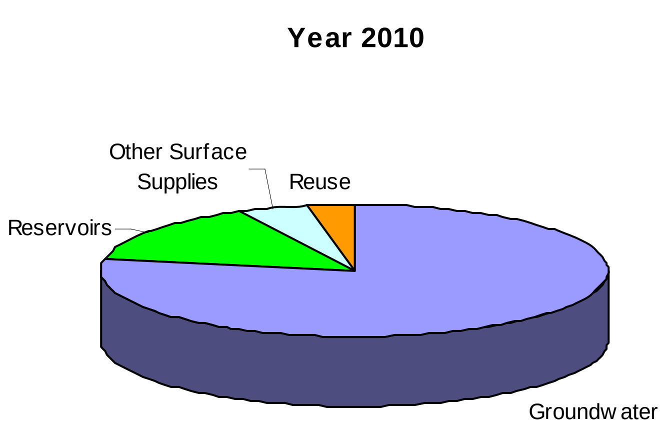
4 IDENTIFICATION, EVALUATION, AND SELECTION OF WATER MANAGEMENT STRATEGIES BASED ON NEEDS

4.1 Comparison of Current Supplies and Demand

4.1.1 Current Supply

The current supply in Region F consists of groundwater, surface water from in-region reservoirs, local supplies and wastewater reuse. There is a small amount of groundwater that comes from outside the region (Regions G and E). Based on the assessment of currently available supplies (Chapter 3), groundwater is the largest source of water in Region F, accounting for 78 percent of the total supply. Reservoirs are the second largest source of water, with 15 percent of the supply. Run-of-the-river supplies and alternative sources such as desalination and wastewater reuse provide the remainder of the region's supply. (Reservoir and run-of-the-river supplies are based on the Colorado WAM, which underestimates the amount of water available from reservoirs in Region F.) The total currently available water supply for Region F is approximately 605,000 acre-feet per year. The distribution of this supply by source type in the year 2010 is shown in Figure 4.1-1.

Figure 4.1-1
Distribution of Available Supply



Surface water supplies are based on the Colorado WAM.

4.1.2 Regional Demands

Regional demands were developed by city, county and category, and are discussed in Chapter 2. In summary, the total demands for the region are projected to increase from 809,478 in 2010 to 827,397 acre-feet per year in 2060. The largest water demand category is irrigation, which accounts for about 72 percent of the total demand in the region. Municipal is the next largest water user in the Region F. Manufacturing, mining, steam electric power and livestock demands together account for only about 11 percent of the total water demands. Over the planning period, irrigation demand is expected to decrease, while municipal, manufacturing, mining and steam electric are projected to increase. Livestock demands are projected to remain the same through 2060. The projected increases in demands are expected to occur near the larger municipalities and to a lesser extent in the rural areas.

Irrigation demands for 2010 through 2060 are significantly higher than the historical irrigation use in the year 2000. Irrigation demands in Region F in 2000 were somewhat lower than they could have been due to reduced surface water supplies and depressed cotton prices. Baseline irrigation demands are based upon full availability of surface water supplies and a recovery of cotton prices. More information on irrigation demands may be found in Section 2.3.3.

4.1.3 Comparison of Demand to Currently Available Supplies

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

Figure 4.1-2 compares the overall supply allocation for historical year 2000 and projected supplies and demands through 2060. The demand exceeds the available supply by about 202,000 acre-feet per year in the year 2010, increasing to over 229,000 acre-feet per year by 2060. Figures 4.1-3 through 4.1-5 compare supply and demand for the three largest water use categories: irrigation, municipal and steam-electric. Irrigation demand exceeds available supply by about 180,000 acre-feet per year in the year 2010, decreasing to 157,000 acre-feet per year by the year 2060. Municipal demand exceeds currently available supplies by over 12,000 acre-feet per year in the year 2010, increasing to over 34,000 acre-feet per year by 2060. Steam-electric demand is expected to exceed supply by over 9,400 acre-feet per year in 2010, increasing to almost 30,000 acre-feet per year by 2060.

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

4.1.4 Identified Needs for Wholesale Water Providers

Table 4.1-4 is a summary of the needs for the seven Wholesale Water Providers in Region F. Needs for CRMWD, San Angelo, Odessa and UCRA are primarily the result of using the Colorado WAM for water availability. (More information on water supplies in the Colorado WAM may be found in Appendix 3D.) Needs for University Lands are the result of contract expiration. More information on contracts with University Lands may be found in Section 3.5.

4.1.5 Socio-Economic Impacts of Not Meeting Projected Shortages

Based on the above analysis, Region F will face substantial shortages in water supply over the planning period. The Texas Water Development Board provided technical assistance to regional water planning groups in the development of specific information on the socio-economic impacts of failing to meet projected water needs. This section is a summary of the TWDB's socio-economic report[1]. The full report may be found in Appendix 4B.

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

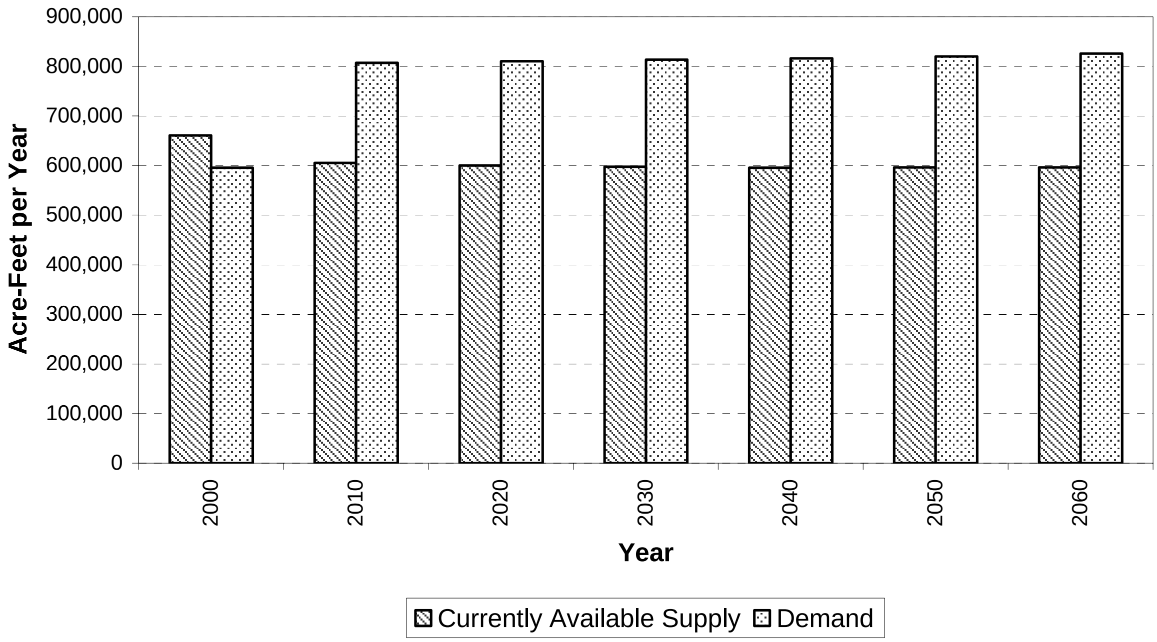
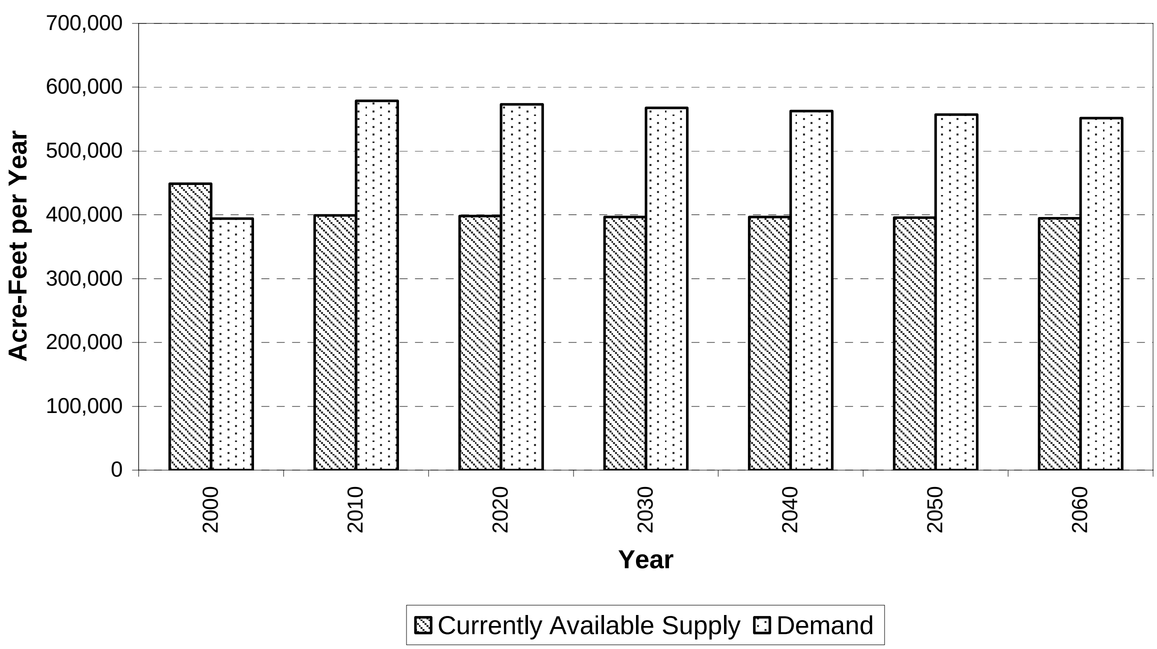


Figure 4.1-3
Comparison of Irrigation Supplies and Demands



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

Figure 4.1-4
Comparison of Municipal Supplies and Demands

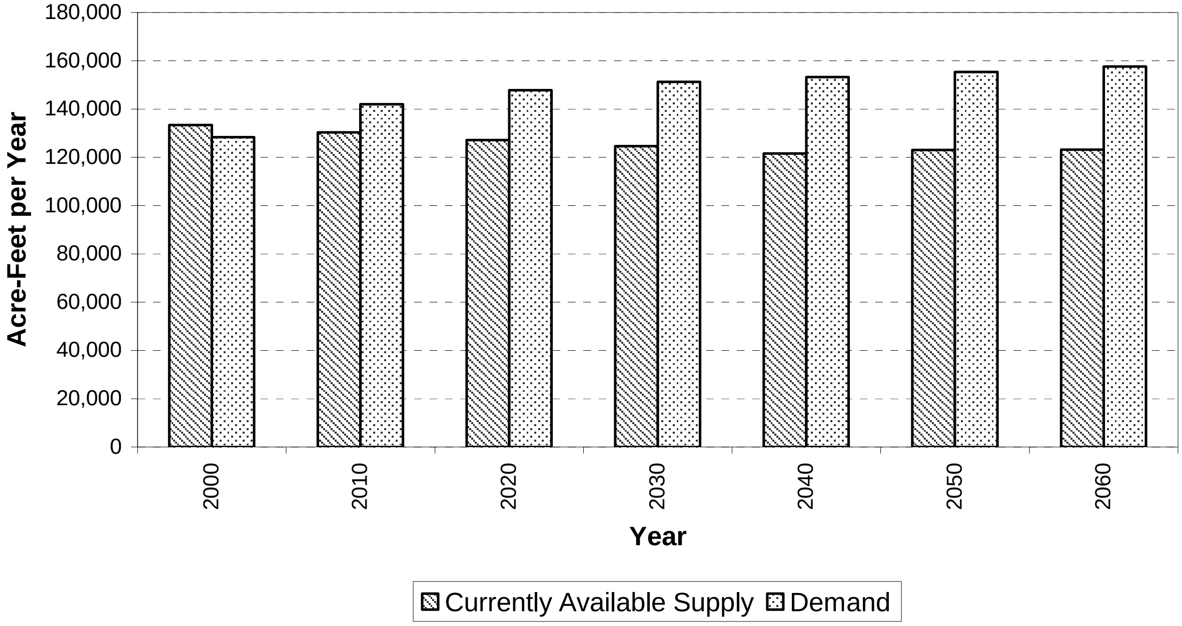
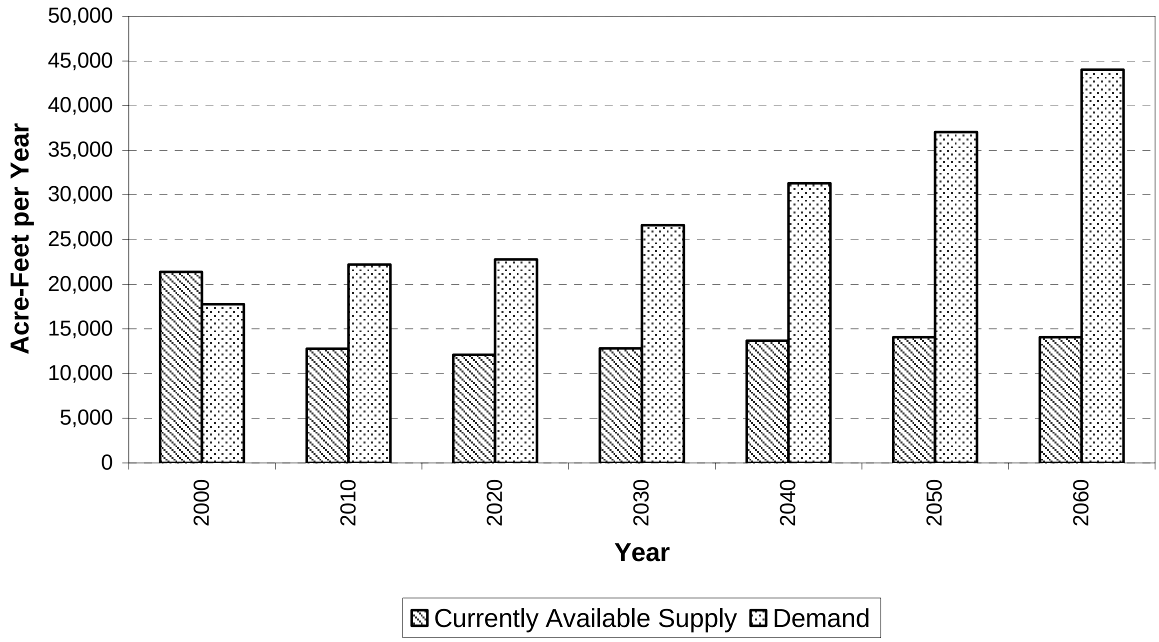


Figure 4.1-5
Comparison of Steam Electric Supplies and Demands



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

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

County*	Irrigation			Manufacturing			Mining			Municipal			Steam Electric Power			Livestock			Total		
	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)
Andrews	18,514	32,608	(14,094)	0	0	0	1,965	1,908	57	3,625	3,625	0	0	0	0	438	438	0	24,542	38,579	(14,037)
Borden	843	2,690	(1,847)	0	0	0	1,014	690	324	178	175	3	0	0	0	281	281	0	2,316	3,836	(1,520)
Brown	9,307	12,313	(3,006)	577	577	0	2,487	2,487	0	7,687	7,106	581	0	0	0	1,636	1,636	0	21,694	24,119	(2,425)
Coke	573	936	(363)	0	0	0	410	488	(78)	539	771	(232)	0	310	(310)	593	593	0	2,115	3,098	(983)
Coleman	31	1,379	(1,348)	0	6	(6)	1	18	(17)	532	1,874	(1,342)	0	0	0	1,259	1,259	0	1,823	4,536	(2,713)
Concho	5,265	4,297	968	0	0	0	0	0	0	965	873	92	0	0	0	775	775	0	7,005	5,945	1,060
Crane	0	337	(337)	0	0	0	1,461	2,221	(760)	1,256	1,256	0	0	0	0	155	155	0	2,872	3,969	(1,097)
Crockett	535	525	10	0	0	0	402	402	0	2,546	1,707	839	1,500	973	527	997	997	0	5,980	4,604	1,376
Ector	274	5,533	(5,259)	2,699	2,759	(60)	10,074	9,888	186	24,422	28,708	(4,286)	6,375	6,375	0	293	293	0	44,137	53,556	(9,419)
Glasscock	24,488	52,272	(27,784)	0	0	0	5	5	0	181	181	0	0	0	0	232	232	0	24,906	52,690	(27,784)
Howard	4,862	4,799	63	1,499	1,648	(149)	1,426	1,783	(357)	6,105	7,308	(1,203)	0	0	0	366	366	0	14,258	15,904	(1,646)
Irion	1,501	2,803	(1,302)	0	0	0	122	122	0	248	238	10	0	0	0	460	460	0	2,331	3,623	(1,292)
Kimble	1,771	985	786	3	702	(699)	104	71	33	203	1,148	(945)	0	0	0	668	668	0	2,749	3,574	(825)
Loving	583	581	2	0	0	0	3	2	1	11	11	0	0	0	0	70	70	0	667	664	3
Martin	13,536	14,324	(788)	39	39	0	705	674	31	396	788	(392)	0	0	0	273	273	0	14,949	16,098	(1,149)
Mason	10,358	10,079	279	0	0	0	6	6	0	956	932	24	0	0	0	1,036	1,036	0	12,356	12,053	303
McCulloch	2,918	2,824	94	844	844	0	154	154	0	1,543	2,252	(709)	0	0	0	1,027	1,027	0	6,486	7,101	(615)
Menard	3,620	6,061	(2,441)	0	0	0	0	0	0	388	458	(70)	0	0	0	642	642	0	4,650	7,161	(2,511)
Midland	25,260	41,493	(16,233)	164	164	0	677	677	0	32,305	32,568	(263)	0	0	0	904	904	0	59,310	75,806	(16,496)
Mitchell	5,564	5,534	30	0	0	0	141	115	26	1,728	1,703	25	0	9,100	(9,100)	449	449	0	7,882	16,901	(9,019)
Pecos	82,583	79,681	2,902	3	2	1	286	159	127	7,660	4,816	2,844	0	0	0	1,240	1,239	1	91,772	85,897	5,875
Reagan	25,600	36,597	(10,997)	0	0	0	2,036	2,036	0	1,035	1,035	0	0	0	0	279	272	7	28,950	39,940	(10,990)
Reeves	66,972	103,069	(36,097)	720	720	0	182	182	0	3,846	3,834	12	0	0	0	2,283	2,283	0	74,003	110,088	(36,085)
Runnels	2,973	4,331	(1,358)	0	63	(63)	44	44	0	291	2,091	(1,800)	0	0	0	1,530	1,530	0	4,838	8,059	(3,221)
Schleicher	3,132	2,108	1,024	0	0	0	150	125	25	852	723	129	0	0	0	787	787	0	4,921	3,743	1,178
Scurry	3,529	2,815	714	0	0	0	3,880	3,107	773	3,161	3,666	(505)	0	0	0	629	629	0	11,199	10,217	982
Sterling	745	648	97	0	0	0	590	590	0	349	349	0	0	0	0	503	503	0	2,187	2,090	97
Sutton	1,812	1,811	1	0	0	0	80	80	0	2,196	1,472	724	0	0	0	796	796	0	4,884	4,159	725
Tom Green	57,531	104,621	(47,090)	0	2,226	(2,226)	150	73	77	15,385	23,494	(8,109)	0	543	(543)	1,978	1,978	0	75,044	132,935	(57,891)
Upton	6,119	16,759	(10,640)	0	0	0	2,662	2,662	0	1,550	942	608	0	0	0	212	212	0	10,543	20,575	(10,032)
Ward	8,266	13,793	(5,527)	7	7	0	153	153	0	3,484	3,484	0	4,914	4,914	0	126	126	0	16,950	22,477	(5,527)
Winkler	10,000	10,000	0	0	0	0	1,878	928	950	4,721	2,377	2,344	0	0	0	169	151	18	16,768	13,456	3,312
Total	*399,065*	*578,606*	*(179,541)*	*6,555*	*9,757*	*(3,202)*	*33,248*	*31,850*	*1,398*	*130,344*	*141,965*	*(11,621)*	*12,789*	*22,215*	*(9,426)*	*23,086*	*23,060*	*26*	*605,087*	*807,453*	*(202,366)*

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

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

County*	Irrigation			Manufacturing			Mining			Municipal			Steam Electric Power			Livestock			Total		
	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)
Andrews	18,136	32,062	(13,926)	0	0	0	2,031	1,976	55	3,937	3,937	0	0	0	0	438	438	0	24,542	38,413	(13,871)
Borden	843	2,682	(1,839)	0	0	0	1,014	646	368	178	169	9	0	0	0	281	281	0	2,316	3,778	(1,462)
Brown	9,284	12,230	(2,946)	686	686	0	2,510	2,510	0	7,671	7,111	560	0	0	0	1,636	1,636	0	21,787	24,173	(2,386)
Coke	573	934	(361)	0	0	0	550	550	0	633	755	(122)	0	289	(289)	593	593	0	2,349	3,121	(772)
Coleman	31	1,379	(1,348)	0	6	(6)	1	19	(18)	530	1,814	(1,284)	0	0	0	1,259	1,259	0	1,821	4,477	(2,656)
Concho	5,265	4,262	1,003	0	0	0	0	0	0	993	884	109	0	0	0	775	775	0	7,033	5,921	1,112
Crane	0	337	(337)	0	0	0	1,303	2,214	(911)	1,453	1,453	0	0	0	0	155	155	0	2,911	4,159	(1,248)
Crockett	535	508	27	0	0	0	431	431	0	2,543	1,865	678	1,500	907	593	997	997	0	6,006	4,708	1,298
Ector	77	5,402	(5,325)	3,125	3,125	0	8,545	10,911	(2,366)	27,471	32,271	(4,800)	6,375	10,668	(4,293)	293	293	0	45,886	62,670	(16,784)
Glasscock	24,466	51,438	(26,972)	0	0	0	5	5	0	203	203	0	0	0	0	232	232	0	24,906	51,878	(26,972)
Howard	4,862	4,690	172	1,848	1,832	16	1,924	1,924	0	7,371	7,310	61	0	0	0	366	366	0	16,371	16,122	249
Irion	1,501	2,682	(1,181)	0	0	0	122	122	0	242	227	15	0	0	0	460	460	0	2,325	3,491	(1,166)
Kimble	1,771	913	858	3	823	(820)	104	65	39	200	1,129	(929)	0	0	0	668	668	0	2,746	3,598	(852)
Loving	583	576	7	0	0	0	3	2	1	10	10	0	0	0	0	70	70	0	666	658	8
Martin	13,500	13,822	(322)	42	42	0	705	634	71	429	858	(429)	0	0	0	273	273	0	14,949	15,629	(680)
Mason	10,358	9,792	566	0	0	0	6	6	0	956	916	40	0	0	0	1,036	1,036	0	12,356	11,750	606
McCulloch	2,918	2,754	164	1,004	1,004	0	162	162	0	1,594	2,236	(642)	0	0	0	1,027	1,027	0	6,705	7,183	(478)
Menard	3,620	6,022	(2,402)	0	0	0	0	0	0	384	446	(62)	0	0	0	642	642	0	4,646	7,110	(2,464)
Midland	24,500	40,848	(16,348)	198	198	0	846	846	0	20,659	35,301	(14,642)	0	0	0	904	904	0	47,107	78,097	(30,990)
Mitchell	5,564	5,479	85	0	0	0	141	108	33	1,704	1,621	83	0	8,910	(8,910)	449	449	0	7,858	16,567	(8,709)
Pecos	82,583	77,191	5,392	3	2	1	286	158	128	7,689	5,071	2,618	0	0	0	1,240	1,239	1	91,801	83,661	8,140
Reagan	25,269	35,385	(10,116)	0	0	0	2,235	2,235	0	1,167	1,167	0	0	0	0	279	272	7	28,950	39,059	(10,109)
Reeves	66,936	101,323	(34,387)	756	756	0	175	175	0	4,288	4,272	16	0	0	0	2,283	2,283	0	74,438	108,809	(34,371)
Runnels	2,973	4,298	(1,325)	0	76	(76)	45	45	0	312	2,174	(1,862)	0	0	0	1,530	1,530	0	4,860	8,123	(3,263)
Schleicher	3,132	2,024	1,108	0	0	0	150	139	11	834	795	39	0	0	0	787	787	0	4,903	3,745	1,158
Scurry	3,477	2,630	847	0	0	0	3,880	3,413	467	3,721	3,721	0	0	0	0	629	629	0	11,707	10,393	1,314
Sterling	745	595	150	0	0	0	605	605	0	387	387	0	0	0	0	503	503	0	2,240	2,090	150
Sutton	1,794	1,742	52	0	0	0	83	83	0	2,206	1,539	667	0	0	0	796	796	0	4,879	4,160	719
Tom Green	57,531	104,107	(46,576)	0	2,737	(2,737)	150	85	65	15,495	24,648	(9,153)	0	909	(909)	1,978	1,978	0	75,154	134,464	(59,310)
Upton	6,099	16,285	(10,186)	0	0	0	2,687	2,687	0	1,551	1,024	527	0	0	0	212	212	0	10,549	20,208	(9,659)
Ward	7,733	13,454	(5,721)	7	7	0	156	156	0	3,122	3,522	(400)	4,937	4,937	0	126	126	0	16,081	22,202	(6,121)
Winkler	10,000	10,000	0	0	0	0	1,878	883	995	4,721	2,444	2,277	0	0	0	169	151	18	16,768	13,478	3,290
Total	*396,659*	*567,846*	*(171,187)*	*7,672*	*11,294*	*(3,622)*	*32,733*	*33,795*	*(1,062)*	*124,654*	*151,280*	*(26,626)*	*12,812*	*26,620*	*(13,808)*	*23,086*	*23,060*	*26*	*597,616*	*813,895*	*(216,279)*

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

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

County*	Irrigation			Manufacturing			Mining			Municipal			Steam Electric Power			Livestock			Total		
	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)	Supply	Demand	Surplus (Need)
Andrews	19,080	31,245	(12,165)	0	0	0	2,089	2,036	53	4,173	4,173	0	0	0	0	438	438	0	25,780	37,892	(12,112)
Borden	847	2,673	(1,826)	0	0	0	1,014	612	402	174	123	51	0	0	0	281	281	0	2,316	3,689	(1,373)
Brown	9,264	12,105	(2,841)	837	837	0	2,530	2,530	0	7,554	6,932	622	0	0	0	1,636	1,636	0	21,821	24,040	(2,219)
Coke	573	933	(360)	0	0	0	588	614	(26)	591	737	(146)	0	477	(477)	593	593	0	2,345	3,354	(1,009)
Coleman	31	1,379	(1,348)	0	6	(6)	1	19	(18)	528	1,766	(1,238)	0	0	0	1,259	1,259	0	1,819	4,429	(2,610)
Concho	5,265	4,213	1,052	0	0	0	0	0	0	980	865	115	0	0	0	775	775	0	7,020	5,853	1,167
Crane	0	337	(337)	0	0	0	1,167	2,208	(1,041)	1,623	1,623	0	0	0	0	155	155	0	2,945	4,323	(1,378)
Crockett	535	482	53	0	0	0	459	459	0	2,539	1,949	590	1,500	1,500	0	997	997	0	6,030	5,387	643
Ector	75	5,204	(5,129)	3,435	3,491	(56)	7,804	11,970	(4,166)	30,587	36,725	(6,138)	6,375	17,637	(11,262)	293	293	0	48,569	75,320	(26,751)
Glasscock	24,468	50,190	(25,722)	0	0	0	5	5	0	201	201	0	0	0	0	232	232	0	24,906	50,628	(25,722)
Howard	4,862	4,527	335	2,021	2,099	(78)	1,952	2,052	(100)	6,955	7,140	(185)	0	0	0	366	366	0	16,156	16,184	(28)
Irion	1,501	2,501	(1,000)	0	0	0	122	122	0	222	185	37	0	0	0	460	460	0	2,305	3,268	(963)
Kimble	1,771	807	964	3	1,002	(999)	104	60	44	200	1,104	(904)	0	0	0	668	668	0	2,746	3,641	(895)
Loving	583	572	11	0	0	0	3	2	1	10	10	0	0	0	0	70	70	0	666	654	12
Martin	13,075	13,075	0	47	47	0	705	603	102	396	789	(393)	0	0	0	273	273	0	14,496	14,787	(291)
Mason	10,358	9,363	995	0	0	0	6	6	0	956	900	56	0	0	0	1,036	1,036	0	12,356	11,305	1,051
McCulloch	2,918	2,649	269	1,233	1,233	0	171	171	0	1,570	2,190	(620)	0	0	0	1,027	1,027	0	6,919	7,270	(351)
Menard	3,620	5,962	(2,342)	0	0	0	0	0	0	384	435	(51)	0	0	0	642	642	0	4,646	7,039	(2,393)
Midland	23,891	39,884	(15,993)	245	245	0	1,046	1,046	0	16,447	37,180	(20,733)	0	0	0	904	904	0	42,533	79,259	(36,726)
Mitchell	5,564	5,398	166	0	0	0	141	104	37	1,639	1,409	230	0	14,730	(14,730)	449	449	0	7,793	22,090	(14,297)
Pecos	82,583	73,475	9,108	3	2	1	286	158	128	7,670	4,980	2,690	0	0	0	1,240	1,239	1	91,782	79,854	11,928
Reagan	25,186	33,579	(8,393)	0	0	0	2,436	2,436	0	1,049	1,049	0	0	0	0	279	272	7	28,950	37,336	(8,386)
Reeves	66,863	98,710	(31,847)	825	825	0	170	170	0	4,533	4,713	(180)	0	0	0	2,283	2,283	0	74,674	106,701	(32,027)
Runnels	2,973	4,241	(1,268)	0	94	(94)	45	45	0	330	2,319	(1,989)	0	0	0	1,530	1,530	0	4,878	8,229	(3,351)
Schleicher	3,132	1,897	1,235	0	0	0	154	154	0	824	824	0	0	0	0	787	787	0	4,897	3,662	1,235
Scurry	3,400	2,355	1,045	0	0	0	3,947	3,693	254	3,574	3,696	(122)	0	0	0	629	629	0	11,550	10,373	1,177
Sterling	745	518	227	0	0	0	620	620	0	379	379	0	0	0	0	503	503	0	2,247	2,020	227
Sutton	1,794	1,639	155	0	0	0	86	86	0	2,196	1,499	697	0	0	0	796	796	0	4,872	4,020	852
Tom Green	57,531	103,338	(45,807)	0	3,425	(3,425)	150	99	51	15,589	24,888	(9,299)	0	1,502	(1,502)	1,978	1,978	0	75,248	135,230	(59,982)
Upton	6,081	15,576	(9,495)	0	0	0	2,708	2,708	0	1,553	1,088	465	0	0	0	212	212	0	10,554	19,584	(9,030)
Ward	6,059	12,947	(6,888)	7	7	0	159	159	0	3,069	3,469	(400)	6,189	8,162	(1,973)	126	126	0	15,609	24,870	(9,261)
Winkler	10,000	10,000	0	0	0	0	1,878	847	1,031	4,721	2,292	2,429	0	0	0	169	151	18	16,768	13,290	3,478
Total	*394,628*	*551,774*	*(157,146)*	*8,656*	*13,313*	*(4,657)*	*32,546*	*35,794*	*(3,248)*	*123,216*	*157,632*	*(34,416)*	*14,064*	*44,008*	*(29,944)*	*23,086*	*23,060*	*26*	*596,196*	*825,581*	*(229,385)*

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

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

Wholesale Water Provider	Category	2010	2020	2030	2040	2050	2060
BCWID	Supply	29,712	29,712	29,712	29,563	29,067	28,570
	Demand	14,960	15,087	15,066	14,975	14,966	15,029
	Surplus (Need)	*14,752*	*14,625*	*14,646*	*14,588*	*14,101*	*13,541*
CRMWD [a]	Supply	74,485	67,935	66,585	65,235	63,885	62,535
	Demand	93,344	96,158	78,662	79,434	79,718	81,036
	Surplus (Need)	*(18,859)*	*(28,223)*	*(12,077)*	*(14,199)*	*(15,833)*	*(18,501)*
City of Odessa	Supply	21,179	16,131	23,733	23,718	24,117	23,987
	Demand	26,150	27,480	28,634	29,866	31,285	32,887
	Surplus (Need)	*(4,971)*	*(11,349)*	*(4,901)*	*(6,148)*	*(7,168)*	*(8,900)*
City of San Angelo	Supply	*20,116*	*19,893*	*19,670*	*19,446*	*19,223*	*19,000*
	Demand	50,419	51,543	52,230	52,634	53,196	53,746
	Surplus (Need)	*(30,303)*	*(31,650)*	*(32,560)*	*(33,188)*	*(33,973)*	*(34,746)*
Great Plains Water System	Supply	6,726	6,726	6,726	6,726	6,726	6,726
	Demand	6,726	6,726	6,726	6,726	6,726	6,726
	Surplus (Need)	*0*	*0*	*0*	*0*	*0*	*0*
UCRA [b]	Supply	0	0	0	0	0	0
	Demand	4,112	3,993	3,875	3,757	3,638	3,520
	Surplus (Need)	*(4,112)*	*(3,993)*	*(3,875)*	*(3,757)*	*(3,638)*	*(3,520)*
University Lands [c]	Supply	5,200	0	0	0	0	0
	Demand	10,593	10,630	10,652	5,950	5,960	5,973
	Surplus (Need)	*(5,393)*	*(10,630)*	*(10,652)*	*(5,950)*	*(5,960)*	*(5,973)*

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

The TWDB analysis of socio-economic impacts is based on information on potential shortages in Region F from the TWDB planning database. Table 4.1-5 and Figures 4.1-6 and 4.1-7 summarize the TWDB's analysis of the impacts of a severe drought occurring in a single year at each decadal period in Region F. It was assumed that all of the projected shortage was attributed to drought. Under these assumptions, the TWDB's findings can be summarized as follows:

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

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

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

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

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

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

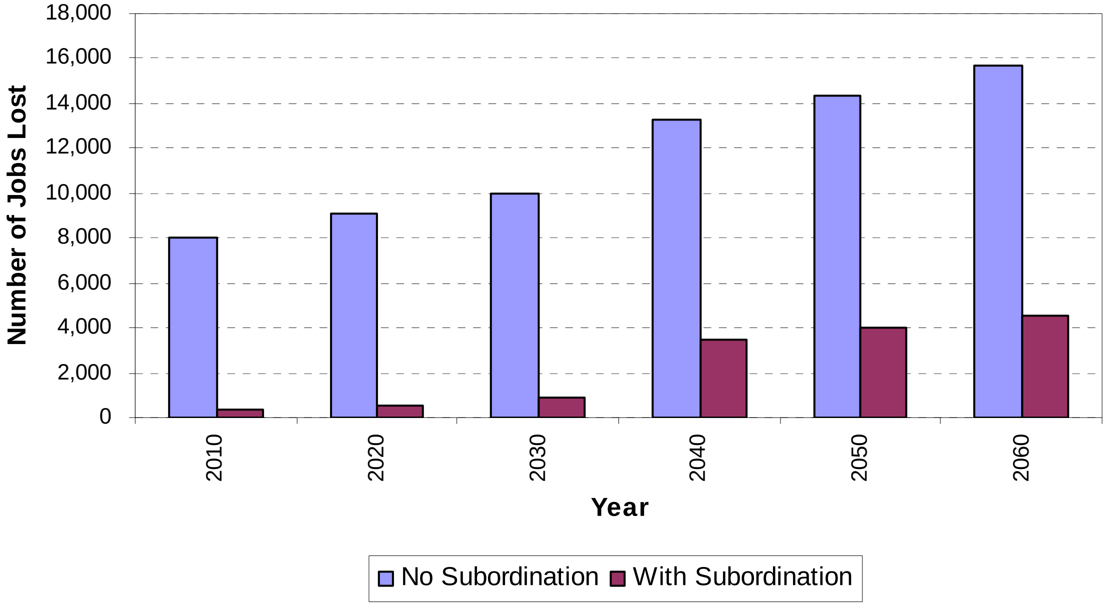
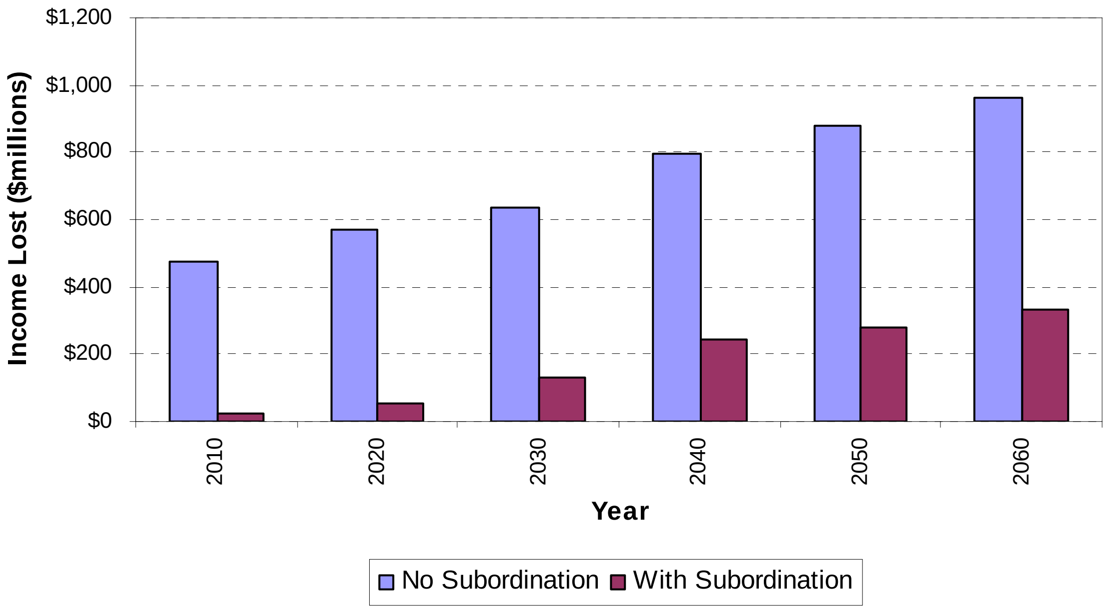


Figure 4.1-7
Income Lost in Region F Due to Water Shortages with and without Subordination Strategy



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

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

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

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

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

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

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

4.2 Identification and Evaluation of Water Management Strategies

4.2.1 Evaluation Procedures

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

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

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

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

4.2.2 Strategy Development

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

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

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

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

In accordance with TWDB guidance, costs are reported using second quarter 2002 prices and debt service is set at a 6 percent annual interest rate over 20 years except for reservoirs, which assumed a 6 percent annual interest rate over a period of 30 years. Cost estimates may be found in Appendix 4F.

4.2.3 Subordination of Downstream Senior Water Rights

The TWDB requires the use of the TCEQ Water Availability Models (WAM) for regional water planning. Most of the water rights in Region F are in the Colorado River Basin. Table 4.2-1 compares the supplies for the Region F water rights using the Colorado WAM to those used in previous state water plans. As Table 4.2-1 shows, the Colorado WAM gives a very different assessment of water availability for many reservoirs in Region F than assumed in previous plans. The primary difference between the supply analysis used in previous plans and the Colorado WAM is that previous plans did not assume that senior lower basin water rights would continuously make priority calls on Region F water rights. Other differences include a shorter period of hydrologic analysis, assumptions about channel losses, and the use of return flows. Appendix 3C contains more information regarding the assumptions used in the Colorado WAM and their impact on water supplies.

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

Although the Colorado WAM does not give an accurate assessment of water supplies based on the way the basin has historically been operated, TWDB requires the regional water planning groups to use the WAM to determine supplies. Therefore these sources in Region F have no supply by definition, even though in practice their supply may be greater than indicated by the WAM. According to the WAM, the cities of Ballinger, Coleman, Junction, and Winters and their customers have no water supply. The Morgan Creek power plant has no supply to generate power. The cities of Big Spring, Bronte, Coahoma, Midland, Miles, Odessa, Robert

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

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

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

Lee, San Angelo, Snyder and Stanton do not have sufficient water to meet current demands. The City of Brady, which recently built a new water treatment plant on Brady Creek Reservoir because its groundwater supplies exceed drinking water standards for radium, has no supply from that reservoir. Overall, the Colorado WAM shows shortages that are the result of modeling assumptions and regional water planning rules rather than the historical operation of the Colorado Basin. This would indicate Region F needs to immediately spend significant funds on new water supplies, when in reality the indicated water shortages are not justified. Conversely, the WAM model shows more water in Region K (Lower Colorado Basin) than may actually be available.

One way for the planning process to reserve water supplies for these communities and their customers is to assume that downstream senior water rights do not make priority calls on major Region F municipal water rights, a process referred to as *subordination*. This assumption is similar to the methodology used to evaluate water supplies in previous water plans.

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

All of the yields presented in this section have been adjusted to account for reduced yield due to drought conditions that have occurred since 1998, the last year simulated in the Colorado WAM. Appendix 4E contains information on the impact of new drought-of-record conditions on water supplies in Region F.

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

The joint modeling was conducted for regional water planning purposes only. By adopting this strategy, the Region F Water Planning Group does not imply that the water rights holders in Table 4.2-2 have agreed to relinquish the ability to make priority calls on junior water rights. The Region F Water Planning Group does not have the authority to create or enforce subordination agreements. Such agreements must be developed by the water rights holders themselves. Region F recommends and supports ongoing discussions on water rights issues in the Colorado Basin that may eventually lead to formal agreements that reserve water for Region F water rights.

Table 4.2-2
Major Water Rights Included in Subordination Analysis

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

CA Certificate of Adjudication number
P Permit number
A Application number

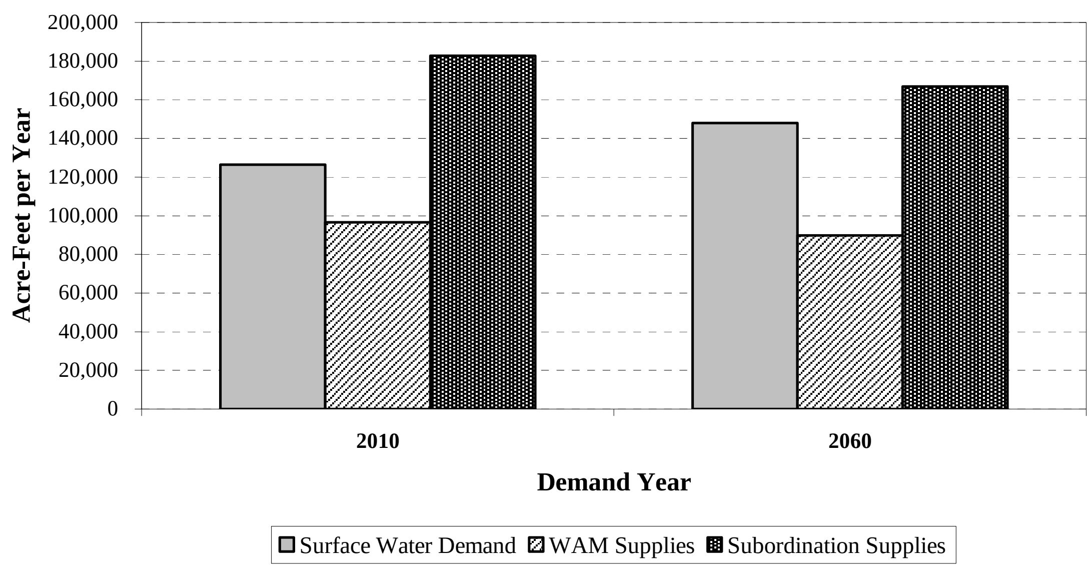
* Oak Creek Reservoir is located in Region F but the supplies are primarily used in Brazos G.

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

Quantity, Reliability and Cost of Subordination

The subordination strategy shows additional supplies of 86,067 in 2010 and 76,958 in 2060. Figure 4.2-1 compares overall Region F surface water supplies and demands in the years 2010 and 2060, with and without the subordination strategy. Table 4.2-3 compares the 2010 and 2060 supplies for Region F water supply sources with and without the subordination strategy. Without the subordination strategy, in 2010 demand exceeds supply by 29,797 acre-feet per. With subordination, the region has a surplus supply of 56,270 acre-feet per year that can be used to meet other needs. By 2060, without subordination demand exceeds supply by 58,100 acre-feet per year. With subordination, the region has a surplus supply of 18,848 acre-feet per year that can be used to meet other needs. Detailed comparisons of supplies and demands may be found in Appendix 4A.

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



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

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

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

Reservoir	2010 Supply WAM Run 3	2010 Supply Subord-ination	2060 Supply WAM Run 3	2060 Supply Subord-ination	Comments
Lake Colorado City	0	2,686	0	1,920	
Champion Creek Reservoir	0	2,337	0	2,220	
Colorado City/Champion System	*0*	*5,023*	*0*	*4,140*	
Oak Creek Reservoir	0	2,118	0	1,760	
Lake Ballinger	0	940	0	890	
Lake Winters	0	720	0	670	
Twin Buttes Reservoir/Lake Nasworthy	0	12,310	0	11,360	
O.C. Fisher Reservoir	0	3,862	0	3,270	
San Angelo System	*0*	*16,172*	*0*	*14,630*	
Hords Creek Reservoir	0	1,390	0	1,240	
Lake Coleman	0	8,507	0	7,990	
Coleman System	*0*	*9,897*	*0*	*9,230*	
Brady Creek Reservoir	0	2,170	0	2,220	
Lake Thomas	0	10,013	0	10,130	
Spence Reservoir (CRMWD system portion)	34	36,164	34	35,090	
Spence Reservoir (Non-system portion)	526	2,308	526	2,240	6% of safe yield
Spence Reservoir Total	*560*	*38,472*	*560*	*37,330*	
Ivie Reservoir (CRMWD system portion)	33,428	33,479	30,026	28,345	
Ivie Reservoir (Non-system portion)	32,922	32,973	29,574	27,915	49.62% of safe yield
Ivie Reservoir Total	*66,350*	*66,452*	*59,600*	*56,260*	
CRMWD Grand Total (Thomas, Spence & Ivie)	*66,910*	*114,937*	*60,160*	*103,720*	
Lake Brownwood	29,712	29,712	29,712	28,570	
City of Junction	0	1,000	0	1,000	

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

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

Environmental Issues Associated with Subordination

The WAM models assume a perfect application of the prior appropriations doctrine. A significant assumption in the model is that junior water rights routinely bypass water to meet the demands of downstream senior water rights and fill senior reservoir storage. If a downstream senior reservoir is less than full, all junior upstream rights are assumed to cease diverting and storing water until that reservoir is full, even if that reservoir does not need to be filled for that water right to meet its diversion targets. Currently in the Region F portion of the Colorado Basin, water rights divert and store inflows until downstream senior water rights make a priority call on upstream junior water rights. Many other assumptions are made in the Colorado WAM model that may be contrary to historical operation of the Colorado Basin in Region F. These assumptions are discussed in detail in Appendix 3C.

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

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

Environmental impacts should be based on an assessment of the actual conditions, not a simulation of a theoretical legal framework such as the WAM. The subordination modeling approaches the actual operation of the upper basin. The actual impacts of implementing this strategy could occur during extreme drought when a downstream senior water right may elect to make a priority call on upstream junior water rights. Flows from priority releases could be used beneficially for environmental purposes in the intervening stream reaches before the water is diverted by the senior water right. Priority calls are largely based on the decision of individual water rights holders, making it difficult to quantify impacts. However, the potential environmental impacts are considered to be medium because this strategy, as modeled, assumes that priority calls are not made by major water rights during times of drought, potentially reducing streamflow in some reaches during drought.

Agricultural and Rural Issues Associated with Subordination

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

Three Region F reservoirs included in the subordination strategy provide a significant amount of water for irrigation: the Twin Buttes Reservoir/Lake Nasworthy system and Lake Brownwood. Twin Buttes Reservoir uses a pool accounting system to divide water between the City of San Angelo and irrigation users. As long as water is in the irrigation pool, water is available for irrigation. Due to drought, no water has been in the irrigation pool since 1998. The total authorized diversion for the Twin Buttes/Nasworthy system is 54,000 acre-feet per year. The two reservoirs have no firm or safe yield in the Colorado WAM. With the subordination analysis the current safe yield of the Twin Buttes/Nasworthy system is 12,500 acre-feet per year. Historical water use from the reservoir has been as high as 40,000 acre-feet per year. The average recent use from the reservoir when irrigation supplies were available has been 29,000 acre-feet per year[3]. Therefore even with subordination there may not be sufficient water to meet both the needs of the City of San Angelo and irrigation demands.

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

Other Natural Resource Issues Associated with Subordination

None identified.

Significant Issues Affecting Feasibility of Subordination

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

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

Other Water Management Strategies Directly Affected by Subordination

All other strategies for this plan are based on water supplies with the subordination strategy in place. Table 4.3-1 is a partial list of Region F strategies potentially impacted by the subordination strategy. The amount of water needed from most of these strategies may be higher without the subordination strategy. Other strategies may be indirectly impacted. Changes to the assumptions made in the subordination strategy may have a significant impact on the amount of water needed from these strategies.

4.3 Municipal Needs

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

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

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

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

4.3.1 City of Andrews

The City of Andrews obtains its water from the Ogallala aquifer. Although sufficient supplies may be available from this source for the City of Andrews, there are insufficient supplies to meet all needs within Andrews County. The city's supply also exceeds drinking water standards for fluoride. The city is interested in desalination as a long-term strategy to improve the reliability and quality of their water supply.

Desalination – Dockum Aquifer

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

Additional information on the Dockum aquifer may be found in Section 3.1.5.

Quantity, Reliability and Cost of Desalination

For the purposes of this plan it is assumed that a 1 mgd desalination plant delivering up to 950 acre-feet of water per year would be constructed in northern Andrews County near the city's existing well field. Delivery to the city would be through the existing pipeline. Disposal of brine reject would be through co-disposal with oil field brines at a near-by oil field. Because of the uncertainty involved with development of this source for municipal water use, the reliability of this source is considered to be moderate. Table 4.3-2 summarizes the expected costs for the project.

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

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

Environmental Issues Associated with Desalination

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

Agricultural and Rural Issues of Desalination

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

Other Natural Resource Issues Associated with Desalination

None identified.

Significant Issues Affecting Feasibility

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

Other Water Management Strategies Directly Affected by Desalination

None identified.

4.3.2 City of Ballinger

Table 4.3-3 compares the current supply and projected demand for the City of Ballinger. Demands for the city (including municipal sales) are 1,068 acre-feet per year in 2010, increasing to 1,337 acre-feet in 2060. The city's primary sources of water are Lake Ballinger and Lake Moonen. These lakes have been heavily impacted by the recent drought. In 2003 the city completed a connection to the City of Abilene's pipeline from Ivie Reservoir and has a contract for emergency supplies from that source. This contract will expire in 2008. In the past the city purchased emergency supplies from Spence Reservoir when the city's lakes have been low. The city has also drilled several wells into a local unclassified aquifer, but has not been able to obtain a significant quantity of water from this source.

TWDB requires use of the TCEQ water availability models (WAM) to determine supplies in regional water planning[4]. Because these models are based on a perfect application of the prior appropriation system, the Colorado WAM shows essentially no yield for Lake Ballinger and Lake Moonen[5]. The reduced supplies are presented in Table 4-8. With implementation of a subordination strategy the current safe yield of Lakes Ballinger and Moonen is estimated to be 950 acre-feet per year. By 2060, the yield of the reservoir would decline to 890 acre-feet per year due to sedimentation. (Supplies from the Colorado WAM and the subordination strategy are discussed in Section 4.2.3 and Appendices 3C, 4D and 4E.) Using the subordination strategy supplies, needs for the City of Ballinger are 202 acre-feet per year in 2010 increasing to 439 acre-feet per year in 2060, or about 18 percent and 33 percent of total demand, respectively.

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

Supply	2010	2020	2030	2040	2050	2060	Comments
Lake Ballinger/Moonen	0	0	0	0	0	0	WAM yield *
Ivie Reservoir	0	0	0	0	0	0	Contract expires in 2008
Other aquifer	0	0	0	0	0	0	Assuming no reliable supply
Total	*0*	*0*	*0*	*0*	*0*	*0*	
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
City of Ballinger	917	998	1,057	1,121	1,178	1,237	
Municipal sales	216	177	148	116	94	77	Rowena & N. Runnels WSC
Industrial Sales	9	10	11	12	13	15	
Total	*1,142*	*1,185*	*1,216*	*1,249*	*1,285*	*1,329*	
Surplus (Need)	*(1,142)*	*(1,185)*	*(1,216)*	*(1,249)*	*(1,285)*	*(1,329)*	

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

Potentially Feasible Water Management Strategies for the City of Ballinger

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

- Subordination of downstream senior water rights
- Voluntary redistribution from Hords Creek Reservoir
- Voluntary redistribution from a proposed regional system from Lake Brownwood
- Voluntary redistribution from the CRMWD system (Spence and Ivie Reservoirs)
- Voluntary redistribution and desalination from the proposed San Angelo desalination project
- Reuse
- Water Conservation

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

Subordination of Downstream Senior Water Rights for the City of Ballinger

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, any water right in Region F with a priority date after 1926 has no firm supply. The priority dates for Lake Ballinger and Moonen are December 4, 1946 and April 7, 1980, so according to the WAM this reservoir has no reliable yield. According to the WAM Ballinger's lakes have no yield. In order to address water availability issues in the Colorado Basin, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights holders in Region F do not make priority calls on each other. The subordination strategy is discussed in detail in Section 4.2.3. Table 4.3-4 is a summary of the supply made available from Lakes Ballinger and Moonen from the subordination strategy.

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

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

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

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

Impacts of the subordination strategy are discussed in Section 4.2.3.

Voluntary Redistribution – Hords Creek Reservoir to Ballinger

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

The City of Ballinger has discussed purchasing water from the City of Coleman and has completed a preliminary engineering feasibility report for this strategy. The proposed transmission line from Hords Creek would consist of 12 miles of 10-inch and 12-inch HDPE raw water transmission line, a pump station and a ground storage tank. The transmission line would tie into the City of Ballinger's existing 10-inch raw water line from the City of Abilene's Ivie pipeline to the city's treatment plant. The system is designed to deliver up to 800 acre-feet per year.[6]

Quantity, Reliability and Cost for the Hords Creek Strategy

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

Figure 4.3-1
Historical Water Use from Hords Creek Reservoir

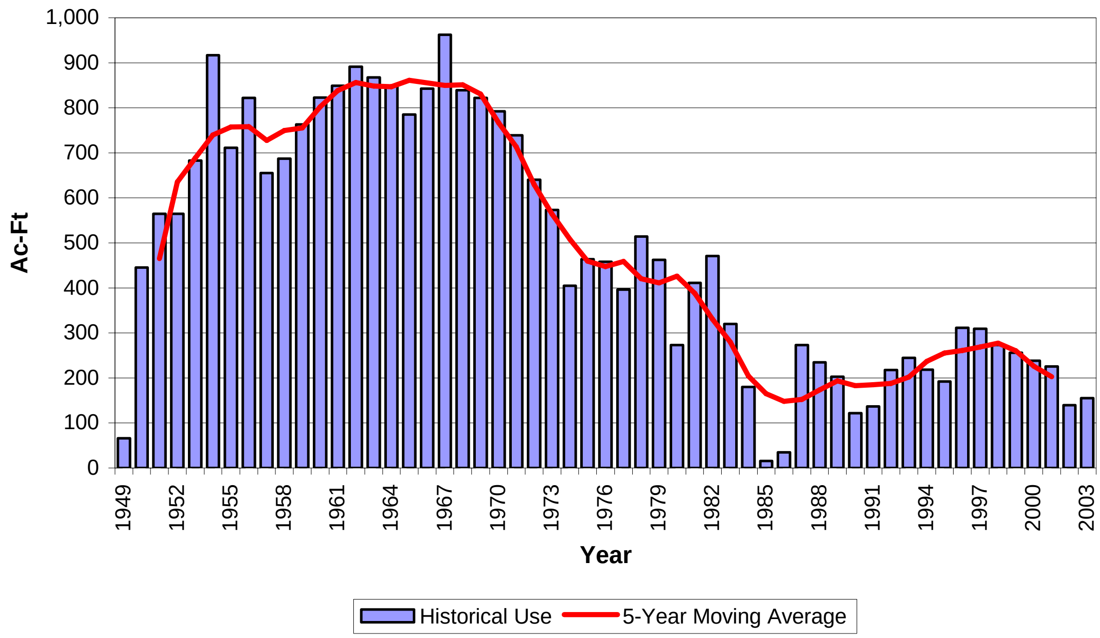
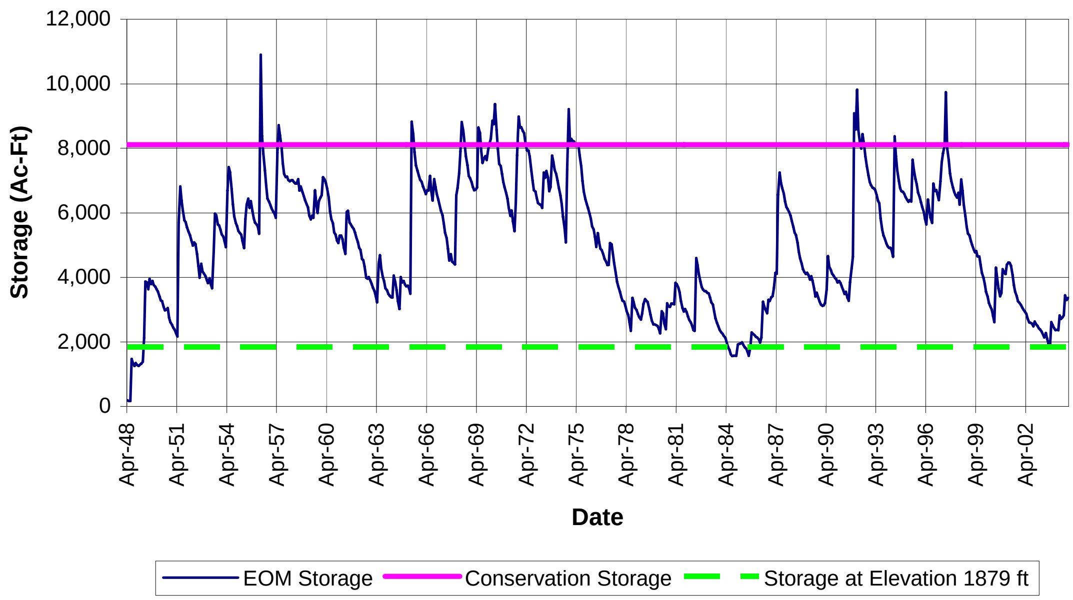


Figure 4.3-2
Historical Storage in Hords Creek Reservoir



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

Another factor impacting the reliability of Hords Creek Reservoir is the potential for a call by downstream water rights. According to the Colorado WAM, if the Colorado Basin is operated on a strict priority basis, Hords Creek Reservoir has no yield. Lake Brownwood, the first major reservoir downstream of Hords Creek, has a priority date of 1925. Other downstream senior water rights can make a priority call as well. Priority calls could significantly impact the yield of Hords Creek Reservoir.

The uncertainty regarding the reliable supply from the reservoir indicates that the reliability of this source may be low.

Total costs for this project may be found in Table 4.3-5. Detailed cost estimates may be found in Appendix 4F.

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

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

Environmental Issues Associated with the Hords Creek Strategy

The proposed route is almost entirely along existing right-of-way, so the environmental impacts should be minimal. It can be assumed that the pipeline could be routed around sensitive environmental areas if needed.

Agricultural and Rural Issues Associated with the Hords Creek Strategy

The City of Ballinger supplies a large portion of the drinking water for rural Runnels County. Since the proposed project will make the city's water supply more reliable, it should have a positive impact on rural and agricultural interests in the area. Hords Creek Reservoir is used exclusively for drinking water, so the project will not be in conflict with existing agricultural water needs.

The City of Ballinger is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially negating the positive impacts of a more reliable water supply.

Other Natural Resource Issues Associated with the Hords Creek Strategy

None identified.

Significant Issues Affecting Feasibility of the Hords Creek Strategy

There are several significant factors that impact the feasibility of this strategy:

- A subordination or some other form of agreement from downstream senior water rights holders may be necessary to ensure a reliable supply from this source.
- A contract must be negotiated with the City of Coleman to use the water.
- A new intake structure may be required if the City of Ballinger desires to withdraw more than 200 acre-feet per year during a drought period.
- An agreement may be necessary with the Corps of Engineers, particularly if the City of Ballinger desires to access storage below the existing City of Coleman intake structure.

Other Water Management Strategies Directly Affected by the Hords Creek Strategy

Other Ballinger strategies; City of Winters strategies.

Regional System from Lake Brownwood to Runnels and Coke Counties

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

Quantity, Reliability and Cost of the Lake Brownwood Strategy

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

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

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

Environmental Issues Associated with the Lake Brownwood Strategy

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

Agricultural and Rural Issues Associated with the Lake Brownwood Strategy

The City of Ballinger supplies a large portion of the drinking water for rural Runnels County. Since the proposed project will make the city's water supply more reliable, the rural and agricultural interests in the area are expected to be positively impacted. Although Lake Brownwood is used for agricultural supplies, there are sufficient supplies available in the reservoir to meet irrigation demands and provide water to these cities.

The City of Ballinger is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially negating the positive impacts of a more reliable water supply.

Other Natural Resource Issues Associated with the Lake Brownwood Strategy

None identified.

Significant Issues Affecting Feasibility of the Lake Brownwood Strategy

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

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

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

Other Water Management Strategies Directly Affected by the Lake Brownwood Strategy

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

Voluntary Redistribution – Purchase Water from CRMWD System

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

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

Quantity, Reliability and Cost of Water from the CRMWD System

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

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

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

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

Environmental Issues Associated with Water from the CRMWD System

This strategy calls for water from an existing source using existing infrastructure which results in minimal impacts.

Agricultural and Rural Issues Associated with Water from the CRMWD System

The City of Ballinger supplies a large portion of the drinking water for rural Runnels County. Since the proposed project will make the city's water supply more reliable, it should have a positive impact on rural and agricultural interests in the area.

Other Natural Resource Issues Associated with Water from the CRMWD System

None identified.

Significant Issues Affecting Feasibility of Water from the CRMWD System

This strategy depends on the success of the city negotiating agreements with MDWSC, CRMWD, WCTMWD and the City of Abilene. Actual quantities and costs will be determined through these negotiations.

This strategy relies on the WCTMWD pipeline from Ivie Reservoir to the City of Abilene to deliver water to Ballinger's tie-in to the water line. Therefore, obtaining water from this source may depend on whether the City of Abilene is currently using the pipeline for its own needs.

Other Water Management Strategies Directly Affected by Water from the CRMWD System

Other strategies for the City of Ballinger.

Voluntary Redistribution - Purchase Water from San Angelo Regional Desalination System

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

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

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

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

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

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

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

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

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

The City of Ballinger supplies a large portion of the drinking water for rural Runnels County. Since the proposed project will make the city's water supply more reliable, it should have a positive impact on rural and agricultural interests in the area.

The City of Ballinger is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially negating the positive impacts of a more reliable water supply.

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

None identified.

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

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

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

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

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

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

Reuse

Reuse has been identified as a feasible strategy for the City of Ballinger. The city currently holds a wastewater discharge permit for 0.48 MGD. This evaluation is based on a generalized direct reuse strategy developed for the Region F plan. This strategy assumes that a portion of the wastewater stream will be sent through membrane filtration and reverse osmosis (RO). The treated water will then be blended with raw water prior to treatment at the city's existing water treatment plant. It is assumed that the waste stream from the reuse facility will be permitted for discharge into a local stream. If this strategy is pursued, additional site-specific studies will be required to determine actual quantities of water available, costs and potential impacts.

Quantity, Reliability and Cost of Reuse

For the City of Ballinger, it is estimated that reuse could provide as much as 200,000 gallons per day of additional supply, or 220 acre-feet per year. This supply would be very reliable. Table 4.3-8 summarizes the costs for this strategy.

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

Supply from Strategy	220 acre-feet per year
Total Capital Costs (2002 Prices)	$ 1,980,000
Annual Costs	$ 219,845
Unit Costs (before amortization)	$ 999 per acre-foot
	$ 3.06 per 1,000 gallons
Unit Costs (after amortization)	$ 345 per acre-foot
	$ 1.06 per 1,000 gallons

Environmental Issues Associated with Reuse

The City of Ballinger currently discharges its wastewater, and it is assumed that the waste stream from the treatment facility will be combined with unused treated effluent and discharged in a similar manner. The potential impacts of this discharge on the receiving stream will need to be evaluated prior to implementation of this strategy. If the impacts are unacceptable, an alternative method of disposal may be required. Alternative disposal methods may significantly increase the cost of the project.

Reuse would result in a reduction in the quantity of water discharged by the city. An analysis of the impacts on the receiving stream will be required in the permitting process. However, because of the relatively small amount of flow reduction associated with this reuse project, the impact is not expected to be significant.

Agricultural and Rural Issues Associated with Reuse

The City of Ballinger supplies a large portion of the drinking water for rural Runnels County. Since the proposed project will make the city's water supply more reliable, it should have a positive impact on rural and agricultural interests in the area.

The City of Ballinger is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially negating the positive impacts of a more reliable water supply.

Other Natural Resource Issues Associated with Reuse

None identified.

Significant Issues Affecting Feasibility of Reuse

Although direct reuse for potable consumption is technically feasible, at this time there are no operating facilities within the State of Texas. Adequate monitoring and oversight will be required to protect public health and safety. There may be public resistance to direct reuse of water.

The infrastructure associated with reuse requires on-going use of water from this source to make the project cost-effective. Reuse water should not be used on an as-needed basis.

The reuse strategy assumes that both the subordination and voluntary redistribution strategies have been implemented.

Other Water Management Strategies Directly Affected by Reuse

Other strategies for the City of Ballinger.

Water Conservation Savings by the City of Ballinger

Recent drought has severely impacted the City of Ballinger. As a result, the city has actively promoted water conservation and drought management. Table 4.3-9 compares projected demands for the City of Ballinger with no conservation, with the expected conservation due to plumbing code (the default projections used in regional water planning), and using Region F water conservation criteria (see Appendix 4I). Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. These water conservation practices are intended to be guidelines. Water conservation strategies determined and implemented by the

City of Ballinger supersede the recommendations in this plan and are considered to meet regulatory requirements for consistency with this plan.

Table 4.3-9
Estimated Water Conservation Saving for the City of Ballinger [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	190	190	190	190	190	190	190
Plumbing Code	Projections	190	187	183	180	177	176	176
	Savings	0	3	7	10	13	14	14
Region F Estimate	Projections	190	180	167	162	158	156	155
	Savings (Region F practices)	0	7	16	18	19	20	21
	Savings (Total)	0	10	23	28	32	34	35
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	903	932	1,037	1,116	1,203	1,271	1,335
Plumbing Code	Projections	903	917	998	1,057	1,121	1,178	1,237
	Savings	0	15	39	59	82	93	98
Region F Estimate	Projections	903	884	910	950	1,002	1,047	1,093
	Savings (Region F practices)	0	33	88	107	119	131	144
	Savings (Total)	0	48	127	166	201	224	242
Costs								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Annual Costs			$18,388	$24,021	$24,602	$25,222	$25,396	$25,803
Cost per Acre-Foot [b]			$557	$273	$230	$212	$194	$179
Cost per 1,000 Gal [b]			$1.71	$0.84	$0.71	$0.65	$0.59	$0.55

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

Quantity, Reliability and Cost of Water Conservation

The Region F recommended conservation strategies reduce the demand of the City of Ballinger by 242 acre-feet per year by 2060, about 18 percent of the expected demand without conservation. Actual experience during the recent drought indicates that the potential to save water may be even greater. The reliability of this supply is considered to be medium because of the uncertainty involved in the potential for savings and the degree to which public participation is needed to realize savings. Site specific data regarding residential, commercial, industrial and other types of use would give a better estimate of the reliable supply from this strategy. Costs range from $557 per acre foot in 2010 to $179 per acre-foot in 2060.

Environmental Issues Associated with Water Conservation

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

Agricultural and Rural Issues Associated with Water Conservation

The City of Ballinger is not in direct competition with agriculture for water, so there are no identified agricultural issues associated with this strategy.

The City of Ballinger is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area. However, other less costly conservation strategies may be identified by the city that achieve similar results.

Other Natural Resource Issues Associated with Water Conservation

None identified.

Significant Issues Affecting Feasibility of with Water Conservation

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

The water conservation strategy assumes that both the subordination and voluntary redistribution strategies have been implemented.

Other Water Management Strategies Directly Affected by Water Conservation

Other Ballinger strategies may be impacted.

Drought Management

Region F has not identified drought strategies for the City of Ballinger other than those included in the city's water conservation and drought management plans.

Recommended Water Management Strategies for the City of Ballinger

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

Table 4.3-10
Recommended Water Management Strategies for the City of Ballinger
(Values in Acre-Feet per Year)

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Lake Ballinger	0	0	0	0	0	0
Subordination of downstream water rights to Lake Ballinger	940	930	920	910	900	890
Voluntary redistribution - MDWSC Contract from Ivie Reservoir	394	372	353	387	0	0
Voluntary redistribution - additional water from Ivie Reservoir	0	0	0	0	165	219
Direct Reuse	0	0	0	220	220	220
Total	*1,334*	*1,302*	*1,273*	*1,517*	*1,285*	*1,329*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential savings*	33	88	107	119	131	144
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Ballinger	917	998	1,057	1,121	1,178	1,237
Municipal sales	216	177	148	116	94	77
Industrial Sales	9	10	11	12	13	15
Total	*1,142*	*1,185*	*1,216*	*1,249*	*1,285*	*1,329*
Surplus (Need) without conservation	*192*	*117*	*57*	*268*	*0*	*0*
Surplus (Need) with conservation	*225*	*205*	*164*	*387*	*131*	*144*

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

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

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

4.3.3 City of Winters

Table 4.3-12 compares the supply and demand for the City of Winters. The maximum expected demand for the city (including outside sales) is 720 acre-feet per year in 2010. Although demand for the city is expected to grow over time, outside sales are expected to diminish as rural residents are annexed into the city, sales to Runnels County WSC are shifted to the City of Ballinger, and water conservation reduces per capita demand. The city's primary source of water is Lake Winters. Lake Winters has been heavily impacted by the recent drought. Without subordination to downstream water rights, the Colorado WAM shows no yield for the reservoir.

Table 4.3-12
Comparison of Supply and Demand for the City of Winters
(Values in Acre-Feet per Year)

Supply	2010	2020	2030	2040	2050	2060	Comments
Lake Winters	0	0	0	0	0	0	WAM yield *
Total	*0*	*0*	*0*	*0*	*0*	*0*	
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
City of Winters	552	561	566	571	575	591	
Municipal sales	114	89	69	49	31	0	N. Runnels WSC, etc.
Industrial Sales	54	60	65	70	74	79	
Total	*720*	*710*	*700*	*690*	*680*	*670*	
Surplus (Need)	(720)	(710)	(700)	(690)	(680)	(670)	

* Supplies from the Colorado WAM. With implementation of a subordination strategy, the supply from Lake Winters is estimated to be 730 acre-feet per year in 2010, declining to 670 acre-feet per year in 2060.

Potentially Feasible Water Management Strategies for the City of Winters

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

- Subordination of downstream senior water rights
- Voluntary redistribution from a proposed regional system from Lake Brownwood
- Voluntary redistribution and desalination from the proposed San Angelo desalination project
- Reuse
- Water conservation
- Drought management

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

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, most reservoirs in Region F with a priority date after 1926 do not have a firm or safe yield. The priority date of Lake Winters is December 18, 1944, so the WAM shows no yield for the reservoir. This result is largely due to the assumptions used in the Colorado WAM. The assumptions used in the Colorado WAM are discussed in more detail in Appendix 3C.

In order to address water availability issues resulting from the Colorado WAM model, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights in Region F do not make priority calls on each other. The subordination strategy is discussed in Section 4.2.3. Table 4.3-13 is a summary of the impacts of the subordination strategy on Lake Winters.

The joint modeling between the two regions was conducted for planning purposes only. Neither Region F nor the Lower Colorado Region mandates the adoption of this strategy by individual water right holders. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including the City of Winters.

Table 4.3-13
Impact of Subordination Strategy on Lake Winters [a]
(Values in acre-feet per year)

Reservoir	Priority Date	Permitted Diversion	2010 Supply WAM Run 3	2010 Supply with Subord-ination	2060 Supply WAM Run 3	2060 Supply with Subord-ination
Lake Winters	12/18/1944	1,360	0	720	0	670

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

Impacts of the subordination strategy are discussed in Section 4.2.3.

Regional System from Lake Brownwood to Runnels and Coke Counties

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

Quantity, Reliability and Cost of Water from Lake Brownwood

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

Table 4.3-14
Costs for Regional System from Lake Brownwood

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

Environmental Issues Associated with Water from Lake Brownwood

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

Agricultural and Rural Issues Associated with Water from Lake Brownwood

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

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

The City of Winters is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially offsetting the positive impacts of a more reliable water supply.

Other Natural Resource Issues Associated with Water from Lake Brownwood

None identified.

Significant Issues Affecting Feasibility of Water from Lake Brownwood

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

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

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

Other Water Management Strategies Directly Affected by Water from Lake Brownwood

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

Voluntary Redistribution - Purchase Water from San Angelo Regional Desalination System

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

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

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

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

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

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

Environmental Issues Associated with Water from San Angelo Regional Desalination System

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

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

The City of Winters supplies a large portion of the drinking water for rural Runnels County. Since the proposed project will make the city’s water supply more reliable, it should have a positive impact on rural and agricultural interests in the area.

The City of Winters is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially offsetting the positive impacts of a more reliable water supply.

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

None identified.

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

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

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

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

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

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

Reuse

Reuse has been identified as a feasible strategy for the City of Winters. The city currently holds a wastewater discharge permit for 0.49 MGD. Treated effluent is also authorized for irrigation. This evaluation is based on a generalized direct reuse strategy developed for the Region F plan. This strategy assumes that a portion of the wastewater stream will be sent through membrane filtration and reverse osmosis (RO). The treated water will then be blended with raw water prior to treatment at the city's existing water treatment plant. It is assumed that the waste stream from the reuse facility will be combined with the remaining treated effluent and discharge into a local stream or disposed of using land application. If this strategy is pursued, additional site-specific studies will be required to determine actual quantities of water available, costs and potential impacts.

Quantity, Reliability and Cost of Reuse by the City of Winters

For the City of Winters, it is estimated that reuse could provide as much as 100,000 gallons per day of additional supply, or 110 acre-feet per year. This supply would be very reliable. Table 4.3-16 summarizes the costs for this strategy.

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

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

Environmental Issues Associated with Reuse by the City of Winters

The City of Winters currently both discharges to a receiving stream and irrigates with its treated wastewater. This strategy assumes that reject from advanced treatment will be blended with the treated effluent that is not reused and disposed of in a similar manner. The potential impacts of this discharge on the receiving stream will need to be evaluated prior to implementation of this strategy. If the impacts are unacceptable, an alternative method of disposal may be required. Alternative disposal methods may significantly increase the cost of the project.

Agricultural and Rural Issues Associated with Reuse by the City of Winters

Reuse may make less water available for irrigation by diverting part of the treated effluent currently use for irrigation.

The City of Winters supplies a large portion of the drinking water for rural Runnels County. Since the proposed project will make the city’s water supply more reliable, it should have a positive impact on rural and agricultural interests in the area

The City of Winters is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially offsetting the positive impacts of a more reliable water supply.

Other Natural Resource Issues Associated with Reuse by the City of Winters

None identified.

Significant Issues Affecting Feasibility of Reuse by the City of Winters

Although direct reuse for potable consumption is technically feasible, at this time there are no operating facilities within the State of Texas. Adequate monitoring and oversight will be required to protect public health and safety. There may be public resistance to direct reuse of water.

The infrastructure associated with reuse requires on-going use of water from this source to make the project cost-effective. Reuse water should not be used on an as-needed basis.

Other Water Management Strategies Directly Affected by Reuse

Other strategies for the City of Winters may be impacted.

Water Conservation

Using the Region F suite of water conservation practices, it is estimated that the City of Winters can reduce water demand by as much as 20 percent. Additional information on Region F recommended water conservation practices may be found in Appendix 4I.

Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. The water conservation practices in this plan are guidelines. Region F considers water conservation strategies determined and implemented by the City of Winters to supersede the recommendations in this plan and meet regulatory requirements for consistency with this plan.

Quantity, Reliability and Cost of Water Conservation

Table 4.3-17 summarizes the estimated water savings and costs associated with the recommended Region F water conservation practices. Based on this evaluation, by 2060 up to 129 acre-feet of water per year could be saved, a reduction of almost 20 percent. The city's experience during the recent drought indicates that more water could potentially be saved. In 2002, the most recent year for which per capita water use data are available, the city had a per capita demand of 128 gpcd. The estimated per capita water demand in 2060 using the Region F criteria is 136 gpcd. The reliability of water conservation is considered to be medium due to the uncertainty of the long-term savings due to implementation of water conservation strategies.

Table 4.3-17
Estimated Water Conservation Savings for the City of Winters [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	102	170	170	170	170	170	170
Plumbing Code	Projections	102	167	164	161	158	156	156
	Savings	0	3	6	9	12	14	14
Region F Estimate	Projections	170 [b]	161	148	143	139	137	136
	Savings (Region F Practices)	0	6	16	18	19	19	20
	Savings (Total)	0	9	22	27	31	33	34
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	548	562	582	597	614	627	644
Plumbing Code	Projections	548	552	561	566	571	575	591
	Savings	0	10	21	31	43	52	53
Region F Estimate	Projections	548	531	506	503	504	504	515
	Savings (Region F Practices)	0	21	55	63	67	71	76
	Savings (Total)	0	31	76	94	110	123	129
Costs [c]								
Annual Costs			$12,392	$16,589	$16,353	$16,134	$15,829	$15,781
Cost per Acre-Foot			$590	$302	$260	$241	$223	$208
Cost per 1,000 Gal			$1.81	$0.93	$0.80	$0.74	$0.68	$0.64

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.
b The City of Winters was under water use restriction in 2000. Base year 2000 demands were extrapolated from historical water use from 1995 to 1997.
c Costs for implementing Region F recommended practices. Costs of implementing plumbing code not included.

Environmental Issues Associated with Water Conservation

Most of the water used by the City of Winters is expected to come from Lake Winters. Conserved water will remain in the reservoir, so there will be little if any impact on instream flows and over-banking flows.

Agricultural and Rural Issues Associated with Water Conservation

Water conservation by the City of Winters will not make more water available for agriculture.

The City of Winters is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially offsetting the positive impacts of water conservation.

Other Natural Resource Issues Associated with Water Conservation

None identified.

Significant Issues Affecting Feasibility of Water Conservation

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

Other Water Management Strategies Directly Affected by Water Conservation

None identified.

Drought Management

The City of Winters has effectively used drought management to control demand during times of drought. Strategies are specified in the city's water conservation and drought contingency plan. Region F has not identified additional drought management strategies for the City of Winters.

Recommended Strategies for the City of Winters

Although subordination of downstream water rights will make sufficient supplies available to meet projected needs, the City of Winters may want to consider another strategy to increase the reliability of their water supply. Although several strategies are feasible, all of the alternatives are costly and would strain the financial resources of the community. Region F recommends that the city consider reuse and water conservation as long-term alternatives to increase the reliability of the city's water supply. Table 4.3-18 is a comparison of supply to demand with the recommended strategies in place. Table 4.3-19 summarizes the expected costs for these strategies.

Table 4.3-18
Recommended Water Management Strategies for the City of Winters
(Values in Acre-Feet per Year)

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Lake Winters	0	0	0	0	0	0
Subordination of downstream water rights to Lake Ballinger	720	710	700	690	680	670
Direct Reuse	0	0	0	110	110	110
Total	720	710	700	800	790	780
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential savings*	21	55	63	67	71	76
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Winters	552	561	566	571	575	591
Municipal sales	114	89	69	49	31	0
Industrial Sales	54	60	65	70	74	79
Total	720	710	700	690	680	670
Surplus (Need) without conservation	0	0	0	110	110	110
Surplus (Need) with conservation	21	55	63	177	181	186

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

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

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

4.3.4 City of Bronte

Table 4.3-20 compares the supply and demand for the City of Bronte. The city of Bronte is expected to have a maximum projected demand of about 274 acre-feet per year (in-city use plus municipal sales). The population of the city is expected to remain relatively stable over the next 50 years. Water demand projections decline over time due to conservation.

Table 4.3-20
Comparison of Supply and Demand for the City of Bronte
(Values in Acre-Feet per Year)

Supply	2010	2020	2030	2040	2050	2060	Comments
Oak Creek Reservoir	0	0	0	0	0	0	WAM shows no yield
Other aquifer	116	129	125	121	120	120	
Total	*116*	*129*	*125*	*121*	*120*	*120*	
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
City of Bronte	245	258	254	250	249	249	No outside sales
Total	*245*	*258*	*254*	*250*	*249*	*249*	
Surplus (Need)	*(129)*	*(129)*	*(129)*	*(129)*	*(129)*	*(129)*	

In the past the city relied exclusively on water from Oak Creek Reservoir, which was heavily impacted by the recent drought. As a result, the city developed a groundwater supply from nine wells in the vicinity of Oak Creek Reservoir. The groundwater is delivered to the city in the Oak Creek pipeline. The groundwater supply is from an unclassified aquifer and the reliability of the source is not well known. Each well has a capacity of about 1.5 acre-feet per day. For the purposes of this plan, it was assumed that this aquifer could produce up to 129 acre-feet per year, or half of the maximum demand for the city.

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

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

Potentially Feasible Water Management Strategies

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

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

- Drought Management

Brush control and precipitation enhancement are discussed in Section 4.9.

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

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, any water right in Region F with a priority date after 1926 has no firm supply. The priority date for Oak Creek Reservoir is April 27, 1949, so according to the WAM Oak Creek Reservoir has no yield. In order to address water availability issues in the Colorado Basin, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights holders in Region F do not make priority calls on each other. The subordination strategy is discussed in detail in Section 4.2.2.

The joint modeling between the two regions was conducted for planning purposes only. By adopting this strategy, neither Region F nor the Lower Colorado Region stipulates that water rights will not make priority calls on junior water rights. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves. Oak Creek Reservoir is owned by the City of Sweetwater. For the purposes of this plan, it will be assumed that, with subordination, the City of Bronte will be able to obtain 129 acre-feet per year during drought from the reservoir.

Impacts of the subordination strategy are discussed in Section 4.2.3.

New Water Wells

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

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

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

Quantity, Reliability and Cost of New Water Wells

The quantity and reliability of water from this source is not well known. The city has only recently begun intensive use of the aquifer. For this plan, the five new wells are assumed to supply an additional 100 acre-feet per year. The reliability of the supply is considered to be medium to low because the source has not been in use for an extended period of time and the reliability is unknown. The city estimates that the cost of the new wells will be $450,000. Table 4.3-21 summarizes the expected costs for the city.

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

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

Environmental Issues Associated with New Water Wells

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

Agricultural and Rural Issues Associated with New Water Wells

No direct agricultural impacts have been identified for this strategy.

The City of Bronte is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources and the surrounding rural area, potentially offsetting the positive impacts of a more reliable water supply.

Other Natural Resource Issues Associated with New Water Wells

None identified.

Significant Issues Affecting Feasibility of New Water Wells

Because the reliability of this supply is unknown, the city may need to develop other alternatives to meet long-term needs. Funding construction of these new wells will be a significant strain on the financial resources of the city.

Other Water Management Strategies Directly Affected by New Water Wells

Other strategies for the City of Bronte may be impacted.

Voluntary Redistribution - Purchase Water from San Angelo Regional Desalination System

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

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

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

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

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

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

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

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

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

No agricultural impacts have been identified.

The City of Bronte is a rural community. Like other water supply strategies, the high cost of this strategy may have an adverse impact on the limited financial resources of the city and the surrounding rural area.

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

None identified.

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

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

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

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

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

Regional System from Lake Brownwood to Runnels and Coke Counties

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

Quantity, Reliability and Cost of Water from Lake Brownwood

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

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

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

Environmental Issues Associated with Water from Lake Brownwood

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

Agricultural and Rural Issues Associated with Water from Lake Brownwood

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

The City of Bronte is a rural community. Like other water supply strategies, the high cost of this strategy may have an adverse impact on the limited financial resources of the city and the surrounding rural area.

Other Natural Resource Issues Associated with Water from Lake Brownwood

None identified.

Significant Issues Affecting Feasibility of Water from Lake Brownwood

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

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

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

Other Water Management Strategies Directly Affected by Water from Lake Brownwood

Other strategies for the cities of Bronte.

Reuse

Reuse has been identified as a feasible strategy for the City of Bronte. The city currently uses land application for disposal of treated effluent. This evaluation is based on a generalized direct reuse strategy developed for the Region F plan. This strategy assumes that a portion of the wastewater stream will be sent through membrane filtration and reverse osmosis (RO). The treated water will then be blended with raw water prior to treatment at the city's existing water treatment plant. It is assumed that the waste stream from the reuse facility will be combined with unused treated effluent and discharged into a local stream or use existing land application facilities. If this strategy is pursued, additional site-specific studies will be required to determine actual quantities of water available, costs and potential impacts.

Quantity, Reliability and Cost of Reuse

For the City of Bronte, it is estimated that reuse could provide as much as 100,000 gallons per day of additional supply, or 110 acre-feet per year. This supply would be very reliable. Table 4.3-24 summarizes the costs for this strategy.

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

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

Environmental Issues Associated with Reuse

The City of Bronte currently uses land application to dispose of treated effluent. This strategy assumes that the waste stream from the treatment facility will be blended with unused treated effluent and disposed of in a similar fashion. The potential impacts of land application may need to be evaluated prior to implementation of this strategy. If the impacts are unacceptable, an alternative method of disposal may be required. Alternative disposal methods may significantly increase the cost of the project.

Agricultural and Rural Issues Associated with Reuse

Less treated wastewater may be available for irrigation with implementation of this strategy.

The City of Bronte is a rural community. Like other water supply strategies, the high cost of this strategy may have an adverse impact on the limited financial resources of the city and the surrounding rural community.

Other Natural Resource Issues Associated with Reuse

None identified.

Significant Issues Affecting Feasibility of Reuse

Although direct reuse for potable consumption is technically feasible, at this time there are no such operating facilities within the State of Texas. Adequate monitoring and oversight will be required to protect public health and safety. There may be public resistance to direct reuse of water for municipal purposes.

The infrastructure associated with reuse requires on-going use of water from this source to make the project cost-effective. Reuse water should not be used on an as-needed basis.

Other Water Management Strategies Directly Affected by Reuse

Other strategies for the City of Bronte.

Rehabilitation of Oak Creek Pipeline

The City of Bronte has a 13-mile 8-inch and 10-inch pipeline to Oak Creek Reservoir. This pipeline is approximately 55 years old and in need of rehabilitation. The proposed strategy includes a new 50,000 gallon raw water ground storage tank.

Quantity, Reliability and Cost of Pipeline Rehabilitation

The pipeline has a capacity of 0.5 mgd and can deliver more than the allocated 129 acre-feet of water per year. Table 4.3-25 is a summary of the expected costs of the project. To facilitate comparison with other strategies, the costs presented in this plan assume that the city will finance the entire project at one time. The city may elect to spread out the costs of the project over a longer period of time. Routine operation and maintenance costs are not included in the costs after the amortization period because these will not be new costs for the city.

Table 4.3-25
Rehabilitation of Pipeline from Oak Creek Reservoir to Bronte

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

Environmental Issues Associated with Pipeline Rehabilitation

Environmental impacts are expected to be minimal because this is rehabilitation of an existing project.

Agricultural and Rural Issues Associated with Pipeline Rehabilitation

Rehabilitation may temporarily impact agricultural activities.

Other Natural Resource Issues Associated with Pipeline Rehabilitation

None identified.

Significant Issues Affecting Feasibility of Pipeline Rehabilitation

The most significant factor affecting rehabilitation of the pipeline is funding of the project. The city plans to use block grants to implement this strategy.

Other Water Management Strategies Directly Affected by Pipeline Rehabilitation

None identified.

Water Conservation

The City of Bronte has actively promoted water conservation and drought management during the recent drought. Peak demands have been reduced from as much as 760,000 gallons per day to about 600,000 gallons per day. The city uses mail outs, newspaper articles, public education and word-of-mouth to distribute information on water conservation. Several sample xeriscape projects have been implemented in the city with assistance from Texas A&M University. School education programs targeting 5-6 grades are used as well.

Table 4.3-26 compares projected demands for the City of Bronte with no conservation, with the expected conservation due to plumbing code (the default projections used in regional water planning), and using Region F water conservation criteria (see Appendix 4I).

Quantity, Reliability and Cost of Water Conservation

Using the Region F criteria, conservation can reduce the demand for the City of Bronte by 68 acre-feet per year, about 25 percent of the expected demand for the city without conservation. The reliability of this supply is considered to be medium because of the uncertainty involved in the analysis used to calculate the savings. Site specific data regarding residential, commercial, industrial and other types of use would give a better estimate of the reliable supply from this strategy. Table 4.3-26 summarizes the estimated costs of implementing the Region F conservation practices. Costs range from over $280 per acre foot in 2010 to $157 per acre-foot in 2060.

Environmental Issues Associated with Water Conservation

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

Agricultural and Rural Issues Associated with Water Conservation

The City of Bronte is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources. However, the city may identify other less costly conservation strategies that achieve similar results.

Other Natural Resource Issues Associated With Water Conservation

None identified.

Table 4.3-26
Estimated Water Conservation Savings for the City of Bronte [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	192	208	208	208	208	208	208
Plumbing Code	Projections	192	205	202	199	196	195	195
	Savings	0	3	6	9	12	13	13
Region F Estimate	Projections	208 [b]	192	167	161	158	156	155
	Savings (Region F practices)	0	13	35	38	38	39	40
	Savings (Total)	0	16	41	47	50	52	53
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	251	248	266	266	266	266	266
Plumbing Code	Projections	251	245	258	254	250	249	249
	Savings	0	3	8	12	16	17	17
Region F Estimate	Projections	251	229	213	206	202	199	198
	Savings (Region F practices)	0	16	45	48	48	50	51
	Savings (Total)	0	19	53	60	64	67	68
Costs [c]								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Annual Costs			$4,472	$8,743	$8,539	$8,340	$8,145	$8,023
Cost per Acre-Foot			$280	$194	$178	$174	$163	$157
Cost per 1,000 Gal			$0.86	$0.60	$0.55	$0.53	$0.50	$0.48

a Costs and savings based on information from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide,* November 2004.
b The City of Bronte was under restrictions in 2000. Base year 2000 demands were extrapolated from historical water use between 1997 and 1999.
c Costs for implementing recommended practices. Costs of implementing plumbing code savings not included in cost calculations.

Significant Issues Affecting Feasibility of Water Conservation

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

Other Water Management Strategies Directly Affected by Water Conservation

If water conservation is successful in reducing water demand, other water management strategies may be delayed or become unnecessary.

Drought Management

Region F has not identified specific drought management strategies for the City of Bronte. Drought management will be conduced through the city's drought contingency plan.

Recommended Strategies for the City of Bronte

The recommended strategies for the City of Bronte are: 1) subordination of downstream water rights, 2) construction of new water wells, 3) rehabilitation of the Oak Creek pipeline and 4) water conservation. Table 4.3-27 compares expected demands for the City of Bronte to water supplies with the strategies in place. Table 4.3-28 summarizes the annual costs of the recommended strategies.

Table 4.3-27
Recommended Water Management Strategies for the City of Bronte
(Values in Acre-Feet per Year)

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Oak Creek Reservoir	0	0	0	0	0	0
Subordination/Pipeline Rehab	129	129	129	129	129	129
Existing Water Wells	116	129	125	121	120	120
New Water Wells	100	100	100	100	100	100
Total	*345*	*358*	*354*	*350*	*349*	*349*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential savings*	16	45	48	48	50	51
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Bronte	*245*	*258*	*254*	*250*	*249*	*249*
Surplus (Need) without conservation	*100*	*100*	*100*	*100*	*100*	*100*
Surplus (Need) with conservation	*116*	*145*	*148*	*148*	*150*	*151*

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

Table 4.3-28
Costs of Recommended Water Management Strategies for the City of Bronte

Strategy *	Capital Costs	Annual Costs					
		2010	2020	2030	2040	2050	2060
Rehabilitation of the Oak Creek pipeline	$1,238,600	$21,600	$21,600	$ 0	$ 0	$ 0	$ 0
New water wells	$464,000	$57,000	$57,000	$17,000	$17,000	$17,000	$17,000
Water Conservation	$ 0	$4,472	$8,743	$8,539	$8,340	$8,145	$8,023
Total	*$1,702,600*	*$83,072*	*$87,343*	$25,539	$25,340	$25,145	$25,023

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

4.3.5 City of Robert Lee

Table 4.3-29 compares the supply and demand for the City of Robert Lee. The City of Robert Lee is expected to have a maximum projected demand of about 420 acre-feet per year, including municipal sales. The city has three sources of water: E.V. Spence Reservoir (owned and operated by CRMWD), Mountain Creek Reservoir (owned by the Upper Colorado River Authority and operated by the city) and a small run-of-the-river right on the Colorado River. Although Spence Reservoir has adequate supplies for the city, the water has historically been high in chlorides, dissolved solids and sulfates. Mountain Creek Reservoir, which is a very small reservoir, is an important supply source for Robert Lee when supplies are available because it has better water quality. Although Mountain Creek Reservoir is a relatively old structure, an inspection conducted as part of this plan found the dam and spillway to be in good condition (see Appendix 4K). The WAM shows a small reliable supply from the city's run-of-the-river right, but in practice this supply is not reliable and is used infrequently.

The city uses a floating pump in both Spence Reservoir and a pump and intake structure in Mountain Creek Reservoir. The intake in Mountain Creek Reservoir limits the ability of the city to obtain water when the reservoir is low. In addition, the city has recently been under restrictions because their water treatment plant was near capacity. An additional 0.5 mgd of capacity would be desirable to prevent overloading of the treatment plant.

Table 4.3-29
Comparison of Supply and Demand for the City of Robert Lee
(Values in Acre-Feet per Year)

Supply	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
Colorado River	7	7	7	7	7	7	Underflow right
Mountain Creek Reservoir	0	0	0	0	0	0	No WAM yield
Spence Reservoir	333	296	435	403	384	357	Supply changes as other CRMWD contracts expire
Total	*340*	*303*	*442*	*410*	*391*	*364*	
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
City of Robert Lee	351	346	342	338	336	336	
Municipal Sales	105	97	95	92	91	91	Coke Co WSC et al.
Total	*456*	*443*	*437*	*430*	*427*	*427*	
Surplus (Need)	(116)	(140)	5	(20)	(36)	(63)	

Potentially Feasible Water Management Strategies

The following potentially feasible water management strategies have been identified for the City of Robert Lee:

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

Brush control and precipitation enhancement are discussed in Section 4.9.

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

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, any water right in Region F with a priority date after 1926 has little or no firm supply.

The priority date of Mountain Creek Reservoir is December 16, 1949 and the priority date of Spence Reservoir is August 17, 1964. According to the WAM, Mountain Creek Reservoir has no yield and Spence Reservoir has a safe yield of 560 acre-feet per year.

In order to address water availability issues in the Colorado Basin, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights holders in Region F do not make priority calls on each other. The subordination strategy is discussed in detail in Section 4.2.3.

The joint modeling between the two regions was conducted for planning purposes only. By adopting this strategy, neither Region F nor the Lower Colorado Region stipulates that water rights will not make priority calls on junior water rights. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves. Mountain Creek Reservoir is owned by the Upper Colorado River Authority, and Spence Reservoir is owned by CRMWD. For the purposes of this plan, it will be assumed that Mountain Creek Reservoir will be overdrafted during normal to wet years and will have no supply during drought. With subordination, the City of Robert Lee should be able to obtain sufficient water from Spence Reservoir to meet projected demands.

Impacts of the subordination strategy are discussed in Section 4.2.3.

Reuse

Reuse has been identified as a feasible strategy for the City of Robert Lee. The city is currently authorized to both discharge and irrigate with treated effluent. This evaluation is based on a generalized direct reuse strategy developed for the Region F plan. This strategy assumes that a portion of the wastewater stream will be sent through membrane filtration and reverse osmosis (RO). The treated water will then be blended with raw water either in Spence Reservoir or Mountain Creek Reservoir prior to treatment at the city's existing water treatment plant. It is assumed that the waste stream from the reuse facility will be permitted for discharge along with unused treated effluent into a local stream or for land application. If this strategy is pursued, additional site-specific studies will be required to determine actual quantities of water available, costs and potential impacts.

Quantity, Reliability and Cost of Reuse

For the City of Robert Lee, it is estimated that reuse could provide as much as 100,000 gallons per day of additional supply, which is about 25 percent of the maximum expected demand for the city and its customers. This supply is considered very reliable. Table 4.3-30 summarizes of the costs for this strategy.

Environmental Issues Associated with Reuse

This strategy assumes that the City of Robert Lee will discharge the waste stream from treatment along with the remaining treated effluent or use existing land application facilities. The potential impacts of discharge will need to be evaluated prior to implementation of this strategy. If the impacts are unacceptable, an alternative method of disposal may be required, which may significantly increase the cost of the project.

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

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

Because of the relatively small amount of treated effluent currently discharged by the city, the strategy is not expected to have a significant impact on the volume of instream flows or over-bank flows. The strategy will have no impact on the Colorado estuary or Matagorda Bay.

Agricultural and Rural Issues Associated with Reuse

Reuse of treated wastewater currently used for land application may make less water available for irrigated agriculture.

The City of Robert Lee is a rural community. Like other water supply strategies, the high cost of this strategy may have an adverse impact on the limited financial resources of the city and the surrounding rural community.

Other Natural Resource Issues Associated with Reuse

None identified.

Significant Issues Affecting Feasibility of Reuse

Although direct reuse for potable consumption is technically feasible, at this time there are no operating facilities within the State of Texas. Adequate monitoring and oversight will be required to protect public health and safety. There may be public resistance to direct reuse of water.

Another significant issue is the on-going use of water from this strategy. The operating costs of the project are relatively high. On-going maintenance and operation of the plant are necessary for the project to be cost-effective. If this project is implemented, it should be considered an integral part of the city's supply and not used on an as-needed basis.

Other Water Management Strategies Directly Affected by Reuse

Other strategies for the City of Robert Lee.

Desalination - Purchase Water from San Angelo Regional Desalination System

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

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

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

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

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

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

Environmental Issues Associated with Water from San Angelo Regional Desalination Facility

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

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

The City of Robert Lee is a rural community. Like other water supply strategies, the high cost of this strategy may have an adverse impact on the limited financial resources of the city and the surrounding rural area.

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

None identified.

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

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

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

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

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

Desalination of Spence Reservoir Water

The city currently obtains 75 percent or more of its water from Spence Reservoir. Historically, water from Spence Reservoir has been high in chlorides, sulfates and dissolved solids. Although water quality has improved with recent inflows, the city may need to consider advanced treatment of Spence water to improve the water quality available to its citizens.

Quantity, Reliability and Cost of Spence Reservoir Desalination

For the purposes of this plan, this strategy assumes that the city would construct an intake structure in Lake Spence to replace its existing floating pump and a reverse osmosis (RO) facility capable of producing up to 1.0 mgd of treated water. This would give the city sufficient capacity to meet most of its projected demand from Spence Reservoir. The reliability of the water is considered to be high. Table 4.3-32 contains a cost summary for this strategy.

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

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

Environmental Issues Associated with Spence Reservoir Desalination

Many surface water sources in this portion of the Colorado Basin have high dissolved solids and most aquatic communities are adapted to these conditions. This strategy assumes that the reject from the RO process will be discharged into Spence Reservoir, the Colorado River or disposed using land application. If this strategy is pursued, additional studies may be required to evaluate potential impacts of reject disposal. If other methods of disposal are required, costs may be significantly higher.

Spence Reservoir has never spilled, so this project is not expected to have significant impacts on instream flows or over-bank flows. There will be no impact on bays and estuaries.

Agricultural and Rural Issues Associated with Spence Reservoir Desalination

No agricultural issues have been identified for this strategy.

The City of Robert Lee is a rural community. Like other water supply strategies, the high cost of this strategy may have an adverse impact on the limited financial resources of the city and the surrounding rural community.

Other Natural Resource Issues Associated with Spence Reservoir Desalination

None identified.

Significant Issues Affecting Feasibility of Spence Reservoir Desalination

The costs for implementing this strategy will be significant, and financing the project will be an issue for the City of Robert Lee.

Feasibility is also dependent upon the city's ability to dispose of brine reject by discharge or land application. If deep well injection or other methods are required, the costs of the project could be significantly higher. If this option is pursued, additional studies may be required to address the disposal issue.

Other Water Management Strategies Directly Affected by Spence Reservoir Desalination

Other strategies for the City of Robert Lee.

Regional System from Lake Brownwood to Runnels and Coke Counties

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

Quantity, Reliability and Cost of Water from Lake Brownwood

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

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

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

Environmental Issues Associated with Water from Lake Brownwood

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

Agricultural and Rural Issues Associated with Water from Lake Brownwood

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

The City of Robert Lee is a rural community. Like other water supply strategies, the high cost of this strategy may have an adverse impact on the limited financial resources of the community and the surrounding rural area.

Other Natural Resource Issues Associated with Water from Lake Brownwood

None identified.

Significant Issues Affecting Feasibility of Water from Lake Brownwood

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

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

Other Water Management Strategies Directly Affected by Water from Lake Brownwood

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

Floating Pump in Mountain Creek Reservoir

The existing intake structure in Mountain Creek Reservoir makes it difficult for the city to taking water when the reservoir is 10 to 15 feet below conservation. A new floating pump could allow the city access to more water during dry periods.

Quantity, Reliability and Cost of Floating Pump

For the purposes of this plan, this strategy assumes that the city would install a new floating pump with a capacity of 1.0 mgd and 1,000 feet of 12-inch piping. This would give the city sufficient capacity to meet most of its demand from Mountain Creek Reservoir when water is available. The reliability of the water is low because supplies from this source are typically unavailable during drought. However, the water quality of this source is typically better than Spence Reservoir. The city uses Mountain Creek Reservoir to supply about 25 percent of its water. Table 4.3-34 contains a cost summary for this strategy. Although the intake has more capacity than shown, the actual amount of reliable supply made available is low, increasing the unit cost of the project.

Table 4.3-34
New Floating Pump in Mountain Creek Reservoir for the City of Robert Lee

Supply from Strategy	50 acre-feet per year
Total Capital Costs (2002 Prices)	$ 140,000
Annual Costs	$ 17,000
Unit Costs (before amortization)	$ 340 per acre-foot
	$ 1.04 per 1,000 gallons
Unit Costs (after amortization)	$ 96 per acre-foot
	$ 0.29 per 1,000 gallons

Environmental Issues Associated with Floating Pump

The impact of this strategy is expected to be minimal.

Agricultural and Rural Issues Associated with Floating Pump

The City of Robert Lee is a rural community. Like other water supply strategies, the high cost of this strategy may have an adverse impact on the community’s limited financial resources.

Other Natural Resource Issues Associated with Floating Pump

None identified.

Significant Issues Affecting Feasibility of Floating Pump

The most significant issues associated with this project are financing for the new facilities.

Another issue is the available supply from the project. Although the project will allow additional water to be used from the reservoir, there are less than 200 acre-feet of storage that the city cannot access. The supply from this storage is not reliable and may not be sufficient to justify the cost of the project.

Other Water Management Strategies Directly Affected by Floating Pump

Lake Spence RO project, other strategies for Robert Lee.

Infrastructure Expansion - Water Treatment Plant and Storage Facility

Infrastructure improvements include a 0.5 mgd expansion of the city's water treatment plant, a new 100,000 gallon treated water storage tank for the city, and improvements to allow the city to simultaneously treat water from both Spence and Mountain Creek Reservoirs.

Quantity, Reliability and Cost of Infrastructure Expansion

The expansions would increase the reliability of existing supplies and make approximately 200 acre-feet per year of additional supply available to the city. The reliability of these supplies would be high. Table 4.3-35 shows the estimated costs for these improvements.

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

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

Improvements to existing infrastructure are not evaluated for impacts. Although this strategy will increase the reliability of the Robert Lee water system, it may not sufficiently reduce chlorides and TDS to meet secondary drinking water standards (see Desalination of Spence Reservoir Water).

Water Conservation

In recent years the City of Robert Lee has been under water use restrictions primarily due to infrastructure limitations. Table 4.3-36 compares projected demands for the city without conservation, with the expected conservation due to the implementation of the plumbing code (the default projections used in regional water planning), and with Region F water conservation criteria (see Appendix 4I).

Quantity, Reliability and Cost of Water Conservation

Using the Region F criteria, conservation can reduce the demand for the City of Robert Lee by 66 acre-feet per year, about 19 percent of the expected demand for the city without conservation. The reliability of this supply is considered to be medium because of the uncertainty involved in the analysis used to calculate the savings. Site specific data would give a better estimate of the reliable supply from this strategy. Costs range from $0.91 per thousand gallons in 2010 to $0.51 per thousand gallons in 2060.

Drought Management

The City of Robert Lee has a water conservation and drought contingency plan. Region F has not identified any additional drought management strategies for the city.

Recommended Strategies for the City of Robert Lee

The recommended strategies for the City of Robert Lee are:

- Subordination of downstream water rights
- Expansion of water treatment plant and storage facilities
- Water Conservation

Table 4.3-37 is a comparison of supplies to demands with strategies in place, and Table 4.3-38 summarizes the costs of the strategies.

The recommended strategies may not sufficiently address treated water quality for the city. As an alternative or supplement to the water treatment plant expansion, the city may wish to consider RO treatment of Spence Reservoir water. Region F considers RO treatment to meet regulatory requirements for consistency with this plan, but the strategy is not recommended because of the cost of the project and the uncertainty involved with disposal of the brine reject.

Table 4.3-36
Estimated Water Conservation for the City of Robert Lee [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	278	278	278	278	278	278	278
Plumbing Code	Projections	278	276	272	269	266	264	264
	Savings	0	2	6	9	12	14	14
Region F Estimate	Projections	278	263	240	232	228	225	224
	Savings (Region F practices)	0	13	32	37	38	39	40
	Savings (Total)	0	15	38	46	50	53	54
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	365	354	354	354	354	354	354
Plumbing Code	Projections	365	351	346	342	338	336	336
	Savings	0	3	8	12	16	18	18
Region F Estimate	Projections	365	335	306	298	293	290	288
	Savings (Region F practices)	0	16	40	44	45	46	48
	Savings (Total)	0	19	48	56	61	64	66
Costs [b]								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Annual Costs			$4,770	$8,727	$8,524	$8,325	$8,130	$8,009
Cost per Acre-Foot			$298	$218	$194	$185	$177	$167
Cost per 1,000 Gal			$0.91	$0.67	$0.60	$0.57	$0.54	$0.51

a Costs and savings based on information from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.

b Costs for implementing recommended practices. Costs of implementing plumbing code savings not included in cost calculations.

Table 4.3-37
Recommended Water Management Strategies for the City of Robert Lee
(Values in Acre-Feet per Year)

Supplies	2010	2020	2030	2040	2050	2060
Colorado River	7	7	7	7	7	7
Mountain Creek Reservoir	0	0	0	0	0	0
Spence Reservoir	333	296	435	403	384	357
Infrastructure Expansion	0	0	0	0	0	0
Subordination	123	147	2	27	43	70
Total	*463*	*450*	*444*	*437*	*434*	*434*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential savings [b]	16	40	44	45	46	48
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Robert Lee	351	346	342	338	336	336
Municipal Sales	105	97	95	92	91	91
Total	*456*	*443*	*437*	*430*	*427*	*427*
Surplus (Need) without conservation	*7*	*7*	*7*	*7*	*7*	*7*
Surplus (Need) with conservation	*23*	*47*	*51*	*52*	*53*	*55*

a The infrastructure expansion increases the reliability of existing supplies but does not make additional water available.

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

Table 4.3-38
Costs of Recommended Water Management Strategies for the City of Robert Lee

Strategy	Capital Costs	Annual Costs					
		2010	**2020**	**2030**	**2040**	**2050**	**2060**
Infrastructure expansion	$2,482,500	$259,000	$259,000	$43,000	$43,000	$43,000	$43,000
Water Conservation		$4,770	$9,770	$9,567	$8,609	$8,414	$8,293
Total	*$2,482,500*	*$263,770*	*$268,770*	*$52,567*	*$51,609*	*$51,414*	*$51,239*

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

4.3.6 City of Menard

The city of Menard has several wells near the banks of the San Saba River that produce water from the San Saba River Alluvium. Reduced flows in the San Saba River during a severe drought have the potential to reduce the city's available supply. Under drought-of-record conditions Menard may experience small shortages. For the purposes of this plan, supplies for the City of Menard are considered to be surface water. However, recent actions by state agencies have re-classified the city's supply as groundwater.

Table 4.3-39 compares the supply and demand for the city. (Supplies are based on the Colorado WAM, which may not give an accurate picture of the city's particular method of obtaining water supply. Based on historical data, the Colorado WAM supply appears to be somewhat conservative and more water may actually be available to the city.) The projected population of the city is expected to remain fairly stable over the planning period, so demands are expected to decline over time due to conservation. The projected need for Menard is 70 acre-feet per year in 2010, decreasing to 54 acre-feet per year by 2060. During the recent drought the city relied on water conservation and drought management to prevent shortages. Although this strategy proved successful, the city desires to increase the reliability of its supplies by developing a groundwater source. The city is currently considering developing a well in the Hickory aquifer.

Table 4.3-39
Comparison of Supply and Demand for the City of Menard
(Values in Acre-Feet per Year)

Supply	2010	2020	2030	2040	2050	2060
San Saba River	304	304	304	304	304	304
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Menard	354	353	347	341	339	339
Municipal sales	20	21	20	20	19	19
Total	*374*	*374*	*367*	*361*	*358*	*358*
Surplus (Need)	*(70)*	*(70)*	*(63)*	*(57)*	*(54)*	*(54)*

Potentially Feasible Strategies

Potentially feasible strategies for the City of Menard include:

- Water conservation
- Drought management
- New groundwater development
- Aquifer storage and recovery.
- Voluntary redistribution – San Saba Off-Channel Reservoir

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

Water Conservation

Using the Region F suite of water conservation practices, it is estimated that the City of Menard can reduce water demand by as much as 17 percent. Additional information on Region F recommended water conservation practices may be found in Appendix 4I.

Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. The water conservation practices in this plan are guidelines. Region F considers water conservation strategies determined and implemented by the City of Menard to supersede the recommendations in this plan and to meet regulatory requirements for consistency with this plan.

Quantity, Reliability and Cost of Water Conservation

Table 4.3-40 summarizes the estimated water savings and costs associated with the recommended Region F water conservation practices. Based on this evaluation, by 2060 up to 61 acre-feet of water per year could be saved, a reduction of almost 17 percent. The estimated reductions compare favorably with actual reductions in demand experienced by the city during the recent drought. The estimated per capita water demand in 2030 using the Region F criteria is 161 gpcd. In 2002, the most recent year for which per capita water use data are available, the city had a per capita demand of 161 gpcd. The reliability of water conservation is considered to be medium due to the uncertainty of the long-term savings from implementation of water conservation strategies.

Environmental Issues Associated with Water Conservation

Water conserved by the City of Menard will most likely be made available for irrigation or livestock purposes in the area. Some of the saved water may contribute to environmental flow needs. Other impacts are expected to be minimal.

Agricultural and Rural Issues Associated with Water Conservation

Water from the San Saba River is also used for irrigation purposes. Some of the conserved water may become available for irrigation needs.

Table 4.3-40
Estimated Water Conservation Savings for the City of Menard [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	185	185	185	185	185	185	185
Plumbing Code	Projections	185	181	178	175	172	171	171
	Savings	0	4	7	10	13	14	14
Region F Estimate	Projections	185	176	166	161	157	155	154
	Savings (Region F Practices)	0	5	12	14	15	16	17
	Savings (Total)	0	9	19	24	28	30	31
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	343	362	367	367	367	367	367
Plumbing Code	Projections	343	354	353	347	341	339	339
	Savings	0	8	14	20	26	28	28
Region F Estimate	Projections	343	344	329	319	311	307	306
	Savings (Region F Practices)	0	10	24	28	30	32	33
	Savings (Total)	0	18	38	48	56	60	61
Costs [b]								
Annual Costs			$7,332	$11,327	$11,009	$10,700	$10,397	$10,209
Cost per Acre-Foot			$733	$472	$393	$357	$325	$309
Cost per 1,000 Gal			$2.25	$1.45	$1.21	$1.09	$1.00	$0.95

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.
b Costs for implementing Region F recommended practices. Costs of implementing plumbing code not included.

The City of Menard is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources.

Other Natural Resource Issues Associated with Water Conservation

None identified.

Significant Issues Affecting Feasibility of Water Conservation

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

Other Water Management Strategies Directly Affected by Water Conservation

None identified.

Drought Management

The City of Menard has effectively used drought management to control demand during times of drought. Strategies are specified in the city's water conservation and drought contingency plan. Region F has not identified additional drought management strategies for the City of Menard.

New Groundwater Development - Hickory Aquifer

The City of Menard has been actively seeking a groundwater source to back up its current supplies. Yields from the Edwards-Trinity Plateau aquifer tend to be low in Menard County and the city has been unsuccessful in locating an adequate supply from that source. An alternative is the Hickory aquifer, which underlies the city at a depth of approximately 3,500 ft. The city is planning to drill a well near its existing storage tanks. In this portion of the aquifer, dissolved solids may be above 1,000 mg/l. Also, much of the water from the Hickory aquifer exceeds drinking water standards for radionuclides. For the purposes of this plan, this strategy assumes that water from the Hickory can meet primary drinking water standards if blended with the city's existing water supply. However, advanced treatment may be required to meet standards, significantly increasing the cost of this strategy.

Quantity, Reliability and Cost of Hickory Aquifer Well

The proposed well will produce water from the down-dip portion of the Hickory aquifer. Faulting may have caused this portion of the aquifer to be compartmentalized and isolated from the recharge zone. Therefore, most of the supply is expected to come from water in storage. The total thickness of the Hickory formation is approximately 500 feet. Although no wells are available in the immediate area of the city, based on other users of the aquifer, such as the City of Brady, there should be sufficient supplies to meet the city's long-term water supply needs. Reliability is medium because water quality may impact the usefulness of the supply. Table 4.3-41 summarizes the estimated costs of the project.

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

Supply from Strategy	160 acre-feet per year
Total Capital Costs (2002 Prices)	$ 1,279,400
Annual Costs	$ 172,500
Unit Costs (before amortization)	$ 1,078 per acre-foot
	$ 3.31 per 1,000 gallons
Unit Costs (after amortization)	$ 381 per acre-foot
	$ 1.17 per 1,000 gallons

Environmental Issues Associated with Hickory Aquifer Well

The proposed well will produce water from the down-dip portion of the Hickory aquifer. Because of the over 3,000 feet of overburden, there is no interconnectedness with the land surface and, therefore, there would be no impact on springs or surface water sources. Subsidence would also not be a factor due to the depth of the source and the competency of the overburden. Therefore environmental impacts are expected to be minimal unless the water requires advanced treatment. If advanced treatment is required to use the aquifer, impacts may be higher depending on the method used to dispose of the reject from the treatment process.

Based on the available data, it is unlikely that pumping limits other than those already imposed by the Hickory Underground Water Conservation District will be required to protect the environment.

Agricultural and Rural Issues Associated with Hickory Aquifer Well

Currently, only a very small amount of water from the Hickory is used for irrigation in Menard County. Because of the relatively small amount of water from this strategy, there are no expected impacts on irrigated agriculture.

The City of Menard is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources.

Other Natural Resource Issues Associated with Hickory Aquifer Well

None identified.

Significant Issues Affecting Feasibility of Hickory Aquifer Well

Much of the water from the Hickory aquifer has radium levels that exceed the maximum contaminant level (MCL) for drinking water. Water in this portion of the Hickory aquifer may be high in dissolved solids as well. The water may require special treatment, blending or some other process to meet standards. A test well will be required to determine if water quality will limit the use of this source. Both financing the test program and development of the well will be an issue for the City of Menard.

Other Water Management Strategies Directly Affected by Hickory Aquifer Well

Aquifer storage and recovery by the City of Menard.

Aquifer Storage and Recovery

Aquifer storage and recovery (ASR) may work well with development of a Hickory aquifer well. It is possible that the Hickory aquifer can be used to store water during the winter months for use during peak summer months. Additional supplies may be held longer for use during times of drought. During extreme droughts, the native water in the Hickory formation may be used to supplement the stored water. This strategy may mitigate any water quality issues associated with the Hickory.

Quantity, Reliability and Cost of ASR

Treated surface water would be injected into the Hickory aquifer during winter months at approximately the same rate that groundwater can be withdrawn from the aquifer. Because of the depth of this aquifer, there are no other Hickory wells in the area. Therefore, water placed in this reservoir would be relatively protected from unauthorized withdrawals. Assuming that the water would be withdrawn within the following few months, a return of approximately 80 to 90 percent can be anticipated. The cost of modifying an existing water well into an ASR injection and retrieval well is slight. The major cost is incorporated into the drilling and construction of the well (see New Groundwater Development - Hickory aquifer above). Additional cost will be required in the permitting phase of the project.

Since more water is made available by this strategy than the Hickory well by itself, the unit costs of the strategy are lower. Table 4.3-42 is a summary of the expected costs of the project.

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

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

Environmental Issues Associated with ASR

This strategy relies on using diversions made under an existing water right and does not represent a significant variation in diversions on an annual basis. Seasonally, this strategy will most likely result in slightly higher diversions in the winter, potentially reducing diversions during the summer. As a result, this strategy should have a positive impact on water quality and environmental water needs because of reduced diversions during the summer months. Therefore instream bypass, diversion limits and other operational factors should not be needed. This strategy should have little or no impact on over-banking flows.

Agricultural and Rural Issues Associated with ASR

Menard is a rural community, and implementation of this and other strategies represents a significant financial drain on the community.

The potential to reduce diversions during the summer may have a positive impact on irrigated agriculture in the Menard area.

Other Natural Resource Issues Associated with ASR

None identified.

Significant Issues Affecting Feasibility of ASR

The suitability of the Hickory aquifer in this area for ASR has not been firmly established. Further studies will be required to evaluate aquifer characteristics. Injection of water into the subsurface will likely require a Class V permit from TCEQ. Also as stated above, the project could have a significant financial impact on the rural community. The price to extract injected water from the proposed Hickory ASR project could be costly given the 3,500 foot well depth and possible deep static water level.

Other Water Management Strategies Directly Affected by ASR

New well in the Hickory aquifer.

San Saba Off-Channel Reservoir

The 2001 Region F Plan evaluated an off-channel reservoir on the San Saba River in McCulloch County with a yield of 1,500 acre-feet per year. For the current plan, the site has been moved upstream near the City of Menard and the yield of the project has been reduced to 500 acre-feet per year. The conceptual design for the project includes a channel weir and pump station, an off channel reservoir with 1,550 acre-feet of storage, a new water treatment plant, and a pipeline from the reservoir to the treatment plant.

There is little unappropriated water available in the San Saba River. If constructed, the reservoir would most likely need to be permitted under the existing City of Menard water right or as an upstream diversion under the LCRA water rights for the Highland Lakes, or both.

Quantity, Reliability and Cost of Off-Channel Reservoir

The project has been designed to yield 500 acre-feet per year. Water was stored in the reservoir at a 1926 priority date, the same priority date as the Highland Lakes, limited by bypass requirements based on the Consensus Method. The reliability of the project is expected to be high. Table 4.3-43 summarizes the costs for this strategy.

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

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

Environmental Issues Associated with Off-Channel Reservoir

A specific location for the off-channel reservoir has not been determined. Before this strategy could be pursued, a site selection study would need to be performed, in addition to other studies to identify and quantify potential environmental impacts associated with the project. For the purposes of this analysis, it is assumed that a site could be selected that would have acceptable impacts. It can be assumed that the impacts of reservoir construction would be greater than the other feasible strategies for the City of Menard.

In accordance with TWDB guidelines, this analysis assumes that the consensus environmental bypass apply to diversions from the San Saba River. Other bypass requirements may change the yield and cost of the project.

Agricultural and Rural Issues Associated with Off-Channel Reservoir

Menard is a rural community, and implementation of this and other strategies represents a significant financial drain on the community.

Other Natural Resource Issues Associated with Off-Channel Reservoir

None identified.

Significant Issues Affecting Feasibility of Off-Channel Reservoir

There is not enough unappropriated water in this reach for a new water right. One possibility for implementation of this project would be as an upstream diversion of the Lower Colorado River Authority water rights in the Highland Lakes. The existing City of Menard water right may be used as well. An agreement with LCRA would be necessary to implement this project. Diversion with a priority date junior to 1926 could significantly impact the feasibility of this project.

The analyses presented in this plan were developed for screening purposes only. Additional studies will be required if this strategy is pursued. The cost and feasibility of this project may change significantly based upon a more detailed analysis.

Other Water Management Strategies Directly Affected by Off-Channel Reservoir

Other City of Menard strategies.

Recommended Strategies for the City of Menard

Region F recommends the following strategies for the City of Menard:

- New groundwater development from the Hickory aquifer
- Water conservation

If possible, the city should explore the possibility of using the Hickory aquifer for ASR when developing the Hickory well. If the city elects to pursue ASR, Region F will consider this option to meet regulatory requirements for consistency with this plan. Table 4.3-44 compares supply to demand with the recommended strategies. Table 4.3-45 summarizes the capital and annual costs associated with these strategies.

Table 4.3-44
Comparison of Supply and Demand with Recommended Water Management Strategies
City of Menard
(Values in Acre-Feet per Year)

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
San Saba River	304	304	304	304	304	304
New Hickory well	160	160	160	160	160	160
Total	*464*	*464*	*464*	*464*	*464*	*464*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential savings	*10*	*24*	*28*	*30*	*32*	*33*
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Menard	354	353	347	341	339	339
Municipal Sales	20	21	20	20	19	19
Total	*374*	*374*	*367*	*361*	*358*	*358*
Surplus (Need) without Conservation	*90*	*90*	*97*	*103*	*106*	*106*
Surplus (Need) with Conservation	*100*	*114*	*125*	*133*	*138*	*139*

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

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

* Costs for water conservation are for Region F practices only. Costs of implementing plumbing code savings not included.

4.3.7 City of Midland

The City of Midland currently uses three sources of water:

- The 1966 Contract with CRMWD, which can provide water from any source in the CRMWD system (Ivie, Spence, Thomas or groundwater sources). The amount of water from this contract increases from 16,624 acre-feet per year in 2010 to 18,257 acre-feet per year in 2020. The contract will expire in 2026.

- The CRMWD Ivie Contract for water from Ivie Reservoir. The contract is currently set at 15,000 acre-feet per year. The contract also has a clause allowing the contract to be reduced to 16.54 percent of the safe yield of the reservoir. For the purposes of this analysis, we have assumed that the amount of water available to Midland over the planning period will be limited to 16.54 percent of the safe yield of Ivie Reservoir based on the Region F assessment of water availability.
- Paul Davis Well Field in Martin and Andrews Counties, which provides an average of 4,722 acre-feet per year from the Ogallala aquifer. The city expects the well field to be depleted by about 2035.

The city also owns an undeveloped well field in Winkler County, known as the T-Bar Ranch. The McMillan Well Field in Midland County was used for aquifer storage and recovery for many years, but has remained idle recently due to elevated concentrations of perchlorate in the water.

TWDB requires use of the TCEQ water availability models (WAM) to determine supplies in regional water planning. Because these models are based on a perfect application of the prior appropriation system, the Colorado WAM[7] shows substantially less water for Region F than previous assessments of water availability. As a result, supplies from CRMWD have been uniformly decreased for all users. The reduced supplies are presented in Table 4.3-46. Supplies from the Colorado WAM are discussed in Appendix 3C and the subordination strategy is discussed in Section 4.2.3.

Table 4.3-46 compares the available supplies to the projected demands for the City of Midland and its current customers. The city provides a small amount of water to industrial users and to municipal customers outside of the city. Demands for the city are expected to increase from about 29,000 acre-feet per year in 2010 to over 32,000 acre-feet per year by 2060.

Based on the Region F analysis, the city may experience short-term needs by 2010. These needs are the result of the water supply analysis using the Colorado WAM and can be met by assuming subordination of downstream senior water rights. Beginning in 2030 the city may experience significant needs if supplies from the 1966 Contract are no longer available. Needs increase in 2040 when the Paul Davis Well Field is no longer available.

Table 4.3-46
Comparison of Current Supplies to Projected Demands for the City of Midland
(Values in Acre-Feet per Year)

Supplies	2010	2020	2030	2040	2050	2060
CRMWD 1966 Contract [a,b]	12,034	12,099	0	0	0	0
Ivie Contract [c]	10,925	10,699	10,473	10,246	10,021	9,795
Paul Davis Well Field [d]	4,722	4,722	4,722	0	0	0
Total Supplies	*27,681*	*27,520*	*15,195*	*10,246*	*10,021*	*9,795*
Demands	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Midland	28,939	30,056	30,804	31,246	31,631	32,112
Outside Sales	49	52	55	58	60	63
Total Demand	*28,988*	*30,108*	*30,859*	*31,304*	*31,691*	*32,175*
Surplus (Need)	*(1,307)*	*(2,588)*	*(15,664)*	*(21,058)*	*(21,670)*	*(22,380)*

a Actual contract amounts for the 1966 Contract are 16,624 acre-feet per year in 2010 and 18,257 acre-feet per year in 2020. Surface water supplies for all CRMWD customers have been reduced to reflect lower supplies from the CRMWD system from the Colorado WAM. With implementation of the subordination strategy, supplies from the 1966 Contract will be increased to current levels because of the additional supply available from the system.

b The 1966 Contract will expire in 2026.

c The Ivie Contract amount has been reduced to 16.54 percent of the safe yield of the reservoir using the Colorado WAM. Currently, the contract is set at 15,000 acre-feet per year. CRMWD has the option to reduce this contract if the safe yield of Ivie Reservoir has been reduced because of sedimentation, drought or other conditions.

d The Paul Davis Well Field is expected to be depleted by 2035.

Potentially Feasible Water Management Strategies for the City of Midland

Three potentially feasible strategies have been identified for the city:

- *New Groundwater* - development of the T-Bar Well Field in Winkler county
- *Voluntary Redistribution* - purchase water from the CRMWD system
- *Water Conservation* – implementation of water conservation management practices to reduce demand

Region F has identified several other feasible strategies for the City of Midland, including subordination of downstream senior water rights, reuse, desalination and aquifer storage and recovery. For the purposes of this plan it was assumed that these strategies would be implemented by CRMWD. These strategies are discussed in Section 4.8.1 regarding strategies for CRMWD. Other feasible strategies are considered less likely to be implemented over the planning period.

T-Bar Well Field

In 1965 the city of Midland purchased the T-Bar Well Field, which consists of approximately 20,230 acres in northwestern Winkler County and northeastern Loving County. Based on previous studies, the City of Midland estimates that there are approximately 650,000 acre-feet of available water in storage in the Cenozoic Pecos Alluvium from this field. The city expects the well field to have a life of approximately 60 years. The annual recharge is estimated at approximately 6,600 acre-feet per year. The city is planning to use this well field during high demand periods. The proposed design capacity is 20 MGD[8]. To develop this well field, it is assumed that 43 wells will be installed and a 70-mile transmission line will be constructed. Costs are based on a draft study re-evaluating supplies from this source[9].

It is possible that this well field could be developed in conjunction with CRMWD resources in Winkler County.

Quantity, Reliability and Cost of T-Bar Well Field

The T-Bar Well Field could provide as much as 40 percent of the city's demand in 2060. The reliability is high over the planning period, since there is available supply from storage in the Pecos Alluvium in Winkler County and annual recharge is approximately half of the proposed annual supply. Expected costs for the project may be found in Table 4.3-47. More detailed cost estimates may be found in Appendix 4F.

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

Supply from Strategy	13,600 acre-feet per year
Total Capital Costs (2002 Prices)	$ 115,772,000
Annual Costs	$ 13,080,000
Unit costs (before amortization)	$ 962 per acre-foot
	$ 2.95 per 1,000 gallons
Unit Costs (after amortization)	$ 220 per acre-foot
	$ 0.67 per 1,000 gallons

Environmental Issues Associated with T-Bar Well Field

There is no flowing surface water in Winkler County, so development of the T-Bar Well Field is expected to have no impact on environmental water needs. Development of the well field and construction of the 70-mile pipeline are expected to have minimal impact on wildlife habitats or cultural resources. It is assumed that the 70-mile pipeline can be routed to minimize or eliminate impact on potentially sensitive areas if needed. Once the pipeline route has been chosen, the potential for environmental impacts will need further investigation.

No subsidence or bay and estuary impacts are expected with well field development.

Agricultural and Rural Issues Associated with T-Bar Well Field

This strategy should have minimal effects on agriculture since the water rights are already owned by the city and there is little agriculture in the area. The right of way for the transmission line may temporarily affect a small amount of agricultural acreage during construction.

Other Natural Resource Issues Associated with T-Bar Well Field

There is adequate supply in the Pecos Alluvium in Winkler County to support the proposed well field. Since the proposed well field is located in a geological trough, pumping of groundwater should have minimal impacts on the aquifer outside of the well field.

Significant Issues Affecting Feasibility of T-Bar Well Field

The most significant obstacle for implementation of this strategy will be financing the project. The cost of the project represents a significant financial commitment by the city. Other issues include possible water quality concerns, including the potential for perchlorate and arsenic concentrations that may exceed drinking water standards. Additional treatment of the water may be required if standards cannot be met by blending with other sources. Also, elevated chloride and TDS levels may be present in some or all of the future wells.

Other Water Management Strategies Directly Affected by T-Bar Well Field

There are no other identified management strategies that will be affected.

Voluntary Redistribution – Purchase Water from CRMWD

Additional water should be available from the CRMWD system to meet potential long-term needs for the city. Sources of water include existing CRMWD reservoirs and groundwater sources, as well as future sources such as reuse, desalination, aquifer storage and recovery or new groundwater sources. Actual sources of water, quantity and costs will be determined by negotiation between the two parties.

Quantity, Reliability and Cost of Purchasing Water from CRMWD

For the purposes of this plan, it will be assumed that Midland will renew its 1966 Contract at 8.45 percent of the total yield of the existing CRMWD system. Supplies are set at 10,000 acre-feet per year in 2030, declining to 9,400 acre-feet per year in 2060. Costs are assumed to be $466 per acre-foot ($1.43 per 1,000 gallons), the same as the existing contract. The actual amount and cost of water depends on negotiations between the two parties. The reliability is considered to be high due to the multiple sources in the CRMWD system. No new infrastructure will be required to implement this strategy.

Impacts of Purchasing Water from CRMWD

Contract renewal strategies are not evaluated for quantified environmental impacts. Because this is a renewal of an existing contract, all impacts are expected to be low. This strategy should not affect any other water management strategies.

Water Conservation

The City of Midland is evaluating and plans to implement an aggressive water conservation program. The city has recently completed a demonstration project at a city park that includes water conserving landscaping and irrigation practices. The city is also considering a rebate program. In addition, the city's wastewater may be used in a proposed reuse project sponsored by CRMWD.

Quantity, Reliability and Cost of Water Conservation

Since the city's water conservation program is under development and not available for inclusion in this plan, the default Region F suite of water conservation practices was used to evaluate the potential water savings and costs of implementation. Table 4.3-48 compares projected demands for the City of Midland with no conservation, with the expected conservation due to plumbing code (the default projections used in regional water planning), and using Region F water conservation criteria (see Appendix 4I).

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

Table 4.3-48
Estimated Water Conservation Savings by the City of Midland [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	262	262	262	262	262	262	262
Plumbing Code	Projections	262	258	254	251	248	247	247
	Savings	0	4	8	11	14	15	15
Region F Estimate [a]	Projections	262	250	234	227	223	221	220
	Savings	0	12	28	35	39	41	42
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	27,879	29,388	31,003	32,154	33,010	33,552	34,062
Plumbing Code	Projections	27,879	28,939	30,056	30,804	31,246	31,631	32,112
	Savings	0	449	947	1,350	1,764	1,921	1,950
Region F Estimate	Projections	27,879	28,009	27,736	27,901	28,136	28,321	28,591
	Savings (Region F practices)	0	930	2,320	2,903	3,110	3,310	3,521
	Savings (Total)	0	1,379	3,267	4,253	4,874	5,231	5,471
Costs								
Annual Costs			$420,493	$463,796	$461,155	$452,873	$440,673	$435,018
Cost per Acre-Foot [b]			$452	$200	$159	$146	$133	$124
Cost per 1,000 Gal [b]			$1.39	$0.61	$0.49	$0.45	$0.41	$0.38

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

Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. These water conservation practices are intended only as guidelines. Region F considers water conservation strategies determined and implemented by the City of Midland to supersede the recommendations in this plan and to meet regulatory requirements for consistency with this plan.

Environmental Issues Associated with Water Conservation

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

Agricultural and Rural Issues Associated with Water Conservation

The City of Midland is not in direct competition with agriculture for water, so there are no identified agricultural issues associated with this strategy.

Other Natural Resource Issues Associated with Water Conservation

None identified.

Significant Issues Affecting Feasibility of Water Conservation

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

Other Water Management Strategies Directly Affected by Water Conservation

The timing and quantity of other recommended strategies for the City of Midland could be impacted by successful implementation of water conservation.

Drought Management

The Midland September 1999 Drought Contingency Plan, the CRMWD Drought Contingency Plan and subsequent revisions of these plans determine drought management for the City of Midland. No other drought management strategies have been identified.

Recommended Strategies for the City of Midland

Table 4.3-49 compares demands to the supplies from the recommended water management strategies for the City of Midland. These include 1) subordination, 2) new groundwater development of the T-Bar Well Field, 3) voluntary redistribution from the CRMWD system and 4) conservation. Although Table 4.3-47 includes adjustments to supplies from subordination, the strategy would be implemented by CRMWD. A discussion of this strategy is included in Section 4.2.3. Note that water conservation may delay implementation or reduce the amount of water needed from other strategies. Because both the renewal of the 1966 Contract and the T-Bar Well Field are long-term strategies, the city can monitor demand reductions due to conservation and adjust the timing and supply from each project as needed before implementation of those strategies. Table 4.3-50 is a breakdown of expected costs for these strategies. Costs for subordination, which will be implemented by CRMWD, are not included in Table 4.3-50.

Table 4.3-49
Recommended Water Management Strategies for the City of Midland
(Values in Acre-Feet per Year)

Supplies	2010	2020	2030	2040	2050	2060
CRMWD 1966 Contract	12,034	12,099	0	0	0	0
Ivie Contract	10,925	10,699	10,473	10,246	10,021	9,795
Subordination Strategy [a]	4,656	6,113	(156)	(266)	(378)	(490)
Paul Davis Well Field	4,722	4,722	4,722	0	0	0
T-Bar Well Field	0	0	13,600	13,600	13,600	13,600
Voluntary Redistribution	0	0	10,000	9,800	9,600	9,400
Total Supplies	32,337	33,633	38,639	33,380	32,843	32,305
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential Savings [b]	930	2,320	2,903	3,110	3,310	3,521
Demands	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Midland	28,939	30,056	30,804	31,246	31,631	32,112
Outside Sales	49	52	55	58	60	63
Total Demand	*28,988*	*30,108*	*30,859*	*31,304*	*31,691*	*32,175*
Surplus (Need) without Conservation	*3,349*	*3,525*	*7,780*	*2,076*	*1,152*	*130*
Surplus (Need) with Conservation	*4,279*	*5,845*	*10,683*	*5,186*	*4,462*	*3,651*

a With implementation of the subordination strategy, near-term supplies are increased. Subordination decreases long-term supplies because of the reduced yield in Ivie Reservoir. See memorandum on subordination strategy for more detailed information.

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

Table 4.3-50
Costs of Water Management Strategies for the City of Midland

Strategy	Capital Cost	Annual Costs					
		2010	2020	2030	2040	2050	2060
T-Bar Well Field	$115,772,000			$13,080,000	$13,080,000	$2,986,000	$2,986,000
Voluntary Redistribution				$4,660,000	$4,566,800	$4,473,600	$4,380,400
Conservation		$420,493	$463,796	$461,155	$452,873	$440,673	$435,018
Total	*$115,772,000*	*$420,493*	*$463,796*	*$18,201,155*	*$18,099,673*	*$7,900,273*	*$7,801,418*

4.3.8 Brown County Other

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

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

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

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

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

Voluntary Redistribution - Lake Brownwood Water to Northern Brown County

Quantity, Reliability and Cost

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

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

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

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

Environmental Issues Associated with Lake Brownwood to Brown County Other

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

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

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

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

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

None identified.

Significant Issues Affecting Feasibility of Lake Brownwood to Brown County Other

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

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

None identified.

Water Conservation and Drought Management

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

4.3.9 City of Coleman

Table 4.3-53 compares the supply and demand for the City of Coleman. The maximum expected demand for the city (including outside sales) is 1,542 acre-feet per year in 2010. Demand declines to 1,474 acre-feet in 2060 due to water conservation. Lake Coleman is the city's primary source of water. The city also obtains a small amount of supply from Hords Creek Reservoir. Without subordination to downstream water rights, the Colorado WAM shows no yield for either reservoir. Supplies from the Colorado WAM are discussed in Appendix 3C.

Table 4.3-53
Comparison of Supply and Demand for the City of Coleman
(Values in Acre-Feet per Year)

Supply	2010	2020	2030	2040	2050	2060	Comments
Lake Coleman	0	0	0	0	0	0	WAM yield *
Hords Creek Reservoir	0	0	0	0	0	0	WAM yield *
Total	*0*	*0*	*0*	*0*	*0*	*0*	
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
City of Coleman	1,285	1,269	1,252	1,235	1,223	1,223	
Municipal sales	251	253	250	244	243	245	Coleman Co WSC, etc.
Manufacturing Sales	6	6	6	6	6	6	
Total	*1,542*	*1,528*	*1,508*	*1,485*	*1,472*	*1,474*	
Surplus (Need)	*(1,542)*	*(1,528)*	*(1,508)*	*(1,485)*	*(1,472)*	*(1,474)*	

* Supplies from the Colorado WAM. With implementation of a subordination strategy, the combined supply from Lake Coleman and Hords Creek Reservoir is estimated to be 9,897 acre-feet per year in 2010, declining to 9,230 acre-feet per year in 2060.

Potentially Feasible Water Management Strategies

With subordination of downstream water rights, the City of Coleman has excess supply. Therefore other water management strategies, except for water conservation, are not necessary.

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, most reservoirs in Region F with a priority date after 1926 do not have a firm or safe yield. The priority dates of Lake Coleman and Hords Creek Reservoir are August 25, 1958 and March 23, 1946, respectively, so the reservoirs have no yield. This result is largely due to the assumptions used in the Colorado WAM, which are discussed in more detail in Appendix 3C.

In order to address water availability issues resulting from the Colorado WAM model, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights in Region F do not make priority calls on each other. The subordination strategy is described in Section 4.2.3. Table 4.3-54 is a summary of the impacts of the subordination strategy on the city's raw water supplies. Available supplies are limited by the city's existing infrastructure to 2,200 acre-feet per year.

Table 4.3-54
Impact of Subordination Strategy on City of Coleman Water Supplies [a]
(Values in acre-feet per year)

Reservoir	Priority Date	Permitted Diversion	2010 Supply WAM Run 3	2010 Supply with Subord-ination	2060 Supply WAM Run 3	2060 Supply with Subord-ination
Lake Coleman	8/25/1958	9,000	0	8,507	0	7,990
Hords Creek Reservoir	3/23/1946	2,240	0	1,390	0	1,240
Total [b]		*11,240*	*0*	*9,897*	*0*	*9,230*

a Water supply is defined as the safe yield of the reservoir.
b Actual supplies are limited to 2,200 acre-feet per year by treatment plant and delivery capacity.

The joint modeling between the two regions was conducted for planning purposes only. Neither Region F nor the Lower Colorado Region mandates the adoption of this strategy by individual water right holders. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including the City of Coleman.

Impacts of the subordination strategy are discussed in Section 4.2.3.

Water Conservation

Using the Region F suite of water conservation practices, it is estimated that the City of Coleman can reduce water demand by as much as 14 percent. Additional information on Region F recommended water conservation practices may be found in Appendix 4I

Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. The water conservation practices in this plan are guidelines. Region F considers water conservation strategies determined and implemented by the City of Coleman to supersede the recommendations in this plan and to meet regulatory requirements for consistency with this plan.

Quantity, Reliability and Cost of Water Conservation

Table 4.3-55 summarizes the estimated water savings and costs associated with the recommended Region F water conservation practices. Based on this evaluation, by 2060 up to 187 acre-feet of water per year could be saved, a reduction of more than 14 percent. Experience during the recent drought indicates that there may be even more opportunity for savings. The city has been under restrictions for much of the period since the year 2000 because of low lake levels. In 2002, the most recent year for which per capita water use data are available, the city had a per capita demand of 145 gpcd. The estimated per capita water demand in 2060 using the Region F criteria is 196 gpcd. The reliability of water conservation is considered to be medium due to the uncertainty of the long-term savings due to implementation of water conservation strategies.

Environmental Issues Associated with Water Conservation

Water conserved by the City of Coleman will most likely remain in Lake Coleman and Hords Creek Reservoir. Because these reservoirs spill infrequently, it is unlikely that conservation will contribute to environmental flow needs or increase over-bank flows. Other impacts are expected to be minimal.

Agricultural and Rural Issues Associated with Water Conservation

No agricultural issues have been identified for this strategy.

The City of Coleman is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources.

Other Natural Resource Issues Associated with Water Conservation

None identified.

Significant Issues Affecting Feasibility of Water Conservation

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

Other Water Management Strategies Directly Affected by Water Conservation

None identified.

Table 4.3-55
Estimated Water Conservation Savings by the City of Coleman [a]

		2000	2010	2020	2030	2040	2050	2060
Per Capita Demand (gpcd)								
No Conservation	Projections	177	229	229	229	229	229	229
Plumbing Code	Projections	177	226	223	220	217	215	215
	Savings	0	3	6	9	12	14	14
Region F Estimate	Projections	229 [b]	220	210	204	200	197	196
	Savings (Region F Practices)	0	6	13	16	17	18	19
	Savings (Total)	0	9	19	25	29	32	33
Water Demand (Ac-Ft/Yr)		**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	1,315	1,302	1,303	1,303	1,303	1,303	1,303
Plumbing Code	Projections	1,315	1,285	1,269	1,252	1,235	1,223	1,223
	Savings	0	17	34	51	68	80	80
Region F Estimate	Projections	1,315	1,252	1,194	1,162	1,140	1,122	1,116
	Savings (Region F Practices)	0	33	75	90	95	101	107
	Savings (Total)	0	50	109	141	163	181	187
Costs [c]								
Annual Costs			$21,311	$24,872	$23,960	$23,072	$22,202	$21,664
Cost per Acre-Foot			$646	$332	$266	$243	$220	$202
Cost per 1,000 Gal			$1.98	$1.02	$0.82	$0.75	$0.67	$0.62

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.
b The City of Coleman was under water use restriction in 2000. Base year 2000 demands were extrapolated from historical water use between 1995 and 1999.
c Costs for implementing Region F recommended practices. Costs of implementing plumbing code not included.

Drought Management

The City of Coleman has effectively used drought management to control demand during times of drought. Strategies are specified in the city's water conservation and drought contingency plan. Region F has not identified additional drought management strategies for the City of Coleman.

Recommended Strategies for the City of Coleman

Region F recommends water conservation and subordination of downstream water rights for the City of Coleman. Table 4.3-56 is a comparison of supply to demand with the recommended strategies in place. Table 4.3-57 summarizes the expected costs for these strategies.

Table 4.3-56
Recommended Water Management Strategies for the City of Coleman
(Values in Acre-Feet per Year)

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Lake Coleman	0	0	0	0	0	0
Hords Creek Reservoir	0	0	0	0	0	0
Subordination of downstream water rights [a]	2,200	2,200	2,200	2,200	2,200	2,200
Total	*2,200*	*2,200*	*2,200*	*2,200*	*2,200*	*2,200*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential savings [b]	33	75	90	95	101	107
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Coleman	1,285	1,269	1,252	1,235	1,223	1,223
Municipal sales	251	253	250	244	243	245
Manufacturing Sales	6	6	6	6	6	6
Total	*1,542*	*1,528*	*1,508*	*1,485*	*1,472*	*1,474*
Surplus (Need) without conservation	*658*	*672*	*692*	*715*	*728*	*726*
Surplus (Need) with conservation	*691*	*747*	*782*	*810*	*829*	*833*

a Limited by treatment and delivery capacity. The combined supply from Lake Coleman and Hords Creek Reservoir is estimated to be 9,897 acre-feet per year in 2010, declining to 9,230 acre-feet per year in 2060.
b Does not include plumbing code savings, which are already included in the water demand projections.

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

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

4.3.10 City of Brady

Table 4.3-58 compares the supply and demand for the City of Brady. The maximum expected demand for the city (including outside sales) is 2,108 acre-feet per year in 2020. Demand declines to 1,967 acre-feet in 2060 due to water conservation. Currently, the city uses the Hickory aquifer for supplies. Supplies from the Hickory aquifer exceed drinking water standards for radionuclides, so city is in the process of constructing a 1.5 MGD treatment plant to obtain water from Brady Creek Reservoir. For the purposes of this plan, it was assumed that the city will obtain at least half of its supply from the new treatment plant. However, without subordination to downstream water rights, the Colorado WAM shows no yield for Brady Creek Reservoir, leaving the city with an unmet need.

Table 4.3-58
Comparison of Supply and Demand for the City of Brady
(Values in Acre-Feet per Year)

Supply	2010	2020	2030	2040	2050	2060	Comments
Brady Creek Reservoir	0	0	0	0	0	0	WAM yield *
Hickory aquifer	1,009	1,009	1,009	1,009	1,009	1,009	Half of maximum demand
Total	*1,009*	*1,009*	*1,009*	*1,009*	*1,009*	*1,009*	
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comments**
City of Brady	1,879	1,893	1,874	1,854	1,842	1,842	
Manufacturing Sales	125	125	125	125	125	125	
Total	*2,004*	*2,018*	*1,999*	*1,979*	*1,967*	*1,967*	
Surplus (Need)	*(995)*	*(1,009)*	*(990)*	*(970)*	*(958)*	*(958)*	

* Supplies from the Colorado WAM. With implementation of a subordination strategy, the supply from Brady Creek Reservoir is 2,170 acre-feet per year.

Potentially Feasible Water Management Strategies for the City of Brady

With subordination of downstream water rights, the City of Brady has excess supply. Therefore other water management strategies, except for water conservation, are not necessary.

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, most reservoirs in Region F with a priority date after 1926 do not have a firm or safe yield. The priority date of Brady Creek Reservoir is September 2, 1959, so the reservoir has no yield. This result is largely due to the assumptions used in the Colorado WAM. The assumptions used in the Colorado WAM are discussed in more detail in Appendix 3C.

In order to address water availability issues resulting from the Colorado WAM model, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights in Region F do not make priority calls on each other. The subordination strategy is discussed in Section 4.2.3. Table 4.3-59 is a summary of the impacts of the subordination strategy on the city's raw water supplies. The actual supply from the reservoir will be limited by the capacity of the new water treatment plant. For the purposes of this plan, the amount of water available from the reservoir is assumed to be 1,350 acre-feet per year.

Table 4.3-59
Impact of Subordination Strategy on City of Brady Water Supplies [a]
(Values in acre-feet per year)

Reservoir	Priority Date	Permitted Diversion	2010 Supply WAM Run 3	2010 Supply with Subord-ination	2060 Supply WAM Run 3	2060 Supply with Subord-ination
Brady Creek Reservoir	9/02/1959	3,500	0	2,170	0	2,170 [b]

a Water supply is defined as the safe yield of the reservoir.
b Although capacity of the reservoir is somewhat less in 2060, the safe yield is the same because fewer downstream senior water rights call on water from the reservoir.

The joint modeling between the two regions was conducted for planning purposes only. Neither Region F nor the Lower Colorado Region mandates the adoption of the subordination strategy by individual water right holders. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including the City of Brady.

Impacts of the subordination strategy are discussed in Section 4.2.3.

Water Conservation

Using the Region F suite of water conservation practices, it is estimated that the City of Brady can reduce water demand by as much as 17 percent. Additional information on Region F recommended water conservation practices may be found in Appendix 4I.

Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. The water conservation practices in this plan are guidelines. Region F considers water conservation strategies determined and implemented by the City of Brady to supersede the recommendations in this plan and to meet regulatory requirements for consistency with this plan.

Quantity, Reliability and Cost of Water Conservation

Table 4.3-60 summarizes the estimated water savings and costs associated with the recommended Region F water conservation practices. Based on this evaluation, by 2060 up to 328 acre-feet of water per year could be saved, a reduction of almost 17 percent. The city's experience during the recent drought indicates that more water could potentially be saved. In 2002, the most recent year for which per capita water use data are available, the city had a per capita demand of 215 gpcd. The estimated per capita water demand in 2060 using the Region F criteria is 251 gpcd. The reliability of water conservation is considered to be medium due to the uncertainty of the long-term savings due to implementation of water conservation strategies.

Environmental Issues Associated with Water Conservation

Most of the water used by the City of Brady is expected to come from Brady Creek Reservoir. Conserved water will remain in the reservoir, so there will be little if any impact on instream flows and over-banking flows.

Agricultural and Rural Issues Associated with Water Conservation

No agricultural issues have been identified for this strategy.

The City of Menard is a rural community. Like other water supply strategies, the cost of this strategy may have an adverse impact on the community's limited financial resources.

Other Natural Resource Issues Associated with Water Conservation

None identified.

Significant Issues Affecting Feasibility of Water Conservation

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

Table 4.3-60
Estimated Water Conservation Savings by the City of Brady [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	303	303	303	303	303	303	303
Plumbing Code	Projections	303	300	297	294	291	289	289
	Savings	0	3	6	9	12	14	14
Region F Estimate	Projections	303	287	267	260	256	253	251
	Savings (Region F Practices)	0	13	30	34	35	36	38
	Savings (Total)	0	16	36	43	47	50	52
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	1,875	1,898	1,931	1,931	1,931	1,931	1,931
Plumbing Code	Projections	1,875	1,879	1,893	1,874	1,854	1,842	1,842
	Savings	0	19	38	57	77	89	89
Region F Estimate	Projections	1,875	1,802	1,701	1,660	1,632	1,612	1,603
	Savings (Region F Practices)	0	77	192	214	222	230	239
	Savings (Total)	0	96	230	271	299	319	328
Costs [c]								
Annual Costs			$23,486	$27,370	$26,348	$25,353	$24,380	$23,777
Cost per Acre-Foot			$305	$143	$123	$114	$106	$99
Cost per 1,000 Gal			$0.94	$0.44	$0.38	$0.35	$0.33	$0.31

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.
b The City of Brady was under water use restriction in 2000. Base year 2000 demands were extrapolated from historical water use from 1997 to 1999.
c Costs for implementing Region F recommended practices. Costs of implementing plumbing code not included.

Other Water Management Strategies Directly Affected by Water Conservation

None identified.

Drought Management

The City of Brady has effectively used drought management to control demand during times of drought. Strategies are specified in the city's water conservation and drought contingency plan. Region F has not identified additional drought management strategies for the City of Brady.

Recommended Strategies for the City of Brady

Region F recommends water conservation and subordination of downstream water rights for the City of Brady. Since the new treatment plant is under construction, a strategy is not necessary. Table 4.3-61 is a comparison of supply to demand with the recommended strategies in place. Table 4.3-62 summarizes the expected costs for these strategies.

Table 4.3-61
Recommended Water Management Strategies for the City of Brady
(Values in Acre-Feet per Year)

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Brady Creek Reservoir	0	0	0	0	0	0
Hickory aquifer	1,009	1,009	1,009	1,009	1,009	1,009
Subordination of downstream water rights [a]	1,350	1,350	1,350	1,350	1,350	1,350
Total	*2,359*	*2,359*	*2,359*	*2,359*	*2,359*	*2,359*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential savings [b]	77	192	214	222	230	239
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of Brady	1,879	1,893	1,874	1,854	1,842	1,842
Manufacturing Sales	125	125	125	125	125	125
Total	*2,004*	*2,018*	*1,999*	*1,979*	*1,967*	*1,967*
Surplus (Need) without conservation	*355*	*341*	*360*	*380*	*392*	*392*
Surplus (Need) with conservation	*432*	*533*	*574*	*602*	*622*	*631*

a Limited by treatment and delivery capacity of the water treatment plant.
b Does not include plumbing code savings, which are already included in the water demand projections.

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

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

4.3.11 Strategies for Hickory Aquifer Users

Among the needs identified previously in the 2001 *Region F Regional Water Plan* was a water shortage resulting from new EPA regulations limiting the permissible amount of radionuclides in drinking water. Some of the Hickory aquifer wells produce water with radionuclide concentrations that exceed the maximum concentration limits (MCLs) for drinking water. Water suppliers currently relying on these wells will need to implement water management strategies that will allow them to continue to serve their customers. The following sections describe these water suppliers, the regulatory framework, and the potential water management strategies.

In the 2001 Region F Plan, water management strategies were evaluated for public water suppliers that were using the Hickory aquifer as a major or as a sole water source. This included public water supplies in McCulloch and Concho Counties, and in portions of Runnels and Tom Green Counties. Treatment to remove radionuclides was considered infeasible due to a lack of options for disposal of treatment residuals. In the 2001 Region F plan, the lack of treatment alternatives effectively eliminated the consideration of the Hickory aquifer as a primary drinking water source after the year 2010. A regional approach to obtaining alternative water supplies was considered in the 2001 Region F plan, but all of the identified strategies were expensive and the smaller communities affected by the radionuclides rule did not opt for a regional strategy.

Further evaluation of water management strategies for Hickory aquifer users has been undertaken for the 2006 *Region F Regional Water Plan*. Each of the affected public water suppliers was contacted in order to update the status of each regarding Hickory aquifer usage. Since the 2001 plan, TCEQ has implemented a regular testing program of Hickory aquifer users, providing additional water quality data for each system. The current status of drinking water and waste disposal regulations as related to radionuclides was investigated. For selected water suppliers, specific water management strategies were identified and evaluated.

A description of the Hickory aquifer may be found in Chapter 3 of this plan.

Hickory Aquifer Water User Groups

The municipal wells in Region F with radionuclide levels exceeding drinking water limits are located in Concho and McCulloch Counties. Nine public water suppliers currently rely on the Hickory aquifer as a supply source. The demands for City of Brady, the Millersview-Doole

Water Supply Corporation (MDWSC), the City of Eden and the Richland Special Utility District (Richland SUD) are listed in Table 4.3-63. These four entities are classified as Water User Groups (WUGs). The remaining Hickory water suppliers are Rochelle WSC, Lakeland Services, Inc., the City of Melvin, Lohn WSC and Live Oak Hills Subdivision. The demands for these small water suppliers are aggregated as McCulloch County Other. The demand for this category is underestimated because the approved TWDB population projections for the County Other category are low.

Table 4.3-63
Hickory Water Suppliers

Public Water System	**Average Annual Demand** (acre-feet per year)
City of Brady	2,078
Millersview-Doole WSC	847
City of Eden	572
Richland SUD	207 [a]
McCulloch County Other	12 [b]

a TWDB approved projections are 113 acre-feet per year. However, TWDB projections do not include water used for livestock or other purposes. Richland SUD expects demands to be closer to 207 acre-feet per year.
b Demands for McCulloch County Other are underestimated because TWDB approved population projections for this category are low.

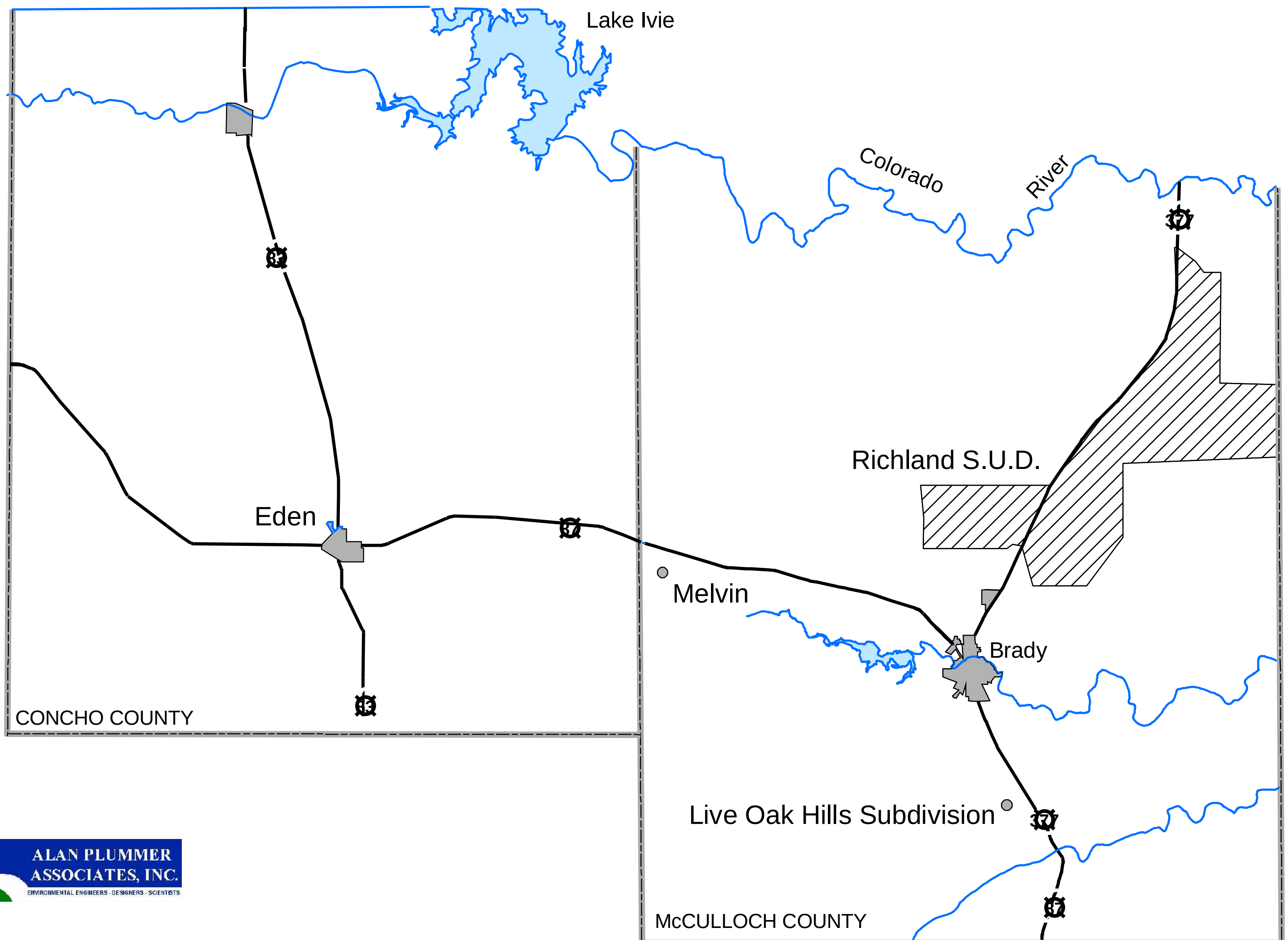
Before the development of the 2001 Region F Plan, the two largest Hickory water suppliers, the City of Brady and MDWSC, had both begun the process of implementing strategies that would enable them to obtain low-radionuclide water. These strategies will enable the City of Brady and MDWSC to meet the projected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

Several of the water suppliers expect to be able to comply with the radionuclides rule without having to treat the Hickory groundwater. Rochelle WSC recently began utilizing a new Hickory well that does not have levels of radionuclides that exceed the drinking water limits. They expect to rely on the new well and reduce or eliminate use of the older well. Lohn WSC also reports radionuclides levels that are under the drinking water standard.[14]

The communities that will continue to utilize the Hickory aquifer as a sole or major source of water serve a combined population of less than 10,000 persons. These communities include the City of Eden, Richland SUD, the City of Melvin and Live Oak Hills Subdivision. Because of the small size of these communities, the 2001 Region F plan recommended consideration of regional systems as a strategy. However, due to the long transmission distances required, these communities have not opted to join with a larger service provider. Figure 4.3-3 shows the locations of these water suppliers.

Radionuclides and the Hickory Aquifer Users

Communities that will continue to rely on Hickory aquifer water wells where radionuclide concentrations exceed the drinking water standards will soon be required to comply with new EPA/TCEQ rules. EPA is concerned that the radionuclides pose a health threat when routinely ingested over a long period of time. The original rules implementing the Safe Water Drinking Act contained maximum concentration limits (MCLs) for radionuclides, but, until recently, the limits were not enforced and water suppliers were not required to treat for radionuclides. In December 2000, EPA published the Radionuclides Rule, retaining the MCLs for combined radium-226 and radium-228, gross alpha particle radioactivity, and beta particle and photon activity. The rule also regulates uranium for the first time.[15] In December 2004, TCEQ amended its rules to implement the EPA radionuclides rule as part of the state's drinking water program (TAC Rule §290.108).[16] The federal and state MCLs for radionuclides are listed in Table 4.3-64. Compliance determinations are based on a running average annual MCL. In some areas, Hickory aquifer water contains radium and gross alpha particle activity. Neither beta/photon emitters nor uranium have been shown to be a problem in the Hickory aquifer.



0 20,000 40,000 80,000
Feet

ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS - DESIGNERS - SCIENTISTS

Area of Evaluation for Hickory Users

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

FIGURE
4.3-3

Table 4.3-64
MCLs for Regulated Radionuclide Contaminants

Contaminant	MCL
Beta/photon emitters	4 mrem/yr
Gross alpha particle activity	15 pCi/L
Combined radium-226/228	5 pCi/L
Uranium	30 μg/L

EPA expects the implementation of the radionuclides rule to reduce the risk of cancer for affected citizens. Many of the Hickory aquifer users in Region F, however, question the assertion that their drinking water increases cancer risk. Anecdotally, residents compare themselves to populations in other areas and see no cause for alarm, in spite of having used Hickory groundwater for their entire lives. A cluster cancer investigation was conducted by the Texas Cancer Registry of the Texas Department of Health (TDH), analyzing incidence and mortality data from the early 1990's through 2001 over a four-county area of Hickory groundwater consumption.[17] The study showed that cancer incidence and mortality in the area were within ranges comparable to the rest of the state. The Texas Radiation Advisory Board has also expressed concern that the EPA rules are unwarranted and unsupported by epidemiological public health data. They describe the rules as relying on models of health impacts which have not been validated.[18]

The affected communities in Region F are also greatly concerned about the costs of compliance with the radionuclides rule. EPA estimates that the 795 water systems nationwide affected by the radionuclides rule will incur a combined annual cost of $81 million to comply with the rules, an average of about $100,000 per system.[19] TCEQ also included cost estimates in the publication of its rules, estimating that large water systems would face increases of less than $3 per household per month, while typical small water systems, serving less than 10,000 persons, would have to charge customers between $4 and $9 extra per month to comply with the radionuclide standard.[20] TCEQ is continuing to study the potential economic impacts on small communities struggling to comply with the December 2004 TCEQ drinking water amendments, and is funding a comprehensive study of drinking water compliance issues and costs for small communities.[21]

Potentially Feasible Water Management Strategies

As previously described, four water suppliers in Region F currently have no expectation of being able to develop a water source where the radionuclide levels are under the drinking water MCLs. The City of Eden is the largest of these providers, serving 1,191 citizens and a private prison with a population of 1,370. The service area includes 590 water meters. Richland SUD serves a rural area encompassing 120 miles of transmission lines serving 326 households and a population of 630. The City of Melvin has a population of 155 on 122 meter connections. Live Oak Hills Subdivision serves a population of 96 and has 33 connections.

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

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

The City of Melvin and the Live Oak Hills Subdivision are both very small communities that do not have the financial resources or staffing to implement water treatment systems. Annual income for water services at Live Oak Hills Subdivision is only about $5,000 per year.[25] Like Richland SUD, these communities also do not operate wastewater collection and treatment systems. Thus, disposal of liquid residuals from water treatment processes would require considerable expense and permitting effort.

Water management strategies have been identified and evaluated for each of these four water suppliers. Other communities who may later find that their source water exceeds the MCLs for radionuclides should be able to implement similar strategies. The strategies that were evaluated include well replacement, advanced treatment processes, specialty media treatment options, treatment at point-of-entry or point-of-use, several configurations of bottled water options, and a no-action alternative. The well replacement strategy is necessary to sustain the water supply currently provided by a well that is beyond its service life. The other types of strategies identified for the Hickory aquifer users represent very different responses to the EPA/TCEQ radionuclides rule. The first type of strategy is to comply by treating all of the water supply for the water supplier (advanced treatment alternatives). The second option involves treating all or a portion of the water supply at the point where water reaches the customer (point-of-entry/point-of-use alternative). In the third strategy, the water supplier treats only the portion of its water supply that is used for human consumption or imports enough water to ensure a sufficient drinking water supply (bottled water alternative). The last strategy would include a decision by the water supplier to simply not comply with the radionuclides rule (no-action alternative). These alternatives are described in further detail in the following sections.

Well Replacement

The first recommended strategy is replacement of existing Hickory wells owned by the City of Eden and Richland SUD. The City of Eden needs to replace the city's older Hickory wells to ensure a continued adequate supply for the city. The proposed well is estimated at a depth of 4,200 feet, with an estimated maximum production of 300 gpm and an average of 200 gpm. Operation and maintenance costs are based on average production rates. Concentrations of radionuclides have been found to vary considerably in the Hickory aquifer. If a low-radium location can be found, the city may be able to comply with the radium MCL through blending.

Richland SUD has been investigating areas of the Hickory aquifer that may have lower radionuclide concentrations. If a low-radium location can be found, Richland SUD will convert most of its supply to the replacement well.

Quantity, Reliability and Cost of Well Replacement

A replacement Hickory aquifer well could provide up to 322 acre-feet of water per year. This source is considered very reliable. Table 4.3-65 summarizes the expected costs for the City of Eden and Table 4.3-66 summarizes the expected costs for Richland SUD.

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

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

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

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

Environmental Issues Associated with Well Replacement

The proposed wells will produce water from the down-dip portion of the Hickory aquifer. Because of the over 4,000 feet of overburden, there is no interconnectedness with the land surface and, therefore, there would be no impact on springs or surface water sources. Subsidence would also not be a factor due to the depth of the source and the competency of the overburden. Therefore environmental impacts are expected to be minimal.

Based on the available data, it is unlikely that pumping limits other than those already imposed by the Hickory Underground Water Conservation District will be required to protect the environment.

Agricultural and Rural Issues Associated with Well Replacement

Currently, no water from the Hickory aquifer is used for irrigation in Concho County. The new well will allow the City of Eden to continue furnishing financial, educational, medical, public safety, and agricultural services. Without these services, agriculture will suffer an increase in cost of doing business, a decrease in productivity, and loss of services that contribute to its overall well-being and safety. As a rural community, drilling a new well represents a significant burden on the public and private economic resources.

Although the Hickory aquifer is used for irrigation in McCulloch County, it is likely that the replacement well for Richland SUD will be located in an area downdip of the agricultural users. Richland SUD provides drinking water to rural residents in McCulloch County, as well as much of the water used for livestock in the area. Therefore, it this strategy should have a positive impact on the rural areas of the county.

Other Natural Resource Issues Associated with Well Replacement

Because these wells will replace existing wells, aquifer withdrawals are not expected to significantly exceed current levels.

Significant Issues Affecting Feasibility of Well Replacement

The primary issue affecting feasibility is funding of the replacement wells. As small communities, the City of Eden and Richland SUD have limited resources available for infrastructure improvements. Furthermore, in order to receive funding the City of Eden may need to agree to treat the water to remove radionuclides. The combined costs of advanced treatment plus new wells could raise the average monthly bill per household in the City of Eden to as much as $65.00 per month. To fund both the well and treatment facility will expend public and private money needed for other services such as education, community health, public safety, streets, wastewater treatment, and recreation. The city is classified as economically disadvantaged.

Other Water Management Strategies Directly Affected by Well Replacement

Other strategies for the City of Eden and Richland SUD will be dependent on the production levels and the radium concentrations in the new wells.

Advanced Treatment Alternatives

Several treatment technologies effectively remove radionuclides from water. Radium and gross alpha particle activity are the two radionuclide contaminants that are of concern in the Hickory aquifer wells. Gross alpha particle activity is an indirect measure for radionuclides, measuring the alpha radiation generated by source contaminants. EPA recommends cation exchange (CAX), reverse osmosis (RO), and specialty media as effective technologies for radium removal for small communities. For removal of gross alpha particle activity, the recommended EPA "best available technology" is limited to RO. However, one EPA expert has stated that if radium is the generator of the gross alpha particle activity, then effective radium removal will also reduce the gross alpha particle activity.[26] For well sources where gross alpha particle activity exceeds the MCL, pilot tests would have to be conducted to assess the effectiveness of treatment processes other than RO.

CAX and RO are both considered advanced treatment processes, beyond what has been historically required to enable a water supplier to produce water that complies with the MCLs. CAX is commonly used to remove the hardness minerals, calcium and magnesium, but will also effectively remove radium. RO involves forcing the water under pressure through very fine membranes that prevent passage of contaminants. Both processes produce a brine waste stream, though their characteristics vary. RO typically produces a continuous waste stream consisting of about 15-25 percent of the influent flow quantity. CAX resins must be periodically regenerated, and therefore the waste stream is typically both saline and highly concentrated. The waste stream typically constitutes approximately 5-15 percent of the influent flow. It should also be noted that radium adsorption sites on the CAX resins are not easily regenerated, reducing the ion exchange capacity of the media over time, and ultimately increasing the frequency of resin replacement. However, because radium concentrations are typically very small (10^{-8} mg/L or less) in terms of the amount of mass present, this effect is not pronounced.

Brine with radium concentrations exceeding 60 pCi/L of either radium-226 or radium-228 may require handling as a low-level radioactive waste and may not be discharged to the environment.[27] Therefore, CAX and RO treatment are only cost-effective in situations where there is a waste stream that the brine can be blended into, such that radium concentrations do not exceed the stated discharge limits. For the City of Eden, which operates a sanitary sewer system and a wastewater treatment plant, the water treatment residual product can possibly be discharged to a sanitary sewer system and combined with wastewater flows. Discharges to a sanitary sewer system may not have radium concentrations exceeding 600 pCi/L and must not adversely affect the ability of the wastewater treatment plant to meet its effluent limits.

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

Quantity, Reliability and Cost of Advanced Treatment Alternatives

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

Table 4.3-67
CAX Treatment Costs for City of Eden

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

Table 4.3-68
RO Treatment Costs for City of Eden

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

Environmental Issues Associated with Advanced Treatment Alternatives

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

Agricultural and Rural Issues Associated with Advanced Treatment Alternatives

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

Other Natural Resource Issues Associated with Advanced Treatment Alternatives

None identified.

Significant Issues Affecting Feasibility of Advanced Treatment Alternatives

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

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

Other Water Management Strategies Directly Affected by Advanced Treatment Alternatives

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

Specialty Media Treatment Systems

Specialty media are designed to preferentially remove particular contaminants. Media that specifically target radium are not as sensitive to competing contaminants as standard media, thus enabling longer use before replacement is required. The disadvantage of a longer life cycle is that radium may build up to high concentration levels before the media replacement is needed, requiring operational precautions for workers who routinely inspect and maintain the water supply system. Specialty media are much more expensive than standard filtration or CAX media. A spent medium typically must be disposed as a low-level radioactive waste.

One specialty media considered for implementation in Region F has been developed and licensed by Water Remediation Technologies, LLC (WRT). The WRT system has been shown to effectively reduce both radium and gross alpha particle activity by capturing the radium on the media. TWDB funded a pilot test of the WRT system for Richland SUD from December 2003 to April 2004. From this study, Richland SUD concluded that the WRT system will successfully treat the water from Richland's well to EPA drinking water standards.[14] WRT would maintain ownership of its system and would be responsible for media replacement and disposal. The company is currently seeking to license an injection well in west Texas, where they would be able to dispose of the spent media in a slurried form.[28]

Quantity, Reliability and Cost of Specialty Media Systems

WRT has provided a proposal to Richland SUD to treat water at a cost of $0.85 per 1,000 gallons. Costs for other specialty media systems are assumed to be similar. At a cost of $0.85 per 1000 gallons, Richland SUD would need to charge about $1.25 per 1000 gallons sold, because of the high transmission losses. In addition to the WRT fees, Richland SUD would be required to provide a facility to house the WRT equipment, connection of the treatment facility Richland SUD's distribution system, and the electricity required to power the equipment.[29] The proposed WRT system would be sized to provide radium removal for all of the water pumped from Richland SUD's existing well. The projected costs are shown in Table 4.3-69.

Table 4.3-69
Specialty Media Treatment System for Richland SUD

Supply from Strategy	113 acre-feet per year
Total Capital Costs	$60,000
Annual Costs for Treatment	$70,000
Unit Costs to be added to Water Rates	$619 per acre-foot
	$1.90 per 1,000 gallons

WRT could also be implemented at Melvin's well, but the per-unit cost is likely to be higher than at Richland because there are a number of fixed costs associated with the system that would not scale down for the lower production at Melvin. The City of Melvin has only about 10 percent of the demand at Richland SUD. Based on an assumption that the per-unit cost would be twice as high for Melvin as compared to Richland SUD, the annual cost for Melvin to implement a specialized media technology is $26,000, or about $18 per residential connection per month.

Environmental Issues Associated with Specialty Media Systems

This treatment technology results in a build-up of radium concentrations in the media over the course of its useful life. Accidental release of the highly concentrated radium to the environment is possible if security systems fail or if there is an accident during transport of the spent media to a regulated disposal site.

Agricultural and Rural Issues Associated with Specialty Media Systems

Richland SUD and the City of Melvin are located in a rural area and their customers include ranchers and seasonal hunters. The expense of specialty media treatment may cause some customers to revert to the use of stock ponds or shallow wells for household and livestock water increasing the potential for human and livestock diseases.

Other Natural Resource Issues Associated with Specialty Media Systems

None identified.

Significant Issues Affecting Feasibility of Specialty Media Systems

Suppliers of specialty media, such as WRT, typically require a long-term contract and a minimum guaranteed payment from communities. For rural areas that do not anticipate significant growth in the future, the communities could be legally obligated to pay for more water treatment than they need. Loss of revenues as users conserve water because of high water costs is another concern. Additionally, communities are concerned about the feasibility of providing adequate security and worker safety for the treatment system. The increased costs to customers may result in a decrease in water sales, potentially causing financial difficulties for the community's water system.

Other Water Management Strategies Directly Affected by Specialty Media Systems

The long-term contracts required for implementation of specialty media could inhibit the flexibility of communities to implement more cost-effective strategies that may become available in the future.

Point-of-Entry/Point-of-Use Alternatives

Because of the expense of advanced treatment, EPA allows an option for small community water suppliers to implement point-of-entry or point-of-use treatment for its customers. Point-of-entry (POE) refers to treatment of the water supply for a residence or business at the point where the water enters. The most typical example of this is home water softeners. Point-of-use (POU) devices are most often installed under a kitchen sink and treat only the water at the kitchen tap. EPA rules require that the water supplier own, maintain, inspect and test all of the POE/POU devices within its system. One hundred percent customer participation is required.[30] The POE/POU strategy has several pitfalls. The most obvious obstacle to a POU/POE strategy is the private property access required for a WUG to fulfill the EPA requirements. Maintenance and testing at levels acceptable to the EPA and TCEQ represent a significant investment in time and personnel for small systems. TCEQ has indicated that each home needs to be tested at least once every three years.[12] The TDH Laboratory lists the current fees for drinking water 226 and 228 radium tests at $66 and $94 respectively.[31]

Quantity, Reliability and Cost of POE/POU

EPA has strict guidelines for implementation of POE/POU options, aimed at ensuring reliable treatment of drinking water for all customers. POE/POU strategies do not affect the reliability of the quantity of water, but these systems may not provide the reliability of water quality that an advanced treatment system provides.

For Richland SUD, the City of Melvin and Live Oak Hills Subdivision, POE/POU options are potential strategies for complying with the radionuclides rule. POE/POU treatment provides an acceptable means of handling treatment residuals because single-family septic systems are exempt from the regulations applicable to disposal of radionuclide waste products. The National Rural Water Association (NRWA) estimates the base case POU reverse osmosis scenario at $16 per month per home.[32] However, this low-cost scenario includes customer maintenance of systems, which is not allowed under current EPA regulations. The NRWA estimate translates to $63,000 per year for the Richland SUD system to implement a POU option, even if EPA regulations were made more flexible. The uncertainties surrounding maintenance and testing requirements and the liabilities associated with modifying customers' interior plumbing, as well as the access issues, prevent POU RO from being considered a recommended strategy. POE CAX systems can be placed outside the customers' home, allowing for easier access, but the POE costs are even more uncertain than POU because installation requirements vary significantly and operational costs are more dependent on raw water quality. Nevertheless, POE is inherently more expensive than POU because the entire household water supply is treated with POE.

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

Environmental Issues Associated with POE/POU

The potential groundwater impacts of long-term disposal of naturally occurring radionuclides through septic systems have not been studied.

Agricultural and Rural Issues Associated with POE/POU

POE/POU systems that would require periodic access to private property are unlikely to be acceptable to residents in rural areas such as are served by Richland SUD, the City of Melvin and Live Oak Hills Subdivision. The high costs associated with POE/POU systems would impose an economic burden on these rural communities.

Other Natural Resource Issues Associated with POE/POU

None Identified

Significant Issues Affecting Feasibility of POE/POU

POU/POE options cannot be recommended as a strategy because of access, cost, and liability uncertainties. The strategy requires full participation by all customers of a water system. NRWA is recommending that EPA modify the regulations for POE/POU to make the implementation of these strategies more economical for small communities.[22]

Other Water Management Strategies Directly Affected by POE/POU

The implementation of POE/POU strategies requires a large initial investment that would likely preclude adoption of an advanced treatment or bottled water strategy.

Bottled Water Alternatives

Another water management strategy considered for Region F Hickory aquifer users is bottled water. Although not presently allowed by EPA as a compliance option, bottled water is allowed on a "temporary basis" to avoid "unreasonable health risks". Some cities in Texas have provided bottled water in cases where the water supply concentrations of fluoride or nitrates exceed levels considered safe for certain segments of the population. These systems have been set up under bilateral compliance agreements, meaning that the water suppliers are not considered to be in compliance with regulations, but have implemented a temporarily acceptable alternative strategy. Regulators from several states are currently lobbying EPA for inclusion of a bottled water compliance option. This option may be limited to home delivery of bottled water.[12]

A different approach to provision of bottled water is supplying drinking water at a central location for customer self-bottling. The City of Andrews has used a bottled water strategy for the past 12 years to supply customers with drinking water that has been treated to remove fluorides. The treatment equipment is installed in a building, but the tap is external and is thus always accessible to customers. Citizens bring their own 1- to 5-gallon containers to refill and are allowed up to 10 gallons per day. Andrews supplies an average of 1,000 gpd of bottled water to its customers.[33] Water suppliers lacking the personnel or expertise to set up treatment facilities could contract for water brought by truck or distributed at commercial water kiosks.

Bottled water strategies would be implemented only as a temporary option, pending the following future developments:

- More definitive rules regarding disposal options for radionuclide treatment residuals: The EPA and TCEQ regulations and guidance for disposal of residuals from radionuclide drinking water treatment processes remains unclear. A new EPA guidance document is due to be published later this year.
- Development of less expensive technologies for radium removal
- Further study by EPA and TCEQ of treatment options and associated costs for small community compliance with the drinking water standards. TCEQ currently has a study underway addressing these issues.
- Possible modification of the EPA rules regarding POE/POU and/or bottled water options, as has been suggested by the NRWA.

Hopefully, these future changes will enable small communities to move forward with more certainty in making the large investments that are likely to be required to enable long-term compliance with the drinking water standards.

Quantity, Reliability and Costs of Bottled Water Alternative for Eden

Because of the expense involved in treating to remove radium and the potential impacts of full-scale treatment systems on the City of Eden's wastewater plant and discharge permit, the recommended water management strategy is for the city to treat only the volume of water necessary to provide adequate supply for drinking and cooking. This strategy involves treating about 1200 gpd, approximately ½ gallon per person per day, with two separate distribution points. The first would be at a central location where citizens could obtain self-serve bottled water, and a second within the prison. It is expected that citizens would fill several 3- to 5-gallons containers on each trip, while inmates would frequently refill a personal drinking water bottle. Prison representatives have tentatively approved the implementation of this type of system.[34] Although a second treatment system is not specifically required because treated water could be piped to the two distribution points, a second system would provide redundancy to help ensure a continuous supply of low-radium water. Some cost savings may be expected if only one 1200-gpd system is implemented.

The bottled water program could provide up to 1.3 acre-feet of bottled water per year. The reliability of the supply is high. A 600 gpd treatment facility is comparable to one used by a business or a small industrial facility. The capital cost estimate is based on information provided by a local supplier of CAX and RO commercial/residential equipment. The estimate also includes $30,000 for small buildings to house the equipment at each location. If the treatment equipment can be housed within a prison building and/or within a city building, the costs incurred would be less. The amortization period for the system is estimated at 10 years, since it is assumed that smaller systems generally require more frequent replacement than larger municipal equipment. Operation and maintenance costs are estimated at $0.02 per gallon of water served. Table 4.3-70 summarizes the costs for this strategy. It is estimated that $0.14 per 1,000 gallons would need to be added to residential customers' water rates to cover the costs associated with the non-prison bottled water supply.

Table 4.3-70
Bottled Water Costs for City of Eden

Supply from Strategy	1.3 acre-feet per year
Total Capital Costs	$133,100
Annual Costs for Treatment	$26,800
Unit Costs	$19,000 per acre-foot
	$61 per 1,000 gallons

Quantity, Reliability and Costs of Bottled Water Alternative for Richland SUD, Melvin and Live Oak Hills

Because of the high costs and uncertain regulatory implications of alternative strategies, the recommended temporary strategy for Richland SUD, along with the City of Melvin, and Live Oak Hills Subdivision, is to set up a self-service bottled water supply point within the City of

Brady where customers of these utilities can obtain tap water that meets the MCLs. Each supplier would decide whether or not to implement this strategy, but costs can be reduced by implementing a cooperative system. The customers of these three utilities typically make trips to Brady at least weekly for shopping or other business and could obtain water during those trips. One possible location for delivery is the office of the Hickory Underground Water Conservation District No. 1 (HUWCD). It is also possible that an arrangement could be made for citizens to obtain water at other locations in Brady. The estimated costs associated with this strategy include $10,000 in annual administrative costs, plus $1,200 per year for purchase of water from the City of Brady. Some initial expenses for plumbing reconfiguration may also be incurred. Combined expenses for the system would be distributed among the three utilities relative to the expected water usage. The estimated system costs are summarized in Table 4.3-71.

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

Supply from Strategy	0.5 acre-feet per year
Annual Costs	$11, 200
Unit Costs to be added to Water Rates	$22,400 per acre-foot
	$70 per 1,000 gallons

Environmental Issues of Bottled Water Alternatives

Impacts of small scale bottled water treatment systems are expected to be minimal.

Agricultural and Rural Issues Associated with Bottled Water Alternatives

Self-serve bottled water will not be as convenient for rural customers as for urban customers. However, as rural communities that serve the area, the low cost of implementation could reserve public and private funds for other uses such as improving educational and medical facilities, providing public safety such as fire protection, and promoting economic development leading to an increase of products and services needed in agriculture and rural communities..

Other Natural Resource Issues Associated with Bottled Water Alternatives

None identified.

Significant Issues Affecting Feasibility of Bottled Water Alternatives

The TCEQ regulatory procedures for setting up a bottled water system as a means of providing low-radium water to customers have not yet been established. The specific requirements for this type of system remain uncertain.

Other Water Management Strategies Directly Affected by Bottled Water Alternatives

Bottled water systems would be set up as a temporary strategy, allowing water suppliers to remain flexible regarding future options. Technology developments, regulatory changes, and availability of funding may change in future years to make other strategies more feasible for these small water suppliers.

No-Action Alternative

Another approach considered for the Hickory aquifer users is a "no action" alternative. This alternative does not bring the water supplier into compliance with TCEQ drinking water rules. However, representatives of some of the supplier utilizing the Hickory aquifer have expressed concern that the questionable health benefits of compliance with the radionuclides rule do not justify the high costs that their customers will be forced to bear. In fact, some have argued that the significant increase in water cost resulting from the implementation of any alternative to reduce radionuclides may force some of their customers to revert to using stock ponds or shallow wells that have a greater likelihood of containing pollutants that pose a serious health risk.

A cluster cancer investigation was conducted by the Texas Cancer Registry of the Texas Department of Health and found that the cancer incidence and mortality in the area were within ranges comparable to the rest of the state[35]. The Texas Radiation Advisory Board also expressed concern that the EPA rules are unsupported by epidemiological public health data[36]. Additional information may be found in Appendix 4J.

Environmental Issues of No Action Alternative

The no-action alternative would have no environmental impacts that differ from current practices. Furthermore, any environmental consequences of disposal of concentrated brine reject will be eliminated.

Agricultural and Rural Issues Associated with No Action Alternative

The lack of compliance with drinking water regulations could have negative impacts on the economic development in this area. It may be difficult for the area to attract new industries if the water supply does not meet drinking water standards. On the other hand, the adverse impact of the high cost of advanced treatment will tie up the area's limited financial resources that could be used for other purposes such as improving educational and medical facilities, providing public safety such as fire protection, and promoting economic development leading to an increase of products and services needed in agriculture and rural communities..

Other Natural Resources Issues Associated with No Action Alternative

None identified.

Significant Issues Affecting Feasibility of No Action Alternative

Water suppliers choosing a no-action alternative would face fines or penalties, or other legal action. Private-action lawsuits are also possible. There could be repercussions for funding of state or federal projects.

Other Water Management Strategies Affected by No Action Alternative

The no-action alternative is only a response to the radionuclides rule and does not impact water management strategies that may be necessary to increase or to ensure water supplies.

Hickory Strategy Summary

Potential water management strategies considered for Hickory aquifer users are listed in Table 4.3-72. Table 4.3-74 provides a summary of the issues associated with each type of strategy.

Table 4.3-72
Strategy Evaluation Matrix for Hickory Aquifer Users

Strategy	Eden	Richland SUD	Melvin	Live Oak Hills
Cation Exchange (CAX)	X			
Reverse Osmosis (RO)	X			
Specialized Media (e.g. WRT)		X	X	
POE/POU (CAX)		X	X	X
Bottled Water – Central Location	X	X	X	X
No Action	X	X	X	X

Recommended Strategies for Hickory Aquifer Users

For each of these four water suppliers, the potential water management strategies involve significant uncertainties regarding costs and regulations. Regulatory uncertainty about disposal options for treatment residuals and the potential economic impact of treatment on rural Texas continue to inhibit implementation of compliance strategies. The more innovative options of POE/POU do not yet have clearly defined requirements for operation, maintenance and testing. Although EPA is being lobbied to include bottled water as a compliance strategy, this option has not yet been defined in that manner. The current regulatory environment is not conducive to the implementation of strategies that would allow these small community water systems to comply with the radionuclides rule. Thus, the bottled water strategies are recommended as a temporary measure until conditions improve such that other options become more economically feasible and involve less regulatory uncertainty. Table 4.3-73 summarizes the costs of the recommended strategies for each Hickory aquifer user.

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

City of Eden

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

Richland SUD

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

City of Melvin

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

Live Oak Hills Subdivision

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

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

Table 4.3-74
Potential Strategies for Hickory Aquifer Users

Type of WMS	Primary Advantages	Primary Disadvantages	Disposal Issues	Other Regulatory Issues
Cation Exchange (CAX)	Provides high level of treatment for radium.	System requires regular backwashing/regeneration. Sodium supply is a constant expense. Ion exchange media must also periodically be replaced.	Brine could be considered low-level radioactive waste unless there is a waste stream to blend the brine into. Potential long-term liability risks.	State needs to address low-level radioactive waste rules to accommodate disposal of treatment residuals in Texas.
Reverse Osmosis (RO)	Provides high level of treatment for radium and gross alpha.	Membranes have to be monitored and periodically cleaned or replaced and 15-25% of water is wasted as brine. High level of operator training is required to properly operate and maintain the system.	Brine could be considered low-level radioactive waste unless there is a waste stream to blend the brine into. Potential long-term liability risks.	State needs to address low-level radioactive waste rules to accommodate disposal of treatment residuals in Texas.
Specialized Media (e.g. WRT Z-88)	No liquid residual requiring disposal, requires little operation/maintenance from the water supplier.	Water supplier is reliant on commercial supplier to maintain and operate. Radium concentrations in the media require precautions re: worker safety and could also expose water supplier to liability risks.	There is no viable disposal option within Texas at this time. WRT is seeking to permit an injection well within Texas. Disposal costs will be higher if the well can't be permitted.	State needs to address low-level radioactive waste rules to accommodate disposal of treatment residuals in Texas.
POE (CAX)	Smaller CAX systems are simpler to operate and maintain than central systems. Water supplier operators could maintain systems that are located in accessible areas outside the customers' homes.	The water supplier must own the system and 100% of customers must agree to participate. Property access by the water supplier operator is required for maintenance and inspection. A contract must be set up between the water supplier and the homeowner to allow the necessary access. Each system has to be tested once every 3 years.	Single-family septic systems are exempt from rules regarding disposal of radionuclides.	Maintenance and inspection intervals have not yet been determined by TCEQ. Radium testing cost would be prohibitive; no adequate substitute test has yet been approved by TCEQ.
POU (RO)	Only a portion of the water supply has to be treated. Home RO systems are less expensive and easier to install and maintain than POE CAX.	Water supplier must own the system and 100% of customers must agree to participate. Access to interior of customers' homes for maintenance and inspection is required. A contract must be set up between the water supplier and the homeowner to allow the necessary access. Each system has to be tested once every 3 years.	Single-family septic systems are exempt from rules regarding disposal of radionuclides.	Maintenance and inspection intervals have not yet been determined by TCEQ. Radium testing costs would be prohibitive; no adequate substitute test has yet been approved by TCEQ.
Bottled Water (delivered)	Convenient supply of drinking water for customers.	Delivery is extremely expensive and typically requires use of 3- to 5-gallon containers that may be too heavy for some customers to handle. Water supplier would be dependent on a commercial water supplier or would have to implement treatment, bottling and delivery themselves.	None if imported by a commercial supplier. Septic system could possibly accommodate disposal of residuals from CAX or RO processes, if there is a sufficient waste stream to blend the brine into.	EPA has not approved bottled water as a compliance option, but TCEQ believes delivery might be viewed the same as POU from a regulatory standpoint. A water supplier that is bottling water for delivery will have to comply with the regulations that govern the bottled water industry.
Bottled Water (central location)	Provides customers a drinking water supply, without the added expense of home delivery or the maintenance access issues of POE or POU.	Customers bear the inconvenience of obtaining drinking water from a central location. Abuse is possible from non-customers taking water or from customers taking too much water. Round-the-clock accessibility to bottled water may be required.	Water suppliers have to dispose of brine residuals in a sanitary sewer system or a septic system. Septic system could possibly accommodate disposal of residuals from CAX or RO processes, if there is a sufficient waste stream to blend the brine into. Drinking water supply could be tanked in from a nearby city.	EPA has not approved bottled water as a compliance option. This option has only been allowed under bilateral compliance agreements.
No Action	Avoids high costs of compliance that could impose an economic hardship on customers. Avoids liability issues of concentrating radium via treatment process.	Customers continue to be supplied with drinking water that exceeds EPA standards. Water supplier could potentially bear liability if health concerns are later validated.	None	Water supplier would face fines and penalties, or other legal action. Private-action lawsuits are also possible. There could be potential repercussions for funding of state or federal projects.

4.4 Manufacturing Needs

Table 4.4-1 summarizes the manufacturing needs for Region F. There are seven counties showing manufacturing needs over the planning period: Coleman, Ector, Howard, Kimble, McCulloch, Runnels and Tom Green Counties. Manufacturing needs in Coleman, Ector, Howard, McCulloch, Runnels and Tom Green Counties are associated with needs for the cities of Coleman, Odessa, Big Spring, Brady, Ballinger and San Angelo, respectively, and will be met by strategies developed for these cities. Needs for the cities of Coleman and Brady are met exclusively with the subordination strategy described in Sections 4.2.3 and 4.2.4. Needs for Odessa and Big Spring are met by strategies discussed with Colorado River Municipal Water District strategies in Section 4.8.1. Strategies for San Angelo are also found in Section 4.8.3. Only manufacturing needs in Kimble County cannot be met with a municipal strategy and requires a stand-alone analysis.

4.4.1 Kimble County

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

The City of Junction is the major user of surface water in Kimble County. However, TWDB records show no industrial sales by the city. There are only two water rights in Kimble County authorized for manufacturing use, with a total authorized diversion of 2,466 acre-feet per year. However, only 51 acre-feet per year are authorized for consumption by these water rights, which is about two percent of the total diversion. The remainder must be returned to the stream. Based on this evidence, it appears that at least part of the historical reported surface water use may be recirculated surface water. Both of these water rights have no reliable supply according to the Colorado WAM.

Table 4.4-1
Manufacturing Needs in Region F
(Values in Acre-Feet per Year)

Source	2010	2020	2030	2040	2050	2060	Comments
Coleman County							
Lake Coleman	*0*	*0*	*0*	*0*	*0*	*0*	City of Coleman sales, no supply in WAM
Demand	*6*	*6*	*6*	*6*	*6*	*6*	
Surplus (Need)	*(6)*	*(6)*	*(6)*	*(6)*	*(6)*	*(6)*	
Ector County							
CRMWD system	183	315	607	748	848	915	Odessa sales
Reuse	2,500	2,500	2,500	2,500	2,500	2,500	Odessa reuse
Edwards-Trinity Plateau	16	17	18	19	19	20	
Total Supply	*2,699*	*2,832*	*3,125*	*3,267*	*3,367*	*3,435*	
Demand	*2,759*	*2,963*	*3,125*	*3,267*	*3,376*	*3,491*	
Surplus (Need)	*(60)*	*(131)*	*0*	*0*	*(9)*	*(56)*	
Howard County							
CRMWD system	750	745	1,099	1,161	1,214	1,272	Big Spring sales
Edwards-Trinity Plateau	288	288	288	288	288	288	
Ogallala	461	461	461	461	461	461	
Total Supply	1,499	1,494	1,848	1,910	1,963	2,021	
Demand	1,648	1,648	1,648	1,648	1,648	1,648	
Surplus (Need)	(149)	(154)	200	262	315	373	
Kimble County							
Edwards-Trinity Plateau	3	3	3	3	3	3	
Johnson Fork	0	0	0	0	0	0	Self-supplied, no supply in WAM
Total Supply	3	3	3	3	3	3	
Demand	702	767	823	880	932	1,002	
Surplus (Need)	(699)	(764)	(820)	(877)	(929)	(999)	
McCulloch County							
Hickory	719	804	879	950	1,012	1,108	
Brady Creek Lake	0	0	0	0	0	0	Brady sales, no supply in WAM
Total Supply	719	804	879	950	1,012	1,108	
Demand	844	929	1,004	1,075	1,137	1,233	
Surplus (Need)	(125)	(125)	(125)	(125)	(125)	(125)	
Runnels County							
Lake Ballinger	0	0	0	0	0	0	City of Ballinger sales, no supply in WAM
Lake Winters	0	0	0	0	0	0	City of Winters sales, no supply in WAM
Total Supply	0	0	0	0	0	0	
Demand	63	70	76	82	87	94	
Surplus (Need)	(63)	(70)	(76)	(82)	(87)	(94)	

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

Source	2010	2020	2030	2040	2050	2060	Comments
Tom Green County							
San Angelo System	0	0	0	0	0	0	San Angelo sales, no supply in WAM
Demand	2,226	2,498	2,737	2,971	3,175	3,425	
Surplus (Need)	(2,226)	(2,498)	(2,737)	(2,971)	(3,175)	(3,425	
Total For Counties with Needs							
Total Supply	4,920	5,133	5,855	6,130	6,345	6,567	
Total Demand	8,248	8,881	9,419	9,929	10,361	10,899	
Total Need	(3,328)	(3,748)	(3,564)	(3,799)	(4,016)	(4,332	

Three potential water management strategies have been identified for Kimble County Manufacturing:

- Subordination of downstream senior water rights
- Voluntary redistribution through purchase or lease of existing surface water rights
- New groundwater development from the Edwards-Trinity Plateau aquifer

Region F does not evaluate water conservation for manufacturing because of the relatively small amount of water used and a lack of specific data on manufacturing processes.

Subordination of Senior Water Rights

These two manufacturing water rights were not included in the larger subordination analysis associated with the major water rights in the Colorado Basin. As a surrogate for a more thorough analysis, the availability for these water rights was determined running the Colorado WAM in natural order. Natural order ignores the priority of water rights and meets demands from upstream to downstream. In natural order, the combined reliable supply from these two rights is 20 acre-feet per year.

Quantity, Reliability and Cost

Assuming that this diversion represents the two percent of water that is actually consumed, the total recirculated use for these rights would be 1,000 acre-feet per year, which is sufficient to meet demands. However, this supply may not be entirely reliable because diversions may not be available when needed during drought. The cost of this strategy depends on negotiations between the water rights holders. For the purposes of this plan, it will be assumed that these costs will be $200 per acre-foot (see Section 4.2.3).

Environmental Issues

Implementation of this strategy is expected to have minimal impacts on environmental flows, over-banking flows, or habitats because of the small consumptive use authorized by these two water rights.

Agricultural and Rural Issues

There are no agricultural or rural issues associated with this project.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

The natural order simulation assumes that no downstream water rights make priority calls on these two water rights. In practice, it would be extremely difficult to enter subordination agreements with all senior downstream rights. Normally only water rights with large diversions enter into subordination agreements. However, these agreements may not prevent smaller rights from making priority calls. Given the relatively small consumptive use associated with these rights, even a priority call by a small water right could impact availability.

Other Water Management Strategies Directly Affected

Voluntary redistribution to meet Kimble County manufacturing needs may be affected.

Voluntary Redistribution through Lease or Purchase of Existing Water Rights

Voluntary redistribution through purchase or lease of existing water rights is a feasible strategy that is complementary to subordination. The leased or purchased water rights must have priority dates senior to the two manufacturing rights for this strategy to be effective. Diversions for these rights could be moved upstream, or the rights could simply not be exercised, eliminating the possibility of a priority call. For example, according to the Colorado WAM there are 1,475 acre-feet per year of reliable irrigation diversions in Kimble County. However, Kimble County irrigation has a surplus of 786 acre-feet per year in 2010, increasing to 964 acre-feet per year by 2060. This implies that at least some irrigation rights may be available for purchase or lease.

Region F has not identified specific rights for purchase, so no quantity, costs or impacts can be developed at this time. These transactions would be made between private corporations and individuals and valuating these transactions is not appropriate for regional water planning.

New Groundwater Development from the Edwards-Trinity Plateau Aquifer

There are undeveloped groundwater supplies in the Edwards-Trinity Plateau aquifer in Kimble County. Water from this source is not widely used because of low well yields in most areas. Some areas have poor water quality as well. However, there appears to be some areas within the county that have sufficient well yields to meet manufacturing water needs. This strategy assumes that 5 new wells with an average transmission distance of 15 miles could be constructed to supply manufacturing water.

Quantity, Reliability and Cost

This strategy could be implemented if the Kimble County manufacturing water needs are for consumptive use and not for recirculated water. This strategy assumes that up to 1,000 acre-feet of water per year could be produced from the Edwards-Trinity (Plateau) aquifer. Reliability would be moderate to high, depending on well capacity. The cost of water would be approximately $670 per acre-foot ($2.06/1,000 gallons). Table 4.4-2 summarizes the costs for this strategy.

Table 4.4-2
New Water Wells in the Edwards-Trinity (Plateau) Aquifer
Kimble County Manufacturing

Supply from Strategy	1,000 acre-feet per year
Total Capital Costs (2002 Prices)	$ 5,676,600
Annual Costs	$ 670,000
Unit costs (before amortization)	$ 670 per acre-foot
	$ 2.06 per 1,000 gallons
Unit Costs (after amortization)	$ 175 per acre-foot
	$ 0.54 per 1,000 gallons

Environmental Issues

A specific drilling location for this strategy has not been identified. Many areas of good well production in the Edwards-Trinity Plateau aquifer are associated with surface water discharge from springs. Groundwater development from this source should be evaluated for potential impacts on spring flows and base flows of are rivers. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Issues

There are no agricultural or rural issues associated with this project.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

The most significant challenge for this strategy is locating areas with sufficient well production and low potential for impacts on spring flows. There is also uncertainty regarding the amount of water actually needed to meet consumptive manufacturing needs in Kimble County. It is quite likely that the actual amount of water needed is overstated in the projections.

Other Water Management Strategies Directly Affected

Other Kimble County manufacturing strategies.

Recommended Strategies for Kimble County Manufacturing

Since it appears that the manufacturing demands for Kimble County include a significant amount of recirculated water, the most likely strategy to meet future manufacturing needs is subordination of downstream water rights. Voluntary redistribution by purchase or lease of other water rights could be effective as well, depending on which water rights are available for purchase. If these supplies are not sufficient, the Region F Water Planning Group considers drilling of water wells by manufacturing interests in Kimble County to meet regulatory requirements for consistency with this plan.

Table 4.4-3 summarizes the recommended strategies for Kimble County manufacturing. Costs for this strategy have not been developed because of the uncertainty regarding the implementation of these strategies.

Table 4.4-3
Recommended Strategies for Kimble County Manufacturing
(Values in Acre-Feet per Year)

	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Existing Supplies	3	3	3	3	3	3
Subordination, voluntary redistribution & recirculation	1,000	1,000	1,000	1,000	1,000	1,000
Total Supplies	*1,003*	*1,003*	*1,003*	*1,003*	*1,003*	*1,003*
Demand	*702*	*767*	*823*	*880*	*932*	*1,002*
Surplus (Need)	*301*	*236*	*180*	*123*	*71*	*1*

4.5 Steam-Electric Power Needs

By 2060 the region has water needs for Steam-Electric Power Generation of almost 30,000 acre-feet. These shortages are the result of three factors:

- Little or no yield in reservoirs using Colorado WAM Run 3, which is required for use in the regional water plans by the TWDB,
- Limited groundwater supplies in Ward and Andrews Counties, and
- Increased demands that cannot be met with existing supplies, particularly in Mitchell and Ector Counties.

Table 4.5-1 compares region-wide demands to available existing supplies. In areas where there are insufficient supplies, steam-electric power generation has been limited to maximum recent historical use.

The projections for growth in steam-electric power water use in Region F are based on state-wide projections for new generation capacity and do not necessarily reflect site- specific water needs[38]. In Region F, the projected growth in water demand exceeds the water supply currently available to existing generation facilities. Because growth in demand is not site-specific, strategies may include movement of demand to other locations as well as new supply development.

Potentially Feasible Strategies

Because of an overall lack of available new water supplies at existing generation facilities, Region F has limited water use for steam-electric power generation to current use. The expected growth in water demand reflects the expected need for additional electrical generation capacity, and that additional capacity can be met using alternative technologies that require significantly less water. Therefore meeting these shortages is not limited to water management strategies.

Strategies to meet steam-electric needs include:

- Moving the power generation need to another existing facility outside of Region F with sufficient water supplies;
- Construction of a new generation facility in an area where there are sufficient water supplies to meet projected demands, either inside or outside of Region F;
- Using an alternative source of water, including brackish water (either groundwater or surface water from chloride control projects such as Mitchell County Reservoir) or treated wastewater, either inside or outside of Region F;

Table 4.5-1
Comparison of Region F Steam-Electric Water Demand Projections to Currently Available Supplies

	Name	County	2010	2020	2030	2040	2050	2060	Comments
Supply	Oak Creek Reservoir	Coke	0	0	0	0	0	0	No supply in priority order WAM
Demand	AEP Oak Creek	Coke	310	247	289	339	401	477	
Surplus (Need)			*(310)*	*(247)*	*(289)*	*(339)*	*(401)*	*(477)*	
Supply	Edwards-Trinity Plateau aquifer	Pecos	1,500	1,500	1,500	1,500	1,500	1,500	Supply based on recent use
Demand	AEP Rio Pecos	Crockett	973	776	907	1,067	1,262	1,500	Source in Pecos County
Surplus (Need)			*527*	*724*	*593*	*433*	*238*	*0*	
Supply	Ogallala aquifer	Andrews	6,375	6,375	6,375	6,375	6,375	6,375	Supply limited to recent use
Demand	Panda Odessa-Ector	Ector	6,375	9,125	10,668	12,549	14,842	17,637	Source in Andrews County
Surplus (Need)			*0*	*(2,750)*	*(4,293)*	*(6,174)*	*(8,467)*	*(11,262)*	
Supply	Champion/Colorado City System	Mitchell	0	0	0	0	0	0	No supply in priority order WAM
Demand	TXU Morgan Creek	Mitchell	9,100	7,621	8,910	10,481	12,396	14,730	
Surplus (Need)			*(9,100)*	*(7,621)*	*(8,910)*	*(10,481)*	*(12,396)*	*(14,730)*	
Supply	Twin Buttes/Nasworthy	Tom Green	0	0	0	0	0	0	No supply in priority order WAM
Demand	AEP San Angelo	Tom Green	543	777	909	1,069	1,264	1,502	
Surplus (Need)			*(543)*	*(777)*	*(909)*	*(1,069)*	*(1,264)*	*(1,502)*	
Supply	Cenozoic Pecos Alluvium	Ward	4,914	4,223	4,937	5,807	6,189	6,189	Supply limited to recent use
Demand	TXU Permian Basin	Ward	4,914	4,223	4,937	5,807	6,868	8,162	
Surplus (Need)			*0*	*0*	*0*	*0*	*(679)*	*(1,973)*	
		Total Supply	*12,789*	*12,098*	*12,812*	*13,682*	*14,064*	*14,064*	
		Total Demand	*22,215*	*22,769*	*26,620*	*31,312*	*37,033*	*44,008*	
		Total Surplus (Need)	*(9,426)*	*(10,671)*	*(13,808)*	*(17,630)*	*(22,969)*	*(29,944)*	

- Voluntary redistribution of water supplies already dedicated to another use, including purchase of existing irrigation supplies; and
- Use of alternative cooling technologies that use less water.

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

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

Other strategies may be employed in Region F, including the voluntary redistribution of existing water supplies. However, the actual strategies are largely a business decision on the part of the power industry. The uncertainty associated with these strategies makes it difficult to perform a meaningful analysis. Therefore these strategies are not included in this plan.

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, most reservoirs in Region F with a priority date after 1926 do not have a firm or safe yield. This result is largely due to the assumptions used in the Colorado WAM. Four reservoirs in Region F provide water for steam-electric power generation:

- Oak Creek Reservoir, which is owned by the City of Sweetwater;
- Champion Creek Reservoir and Lake Colorado City, which are owned by TXU and operated as system; and
- Lake Nasworthy, which is owned by the City of San Angelo.

All of these reservoirs have priority dates after 1926, so these reservoirs have no yield.

In order to address water availability issues associated with the Colorado WAM model, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights in Region F do not make priority calls on each other. The subordination strategy is discussed in Section 4.2.3. Table 4.5-2 is a summary of the impacts of the subordination strategy on supplies used for steam-electric power generation.

Table 4.5-2
Impact of Subordination Strategy on Steam-Electric Water Supplies [a]
(Values in acre-feet per year)

Reservoir	Priority Date	Permitted Diversion	2010 Supply WAM Run 3	2010 Supply with Subord-ination	2060 Supply WAM Run 3	2060 Supply with Subord-ination
Oak Creek Reservoir	4/27/1949	10,000 [b]	0	2,118	0	1,760
Champion Creek Reservoir	4/08/1957	6,750 [c]	0	2,337	0	2,220
Lake Colorado City	11/22/1948	5,500	0	2,686	0	1,920
Lake Nasworthy [d]	3/11/1929	25,000 [e]	0	12,310 [f]	0	11,360 [f]
Total		*47,250*	*0*	*19,451*	*0*	*17,260*

a Water supply is defined as the safe yield of the reservoir.

b 4,000 acre-feet per year for industrial purposes and 6,000 acre-feet per year for municipal purposes, making the total authorized diversion from Oak Creek Reservoir 10,000 acre-feet per year. Steam-electric power generation is considered an industrial use.

c 2,700 acre-feet per year of the authorized diversions can be used for municipal purposes. However, at this time there is no municipal use from the reservoir, so the entire 6,750 acre-feet per year can be used for power generation.

d Diversions from Lake Nasworthy are backed up by storage in Twin Buttes Reservoir, which has a priority date of 5/06/1959.

e 7,000 acre-feet per year for industrial, 17,000 acre-feet per year for municipal and 1,000 acre-feet per year for irrigation, making the total authorized diversions from Lake Nasworthy 25,000 acre-feet per year.

f Yield from Twin Buttes Reservoir and Lake Nasworthy operating as a system.

The joint modeling between the two regions was conducted for planning purposes only. Neither Region F nor the Lower Colorado Region mandates the adoption of this strategy by individual water right holders. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including steam-electric power generators.

Impacts of the subordination strategy are discussed in Section 4.2.3.

Alternative Cooling Technologies

Region F considers alternative cooling technologies on new power generation project the most likely method for developing new generation capacity within Region F. This technology, which uses air for cooling instead of water, can be utilized on any steam cycle based power generation project, for an incremental cost. This cost, calculated on a dollar per installed megawatt basis, would be above the cost of conventional cooling.

Quantity, Reliability and Cost

Table 4.5-3 shows the results of this analysis. Using the suggested technology up to 24,306 acre-feet per year of unmet needs can be met by 2060. This technology is currently in use and is very reliable. Capital costs, which are based on the incremental difference between more conventional cooling technologies and the alternative technology, are approximately $37.5 million in 2010, increasing to $600 million by 2060.

Agricultural and Rural Issues

There are no agricultural or rural issues associated with this project.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

The implementation of this strategy is dependent upon a distribution of state-wide generation needs that may not represent the actual needs for generation within Region F. Location of new generation facilities within Region F is largely an economic issue that will be made by the power industry. Other technologies or strategies may be more attractive for meeting the need for new generation capacity.

Other Water Management Strategies Directly Affected

No other water management strategies are impacted by this project.

Recommended Water Management Strategies for Steam Electric Power Generation

Table 4.5-4 is a summary of the water management strategies for steam-electric power generation, which include subordination of downstream water rights and alternative cooling technology. Because it significantly reduces water usage, ACC cooling technology on future generation projects may be considered a water conservation strategy.

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

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

* Assuming 2.5 percent of construction for O&M.

Table 4.5-4
Recommended Strategies for Steam-Electric Power Generation

Category	Name	County	2010	2020	2030	2040	2050	2060
Supply	Oak Creek Reservoir	Coke	0	0	0	0	0	0
	Subordination		310	247	289	339	401	477
	Total		310	247	289	339	401	477
Demand	AEP Oak Creek	Coke	310	247	289	339	401	477
Surplus (Need)			0	0	0	0	0	0
Supply	Edwards-Trinity Plateau aquifer	Pecos	1,500	1,500	1,500	1,500	1,500	1,500
Demand	AEP Rio Pecos	Crockett	973	776	907	1,067	1,262	1,500
Surplus (Need)			527	724	593	433	238	0
Supply	Ogallala aquifer	Andrews	6,375	6,375	6,375	6,375	6,375	6,375
Demand	Panda Odessa-Ector	Ector	6,375	9,125	10,668	12,549	14,842	17,637
Surplus (Need)			0	(2,750)	(4,293)	(6,174)	(8,467)	(11,262)
Supply	Champion/Colorado City System	Mitchell	0	0	0	0	0	0
	Subordination		5,023	4,847	4,670	4,493	4,317	4,140
	Total		5,023	4,847	4,670	4,493	4,317	4,140
Demand	TXU Morgan Creek	Mitchell	9,100	7,621	8,910	10,481	12,396	14,730
Surplus (Need)			(4,077)	(2,774)	(4,240)	(5,988)	(8,079)	(10,590)
Supply	Twin Buttes/Nasworthy	Tom Green	0	0	0	0	0	0
	Subordination		1,021	1,021	1,021	1,021	1,021	1,021
	Total		1,021	1,021	1,021	1,021	1,021	1,021
Demand	AEP San Angelo	Tom Green	543	777	909	1,069	1,264	1,502
Surplus (Need)			478	244	112	(48)	(243)	(481)
Supply	Cenozoic Pecos Alluvium	Ward	4,914	4,223	4,937	5,807	6,189	6,189
Demand	TXU Permian Basin	Ward	4,914	4,223	4,937	5,807	6,868	8,162
Surplus (Need)			0	0	0	0	(679)	(1,973)
Total Supply			*19,143*	*18,213*	*18,792*	*19,535*	*19,803*	*19,702*
Total Demand			*22,215*	*22,769*	*26,620*	*31,312*	*37,033*	*44,008*
Total Surplus (Need)			*(3,072)*	*(4,556)*	*(7,828)*	*(11,777)*	*(17,230)*	*(24,306)*
Alternative Generation Technology			4,077	5,524	8,533	12,210	17,468	24,306
Total Surplus (Need) with alternative generation			*1,005*	*968*	*705*	*433*	*238*	*0*

4.6 Irrigation Needs

Sixteen of the thirty-two counties in Region F have identified irrigation needs. However, the adoption of advanced conservation technologies throughout the region will help preserve existing water resources for continued agricultural use and provide for other demands. Therefore, this analysis presents water savings for all counties in Region F. The counties with identified irrigation needs are listed in Table 4.6-1.

Region F recommends improvements in the efficiency of irrigation equipment as the most effective water conservation strategy for irrigation within the region. The analysis presented in this plan is an update of the analysis performed in the 2001 *Region F Regional Water Plan*[39].

Table 4.6-1
Counties with Projected Irrigation Needs
(Values in Acre-Feet per Year)

County	Projected Irrigation Needs					
	2010	2020	2030	2040	2050	2060
Andrews	14,094	14,064	13,926	12,536	12,333	12,165
Borden	1,847	1,844	1,839	1,835	1,829	1,826
Brown	3,006	2,982	2,946	2,905	2,868	2,841
Coke	363	363	361	360	360	360
Coleman	1,348	1,348	1,348	1,348	1,348	1,348
Glasscock	27,784	27,381	26,972	26,552	26,131	25,722
Irion	1,302	1,241	1,181	1,120	1,060	1,000
Martin	788	564	322	-	-	-
Menard	2,441	2,421	2,402	2,383	2,361	2,342
Midland	16,233	16,359	16,348	16,254	16,112	15,993
Reagan	10,997	10,607	10,116	9,559	8,976	8,393
Reeves	36,097	35,245	34,387	33,525	32,664	31,847
Runnels	1,358	1,344	1,325	1,306	1,287	1,268
Tom Green	47,090	46,831	46,576	46,321	46,062	45,807
Upton	10,672	10,451	10,223	9,992	9,762	9,539
Ward	5,527	4,973	5,721	6,539	6,905	6,888
Total	*180,947*	*178,018*	*175,993*	*172,535*	*170,058*	*167,339*

Six alternative irrigation systems were evaluated based on current use in Region F or the potential to improve water use efficiency. The alternative irrigation systems analyzed included furrow flood (FF), surge flow (SF), mid-elevation sprinkler application (MESA), low elevation spray application (LESA), low energy precision application (LEPA) and subsurface drip irrigation (drip). This analysis assumed an irrigation system was installed on a "square" quarter section of land (160 acres). Terrain and soil types were assumed to not limit the feasibility of adopting an irrigation system. Application efficiencies for the various irrigation technologies were assumed as follows:

- Furrow irrigation (FF) – 60 percent,
- Surge flow (SF) – 75 percent,
- MESA – 78 percent,
- LESA – 88 percent,
- LEPA – 95 percent, and
- Drip irrigation – 97 percent[40].

The system with the higher efficiency rating is considered more efficient because it uses less water.

Table 4.6-2 contains data on irrigated acreage by crop type from the Texas Water Development Board (TWDB). As shown in Table 4.6-2, there were 221,276 irrigated acres within Region F in 2002[41]. Cotton was the most significant irrigated crop with 41 percent of the irrigated acreage. Wheat and hay-pasture represented 14 percent and 9 percent, respectively, of the irrigated acreage. Seven counties (Andrews, Glasscock, Martin, Midland, Pecos, Reeves, and Tom Green) account for 70 percent of the region's irrigated acreage.

The procedure used to evaluate potential savings is dependent upon data regarding the current irrigation equipment types used in the region, which are summarized in Table 4.6-3. However, the most recent data available on the types of irrigation equipment is the 1997 data developed for the previous Region F plan. Since up-to-date distribution of irrigation technologies was not available, the current distribution was estimated based on the 1997 data. In some counties new crop types were irrigated in 2002 which were not irrigated in 1997. In these cases, a representative distribution of irrigation equipment for the same crop in other counties was assumed to apply to that county.

Based on this methodology, 42 percent of the region's irrigated crop production used some form of advanced irrigation technology (surge, sprinkler or drip) in 2002. Accelerated adoption of advanced irrigation technologies, and in particular, adoption of the most feasible advanced technologies could potentially reduce irrigation demands while maintaining the highest level of irrigated acreage possible. To examine the impact of an aggressive rate of water-conserving

Table 4.6-2
Irrigated Acreage by Crop Type
(Values in Acres)

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

Irrigated crops as reported by the TWDB in 2002. Acreages and/or crop types may have changed since 2002, but such changes are not reflected in this table.

Table 4.6-3
Estimated Distribution of Irrigation Equipment in 2002

County	Irrigated Acres	Acres by Equipment Type						Percentage of Acreage		
		Furrow	Surge	MESA	LESA	LEPA	Drip	% Furrow & Surge	% Sprinkler	% Drip
Andrews	20,326	12,183	177	0	5,046	2,800	120	60.8	38.6	0.6
Borden	2,149	861	0	640	648	0	0	40.1	59.9	0.0
Brown	7,642	6,012	0	691	909	0	31	78.7	20.9	0.4
Coke	564	289	0	224	51	0	0	51.2	48.9	0.0
Coleman	188	188	0	0	0	0	0	100.0	0.0	0.0
Concho	4,478	3,937	0	212	329	0	0	87.9	12.1	0.0
Crane	0	0	0	0	0	0	0	0.0	0.0	0.0
Crockett	96	9	0	23	64	0	0	9.2	90.5	0.0
Ector	1,632	1,052	0	0	402	0	179	64.4	24.6	11.0
Glasscock	26,598	16,650	41	80	80	1,190	8,555	62.8	5.1	32.2
Howard	2,315	1,308	0	36	272	628	72	56.5	40.4	3.1
Irion	1,245	884	0	361	0	0	0	71.0	29.0	0.0
Kimble	922	548	0	39	335	0	0	59.4	40.6	0.0
Loving	100	100	0	0	0	0	0	100.0	0.0	0.0
McCulloch	2,258	310	0	1,821	102	0	25	13.7	85.2	1.1
Martin	14,502	5,574	0	1,509	2,090	4,845	486	38.4	58.2	3.4
Mason	6,610	1,606	0	4,230	704	0	68	24.3	74.6	1.0
Menard	3,188	2,567	0	360	49	0	212	80.5	12.8	6.6
Midland	15,954	5,832	0	3,067	6,476	0	579	36.6	59.8	3.6
Mitchell	4,837	4,061	150	213	394	0	20	87.1	12.5	0.4
Pecos	23,848	8,800	10,165	0	2,447	57	2,379	79.5	10.5	10.0
Reagan	10,716	9,480	2	68	46	85	1,035	88.5	1.9	9.7
Reeves	22,078	5,843	12,726	0	2,021	20	1,467	84.1	9.2	6.6
Runnels	3,646	3,298	161	0	186	0	1	94.9	5.1	0.0
Schleicher	820	757	0	62	1	0	0	92.3	7.7	0.0
Scurry	3,490	2,929	42	72	432	0	15	85.1	14.4	0.4
Sterling	647	187	0	460	0	0	0	28.9	71.1	0.0
Sutton	851	776	0	10	67	0	0	91.1	9.0	0.0
Tom Green	30,820	25,004	1,567	261	3,419	0	568	86.2	11.9	1.8
Upton	6,301	5,029	0	0	0	0	1,272	79.8	0.0	20.2
Ward	1,426	1,414	0	12	0	0	0	99.1	0.9	0.0
Winkler	1,029	409	375	47	11	0	188	76.2	5.6	18.2
Crop Totals	*221,276*	*127,896*	*25,405*	*14,497*	*26,581*	*9,624*	*17,272*	*69.3*	*22.9*	*7.8*

Estimated irrigated crops in 2002 based on distribution of equipment in 1997.

technology implementation, one half of the necessary adoption of advanced irrigation technologies was assumed to take place by the year 2020, with 100 percent adoption by the year 2030.

The selection of the most feasible advanced irrigation technology for each crop within a county was based on several assumptions and constraints relating to crop type, water source, and water quality considerations. The following guidelines were used:

- Furrow and surge acres were moved to drip or sprinkler whenever feasible.
- Existing sprinkler acres were moved to the most efficient sprinkler technology whenever feasible.
- Surface water supplies were assumed to remain as furrow or flood due to problems associated with the use of sprinkler or drip technologies with surface supplies. While there may be ways to make more efficient use of surface water supplies, this would involve a county by county assessment, which was beyond the scope of this analysis.
- The shift of furrow to drip was considered feasible for cotton and grain sorghum.
- Other crops such as wheat, alfalfa, peanuts, forage crops, and hay-pasture were shifted from furrow to the most feasible sprinkler technology.
- Orchard and vineyard crops currently using flood irrigation were not changed to alternative technologies.
- The application efficiency of drip and LEPA in Reeves, Ward, Loving, and Pecos counties was reduced to 93 percent and 91 percent, respectively, to allow for a flood irrigation at least once every 3 years to flush any buildup of salts in the upper soil profile.
- No additional sprinkler acreage was included in Glasscock, Midland, Upton, and Reagan counties due to the low water well yields in those counties. This strategy would involve using multiple wells per system and was deemed unlikely.

Utilizing these assumptions, the projected percentages of use for different irrigation equipment are shown in Table 4.6-4.

The methodology for calculating annual water savings in acre-feet was to shift acreages of furrow irrigated crops to LEPA or drip, from Surge to LEPA or drip, from MESA to LEPA and from LESA to LEPA when an advanced technology was considered feasible. The gross irrigation application rate per acre for each crop in a given county using a furrow system was used as the base water application rate. This base rate was then compared to the required equivalent irrigation application rate with advanced irrigation technology. The difference in

Table 4.6-4
Estimated Percentage of Projected Adoption of Advanced Irrigation Technology in Region F

County	Irrigated Acres	2002 (current)			2020			2030 - 2060		
		% Furrow & Surge	% Sprinkler	% Drip	% Furrow & Surge	% Sprinkler	% Drip	% Furrow & Surge	% Sprinkler	% Drip
Andrews	20,326	60.8	38.6	0.6	37.9	54.5	7.6	15.0	70.4	14.6
Borden	2,149	40.1	59.9	0.0	22.1	70.4	7.4	4.2	80.9	14.9
Brown	7,642	78.7	20.9	0.4	78.7	20.9	0.4	78.7	20.9	0.4
Coke	564	51.2	48.9	0.0	51.2	48.9	0.0	51.2	48.9	0.0
Coleman	188	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0
Concho	4,478	87.9	12.1	0.0	47.2	39.4	13.4	6.5	66.7	26.8
Crane	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crockett	96	9.2	90.5	0.0	9.2	90.5	0.0	9.2	90.5	0.0
Ector	1,632	64.4	24.6	11.0	40.1	48.9	11.0	15.8	73.2	11.0
Glasscock	26,598	62.8	5.1	32.2	35.9	5.1	59.0	9.1	5.1	85.8
Howard	2,315	56.5	40.4	3.1	33.2	51.5	15.3	9.8	62.7	27.5
Irion	1,245	71.0	29.0	0.0	71.0	29.0	0.0	71.0	29.0	0.0
Kimble	922	59.4	40.6	0.0	40.1	59.9	0.0	20.8	79.2	0.0
Loving	100	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0
McCulloch	2,258	13.7	85.2	1.1	9.8	89.1	1.1	5.8	93.1	1.1
Martin	14,502	38.4	58.2	3.4	19.9	61.7	18.4	1.4	65.2	33.4
Mason	6,610	24.3	74.6	1.0	14.8	84.1	1.0	5.4	93.5	1.0
Menard	3,188	80.5	12.8	6.6	80.5	12.8	6.6	80.5	12.8	6.6
Midland	15,954	36.6	59.8	3.6	25.3	59.8	14.9	14.1	59.8	26.1
Mitchell	4,837	87.1	12.5	0.4	47.0	26.2	26.8	7.0	39.8	53.1
Pecos	23,848	79.5	10.5	10.0	46.3	31.4	22.3	13.1	52.3	34.5
Reagan	10,716	88.5	1.9	9.7	51.9	1.9	46.3	15.3	1.9	82.9
Reeves	22,078	84.1	9.2	6.6	45.9	36.4	17.7	7.7	63.6	28.7
Runnels	3,646	94.9	5.1	0.0	94.9	5.1	0.0	94.9	5.1	0.0
Schleicher	820	92.3	7.7	0.0	63.9	36.1	0.0	35.5	64.5	0.0
Scurry	3,490	85.1	14.4	0.4	47.3	42.6	10.1	9.5	70.8	19.7
Sterling	647	28.9	71.1	0.0	28.9	71.1	0.0	28.9	71.1	0.0
Sutton	851	91.1	9.0	0.0	61.0	39.1	0.0	30.8	69.3	0.0
Tom Green	30,820	86.2	11.9	1.8	58.8	25.9	15.3	30.5	40.2	29.2
Upton	6,301	79.8	0.0	20.2	50.6	0.0	49.4	21.4	0.0	78.6
Ward	1,426	99.1	0.9	0.0	58.7	41.3	0.0	18.3	81.7	0.0
Winkler	1,029	76.2	5.6	18.2	50.1	31.7	18.2	23.9	57.8	18.2
System Totals	*221,276*	*69.3*	*22.9*	*7.8*	*44.2*	*34.2*	*21.6*	*19.0*	*45.6*	*35.4*

application rates was the assumed water savings. For example, the total per acre applied irrigation water for cotton using a furrow system was 16 acre-inches in Glasscock County. Using the 60 percent application efficiency for furrow resulted in an effective application rate of 9.6 acre-inches. If a drip system were used with an application efficiency of 97 percent, the resulting total application rate would be 9.9 acre-inches. Therefore, the potential water savings for a shift from furrow to drip would be 6.1 acre-inches.

Quantity, Reliability and Cost of Irrigation Conservation

Table 4.6-5 presents the estimates of water savings by decade from accelerated adoption of water-efficient technology for all counties in Region F. With partial adoption (50%) completed by 2020, the annual water savings for the region is 40,470 acre-feet. Following full adoption in 2030, these annual water savings increase to 81,112 acre-feet. For the counties with irrigation needs, 22 percent of the initial deficit was recovered by 2020 and 44 percent was recovered by 2030. As shown on Table 4.6-5, all of the projected irrigation need can be met by advanced conservation for Brown and Martin Counties. The large irrigation counties, including Andrews, Glasscock, Midland, Reeves and Tom Green, still have considerable unmet irrigation demands. No specific alternative strategies were identified for these needs. It is anticipated that in the counties with unmet irrigation demands, some portion of the irrigated acreage will shift to non-irrigated crop production or to other uses. While it is difficult to predict what crops will likely be removed from production, the crops with the lower relative value of water will most likely be removed first. Table 4.6-6 presents the revised projected irrigation needs after accounting for advanced irrigation technologies. Also shown are estimates of the number of irrigated acres that would need to be converted to dryland farming or taken out of production to remain within the available supplies in each decade.

The actual amount of water saved by using advanced irrigation conservation is dependent upon a large number of factors, including weather, crop prices, funding, technical assistance, and individual preference. Therefore the reliability of this strategy is expected to be medium because of the uncertainty involved in the actual savings associated with this strategy.

Table 4.6-5
Projected Water Savings with Advanced Irrigation Technologies

County	Irrigation Need	Projected Water Savings (acre-feet/year)		% Reduction of 2000 Need	
	2010	2020	2030-2060	2020	2030-2060
Andrews	14,094	2,727	5,455	19.4%	38.7%
Borden	1,847	230	460	12.5%	24.9%
Brown	3,006	93	185	3.1%	6.2%
Coke	363	0	0	0.0%	0.0%
Coleman	1,348	0	0	0.0%	0.0%
Concho		748	1,496		
Crane		0	0	0.0%	0.0%
Crockett		0	0		
Ector		245	490		
Glasscock	27,784	3,631	7,262	13.1%	26.1%
Howard		327	653		
Irion	1,302	36	73	2.8%	5.6%
Kimble		74	147		
Loving		0	0		
McCulloch		197	394		
Martin	788	1,751	3,502	100.0%	100.0%
Mason		746	1,491		
Menard	2,441	23	46	0.9%	1.9%
Midland	16,233	1,800	3,600	11.1%	22.2%
Mitchell		865	1,729		
Pecos		6,300	12,600		
Reagan	10,997	1,968	3,936	17.9%	35.8%
Reeves	36,097	5,824	11,648	16.1%	32.3%
Runnels	1,358	0	0	0.0%	0.0%
Schleicher		107	214		
Scurry		572	1,143		
Sterling		44	89		
Sutton		142	284		
Tom Green	47,090	5,690	11,548	12.1%	24.5%
Upton	10,672	920	1,840	8.6%	17.2%
Ward	5,527	785	1,570	14.2%	28.4%
Winkler		194	389		
Total	*186,543*	*36,039*	*72,245*	*19.3%*	*38.7%*

Table 4.6-6
Revised Irrigation Needs Incorporating Advanced Irrigation Technologies

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

* Values are for each decade and do not represent incremental reductions in irrigated acreage.

Estimated costs for implementing this strategy are based on the analysis performed in the 2001 Region F plan. Assuming a static pumping lift of 350 feet, the cost of implementing a furrow flood system is $466/acre, a surge flow system $486/acre, MESA system $733/acre, LESA system $770/acre, LEPA system $784/acre and drip system $1,133/acre.

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

The estimated per acre water savings achieved with shifts from one irrigation technology to another varies by county. Therefore, the costs to adopt alternative irrigation systems are given by county. In general, the highest cost per acre-foot of water savings is for shifts from furrow or surge to drip. However, this represents only capital costs associated with equipment changes. Cost savings associated with reduced labor requirements for the more advanced irrigation technologies (sprinkler and drip) are not included in this analysis. To fully assess the economic feasibility of a strategy, a more complete economic evaluation is required.

Environmental Issues Associated with Irrigation Conservation

This strategy is expected to have minimal impact on the environment, either positive or negative. Most of the areas in Region F with significant irrigation needs rely on groundwater for irrigation, and most of the conservation strategies developed in this analysis are specifically for groundwater-based irrigation. In areas where conserved groundwater is discharged as springs or base flow, conservation will have a positive impact. However, in many cases projected irrigation demand exceeds available supply even with implementation of advanced irrigation technologies.

Agricultural and Rural Issues Associated with Irrigation Conservation

Irrigated agriculture is vital to the economy and culture of Region F. Implementation of water-conserving irrigation practices may be necessary to retain the economic viability of many areas that show significant water supply needs throughout the planning period.

Other Natural Resource Issues Associated with Irrigation Conservation

None identified.

Significant Issues Affecting Feasibility of Irrigation Conservation

The most significant issue associated with implementation of this strategy is the lack of a clear sponsor for the strategy. Although the TWDB and other state and federal agencies sponsor many excellent irrigation conservation programs, the actual implementation is the responsibility of individual irrigators. Because this strategy relies largely on individual behavior, it is difficult to quantify the actual savings that can be achieved.

Another significant factor is the lack of detailed data on both irrigation equipment in use and the quantity of water used for individual crops. The conservation calculations included in this analysis were hampered by a lack of current data for these two items.

Other Water Management Strategies Directly Affected by Irrigation Conservation

None identified.

4.7 Mining Needs

There are four counties in Region F with mining needs: Coke, Coleman and Howard Counties. Table 4.7-1 compares supplies to demands for these counties. These mining needs are the result of using the Colorado WAM for water supplies and can be met by the implementation of a subordination strategy.

Potentially Feasible Strategies

Region F has identified subordination of downstream water rights and use of non-potable water to meet mining needs. Most of the water used for mining purposes in Region F is for enhanced oil and gas production. According to §27.0511 of the Texas Water Code, the oil and gas industry is required by law to use non-potable supplies whenever possible for enhanced production[42]. As a result, it is unclear to what extent the water demand projections for the region actually represent direct competition with other types of use that require better water quality. The actual amount of mining needs may be considerably less than indicated.

Table 4.7-1
Mining Needs in Region F
(Values in Acre-Feet per Year)

	Source	2010	2020	2030	2040	2050	2060
Coke County							
Supply	CRMWD diverted water	232	239	378	378	380	372
	Other aquifer	170	170	170	170	170	170
	Total	*402*	*409*	*548*	*548*	*550*	*542*
Demand	*Mining*	*488*	*528*	*550*	*572*	*593*	*614*
Surplus (Need)		*(86)*	*(119)*	*(2)*	*(24)*	*(43)*	*(72)*
Coleman County							
Supply	Lake Coleman	0	0	0	0	0	0
	Other aquifer	1	1	1	1	1	1
	Total	*1*	*1*	*1*	*1*	*1*	*1*
Demand	*Mining*	*18*	*19*	*19*	*19*	*19*	*19*
Surplus (Need)		*(17)*	*(18)*	*(18)*	*(18)*	*(18)*	*(18)*
Howard County							
Supply	Edwards-Trinity Plateau	82	82	82	82	82	82
	Ogallala	119	119	119	119	119	119
	Dockum	106	106	106	106	106	106
	CRMWD diverted water	1,076	1,053	1,608	1,555	1,523	1,460
	Total	*1,383*	*1,360*	*1,915*	*1,862*	*1,830*	*1,767*
Demand	*Mining*	*1,783*	*1,883*	*1,924*	*1,963*	*2,001*	*2,052*
Surplus (Need)		*(400)*	*(523)*	*(9)*	*(101)*	*(171)*	*(285)*
Total Needs		*(503)*	*(660)*	*(29)*	*(143)*	*(232)*	*(375)*

Subordination of Downstream Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, most reservoirs in Region F with a priority date after 1926 do not have a firm or safe yield. This result is largely due to the assumptions used in the Colorado WAM. Mining water in Coke and Howard Counties is from the CRMWD system. Mining water in Coleman County comes from Lake Coleman. All of these sources have reduced supplies because of the WAM. The assumptions used in the Colorado WAM are discussed in more detail in Appendix 3C.

In order to address water availability issues resulting from the Colorado WAM model, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights in Region F do not make priority calls on each other. The subordination strategy is discussed in Section 4.2.3. With implementation of the subordination strategy there are sufficient supplies in these counties to meet demands.

The joint modeling between the two regions was conducted for planning purposes only. Neither Region F nor the Lower Colorado Region mandates the adoption of this strategy by individual water right holders. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including CRMWD and the City of Coleman. Impacts of the subordination strategy are discussed in Section 4.2.3.

Recommended Strategies

Table 4.7-2 is a summary of the recommended strategies to meet mining needs in Coke, Coleman, and Howard Counties. Meaningful costs for these strategies are difficult to develop because of the uncertainty regarding the magnitude of the shortages and the actual way that these strategies will be implemented. For the purposes of this plan, costs will be set at $200 per acre-foot (see Section 4.2.3).

Table 4.7-2
Strategies to Meet Mining Needs
(Values in Acre-Feet per Year)

Category	2010	2020	2030	2040	2050	2060
Coke County						
Existing supplies	402	409	548	548	550	542
Subordination	86	119	2	24	43	72
Total Supply	*488*	*528*	*550*	*572*	*593*	*614*
Demand	*488*	*528*	*550*	*572*	*593*	*614*
Surplus (need)	*0*	*0*	*0*	*0*	*0*	*0*
Coleman County						
Existing supplies	1	1	1	1	1	1
Subordination	17	18	18	18	18	18
Total Supply	*18*	*19*	*19*	*19*	*19*	*19*
Demand	*18*	*19*	*19*	*19*	*19*	*19*
Surplus (need)	*0*	*0*	*0*	*0*	*0*	*0*
Howard County						
Existing Supplies	1,383	1,360	1,915	1,862	1,830	1,767
Subordination	400	523	9	101	171	285
Total Supply	*1,783*	*1,883*	*1,924*	*1,963*	*2,001*	*2,052*
Demand	*1,783*	*1,883*	*1,924*	*1,963*	*2,001*	*2,052*
Surplus (need)	*0*	*0*	*0*	*0*	*0*	*0*

4.8 Strategies for Wholesale Water Providers

Strategies have been developed for the Colorado River Municipal Water District, the Brown County Water Improvement District No. 1, and the City of San Angelo. For the purposes of this plan, contracts between University Lands and CRMWD, the City of Andrews and the City of Midland are expected to be renewed when they expire. If these contracts are not renewed, the timing of recommended strategies for the City of Midland and CRMWD may be impacted. The City of Andrews may not have sufficient supplies even with the contract renewal and may require a new source of water.

4.8.1 Colorado River Municipal Water District

The Colorado River Municipal Water District (CRMWD), the largest water supplier in Region F, provides raw water from both groundwater and surface water sources. CRMWD owns and operates three major reservoirs, Lake J.B. Thomas, E.V. Spence Reservoir, and O.H. Ivie Reservoir, as well as several chloride control reservoirs. Groundwater sources include well fields in Ward, Scurry and Martin Counties. CRMWD member cities include Big Spring, Odessa and Snyder. CRMWD also supplies water to Midland, San Angelo and Abilene (through West Central Texas MWD) as well as several smaller cities in Ward, Martin, Howard and Coke Counties.

Table 4.8-1 compares supplies to projected demands for CRMWD customers. As shown in Table 4.8-1, CRMWD has needs throughout the planning period. These needs are the result of the use of the Colorado WAM as the basis for water availability. Supplies from the Colorado WAM are discussed in Appendix 3C.

Potentially Feasible Strategies for CRMWD

The following potentially feasible strategies have been identified for CRMWD:

- Subordination of downstream senior water rights
- Water conservation
- Drought management
- Reuse

Table 4.8-1
Comparison of Supply and Demand for CRMWD
(Values in Acre-Feet per Year)

Supplies	2010	2020	2030	2040	2050	2060
Thomas	0	0	0	0	0	0
Spence	560	560	560	560	560	560
Ivie	66,350	65,000	63,650	62,300	60,950	59,600
Ward County Well Field (Cenozoic Pecos Alluvium) *	5,200	0	0	0	0	0
Scurry County Well Field (Dockum)	900	900	900	900	900	900
Ector County Well Field (Edwards-Trinity)	440	440	440	440	440	440
Martin County Well Field (Ogallala)	1,035	1,035	1,035	1,035	1,035	1,035
Total	*74,485*	*67,935*	*66,585*	*65,235*	*63,885*	*62,535*
Demands	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Member Cities	34,108	35,599	36,744	37,912	39,358	41,064
Others	59,928	61,264	42,637	42,255	41,106	40,732
Total	*94,036*	*96,863*	*79,381*	*80,167*	*80,464*	*81,796*
Surplus (Need)	*(19,551)*	*(28,928)*	*(12,796)*	*(14,932)*	*(16,579)*	*(19,261)*

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

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

Precipitation enhancement and brush control are discussed in Section 4.9.

With subordination agreements CRMWD will have sufficient water to meet projected demands throughout the planning period. However, new supplies are needed to increase the reliability of the CRMWD system and to improve water quality. Water quality considerations often prevent CRMWD from operating its system at full capacity. The total dissolved solids (TDS) concentration of water varies among CRMWD's sources of water, ranging from less than

500 mg/l in Lake Thomas to up to 4,000 mg/l in Lake Spence. The CRMWD system is operated so that all of its customers receive water of approximately the same quality. To fully utilize the yield of Spence Reservoir and maintain water quality, additional low TDS water is needed.

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, most reservoirs in Region F with a priority date after 1926 do not have a firm or safe yield. This result is largely due to the assumptions used in the Colorado WAM. The priority dates for CRMWD reservoirs are 1946 for Lake Thomas, 1964 for Spence Reservoir and 1978 for Ivie Reservoir. However, TCEQ modeled Ivie Reservoir so that it can impound water at a 1926 priority date as the Highland Lakes. As a result, Thomas and Spence have little or no yield, while Lake Ivie has a safe yield of over 66,000 acre-feet. The assumptions used in the Colorado WAM are discussed in more detail in Appendix 3C.

In order to address water availability issues resulting from the Colorado WAM model, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights in Region F do not make priority calls on each other. The subordination strategy is discussed in Section 4.2.3. Table 4.8-2 is a summary of the impacts of the subordination strategy on CRMWD supplies.

Table 4.8-2
Impact of Subordination Strategy on CRMWD Water Supplies [a]
(Values in acre-feet per year)

Reservoir	Priority Date	Permitted Diversion	2010 Supply WAM Run 3	2010 Supply with Subord-ination	2060 Supply WAM Run 3	2060 Supply with Subord-ination
Lake Thomas	5/08/1946	23,000	0	10,013	0	10,130
Spence Reservoir	8/17/1964	41,573	560	38,472	560	37,330
Ivie Reservoir	2/21/1978 [b]	113,000	66,350	66,452	59,600	56,260
Total		*177,573*	*66,910*	*114,937*	*60,160*	*103,720*

a Water supply is defined as the safe yield of the reservoir.

b Although Ivie Reservoir has a junior priority date, in the Colorado WAM TCEQ assumed that the reservoir could store water at a 1926 priority date because of the subordination of Ivie to the Highland Lakes. Water supplies in the Colorado WAM are discussed in separate memoranda.

The joint modeling between the two regions was conducted for planning purposes only. Neither Region F nor the Lower Colorado Region mandates the adoption of this strategy by individual water right holders. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including CRMWD.

Impacts of the subordination strategy are discussed in Section 4.2.3.

CRMWD Reclamation Project

Wastewater reuse is becoming an increasingly important source of water across the state, especially in West Texas where there are few new water sources. Reuse provides a reliable source that remains available in a drought. The quantity of available reuse increases as water demands increase. This strategy also represents an effective means of conserving existing water sources, which can defer development of new water sources.

CRMWD serves several large municipal areas that could potentially benefit from wastewater reuse, reducing the demand for water from CRMWD's existing sources. To evaluate a regional reclamation project, three reuse projects were studied to serve the District's primary customers: Snyder, Big Spring and Odessa-Midland. Each of these projects could be implemented independently or collectively as a regional wastewater reuse plan for the District. A discussion of each proposed reuse project is presented in the following sections. Additional information on these projects may be found in the report *Regional Water Reclamation Project Feasibility Study*[43].

Snyder Reuse Project

The City of Snyder is a CRMWD member city and obtains all of its water from Lake J.B. Thomas. During times of drought and low water levels in the lake CRMWD must move water from its other sources through Lake Thomas to serve Snyder. This operation is less than desirable due to increased water losses and higher TDS concentrations of the transferred water. The proposed Snyder Reclamation Project would provide additional water to the city and minimize the transfer of water from other sources.

The proposed Snyder Reclamation Project would blend the city's treated effluent, which is currently discharged to Deep Creek, with raw water from Lake Thomas. Approximately 0.9 MGD of wastewater effluent would be subjected to advanced treatment using membrane filtration, reverse osmosis and ultraviolet oxidation, and then blended with raw surface water in a new 15 million gallon terminal storage facility.

Treated effluent that is not needed during wet seasons or periods of low demand would be stored underground at a suitable site with an aquifer storage and recovery (ASR) system. An 8-inch transmission pipeline would be constructed to move the treated effluent to and from the ASR facility. Two new wells would be used for injection and extraction of the water.

Quantity, Reliability and Cost of Snyder Reuse Project

This strategy would provide approximately 726 acre-feet per year of additional supply to Snyder, or about 22 percent of the maximum expected demand for the city and its customers during the planning period. The reliability of this water source is high. Table 4.8-4 is a summary of the costs of the project. Capital costs are estimated at $7.5 million, with a unit cost of $3.61 per 1,000 gallons of reclaimed water.

Table 4.8-3
Snyder Reuse Project

Supply from Strategy	726 acre-feet per year
Total Capital Costs (2002 Prices)	$ 7,499,000
Annual Costs	$ 854,000
Unit costs (before amortization)	$ 1,176 per acre-foot
	$ 3.61 per 1,000 gallons
Unit Costs (after amortization)	$ 275 per acre-foot
	$ 0.85 per 1,000 gallons

Environmental Issues Associated with Snyder Reuse Project

Wastewater reuse will reduce low flows in Deep Creek and, to a much lesser extend, flows in the Colorado River below Lake Thomas. The advanced treatment will produce a reject stream that will be blended with other wastewater effluent and discharged to Deep Creek, which may increase TDS levels. However, TDS levels in Deep Creek and this portion of the Colorado River are already very high, and downstream impacts will be mitigated by diversion of high TDS water at the existing chloride control project near Colorado City and stored in Barber Reservoir.

Because of the relatively small volume of effluent currently discharged, the impact on overbanking flows is expected to be minimal. There is no impact on bays and estuaries because all of the current discharge is lost, impounded or used before reaching the Colorado estuary or Matagorda Bay.

This strategy should have a positive impact on water quality in Lake Thomas because the need to pass water from other sources through the reservoir during drought will be reduced or eliminated.

The project does not require a bed-and-banks permit because the reuse occurs prior to discharge.

Agricultural and Rural Issues Associated with Snyder Reuse Project

There are no agricultural or rural issues associated with this project.

Other Natural Resource Issues Associated with Snyder Reuse Project

This strategy will provide an alternative source of water for Snyder, which will conserve water from CRMWD sources that otherwise would be needed to meet Snyder's water needs.

Significant Issues Affecting Feasibility of Snyder Reuse Project

Public acceptability of wastewater reuse for municipal use may affect the feasibility of this project. Also, current TCEQ rules for use of reclaimed water do not address its use for supplementing municipal water supplies. Changes to TCEQ rules may change the feasibility of this strategy.

Other Water Management Strategies Directly Affected by Snyder Reuse Project

Voluntary redistribution of water from Lake Alan Henry.

Big Spring Reuse Project

Similar to the Snyder Reclamation Project, the Big Spring Reclamation Project would blend treated wastewater effluent from Big Spring with raw water from Spence Reservoir. This project proposes to treat 2.3 MGD of wastewater effluent with advanced treatment (membrane filtration, reverse osmosis and UV oxidation) and blend the treated water directly with raw water in the District's Spence Pipeline that runs along the northeast side of Big Spring. The raw water/effluent blend would then be treated at the city's water treatment plant for municipal and industrial use. Water from Spence Reservoir has historically been high in TDS and the reclaimed water should improve the quality of the water from this source.

The reject water from the reverse osmosis treatment would be discharged to Beals Creek and subsequently re-diverted at the existing Beals Creek chloride control project and stored in Red Draw Reservoir.

An alternative to the proposed project is to use all or a portion of the reclaimed water for industrial purposes. The industrial water will require less treatment.

Quantity, Reliability and Cost of the Big Spring Reuse Project

The annual yield of the project is estimated at 1,855 acre-feet per year, which is approximately 25 percent of the maximum projected municipal demand for the city and its customers. The reliability of the water source is high. Capital costs are estimated at $7.6 million, with unit costs for the reclaimed water at $1.92 per 1,000 gallons. Table 4.8-4 summarizes the costs for the project.

Table 4.8-4
Big Spring Reuse Project

Supply from Strategy	1,855 acre-feet per year
Total Capital Costs (2002 Prices)	$ 7,606,000
Annual Costs	$ 1,168,000
Unit costs (before amortization)	$ 630 per acre-foot
	$ 1.93 per 1,000 gallons
Unit Costs (after amortization)	$ 272 per acre-foot
	$ 0.84 per 1,000 gallons

Environmental Issues Associated with the Big Spring Reuse Project

Currently almost all of the treated wastewater discharge from the City of Big Spring is re-diverted at the Beals Creek chloride control project, and this operation is not expected to change with the proposed project. Except for the short reach between the existing discharge point and the diversion project, there should be little impact on instream flows. The water quality of this stream reach is already high in TDS and the discharge is expected to have little impact on water quality. The existing chloride control project will mitigate any impacts on downstream water quality.

Because of the relatively small volume of effluent currently discharged, the impact on overbanking flows is expected to be minimal. There will be no impact on bays and estuaries because all of the water currently discharged is lost, diverted or stored in reservoirs before reaching the Colorado estuary or Matagorda Bay. The project does not require a bed-and-banks permit because the reuse occurs prior to discharge.

Agricultural and Rural Issues Associated with the Big Spring Reuse Project

There are no agricultural or rural issues associated with this project.

Other Natural Resource Issues Associated with the Big Spring Reuse Project

This strategy will provide an alternative source of water for Big Spring, which will conserve water from CRMWD sources that would be needed to meet the city's water needs.

Significant Issues Affecting Feasibility of the Big Spring Reuse Project

Public acceptability of wastewater reuse for municipal use may affect the feasibility of this project. Current TCEQ rules for use of reclaimed water do not address its use for supplementing municipal water supplies. Changes to TCEQ rules may change the feasibility of this strategy.

Other Water Management Strategies Directly Affected by the Big Spring Reuse Project

No other water management strategies are impacted by this project.

Odessa-Midland Reuse Project

The proposed Odessa-Midland Reuse Project would utilize wastewaters from both cities and reclaim approximately 10.8 MGD of treated wastewater. The effluent would undergo advanced treatment at a Regional Reclamation Facility prior to blending with raw water at the District's 100 million gallon terminal storage reservoir between the two cities. The City of Odessa already has an extensive water reclamation system which could be used as part of this project. Treatment will consist of membrane filtration, reverse osmosis and ultraviolet oxidation. This strategy includes ASR using the City of Midland's abandoned McMillan well field for underground storage.

Handling and disposal of the brine reject from the treatment process is a large part of the cost of this project. The disposal process includes a combination of disposal wells, storage and evaporation reservoirs, and transfers to oil operations at the Mabee Oil Field. The strategy also calls for construction of secondary treatment facilities at the City of Midland's existing treatment plant.

Quantity, Reliability and Cost of the Odessa/Midland Reuse Project

The annual yield of the project is estimated at 9,799 acre-feet per year, or about 17 percent of the combined demand for the cities of Odessa and Midland and their municipal customers. The reliability of the water source is high. Capital costs are estimated at $82.1 million, with unit costs for the reclaimed water at $3.13 per 1,000 gallons. Table 4.8-5 summarizes the costs for the project.

Table 4.8-5
Odessa-Midland Reuse Project

Supply from Strategy	9,799 acre-feet per year
Total Capital Costs (2002 Prices)	$ 82,144,000
Annual Costs	$ 10,013,000
Unit costs (before amortization)	$ 1,022 per acre-foot
	$ 3.14 per 1,000 gallons
Unit Costs (after amortization)	$ 291 per acre-foot
	$ 0.89 per 1,000 gallons

Environmental Issues Associated with the Odessa/Midland Reuse Project

Currently the City of Midland disposes of treated effluent using land application; none of the treated effluent is discharged. The City of Odessa also uses a large part of its treated effluent for irrigation, with some water contracted for industrial use. Unused treated wastewater is discharged into Monahans Draw. Almost all of the flow in Monahans Draw is treated wastewater, and during the summer very little treated wastewater is discharged. Although reuse will reduce current flows in Monahans Draw, most of the current discharge is lost due to evapotranspiration and infiltration before reaching Beals Creek just above Big Spring. Therefore downstream impacts will be negligible.

Reuse is expected to have minimal impacts on overbank flows and no impact on bays and estuaries.

The proposed project does not call for discharge of the waste stream from treatment, so implementation will not cause a degradation of water quality because of the waste stream. The project does not require a bed-and-banks permit.

Agricultural and Rural Issues Associated with the Odessa/Midland Reuse Project

The City of Midland currently irrigates with treated effluent. Therefore, this project may make less water available for irrigation in Midland County.

Other Natural Resource Issues Associated with the Odessa/Midland Reuse Project

This strategy will provide an alternative source of water for the cities of Odessa and Midland, which will conserve water from CRMWD sources.

Significant Issues Affecting Feasibility of the Odessa/Midland Reuse Project

Public acceptability of wastewater reuse for municipal use may affect the feasibility of this project. Also, current TCEQ rules for use of reclaimed water do not address its use for supplementing municipal water supplies. Changes to TCEQ rules may change the feasibility of this strategy.

Other Water Management Strategies Directly Affected by the Odessa/Midland Reuse Project

CRMWD Winkler County Well Field project.

New Groundwater Development - Winkler Well Field

CRMWD owns water rights to an undeveloped well field in southern Winkler County. The well field will produce water from the Cenozoic Pecos Alluvium aquifer. For the purposes of this plan it has been assumed that water from the well field would be pumped approximately 43 miles directly to the City of Odessa. At Odessa the water could be blended with other sources and distributed to CRMWD's customers.

The proposed well field is near the City of Midland's undeveloped T-Bar Well Field. As an alternative, these two projects could use the same transmission facilities.

Quantity, Reliability and Cost of Winkler County Well Field

CRMWD estimates that the Winkler County Well Field could provide 6,000 acre-feet per year. Water from this source is considered to be very reliable. Table 4.8-6 summarizes the expected costs of developing the well field.

Table 4.8-6
Costs for CRMWD Winkler County Well Field

Supply from Strategy	6,000 acre-feet per year
Total Capital Costs (2002 Prices)	$ 39,934,000
Annual Costs	$ 4,987,000
Unit costs (before amortization)	$ 831 per acre-foot
	$ 2.55 per 1,000 gallons
Unit Costs (after amortization)	$ 251 per acre-foot
	$ 0.77 per 1,000 gallons

Environmental Issues Associated with Winkler County Well Field

Winkler County has no flowing water. Therefore development of this source has very little potential of impacting springflow, baseflow in rivers, or habitats. Based on the available data, it is unlikely that pumping limits will be needed to prevent impacts on aquatic or terrestrial ecosystems. It is not anticipated that groundwater development will cause subsidence.

Agricultural and Rural Issues Associated with Winkler County Well Field

The Region F water supply analysis shows sufficient water supply in Winkler County to meet local agricultural and municipal needs and support well field development by CRMWD and the City of Midland. Therefore, this strategy should have minimal effects on agriculture and rural areas. The right of way for the transmission line may temporarily affect a small amount of agricultural acreage during construction.

Other Natural Resource Issues Associated with Winkler County Well Field

None identified.

Significant Issues Affecting Feasibility of Winkler County Well Field

None identified.

Other Water Management Strategies Directly Affected by Winkler County Well Field

Odessa-Midland Reuse project.

Voluntary Redistribution - Lake Alan Henry

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

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

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

Quantity, Reliability and Cost of Water from Lake Alan Henry

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

Table 4.8-7
Estimated Costs Lake Alan Henry to Snyder

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

Environmental Issues Associated with Water from Lake Alan Henry

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

Agricultural and Rural Issues Associated with Water from Lake Alan Henry

None identified.

Other Natural Resource Issues Associated with Water from Lake Alan Henry

None identified.

Significant Issues Affecting Feasibility of Water from Lake Alan Henry

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

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

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

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

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

Snyder Reuse.

Water Marketing – Water from Southwestern Pecos County

A group of landowners in southwestern Pecos County has proposed selling groundwater from an unclassified aquifer in southwestern Pecos County. Initial estimates indicate that this area can produce a large quantity of water of acceptable quality.

Quantity, Reliability and Cost of Water from Pecos County

The sustainable quantity of water from Southwestern Pecos County has not been established, although preliminary estimates indicate that 50,000 to 100,000 acre-feet per year could be available from this source. This strategy assumes that CRMWD would take up to 15,000 acre-feet per year from this source. Because of the uncertainty associated with the sustained availability of water from this source, the reliability of supply is medium. Table 4.8-8 shows the estimated costs associated with this strategy.

Table 4.8-8
Costs for Water from Southwestern Pecos County

Supply from Strategy	15,000 acre-feet per year
Total Capital Costs (2002 Prices)	$ 150,150,000
Annual Costs	$ 18,726,000
Unit costs (before amortization)	$ 1,248 per acre-foot
	$ 3.83 per 1,000 gallons
Unit Costs (after amortization)	$ 376 per acre-foot
	$ 1.15 per 1,000 gallons

Environmental Issues Associated with Water from Pecos County

Information provided by the sponsors of this project indicates possible impacts on flow in the Pecos River from development of this strategy[47], which should be investigated if this strategy is pursued. If linkage between groundwater development and flows in the Pecos River can be established, the local groundwater conservation district may wish to impose pumping limits if needed to protect endangered and threatened species and environmental flows. It is unlikely that development of water from this source will cause subsidence.

Agricultural and Rural Issues Associated with Water from Pecos County

According to information provided by the developers of this project, the supply in the immediate area is primarily used for cattle ranching and development of the project will have minimal impact on existing uses. However, it is possible that large-scale production from this source could impact irrigation supplies in the Belding Farms area. Additional studies may be needed to quantify this impact.

Other Natural Resource Issues Associated with Water from Pecos County

None identified.

Significant Issues Affecting Feasibility of Water from Pecos County

The most significant issue facing this project is the lack of site-specific studies regarding supplies from this source and the potential impacts of large-scale groundwater development. These studies will be needed before this source can be recommended as a strategy. Also, the source is located more than 100 miles from the nearest potential user and will require a significant investment in infrastructure to make the water available.

Other Water Management Strategies Directly Affected by Water from Pecos County

Winkler Well Field, Odessa-Midland Reuse.

Water Marketing – Water from Roberts County

In the year 2000, Mesa Water, Inc., published a study that included an evaluation of delivery of Ogallala aquifer water from Roberts County in the Texas Panhandle to CRMWD and other users in Texas[48]. Delivery of water from this source requires construction of over 300 miles of pipeline.

Quantity, Reliability and Cost of Water from Roberts County

According to previous studies, there is a substantial amount of water available in Roberts County and this supply is very reliable[49]. For the purposes of this plan, this strategy assumes that CRMWD would take up to 25,000 acre-feet per year from this source. Table 4.8-8 shows the estimated costs associated with this strategy. Capital costs include the estimated development fee for this project. Costs are dependent upon the amount of water assumed to be used from this project. If other entities would participate in the project, costs could be lower.

Table 4.8-9
Costs for Water from Roberts County

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

Environmental Issues Associated with Water from Roberts County

There is some concern that large-scale groundwater use from Roberts County could impact baseflow of the Canadian River, potentially impacting habitat of the Arkansas River Shiner, a threatened species. If this strategy is implemented, mitigation may be required. It is unlikely that development of water from this source will cause subsidence.

Agricultural and Rural Issues Associated with Water from Roberts County

According to previous studies, only a small amount of water from this portion of Roberts County is currently being used for local purposes. There is no irrigated agriculture in the area.

Other Natural Resource Issues Associated with Water from Roberts County

None identified.

Significant Issues Affecting Feasibility of Water from Roberts County

The most significant issue facing this project is the significant investment in infrastructure needed to deliver water from Roberts County. Without the participation of other large water users it may not be cost-effective to deliver water from Roberts County to Region F.

Other Water Management Strategies Directly Affected by Water from Roberts County

Other CRMWD strategies.

Water Conservation

Potential water savings due to implementation of the recommended Region F conservation practices has been evaluated for the CRMWD member cities: Big Spring, Odessa and Snyder. Water conservation savings for the cities of Midland and San Angelo may be found in the Section 4.3.6 and 4.8.3, respectively. Water conservation for smaller customer cities which have needs that are met through subordination and contract renewal have not been evaluated because of the small quantity of water used by these entities.

Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. The water conservation practices in this plan are guidelines. Region F considers water conservation strategies determined and implemented by the CRMWD, the CRMWD member cities and CRMWD customers to supersede the recommendations in this plan and to meet regulatory requirements for consistency with this plan.

Quantity, Reliability and Cost

Table 4.8-10, Table 4.8-11 and Table 4.8-12 show potential water conservation savings and costs of water conservation programs for the cities of Snyder, Big Spring and Odessa, respectively. Potential savings range from approximately 14 percent to 18 percent of the demand with no conservation. The reliability of this supply is classified as medium because of the uncertainty involved in the analysis used to calculate the savings. Site specific data regarding residential, commercial, industrial and other types of use would give a better estimate of the reliable supply from this strategy.

Environmental Issues

Most of the CRMWD's water supply comes from reservoirs which spill infrequently. Therefore water conservation could result in more water remaining in reservoir storage, and will have minimal impact on downstream flows. Much of the conserved water in storage will be used for other purposes or lost to evaporation. The additional water in storage may result in a minimal positive impact on recreation use and environmental water needs associated with those reservoirs.

Much of the new water supply development for CRMWD is driven by water quality concerns. CRMWD needs additional high-quality water sources to blend with existing water of lesser quality. As a result, water conservation may not delay or eliminate the need for new water supply development.

Table 4.8-10
Potential Water Conservation Summary for the City of Snyder [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	194	227	227	227	227	227	227
Plumbing Code	Projections	227 [b]	223	219	216	213	212	212
	Savings	0	4	8	11	14	15	15
Region F Estimate	Projections	227 [b]	217	207	201	197	195	194
	Savings (Region F practices)	0	6	12	15	16	17	18
	Savings (Total)	0	10	20	26	30	32	33
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	2,343	2,843	2,938	2,988	3,015	3,033	3,033
Plumbing Code	Projections	2,742	2,792	2,834	2,844	2,829	2,832	2,832
	Savings	0	51	104	144	186	201	201
Region F Estimate	Projections	2,742	2,722	2,680	2,653	2,624	2,612	2,598
	Savings (Region F practices)	0	70	154	191	205	220	234
	Savings (Total)	0	121	258	335	391	421	435
Costs								
Annual Costs			$46,943	$51,385	$50,089	$48,426	$46,643	$45,378
Cost per Acre-Foot [c]			$671	$334	$262	$236	$212	$194
Cost per 1,000 Gal [c]			$2.06	$1.02	$0.80	$0.72	$0.65	$0.60

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.

b Year 2000 water use is based on a per capita water use of 227 gpcd. Actual year 2000 use was 2,343 acre-feet, equivalent to a per capita water demand of 194 gpcd.

c Costs for implementing recommended practices. Costs of implementing plumbing code savings not included in unit cost calculations.

Table 4.8-11
Potential Water Conservation Summary for the City of Big Spring [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	198	210	210	210	210	210	210
Plumbing Code	Projections	210	207	204	201	198	197	197
	Savings	0	3	6	9	12	13	13
Region F Estimate	Projections	210	199	184	178	175	173	172
	Savings (Region F practices)	0	8	20	23	23	24	25
	Savings (Total)	0	11	26	32	35	37	38
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	5,596	6,103	6,255	6,305	6,305	6,305	6,305
Plumbing Code	Projections	5,936	6,016	6,077	6,035	5,945	5,915	5,915
	Savings	0	87	178	270	360	390	390
Region F Estimate	Projections	5,936	5,775	5,474	5,359	5,247	5,190	5,161
	Savings (Region F practices)	0	241	603	676	698	725	754
	Savings (Total)	0	328	781	946	1,058	1,115	1,144
Costs								
Annual Costs			$108,944	$112,960	$109,009	$104,321	$99,734	$96,894
Cost per Acre-Foot [c]			$452	$187	$161	$149	$138	$129
Cost per 1,000 Gal [c]			$1.39	$0.57	$0.49	$0.46	$0.42	$0.39

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.

b Year 2000 water use is based on a per capita water use of 210 gpcd. Actual year 2000 use was 5,596 acre-feet, equivalent to a per capita water demand of 198 gpcd.

c Costs for implementing recommended practices. Costs of implementing plumbing code savings not included in unit cost calculations.

Table 4.8-12
Potential Water Conservation Summary for the City of Odessa [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	208	208	208	208	208	208	208
Plumbing Code	Projections	208	205	202	198	195	194	194
	Savings	0	3	6	10	13	14	14
Region F Estimate	Projections	208	200	191	185	181	179	178
	Savings (Region F practices)	0	5	11	13	14	15	16
	Savings (Total)	0	8	17	23	27	29	30
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	21,189	22,248	23,361	24,528	25,755	27,043	28,394
Plumbing Code	Projections	21,189	21,927	22,687	23,350	24,145	25,222	26,484
	Savings	0	321	674	1,178	1,610	1,821	1,910
Region F Estimate	Projections	21,189	21,376	21,487	21,814	22,430	23,302	24,335
	Savings (Region F practices)	0	551	1,200	1,536	1,715	1,920	2,149
	Savings (Total)	0	872	1,874	2,714	3,325	3,741	4,059
Costs								
Annual Costs			$400,979	$416,656	$418,272	$419,543	$420,351	$428,145
Cost per Acre-Foot [c]			$728	$347	$272	$245	$219	$199
Cost per 1,000 Gal [c]			$2.23	$1.07	$0.84	$0.75	$0.67	$0.61

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.

b Year 2000 water use is based on a per capita water use of 210 gpcd. Actual year 2000 use was 5,596 acre-feet, equivalent to a per capita water demand of 198 gpcd.

c Costs for implementing recommended practices. Costs of implementing plumbing code savings not included in unit cost calculations.

Agricultural and Rural Issues

None identified.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

This strategy is based on a generalized assessment of water conservation practices and may not accurately reflect the actual costs or water savings that can be achieved by the CRMWD and its member cities. Site-specific data will be required for a better assessment of the potential for water conservation by the city. Technical assistance and funding by the state may be required to implement this strategy.

Other Water Management Strategies Directly Affected

Timing and quantity from other CRMWD strategies.

Drought Management

Drought management strategies are designed to temporarily reduce water demand during extreme drought periods. The April 2005 Draft CRMWD Drought Contingency Plan, drought contingency plans developed by CRMWD customers, and subsequent revisions of these plans determine drought management strategies for CRMWD and its customers. Region F has not identified additional drought management strategies.

Voluntary Redistribution – Renew Contract with University Lands

CRMWD's Ward County Well Field is leased from University Lands, the managing agency for properties belonging to the University of Texas System. The contract expires in 2019. For the purposes of this plan it is assumed that CRMWD and University Lands will renew the contract without change in the quantity of water available from the source. Actual quantities and costs will be determined at the time of renewal.

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

Voluntary Redistribution – New Contracts to Provide Water

The planning process has identified several new CRMWD contracts to provide water, which are shown in Table 4.8-13. All of these contracts are the result of expiration of existing customer contracts. The amounts shown in Table 4.8-13 are for planning purposes. The actual amount of water and cost for the water will be negotiated between the contracting parties.

Other CRMWD contracts do not expire during the planning period.

Table 4.8-13
New CRMWD Contracts to Supply Water

Water User	**Amount** (Acre-Feet per Year)						**Comments**
	2010	**2020**	**2030**	**2040**	**2050**	**2060**	
Midland			10,000	9,800	9,600	9,400	8.45 percent of system yield
Stanton	392	422	429	430	415	393	Set to demands
Millersview-Doole WSC					600	600	
Ballinger					165	219	Set to demands
Total	*392*	*422*	*10,429*	*10,230*	*10,780*	*10,612*	

Desalination – Capitan Reef Complex

The Capitan Reef aquifer has been identified as a potential source of brackish groundwater for CRMWD. In Region F, the Capitan Reef aquifer extends from the New Mexico border in Winkler County, through Ward County and into Pecos County. The Region F water supply analysis shows about 27,000 acre-feet of water per year available from this source. Development of this aquifer could occur concurrently with development of the CRMWD well field in Winkler County. Brackish water production from the Dockum or Cenozoic Pecos Alluvium aquifer could also be developed as an alternative or in conjunction with brackish water from the Capitan Reef aquifer.

Additional information on the Capitan Reef aquifer may be found in Section 3.1.11.

Quantity, Reliability and Cost of Capitan Reef Desalination Project

For the purposes of this plan it is assumed that a 10 MGD desalination plant delivering up to 9,500 acre-feet of water per year would be constructed in Winkler County near the proposed Winkler County Well Field. A parallel pipeline would be constructed to deliver the water to CRWMD customers. Disposal of brine reject would be through deep well injection. Because of the uncertainty involved with development of this source for municipal water use, the reliability of this source is considered to be moderate. Table 4.8-14 summarized the expected costs for the project.

Table 4.8-14
Capitan Reef Brackish Water Desalination Project

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

Environmental Issues Associated with Capitan Reef Desalination Project

This strategy relies on brackish groundwater from formations which have no surface outflow in the vicinity of the proposed project. It is unlikely that pumping from these formations will result in any alteration of terrestrial habitats. The conceptual design for the project uses deep well injection for brine disposal. A properly designed and maintained facility should have minimal environmental impact. Well field development and construction of the treatment facility should have minimal environmental impact as well.

Agricultural and Rural Issues of Capitan Reef Desalination Project

Water from the Capitan Reef aquifer is currently used only for oil field flooding. No competition is expected with municipal or agricultural water users. Therefore agricultural and rural impacts are expected to be minimal.

Other Natural Resource Issues Associated with Capitan Reef Desalination Project

None identified.

Significant Issues Affecting Feasibility

Because this source of water is only used for oil field flooding, very little is known about the suitability of this source for municipal water supply. Additional studies will be required to evaluate the merit of this source.

Other Water Management Strategies Directly Affected by Capitan Reef Desalination Project

None identified.

Recommended Strategies for CRMWD

Recommended strategies for CRMWD include:

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

Table 4.8-15 compares the supply from the strategies to demands with these strategies in place, and Table 4.8-16 summarizes the capital costs for the recommended strategies. For the purposes of this plan, it has been assumed that water conservation activities will be financed by the member cities, so costs for water conservation do not appear in Table 4.8-16.

Table 4.8-15
Recommended Water Management Strategies for CRMWD
(Values in Acre-Feet per Year)

Supplies	2010	2020	2030	2040	2050	2060
Existing Supplies	*74,485*	*67,935*	*66,585*	*65,235*	*63,885*	*62,535*
Subordination	48,027	47,134	46,240	45,347	44,453	43,560
Winkler County Well Field	0	0	0	6,000	6,000	6,000
CRMWD Reclamation Project	0	12,380	12,380	12,380	12,380	12,380
Lake Alan Henry to Snyder	0	3,360	3,360	3,360	3,360	3,360
Renew Contract with University Lands	0	5,200	5,200	5,200	5,200	5,200
Desalination			9,500	9,500	9,500	9,500
Total Supplies	*122,512*	*136,009*	*143,265*	*147,022*	*144,778*	*142,535*
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential Savings [a]	862	1,957	2,403	2,618	2,865	3,137
Demands	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Existing customers	94,036	96,863	79,381	80,167	80,464	81,796
New Contracts	392	422	10,429	10,230	10,780	10,612
Total Demand	*94,428*	*97,285*	*89,810*	*90,397*	*91,244*	*92,408*
Surplus (Need) without Conservation	*28,084*	*38,724*	*53,455*	*56,625*	*53,534*	*50,127*
Surplus (Need) with Conservation	*28,946*	*40,681*	*55,858*	*59,243*	*56,399*	*53,264*

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

Table 4.8-16
Capital Costs for Recommended Strategies *

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

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

4.8.2 Brown County Water Improvement District Number 1

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

Regional System from Lake Brownwood to Runnels and Coke Counties

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

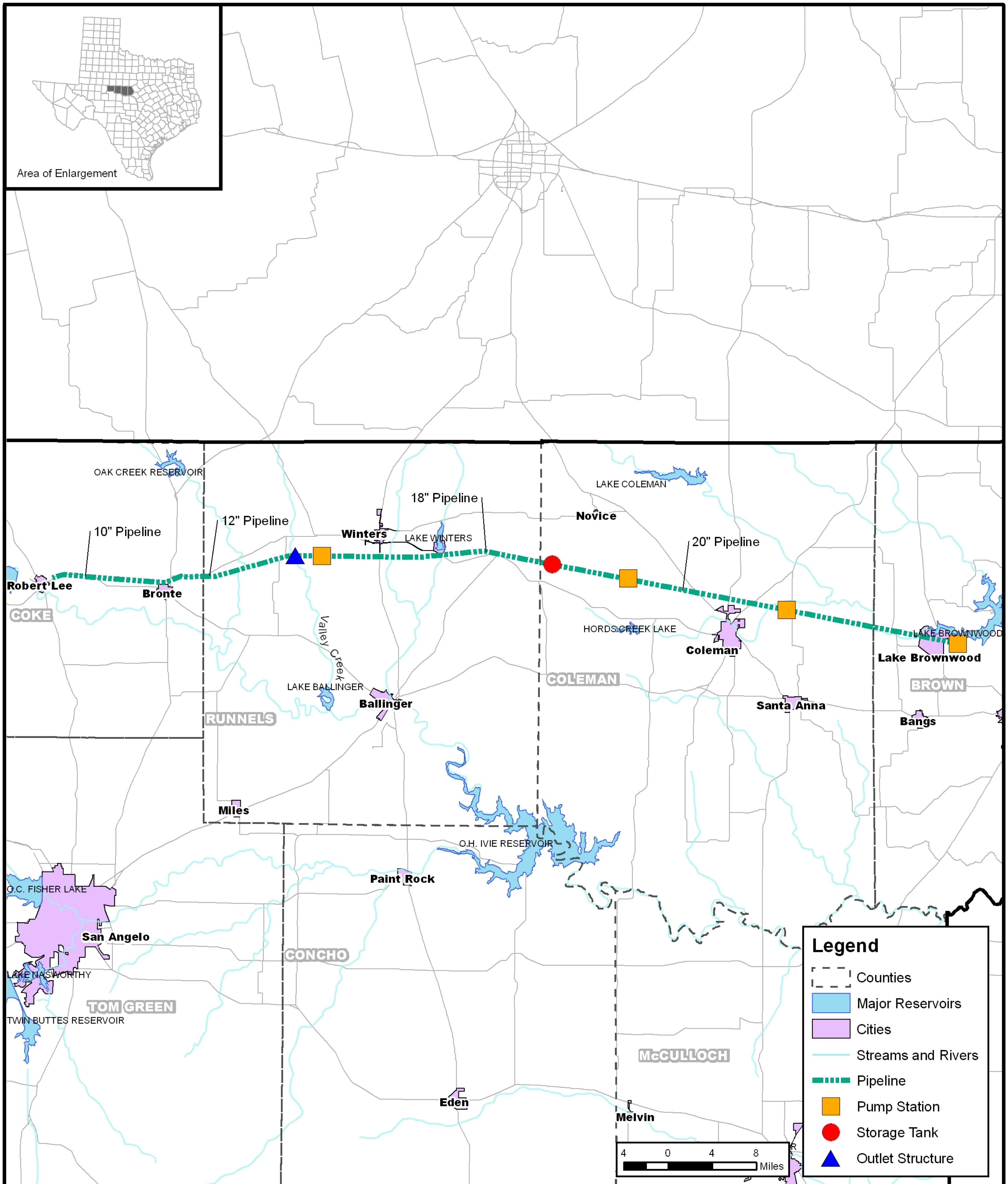
Alternative variations of this project could include delivery to different combinations of the four cities or delivery of treated water from the BCWID treatment plant in Brownwood.

Quantity, Reliability and Cost

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

Table 4.8-17
Costs for Regional System from Lake Brownwood

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



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N W E S

Region F

Regional System from Lake Brownwood to Coke and Runnels Counties

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

4.8-1

FIGURE

Environmental Issues

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

Agricultural and Rural Issues

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

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

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

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

Other Water Management Strategies Directly Affected

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

Recommended Strategies for BCWID

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

4.8.3 City of San Angelo

The city of San Angelo is located in Tom Green County near the center of Region F. As one of the largest cities in the region, it is a major center of employment, trade and cultural activities in the region. The city receives water from six sources: Lake Nasworthy, Twin Buttes Reservoir, the Concho River, O.C. Fisher Reservoir, Ivie Reservoir, and Spence Reservoir. The water rights for Lake Nasworthy, Twin Buttes Reservoir and the Concho River are owned by the city. The rights for O.C. Fisher are owned by the Upper Colorado River Authority (UCRA). Ivie and Spence Reservoirs are owned by the Colorado River Municipal Water District (CRMWD). The city also owns an undeveloped groundwater well field in McCulloch County.

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

Table 4.8-18 is a comparison of the Region F supply and demand for the City of San Angelo. For this analysis it is assumed that the city will provide all of the water for the City of San Angelo, approximately 250 acre-feet per year to connections outside of the city (County-Other), all of the manufacturing demand in Tom Green County, and up to 1,021 acre-feet of raw water for steam electric power generation. (Steam-electric demand is limited to recent historical use in areas with limited supplies. According to historical data from the Texas Water Development Board (TWDB), 1,021 acre-feet of water was used for steam-electric generation in Tom Green County in 1999.) The city also supplies treated O.C. Fisher water to the City of Miles through an agreement with UCRA.

Table 4.8-18
Comparison of Supply and Demand for the City of San Angelo
(Values in Acre-Feet per Year)

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comment**
Twin Buttes/Nasworthy	0	0	0	0	0	0	WAM supply
O.C. Fisher	0	0	0	0	0	0	WAM supply
Concho River	642	642	642	642	642	642	WAM supply
Spence Contract	0	0	0	0	0	0	Currently not available
Ivie Contract	10,974	10,751	10,528	10,304	10,081	9,858	Supply limited to 16.54 % of safe yield
Total	*11,616*	*11,393*	*11,170*	*10,946*	*10,723*	*10,500*	
Demand	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Comment**
City of San Angelo	20,800	21,418	21,734	21,744	21,907	21,969	
City of Miles	100	100	100	100	100	100	
Municipal Sales	250	250	250	250	250	250	Assumed
Manufacturing	2,226	2,498	2,737	2,971	3,175	3,425	100% of demand
Steam-Electric	543	777	909	1,021	1,021	1,021	Limited to recent use
Total	*23,919*	*25,043*	*25,730*	*26,086*	*26,453*	*26,765*	
Surplus (Need)	*(12,203)*	*(13,650)*	*(14,560)*	*(15,140)*	*(15,730)*	*(16,265)*	

Table 4.8-18 contains the Region F supplies for the City of San Angelo based on the Texas Commission on Environmental Quality (TCEQ) Colorado Water Availability Model (WAM)[50]. TWDB requires use of the Colorado WAM Run 3 in regional water planning by TWDB. In this model, all of San Angelo's local reservoir supplies and Spence Reservoir have little or no firm yield. Ivie Reservoir is the only significant source of water with a reliable yield. The model shows a small reliable supply from three of the city's run-of-the-river permits, namely CA 1325 (Lone Wolf), CA 1333 and CA 1337. (Note: CA 1357 was not included in the version of the Colorado WAM used for this analysis). Using these supplies, the City of San Angelo has needs for over 12,000 acre-feet of water in 2010 which increases to over 16,000 acre-feet by 2060.

The supplies from CRMWD reservoirs (Spence and Ivie) have been adjusted to reflect yields determined with the Colorado WAM. The city's contracts with CRMWD are currently set at 3,000 acre-feet per year from Spence Reservoir and 15,000 acre-feet per year from Ivie Reservoir. These contracts also specify that, at the option of CRMWD, the contracted amount from these reservoirs can be reduced to 6 percent of the safe yield of Spence Reservoir and 16.54 percent of the safe yield of Ivie Reservoir. For the purposes of this plan, it was assumed that CRMWD will reduce available supplies to San Angelo based on the Region F safe yield of each source. Also, the city's pipeline to Spence Reservoir is not usable at this time and requires extensive rehabilitation. Therefore supplies from Spence Reservoir are considered to be unavailable until the pipeline has been repaired. This plan includes the repair of the pipeline as a water management strategy.

Potentially Feasible Strategies

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

In addition to the Region F analysis, the city used an extensive public process to evaluate potential strategies to meet the City's future needs. In February of 2004, the San Angelo City Council, the Citizen's Water Advisory Board, and the City Staff published the results of this process in the report *San Angelo Water Preparing for the Next 50 Years*[51]. In this report five preferred strategies were identified:

- Develop and communicate public and private conservation and drought management programs
- Develop reclamation, reuse and water storage alternatives
- Protect and enhance existing surface water resources
- Expand cooperative efforts and agreements to increase water availability for both urban and rural areas
- Identify and develop fresh and brackish groundwater alternatives

Combining these strategies with standard categories results in the following list of potentially feasible strategies for the City of San Angelo:

- Water conservation

- Drought management
- Subordination of downstream senior water rights
- Desalination – San Angelo regional desalination facility
- New groundwater – development of the McCulloch County well field
- New groundwater – water from southwest Pecos County
- Reuse
- System Optimization through system operation and conjunctive use
- Voluntary redistribution through purchase of additional water rights or contracts for additional supplies
- Other – Rehabilitation of the Spence pipeline

Precipitation enhancement and brush control are discussed in Section 4.9.

Water Conservation

During the recent drought the City of San Angelo succeeded in significantly reducing per capita water demand. Between 1980 and 2000, the average per capita water demand for the city was 196 gallons per person per day (gpcd). In 2002, the latest year for which data are available, the per capita water demand was 118 gpcd[52]. Some of this reduction is the result of implementation of water use restrictions and other drought management strategies. Water conservation activities conducted by the city include public awareness and education programs and infrastructure improvements to reduce water loss.

Quantity, Reliability and Cost

At the time of this plan the city had not implemented a formal water conservation program. Therefore the default Region F package of water conservation practices was used to evaluate the potential water savings and costs of implementation. Table 4.8-19 compares projected demands for the City of San Angelo with no conservation, with the expected conservation due to plumbing code (the default projections used in regional water planning), and with Region F water conservation criteria (see the Appendix 4I).

Table 4.8-19
Potential Water Conservation Summary for the City of San Angelo [a]

Per Capita Demand (gpcd)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	162	200	200	200	200	200	200
Plumbing Code	Projections	162	197	193	190	187	186	186
	Savings	0	3	7	10	13	14	14
Region F Estimate [b]	Projections	200 [c]	190	178	172	169	167	166
	Savings	0	10	22	28	31	33	34
Water Demand (Ac-Ft/Yr)								
		2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
No Conservation	Projections	19,813	21,117	22,195	22,878	23,256	23,556	23,623
Plumbing Code	Projections	19,813	20,800	21,418	21,734	21,744	21,907	21,969
	Savings	0	317	777	1,144	1,512	1,649	1,654
Region F Estimate [b]	Projections	19,813	20,099	19,713	19,725	19,617	19,652	19,598
	Savings	0	1,018	2,482	3,153	3,639	3,904	4,025
Costs								
Annual Costs			$395,818	$304,896	$297,151	$284,442	$271,143	$261,243
Cost per Acre-Foot [d]			$565	*$244*	*$204*	*$187*	*$171*	*$158*
Cost per 1,000 Gal [d]			$1.73	*$0.75*	*$0.63*	*$0.57*	*$0.52*	*$0.48*

a Costs and water saving are based on data from TWDB *Report 362 Water Conservation Task Force Water Conservation Best Management Practices Guide*, November 2004.
b Includes plumbing code savings.
c Year 2000 water use is based on a per capita water use of 200 gpcd. Actual year 2000 use was 16,048 acre-feet, equivalent to a per capita water demand of 162 gpcd.
d Costs for implementing recommended practices. Plumbing code savings not included in unit cost calculations.

Based on these data, savings due to conservation could be about 1,000 acre-feet per year in 2010, increasing to about 4,000 acre-feet per year by 2060. The reliability of these supplies has been determined to be medium due to the lack of site-specific data regarding the long-term savings associated with implementing these strategies. Costs range from $565 per acre-foot in 2010 to $158 per acre-foot in 2060.

Recent experience in the City of San Angelo has shown that per capita water demand can be even lower than estimated using these techniques. There are several possible explanations for this:

- The base per capita demand of 200 gpcd used to develop the projections may be high
- Replacement of old 2-inch pipes and other leak reduction and water accounting activities implemented by the city
- Drought contingency measures implemented by the city (these measures are assumed to be temporary and water demand would increase as these restrictions are removed)
- Public awareness of the city's water supply problems, creating a 'culture of conservation'

Region F recognizes that it has no authority to implement, enforce or regulate water conservation practices. The water conservation practices in this plan are guidelines. Region F considers water conservation strategies determined and implemented by the City of San Angelo to supersede the recommendations in this plan and to meet regulatory requirements for consistency with this plan.

Environmental Issues

Most of the City of San Angelo's water supply comes from reservoirs which spill infrequently. Therefore water conservation could result in more water remaining in reservoir storage, and will have minimal impact on downstream flows. Much of the conserved water in storage will be used for other purposes or lost to evaporation. The additional water in storage may result in a minimal positive impact on recreation use and environmental water needs associated with those reservoirs.

Agricultural and Rural Issues

Conservation is expected to have a small positive impact on agricultural resources because some of the conserved water may be available for irrigation.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

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

Other Water Management Strategies Directly Affected

None identified.

Drought Management

Drought management strategies are designed to temporarily reduce water demand during drought periods. The San Angelo Drought Contingency Plan, the CRMWD Drought Contingency Plan and subsequent revisions of these plans determine drought management for the City of San Angelo. Some of the recent reduction in water demand by the city may be attributable to practices that result in temporary reductions in water use. Examples include landscape watering or car washing restrictions that will be discontinued once the area is out of critical drought conditions. Until additional data are available after these restrictions have been lifted, it is uncertain how much water has been saved by implementation of these practices.

During the current drought, use of Lake Nasworthy water for power generation was reduced. No irrigation water has been used from Twin Buttes Reservoir because the irrigation pool is empty. During part of the drought Twin Buttes ceased impounding water in order to pass water for downstream senior water rights. All of these activities could be considered drought management strategies.

Subordination of Downstream Senior Water Rights

TWDB requires the use of the TCEQ WAM for regional water planning. In the Colorado WAM, reservoirs in Region F with a priority date after 1926 do not have a firm or safe yield. This result is largely due to the assumptions used in the Colorado WAM. (Supplies from the Colorado WAM are discussed in Appendix 3C.) In order to address water availability issues in the Colorado Basin associated with the WAM model, Region F and the Lower Colorado Region (Region K) participated in a joint modeling effort to evaluate a strategy in which lower basin senior water rights do not make priority calls on major upstream water rights. This strategy also assumes that major water rights in Region F do not make priority calls on each other. The subordination strategy is discussed in detail in Section 4.2.3. Table 4.8-20 is a summary of the impacts of the subordination strategy on supplies for the city.

Table 4.8-20
Impact of Subordination Strategy on San Angelo Water Supplies
(Values in acre-feet per year)

Reservoir	Priority Date	Permitted Diversion	2010 Supply WAM Run 3	2010 Supply Subord-ination	2060 Supply WAM Run 3	2060 Supply Subord-ination	Comments
San Angelo System							
Twin Buttes Reservoir	5/6/1959	29,000	0	12,310	0	11,360	
Lake Nasworthy	3/11/1929	25,000					
O.C. Fisher Reservoir	5/27/1949	80,400	0	3,862	0	3,270	
San Angelo System Total		*134,400*	*0*	*16,172*	*0*	*14,630*	
Spence Reservoir	8/17/1964	41,573					
CRMWD system portion			526	36,164	526	35,090	
San Angelo contract			34	2,308	34	2,240	6% of safe yield
Spence Reservoir Total			*560*	*38,472*	*560*	*37,330*	
Ivie Reservoir	2/21/1978	113,000					
CRMWD, Midland, Abilene			55,376	55,461	49,742	46,955	
San Angelo contract			10,974	10,991	9,858	9,305	16.54% of safe yield
Ivie Reservoir Total			*66,350*	*66,452*	*59,600*	*56,260*	

The joint modeling between the two regions was conducted for planning purposes only. Neither Region F nor the Lower Colorado Region mandates the adoption of this strategy by individual water right holders. A subordination agreement is not within the authority of the Region F Water Planning Group. Such an agreement must be developed by the water rights holders themselves, including the City of San Angelo and CRMWD.

Impacts of the subordination strategy are discussed in Section 4.2.3.

Reuse

The City of San Angelo has historically disposed of its treated effluent through land application. In the past few years the city has sold treated effluent to the local irrigation district as a substitute for Twin Buttes water. The city has recently initiated a reuse study to investigate alternative uses for its treated effluent. The results of this study are not available at this time.

Potential reuse strategies include:

- In-city landscape irrigation (parks, cemeteries, golf courses, Angelo State University, air base, etc.)
- Manufacturing purposes

- Steam-electric power generation
- Blending with other sources of water for indirect reuse
- Aquifer storage and recovery (in conjunction with one or more of the above strategies)

Under current rules, ASR would require treatment of wastewater to drinking water standards before injection. This strategy would most likely use reverse osmosis or a similar membrane process.

An analysis of quantity and impacts will be completed once specific strategies have been identified in the reuse study.

Desalination - Regional Desalination Facility

The Region F Water Planning Group, in association with the City of San Angelo and UCRA, has identified four potential brackish groundwater sources north and west of the city. These sources would produce water from the geologic formations known as the Whitehorse and Pease River Groups. For the purposes of this plan, a conceptual design was developed for phased development of a facility with an initial capacity of 5 MGD and an ultimate capacity of 10 MGD. The most likely location for desalination facility is on the northwest side of the city. The conceptual design for this strategy calls for disposal of brine reject through deep-well injection.

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

Quantity, Reliability and Cost

Geophysical logs from oil wells in the area indicate that there are several favorable water-bearing sands in these formations. However, the amount of water available from the formation and the quality of the water is largely unknown. UCRA and the City of San Angelo have proposed drilling test wells to facilitate evaluation of the formations. For the purposes of this plan, it will be assumed that sufficient water is available from these sources to provide up to 11,200 acre-feet of water per year. The reliability of this source is considered to be medium due to the uncertainty associated with the available water from the source. Table 4.8-21 is a summary of costs for the project.

Environmental Issues

This strategy relies on brackish groundwater for its source. These formations have no surface outflow in the vicinity of the proposed project. It is unlikely that pumping from these formations will result in any alteration of terrestrial habitats. The conceptual design for the project uses deep well injection for brine disposal. A properly designed and maintained facility should have minimal environmental impact. Well field development and construction of the treatment facility should have minimal environmental impact as well.

Table 4.8-21
Regional Desalination Facility for San Angelo

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

Agricultural and Rural Issues

One of the most productive agricultural areas in the region is located east of the City of San Angelo. Some of this area is irrigated with surface water from Twin Buttes Reservoir and the Concho River, resulting in direct competition for water during dry periods. One of the chief benefits of this strategy is that there is no competition for this source of water with other interests; at present water from these formations is not used for any beneficial purpose. Therefore this strategy has a positive impact on agricultural interests by reducing the competition for water supplies.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

The most significant factor affecting feasibility is the lack of data on water quality and quantity from these formations. It has been demonstrated that there is water in these formations and geophysical logs indicate favorable formation conditions. However, specific data on chemistry and quantity of water are not available at this time. Water chemistry could have a significant impact on the cost and feasibility of this project.

Other Water Management Strategies Directly Affected

Other San Angelo strategies, delivery of desalination water to Runnels and Coke Counties

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

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

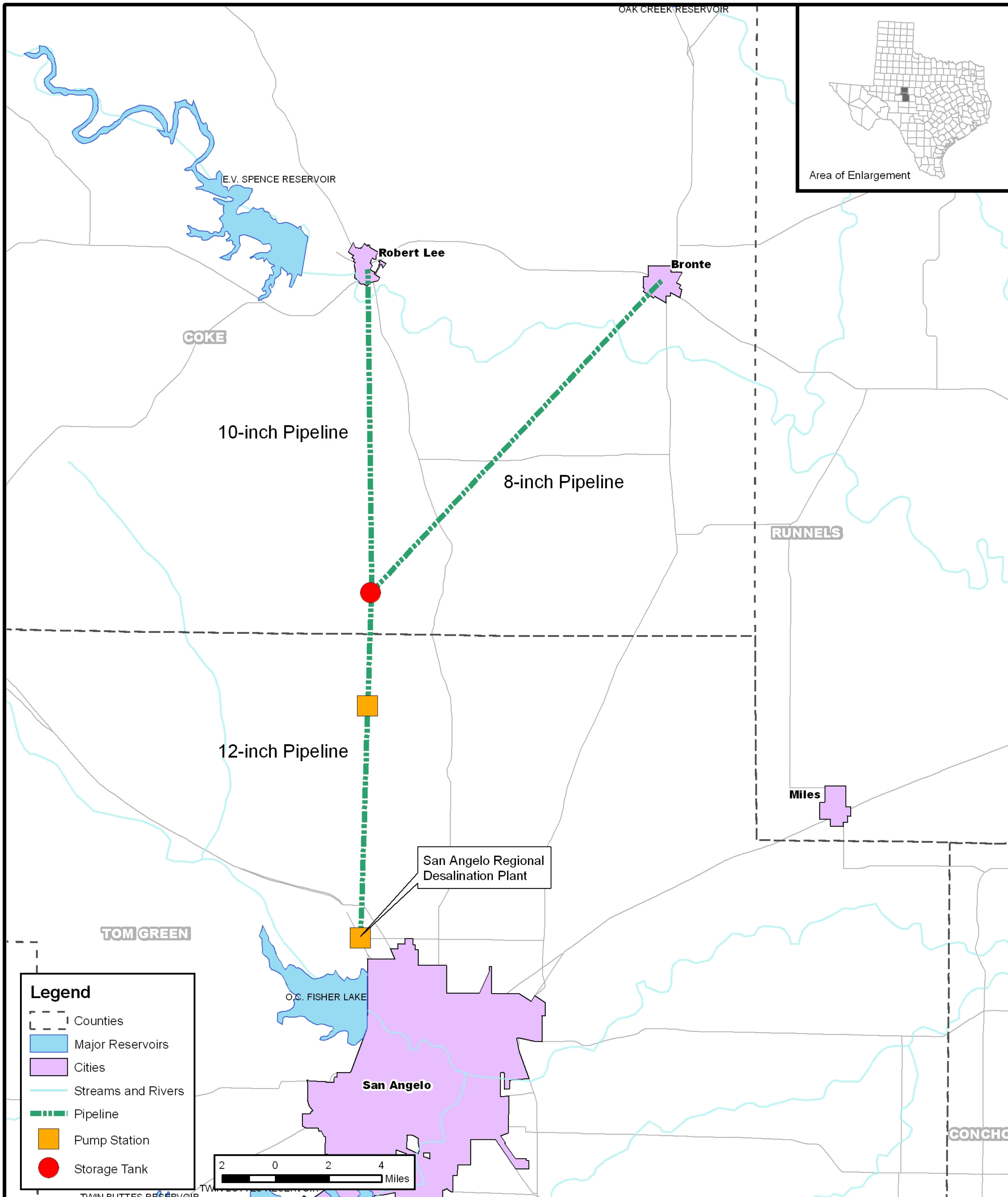
1. *Coke County System* – This scenario includes a 12-inch pipeline and two pump stations that deliver water to a storage tank located in southern Coke County. From this storage tank, a 10-inch pipeline and an 8-inch pipeline feed water by gravity to the cities of Robert Lee and Bronte, respectively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

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

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

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

Impacts of the distribution systems are discussed in Section 4.3.



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N W E S

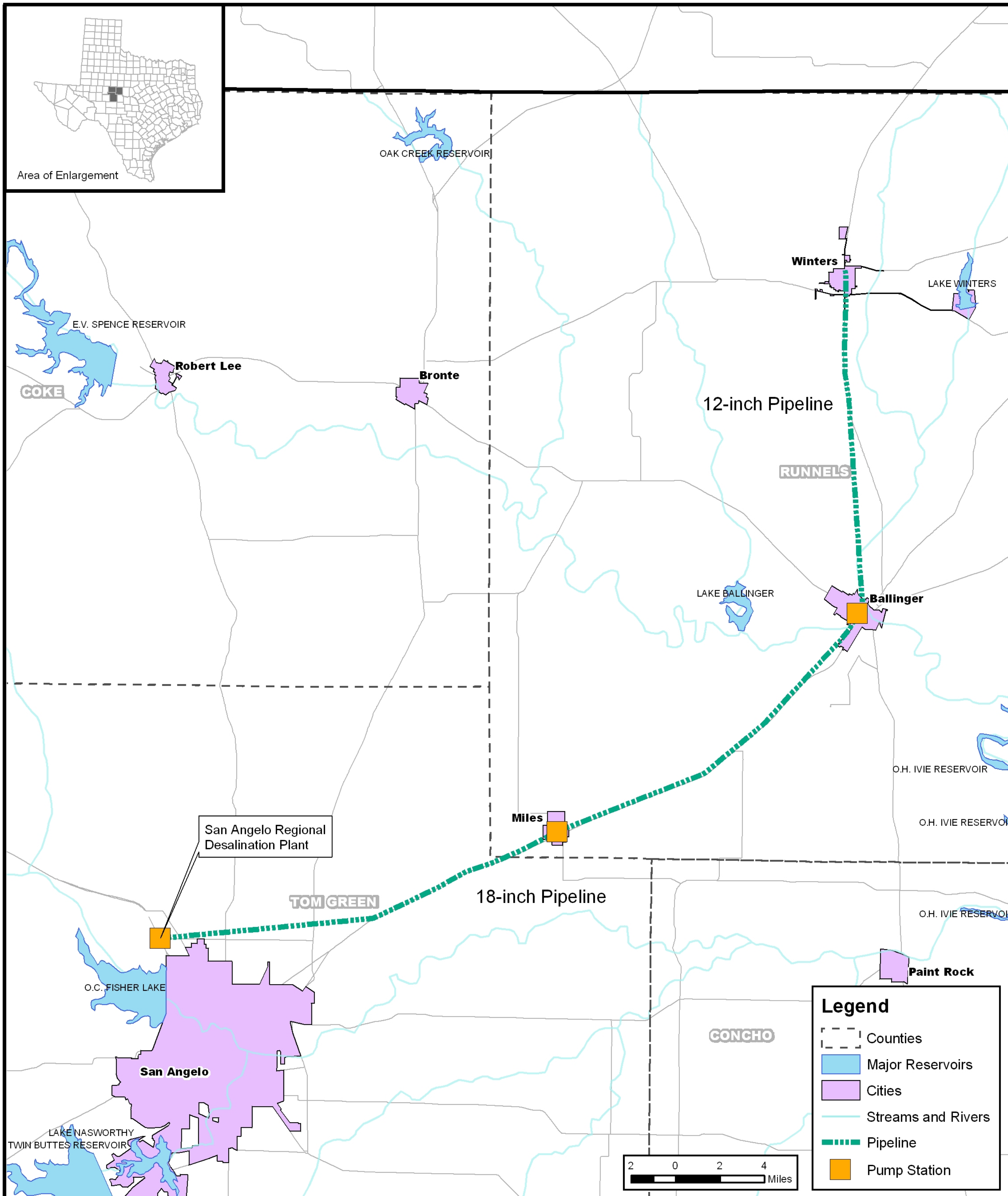
Delivery Options from San Angelo Regional Desalination Facility

Coke County Delivery

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

4.8-2

FIGURE



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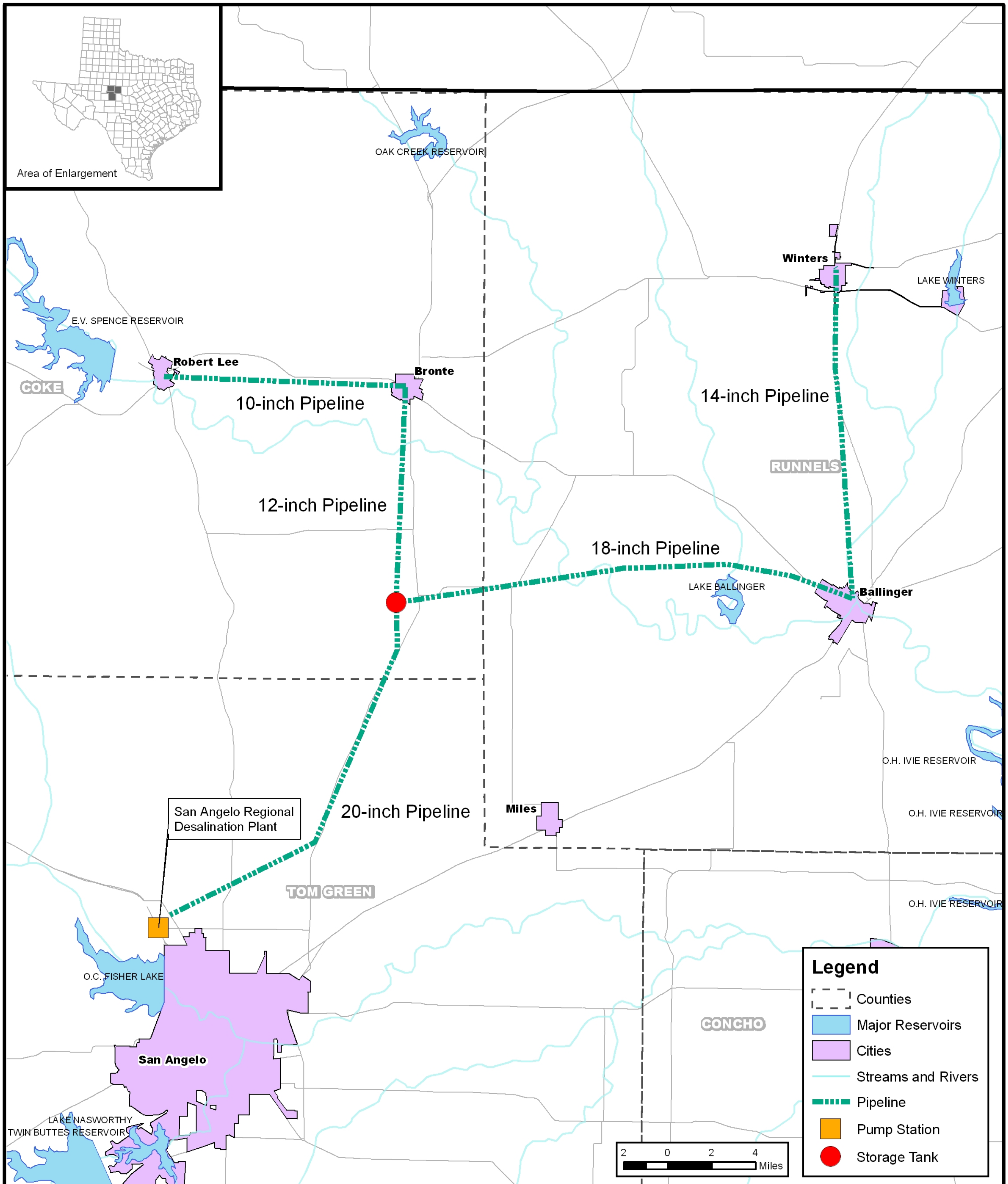
Delivery Options from San Angelo Regional Desalination Facility

Runnels County Delivery

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

4.8-3
FIGURE



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Delivery Options from San Angelo Regional Desalination Facility

Coke and Runnels County Delivery

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

4.8-4

FIGURE

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

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

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

New Groundwater Development - McCulloch County Well Field

The City of San Angelo owns an undeveloped well field on the border of McCulloch and Concho Counties. This well field produces water from the Hickory aquifer. Water from this well field may not meet current drinking water standards for radium. The city is currently conducting a study evaluating the water quality of the aquifer, options to meet drinking water standards for radionuclides, well field layout and alternatives to deliver the water to the city. There are two alternatives delivering water from the McCulloch well field to San Angelo:

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

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

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

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

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

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

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

Quantity, Reliability and Cost

The quantity of water available from the McCulloch well field is limited by an agreement with the Hickory Underground Water Conservation District to 5,000 acre-feet per year when the well field is brought on line in about 2024, increasing to 10,000 acre-feet in 2026. By 2036, the maximum amount of water available will be 12,000 acre-feet per year. The reliability of water from the well field is high. Table 4.8-23 shows the costs associated with this strategy.

Table 4.8-23
Costs for the McCulloch County Well Field

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

Environmental Issues

Previous studies of the McCulloch County Well Field have not assessed the potential for impacts on springflows[56,57]. The well field will produce water from the down-dip portion of the Hickory aquifer. Faulting may have caused portions of the well field to be cut off from the recharge zone of the aquifer, and most of the supply is expected to come from water in storage. Based on this information, it is unlikely that development of this well field will have a significant impact on springflow and streamflows, or cause subsidence. Therefore environmental impacts are expected to be minimal.

Based on the available data, it is unlikely that pumping limits other than those already imposed by the Hickory Underground Water Conservation District will be required to protect the environment. There are no subsidence districts in Region F.

Agricultural and Rural Issues

The Hickory aquifer is used extensively for irrigation and for municipal water supply in the area. There is concern that other users of the Hickory aquifer, particularly the city of Eden, will be affected by lowering of the water table caused by pumping for San Angelo. It is recommended that additional investigations be performed prior to implementation of this strategy to assess the impacts on other users.

This strategy should have minimal impacts on agriculture since most of the irrigated acreage using the Hickory aquifer is located upgradient of the well field in the recharge zone or shallower areas of the aquifer. San Angelo's holdings are in the deeper portion of the aquifer. The right of way for the transmission line may affect a small amount of agricultural acreage that will need to be determined once the pipeline route has been finalized.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

Much of the water from the Hickory aquifer has radium levels that exceed the maximum contaminant level (MCL) for drinking water. Water from the McCulloch County well field may require special treatment, blending or some other process to meet standards. The city will be studying this option in detail in a separate study.

Other Water Management Strategies Directly Affected

Other San Angelo strategies.

System Optimization

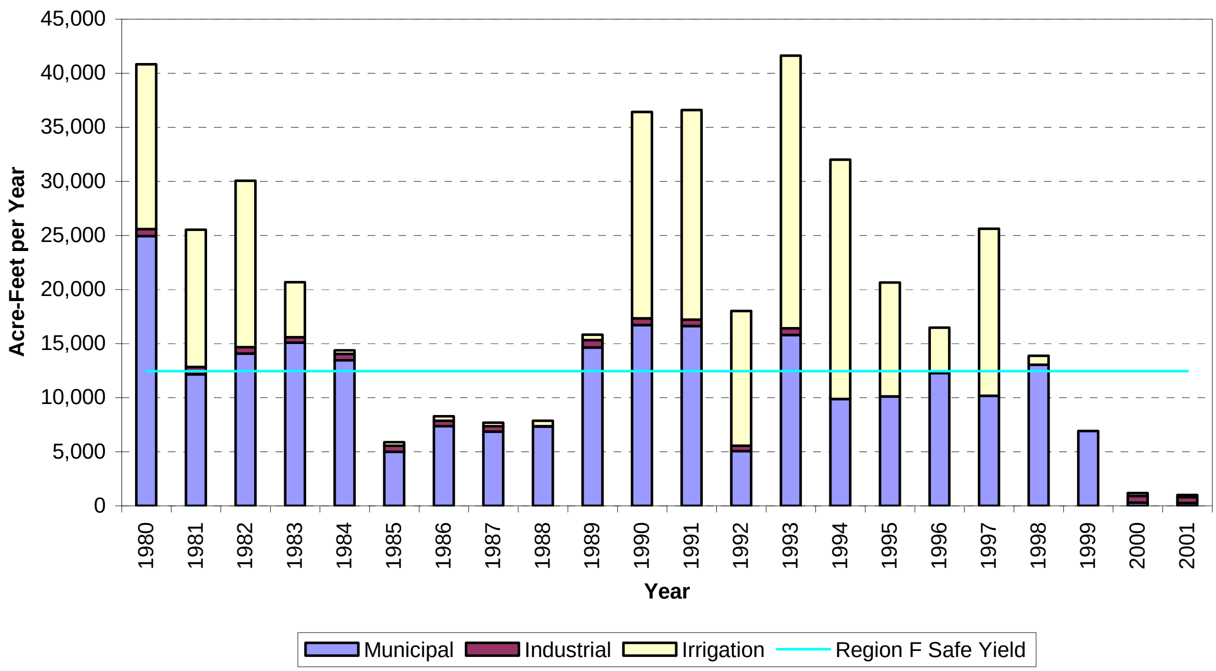
The City of San Angelo uses multiple sources of water. Previous studies have shown some increased yield from operating these sources in a coordinated fashion. In the first round of planning, it was estimated that an additional 2,100 acre-feet of water could be generated by operating Twin Buttes, Lake Nasworthy and O.C. Fisher in a coordinated fashion. If other existing and potential sources are added, additional supplies may be generated.

As part of system optimization, the city is pursuing changes to its water rights in O.C. Fisher Reservoir to allow storage of water pumped from Ivie Reservoir, Spence Reservoir or other sources in the reservoir. Water from these sources could be stored in the reservoir during lower-demand winter months for use later in the year.

Another issue associated with system optimization is the overdrafting of Twin Buttes Reservoir and Lake Nasworthy. The contract between the city and the Tom Green County Water Control and Improvement District (Tom Green County WCID) specifies a pool accounting system that reserves the lower 50,000 acre-feet of storage in the reservoir for municipal use. The remaining storage may be used for irrigation supplies. The amount of water in each storage pool is tracked over time based on an accounting system defined in the contract. During an extended drought, the reservoir may drop below 50,000 acre-feet of storage and no water from the irrigation pool will be available.

Figure 4.8-5 shows historical water use from the two reservoirs between 1980 and 2001. During this period as much as 41,000 acre-feet of water has been used from the two reservoirs, which greatly exceeds the safe supply of the two reservoirs of 12,400 acre-feet per year.

Figure 4.8-5
Historical Water Use from the Twin Buttes Reservoir/Lake Nasworthy System



Quantity, Reliability and Cost

The 2001 Region F plan estimated that an additional 2,100 acre-feet of water could be made available by operating Twin Buttes, Nasworthy and O.C. Fisher as a coordinated system. However, the 2001 Region F plan did not consider the impact of this type of operation on senior water rights. Additional studies will be required to determine potential supplies taking into account priority of other water rights, subordination of major water rights, additional sources of water and the impact of recent drought. Until further studies have been performed, no water should be considered available from this strategy.

Impacts

Impacts cannot be determined until the amount of water available from this strategy has been defined.

Rehabilitation of the Spence Pipeline

Currently the city's pipeline from Spence Reservoir is not operational. Rehabilitation of the pipeline will be required for the city to access this source.

Quantity, Reliability and Cost

For the purposes of this plan it was assumed that the supply from Spence Reservoir is limited to 6 percent of the safe yield. With subordination, the 2010 supply is 2,308 acre-feet per year and the 2060 supply is 2,240 acre-feet per year. The reliability of this source is medium because of the water rights issues associated with subordination. Table 4.8-24 shows the expected costs of this strategy.

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

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

* Costs do not include purchase of water from CRMWD

Impacts

Because this is an existing source for the City of San Angelo, an impact analysis was not conducted.

Water Marketing – Water from Southwestern Pecos County

A group of landowners in southwestern Pecos County has proposed selling groundwater from the Edwards-Trinity (Plateau) aquifer in southwestern Pecos County. Initial estimates indicate that this area can produce a large quantity of water of reasonable quality.

Quantity, Reliability and Cost

The sustainable quantity of water from Southwestern Pecos County has not been established, although preliminary estimates indicate that 50,000 to 100,000 acre-feet per year could be provided from this source. For this analysis, we are assuming that the City of San Angelo could take up to 12,000 acre-feet per year from Pecos County. Because of the uncertainty associated with this source, the reliability of the supply is medium. Table 4.8-25 shows the costs associated with this strategy.

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

Supply from Strategy	12,000 acre-feet per year
Total Capital Costs (2002 Prices)	$ 194,052,000
Annual Costs	$ 22,401,000
Unit costs (before amortization)	$ 1,867 per acre-foot
	$ 5.73 per 1,000 gallons
Unit Costs (after amortization)	$ 457 per acre-foot
	$ 1.40 per 1,000 gallons

Environmental Issues

Information provided by the sponsors of this project indicates possible impacts on flow in the Pecos River from development of this strategy[58], which should be investigated if this strategy is pursued. If linkage between groundwater development and flows in the Pecos River can be established, the local groundwater conservation district may wish to impose pumping limits. There are no subsidence districts in Region F.

Agricultural and Rural Issues

According to information provided by the developers of this project, the supply in the immediate area is primarily used for cattle ranching and development of the project will have minimal impact on existing uses. However, it is possible that large-scale production from this source could impact irrigation supplies in the Belding Farms area. Additional studies may be needed to quantify this impact.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

The most significant issue facing this project is the lack of funds to perform studies to verify the potential supplies from this source. Also, the source is located over 175 miles from the City of San Angelo.

Other Water Management Strategies Directly Affected

Other San Angelo strategies.

New Groundwater – Water from the Edwards-Trinity (Plateau) Aquifer

In 1985 the City of San Angelo investigated the possibility of developing a water supply from the Edwards-Trinity (Plateau) aquifer in northern Schleicher County[59]. This study concluded the following:

- Water quality of the Edwards limestones was of good quality. The water quality of the Trinity sands was somewhat poorer in quality.
- Water production from the Edwards limestones appears to be from cavernous porosity and could provide sufficient water for municipal supply. The Trinity sand is poorly developed, contains a high percentage of clay and is less attractive for large-scale water development.
- Drought conditions from 1962 to 1967 caused water levels in the Edwards to drop by 15 to 20 feet.
- Models of production from a proposed well field near Hulldale had a significant impact on the Anson springs. These springs provide much of the base flow of the South Concho River, which flows into Twin Buttes Reservoir.

Other areas in the Edwards-Trinity (Plateau) aquifer south of the city may provide water in sufficient quantities for municipal supplies. However, the quantity of water can vary greatly depending on the presence of porosity in the Edwards limestones. An exploration program would be required to find other suitable areas for municipal development.

Quantity, Reliability and Cost

According to the Region F water supply analysis, over 62,000 acre-feet of water per year are available from the Edwards-Trinity in Crockett, Schleicher and Sutton Counties. However, most of the water is contained in caverns or fractures in the Edwards limestone. This type of porosity tends to be highly localized, making it difficult to find areas with sufficient production for municipal supplies. Studies have also indicated that production from the aquifer may be significantly impacted by drought. Therefore the reliability of the supply has been classified as medium.

The 1985 San Angelo study proposed construction of a 30-mile 30-inch pipeline with a capacity of 15 MGD. The proposed well field had 10 wells. Table 4.8-26 is a cost estimate based on this study. If this strategy is pursued, additional engineering studies will be required to refine these estimates.

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

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

Environmental Issues

Previous studies have indicated that groundwater development from the Edwards-Trinity aquifer may significantly impact springflow. If this strategy is pursued, a detailed study of the potential impacts of groundwater development should be conducted. If necessary, pumping limits in addition to those already imposed by the local groundwater conservation districts may be necessary to protect the environment. Development of water from this source is unlikely to cause subsidence.

Agricultural and Rural Issues

Springflows from the Edwards-Trinity supply much of the base flow of the South Concho and other flowing streams in the area. Many of these streams are used extensively for irrigation. Wells provide water for ranching, domestic and municipal supplies throughout the area. Studies will be required to evaluate potential impacts on the area.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

Local groundwater district rules in the area discourage the large-scale development of groundwater. Rule changes may be necessary for development of water from these counties.

Other Water Management Strategies Directly Affected

Other San Angelo strategies.

Recommended Strategies for the City of San Angelo

The recommended strategies include for the City of San Angelo include:

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

Table 4.8-27 compares the supply from recommended strategies to projected demands for the City of San Angelo. Alternative strategies such as reuse and other water sources may be required if studies currently being conducted by the City of San Angelo prove that one or more of these strategies is more costly, produces less water or has greater impacts than determined in this analysis.

Table 4.8-27
Recommended Water Management Strategies for the City of San Angelo

Supplies	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Existing Supplies	11,616	11,393	11,170	10,946	10,723	10,500
Subordination	11,791	11,472	11,153	10,835	10,516	10,196
Rehabilitation of Spence Pipeline	2,308	2,295	2,281	2,267	2,254	2,240
Regional Desalination Facility	0	5,600	5,600	5,600	5,600	5,600
McCulloch County Well Field	0	0	5,000	12,000	12,000	12,000
Total Supplies	25,715	30,760	35,204	41,648	41,093	40,536
Conservation	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Potential Savings [a]	701	1,705	2,009	2,127	2,255	2,371
Demands	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
City of San Angelo	20,800	21,418	21,734	21,744	21,907	21,969
Outside Sales	3,119	3,625	3,996	4,342	4,546	4,796
Total Demand	23,919	25,043	25,730	26,086	26,453	26,765
Surplus (Need) without Conservation	1,796	5,717	9,474	15,562	14,640	13,771
Surplus (Need) with Conservation	2,497	7,422	11,483	17,689	16,895	16,142

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

4.9 Other Strategies

4.9.1 Weather Modification

Weather modification is a water management strategy currently used in Texas to increase precipitation released from clouds over a specified area typically during the dry summer months. The most common form of weather modification or rainfall enhancement is cloud seeding. Early forms of weather modification began in Texas in the 1880s by firing cannons to induce convective cloud formation. Current cloud seeding techniques are used to enhance the natural process for the formation of precipitation in a select group of convective clouds.

Convective clouds, also known as cumulus clouds, are responsible for producing the bulk of rainfall during any given year in Texas[60]. The cloud seeding process increases the availability of ice crystals, which bond with moisture in the atmosphere to form raindrops, by injecting a target cloud with artificial crystals, such as silver iodide. Specially equipped aircraft release the seeding crystals into clouds as flares that are rich in supercooled droplets. The silver iodide crystals form water droplets from available moisture in the air. Droplets then collide with droplets transforming the ice crystal into a raindrop.

While weather modification is most often utilized as a water management strategy during the dry summers in West Texas. The water produced by weather modification augments existing surface and groundwater supplies. It also reduces the reliance on other supplies for irrigation during times of normal and slightly below normal rainfall. However, not all of this water is available for water demands. Some of this precipitation is lost to evaporation, evapotranspiration, and local ponds. During drought years the amount of additional rainfall produced by weather modification may not be significant.

The amount of water made available to a specific entity from this strategy is difficult to quantify, yet there are regional benefits. Three major benefits associated with weather modification include:

- Improved rangeland and agriculture due to increased precipitation
- Greater runoff to streams and rivers due to higher soil moisture
- Groundwater recharge

Weather Modification Programs in Region F

In Region F, there are several ongoing weather modification programs, including the Colorado River Municipal Water District (CRMWD) rain enhancement project, the West Texas Weather Modification Association (WTWMA) project, the Trans Pecos Weather Modification Association (TPWMA) program and the Southern Ogallala Aquifer Rain (SOAR) program. Another weather modification program, conducted by the West Central Texas Weather Modification Association (WCTWMA), was started in 2001, but due to budgetary issues, stopped cloud seeding after the 2003 season.

Colorado River Municipal Water District (CRMWD) Rain Enhancement Project

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

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

West Texas Weather Modification Association (WTWMA) Project

The WTWMA began weather modification efforts in 1995. The intent of the rainfall enhancement program was to increase ground water recharge, spring flow, and runoff resulting in increased agricultural productivity and reduction in ground water withdrawals. WTWMA operates in eight counties covering an area of 10 thousand square miles. The City of San Angelo, Emerald Underground Water Conservation District (UWCD), Glasscock County UWCD, Irion County Water Conservation District (WCD), Plateau Underground Water Conservation and Supply District (UWC & SD), Santa Rita UWCD, Sterling County UWCD and Sutton County UWCD are the current participants in the rainfall enhancement effort. In 2003, a total of 265 clouds were seeded as part of WTWMA's rain enhancement efforts in 50 operational days. A 1999 study of WTWMA's efforts shows a 17-percent increase in rainfall in the target area during the months the program was in operation[62].

Southern Ogallala Aquifer Rain (SOAR) Program

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

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

Trans Pecos Weather Modification Association (TPWMA) Program

The TPWMA, which is the newest rain enhancement project in Texas, was developed in 2003. The TPWMA consists of the Ward County Irrigation District and other political entities from a 4-county area, including Culberson, Loving, Reeves, and Ward counties. The program's target area covers over 5.1 million acres along and to the west of the Pecos River from El Paso to Midland. The program is currently funded by local ranchers, farmers, and landowners, Loving County, the Ward County Irrigation District, and a grant from the Texas Department of Agriculture. Precipitation data from this program's inaugural season were not available at the time of this report[64]

West Central Texas Weather Modification Association (WCTWMA) Program

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

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

Quantity, Reliability and Cost

Benefits of the weather modification programs are widespread and are difficult to quantify in the context of regional water planning. To precisely estimate the benefit of weather modification requires an estimate of how much precipitation would have occurred naturally without weather modification, and an estimate of how much of the increase in precipitation becomes directly available to a water user. Research indicates that rainfall can increase by 15 percent or more in areas participating in weather modification. Some locations have shown rainfall increases of as much as 27 percent. Other methods of measuring the effects of rainfall enhancement have shown positive benefits of weather modification. Dry land farm production, a common measurement, has increased in regions participating in rainfall enhancement. However, because there is no direct method to quantify the benefits to individual water user groups, no specific quantity will be assigned by Region F for this planning cycle.

The reliability of water supplies from precipitation enhancement is considered to be low for two reasons. First, it is uncertain how much water is made directly available per water user. Second, during drought conditions precipitation enhancement may not result in a significant increase in water supply. (The guidelines for regional water planning in TAC §357.5(a) specifies that regional water planning evaluate supplies from water management strategies during critical drought conditions.) Cloud formations suitable for seeding may not occur frequently during drought, so benefits during drought may be negligible.

The cost of operating the weather modification program is approximately nine to ten cents per acre. Additional data collection may be vital in determining if weather modification could be used as a long-term water management strategy in the region.

Environmental Issues

Weather modification should have a positive impact on the environment due to the increased rainfall from storms. The chemicals used in weather modification should be sufficiently diluted to minimize any threat of contamination.

Agricultural and Rural Issues

Weather modification has a positive impact on agriculture and ranching by increasing productivity. Another benefit of weather modification is hail suppression, which helps minimize damage from severe weather.

Other Natural Resource Issues

None identified.

Significant Issues Affecting Feasibility

The most significant issue facing existing weather modification programs is funding. In many cases these programs rely on the cooperation of several entities and the availability of outside funding to continue operations. In addition, local opposition to weather modification programs has caused some programs to be discontinued.

Other Water Management Strategies Directly Affected

None identified.

4.9.2 Brush Control

Brush control has been identified as a potentially feasible water management strategy for Region F. It has the potential to create additional water supply that could be used for some of the unmet needs in the Region as well as enhance the existing supply from the Region's reservoirs.

Background

Prior to settlement, most of Texas was grassland. Along with settlement came grazing animals which, for a number of reasons, created an environment that favored shrubs and trees (brush) rather than grasslands. Brush not only increases the costs of land management and decreases the livestock carrying capacity of the land, but as shown in Table 4.9-1, certain species of brush can drastically reduce water yield in a watershed. For these reasons, an effort was bought forth to control this brush and convert land back to grasslands.

In 1985, the Texas Legislature authorized the Texas State Soil and Water Conservation Board (TSSWCB) to conduct a program for the "selective control, removal, or reduction of … brush species that consume water to a degree that is detrimental to water conservation." In 1999 the TSSWCB began the Brush Control Program. This is a voluntary program in which landowners may contract with the state for cost-share assistance. Working through local soil and water conservation districts, landowners develop resource management plans addressing brush control, soil erosion, water quality, wildlife habitat and other natural resource issues.

Table 4.9-1
Plant Water Use Rates

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

The TSSWCB has designated areas of critical need in the State in which to implement the Brush Control Program. Currently four watersheds have been designated as critical areas based on water needs and the results of the completed feasibility studies. Three of those four critical watersheds lie within Region F. They are the North Concho River Watershed, Twin Buttes Reservoir Watershed, and the Upper Colorado River Watershed.

Methods of Brush Control

A number of methods can be employed to control brush. They include: mechanical, chemical, prescribed burning, bio-control, and range management. Mechanical brush control methods can range from selective cutting with a hand axe and chain saw to large bulldozers. Moderate to heavy mesquite or cedar can be grubbed or plowed for \$100 to \$165/acre[78].

Several herbicides are approved for chemical brush control. The herbicides may be applied from aircraft, from booms on tractor-pulled spray rigs, or from hand tanks. Some herbicides are also available in pellet form. The herbicides Triclopyr (Remedy®) and Clopyralid methyl (Reclaim®) are approved herbicides for on-going TSSWCB brush programs. Arsenal is the herbicide typically used for removal of salt cedar. These chemical were shown to achieve about 70 percent root kill in studies around the state and in adjacent states. Specific soil temperature and foliage conditions must be met in order for chemical brush control to be effective. Aerial spraying of brush such as mesquite costs the same regardless of the plant density or canopy cover, about \$25 per acre.[78]

Prescribed burning is also used to control brush. Burning is conducted under prescribed conditions to specifically target desired effects. Prescribed burning is estimated at $15 per acre for the TSSWCB programs. There are some limitations however. Burning rarely affects moderate to heavy stands of mature mesquite. Burning only topkills the smooth-bark mesquite plants and they re-sprout profusely. In addition, for mesquite, fire only gives short-term suppression and it stimulates the development of heavier canopy cover than was present pre-burn. Fire is not usually an applicable tool in moderate to heavy cedar (juniper) because these stands suppress production of an adequate amount of grass for fine fuel. Fire can be excellent for controlling junipers over 4 feet tall, if done correctly. Prescribed burning is often not recommended for initial clearing of some heavy brush due to the concern that the fire could become too hot and sterilize the soil. Burning is often used for maintenance of brush removal that has been initially performed through some other method.[78]

Bio-control of salt cedar is a relatively new technique to be used in Texas. It has been studied for nearly 20 years, and there have been pilot studies in the Lake Meredith watershed and most recently in the Colorado River Basin.[79] Research has shown that the Asian leaf beetle can consume substantial quantities of salt cedar in a relatively short time period, and generally does not consume other plants. Different subspecies of the Asian beetle appear to be sensitive to varying climatic conditions, and there is on-going research on appropriate subspecies for Texas. It is recommended that this control method be integrated with chemical and mechanical removal to best control re-growth. The cost per acre is unknown.

Range or grazing management should follow any type of upland brush control. It allows the regrowth of desirable grasses, maintaining good groundcover that hinders establishment of woody plant seedlings. Continued maintenance of brush is necessary to ensure the benefits of brush control.

Brush Control in Region F

Brush control is a potential water management strategy that could possibly create additional water supply within Region F. Predicting the amount of water that would be made available by implementing a brush control program is difficult, but some estimates have been made through ongoing pilot projects. Feasibility studies were conducted in many areas, and based on those feasibility studies, a number of brush control projects were initiated in Region F.

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

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

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

Source: TSSWCB Brush Control Program 2003 Annual Report

North Concho River Pilot Brush Control Project

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

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

Twin Buttes Reservoir/Lake Nasworthy Brush Control Projects

In September 2002, brush control projects were initiated to enhance the amount of water flowing into the Twin Buttes Reservoir/Lake Nasworthy complex. Twin Buttes Reservoir is used to maintain sufficient water levels in Lake Nasworthy, which serves as a water supply for the City of San Angelo. Lake Nasworthy also provides cooling water for a power generation plant. As of November 2004, Twin Buttes Reservoir was at only 3 percent of its capacity. As of December 2003, TSSWCB has contracted 160,000 acres for treatment, and over 100,000 acres have already been treated[80]. It is projected that the current allocation ($9.5 million) will allow treatment of nearly 203,000 acres of brush. Modeling studies estimate that this project could produce as much as 191,000 acre-feet of water over the life of the project. Additional allocation of funds will be needed to complete the treatment of the more than 555,000 acres of eligible brush in the Twin Buttes Subbasin.

Lake Ballinger Brush Control Project

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

Mountain Creek Reservoir Brush Control Project

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

Oak Creek Reservoir Brush Control Project

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

Pecos/Upper Colorado Salt Cedar Project

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

Champion Creek Reservoir Brush Control Project

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

Quantity, Reliability and Cost

Although many studies have illustrated the benefits of brush control, until recently it has been difficult to quantify the benefits in the context of regional water planning. This quantification is very important because in most areas that the program is currently being implemented, hydrologic records indicate long term declines in reservoir watershed yields (some as much as 80%). Region F has been in critical drought conditions during most of the time that the current brush removal programs have been in place, so the monitoring programs associated with these projects may not have shown significant gains due to the lack of rainfall events. Also, the benefits from brush control are long term; it takes time for aquifers to recharge and for watersheds to return to pre-brush conditions. This fact was recognized by the various scientists during the initial planning for the Texas Brush Control Program and the preparation of numerous feasibility studies. Measuring success and hydrologic responses to brush control projects is going to be a long-term process, even under ideal conditions. Until recently, the projects have been implemented under less than ideal conditions due to the record drought. While the relatively short period of time these programs have been in place may not be indicative of the long term gains of the programs, evidence is beginning to manifest that should serve to offer some indications.

Considering the above facts as a point of reference, the measured hydrologic responses and ongoing research findings to date have been nothing short of spectacular. Some of the indications of water production successes observed to date are as follows:

- Following modest surface water inflows in November 2004, unprecedented base flows into Twin Buttes Reservoir essentially doubled reservoir capacity (to 47,500 acre feet by mid June) and is effectively mitigating summer evaporation losses from the reservoir. The Twin Buttes watershed has been the recent recipient of a major brush removal effort on targeted and high priority sub-basins.
- Base flows on Pecan Creek (a long dormant perennial tributary to Lake Nasworthy and the subject of a special brush control project) provided so much base flow to Lake Nasworthy that water had to be released downstream on several occasions during the winter and spring of 2004-2005. This condition has been unprecedented in recent history.
- Long dormant tributary springs through out the region have begun to flow following brush removal. Most of these became active during the drought and without benefit of any rainfall.
- The East Fork of Grape Creek, which is a portion of a major tributary to O.C. Fisher Reservoir, has received extensive brush removal (approximately 70 percent of targeted brush in the sub-basin). This tributary has been measured to have produced hundreds of acre feet of water in base flows since November, 2004. A similarly sized adjacent watershed (West Fork of Grape Creek) that has not received brush removal produced no downstream water base flows. Hydrologic calculations of data from the East Fork indicate that this watershed is producing in excess of 1.0 acre inch of water per year in base flows. Prior to brush removal, the hydrologic characteristics of this watershed were similar to that of the West Fork. An August, 2005 runoff event on both watersheds revealed a dramatic difference in the flood hydrographs from each stream. The untreated

watershed produced a rapid short flow event, while the treated watershed produced a longer and sustained flow.

- For the first time since the mid 20^{th} century, the North Concho River has experienced perennial base flows for an extended period of the year through out the stream reach. As a result of this saturated stream condition, the watershed yield from an August, 2005 storm runoff event was undoubtedly increased.
- Regional groundwater monitoring within the North Concho watershed during the last 48 months is indicating a significant trend in increasing ground water levels. Much of this data has been collected during a period of record drought.
- Preliminary evapotranspiration data from on-going paired watershed studies conducted by the Texas Institute for Applied Environmental Research (TIAER) at Tarleton State University for the Upper Colorado River Authority (UCRA) is indicating a significant difference in water use between treated and untreated mesquite infested sites. This data, which is due to be published by TIAER by early 2006, will likely confirm existing watershed model predictions and other ongoing research and monitoring initiatives.

Based on anecdotal accounts and observations, almost everyone in the area from participating landowners to water supply and elected officials are recognizing the water producing value of the program. It would appear from preliminary observations and findings that brush control as a water producing strategy is viable and should be incorporated into water supply planning. Since the region appears to be moving out of the drought period of the last few years and reliable experimental data is emerging from monitoring efforts, accurate quantification of the hydrological effects of brush control may soon be possible. This quantification will likely be based on existing modeling output found in a completed watershed feasibility study and confirmation or adjustment of that modeling prediction. Also, since the program is based on voluntary participation by landowners, an analysis of the completed brush control work as to the extent within each sub-basin, location of each sub-basin in relationship to the overall watershed and anticipated water production from each sub-basin should be performed. The feasibility studies and models assume removal of all of the targeted brush, which will not often happen. A summary of each sub-basin within the Upper Colorado watershed by production and costs was published by the Upper Colorado River Authority (UCRA) in 2002 and is available for use in performing an analysis.

The UCRA document referenced above is also a good source of information regarding the cost of water produced through brush control. In consideration of the entire upper Colorado River basin, there is tremendous variability in sub-basin water yields and therefore tremendous variability in costs per acre-feet of water produced. According to existing feasibility studies, treating the entire upper Colorado River basin (nine reservoir watersheds) would result in a composite cost of slightly over $70 per acre foot of water produced. Treating only the most productive sub-basins, however, could produce a high percentage of the modeled water production and reduce the composite costs to less than $50 per acre foot. This (priority sub-basin) approach has been utilized in allocating initial funding available for brush control in the region. An assumption of water yields (from feasibility studies) based on 50 percent of high priority brush removal and 65 percent of modeled water yield will result in 191,817 acre feet of water being produced in ten (10) upper basin reservoirs, including 30,000 acre feet in the O.C. Fisher watershed and 49,856 acre feet in the Twin Buttes/Nasworthy watershed.

In order to be an effective and reliable long term water production strategy, areas of brush once removed, must be maintained. Follow –up treatment is essential to the program and has been built into the TSSWCB landowner contracts. During the 10-year contract period landowners must perform any needed follow- up treatment if state funding is available. Toward this end, the NRCS has made funding available for landowners in the O.C. Fisher and Twin Buttes watersheds for follow-up treatment through the EQIP program.

In 2003 the cost of the existing brush control program in Region F was $26,000,000. Near-term funding for brush control in the region would be at similar levels.

Environmental Issues

The Texas Parks and Wildlife Department (TPWD) list the potential environmental impacts of brush control as alteration of terrestrial habitat, increased sediment runoff and erosion, impacts from chemical control measures, potential for increase groundwater recharge, impacts to aquatic and terrestrial communities and ecosystem process, and influence on energy and nutrient inputs and processing[81]. Region F suggests coordinating with TPWD and other state and federal agencies regarding any brush control program.

Agricultural and Rural Issues

Invasive brush has altered the landscape of Region F and the rest of West Texas. Restoration of much of the landscape to natural grassland conditions will benefit the ranching economy of the region as well as enhance water supplies.

Other Natural Resource Issues

Although invasive brush has impacted water supplies and altered the natural landscape of the region and reduced runoff, in some cases the brush has provided habitat for wildlife. In addition to the environmental benefits of this habitat, some of this habitat is suitable for deer and other game. Hunting is an important part of the economy of Region F. Therefore it may be desirable to leave portions of a watershed with brush to maintain habitat.

Significant Issues Affecting Feasibility

The most significant factor regarding the feasibility of this strategy is on-going funding for brush control projects. Brush control is an on-going process that must be constantly maintained for the project to be successful. Existing programs provide funding for the initial clearing of brush but generally do not provide funding for on-going maintenance and monitoring. Without maintenance and monitoring, brush control will not be effective as either a range management or water management strategy.

Like other similar activities, brush control is dependent upon the on-going cooperation and financial contributions of individual landowners. Therefore each program should be tailored to local conditions.

Other Water Management Strategies Directly Affected

If the findings of the existing upper basin feasibility studies are verified and/or adjusted, and if the program is adequately implemented and maintained, brush control could delay or eliminate the need for new water supply projects. Currently, the major on-going brush removal projects are located above O.C. Fisher and the Twin Buttes/Nasworthy reservoirs. Both of these reservoirs are a part of the San Angelo water supply system. To date, approximately 300,000 acres have been completed on the O.C. Fisher watershed and 200,000 acres completed on the Twin Buttes/Nasworthy watershed. Neither of the projects are currently complete with an additional 10,000 acres targeted on the O.C. Fisher watershed and 25,000 acres targeted on the Twin Buttes/Nasworthy watershed during the FY 2006-2007 biennium. However, hydrologic observations and response monitoring on these watersheds previously reported herein, indicates a trend toward watershed restoration and partial return to pre-brush conditions. While this process is not complete, it is apparent that an improvement in watershed yields is occurring and should be recognized in planning.

With an intention of being prudent and in consideration of relevant factors, it is recommended that during the current planning period, an additional 8,362 acre feet of water per year should be recognized as available to San Angelo from local sources due to brush control. This estimate is based on the short term availability of approximately 20 percent of the ultimate increased watershed yield based on the current status of the brush removal program.

4.10 Summary of Needs and Strategies by County

Table 4.10-1 is a summary of the recommended water management strategies for water user groups in Region F grouped by county, as well as a summary by strategy type. Table 4.10-2 shows additional strategies whose capital costs are associated with wholesale water providers. (There is some overlap for the supplies in these two tables, but no overlap in capital costs.) Only three counties, Crane, Crockett, Loving, do not have water management strategies. The largest single category of water management strategies is conservation, totaling over 82,000 acre-feet per year in 2060. The largest contribution to this strategy comes from irrigation conservation, which contributes about 88 percent of the total. Other significant strategies include subordination, alternative cooling technology, new groundwater sources, and voluntary redistribution. Altogether, these strategies result in over 228,000 acre-feet of water becoming available to water user groups by 2060, with an overall capital cost of almost $1.2 billion.

Table 4.10-3 shows the unmet needs in Region F. All of these needs are for irrigation. Unmet irrigation needs are the result of either insufficient groundwater supplies to meet projected demand or surface water availability for run-of-the-river irrigation rights from the Colorado WAM (any run-of-the-river right with a priority date after 1926 will have no supply by definition). In most cases conservation is the only cost-effective method to reduce irrigation needs. In every county except Martin County conservation was insufficient to prevent unmet needs.

In this plan, the default method to allocate groundwater was to first meet municipal, manufacturing, livestock, mining and steam-electric demands. (Steam-electric demands were limited to current use. Any growth in demand was given last priority). In most cases, irrigation was allocated water last, resulting in a need if insufficient supplies were available to meet all demands. For most of the aquifers in counties with irrigation shortages, irrigation represents from 70 to 99 percent of the demand from these aquifers in 2010, so it is appropriate to assign water supply needs to irrigation demands. An exception is Ward County, where irrigation accounts for only 34 percent of the 2010 demand from the Cenozoic Pecos Alluvium aquifer. In Ward County there are significant demands for municipal, mining and steam-electric use. For the purposes of this plan, it was assumed that these demand categories would have priority over irrigation demand.

Unmet surface water needs are strictly the result of the priority of the water rights in each county as allocated by the Colorado and Rio Grande WAMs. In the Colorado Basin, any run-of-the-river water right with a priority date after 1926 will have no reliable supply. Water rights with priority dates senior to 1926 may not have sufficient supplies in all years. (Run-of-the-river irrigation rights were not part of the subordination analysis performed with Region K.) Although historical surface water use from these sources may be greater than indicated, the shortage may be appropriate if it is assumed that senior downstream rights make priority calls on these irrigation rights.

Table 4.10-1
Strategy Summary by County

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

Table 4.10-1 Strategy Summary by County (Continued)

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

Table 4.10-1 Strategy Summary by County (Continued)

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

Table 4.10-1 Strategy Summary by County (Continued)

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

Table 4.10-2
Strategy Summary for Wholesale Water Providers

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

Table 4.10-3
Unmet Needs in Region F
(Values in Acre-Feet per Year)

Water User Group	County	Basin	Source(s)	2010	2020	2030	2040	2050	2060
Irrigation	Andrews	Colorado	Ogallala aquifer	(14,094)	(11,336)	(8,471)	(7,080)	(6,876)	(6,707)
Irrigation	Borden	Brazos	Ogallala aquifer	(1,019)	(924)	(827)	(824)	(821)	(819)
Irrigation	Borden	Colorado	Ogallala aquifer	(828)	(690)	(552)	(551)	(548)	(547)
Irrigation	Brown	Colorado	Trinity aquifer, run-of-river	(3,006)	(2,889)	(2,761)	(2,720)	(2,683)	(2,656)
Irrigation	Coke	Colorado	Other aquifer, run-of-river	(363)	(363)	(361)	(360)	(360)	(360)
Irrigation	Glasscock	Colorado	Edwards-Trinity aquifer, Ogallala aquifer	(27,784)	(23,750)	(19,710)	(19,290)	(18,869)	(18,460)
Irrigation	Irion	Colorado	Run-of-river	(1,302)	(1,204)	(1,108)	(1,047)	(987)	(927)
Irrigation	Martin	Colorado	Ogallala aquifer	(788)	0	0	0	0	0
Irrigation	Menard	Colorado	Run-of-river	(2,441)	(2,398)	(2,356)	(2,337)	(2,315)	(2,296)
Irrigation	Midland	Colorado	Edwards-Trinity aquifer, Ogallala aquifer	(16,233)	(14,559)	(12,748)	(12,654)	(12,512)	(12,393)
Irrigation	Reagan	Colorado	Edwards-Trinity aquifer	(10,997)	(8,639)	(6,180)	(5,623)	(5,040)	(4,457)
Irrigation	Reeves	Rio Grande	Cenozoic Pecos Alluvium aquifer	(36,097)	(29,421)	(22,739)	(21,877)	(21,016)	(20,199)
Irrigation	Runnels	Colorado	Run-of-river	(1,358)	(1,344)	(1,325)	(1,306)	(1,287)	(1,268)
Irrigation	Tom Green	Colorado	Lipan aquifer, run-of-river	(43,713)	(37,784)	(31,858)	(31,707)	(31,821)	(31,399)
Irrigation	Upton	Colorado	Edwards-Trinity aquifer	(10,672)	(9,540)	(8,401)	(8,170)	(7,940)	(7,717)
Irrigation	Ward	Rio Grande	Cenozoic Pecos Alluvium aquifer	(5,527)	(4,188)	(4,151)	(4,969)	(5,335)	(5,318)
Total				*(176,222)*	*(149,029)*	*(123,548)*	*(120,515)*	*(118,410)*	*(115,523)*

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