1 DESCRIPTION OF THE 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 future water needs of all Texans. To implement this planning process, the Texas Water Development Board (TWDB) created 16 regional water planning areas across the state and established regulations governing regional planning efforts. The first 16 Regional Water Plans developed as part of the SB1 planning process were submitted to the TWDB in 2001. The TWDB combined these regional plans into one statewide plan. SB1 calls for these plans to be updated every five years. Since 2001, the regional water plans have been updated three times, in 2006, 2011, and 2016, and then consolidated into the state water plans, Water for Texas 2007, 2012, and 2017, respectively.

The TWDB refers to the current round of regional planning as SB1, Fifth Round. This report is the update to the 2016 Region F Water Plan and will become part of the basis for the next state water plan.

This chapter presents a description of Region F, one of the 16 regions created to implement SB1. Figure 1-1 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 each chapter, and a bibliography is included in Appendix A.

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 shows historical populations for these counties from 1900 through 2010 and estimated populations for 2017[1].

Region F at a Glance:

- 32 Counties
- Mostly rural
- Major cities include Midland, Odessa, and San Angelo
- Heart of Permian Basin development of oil & gas
- Major economic drivers include agriculture, oil & gas, and service industries
- 76 % of total regional water use came from groundwater in 2016
- 49 % of municipal water supply is from surface water
- 17 major reservoirs in Region F
- 14 named aquifers
- Wide range of climate variability across region
- Area is subject to frequent droughts

Figure 1-1
Area Map

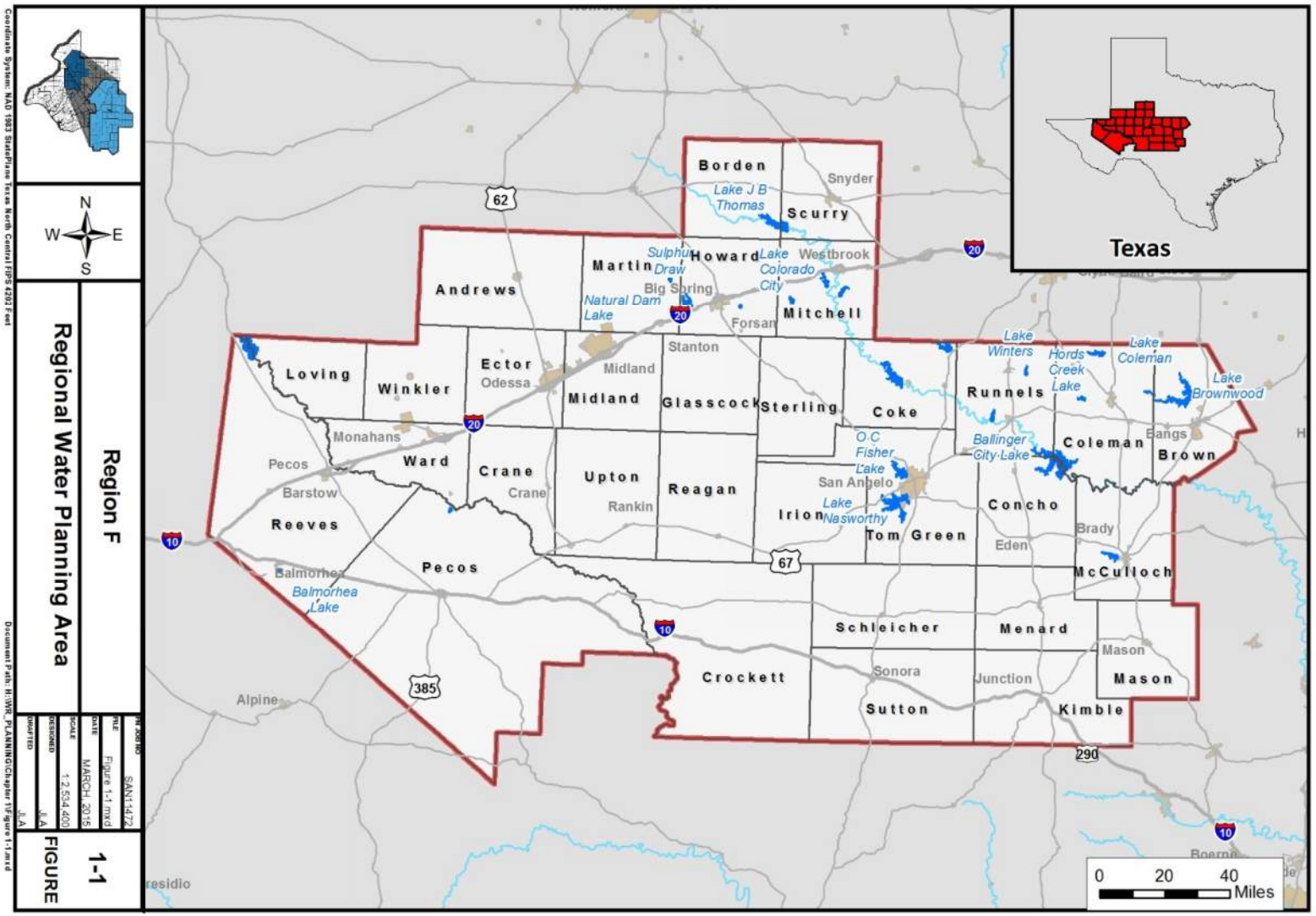


Table 1-1
Historical Population of Region F Counties[a]

County	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	2017
Andrews	87	975	350	736	1,277	5,002	13,450	10,372	13,323	14,338	13,004	14,786	17,631
Borden	776	1,386	965	1,505	1,396	1,106	1,076	888	859	799	729	641	670
Brown	16,019	22,935	21,682	26,382	25,924	28,607	24,728	25,877	33,057	34,371	37,674	38,106	37,870
Coke	3,430	6,412	4,557	5,253	4,590	4,045	3,589	3,087	3,196	3,424	3,864	3,320	3,303
Coleman	10,077	22,618	18,805	23,669	20,571	15,503	12,458	10,288	10,439	9,710	9,235	8,895	8,415
Concho	1,427	6,654	5,847	7,645	6,192	5,078	3,672	2,937	2,915	3,044	3,966	4,087	4,311
Crane	51	331	37	2,221	2,841	3,965	4,699	4,172	4,600	4,652	3,996	4,375	4,713
Crockett	1,591	1,296	1,500	2,590	2,809	3,981	4,209	3,885	4,608	4,078	4,099	3,719	3,555
Ector	381	1,178	760	3,958	15,051	42,102	90,995	91,805	115,374	118,934	121,123	137,130	157,173
Glasscock	286	1,143	555	1,263	1,193	1,089	1,118	1,155	1,304	1,447	1,406	1,226	1,360
Howard	2,528	8,881	6,962	22,888	20,990	26,722	40,139	37,796	33,142	32,343	33,627	35,012	36,198
Irion	848	1,283	1,610	2,049	1,963	1,590	1,183	1,070	1,386	1,629	1,771	1,599	1,511
Kimble	2,503	3,261	3,581	4,119	5,064	4,619	3,943	3,904	4,063	4,122	4,468	4,607	4,406
Loving	33	249	82	195	285	227	226	164	91	107	67	82	136
Martin	332	1,549	1,146	5,785	5,556	5,541	5,068	4,774	4,684	4,956	4,746	4,799	5,562
Mason	5,573	5,683	4,824	5,511	5,378	4,945	3,780	3,356	3,683	3,423	3,738	4,012	4,203
McCulloch	3,960	13,405	11,020	13,883	13,208	11,701	8,815	8,571	8,735	8,778	8,205	8,283	7,960
Menard	2,011	2,707	3,162	4,447	4,521	4,175	2,964	2,646	2,346	2,252	2,360	2,242	2,121
Midland	1,741	3,464	2,449	8,005	11,721	25,785	67,717	65,433	82,636	106,611	116,009	136,872	165,386
Mitchell	2,855	8,956	7,527	14,183	12,477	14,357	11,255	9,073	9,088	8,016	9,698	9,403	8,232
Pecos [c]	2,360	2,071	3,857	7,812	8,185	9,939	11,957	13,748	14,618	14,675	16,809	15,507	15,618
Reagan [b]		392	377	3,026	1,997	3,127	3,782	3,239	4,135	4,514	3,326	3,367	3,700
Reeves	1,847	4,392	4,457	6,407	8,006	11,745	17,644	16,526	15,801	15,852	13,137	13,783	15,295
Runnels	5,379	20,858	17,074	21,821	18,903	16,771	15,016	12,108	11,872	11,294	11,495	10,501	10,333
Schleicher	515	1,893	1,851	3,166	3,083	2,852	2,791	2,277	2,820	2,990	2,935	3,461	2,995
Scurry	4,158	10,924	9,003	12,188	11,545	22,779	20,369	15,760	18,192	18,634	16,361	16,921	17,004
Sterling	1,127	1,493	1,053	1,431	1,404	1,282	1,177	1,056	1,206	1,438	1,393	1,143	1,301
Sutton	1,727	1,569	1,598	2,807	3,977	3,746	3,738	3,175	5,130	4,135	4,077	4,128	3,798
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	110,224	117,689
Upton	48	501	253	5,968	4,297	5,307	6,239	4,697	4,619	4,447	3,404	3,355	3,661
Ward	1,451	2,389	2,615	4,599	9,575	13,346	14,917	13,019	13,976	13,115	10,909	10,658	11,423
Winkler	60	442	81	6,784	6,141	10,064	13,652	9,640	9,944	8,626	7,173	7,110	7,574
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***	***623,354***	***685,107***
% Change		*119%*	*-14%*	*73%*	*4%*	*32%*	*30%*	*-5%*	*15%*	*7%*	*2%*	*6%*	*10%*

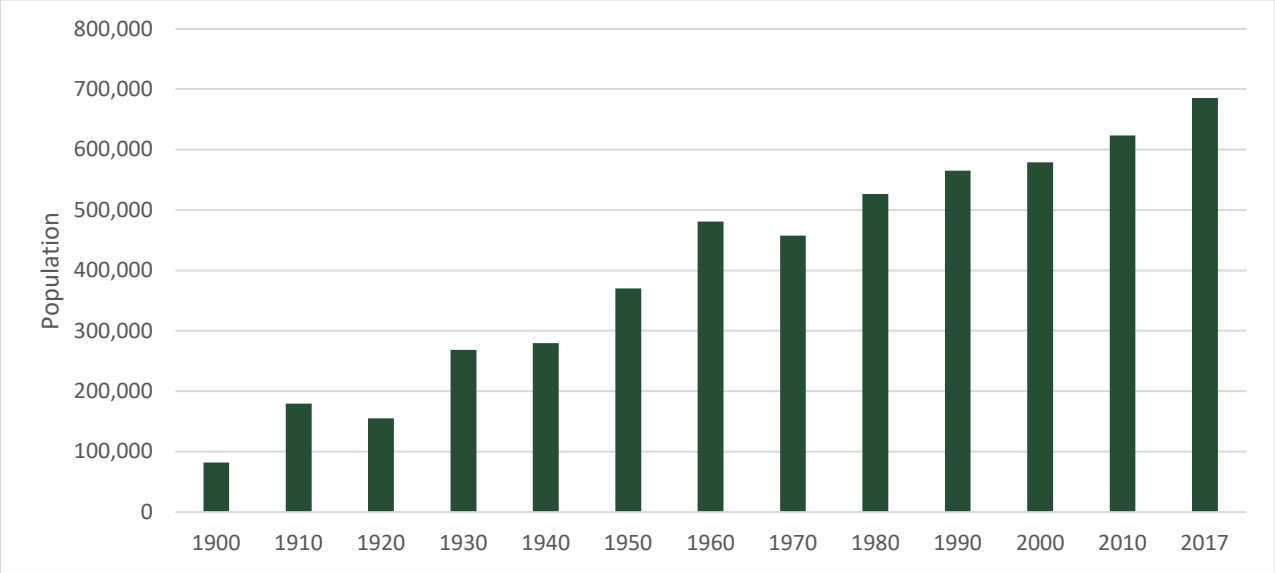
Notes: a. Historical and estimated population data are from the U.S. Census Bureau[1]

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.

Figure 1-2 shows graphically the total population of the region. The population of Region F has increased from 81,985 in 1900 to 623,354 in 2010. Since the 2010 census, it is estimated that the population of Region F increased to 683,918 in the year 2017.

Figure 1-2
Historical Population of Region F



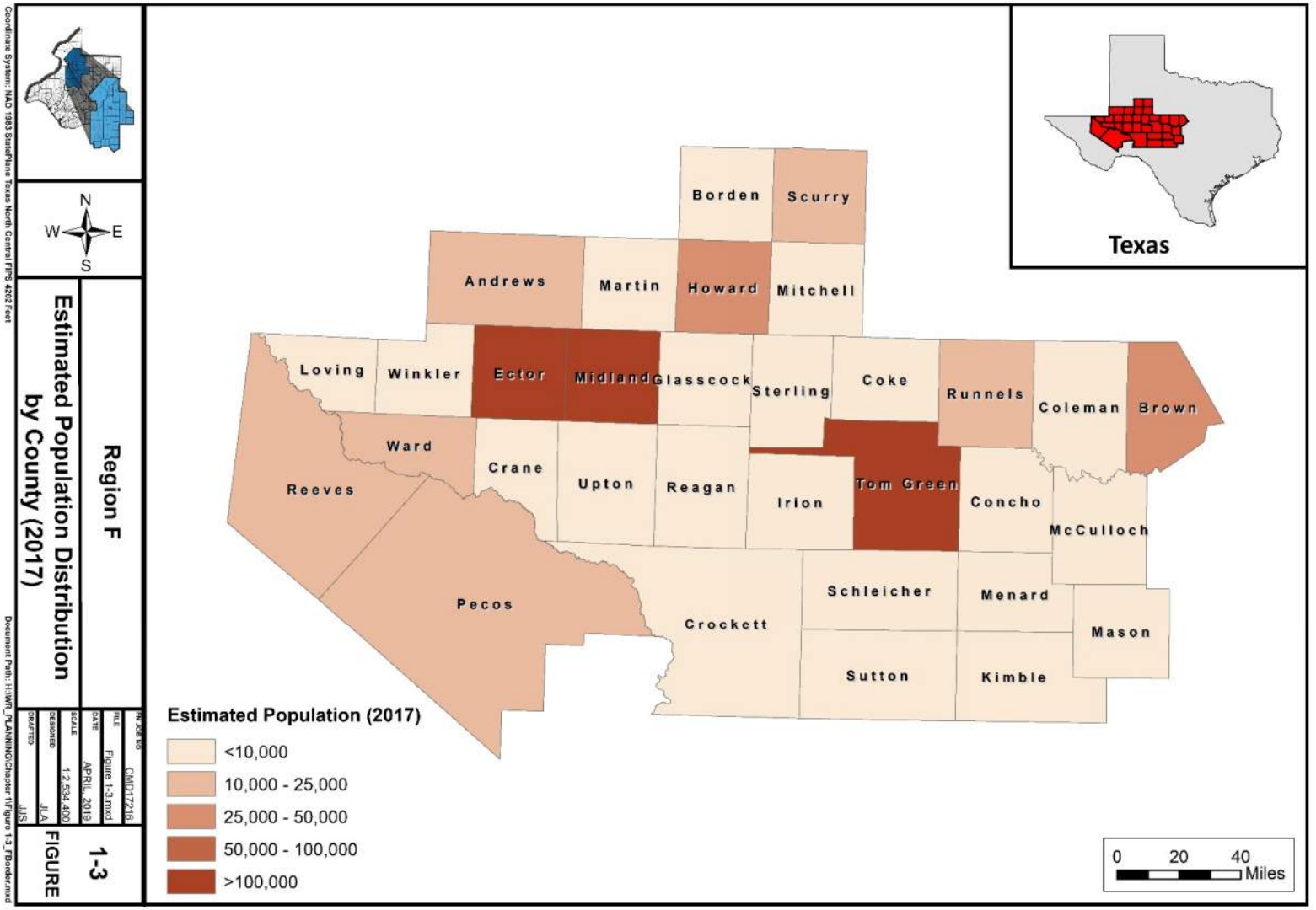
According to 2017 population estimates by the U.S. Census Bureau, Region F accounted for 2.5 percent of Texas' total population. Figure 1-3 shows the distribution of population in Region F counties based on the census data. Ector, Midland, and Tom Green were the three most populous counties in Region F, accounting for 65 percent of the region's population. Brown and Howard Counties were the next most populous counties with more than 35,000 people in each. Table 1-2 lists the seven cities in Region F with a 2017 population of more than 10,000, which encompass over 60 percent of the population in Region F.

Table 1-2
Region F Cities with a Year 2017 Population Greater than 10,000

City	Year 2017 Population
Midland	136,089
Odessa	116,861
San Angelo	100,119
Big Spring	27,905
Brownwood	18,831
Andrews	13,472
Snyder	11,320
Total	***424,597***

Data are from the 2017 US Census Bureau Estimates[1].

Figure 1-3
Estimated Population Distribution by County (2017)



1.1.1 Economic Activity in Region F

Region F includes the Midland, Odessa, and San Angelo Metropolitan Statistical Areas (MSAs). The largest employment sectors in both the Midland and Odessa MSAs are the oil and gas industry, retail trade, and healthcare services[2]. Educational services, construction, and leisure and hospitality are also important employment sectors in these areas. In the San Angelo MSA the largest employment sectors are health services and retail trade, followed by educational services and leisure and hospitality.

Table 1-3 summarizes 2017 payroll data for Region F by county and economic sector[3]. Figure 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 private business sectors in Region F in terms of payroll in 2017 are natural resources and mining, trade, transportation, and utilities, and professional and business services, which together account for 54 percent of the region's total payroll.

Over the past decade, the oil and gas industry has been growing rapidly in the Permian Basin, particularly over the last decade (see Section 1.4.3). Since 2007, the payroll for mining and natural resources has more than doubled from $2.0 billion to nearly $4.5 billion in 2017 in Region F3. In 2017, Region F counties accounted for nearly 15% of the total state payroll for natural resources and mining. This increase in production has led to increased population for many cities within the region and subsequently, increased water use. The Permian Basin underlies most of Region F, as shown in Figure 1-5.

Table 1-3
2017 County Payroll by Category ($1000)

Category	Andrews	Borden	Brown	Coke	Coleman	Concho	Crane	Crockett	Ector	Glasscock	Howard
Federal Government	728	31	6,956	494	1,480	598	244	225	10,916	273	68,034
State Government	1,567	315	41,237	608	1,171	781	475	1,655	82,367	0	27,087
Local Government	62,513	3,302	69,285	8,214	17,405	7,897	16,643	11,883	415,653	0	75,367
Private Industry, Total	376,534	3,545	465,699	14,019	45,703	19,929	47,626	47,733	3,481,114	18,135	453,729
Goods-Producing	212,224	1,286	215,066	3,559	8,872	2,424	24,907	21,846	1,646,308	12,941	198,156
Natural Resources and Mining	137,546	0	8,891	0	1,915	1,208	23,107	19,070	890,468	12,283	81,477
Construction	61,389	0	25,163	1,470	3,620	0	0	0	458,391	0	36,786
Manufacturing	13,289	0	181,012	0	3,337	0	0	0	297,449	0	79,892
Service Providing	164,310	2,259	250,633	10,460	36,831	17,506	22,719	25,887	1,834,806	5,194	255,573
Trade, Transportation, and Utilities	84,582	933	85,648	2,275	10,852	2,757	14,712	10,630	842,451	4,048	99,332
Information	5,098	0	5,606	0	0	0	0	0	21,396	0	4,726
Financial Activities	22,205	0	18,655	1,072	7,103	1,977	3,222	7,364	205,127	0	19,081
Professional and Business Services	26,144	998	20,439	5,523	1,795	0	1,852	1,675	228,501	0	22,201
Education and Health Services	5,411	0	93,147	554	11,208	4,386	1,900	0	251,741	0	75,277
Leisure and Hospitality	11,551	0	19,583	255	3,147	1,268	610	3,314	161,257	0	21,999
Other Services	9,044	239	7,205	0	1,124	261	0	2,289	123,357	0	12,755
Unclassified	274	0	349	0	0	0	0	0	976	7	202
Total Payroll	***441,341***	***7,193***	***583,178***	***23,334***	***65,759***	***29,206***	***64,987***	***61,495***	***3,990,051***	***23,412***	***624,217***
Total Employees	***7,187***	***194***	***15,851***	***676***	***2,131***	***717***	***1,189***	***1,536***	***70,917***	***546***	***12,693***

Table 1-3 (cont.)
2017 County Payroll by Category ($1000)

Category	Irion	Kimble	Loving	Martin	Mason	McCulloch	Menard	Midland	Mitchell	Pecos	Reagan
Federal Government	101	633	0	816	719	1,164	240	39,681	919	3,716	530
State Government	261	3,146	0	655	1,026	2,126	616	32,612	17,431	23,951	609
Local Government	3,830	6,699	0	23,320	8,232	17,061	5,440	392,007	24,622	54,449	16,892
Private Industry, Total	50,708	28,745	0	79,091	25,326	99,502	4,538	5,814,323	42,213	170,817	90,232
Goods-Producing	42,534	6,765	0	35,940	8,429	38,918	1,141	3,135,739	20,197	69,458	41,605
Natural Resources and Mining	40,035	1,071	1,487	0	5,336	28,718	576	2,625,271	16,648	50,133	38,139
Construction	0	3,354	0	23,256	2,322	2,695	0	305,992	0	13,899	3,466
Manufacturing	0	2,340	0	0	770	7,504	0	204,476	0	5,427	0
Service Providing	8,174	21,980	1,328	43,151	16,897	60,584	3,397	2,678,584	22,016	101,358	48,628
Trade, Transportation, and Utilities	5,795	7,972	0	29,945	6,107	34,784	1,903	1,024,227	11,284	57,872	44,098
Information	0	0	0	0	0	804	0	54,527	347	782	0
Financial Activities	0	2,194	0	2,360	3,657	4,496	676	275,627	2,338	10,747	957
Professional and Business Services	371	1,012	0	1,949	2,195	2,034	96	692,947	1,391	9,871	499
Education and Health Services	511	4,733	0	3,722	1,835	12,848	0	309,505	4,263	7,438	0
Leisure and Hospitality	0	4,933	0	1,297	2,007	4,030	462	194,901	1,861	11,971	2,033
Other Services	166	1,043	0	1,737	753	1,489	163	123,958	532	2,616	995
Unclassified	0	0	0	0	0	100	6	2,892	0	62	0
Total Payroll	***54,900***	***39,223***	***3,852***	***103,882***	***35,303***	***119,853***	***10,834***	***6,278,624***	***85,185***	***252,932***	***108,262***
Total Employees	***789***	***1,293***	***85***	***1,987***	***1,109***	***2,886***	***398***	***89,895***	***2,093***	***5,559***	***1,913***

Table 1-3 (cont.)
2017 County Payroll by Category ($1000)

Category	Reeves	Runnels	Schleicher	Scurry	Sterling	Sutton	Tom Green	Upton	Ward	Winkler	Region F Total
Federal Government	4,353	1,843	588	1,607	250	234	67,817	288	719	482	**216,679**
State Government	2,978	1,923	173	15,019	674	1,853	109,973	544	2,101	529	**375,463**
Local Government	66,081	25,837	7,675	54,755	4,627	14,545	197,584	20,300	32,036	23,215	**1,687,367**
Private Industry, Total	195,495	70,505	23,478	274,817	18,699	101,539	1,547,089	82,322	226,498	137,480	**14,057,183**
Goods-Producing	106,721	30,514	13,500	134,663	11,487	47,865	367,559	53,253	135,948	91,348	**6,741,172**
Natural Resources and Mining	39,841	6,888	0	115,792	10,429	35,877	80,493	48,143	108,247	55,966	**4,485,054**
Construction	43,737	4,258	9,205	9,312	1,058	6,444	103,342	5,110	18,965	34,668	**1,177,904**
Manufacturing	23,143	19,368	0	9,559	0	5,545	183,724	0	8,736	713	**1,046,284**
Service Providing	88,774	39,990	9,978	140,154	7,211	53,674	1,179,530	29,069	90,550	46,132	**7,317,339**
Trade, Transportation, and Utilities	51,012	20,900	5,170	75,013	4,638	44,044	339,096	19,499	55,029	27,620	**3,024,231**
Information	1,239	0	0	1,761	0	0	34,554	0	1,705	0	**132,547**
Financial Activities	11,950	3,781	1,036	10,568	1,473	2,514	133,267	1,536	11,883	4,856	**771,721**
Professional and Business Services	6,363	4,493	908	30,114	262	2,714	140,586	573	10,936	8,517	**1,226,957**
Education and Health Services	2,895	7,985	2,406	6,649	0	1,406	392,933	394	2,356	515	**1,206,021**
Leisure and Hospitality	13,342	1,931	0	7,339	0	2,156	97,361	274	6,864	1,963	**577,709**
Other Services	1,737	892	219	8,622	0	631	41,054	0	1,777	2,491	**347,147**
Unclassified	236	8	17	88	0	0	680	0	0	0	**5,897**
Total Payroll	***268,908***	***100,107***	***31,914***	***346,197***	***24,249***	***118,171***	***1,922,464***	***103,454***	***261,353***	***161,706***	***16,345,548***
Total Employees	***5,463***	***2,870***	***764***	***6,694***	***537***	***1,850***	***47,212***	***1,535***	***4,579***	***2,732***	***295,880***

Notes: Data are from U.S. Bureau of Labor Statistics 2017 Census of Employment and Wages data [3]

Figure 1-4
Total County Payrolls (2017)

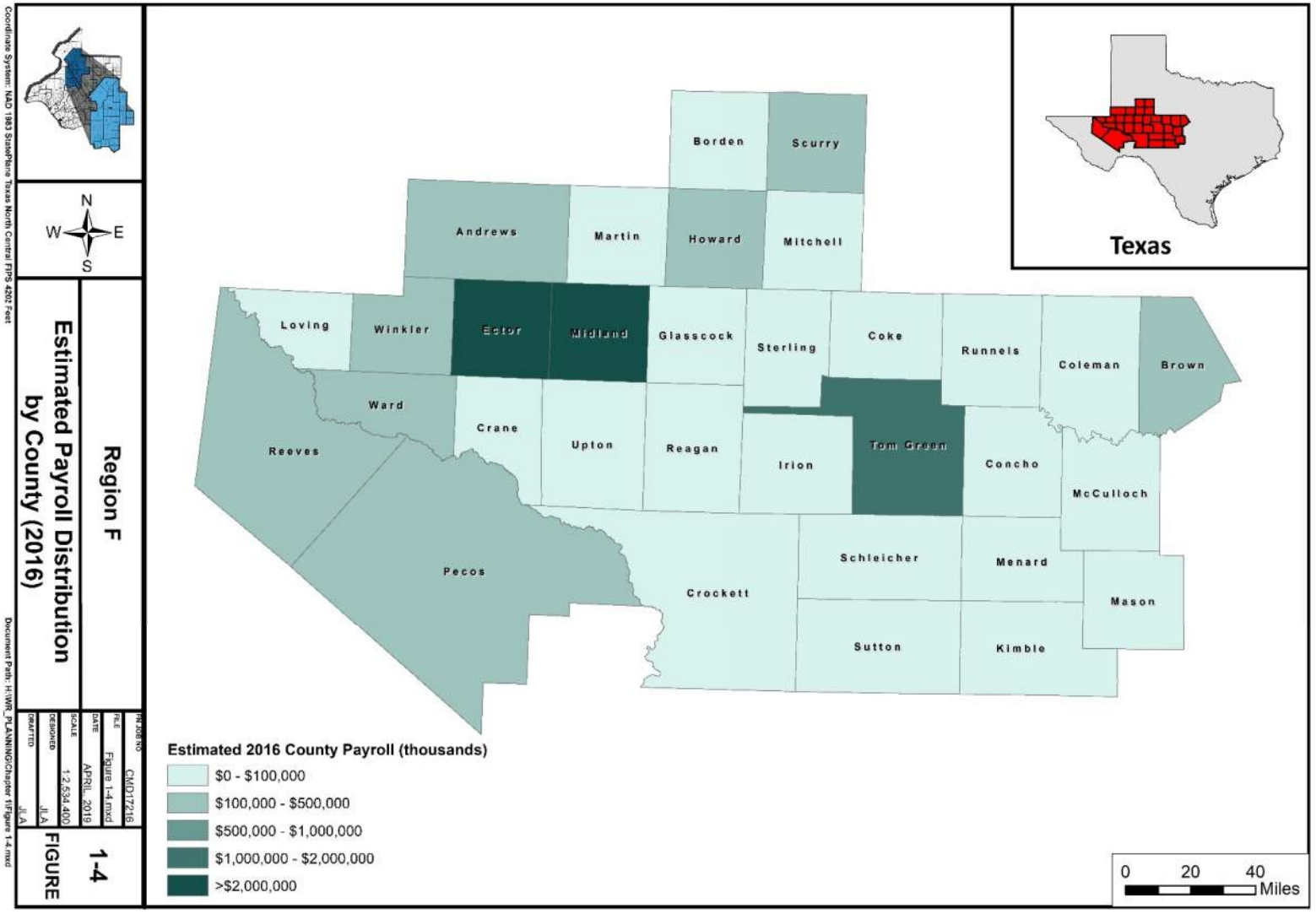
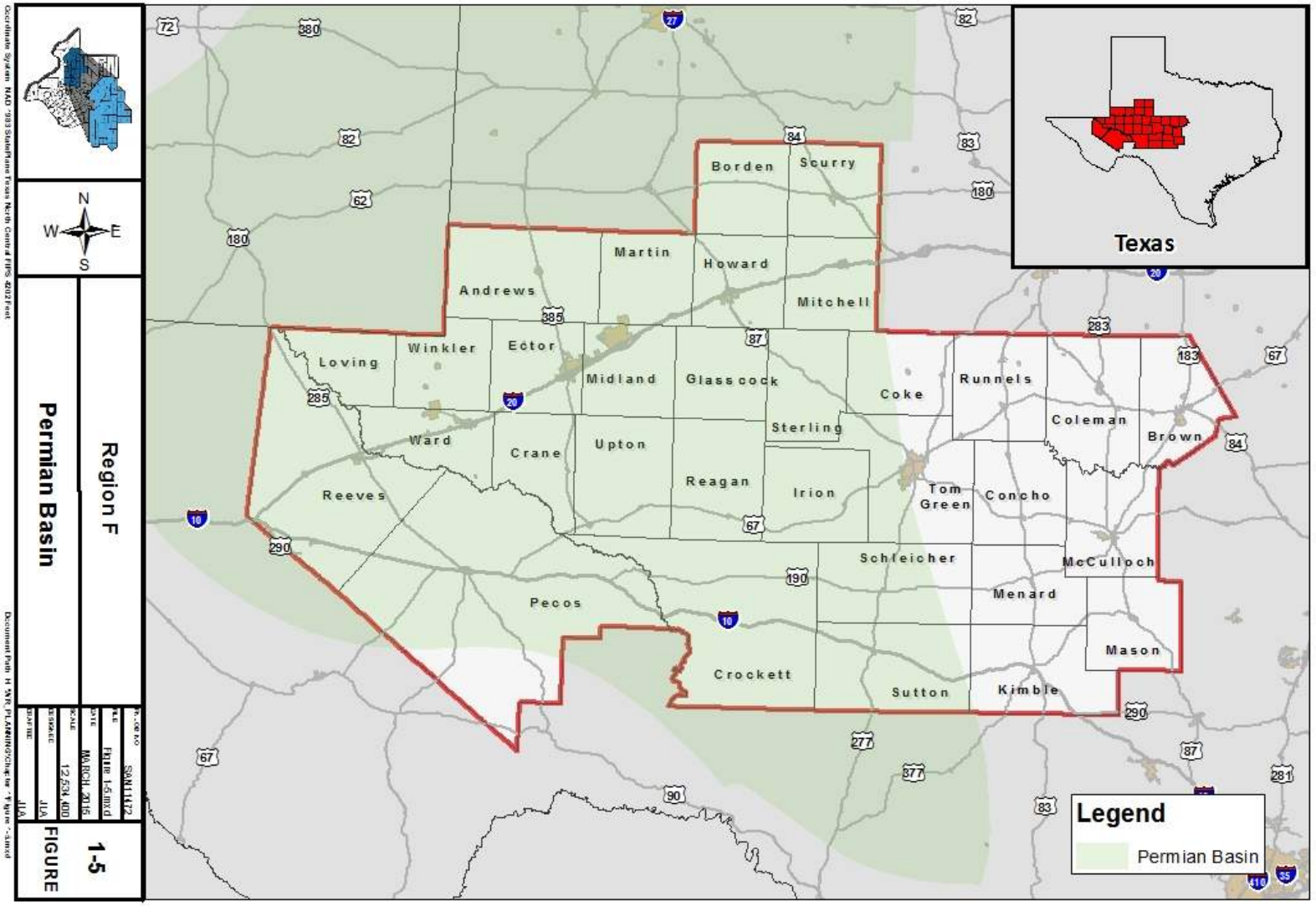


Figure 1-5
Permian Basin in Region F



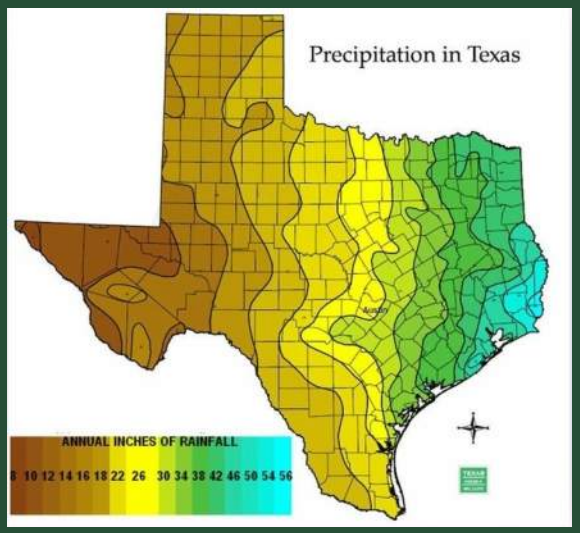
1.1.2 Water-Related Physical Features and Climate in Region F

Most of Region F is in the upper portion of the Colorado River Basin and in the Pecos River portion of the Rio Grande River Basin. A small part of the region is in the Brazos Basin. Figure 1-6 shows the surface water features in the Region F, which include the Colorado River, Concho River, Pecan Bayou, San Saba River, Llano River, and Pecos River.

Table 1-4 lists the 17 major water supply reservoirs in Region F. 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.

Figure 1-7 shows the average annual precipitation throughout Region F[4]. Average precipitation ranges from slightly more than 11 inches per year in Reeves County to approximately 30 inches per year in Brown County. Precipitation generally increases from the western to the eastern portions of the region. Some of the highest evaporation rates in the state are in Region F, which often exceed rainfall throughout the region. Figure 1-8 illustrates the mean annual temperatures throughout Region F[4]. The mean annual temperatures for the entire region varied from a mean minimum temperature of 46.0 °F in Pecos County to a mean maximum temperature of 81.6 °F in Reeves County. The patterns of rainfall, runoff, evaporation, and temperature result in more abundant water supplies in the eastern portion of Region F.

Figure 1-9 shows the major aquifers in Region F, and Figure 1-10 shows the minor aquifers. There are 14 aquifers that supply water to the 32 counties of Region F. The major aquifers are the Edwards-Trinity Plateau, Ogallala, Pecos Valley, and a small portion of the Trinity. The minor aquifers are the Capitan Reef Complex, Cross Timbers, Dockum, Ellenberger-San Saba, Hickory, Igneous, Lipan, Marble Falls, and the Rustler. 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.



Water Related Facts for Region F:

- Three river basins in Region F: Colorado River, Pecos River, Brazos River
- Four major aquifers
- Ten minor aquifers
- Precipitation ranges from 11 inches in the west to 30 inches in the east
- Evaporative losses from area lakes can exceed 5 feet per year

Table 1-4
Major Water Supply Reservoirs in Region F[a,d]

Reservoir Name	Basin	Stream	County(ies)	Water Right Number(s)	Priority Date	Permitted Conservation Storage (Ac-Ft)	Permitted Diversion (Ac-Ft/Yr)	Year 2016 Use (Acre-Feet)	Owner	Water Rights Holder(s)
Lake J B Thomas	Colorado	Colorado River	Borden, Scurry	CA-1002	08/05/1946	204,000	30,000	11,167	CRMWD	CRMWD
Lake Colorado City	Colorado	Morgan Creek	Mitchell	CA-1009	11/22/1948	29,934	5,500	2,837	Luminant Generation	Luminant Generation
Champion Creek Reservoir	Colorado	Champion Creek	Mitchell	CA-1009	04/08/1957	40,170	6,750		Luminant Generation	Luminant Generation
Oak Creek Reservoir	Colorado	Oak Creek	Coke	CA-1031	04/27/1949	30,000	10,000	835	City of Sweetwater	City of Sweetwater
Lake Coleman	Colorado	Jim Ned Creek	Coleman	CA-1702	08/25/1958	40,000	9,000	546	City of Coleman	City of Coleman
E V Spence Reservoir	Colorado	Colorado River	Coke	CA-1008	08/17/1964	488,760	43,000	9,904	CRMWD	CRMWD
Mitchell County Reservoir	Colorado	Off-Channel	Mitchell		2/14/1990	27,266				
Lake Winters	Colorado	Elm Creek	Runnels	CA-1095	12/18/1944	8,374	1,755	No data	City of Winters	City of Winters
Lake Brownwood	Colorado	Pecan Bayou	Brown	CA-2454	09/29/1925	114,000	29,712	8,522	Brown Co. WID	Brown Co. WID
Hords Creek Lake	Colorado	Hords Creek	Coleman	CA-1705	03/23/1946	7,959	2,240	496	COE	City of Coleman
Lake Ballinger	Colorado	Valley Creek	Runnels	CA-1072	10/04/1946	6,850	1,000	260	City of Ballinger	City of Ballinger
O. H. Ivie Reservoir	Colorado	Colorado River	Coleman, Concho & Runnels	A-3866 P-3676	02/21/1978	554,340	113,000	32,534	CRMWD	CRMWD
O. C. Fisher Lake	Colorado	N. Concho River	Tom Green	CA-1190	05/27/1949	80,400	80,400	No data	COE	Upper Colorado River Authority
Twin Buttes Reservoir	Colorado	S. Concho River	Tom Green	CA-1318	05/06/1959	170,000	29,000	No data	U.S. Bureau of Reclamation	City of San Angelo
Lake Nasworthy	Colorado	S. Concho River	Tom Green	CA-1319	03/11/1929	12,500	25,000	No data	City of San Angelo	City of San Angelo
Brady Creek Reservoir	Colorado	Brady Creek	McCulloch	CA-1849	09/02/1959	30,000	3,500	1	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	48,147	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	8,266	Reeves Co WID #1	Reeves Co WID #1
Total						***2,158,136***	***723,757***	***123,515***		

a. A major reservoir has more than 5,000 acre-feet of storage.
b. Total diversions under CA 1002 and CA 1008 limited to 73,000 acre-feet per year. CA 1008 allows up to 50,000 acre-feet per year of diversion. For purposes of this table, the limitation is placed on CA 1008.
c. Permitted storage is reported for water conservation storage. UCRA has permission to use water from the sediment pool.
d. Data are from TCEQ active water rights list[5], TCEQ water rights permits[6], and TCEQ historical water use by water right[7]. Year 2016 use is consumptive.

CA: Certificate of Adjudication; A: Application; P Permit; COE: Corps of Engineers; NA – Data Not Available

Figure 1-6
Surface Water Features in Region F

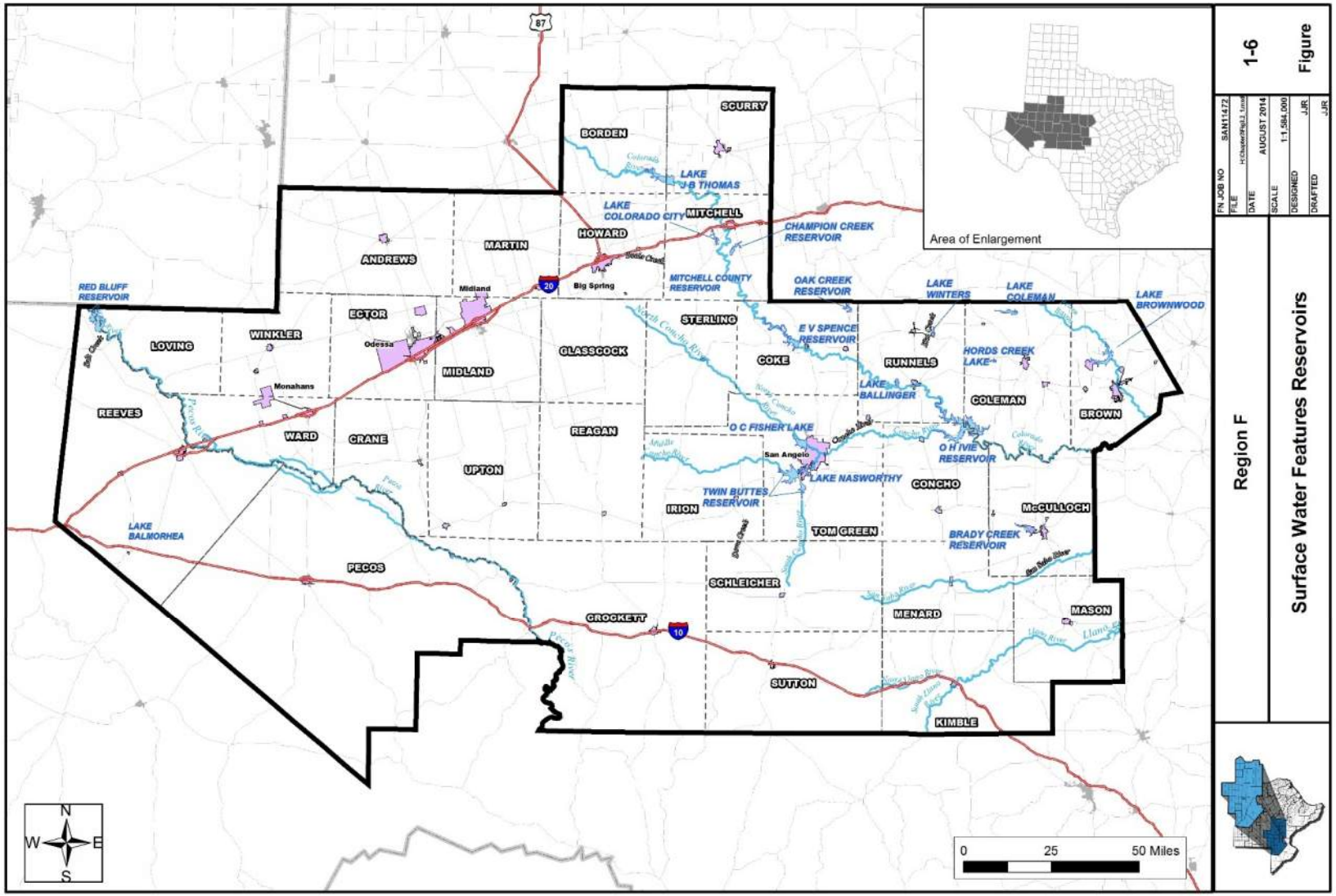


Figure 1-7
Mean Annual Precipitation

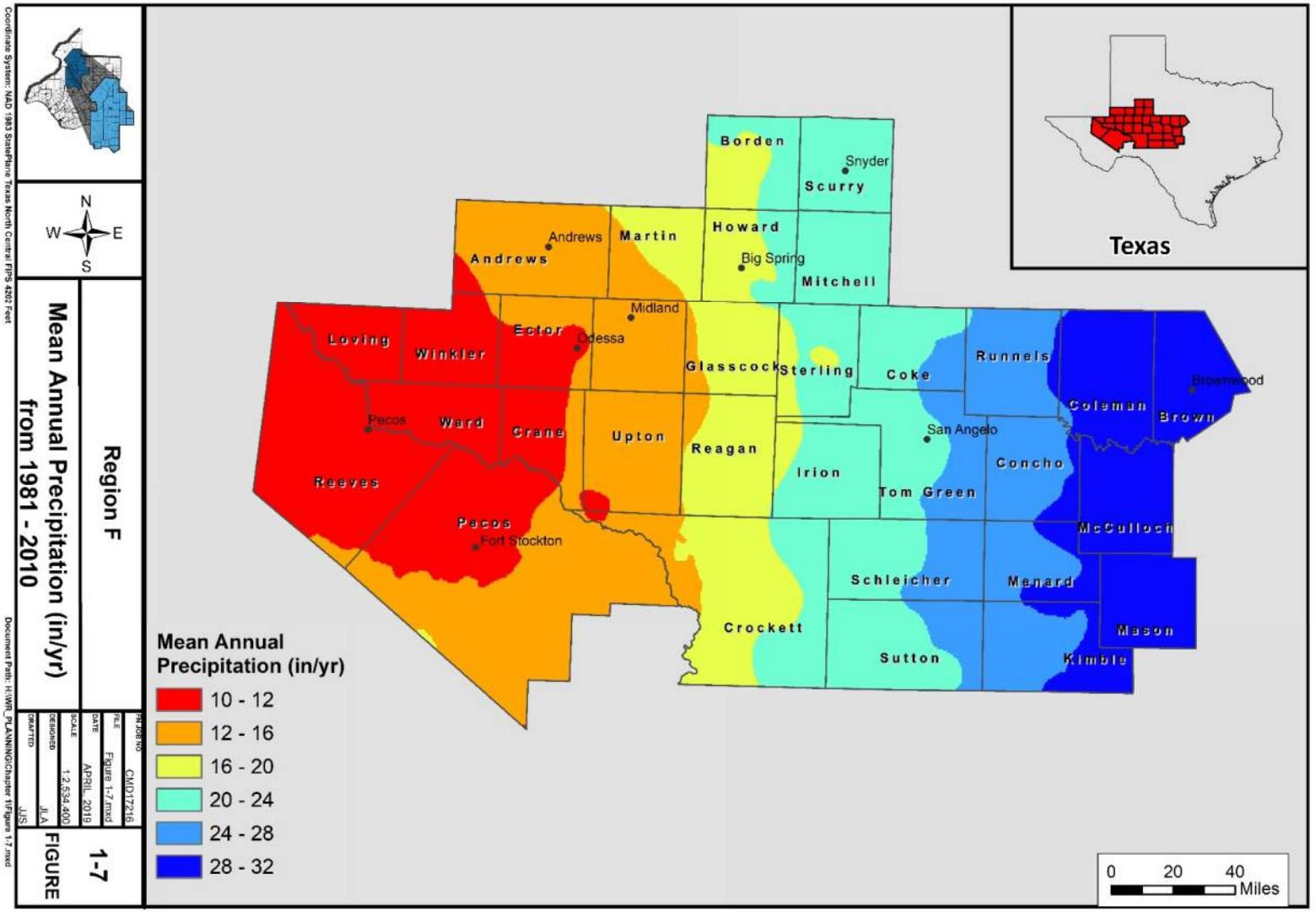


Figure 1-8
Mean Annual Temperature

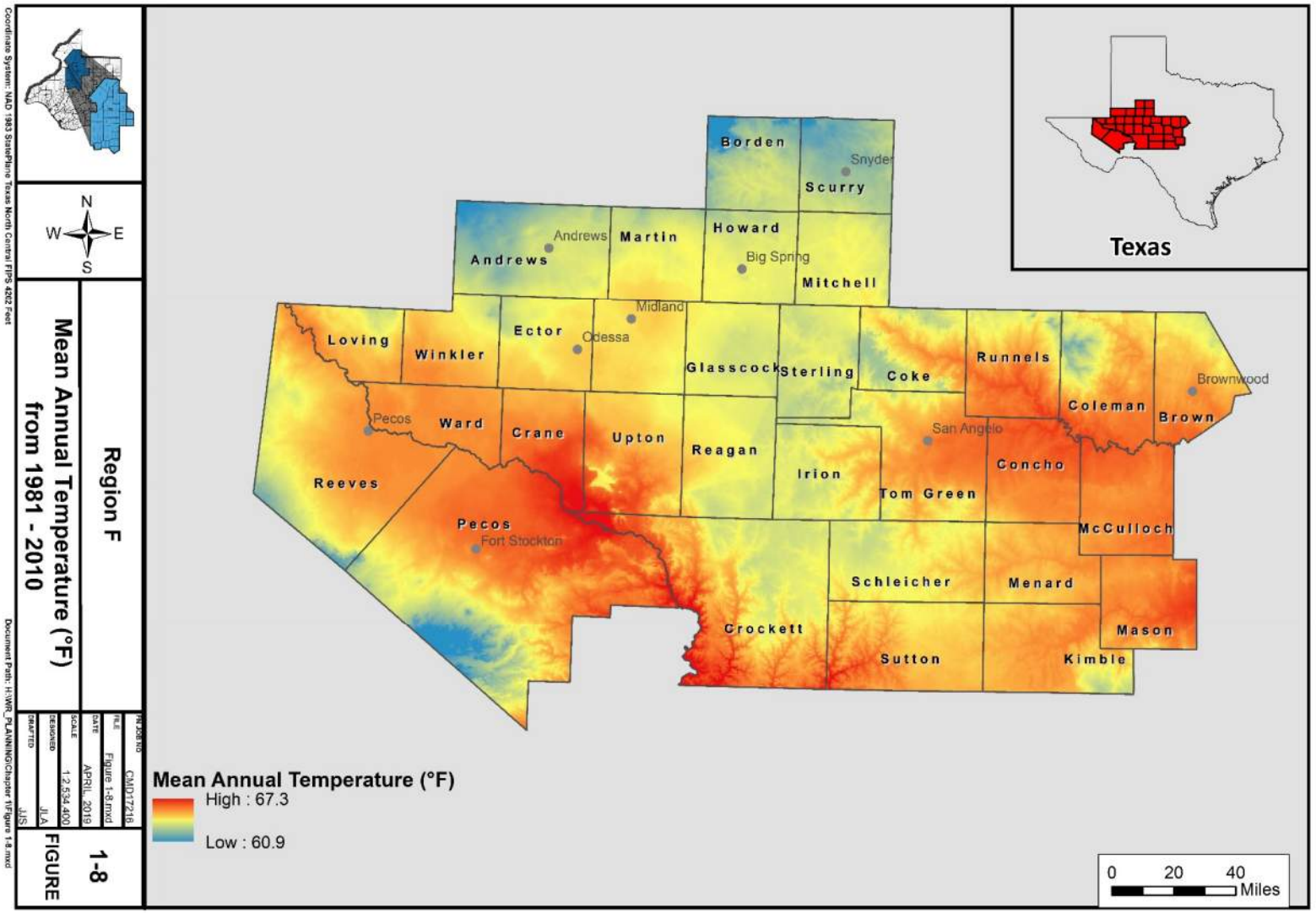


Figure 1-9
Region F Major Aquifer Map

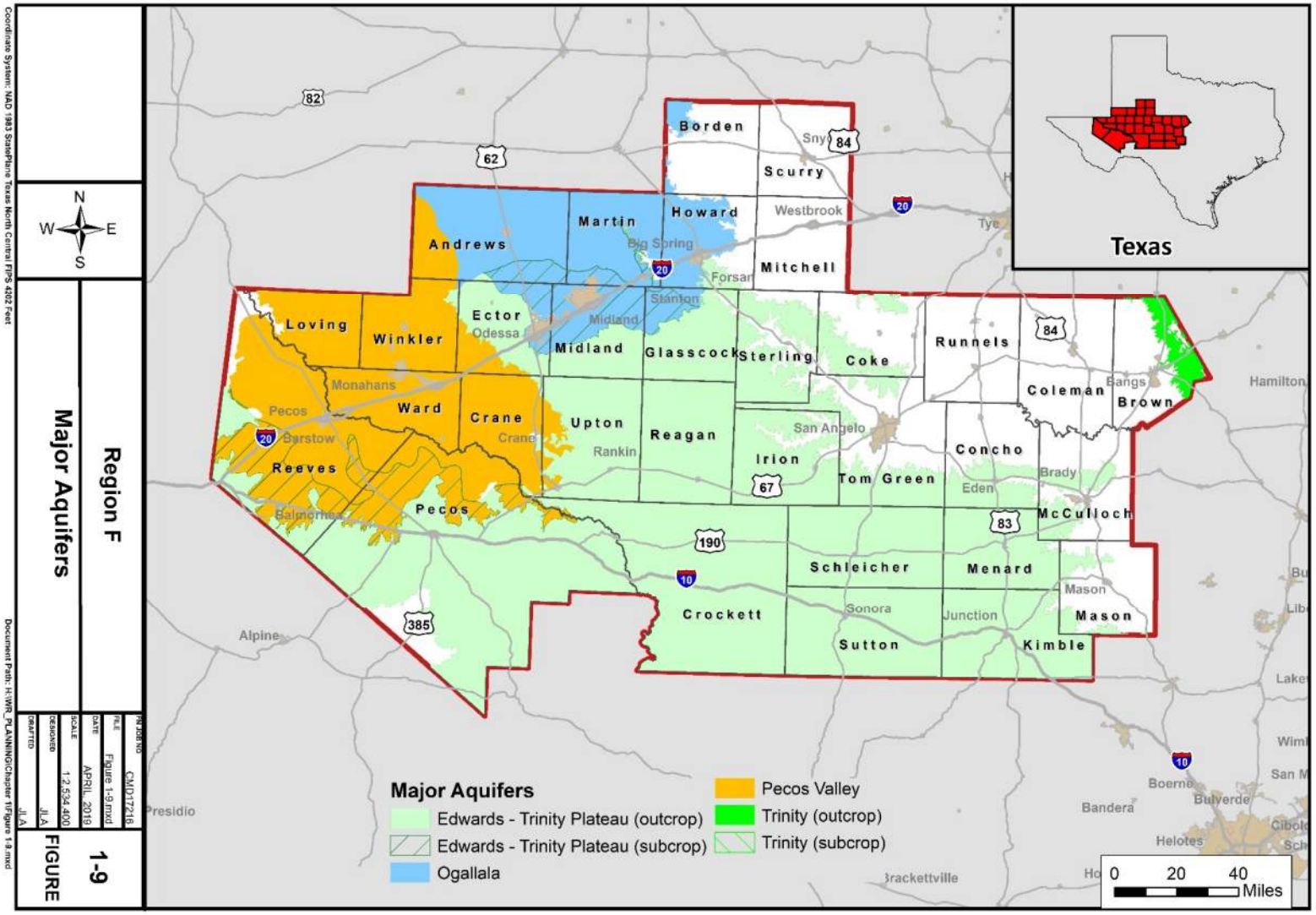
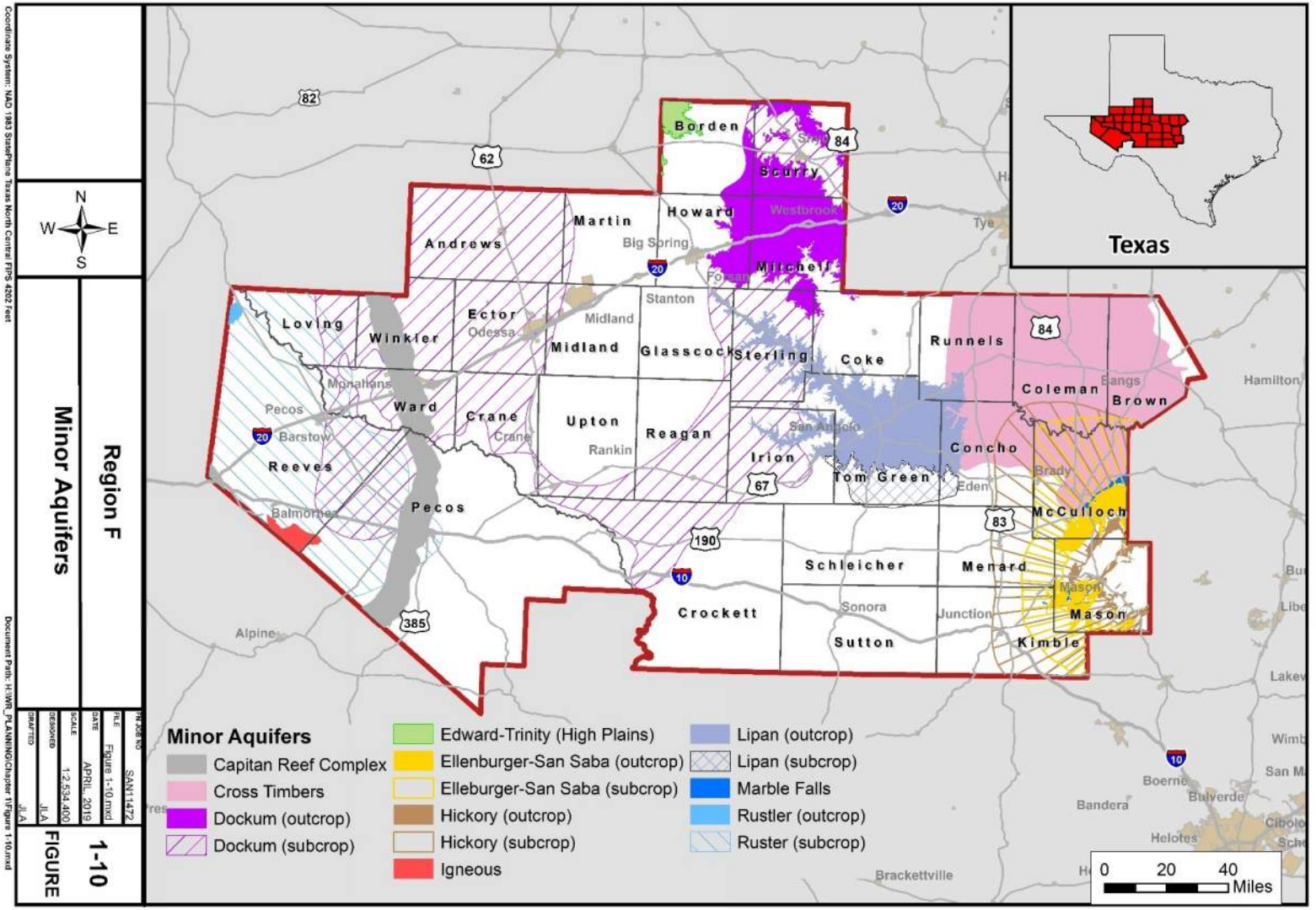


Figure 1-10
Region F Minor Aquifer Map



1.2 Current Water Uses and Demand Centers in Region F

Table 1-5 shows water use from 2006-2016 by TWDB use category and Figure 1-11 illustrates a graph of the data.[8] Table 1-6 shows the total water use by county in Region F for the same period. Water use in Region F increased between 2006 and 2016 and has generally increased in recent years. Since 2008, mining activity and its associated water use has markedly increased.

Table 1-5
Historical Water Use by Category in Region F (Values in acre-feet)

Year	Municipal	Manufacturing	Irrigation	SEP	Mining	Livestock	Total
2006	158,671	10,839	418,636	3,731	4,922	15,206	612,005
2007	114,630	12,704	408,888	3,670	4,253	14,690	558,835
2008	119,335	11,718	381,254	6,081	21,136	14,409	553,933
2009	148,843	13,383	446,157	6,010	20,399	14,343	649,135
2010	142,873	10,363	458,658	6,068	22,354	13,905	654,221
2011	162,266	6,898	494,192	3,567	33,362	14,006	714,291
2012	117,781	5,955	447,476	3,747	29,394	11,597	615,951
2013	123,902	5,913	466,502	3,601	27,234	10,094	637,246
2014	130,839	5,524	470,242	3,573	38,730	10,187	659,095
2015	119,988	5,892	438,822	3,202	62,454	10,001	640,359
2016	115,624	5,716	459,192	9,249	74,438	10,170	674,389
State Total in 2016	*4,412,828*	*1,068,124*	*7,831,789*	*464,763*	*168,312*	*325,385*	*14,271,201*
% of State Total in Reg F	*2.62%*	*0.54%*	*5.86%*	*1.99%*	*44.23%*	*3.13%*	*4.73%*

Note: Data are from the Texas Water Development Board.[8]

Figure 1-11
Historical Water Use by Category in Region F

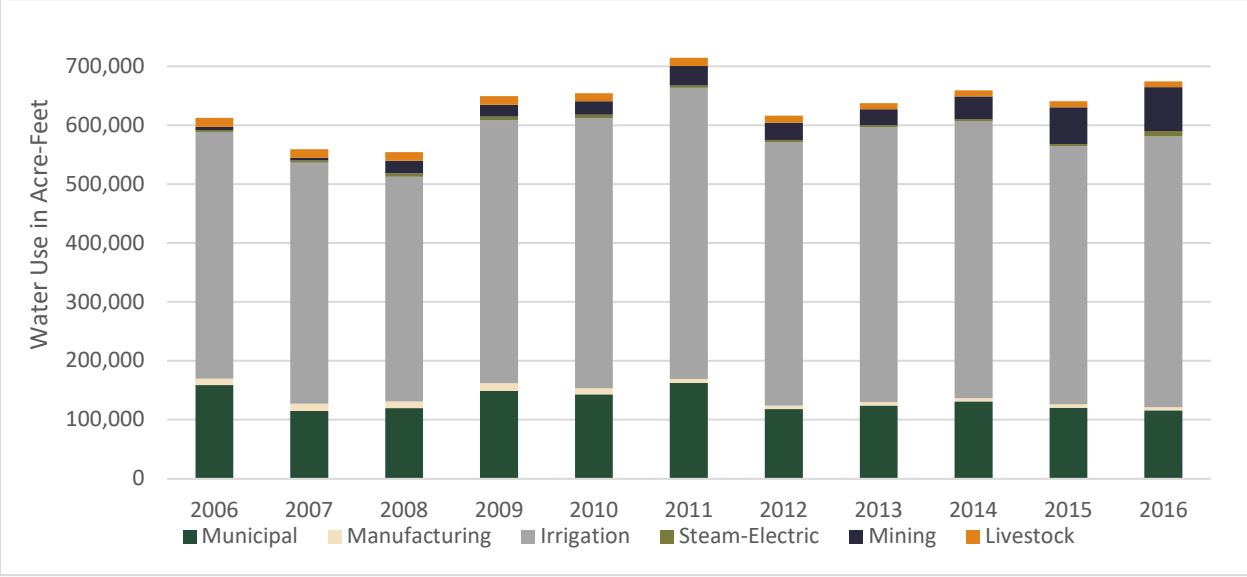


Table 1-6
Historical Total Water Use by County in Region F (Values in acre-feet)

County	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Andrews	34,637	42,249	35,479	29,221	28,083	29,204	29,788	23,873	20,293	20,836	22,162
Borden	2,788	2,951	2,888	4,592	2,180	4,326	3,848	4,450	2,300	2,238	2,682
Brown	18,145	12,380	18,534	16,447	17,592	18,451	14,708	13,699	12,842	13,708	12,803
Coke	1,825	1,392	1,621	1,638	2,028	2,246	1,430	1,269	1,070	963	1,259
Coleman	3,461	2,891	3,161	3,244	2,769	2,962	2,458	2,223	2,305	2,330	2,705
Concho	9,009	6,496	10,807	3,667	8,224	3,911	5,706	6,010	5,593	5,464	5,484
Crane	1,869	1,665	2,515	1,768	1,617	1,987	1,939	1,859	1,709	2,118	1,315
Crockett	2,518	2,386	2,646	2,274	2,315	3,182	3,857	4,579	4,632	3,595	3,129
Ector	29,334	25,246	25,788	26,985	28,743	30,510	23,750	25,968	24,263	22,005	25,458
Glasscock	46,925	38,203	43,775	46,868	58,316	55,648	48,750	52,337	54,900	30,093	41,496
Howard	10,285	16,717	14,120	15,329	15,935	18,641	13,146	13,299	14,778	15,741	16,752
Irion	1,120	812	1,308	2,226	2,268	3,238	3,777	4,235	4,300	3,353	2,871
Kimble	4,355	2,744	4054	4693	4812	4670	4367	4204	3912	3,900	3,708
Loving	108	67	147	209	258	477	839	326	543	4,411	6,006
Martin	16,187	26,412	29,740	38,263	37,706	38,303	35,181	44,968	41,722	42,873	35,629
Mason	8,903	4,884	7,811	9,032	5,864	8,065	7,174	6,483	6,880	6,422	6,399
McCulloch	8,685	6,858	10,893	12,095	13,203	13,205	7,518	6,866	8,086	8,457	8,062
Menard	3,228	2,771	1,675	2,471	3,048	6,067	2,622	5,827	5,104	4,766	4,312
Midland	53,624	44,433	53,691	55,170	42,420	57,661	45,287	29,345	36,468	55,081	72,169
Mitchell	9,152	11,622	13,113	16,841	14,832	15,626	21,212	18,671	20,400	17,916	16,832
Pecos	74,827	63,436	63,644	98,399	132,030	187,827	115,433	145,945	165,572	163,235	161,528
Reagan	20,274	17,882	21,047	18,415	21,002	28,707	23,223	24,316	31,317	28,194	26,384
Reeves	94,549	84,066	31,535	63,449	63,896	57,984	59,368	81,055	60,411	61,286	78,841
Runnels	5,922	4,449	6,163	5,607	5,657	4,416	5,573	5,262	5,219	6,235	5,421
Schleicher	2,037	1,536	2,248	2,600	2,587	3,371	3,160	2,833	3,099	2,613	3,004
Scurry	9,005	8,087	8,121	10,586	9,365	10,078	12,691	10,287	10,623	8,932	9,411
Sterling	1,169	1,005	1,349	1,672	1,337	1,630	1,501	1,785	1,675	1,414	1,199
Sutton	3,295	3,265	2,208	2,210	2,728	3,343	2,669	2,460	2,671	2,324	2,356
Tom Green	70,393	92,453	106,446	92,724	67,915	36,919	76,657	56,306	64,204	74,598	64,504
Upton	8,370	7,156	11,965	10,569	12,014	17,486	13,876	12,459	14,722	13,655	15,249
Ward	12,650	9,895	7,643	11,324	10,747	9,935	5,069	4,785	7,011	7,807	9,794
Winkler	11,372	9,787	4,691	5,522	4,900	6,707	6,405	5,180	5,927	3,796	5,465
Total	***580,021***	***556,196***	***550,826***	***616,110***	***626,391***	***686,783***	***602,982***	***623,164***	***644,551***	***640,359***	***674,389***

Note: Data are from the Texas Water Development Board.[8]
Data for Reeves County after 2003 includes all water released from the Red Bluff Reservoir. Approximately 25% of this water is delivered to customers in Pecos, Reeves, Ward and Loving Counties. The remaining 75% of the water is lost to evaporation and stream losses.

2016 Water Use in Region F:

- 2016 water use was higher than previous years but less than 2011 water use
- Municipal water use continues to decline. 2016 was the lowest total municipal use year.
- Continued increases in water use for mining
- Declining water use for manufacturing
- Irrigation continues to be the largest water user
- Midland County had the highest total water use in 2016 in the past decade

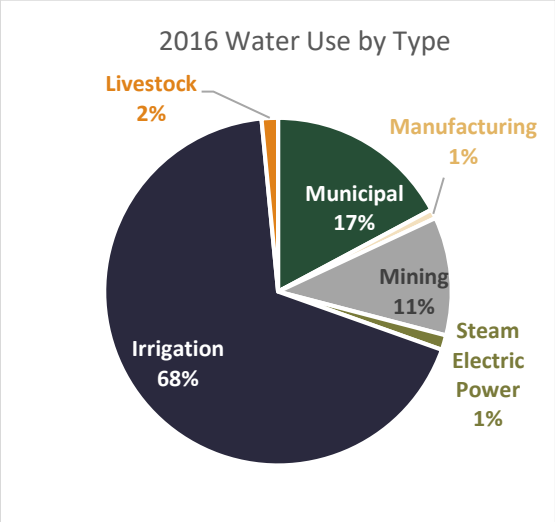


Table 1-7 shows water use by category and county in 2016, and Figure 1-12 shows the distribution of water use by county.

The areas with the highest water use are Midland, Pecos, Reeves, and Tom Green Counties, accounting for over half of the total water used in the region. Most of the municipal water use occurred in Ector, Midland, and Tom Green Counties, location of the cities of Odessa, Midland, and San Angelo, respectively. In the 2016, these counties accounted for about 60 percent of the water use in this category. Other significant municipal demand centers include Brown County (Brownwood), Pecos County (Fort Stockton), Reeves County (Pecos), & Howard County (Big Spring).

Manufacturing water use is small in Region F. Use in this category is concentrated in Kimble and Tom Green counties.

Reeves, Pecos, and Tom Green Counties accounted for most of the reported irrigation water use in 2016, accounting for more than a half of the irrigation water use in the region. However, some of the water reported for irrigation in Reeves County is associated with delivery losses from the Red Bluff Reservoir. The actual use of irrigation water in Reeves County is somewhat less than shown. Other significant demand centers for irrigation water include Glasscock, Martin, and Reagan Counties.

Steam-electric power generation water use occurred only in Ector, Howard, Mitchell, Scurry, and Ward Counties during the year 2016. Facilities in other counties have temporarily or permanently ceased operations.

Most of the water used for mining purposes occurred in Martin, Midland, Reeves, and Upton Counties, accounting for approximately 58 percent of the total use. Mining activities across the region have increased significantly since 2007. Region F accounted for nearly 45% of the mining water use in the entire state in 2016.

Livestock is a small water use category in Region F. Most of the livestock water use occurred in Brown, Coleman, Mason, Pecos, and Tom Green Counties.

In addition to the consumptive water uses discussed previously, water-oriented recreation is important in Region F. Table 1-8 summarizes recreational opportunities at major reservoirs in the region[7]. Smaller lakes and streams provide opportunities for fishing, boating, swimming, and other water-related recreational activities. Water in streams and lakes is also important to fish and wildlife in the region, providing a wide variety of habitats.

Table 1-7
Year 2016 Water Use by Category and County (Values in acre-feet)

County	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining	Livestock	Total
ANDREWS	3,396	42	16,536	0	1,997	191	22,162
BORDEN	161	0	2,214	0	178	129	2,682
BROWN	4,785	387	6,622	0	0	1,009	12,803
COKE	488	31	511	0	8	221	1,259
COLEMAN	1,789	1	273	0	0	642	2,705
CONCHO	530	0	4,622	0	0	332	5,484
CRANE	919	288	0	0	43	65	1,315
CROCKETT	1,080	33	17	0	1550	449	3,129
ECTOR	18,960	355	804	4853	387	99	25,458
GLASSCOCK	122	35	37,376	0	3,852	111	41,496
HOWARD	5,076	2,569	3,662	331	4,894	220	16,752
IRION	148	5	910	0	1,606	202	2,871
KIMBLE	562	546	2,376	0	0	224	3,708
LOVING	23	0	0	0	5948	35	6,006
MARTIN	669	0	28,245	0	6,629	86	35,629
MASON	639	0	4,894	0	187	679	6,399
MCCULLOCH	1,289	72	1,168	0	5,048	485	8,062
MENARD	274	0	3,738	0	0	300	4,312
MIDLAND	34,391	227	19,322	0	17,958	271	72,169
MITCHELL	1,352	2	11,943	3,180	0	355	16,832
PECOS	6,427	221	153,014	0	1,235	631	161,528
REAGAN	623	0	20,244	0	5,368	149	26,384
REEVES[b]	5,145	6	65,423	0	7,791	476	78,841
RUNNELS	1,268	4	3,559	0	6	584	5,421
SCHLEICHER	467	0	2,209	0	10	318	3,004
SCURRY	1,982	117	5,995	845	64	408	9,411
STERLING	235	0	720	0	7	237	1,199
SUTTON	870	1	1,140	0	0	345	2,356
TOM GREEN	15,773	701	47,400	0	1	629	64,504
UPTON	821	41	6,685	0	7,566	136	15,249
WARD	3,570	0	4,830	40	1,292	62	9,794
WINKLER	1,790	32	2,740	0	813	90	5,465
REGIONAL TOTAL	115,624	5,716	459,192	9,249	74,438	10,170	674,389
STATE TOTAL	4,412,828	1,068,124	7,831,789	464,763	168,312	325,385	14,271,201

Note: Data are from the Texas Water Development Board.[8]

a. Great Plains sells water to a Steam Electric Facility in Ector County
b. Data for Reeves County includes all water released from the Red Bluff Reservoir.

Figure 1-12
Water Use by County (2016) in Region F

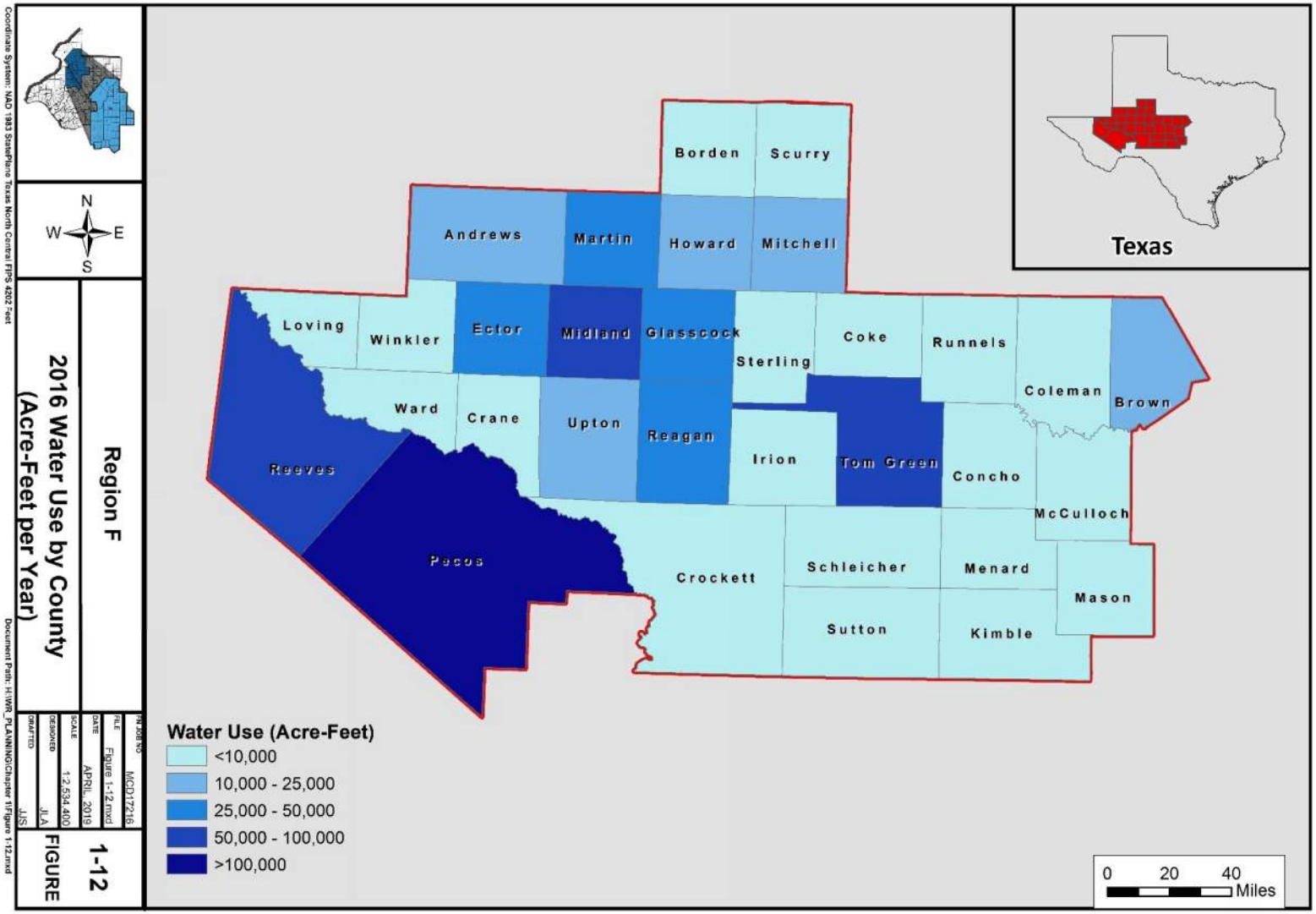


Table 1-8
Recreational Use of Reservoirs in Region F

Reservoir Name	County	Fishing	Boat Launch	Swimming Area	Marina	Picnic Area	Camping	Hiking Trails	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	X	X		X
Champion Creek Reservoir	Mitchell	X	X			X	X				
Oak Creek Reservoir	Coke	X	X	X	X	X	X				
Lake Coleman	Coleman	X	X	X	X	X	X				
E. V. Spence Reservoir	Coke	X	X	X	X	X	X				X
Lake Winters/ New Lake Winters	Runnels	X	X	X		X	X	X			X
Lake Brownwood	Brown	X	X	X		X	X	X	X		X
Hords Creek Lake	Coleman	X	X	X		X	X	X	X		X
Lake Ballinger / Lake Moonen	Runnels	X	X	X		X	X				
O. H. Ivie Reservoir	Concho and Coleman	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	X			
Lake Nasworthy	Tom Green	X	X	X	X	X	X	X	X		X
Brady Creek Reservoir	McCulloch	X	X	X	X	X	X	X		X	X
Mountain Creek Lake	Coke										
Red Bluff Reservoir	Reeves and Loving	X	X			X	X				
Lake Balmorhea	Reeves	X	X	X		X	X				

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

1.3 Current Sources of Water

Table 1-9 summarizes the total surface water, groundwater, and reuse water use in Region F from 2006 through 2016, and Figure 1-13 graphically illustrates the same data. Total water use increased by approximately 62,000 acre-feet (10 percent) between 2006 and 2016. Groundwater use increased by more than 130,000 feet (34.1 percent) and surface water use decreased by over 95,000 acre-feet (48.2 percent) over the same period. Estimates of reuse water and brackish water (for mining) use were first recorded by the TWDB on a countywide basis in the year 2015. Between 2015 and 2016, there was an increase of over 7,000 acre-feet (11 percent) of reuse water use.

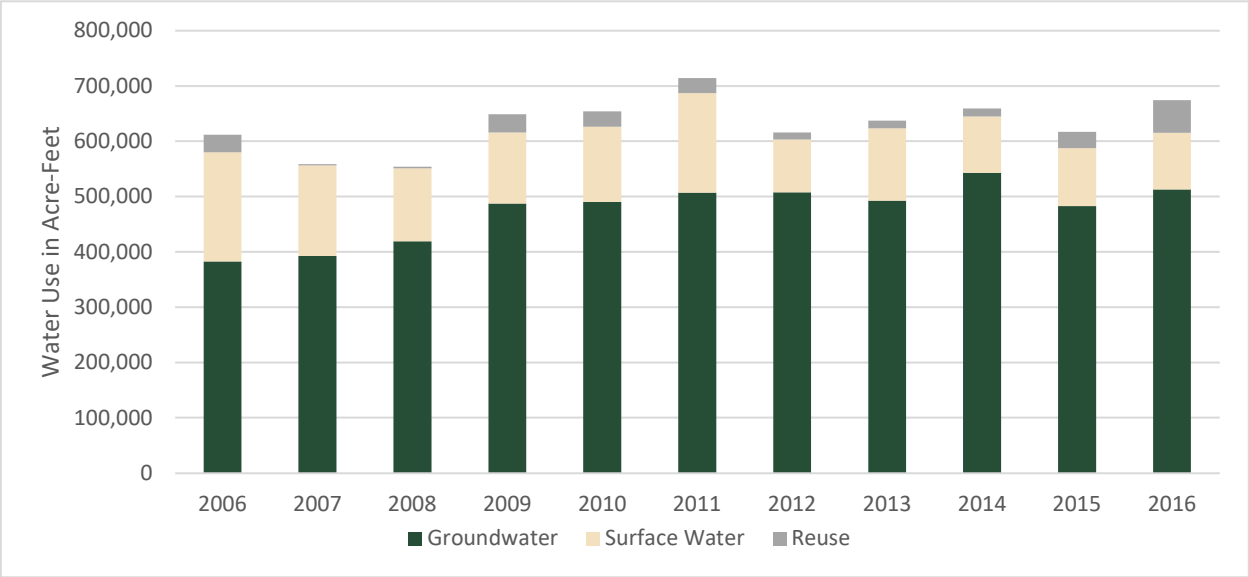
Figure 1-15 shows the percentage of supply from groundwater, broken down by county, in the region in the year 2016. Overall, groundwater use has shown an increasing trend ranging from 62 percent of total water use in 2006 to 76 percent in 2016. In contrast, surface water use has shown a decreasing trend ranging from 32 percent of total water use in 2006 to 15 percent in 2016.

Table 1-9
Historical Groundwater, Surface Water, and Reuse Water Use in Region F

Year	Water Use in Acre-Feet			
	Groundwater	Surface Water	Reuse[a]	Total
2006	382,461	197,560	31,984	580,021
2007	392,721	163,475	2,639[b]	556,196
2008	419,370	131,456	3,107[b]	550,826
2009	487,538	128,572	33,025	616,110
2010	490,590	135,801	27,830	626,391
2011	507,301	179,482	27,508	686,783
2012	507,814	95,166	12,969	602,980
2013	492,875	130,285	14,082	623,160
2014	542,963	101,589	14,544	644,552
2015	482,762	104,603	52,994	640,359
2016	512,919	102,416	59,054	674,389

Note: Data are from Texas Water Development Board.[8]
a. Values from 2000-2014 only reflect entities that reported water reuse during that year. Annual reuse and brackish water (for mining) use was not reported through all of Region F until 2015.
b. Odessa reported substantially less water reuse in 2007 and 2008.

Figure 1-13
Historical Groundwater, Surface Water, and Reuse Water Use in Region F*



*Values from 2000-2014 only reflect entities that reported water reuse during that year. Annual water reuse was not reported through all of Region F until 2015.

Figure 1-14
Groundwater, Surface Water, and Reuse Water Use in Region F in 2016

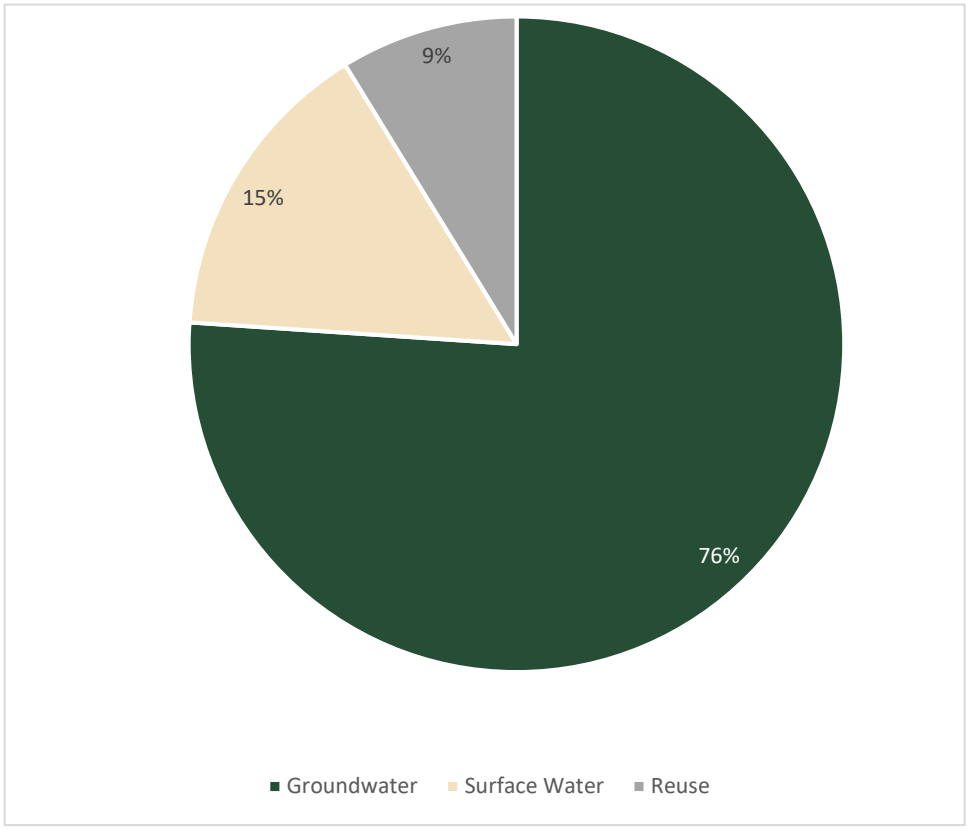
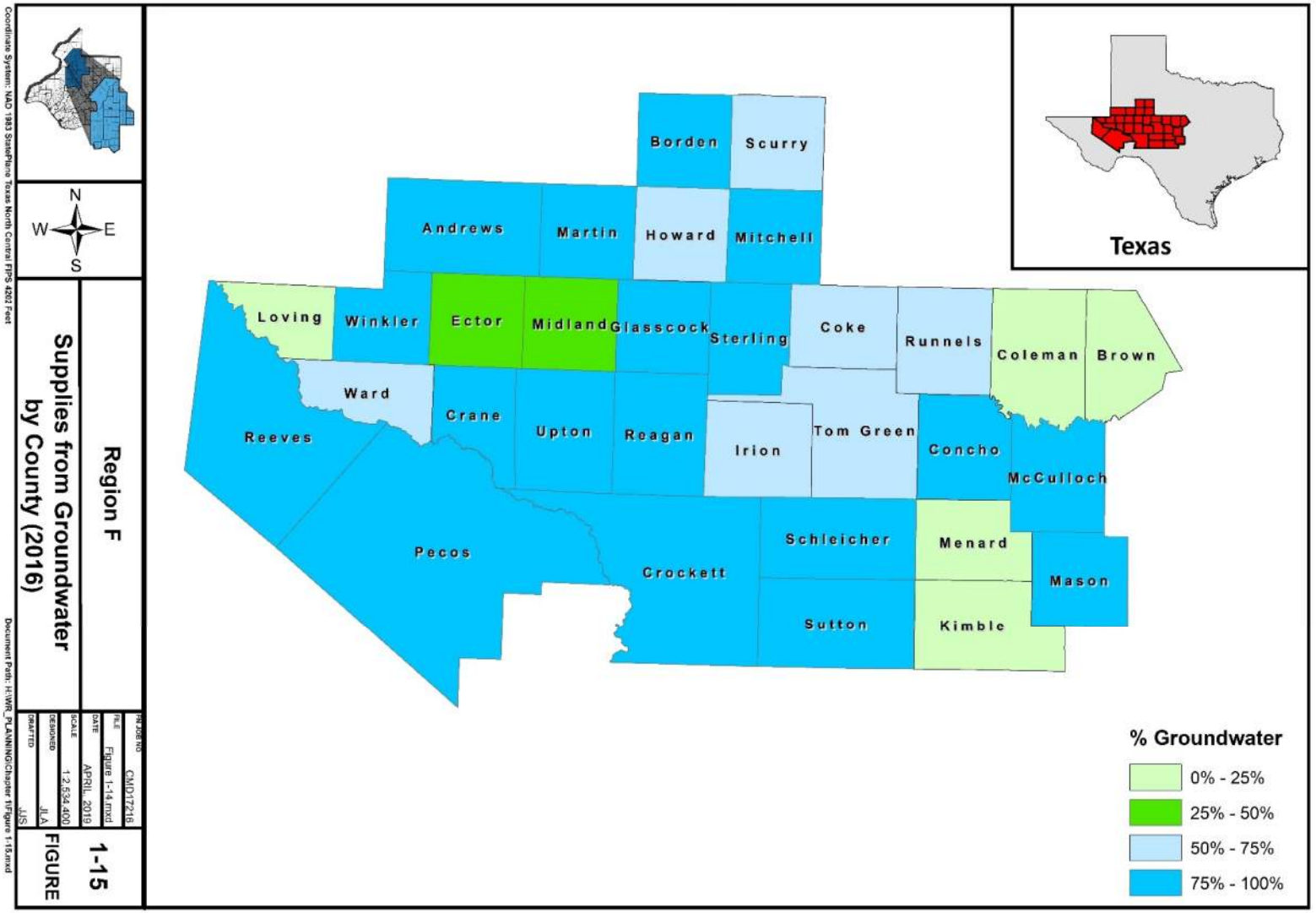


Figure 1-15
Supplies from Groundwater by County (2016)



1.3.1 Surface Water Sources

Table 1-10 summarizes permitted surface water diversions by use category for each county in Region F. (These categories differ slightly from the demand categories used by TWDB for regional water planning.) Table 1-10 does not include non-consumptive use categories such as recreation. Figure 1-16 shows the distribution of permitted diversions by county and use type. Most of the large surface water diversions in Region F are associated with major reservoirs. Table 1-4 in Section 1.1.2 lists the permitted diversions and the reported year 2016 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 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 Abilene has a contract with the Colorado River Municipal Water District (CRMWD) for 16.54% of the safe yield of O.H. Ivie Reservoir. Facilities to transfer water from Lake O.H. Ivie to Abilene became operational in September 2003. Small amounts of surface water are supplied to the Cities of Lawn and Rotan, which are both in Region G. Several rural water supply corporations also supply small amounts of surface water to neighboring regions.

Lake Ivie
Colorado River Municipal Water District

Lake Brownwood
Brown County Water Improvement District #1

Table 1-10
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	29,712	0	8,729	0	0	38,441
Coke	44,865	6,000	969	16,361[a]	0	68,195
Coleman[b]	110,890	14,509	6,522	0	20	131,941
Concho	35	0	2,356	0	16	2,407
Ector	0	0	3,200	0	0	3,200
Howard	1,700	0	89	8,215	0	10,004
Irion	0	0	5,426	0	0	5,426
Kimble	1,000	2,472	8,450	60	0	11,982
Martin	0	2,500	0	0	0	2,500
Mason	0	0	356	0	0	356
McCulloch	3,500	0	2,152	0	0	5,652
Menard	1,016	0	10,586	3	2	11,607
Mitchell	8,200	4,050	123	0	0	12,373
Pecos	0	0	66,902	0	0	66,902
Reeves[c]	0	0	347,366	0	0	347,366
Runnels	2,919	0	7,024	70	0	10,013
Schleicher	0	0	38	3	0	41
Scurry[d]	30,000	0	503	0	0	30,503
Sterling	0	0	168	0	0	168
Sutton	0	0	99	3	0	102
Tom Green	108,069	8,002	40,985	0	16	157,072
Total	***342,106***	***37,533***	***512,105***	***24,715***	***54***	***916,513***

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

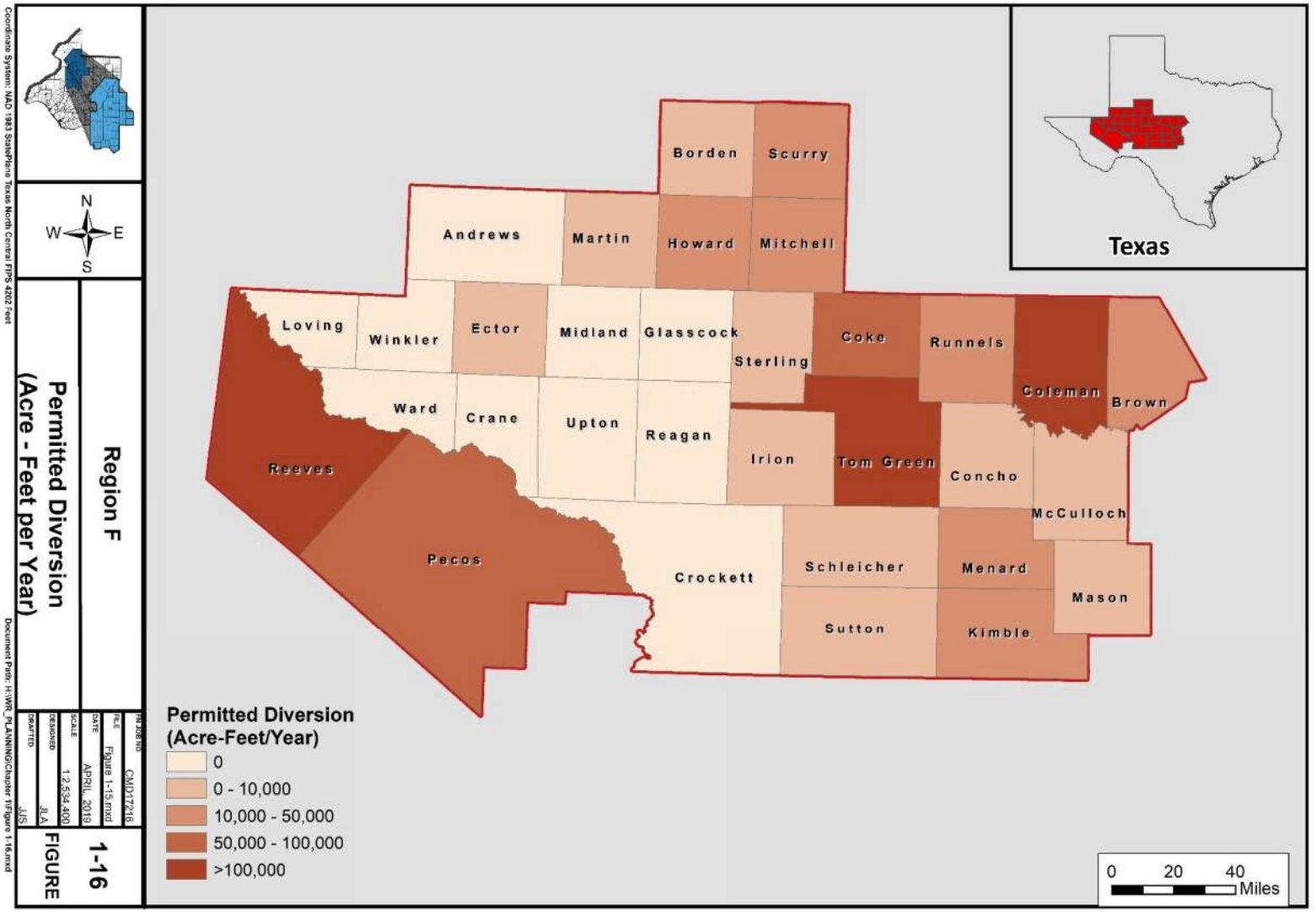
b. Includes water rights for Ivie Reservoir, which is located in Coleman, Concho and Runnels Counties.

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

d. Includes rights for Lake J.B. Thomas, which is located in Borden and Scurry Counties.

Note: Data are from TCEQ's active water rights list.[5] Other counties have no permitted water rights on the TCEQ list. Does not include recreation rights.

Figure 1-16
Total Permitted Surface Water Diversion by County



1.3.2 Groundwater Sources

As previously discussed in section 1.1.2, there are 14 aquifers that supply water to the 32 counties of Region F: four major aquifers (Edwards-Trinity Plateau, Ogallala, Pecos Valley, and Trinity) and ten minor aquifers (Capitan Reef Complex, Cross Timbers, Dockum, Edwards-Trinity High Plains, Ellenberger-San Saba, Hickory, Igneous, Lipan, Marble Falls, and Rustler). The TWDB defines a major aquifer as an aquifer that supplies large quantities of water to large areas.[9] 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 1-11 shows the 2016 groundwater use by county and aquifer.[8] The Edwards-Trinity Plateau, Pecos Valley, and Ogallala are the largest sources of groundwater in Region F, providing 35.7 percent, 20.2 percent, and 13.0 percent of the total groundwater pumped in 2016, respectively. The Lipan aquifer provided approximately 5.4 percent of the 2016 totals, with all remaining aquifers contributing 25.7 percent combined. Groundwater pumping is highest in Glasscock, Martin, Pecos, Reeves, Reagan, and Tom Green Counties. Approximately 70 percent of the regions total pumping occurs in these six counties.

Groundwater conservation districts are the preferred method for managing groundwater in the State of Texas. There are 16 Underground Water Conservation Districts (GCDs) in Region F (Figure 1-17). 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.[10]

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

The GCDs are also required to participate in joint groundwater planning through Groundwater Management Areas (GMAs). There are 16 GMAs in the State of Texas whose boundaries generally coincide with major aquifers. Each GMA is tasked with determining Desired Future Conditions for the aquifers in the management area for planning purposes. There are four GMAs that include one or more counties in Region F: GMA-7, GMA-3, GMA-2, and GMA-8 (Figure 1-17). Additional information on GCDs, the GMA process, and groundwater availability is included in Chapter 3.

In areas, where no there is no GCD, the state may designate a Priority Groundwater Management Area (PGMA). The Priority Groundwater Management Area (PGMA) process is initiated by the TCEQ, who designates a PGMA when an area is experiencing critical groundwater problems, or is expected to do so within 25 years. These problems include shortages of surface water or groundwater, land subsidence resulting from groundwater withdrawal, or contamination of groundwater supplies.

Table 1-11
Groundwater Pumping by County and Aquifer 2016 (Values in Acre-Feet)

County	Edwards-Trinity Plateau	Ogallala	Pecos Valley	Lipan	Hickory	Dockum	Trinity	Ellen-berger-San Saba	Marble Falls	Edwards-Trinity High Plains	Rustler	Capitan Reef Complex	Igneous	Other[a]	*Total*
Andrews	2	19,815	138	0	0	10	0	0	0	0	0	0	0	1,360	21,325
Borden	0	2,008	0	0	0	23	0	0	0	9	0	0	0	521	2,561
Brown	0	0	0	0	0	0	958	0	0	0	0	0	0	95	1,053
Coke	92	0	0	0	0	0	0	0	0	0	0	0	0	706	798
Coleman	0	0	0	0	0	0	0	0	0	0	0	0	0	65	65
Concho	149	0	0	2,642	425	0	0	0	0	0	0	0	0	1,792	5,008
Crane	0	0	1,055	0	0	175	0	0	0	0	0	0	0	29	1,259
Crockett	1,578	0	0	0	0	2	0	0	0	0	0	0	0	1,054	2,634
Ector	2,453	165	0	0	0	67	10	0	0	0	0	0	0	255	2,950
Glasscock	32,455	4,849	0	0	0	0	0	0	0	0	0	0	0	3,000	40,304
Howard	1,585	2,932	0	0	0	314	0	0	0	0	0	0	0	3,604	8,435
Irion	419	0	0	1,132*	0	1	0	0	0	0	0	0	0	0*	1,552
Kimble	272	0	0	0	25	0	2	4	0	0	0	0	0	255	558
Loving	0	0	36	0	0	19	0	0	0	0	1	0	0	1,192	1,248
Martin	0	30,190	0	0	0	0	0	0	0	0	0	0	0	4,505	34,695
Mason	10	0	0	0	5,798	0	1	73	0	0	0	0	0	244	6,126
McCulloch	77	0	0	0	8,941	0	0	198	17	0	0	0	0	119	9,352
Menard	376	0	0	0	400	0	0	4	0	0	0	0	0	207	987
Midland	5,978	6,055	0	0	0	1	0	0	0	0	0	0	0	11,996	24,030
Mitchell	0	0	1	0	0	13,413	0	0	0	0	0	0	0	17	13,431
Pecos	94,824	0	40,771	0	0	0	0	0	0	0	4,271	3,206	0	11,975	155,047
Reagan	20,918	0	0	0	0	78	0	0	0	0	0	0	0	3,730	24,726
Reeves	6,625	0	44,873	0	0	2,332	0	0	0	0	3,014	0	372	3,691	60,907
Runnels	13	0	0	29	0	0	0	0	0	0	0	0	0	3,267	3,309
Schleicher	2,978	0	0	0	0	0	0	0	0	0	0	0	0	7	2,985
Scurry	0	0	0	0	0	6,981	0	0	0	0	0	0	0	56	7,037
Sterling	460	0	0*	469*	0	7	0	0	0	0	0	0	0	69*	1,005
Sutton	2,167	0	0	0	0	0	0	0	0	0	0	0	0	182	2,349
Tom Green	1,657	0	0	25,065	0	0	0	0	0	0	0	0	0	16,413	43,135
Upton	6,868	116	1	0	0	117	0	0	0	0	0	0	0	5,063	12,165
Ward	0	0	6,989	0	0	35	0	0	0	0	2	0	0	922	7,948
Winkler	2	0	9,364	0	0	1,473	0	0	0	0	0	0	0	549	11,388
Total	181,958	66,130	103,297	27,736	15,589	25,048	971	279	17	9	7,288	3,206	372	78,472	510,372

a. "Other" Aquifer category is the sum of groundwater pumping from aquifers not listed and unknown sources of pumping

*Reclassified based on input from the Sterling County Underground Water District

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

Once an area is designated a PGMA, landowners have two years to create a Groundwater Conservation District (GCD). Otherwise, the TCEQ is required to create a GCD or to recommend that the area be added to an existing district. The TWDB works with the TCEQ to produce a legislative report every two years on the status of PGMAs in the state. The PGMA process is completely independent of the current Groundwater Management Area (GMA) process and each process has different goals. The goal of the PGMA process is to establish GCDs in these designated areas so that there will be a regulating entity to address the identified groundwater issues. PGMAs are still relevant as long as there remain portions within these designated areas without GCDs. There is one PGMA in Region F, the Reagan, Upton, and Midland County PGMA as shown in Figure 1-18.

There have been previous efforts to create GCDs in Upton and Midland Counties. In November 1991, landowners in Midland County attempted to join the Permian Basin UWCD but were unsuccessful. In 1999, House Bill 437 proposed to expand the authority of the existing Upton County Water District, and subsequently failed.

The Santa Rita UWCD (created in 1989) includes all but 65,000 acres of Reagan County, which were incorporated into the existing Glasscock GCD in 1989 and 1990, when landowners petitioned to join the Glasscock GCD. The Reagan, Upton and Midland County PGMA was designated in 1990. The name of the PGMA is somewhat of a misnomer because it only includes portions of Midland and Upton Counties as shown in Figure 1-16. All portions of Reagan County are included in either Glasscock or Santa Rita GCD.

The TCEQ Executive Director is authorized to petition the Commission to establish groundwater management in PGMAs in areas that have no GCD. The Executive Director of the TCEQ published a final report in February 2017 addressing the options available to the portions of Midland and Upton Counties that are located within the PGMA boundary[11].

In this report, the Executive Director recommended that the TCEQ issue an order for option 1 due to its feasible, practical, and economic benefits for landowners in the PGMA to secure groundwater management of the Edwards-Trinity Plateau Aquifer. As of this time, no order has been issued by TCEQ and no county commissioner's court has promulgated groundwater regulations or availability values for areas within the PGMA that have no GCD. However, TCEQ administrative actions will continue for the establishment of groundwater management in these areas and the matter is proceeding to the contested case process at the State Office of Administrative Hearings[7].

Options proposed by TCEQ for PGMA Area:

- Adding PGMA-bound portions of both counties to the Glasscock GCD,
- Adding PGMA-bound portions of both counties to the Santa Rita GCD,
- Add the PGMA-bound portion of Midland County to the Glasscock GCD and add the PGMA-bound portion of Upton County to the Santa Rita GCD,
- Create a new and separate GCD for the portions in both counties, or
- Create two new GCDs for the portions in both counties splitting the GCDs at the county line.

Figure 1-17
GCD and GMA Areas in Region F

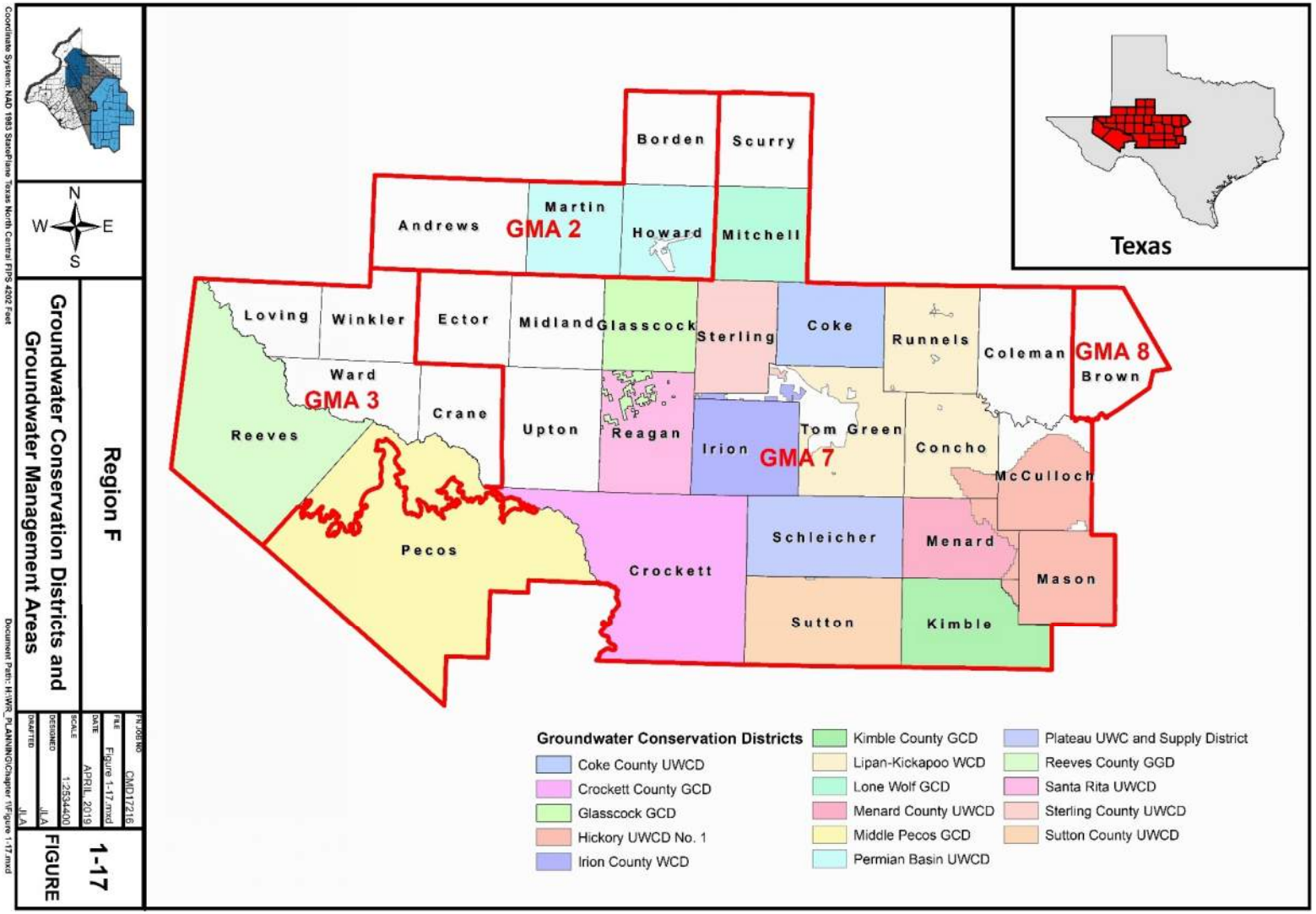
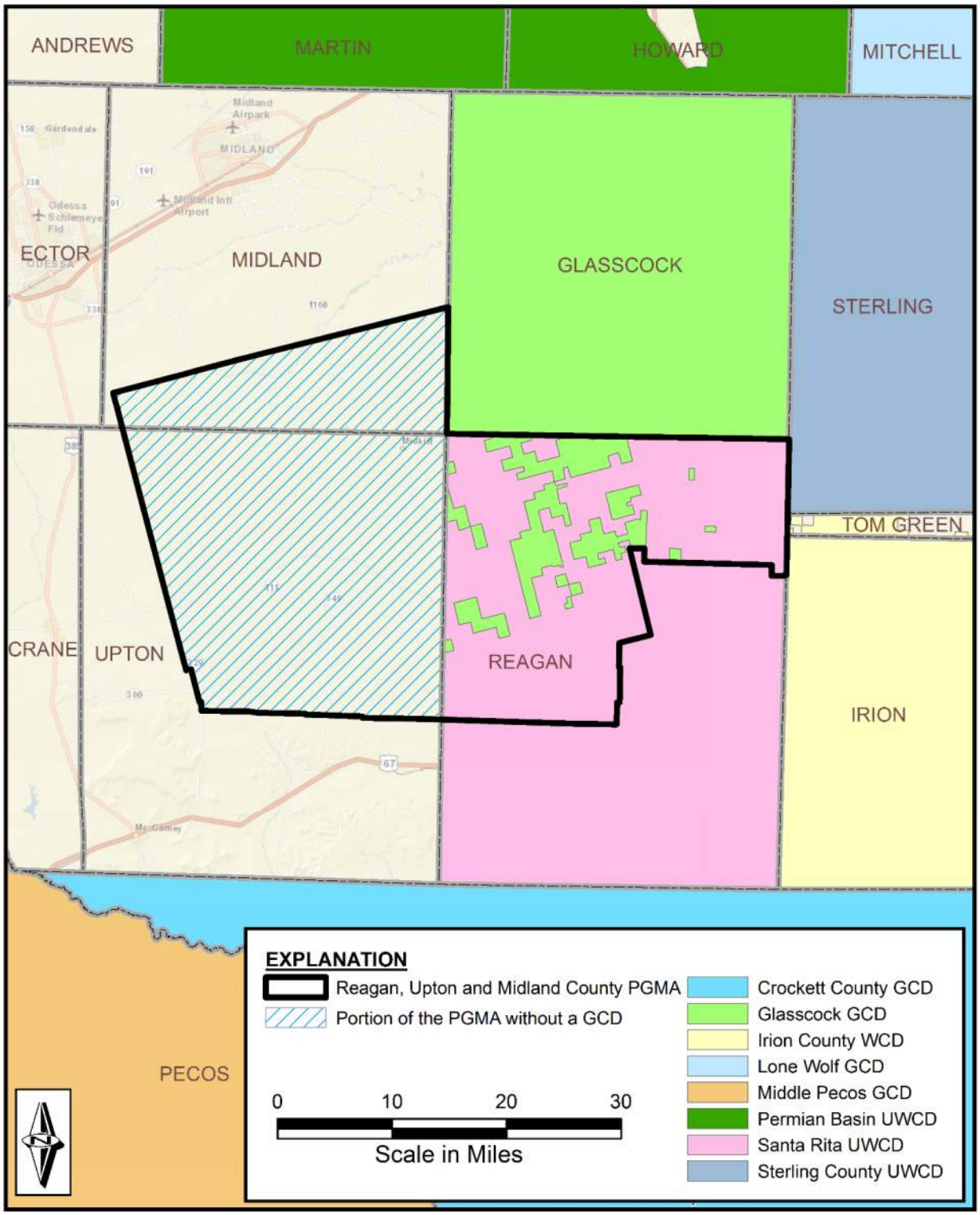


Figure 1-18
Reagan, Upton, and Midland County PGMA Boundary (Source: TCEQ)



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 some springs to disappear over time and have greatly diminished the flow from many of those that remain. Even though spring flows are declining throughout the region due to groundwater development, brush infestation, and climatic conditions, many springs are still 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 stopped flowing in 2018 but have maintained very low discharge volumes since that occurred. 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 14 major springs in the region that are important for water supply or natural resources protection. Figure 1-19 contains a map of the major springs in Region F. For convenience, the following spring descriptions are grouped into related geographic areas. Discussions pertaining to the historical significance of these springs are taken from *Springs of Texas*, by Gunner Brune.[12,13]

Balmorhea Area Springs

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

Region F Springs:

- Balmorhea Area Springs
- San Solomon Springs
- Giffin Springs
- East and West Sandia Springs
- Fort Stockton Area Springs
- Diamond Y Springs
- Santa Rosa Spring
- San Angelo Area Springs
- Dove Creek Springs
- Anson Springs
- Spring Creek Springs
- Rocky Creek Springs
- Lipan Spring
- Kickapoo Spring
- Fort McKavett Area Springs
- Clear Creek (or Wilkinson) Springs

San Solomon Springs are in Balmorhea State Park and are the largest spring in Reeves County. The spring's importance begins with its recreational use, then its habitat for endangered species in the ditches leading from the pool,[14] 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 and 30 cubic feet per second (cfs). After strong rains, the spring flow often increases rapidly and becomes somewhat turbid. These bursts in spring flow 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 3 and 4 cfs. Discharge from Giffin Springs responds much more closely to precipitation than other Balmorhea-area springs.

East and West Sandia Springs are located about one mile east of Balmorhea at an elevation slightly lower than San Solomon and Giffin Springs. 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.[15] 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. The Nature Conservancy manages the 246-acre Sandia Springs Preserve to sustain the unique spring habitat and its vulnerable species.

Fort Stockton Area Springs

Comanche Springs flow 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) are 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. The springs stopped flowing in 2018

but have maintained very low discharge volumes since that occurred.

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

San Angelo Area Springs

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

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

Anson Springs (or 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 spring flow 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.

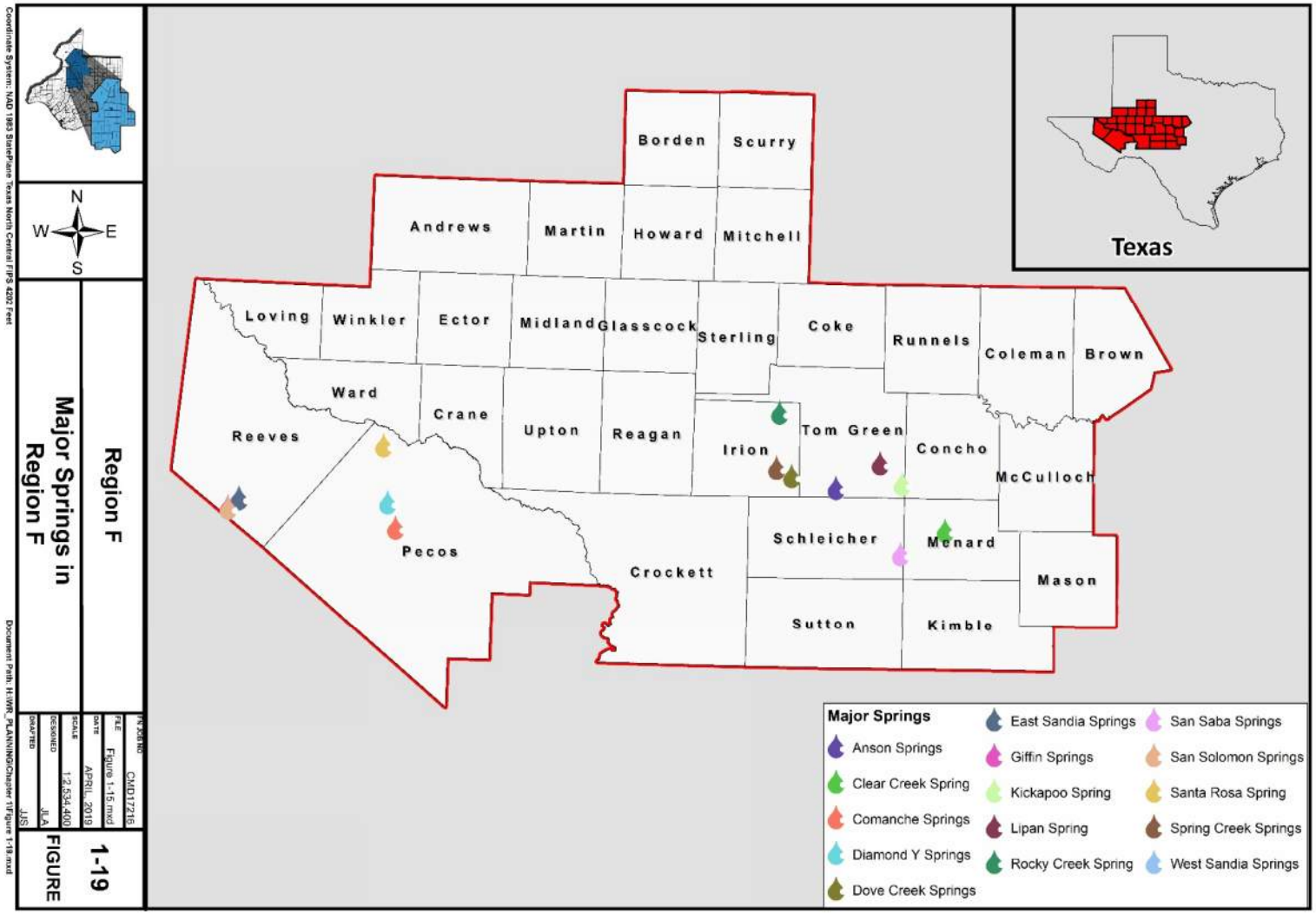
Kickapoo Spring also discharges from Edwards limestone and is located approximately twelve miles south of Vancourt. This spring was used for irrigation in the early days of settlement and historically has flowed between 1 and 4 cfs.

Fort McKavett Area Springs

San Saba Springs (or Government or Main Springs) are 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 (or Wilkinson Springs) form 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.

Figure 1-19
Springs in Region F



1.4 Agricultural and Natural Resources in Region F

This section describes agricultural and natural resources in Region F. Specifically, it addresses the endangered and threatened species known to be present or potentially present in the region. It also describes the natural resources, including prime farmland, agricultural, and mineral resources.

1.4.1 Endangered or Threatened Species

Table 1-12 is a compilation of federal and state threatened and endangered species found in Region F counties. Section 7 of the Federal Endangered Species Act requires federal agencies to consult with the U.S. Fish and Wildlife Services (USFWS) to ensure that any 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. There are nine federal and sixteen state species listed as endangered that are known to, or may occur, in counties in Region F. The Northern Aplomado Falcon, Whooping Crane, and Rio Grande Silvery Minnow are the federally listed endangered species most frequently cited in Table 1-12 for counties in Region F. The Black-capped Viero and Pecos Gambusia are the state listed endangered species most frequently cited in Table 1-12 for counties in Region F.

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

The Texas Endangered Species Act does not protect wildlife species from indirect take (e.g., destruction of habitat or unfavorable management practices). The TPWD has a Memorandum of Understanding with every state agency to conduct a thorough environmental review of state initiated and funded projects, such as highways, reservoirs, land acquisition, and building construction, to determine their potential impact on state endangered or threatened species. There are 44 species identified by the state as threatened or endangered that are known to, or may potentially occur in Region F.

Table 1-12
Endangered and Threatened Species in Region F

Species		Status		County																																	
Common Name	Scientific Name	Federal	State	Andrews	Borden	Brown	Coke	Coleman	Concho	Crane	Crockett	Ector	Glasscock	Howard	Irion	Kimble	Loving	Martin	Mason	McCulloch	Menard	Midland	Mitchell	Pecos	Reagan	Reeves	Runnels	Schleicher	Scurry	Sterling	Sutton	Tom Green	Upton	Ward	Winkler
Birds																																						
American Peregrine Falcon	*Falco peregrinus anatum*		T	S						S	S	S					S							S		S								S	S
Bald Eagle	*Haliaeetus leucocephalus*	R	T	B	B	B	B	B	B	B	S	B	B	B	B	B	F	B	B	B	B	B	B	S	B		B	B	B	B	S	B	B	B	B
Black-Capped Vireo	*Vireo atricapilla*	R	E				B	B	B		B		F	F	B	B			B	B	B		F	B	B		B	B		B	B	B	F		
Common Black-Hawk	*Buteogallus anthracinus*		T																													S			
Golden-Cheeked Warbler	*Setophaga chrysoparia*	E	E													B			B		F														
Lesser Praire-Chicken	*Falco femoralis septentrionalis*	C		F														F																		
Least Tern	*Sterna antillarum*	E																														F				
Mexican Spotted Owl	*Strix occidentalis lucida*	T																						F		F										
Northern Aplomado Falcon	*Tympanuchus pallidicinctus*	E		F								F					F							F		F								F	F
Piping Plover	*Charadrius melodus*	T			F																								F						
Red Knot	*Calidris canutus rufa*	T		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
Reddish Egret	*Egretta rufescens*		T																							S										
Sooty Tern	*Onychoprion fuscatus*		T				S																									S				
White-Faced Ibis	*Plegadis chihi*		T	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Whooping Crane	*Grus americana*	E	E			B		B										F	F	F																
Zone-Tailed Hawk	*Buteo albonotatus*		T			S	S		S		S		S		S	S			S	S	S	S		S	S	S		S		S	S	S	S		
Crustaceans																																						
Diminutive Amphipod	*Gammarus hyalelloides*	E	E														F							F		B									F	
Pecos Amphipod	*Gammarus pecos*	E	E																					B												
Fish																																						
Blue Sucker	*Cycleptus elongatus*		T	S		S	S	S	S	S	S	S	S	S			S			S			S	S		S	S	S	S		S	S	S	S	S
Clear Creek Gambusia	*Gambusia heterochir*		E																		B															
Comanche Springs Pupfish	*Cyprinodon elegans*		E																					S		B										
Devils River Minnow	*Dionda diaboli*		T								S																	S			S					
Leon Springs Pupfish	*Cyprinodon bovinus*		E																					B												
Pecos Gambusia	*Gambusia nobilis*		E							S	S													B		B										
Pecos Pupfish	*Cyprinodon pecosensis*		T							S	S						S							S		S							S	S	S
Proserpine Shiner	*Cyprinella proserpina*		T							S	S													S	S						S	S	S		
Rio Grande Darter	*Etheostoma grahami*		T							S	S													S							S	S	S		
Rio Grande Silvery Minnow	*Hybognathus amarus*	E									F													F		F										
Sharpnose Shiner	*Notropis oxyrhynchus*	E																											F							
Smalleye Shiner	*Notropis buccula*	E			F																								F							
Mammals																																						
White-Nosed Coati	*Nasua narica*		T								S					S															S					
Reptiles																																						
Brazos Water Snake	*Nerodia harteri*		T				S	S	S											S			S			S					S					
Chihuahuan Desert Lyre Snake	*Trimorphodon vilkinsonii*		T								S																				S					
Chihuahuan Mud Turtle	*Kinosternon hirtipes murrayi*		T																										S							
Concho Water Snake	*Nerodia paucimaculata*	R				F	F	F	F											F			F			F					F					
Mountain Short-Horned Lizard	*Phrynosoma hernandesi*		T																										S							
Reticulate Collared Lizard	*Crotaphytus reticulatus*		T								S																									
Texas Horned Lizard	*Phrynosoma cornutum*		T	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Texas Tortoise	*Gopherus berlandieri*		T			S		S								S															S					
Trans-Pecos Black-Headed Snake	*Tantilla cucullata*		T																					S												

Species		Status		County																																
Common Name	Scientific Name	Federal	State	Andrews	Borden	Brown	Coke	Coleman	Concho	Crane	Crockett	Ector	Glasscock	Howard	Irion	Kimble	Loving	Martin	Mason	McCulloch	Menard	Midland	Mitchell	Pecos	Reagan	Reeves	Runnels	Schleicher	Scurry	Sterling	Sutton	Tom Green	Upton	Ward	Winkler
Lloyd's Mariposa Cactus	*Echinomastus mariposensis*																							F												
Pecos Sunflower	*Helianthus paradoxus*	T	T																					B		B										
Texas Poppy-Mallow	*Callirhoe scabriuscula*	R	E				B																B				B		S							
Tobusch Fishhook Cactus	*Sclerocactus brevihamatus ssp. tobuschii*	T	E													B																				
Mollusks																																				
Diamond Y Springsnail	*Pseudotryonia adamantina*		E																					B												
False Spike Mussel	*Fusconaia mitchelli*	C	T			F		F	B							B			B	B	B						F	F			F					
Gonzales Tryonia	*Tryonia circumstriata*		E																					B												
Pecos Assiminea Snail	*Assiminea pecos*		E																					B		B										
Phantom Springsnail	*Pyrgulopsis texana*		E																							B										
Phantom Tryonia	*Tryonia cheatumi*		E																					S		B										
Smooth Pimpleback	*Quadrula houstonensis*	C	T			B	F	S	B							F			S	S	S						S									
Texas Fatmucket	*Lampsilis bracteata*	C	T			F	B	B	B		F				B	B			B	B	B						B	B			B	B				
Texas Fawnsfoot	*Truncilla macrodon*		T			S		S	S						S	S			S	S	S						S					S				
Texas Hornshell	*Popenaias popeii*		T							S	S						S							S		S								S		
Texas Pimpleback	*Cyclonaias petrina*	C	T			B		B	B							S			B	B	B		F				B	F		B	F	B				

***Status:**
T - Threatened
E - Endangered
R - Recovery
C - Candidate

Key:
F - Federal listings only (US Fish and Wildlife Service. 2019. Endangered Species List. http://www.fws.gov/endangered/)
S - State listings only (Texas parks and Wildlife Department. 2019. Annotated County Lists of Rare Species. http://tpwd.texas.gov/gis/rtest/)[16]
B - both Federal and State listings

1.4.2 Agriculture and Prime Farmland

Agriculture plays a significant role in the economy of Region F. Table 1-13 provides basic data regarding agricultural production in Region F.[17] Region F includes approximately 22,342,000 acres in farms and over 2,420,000 acres of potential cropland. In 2017, the market value of agriculture products (crops and livestock) for Region F was over $717,000,000, with livestock accounting for approximately 50 percent of the total.

Figure 1-20 shows the distribution of prime farmland in Region F.[18] 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 1-20 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 Andrews, Crockett, Pecos, Reeves, Sutton, and Tom Green Counties. These six counties accounted for about 18 percent of the total land in farms and 44 percent of the total crop value for Region F in 2017.

It is interesting to note that major agricultural production also occurs in some counties with a relatively small amount of prime farmland. For example, Brown, Glasscock, Martin, Runnels, and Scurry Counties have 10 percent or less acreage identified as prime farmland. However, these five counties combined accounted for approximately 24 percent of the total land in farms and 24 percent of the crop value for the region in 2017.

Texas Criteria for Prime Farmland:

- Moisture: Most of Region F lies in Zone 3, which must have water capacity >4 inches in the upper40-inch zone
- Temperature must be > 32 degrees at a depth of 20inches
- pH should be between 4.5 and 8.4
- Mineral characteristics (salinity and calcium carbonate)
- Flooding occurs less than once in 2 years
- Slope and erosion considerations (including wind erodibility)
- Permeability rate > 0.6 inch per hour
- Rock fragments – limited based on size

Table 1-13
2017 U.S. Department of Agriculture County Census Data for Region F

Category	Andrews	Borden	Brown	Coke	Coleman	Concho	Crane	Crockett
Farms	156	127	1,838	449	976	396	30	219
Irrigated Land (acres)	12,823	2,214	4,080	749	709	4,265	(D)	13
Land in Farms (acres)								
- Crop Land[a]	78,257	90,753	76,623	42,989	146,339	108,538	222	6,266
- Pasture Land	805,283	396,182	364,878	410,458	472,806	417,448	243,832	1,514,135
- Other	3,225	7,494	105,267	15,856	53,136	35,011	41	13,705
- Total	886,765	494,429	546,768	469,303	672,281	560,997	244,095	1,534,106
Market Value ($1,000)								
- Crops	$5,128	$17,039	$9,245	$1,253	$13,354	$13,389	(D)	(D)
- Livestock	$5,487	$11,749	$36,725	$6,586	$16,988	$14,730	(D)	(D)
- Total	$10,615	$28,788	$45,970	$7,839	$30,342	$28,119	(D)	(D)

Category	Ector	Glasscock	Howard	Irion	Kimble	Loving	Martin	Mason
Farms	275	175	373	175	602	8	356	680
Irrigated Land (acres)	881	39,669	6,925	923	8,506	(D)	12,227	3,935
Land in Farms (acres)								
- Crop Land[a]	1,891	180,347	148,291	4,349	15,535	(D)	298,913	21,761
- Pasture Land	548,732	311,171	342,072	594,105	700,515	467,485	136,372	457,747
- Other	7,266	4,696	30,600	14,193	84,590	(D)	9,273	59,905
- Total	557,889	496,214	520,963	612,647	694,230	468,140	444,558	539,413
Market Value ($1,000)								
Crops	$256	$47,444	$20,266	$301	(D)	(D)	$52,494	$2,316
Livestock	$3,126	$3,201	$6,600	$8,974	$6,709	(D)	$1,804	$19,363
Total	$3,382	$50,645	$26,866	$9,275	$6,709	(D)	$54,298	$21,679

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

Table 1-13 (Cont'd)
2017 U.S. Department of Agriculture County Census Data for Region F

Category	McCulloch	Menard	Midland	Mitchell	Pecos	Reagan	Reeves	Runnels
Farms	682	346	410	362	309	112	224	833
Irrigated Land (acres)	1,936	1,152	7,404	3,039	12,887	8,098	8,138	5,563
Land in Farms (acres)								
- Crop Land[a]	83,660	10,541	75,819	153,108	50,780	55,572	54,659	256,203
- Pasture Land	443,595	469,138	239,436	419,021	(D)	652,405	996,558	392,384
- Other	35,855	27,888	29,733	10,888	(D)	28,355	12,682	23,717
- Total	563,110	507,567	344,988	583,017	2,867,712	736,332	1,063,899	672,304
Market Value ($1,000)								
Crops	$6,856	$567	$13,013	$13,584	$24,371	$11,947	$5,175	$31,877
Livestock	$15,635	$8,505	$3,326	$8,158	$21,793	$6,256	$5,716	$21,557
Total	$22,491	$9,072	$16,339	$21,742	$46,164	$18,203	$10,891	$53,434

Category	Schleicher	Scurry	Sterling	Sutton	Tom Green	Upton	Ward	Winkler	Total
Farms	327	560	76	261	1,303	98	102	46	12,886
Irrigated Land (acres)	1,412	5,509	411	341	19,604	15,778	3,276	(D)	192,467
Land in Farms (acres)									
- Crop Land[a]	30,559	201,705	9,421	12,412	125,014	74,922	6,457	(D)	2,421,906
- Pasture Land	777,107	312,248	574,488	851,546	668,092	(D)	396,350	479,950	15,855,539
- Other	3,316	16,851	381	36,906	19,779	(D)	2,983	(D)	693,592
- Total	810,982	530,804	584,290	900,864	812,885	725,139	405,790	489,230	22,341,711
Market Value ($1,000)									
Crops	$3,439	$24,361	(D)	$131	$29,864	$13,873	(D)	(D)	361,543
Livestock	$14,351	$20,791	(D)	$10,219	$70,166	$5,190	$1,361	(D)	355,066
Total	$17,790	$45,152	(D)	$10,350	$100,030	$19,063	$1,361	(D)	716,609

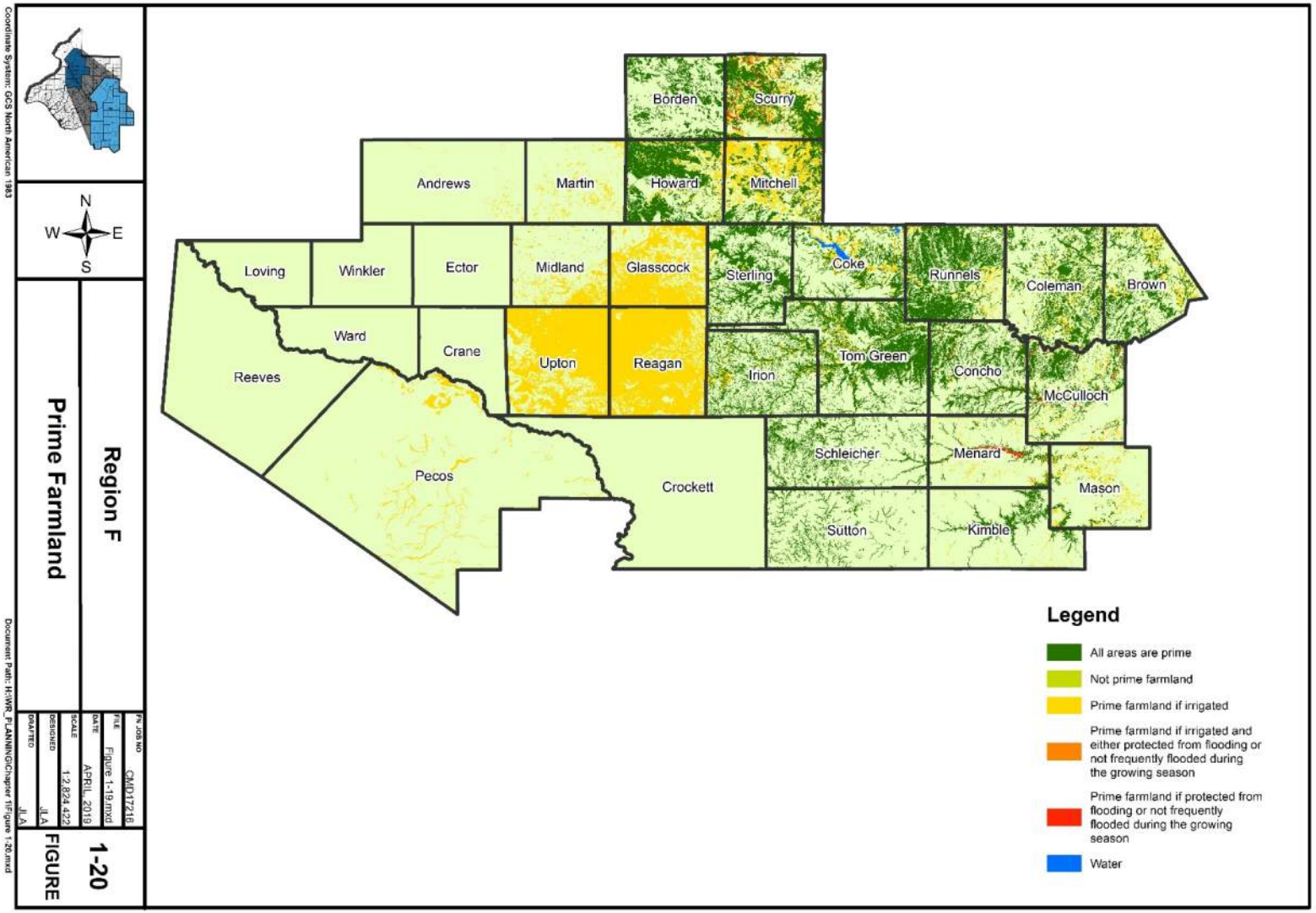
a. Crop land is the land that is currently or recently cultivated for farming. Acreages in active farms may be less.

NOTES: (D) – Data withheld to avoid disclosing data for individual farms.

Total Market Value amounts include value of crops and livestock listed as (D) (data withheld).

Source: Data are from the U.S. Department of Agriculture (USDA, 2017).[17]

Figure 1-20
Prime Farmland Percentage of Total Area



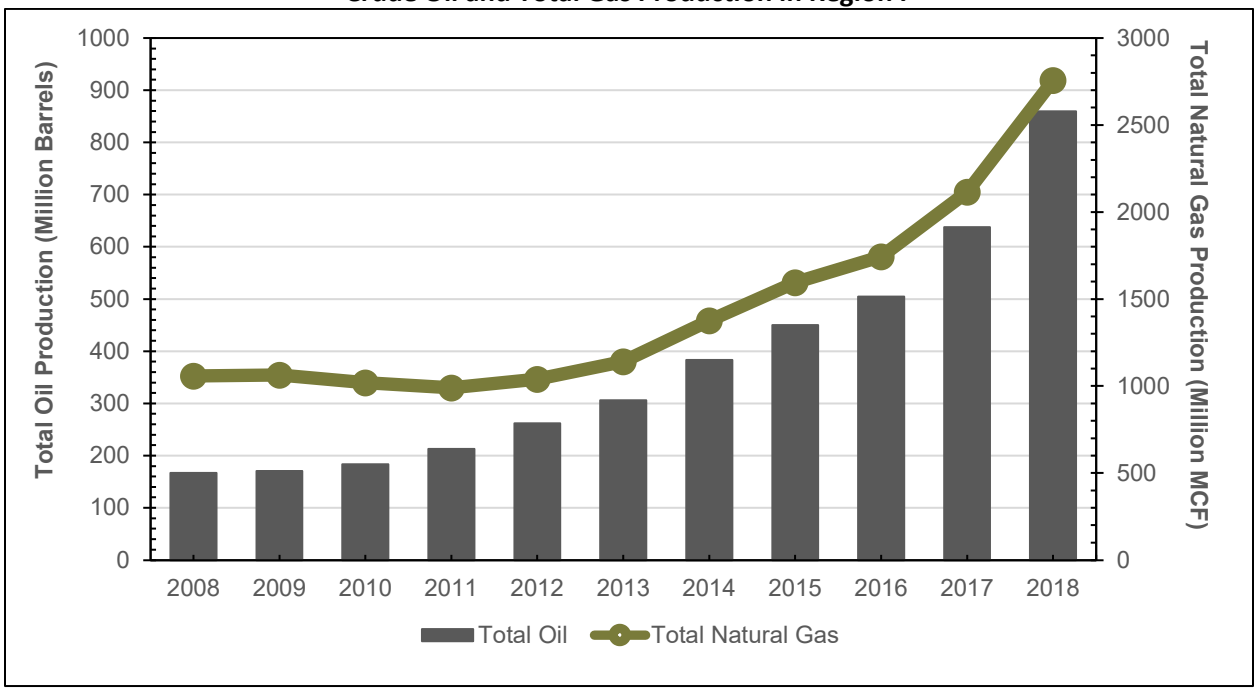
1.4.3 Mineral Resources

Oil and natural gas fields are significant natural resources throughout Region F. Recent developments in drilling technology along with increased commodity prices have led to significant oil and gas production in the Permian Basin. Other significant mineral resources in Region F include bituminous coal resources in Brown, Coleman, and McCulloch Counties, and stone, sand and gravel in various parts of the region.

Petroleum Production

Oil and gas fields are a valuable natural resource throughout most of Region F. As discussed previously in Section 1.1.1, the petroleum industry heavily influences the Region F economy. Over the last decade, Region F has experienced a notable increase in oil and gas production, as technological advancements have made it feasible for companies to develop petroleum in the continental United States. In particular, the Permian Basin (Figure 1-5), which underlies a significant portion of the counties in Region F, has experienced a rapid growth and has become the second largest producer of oil and gas shale in the world[19]. According to data from the Railroad Commission of Texas, annual total oil production (including crude oil and condensate) has increased by over 400% and annual total natural gas (including gas well gas and casinghead gas) production has increased by over 150% in Region F since 2008 (Figure 1-21)[20].

Figure 1-21
Crude Oil and Total Gas Production in Region F



Counties in Region F play an integral role in oil and gas production throughout the state of Texas. In fact, in the year 2018, Region F counties accounted for over 55% of the state's total oil production and over 30% of state's total natural gas production[20]. Six of the top ten largest total oil producing counties (Midland, Reeves, Loving, Martin, Upton, Howard) and three of the top ten largest total natural gas producing counties (Reeves, Loving and Midland) in the state of Texas are located in Region F. In 2018, Midland County alone produced 144.2 million barrels (BBL) of crude oil, which accounted for over 10% of the crude oil production in the entire state.

In 2018, every county in Region F, with the exception of Martin County, produced some form of oil (crude oil or condensate). Furthermore, in 2018, every county, with the exception of Martin and McCulloch Counties, produced some form of natural gas (gas well gas and/or casinghead gas). Figure 1-22and Figure 1-23 illustrate the distribution of total oil (BBL) and total natural gas (MCF) production in each Region F county during the year 2018, respectively.

Coal Mining

Mining activity for bituminous coal resources have historically occurred in Coleman, Brown, and McCulloch Counties in Region F[21]. The coal resources are historically mined in the Cisco Group, which consists of shale, lenticular sandstone, many thin beds of limestone, and minor amounts of coal. The group has a thickness of about 350 feet in outcrops along the west side of the Llano region in Brown and Coleman Counties. According to the Railroad Commission (RRC), there are a total of seven, five, and three historical mining sites in McCulloch, Coleman, and Brown Counties, respectively. These mining sites are now part of the Abandoned Mine Land (AML) Program, which aims to reclaim and restore the land and water resources within previous mining areas. There are no active coal mining permits in Region F.

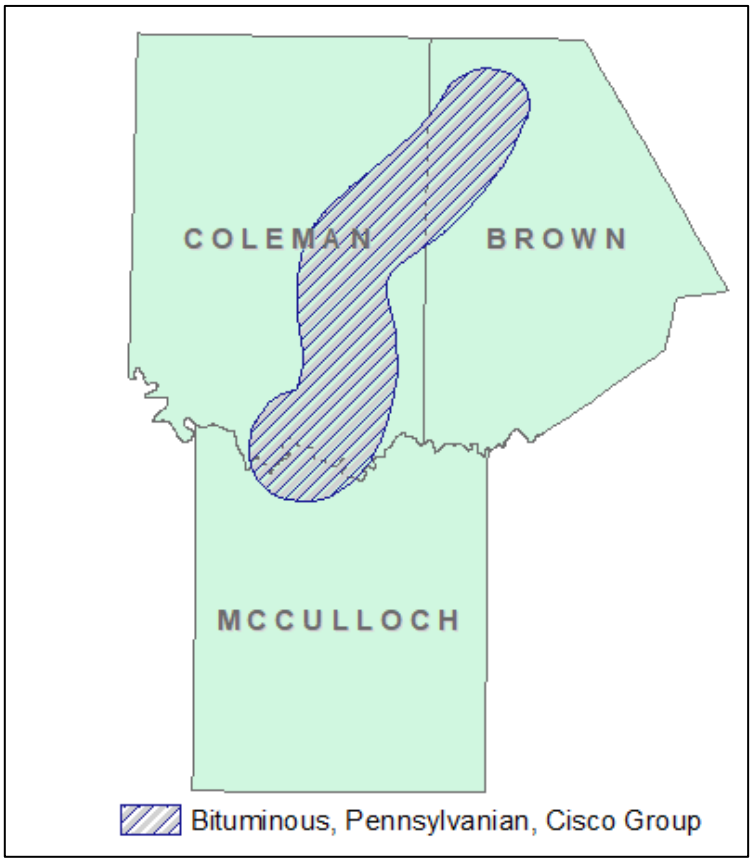


Figure 1-22
Crude Oil Production in Each County (2018)

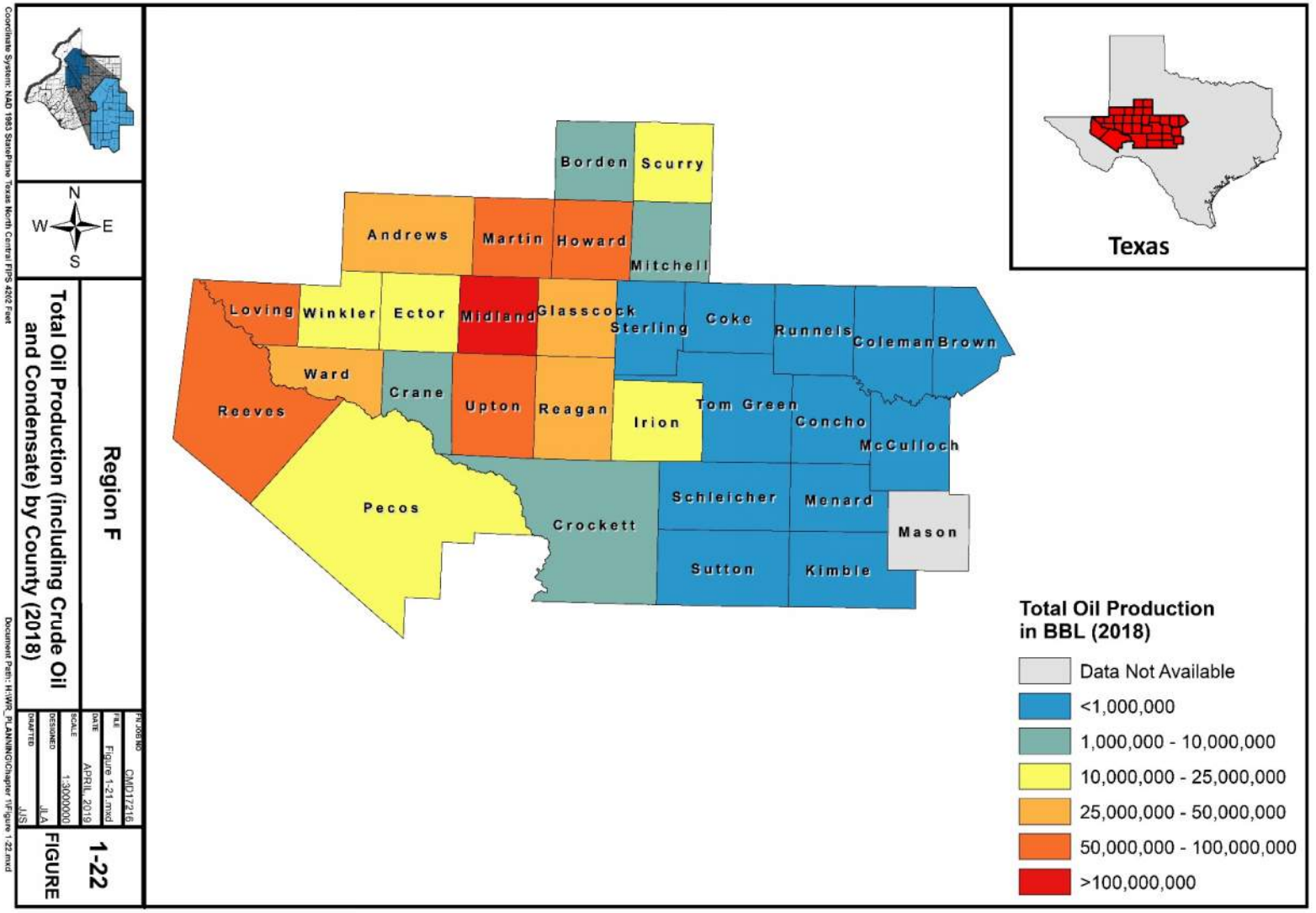
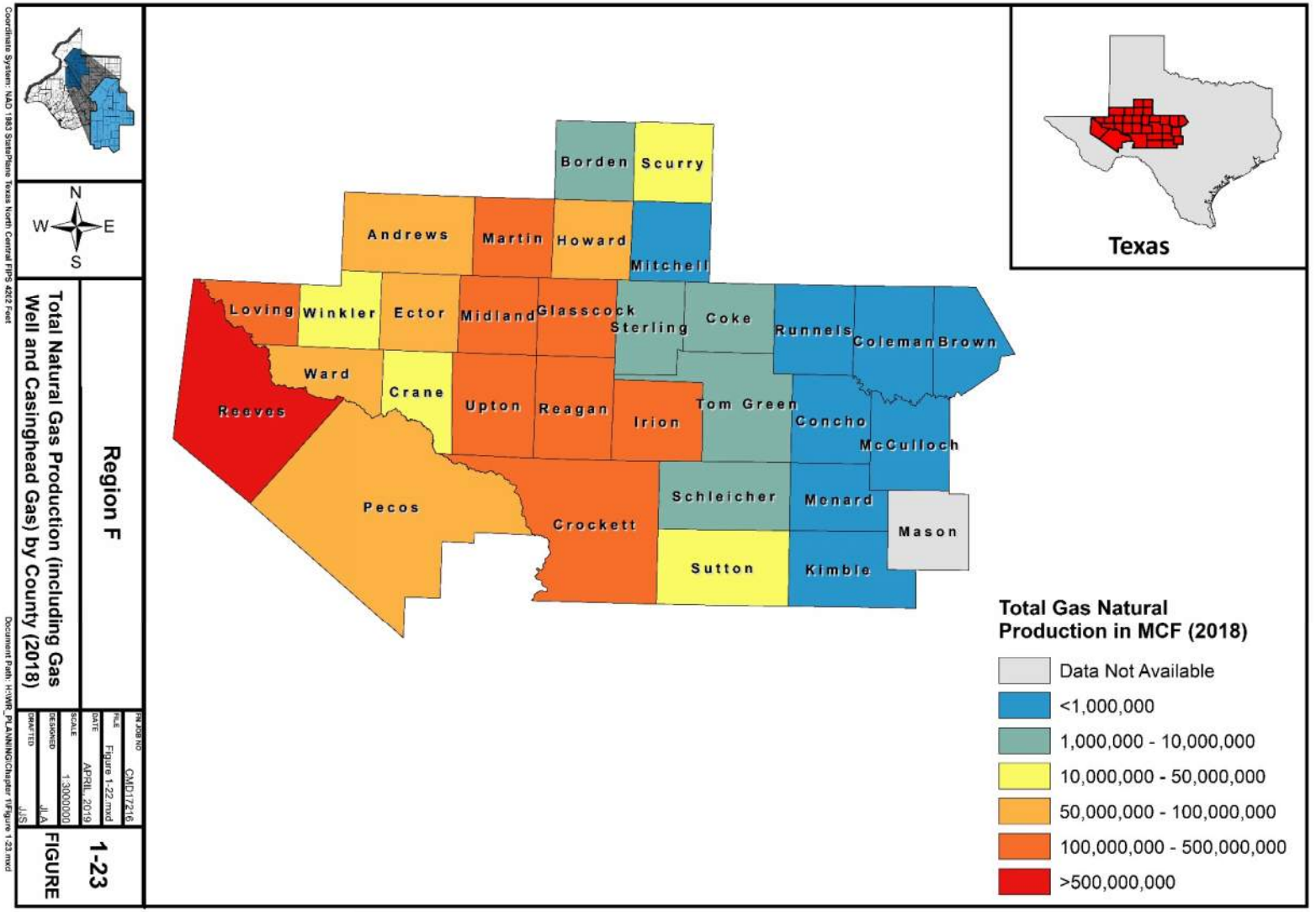


Figure 1-23
Total Gas Production in Each County (2018)



1.5 WATER PROVIDERS IN REGION F

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

1.5.1 Major Water Providers

The TWDB defines the term major water provider (MWP) as "a water user group or wholesale water provider of particular significance to the regions' water supply as determined by the RWPG."[22] Six major water providers have been identified by the Region F RWPG:

- Colorado River Municipal Water District (CRMWD)
- Brown County Water Improvement District Number One (BCWID)
- City of Odessa
- City of Midland
- City of San Angelo
- City of Fort Stockton

There are no implications of designation as a "major water provider" except for the additional data required by TWDB. The major 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.

Brown County Water Improvement District Number One (BCWID).

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.

City of Midland

The City of Midland has several well fields for groundwater supply and purchases water from CRMWD. As the largest city in Region F, Midland provides retail surface water to over 134,000 municipal users and small quantities of water to manufacturing within city limits. In addition, Midland has a contract to sell treated wastewater effluent to the mining industry. Increased oil and gas activities in the Permian Basin (discussed in Section 1.4.3) around Midland have caused a rapid growth in city population and water service areas.

City of Odessa

The City of Odessa is a member city of CRMWD. Odessa sells treated water to the Ector County Utility District, Ector County Other, the Odessa Country Club, and manufacturing users. In addition, Odessa sells raw wastewater to the Gulf Coast Water Authority (GCA) to treat and sell to the mining industry, as well as treated wastewater directly to the mining industry.

City of San Angelo

The City of San Angelo's sources of supply are Lake O.C. Fisher (water is purchased from Upper Colorado River Authority), Twin Buttes Reservoir, Lake Nasworthy, local surface water rights, and O.H. Ivie Reservoir (purchased from CRMWD). San Angelo also developed a groundwater supply from the Hickory Aquifer near Melvin, Texas (McCullough County). As part of an agreement with UCRA, San Angelo

treats water for customers of UCRA. San Angelo also provides water to the Goodfellow Air Force Base.

City of Fort Stockton

The City of Fort Stockton is supplied by groundwater from Pecos and Reeves Counties. Fort Stockton provides retail water to municipal users and plans to supply water to a new refinery (manufacturing) in Pecos County. In addition, Fort Stockton signed a water purchase agreement to supply up to 18,000 acre-feet of water per year for mining purposes in Pecos, Reeves, and possibly Ward Counties.

1.6 EXISTING PLANS FOR WATER SUPPLY DEVELOPMENT

In 2017, the Texas Water Development Board released the State Water Plan, Water for Texas – 2017, which was a compilation of the 16 regional water plans developed under SB1.[23] The Region F Water Planning Group published the Region F Regional Water Plan in January 2016. Some of the findings of the 2016 Region F plan included:

- Approximately 70 water user groups had projected water shortages over the planning period (through 2070). In the event of a drought Region F was projected to have a total water supply shortage of 183,000 acre-feet by 2020 and 237,000 acre-feet by 2070. Many of these shortages were associated with diminishing supplies under new drought of record conditions and decreased groundwater due to a new definition of availability. In total, 291 water management strategies and 145 projects were developed to address these needs.
- Groundwater availability was significantly lower in the 2016 plan compared to previous plans due to the new definition of groundwater availability. In accordance with TWDB rules, the groundwater availability in the 2016 plan was determined by estimates from the Modeled Available Groundwater (MAG). This was the first cycle of planning that required groundwater estimates developed through the state-sponsored groundwater joint planning process.
- Decreases in surface water availability were attributed to ongoing drought of record conditions, which reduced reservoir yields from the TCEQ WAM priority analysis of surface water supplies. Also, the priority analysis does not reflect actual surface water operation in the Upper Colorado River Basin. Subordination of Lower Colorado River Basin water rights provide a significant amount of surface water supplies to Region F. However, these supplies were less in the 2016 regional plan than previous plans, due to ongoing drought of record conditions.
- The majority of water supply deficits were associated with irrigated agriculture. Sixteen counties had a collective irrigation need of nearly 114,000 acre-feet per year by 2020 and 110,000 acre-feet by 2070. No water supply is readily available to meet this need. Improved irrigation efficiency strategies 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.
- A relatively small volume of municipal needs remained unmet in Region F in large cities, e.g., Midland and Andrews. Studies are planned to assess potential options for future water supplies. Additionally, conservation was recommended as a strategy to reduce unmet needs and protect human health and safety.
- General water management strategies recommended in the plan included: subordination, water conservation, brush control, weather modification, wastewater reuse, and desalination.

- Water conservation strategies accounted for 48 percent of the total volume associated with all recommended strategies in 2070. The majority of this volume is associated with irrigation demand reduction. Conservation strategies were also recommended for discrete municipal and other (rural municipal) water users.
- Innovative technologies, such as direct potable reuse, aquifer storage and recovery (ASR), and groundwater desalination accounted for approximately 7 percent of the total volume of recommended strategies in 2070.

The City of San Angelo recently completed a Water Supply Engineering Feasibility Study.[24] The study considered twenty-four possible water supply options and completed a detailed assessment of four options. One of those options was groundwater and three were different versions of potable reuse. The study recommended a potable reuse strategy termed the "Concho River Water Supply" which entailed potable reuse of Concho River water. This option provided the lowest unit cost, the highest yield, and improves the treatment infrastructure of the City.

The cities of Abilene, Midland, and San Angelo formed the West Texas Water Partnership (the Partnership) to evaluate long-term water supplies the Partnership could develop jointly. The Partnership is conducting a separate study to determine the most feasible water management strategies for these cities, but the results were not available at the writing of this plan.

There are no known publicly available plans for agricultural, manufacturing, and commercial water users in Region F. To the extent these types of plans are known, they are considered by the Region F Water Planning Group in the development of the Regional Water Plan.

1.6.1 Conservation Planning in Region F

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

Many cities in Region F have developed water conservation plans. Water conservation education is stressed in most cities. These cities plan to provide educational brochures to new and existing customers. Other measures to conserve water include retrofit programs, leak detection and repair, recycling of wastewater, water conservation landscaping, and adoption of the plumbing code. This plan recommends water conservation for all cities including those without shortages. As part of this plan, model water conservation plans can be accessed online at www.regionfwater.org and clicking on the Documents tab (http://regionfwater.org/index.aspx?id=Documents). These models can serve as templates for entities to develop or update their water conservation plan. More information on water conservation planning, including recommended strategies to conserve water may be found in Subchapter 5B.

1.6.2 Water Loss Audits

Retail public water utilities are required to complete and submit a water loss audit form to the Texas Water Development Board every five years. The first water loss audit reports were submitted to the TWDB by March 31, 2006. The water audit reporting requirements follow the International Water Association (IWA) and American Water Works Association (AWWA) Water Loss Control Committee methodology.[25]

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

In the Region F planning area, 24 public water suppliers submitted a water loss audit to TWDB[26]. The average total water loss for Region F is 14.5 percent. The amount of reported losses in Region F totaled 1.1 billion gallons in 2017. This represents 6.8 percent of the total estimated municipal water demand for the region. This information was used in developing municipal conservation strategies. Table 1-14summarizes the water loss audit information that was collected by the TWDB for 2017. The region encourages the reduction in water loss where feasible.

Table 1-14
Summary of TWDB Water Loss Audits

Total Water Loss	WUGS	SUDS/WSCs
≤ 10%	14	0
10% - 25%	4	0
≥ 25%	2	4

Source: 2017 Water Loss Audit Dataset from TWDB[26]

1.6.3 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. The Lower Colorado River Authority (LCRA) determined that the 2008-2016 drought surpassed the historic drought-of-record from the 1950s for LCRA's Highland Lakes and the lower basin and is now the new drought of record. This is significant for Region F because some of the eastern portion of Region F is in the watershed for the Highland Lakes System, which is located in Region K, east of Region F. The low inflows into the Highland Lakes parallels the lower than normal runoff that has occurred in Region F as well. A detailed discussion of the impact of drought on water supplies and water suppliers is included in Chapter 7.

Model drought contingency plans were developed for Region F and can be accessed online at www.regionfwater.org. 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.

1.6.4 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, Water Supply Enhancement Program, and precipitation enhancement programs.

Texas Commission on Environmental Quality (TCEQ) Water Rights Permitting

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

Texas Pollutant Discharge Elimination System (TPDES) Program

The TPDES is the state program to carry out the National Pollutant Discharge Elimination System (NPDES) promulgated under the Clean Water Act. The Railroad Commission of Texas maintains authority in Texas over discharges associated with oil, gas, and geothermal exploration and development activities. The TPDES program covers all permitting, inspection, public assistance, and enforcement associated with:

- discharges of industrial or municipal waste;
- discharges and land application of manure from concentrated animal feeding operations;
- discharges of industrial and construction site storm water;
- discharges of storm water associated with city storm sewers;
- oversight of municipal pretreatment programs; and
- disposal and use of sewage sludge.

Wellhead Protection Areas

The Texas Water Code provides for a wellhead source water protection zone around public water supply wells extending to activities within a 0.25 mile radius. Specific types of sources of potential contamination within this wellhead/source water protection zone may be further restricted by TCEQ rule or regulation. For example, wellhead/source water protection zones have been designated for many public water supply wells within or near Pantex (May and Block, 1997). More specific information on well head protection zones is available from TCEQ.

The Texas Water Code further provides for all wells to be designed and constructed according to TCEQ well construction standards (30 TAC 290). These standards require new wells to be encased with concrete extending down to a depth of 20 feet, or to the water table or a restrictive layer, whichever is the lesser. An impervious concrete seal must extend at least 2 feet laterally around the well head and a riser installed at least 1 foot high above the impervious seal.

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.[27]

Clean Water Act - The Clean Water Act is a federal law designed to protect water quality. The Act does not directly address groundwater nor water quantity issues. The statute employs a variety of regulatory and non-regulatory tools to reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff. These tools are employed to achieve the broader goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters so that they can support "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water." [28]

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 and infrastructure projects that may affect wetlands or rivers. In Texas, the state oversees the NPDES permitting system, which sets the operating requirements for wastewater treatment plants. The Section 404 permitting process is facilitated by the Corps of Engineers.

The TCEQ administers a Total Maximum Daily Load (TMDL) Program for surface water bodies in the state of Texas. TMDL programs are a result of the Clean Water Act. In this program, water quality analyses are performed for water bodies to determine the maximum load of pollutants the water body can handle and still support its designated uses. The load is then allocated to potential sources of pollution in the watershed, and implementation plans are developed which contain measures to reduce the pollutant loads. The Implementation Plan for Sulfate and Total Dissolved Solids (TDS) TMDLs in the E.V. Spence Reservoir (Segment 1411) was established in August 2001. The TCEQ has completed analyzing the Colorado River below E.V. Spence Reservoir (Segment 1426) for chloride, sulfate, and TDS concentrations and updated the Implementation Plan (further information on the updated plan is included in Section 1.7.1).

Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) was originally passed by Congress to protect public health by regulating the nation's public drinking water supply. The law requires many actions to protect drinking water and its sources – rivers, lakes, reservoirs, springs, and groundwater wells. To ensure that drinking water is safe, SDWA sets up multiple barriers against pollution including source water protection, treatment, distribution system integrity, and public information.[29] Some of the initiatives that will most likely have significant impacts in Region F are the reduction in allowable levels of trihalomethanes in treated water, the requirement for reduction of total organic carbon levels in raw water, and the reduction in the allowable level of arsenic and radionuclides in drinking water. The allowable limit on arsenic has been reduced from 50 micrograms per liter to 10 micrograms per liter.

Water Supply Enhancement Program

The Water Supply Enhancement Program, formerly known as the State Brush Control Program, was developed pursuant to Chapter 203 of the Texas Agricultural Code. Feasibility studies have been conducted for seven watersheds in the region including Lake Brownwood, O.C. Fisher, O.H. Ivie Lake Basin, E.V. Spence, Lake J.B. Thomas, Twin Buttes Reservoir, and Upper Llano River. These projects are discussed further in Subchapter 5C.

Precipitation Enhancement Programs

In Region F, there are several ongoing weather modification programs, including the West Texas Weather Modification Association (WTWMA) project, and the Trans Pecos

Weather Modification Association (TPWMA) program. 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 5C.

Bio-Terrorism Preparedness and Response Act

Following the events of September 11th, Congress passed the Bio-Terrorism Preparedness and Response Act. Drinking water utilities serving more than 3,300 people were required and have completed vulnerability preparedness assessments and response plans for their water, wastewater, and stormwater facilities. The U.S. Environmental Protection Agency (EPA) funded the development of three voluntary guidance documents, which provide practical advice on improving security in new and existing facilities of all sizes. The guidance document for water utilities can be found through the American Water Works Association.

1.7 Summary of Threats and Constraints to Water Supply

1.7.1 Threats to Water Supply

Threats to water supply in Region F include:

- Water quality concerns in several areas of the region,
- The impact of drought,
- Changes in groundwater regulation,
- Rainfall/runoff patterns in the Upper Colorado River Basin, and
- Strict enforcement of State's Priority System for Surface Water.

Brief discussions of each of these concerns is presented in this section. The water quality concerns are discussed by source. 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. Surface water quality concerns identified by the TCEQ within Region F are summarized in Table 1-15. The Region F Plan was developed under the guiding principal that the designated water quality and related water uses shall be improved or maintained.

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, chlorides, and sulfates. 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.[30] 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. In 2007, the TCEQ adopted Two Total Maximum Daily Loads for Chlorides and Total Dissolved Solids for the Colorado River below the E.V. Spence Reservoir. Later that year, the TCEQ approved the Implementation plan (I-plan) to achieve the pollutant reduction identified in the TMDL report.[31] The Railroad Commission has since eliminated many potential sources of contamination and the Texas State Soil and Water Conservation Board removed salt cedar in the watershed. Prior to the current drought, the salinity levels in the segment of stream were improving. However, the drought has lowered water levels in Spence, leading to a re-concentration of chloride and TDS. In 2014, the Upper Colorado River Authority (UCRA) and TCEQ updated the I-plan. In 2016, stakeholders met to discuss progress of the I-Plan to evaluate actions taken, identify actions that may not be working, and make any changes necessary. Continued monitoring of the area should show improving water quality as the I- Plan is implemented.[32]

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.[33] Further analysis of data collected near Paint Rock shows an increasing trend in chloride, which is likely attributed to lower inflows from the Lipan Aquifer due to drought, increased irrigation withdrawals, and brush infestation. [34]

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. The implementation of this program has proved to be successful as water quality has shown significant improvement and fish kills have been virtually eliminated. In 2016, water quality data in the North Concho River indicate that concentrations of E. coli have decreased, and TCEQ proposed to remove the bacteria impairment from the list of impaired waters[35].

Table 1-15
Summary of Identified Surface Water Quality Problems in Region F

Segment ID	Segment Name	Concern Location	Water Quality Concern	Status
1411	E.V. Spence Reservoir	From Robert Lee Dam in Coke County to a point immediately upstream of the confluence of Little Silver Creek in Coke County, up to the normal pool elevation of 1898 feet (impounds Colorado River)	Chloride	Additional data and information will be collected before a TMDL is scheduled.
1412	Colorado River Below J.B Thomas	From the confluence of Beals Creek upstream to the dam below Barber Reservoir pump station	bacteria	Additional data and information will be collected before a TMDL is scheduled.
1412 B	Beals Creek	From the confluence of Gutherie Draw upstream to the confluence of Mustang Draw and Sulphur Springs Draw in Howard County	bacteria	A review of the standards for one or more parameters will be conducted before a management strategy is selected, including the possible revision to the water quality standards.
1413	Lake J. B. Thomas	From Colorado River Dam in Scurry County up to normal pool elevation of 2258 feet (impounds Colorado River)	chloride	Additional data and information will be collected before a TMDL is scheduled.
			sulfate	
			total dissolved solids	
1416	San Saba River	From the confluence with the Colorado River in San Saba County upstream to US 190	bacteria	Additional data and information will be collected before a TMDL is scheduled.
1416 A	Brady Creek	From FM 714 upstream to Brady Lake dam	depressed dissolved oxygen	Additional data and information will be collected before a TMDL is scheduled.
1421	Concho River	North Concho River, from the confluence with the South Concho River upstream to O.C. Fisher dam	depressed dissolved oxygen	Additional data and information will be collected before a TMDL is scheduled.
1425	O.C. Fisher Lake	From San Angelo Dam in Tom Green County up to normal pool elevation of 1908 feet (impounds North Concho River)	chloride	Additional data and information will be collected before a TMDL is scheduled.
			total dissolved solids	Additional data and information will be collected before a TMDL is scheduled.
1432	Upper Pecan Bayou	From a point immediately upstream of the confluence of Willis Creek in Brown County to Lake Brownwood Dam in Brown County	bacteria	Additional data and information will be collected before a TMDL is scheduled.
2311	Upper Pecos River	From US Hwy 67 upstream to the Ward Two Irrigation Turnout	depressed dissolved oxygen	Additional data and information will be collected before a TMDL is scheduled.
2312	Red Bluff Reservoir	From Red Bluff Dam to mid-lake From mid-lake to the Texas/New Mexico state line	chloride	Additional data and information will be collected before a TMDL is scheduled.
			sulfate	Additional data and information will be collected before a TMDL is scheduled.

Source: Data from 2016 Draft 303(d) list (October 17, 2018)[36]

Hickory Aquifer

Radionuclides present in the Hickory aquifer originate from geologic formations. Several of the public water systems that rely on this aquifer sometimes exceed the TCEQ's radionuclide limits, including limits on radon. Some users are blending water from other sources with Hickory supplies to reduce radionuclide concentrations while other users have implemented radionuclide removal systems. 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. Generally, agricultural use is not impaired by the presence of the radionuclides.

Dockum Aquifer

Water quality in the Dockum Aquifer ranges from fresh (TDS < 1,000 mg/L) in outcrop areas and the edges of the depositional basin to brines with over 50,000 mg/L TDS in the center of the basin. Upward movement of water in some areas, such as Andrews County, can result in poorer water quality in the overlying Ogallala Aquifer. In Ector County, Dockum wells produce groundwater with TDS concentrations between 2,000 and 7,000 mg/L and sulfate and chloride concentrations up to 2,500 mg/L from wells that are less than 750 feet deep. The presence of uranium minerals in the Dockum Group has long been recognized and is the source of some radiological constituents (radium-226 and -228) reported in some Dockum Aquifer groundwater samples. The concentrations of some trace metals, including antimony, beryllium, cadmium, lead, mercury, selenium, and thallium, were reported to exceed drinking water regulatory limits in several counties.

Other Groundwater Quality Issues

Other groundwater quality issues in Region F include elevated levels of fluoride, nitrate, arsenic and perchlorate.

Table 1-16 shows the percentage of water wells sampled by the TWDB that exceed drinking water standards for dissolved fluoride, dissolved nitrate (nitrogen as NO_3), and dissolved 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 Borden, Howard, Martin, and Runnels Counties. The highest percentages of wells exceeding arsenic standards are found in Andrews, Borden, Howard, Midland, and Martin Counties. Perchlorate is a growing water quality concern for water from the Ogallala aquifer in west Texas. Preliminary research found perchlorate levels exceeding drinking water standards in 35 percent of the public drinking water wells.[37] Texas has not established an MCL for perchlorate. However, in 2001, TCEQ did establish an Interim Action Level (IAL) of 0.004 mg/L for perchlorate, and in its 2006 guidance for assessing the health of surface waters for the purposes of drinking water quality, TCEQ required monitoring and reporting of perchlorate levels that exceed 0.022 mg/L.[38]

Table 1-16
Percentage of Sampled Water Wells Exceeding Drinking Water Standards for Fluoride, Nitrate (as NO_3) and Arsenic

County	Fluoride	Nitrate	Arsenic
Andrews	27%	6%	38%
Borden	13%	33%	48%
Brown	2%	16%	0%
Coke	0%	3%	0%
Coleman	4%	24%	0%
Concho	1%	17%	0%
Crane	7%	18%	24%
Crockett	0%	0%	0%
Ector	3%	5%	24%
Glasscock	3%	13%	7%
Howard	16%	33%	35%
Irion	0%	0%	3%
Kimble	0%	9%	0%
Loving	0%	2%	6%
Martin	45%	35%	71%
Mason	0%	11%	0%
McCulloch	1%	5%	0%
Menard	0%	5%	0%
Midland	10%	9%	32%
Mitchell	6%	21%	0%
Pecos	0%	0%	0%
Reagan	1%	0%	3%
Reeves	2%	6%	6%
Runnels	0%	9%	1%
Schleicher	2%	74%	0%
Scurry	2%	14%	5%
Sterling	0%	1%	0%
Sutton	0%	0%	0%
Tom Green	0%	1%	0%
Upton	0%	14%	0%
Ward	0%	4%	0%
Winkler	1%	9%	1%

Data are from the Texas Water Development Board 06-2019[39]

Regional Drought

Most of Region F has experienced drought-of-record conditions since the mid-1990s. These conditions have led to reduced inflow, high evaporation and low lake levels limiting the supply. Many suppliers in the region responded by implementing their drought contingency plans and in some cases expedited implementation of water supply strategies. Drought conditions also have a negative impact on water quality. As water levels decline, reservoirs tend to concentrate dissolved materials. Without significant freshwater inflows the water quality in a reservoir degrades. The lack of recharge to aquifers has a similar effect on groundwater. A detailed discussion of the impact of drought on water supplies and water suppliers is included in Chapter 7.

Changes in Groundwater Regulation

Changes in groundwater regulation can have a major impact on water supply in Region F, especially during drought conditions when surface water is not available. Recent droughts have helped identify the importance of groundwater supplies to Region F and how they serve to balance water supply sources and serve as a critical safety net for several major cities in the region. Many cities and wholesale water providers plan to use surface water and groundwater conjunctively to optimize and maximize water supplies in the region by using as much surface water as possible when it is available in order to reduce evaporation losses and to conserve groundwater. When surface water is not available, groundwater will be used as necessary to meet demands. This shift towards a fully-integrated conjunctive use approach is dependent upon adequate groundwater availability during drought conditions. If groundwater availability is reduced (either physically or through regulatory restrictions), the safety net for the region can be significantly impaired. Under current law, and in counties with GCDs to enforce Desired Future Conditions (DFCs), groundwater availability could be significantly reduced by adoption of more restrictive DFCs. Additionally, TWDB funding for water projects might be limited by DFCs and MAGs even in areas without GCDs where physical groundwater availability is adequate to meet projected demands.

Rainfall and Runoff Patterns in the Upper Colorado River Basin

Region F surface water supply is heavily dependent upon consistent streamflow (runoff) throughout the Colorado River Basin. In 2017, a detailed evaluation of historical rainfall-runoff patterns in the Upper Colorado River Basin determined that observed flow trends have declined over the period of record (1940-2016)[40]. Analysis of naturalized flows from the Colorado Basin WAM indicated that most of this diminishing trend is likely caused by construction of large reservoir systems and historical water use, which are both associated with existing water rights in the basin area. Additionally, all sites in the study demonstrated some decline in naturalized flow, signifying that activities not accounted for in the naturalization flow process could have impacted observed flows. Further investigations determined that four activities had some effect on the trend of observed and naturalized flows over the study period: (1) the proliferation of noxious brush; (2) the construction of small reservoirs, not accounted for in naturalized flows; (3) groundwater use and aquifer water level declines; and (4) changes in average temperature in drought conditions. If this declining trend of observed and naturalized flows continue, and these activities continue to cause negative effects, then threats to surface water supplies in the Upper Colorado River Basin will likely persist and could potentially magnify.

Strict Enforcement of State's Priority System for Surface Water

Texas surface water is governed by a priority system, which means "first in time, first in right." The TCEQ is charged with regulating the state's surface water, including issuing water rights and enforcing those rights. Historically, the TCEQ has only enforced the priority system when there was a request for water from a senior downstream water right holder, referred to as a priority call. Even then, the TCEQ would consider public health and safety when requiring pass-through of inflows from upstream to downstream users. With the development of the Water Availability Models (WAMs), which models strict interpretation of the priority system, it became apparent that many of the Region F reservoirs have little to no reliable supply, given that assumption. The WAM interpretation applies to the priority system to both storage and diversion that results in more water passed through to downstream water right holders than previously modeled for supply analyses.

During the recent drought (2011-2013), there were several priority calls across the state. As part of the response to these calls, TCEQ considered public health and safety as a factor in requiring pass-throughs. However, recent judicial decisions have stated that the state must enforce the priority system without regard to the type of use. If the state enforces the priority system in accordance with the assumptions in the WAMs, surface water supplies in Region F would be significantly impacted. More discussions on these impacts is included in Chapter 3 and Subchapter 5C.

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 and/or existing 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.

As previously discussed, much of the surface water and groundwater in the region contains high concentrations of dissolved solids, originating from natural and man-made sources. It is possible to make use of these resources, but the cost to treat this water can be high. Much of the region is rural with limited resources. 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.

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 supplies. Water-related threats to natural resources include changes to natural flow conditions and water quality concerns.

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 some cases these disposal pits have not been remediated and remain as sources of salt contamination. Current brine disposal practices involve repressurizing hydrocarbon-producing

formations or disposing through deep well injection. These practices lead to the possibility of leaks into water supply aquifers since the hydraulic pressure of the injected water routinely exceeds the pressure needed to raise the water to the ground's surface. In other aquifers, excessive pumping may cause naturally occurring poor quality water to migrate into fresh water zones.

Most of Region F depends on groundwater for irrigation. Based on current use, agricultural demand exceeds the available groundwater supply in several counties. Parts of three counties (Midland, Reagan and Upton) were declared a Priority Groundwater Management Area by the TCEQ in 1990. Since that time the Santa Rita GCD has formed for most of Reagan County with Glasscock GCD covering small portions of the county as well. In February 2017, the Executive Director of TCEQ provided a report for northeastern Upton and southeastern Midland Counties recommending these areas be added to the Glasscock GCD.

1.8.2 Water Related Threats to Natural Resources

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

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