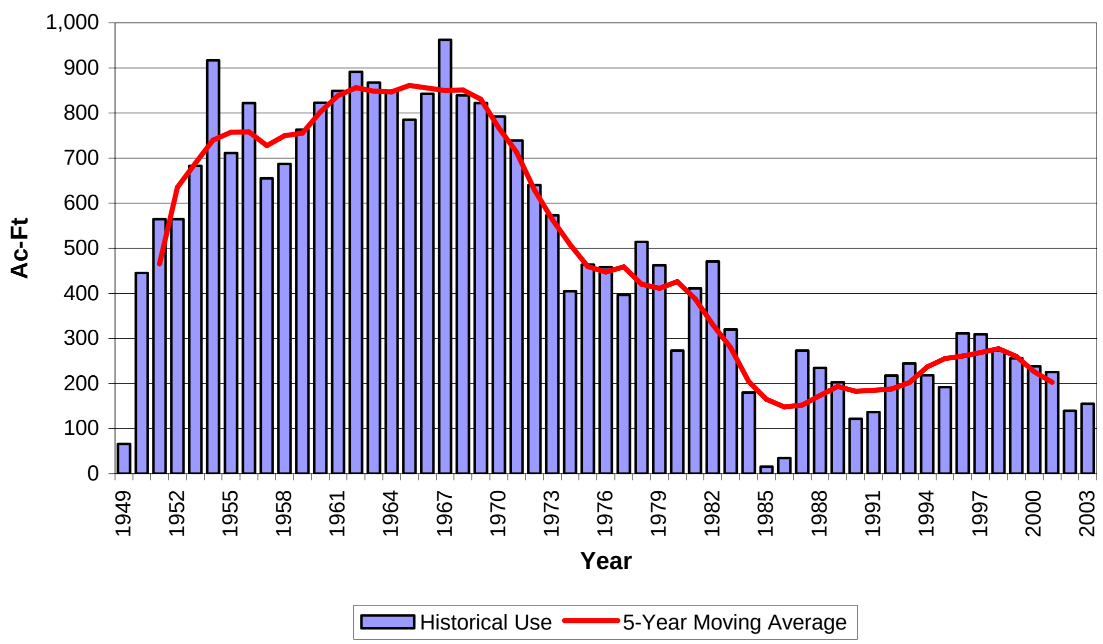
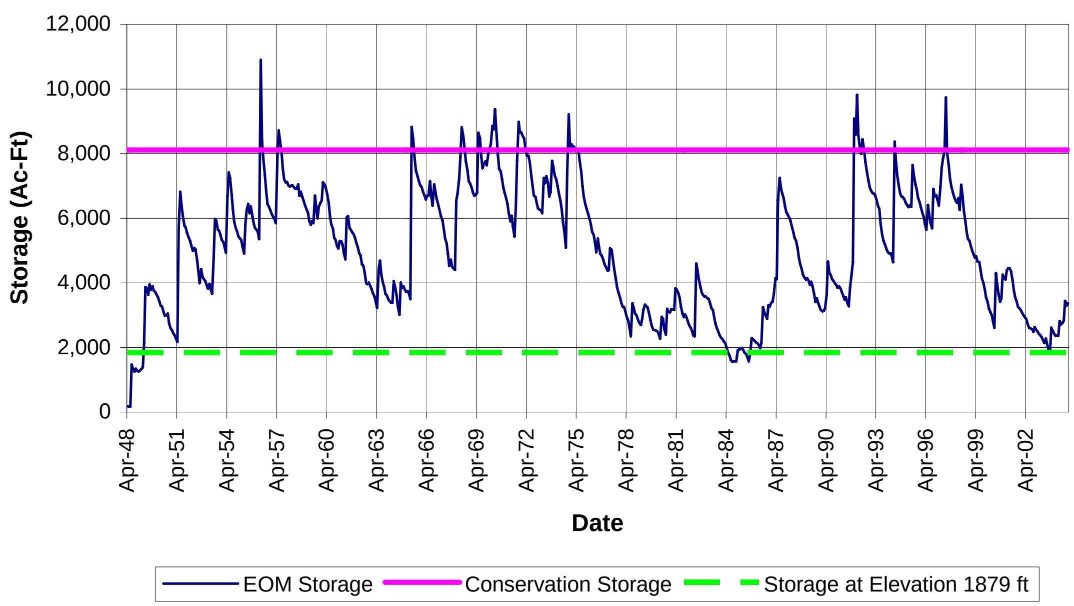


Figure 4.3-2
Historical Storage in Hords Creek Reservoir



reservoir has produced much less water in recent years. Since the reservoir was last full in late 1997, the City of Coleman has used an average of 217 acre-feet per year from the reservoir. The reservoir reached a minimum elevation of 1,879.77 feet msl (1,837 acre-feet of storage) on October 5, 2003, a little more than one foot above the top of the city's inlet structure. These data imply that without modifications to existing infrastructure, the current available supply from the reservoir is somewhere around 220 acre-feet per year.

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.

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 4F.

Table 4.3-5
Costs for Hords Creek Reservoir to Ballinger Pipeline

Supply from Strategy	220 acre-feet per year
Total Capital Costs (2002 Prices)	$4,103,900
Annual Costs	$436,000
Unit Costs (before amortization)	$1,982 per acre-foot
	$6.08 per 1,000 gallons
Unit Costs (after amortization)	$355 per acre-foot
	$1.09 per 1,000 gallons

Environmental Issues Associated with the Hords Creek Strategy

The proposed route is almost entirely along existing 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; City of Winters strategies.

Regional System from Lake Brownwood to Runnels and Coke Counties

Lake Brownwood is one of the few surface water resources in Region F with a significant amount of uncommitted supply. A conceptual design for a regional system providing water to the cities of Winters, Ballinger, Bronte and Robert Lee was developed to evaluate the potential for water supply from this source. The conceptual design assumes that water will be released from the pipeline into Valley Creek upstream of Lake Ballinger. Losses are assumed to be approximately 30 percent during drought conditions. This strategy is described in more detail in Section 4.8.2.

Quantity, Reliability and Cost of the Lake Brownwood Strategy

The City of Ballinger could receive as much as 1,329 acre-feet of water per year from the system. This source is considered to be very reliable. Table 4.3-6 contains estimated costs of water from the project for the City of Ballinger. Capital costs for the strategy are associated with Brown County WID, the assumed sponsor of the strategy, and are presented in Section 4.8.2.

Table 4.3-6
Costs for Purchase of Water from the Lake Brownwood to Runnels County System

Supply from Strategy	1,329 acre-feet per year
Annual Costs	$ 2,550,351
Unit Costs (before amortization)	$ 1,919 per acre-foot
	$ 5.89 per 1,000 gallons
Unit Costs (after amortization)	$ 654 per acre-foot
	$ 2.01 per 1,000 gallons

Environmental Issues Associated with the Lake Brownwood Strategy

The environmental issues associated with this strategy are expected to be minimal. It can be assumed that the pipeline could be routed around sensitive environmental areas if needed. For this strategy, it is assumed that there are no water quality issues associated with importing Lake Brownwood water into Lake Ballinger. More detailed studies of potential environmental impacts will be required if this strategy is pursued.

Agricultural and Rural Issues Associated with the Lake Brownwood 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, the rural and agricultural interests in the area are expected to be positively impacted. Although Lake Brownwood is used for agricultural supplies, there are sufficient supplies available in the reservoir to meet irrigation demands and provide water to these cities.

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 Lake Brownwood Strategy

None identified.

Significant Issues Affecting Feasibility of the Lake Brownwood Strategy

The most significant issues affecting the feasibility of this project are sponsorship and financing. It is not clear which entity would be responsible for implementing and obtaining financing for the project. The project is outside of the traditional service area of the Brown County WID, the owner of Lake Brownwood. Implementation may require development of a new political subdivision to administer and finance the project. The cost of the project is significant and would be a financial strain on the area.

Another issue associated with development of this pipeline is the on-going use of water from this source. Lake Ballinger is the most economical source of water for the City of Ballinger. Historically, the City of Ballinger has relied on Lake Ballinger for all of its supplies, purchasing water from Spence Reservoir or Ivie Reservoir on an as-needed basis during drought. The significant investment in infrastructure associated with this strategy makes it unlikely that this system could be operated in a cost-effective manner on an as-needed basis.

This strategy requires the cooperation of other cities. Changes in participation could significantly impact the costs associated with the project.

Other Water Management Strategies Directly Affected by the Lake Brownwood Strategy

Other strategies for the cities of Ballinger, Winters, Bronte and Robert Lee may be impacted.

Voluntary Redistribution – Purchase Water from CRMWD System

In 2003, the City of Ballinger completed a 10-mile pipeline to the Abilene pipeline from Ivie Reservoir to the City of Abilene. Ballinger and Abilene executed an emergency supply agreement to obtain up to 0.7 MGD (780 acre-feet per year) from this source when Lake Ballinger reaches approximately 13.7 percent of capacity. The contract will expire in 2008.

An alternative to meet the city's needs is to obtain a long-term commitment for water from Ivie Reservoir. Currently, the City of Ballinger is having discussions with CRMWD and the Millersview-Doole Water Supply Corporation (MDWSC) regarding transfer of part of the MDWSC contract with CRMWD to Ballinger. The MDWSC contract is for 1,100 acre-feet per year from the CRMWD system. In 2010, the expected demand for MDWSC is 706 acre-feet per year, increasing to 847 acre-feet per year in 2060. The MDWSC contract with CRMWD will expire in 2044.

Quantity, Reliability and Cost of Water from the CRMWD System

For the purposes of this plan, it was assumed that MDWSC would meet all of its demand from Ivie Reservoir and the City of Ballinger could contract for Ivie Reservoir water that is not needed to meet MDWSC demand. Therefore, 394 acre-feet per year are available in 2010, decreasing to 353 acre-feet per year in 2030. After the MDWSC contract expires, it has been assumed that the city will directly contract with CRMWD for enough water to prevent shortages.

In addition to supplies from the CRMWD system, MDWSC has existing supplies from the Hickory aquifer. Although these supplies exceed drinking water standards for radium, it is possible that Hickory aquifer water could be blended with treated Ivie water to meet standards. Therefore, there may be more water available than assumed in this analysis. The actual amount available will depend upon future operations of the MDWSC system.

The reliability of the water is considered to be high because sufficient reliable supplies are available from Ivie Reservoir.

The cost of water is estimated to be $1.31 per 1,000 gallons, or $426 per acre-foot. The cost includes $0.81 per 1,000 gallons for water under the MDWSC contract plus $0.50 per 1,000 gallons to cover the cost of pumping using the WCTMWD and City of Ballinger pipelines.

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 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.

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 MDWSC, 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.

Voluntary Redistribution - Purchase Water from San Angelo Regional Desalination System

A proposed strategy for a regional desalination facility located near the City of San Angelo is described in Section 4.8.3. This facility could provide high-quality drinking water to areas in Coke and Runnels Counties with potential water supply needs. The conceptual design for this project assumes that treated water would be pumped to a large storage tank located in the hills north of the City of San Angelo. From that point, water could be delivered by gravity flow to Ballinger and other locations in Runnels and Coke Counties.

Quantity, Reliability and Cost of Water from the San Angelo Regional Desalination System

Table 4.3-7 summarizes the estimated cost of water from this project. All capital costs are associated with the City of San Angelo, the assumed sponsor of the project.

Table 4.3-7
Costs of Purchasing Water from the San Angelo Regional Desalination System

Supply from Strategy	1,329 acre-feet per year
Annual Costs	$ 2,355,000
Unit Costs (before amortization)	$ 1,751per acre-foot
	$ 5.37 per 1,000 gallons
Unit Costs (after amortization)	$ 1,085 per acre-foot
	$ 3.33 per 1,000 gallons

The impacts described below are associated only with delivery of water to Ballinger. The potential impacts of the regional desalination facility are discussed in Section 4.8.3.

Environmental Issues Associated with Water from the San Angelo Regional Desalination System

The environmental issues associated with this strategy are expected to be minimal. It can be assumed that the pipeline could be routed around sensitive environmental areas if needed.

Agricultural and Rural Issues Associated with Water from the San Angelo Regional Desalination System

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 Water from the San Angelo Regional Desalination System

None identified.

Significant Issues Affecting Feasibility of Water from the San Angelo Regional Desalination System

This strategy is predicated on availability of excess treatment capacity for the project and the willingness of the City of San Angelo to participate in a regional facility. The costs for implementing this strategy will be significant, and financing the project will be an issue for this region.

Another issue associated with development of this pipeline is the on-going use of water from other sources. Continued use of Lake Ballinger and water purchased from CRMWD makes it unlikely that the regional distribution system could be operated in a cost-effective manner on an as-needed basis.

This strategy requires the cooperation of other cities. Changes in participation could significantly impact the costs associated with the project.

Other Water Management Strategies Directly Affected by Water from the San Angelo Regional Desalination System

Other strategies for the cities of Ballinger, Winters, Bronte and Robert Lee may be impacted.

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 4.3-8 summarizes the costs for this strategy.

Table 4.3-8
Costs of Direct Reuse of Treated Effluent by the City of Ballinger

Supply from Strategy	220 acre-feet per year
Total Capital Costs (2002 Prices)	$ 1,980,000
Annual Costs	$ 219,845
Unit Costs (before amortization)	$ 999 per acre-foot
	$ 3.06 per 1,000 gallons
Unit Costs (after amortization)	$ 345 per acre-foot
	$ 1.06 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 4.3-9 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 4I). 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 4.3-9
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			$18,388	$24,021	$24,602	$25,222	$25,396	$25,803
Cost per Acre-Foot [b]			$557	$273	$230	$212	$194	$179
Cost per 1,000 Gal [b]			$1.71	$0.84	$0.71	$0.65	$0.59	$0.55

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 $557 per acre foot in 2010 to $179 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: 1) subordination of downstream water rights, 2) voluntary redistribution of water from Ivie Reservoir, 3) reuse and 4) water conservation. Table 4.3-10 compares expected demands for the City of Ballinger and its customers to water supplies with the strategies in place. Table 4.3-11 summarizes the annual costs of the recommended strategies.

Table 4.3-10
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
Subordination of downstream water rights to Lake Ballinger	940	930	920	910	900	890
Voluntary redistribution - MDWSC Contract from Ivie Reservoir	394	372	353	387	0	0
Voluntary redistribution - additional water from Ivie Reservoir	0	0	0	0	165	219
Direct Reuse	0	0	0	220	220	220
Total	*1,334*	*1,302*	*1,273*	*1,517*	*1,285*	*1,329*
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	*192*	*117*	*57*	*268*	*0*	*0*
Surplus (Need) with conservation	*225*	*205*	*164*	*387*	*131*	*144*

* Does not include plumbing code savings, which are already included in the water demand projections.

Table 4.3-11
Costs of Recommended Water Management Strategies for the City of Ballinger

Strategy	Capital Costs	Annual Costs					
		2010	2020	2030	2040	2050	2060
Subordination of downstream water rights to Lake Ballinger	$188,000	$16,391	$16,391	$0	$0	$0	$0
Voluntary redistribution - MDWSC Contract from Ivie Reservoir	$0	$167,844	$158,472	$150,378	$164,862	$0	$0
Voluntary redistribution - additional water from Ivie Reservoir	$0	$0	$0	$0	$0	$70,290	$93,294
Direct Reuse	$1,980,000	$0	$0	$0	$219,845	$219,845	$219,845
Water Conservation	$0	$18,388	$24,021	$24,602	$25,222	$25,396	$25,803
Total	*$1,980,000*	*$202,623*	*$198,884*	*$174,980*	*$409,929*	*$315,531*	*$338,942*

4.3.3 City of Winters

Table 4.3-12 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.

Table 4.3-12
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 730 acre-feet per year in 2010, declining to 670 acre-feet per year in 2060.

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
- Voluntary redistribution from a proposed regional system from Lake Brownwood
- Voluntary redistribution and desalination from the proposed San Angelo desalination project
- Reuse
- Water conservation
- Drought management

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. The assumptions used in the Colorado WAM are discussed in more detail in Appendix 3C.

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 4.3-13 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 4.3-13
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.

Regional System from Lake Brownwood to Runnels and Coke Counties

Lake Brownwood is one of the few surface water resources in Region F with a significant amount of uncommitted supply. A conceptual design for a regional system providing water to the cities of Winters, Ballinger, Bronte and Robert Lee was developed to evaluate the potential for water supply from this source. This strategy is described in more detail in Section 4.8.2.

Quantity, Reliability and Cost of Water from Lake Brownwood

The City of Winters could receive as much as 729 acre-feet of water per year from the system. This source is considered to be very reliable. Table 4.3-14 contains estimated costs of water from the project for the City of Winters. Capital costs for the strategy are associated with Brown County WID, the assumed sponsor of the strategy, in Section 4.8.2.

Table 4.3-14
Costs for Regional System from Lake Brownwood

Supply from Strategy	729 acre-feet per year
Annual Costs	$ 1,309,284
Unit Costs (before amortization)	$ 1,919 per acre-foot
	$ 5.89 per 1,000 gallons
Unit Costs (after amortization)	$ 654 per acre-foot
	$ 2.01 per 1,000 gallons

Environmental Issues Associated with Water from Lake Brownwood

The environmental issues associated with this strategy are expected to be minimal. It can be assumed that the pipeline could be routed around sensitive environmental areas if needed.

Agricultural and Rural Issues Associated with Water from Lake Brownwood

Although Lake Brownwood is used for agricultural supplies, there are sufficient supplies available in the reservoir to meet irrigation demands and provide water to these cities.

The City of Winters supplies a large portion of the drinking water for rural areas in Runnels County. Since the proposed project will make the city's water supply more reliable, the rural and agricultural interests in the area are expected to be positively impacted.

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 Water from Lake Brownwood

None identified.

Significant Issues Affecting Feasibility of Water from Lake Brownwood

The most significant issues affecting the feasibility of this project are sponsorship and financing. It is not clear which entity would be responsible for implementing and obtaining financing for the project. The project is outside of the traditional service area of the Brown County WID, the owner of Lake Brownwood. Implementation may require development of a new political subdivision to administer and finance the project. The cost of the project is significant and would be a financial strain on the area.

Another issue associated with development of this pipeline is the on-going use of water from other sources. Lake Winters is the most economical source of water for the City of Winters. Historically, the City of Winters has relied on Lake Winters for all of its supplies. The significant investment in infrastructure associated with this strategy makes it unlikely that this system could be operated in a cost-effective manner on an as-needed basis.

This strategy requires the cooperation of other cities. Changes in participation could significantly impact the costs associated with the project.

Other Water Management Strategies Directly Affected by Water from Lake Brownwood

Other strategies for the cities of Ballinger, Winters, Bronte and Robert Lee may be impacted.

Voluntary Redistribution - Purchase Water from San Angelo Regional Desalination System

A proposed strategy for a regional desalination facility located near the City of San Angelo is described in Section 4.8.3. This facility could provide high-quality drinking water to areas in Coke and Runnels Counties with potential water supply needs. The conceptual design for this project assumes that treated water would be pumped to a large storage tank located in the hills north of the City of San Angelo. From that point, water could be delivered by gravity flow to Winters and other locations in Runnels and Coke Counties.

Quantity, Reliability and Cost of Water from San Angelo Regional Desalination System

Table 4.3-15 summarizes the estimated cost of water from this project. All capital costs are associated with the City of San Angelo, the assumed sponsor of the project.

Table 4.3-15
Purchase Water from San Angelo Regional Desalination Facility

Supply from Strategy	729 acre-feet per year
Annual Costs	$ 1,276,479
Unit Costs (before amortization)	$ 1,751per acre-foot
	$ 5.37 per 1,000 gallons
Unit Costs (after amortization)	$ 1,085 per acre-foot
	$ 3.33 per 1,000 gallons

The impacts described below are associated with delivery of water to Winters. The potential impacts of the regional desalination facility are discussed with the San Anglo strategies in Section 4.8.3.

Environmental Issues Associated with Water from San Angelo Regional Desalination System

The environmental issues associated with delivery of water are expected to be minimal. It can be assumed that the pipeline could be routed around sensitive environmental areas if needed.

Agricultural and Rural Issues Associated with Water from San Angelo Regional Desalination System

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 Water from San Angelo Regional Desalination System

None identified.

Significant Issues Affecting Feasibility of Water from San Angelo Regional Desalination System

This strategy is predicated on availability of excess treatment capacity for the project and the willingness of the City of San Angelo to participate in a regional facility. The costs for implementing this strategy will be significant, and financing the project will be an issue for this region.

Another issue associated with development of this pipeline is the on-going use of water from other sources. Lake Winters is the most economical source of water for the City of Winters. Historically, the City of Winters has relied on Lake Winters for all of its supplies. The significant investment in infrastructure associated with this strategy makes it unlikely that this system could be operated in a cost-effective manner on an as-needed basis.

This strategy requires the cooperation of other cities. Changes in participation could significantly impact the costs associated with the project.

Other Water Management Strategies Directly Affected by Water from San Angelo Regional Desalination System

Other strategies for the cities of Ballinger, Winters, Bronte and Robert Lee may be impacted.

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 4.3-16 summarizes the costs for this strategy.

Table 4.3-16
Direct Reuse of Treated Effluent by the City of Winters

Supply from Strategy	110 acre-feet per year
Total Capital Costs (2002 Prices)	$ 1,660,000
Annual Costs	$ 198,000
Unit Costs (before amortization)	$ 1,800 per acre-foot
	$ 5.42 per 1,000 gallons
Unit Costs (after amortization)	$ 482 per acre-foot
	$ 1.45 per 1,000 gallons

Environmental Issues Associated with Reuse by the City of Winters

The City of Winters currently both 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 4I.

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 4.3-17 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 2002, the most recent year for which per capita water use data are available, the city had a per capita demand of 128 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 4.3-17
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			$12,392	$16,589	$16,353	$16,134	$15,829	$15,781
Cost per Acre-Foot			$590	$302	$260	$241	$223	$208
Cost per 1,000 Gal			$1.81	$0.93	$0.80	$0.74	$0.68	$0.64

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. Although 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 4.3-18 is a comparison of supply to demand with the recommended strategies in place. Table 4.3-19 summarizes the expected costs for these strategies.

Table 4.3-18
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 Ballinger	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 4.3-19
Costs of Recommended Water Management Strategies for the City of Winters

Strategy	Capital Costs	Annual Costs					
		2010	2020	2030	2040	2050	2060
Subordination of downstream water rights	$144,000	$12,555	$12,555	$0	$0	$0	$0
Direct Reuse	$1,660,000	$0	$0	$0	$198,000	$198,000	$53,000
Water Conservation		$12,392	$16,589	$16,353	$16,134	$15,829	$15,781
Total	$1,660,000	$24,947	$29,144	$16,353	$214,134	$213,829	$68,781

4.3.4 City of Bronte

Table 4.3-20 compares the supply and demand for the City of Bronte. The city of Bronte is expected to have a maximum projected demand of about 274 acre-feet per year (in-city use plus municipal sales). 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.

Table 4.3-20
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	116	129	125	121	120	120	
Total	*116*	*129*	*125*	*121*	*120*	*120*	
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)	*(129)*	*(129)*	*(129)*	*(129)*	*(129)*	*(129)*	

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 nine 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. Each well has a capacity of about 1.5 acre-feet per day. For the purposes of this plan, it was assumed that this aquifer could produce up to 129 acre-feet per year, or half of the maximum demand for the city.

Without subordination to downstream water rights, Oak Creek Reservoir has no yield. See Appendix 3C for additional information.

The city has plans to drill up to 5 new wells to supplement their groundwater supply. The city also needs to rehabilitate its supply pipe from Oak Creek Reservoir.

Potentially Feasible Water Management Strategies

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

- Subordination of downstream water rights
- Additional water wells
- Reuse
- Desalination from San Angelo Regional Desalination Facility
- Regional system from Lake Brownwood
- Rehabilitation of Oak Creek pipeline
- Water Conservation

- Drought Management

Brush control and precipitation enhancement are discussed in Section 4.9.

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 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 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.

New Water Wells

The city has plans to drill 5 additional water wells by 2010. The most likely location for these wells would be near the city's existing wells near Oak Creek Reservoir. These wells produce water from an unclassified aquifer approximately 275 feet below the surface. An alternative location has been identified in another unclassified aquifer in eastern Coke County.

However, water from this source is high in sulfides and may require advanced treatment for municipal use.

For the purposes of this plan, the additional wells are assumed to be located near Oak Creek Reservoir, the same area as those already drilled by the city.

Quantity, Reliability and Cost of New Water Wells

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 five new wells are assumed to supply an additional 100 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. The city estimates that the cost of the new wells will be $450,000. Table 4.3-21 summarizes the expected costs for the city.

Table 4.3-21
Costs for New Water Wells for the City of Bronte

Supply from Strategy	100 acre-feet per year
Total Capital Costs (2002 Prices)	$464,000
Annual Costs	$57,000
Unit Costs (before amortization)	$570 per acre-foot
	$1.75 per 1,000 gallons
Unit Costs (after amortization)	$170 per acre-foot
	$0.52 per 1,000 gallons

Environmental Issues Associated with New Water Wells

Little is known about the aquifer that is used for supply by the city. If a link between reduction in surface flows and groundwater pumping can be established, pumping limits may be a way to minimize potential impacts. There are no subsidence districts in Region F, and it is unlikely that water production by the City of Bronte will result in subsidence.

Agricultural and Rural Issues Associated with New Water Wells

No direct agricultural impacts have been identified for this strategy.

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 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.

Other Water Management Strategies Directly Affected by New Water Wells

Other strategies for the City of Bronte may be impacted.

Voluntary Redistribution - Purchase Water from San Angelo Regional Desalination System

A proposed strategy for a regional desalination facility located near the City of San Angelo is described in Section 4.8.3. This facility could provide high-quality drinking water to areas in Coke and Runnels Counties with potential water supply needs. The conceptual design for this project assumes that treated water would be pumped to a large storage tank located in the hills north of the City of San Angelo. From that point, water could be delivered by gravity flow to Bronte and other locations in Runnels and Coke Counties.

Quantity, Reliability and Cost of Purchasing Water from San Angelo Regional Desalination System

Table 4.3-22 summarizes the estimated cost of water from this project. All capital costs are associated with the City of San Angelo, the assumed sponsor of the project.

Table 4.3-22
Purchase Water from San Angelo Regional Desalination Facility

Supply from Strategy	280 acre-feet per year
Annual Costs	$ 537,600
Unit Costs (before amortization)	$ 1,920 per acre-foot
	$ 5.89 per 1,000 gallons
Unit Costs (after amortization)	$ 1,178 per acre-foot
	$ 3.62 per 1,000 gallons

The impacts reported below are for the water delivery facilities to Bronte. The potential impacts of the regional desalination facility are discussed with San Angelo strategies in Section 4.8.3.

Environmental Issues Associated with Purchasing Water from San Angelo Regional Desalination System

The environmental issues associated with the water delivery system are expected to be minimal. It is assumed that the pipeline could be routed around sensitive environmental areas if needed.

Agricultural and Rural Issues Associated with Purchasing Water from San Angelo Regional Desalination System

No agricultural impacts have been identified.

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 area.

Other Natural Resource Issues Associated with Purchasing Water from San Angelo Regional Desalination System

None identified.

Significant Issues Affecting Feasibility of Purchasing Water from San Angelo Regional Desalination System

This strategy is predicated on the availability of excess treatment plant capacity for the project and on the willingness of the City of San Angelo and other cities to participate in a regional facility. The costs for implementing this strategy will be significant, and financing the project will be an issue for this area.

Another issue associated with development of this pipeline is the on-going use of water from this source. Water from this source would need to be used much of the time to make the project cost-effective. Using water on an as-needed basis may not be the best way to make use of this project.

Other Water Management Strategies Directly Affected by Purchasing Water from San Angelo Regional Desalination System

Other strategies for the cities of Ballinger, Winters, Bronte and Robert Lee may be impacted.

Regional System from Lake Brownwood to Runnels and Coke Counties

Lake Brownwood is one of the few surface water resources in Region F with a significant amount of uncommitted supply. A conceptual design for a regional system providing water to the cities of Winters, Ballinger, Bronte and Robert Lee was developed to evaluate the potential for water supply from this source. This strategy is described in more detail in Section 4.8.2.

Quantity, Reliability and Cost of Water from Lake Brownwood

The City of Bronte could receive as much as 280 acre-feet of water per year from the system. This source is considered to be very reliable. Table 4.3-23 contains estimated costs of water from the project for the City of Bronte. Capital costs for the strategy are associated with Brown County WID, the assumed sponsor of the strategy, and are not presented in this memorandum.

Table 4.3-23
Costs for Regional System from Lake Brownwood to Runnels and Coke Counties

Supply from Strategy	280 acre-feet per year
Annual Costs	$ 502,880
Unit Costs (before amortization)	$ 1,796 per acre-foot
	$ 5.51 per 1,000 gallons
Unit Costs (after amortization)	$ 633 per acre-foot
	$ 1.94 per 1,000 gallons

Environmental Issues Associated with Water from Lake Brownwood

The environmental issues associated with this strategy are expected to be minimal. It is assumed that the pipeline could be routed around sensitive environmental areas if needed.

Agricultural and Rural Issues Associated with Water from Lake Brownwood

Although Lake Brownwood is used for agricultural supplies, there are sufficient supplies available in the reservoir to meet irrigation and municipal demands.

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 area.

Other Natural Resource Issues Associated with Water from Lake Brownwood

None identified.

Significant Issues Affecting Feasibility of Water from Lake Brownwood

The most significant issues affecting the feasibility of this project are sponsorship and financing. At this time it is unclear what entity would be responsible for implementing and obtaining financing for the project. The project is outside of the traditional service area of the

Brown County WID, the owner of Lake Brownwood. Implementation may require development of a new political subdivision to administer and finance the project. The cost of the project is significant and would be a significant financial strain on the area.

Another issue associated with development of this pipeline is the frequency of use of water from this source. Historically, the City of Bronte has relied on Oak Creek Reservoir and groundwater for all of its supplies. Because of the significant investment in infrastructure associated with this project it may not be practical to operate this project on an as-needed basis. .

Other Water Management Strategies Directly Affected by Water from Lake Brownwood

Other strategies for the cities of Bronte.

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 4.3-24 summarizes the costs for this strategy.

Table 4.3-24
Direct Reuse of Treated Effluent by the City of Bronte

Supply from Strategy	110 acre-feet per year
Total Capital Costs (2002 Prices)	$ 1,660,000
Annual Costs	$ 198,000
Unit Costs (before amortization)	$ 1,800 per acre-foot
	$ 5.42 per 1,000 gallons
Unit Costs (after amortization)	$ 482 per acre-foot
	$ 1.45 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. 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 more than the allocated 129 acre-feet of water per year. Table 4.3-25 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 4.3-25
Rehabilitation of Pipeline from Oak Creek Reservoir to Bronte

Supply from Strategy	129 acre-feet per year
Total Capital Costs (2002 Prices)	$ 1,265,400
Annual Costs	$ 110,000
Unit Costs (before amortization)	$ 855 per acre-foot
	$ 262 per 1,000 gallons
Unit Costs (after amortization)	$ 0 per acre-foot
	$ 0 per 1,000 gallons

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.

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 5-6 grades are used as well.

Table 4.3-26 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 4I).

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 4.3-26 summarizes the estimated costs of implementing the Region F conservation practices. Costs range from over $280 per acre foot in 2010 to $157 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 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.

Table 4.3-26
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			$4,472	$8,743	$8,539	$8,340	$8,145	$8,023
Cost per Acre-Foot			$280	$194	$178	$174	$163	$157
Cost per 1,000 Gal			$0.86	$0.60	$0.55	$0.53	$0.50	$0.48

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.

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 conduced 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) construction of new water wells, 3) rehabilitation of the Oak Creek pipeline and 4) water conservation. Table 4.3-27 compares expected demands for the City of Bronte to water supplies with the strategies in place. Table 4.3-28 summarizes the annual costs of the recommended strategies.

Table 4.3-27
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	116	129	125	121	120	120
New Water Wells	100	100	100	100	100	100
Total	*345*	*358*	*354*	*350*	*349*	*349*
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	*100*	*100*	*100*	*100*	*100*	*100*
Surplus (Need) with conservation	*116*	*145*	*148*	*148*	*150*	*151*

* Does not include plumbing code savings, which are already included in the water demand projections.

Table 4.3-28
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	$1,238,600	$21,600	$21,600	$ 0	$ 0	$ 0	$ 0
New water wells	$464,000	$57,000	$57,000	$17,000	$17,000	$17,000	$17,000
Water Conservation	$ 0	$4,472	$8,743	$8,539	$8,340	$8,145	$8,023
Total	*$1,702,600*	*$83,072*	*$87,343*	$25,539	$25,340	$25,145	$25,023

* Costs of subordination strategy are associated with the City of Sweetwater, the owner of Oak Creek Reservoir. Sweetwater is in Region G.

4.3.5 City of Robert Lee

Table 4.3-29 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 420 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. Although Mountain Creek Reservoir is a relatively old structure, an inspection conducted as part of this plan found the dam and spillway to be in good condition (see Appendix 4K). 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 both 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, the city has recently been under restrictions because their water treatment plant was near capacity. An additional 0.5 mgd of capacity would be desirable to prevent overloading of the treatment plant.

Table 4.3-29
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 following potentially feasible water management strategies have been identified for the City of Robert Lee:

- Subordination of downstream water rights
- Reuse
- Desalination from San Angelo Regional Desalination Facility
- Desalination of Spence Reservoir water
- Regional system from Lake Brownwood
- New floating pump in Mountain Creek Reservoir
- Expansion of water treatment plant and storage facilities
- Water Conservation
- Drought Management

Brush control and precipitation enhancement are discussed in Section 4.9.

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, 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 either in 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 4.3-30 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.

Table 4.3-30
Direct Reuse of Treated Effluent for the City of Robert Lee

Supply from Strategy	110 acre-feet per year
Total Capital Costs (2002 Prices)	$ 1,660,000
Annual Costs	$ 198,000
Unit Costs (before amortization)	$ 1,800 per acre-foot
	$ 5.42 per 1,000 gallons
Unit Costs (after amortization)	$ 482 per acre-foot
	$ 1.45 per 1,000 gallons

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.

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 - Purchase Water from San Angelo Regional Desalination System

A proposed strategy for a regional desalination facility located near the City of San Angelo is described in Section 4.8.3. This facility could provide high-quality drinking water to areas in Coke and Runnels Counties with potential water supply needs. The conceptual design for this project assumes that treated water would be pumped to a large storage tank located in the hills north of the City of San Angelo. From that point, water could be delivered by gravity flow to Bronte and other locations in Runnels and Coke Counties.

Quantity, Reliability and Cost of Water from San Angelo Regional Desalination Facility

Table 4.3-31 summarizes the estimated cost of water from this project. All capital costs are associated with the City of San Angelo, the assumed sponsor of the project.

Table 4.3-31
Purchase Water from San Angelo Regional Desalination Facility
City of Robert Lee

Supply from Strategy	448 acre-feet per year
Annual Costs	$ 860,160
Unit Costs (before amortization)	$ 1,920 per acre-foot
	$ 5.89 per 1,000 gallons
Unit Costs (after amortization)	$ 1,178 per acre-foot
	$ 3.62 per 1,000 gallons

The impacts reported below are for delivery facilities to Robert Lee. The potential impacts of the regional desalination facility are discussed with other strategies for the City of San Angelo in Section 4.8.3.

Environmental Issues Associated with Water from San Angelo Regional Desalination Facility

The environmental issues associated with this strategy are expected to be minimal. It can be assumed that the pipeline could be routed around sensitive environmental areas if needed.

Agricultural and Rural Issues Associated with Water from San Angelo Regional Desalination Facility

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 area.

Other Natural Resource Issues Associated with Water from San Angelo Regional Desalination Facility

None identified.

Significant Issues Affecting Feasibility of Water from San Angelo Regional Desalination Facility

This strategy depends on availability of excess treatment capacity and the willingness of the City of San Angelo and the other cities to participate in a regional facility. The costs for implementing this strategy will be significant, and financing the project will be an issue for the area.

Another issue associated with development of this pipeline is the on-going use of water from this source. Water from this source would need to be used much of the time to make the project cost-effective.

Other Water Management Strategies Directly Affected by Water from San Angelo Regional Desalination Facility

Other strategies for the cities of Ballinger, Winters, Bronte and Robert Lee may be impacted.

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 4.3-32 contains a cost summary for this strategy.

Table 4.3-32
Desalination of Spence Reservoir Water by the City of Robert Lee

Supply from Strategy	500 acre-feet per year
Total Capital Costs (2002 Prices)	$ 6,106,500
Annual Costs	$ 682,000
Unit Costs (before amortization)	$ 1,364 per acre-foot
	$ 4.19 per 1,000 gallons
Unit Costs (after amortization)	$ 318 per acre-foot
	$ 0.98 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.

Regional System from Lake Brownwood to Runnels and Coke Counties

Lake Brownwood is one of the few surface water resources in Region F with a significant amount of uncommitted supply. A conceptual design for a regional system providing water to the cities of Winters, Ballinger, Bronte and Robert Lee was developed to evaluate the potential for water supply from this source. This strategy is described in more detail with the strategies for the Brown County Water Improvement District No. 1 (BCWID), the assumed sponsor of this project, in Section 4.8.2.

Quantity, Reliability and Cost of Water from Lake Brownwood

The City of Robert Lee could receive as much as 448 acre-feet of water per year from the system. This source is considered to be very reliable. Table 4.3-33 contains estimated costs of water from the project for the city. Capital costs for the strategy are associated with BCWID, the assumed sponsor of the strategy, in Section 4.8.2.

Table 4.3-33
Costs for Regional System from Lake Brownwood to the City of Robert Lee

Supply from Strategy	448 acre-feet per year
Annual Costs	$ 804,545
Unit Costs (before amortization)	$ 1,796 per acre-foot
	$ 5.51 per 1,000 gallons
Unit Costs (after amortization)	$ 633 per acre-foot
	$ 1.94 per 1,000 gallons

Environmental Issues Associated with Water from Lake Brownwood

The environmental issues associated with this strategy are expected to be minimal. It can be assumed that the pipeline could be routed around sensitive environmental areas if needed.

Agricultural and Rural Issues Associated with Water from Lake Brownwood

Although Lake Brownwood is used for agricultural supplies, there are sufficient supplies available in the reservoir to meet irrigation demands and provide water to these cities.

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 community and the surrounding rural area.

Other Natural Resource Issues Associated with Water from Lake Brownwood

None identified.

Significant Issues Affecting Feasibility of Water from Lake Brownwood

The most significant issues affecting the feasibility of this project are sponsorship and financing. It is not clear which entity would be responsible for implementing and obtaining financing for the project. The project is outside of the traditional service area of the Brown County WID, the owner of Lake Brownwood. Implementation may require development of a new political subdivision to administer and finance the project. The high cost of the project would be a significant financial strain on the area.

Another significant issue associated with development of this pipeline is the on-going use of water from this source. Historically, the City of Robert Lee has relied on Mountain Creek and Spence Reservoirs for all of its supplies. If this strategy is implemented, the city would not be able to use the same mode of operation. Water from this source would need to be used much of the time to make the project cost-effective.

Other Water Management Strategies Directly Affected by Water from Lake Brownwood

Other strategies for the cities of Bronte, Ballinger, Robert Lee and Winters.

Floating Pump in Mountain Creek Reservoir

The existing intake structure in Mountain Creek Reservoir makes it difficult for the city to taking 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 4.3-34 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 4.3-34
New Floating Pump in Mountain Creek Reservoir for the City of Robert Lee

Supply from Strategy	50 acre-feet per year
Total Capital Costs (2002 Prices)	$ 140,000
Annual Costs	$ 17,000
Unit Costs (before amortization)	$ 340 per acre-foot
	$ 1.04 per 1,000 gallons
Unit Costs (after amortization)	$ 96 per acre-foot
	$ 0.29 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 supply available to the city. The reliability of these supplies would be high. Table 4.3-35 shows the estimated costs for these improvements.

Table 4.3-35
0.5 MGD Water Treatment Plant Expansion for the City of Robert Lee

Supply from Strategy	200 acre-feet per year
Total Capital Costs (2002 Prices)	$ 2,482,500
Annual Costs	$ 216,000
Unit Costs (before amortization)	$ 1,297 per acre-foot
	$ 3.98 per 1,000 gallons
Unit Costs (after amortization)	$ 217 per acre-foot
	$ 0.66 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).

Water Conservation

In recent years the City of Robert Lee has been under water use restrictions primarily due to infrastructure limitations. Table 4.3-36 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 4I).

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 $0.91 per thousand gallons in 2010 to $0.51 per thousand gallons in 2060.

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 4.3-37 is a comparison of supplies to demands with strategies in place, and Table 4.3-38 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. Region F considers RO treatment to meet regulatory requirements for consistency with this plan, but the strategy is not recommended because of the cost of the project and the uncertainty involved with disposal of the brine reject.

Table 4.3-36
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			$4,770	$8,727	$8,524	$8,325	$8,130	$8,009
Cost per Acre-Foot			$298	$218	$194	$185	$177	$167
Cost per 1,000 Gal			$0.91	$0.67	$0.60	$0.57	$0.54	$0.51

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.

Table 4.3-37
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	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 4.3-38
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	$2,482,500	$259,000	$259,000	$43,000	$43,000	$43,000	$43,000
Water Conservation		$4,770	$9,770	$9,567	$8,609	$8,414	$8,293
Total	*$2,482,500*	*$263,770*	*$268,770*	*$52,567*	*$51,609*	*$51,414*	*$51,239*

Note: The subordination strategy will be implemented by CRWMD. Therefore no costs for this strategy are associated with the City of Robert Lee.

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 4.3-39 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.

Table 4.3-39
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 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 4I.

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 4.3-40 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.

Table 4.3-40
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			$7,332	$11,327	$11,009	$10,700	$10,397	$10,209
Cost per Acre-Foot			$733	$472	$393	$357	$325	$309
Cost per 1,000 Gal			$2.25	$1.45	$1.21	$1.09	$1.00	$0.95

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.

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.

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 4.3-41 summarizes the estimated costs of the project.

Table 4.3-41
Costs for New Hickory Water Well for the City of Menard

Supply from Strategy	160 acre-feet per year
Total Capital Costs (2002 Prices)	$ 1,279,400
Annual Costs	$ 172,500
Unit Costs (before amortization)	$ 1,078 per acre-foot
	$ 3.31 per 1,000 gallons
Unit Costs (after amortization)	$ 381 per acre-foot
	$ 1.17 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 interconnectedness 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 4.3-42 is a summary of the expected costs of the project.

Table 4.3-42
Costs for Aquifer Storage and Recovery by the City of Menard

Supply from Strategy	240 acre-feet per year
Total Capital Costs (2002 Prices)	$ 1,340,200
Annual Costs	$ 219,000
Unit Costs (before amortization)	$ 913 per acre-foot
	$ 2.80 per 1,000 gallons
Unit Costs (after amortization)	$ 426 per acre-foot
	$ 1.31 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

The 2001 Region F Plan evaluated an off-channel reservoir on the San Saba River in McCulloch County with a yield of 1,500 acre-feet per year. For the current plan, the site has been moved upstream near the City of Menard and the yield of the project has been reduced to 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 LCRA 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 4.3-43 summarizes the costs for this strategy.

Table 4.3-43
San Saba Off-Channel Reservoir - City of Menard

Supply from Strategy	500 acre-feet per year
Total Capital Costs (2002 Prices)	$ 19,225,100
Annual Costs	$ 1,719,000
Unit Costs (before amortization)	$ 3,438 per acre-foot
	$ 10.55 per 1,000 gallons
Unit Costs (after amortization)	$ 644 per acre-foot
	$ 1.98 per 1,000 gallons

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.

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

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 4.3-44 compares supply to demand with the recommended strategies. Table 4.3-45 summarizes the capital and annual costs associated with these strategies.

Table 4.3-44
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 4.3-45
Costs of Recommended Strategies for the City of Menard

Strategy	**Capital Costs**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
New Hickory well	$1,279,400	$172,500	$172,500	$61,000	$61,000	$61,000	$61,000
Water Conservation *	$0	$7,332	$11,327	$11,009	$10,700	$10,397	$10,209
Total	*$1,279,400*	*$179,832*	*$183,827*	*$72,009*	*$71,700*	*$71,397*	*$71,209*

* 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[7] 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 are presented in Table 4.3-46. Supplies from the Colorado WAM are discussed in Appendix 3C and the subordination strategy is discussed in Section 4.2.3.

Table 4.3-46 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 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 the Paul Davis Well Field is no longer available.

Table 4.3-46
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]	12,034	12,099	0	0	0	0
Ivie Contract [c]	10,925	10,699	10,473	10,246	10,021	9,795
Paul Davis Well Field [d]	4,722	4,722	4,722	0	0	0
Total Supplies	*27,681*	*27,520*	*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)	*(1,307)*	*(2,588)*	*(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.

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, desalination and aquifer storage and recovery. For the purposes of this plan it was assumed that these strategies would be implemented by 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.

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 are approximately 650,000 acre-feet of available water in storage in the Cenozoic Pecos Alluvium from this field. The city expects the well field to have a life of approximately 60 years. The annual 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[8]. 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[9].

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 Alluvium in Winkler County and annual recharge is approximately half of the proposed annual supply. Expected costs for the project may be found in Table 4.3-47. More detailed cost estimates may be found in Appendix 4F.

Table 4.3-47
Costs for T-Bar Well Field - City of Midland

Supply from Strategy	13,600 acre-feet per year
Total Capital Costs (2002 Prices)	$ 115,772,000
Annual Costs	$ 13,080,000
Unit costs (before amortization)	$ 962 per acre-foot
	$ 2.95 per 1,000 gallons
Unit Costs (after amortization)	$ 220 per acre-foot
	$ 0.67 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 Alluvium 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 $466 per acre-foot ($1.43 per 1,000 gallons), the same as the existing contract. 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 quantified 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 is evaluating and plans to implement an aggressive water conservation program. The city has recently completed a demonstration project at a city park that includes water conserving landscaping and irrigation practices. The city is also considering a rebate program. 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 the city's water conservation program is under development and not available for inclusion in this plan, the default Region F suite of water conservation practices was used to evaluate the potential water savings and costs of implementation. Table 4.3-48 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 4I).

The reliability of this supply is considered to be medium because of the uncertainty involved in the analysis used to calculate the savings.

Table 4.3-48
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	250	234	227	223	221	220
	Savings	0	12	28	35	39	41	42
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	28,009	27,736	27,901	28,136	28,321	28,591
	Savings (Region F practices)	0	930	2,320	2,903	3,110	3,310	3,521
	Savings (Total)	0	1,379	3,267	4,253	4,874	5,231	5,471
Costs								
Annual Costs			$420,493	$463,796	$461,155	$452,873	$440,673	$435,018
Cost per Acre-Foot [b]			$452	$200	$159	$146	$133	$124
Cost per 1,000 Gal [b]			$1.39	$0.61	$0.49	$0.45	$0.41	$0.38

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 Region F practices. Plumbing code savings not included in unit cost calculations.

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.

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 Midland September 1999 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 4.3-49 compares demands to the supplies from the recommended water management strategies for the City of Midland. These include 1) subordination, 2) new groundwater development of the T-Bar Well Field, 3) voluntary redistribution from the CRMWD system and 4) conservation. Although Table 4.3-47 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 4.3-50 is a breakdown of expected costs for these strategies. Costs for subordination, which will be implemented by CRMWD, are not included in Table 4.3-50.

Table 4.3-49
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	12,034	12,099	0	0	0	0
Ivie Contract	10,925	10,699	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	0	0	10,000	9,800	9,600	9,400
Total Supplies	32,337	33,633	38,639	33,380	32,843	32,305
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential Savings [b]	930	2,320	2,903	3,110	3,310	3,521
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	*3,349*	*3,525*	*7,780*	*2,076*	*1,152*	*130*
Surplus (Need) with Conservation	*4,279*	*5,845*	*10,683*	*5,186*	*4,462*	*3,651*

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. See memorandum on subordination strategy for more detailed information.
b Does not include plumbing code savings, which are already included in the water demand projections.

Table 4.3-50
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	$115,772,000			$13,080,000	$13,080,000	$2,986,000	$2,986,000
Voluntary Redistribution				$4,660,000	$4,566,800	$4,473,600	$4,380,400
Conservation		$420,493	$463,796	$461,155	$452,873	$440,673	$435,018
Total	*$115,772,000*	*$420,493*	*$463,796*	*$18,201,155*	*$18,099,673*	*$7,900,273*	*$7,801,418*

4.3.8 Brown County Other

Table 4.3-51 is a comparison of supply and demand for Brown County Other, the water user group that includes rural Brown County. (The Brazos Basin portion of the county is very small and has sufficient groundwater supplies to meet needs.) Water supply corporations (WSCs) provide most of the water for municipal use in the rural portions of Brown County. Most of this water comes from Lake Brownwood and is very reliable. However, most of the northern portion of the county relies exclusively on groundwater supplies from either the Trinity aquifer or formations classified by TWDB as 'other aquifers'. Historically, more water has been used from the Trinity aquifer in Brown County than has been recharged to the aquifer. Municipal users of the Trinity aquifer must compete with irrigation and livestock use. The reliability of supplies from the unclassified aquifers is unknown, so supplies are based on historical use from the source.

Because of concerns about the reliability of municipal supplies from groundwater, it is anticipated that more of the existing and future municipal water use in northern Brown County will come from treated Lake Brownwood water. Brookesmith WSC has completed studies to provide water to approximately 400 connections north of Lake Brownwood. Zephyr WSC also may expand its service area to include areas currently using groundwater supplies.

Table 4.3-51
Comparison of Supply and Demand for Brown County Other (Colorado Basin)
(Values in Acre-Feet per Year)

Supplies	2010	2020	2030	2040	2050	2060	Comment
Lake Brownwood	229	229	223	214	211	211	Brownwood & Bangs sales, new customers for Zephyr and Brookesmith, Thunderbird Bay
Trinity aquifer (Colorado Basin)	0	0	0	0	0	0	No supply after irrigation, livestock & mining
Other aquifer	9	9	9	9	9	9	Supply based on historical use
Total	*238*	*238*	*232*	*223*	*220*	*220*	
County Other	342	342	336	327	324	324	Less amount supplies by Bangs & Brownwood
Surplus (Need)	(104)	(104)	(104)	(104)	(104)	(104)	

Although several strategies are technically feasible to meet needs in Northern Brown County, water from Lake Brownwood is an existing source, has existing infrastructure to treat and deliver water, has several local sponsors to implement the strategy, and is an economical source of water. Therefore Region F considers water from Lake Brownwood as the most likely strategy to meet future needs.

Voluntary Redistribution - Lake Brownwood Water to Northern Brown County

Quantity, Reliability and Cost

Brown County Water Improvement District's (BCWID) water treatment plant has sufficient capacity to meet these needs, and there is available supply from Lake Brownwood. The reliability of this source is high.

The configuration of this strategy is largely unknown pending more specific information regarding future development in Brown County. For the purposes of this plan, a conceptual design was developed calling for a 22-mile 8-inch distribution line from the BCWID Plant to a 0.3 MG storage tank at an unspecified point in northern Brown County. This project could provide as much as 300 acre-feet per year. Table 4.3-52 summarizes the cost of this conceptual design. More specific engineering studies will be required before implementing this strategy.

Table 4.3-52
Costs of Lake Brownwood Water to Northern Brown County

Supply from Strategy	300 acre-feet per year
Total Capital Costs (2002 Prices)	$ 5,284,000
Annual Costs	$ 758,000
Unit costs (before amortization)	$ 2,527 per acre-foot
	$ 7.75 per 1,000 gallons
Unit Costs (after amortization)	$ 990 per acre-foot
	$ 3.04 per 1,000 gallons

Environmental Issues Associated with Lake Brownwood to Brown County Other

Environmental impacts should be low. The only major infrastructure expansion is the pipeline, which is limited to the northern portion of the county. The distribution lines can be routed to minimize impacts on environmentally sensitive areas if needed.

The quantity of water provided by this strategy should have minimal impacts to water resources since there is available supply from Lake Brownwood and excess capacity in the BCWID treatment plan.

Agricultural and Rural Issues Associated with Lake Brownwood to Brown County Other

This strategy should have a positive impact on the rural community in Brown County because it will reduce competition for water from the Trinity aquifer and increase the reliability for rural water users.

Other Natural Resource Issues Associated with Lake Brownwood to Brown County Other

None identified.

Significant Issues Affecting Feasibility of Lake Brownwood to Brown County Other

This strategy has been developed for regional water planning only. Other studies may determine better, less expensive options for providing treated Lake Brownwood water using existing facilities owned by Brookesmith SUD, Zephyr WSC or others.

Other Water Management Strategies Directly Affected by Lake Brownwood to Brown County Other

None identified.

Water Conservation and Drought Management

Water conservation and drought management were not evaluated for Brown County Other because the demand is small and there is no identified sponsor to implement water conservation or drought management. Based on similar areas, water conservation savings could be expected to be about 14 percent of the demand, or 23 acre-feet per year. Once these users are connected to a surface water source, BCWID and either Brookesmith SUD or Zephyr WSC would be responsible for water conservation and drought management planning in the area.

4.3.9 City of Coleman

Table 4.3-53 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. Supplies from the Colorado WAM are discussed in Appendix 3C.

Table 4.3-53
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 9,897 acre-feet per year in 2010, declining to 9,230 acre-feet per year in 2060.

Potentially Feasible Water Management Strategies

With subordination of downstream water rights, the City of Coleman 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 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, which are discussed in more detail in Appendix 3C.

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 described in Section 4.2.3. Table 4.3-54 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 4.3-54
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	8,507	0	7,990
Hords Creek Reservoir	3/23/1946	2,240	0	1,390	0	1,240
Total [b]		*11,240*	*0*	*9,897*	*0*	*9,230*

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 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 Coleman.

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 4I

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 4.3-55 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 2002, the most recent year for which per capita water use data are available, the city had a per capita demand of 145 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.

Table 4.3-55
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			$21,311	$24,872	$23,960	$23,072	$22,202	$21,664
Cost per Acre-Foot			$646	$332	$266	$243	$220	$202
Cost per 1,000 Gal			$1.98	$1.02	$0.82	$0.75	$0.67	$0.62

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.

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 4.3-56 is a comparison of supply to demand with the recommended strategies in place. Table 4.3-57 summarizes the expected costs for these strategies.

Table 4.3-56
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 9,897 acre-feet per year in 2010, declining to 9,230 acre-feet per year in 2060.
b Does not include plumbing code savings, which are already included in the water demand projections.

Table 4.3-57
Costs of Recommended Water Management Strategies for the City of Coleman

Strategy	**Capital Costs**	**Annual Costs**					
		2010	**2020**	**2030**	**2040**	**2050**	**2060**
Subordination of downstream water rights	$1,979,400	$172,573	$172,573	$0	$0	$0	$0
Water Conservation		$21,311	$24,872	$23,960	$23,072	$22,202	$21,664
Total	*$1,979,400*	*$193,844*	*$197,445*	*$23,960*	*$23,072*	*$22,202*	*$21,664*

4.3.10 City of Brady

Table 4.3-58 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. Currently, the city uses the Hickory aquifer for supplies. Supplies from the Hickory aquifer exceed drinking water standards for radionuclides, so city is in the process of constructing a 1.5 MGD treatment plant to obtain water from Brady Creek Reservoir. For the purposes of this plan, it was assumed that the city will obtain at least half of its supply from the new treatment plant. 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 4.3-58
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. The assumptions used in the Colorado WAM are discussed in more detail in Appendix 3C.

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 4.3-59 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 4.3-59
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.
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 4I.

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 4.3-60 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 2002, the most recent year for which per capita water use data are available, the city had a per capita demand of 215 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 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 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 4.3-60
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			$23,486	$27,370	$26,348	$25,353	$24,380	$23,777
Cost per Acre-Foot			$305	$143	$123	$114	$106	$99
Cost per 1,000 Gal			$0.94	$0.44	$0.38	$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 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 4.3-61 is a comparison of supply to demand with the recommended strategies in place. Table 4.3-62 summarizes the expected costs for these strategies.

Table 4.3-61
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 4.3-62
Costs of Recommended Water Management Strategies for the City of Brady

Strategy	**Capital Costs**	**Annual Costs**					
		2010	**2020**	**2030**	**2040**	**2050**	**2060**
Subordination of downstream water rights	$434,000	$37,838	$37,838	$0	$0	$0	$0
Water Conservation		$23,486	$27,370	$26,348	$25,353	$24,380	$23,777
Total	*$434,000*	*$61,324*	*$65,208*	*$26,348*	*$25,353*	*$24,380*	*$23,777*

4.3.11 Strategies for Hickory Aquifer Users

Among the needs identified previously in the 2001 *Region F Regional Water Plan* 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 has been 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 was investigated. For selected water suppliers, specific water management strategies were identified and evaluated.

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 4.3-63. 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.

Table 4.3-63
Hickory Water Suppliers

Public Water System	**Average Annual Demand** (acre-feet per year)
City of Brady	2,078
Millersview-Doole WSC	847
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.

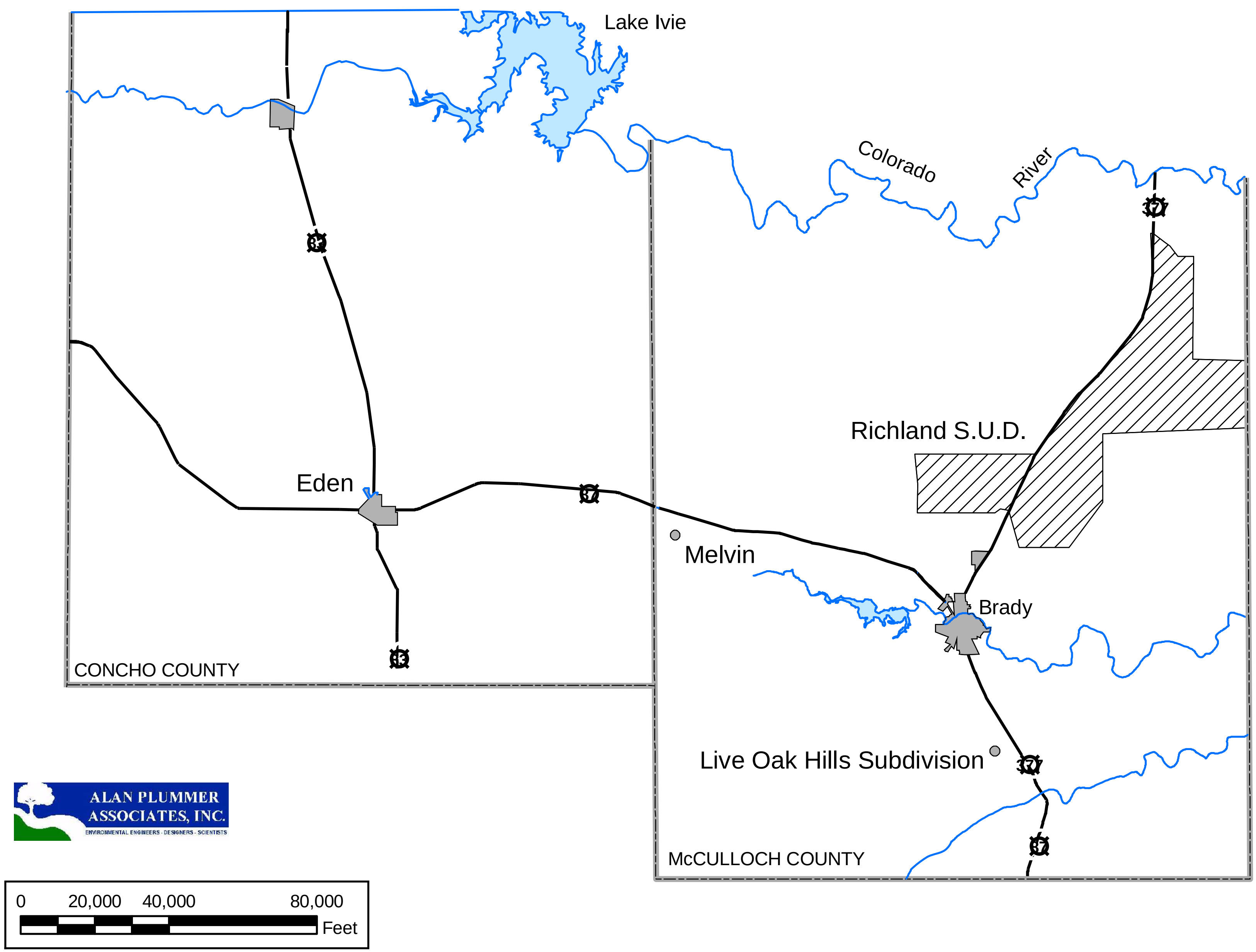
Before the development of the 2001 Region F Plan, the two largest Hickory water suppliers, the City of Brady and MDWSC, had both begun the process of implementing strategies that would enable them to obtain low-radionuclide water. These strategies will enable the City of Brady and MDWSC to meet the projected demand increases due to expected population growth, as well as to comply with the MCLs for radionuclides. The City of Brady is constructing 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 such that the MCLs for radionuclides are not exceeded. The plant will initially operate at 1.5 MGD.[10] Lakeland Services, Inc. will be supplied by the City of Brady when the new Brady treatment plant comes online.[11] MDWSC is planning to construct a 3.0 MGD plant that will treat water from Lake Ivie, using treatment processes similar to those at the Brady plant. [12] Although MDWSC has considered the option of blending treated surface water with Hickory groundwater, blending is not considered a cost-effective option except possibly in a small portion of the distribution system. Once construction of the Lake Ivie treatment plant is complete, MDWSC will likely abandon use of its Hickory aquifer wells altogether.[13]

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.[14]

The communities that will continue to utilize the Hickory aquifer as a sole or major source of water serve a combined population of less than 10,000 persons. These communities include the City of Eden, Richland SUD, the City of Melvin and Live Oak Hills Subdivision. Because of the small size of these communities, the 2001 Region F plan recommended consideration of regional systems as a strategy. However, 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 will continue to rely on Hickory aquifer water wells where radionuclide concentrations exceed the drinking water standards will soon be required to comply with new 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.[15] In December 2004, TCEQ amended its rules to implement the EPA radionuclides rule as part of the state's drinking water program (TAC Rule §290.108).[16] The federal and state MCLs for radionuclides are listed in Table 4.3-64. 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.



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Area of Evaluation for Hickory Users

DRAFTED	DESIGNED	SCALE	DATE	FILE	FN JOB NO
	CCL		July 22, 2005		

FIGURE
4.3-3

Table 4.3-64
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.[17] 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.[18]

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.[19] 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.[20] 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.[21]

Potentially Feasible Water Management Strategies

As previously described, four 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 Eden is the largest of these providers, serving 1,191 citizens and a private prison with a population of 1,370. The service area includes 590 water meters. Richland SUD serves a rural area encompassing 120 miles of transmission lines serving 326 households and a population of 630. The City of Melvin has a population of 155 on 122 meter connections. Live Oak Hills Subdivision serves a population of 96 and has 33 connections.

The City of Eden operates two deep wells in the Hickory aquifer and three shallow wells in the Edwards Limestone (classified as Other aquifer by TWDB). One of the Hickory wells is over fifty years old and needs to be replaced. During normal to wet years, the city blends water from the shallow wells with Hickory aquifer water in order to comply with drinking water standards. However, production from the shallow wells is limited during periods of low rainfall, such that the city may not be able to keep the combined radium levels below 5 pCi/L. In November 2002, after several years of persistent drought, TCEQ placed the City of Eden under a Bilateral Compliance Agreement because of violations of the radium MCL. In addition, TCEQ has notified the city that a filtration process will be required for the water from the shallow wells because they are under the influence of surface water.[22] As a result, the city is considering abandoning its shallow wells in favor of the more reliable Hickory supply.

Richland SUD provides water to a relatively small number of rural customers spread over a large area. The system has over 120 miles of pipeline. Most of the water provided by the system is used for livestock. According to representatives of Richland SUD, only 0.5 percent of the water supplied by the system is actually used for potable purposes[23]. The system losses are relatively high, averaging 32 percent for the year 2004.[24] Losses include water used for flushing as required by TCEQ. In order to recoup production expenses, Richland SUD needs to charge customers $1.47 for every dollar spent to produce water. Also, Richland SUD does not operate, or have access to, a wastewater treatment system to handle the residuals that would be generated by some treatment processes. Lastly, the Richland SUD wells have some of the highest reported radium levels in the area. The higher concentrations in the raw water would result in higher radium concentrations in the treatment residuals than would be expected from other Hickory aquifer users. Thus, Richland SUD has a number of characteristics that limit the feasibility of implementing a treatment system for removal of radionuclides.

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.[25] Like Richland SUD, 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 four water suppliers. 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 to ensure a continued adequate supply for the city. 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. Concentrations of radionuclides have been found to vary considerably in the Hickory aquifer. If a low-radium location can be found, the city may be able to comply with the radium MCL through blending.

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 will 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 322 acre-feet of water per year. This source is considered very reliable. Table 4.3-65 summarizes the expected costs for the City of Eden and Table 4.3-66 summarizes the expected costs for Richland SUD.

Table 4.3-65
Costs for Replacement Hickory Well for the City of Eden

Supply from Strategy	322 acre-feet per year
Total Capital Costs	$1,367,372
Annual Costs	$ 278,679
Additional Unit Costs (before amortization)	$864 per acre-foot
	$2.65 per 1,000 gallons
Additional Unit Costs (after amortization)	$494 per acre-foot
	$1.52 per 1,000 gallons

Table 4.3-66
Costs for Replacement Hickory Well for Richland SUD

Supply from Strategy	113 acre-feet per year
Total Capital Costs	$1,291,720
Annual Costs	$ 172,191
Additional Unit Costs (before amortization)	$1,524 per acre-foot
	$4.68 per 1,000 gallons
Additional Unit Costs (after amortization)	$527 per acre-foot
	$1.62 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 interconnectedness 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, it 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.

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.[26] 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.[27] 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. For the City of Eden, which operates a sanitary sewer system and a wastewater treatment plant, the water treatment residual product can possibly be discharged to a sanitary sewer system and combined with wastewater flows. 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.

Of the four communities relying on Hickory water with radionuclide concentrations above the MCLs, advanced treatment is a potential strategy available to the only to the City of Eden. The city operates a sanitary sewer system and a wastewater treatment plant and thus has a disposal mechanism for drinking water treatment residuals, but the impacts of these residuals may require upgrades or expansion of the wastewater treatment plant. Several radium-removal treatment options are available to the City of Eden. CAX or RO could be implemented at Eden to provide radium removal, and generalized cost estimates are provided for both options. However, further characterization of the groundwater and study of the treatment alternatives is required to determine the most cost-effective system. CAX may not provide adequate reduction of gross alpha particles. An RO system could offer the advantage of also providing treatment for water from the shallow wells. However, the RO system is expected to generate 15-25 percent brine reject, thus requiring the plant to be sized slightly larger than an equivalent CAX plant. The additional chlorides in the CAX residuals could pose problems for the wastewater plant, but the increased volumes generated by RO treatment may exceed the plant's capacity.

Quantity, Reliability and Cost of Advanced Treatment Alternatives

The water treatment plants are sized to handle a peak volume of twice the daily average amount of water requiring treatment. The radium concentrations in Eden's Hickory wells are low enough that only about 70 percent of the water would need to be treated to enable the blended water supply to stay under the radium MCL. Note that the projected treatment costs do not include potential cost impacts on the wastewater treatment plant. Projected costs for CAX and RO treatment systems are listed in Table 4.3-67 and Table 4.3-68.

Table 4.3-67
CAX Treatment Costs for City of Eden

Supply from Strategy	392 acre-feet per year
Total Capital Costs	$1,656,286
Annual Costs for Treatment	$ 31,935
Additional Unit Costs (before amortization)	$ 450 per acre-foot
	$ 1.38 per 1,000 gallons
Additional Unit Costs (after amortization)	$ 81 per acre-foot
	$ 0.25 per 1,000 gallons

Table 4.3-68
RO Treatment Costs for City of Eden

Supply from Strategy	392 acre-feet per year
Total Capital Costs	$1,685,731
Annual Costs for Treatment	$ 57,484
Additional Unit Costs (before amortization)	$ 522 per acre-foot
	$ 1.60 per 1,000 gallons
Additional Unit Costs (after amortization)	$ 147 per acre-foot
	$ 0.45 per 1,000 gallons

Environmental Issues Associated with Advanced Treatment Alternatives

The City of Eden's wastewater treatment plant has a no-discharge land application permit. Radium concentrations in the city's effluent may be slightly higher after implementation of drinking water treatment. The long-term impacts of land application of naturally occurring radionuclides are unknown.

Agricultural and Rural Issues Associated with Advanced Treatment Alternatives

The costs of constructing a water treatment plant would present a significant financial burden for this small rural community, potentially reducing funds available for financial, educational, medical, and public safety services and needed agricultural products and supplies. The local agricultural economy relies on these services. Without these services, agriculture may experience increased costs and loss of services that contribute to its overall well-being and safety.

Other Natural Resource Issues Associated with Advanced Treatment Alternatives

None identified.

Significant Issues Affecting Feasibility of Advanced Treatment Alternatives

The primary issue affecting feasibility of advanced treatment systems is the large-scale investment required to construct, operate and maintain a water treatment plant. As a small community, the City of Eden has limited resources available for infrastructure improvements. Also, installation of a water treatment plant could cause complications for Eden's existing wastewater treatment facility by increasing the wastewater volumes (RO) or by changing the character of the wastewater (CAX). In either case, this could result in additional costs to the city if the wastewater plant requires upgrading.

The increased costs to customers associated with advanced treatment may result in a decrease in water sales, potentially leading to financial difficulties for the city's water system.

Other Water Management Strategies Directly Affected by Advanced Treatment Alternatives

If the City of Eden continues to use water from its shallow wells, TCEQ will require filtration of that water. An RO plant could be expanded to treat water from the shallow wells.

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.[28]

Quantity, Reliability and Cost of Specialty Media Systems

WRT has provided a proposal to Richland SUD to treat water at a cost of $0.85 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.[29] 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 4.3-69.

Table 4.3-69
Specialty Media Treatment System for Richland SUD

Supply from Strategy	113 acre-feet per year
Total Capital Costs	$60,000
Annual Costs for Treatment	$70,000
Unit Costs to be added to Water Rates	$619 per acre-foot
	$1.90 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 $26,000, or about $18 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 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.[30] The POE/POU strategy has several pitfalls. The most obvious obstacle to a POU/POE strategy is the private property access required for a WUG 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.[31]

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 National Rural Water Association (NRWA) estimates the base case POU reverse osmosis scenario at $16 per month per home.[32] However, this low-cost scenario includes customer maintenance of systems, which is not allowed under current EPA regulations. The NRWA estimate translates to $63,000 per year for the Richland SUD system to implement a POU option, even if EPA regulations were made more flexible. The uncertainties surrounding maintenance and testing requirements and the liabilities associated with modifying customers' interior plumbing, as well as the access issues, prevent POU RO from being considered a recommended strategy. POE CAX systems can be placed outside the customers' home, allowing for easier access, but the POE costs are even more uncertain than POU because installation requirements vary significantly and operational costs are more dependent on raw water quality. Nevertheless, POE is inherently more expensive than POU because the entire household water supply is treated with POE.

Even for the very small communities of Melvin and Live Oak Hills, POE/POU systems do not prove to be a feasible strategy. POE/POU is not a cost-effective option for Melvin because the city has so many connections relative to the amount of water supplied. Melvin averages only 4,500 gallons per connection per month. Based on the base case NRWA cost projections for POU, the total annual cost for the City of Melvin would be $23,000, or $16 per home. For water suppliers such as Live Oak Hills Subdivision, serving 100 people or less, NWRA estimates $6,400 per year for POU RO. This expense would double the current water costs for Live Oak Hills customers. [22]

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. 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, but the tap is external and is thus 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.[33] 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. A new EPA guidance document is due to be published later this year.
- 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.[34] 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 $30,000 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 4.3-70 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 4.3-70
Bottled Water Costs for City of Eden

Supply from Strategy	1.3 acre-feet per year
Total Capital Costs	$133,100
Annual Costs for Treatment	$26,800
Unit Costs	$19,000 per acre-foot
	$61 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 $10,000 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 4.3-71.

Table 4.3-71
Bottled Water System Costs for Richland SUD, Melvin and Live Oak Hills

Supply from Strategy	0.5 acre-feet per year
Annual Costs	$11, 200
Unit Costs to be added to Water Rates	$22,400 per acre-foot
	$70 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[35]. The Texas Radiation Advisory Board also expressed concern that the EPA rules are unsupported by epidemiological public health data[36]. Additional information may be found in Appendix 4J.

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 would 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 4.3-72. Table 4.3-74 provides a summary of the issues associated with each type of strategy.

Table 4.3-72
Strategy Evaluation Matrix for Hickory Aquifer Users

Strategy	Eden	Richland SUD	Melvin	Live Oak Hills
Cation Exchange (CAX)	X			
Reverse Osmosis (RO)	X			
Specialized Media (e.g. WRT)		X	X	
POE/POU (CAX)		X	X	X
Bottled Water – Central Location	X	X	X	X
No Action	X	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. 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 4.3-73 summarizes the costs of the recommended strategies for each Hickory aquifer user.

Table 4.3-73
Costs of Recommended Strategies for Hickory Aquifer Users

City of Eden

Strategy	Capital Costs	2010	2020	2030	2040	2050	2060
Hickory well replacement	$1,366,000	$258,700	$258,700	$159,500	$159,500	$159,500	$159,500
Bottled water system	$133,320	$26,874	$26,874	$8,760	$8,760	$8,760	$8,760
Total	*$1,499,320*	*$285,574*	*$285,574*	*$168,260*	*$168,260*	*$168,260*	*$168,260*

Richland SUD

Strategy	Capital Costs*	2010	2020	2030	2040	2050	2060
Bottled water system	$2,000	$8,000	$8,000	$8,000	$8,000	$8,000	$8,000
Low Radium well	$1,291,720	$172,191	$172,191	$59,573	$59,573	$59,573	$59,573
Total	*$1,293,720*	*$180,191*	*$180,191*	*$67,573*	*$67,573*	*$67,573*	*$67,573*

City of Melvin

Strategy	Capital Costs*	2010	2020	2030	2040	2050	2060
Bottled water system	$0	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000
Total	*$0*	*$2,000*	*$2,000*	*$2,000*	*$2,000*	*$2,000*	*$2,000*

Live Oak Hills Subdivision

Strategy	Capital Costs*	2010	2020	2030	2040	2050	2060
Bottled water system	$0	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200
Total	*$0*	*$1,200*	*$1,200*	*$1,200*	*$1,200*	*$1,200*	*$1,200*

* Capital costs are assigned to Richland SUD for the purposes of this plan. Actual costs will be shared by program participants.

Table 4.3-74
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 re: 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 seven counties showing manufacturing needs over the planning period: Coleman, Ector, Howard, Kimble, McCulloch, Runnels and Tom Green Counties. Manufacturing needs in Coleman, Ector, Howard, McCulloch, Runnels and Tom Green Counties are associated with needs for the cities of Coleman, Odessa, Big Spring, Brady, Ballinger and San Angelo, respectively, and will be met by strategies developed for these cities. Needs for the cities of Coleman and Brady 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 also found in Section 4.8.3. Only manufacturing needs in Kimble County cannot be met with a municipal strategy and requires a stand-alone analysis.

4.4.1 Kimble County

Kimble County has three of the largest cedar processing operations in the world[37]. These operations account for most of the manufacturing water in Kimble County. According to data from the Texas Water Development Board (TWDB), an average of 433 acre-feet of surface water and 2 acre-feet of groundwater were used for manufacturing purposes in Kimble County between 1995 and 2000, the most recent years for which data are available.

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. Based on this evidence, it appears that at least part of the historical reported surface water use may be recirculated surface water. Both of these water rights have no reliable supply according to the Colorado WAM.

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*	City of 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	183	315	607	748	848	915	Odessa sales
Reuse	2,500	2,500	2,500	2,500	2,500	2,500	Odessa reuse
Edwards-Trinity Plateau	16	17	18	19	19	20	
Total Supply	*2,699*	*2,832*	*3,125*	*3,267*	*3,367*	*3,435*	
Demand	*2,759*	*2,963*	*3,125*	*3,267*	*3,376*	*3,491*	
Surplus (Need)	*(60)*	*(131)*	*0*	*0*	*(9)*	*(56)*	
Howard County							
CRMWD system	750	745	1,099	1,161	1,214	1,272	Big Spring sales
Edwards-Trinity Plateau	288	288	288	288	288	288	
Ogallala	461	461	461	461	461	461	
Total Supply	1,499	1,494	1,848	1,910	1,963	2,021	
Demand	1,648	1,648	1,648	1,648	1,648	1,648	
Surplus (Need)	(149)	(154)	200	262	315	373	
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)	
McCulloch County							
Hickory	719	804	879	950	1,012	1,108	
Brady Creek Lake	0	0	0	0	0	0	Brady sales, no supply in WAM
Total Supply	719	804	879	950	1,012	1,108	
Demand	844	929	1,004	1,075	1,137	1,233	
Surplus (Need)	(125)	(125)	(125)	(125)	(125)	(125)	
Runnels County							
Lake Ballinger	0	0	0	0	0	0	City of Ballinger sales, no supply in WAM
Lake Winters	0	0	0	0	0	0	City of 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)	

Table 4.4-1: Manufacturing Needs in Region F (continued)

Source	2010	2020	2030	2040	2050	2060	Comments
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 Supply	4,920	5,133	5,855	6,130	6,345	6,567	
Total Demand	8,248	8,881	9,419	9,929	10,361	10,899	
Total Need	(3,328)	(3,748)	(3,564)	(3,799)	(4,016)	(4,332	

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

These two manufacturing water rights were not included in the larger subordination analysis associated with the major water rights in the Colorado Basin. 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. For the purposes of this plan, it will be assumed that these costs will be $200 per acre-foot (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 $670 per acre-foot ($2.06/1,000 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 (2002 Prices)	$ 5,676,600
Annual Costs	$ 670,000
Unit costs (before amortization)	$ 670 per acre-foot
	$ 2.06 per 1,000 gallons
Unit Costs (after amortization)	$ 175 per acre-foot
	$ 0.54 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 are 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. If these supplies are not sufficient, the Region F Water Planning Group considers drilling of water wells by manufacturing interests in Kimble County to meet regulatory requirements for consistency with this plan.

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 30,000 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 Mitchell and Ector Counties.

Table 4.5-1 compares region-wide demands to available existing supplies. In areas where there are insufficient supplies, steam-electric power generation has been limited to 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[38]. 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, and that additional capacity can be met using alternative technologies that require significantly less water. 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;

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
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)*	
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*	
Supply	Ogallala aquifer	Andrews	6,375	6,375	6,375	6,375	6,375	6,375	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)			*0*	*(2,750)*	*(4,293)*	*(6,174)*	*(8,467)*	*(11,262)*	
Supply	Champion/Colorado City System	Mitchell	0	0	0	0	0	0	No supply in priority order WAM
Demand	TXU Morgan Creek	Mitchell	9,100	7,621	8,910	10,481	12,396	14,730	
Surplus (Need)			*(9,100)*	*(7,621)*	*(8,910)*	*(10,481)*	*(12,396)*	*(14,730)*	
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)*	
Supply	Cenozoic Pecos Alluvium	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 Supply		*12,789*	*12,098*	*12,812*	*13,682*	*14,064*	*14,064*	
	Total Demand		*22,215*	*22,769*	*26,620*	*31,312*	*37,033*	*44,008*	
	Total Surplus (Need)		*(9,426)*	*(10,671)*	*(13,808)*	*(17,630)*	*(22,969)*	*(29,944)*	

- 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.

Region F, in consultation with Andrew Valencia, the power generation representative on the Region F Water Planning Group, has identified two strategies which are the most likely strategies to meet future power generation needs within Region F:

- Subordination of downstream water rights, and
- Use of alternative cooling technologies such as Air-Cooled Condenser (ACC) technology on new power plant projects.

Other strategies may be employed in Region F, including the voluntary redistribution of existing water supplies. However, the actual strategies are largely a business decision on the part of the power industry. The uncertainty associated with these strategies makes it difficult to perform a meaningful analysis. Therefore 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 TXU 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.

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.

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.

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 project the most 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 24,306 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 $37.5 million in 2010, increasing to $600 million by 2060.

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 the water management strategies for steam-electric power generation, which include subordination of downstream water rights and alternative cooling technology. Because it significantly reduces water usage, ACC cooling technology on future generation projects may be considered a water conservation strategy.

Table 4.5-3
Needed Generation Capacity on Incremental Cost of ACC Technology

	2010	2020	2030	2040	2050	2060
Steam Electric Needs (Ac-Ft)	4,077	5,524	8,533	12,210	17,468	24,306
Equivalent needs (GWh)	2,315	3,245	5,244	8,008	12,216	18,071
MW Capacity Needed (MW)	386	541	874	1,335	2,036	3,012
Cumulative Capacity Needed (MW)	386	927	1,801	3,135	5,171	8,183
Incremental Capacity Installed (MW)	500	500	1,000	1,000	2, 000	3,000
Total Capacity Installed (MW)	500	1,000	2,000	3,000	5,000	8,000
Capacity Factor of New Capacity (%)	53	74	60	91	70	69
Incremental cost of ACC (million $)	$37.5	$37.5	$75.0	$75.0	$150.0	$225.0
Total Capital Cost *(million $)*	*$37.5*	*$75.0*	*$150.0*	*$225.0*	*$375.0*	*$600.0*
Debt Service (million $)	$3.3	$6.5	$9.8	$13.1	$19.6	$32.7
O&M (million $) *	$0.9	$1.9	$3.8	$5.6	$9.4	$15.0
Total Annual Cost *(million $)*	*$4.2*	*$8.4*	*$13.6*	*$18.7*	*$29.0*	*$47.7*
Cost/Ac-Ft	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
Cost/1,000 Gal	$3.07	$3.07	$3.07	$3.07	$3.07	$3.07

* 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	6,375	6,375	6,375	6,375	6,375	6,375
Demand	Panda Odessa-Ector	Ector	6,375	9,125	10,668	12,549	14,842	17,637
Surplus (Need)			0	(2,750)	(4,293)	(6,174)	(8,467)	(11,262)
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	9,100	7,621	8,910	10,481	12,396	14,730
Surplus (Need)			(4,077)	(2,774)	(4,240)	(5,988)	(8,079)	(10,590)
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	Cenozoic Pecos Alluvium	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			*19,143*	*18,213*	*18,792*	*19,535*	*19,803*	*19,702*
Total Demand			*22,215*	*22,769*	*26,620*	*31,312*	*37,033*	*44,008*
Total Surplus (Need)			*(3,072)*	*(4,556)*	*(7,828)*	*(11,777)*	*(17,230)*	*(24,306)*
Alternative Generation Technology			4,077	5,524	8,533	12,210	17,468	24,306
Total Surplus (Need) with alternative generation			*1,005*	*968*	*705*	*433*	*238*	*0*

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.

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 in the 2001 *Region F Regional Water Plan*[39].

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	14,094	14,064	13,926	12,536	12,333	12,165
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	36,097	35,245	34,387	33,525	32,664	31,847
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	*180,947*	*178,018*	*175,993*	*172,535*	*170,058*	*167,339*

Six alternative irrigation systems were evaluated based on current 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[40].

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 221,276 irrigated acres within Region F in 2002[41]. Cotton was the most significant irrigated crop with 41 percent of the irrigated acreage. Wheat and hay-pasture represented 14 percent and 9 percent, respectively, of the irrigated acreage. Seven counties (Andrews, Glasscock, Martin, Midland, Pecos, Reeves, and Tom Green) account for 70 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. However, the most recent data available on the types of irrigation equipment is the 1997 data developed for the previous Region F plan. Since up-to-date distribution of irrigation technologies was not available, the current distribution was estimated based on the 1997 data. In some counties new crop types were irrigated in 2002 which were not irrigated in 1997. In these cases, a representative distribution of irrigation equipment for the same crop in other counties was assumed to apply to that county.

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

Table 4.6-2
Irrigated Acreage by Crop Type
(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	7,112	94	356	185	500	561	32	236	5,600	150	0	0	5,500	*20,326*
Borden	1,600	0	450	0	32	0	0	0	0	67	0	0	0	*2,149*
Brown	0	37	14	0	586	1,963	61	0	418	2,400	0	1,667	496	*7,642*
Coke	157	0	134	10	99	50	0	0	0	0	0	0	114	*564*
Coleman	0	0	188	0	0	0	0	0	0	0	0	0	0	*188*
Concho	1,600	13	1,777	0	570	215	0	0	0	0	0	86	217	*4,478*
Crane	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
Crockett	0	0	76	10	0	10	0	0	0	0	0	0	0	*96*
Ector	0	14	450	240	310	315	0	0	0	275	0	0	28	*1,632*
Glasscock	23,797	43	450	213	872	321	43	54	0	405	0	2	398	*26,598*
Howard	1,255	0	358	215	276	162	0	0	0	45	0	0	4	*2,315*
Irion	0	50	200	36	495	371	0	0	0	37	0	0	56	*1,245*
Kimble	0	0	0	0	76	711	0	0	0	135	0	0	0	*922*
Loving	0	100	0	0	0	0	0	0	0	0	0	0	0	*100*
McCulloch	0	0	250	0	179	772	10	0	616	6	20	0	405	*2,258*
Martin	9,689	155	1,567	774	1,169	674	0	0	312	10	0	0	152	*14,502*
Mason	389	14	1,356	13	1,377	882	95	0	1,248	23	20	191	1,002	*6,610*
Menard	0	0	97	65	1,285	1,068	0	0	98	363	212	0	0	*3,188*
Midland	5,478	297	1,386	984	1,086	4,752	50	0	0	543	9	575	794	*15,954*
Mitchell	3,000	0	1,265	83	261	44	40	0	0	16	0	0	128	*4,837*
Pecos	5,701	300	3,300	5,188	984	2,301	1,147	435	0	2,601	1,040	0	851	*23,848*
Reagan	8,531	423	762	52	145	9	21	2	0	109	0	0	662	*10,716*
Reeves	2,000	2,900	6,037	4,335	1,189	1,145	1,288	637	0	555	0	81	1,911	*22,078*
Runnels	2,103	277	634	0	140	281	0	4	0	199	0	8	0	*3,646*
Schleicher	0	0	175	0	343	3	0	0	0	204	0	0	95	*820*
Scurry	841	82	300	181	1,062	893	30	0	0	0	0	7	94	*3,490*
Sterling	0	0	31	0	539	0	0	0	0	41	0	0	36	*647*
Sutton	0	0	513	0	100	84	0	0	0	154	0	0	0	*851*
Tom Green	12,900	2,100	7,990	412	1,480	995	556	22	0	496	3	2,819	1,047	*30,820*
Upton	4,703	247	772	0	160	94	5	0	0	135	0	0	185	*6,301*
Ward	0	70	0	80	0	1,152	0	0	0	0	0	0	124	*1,426*
Winkler	0	0	0	0	0	42	125	500	0	0	0	0	362	*1,029*
Crop Totals	*90,856*	*7,216*	*30,888*	*13,076*	*15,315*	*19,870*	*3,503*	*1,890*	*8,292*	*8,969*	*1,304*	*5,436*	*14,661*	*221,276*

Irrigated crops as reported by the TWDB in 2002. Acreages and/or crop types may have changed since 2002, 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 based on distribution of equipment in 1997.

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.

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

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*

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 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 2000 Need	
	2010	2020	2030-2060	2020	2030-2060
Andrews	14,094	2,727	5,455	19.4%	38.7%
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	36	73	2.8%	5.6%
Kimble		74	147		
Loving		0	0		
McCulloch		197	394		
Martin	788	1,751	3,502	100.0%	100.0%
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	36,097	5,824	11,648	16.1%	32.3%
Runnels	1,358	0	0	0.0%	0.0%
Schleicher		107	214		
Scurry		572	1,143		
Sterling		44	89		
Sutton		142	284		
Tom Green	47,090	5,690	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		194	389		
Total	*186,543*	*36,039*	*72,245*	*19.3%*	*38.7%*

Table 4.6-6
Revised Irrigation Needs Incorporating Advanced Irrigation Technologies

County	Projected Irrigation Need (ac-ft/yr)						Reduction in Irrigated Acres Needed to Prevent a Shortage* (Acres)					
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Andrews	14,094	11,337	8,471	7,081	6,878	6,710	10,194	8,200	6,128	5,122	4,975	4,854
Borden	1,847	1,614	1,379	1,375	1,369	1,366	1,736	1,517	1,296	1,292	1,287	1,284
Brown	3,006	2,889	2,761	2,720	2,683	2,656	2,712	2,607	2,491	2,454	2,420	2,396
Coke	363	363	361	360	360	360	228	228	227	226	226	226
Coleman	1,348	1,348	1,348	1,348	1,348	1,348	899	899	899	899	899	899
Glasscock	27,784	23,750	19,710	19,290	18,869	18,460	28,072	23,996	19,915	19,490	19,065	18,652
Irion	1,302	1,205	1,108	1,047	987	927	996	922	848	801	755	710
Martin	788						698					
Menard	2,441	2,398	2,356	2,337	2,315	2,296	2,225	2,186	2,148	2,131	2,110	2,093
Midland	16,233	14,559	12,748	12,654	12,512	12,393	10,720	9,614	8,419	8,357	8,263	8,184
Reagan	10,997	8,639	6,180	5,623	5,040	4,457	7,932	6,231	4,458	4,056	3,635	3,215
Reeves	36,097	29,421	22,739	21,877	21,016	20,199	12,524	10,208	7,889	7,590	7,292	7,008
Runnels	1,358	1,344	1,325	1,306	1,287	1,268	1,419	1,404	1,385	1,365	1,345	1,325
Tom Green	47,090	41,141	35,028	34,773	34,514	34,259	34,770	30,377	25,863	25,675	25,484	25,295
Upton	10,672	9,531	8,383	8,152	7,922	7,699	8,356	7,463	6,564	6,383	6,203	6,028
Ward	5,527	4,188	4,151	4,969	5,335	5,318	2,392	1,813	1,797	2,151	2,309	2,302
Totals	*180,947*	*152,540*	*124,869*	*121,411*	*118,934*	*116,215*	*125,874*	*106,614*	*87,508*	*84,890*	*83,167*	*81,369*

* 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 $466/acre, a surge flow system $486/acre, MESA system $733/acre, LESA system $770/acre, LEPA system $784/acre and drip system $1,133/acre.

The costs of implementing advanced irrigation technologies in Region F are presented in Appendix 4G. The additional investment for converting a furrow irrigation system to LEPA and drip is $320 and $670 per acre respectively; from Surge to LEPA and drip is $300 and $650 per acre respectively; from MESA to LEPA and from LESA to LEPA is $50 and $15 per acre respectively. The corresponding annualized cost per acre for each strategy amortized over 30 years at 6 percent interest is $23.25, $48.67, $21.79, $47.22, $3.63 and $1.09, 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[42]. 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. The assumptions used in the Colorado WAM are discussed in more detail in Appendix 3C.

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. For the purposes of this plan, costs will be set at $200 per acre-foot (see Section 4.2.3).

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*

4.8 Strategies for Wholesale Water Providers

Strategies have been developed for the Colorado River Municipal Water District, the Brown County Water Improvement District No. 1, 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. Supplies from the Colorado WAM are discussed in Appendix 3C.

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 (Cenozoic Pecos Alluvium) *	5,200	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	34,108	35,599	36,744	37,912	39,358	41,064
Others	59,928	61,264	42,637	42,255	41,106	40,732
Total	*94,036*	*96,863*	*79,381*	*80,167*	*80,464*	*81,796*
Surplus (Need)	*(19,551)*	*(28,928)*	*(12,796)*	*(14,932)*	*(16,579)*	*(19,261)*

* The contract with University Lands for the Ward County Well Field expires in 2019.

- Voluntary redistribution
  - Lake Alan Henry
  - Roberts County groundwater
  - Renew contract with University Lands
  - New contracts to provide water
- New groundwater
  - Winkler County Well Field
  - Groundwater from southwestern Pecos County
- Desalination – Capitan Reef Complex

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 Ivie Reservoir so that it can impound water at a 1926 priority date as the Highland Lakes. As a result, Thomas and Spence have little or no yield, while Lake Ivie has a safe yield of over 66,000 acre-feet. The assumptions used in the Colorado WAM are discussed in more detail in Appendix 3C.

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. Water supplies in the Colorado WAM are discussed in separate memoranda.

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*[43].

Snyder Reuse Project

The City of Snyder is a CRMWD member city and obtains all of its water from Lake J.B. Thomas. During times of drought and low water levels in the lake CRMWD must move 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 4.8-4 is a summary of the costs of the project. Capital costs are estimated at $7.5 million, with a unit cost of $3.61 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 (2002 Prices)	$ 7,499,000
Annual Costs	$ 854,000
Unit costs (before amortization)	$ 1,176 per acre-foot
	$ 3.61 per 1,000 gallons
Unit Costs (after amortization)	$ 275 per acre-foot
	$ 0.85 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 extend, 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. Also, current TCEQ rules for use of reclaimed water do not address its use for supplementing municipal water supplies. Changes to TCEQ rules may change the feasibility of this strategy.

Other Water Management Strategies Directly Affected by Snyder Reuse Project

Voluntary redistribution of water from Lake Alan Henry.

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. 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 $7.6 million, with unit costs for the reclaimed water at $1.92 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 (2002 Prices)	$ 7,606,000
Annual Costs	$ 1,168,000
Unit costs (before amortization)	$ 630 per acre-foot
	$ 1.93 per 1,000 gallons
Unit Costs (after amortization)	$ 272 per acre-foot
	$ 0.84 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. Current TCEQ rules for use of reclaimed water do not address its use for supplementing municipal water supplies. Changes to TCEQ rules may change the feasibility of this strategy.

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 $82.1 million, with unit costs for the reclaimed water at $3.13 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 (2002 Prices)	$ 82,144,000
Annual Costs	$ 10,013,000
Unit costs (before amortization)	$ 1,022 per acre-foot
	$ 3.14 per 1,000 gallons
Unit Costs (after amortization)	$ 291 per acre-foot
	$ 0.89 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. Also, current TCEQ rules for use of reclaimed water do not address its use for supplementing municipal water supplies. Changes to TCEQ rules may change the feasibility of this strategy.

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 water rights to an undeveloped well field in southern Winkler County. The well field will produce water from the Cenozoic Pecos Alluvium 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.

The proposed 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.

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 (2002 Prices)	$ 39,934,000
Annual Costs	$ 4,987,000
Unit costs (before amortization)	$ 831 per acre-foot
	$ 2.55 per 1,000 gallons
Unit Costs (after amortization)	$ 251 per acre-foot
	$ 0.77 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.

Voluntary Redistribution - Lake Alan Henry

Lake Alan Henry is located on the South Fork of the Double Mountain Fork of the Brazos River in Garza and Kent Counties. Permit 12-4146 (Application 4155), which is owned by the Brazos River Authority, authorizes the storage of 115,937 acre-feet of water and the diversion of

35,000 acre-feet per year for municipal purposes. The permit also authorizes the reuse of 21,000 acre-feet per year of the 35,000 acre-feet annual diversion for irrigation in Lubbock and Lynn Counties. The Llano Estacado Regional Water Planning Group (Region O) estimates the current yield of Lake Alan Henry to be 29, 900 acre-feet per year. (This yield is larger than the firm yield of 9,559 acre-feet per year reported in the Brazos WAM report[44]. It is likely that the Region O yield assumes the subordination of downstream senior water rights.) The reservoir was originally intended as a water supply for the City of Lubbock. Lubbock has not developed the reservoir as a source of supply. Lubbock has sufficient groundwater supplies to meet its projected needs for many years[45]. Therefore Lake Alan Henry may be available for other uses.

One way the water from Lake Alan Henry could be used is to supply the City of Snyder, a CRMWD member city located in Scurry County approximately 25 miles from the reservoir. Currently, the City of Snyder gets the majority of its water from Lake Thomas and local groundwater wells. In order to obtain water from the rest of the CRMWD system, water must be passed through Lake Thomas. Water from Lake Alan Henry would give CRMWD another supply of water for Scurry County, as well as allow more use of Lake Thomas water in the CRMWD system.

Quantity, Reliability and Cost of Water from Lake Alan Henry

The conceptual strategy developed for this plan is for a 25-mile pipeline with a capacity of 20 MGD. Because the amount of water used in this strategy is potentially more than the yield of the reservoir unless downstream senior water rights are subordinated to the reservoir, the reliability of the supply is medium. Table 4.8-8 summarizes the costs for the strategy based on an annual supply of 11,210 acre-feet per year.

Table 4.8-7
Estimated Costs Lake Alan Henry to Snyder

Supply from Strategy	11,210 acre-feet per year
Total Capital Costs (2002 Prices)	$ 30,384,000
Annual Costs	$ 10,059,000
Unit costs (before amortization)	$ 897 per acre-foot
	$ 2.75 per 1,000 gallons
Unit Costs (after amortization)	$ 661 per acre-foot
	$ 2.03 per 1,000 gallons

Environmental Issues Associated with Water from Lake Alan Henry

Lake Alan Henry is an existing source of water that is largely unused for any purpose. Changes to reservoir elevations and spills are expected with implementation of this strategy. Therefore impacts on downstream flows and habitats may need to be evaluated if this strategy is implemented. Although spills are rare from West Texas reservoirs, Lake Alan Henry has not been used for water supply in the past. It is possible that spills and over-bank flows may be somewhat less frequent with this strategy. This strategy will have no impact on bays and estuaries.

Agricultural and Rural Issues Associated with Water from Lake Alan Henry

None identified.

Other Natural Resource Issues Associated with Water from Lake Alan Henry

None identified.

Significant Issues Affecting Feasibility of Water from Lake Alan Henry

Lake Alan Henry has a relatively junior priority date of October 5, 1981. According to the Brazos WAM report, the yield of the reservoir is 9,559 acre-feet per year assuming full exercise of all downstream senior water rights. A subordination agreement may be necessary to ensure full supply from the reservoir.

The assumed cost of purchasing raw water from this reservoir is assumed to be $1.80 per 1,000 gallons (about $587 per acre-foot). This assumption greatly increases the unit cost of water.

Obtaining water from Lake Alan Henry would require an interbasin transfer authorization. However, because Scurry County is partially within the Brazos Basin, the transfer would retain its original priority date and be exempt from most of the provisions in §11.085 of the Texas Water Code[46] as long as the water was used only in Scurry County. The provisions of §11.085 would apply if the water was used in other parts of the CRMWD system.

The 2001 Llano Estacado *Regional Water Plan* assumes that water from Lake Alan Henry will be used to meet the long-term needs of the area. It is possible that this source would only be a temporary supply for the City of Snyder, requiring other water resources to be developed to meet the long-term needs of the city.

Other Water Management Strategies Directly Affected by Water from Lake Alan Henry

Snyder Reuse.

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 4.8-8 shows the estimated costs associated with this strategy.

Table 4.8-8
Costs for Water from Southwestern Pecos County

Supply from Strategy	15,000 acre-feet per year
Total Capital Costs (2002 Prices)	$ 150,150,000
Annual Costs	$ 18,726,000
Unit costs (before amortization)	$ 1,248 per acre-foot
	$ 3.83 per 1,000 gallons
Unit Costs (after amortization)	$ 376 per acre-foot
	$ 1.15 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[47], 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[48]. Delivery of water from this source requires construction of over 300 miles of pipeline.

Quantity, Reliability and Cost of Water from Roberts County

According to previous studies, there is a substantial amount of water available in Roberts County and this supply is very reliable[49]. 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 4.8-9
Costs for Water from Roberts County

Supply from Strategy	25,000 acre-feet per year
Total Capital Costs (2002 Prices)	$ 583,627,000
Annual Costs	$ 52,659,000
Unit costs (before amortization)	$ 2,106 per acre-foot
	$ 6.46 per 1,000 gallons
Unit Costs (after amortization)	$ 410 per acre-foot
	$ 1.26 per 1,000 gallons

Environmental Issues Associated with Water from Roberts County

There is some concern that large-scale groundwater use from Roberts County 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 is currently being used for local purposes. There is no 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 Roberts County. 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 4.8-10, Table 4.8-11 and Table 4.8-12 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 4.8-10
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			$46,943	$51,385	$50,089	$48,426	$46,643	$45,378
Cost per Acre-Foot [c]			$671	$334	$262	$236	$212	$194
Cost per 1,000 Gal [c]			$2.06	$1.02	$0.80	$0.72	$0.65	$0.60

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 4.8-11
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			$108,944	$112,960	$109,009	$104,321	$99,734	$96,894
Cost per Acre-Foot [c]			$452	$187	$161	$149	$138	$129
Cost per 1,000 Gal [c]			$1.39	$0.57	$0.49	$0.46	$0.42	$0.39

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 4.8-12
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			$400,979	$416,656	$418,272	$419,543	$420,351	$428,145
Cost per Acre-Foot[c]			$728	$347	$272	$245	$219	$199
Cost per 1,000 Gal[c]			$2.23	$1.07	$0.84	$0.75	$0.67	$0.61

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.

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 April 2005 Draft CRMWD Drought Contingency Plan, 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.

Renewals of existing contracts for the same quantity of water are not evaluated for impacts.

Voluntary Redistribution – New Contracts to Provide Water

The planning process has identified several new CRMWD contracts to provide water, which are shown in Table 4.8-13. All of these contracts are the result of expiration of existing customer contracts. The amounts shown in Table 4.8-13 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 4.8-13
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					600	600	
Ballinger					165	219	Set to demands
Total	*392*	*422*	*10,429*	*10,230*	*10,780*	*10,612*	

Desalination – Capitan Reef Complex

The Capitan Reef aquifer has been identified as a potential source of brackish groundwater for CRMWD. 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. Brackish water production from the Dockum or Cenozoic Pecos Alluvium aquifer could also be developed as an alternative 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 4.8-14 summarized the expected costs for the project.

Table 4.8-14
Capitan Reef Brackish Water Desalination Project

Supply from Strategy	9,500 acre-feet per year
Total Capital Costs (2002 Prices)	$ 86,183,530
Annual Costs	$ 12,352,556
Unit costs (before amortization)	$ 1,300 per acre-foot
	$ 3.99 per 1,000 gallons
Unit Costs (after amortization)	$ 509 per acre-foot
	$ 1.56 per 1,000 gallons

Environmental Issues Associated with Capitan Reef 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 Capitan Reef 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 Capitan Reef 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 Capitan Reef Desalination Project

None identified.

Recommended Strategies for CRMWD

Recommended strategies for CRMWD include:

- Subordination of downstream senior water rights
- New groundwater – Winkler Well Field
- Reuse – CRMWD Reclamation Project
- Voluntary redistribution – water from Lake Alan Henry
- Renew contract with University Lands
- Desalination – Capitan Reef Complex
- Water conservation

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	0	6,000	6,000	6,000
CRMWD Reclamation Project	0	12,380	12,380	12,380	12,380	12,380
Lake Alan Henry to Snyder	0	3,360	3,360	3,360	3,360	3,360
Renew Contract with University Lands	0	5,200	5,200	5,200	5,200	5,200
Desalination			9,500	9,500	9,500	9,500
Total Supplies	*122,512*	*136,009*	*143,265*	*147,022*	*144,778*	*142,535*
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	94,036	96,863	79,381	80,167	80,464	81,796
New Contracts	392	422	10,429	10,230	10,780	10,612
Total Demand	*94,428*	*97,285*	*89,810*	*90,397*	*91,244*	*92,408*
Surplus (Need) without Conservation	*28,084*	*38,724*	*53,455*	*56,625*	*53,534*	*50,127*
Surplus (Need) with Conservation	*28,946*	*40,681*	*55,858*	*59,243*	*56,399*	*53,264*

a Savings for member cities only. Does not include plumbing code savings, which are already included in the water demand projections.

Table 4.8-16
Capital Costs for Recommended Strategies *

Strategy	**Capital Costs**	**Annual Costs**					
		2010	**2020**	**2030**	**2040**	**2050**	**2060**
Winkler County Well Field	$ 39,934,000	$-	$-	$-	$ 4,987,000	$ 4,987,000	$ 1,505,000
CRMWD Reclamation Project	$ 97,249,000	$-	$12,035,000	$12,035,000	$ 3,556,000	$ 3,556,000	$ 3,556,000
Lake Alan Henry to Snyder	$30,384,000	$0	$10,059,000	$10,059,000	$7,410,000	$7,410,000	$7,410,000
Subordination	$9,605,400	$837,443	$837,443	$0	$0	$0	$0
Desalination	$86,183,530	$0	$12,352,556	$12,352,556	$4,838,556	$4,838,556	$4,838,556
Total	*$263,355,930*	*$837,443*	*$35,283,999*	*$34,446,556*	*$20,791,116*	*$20,791,116*	*$17,309,116*

* Water conservation would be implemented by individual member cities and would not be a CRMWD cost

4.8.2 Brown County Water Improvement District Number 1

The Brown County Water Improvement District Number 1 (BCWID) owns and operates Lake Brownwood and a water treatment plant located in the City of Brownwood. Lake Brownwood is one of the few surface water sources in Region F with a surplus after meeting all expected local needs. Because of its relatively senior priority date of 1925, the reservoir is able to provide its permitted diversion of 29,712 acre-feet with and without subordination. The planning process has identified Lake Brownwood as a potential source to meet needs in Runnels and Coke Counties.

Regional System from Lake Brownwood to Runnels and Coke Counties

A conceptual design for a regional system providing raw water to the cities of Winters, Ballinger, Bronte and Robert Lee was developed to evaluate the potential for water supply from this source. The pipeline would consist of 44 miles of 20-inch pipe from Lake Brownwood to the City of Winters, 18 miles of 18-inch pipe from Winters to an outlet on Valley Creek, 12 miles of 12-inch pipe to the City of Bronte, and 10 miles of 10-inch pipe from Bronte to the City of Robert Lee. Water for the City of Ballinger would be released down Valley Creek to Lake Ballinger. Figure 4.8-1 is a schematic of the proposed project.

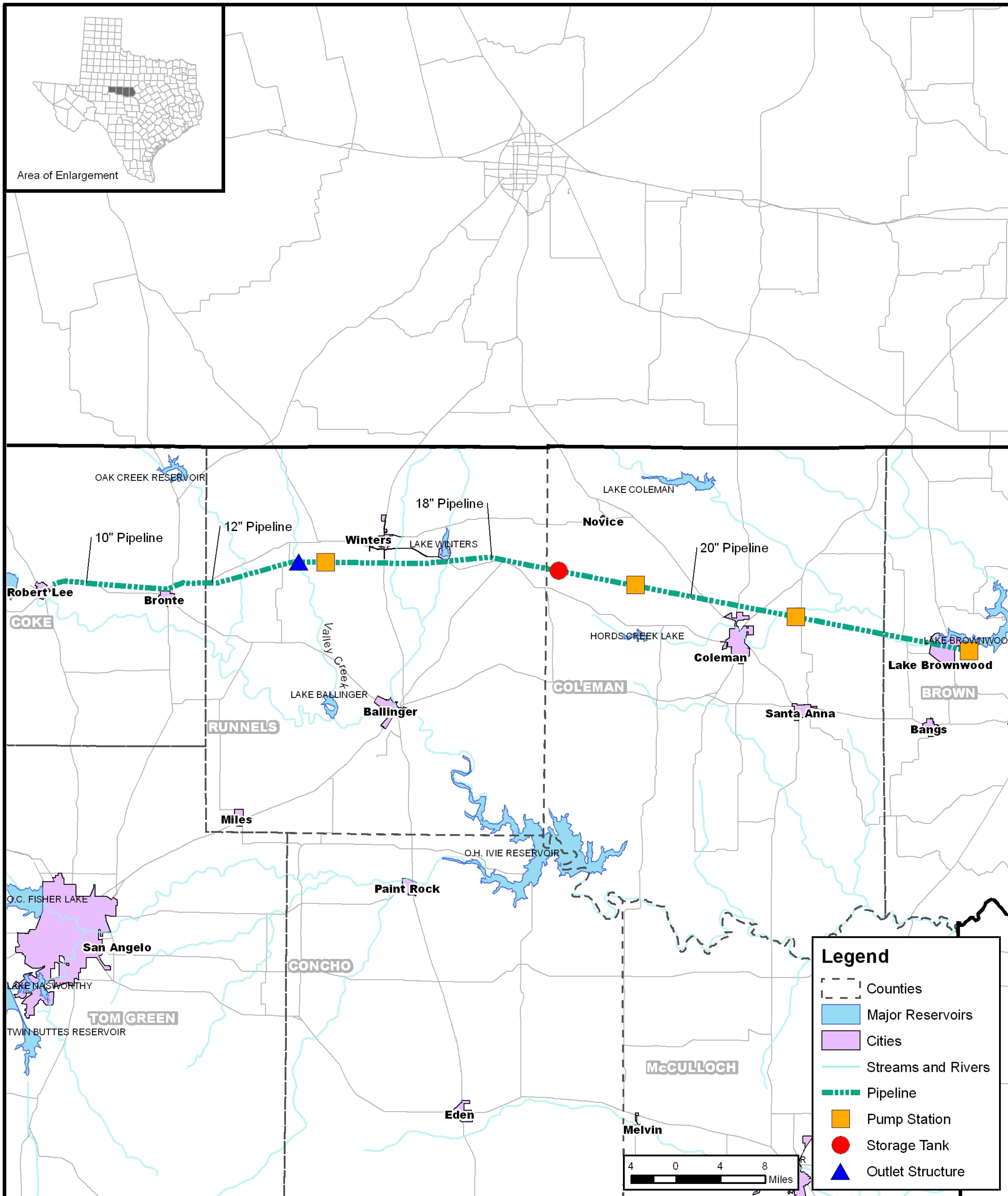
Alternative variations of this project could include delivery to different combinations of the four cities or delivery of treated water from the BCWID treatment plant in Brownwood.

Quantity, Reliability and Cost

The conceptual design could deliver up to 2,800 acre-feet of raw water to Runnels and Coke Counties. Lake Brownwood is considered to be very reliable. Table 4.8-17 is a summary of the costs for this strategy.

Table 4.8-17
Costs for Regional System from Lake Brownwood

Supply from Strategy	2,800 acre-feet per year
Total Capital Costs	$ 37,362,400
Annual Costs	$ 5,032,000
Unit Costs (before amortization)	$ 1,796 per acre-foot
	$ 5.51 per 1,000 gallons
Unit Costs (after amortization)	$ 633 per acre-foot
	$ 1.94 per 1,000 gallons



Freese and Nichols
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Phone - (817) 735 - 7300

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W E
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Region F

Regional System from Lake Brownwood to Coke and Runnels Counties

FN JOB NO	CMD01311
FILE	Profile 3 Location
DATE	May 20, 2005
SCALE	1:755,145
DESIGNED	GGJ
DRAFTED	GGJ

4.8-1

FIGURE

Environmental Issues

This proposed diversion from Lake Brownwood may slightly impact reservoir storage. Spills may be somewhat less frequent, potentially having a minor impact on downstream flows and over-banking flows. It is assumed that the pipeline could be routed around sensitive environmental areas if needed. There are no expected water quality issues associated with importing Lake Brownwood water into Lake Ballinger. More detailed studies of potential environmental impacts associated with the transmission and storage components of this strategy, including an analysis of potential water quality issues, will be required if this strategy is pursued.

Agricultural and Rural Issues

Although Lake Brownwood is used for agricultural supplies, there are sufficient supplies available in the reservoir to meet irrigation demands and provide water to these cities. The communities supplied by these strategies are rural communities which have been heavily impacted by recent drought and water quality problems. This strategy could alleviate most of those issues. However, the high cost of the project will be a significant burden on the financial resources of these communities.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

The most significant issues affecting the feasibility of this project are sponsorship and financing. It is not clear which entity would be responsible for implementing and obtaining financing for the project. The project is outside of the traditional service area of BCWID. Implementation may require development of a new political subdivision to administer and finance the project. The cost of the project is significant and would be a significant financial strain on the area.

Another significant issue associated with development of this pipeline is the on-going use of water from other sources. The communities that would be served by this project already have water supplies which are used most of the time but may not be sufficient during drought. For this strategy to be cost-effective, water from Lake Brownwood would need to be used much of the time. However, local existing supplies that are less costly to use would likely be used first when they are available.

Other Water Management Strategies Directly Affected

Other strategies for the cities of Ballinger, Winters, Bronte and Robert Lee may be impacted.

Recommended Strategies for BCWID

Although this strategy offers a high-quality, reliable supply, this plan does not recommend implementation of this strategy due to the high cost of the project. Other less expensive alternatives are available for these communities. However, if further studies make these other strategies less attractive, the Region F Water Planning Group would consider supplies from this source to be consistent with this plan.

4.8.3 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.

Since 1998, the city has been hard-hit by a region-wide drought. Twin Buttes Reservoir and O.C. Fisher Reservoir have been at 10 percent capacity or less. Downstream senior irrigation water right holders on the Concho River made priority calls on Twin Buttes Reservoir, obligating the city to pass inflows. During the drought, the city obtained most of its water from Ivie Reservoir. Through water conservation and drought management the city never experienced a shortage during the drought. As a result of the drought, the city convened a citizens group to guide water supply activities and initiated several studies. The results of these studies were not available for inclusion in the 2006 *Region F Water Plan*.

Table 4.8-18 is a comparison of the Region F supply and demand for the City of San Angelo. 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 in areas with limited supplies. According to historical data from the Texas Water Development Board (TWDB), 1,021 acre-feet of water was used for steam-electric generation in Tom Green County in 1999.) The city also supplies treated O.C. Fisher water to the City of Miles through an agreement with UCRA.

Table 4.8-18
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	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comment**
City of San Angelo	20,800	21,418	21,734	21,744	21,907	21,969	
City of Miles	100	100	100	100	100	100	
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	*23,919*	*25,043*	*25,730*	*26,086*	*26,453*	*26,765*	
Surplus (Need)	*(12,203)*	*(13,650)*	*(14,560)*	*(15,140)*	*(15,730)*	*(16,265)*	

Table 4.8-18 contains the Region F supplies for the City of San Angelo based on the Texas Commission on Environmental Quality (TCEQ) Colorado Water Availability Model (WAM)[50]. TWDB requires use of the Colorado WAM Run 3 in regional water planning by TWDB. 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.

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*[51]. 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 – San Angelo regional desalination facility
- New groundwater – development of the McCulloch County well field
- New groundwater – water from southwest Pecos County
- 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 2002, the latest year for which data are available, the per capita water demand was 118 gpcd[52]. 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 and infrastructure improvements to reduce water loss.

Quantity, Reliability and Cost

At the time of this plan the city had not implemented a formal water conservation program. Therefore the default Region F package of water conservation practices was used to evaluate the potential water savings and costs of implementation. Table 4.8-19 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 4I).

Table 4.8-19
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	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	0	1,018	2,482	3,153	3,639	3,904	4,025
Costs								
Annual Costs			$395,818	$304,896	$297,151	$284,442	$271,143	$261,243
Cost per Acre-Foot [d]			$565	*$244*	*$204*	*$187*	*$171*	*$158*
Cost per 1,000 Gal [d]			$1.73	*$0.75*	*$0.63*	*$0.57*	*$0.52*	*$0.48*

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 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.

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.

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 will 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. (Supplies from the Colorado WAM are discussed in Appendix 3C.) 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 4.8-20 is a summary of the impacts of the subordination strategy on supplies for the city.

Table 4.8-20
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*	

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.

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 (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 - Regional Desalination Facility

The Region F Water Planning Group, in association with the City of San Angelo and UCRA, has identified four potential brackish groundwater sources north and west of the city. These sources would produce water from the geologic formations known as the Whitehorse and Pease River Groups. 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.

The desalination facility could potentially provide water for others in the area with water supply needs, specifically Miles, Ballinger, Winters, Bronte and Robert Lee. An associated strategy includes delivery facilities to supply these cities.

Quantity, Reliability and Cost

Geophysical logs from oil wells in the area indicate that there are several favorable water-bearing sands in these formations. However, the amount of water available from the formation and the quality of the water is largely unknown. UCRA and the City of San Angelo have proposed drilling test wells to facilitate evaluation of the formations. 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. The reliability of this source is considered to be medium due to the uncertainty associated with the available water from the source. Table 4.8-21 is a summary of costs for the project.

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 4.8-21
Regional Desalination Facility for San Angelo

5 MGD Capacity	
Supply from Strategy	5,600 acre-feet per year
Total Capital Costs (2002 Prices)	$ 40,590,000
Annual Costs	$ 5,621,000
Unit costs (before amortization)	$ 1,004 per acre-foot
	$ 3.08 per 1,000 gallons
Unit Costs (after amortization)	$ 372 per acre-foot
	$ 1.14 per 1,000 gallons
10 MGD Capacity	
Supply from Strategy	11,200 acre-feet per year
Total Capital Costs (2002 Prices)	$ 69,354,000
Annual Costs	$ 9,969,000
Unit costs (before amortization)	$ 890 per acre-foot
	$ 2.73 per 1,000 gallons
Unit Costs (after amortization)	$ 350 per acre-foot
	$ 1.07 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, delivery of desalination water to Runnels and Coke Counties

Voluntary Redistribution – Delivery to Coke and Runnels County from Proposed Regional Desalination Facility

A strategy associated with the Regional Desalination facility is transmission facilities to users in Coke and Runnels Counties. Three scenarios have been developed for these facilities:

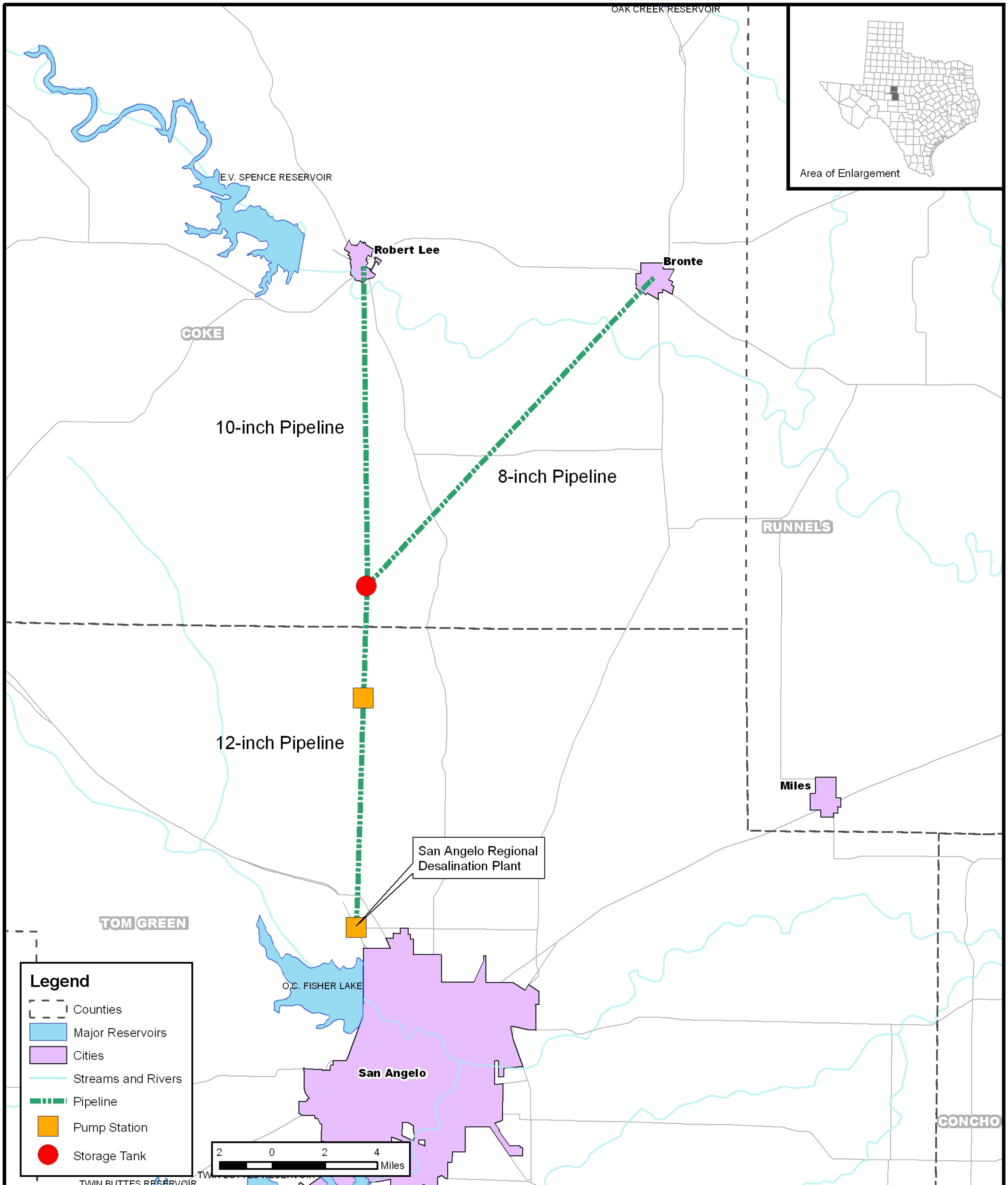
1. *Coke County System* – This scenario includes a 12-inch pipeline and two pump stations that deliver water to a storage tank located in southern Coke County. From this storage tank, a 10-inch pipeline and an 8-inch pipeline feed water by gravity to the cities of Robert Lee and Bronte, respectively (Figure 4.8-2)

2. *Runnels County System* – This scenarios consists of an 18-inch pipeline following US 67 from San Angelo to the City of Ballinger. From Ballinger, a 12-inch pipeline turns north to the City of Winters (Figure 4.8-3).

3. *Combined Coke and Runnels County System* – This scenario calls for a 20-inch pipeline from San Angelo to a storage tank in southeastern Coke County. From this tank, a 12-inch and 10-inch pipeline feeds water by gravity to the cities of Bronte and Robert Lee, and an 18-inch and 14-inch pipeline feeds water to the cities of Ballinger and Winters (Figure 4.8-4).

Costs for these three scenarios may be found in Table 4.8-22.

Impacts of the distribution systems are discussed in Section 4.3.



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Phone - (817) 735 - 7300

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W E
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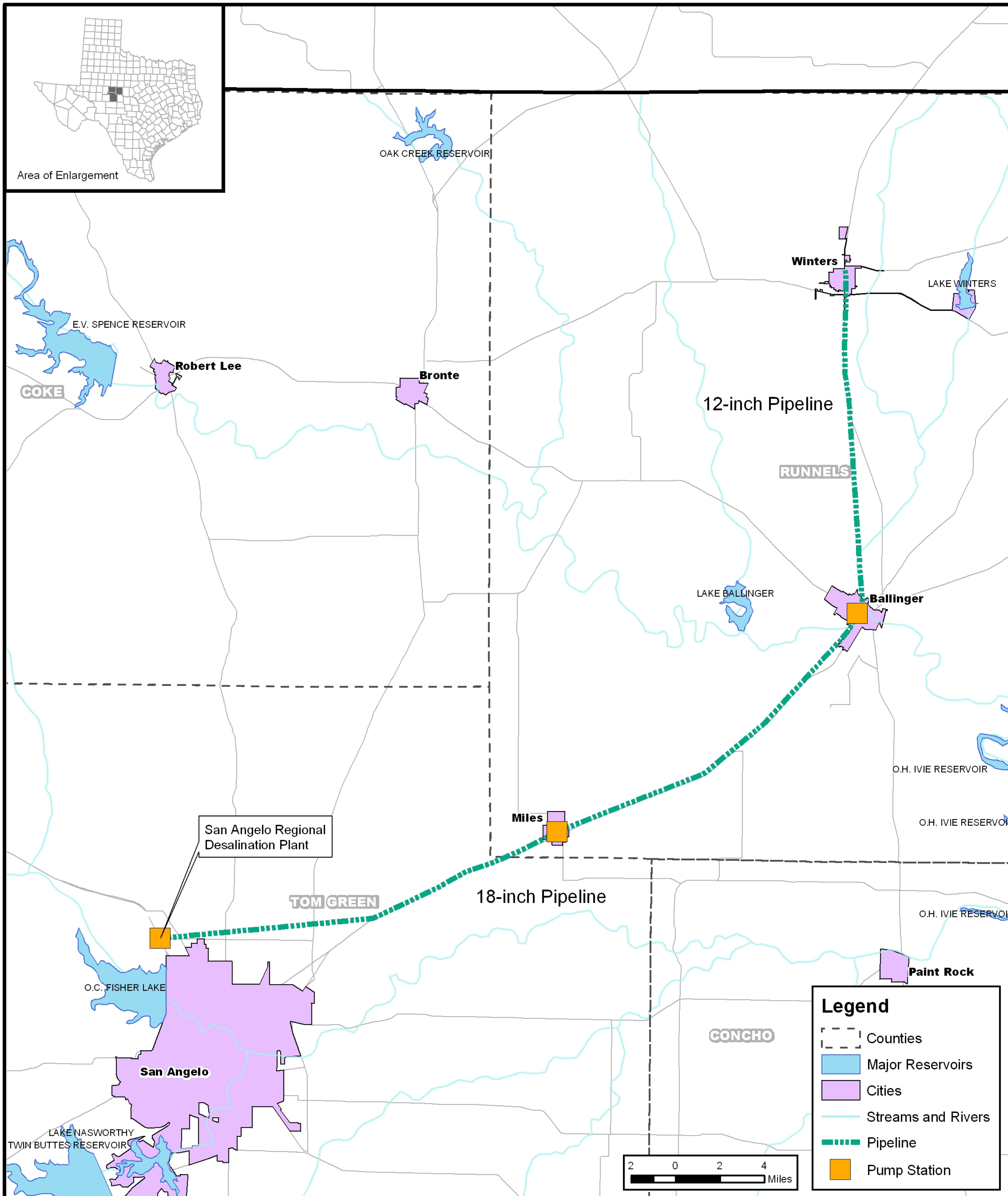
Delivery Options from San Angelo Regional Desalination Facility

Coke County Delivery

FN JOB NO	CMD01311
FILE	Profile 1a Location
DATE	May 20, 2005
SCALE	1:316,800
DESIGNED	GGJ
DRAFTED	GGJ

4.8-2

FIGURE



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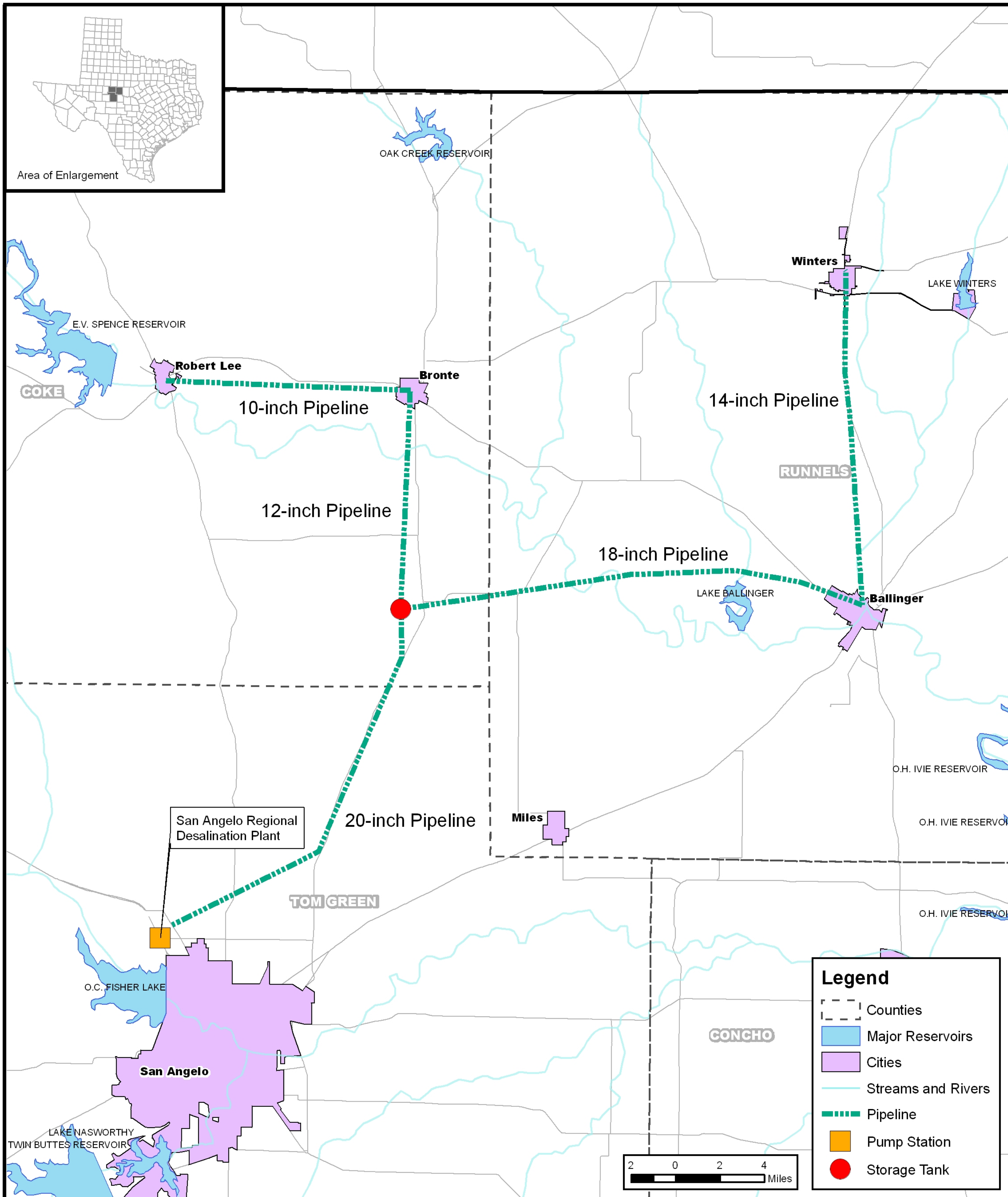
Delivery Options from San Angelo Regional Desalination Facility

Runnels County Delivery

FN JOB NO	CMD01311
FILE	Profile 1c Location
DATE	May 20, 2005
SCALE	1:380,160
DESIGNED	GGJ
DRAFTED	GGJ

4.8-3

FIGURE



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Delivery Options from San Angelo Regional Desalination Facility

Coke and Runnels County Delivery

FN JOB NO	CMD01311
FILE	Profile 2 Location
DATE	May 20, 2005
SCALE	1:380,160
DESIGNED	GGJ
DRAFTED	GGJ

4.8-4

FIGURE

Table 4.8-22
Transmission Costs to Deliver Water from the San Angelo Regional Desalination Facility to Coke and Runnels Counties *

Coke County System	
Supply from Strategy	728 acre-feet per year
Total Capital Costs (2002 Prices)	$ 9,830,940
Annual Costs	$ 1,013,000
Unit costs (before amortization)	$ 1,391 per acre-foot
	$ 4.27 per 1,000 gallons
Unit Costs (after amortization)	$ 214 per acre-foot
	$ 0.66 per 1,000 gallons
Runnels County System	
Supply from Strategy	2,298 acre-feet per year
Total Capital Costs (2002 Prices)	$ 18,429,974
Annual Costs	$ 1,874,000
Unit costs (before amortization)	$ 815 per acre-foot
	$ 2.50 per 1,000 gallons
Unit Costs (after amortization)	$ 116 per acre-foot
	$ 0.36 per 1,000 gallons
Coke and Runnels County System	
Supply from Strategy	2,802 acre-feet per year
Total Capital Costs (2002 Prices)	$ 23,407,880
Annual Costs	$ 2,599,000
Unit costs (before amortization)	$ 928 per acre-foot
	$ 2.85 per 1,000 gallons
Unit Costs (after amortization)	$ 199 per acre-foot
	$ 0.61 per 1,000 gallons

* Costs are for delivery only and do not include cost of water purchased from regional desalination facility. For costs of purchased water see Table 4.8-21.

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. There are two alternatives delivering water from the McCulloch well field to San Angelo:

- *A pipeline from the well field to Ivie Reservoir*. Water from the well field would be delivered to Ivie Reservoir and pumped to San Angelo using the CRMWD Ivie pipeline.
- *A direct pipeline from the well field to San Angelo.* A stand-alone pipeline dedicated solely to this source of supply.

Results of the updated study of the McCulloch County well field are not available for the 2006 *Region F Water Plan*. The evaluation in this plan is based on the 2001 *Region F Regional Water Plan*[53], the November 2000 *Long-Range Water Supply Plan*[54] and a preliminary cost estimates from the current study[55].

The advantages of the Ivie option when compared to the direct pipeline are:

- The initial capital costs are less than the direct option,
- The city would have lower maintenance cost on the delivery facilities, and
- Radionuclides may be diluted more than in the direct option.

The disadvantages of the Ivie option when compared to the direct pipeline are:

- The city's raw delivery capacity would remain the same because the city would be limited by their share of the capacity of the Ivie pipeline,
- The water may need to be treated to remove radionuclides before being added to the Ivie pipeline to prevent adverse water quality impacts on CRMWD member cities and customers, and
- All of the water from the well field would have to be treated at the city's water treatment plant because it is blended with surface water. (Groundwater typically can be used for municipal supplies with minimal treatment.)

This plan assumes that the direct pipeline option will be used because of the higher degree of operational flexibility this scenario gives the city and uncertainties involved with using the Ivie pipeline. This analysis assumes that drinking water standards for radionuclides will be met by blending with other sources and no advanced treatment will be required. The actual configuration of the pipeline and the method to meet drinking water standards will be determined in other studies.

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 5,000 acre-feet per year when the well field is brought on line in about 2024, 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 4.8-23 shows the costs associated with this strategy.

Table 4.8-23
Costs for the McCulloch County Well Field

Supply from Strategy	12,000 acre-feet per year
Total Capital Costs (2002 Prices)	$ 91,582,000
Annual Costs	$ 12,969,000
Unit costs (before amortization)	$ 1,081 per acre-foot
	$ 3.32 per 1,000 gallons
Unit Costs (after amortization)	$ 415 per acre-foot
	$ 1.27 per 1,000 gallons

Environmental Issues

Previous studies of the McCulloch County Well Field have not assessed the potential for impacts on springflows[56,57]. 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 city of Eden, will 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. Water from the McCulloch County well field may require special treatment, blending or some other process to meet standards. The city will be studying this option in detail in a separate study.

Other Water Management Strategies Directly Affected

Other San Angelo strategies.

System Optimization

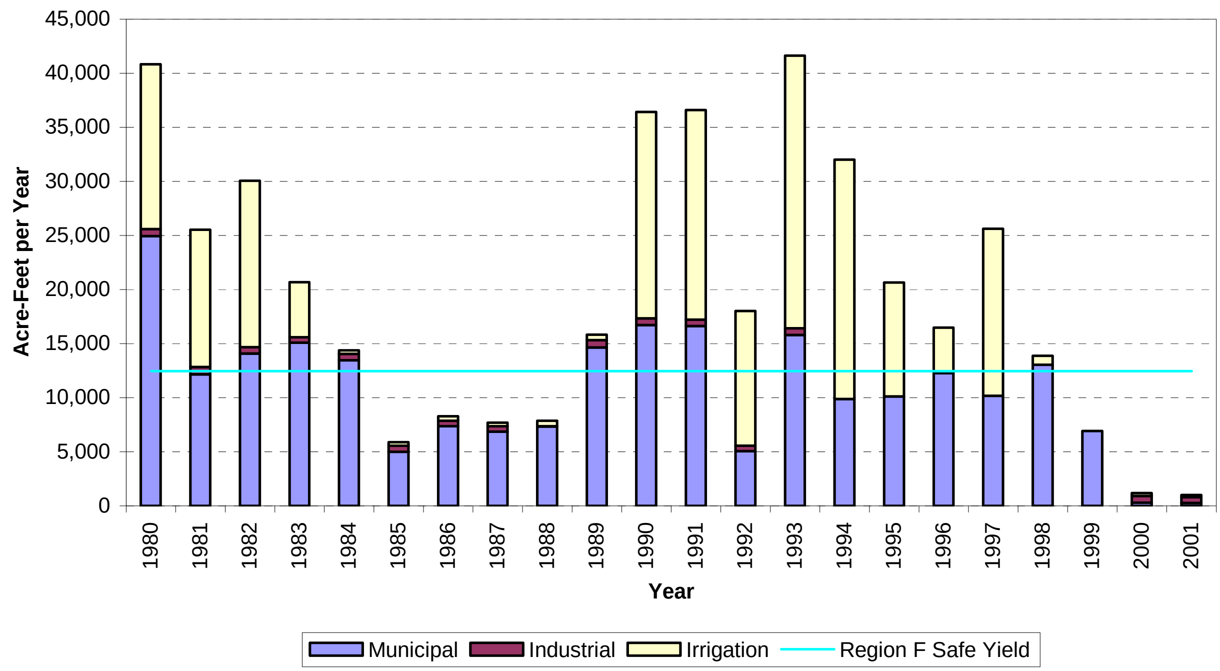
The City of San Angelo uses multiple sources of water. Previous studies have shown some increased yield from operating these sources in a coordinated fashion. In the first round of planning, it was estimated that an additional 2,100 acre-feet of water could be generated by operating Twin Buttes, Lake 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 4.8-5 shows historical water use from the two reservoirs between 1980 and 2001. During this period 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.

Figure 4.8-5
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. 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 4.8-24 shows the expected costs of this strategy.

Table 4.8-24
Costs for Rehabilitation of the Spence Pipeline *

Supply from Strategy	2,300 acre-feet per year
Total Capital Costs (2002 Prices)	$ 5,000,000
Annual Costs	$ 555,500
Unit costs (before amortization)	$ 241 per acre-foot
	$ 0.74 per 1,000 gallons
Unit Costs (after amortization)	$ 52 per acre-foot
	$ 0.16 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 4.8-25 shows the costs associated with this strategy.

Table 4.8-25
Costs for water from Southwestern Pecos County
City of San Angelo

Supply from Strategy	12,000 acre-feet per year
Total Capital Costs (2002 Prices)	$ 194,052,000
Annual Costs	$ 22,401,000
Unit costs (before amortization)	$ 1,867 per acre-foot
	$ 5.73 per 1,000 gallons
Unit Costs (after amortization)	$ 457 per acre-foot
	$ 1.40 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[58], 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[59]. This study concluded the following:

- Water quality of 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 4.8-26 is a cost estimate based on this study. If this strategy is pursued, additional engineering studies will be required to refine these estimates.

Table 4.8-26
Costs for Water from Edwards-Trinity (Plateau) Aquifer
City of San Angelo

Supply from Strategy	12,000 acre-feet per year
Total Capital Costs (2002 Prices)	$ 31,365,000
Annual Costs	$ 5,620,000
Unit costs (before amortization)	$ 468 per acre-foot
	$ 1.44 per 1,000 gallons
Unit Costs (after amortization)	$ 240 per acre-foot
	$ 0.74 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 include for the City of San Angelo include:

- Subordination of downstream senior water rights
- Rehabilitation of the Spence pipeline by 2010
- Development of a brackish groundwater desalination facility by 2020
- Development of the McCulloch County Well Field by 2030
- Water Conservation

Table 4.8-27 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 4.8-27
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	11,791	11,472	11,153	10,835	10,516	10,196
Rehabilitation of Spence Pipeline	2,308	2,295	2,281	2,267	2,254	2,240
Regional 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	25,715	30,760	35,204	41,648	41,093	40,536
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential Savings [a]	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	3,119	3,625	3,996	4,342	4,546	4,796
Total Demand	23,919	25,043	25,730	26,086	26,453	26,765
Surplus (Need) without Conservation	1,796	5,717	9,474	15,562	14,640	13,771
Surplus (Need) with Conservation	2,497	7,422	11,483	17,689	16,895	16,142

a Does not include plumbing code savings, which are already included in the water demand projections.

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[60]. 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.

While 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 several ongoing weather modification programs, including the Colorado River Municipal Water District (CRMWD) rain enhancement project, the West Texas Weather Modification Association (WTWMA) project, the Trans Pecos Weather Modification Association (TPWMA) program and the Southern Ogallala Aquifer Rain (SOAR) 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.

Colorado River Municipal Water District (CRMWD) Rain Enhancement Project

The CRMWD rain enhancement project, which is based in Big Spring, Texas, has been actively conducting weather modification activities since 1971. Since the program has been in operation for over three decades, most of the research data on weather modification that is collected by the State of Texas is from the CRMWD program. The CRMWD has a weather modification permit to operate in a 15-county area along the Colorado River between the cities of Big Spring, Lamesa, Snyder, and Sweetwater. The target area covers 2.6 million acres. The additional runoff from the program supplements the yield of two CRMWD reservoirs: Lake Thomas and E. V. Spence Reservoir.

The CRMWD rain enhancement project has been attributed to both increased rainfall and higher cotton yields within the target area during the life of the project. According to CRMWD, since 1971 precipitation has increased by 35 percent within the target area. Over the same period, precipitation shows an average increase of 12 percent outside of the target area. Precipitation and crop yield data from more recent years indicate that cotton yields have increased an average of 44 percent for counties in the target area. Of that increase, 37 percent has occurred in the downwind counties of the target area.[61]

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 2003, a total of 265 clouds were seeded as part of WTWMA's rain enhancement efforts in 50 operational days. A 1999 study of WTWMA's efforts shows a 17-percent increase in rainfall in the target area during the months the program was in operation[62].

Southern Ogallala Aquifer Rain (SOAR) Program

The SOAR program was established in the 2002 in order to increase rainfall and the recharge of groundwater, increase soil moisture for agriculture, and reduce water demands on ground and surface water resources. The program is operated by the Sandyland Water Conservation District and conducts rainfall enhancement activities in three Texas counties, Gaines, Terry and Yoakum, encompassing 3.8 million acres and in 2 million acres in eastern New Mexico. The SOAR program is the only weather modification program that covers territory in both Texas and a neighboring state.

Recent precipitation data from the SOAR program has been attributed to a 52 to 65 percent average increase in rainfall in the target area. The SOAR program estimates that during the 2002 to 2003 cloud-seeding season, average rainfall increased by 555,230 acre-feet over a target area of approximately 5,916,000 acres. SOAR estimated cost of the program during the same time period as $0.51 per acre-foot. According to SOAR, the agricultural resources in the target area benefited by as much as $235 for every dollar spent in the program[63].

Trans Pecos Weather Modification Association (TPWMA) Program

The TPWMA, which is the newest rain enhancement project in Texas, was developed 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. Precipitation data from this program's inaugural season were not available at the time of this report[64]

West Central Texas Weather Modification Association (WCTWMA) Program

The WCTWMA's program is sponsored by an alliance of nine counties and the city of Abilene. WCTWMA performed cloud seeding activities over 4.9 million acres in nine counties during the 2001-2003 seasons. The program conducted seeding activities between May 1 and September 30 of each year. The 2003 operating budget was $496,000, of which a portion was provided in a grant from the State[65].

Since the WCTWMA program was active for only three seasons, documented data is limited. According to Tom Mann of the West Central Texas Council of Governments, during the three years of the program, there was a 62 percent average increase in normal precipitation recorded that generated an average of 40,550 acre-feet of additional rainwater[65]. Even though 2002 was a drought year in the study area, there were more opportunities for cloud seeding, which resulted in a higher yield from the program. According to Mr. Mann, the increases in rainfall recorded to date, if distributed uniformly over the target area, corresponded to 0.0068 inches in 2001 and 0.011 inches in 2002. In 2003, seeded clouds produced 1.5 inches more rainfall than similar clouds that went unseeded.[66].

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 4.9-1, 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 4.9-1
Plant Water Use Rates

Plant	Water Loss (in/yr)	Water Loss (ac-ft/ac/yr)
Cottonwood	43.5 – 64.5	3.63 – 5.38 [67,68]
Crops	30.8 – 37.0	2.57 – 3.08 [69]
Fourwing Saltbush	28.5 – 68.8	2.38 – 5.73 [70]
Grass	6.0	0.50 [71]
Honey Mesquite	13.7 – 25.4	1.14 – 2.12 [72]
Juniper	23.3 – 25.0	1.94 – 2.08 [73]
Mesquite	19.2 – 26.3	1.60 – 2.19 [67]
Salt cedar	27.3 – 234	2.28 – 19.52 [67,74,75,76]
Salt grass	11.9 – 44.8	0.99 – 3.73 [77]

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[78].

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.[78]

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.[78]

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.[79] 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.

They include: North Concho River Pilot Project, Twin Buttes Reservoir/Lake Nasworthy Projects, Lake Ballinger Project, Mountain Creek Reservoir Project, Oak Creek Reservoir Project, and Pecos/Upper Colorado Salt Cedar Project. Summary information for these projects is shown in Table 4.9-2.

Table 4.9-2
Brush Control Project Status as of December 31, 2003

Project	Total Allocation	Acres Under Contract	Treated Acres	Avg. Cost per Acre	Expected Water Yield (Acre-feet over 10 years)
North Concho River	$13,254,024	351,689	207,537	$41	157,728
Twin Buttes/Nasworthy	$9,765,989	207,058	115,518	$43	108,586
Lake Ballinger	$484,886	10,235	4,559	$45	6,063
Mountain Creek	$95,532	2,034	1,414	$49	1,230
Oak Creek Lake	$1,095,765	15,214	10,752	$47	12,149
Champion Creek	$906,932	14,338	7,241	$45	5,503
Pecos-Upper Colorado	$410,710	6,220			
Total	*$26,013,838*	*606,788*	*347,021*		*291,259*

Source: TSSWCB Brush Control Program 2003 Annual Report

North Concho River Pilot Brush Control Project

In 1999, this project was authorized by the Legislature for the purpose of enhancing the amount of water flowing from the North Concho River Watershed into O.C. Fisher Reservoir. This is one of the longer on-going brush programs in the state. O.C. Fisher Reservoir serves as a water supply source for the City of San Angelo, and as of November 2004, the reservoir was at less than 2 percent of its capacity. TSSWCB has allocated $13.2 million for this project and has already contracted 352,000 acres of the 950,000-acre North Concho River Watershed for brush control[80]. Modeling studies estimate that this project could produce as much as 267,000 acre-feet of water over the 10-year life of the project. Almost 59 percent of the contracted acres have been treated to date. Current drought conditions have limited chemical treatment of mesquite and have limited a majority of the brush removal activities to mechanical treatment. Depleted aquifer conditions have made it difficult to monitor the effects of the brush removal. Even with these difficulties, the following effects have been observed thus far:

- Areas where brush control work has been concentrated thus far exhibit more frequent runoff events of greater intensity and duration than other tributaries along the North Concho River.
- Field observations of the North Concho River indicate that flow responses to rainfall are more frequent and pools hold water for longer periods of time following rainfall events.
- Following aerial treatment of mesquite, a pronounced increase in soil moisture and decrease in evapotranspiration has been observed.

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. Lake Nasworthy also provides cooling water for a power generation plant. As of November 2004, Twin Buttes Reservoir was at only 3 percent of its capacity. As of December 2003, TSSWCB has contracted 160,000 acres for treatment, and over 100,000 acres have already been treated[80]. It is projected that the current allocation ($9.5 million) will allow treatment of nearly 203,000 acres of brush. Modeling studies estimate that this project could produce as much as 191,000 acre-feet of water 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 Ballinger Brush Control Project

In September 2002, the TSSWCB initiated a brush control project to enhance the inflow to Lake Ballinger in the Upper Colorado Watershed. The lake is the primary source of water for the City of Ballinger. During the recent drought, the lake was empty. So far, $484,000 has been allocated for this project, which will fund treatment of 11,000 acres[80]. As of December 2003, 9,694 acres have been contracted for treatment. Modeling studies estimate that that the current funding allocation for this project could produce as much as 6,063 acre-feet of water over the life of the project.

Mountain Creek Reservoir Brush Control Project

In September 2002, the TSSWCB initiated a brush control project to enhance the inflow to Mountain Creek Reservoir in the upper Colorado watershed. The lake supplies water to the City of Robert Lee. So far, $95,500 has been allocated for this project, which will fund treatment of 7,500 acres[80]. As of December 2003, 2,034 acres have been contracted for treatment and 1,414 acres have already been treated. Modeling studies estimate that this project could produce as much as 1,230 acre-feet of water over the life of the project.

Oak Creek Reservoir Brush Control Project

The TSSWCB has initiated a brush control project to enhance the inflow to Oak Creek Reservoir in the upper Colorado watershed. The lake supplies water to the Cities of Sweetwater, Blackwell, and Bronte. As of November 2004, the lake was at 14 percent of its capacity[80]. So far, a little over $1 million has been allocated for this project, which will fund treatment of 23,000 acres. As of December 2003, 15,214 acres have been contracted for treatment and 10,193 acres have already been treated. Modeling studies estimate that this project could produce as much as 66,000 acre-feet of water over the life of the project. Additional funding will be needed to complete the treatment in the 152,000-acre watershed.

Pecos/Upper Colorado Salt Cedar Project

In September 2003, the TSSWCB along with other agencies became involved in an effort to treat salt cedar along the Pecos and upper Colorado Rivers. Salt cedar, which can use up to 200 gallons of water per tree per day, has become an increasing problem in these areas. As of December 2003, $410,700 had been allocated and 6,220 acres were under contract[80]. No results or estimates of water savings are available for this project.

Champion Creek Reservoir Brush Control Project

In September 2002, the TSSWCB initiated a brush control project to enhance the inflow to Champion Creek Reservoir in the Upper Colorado Watershed. The lake provides water for the TXU steam-electric power plant in Colorado City. As of November 2004, the lake was just above 10 percent of its capacity. So far, $907,000 has been allocated for this project, which will fund treatment of 24,000 acres[80]. As of December 2003, 7,241 acres have been treated. Modeling studies estimate that this project could produce as much as 19,000 acre-feet of water over the next ten years.

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 through out 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 through out 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[81]. 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, 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, alternative cooling technology, new groundwater sources, and voluntary redistribution. Altogether, these strategies result in over 228,000 acre-feet of water becoming available to water user groups by 2060, with an overall capital cost of almost $1.2 billion.

Table 4.10-3 shows the unmet needs in Region F. All of these needs are for irrigation. Unmet irrigation needs are the result of either insufficient groundwater supplies to meet projected demand or 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 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 Cenozoic Pecos Alluvium 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 surface water needs are strictly 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.

Table 4.10-1
Strategy Summary by County

Water User Group Name	County	Basin Name	Water Management Strategy Name	Source Name	Implemen-tation Date	Strategy Supply Increase (Decrease) for 2010	Strategy Supply Increase (Decrease) for 2020	Strategy Supply Increase (Decrease) for 2030	Strategy Supply Increase (Decrease) for 2040	Strategy Supply Increase (Decrease) for 2050	Strategy Supply Increase (Decrease) for 2060	Capital Cost	Annual Cost 2010	Annual Cost 2020	Annual Cost 2030	Annual Cost 2040	Annual Cost 2050	Annual Cost 2060
City of Andrews	Andrews	Colorado	Voluntary Redistribution	Ogallala aquifer	2010	671	708	730	750	760	773	$0	$0	$0	$0	$0	$0	$0
City of Andrews	Andrews	Colorado	Desalination	Dockum aquifer	2020	0	1,121	1,121	1,121	1,121	1,121	$4,678,300	$0	$796,000	$796,000	$388,000	$388,000	$388,000
Irrigation	Andrews	Colorado	Conservation		2020	0	2,728	5,455	5,456	5,457	5,458	$4,041,459	$0	$146,804	$293,608	$293,608	$293,608	$293,608
Andrews County Total						*671*	*4,557*	*7,306*	*7,327*	*7,338*	*7,352*	*$8,719,759*	*$0*	*$942,804*	*$1,089,608*	*$681,608*	*$681,608*	*$681,608*
Irrigation	Borden	Brazos	Conservation		2020	0	94	189	189	189	189	$164,000	$0	$5,957	$11,915	$11,915	$11,915	$11,915
Irrigation	Borden	Colorado	Conservation		2020	0	136	271	271	271	271	$236,000	$0	$8,573	$17,145	$17,145	$17,145	$17,145
Borden County Total						*0*	*230*	*460*	*460*	*460*	*460*	*$400,000*	*$0*	*$14,530*	*$29,060*	*$29,060*	*$29,060*	*$29,060*
Brown County Other	Brown	Colorado	Voluntary Redistribution	Lake Brownwood	2010	300	300	300	300	300	300	$5,284,000	$758,000	$758,000	$297,000	$297,000	$297,000	$297,000
Irrigation	Brown	Colorado	Conservation		2020	0	93	185	185	185	185	$44,386	$0	$1,613	$3,225	$3,225	$3,225	$3,225
Brown County Total						*300*	*393*	*485*	*485*	*485*	*485*	*$5,328,386*	*$758,000*	*$759,613*	*$300,225*	*$300,225*	*$300,225*	*$300,225*
City of Bronte	Coke	Colorado	Subordination	Oak Creek Reservoir	2010	129	129	129	129	129	129	$0	$0	$0	$0	$0	$0	$0
City of Bronte	Coke	Colorado	Infrastructure Improvements	Oak Creek Reservoir	2010	0	0	0	0	0	0	$1,238,600	$21,600	$21,600	$0	$0	$0	$0
City of Bronte	Coke	Colorado	New Groundwater	Other aquifer	2010	100	100	100	100	100	100	$464,000	$57,000	$57,000	$17,000	$17,000	$17,000	$17,000
City of Bronte	Coke	Colorado	Conservation		2010	16	45	48	48	50	51	$0	$4,472	$8,743	$8,539	$8,340	$8,145	$8,023
City of Robert Lee	Coke	Colorado	Conservation		2010	16	40	44	45	46	48	$0	$4,770	$8,727	$8,524	$8,325	$8,130	$8,009
City of Robert Lee	Coke	Colorado	Infrastructure Improvements	Spence Reservoir	2010	200	200	200	200	200	200	$2,482,500	$259,000	$259,000	$43,000	$43,000	$43,000	$43,000
City of Robert Lee	Coke	Colorado	Subordination	Colorado River MWD System	2010	95	115	2	21	34	55	$0	$0	$0	$0	$0	$0	$0
City of Robert Lee	Coke	Colorado	Brush control		2010	0	0	0	0	0	0	$95,532	$19,000	$19,000	$19,000	$19,000	$19,000	$19,000
County-Other	Coke	Colorado	Subordination	Colorado River MWD System	2010	28	32	0	6	9	15	$0	$0	$0	$0	$0	$0	$0
Mining	Coke	Colorado	Subordination	Colorado River MWD System	2010	86	119	2	24	43	72	$0	$0	$0	$0	$0	$0	$0
Steam Electric Power	Coke	Colorado	Subordination	Oak Creek Reservoir	2010	310	247	289	339	401	477	$0	$0	$0	$0	$0	$0	$0
Coke County Total						*980*	*1,027*	*814*	*912*	*1,012*	*1,147*	*$4,280,632*	*$365,842*	*$374,070*	*$96,063*	*$95,665*	*$95,275*	*$95,032*
City of Coleman	Coleman	Colorado	Subordination	Lake Coleman	2010	6,886	6,778	6,679	6,581	6,478	6,373	$1,701,400	$148,336	$148,336	$0	$0	$0	$0
City of Coleman	Coleman	Colorado	Subordination	Hords Creek Reservoir	2010	1,390	1,360	1,330	1,300	1,270	1,240	$278,000	$24,237	$24,237	$0	$0	$0	$0
City of Coleman	Coleman	Colorado	Conservation		2010	50	109	141	163	181	187	$0	$21,311	$24,872	$23,960	$23,072	$22,202	$21,664
Coleman County WSC	Coleman	Colorado	Subordination	Lake Coleman	2010	145	133	128	121	119	117	$0	$0	$0	$0	$0	$0	$0
County-Other	Coleman	Colorado	Subordination	Lake Coleman	2010	20	19	19	18	18	18	$0	$0	$0	$0	$0	$0	$0
Irrigation	Coleman	Colorado	Subordination	Lake Coleman	2010	1,348	1,348	1,348	1,348	1,348	1,348	$0	$0	$0	$0	$0	$0	$0
Manufacturing	Coleman	Colorado	Subordination	Lake Coleman	2010	6	6	6	6	6	6	$0	$0	$0	$0	$0	$0	$0
Mining	Coleman	Colorado	Subordination	Lake Coleman	2010	17	18	18	18	18	18	$0	$0	$0	$0	$0	$0	$0
Coleman County Total						*9,862*	*9,771*	*9,669*	*9,555*	*9,438*	*9,307*	*$1,979,400*	*$193,884*	*$197,445*	*$23,960*	*$23,072*	*$22,202*	*$21,664*
City of Eden	Concho	Colorado	Infrastructure Improvements	Hickory aquifer	2010	0	0	0	0	0	0	$1,366,000	$258,700	$258,700	$159,500	$159,500	$159,500	$159,500
City of Eden	Concho	Colorado	Bottled Water Program	Hickory aquifer	2010	0	0	0	0	0	0	$133,320	$26,874	$26,874	$8,760	$8,760	$8,760	$8,760
Irrigation	Concho	Colorado	Conservation		2020	0	748	1,496	1,496	1,496	1,496	$1,591,088	$0	$57,796	$115,591	$115,591	$115,591	$115,591
Millersview-Doole WSC	Concho	Colorado	Subordination	Colorado River MWD System	2010	34	42	1	7	0	0	$0	$0	$0	$0	$0	$0	$0
Millersview-Doole WSC	Concho	Colorado	Voluntary Redistribution	Colorado River MWD System	2050	0	0	0	0	118	118	$0	$0	$0	$0	$0	$0	$0
Concho County Total						*34*	*790*	*1,497*	*1,503*	*1,614*	*1,614*	*$3,090,408*	*$285,574*	*$343,370*	*$283,851*	*$283,851*	*$283,851*	*$283,851*
Ector County UD	Ector	Colorado	Subordination	Colorado River MWD System	2010	400	613	11	151	272	478	$0	$0	$0	$0	$0	$0	$0
Irrigation	Ector	Colorado	Conservation		2020	0	243	485	485	485	485	$253,720	$0	$9,216	$18,433	$18,433	$18,433	$18,433
Irrigation	Ector	Rio Grande	Conservation		2020	0	2	5	5	5	5	$2,563	$0	$93	$186	$186	$186	$186
Manufacturing	Ector	Colorado	Subordination	Colorado River MWD System	2010	66	149	3	46	86	158	$0	$0	$0	$0	$0	$0	$0
City of Odessa	Ector	Colorado	Conservation		2010	551	1,200	1,536	1,715	1,920	2,149	$0	$400,979	$416,656	$418,272	$419,543	$420,351	$428,145
City of Odessa	Ector	Colorado	New Groundwater	Cenozoic Pecos Alluvium	2040	0	0	0	6,000	6,000	6,000	$0	$0	$0	$0	$0	$0	$0
City of Odessa	Ector	Colorado	Reuse		2020	0	4,410	4,410	4,410	4,410	4,410	$0	$0	$0	$0	$0	$0	$0
City of Odessa	Ector	Colorado	Subordination	Colorado River MWD System	2010	4,392	5,587	83	1,102	1,923	3,313	$0	$0	$0	$0	$0	$0	$0
City of Odessa	Ector	Colorado	Voluntary Redistribution	Cenozoic Pecos Alluvium	2020	0	4,800	4,800	4,800	4,800	4,800	$0	$0	$0	$0	$0	$0	$0
Steam Electric Power	Ector	Colorado	Alternative Cooling Technology		2020	0	2,750	4,293	6,174	8,467	11,262	$297,786,650	$0	$4,188,224	$6,821,106	$9,457,193	$14,052,855	$22,099,115
Ector County Total						*5,409*	*19,754*	*15,626*	*24,888*	*28,368*	*33,060*	*$298,042,933*	*$400,979*	*$4,614,189*	*$7,257,997*	*$9,895,355*	*$14,491,825*	*$22,545,879*

Table 4.10-1 Strategy Summary by County (Continued)

Water User Group Name	County	Basin Name	Water Management Strategy Name	Source Name	Implemen-tation Date	Strategy Supply Increase (Decrease) for 2010	Strategy Supply Increase (Decrease) for 2020	Strategy Supply Increase (Decrease) for 2030	Strategy Supply Increase (Decrease) for 2040	Strategy Supply Increase (Decrease) for 2050	Strategy Supply Increase (Decrease) for 2060	Capital Cost	Annual Cost 2010	Annual Cost 2020	Annual Cost 2030	Annual Cost 2040	Annual Cost 2050	Annual Cost 2060
Irrigation	Glasscock	Colorado	Conservation		2020	0	3,631	7,262	7,262	7,262	7,262	$9,566,394	$0	$347,494	$694,988	$694,988	$694,988	$694,988
City of Big Spring	Howard	Colorado	Conservation		2010	241	603	676	698	725	754	$0	$108,944	$112,960	$109,009	$104,321	$99,734	$96,894
City of Big Spring	Howard	Colorado	Reuse		2020	0	1,855	1,855	1,855	1,855	1,855	$0	$0	$0	$0	$0	$0	$0
City of Big Spring	Howard	Colorado	Subordination	Colorado River MWD System	2010	1,345	1,672	24	299	491	796	$0	$0	$0	$0	$0	$0	$0
City of Coahoma	Howard	Colorado	Subordination	Colorado River MWD System	2010	49	61	1	11	18	29	$0	$0	$0	$0	$0	$0	$0
Irrigation	Howard	Colorado	Conservation		2020	0	327	653	653	653	653	$543,311	$0	$19,736	$39,471	$39,471	$39,471	$39,471
Manufacturing	Howard	Colorado	Subordination	Colorado River MWD System	2010	267	349	5	71	124	220	$0	$0	$0	$0	$0	$0	$0
Mining	Howard	Colorado	Subordination	Colorado River MWD System	2010	400	523	9	101	171	285	$0	$0	$0	$0	$0	$0	$0
Howard County Total						*2,302*	*5,390*	*3,223*	*3,688*	*4,037*	*4,592*	*$543,311*	*$108,944*	*$132,696*	*$148,480*	*$143,792*	*$139,205*	*$136,365*
Irrigation	Irion	Colorado	Conservation		2020	0	37	73	73	73	73	$17,614	$0	$640	$1,280	$1,280	$1,280	$1,280
City of Junction	Kimble	Colorado	Subordination	Llano River	2010	991	991	991	991	991	991	$200,000	$17,437	$17,437	$0	$0	$0	$0
County-Other	Kimble	Colorado	Subordination	Llano River	2010	9	9	9	9	9	9	$0	$0	$0	$0	$0	$0	$0
Irrigation	Kimble	Colorado	Conservation		2020	0	74	147	147	147	147	$118,702	$0	$4,312	$8,624	$8,624	$8,624	$8,624
Manufacturing	Kimble	Colorado	Subordination	Llano River	2010	1,000	1,000	1,000	1,000	1,000	1,000	$200,000	$17,437	$17,437	$0	$0	$0	$0
Kimble County Total						*2,000*	*2,074*	*2,147*	*2,147*	*2,147*	*2,147*	*$518,702*	*$34,874*	*$39,186*	*$8,624*	*$8,624*	*$8,624*	*$8,624*
City of Stanton	Martin	Colorado	Voluntary Redistribution	Colorado River MWD System	2010	385	414	421	422	407	385	$0	$0	$0	$0	$0	$0	$0
Irrigation	Martin	Colorado	Conservation		2020	0	1,751	3,502	3,502	3,502	3,502	$121,659	$0	$121,659	$243,318	$243,318	$243,318	$243,318
Martin County Total						*385*	*2,165*	*3,923*	*3,924*	*3,909*	*3,887*	*$121,659*	*$0*	*$121,659*	*$243,318*	*$243,318*	*$243,318*	*$243,318*
Irrigation	Mason	Colorado	Conservation		2020	0	746	1,491	1,491	1,491	1,491	$598,026	$0	$21,723	$43,446	$43,446	$43,446	$43,446
City of Brady	McCulloch	Colorado	Conservation		2010	77	192	214	222	230	239	$0	$23,486	$27,370	$26,348	$25,353	$24,380	$23,770
City of Brady	McCulloch	Colorado	Subordination	Brady Creek Reservoir	2010	2,170	2,170	2,170	2,170	2,170	2,170	$434,000	$37,838	$37,838	$0	$0	$0	$0
County Other	McCulloch	Colorado	Bottled Water Program	Hickory aquifer	2010	0	0	0	0	0	0	$0	$3,191	$3,191	$3,191	$3,191	$3,191	$3,191
Irrigation	McCulloch	Colorado	Conservation		2020	0	1,977	394	394	394	394	$139,633	$0	$5,072	$10,144	$10,144	$10,144	$10,144
Millersview-Doole WSC	McCulloch	Colorado	Subordination	Colorado River MWD System	2010	67	81	1	14	0	0	$0	$0	$0	$0	$0	$0	$0
Millersview-Doole WSC	McCulloch	Colorado	Voluntary Redistribution	Colorado River MWD System	2050	0	0	0	0	228	228	$0	$0	$0	$0	$0	$0	$0
Richland SUD	McCulloch	Colorado	Bottled Water Program	Hickory aquifer	2010	0	0	0	0	0	0	$2,000	$8,000	$8,000	$8,000	$8,000	$8,000	$8,000
Richland SUD	McCulloch	Colorado	Infrastructure Improvements	Hickory aquifer	2010	0	0	0	0	0	0	$1,291,720	$172,191	$172,191	$59,573	$59,573	$59,573	$59,573
McCulloch County Total						*2,314*	*4,420*	*2,779*	*2,800*	*3,022*	*3,031*	*$1,867,353*	*$244,706*	*$253,662*	*$107,256*	*$106,261*	*$105,288*	*$104,678*
City of Menard	Menard	Colorado	New Groundwater	Hickory aquifer	2010	140	139	140	140	141	141	$1,279,400	$172,500	$172,500	$61,000	$61,000	$61,000	$61,000
City of Menard	Menard	Colorado	Conservation		2010	10	24	28	30	32	33	$0	$7,332	$11,327	$11,009	$10,700	$10,397	$10,209
County-Other	Menard	Colorado	New Groundwater	Hickory aquifer	2010	20	21	20	20	19	19	$0	$0	$0	$0	$0	$0	$0
Irrigation	Menard	Colorado	Conservation		2020	0	23	46	46	46	46	$13,358	$0	$485	$970	$970	$970	$970
Menard County Total						*170*	*207*	*234*	*236*	*238*	*239*	*$1,292,758*	*$179,832*	*$184,312*	*$72,979*	*$72,670*	*$72,367*	*$72,179*
City of Midland	Midland	Colorado	Reuse		2020	0	5,389	5,389	5,389	5,389	5,389	$0	$0	$0	$0	$0	$0	$0
City of Midland	Midland	Colorado	Conservation		2010	930	2,320	2,903	3,110	3,310	3,521	$0	$420,493	$463,796	$461,155	$452,873	$440,673	$435,018
City of Midland	Midland	Colorado	Subordination	Colorado River MWD System	2010	4,488	6,055	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
City of Midland	Midland	Colorado	Voluntary Redistribution	Colorado River MWD System	2030	0	0	10,000	9,800	9,600	9,400	$0	$0	$0	$4,660,000	$4,566,800	$4,473,600	$4,380,400
City of Midland	Midland	Colorado	Subordination	O.H. Ivie Reservoir	2010	17	(97)	(211)	(324)	(438)	(553)	$0	$0	$0	$0	$0	$0	$0
City of Midland	Midland	Colorado	Voluntary Redistribution	Ogallala aquifer	2010	1,237	1,237	1,237	0	0	0	$0	$0	$0	$0	$0	$0	$0
City of Midland	Midland	Colorado	Voluntary Redistribution	Ogallala aquifer	2010	3,485	3,485	3,485	0	0	0	$0	$0	$0	$0	$0	$0	$0
City of Midland	Midland	Colorado	New Groundwater	Cenozoic Pecos Alluvium	2030	0	0	13,600	13,600	13,600	13,600	$115,772,000	$0	$0	$13,080,000	$13,080,000	$2,986,000	$2,986,000
Irrigation	Midland	Colorado	Conservation		2020	0	1,800	3,600	3,600	3,600	3,600	$2,642,806	$0	$95,989	$191,977	$191,977	$191,977	$191,977
City of Odessa	Midland	Colorado	Subordination	Colorado River MWD System	2010	113	200	4	49	87	151	$0	$0	$0	$0	$0	$0	$0
Midland County Total						*10,270*	*20,389*	*40,007*	*35,224*	*35,148*	*35,108*	*$118,414,806*	*$420,493*	*$559,785*	*$18,393,132*	*$18,291,650*	*$8,092,250*	*$7,993,395*

Table 4.10-1 Strategy Summary by County (Continued)

Water User Group Name	County	Basin Name	Water Management Strategy Name	Source Name	Implemen-tation Date	Strategy Supply Increase (Decrease) for 2010	Strategy Supply Increase (Decrease) for 2020	Strategy Supply Increase (Decrease) for 2030	Strategy Supply Increase (Decrease) for 2040	Strategy Supply Increase (Decrease) for 2050	Strategy Supply Increase (Decrease) for 2060	Capital Cost	Annual Cost 2010	Annual Cost 2020	Annual Cost 2030	Annual Cost 2040	Annual Cost 2050	Annual Cost 2060
Irrigation	Mitchell	Colorado	Conservation		2020	0	865	1,729	1,729	1,729	1,729	$2,135,784	$0	$77,581	$155,162	$155,162	$155,162	$155,162
Steam Electric Power	Mitchell	Colorado	Alternative Cooling Technology		2010	4,077	2,774	4,240	5,988	8,079	10,590	$297,786,650	$4,206,500	$4,224,776	$6,736,894	$9,172,282	$13,408,883	$20,780,468
Steam Electric Power	Mitchell	Colorado	Subordination	Colorado City/Champion Creek	2010	5,023	4,847	4,670	4,493	4,317	4,140	$1,004,600	$87,586	$87,586	$0	$0	$0	$0
Steam Electric Power	Mitchell	Colorado	Brush Control		2010	0	0	0	0	0	0	$906,932	$181,386	$181,386	$181,386	$181,386	$181,386	$181,386
Mitchell County Total						*9,100*	*8,486*	*10,639*	*12,210*	*14,125*	*16,459*	*$301,833,966*	*$4,475,472*	*$4,571,329*	*$7,073,442*	*$9,508,830*	*$13,745,431*	*$21,117,016*
Irrigation	Pecos	Colorado	Conservation		2020	0	6,300	12,600	12,600	12,600	12,600	$6,956,821	$0	$252,703	$505,405	$505,405	$505,405	$505,405
Irrigation	Reagan	Colorado	Conservation		2020	0	1,968	3,936	3,936	3,936	3,936	$190,926	$0	$190,926	$381,852	$381,852	$381,852	$381,852
Irrigation	Reeves	Colorado	Conservation		2020	0	5,824	11,648	11,648	11,648	11,648	$6,891,034	$0	$250,313	$500,626	$500,626	$500,626	$500,626
City of Ballinger	Runnels	Colorado	Conservation		2010	33	88	107	119	131	144	$0	$18,388	$24,012	$24,602	$25,222	$25,396	$25,803
City of Ballinger	Runnels	Colorado	Reuse		2040	0	0	0	220	220	220	$1,980,000	$0	$0	$0	$219,845	$219,845	$75,900
City of Ballinger	Runnels	Colorado	Subordination	Lake Ballinger	2010	917	930	920	910	900	890	$188,000	$16,391	$16,391	$0	$0	$0	$0
City of Ballinger	Runnels	Colorado	Voluntary Redistribution	Colorado River MWD System	2010	192	185	194	259	58	127	$0	$81,792	$78,810	$82,644	$110,334	$24,708	$54,102
City of Miles	Runnels	Colorado	Subordination	OC Fisher Reservoir	2010	100	100	100	100	100	100	$0	$0	$0	$0	$0	$0	$0
City of Winters	Runnels	Colorado	Conservation		2010	21	55	63	67	71	76	$0	$12,392	$16,589	$16,353	$16,134	$15,829	$15,781
City of Winters	Runnels	Colorado	Reuse		2040	0	0	0	110	110	110	$1,660,000	$0	$0	$0	$198,000	$198,000	$53,020
City of Winters	Runnels	Colorado	Subordination	Lake Winters	2010	552	561	566	571	575	591	$144,000	$12,555	$12,555	$0	$0	$0	$0
Coleman County WSC	Runnels	Colorado	Subordination	Lake Coleman	2010	18	30	39	48	56	66	$0	$0	$0	$0	$0	$0	$0
County-Other	Runnels	Colorado	Subordination	Lake Ballinger	2010	23	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
County-Other	Runnels	Colorado	Subordination	Lake Winters	2010	114	89	69	49	31	0	$0	$0	$0	$0	$0	$0	$0
County-Other	Runnels	Colorado	Voluntary Redistribution	Colorado River MWD System	2010	193	177	148	116	94	77	$0	$82,218	$75,402	$63,048	$49,416	$40,044	$32,802
Manufacturing	Runnels	Colorado	Subordination	Lake Winters	2010	54	60	65	70	74	79	$0	$0	$0	$0	$0	$0	$0
Manufacturing	Runnels	Colorado	Voluntary Redistribution	Colorado River MWD System	2010	9	10	11	12	13	15	$0	$3,834	$4,260	$4,686	$5,112	$5,538	$6,390
Millersview-Doole WSC	Runnels	Colorado	Subordination	Colorado River MWD System	2010	25	31	0	6	0	0	$0	$0	$0	$0	$0	$0	$0
Millersview-Doole WSC	Runnels	Colorado	Voluntary Redistribution	Colorado River MWD System	2050	0	0	0	0	92	93	$0	$0	$0	$0	$0	$0	$0
Runnels County Total						*2,251*	*2,316*	*2,282*	*2,657*	*2,525*	*2,588*	*$3,972,000*	*$227,570*	*$228,019*	*$191,333*	*$624,063*	*$529,360*	*$263,798*
Irrigation	Schleicher	Colorado	Conservation		2020	0	89	178	178	178	178	$123,711	$0	$4,494	$8,987	$8,987	$8,987	$8,987
Irrigation	Schleicher	Rio Grande	Conservation		2020	0	18	36	36	36	36	$25,327	$0	$920	$1,840	$1,840	$1,840	$1,840
Schleicher County Total						*0*	*107*	*214*	*214*	*214*	*214*	*$149,038*	*$0*	*$5,414*	*$10,827*	*$10,827*	*$10,827*	*$10,827*
City of Snyder	Scurry	Colorado	Conservation		2010	70	154	191	205	220	234	$0	$46,943	$51,385	$50,089	$48,426	$46,643	$45,378
City of Snyder	Scurry	Colorado	Reuse		2020	0	726	726	726	726	726	$0	$0	$0	$0	$0	$0	$0
City of Snyder	Scurry	Colorado	Subordination	Colorado River MWD System	2010	511	641	9	117	194	315	$0	$0	$0	$0	$0	$0	$0
City of Snyder	Scurry	Colorado	Voluntary Redistribution	Lake Alan Henry	2020	0	3,360	3,360	3,360	3,360	3,360	$0	$0	$0	$0	$0	$0	$0
County-Other	Scurry	Colorado	Subordination	Colorado River MWD System	2010	54	66	1	12	20	33	$0	$0	$0	$0	$0	$0	$0
Irrigation	Scurry	Brazos	Conservation		2020	0	160	320	320	320	320	$303,477	$0	$11,024	$22,047	$22,047	$22,047	$22,047
Irrigation	Scurry	Colorado	Conservation		2020	0	411	823	823	823	823	$780,370	$0	$28,346	$56,693	$56,693	$56,693	$56,693
Scurry County Total						*635*	*5,518*	*5,430*	*5,563*	*5,663*	*5,811*	*$1,083,847*	*$46,943*	*$90,755*	*$128,829*	*$127,166*	*$125,383*	*$124,118*
Irrigation	Sterling	Colorado	Conservation		2020	0	45	89	90	91	92	$21,550	$0	$783	$1,566	$1,566	$1,566	$1,566
Irrigation	Sutton	Colorado	Conservation		2020	0	44	88	88	88	88	$50,783	$0	$1,845	$3,689	$3,689	$3,689	$3,689
Irrigation	Sutton	Rio Grande	Conservation		2020	0	98	196	196	196	196	$113,377	$0	$4,118	$11,926	$11,926	$11,926	$11,926
Sutton County Total						*0*	*142*	*284*	*284*	*284*	*284*	*$164,160*	*$0*	*$5,963*	*$15,615*	*$15,615*	*$15,615*	*$15,615*

Table 4.10-1 Strategy Summary by County (Continued)

Water User Group Name	County	Basin Name	Water Management Strategy Name	Source Name	Implementation Date	Strategy Supply Increase (Decrease) for 2010	Strategy Supply Increase (Decrease) for 2020	Strategy Supply Increase (Decrease) for 2030	Strategy Supply Increase (Decrease) for 2040	Strategy Supply Increase (Decrease) for 2050	Strategy Supply Increase (Decrease) for 2060	Capital Cost	Annual Cost 2010	Annual Cost 2020	Annual Cost 2030	Annual Cost 2040	Annual Cost 2050	Annual Cost 2060
County-Other	Tom Green	Colorado	Subordination	Nasworthy/Twin Buttes	2010	250	250	250	250	250	250	$0	$0	$0	$0	$0	$0	$0
Irrigation	Tom Green	Colorado	Conservation		2020	0	5,774	11,548	11,548	11,548	11,548	$2,465,727	$0	$89,566	$179,132	$179,132	$179,132	$179,132
Irrigation	Tom Green	Colorado	Subordination	Nasworthy/Twin Buttes	2010	3,377	3,273	3,170	3,066	2,693	2,860	$0	$0	$0	$0	$0	$0	$0
Manufacturing	Tom Green	Colorado	Subordination	Nasworthy/Twin Buttes	2010	2,226	2,498	2,737	2,971	3,175	3,425	$0	$0	$0	$0	$0	$0	$0
Millersview-Doole WSC	Tom Green	Colorado	Subordination	Colorado River MWD System	2010	64	87	1	19	0	0	$0	$0	$0	$0	$0	$0	$0
Millersview-Doole WSC	Tom Green	Colorado	Voluntary Redistribution	Colorado River MWD System	2050	0	0	0	0	359	408	$0	$0	$0	$0	$0	$0	$0
Steam Electric Power	Tom Green	Colorado	Alternative Cooling Technology		2040	0	0	0	48	243	481	$6,834,117	$0	$0	$0	$73,525	$403,312	$943,853
Steam Electric Power	Tom Green	Colorado	Subordination	Nasworthy/Twin Buttes	2010	1,021	1,021	1,021	1,021	1,021	1,021	$0	$0	$0	$0	$0	$0	$0
City of San Angelo	Tom Green	Colorado	Desalination	Other aquifer	2020	0	5,600	5,600	5,600	5,600	5,600	$40,590,000	$0	$5,621,000	$5,621,000	$2,083,200	$2,083,200	$2,083,200
City of San Angelo	Tom Green	Colorado	New Groundwater	Hickory aquifer	2030	0	0	5,000	12,000	12,000	12,000	$91,582,000	$0	$0	$5,405,000	$12,972,000	$4,980,000	$4,980,000
City of San Angelo	Tom Green	Colorado	Conservation		2010	701	1,705	2,009	2,127	2,255	2,371	$0	$395,818	$415,843	$409,987	$398,440	$385,447	$375,342
City of San Angelo	Tom Green	Colorado	Infrastructure Improvements	Spence Reservoir	2010	2,274	2,261	2,247	2,233	2,220	2,206	$5,000,000	$555,500	$555,500	$119,600	$119,600	$119,600	$119,600
City of San Angelo	Tom Green	Colorado	Subordination	Nasworthy/Twin Buttes	2010	5,436	5,078	4,752	4,431	4,141	3,804	$0	$0	$0	$0	$0	$0	$0
City of San Angelo	Tom Green	Colorado	Subordination	OC Fisher Reservoir	2010	3,762	3,643	3,525	3,407	3,288	3,170	$0	$0	$0	$0	$0	$0	$0
City of San Angelo	Tom Green	Colorado	Subordination	OH Ivie Reservoir	2010	17	(97)	(211)	(324)	(438)	(553)	$0	$0	$0	$0	$0	$0	$0
City of San Angelo	Tom Green	Colorado	Brush Control		2010	8,362	8,362	8,362	8,362	8,362	8,362	$23,020,000	$4,604,000	$4,604,000	$4,604,000	$4,604,000	$4,604,000	$4,604,000
Tom Green County Total						*27,490*	*39,455*	*50,011*	*56,759*	*56,717*	*56,953*	*$169,491,844*	*$5,555,318*	*$11,285,909*	*$16,338,719*	*$20,429,897*	*$12,754,691*	*$13,285,127*
Irrigation	Upton	Colorado	Conservation		2020	0	911	1,822	1,822	1,822	1,822	$2,441,070	$0	$88,670	$177,341	$177,341	$177,341	$177,341
Irrigation	Upton	Rio Grande	Conservation		2020	0	9	18	18	18	18	$24,657	$0	$896	$1,791	$1,791	$1,791	$1,791
Upton County Total						*0*	*920*	*1,840*	*1,840*	*1,840*	*1,840*	*$2,465,727*	*$0*	*$89,566*	*$179,132*	*$179,132*	*$179,132*	*$179,132*
County Other	Ward	Colorado	Voluntary Redistribution	Cenozoic Pecos Alluvium aquifer	2020	0	400	400	400	400	400	$0	$0	$0	$0	$0	$0	$0
Irrigation	Ward	Colorado	Conservation		2020	0	785	1,570	1,570	1,570	1,570	$368,640	$0	$13,391	$26,781	$26,781	$26,781	$26,781
Steam Electric Power	Ward	Rio Grande	Alternative Cooling Technology		2050	0	0	0	0	679	1,973	$24,094,671	$0	$0	$0	$0	$1,126,950	$3,871,564
Ward County Total						*0*	*1,185*	*1,970*	*1,970*	*2,649*	*3,943*	*$24,463,311*	*$0*	*$13,391*	*$26,781*	*$26,781*	*$1,153,731*	*$3,898,345*
Irrigation	Winkler	Colorado	Conservation		2020	0	195	389	389	389	389	$164,628	$0	$5,980	$11,960	$11,960	$11,960	$11,960
			Conservation			2,716	44,441	80,204	80,795	81,419	82,057	$43,152,601	$1,465,328	$3,450,998	$5,308,966	$5,281,868	$5,248,446	$5,235,155
			Alternative Cooling Technology			4,077	5,524	8,533	12,210	17,468	24,306	$626,502,088	$4,206,500	$8,413,000	$13,558,000	$18,703,000	$28,992,000	$47,695,000
			Desalination			0	6,721	6,721	6,721	6,721	6,721	$45,268,300	$0	$6,417,000	$6,417,000	$2,471,200	$2,471,200	$2,471,200
			New Groundwater			260	260	18,860	31,860	31,860	31,860	$209,097,400	$229,500	$229,500	$18,563,000	$26,130,000	$8,044,000	$8,044,000
			Infrastructure Improvements			2,474	2,461	2,447	2,433	2,420	2,406	$11,378,820	$1,266,991	$1,266,991	$381,673	$381,673	$381,673	$381,673
			Reuse			0	12,380	12,380	12,710	12,710	12,710	$3,640,000	$0	$0	$0	$417,845	$417,845	$128,920
			Bottled Water Program			0	0	0	0	0	0	$135,320	$38,065	$38,065	$19,951	$19,951	$19,951	$19,951
			Brush Control			8,362	8,362	8,362	8,362	8,362	8,362	$24,022,464	$4,804,386	$4,804,386	$4,804,386	$4,804,386	$4,804,386	$4,804,386
			Subordination			49,812	52,817	35,735	36,825	37,174	39,106	$4,150,000	$361,817	$361,817	$0	$0	$0	$0
			Voluntary Redistribution			6,472	15,076	25,086	20,219	20,589	20,484	$5,284,000	$925,844	$916,472	$5,107,378	$5,028,662	$4,840,890	$4,770,694
			Total for All Strategies			*74,173*	*148,042*	*198,328*	*212,135*	*218,723*	*228,012*	*$972,630,993*	*$13,298,431*	*$25,898,229*	*$54,160,354*	*$63,238,585*	*$55,220,391*	*$73,550,979*

Table 4.10-2
Strategy Summary for Wholesale Water Providers

Wholesale Water Provider	Water Management Strategy Name	Source Name	Implementation Date	Strategy Supply Increase (Decrease) for 2010	Strategy Supply Increase (Decrease) for 2020	Strategy Supply Increase (Decrease) for 2030	Strategy Supply Increase (Decrease) for 2040	Strategy Supply Increase (Decrease) for 2050	Strategy Supply Increase (Decrease) for 2060	Capital Cost	Annual Cost 2010	Annual Cost 2020	Annual Cost 2030	Annual Cost 2040	Annual Cost 2050	Annual Cost 2060
CRMWD	Reuse		2020	0	12,380	12,380	12,380	12,380	12,380	$97,249,000	$0	$12,035,000	$12,035,000	$3,555,560	$3,555,560	$3,555,560
	Subordination	CRMWD System	2010	48,027	47,134	46,240	45,347	44,453	43,560	$9,605,400	$837,443	$837,443	$0	$0	$0	$0
	Voluntary Redistribution	Lake Alan Henry	2020	0	11,210	11,210	11,210	11,210	11,210	$30,384,000	$0	$10,059,000	$10,059,000	$7,410,000	$7,410,000	$7,410,000
	New Groundwater	Cenozoic Pecos Alluvium aquifer	2040	0	0	0	6,000	6,000	6,000	$39,934,000	$0	$0	$0	$4,987,000	$4,987,000	$1,505,000
	Desalination	Capitan Reef aquifer	2020	0	9,500	9,500	9,500	9,500	9,500	$86,183,530	$0	$12,352,556	$12,352,556	$4,838,556	$4,838,556	$4,838,556
CRMWD Total				*48,027*	*80,224*	*79,330*	*84,437*	*83,543*	*82,650*	*$263,355,930*	*$837,443*	*$35,283,999*	*$34,446,556*	*$20,791,116*	*$20,791,116*	*$17,309,116*
San Angelo	Subordination	San Angelo system	2010	7,912	7,826	7,739	7,652	7,566	7,479	$1,582,400	$137,961	$137,961	$0	$0	$0	$0
UCRA	Subordination	OC Fisher Reservoir	2010	3,862	3,743	3,625	3,507	3,388	3,270	$772,400	$67,341	$67,341	$0	$0	$0	$0
	Reuse			0	12,380	12,380	12,380	12,380	12,380	$97,249,000	$0	$12,035,000	$12,035,000	$3,555,560	$3,555,560	$3,555,560
	Subordination			59,801	58,703	57,604	56,506	55,407	54,309	$11,960,200	$1,042,745	$1,042,745	$0	$0	$0	$0
	Voluntary Redistribution			0	11,210	11,210	11,210	11,210	11,210	$30,384,000	$0	$10,059,000	$10,059,000	$7,410,000	$7,410,000	$7,410,000
	New Groundwater			0	0	0	6,000	6,000	6,000	$39,934,000	$0	$0	$0	$4,987,000	$4,987,000	$1,505,000
	Desalination			0	9,500	9,500	9,500	9,500	9,500	$86,183,530	$0	$12,352,556	$12,352,556	$4,838,556	$4,838,556	$4,838,556
	Total for All Strategies			*59,801*	*91,793*	*90,694*	*95,596*	*94,497*	*93,399*	*$265,710,730*	*$1,042,745*	*$35,489,301*	*$34,446,556*	*$20,791,116*	*$20,791,116*	*$17,309,116*

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	(14,094)	(11,336)	(8,471)	(7,080)	(6,876)	(6,707)
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)
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	Reagan	Colorado	Edwards-Trinity aquifer	(10,997)	(8,639)	(6,180)	(5,623)	(5,040)	(4,457)
Irrigation	Reeves	Rio Grande	Cenozoic Pecos Alluvium aquifer	(36,097)	(29,421)	(22,739)	(21,877)	(21,016)	(20,199)
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)
Irrigation	Upton	Colorado	Edwards-Trinity aquifer	(10,672)	(9,540)	(8,401)	(8,170)	(7,940)	(7,717)
Irrigation	Ward	Rio Grande	Cenozoic Pecos Alluvium aquifer	(5,527)	(4,188)	(4,151)	(4,969)	(5,335)	(5,318)
Total				*(176,222)*	*(149,029)*	*(123,548)*	*(120,515)*	*(118,410)*	*(115,523)*

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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)	X	X	X		X
Alkalinity			X		
Hardness			X		
Dissolved Oxygen (DO)	X	X			
Nitrogen	X	X	X		X
Phosphorus	X	X			
Radionuclides			X		
Metals [b]	X [b]		X [b]		
Sediment Quality					X

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.

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 implementation of subordination agreements with downstream water rights holders, which will utilize water from existing surface water sources. The subordination agreements will have little to no impact on stream flow or water quality because no changes will be made to the operations of the water resources in the basin.

5.2.2 Voluntary Redistribution

If 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 total dissolved solids (TDS), nutrients, dissolved oxygen (DO), and, in some cases, metals.

Additionally, changes in alkalinity, hardness, or turbidity due to higher TDS loading can impact water users, particularly industrial 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.

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.
- 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.
- Reusing water multiple times and then discharging it can significantly increase the TDS concentration in the effluent and in the receiving stream. Total loading to the stream should not change significantly.

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. 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 most likely to be implemented in Region F is improvements in the efficiency of irrigation equipment (advanced irrigation technologies) and alternative generation technologies for steam electric power. 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

Regional desalination of brackish groundwater 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 - purchase of water from Lake Alan Henry
- 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 Cenozoic Pecos Alluvium, 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 Bronte – new wells in an unclassified aquifer (Other aquifer)
- City of Menard – new Hickory aquifer well
- City of Midland – T-Bar Well Field (Cenozoic Pecos Alluvium aquifer)
- CRMWD – Winkler County Well Field (Cenozoic Pecos Alluvium aquifer)
- Ector County Mining – new Dockum aquifer wells
- San Angelo – McCulloch County Well Field (Hickory aquifer)

5.3.3 Reuse

Wastewater reuse is a proposed strategy for the City of Ballinger, 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 Cities of Ballinger and 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 three recommended desalination water management strategies: the City of San Angelo, the City of Andrews and CRMWD. These strategies proposes to desalinate brackish groundwater and dispose of the waste stream through deep well injection. 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:

- 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.

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 7 percent reduction in municipal water use (10,688 acre-feet per year) by year 2060. Additional municipal water savings may be expected as the Federal mandate for energy efficient clothes washing machines takes 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 16,200 acre-feet per year in Region F. Based on factors developed by the TWDB, irrigation demands are expected to decline approximately 6 percent over the planning period, primarily due to conservation. However, studies described in this report indicate irrigation demands may decline as much as 22 percent by the year 2020 and 43 percent by the year 2060. 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. Severe 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 12,000 acre-feet per year in 2002. The cities of Bronte, Ballinger, Miles and Winters report similar reductions in demand. 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.

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 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 the Region F area, 17 entities hold municipal or industrial rights in excess of 1,000 acre-feet per year and 5 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. 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[2].

Table 6.1-1
Municipal, Industrial and Irrigation Water Rights Holders in Region F Required to Submit Water Conservation Plans by §11.1271 of the Texas Water Code

Municipal		
Brown County WID #1	TXU	City of Big Spring
CRMWD	City of Sweetwater	City of Ballinger
Joseph T Moore & J T Moore Inc	City of Winters	City of San Angelo
San Angelo Water Supply Corporation	Upper Colorado River Authority	City of Coleman
City of Menard	City of Brady	Kimble Co WCID
Industrial		
TXU	CRMWD	City of Sweetwater
City of San Angelo	Texas Parks & Wildlife Department	City of Coleman
Brown County WID #1	The Paks Corporation	
Irrigation		
Red Bluff Water Power Control District	Reeves County WID #1	Wayne Moore & W H Gilmore
San Angelo Water Supply Corporation	Pecos County WCID #1	

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 2004 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

The focus of the 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.

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 81,000 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 will not be significant. Most manufacturing needs are associated with water supply needs for municipalities. For regional planning purposes, water conservation strategies will be 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. In addition, Region F has added water to account for wildlife that relies on the same water sources as commercial 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 4.2.6. 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.

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 adverse impacts of 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, 2005.

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 2006 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 2006 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, Cenozoic Pecos Alluvium, 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.

The Edwards-Trinity Plateau, Cenozoic Pecos Alluvium, and Ogallala aquifers are the largest sources of groundwater in Region F, providing 37 percent, 27 percent, and 15 percent of the total groundwater pumped in 1997, respectively. The Lipan aquifer provided almost 12 percent of the 1997 totals, with all other aquifers contributing less than 9 percent.

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. The assumptions used in the Colorado WAM are discussed in Appendix 3C. In conjunction with the

Lower Colorado Region (Region K), a subordination strategy was developed that protects the supply of Region F water rights. 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 6,800 acre-feet of water annually by 2010, reducing impacts on both groundwater and surface water resources. The proposed plan also assumes an additional 115,600 acre-feet per year in savings by 2060.
- *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.
- *Voluntary Redistribution.* Under this strategy, water rights holders with surplus water supplies will provide water to areas with current or projected demands. This strategy is proposed for users in Andrews, Brown, Concho, Ector, Kimble, McCulloch, Midland, Runnels, and Tom Green 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, in association with the RWPG and Upper Colorado River Authority (UCRA), has developed a conceptual design for a regional desalination facility to be located northwest of the City of San Angelo. As proposed, the phased-in facility will have an initial capacity of 5 MGD to provide water to the city from a currently unused water source. This will reduce the demands on other water sources in the region. In addition, the facility could potentially provide treated water to other areas

in the region with supply needs. Desalination is also a recommended long-term strategy for CRMWD and the City of Andrews.

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: (a) Oak Creek Reservoir, which supplies water to the City of Sweetwater in Brazos G, and (b) 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 nine species of birds, four mammals, three reptiles, and eight fishes. 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

Six state parks (Lake Brownwood, Big Spring, Lake Colorado City, Monahans Sandhills, San Angelo, and South Llano River) and one state wildlife management area (Mason Mountain) are located in Region F. The Lake Colorado City and San Angelo State Parks may be positively impacted by the subordination strategy because water will be retained in the reservoirs that otherwise would be passed downstream. Lake Brownwood State Park may be adversely impacted because of water that may be retained by upstream reservoirs. Other state parks are not expected to be impacted.

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 in Figure 8.1-1 as ecologically significant.

Table 8.1-1
Texas Parks and Wildlife Department Ecologically Significant River and Stream Segments

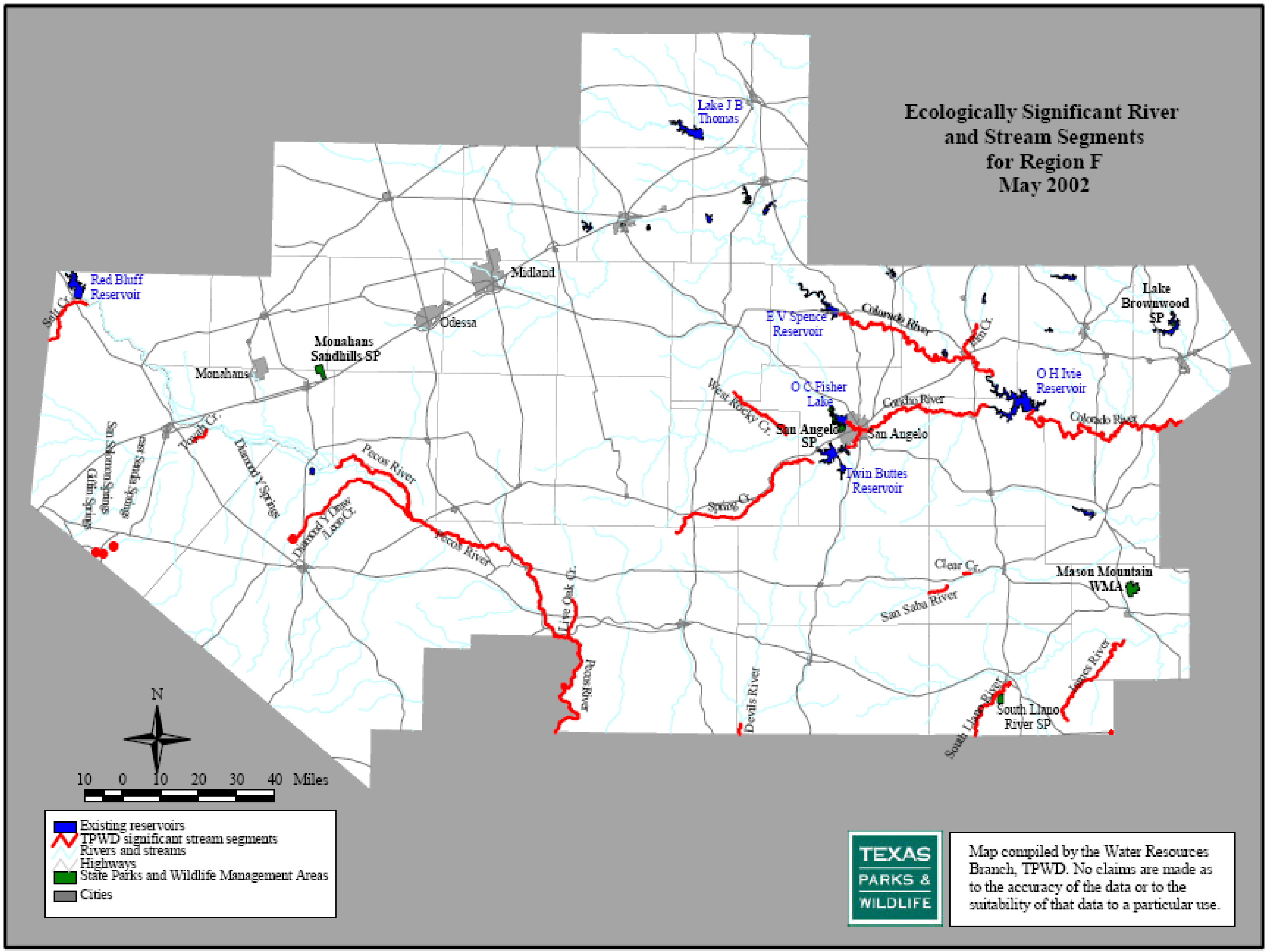
River or Stream Segment	Description	Basin	County	TPWD Reasons for Designation[a]				
				Biological Function	Hydrologic Function	Riparian Conservation Area	Water Quality/ Aesthetic Value	Endangered Species/ Unique Communities
Clear Creek	Impounded headwater springs	Colorado	Menard					X
Colorado River	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 Leon 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 the 2001 *Region F Water Plan*, 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 Texas Water Development Board 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. The Regional Water Planning Group recognizes the ecological benefits of major springs, which are discussed in Chapter 1.

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 indicate 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 this 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.

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 export of a significant amount of water from a groundwater district must submit notice of their plan to the Regional Water Planning Group, regardless of whether or not the proponents of the strategy will seek state funding.
- 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 which 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.

Since 1999, Region F has been the center for state funding to remove noxious brush so as to enhance recharge of underground aquifers and restore perennial streams and springs producing increased runoff from natural flows as well as storm water runoff into West Texas Reservoirs in the Colorado and Concho River Basins. To date the State of Texas has spent or contracted to spend almost $25 million and private landowners have expended another $8 million to remove mesquite and juniper from almost 480,000 acres of land primarily located on the O.C. Fisher Reservoir and Twin Buttes Reservoir watersheds.

Initial monitoring results have produced information showing increased groundwater recharge, plus reactivation of once dead springs. The North Concho River which feeds O.C. Fisher Reservoir near San Angelo, Texas, in late 2004 again became a perennial stream flowing from its headwaters in northern Sterling County along a 55 mile route all the way to where it enters O. C. Fisher Reservoir in Tom Green County. Other major tributaries of the North Concho River such as Grape Creek, Sterling Creek and Chalk Creek which also became perennial in 2004 contributing to the return of the river to a perennial and once natural status.

The North Concho watershed brush control project is in its final phase of completion with only 60,000 acres remaining to be cleared in the intended 410,000 acres targeted by the initial feasibility study approved by the Texas Legislature.

It is anticipated that the final funding requirement to complete the North Concho project will require funding from the Texas Legislature of approximately $750,000 with landowners contributing an additional $420,000.

Removal of brush on almost 350,000 acres of mesquite and juniper on the North Concho River watershed is credited with the primary reason for stream rejuvenation to a condition which has restored the watershed more nearly to its original natural state.

The second major brush control program is centered on the Twin Buttes Reservoir watershed and comprises a targeted 600,000 acres. To date almost one-fourth of this anticipated acreage has been completed or contracted for brush removal.

Already increased spring flow has been monitored and documented on springs and river flows on the South Concho River, Dove Creek and Spring Creek which feed Twin Buttes Reservoir. This spring flow alone resulted in more than 10,000 acre feet of water captured in Twin Buttes Reservoir from December 2004 through April 2005.

The Anson Springs at the headwaters of the South Concho River which normally flow 20 to 25 cfs have been measured at an increased flow of 45 to 50 cfs daily. Dove Creek Springs at the headwaters of Dove Creek normally flow 10 to 15 cfs in that same four month period showed increased flows of 20 to 30 cfs daily. And Spring Creek flow materially increased in that same period from 10 cfs to 20 cfs daily.

Twin Buttes Reservoir net gain per day from all this spring flow with no rainfall, averaged almost 150 acre feet per day. To complete the Twin Buttes brush project during the next four years, an appropriation of $4 million per biennium will be required from the Texas Legislature.

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 and Champion Creek Reservoirs, and
- Continued cooperation with federal agencies to secure funds for project brush control projects that will improve water quality such as salt cedar control.

8.3.8 Desalination

The City of San Angelo, Upper Colorado River Authority and Region F Planning Group have completed a comprehensive regional study of potential sources of brackish water supplies which could be treated and utilized for fresh water for San Angelo and surrounding regional political subdivisions.

Eight potential locations for well field development have been identified in Tom Green, Coke and Irion Counties where significant brackish water supplies in the Dockum and Whitehorse formations have been documented.

This study has recommended test well drilling and pumping analysis of different sites to prove quantity and quality. Also included in this feasibility study will be facility recommendations and cost estimates for treatment collection, transmission and treatment of brackish water supplies to municipalities in the region.

Region F Planning Group recommends the Texas Legislature provide funds to assist local governments in the implementation of development of these water resources.

8.3.9 Weather Modification

There are currently three 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 water rights 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 SB1.

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.

8.4 Regional Planning Process

Data Development and Availability

Data collection and quality control of data are an integral part of water planning. At the beginning of the first round of regional water planning, TWDB provided every region with detailed, up-to-date summaries of data collected by the TWDB. For this round, the 2006 regional water plans and the 2007 State Water Plan will be developed using data that is six or seven years old. Region F recommends that before the next round of regional water planning that TWDB meet with the regions and their consultants to discuss the roles of TWDB and the regions in data collection and quality control of data.

Rule Simplification

The rules governing regional water planning are overly complex and unnecessarily add to the cost of regional water planning. Before developing the scopes of work for the next round of planning, Region F recommends that TWDB meet with the regions and their consultants regarding rule simplification.

Alternative Strategies

Section 357.7(a) (9) of the TWDB Regional Water Planning guidelines (1) requires "specific recommendations of water management strategies to meet the needs…". Listing alternative strategies among which a water supplier can choose is not considered part of the recommended water plan and creates consistency issues for permitting and funding.

To maintain local control and flexibility in water supply development, water suppliers need to have a full range of options as they seek to provide new water supplies for Texas' future. Changing circumstances and additional studies can change the preferred alternative for new supplies very quickly. To allow the water user groups the most efficient and economical approach to developing water supplies, the Region F Water Planning Group recommends:

- Legislature and state agencies allow willing buyer/willing seller transactions of water rights and treated water to occur without additional regulations.
- The TWDB and TCEQ interpret existing legislation to give the maximum possible flexibility in determining "consistency" with the regional water plan. Changes in the timing of development, the order in which strategies are developed, the amount of supply, or details of a project should be considered to meet regulatory requirements for with the regional plan.
- The TWDB and TCEQ make liberal use of their ability to waive consistency requirements.
- Legislative and/or regulatory changes be revised to allow alternative water management strategies to be included in the regional water plan.

Clear Guidance on Resolving Consistency Issues

The Texas Water Development Board has implemented a policy that greatly limits the interpretation of consistency with the State Water Plan by not considering the text of the 2001 regional water plans in their determination of "consistency". This policy was not made clear to the regional water planning groups prior to adoption of the 2001 plans. To better assist the RWPGs with developing a regional water plan that best serves the water users and providers within the regions, the TWDB should publish the criteria for what projects will be considered consistent with the 2006 regional water plans prior to these plans being adopted by the regional water planning groups.

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.

8.4 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. Supports protection of existing water rights and encourages review and study of mechanisms to protect rights, including potential modification of the prior appropriation doctrine.

3. Supports the protection of environmental values and developing water supply using brush control and desalination.

4. Supports state funding for environmental studies with local stakeholder input.

5. Supports protection of existing water rights when considering instream flows.

6. 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.

7. Supports state funding of land management activities to promote conservation of the region's natural resources.

8. 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.

9. 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.

10. Opposes cancellation of uncommitted or unused water contracts or water rights.

11. 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.

12. 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.

13. Supports State funding for desalination projects of brackish groundwater.
14. Recommends TCEQ develop rules for disposal wells which would facilitate the disposal of reject water from a membrane treatment plant, including desalination plants.
15. Supports State funding for existing weather modification programs and the creation of new programs.
16. 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.
17. Recommends that TCEQ develop rules for the disposal of constituent residuals from the treatment of radionuclides.
18. 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.
19. Recommends that TCEQ revise its policy on requiring the use of secondary water standards, particularly TDS, when granting permits.
20. Recommends state participation in water conservation through technical assistance to water users and monetary incentives to entities that implement advanced conservation.
21. Opposes mandatory targets and goals for water use.
22. Supports continued State participation in research and demonstration projects for conservation.
23. Supports the development of a state-wide public information and education program to promote water conservation.

24. Supports the use of water conservation pricing and recognition of water conservation as an appropriate goal when setting rates.

25. Supports legislation that would allow the reuse of water in a safe and economical manner.

26. Supports the development of procedures for disposal of waste streams from desalination and reclamation projects in a safe and economical manner.

27. Supports legislation that will encourage and allow aquifer storage and recovery projects to be developed in an economical manner.

28. Supports state funding of pilot projects for desalination, reclamation and aquifer storage and recovery projects.

29. 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.

30. 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 water rights 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.

31. Supports retention of the Rule of Capture while encouraging fair treatment of all stakeholders.

32. Supports basing groundwater supplies used for regional water planning on the governing water conservation districts' management goals and regulatory requirements.

33. Supports a requirement for notification of Regional Water Planning Groups whenever a significant amount of water is being exported from a groundwater conservation district.

34. Supports the collection of groundwater data that would be used to carry out the intent of SB 1.

35. Encourages the state to review its groundwater resources on all state owned land and determine how those resources should be managed.

36. Supports the protection of groundwater resources through the current oil and gas operation rules and the state-initiated well plugging program.

37. 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.

38. Recommends the legislature restore funds to the well plugging account, which were transferred to the general revenue fund in 2003.

39. Recommends the clean-up and remediation of all contamination related to the processing and transportation of oil and gas.

40. Encourages the use of higher TDS water for stream-electric generation.

41. 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. The ability to use alternative strategies,

    d. Provision of clear guidance on resolving consistency issues,

    e. Waivers of the requirement to amend the regional water plan for small entities, and

f. Coordination between TWDB and TCEQ regarding the use of WAMs for regional water planning.

8.5 List of References

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[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

This plan has identified about $1.2 billion in improvements (2002 dollars) needed by 2060 to meet the projected water demands in Region F. In response to potentially significant increases in state and local financial contributions for water infrastructure projects, the Texas Legislature requested that an infrastructure financing survey be conducted as part of the regional water planning process to better assess the State's role in financing the identified water projects. This chapter identifies the portion of capital improvements recommended for Region F that will require outside financial assistance and identify potential financing sources.

9.1 Surveys

The Region F consultants sent a survey about potential funding options as part of the strategy approval process. This survey was part of a package sent to municipal water user groups for comment and approval of strategies. The package included a description of the strategy, the impacts of the strategy and the costs of the strategy in addition to the financing survey. The descriptions of the strategies are the basis for the Chapter 4 of this plan. These packages were mailed out at various times in the planning process to 11 entities representing 31 water user groups in Region F with identified needs.

No attempt was made to survey needs for aggregated demands unless a specific entity could be identified as the sponsor of the strategy. Aggregated demands include County Other in the municipal category, as well as county-wide demands for irrigation, manufacturing, and steam-electric power generation. There are no identified needs for livestock. For the purposes of this plan, it can be assumed that financing for the irrigation conservation strategy will come primarily from state programs, while needs associated with manufacturing and steam-electric power generation will be met entirely with private funds.

One of the major strategies in the current Region F plan is the subordination strategy. Implementation of this strategy meets most of the municipal needs in Region F. Implementation and cost of this strategy is uncertain at this time. Therefore municipalities with needs that are completely met by the subordination strategy were not surveyed as part of the planning process. Also, entities that have needs that are solely the result of contract expiration were not surveyed unless implementing a new contract was associated with infrastructure improvements.

Ten responses were obtained from the surveyed entities. Richland SUD declined to return a survey because they were uncertain how to meet standards for radionuclides. Table 9.1-1 summarizes the results of the survey. Table 9.1-1 gives a more detailed summary of the responses. The actual responses to the survey may be found in Appendix 9A.

Most survey respondents did not identify specific programs that would be used for financing. Federal funds seem to be a popular financing method for smaller communities, with state programs preferred by larger entities. Appendix 9B contains a summary of possible options for financing projects in Region F.

Table 9.1-1
Summary of Infrastructure Financing Surveys

Source of Funding	Cost	Percentage
Cash Reserves	$8,391,898	2%
Bonds	$104,194,800	26%
Bank Loans	$0	0%
Federal Programs	$10,897,830	3%
State Programs	$2,248,220	1%
Other	$1,383,372	0%
Not Specified	$268,289,650	68%
Total Capital Costs	*$395,405,770*	*100%*

Table 9.1-2
Results of Infrastructure Financing Surveys

Entity	Representing Water User Groups	Percentage						Cost								Comments
		Cash Reserves	Bonds	Bank Loans	Federal Programs	State Programs	Other	Cash Reserves	Bonds	Bank Loans	Federal Programs	State Programs	Other	Not Specified	Total	
City of Andrews	Andrews	50%			10%	40%		$2,189,150	$0	$0	$437,830	$1,751,320	$0	$0	$4,378,300	
	Andrews County Other (partial)															
City of Ballinger	Ballinger							$0	$0	$0	$0	$0	$0	$1,980,000	$1,980,000	Returned survey but did not specify programs
	Runnels County Other (partial)															
	Runnels County Manufacturing (partial)															
CRMWD	Big Spring	Yes	Yes		Yes	Yes		X	X	$0	X	X	$0	$263,355,930	$263,355,930	Indicated programs but did not identify specific percentages
	Howard County Manufacturing (partial)															
	Coahoma															
	Ector County UD															
	Odessa															
	Ector County Manufacturing (partial)															
	Snyder															
	Scurry County Other (partial)															
	Stanton															
City of Bronte	Bronte Village	10%			90%			$170,260	$0	$0	$1,532,340	$0	$0	$0	$1,702,600	
City of Eden	Eden	12%					88%	$179,918	$0	$0	$0	$0	$1,319,402	$0	$1,499,320	Other specified as State and Federal grants
	Concho County Other (partial)															
City of Menard	Menard	5%			90%		5%	$63,970	$0	$0	$1,151,460	$0	$63,970	$0	$1,279,400	ORCA water improvements
	Menard County Other (partial)															
City of Midland	Midland	5%	90%		5%			$5,788,600	$104,194,800	$0	$5,788,600	$0	$0	$0	$115,772,000	
	Midland County Other (partial)															
	Midland County Manufacturing (partial)															
Richland SUD	Richland SUD							$0	$0	$0	$0	$0	$0	$1,293,720	$1,293,720	Declined to fill out survey
City of Robert Lee	Robert Lee				80%	20%		$0	$0	$0	$1,987,600	$496,900	$0	$0	$2,484,500	TWDB loans and/or grants, Texas Community Development Grant Program
	Coke County Other (partial)															
City of San Angelo	San Angelo	10%	40%		50%			$0	$0	$0	$0	$0	$0	$0	$0	TWDB State Revolving Funds & TWDB Demonstration Grants
	Tom Green County Other (partial)															
	Tom Green County Manufacturing															
City of Winters	Winters							$0	$0	$0	$0	$0	$0	$1,660,000	$1,660,000	Survey not returned. Strategy implementation date after 2020.
	Runnels County Other (partial)															
	Runnels County Manufacturing (partial)															
Total								*$8,391,898*	*$104,194,800*	*$0*	*$10,897,830*	*$2,248,220*	*$1,383,372*	*$268,289,650*	*$395,405,770*	

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 10.2-1 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 10.2-2 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 10.2-1
Voting Members of the Region F Water Planning Group

Name	Interest	County
Len Wilson	Public	Andrews
Wendell Moody	Public	Concho
Judge Marilyn Egan	Counties	Runnels
Judge Johnny Jones	Counties	Crockett
Will Wilde	Municipalities	Tom Green
Buddy Sipes	Industries	Midland
Kenneth Dierschke	Agricultural	Tom Green
Terry Scott	Agricultural	Coleman
Lowell Woodward	Agricultural	Pecos
Steven C. Hofer	Environmental	Midland
Caroline Runge	Environmental	Menard
Stuart Coleman	Small Business	Brown
Andrew Valencia	Elec. Gen. Util.	Ward
Stephen Brown	River Authorities	Tom Green
John Grant	Water Districts	Howard
Scott Holland	Water Districts	Irion
Cindy Cawley	Water Districts	Schleicher
Larry Turnbough	Water Districts	Reeves
Richard Gist	Water Utilities	Brown

Table 10.2-2
Non-Voting Members of the Region F Water Planning Group

Name	County
Winton Milliff	Coke
Gordon Hooper	Crane
Rick Harston	Glasscock
Billy Hopper	Loving
Ken Carver	Martin
Don Daniel	Mason
Sue Young	Mitchell
Cindy Weatherby	Reagan
Gary Foster	Sterling
Joe David Ross	Sutton
John Shepard	Winkler

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. Outreach included both questionnaires and meetings with selected water user groups. The questionnaires sought information on population and water use projections, drought planning, water quality issues, financing, and other water supply issues. Particular emphasis was placed on receiving input from water user groups with water supply needs.

The subordination strategy was carried out in conjunction with the Lower Colorado Region (Region K). Included in this effort were presentations at public meetings in Region K on March 9, 2005 and April 13, 2005.

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.
- Special Surface and Groundwater Workshops were held in Big Spring on October 27, 2003. These workshops focused on technical issues associated with surface water and groundwater supplies in Region F.
- Scope of Work, meeting minutes and other information were available on the CRMWD and TWDB websites.

10.4 Public Meetings and Public Hearings

As required by Senate Bill 1 rules, the Region F Water Planning Group held initial public hearing to discuss the planning process and the scope of work for the region on March 28, 2002. 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 July 27, 2005 copies of the draft *Initially Prepared Region F Water Plan* were mailed to Region F county courthouses and libraries for public review. Copies of the draft plan were also posted on the TWDB website, and additional hard copies were made available to interested parties. 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 August 29, 2005, the Region F Water Planning Group held a public hearings 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 November 7, 2005. 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*.

10.5 Comments from State and Federal Agencies

Appendix 10B contains comments on the draft *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.

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, 3) lack of clear options for water users of the Hickory aquifer and 4) 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 Options for Users of the Hickory Aquifer

Many users of the Hickory aquifer are small communities or rural water systems. In these areas the Hickory aquifer is the only significant source of water for municipal, industrial and agricultural use. These users are concerned that the expense of treatment to meet drinking water standards is not justified by the health risk posed by the presence of radionuclides in water from this aquifer. Lack of clear regulations regarding the handling and disposal of waste byproducts of treatment for radionuclides is a concern as well. Many are concerned that the economic impact of compliance will take scarce economic resources away from other, more significant issues in these areas.

10.6.4 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 required for a more thorough evaluation of water conservation are not available. Experience during the recent drought 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. Additional studies will be needed to quantify savings from water conservation.