APPPENDIX C

WATER MANAGEMENT STRATEGY EVALUATION TECHNICAL MEMORANDUMS

APPENDIX C

C.1 INTRODUCTION, CONSERVATION, SUBORDINATION

Introduction

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

- Improved conservation
- Reuse
- Expanded use of existing supplies
- Development of new water supplies
- Desalination
- Developing regional water supply facilities or providing regional management of water supply facilities
- Voluntary transfer of water within the region using, but not limited to, regional water banks, sales, leases, options, subordination agreements and financing agreements; and
- Emergency transfer of water

The methodology for selecting potentially feasible strategies for each water user group (WUG) is in Chapter 5A. After the potentially feasible water management strategies were selected, each strategy was evaluated in accordance with Chapter 31 of the Texas Administrative Code, Sections 357.34 and 357.35. These statutes dictate that each strategy be evaluated based on:

- Quantity, reliability, and cost
- Environmental factors
- Impacts to agricultural and natural resources including impacts of moving water from rural and agricultural areas
- Impacts on key parameters of water quality
- Impacts on other water resources including other water management strategies
- Other factors as deemed relevant by the RWPG

This Appendix documents each potentially feasible strategy's description and evaluation in accordance to the rules as outlined above. 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 was 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 region.

Some strategy evaluations were performed as a group. These strategies include:

- Municipal conservation
- Irrigation conservation
- Mining reuse/recycling
- Subordination of downstream water rights
- Purchase water (voluntary transfer) strategies
- Brush control

- Weather modification

The remaining water management strategies were evaluated individually. This appendix is organized by major strategy category. Cost tables are included in Appendix D. The technical analyses for all potentially feasible strategies are summarized in a matrix in Appendix E. References are included at the of this appendix.

WUG:	**Municipal WUGs**	**Capital Cost:**	N/A
WMS Name:	**Municipal Conservation**	**Annual Cost** (During Amortization):	N/A
WMS Type:	Conservation	**Annual Cost** (After Amortization):	$606 per acre-foot $1.86 per 1,000 gal
WMS Yield:	2,523 – 3,922 acre-feet pear year		
WMS Status:	Recommended	**Implementation:**	2020 & 2030

Strategy Description

Water conservation is a demand management strategy that pro-actively decreases future water needs. Conservation facilitates more efficient use of existing water supplies and may delay the need to develop new water supplies. An expected level of conservation is included in the demand projections from the Texas Water Development Board (TWDB) due to the natural replacement of inefficient plumbing fixtures with low flow fixtures, as mandated under the Plumbing Code. The TWDB also considers expected reductions in municipal water use due to energy efficiency requirements for dish washers and clothes washers. Additional conservation savings can potentially be achieved in the region through the implementation of conservation best management practices (BMPs). These additional conservation measures were considered for all named municipal water user groups in Region F. These conservation measures were considered for County-Other WUGs only if the County-Other WUG had an identified water need. Based on this criterion, five County-Other WUGs were evaluated for municipal conservation. 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 individual water user group supersede the recommendations in this plan and are considered to meet regulatory requirements for consistency with this plan.

Public water suppliers with 3,300 connections or more are required to update and submit a Water Conservation Plan (WCP) to the Texas Commission on Environmental Quality (TCEQ) every five years. Per Title 30, Part 1, Chapter 288, Subchapter A, Rule 288.2 of the Texas Administrative Code, some conservation strategies are required to be included as part of this plan. Required strategies include a program for universal metering, measures to determine and control water loss, a program of continuing public education, and a non-promotional water rate structure. If a public water supplier serves over 5,000 people, they are additionally required to have a conservation-oriented rate structure and a program of leak detection, repair, and water loss accounting for the water transmission, delivery, and distribution system.

Screening of BMPs

To assess the appropriateness of conservation BMPs for Region F, 70 potential strategies were identified and a screening level evaluation was conducted. The screening evaluation was performed both for entities with populations less than 20,000 and entities with populations greater than 20,000. If an entity's population crossed the 20,000 person threshold, the larger city strategies and assumptions were applied to the appropriate decades. The evaluation considered six criteria:

- Cost
- Potential Water Savings
- Time to Implement
- Public Acceptance

- Technical Feasibility
- Staff Resources

Each criterion was scored from 1 to 5 with 5 being the most favorable. Scores for all the criteria were added to create a composite score. The strategies were then ranked and selected based on their composite score. These strategies were selected for purposes of estimating savings and costs for planning purposes only. Region F supports all of the 70 BMPs an individual water user group may choose to employ and all are considered to meet regulatory requirements for consistency with this plan.

Selected Strategies for Entities under 20,000

Based on the screening level evaluation and requirements from the TCEQ, the following strategies were selected for consideration for entities in Region F with less than 20,000 people:

- Education and Outreach
- Water Audits and Leak Repair
- Rate Structure
- Water Waste Ordinance

Selected Strategies for Entities over 20,000

Based on the screening level evaluation and requirements from the TCEQ, the following strategies were selected for consideration for entities in Region F with more than 20,000 people:

- Education and Outreach
- Water Audits and Leak Repair
- Rate Structure
- Water Waste Ordinance
- Landscape Ordinance
- Time of Day Watering Limit

These strategies were evaluated individually for each water user as appropriate (greater than or less than 20,000) and the water savings and costs are aggregated for the selected strategies with the exception of the water audit and leak repair strategy. This strategy was considered separately for each water user because the quantity of savings and associated cost was quite variable. For smaller cities, a robust leak detection and repair program may not be cost effective, especially if the savings are small. This strategy is discussed separately in this Appendix.

For the purposes of strategy evaluation, each household was assumed to have an average of three people. The following assumptions were used in the evaluation of the selected municipal conservation measure.

Education and Outreach

Local officials would offer water conservation education to schools and civic associations, include information in water bills, and provide pamphlets and other materials as appropriate. It was assumed that the education and outreach programs would be needed throughout the planning period in order to maintain the level of water savings.

Potential Savings Assumptions

- Education and Outreach has an assumed water savings of 5,000 gallons per household per year with 30% adoption rate (assumes that 30% of the customers respond to this measure by reducing water use).

Costs Assumptions

- Education and Outreach has a $2.75 per person per year with a maximum cost of $15,000 for entities with a population less than 20,000.
- Education and Outreach costs $1.80 per person per year for entities with a population greater 20,000.

Rate Structure

Local officials would implement an increasing block rate structure where the unit cost of water increases as consumption increases. Increasing block rate structures discourage the inefficient use or waste of water. Many cities already have a non-promotional rate structure. This strategy assumes that the entity adopts a higher level of a non-promotional rate structure.

Potential Savings Assumptions

- Increasing block rates is projected to save 6,000 gallons per household per year with a 10% adoption rate (assumes that 10% of the customers respond to this measure by reducing water use).

Costs Assumptions

- It is likely the entity would do any rate structure modifications themselves and incur no additional costs.

Water Waste Ordinance

Local officials would implement an ordinance prohibiting water waste such as watering of sidewalks and driveways or runoff into public streets. would treat about half of

Potential Savings Assumptions

- The assumed savings are 3,000 gallons per household per year with a 30% adoption rate for entities with a population less than 20,000 and 50% adoption rate for entities with a population greater than 20,000.

Costs Assumptions

- Annual enforcement costs $2,500 per year for entities with a population less than 20,000.
- Annual enforcement costs $10,000 per year for entities with a population greater than 20,000.

Landscape Ordinance (Entities with a population greater than 20,000)

Local officials would implement an ordinance that would promote residential plantings that conserve water for all new construction.

Potential Savings Assumptions

- Landscape ordinances would only apply to only new construction.
- Would include both residential and commercial properties.
- Assumed to save 1,000 gallons per increased number of households per year with 100% adoption rate.

Costs Assumptions

- Annual enforcement cost of $10,000 per year for entities with a population greater than 20,000.

Time of Day Watering Limit Landscape Ordinance (Entities greater than 20,000)

Local officials would implement an ordinance prohibiting outdoor watering during the hottest part of the day when most of that water is lost (wasted) through evaporation. Many ordinances limit outdoor watering to between 6 p.m. and 10 a.m. on a year round basis.

Potential Savings Assumptions

- Savings of 1,000 gallons per household per year.
- 75 percent of the population would realize these savings (the other 25 percent is either not irrigating or already abide by this practice).

Costs Assumptions

- Annual enforcement cost of $10,000 per year for entities with a population greater than 20,000.

Time to Implement

For planning purposes, it is assumed that all but one of the BMPs identified here could be adopted and in place by 2023, the TWDB cutoff date for listing the water volumes in the 2020 decade. The landscape ordinance, which is an identified for entities with a population of greater than 20,000, is anticipated to be in place after 2023 but before 2030.

Quantity, Reliability and Cost

Region F as a whole is expected to save around 3,700 acre-feet per year in 2020, increasing to nearly 5,500 acre-feet of savings by 2070. Individual entities are shown to save between 3 and 1,236 acre-feet by 2070. The larger cities show greater quantities of savings due to a larger number of people and additional BMPs. As a percentage, entities are shown to save between 1 and 4 percent of their projected municipal demand. Table C- 1 shows the potential savings from the enhanced conservation measures described above over the next 50 years.

Table C- 1
Estimated Savings from Municipal Conservation (acre-feet per year)

Water User Group	2020	2030	2040	2050	2060	2070
Airline Mobile Home Park	7	7	8	9	10	10
Andrews	45	55	96	111	129	150
Andrews County-Other	14	15	17	18	20	21
Ballinger	12	12	12	12	12	12
Bangs	8	8	8	8	8	8
Balmorhea	2	2	2	2	2	2
Barstow	1	1	1	1	1	1
Big Lake	10	12	12	13	13	14
Big Spring	131	138	140	139	139	139
Brady	18	18	19	19	19	19
Bronte	3	3	3	3	3	3
Brookesmith SUD	25	25	25	25	25	25
Brownwood	61	91	91	91	91	91
Coahoma	8	8	8	8	8	8
Coleman	15	15	15	15	15	15
Coleman County-Other	1	1	1	1	1	1
Coleman County SUD	10	10	10	10	10	10
Colorado City	16	18	18	18	18	19
Concho Rural WSC	20	21	22	23	24	24
Concho County-Other	3	3	3	3	3	3
Crockett County WCID	12	13	13	13	13	13

Water User Group	2020	2030	2040	2050	2060	2070
Crane	11	12	13	13	14	14
DADS SLC	1	1	1	1	1	1
Early	9	9	9	9	9	9
Ector County Utility District	60	84	94	125	137	149
Eden	4	4	4	4	4	4
El Dorado	6	6	6	6	6	6
Fort Stockton	36	39	42	44	46	48
Goodfellow AFB	8	9	9	10	10	11
Grandfalls	1	1	1	1	2	2
Greater Gardendale WSC	12	13	15	17	19	20
Greenwood Water	3	3	4	4	4	5
Iraan	4	4	5	5	5	5
Junction	8	8	8	8	8	8
Kermit	18	18	19	19	19	19
Loraine	2	2	2	2	2	2
Madera Valley WSC	5	5	5	6	6	6
Mason	7	7	7	7	7	7
McCamey	7	7	8	8	8	8
Menard	5	5	5	5	5	5
Mertzon	3	3	3	3	3	3
Midland	631	755	816	882	944	1,012
Miles	3	3	3	3	3	3
Mitchell County Utility	5	5	5	5	5	6
Millersview-Doole WSC	13	14	14	14	14	15
Monahans	23	24	25	26	27	27
North Runnels WSC	5	5	5	5	5	5
Odessa	568	680	752	829	905	990
Pecos	29	31	33	34	35	35
Pecos WCID	9	10	11	11	12	12
Pecos County Fresh Water	2	2	3	3	3	3
Rankin	3	3	3	3	3	3
Richland SUD	3	3	3	3	3	3
Robert Lee	3	3	3	3	3	3
Runnels County-Other	2	2	2	2	2	2
San Angelo	459	532	558	592	629	668
Snyder	41	47	51	55	59	93
Santa Anna	3	4	4	4	4	4
Scurry County-Other	20	22	24	26	28	30
Sonora	9	9	9	10	10	10
Southwest Sandhills WSC	20	22	24	26	28	30
Stanton	8	9	10	10	11	11
Sterling City	3	3	3	3	3	3
Tom Green County FWSD 3	3	4	4	4	5	5
Wickett	2	2	2	2	2	2
Wink	3	4	4	4	4	5
Winters	8	9	9	9	9	9
Zephyr WSC	13	13	13	13	13	13
Total	**2,523**	**2,936**	**3,177**	**3,420**	**3,648**	**3,922**

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.

The total average annual cost across Region F for this strategy is over $1.5 million in 2020 increasing to over $2.1 million by 2070. The average unit cost across the region is approximately $606 per acre foot in 2020 and $551 per acre foot in 2070. Unit costs vary considerably between water user groups depending on the population size. Table C- 2 below shows the projected annual cost of implementing the selected conservation strategies. Generally, conservation programs are funded through a city's annual operating budget and are not capitalized. However, in some cases, an entity may choose to capitalize a portion or all of their program. These kinds of costs are difficult to estimate for each individual entity due to the wide variety of factors at play. However, all capital expenditures for conservation are considered consistent with the Region F Plan.

Table C- 2
Annual Cost per Acre-Foot of Municipal Conservation Savings

Water User Group	2020	2030	2040	2050	2060	2070
Airline Mobile Home Park	$1,263	$1,235	$1,202	$1,175	$1,153	$1,134
Andrews	$952	$942	$706	$662	$625	$592
Andrews County-Other	$1,080	$1,061	$1,046	$960	$885	$821
Ballinger	$1,107	$1,101	$1,101	$1,101	$1,101	$1,101
Bangs	$1,221	$1,214	$1,214	$1,214	$1,214	$1,214
Balmorhea	$2,472	$2,369	$2,293	$2,247	$2,212	$2,189
Barstow	$3,068	$2,943	$2,864	$2,804	$2,765	$2,731
Big Lake	$1,139	$1,113	$1,101	$1,090	$1,084	$1,079
Big Spring	$557	$618	$618	$620	$620	$620
Brady	$988	$948	$944	$935	$932	$930
Bronte	$1,647	$1,647	$1,647	$1,647	$1,647	$1,647
Brookesmith SUD	$705	$689	$688	$689	$689	$688
Brownwood	$937	$731	$735	$735	$735	$735
Coahoma	$1,222	$1,208	$1,203	$1,203	$1,203	$1,203
Coleman	$1,065	$1,061	$1,061	$1,061	$1,061	$1,061
Coleman County-Other	$5,095	$5,161	$5,161	$5,161	$5,161	$5,161
Coleman County SUD	$1,144	$1,138	$1,138	$1,138	$1,138	$1,138
Colorado City	$1,054	$986	$967	$957	$948	$938
Concho Rural WSC	$894	$839	$800	$768	$740	$714
Concho County-Other	$1,836	$1,821	$1,821	$1,821	$1,821	$1,821
Crockett County WCID	$1,106	$1,089	$1,086	$1,084	$1,083	$1,083
Crane	$1,120	$1,104	$1,092	$1,083	$1,075	$1,070
DADS SLC	$4,116	$4,116	$4,116	$4,116	$4,116	$4,116
Early	$1,176	$1,170	$1,170	$1,170	$1,170	$1,170
Ector County Utility District	$292	$832	$795	$636	$615	$598
Eden	$1,541	$1,518	$1,518	$1,518	$1,518	$1,518
El Dorado	$1,283	$1,283	$1,283	$1,283	$1,283	$1,283
Fort Stockton	$484	$448	$414	$393	$377	$363
Goodfellow AFB	$1,222	$1,185	$1,168	$1,152	$1,137	$1,123
Grandfalls	$2,804	$2,694	$2,626	$2,572	$2,535	$2,509

Water User Group	2020	2030	2040	2050	2060	2070
Greater Gardendale WSC	$1,108	$1,082	$1,061	$1,035	$939	$859
Greenwood Water	$1,716	$1,654	$1,581	$1,521	$1,471	$1,430
Iraan	$1,501	$1,459	$1,423	$1,394	$1,371	$1,351
Junction	$1,206	$1,203	$1,203	$1,203	$1,203	$1,203
Kermit	$964	$952	$941	$931	$923	$916
Loraine	$2,138	$2,099	$2,075	$2,058	$2,047	$2,039
Madera Valley WSC	$1,425	$1,390	$1,365	$1,349	$1,338	$1,330
Mason	$1,278	$1,278	$1,278	$1,278	$1,278	$1,278
McCamey	$1,264	$1,236	$1,225	$1,214	$1,207	$1,203
Menard	$1,442	$1,442	$1,442	$1,442	$1,442	$1,442
Mertzon	$1,886	$1,875	$1,875	$1,875	$1,875	$1,875
Midland	$436	$432	$433	$432	$430	$428
Miles	$1,730	$1,614	$1,614	$1,614	$1,614	$1,614
Mitchell County Utility	$1,407	$1,371	$1,361	$1,355	$1,351	$1,347
Millersview-Doole WSC	$1,088	$1,081	$1,077	$1,074	$1,071	$1,068
Monahans	$763	$720	$692	$671	$656	$645
North Runnels WSC	$1,407	$1,388	$1,383	$1,380	$1,377	$1,375
Odessa	$440	$436	$435	$432	$430	$427
Pecos	$607	$567	$538	$520	$507	$498
Pecos WCID	$1,166	$1,147	$1,131	$1,118	$1,108	$1,099
Pecos County Fresh Water	$1,985	$1,909	$1,846	$1,793	$1,750	$1,716
Rankin	$1,848	$1,776	$1,746	$1,718	$1,701	$1,690
Richland SUD	$1,712	$1,679	$1,676	$1,668	$1,666	$1,665
Robert Lee	$1,672	$1,672	$1,672	$1,672	$1,672	$1,672
Runnels County-Other	$1,953	$1,927	$1,949	$1,965	$1,978	$1,988
San Angelo	$448	$451	$453	$450	$447	$444
Snyder	$957	$949	$945	$942	$938	$720
Santa Anna	$1,623	$1,606	$1,606	$1,606	$1,606	$1,606
Scurry County-Other	$863	$793	$736	$680	$632	$589
Sonora	$1,187	$1,168	$1,161	$1,156	$1,153	$1,152
Southwest Sandhills WSC	$863	$793	$736	$680	$632	$589
Stanton	$1,199	$1,171	$1,154	$1,140	$1,131	$1,124
Sterling City	$1,759	$1,728	$1,718	$1,718	$1,718	$1,718
Tom Green County FWSD 3	$1,616	$1,540	$1,504	$1,470	$1,438	$1,409
Wickett	$2,487	$2,396	$2,338	$2,296	$2,263	$2,240
Wink	$1,665	$1,597	$1,550	$1,505	$1,474	$1,449
Winters	$1,191	$1,183	$1,183	$1,183	$1,183	$1,183
Zephyr WSC	$1,091	$1,087	$1,087	$1,087	$1,087	$1,087
Total	***$606***	***$600***	***$589***	***$574***	***$563***	***$551***

Environmental Factors
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 to meet future demands.

Agricultural and Rural Impacts
Due to the limited availability of water, any municipal water user group may be competing with agricultural users for water. Reducing the demand on limited resources could have positive impacts on water availability for agriculture.

Impacts to Natural Resources and Key Parameters of Water Quality
No impacts to natural resources or key parameters of water quality were identified for this strategy since it reduces demands and does not actually develop new supplies.

Impacts on Other Water Resources and Management Strategies
This may reduce the demand for water from other water management strategies. It may also reduce available supplies for reuse strategies. However, if much of the water saved is associated with outdoor water use, this impact would be negligible.

Other Issues Affecting Feasibility
This strategy is based on generic procedures and may not accurately reflect the actual costs or water savings that can be achieved by an individual water user group. Site specific data will be required for a better assessment for the potential for conservation in Region F. Technical and financial assistance by the State may be required to implement this strategy.

WUG:	**Multiple Municipal WUGs**	**Capital Cost:**	$16,500,000
WMS Name:	**Water Audits and Leak Repairs**	**Annual Cost** (During Amortization):	$1,152 per acre-foot $3.53 per 1,000 gal
WMS Type:	Conservation		
WMS Yield:	330 – 339 acre-feet per year	**Annual Cost** (After Amortization):	N/A
WMS Status:	Recommended	**Implementation:**	2020 and 2040

Strategy Description

Water losses in distribution systems can account for significant portions of water demand in some cases. Water losses tend to be higher in systems with fewer users per mile of pipeline. Identifying and repairing leaks in water distribution and transmission lines can help reduce demands by reducing water waste throughout the system. As part of this strategy, local officials would perform a system wide water audit and create a program of leak detection and repair, including infrastructure replacement and repair as necessary. It was assumed that the leak detection and repair program is an ongoing activity to maintain the level of water loss reductions assumed below. Advanced Metering Infrastructure (AMI) is one potential way to enhance the ability of local officials to perform water audits. While no entities in Region F have expressed interest in developing AMI at this time, development of this infrastructure is considered consistent with the 2021 Region F Water Plan.

Potential Savings Assumptions

- If TWDB water loss data was available for the entity, it was utilized.
- This strategy was considered for all cities with greater than or equal to 15% losses.
- This strategy was considered for all Water Supply Corporations (WSCs) or Special Utility Districts (SUDs) with greater than or equal to 25% losses.
- It was assumed that 20% of an entity's losses could be recovered through a water audit and leak repair program.
- If no water loss data was available, this strategy was not considered for an entity.

Costs Assumptions

- Water Audits and Leak Repairs has $5,000 base cost plus $10 per person for entities with a population less than 20,000.
- Water Audits and Leak Repairs costs $10 per person for entities with a population greater than 20,000.
- Capital costs from the Water Audits and Leak Repairs strategy and applicable debt services are calculated every twenty years, i.e., the recommended debt service period for non-reservoir infrastructure from TWDB general costing guidelines.
- It is assumed that an entity would finance repairs every 20 years, resulting in a capital cost in years 2020, 2040, and 2060.

Quantity, Reliability and Cost

The estimated quantity of supply for this strategy is uncertain due to lack of detailed data. Savings range from 18 to 118 acre-feet for individual entities with a population under 20,000 throughout the planning period. No entities with a population over 20,000 met the required loss thresholds to be considered for this strategy. Across Region F, it is estimated that nearly 330 acre-feet of supply could be obtained through a water audits and leak repairs program in 2020. This increases to around 340 acre-feet of savings by 2070. Table C- 3 shows the estimated savings by water user group.

The reliability of this supply is considered to be low due to uncertainty associated with estimated savings and the extent to which this strategy relies on individual utilities to adopt a water audits and leak repairs program, which can be costly and time intensive, especially for smaller users.

Due to the relatively high costs of implementing this strategy, especially for smaller or rural water user groups, this strategy may not be feasible. The estimated cost is shown in Table C- 4.

Table C- 3
Water Audits and Leak Repairs Savings (acre-feet per year)

Water User Group	2020	2030	2040	2050	2060	2070
Brookesmith SUD	81	81	79	78	78	78
Coleman	59	58	57	57	57	57
Millersview-Doole WSC	65	66	65	66	67	68
Sonora	106	112	114	116	117	118
Zephyr WSC	19	19	18	18	18	18
Total	**330**	**336**	**333**	**335**	**337**	**339**

Table C- 4
Water Audits and Leak Repairs Cost Per Acre-Foot

Water User Group	2020 Capital Cost	2040 Capital Cost	2060 Capital Cost	Cost ($/ac-ft/yr)					
				2020	2030	2040	2050	2060	2070
Brookesmith SUD	$1,737,000	$1,756,500	$1,756,500	$1,509	$1,509	$1,564	$1,584	$1,584	$1,584
Coleman	$1,074,800	$1,085,600	$1,085,600	$1,282	$1,304	$1,340	$1,340	$1,340	$1,340
Millersview-Doole WSC	$965,800	$1,009,100	$1,040,100	$1,045	$1,030	$1,092	$1,076	$1,092	$1,076
Sonora	$679,900	$720,800	$734,800	$451	$427	$445	$437	$442	$438
Zephyr WSC	$944,700	$954,800	$954,800	$3,498	$3,498	$3,732	$3,732	$3,732	$3,732
Total	**$5,402,200**	**$5,526,800**	**$5,571,800**	**$1,152**	**$1,131**	**$1,168**	**$1,161**	**$1,163**	**$1,156**

Environmental Factors

Environmental issues associated with this strategy are expected to be minimal since it is only the repair of infrastructure currently in place. This strategy may have a positive impact on the environment by reducing the quantity of water needed to meet future demands.

Agricultural and Rural Impacts

Due to the limited availability of water, any municipal water user group may be competing with agricultural users for water. Reducing the demand on limited resources could have positive impacts on water availability for agriculture.

Impacts to Natural Resources and Key Parameters of Water Quality

Impacts to natural resources of key parameters of water quality are expected to be minimal since it only involves the repair of existing infrastructure and no new facilities.

Impacts on Other Water Resources and Management Strategies

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

Other Issues Affecting Feasibility

This strategy is based on generic procedures and may not accurately reflect the actual costs or water savings that can be achieved by an individual water user group. Site specific data will be required for a better assessment for the potential for conservation in Region F. Due to high costs, many smaller and rural water user groups may find this strategy to be unfeasible. Technical and financial assistance by the State may be required to implement this strategy.

WUG:	**Irrigation WUGs**	**Capital Cost:**	$45,800,000
WMS Name:	**Irrigation Conservation**	**Annual Cost** (During Amortization):	$21 per acre-foot $0.06 per 1,000 gal
WMS Type:	Conservation		
WMS Yield:	23,000 – 60,000 acre-feet per year	**Annual Cost** (After Amortization):	$0 per acre-foot $0 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description

Irrigation conservation is a strategy that proactively causes a decrease in future water needs by increasing the efficiency of current irrigation practices throughout the region. The adoption of irrigation conservation will help preserve the existing water resources for continued agriculture use and provide for other demands. Irrigation efficiency increases can be achieved by implementing a combination of strategies that lead to irrigation demand reductions. These may include but are not limited to:

- Changes in irrigation equipment
- Crop type changes and crop variety changes
- Conversion from irrigated to dry land farming
- Water loss reduction in irrigation canals

Region F recognizes that it has no authority to implement, enforce, or regulate irrigation conservation practices. These water conservation practices are intended to be guidelines. Water conservation strategies determined and implemented by the individual water user group superseded the recommendations in this plan and are considered to meet regulatory requirements for consistency with this plan.

Region F recommends improvements in the efficiency of irrigation equipment as an effective water conservation strategy for irrigation within Region F. This strategy replaces less efficient irrigation systems with new equipment types with higher efficiency ratings. These can include

- Furrow irrigation (FF) – 60 percent
- Surge flow (SF) – 75 percent
- Mid-elevation sprinkler application (MESA) – 78 percent
- Low-elevation sprinkler application (LESA) – 88 percent
- Low Energy Precision Application (LEPA) – 95 percent
- Subsurface Drip Irrigation (DRIP) – 97 percent

Any changes from a less efficient irrigation technology to a more efficient irrigation technology will save water and help the water user group reach a higher water use efficiency overall.

Crop type changes and crop variety changes

Certain crops are more water intensive than others. Shifting higher water use crops to lower water use crops could generate substantial water savings. Similarly, shifting long season to short season varieties is another water savings strategy. However, lower yields are typically associated with short season varieties (assuming the same irrigation technology). Additionally, advanced plant breeding has played a major role in increasing crop productivity and enhancing the efficiency of input such as irrigation. The adoption of drought resistant varieties with high water use efficiency can be a potential water conservation strategy.

Conversion from irrigated to dryland farming

Reducing the amount of irrigated acreage in Region F will reduce the amount of water applied to crops in the area. While converting from an irrigated to dryland cropping system may be a viable economic alternative for many Region F producers, only a limited number of dryland crops may be able to be produced profitably in the area. Region F also has an extensive dryland farming community. Further conversion may be limited.

Water loss reduction in irrigation canals

Many irrigation canals in Region F are open and unlined. This allows water to be lost both to evaporation and seepage into the ground. By lining these canals, seepage can be reduced and a larger portion of the water can go towards the beneficial use of crop irrigation. Converting these canals to a pipe system would save larger amounts of water by eliminating seepage and evaporation losses. However, the cost of doing this is likely prohibitive.

Assumptions

Depending on the method employed to achieve irrigation conservation, the composition of crops grown, sources of water, and method of delivery, will impact the potential savings and costs of this strategy. Since Region F does not have data on county-specific irrigation equipment employed by crop type, a general approach to irrigation conservation savings was taken. For planning purposes, a 5% increase in irrigation efficiency was assumed in decades 2020, 2030 and 2040. The efficiency level was held constant for decades 2050, 2060, and 2070. A maximum regional efficiency level of 85% was assumed. For planning purposes, it was assumed that on average, irrigation conservation would have a capital cost of $760 per acre-foot saved. This is based on the Water Conservation Implementation Task Force Water Conservation Best Management Practices cost per acre for irrigation equipment changes indexed to December 2018 dollars.

Time to Implement

For planning purposes, it was assumed that these strategies would be implemented in phases over the first 3 decades of the planning period (2020, 2030, and 2040).

Quantity, Reliability and Cost

This strategy is estimated to save nearly 23,000 acre-feet of supply in 2020 and around 60,000 acre-feet in 2070. Savings by county are presented in Table C- 5.

The reliability of this supply is considered to be medium due to lack of data and uncertainty involved in estimating the amount of supply that can be saved and the extent to which this strategy relies on the behavior of each individual irrigator.

The region wide capital cost and annual cost per acre-foot and per thousand gallons are shown in Table C-6. The annual cost per acre-foot was estimated at $31.01 during amortization. This will vary greatly depending on the individual circumstances and irrigation conservation strategy employed by each individual irrigator.

Table C- 5
Irrigation Conservation Savings (acre-feet per year)

County Name	2020	2030	2040	2050	2060	2070
Andrews	1,018	2,037	2,037	2,037	2,037	2,037
Borden	147	295	295	295	295	295
Brown	406	650	650	650	650	650
Coke	34	69	83	83	83	83
Coleman	23	47	47	47	47	47
Concho	245	490	539	539	539	539
Crane	0	0	0	0	0	0
Crockett	7	14	20	20	20	20
Ector	38	76	113	113	113	113
Glasscock	2,050	2,050	2,050	2,050	2,050	2,050
Howard	344	688	757	757	757	757
Irion	53	105	158	158	158	158
Kimble	133	266	319	319	319	319
Loving	0	0	0	0	0	0
Martin	1,825	3,649	5,474	5,474	5,474	5,474
Mason	248	497	745	745	745	745
McCulloch	116	232	349	349	349	349
Menard	183	366	549	549	549	549
Midland	905	1,811	2,716	2,716	2,716	2,716
Mitchell	256	256	256	256	256	256
Pecos	7,167	14,335	21,502	21,502	21,502	21,502
Reagan	1,102	2,203	3,305	3,305	3,305	3,305
Reeves	2,947	5,894	8,841	8,841	8,841	8,841
Runnels	155	311	373	373	373	373
Schleicher	91	109	109	109	109	109
Scurry	378	756	983	983	983	983
Sterling	45	90	135	135	135	135
Sutton	56	112	168	168	168	168
Tom Green	2,125	4,249	5,099	5,099	5,099	5,099
Upton	520	1,040	1,560	1,560	1,560	1,560
Ward	158	316	474	474	474	474
Winkler	175	351	526	526	526	526
Total	***22,950***	***43,364***	***60,232***	***60,232***	***60,232***	***60,232***

Table C- 6
Irrigation Conservation Costs

	2020	2030	2040	2050	2060	2070
Region F Capital Cost	$17,442,684	$15,511,646	$12,819,946	$0	$0	$0
Annual Cost per acre-foot	$20.89	$20.89	$12.93	$5.85	$0.00	$0.00
Annual Cost per 1,000 gal	$0.06	$0.06	$0.04	$0.02	$0.00	$0.00

Environmental Factors

Most of the areas in Region F with significant irrigation needs rely on groundwater for irrigation. In areas where conserved groundwater finds expression as springs or base flow, conservation will have a positive impact. However, in most cases irrigation demand exceeds available supply even with implementation of advanced irrigation technologies. This strategy is expected to have a minimal impact on the environment, either positive or negative.

Agricultural and Rural Impacts

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. Water conservation measures identified as part of this strategy could have positive or negative economic impacts to agricultural communities, depending on the selected BMPs. However, the BMPs selected by the individual producer would have to be economically feasible or the producer would not implement the BMP. No agricultural acreage is expected to be taken out of production with this strategy. Some producers may choose to change crop types or convert to dry land farming, but total acreage is not expected to decrease. For purposes of this analysis, it is assumed that up to 3 percent of the total irrigated acreage is converted to dryland farming in counties with an irrigation water shortage.

Impacts to Natural Resources and Key Parameters of Water Quality

In areas where conserved water can be used to enhance the environment (increase spring flow, base flow or streamflow), irrigation conservation will positively impact natural resources and water quality. However, in areas where the demand already exceeds available supply, impacts will be minimal to none.

Impacts on Other Water Resources and Management Strategies

This may reduce the demand for water from other water management strategies involving irrigation water user groups.

Other Issues Affecting Feasibility

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

The economic viability of irrigation conservation is critical to its implementation. Changing crop prices can impact the ability of a producer to implement conservation practices while maintaining profitability.

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 the lack of current data for these two items.

WUG:	**Mining WUGs**	**Capital Cost:**	$111,6600,000
WMS Name:	**Mining Conservation (Recycling)**	**Annual Cost** (During Amortization):	$655 per acre-foot $2.01 per 1,000 gal
WMS Type:	Conservation		
WMS Yield:	1,493 – 5,494 acre-feet per year	**Annual Cost** (After Amortization):	$0 per acre-foot $0 per 1,000 gal
WMS Status:	Recommended	Implementation:	2020

Strategy Description

Mining conservation or recycling is a demand management strategy that decreases future water needs by treating and reusing water used in mining operations. Mining conservation and recycling is possible for both oil and gas mining as well as sand and gravel mining. Mining recycling and conservation was considered for all mining operations in Region F.

The majority of mining demand in Region F is driven by the oil and gas boom in the Permian Basin which underlies most of Region F. Therefore, much of this discussion is focused on recycling by the oil and gas industry in the Permian Basin.

According to the September 2012 *Oil & Gas Water Use in Texas: Update to the 2011 Mining Water Use Report* done by the Bureau of Economic Geology[1], very little water was reused/recycled as of 2011 in the Permian Basin, compared to other areas in the state. However, significantly more brackish water is used in the region.

Play / Region	Type	Current (2011) %
Permian Far West	Recycled/reused	0%
	Brackish	80%
	Fresh	**20%**
Permian Midland	Recycled/reused	2%
	Brackish	30%
	Fresh	**68%**
Anadarko Basin	Recycled/reused	20%
	Brackish	30%
	Fresh	**50%**
Barnett Shale	Recycled/reused	5%
	Brackish	3%
	Fresh	**92%**
Eagle Ford Shale	Recycled/reused	0%
	Brackish	20%
	Fresh	**80%**
East Texas Basin	Recycled/reused	5%
	Brackish	0%
	Fresh	**95%**

The amount of water than can be reused/recycled is dependent on the amount of flowback. Flowback refers to the water based solution that flows back to the surface during and after the completion of the hydraulic fracturing. The fluid contains clays, chemical additives, dissolved metal ions and total dissolved solids (TDS). The volume of flowback varies across plays but is generally between 20-40% in the Permian Basin. For planning purposes, it is assumed that 20% of water used for mining purposes will be available through flowback and can be reused/recycled.

The flowback water is of low quality and requires treatment or must be blended with fresh water. The process used to recycle/reuse water can employ either conventional treatment or advanced treatment technologies. Conventional treatment technologies include flocculation, coagulation, sedimentation, filtration and lime softening. Advanced treatment technologies include reverse osmosis membranes, thermal distillation, evaporation, and/or crystallization processes and often use more energy than conventional treatment. It is assumed that 30% of the flowback water will be lost during the treatment process.

As competition for water grows, and water resources become more scarce, individual mining operators may find it more attractive to implement a reuse/recycling strategy. Reusing/recycling flow back water may also reduce brine disposal costs for the operator to help offset the cost of treatment and transportation. Ultimately, the decision to implement this strategy will be based on the economics of each individual well field. If brackish water is readily available and not in demand by other users, it may be more attractive to use brackish supplies. For planning purposes, it is assumed that adoption rates of this strategy will depend on the county mining water supply availability. In this case, the following assumptions are made:

- If there is a mining water shortage, the county will adopt this strategy 50% of the time
- If there is no mining shortage, the county will adopt this strategy 30% of the time
- If there is a surplus of mining water, the county will adopt this strategy 10% of the time

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. Any water management strategies that reduce the demand for mining water are considered to meet regulatory requirements for consistency with this plan.

Quantity, Reliability and Cost

The estimated quantity available from this strategy is around 5,500 acre-feet in 2020 and nearly 1,500 acre-feet in 2070 when demands have decreased significantly. Estimated savings by county are shown in the table below. The actual quantity of water available from this strategy will vary. Since this strategy is largely dependent on each individual operator and economic factors specific to each mining operation, it is difficult to estimate the actual quantity of water that could be made available through this strategy.

The reliability of this supply is considered to be low because of the uncertainty involved in the potential for savings and the degree to which participation of mining companies is needed to realize savings.

Table C- 7
Mining Conservation (Recycling) Supplies (acre feet per year)

Mining Conservation (Recycling) Supplies						
County	2020	2030	2040	2050	2060	2070
Andrews	277	260	222	176	135	104
Borden	29	39	33	21	10	5
Brown	66	66	67	67	66	66
Coke	20	20	18	16	14	12
Coleman	5	4	4	4	3	3
Concho	20	20	18	15	13	12
Crane	26	35	36	29	22	17
Crockett	315	315	43	24	7	3
Ector	28	30	27	22	18	15
Glasscock	248	248	189	134	88	63
Howard	143	143	101	59	25	13
Irion	322	322	231	28	14	7
Kimble	1	1	1	1	1	1
Loving	525	525	462	378	301	238
Martin	302	302	227	49	27	14
Mason	43	40	30	24	19	16
McCulloch	375	351	279	236	203	176
Menard	46	45	40	35	30	26
Midland	445	445	344	231	46	32
Mitchell	25	31	27	21	16	12
Pecos	539	539	539	434	67	52
Reagan	445	445	323	62	24	8
Reeves	882	882	847	693	546	434
Runnels	11	11	10	9	8	7
Schleicher	26	31	24	16	10	6

Mining Conservation (Recycling) Supplies						
County	2020	2030	2040	2050	2060	2070
Scurry	20	32	34	25	17	12
Sterling	33	40	34	22	11	6
Sutton	19	30	32	24	16	11
Tom Green	44	45	47	47	48	49
Upton	101	101	80	53	32	22
Ward	80	80	71	55	38	25
Winkler	33	49	42	32	22	16
Total	***5,494***	***5,527***	***4,482***	***3,042***	***1,897***	***1,483***

The costs associated with this strategy vary based on the amount of flowback, the geographic location of the flowback, the amount of treatment required and transportation distances required. For the purposes of this plan, a $20,000 per acre-foot capital investment for the maximum amount of water saved over the planning period was assumed. This investment was amortized over 20 years. However, individual operators may plan to invest the capital with no debt service and would likely implement capital improvements at the level needed for each decade. The costs in Table C- 8 assume a single capital investment beginning in 2020. A 10 cent per barrel ($775 per acre-foot) annual savings from not having to dispose of the brine was assumed for the decades with capital cost. If an operator continued to employ this strategy in the later decades, they may realize a net savings over treating and disposing of the brine. However, for planning purposes, the annual cost was assumed to be $0 after the capital investment is paid off.

Table C- 8
Mining Conservation (Recycling) Costs

County	Capital Cost	Annual Cost Per Acre-Foot					
		2020	2030	2040	2050	2060	2070
Andrews	$5,540,000	$632	$724	$0	$0	$0	$0
Borden	$780,000	$1,117	$632	$0	$0	$0	$0
Brown	$1,340,000	$654	$654	$0	$0	$0	$0
Coke	$400,000	$632	$632	$0	$0	$0	$0
Coleman	$100,000	$632	$984	$0	$0	$0	$0
Concho	$400,000	$632	$632	$0	$0	$0	$0
Crane	$720,000	$1,173	$672	$0	$0	$0	$0
Crockett	$6,300,000	$632	$632	$0	$0	$0	$0
Ector	$600,000	$733	$632	$0	$0	$0	$0
Glasscock	$4,960,000	$632	$632	$0	$0	$0	$0
Howard	$2,860,000	$632	$632	$0	$0	$0	$0
Irion	$6,440,000	$632	$632	$0	$0	$0	$0
Kimble	$20,000	$632	$632	$0	$0	$0	$0
Loving	$10,500,000	$632	$632	$0	$0	$0	$0
Martin	$6,040,000	$632	$632	$0	$0	$0	$0
Mason	$860,000	$632	$738	$0	$0	$0	$0
McCulloch	$7,500,000	$632	$728	$0	$0	$0	$0
Menard	$920,000	$632	$663	$0	$0	$0	$0
Midland	$8,900,000	$632	$632	$0	$0	$0	$0
Mitchell	$620,000	$970	$632	$0	$0	$0	$0
Pecos	$10,780,000	$632	$632	$0	$0	$0	$0
Reagan	$8,900,000	$632	$632	$0	$0	$0	$0
Reeves	$17,640,000	$632	$632	$0	$0	$0	$0
Runnels	$220,000	$632	$632	$0	$0	$0	$0

County	Capital Cost	Annual Cost Per Acre-Foot					
		2020	2030	2040	2050	2060	2070
Schleicher	$620,000	$903	$632	$0	$0	$0	$0
Scurry	$680,000	$1,617	$720	$0	$0	$0	$0
Sterling	$800,000	$931	$632	$0	$0	$0	$0
Sutton	$640,000	$1,595	$726	$0	$0	$0	$0
Tom Green	$980,000	$792	$757	$0	$0	$0	$0
Upton	$2,020,000	$632	$632	$0	$0	$0	$0
Ward	$1,600,000	$632	$632	$0	$0	$0	$0
Winkler	$980,000	$1,315	$632	$0	$0	$0	$0
Total	**$111,660,000**	**$655**	**$646**	**$0**	**$0**	**$0**	**$0**

Environmental Factors

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 to meet future demands and reducing the waste disposal of flowback water.

Agricultural and Rural Impacts

Due to the limited availability of water, any mining operation may be competing with agricultural and rural users for water. Reducing the demand on limited resources could have positive impacts on water availability for agriculture and rural users.

Impacts to Natural Resources and Key Parameters of Water Quality

No impacts to natural resources or key parameters of water quality were identified for this strategy since it reduces demands and does not develop new supplies. Positive impacts due to reduced wastewater discharges, which were likely disposed of through deep well injection, are possible.

Impacts on Other Water Resources and Management Strategies

This may reduce the demand for water from other water management strategies involving mining water user groups.

Other Issues Affecting Feasibility

Since this strategy relies largely on the behavior of each individual mining company, it is difficult to quantify the expected level of savings. This strategy is based on generic procedures and may not accurately reflect the actual costs or water savings that can be achieved by an individual mining operator. Site specific data will be required for a better assessment for the potential for mining conservation (recycling/reuse) in Region F.

WUG:	**Multiple**	**Capital Cost:**	$0
WMS Name:	**Subordination of Downstream Water Rights**	**Annual Cost** (During Amortization):	N/A
WMS Type:	Subordination	**Annual Cost** (After Amortization):	N/A
WMS Yield:	43,597 – 42,993 acre-feet per year	**Implementation:**	2020
WMS Status:	Recommended		

Strategy Description

The TWDB requires the use of the TCEQ Water Availability Models (WAM) for regional water planning. Most of the water rights in Region F are in the Colorado River Basin. Chapter 3 discusses the use of the WAM models for water supply estimates and the impacts to the available supplies in the Upper Colorado River Basin. The Colorado WAM assumes that senior lower basin water rights would continuously make priority calls on Region F water rights. This assumption is not in line with the historical operation of the Colorado River Basin and likely underestimates the amount of surface water supplies available in Region F.

Although the Colorado WAM does not give an accurate assessment of water supplies based on the way the basin has historically been operated, TWDB requires the regional water planning groups to use the WAM to determine supplies. Therefore, several sources in Region F have no supply by definition, even though in practice their supply may be greater than indicated by the WAM. According to the WAM, the Cities of Ballinger, Brady, Coleman, Junction, and Winters and their customers have no water supply. The Morgan Creek power plant has no supply to generate power. The Cities of Big Spring, Bronte, Coahoma, Midland, Miles, Odessa, Robert Lee, San Angelo, Snyder and Stanton do not have sufficient water to meet current demands. 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 magnitude of 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, coordination with the Lower Colorado Regional Water Planning Group (Region K) was conducted. For the development of the 2006 regional water plans, a joint modeling effort was conducted with Region K and an agreement was reached for planning purposes. In subsequent planning cycles, Region K developed its own version of this subordination strategy, called the “cutoff model” that modified the priority dates for all water rights above Lakes Ivie and Brownwood. Region F has adopted the premise of the Region K’s cutoff model with only minor variations for purposes of the subordination strategy in this plan.

Figure C- 2 shows the divide between the upper and lower basin and depict which reservoirs were included in the subordination modeling. For the 2021 Region F Plan, the Region K model developed for LCRA with hydrology through December 2016 was used for subordination modeling.

The Region F model differs from the Region K model by including the City of Junction's run-of-river rights in the upper basin. Other refinements to the subordination modeling include modifications for the Pecan Bayou. To better reflect reality, an assumption was made that the upstream reservoirs hold inflows that would have been passed to Lake Brownwood under strict priority analysis if Lake Brownwood is above 50 percent of the conservation capacity. This scenario provides additional supplies in the upper watershed while allowing Lake Brownwood to make priority calls at certain times during drought, i.e., when Lake Brownwood is below 50 percent of the conservation pool.

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

The subordination strategy modeling was conducted for regional water planning purposes only. By adopting this strategy, the Region F Water Planning Group does not imply that the water rights holders 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.

For three water suppliers, additional infrastructure was identified to fully utilize the subordinated supplies. These entities include the Cities of Odessa, Junction and Big Spring. Big Spring requires expansion of its water treatment facilities to meet its future demands. Odessa is implementing advanced treatment of the subordinated supplies to improve water quality, and Junction requires infrastructure improvements to its intake for quantity and quality concerns. Each of these improvements is discussed under Expanded Use of Existing Water Supplies in this appendix. The associated costs are shown in Appendix D.

Quantity, Reliability and Cost

Approximately 43,600 acre-feet of additional supply is available through this strategy in 2020 and around 43,000 acre-feet in 2070. Figure C- 1 compares overall Region F surface water supplies with and without the subordination strategy over the planning period. Table C-9 compares the 2020 and 2070 Region F water supply sources with and without subordination.

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

Figure C- 1
Comparison of Region F Surface Water Supplies with and without Subordination

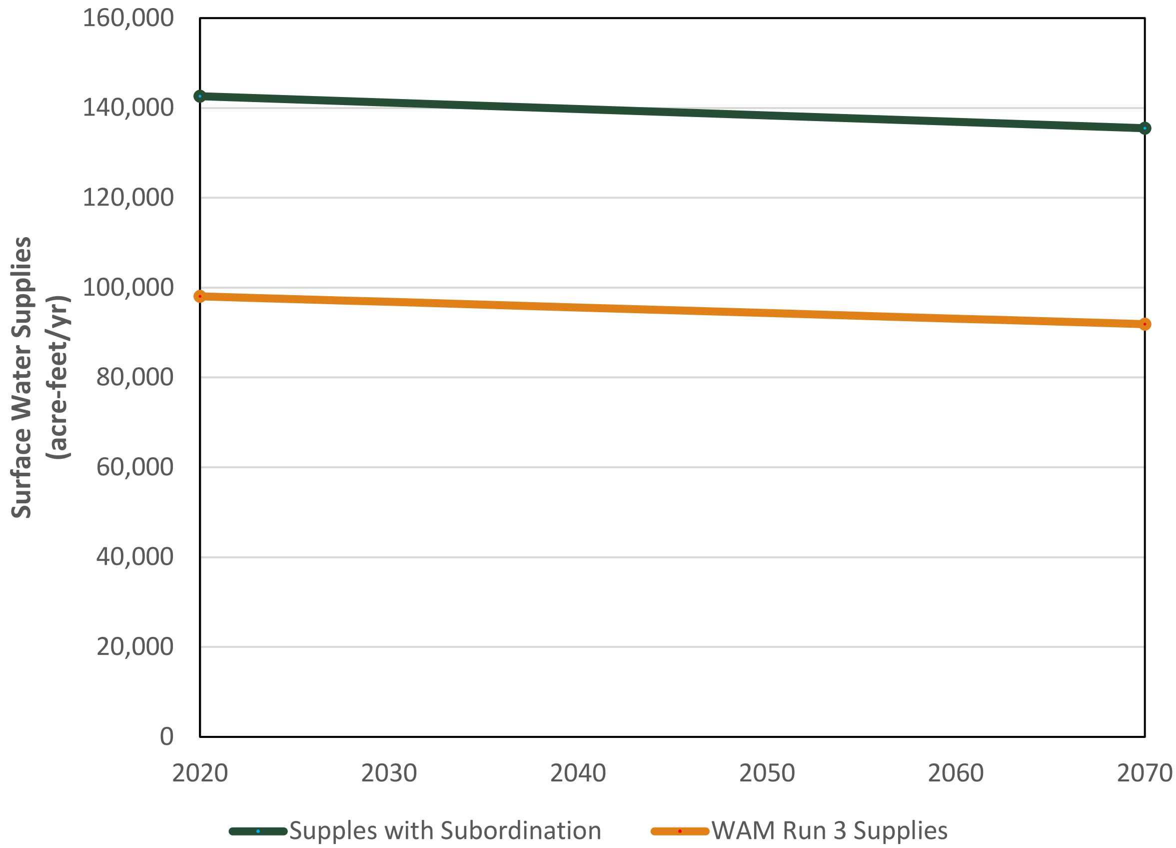

Figure C- 2
Subordination Strategy Map

Table C- 9
Region F Surface Water Supplies with and without Subordination

Reservoir Name	2020 Supply WAM Run 3	2020 Supply Subordination	2070 Supply WAM Run 3	2070 Supply Subordination
Lake Colorado City	0	1800	0	1550
Champion Creek Reservoir	0	1,170	0	1,100
Colorado City/Champion System	0	2,970	0	2,650
Lake Coleman	0	1,792	0	1,692
Hords Creek Lake	0	180	0	146
Coleman System	0	1,972	0	1,838
O. C. Fisher Lake[a]	0	0	0	0
Twin Buttes Reservoir[a]	0	1,670	0	1,195
Lake Nasworthy	0	See Twin Buttes	0	See Twin Buttes
San Angelo System	0	1,670	0	1,195
Lake J. B. Thomas (CRMWD System)	0	3,725	0	3,610
E.V. Spence Reservoir (CRMWD System)	0	21,575	0	21,355
O.H. Ivie Reservoir (CRMWD System)	14,285	15,193	11,709	13,067
O.H. Ivie Reservoir (Non-System)	16,065	17,147	13,491	15,053
O.H. Ivie Reservoir Total	30,350	32,340	25,200	28,120
CRMWD System Total (Thomas, Spence & Ivie)	14,285	40,493	11,709	38,032
Lake Ballinger / Lake Moonen	0	785	0	770
Lake Balmorhea	18,800	18,800	18,800	18,800
Brady Creek Reservoir	0	1,950	0	1,750
Lake Brownwood	18,900	24,340	18,200	23,770
Mountain Creek Reservoir	0	70	0	70
Oak Creek Reservoir	0	1,025	0	840
Red Bluff Reservoir	30,050	30,050	29,700	29,700
Lake Winters/ New Lake Winters	0	175	0	175
Junction ROR	0	250	0	250
TOTAL	***98,100***	***141,697***	***91,900***	***134,893***
Increase with Subordination	***43,597***		***42,993***	

[a] Supplies are less than theoretically available from the subordination model.

Environmental Factors

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

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

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

Agricultural and Rural Impacts

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 or have water quality concerns. This strategy reserves water for these rural communities, which provides a positive impact.

Three Region F reservoirs included in the subordination strategy are permitted to 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 1,670 acre-feet per year in 2020. Historical use of this reservoir system has been much higher. Therefore, even with subordination there is not sufficient water to meet both the needs of the City of San Angelo and irrigation demands. Subordination has no impact on irrigation users of Twin Buttes/Lake Nasworthy.

The reliable supply from Lake Brownwood does increase with subordination but the entire supply is not currently used. Subordination does not have an impact on rural or agricultural users of Lake Brownwood. It may have a positive impact with greater supplies. However, the occurrence of drought conditions more severe than those encountered during the historical modeling period could impact supplies available from this source.

Impacts to Natural Resources and Key Parameters of Water Quality

The subordination modeling approaches the actual operation of the upper basin. There is no change in operation or distinct action taken under this strategy. Therefore, impacts to natural resources and water quality are expected to be minimal.

Impacts on Other Water Resources and Management Strategies

All other strategies for this Plan are based on water supplies with the subordination strategy in place. The amount of water needed from some of these strategies may be higher without the subordination strategy and/or the timing for implementation may need to be sooner. Other strategies may be indirectly impacted. Changes to the assumptions made in the subordination strategy may have a significant impact on the amount of water needed from these strategies.

Other Issues Affecting Feasibility

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 consider 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.

APPENDIX C

C.2 REUSE

WUG:	**Bangs**	**Capital Cost:**	$581,000
WMS Name:	**Direct Reuse**	**Annual Cost** (During Amortization):	$1,816 per acre-foot $5.57 per 1,000 gal
WMS Type:	Direct Non-Potable Reuse (Type I)		
WMS Yield:	25 acre-feet pear year	**Annual Cost** (After Amortization):	$176 per acre-foot $0.54 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description

Direct non-potable reuse (Type 1) has been identified as a feasible solution for the City of Bangs. The City plans on using reuse for irrigation of public parks. This evaluation is based on a generalized direct non-potable reuse strategy developed for the Region F plan. This strategy assumes that the current WWTP will need to construct the necessary improvements in order to bring a portion of the plant's effluent to Type 1 standards. If the plant's effluent already meets Type 1 standards than the cost will be significantly reduced. The strategy also assumes that along with the WWTP improvements, two miles of 6-inch transmission pipeline will need to be constructed in order to convey the reuse water from the plant to the public parks. No additional pump stations are assumed. 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

For the City of Bangs, it is estimated that reuse could provide as much as 22,300 gallons per day of additional irrigation supply, or 25 acre-feet per year. Currently Bangs purchases all of its water from the BCWID#1. By reusing the water generated by the City of Bangs Wastewater Treatment Facility, the City will not need to rely as heavily on external water supplies. This strategy would supply an extremely reliable water source for irrigation purposes. The capital cost for this strategy is estimated at $581,000. This cost could be significantly less if no wastewater treatment plant improvements are needed.

Environmental Factors

The City of Bangs currently discharges its wastewater into an unnamed tributary that ultimately flows into the Colorado River. Reuse would result in a reduction in the quantity of water discharged by the City. Because of the relatively small amount of flow reduction associated with this reuse project, any possible impacts are not expected to be significant.

Agricultural and Rural Impacts

None identified.

Impacts to Natural Resources and Key Parameters of Water Quality

Reuse would result in a reduction in the quantity of water that is ultimately introduced to the Colorado River. This minimal reduction in water supply is not expected to significantly impact downstream WUGs that rely on the Colorado River for their own water needs.

Impacts on Other Water Resources and Management Strategies

None identified.

Other Issues Affecting Feasibility

None identified.

WUG:	**Menard**	**Capital Cost:**	$696,500
WMS Name:	**Direct Non-Potable Reuse**	**Annual Cost** (During Amortization):	$820 per acre-foot $2.52 per 1,000 gal
WMS Type:	Direct Non-Potable Reuse (Type I)		
WMS Yield:	67 acre-feet per year	**Annual Cost** (After Amortization):	$88 per acre-foot $0.27 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description

Direct non-potable reuse (Type 1) has been identified as a feasible solution for the City of Menard. The City plans on using the reuse for the irrigation of city farms. This evaluation is based on a generalized direct non-potable reuse strategy developed for the Region F plan. This strategy assumes that the current WWTP will need to construct the necessary improvements in order to bring a portion of the plant's effluent to Type 1 standards. If the plant's effluent already meets Type 1 standards, then the cost will be significantly reduced. The strategy also assumes that along with the WWTP improvements, two miles of 6-inch transmission pipeline will need to be constructed in order to convey the reuse water from the plant to the city farms. 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

For the City of Menard, it is estimated that reuse could provide as much as 67 acre-feet per year of additional irrigation supply, or 0.12 MGD. Currently the water users in Menard obtain their water from wells located along the banks of the San Saba River that produce water from the San Saba Alluvium. Reduced flows in the river due to drought, therefore, have a severe impact on the availability of water. Reuse will introduce a much more reliable water source for the irrigation of the city farms.

Environmental Factors

The City of Menard currently discharges its wastewater into the San Saba River. Reuse would result in a reduction in the quantity of water discharged by the City. 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 Impacts

The City of Menard obtains water from wells located along the banks of the San Saba River that produce water from the San Saba Alluvium. To the extent that implementing this strategy reduces the amount of water extracted from these wells to service Menard's needs, it may improve the reliability of this water source for agricultural and rural users. Also, the water will be used for agricultural purposes, providing a positive impact to agriculture.

Impacts to Natural Resources and Key Parameters of Water Quality

It is assumed that the quality of the treated effluent to the San Saba River will not change significantly. Therefore, minimal impacts to the San Saba's overall water quality are expected.

Impacts on Other Water Resources and Management Strategies

None identified.

Other Issues Affecting Feasibility

None identified.

WUG:	**Mitchell County, Steam Electric Power**	**Capital Cost:**	$8,642,000
WMS Name:	**Reuse Sales from Colorado City**	**Annual Cost** (During Amortization):	$1,428 per acre-foot $4.38 per 1,000 gal
WMS Type:	Direct Non-Potable Reuse (Type II)		
WMS Yield:	500 acre-feet per year	**Annual Cost** (After Amortization):	$212 per acre-foot $0.65 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description

Colorado City plans to sell most, if not all, of their wastewater effluent to FGE Power for use as cooling water at a new power plant being built in Mitchell County. This water management strategy is a generalized direct non-potable reuse strategy developed for the Region F Plan that assumes all of Colorado City's wastewater is sold to the steam electric power industry in Mitchell County. This strategy assumes that the current WWTP will need no improvements in order to bring a portion of the plant's effluent to Type II standards. If the plant's effluent does not already meet Type II standards, then the cost will be greater than shown in this plan. The strategy assumes ten miles of 10-inch transmission pipeline will need to be constructed in order to convey the reuse water from the plant to the FGE power plant. 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

This strategy is based on an additional reuse supply of 500 acre-feet per year of Type II non-potable reuse supply for sales to the steam electric power industry in Mitchell County. This supply is considered to be very reliable. The cost of this strategy is estimated at $8,462,000 but may be different depending on site specific situations.

Environmental Factors

This strategy assumes that 500 acre-feet of reuse supply will be used for the steam electric power industry. This may reduce the demand on other water sources and decrease the environmental impacts of those uses.

Since Colorado City does not currently discharge their wastewater into a water body, streamflows will not be impacted.

Agricultural and Rural Impacts

None identified.

Impacts to Natural Resources and Key Parameters of Water Quality

Reuse would result in a reduction in the quantity of water discharged by the City. It is not expected to adversely impact natural resources or key parameters of water quality.

Impacts on Other Water Resources and Management Strategies

To the extent that this supply reduces the demand on other water resources that the FGE power plant in Mitchell County utilizes, this strategy may reduce competition for water from those sources.

Other Issues Affecting Feasibility

None identified.

WUG:	**Pecos**	**Capital Cost:**	$29,541,000
WMS Name:	**Direct Potable Reuse**	**Annual Cost** (During Amortization):	$4,691 per acre-foot $14.39 per 1,000 gal
WMS Type:	Direct Potable Reuse	**Annual Cost** (After Amortization):	$2,443 per acre-foot $7.50 per 1,000 gal
WMS Yield:	925 acre-feet per year	**Implementation:**	2030
WMS Status:	Recommended		

Strategy Description

Pecos City is considering a direct potable reuse project that would be triggered if population and demand continues to grow rapidly around the City. Depending on the changing conditions in Pecos City, the size and timing may change. For planning purposes, it was assumed that a 2.2 MGD advanced treatment facility would be needed to treat wastewater to a potable water quality. This advanced treatment may include microfiltration and/or reverse osmosis. A 12-inch two-mile transmission line was assumed to connect the wastewater treatment facility to the advanced treatment facility. Concentrate from the treatment facility was assumed to be disposed of in a local water body, such as the Pecos River. If a suitable discharge location cannot be found, injection wells may be needed. The evaluation for this strategy is based on a generalized direct potable reuse strategy developed for the Region F plan. Site specific evaluations will be conducted as a part of the permitting process.

Quantity, Reliability and Cost

For Pecos City, it is estimated that a 2.2 MGD direct potable reuse plant could provide as much as 925 acre-feet per year, assuming 25 percent losses due to advanced treatment. Currently, Pecos City obtains all of its water supply from groundwater wells. By reusing the water generated by the City's wastewater treatment facility, the City will not rely as heavily on groundwater supplies. This strategy would supply a very reliable water source for additional potable water. Capital costs for this strategy are estimated at $29.6 million.

Environmental Factors

Pecos City currently discharges its wastewater that ultimately flows into the Pecos River. 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 environmental impacts on the receiving stream will be required in the permitting process.

It is expected that construction of the advanced water treatment facility and transmission infrastructure should have minimal environmental impact.

Agricultural and Rural Impacts

No impacts are expected.

Impacts to Natural Resources and Key Parameters of Water Quality

Pending the water quality of the discharge stream to the Pecos River, this strategy could increase the levels of TDS and other key water quality parameters to the stream. This would be evaluated during permitting for the project.

Impacts on Other Water Resources and Management Strategies

None identified.

Other Issues Affecting Feasibility

Direct potable reuse plants may face public opposition. They can also be challenging to permit and operate. Further studies may be needed to evaluate the long-term impacts from multiple cycles of direct reuse.

WUG:	**Pecos**	**Capital Cost:**	$34,456,000
WMS Name:	**Potable Reuse with Aquifer Storage and Recovery (ASR)**	**Annual Cost** (During Amortization):	$6,790 per acre-foot $20.83 per 1,000 gal
WMS Type:	Indirect Potable Reuse	**Annual Cost** (After Amortization):	$3,301 per acre-foot $10.13 per 1,000 gal
WMS Yield:	695 acre-feet per year	**Implementation:**	NA
WMS Status:	Alternative		

Strategy Description

Population and demands in Pecos City are rapidly changing; however, if water supply is not needed for immediate demands, treated water could be stored in an underlying aquifer for later recovery. As an alternative to direct potable reuse, Pecos City is considering an indirect potable reuse strategy in conjunction with aquifer storage and recovery (ASR) in a nearby aquifer, such as the Dockum or Pecos Valley aquifers. This strategy is a generalized indirect potable reuse project combined with an ASR well field. Before construction, extensive studies will need to be conducted to determine the technical and economic feasibility of ASR in this area.

For planning purposes, it was assumed that a 2.2 MGD advanced treatment facility would be needed to treat wastewater to a suitable water quality before injection. Concentrate from the facility was assumed to be disposed of in a local water body, such as the Pecos River. If a suitable discharge location cannot be found, injection wells may be needed to dispose of the concentrate.

This strategy also includes a well field consisting of 6 injection wells for storage and recovery in a nearby aquifer, as well as associated piping and land acquisition.

Quantity, Reliability and Cost

For planning purposes, it is estimated that a 2.2 MGD direct potable reuse plant could provide as much as 925 acre-feet per year of treated water. It was assumed that this entire supply could be injected into an underlying aquifer at a similar rate as local pumping wells are withdrawing water. Recovery rates from an ASR project vary depending various factors, such as the hydrogeologic characteristics of the aquifer, storage time, pumping rate, etc. As a conservative estimate for this strategy, it was assumed that the City would be able to recover 75 percent of the water that they inject into an aquifer, which equates to 695 acre-feet per year.

By reusing, storing, and recovering the water generated by the City’s wastewater treatment facility, the City may have additional supplies to accommodate higher demands. Depending upon the recovery rates from the aquifer, this strategy would supply a moderately reliable water source for additional potable water. Capital costs for this strategy are estimated at $33.0 million.

Environmental Factors

Pecos City currently discharges its wastewater that ultimately flows into the Pecos River. 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 and storage would result in a reduction in the quantity of water discharged by the City.

Environmental impacts associated with the construction and operation of the advanced water treatment facility, transmission infrastructure, and ASR well field are considered to be minimal and could be mitigated.

Agricultural and Rural Impacts

No impacts are expected.

Impacts to Natural Resources and Key Parameters of Water Quality

Pending the water quality of the concentrate discharge stream to the Pecos River, this strategy could increase the levels of TDS and other key water quality parameters to the stream. This would be evaluated during permitting for the project.

Water will be treated to a level suitable for the aquifer before injection, so impacts on water quality within the aquifer are expected to be minimal to positive. Recovered water quality is dependent upon the quality of the groundwater within the aquifer and may require additional treatment before potable use.

Impacts on Other Water Resources and Management Strategies

If water demands are not immediate, ASR could provide Pecos City the ability to store water for use when needed. ASR also may increase groundwater availability for Pecos City by supplemental recharging of groundwater.

Other Issues Affecting Feasibility

The suitability of the aquifers in this area (Pecos Valley or Dockum aquifers) for ASR have not been firmly established. Extensive tests and studies will be required to evaluate hydrogeologic characteristics of the aquifer, as well as economic feasibility of the project, before implementation. Injection of water into the subsurface will likely require a Class V permit from TCEQ. It will likely also require permits from the Reeves County GCD.

WUG:	**Pecos**	**Capital Cost:**	$8,707,000
WMS Name:	**Direct Non-Potable Reuse**	**Annual Cost** (During Amortization):	$1,286 per acre-foot $3.95 per 1,000 gal
WMS Type:	Direct Non-Potable Reuse (Type I)		
WMS Yield:	560 acre-feet per year	**Annual Cost** (After Amortization):	$191 per acre-foot $0.59 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description

Pecos City plans to develop a "purple pipe" system to supply reuse supplies to municipal irrigation (public spaces, athletic fields, etc.). It is estimated that this supply would provide a peak amount of 1 MGD, or on average, approximately 560 acre-feet per year. For planning purposes, this strategy assumes that ten miles of pipeline, as well as transmission infrastructure (pump station, storage tank) will be needed to convey the reuse water. It was also assumed that no wastewater treatment plant improvements are needed.

Quantity, Reliability and Cost

It is estimated that Pecos City could provide a peak supply of 1 MGD of their wastewater effluent to irrigation users. This strategy would supply an extremely reliable water source for irrigation purposes and offset the user of other surface water and groundwater that irrigation users currently utilize. The capital cost for this strategy is estimated at $8,707,000. This cost is shown to be significantly less because it is assumed that no wastewater treatment plant improvements are needed.

Environmental Factors

Pecos City currently discharges its wastewater into an unnamed tributary that ultimately flows into the Pecos River. Reuse would result in a reduction in the quantity of water discharged by the City. An analysis of the environmental 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 Impacts

This strategy is expected to have no impacts on agricultural or rural users.

Impacts to Natural Resources and Key Parameters of Water Quality

It is assumed that the quality of the treated effluent to the Pecos River will not change significantly. Therefore, minimal impacts to the overall water quality in the Pecos River are expected.

Impacts on Other Water Resources and Management Strategies

Irrigation users in Reeves County obtain their water supplies from surface water (Lake Balmorhea, Red Bluff Reservoir, Pecos Run-of-River) and groundwater. To the extent that implementing this strategy reduces the amount of water extracted from these supplies, it may improve the reliability of this water source for agricultural and rural users.

Other Issues Affecting Feasibility

None identified.

MWP:	**San Angelo**	**Capital Cost:**	$116,861,000
WMS Name:	**Indirect Reuse – Concho River Water Project**	**Annual Cost** (During Amortization):	$1,250 per acre-foot $3.84 per 1,000 gal
WMS Type:	Indirect Potable Reuse	**Annual Cost** (After Amortization):	$269 per acre-foot $0.83 per 1,000 gal
WMS Yield:	8,400 acre-feet per year	**Implementation:**	2020
WMS Status:	Recommended		

Strategy Description

The City of San Angelo currently produces approximately 7.5 MGD (8,400 acre-feet per year) on average of treated wastewater. Historically, Tom Green County WCID #1 has used these reuse supplies for irrigation prior to taking their water supplies from Twin Buttes (when available). However, the City recently examined other potential uses for this water as part of a Long Range Water Supply Plan. The City ultimately decided to pursue the Concho River Water Project, which will repurpose this treated effluent as indirect reuse for municipal purposes. The City of San Angelo will continue to provide wastewater to the irrigators when it is not needed as a municipal supply.

The Concho River Water Project involves discharging highly treated effluent water from the City's wastewater treatment plant into the Concho River. Improvements will be made to the City's existing wastewater treatment plant to facilitate this project. The water will be diverted out of the Concho River approximately 8 miles downstream and piped to the City's water treatment plant, where it will be treated to drinking water standards.

The City is currently pursuing two necessary state permits through the TCEQ: one to release water into the Concho River and the other to divert the water at the City-owned facilities downstream. Completion of the entire project could take about five years.

When completed, the Concho River Water Project will provide about 7.5 million gallons per day on an average annual basis (~8,400 acre-feet per year). The Concho River Project will provide supply for municipal use.

Quantity, Reliability and Cost

This strategy is expected to yield 8,400 acre-feet of reliable supply. Capital costs are estimated at $116.9 million. These costs include permitting, as well as upgrades to the water and wastewater treatment facilities. During debt service, it is estimated that the unit cost for treated water will be $3.84 per thousand gallons. After the infrastructure is fully paid for, the unit price decreases to $0.83 per thousand gallons.

Environmental Factors

The environmental impacts of indirect reuse are minimal. Wastewater will be treated to state permit standards before being discharged into the Concho River. Properly designed and maintained treatment facilities should have minimal environmental impact.

Agricultural and Rural Impacts

Implementation of this strategy will result in limited water being available to the Tom Green County Water Control and Improvement District (WCID) from this particular water supply source. However, irrigation water needs in Tom Green County may be met through other water sources.

Impacts to Natural Resources and Key Parameters of Water Quality

The wastewater effluent will be highly treated, in accordance with state permits, before it is discharged into the Concho River. As a result, this should have minimal impacts on natural resources.

Impacts on Other Water Resources and Management Strategies

Implementation of this reuse strategy will make less water available for irrigation by repurposing the supply for municipal use.

Other Issues Affecting Feasibility

None identified.

APPENDIX C

C.3 EXPANDED USE OF EXISTING WATER SUPPLIES

WUG:	**Big Spring**	**Capital Cost:**	$104,651,000
WMS Name:	**New Water Treatment**	**Annual Cost** (During Amortization):	$1,128 per acre-foot $3.46 per 1,000 gal
WMS Type:	Expanded Use of Existing Supplies	**Annual Cost** (After Amortization):	$471 per acre-foot $1.45 per 1,000 gal
WMS Yield:	11,210 acre-feet pear year	**Implementation:**	2020
WMS Status:	Recommended		

Strategy Description
The City of Big Spring currently supplies water to Coahoma, steam electric power, and some manufacturers in Howard County. The City also plans to provide additional water to Howard County-Other and Howard County-Manufacturing. Given the current projected demand levels of these entities, the City of Big Spring will exceed their water treatment plant capacity starting in 2020. As a result, the City plans to construct a new water treatment plant in 2020.

Quantity, Reliability and Cost
The supply related to this strategy originates from CRMWD supplies and must be treated for Big Spring to use as municipal supply. This strategy assumes the construction of a new 20 MGD water treatment facility. The reliability of the supply treated by this strategy is considered to be high due CRMWD's multiple sources. The cost of this strategy is estimated to be $104.6 million.

Environmental Factors
Environmental impacts of constructing a new water treatment plant are expected to be minimal.

Agricultural and Rural Impacts
None identified.

Impacts to Natural Resources and Key Parameters of Water Quality
No impacts.

Impacts on Other Water Resources and Management Strategies
This strategy makes more treated water available to potential future customers of Big Spring in Howard County.

Other Issues Affecting Feasibility
None.

WUG:	**Brady**	**Capital Cost:**	$29,719,000
WMS Name:	**Advanced Groundwater Treatment**	**Annual Cost** (During Amortization):	$2,069 per acre-foot $6.35per 1,000 gal
WMS Type:	Expanded Use of Existing Supplies		
WMS Yield:	1,200 acre-feet per year	**Annual Cost** (After Amortization):	$327 per acre-foot $1.00 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description

The City of Brady obtains water from groundwater wells in the Hickory aquifer and surface water from Brady Creek Reservoir. However, drought has severely impacted Brady Creek Reservoir and the City is unable to use supply from this source at this time. Without surface water supplies to blend the Hickory supplies with, the City is unable to meet the TCEQ standards for radon and gross alpha particles. To address these water quality issues, the City of Brady plans to pursue the development of an advanced treatment facility so that their groundwater source can be used when surface water supplies are not available for blending.

For planning purposes, it was assumed that Brady would construct microfiltration and reverse osmosis facility. The treatment plant was sized to treat 1,200 acre-feet of supply, which is the amount the City intends to treat.

Quantity, Reliability and Cost

This strategy during times of drought is estimated to provide slightly over 1,200 acre-feet per year of supply to Brady by advanced treatment of groundwater to meet their overall water quality and TCEQ regulations. This supply would be used in conjunction with surface water supplies from Brady Creek Reservoir when they are available. In some years, the full 1,200 acre-feet may be used from this source. In other years, little or no groundwater may be used. On average, over an entire decade, this strategy will provide around 600 acre-feet per year. This supply is considered to be reliable. Project costs were provided by the City of Brady and are estimated at just over $29.7 million.

Environmental Factors

Construction of the treatment facility should have minimal environmental impact.

Agricultural and Rural Impacts

This strategy is expected to have no impacts on agricultural or rural users.

Impacts to Natural Resources and Key Parameters of Water Quality

Depending on the disposal method, this strategy may increase radionuclide concentrations of effluent discharge. However, this impact is expected to be minimal since the contaminants are already present in the water supply and thus, wastewater today.

Impacts on Other Water Resources and Management Strategies

None identified.

Other Issues Affecting Feasibility

None identified.

WUG:	**Bronte**	**Capital Cost:**	$10,270,000
WMS Name:	**Water Treatment Plant Expansion**	**Annual Cost** (During Amortization):	$1,720 per acre-foot $5.28 per 1,000 gal
WMS Type:	Expanded Use of Existing Supplies		
WMS Yield:	800 acre-feet per year	**Annual Cost** (After Amortization):	$816 per acre-foot $2.50 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description

The City of Bronte currently supplies treated water to Robert Lee in Coke County. Given the current projected demand levels of these entities, the City of Bronte will exceed their water treatment plant capacity starting in 2020. To provide water to all of these entities over the planning period, a 1.5 MGD expansion in 2020 of the current facility was considered.

Quantity, Reliability and Cost

The supply related to this strategy originates from other strategies being considered for Bronte but must be included for Bronte to utilize these sources as municipal supply for their residents and the residents of Robert Lee. This strategy assumes a 1.5 MGD expansion of Bronte's current facility. The reliability of the supply treated by this strategy is considered under Bronte's other strategies. The cost of this strategy is estimated at $10.3 million.

Environmental Factors

Environmental impacts of expanding the existing water treatment plant are expected to be minimal.

Agricultural and Rural Impacts

None identified.

Impacts to Natural Resources and Key Parameters of Water Quality

None identified.

Impacts on Other Water Resources and Management Strategies

This strategy makes more treated water available to Robert Lee, reducing Robert Lee's need to pursue their own treatment facilities or other supplies independently.

Other Issues Affecting Feasibility

None identified.

WUG:	**Bronte**	**Capital Cost:**	$9,896,000
WMS Name:	**Rehabilitation of Oak Creek Pipeline**	**Annual Cost** (During Amortization):	$1,748 per acre-foot $5.37 per 1,000 gal
WMS Type:	Expanded Use of Existing Supplies	**Annual Cost** (After Amortization):	$202 per acre-foot $0.62 per 1,000 gal
WMS Yield:	450 acre-feet per year	**Implementation:**	2020
WMS Status:	Recommended		

Strategy Description
The City of Bronte has a 13-mile, 8-inch and 10-inch pipeline to Oak Creek Reservoir in Coke County. This pipeline is over 60 years old and needs to be replaced and upsized to provide adequate capacity for the municipal demands served by the City. The proposed strategy includes a new 50,000 gallon raw water ground storage tank, upgrades to the pump station at the intake, and 13 miles of 14-inch pipeline.

Quantity, Reliability and Cost
The yield from this strategy represents the Oak Creek Reservoir subordination supply (purchased from the City of Sweetwater in Region G) that the City purchases for their residents and the residents of Robert Lee. This source is considered to be of moderate reliability because of the impact of the drought on Oak Creek's reliable supply. The estimated capital cost to rehabilitate and upsize this pipeline is approximately $9.8 million.

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

Agricultural and Rural Impacts
No impacts are expected.

Impacts to Natural Resources and Key Parameters of Water Quality
None identified.

Impacts on Other Water Resources and Management Strategies
None identified.

Other Issues Affecting Feasibility
The most significant factor affecting rehabilitation of the pipeline is funding. The City will have to further analyze the cost versus benefit of rehabilitating the pipeline.

WUG:	**Mason**	**Capital Cost:**	$2,605,000
WMS Name:	**Additional Treatment**	**Annual Cost** (During Amortization):	$856 per acre-foot $2.63 per 1,000 gal
WMS Type:	Expanded Use of Existing Supplies		
WMS Yield:	700 acre-feet per year	**Annual Cost** (After Amortization):	$594 per acre-foot $1.82 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description

To address water quality concerns associated with gross alpha particles, the City of Mason plans to pursue the development of an ion exchange facility. For planning purposes, it was assumed that this project would treat around half of Mason's supply. This water would then be blended with the City's remaining supplies to improve the overall drinking water quality and come into compliance with Maximum Contaminant Level (MCL) set by the TCEQ.

Quantity, Reliability and Cost

This strategy is estimated to treat 350 acre-feet of supply but provide over 700 acre-feet per year of supply to Mason by blending to increase their overall water quality and meet TCEQ regulations. This supply is considered to be reliable. The project is estimated to cost just over $2.6 million.

Environmental Factors

Construction of the treatment facility should have minimal environmental impact. For a town of Mason's size, it is likely that they would contract with a company to change the media filters and dispose of the waste created by the used filters. These filters would be disposed of in a properly designed waste facility and should have minimal environmental impacts.

Agricultural and Rural Impacts

This strategy is expected to have no impacts on agricultural or rural users.

Impacts to Natural Resources and Key Parameters of Water Quality

None identified.

Impacts on Other Water Resources and Management Strategies

None identified.

Other Issues Affecting Feasibility

None.

WUG:	**Junction**	**Capital Cost:**	$7,505,000
WMS Name:	**Dredging River Intake**	**Annual Cost** (During Amortization):	$2,112 per acre-foot $6.48 per 1,000 gal
WMS Type:	Expanded Use of Existing Supplies		
WMS Yield:	250 acre-feet per year	**Annual Cost** (After Amortization):	N/A
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description
The City of Junction currently utilizes run-of-river supplies from the S. Llano River. Without subordination, this source has no supply. When considering subordination, it is shown to have 250 acre-feet of supply. This strategy would dredge the City of Junction's intake, increasing the accessibility and reliability of the subordination supply.

Quantity, Reliability and Cost
The supply associated with this strategy of 250 acre-feet is already made available through the subordination strategy. The river dredging is necessary for the City of Junction to be able to fully access this water. The cost of this strategy is estimated at around $7.5 million dollars. During debt service, this is equal to $6.48 per thousand gallons. The only annual costs associated with this strategy are debt service, so once that is fully paid, there is no cost.

Environmental Factors
Environmental issues associated with dredging mainly center around the disposal of the dredged material. In some cases, it may be possible to find a beneficial use for the waste material such as sales to a sand or gravel operation. However, if this is not possible, a proper disposal location will need to be found. The City is currently evaluating its options. Finding a suitable disposal location can be a challenge and may increase the cost if one cannot be found near the dredging site.

Agricultural and Rural Impacts
None identified.

Impacts to Natural Resources and Key Parameters of Water Quality
This strategy assumes that the dredged material is relatively clean and not contaminated. If contamination is found, the impacts of dredging on water quality will need to be evaluated.

Impacts on Other Water Resources and Management Strategies
This strategy is expected to have minimal impacts on other water resources and management strategies.

Other Issues Affecting Feasibility
Finding a suitable location for disposal of the dredged material is a significant hurdle and may make this strategy economically infeasible if the material must be hauled a long distance. Even if a nearby disposal location can be found, this strategy may prove to be too expensive for a small entity such as Junction.

WUG:	**Multiple**	**Capital Cost:**	$7,108,000
WMS Name:	**Purchase from Provider (Voluntary Transfer)**	**Annual Cost** (During Amortization):	Varies based on WUG
WMS Type:	Expanded Use of Existing Supplies	**Annual Cost** (After Amortization):	Varies based on WUG
WMS Yield:	1,294 acre-feet per year	**Implementation:**	Varies based on WUG
WMS Status:	Recommended		

Strategy Description

The purchase from provider strategy is part of a generalized strategy in Region F that facilitates the sale of water from one entity to another. This could either be through the sale of a water right or through the sales of raw or treated water via contract. This strategy only considers new purchases or contracts that are not currently in place. In some cases, this strategy may require infrastructure to transport the water from the seller to the buyer. In other cases, there is existing infrastructure in place and only a contract is needed.

Quantity, Reliability and Cost

The reliability of this strategy is considered medium since the purchasing entity is reliant on the provider for their water supplies. The quantity of water and associated capital costs vary depending upon the entities involved. Some entities have infrastructure in place to transport water and only a contract is needed, so no capital costs are shown. Conversely, other entities need to develop infrastructure to access the water they are purchasing from a provider, thus necessitating a capital investment. Table C-10 shows the quantity of water and capital costs (if necessary) for all entities where purchasing water is a recommended strategy.

Table C- 10
Recommended Strategy - Quantity and Cost

County	Purchaser	Provider	Capital Cost	2020	2030	2040	2050	2060	2070
Coke	Robert Lee	Bronte	$0	80	80	80	80	80	80
Ector	Concho Rural WSC	UCRA (San Angelo)	$0	50	50	50	50	50	50
Ector	Greater Gardendale WSC	Odessa	$6,078,000	0	375	445	445	445	445
Runnels	Winters	Abilene	$974,000	220	220	220	220	220	220
Scurry	County-Other	Snyder (CRMWD)	$0	373	414	447	491	547	607
WMS Total			**$7,052,000**	**723**	**1,139**	**1,242**	**1,286**	**1,342**	**1,402**

Some entities plan on pursuing other strategies to meet their needs but could potentially negotiate a contract to purchase water from a provider. In these cases, this is considered as an alternative strategy. Table C- 11 shows the quantity of water and capital costs (if necessary) for entities that have this as an alternative strategy.

Table C- 11
Alternative Strategy - Quantity and Cost

County	Purchaser	Provider	Capital Cost	2020	2030	2040	2050	2060	2070
Ector	Greater Gardendale WSC	Midland FWSD No. 1	$2,946,000	0	445	445	445	445	445
Midland	Midland	CRMWD	$0	4000	4000	4000	4000	4000	4000
Ector	Grandfalls	CRMWD	$0	0	0	0	0	155	155
WMS Total			**$2,946,000**	**4,000**	**4,445**	**4,455**	**4,445**	**4,600**	**4,600**

Environmental Factors

In some instances, no new infrastructure is required to facilitate the sale of the water. In these cases, no environmental impacts are expected. Any impacts associated with new supplies developed by the provider are discussed under those individual strategies. In cases where a new infrastructure is required, the impacts from construction are expected to be temporary and minimal. Pipeline routes are assumed to be selected such that environmental impacts are minimized.

Agricultural and Rural Impacts

Many of these sales are to rural areas of a county, such as County-Other. In these cases, having a sustainable water supply will increase the vitality of the rural area. In instances where the transfer is from irrigators to municipal or manufacturing users, the impacts may be the opposite. However, irrigators may find this option financially attractive. This strategy assumes that all sales are voluntary.

Impacts to Natural Resources and Key Parameters of Water Quality

Since this does not involve the development of any new sources of water, no impacts to natural resources and key parameters of water quality are expected.

Impacts on Other Water Resources and Management Strategies

None identified.

Other Issues Affecting Feasibility

This strategy assumes that mutually agreeable contractual terms can be reached by the involved parties. This kind of contract negotiation is outside of the scope of regional planning, but the results will greatly impact the feasibility of this strategy.

MWP:	**Midland**	**Capital Cost:**	$60,804,000
WMS Name:	**Advanced RO Treatment, Expanded Use of Paul Davis Well Field**	**Annual Cost** (During Amortization):	$1,266 per acre-foot $3.89 per 1,000 gal
WMS Type:	Expanded Use of Existing Supplies	**Annual Cost** (After Amortization):	$763 per acre-foot $2.34 per 1,000 gal
WMS Yield:	8,500 acre-feet per year	**Implementation:**	2040
WMS Status:	Recommended		

Strategy Description

The City of Midland is planning to pursue the development of a 9 MGD advanced treatment (RO) facility to address water quality concerns associated with existing high TDS levels in their Paul Davis Well Field groundwater supply. For planning purposes, it was assumed that this project would produce up to 8,500 acre-feet per year of finished water, based on a peaking factor of 1.2. This would enable the City to bring the total supply from their Paul Davis Well Field to 10 MGD. Treated water from this source would be blended with the rest of the City's supplies to improve the overall drinking water quality. The City currently has transmission infrastructure in place to transport this water for treatment and distribution.

Treatment losses from this facility were assumed to be 25 percent. It was assumed that the reject stream from this facility would be transported from the City's water purification plant (WPP) to their wastewater treatment plant (WWTP) for treatment, which would be available for mining use. Transmission infrastructure for the brine reject stream (piping, pump stations, storage) was included in the project costs.

Quantity, Reliability and Cost

This strategy would increase the quality and accessibility of the Paul Davis Well Field supplies available to the City of Midland. The reliability of this supply is considered medium because of MAG limitations in Andrews and Martin Counites and competition for water supply. The MAG in Andrews County is limiting to all existing users in all decades, including existing supplies to the City of Midland. The MAG in Martin County is adequate in the early decades but declines sharply over time, resulting in shortages for existing users in later decades. This strategy assumes existing irrigation users would make a voluntary transfer of their supplies to the City of Midland to support the expanded use from this source. The project is sized to produce up to an additional 8,500 acre-feet of finished water, which would bring the total supply produced from the Paul Davis Well Field to 11,200 ac-ft per year (10 MGD). It is estimated that this would require around $60 million of capital investment.

Environmental Factors

The conceptual design for this project assumes that the brine waste stream would be transported to and treated at the City's WWTP for mining use. A properly designed and maintained facility should have minimal environmental impact. Construction of the advanced treatment (RO) facility should have minimal environmental impact as well.

Agricultural and Rural Impacts

This strategy is expected to reduce available supplies to irrigation users. However, it is assumed that the transfers of water from irrigation and rural users is on a willing seller-willing buyer basis.

Impacts to Natural Resources and Key Parameters of Water Quality
It is assumed that the total amount of groundwater used from Martin county will no exceed the MAG values. Therefore, impacts to water resources should be minimal. Advanced RO treatment of groundwater from the Paul Davis Well Field will improve the water quality and availability of this supply for use by the City of Midland. The conceptual design for this project assumes that the brine waste stream would be transported to and treated at the City's WWTP, which would then be available for mining use. This is expected to have minimal effects on natural resources or water quality.

Impacts on Other Water Resources and Management Strategies
The City of Midland's water supply is currently limited by the groundwater quality it can produce from the Paul Davis Well Field. This advanced treatment (RO) facility would enable the City to produce up to 10 MGD of treated water from the Paul Davis Well Field.

Other Issues Affecting Feasibility
None identified.

MWP:	**Odessa**	**Capital Cost:**	$83,062,000
WMS Name:	**RO Treatment of Existing Supplies**	**Annual Cost** (During Amortization):	$1,111 per acre-foot $3.41 per 1,000 gal
WMS Type:	Expanded Use of Existing Supplies		
WMS Yield:	12,555 acre-feet per year	**Annual Cost** (After Amortization):	$738 per acre-foot $2.27 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description
To address water quality concerns associated with existing high TDS levels in CRMWD's surface water system, the City of Odessa is planning to pursue the development of an advanced treatment (RO) facility. For planning purposes, it was assumed that the RO treatment facility would have a capacity of 20 MGD. It is anticipated this treatment plant would produce on average, 14 MGD or 15,700 acre-feet per year. Treatment losses were assumed to be 20%, so this project would produce approximately 3,930 acre-feet per year of waste. The finished water produced from this facility would be blended with the rest of the City's supplies to improve the overall drinking water quality. The conceptual design for this project disposes of the brine waste stream into a nearby water body, such as a stream. Cost estimates for this project include infrastructure to transmit the brine waste stream, including a 16-inch pipeline, pump station, and ground storage tank.

Quantity, Reliability and Cost
This strategy would increase the quality and accessibility of the subordination supplies Odessa obtains from CRMWD. The reliability of this supply is considered medium, as discussed in further detail under the subordination strategy. The project is sized to produce 20 MGD of finished water at peak capacity and requires $83.1 million of capital investment. The conceptual design for this project disposes of brine waste into a nearby water body; however, the City is also considering selling its effluent to the petroleum industry.

Environmental Factors
The conceptual design for this project disposes of brine waste into a water body. Impacts to the receiving water body would need to be evaluated to ensure that environmental impacts are mitigated, and that discharges are compliant with the facility's National Pollutant Discharge Elimination System (NPDES) permits. A properly designed and maintained facility should limit environmental impacts. Construction of the treatment facility should have minimal environmental impact as well.

Agricultural and Rural Impacts
This strategy is expected to have no impacts on agricultural or rural users.

Impacts to Natural Resources and Key Parameters of Water Quality
The current conceptual design for this project disposes of brine waste into a nearby stream. Impacts to the receiving water body would need to be evaluated to ensure that any impacts to natural resources or water quality are mitigated.

Impacts on Other Water Resources and Management Strategies
This advanced treatment (RO) facility would improve the water quality of the water that the City of Odessa provides to its customers.

Other Issues Affecting Feasibility
None identified.

WUG:	**Pecos**	**Capital Cost:**	$27,680,000
WMS Name:	**Advanced Water Treatment Plant**	**Annual Cost** (During Amortization):	$754 per acre-foot $2.31 per 1,000 gal
WMS Type:	Expanded Use of Existing Supplies		
WMS Yield:	3,360 acre-feet per year	**Annual Cost** (After Amortization):	$319 per acre-foot $0.98 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description
Pecos City has poor water quality in their existing North Worsham well field, which severely limits its use. At its current state, the water from this well field can only be blended at up to 5% of the total supply. This strategy involves developing an 8 MGD advanced water treatment plant, which will treat the blended supplies from all three of the City's well fields. This strategy will provide additional water supplies by increasing the usable supply from the North Worsham well field.

Quantity, Reliability and Cost
This strategy would increase the water quality of Pecos City's current water supply and enable the City to increase the usable supply from the North Worsham well field. The reliability of this supply is considered medium. The project is sized to produce 8 MGD of finished water and requires approximately $27.7 million of capital investment.

Environmental Factors
Construction of the treatment facility should have minimal environmental impact.

Agricultural and Rural Impacts
This strategy is expected to have no impacts on agricultural or rural users.

Impacts to Natural Resources and Key Parameters of Water Quality
This strategy is expected to increase the water quality that the City produces from its three well fields and distributes for municipal use.

Impacts on Other Water Resources and Management Strategies
This advanced water treatment plant would enable the City to blend water from all three of their well fields and will increase the supply that they can use from their North Worsham well field.

Other Issues Affecting Feasibility
None identified.

WUG:	**Pecos County WCID #1**	**Capital Cost:**	$26,102,000
WMS Name:	**Transmission Pipeline**	**Annual Cost** (During Amortization):	$2,767 per acre-foot $8.49 per 1,000 gal
WMS Type:	Expanded Use of Existing Supplies	**Annual Cost** (After Amortization):	$317 per acre-foot $0.97 per 1,000 gal
WMS Yield:	750 acre-feet per year	**Implementation:**	2020
WMS Status:	Recommended		

Strategy Description
Developing additional groundwater supplies is a recommended strategy to increase the reliability of Pecos County WCID's current system. The WCID will also need a larger transmission pipeline to transport the new groundwater supplies and their existing supplies. For planning purposes, 20 miles of 18-inch pipeline were assumed. The well field expansion is costed and evaluated as a separate strategy (see Develop Edwards-Trinity Aquifer Supplies, Pecos County WCID #1).

Quantity, Reliability and Cost
This strategy is expected to transport 750 acre-feet per year (250 acre-feet per year from two additional wells plus 500 acre-feet of existing supplies). This source is already in use by the WCID and the reliability is considered high. The cost for the transmission pipeline is estimated at $26.1 million.

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

Agricultural and Rural Impacts
This strategy is expected to have no impacts on agricultural or rural users.

Impacts to Natural Resources and Key Parameters of Water Quality
Additional supply does not exceed the MAG so there are minimal impacts to existing water sources expected.

Impacts on Other Water Resources and Management Strategies
There are no impacts to other water resources or water management strategies.

Other Issues Affecting Feasibility
None.

WUG:	**Robert Lee**	**Capital Cost:**	$6,541,000
WMS Name:	**Repair and Expand Water Treatment Plant**	**Annual Cost** (During Amortization):	$2,657 per acre-foot $8.15 per 1,000 gal
WMS Type:	Expanded Use of Existing Supplies	**Annual Cost** (After Amortization):	$1,284 per acre-foot $3.94 per 1,000 gal
WMS Yield:	335 acre-feet per year	**Implementation:**	NA
WMS Status:	Alternative		

Strategy Description

Currently, due to the prolonged drought, the City of Robert Lee has not been able to utilize their current surface water treatment plant. If the Spence and Mountain Creek Reservoirs once again become a dependable surface water source or the City enters into a contract with a wholesale water provider, the City could reopen the plant. Bringing the plant online and up to operational standards would require considerable repairs and infrastructure expansion. This strategy is necessary for Robert Lee to utilize supplies from the subordination strategy.

Quantity, Reliability and Cost

The water treatment plant is sized for 0.6 MGD and is expected to treat 335 acre-feet per year on average. Given this source was unreliable during the recent drought, the reliability of this supply is considered to be low. The cost of this strategy is estimated at around $6.5 million.

Environmental Factors

Robert Lee previously operated a plant from these sources, so no additional environmental impacts are expected from reopening the plant.

Agricultural and Rural Impacts

This strategy should have minimal effects on agriculture since the water has traditionally been used as municipal supply for Robert Lee.

Impacts to Natural Resources and Key Parameters of Water Quality

None identified.

Impacts on Other Water Resources and Management Strategies

None identified.

Other Issues Affecting Feasibility

This strategy is a very expensive option for an unreliable supply during drought. Robert Lee is a small, rural community and this project may cause an economic burden on the community. This strategy is included in this plan as an alternate strategy.

APPENDIX C

C.4 GROUNDWATER DEVELOPMENT

MWP:	**Brown County WID #1 (BCWID)**	**Capital Cost:**	$13,947,000
WMS Name:	**Develop Groundwater Supplies from Brown County**	**Annual Cost** (During Amortization):	$12,553 per acre-foot $7.83 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$1,336 per acre-foot $4.10 per 1,000 gal
WMS Yield:	806 acre-feet pear year	**Implementation:**	NA
WMS Status:	Alternative		

Strategy Description
BCWID is pursuing developing groundwater supplies in the Ellenburger San Saba aquifer after previously drilling a test well in the same formation. Due to the high TDS concentrations from the test well, additional treatment will be required for municipal use.

This strategy evaluates the development of 806 acre-feet of supply per year from the Ellenburger San Saba aquifer in Brown County. The conceptual design for this strategy includes one 500 gpm well drilled to a depth of 4,000 feet and 2 miles of 8-inch transmission pipeline.

Quantity, Reliability and Cost
The quantity expected to be obtained from this source is 806 acre-feet per year. The reliability of the source is considered medium due to the lack of specific information pertaining to the well field. The cost of this strategy is estimated at $14 million. This equates to $7.83 per thousand gallons during debt service.

Environmental Factors
The well would be located to minimize any potential environmental impacts. As such, the environmental impacts are expected to be minimal.

Agricultural and Rural Impacts
Development of groundwater is not expected to divert water that was previously used for agricultural and rural purposes due to the poor water quality and well depth. This strategy assumes that the groundwater rights are obtained on a willing buyer – willing seller basis which would minimize impacts to agriculture.

Impacts to Natural Resources and Key Parameters of Water Quality
The impacts to natural resources are expected to be minimal. No impacts to water quality are expected.

Impacts on Other Water Resources and Management Strategies
To the extent that this water source lessens the demand on Lake Brownwood, additional water from Lake Brownwood may be available for other use.

Other Issues Affecting Feasibility
Additional study will be needed once a more specific location for this strategy has been selected.

MWP:	**Colorado River Municipal Water District**	**Capital Cost:**	$168,324,000
WMS Name:	**Ward County Well Field Expansion and Winkler County Well Field Development**	**Annual Cost** (During Amortization):	$849 per acre-foot $2.61 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$321 per acre-foot $0.99 per 1,000 gal
WMS Yield:	22,400 acre-feet per year	**Implementation:**	2050
WMS Status:	Recommended		

Strategy Description

CRMWD currently owns and operates a well field in Ward County in the Pecos Valley aquifer. CRMWD also owns the groundwater rights to an undeveloped well field in southern Winkler County. This well field will produce water from the Pecos Valley aquifer. For the purposes of this plan, it was assumed that the Ward County Well Field Expansion and the development of the Winkler County Well Field will happen concurrently as a single strategy. Due to MAG limitations of the Pecos Valley aquifer in Ward County, all water supply from this strategy is assumed to be from the Winkler County Well Field. However, expansion of the Ward County well field is still a recommended component of this strategy.

This strategy assumes that 20 MGD (22,400 acre-feet per year) will be developed from the Winkler County Well Field, and then pumped to the Ward County Well Field for transmission to CRMWD customers using a new 36-inch pipeline and new 20 MGD pump station. The water will use the same existing transmission lines from the current Ward County Well Field to Odessa. The pumping capacity of the current transmission system will require multiple upgrades, including one new 50 MGD booster pump station and one 20 MGD pump station expansion along the existing transmission line to Odessa. An additional shared pipeline and 20 MGD pump station expansion would also be developed from Odessa to the terminal storage reservoir. A new pump station is also included to transport water from the terminal storage reservoir to Big Spring.

Quantity, Reliability and Cost

It is estimated that this strategy could provide 22,400 acre-feet per year (20 MGD) beginning in the year 2050. Water from these sources is considered to be very reliable. The capital cost for this strategy is estimated at $168.3 million.

Environmental Factors

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 the proposed pumping will have impacts on aquatic or terrestrial ecosystems. It is not anticipated that groundwater development will cause subsidence.

The Ward County Well Field already exists and has enough supply to support an expansion by CRMWD without causing any major environmental impacts.

Agricultural and Rural Impacts

The Region F water supply analysis shows sufficient water supply in Winkler County to meet local agricultural and municipal needs, as well as to support well field development by CRMWD. Well field expansion in Ward County is limited by the MAG, so all water from this strategy is shown to come from Winkler County. Therefore, this strategy should have minimal effects on agriculture and rural areas. The right of way for the small portion of additional transmission lines may temporarily affect a small amount of agricultural acreage during construction.

Impacts to Natural Resources and Key Parameters of Water Quality

None identified.

Impacts on Other Water Resources and Management Strategies

The Region F water supply analysis shows sufficient water supply in Winkler County to meet local needs and support well field development by CRMWD. Well field expansion in Ward County is limited by the MAG, so all water from this strategy is shown to come from Winkler County. Impacts to other strategies are expected to be minimal.

Other Issues Affecting Feasibility

None identified.

MWP:	**Colorado River Municipal Water District**	**Capital Cost:**	$10,440,000
WMS Name:	**Ward County Well Field Well Replacement**	**Annual Cost** (During Amortization):	$102 per acre-foot $0.31 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$76 per acre-foot $0.23 per 1,000 gal
WMS Yield:	755 – 10,500 acre-feet per year	**Implementation:**	2030
WMS Status:	Recommended		

Strategy Description

CRMWD currently owns and operates a well field in Ward County that pumps from the Pecos Valley aquifer. The integrity of the wells and pipelines will deteriorate over time, reducing the supply available to CRMWD from this strategy. As a result, CRMWD plans to actively rehabilitate and/or replace out-of-service wells in order to operate their Ward County well field at an optimal efficiency and supply the optimum amount of water from the well field throughout the planning horizon. The strategy infrastructure was sized for its ultimate capacity in 2070 but would likely be implemented in phases.

In this strategy, it was assumed that enough water wells and piping would need to be replaced per decade to enable CRMWD to withdraw the expected amount of groundwater from their Ward County well field. CRMWD already owns the land, water rights, and infrastructure to transport and treat this supply, so only water well and well field piping infrastructure were included in this project.

Quantity, Reliability and Cost

This strategy could optimize the amount of water that CRMWD obtains from their Ward County Well Field. It is estimated that this could provide an additional 755 acre-feet per year in 2030 and increase to 10,500 acre-feet per year in 2070. Water from the Ward County Well Field is considered to be reliable. The total capital cost for this strategy is estimated at $10.4 million.

Environmental Factors

The Ward County Well Field already exists and has enough supply to support replacement with new wells without causing any major environmental impacts. The construction of replacement wells should have minimal environmental impact.

Agricultural and Rural Impacts

The Region F water supply analysis shows sufficient water supply in Ward County to meet local agricultural and municipal needs and support replacement of old wells with new wells by CRMWD. Therefore, this strategy should have minimal effects on agriculture and rural areas.

Impacts to Natural Resources and Key Parameters of Water Quality

None identified.

Impacts on Other Water Resources and Management Strategies

The Region F water supply analysis shows sufficient water supply in Ward Counties to meet local needs and support replacement of old wells with new wells by CRMWD. This strategy is expected to enable CRMWD to optimize the amount of groundwater that they can withdraw from their well field in Ward County.

Other Issues Affecting Feasibility

None identified.

MWP:	**Colorado River Municipal Water District**	**Capital Cost:**	$147,558,000
WMS Name:	**Develop Additional Groundwater in Pecos, Reeves, Ward, and Winkler Co.**	**Annual Cost** (During Amortization):	$1,348 per acre-foot $4.14 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$310 per acre-foot $0.95 per 1,000 gal
WMS Yield:	10,000 acre-feet per year	**Implementation:**	NA
WMS Status:	Alternative		

Strategy Description

The Colorado Municipal Water District (CRMWD) plans to pursue new groundwater development. The exact location of the wells is not yet known. For the purposes of this plan, this project will seek to develop 10,000 acre-feet of supply from Pecos, Reeves, Ward, and Winkler Counties. This project is for new groundwater supplies and does not include water rights currently held by CRMWD. Region F considers development from any single or combination of these sources to be consistent with the plan. This strategy involves the development of the groundwater, as well as the transmission of this groundwater to CRMWD's system. Some portions of this groundwater may be brackish and need additional treatment, but these supplies will not be needed until after the end of this Plan (post-2070).

This strategy includes the acquisition of groundwater rights and development of well infrastructure (water well, well field piping) in either Pecos, Reeves, Ward, and Winkler Counties. In addition, this strategy involves the development of transmission infrastructure, including pipeline, pump stations, and storage tanks, to transport the 10,000 acre-feet of groundwater supply developed in these four counties Region F by CRMWD. Since the exact location of the development of these supplies is still unknown, for planning purposes it was assumed that 40 miles of new transmission system would be needed to connect to CRMWD's transmission system in Ward County.

Quantity, Reliability and Cost

In total, this strategy will provide 10,000 acre-feet of supply per year. Since the location of the well field is not yet known, a combination of aquifers and counties was assumed.

The reliability of this strategy is considered to be high due to the large number of sources being employed. Additional study will be required once an exact location and source for the well fields have been determined and the transmission pipeline route has been defined. For planning purposes, the strategy includes the purchase of the groundwater rights, the costs to drill approximately 10 wells, and associated well field piping. In addition, the capital cost of this strategy includes the construction of 40 miles of 36-inch pipeline, 3 new pump stations and 1.25 MG of storage. The capital cost for this project is estimated at $147.6 million.

Environmental Factors

The well fields would be located to minimize any potential environmental impacts. The right of way for the transmission line may temporarily affect the environment during construction. Additional study and mitigation may be required before construction of the transmission pipeline. The pipeline may be routed to avoid environmentally sensitive areas. As such, the environmental impacts are expected to be minimal.

Agricultural and Rural Impacts

Development of groundwater may divert water that was previously used for agricultural and rural purposes. However, this strategy assumes that the groundwater rights are obtained on a willing buyer – willing seller basis which would minimize the impacts to agriculture. The right of way for the transmission line may temporarily affect a small amount of agricultural acreage during construction.

Impacts to Natural Resources and Key Parameters of Water Quality

The strategy proposes to utilize a sustainable level of groundwater. The impacts to natural resources are expected to be minimal when constructing the well field. No impacts to water quality are expected. Other natural resources may be temporarily impacted during construction of the pipeline. These impacts are expected to be minimal and the mitigation of impacts will be addressed through further study once the exact pipeline route has been selected.

Impacts on Other Water Resources and Management Strategies

This strategy could impact the Expanded Ward County and Winkler County Well Fields, but it is assumed that the new wells would be located so as not to impact these well fields. No impacts on water resources or management strategies are anticipated from the transmission pipeline.

Other Issues Affecting Feasibility

Additional study will be needed to determine feasibility and potential impacts once a more specific location for the well fields and the more defined pipeline route has been selected. Some portions of this groundwater may be also brackish and need additional treatment, but these supplies will not be needed until after the end of this Plan (post-2070).

MWP:	**Odessa**	**Capital Cost:**	$154,165,000
WMS Name:	**Develop Capitan Reef Complex Aquifer Supplies in Ward County**	**Annual Cost** (During Amortization):	$2,175 per acre-foot $6.68 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$884 per acre-foot $2.71 per 1,000 gal
WMS Yield:	8,400 acre-feet per year	**Implementation:**	NA
WMS Status:	Alternative		

Strategy Description

The City of Odessa has purchased the water rights to the brackish groundwater beneath the CRMWD Ward County Well Field. Odessa is considering developing this source and supplementing the supplies produced by CRMWD. In compliance with the guidance and rules for regional water planning, the TWDB requires the use of the Modeled Available Groundwater (MAG) in regional water planning. The MAG for the Capitan Reef Complex aquifer in Ward County is severely limiting and causes the supplies from the City of Odessa's well field to be artificially shorted. This strategy is developed with the understanding that the MAG may be changed in the future to allow inclusion of this strategy in the regional water plan. Currently, Ward County does not have a GCD to enforce the MAG.

The Capitan Reef Complex aquifer in Ward County has been identified as a potential source for municipal, industrial and agricultural purposes. For the purpose of this plan, groundwater development in Ward County is not a recommended strategy due to current existing MAG limitations. However, this strategy was evaluated as a potential alternative strategy.

This strategy assumes that Odessa would pump up to 10 MGD of brackish water from the Capitan Reef Complex and treat the water on-site. It is assumed that 25% of the groundwater would be discharged as brine waste, resulting in a net supply of 8,400 acre-feet per year. The brine discharge would be injected into a deep saline formation. The treated water would then be transported using the existing infrastructure developed by CRMWD.

To provide the 10 MGD of raw groundwater, 15 new wells would need to be drilled. These wells would produce water from approximately 4,500 feet below the surface.

This strategy assumes that the wells would be spaced about 1,500 to 3,000 feet apart along the Capitan Reef Complex aquifer within the existing well field area. The wells would be connected by up to three sections of continuous well field piping. The well field would also include a new 2 MG covered ground storage tank.

This project includes a reverse osmosis water treatment plant at the well field and five disposal wells.

Quantity, Reliability and Cost

The quantity and reliability of water from this source is expected to be approximately 950 gpm. Previous investigations indicate that the Capitan Reef Complex aquifer may be a viable source but high TDS will require advanced treatment. For this plan, the 15 new wells are assumed to supply an additional 8,400 acre-feet per year of treated water. The reliability of the supply is considered to be medium because of aquifer and water quality properties. The total capital cost is estimated at $154.2 million.

Environmental Factors

This strategy should have minimal impacts to the environment since the proposed wells are located within an existing well field and the transmission system is existing. The discharge of the brackish wastewater would be to a saline formation and would not impact its water quality. Care should be taken to ensure that the discharge wells are properly constructed such so that the brackish discharge would not impact freshwater zones.

Agricultural and Rural Impacts

This source is currently not used for agricultural or rural purposes, and likely would not be used for these purposes due to the depth of the aquifer and poor water quality. No impacts are expected.

Impacts to Natural Resources and Key Parameters of Water Quality

The water quality in the Capitan Reef Complex aquifer is generally poor, yielding small to large quantities of slightly saline to saline groundwater. Brackish groundwater often contains water with greater than 5,000 TDS. Very little to no water is currently used from the Capitan Reef in Ward County. Most of the groundwater pumped from the aquifer is from other areas of the formation and used for oil reservoir flooding. No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

This strategy would impact the ability of CRMWD to transport additional water from the Ward County Well Field since this strategy proposes to use the same infrastructure. If constructed, it is likely that this strategy would be used conjunctively with the Ward County Expansion for CRMWD.

Other Issues Affecting Feasibility

The most significant challenge for this strategy is whether or not the strategy is economically feasible. The necessary infrastructure to pump and treat water from the Capitan Reef Complex aquifer will be a financial challenge. This strategy is not recommended for this planning cycle. However, it was analyzed as an alternative strategy to be considered for future planning periods should the desired future condition and MAG availability support it.

MWP:	**Odessa**	**Phase 1 Capital Cost:**	$507,656,000
		Phase 2 Capital Cost:	$319,152,000
WMS Name:	**Develop Edwards-Trinity and Capitan Reef Complex Aquifer Supplies in Pecos County**	**Phase 1 Annual Cost** (During Amortization):	$4,500 per acre-foot $13.81 per 1,000 gal
WMS Type:	Groundwater Development	**Phase 2 Annual Cost** (During Amortization):	$2,416 per acre-foot $7.41 per 1,000 gal
Phase 1 Yield:	11,200 acre-feet per year	**Phase 1 Annual Cost** (After Amortization):	$1,311 per acre-foot $4.02 per 1,000 gal
Phase 2 Yield:	16,800 acre-feet per year		
WMS Status:	Alternative	**Phase 2 Annual Cost** (After Amortization):	$1,079 per acre-foot $3.31 per 1,000 gal
		Implementation:	NA

Strategy Description

The City of Odessa is considering developing a groundwater supply in Pecos County. This supply likely would be developed in the Edwards-Trinity and/or Capitan Reef Complex. Water quality of these formations is variable, with fresh water supplies adjacent to brackish water. Due to this uncertainty, it is assumed that the supplies from this strategy would require advanced treatment.

A study is currently being conducted on the feasibility of developing this water for Odessa. The proposed transmission system is sized for a peak capacity of 50 MGD. The City would develop this project in stages with an initial development of 10 MGD average annual supply and increasing to the full capacity of the transmission system by 2070. Assuming a peaking factor of 1.5 for this source, the ultimate average annual supply from the well field would be about 37,300 acre-feet per year before treatment losses. To provide approximately this amount of water, 36 new wells would need to be drilled. These wells would produce water from approximately 2,000 to 3,000 feet below the surface.

This strategy assumes that well field piping will connect the water wells to a new 90–mile transmission line that would carry the water from Pecos County to the City of Odessa. The water treatment facility is assumed to be located near Odessa. Due to the large quantity of water to be developed, it is assumed that a new advanced water treatment facility would be built. The facility would be built in phases with Phase 1 sized for 20 MGD and a Phase 2 expansion of 30 MGD for a total ultimate capacity of 50 MGD.

Quantity, Reliability and Cost

The quantity and reliability of water from this source is expected to be approximately 1,000 gpm. Historical industrial and agricultural use indicates that the Edwards-Trinity and Capitan Reef Complex aquifers may be a viable source, but high TDS will require advanced treatment. For this plan, the 36 new wells are assumed to supply an additional 37,300 acre-feet per year. Assuming a loss of 25 percent, the amount of reliable treated supply for municipal use is about 28,000 acre-feet per year for both phases. The reliability of the supply is considered to be medium because of the potential for competing demands and limitations of the aquifers. The total capital cost for both phases is estimated at approximately $826,808,000.

Environmental Factors

The aquifer is a proven groundwater source for municipal, industrial, and agricultural purposes. However, the long-term water quality is unknown. Groundwater development from this source should be evaluated for potential impacts on springflows and base flows of area rivers. There are several springs in the Fort Stockton area that could potentially be impacted by large development of groundwater. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts

Wells provide water for ranching, domestic and municipal supplies throughout the area. It is assumed that this project would acquire sufficient water rights to mitigate potential impacts to agricultural and rural areas. Studies may be required to evaluate potential impacts on the area.

Impacts to Natural Resources and Key Parameters of Water Quality

The water quality in the Edwards-Trinity Plateau aquifer ranges from fresh to slightly saline in the outcrop areas, and brine water in subsurface portions. The water quality in the Capitan Reef Complex aquifer is generally poor, yielding small to large quantities of slightly saline to saline groundwater. Water levels have remained relatively stable because recharge has generally kept pace with the relatively low amounts of pumping over the extent of the aquifer. No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

Other strategies for Pecos County may be impacted. Also, CRMWD is considering developing additional groundwater in Pecos County. It is likely that only one strategy for groundwater from Pecos County to Odessa will be developed.

Other Issues Affecting Feasibility

The most significant challenge for this strategy is whether or not the strategy is economically feasible. The necessary infrastructure to pump and treat water from the Capitan Reef Complex aquifer will be a financial challenge. This strategy is not recommended for this planning cycle. However, it was analyzed as an alternative strategy to be considered for future planning periods should Odessa need additional supplies and CRMWD choose not to develop these supplies.

MWP:	**San Angelo**	**Capital Cost:**	$55,491,000
WMS Name:	**Develop Hickory Aquifer Supplies in McCulloch County**	**Annual Cost** (During Amortization):	$2,321 per acre-foot $7.12 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$1,037 per acre-foot $3.18 per 1,000 gal
WMS Yield:	3,040 acre-feet per year (12,000 AFY including existing and future supplies)	**Implementation:**	2030
WMS Status:	Recommended		

Strategy Description

The most recent phase of the City of San Angelo's Hickory Well Field expansion was substantially completed in June 2016. During this phase, the total pumping capacity of the well field was increased from 7,280 ac-ft per year (6.5 MGD) to 12,000 ac-ft per year (10.8 MGD) by installing five additional wells (increasing the well field to 15 total wells) and supporting infrastructure. Currently, the City can divert 2,750 acre-feet per year, plus any banked water, according to their agreement with the Hickory Underground Water District. Starting in 2026, the City's permitted supply increases to an annual amount of 10,000 acre-feet per year plus any banked water. By 2036, the project's permitted supply will reach its ultimate annual amount of 12,000 acre-feet per year. Even though the City is able to produce this ultimate amount from its Hickory Well Field, it is limited by the City's current water treatment plant capacity of 8,960 ac-ft per year (8 MGD).

The City will need to expand its well field and groundwater treatment facility to reach the maximum system capacity of 12 MGD. Additional infrastructure that will be required to reach this 12 MGD capacity include: additional wells (up to five new wells), well field piping, additional 4 MGD water treatment (radium removal) trains to increase treatment capacity, a clear well and upgraded booster pump station facilities. The additional wells would produce water from approximately 3,000 feet below the surface. Groundwater would be transported to the City of San Angelo's groundwater treatment plant through the existing 30-inch McCulloch Well Field transmission pipeline. It is assumed that San Angelo's existing and future treatment facilities will be sufficient to treat the full authorized amount of Hickory aquifer supplies.

Quantity, Reliability and Cost

The quantity and reliability of water from this source is expected to be approximately 500 gpm per well. The Hickory aquifer is a viable source, but elevated radionuclide concentrations will require advanced treatment. The total permitted supply from the Hickory aquifer, which includes existing supplies as well as upgrades to ultimate capacity, is 12,000 acre-feet per year beginning in 2036 through the planning period. The reliability of the supply is medium to high. There is plenty of water in storage, but water quality issues and competing demands may limit the availability. This strategy is estimated to cost $55.5 million.

Environmental Factors

The proposed wells will produce water from the down-dip portion of the Hickory aquifer. Because of the 3,000 feet of overburden, there is no connection with the land surface and as a result, 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. Groundwater development from this source is expected to cause minimal environmental impacts.

Agricultural and Rural Impacts

This source is currently used for agricultural, industrial, and municipal purposes. This strategy is not expected to affect other users in the area. San Angelo has the necessary water rights to produce the quantities included in this strategy.

Impacts to Natural Resources and Key Parameters of Water Quality

Much of the water from the Hickory aquifer exceeds drinking water standards for radionuclides and will be treated through ion exchange. San Angelo has an existing treatment facility for this supply. The reject water from the treatment process is disposed separately and not discharged. There are no impacts to key parameters of water quality.

No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

No impacts to other water resources or management strategies are identified.

Other Issues Affecting Feasibility

None identified.

MWP:	**San Angelo**	**Capital Cost:**	$102,100,000
WMS Name:	**Develop Edwards-Trinity Plateau Aquifer Supplies in Schleicher County**	**Annual Cost** (During Amortization):	$1,800 per acre-foot $5.52 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$209 per acre-foot $0.64 per 1,000 gal
WMS Yield:	4,500 acre-feet per year	**Implementation:**	NA
WMS Status:	Alternative		

Strategy Description

The Edwards-Trinity Plateau aquifer in Schleicher County has been identified as a potential source for municipal, industrial and agricultural purposes. This source is currently used for agricultural purposes and may require advanced treatment for municipal use. Groundwater studies project that approximately 4,500 acre-feet per year could be produced from this source; however, that quantity is not available under MAG limitations from this source. Therefore, for the purpose of this plan, groundwater development in Schleicher County is not a recommended strategy. However, this strategy was evaluated as a potential alternative strategy if the exportation of water outside of Schleicher County was agreed upon.

To provide approximately 4,500 acre-feet per year, 18 new wells would need to be drilled. These wells would produce water from approximately 500 feet below the surface. It was estimated that the City would need to purchase approximately 4,500 acres of land above the aquifer for well construction and piping. This strategy assumes that the wells will be connected by 49,560 linear feet of well field piping, with diameters of 6-, 8-, 10-, 14-, 16-, and 20-inches. In addition, it was assumed that the groundwater well field would include a 0.25 MGD ground storage tank.

This project also includes a transmission pipeline and pump station that will transport the water from the well field to existing infrastructure located in the City of San Angelo. It is assumed that the water produced from the new well field will be blended with the existing water supply or treated at the City's water treatment plant. Desalination of new groundwater is evaluated as a separate strategy. The transmission pipeline is assumed to be a 50-mile pipeline with a diameter of 20 inches.

Quantity, Reliability and Cost

The quantity and reliability of water from this source is expected to be moderate to low, in the 150 – 250 gpm range for individual wells. Historical municipal and agricultural use indicates that the Edwards-Trinity Plateau aquifer may be a viable source, but high TDS will require advanced treatment. For this plan, the 18 new wells are assumed to supply an additional 4,500 acre-feet per year. The reliability of the supply is considered to be medium because of the potential competing demands.

Environmental Factors

The aquifer is a proven groundwater source for municipal, industrial, and agricultural purposes. However, the long-term water quality is unknown. Groundwater development from this source should be evaluated for potential impacts on spring flows and base flows of area rivers. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts

Spring flows from the Edwards-Trinity Plateau 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.

Impacts to Natural Resources and Key Parameters of Water Quality

The water quality in the Edwards-Trinity Plateau aquifer ranges from fresh to slightly saline in the outcrop areas, and brine water in subsurface portions. Water levels have remained relatively stable because recharge has generally kept pace with the relatively low amounts of pumping over the extent of the aquifer.

No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

Other strategies that use the Edwards-Trinity aquifer in Schleicher County may be impacted.

Other Issues Affecting Feasibility

None identified.

MWP:	**San Angelo**	**Capital Cost:**	$327,576,000
WMS Name:	**Develop Pecos Valley, Edwards-Trinity Plateau Aquifer Supplies in Pecos Co.**	**Annual Cost** (During Amortization):	$2,604 per acre-foot $7.99 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$470 per acre-foot $1.44 per 1,000 gal
WMS Yield:	10,800 acre-feet per year		
WMS Status:	Alternative	**Implementation:**	NA

Strategy Description

The Pecos Valley and/or Pecos Valley-Edwards-Trinity aquifer in Pecos County has been identified as a potential source for municipal, industrial, and agricultural purposes. This source may require advanced treatment for municipal use. To provide approximately 10,800 acre-feet per year, 15 new wells would need to be drilled. These wells would produce water from approximately 200 feet below the surface and are anticipated to produce between 800-1,000 gpm.

This strategy assumes 33,000 linear feet of 12 inch well field piping. This project also includes a transmission pipeline that will transport the water from the well field to existing infrastructure located in the City of San Angelo. The transmission pipeline is assumed to be a 186-mile pipeline with a diameter of 30 inches. One well field pump station and 3 booster pump stations will be needed to convey the water to San Angelo.

This strategy does not include treatment but depending upon the water quality of the well field, some or all of the water may need advanced treatment. Potential advanced treatment is included in a separate strategy for San Angelo, *Desalination of Brackish Groundwater*.

Quantity, Reliability and Cost

The quantity and reliability of water from this source is expected to be approximately 800-1,000 gpm. In parts of the aquifer there are elevated levels of chloride and sulfate, resulting from previous oil field activities, which would require advanced treatment. If treatment is needed, the treated water supply would be 20-25% less. For this plan, the 15 new wells are assumed to supply 10,800 acre-feet per year. The reliability of the supply is considered to be medium because of potential water quality properties.

The capital cost of this strategy is $327.6 million. Unit costs during amortization are $7.99 per 1,000 gallons. Following repayment of debt, the unit costs decrease to $1.44 per 1,000 gallons, assuming no treatment is needed. Costs of treatment are evaluated in a separate strategy. This strategy is relatively expensive due to the long transmission pipeline and transport costs.

Environmental Factors

The aquifer is a proven groundwater source for industrial, agricultural, and municipal purposes. However, the long-term water quality is unknown. Groundwater development from this source should be evaluated for potential impacts on springflows and base flows of area rivers. Depending upon the well field location and connectivity to surface water, there may be possible impacts on the Pecos River from this strategy. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts

This source is currently used for agricultural purposes. The area of potential interest is currently being used mainly for livestock and ranching. It is possible that large scale production from this aquifer could impact irrigation supplies in the Belding Farms area. This strategy could reduce the amount of water currently available to other users in the area.

Impacts to Natural Resources and Key Parameters of Water Quality

The water quality in Pecos Valley and Edwards-Trinity aquifers is highly variable. This is due to there being several structural basins, the largest of which are the Pecos Trough in the west and Monument Draw Trough in the east. Water is generally better in the Monument Draw Trough. The aquifer is characterized by high levels of chloride and sulfate in excess of secondary drinking standards in some areas. In addition, naturally occurring arsenic and radionuclides occur in excess of primary drinking water standards. Water levels of the aquifer continue to decline due to increased municipal and industrial pumping.

No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

Other strategies for water from Pecos County may be impacted. This includes Pecos County groundwater development strategies identified for CRMWD and the City of Odessa.

Other Issues Affecting Feasibility

The most significant challenge for this strategy is whether or not the strategy is economically feasible. The necessary infrastructure to move water from Pecos County to Tom Green County where it may need advanced treatment will be expensive. This may be too great of a financial burden for the City of San Angelo. This strategy is not recommended for this planning cycle. However, it was analyzed as a potential strategy to be considered for future use should the opportunity present itself.

WUG:	**Andrews**	**Capital Cost:**	$15,663,000
WMS Name:	**Develop Ogallala Aquifer Supplies**	**Annual Cost** (During Amortization):	$496 per acre-foot $1.52 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$104 per acre-foot $0.32 per 1,000 gal
WMS Yield:	2,810 acre-feet per year	**Implementation:**	2020
WMS Status:	Alternative		

Strategy Description

To provide additional supply, the City of Andrews plans to develop additional groundwater in two phases. The first phase involves developing new groundwater near the existing Florey Well Field and has been completed. The second phase is to develop groundwater located south of town and construct a new pipeline.

The next phase involves developing groundwater from a different location south of town. The City has drilled 16 test wells in this area and discovered the wells are slower producing than those located near the Florey Well Field. The next phase assumes 14 new wells and an 8-mile, 18-inch diameter pipeline to town. This portion is expected to be online in 2040 and the total water supply provided by the strategy is approximately 2,810 acre-feet per year.

The City recently completed a new water treatment plant to treat naturally occurring fluoride and arsenic levels found in local groundwater. It was assumed that this plant could handle any potential water quality issues that may arise. Therefore, no treatment plant was included in the evaluation and cost estimate of this strategy. If a new treatment plant is determined to be needed, the cost of this strategy will increase.

Quantity, Reliability and Cost

The quantity and reliability of water from this source is expected to be good given the test wells and studies already performed by the City of Andrews. For this plan, the 14 new wells are assumed to supply an additional 2,810 acre-feet per year by the time the phased strategy is fully implemented. Due to limitations from the MAG, this strategy is considered alternative.

The total cost of the project will be approximately $15.6 million. This equates to $496 per acre-foot ($1.52 per 1,000 gallons) of treated water during debt service. After the infrastructure is fully paid for, the cost drops to $104 per acre-foot ($0.32 per 1,000 gallons) of treated water.

Environmental Factors

The aquifer is a proven groundwater source for municipal, industrial, and agricultural purposes. However, the long-term water quality is unknown. Throughout much of the aquifer, groundwater withdrawals exceed the amount of recharge, and water levels have declined fairly consistently through time. However, the City has an agreement with other users in the area to minimize the impacts of drawdown near their well field. Groundwater development from this source is expected to cause minimal environmental impacts.

Agricultural and Rural Impacts

This source is currently used for agricultural purposes. This strategy would reduce the amount of water currently available to agricultural users. It is assumed that the transfer of water rights will be between a willing buyer and willing seller, and there would be minimal impacts to agricultural users.

Impacts to Natural Resources and Key Parameters of Water Quality
There are no identified impacts to natural resources.

Impacts on Other Water Resources and Management Strategies
This strategy may impact other groundwater strategies in Andrews County due to competition for available supplies.

Other Issues Affecting Feasibility
The most significant challenge for this strategy is the planning constraints of the Modeled Available Groundwater volume amount for the County of Andrews from the Ogallala aquifer. Due to these limitations, the supply available from the Ogallala aquifer is less than proposed for this strategy. As such, this strategy cannot be recommended in the plan at the quantities shown. However, since Andrews County does not have a GCD to enforce ground restrictions, such as MAG limits, the City could pursue this strategy independently, but it could not receive State funding to construct it.

WUG:	**Andrews**	**Capital Cost:**	$24,927,000
WMS Name:	**Develop Edwards-Trinity Plateau Aquifer Supplies (Antlers Formation)**	**Annual Cost** (During Amortization):	$891 per acre-foot $2.73 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$217 per acre-foot $0.66 per 1,000 gal
WMS Yield:	2,600 acre-feet per year	**Implementation:**	2020
WMS Status:	Alternative		

Strategy Description

The Edwards-Trinity Plateau aquifer in the Antlers formation has been identified as a potential source for additional municipal purposes. Along the southern county border, there may lie groundwater supplies suitable for development. It is unclear if this formation is truly from the Edwards-Trinity Plateau or if it is fed by leakage from the overlaying Ogallala aquifer. This potential source is only located in the southern part of Andrews County. Further study would be needed to determine if this was a feasible strategy for the specific user depending on their location within the county and local hydrogeologic conditions. This strategy assumes that 38 new wells would need to be drilled to provide approximately 2,600 acre-feet per year. These wells would produce water from approximately 150 feet deep.

Quantity, Reliability and Cost

The quantity and reliability of water from this source is expected to be approximately 50 gpm. Historical municipal use indicates that the Edwards-Trinity Plateau outcrops may be a viable source but high TDS may require advanced treatment for municipal use, which would increase the cost if required. For this plan, the 38 new wells are assumed to supply an additional 2,600 acre-feet per year. It also includes 15 miles of 18-inch pipeline. The reliability of the supply is considered to be medium, based on the aquifer characteristics and water quality. Due to MAG limitations, this strategy is listed as Alternative. The capital costs are estimated at $24.9 million.

Environmental Factors

The aquifer is currently not used for municipal purposes in Andrews County. Wastewater discharges from this source may contain elevated TDS if the water is not treated. This strategy is not expected to have other environmental impacts. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts

Since this source is not currently being used to any extent in Andrews County, the strategy should not have any impacts to agricultural users. It would provide additional water to rural users.

Impacts to Natural Resources and Key Parameters of Water Quality

The water quality in the Edwards-Trinity Plateau aquifer can be variable, with water quality ranging from fresh to slightly saline in the outcrop areas, and brine water in subsurface portions. Water levels have remained relatively stable because recharge has generally kept pace with the relatively low amounts of pumping over the extent of the aquifer. No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

No other water management strategies will be impacted.

Other Issues Affecting Feasibility

The most significant challenge for this strategy is locating areas with sufficient well production where the water quality is good. In addition, this project requires financing for the new facilities.

WUG:	**Andrews County Other**	**Capital Cost:**	$751,000
WMS Name:	**Develop Edwards-Trinity-Plateau Aquifer Supplies**	**Annual Cost** (During Amortization):	$252 per acre-foot $0.77 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$40 per acre-foot $0.12 per 1,000 gal
WMS Yield:	250 acre-feet per year	**Implementation:**	2020
WMS Status:	Alternative		

Strategy Description

The Edwards-Trinity Plateau aquifer has been identified as a potential source for municipal, industrial and agricultural purposes. Along the southern county border, there may lie groundwater supplies suitable for development. It is unclear if this formation is truly from the Edwards-Trinity Plateau or if it is fed by leakage from the overlaying Ogallala aquifer. This potential source is only located in the southern part of Andrews County. Further study would be needed to determine if this was a feasible strategy for the specific user depending on their location within the county and local hydrogeologic conditions. This strategy assumes that five new wells would need to be drilled to provide approximately 250 acre-feet per year. These wells would produce water from approximately 150 feet below the surface.

Quantity, Reliability and Cost

The quantity and reliability of water from this source is expected to be approximately 50 gpm. Historical municipal and agricultural use indicates that the Edwards-Trinity Plateau outcrops may be a viable source but high TDS may require advanced treatment for municipal use. For this plan, the five new wells are assumed to supply an additional 250 acre-feet per year. Since there is not a specific sponsor for this strategy, it is assumed that the water would be treated at the Point of Use if needed and the infrastructure costs for treatment and transmission are not included in the costs for this strategy. The reliability of the supply is considered to be medium, based on the aquifer characteristics and water quality. The capital costs are estimated at $751,000.

Environmental Factors

The aquifer is currently not used for municipal purposes in Andrews County. Wastewater discharges from this source may contain elevated TDS if the water is not treated. This strategy is not expected to have other environmental impacts. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts

Since this source is not currently being used to any extent in Andrews County, the strategy should not have any impacts to agricultural users. It would provide additional water to rural users.

Impacts to Natural Resources and Key Parameters of Water Quality

The water quality in the Edwards-Trinity Plateau aquifer can be variable, with water quality ranging from fresh to slightly saline in the outcrop areas, and brine water in subsurface portions. Water levels have remained relatively stable because recharge has generally kept pace with the relatively low amounts of pumping over the extent of the aquifer. No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

No other water management strategies will be impacted.

Other Issues Affecting Feasibility

The most significant challenge for this strategy is locating areas with sufficient well production where the water quality is good. In addition, this project requires financing for the new facilities.

WUG:	**Andrews County Livestock**	**Capital Cost:**	$327,000
WMS Name:	**Develop Edwards-Trinity-Plateau Aquifer Supplies**	**Annual Cost** (During Amortization):	$433 per acre-foot $1.33 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$50 per acre-foot $0.15 per 1,000 gal
WMS Yield:	60 acre-feet per year	**Implementation:**	2020
WMS Status:	Alternative		

Strategy Description

The Edwards-Trinity Plateau aquifer has been identified as a potential source of water for livestock in Andrews County. Water from this source ranges from fresh to slightly saline in the outcrop areas, and brine water in subsurface portions. Along the southern border of the county, there may lie undeveloped brackish groundwater supplies suitable for agricultural use. It is unclear whether supply is truly from the Edwards-Trinity Plateau or if it is fed by leakage from the overlaying Ogallala aquifer. This source is only located in the southern part of Andrews County. Further study would be needed to determine if this is a feasible strategy for the user depending on their location within the county and local hydrogeologic conditions. This strategy assumes that three new wells would need to be drilled to provide approximately 60 acre-feet per year. These wells would produce water from approximately 150 feet below the surface.

Quantity, Reliability and Cost

The quantity and reliability of water from this source is expected to be approximately 30 gpm. For this plan, the three new wells are assumed to supply an additional 60 acre-feet per year. The reliability of the supply is considered to be low to medium, based on the unproven use of this source. Due to MAG limitations, this strategy is considered Alternative.

The total cost of the project will be approximately $327,000. This equates to $433 per acre-foot ($1.33 per 1,000 gallons) of treated water during debt service. After the infrastructure is fully paid for, the cost drops to $50 per acre-foot ($0.15 per 1,000 gallons) of treated water.

Environmental Factors

Environmental impacts from this strategy are expected to be low. Groundwater development from this source should be evaluated for potential impacts on springflows and base flows of area rivers. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts

This source is currently not used in Andrews County. This strategy should not impact current rural users. It should provide additional water for agricultural purposes.

Impacts to Natural Resources and Key Parameters of Water Quality

Water quality in the Edwards-Trinity Plateau aquifer ranges from fresh to slightly saline in the outcrop areas, and brine water in subsurface portions. Water levels have remained relatively stable because recharge has generally kept pace with the relatively low amounts of pumping over the extent of the aquifer.

No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

This strategy could potentially impact the development of groundwater from the Edwards-Trinity Plateau aquifer for rural County-Other in Andrews County if located in the same vicinity. However, the combined supplies from these strategies do not exceed the MAG value, indicating there is sufficient supplies for both strategies.

Other Issues Affecting Feasibility

An adequate drinking water supply is an essential component of livestock production. The most significant challenge for this strategy is locating areas with sufficient well production. Generally, livestock can tolerate higher salinity levels than municipal use; however, long-term use could negatively impact overall livestock performance. This might potentially offset the positive impacts of a more reliable water supply.

WUG:	**Andrews County Manufacturing**	**Capital Cost:**	$591,000
WMS Name:	**Develop Edwards-Trinity-Plateau Aquifer Supplies**	**Annual Cost** (During Amortization):	$243 per acre-foot $0.75 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$43 per acre-foot $0.13 per 1,000 gal
WMS Yield:	210 acre-feet per year	**Implementation:**	2020
WMS Status:	Alternative		

Strategy Description

There are undeveloped groundwater supplies in the Edwards-Trinity Plateau aquifer in Andrews 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 four new wells would be drilled to provide approximately 210 acre-feet per year. These wells would produce water approximately 150 feet below the surface.

Quantity, Reliability and Cost

This strategy assumes that up to 210 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. Due to MAG limitations, this strategy is considered Alternative.

Environmental Factors

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 springflows and base flows of area rivers. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts

Wells provide water for ranching, industrial, domestic and municipal supplies throughout the area. This strategy assumes sufficient groundwater rights would be obtained on a willing buyer-willing seller basis, which should mitigate potential impacts to agricultural and rural water users.

Impacts to Natural Resources and Key Parameters of Water Quality

The water quality in the Edwards-Trinity Plateau aquifer ranges from fresh to slightly saline in the outcrop areas, and brine water in subsurface portions. Water levels have remained relatively stable because recharge has generally kept pace with the relatively low amounts of pumping over the extent of the aquifer. This strategy is not expected to impact key parameters of water quality.

No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

This strategy may compete with other Andrews County strategies for limited supplies. However, the strategies were sized with respect to the MAG for the Edwards-Trinity Plateau aquifer, so there should be no impacts to other strategies.

Other Issues Affecting Feasibility

The most significant challenge for this strategy is locating areas with sufficient well production and low potential for impacts on springflows.

WWP:	**Texland Great Plains**	**Capital Cost:**	$380,000
WMS Name:	**Develop Ogallala Aquifer Supplies**	**Annual Cost** (During Amortization):	$190 per acre-foot $0.58 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$55 per acre-foot $0.17 per 1,000 gal
WMS Yield:	200 acre-feet per year	**Implementation:**	2020
WMS Status:	Alternative		

Strategy Description

Texland Great Plains is a wholesale water provider in Andrews and Gaines counties. They currently produce water from an existing well field in the Ogallala Aquifer. The MAG limits the availability for additional development from the Ogallala under regional planning rules and guidelines. However, it is anticipated that Great Plains would develop additional wells in Andrews and/or Gaines counties. This is an alternative strategy since the MAG limits in Andrews and Gaines counties. This strategy assumes one additional 250 gpm well.

Quantity, Reliability and Cost

This strategy is anticipated to provide an average of 200 acre-feet per year. The reliability of this supply is considered medium-high because the it is an existing well field in a proven aquifer. However, the MAG limitations indicate there may be competition for the water supply. The estimated cost of the additional well is $380,000.

Environmental Factors

Environmental impacts are expected to be low.

Agricultural and Rural Impacts

As some farmers cease to irrigate, Texland Great Plains may purchase their groundwater rights and drill or take over those wells as part of this strategy. It is assumed this would happen on a willing-buyer, willing-seller basis, limiting the impact on the agricultural users.

Impacts to Natural Resources and Key Parameters of Water Quality

Use of this source is not expected to impact key parameters of water quality. No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

MAG availability from the Ogallala Aquifer limits official development of strategies from this source. This strategy will increase the competition for available groundwater in the area.

Other Issues Affecting Feasibility

The most significant challenge for this strategy is MAG availability.

WUG:	**Balmorhea**	**Capital Cost:**	$1,948,000
WMS Name:	**Develop Edwards-Trinity Plateau Aquifer Supplies**	**Annual Cost** (During Amortization):	$1,053 per acre-foot $3.23 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$140 per acre-foot $0.43 per 1,000 gal
WMS Yield:	150 acre-feet per year	**Implementation:**	2020
WMS Status:	Recommended		

Strategy Description

The City of Balmorhea is evaluating a groundwater source in the Edwards-Trinity Plateau aquifer. This source has been identified as currently supplying water for municipal, industrial and agricultural uses. However, the long-term water availability and quality of the proposed well field should be assessed further. This strategy assumes that two new wells would be drilled to provide approximately 150 acre-feet per year. This well would produce water from approximately 600 feet below the surface.

This strategy also includes 5 miles of 6-inch diameter pipeline that will connect the well to the current infrastructure.

Quantity, Reliability and Cost

The quantity and reliability of water from this source is expected to be approximately 125 gpm. Historical municipal and agricultural use indicates that the Edwards-Trinity Plateau may be a viable source for municipal use but may require some treatment or blending based on local groundwater conditions. For this plan, the new well is assumed to supply an additional 150 acre-feet per year. The reliability of the supply is considered to be high, based on the aquifer characteristics observed to contain large pools of mostly potable water. The total capital cost is estimated at $1.9 million. This strategy assumes that adequate water quality for municipal use can be reached through blending with Balmorhea's other groundwater sources. If the quality of water requires advanced treatment, costs would be higher than estimated here.

Environmental Factors

The aquifer is a proven groundwater source for municipal, industrial and agricultural purposes. However, the long-term water quality is unknown. Groundwater development from this source should be evaluated for potential impacts on springflows and base flows of area rivers. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts

Springflows from the Edwards-Trinity Plateau supply much of the base flow of flowing streams in the area. Many of these streams are used for irrigation. Wells provide water for ranching, domestic and municipal supplies throughout the area. It is assumed that the proposed level of additional groundwater development will not impact agricultural or rural users.

Impacts to Natural Resources and Key Parameters of Water Quality

The water quality in the Edwards-Trinity Plateau aquifer ranges from generally fresh to slightly saline in the outcrop areas, and brackishwater in subsurface portions. Water levels have remained relatively stable because recharge has generally kept pace with the relatively low amounts of pumping over the extent of the aquifer. This strategy is not expected to impact key parameters of water quality.

No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

No other water management strategies will be impacted.

Other Issues Affecting Feasibility

The economic viability of the project will depend upon the ability to locate groundwater of sufficient quality to blend with existing sources without advanced treatment.

WUG:	**Bronte**	**Capital Cost:**	$23,694,000
WMS Name:	**Develop Other Aquifer Supplies in Southwest Coke County**	**Annual Cost** (During Amortization):	$2,424 per acre-foot $7.44 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$340 per acre-foot $1.04 per 1,000 gal
WMS Yield:	800 acre-feet per year	**Implementation:**	2020
WMS Status:	Recommended		

Strategy Description

The Coke County Underground Water District has done some groundwater exploration in southwest Coke County. Bronte is considering developing 5 new wells in this area. It is estimated that the wells would produce around 100 gpm from a 300 ft depth and be of adequate quality for municipal use without advanced treatment. A 31-mile, 10-inch transmission pipeline would be needed to deliver these supplies to the City.

Quantity, Reliability and Cost

This strategy is estimated to supply 800 acre-feet per year. The reliability is considered medium based on the work done by the Coke County Underground Water District but the strategy is still dependent on locating wells with adequate production and water quality. The costs are estimated at $23.7 million.

Environmental Factors

Some testing and exploration has been done in this area but the long term water quality is unknown. Other environmental factors were not identified.

Agricultural and Rural Impacts

No agricultural and rural impacts are anticipated.

Impacts to Natural Resources and Key Parameters of Water Quality

None identified.

Impacts on Other Water Resources and Management Strategies

Other strategies for the City of Bronte may be impacted. The need for this strategy may be reduced if Robert Lee were to develop independent supplies from one of their Alternative Water Management Strategies.

Other Issues Affecting Feasibility

Because the long-term reliability and quality of this supply is unknown, the City may need to develop other alternatives to meet long-term needs. Funding construction of this infrastructure will be a significant strain on the financial resources of the City.

WUG:	**Bronte**	**Capital Cost:**	$2,666,000
WMS Name:	**Develop Other Aquifer Supplies in Runnels County**	**Annual Cost** (During Amortization):	$2,787 per acre-foot $8.55 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$280 per acre-foot $0.86 per 1,000 gal
WMS Yield:	75 acre-feet per year	**Implementation:**	NA
WMS Status:	Alternative		

Strategy Description

This strategy is to develop two 50 gpm wells from Other Aquifer in Runnels county. The wells are estimated to produce water from 150-foot depth. A 6-inch, 9.5-mile transmission pipeline is also assumed.

Quantity, Reliability and Cost

This strategy is estimated to yield 75 acre-feet per year. The reliability is considered medium because it is dependent upon finding an area with adequate production and water quality for municipal use. The cost is estimated at $2.7 million.

Environmental Factors

The long-term water quality of this source is unknown. No other environmental concerns were identified. This strategy is unlikely to cause subsidence.

Agricultural and Rural Impacts

Bronte is a rural community. Increased water security provided by this strategy will have a positive impact on the vitality of this rural community.

Impacts to Natural Resources and Key Parameters of Water Quality

None identified.

Impacts on Other Water Resources and Management Strategies

Other strategies for the City of Bronte may be impacted. The need for this strategy may be reduced if Robert Lee were to develop independent supplies from one of their Alternative Water Management Strategies.

Other Issues Affecting Feasibility

Because the long-term reliability and quality of this supply is unknown, the City may need to develop other alternatives to meet long-term needs. Funding construction of this infrastructure will be a significant strain on the financial resources of the City.

WUG:	**Brown County Mining**	**Capital Cost:**	$2,440,000
WMS Name:	**Develop Cross Timbers Aquifer Supplies**	**Annual Cost** (During Amortization):	$948 per acre-foot $2.91 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$129 per acre-foot $0.39 per 1,000 gal
WMS Yield:	210 acre-feet per year	**Implementation:**	2020
WMS Status:	Recommended		

Strategy Description
The Cross Timbers formation has been identified as a potential source of water for mining in Brown County. This strategy assumes that 32 new wells would be drilled to provide approximately 210 acre-feet per year. These wells are assumed to produce water from approximately 320 feet below the surface.

Quantity, Reliability and Cost
It is assumed that for this strategy, each well will provide an additional 5 gpm for mining purposes in Coke County. This brings the total strategy yield up to 210 acre-feet per year. The reliability of the supply is considered to be low to medium, based on the unproven use of this source.

The total cost of the project will be approximately $2.4 million. This equates to $948 per acre-foot ($2.91 per 1,000 gallons) of water during debt service. After the infrastructure is fully paid for, the cost drops to $129 per acre-foot ($0.39 per 1,000 gallons) of treated water.

Environmental Factors
Environmental impacts from this strategy are expected to be low. Groundwater development from this source should be evaluated for potential impacts on springflows and base flows of area rivers. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts
None identified.

Impacts to Natural Resources and Key Parameters of Water Quality
The water quality in this area tends to be poor, but should be more than adequate for mining purposes.

No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies
None identified.

Other Issues Affecting Feasibility
The most significant challenge for this strategy is locating areas with sufficient well production.

WUG:	**Colorado City**	**Capital Cost:**	$3,744,000
WMS Name:	**Dockum Well Field Expansion**	**Annual Cost** (During Amortization):	$1,824 per acre-foot $5.60 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$276 per acre-foot $0.85 per 1,000 gal
WMS Yield:	170 acre-feet per year	**Implementation:**	2020
WMS Status:	Alternative		

Strategy Description

In compliance with the guidance and rules for regional water planning, the TWDB requires the use of Modeled Available Groundwater (MAG) in regional water planning. The MAG for the City's current well field in the Dockum aquifer is severely limiting. To meet the City's water demands, Colorado City is considering an alternative water management strategy. This strategy is not recommended for this planning cycle due to the supply volume exceeding the current MAG in the Dockum aquifer.

Colorado City currently obtains its water supply from several well fields in the Dockum aquifer. The City recently drilled two new well fields, but one was high in sulfides and must be blended with other supplies before use. There are concerns about potential oil field contamination and the City is seeking to expand groundwater development in the Dockum Aquifer. This source is currently used for municipal and agricultural purposes and has been identified as a potential supply to meet the City's needs. This strategy assumes that one new well would need to be drilled to provide approximately 170 acre-feet per year. This well would produce water approximately 200 feet below surface. It is assumed that the water quality of the new well would be equivalent to the quality of the City's original wells that no additional treatment will be needed. If adequate water quality cannot be found, advanced treatment may be needed, which would increase the estimated cost of this strategy.

Piping infrastructure is currently in place to transport water from the first field 9 miles east of town to the existing standpipe. An 8-mile pipeline, 6-inches in diameter, will connect water from the second field to the current pipeline running from the first field to the standpipe. The well pumps will be used to convey the water through the pipeline.

Quantity, Reliability and Cost

The quantity and reliability of water from this source is expected to be 150 gpm. Historical municipal and agricultural use indicates that the Dockum aquifer may be a viable source. For this plan, the new well is assumed to supply an additional 170 acre-feet per year. The reliability of the supply is considered to be medium because of aquifer and water quality properties.

The total cost of the project will be approximately $3.7 million. This equates to $1,824 per acre-foot ($5.60 per 1,000 gallons) of treated water during debt service. After the infrastructure is fully paid for, the cost drops to $276 per acre-foot ($0.85 per 1,000 gallons) of treated water.

Environmental Factors

The aquifer is a proven groundwater source for municipal, industrial, and agricultural purposes. However, the long-term water quality is unknown. Groundwater development from this source should be evaluated for potential impacts on springflows and base flows of area rivers. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts

This source is currently used for agricultural purposes. It is assumed that the transfer of water rights will be between a willing buyer and willing seller, and there would be minimal impacts to agricultural users.

Impacts to Natural Resources and Key Parameters of Water Quality

The water quality in the Dockum aquifer is generally variable, with freshwater in outcrop areas and brine in the subsurface portions. The water tends to be very hard. Advanced treatment may be required for municipal use.

No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

None identified.

Other Issues Affecting Feasibility

The most significant challenge for this strategy is locating areas with sufficient well production, and funding. Due to MAG limitations, this strategy is not recommended; however, it was analyzed as an alternative strategy to be considered for future use should the DFC and MAG change.

WUG:	**Grandfalls**	**Capital Cost:**	$2,410,000
WMS Name:	**Develop Pecos Valley Aquifer Supplies**	**Annual Cost** (During Amortization):	$1,245 per acre-foot $3.82 per 1,000 gal
WMS Type:	Groundwater Development		
WMS Yield:	155 acre-feet per year	**Annual Cost** (After Amortization):	$148 per acre-foot $0.46 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description
Grandfalls existing water supplies are from CRMWD's Ward County Well Field. Grandfalls' contract with CRMWD for water supplies will expires in 2049. Starting in 2050, it is assumed they will need to develop their own well field in the Pecos Valley Aquifer in Ward County. This strategy assumes Grandfalls will drill two wells, connect them with necessary collection piping, and then transport the supplies to Grandfalls via a 6 mile, 6-inch transmission line.

Quantity, Reliability and Cost
This strategy is estimated to supply 155 acre-feet per year from two 100 gpm wells producing from about 200 ft below the surface in the Pecos Valley Aquifer. The reliability from this strategy is considered high. The estimated cost of this strategy is $2.4 million.

Environmental Factors
Environmental impacts are expected to be low. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts
There are no agricultural or rural issues associated with this strategy.

Impacts to Natural Resources and Key Parameters of Water Quality
The strategy proposes to utilize a sustainable level of groundwater that does not exceed the Modeled Available Groundwater (MAG). The impacts to natural resources are expected to be minimal. No impacts to water quality are expected.

Impacts on Other Water Resources and Management Strategies
No impacts on other water management strategies are anticipated.

Other Issues Affecting Feasibility
If Grandfalls is able to negotiate a new contract agreement with CRMWD for supplies from CRMWD's Ward County well field, they may not need to develop independent supplies. This would have to be negotiated at that time and would be subject to both parties reaching mutually agreeable terms.

WUG:	**Junction**	**Capital Cost:**	$3,634,000
WMS Name:	**Develop Edwards-Trinity-Plateau Aquifer Supplies**	**Annual Cost** (During Amortization):	$822 per acre-foot $2.52 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$130 per acre-foot $0.40 per 1,000 gal
WMS Yield:	370 acre-feet per year	**Implementation:**	2020
WMS Status:	Recommended		

Strategy Description

The City of Junction is evaluating a groundwater source in the Edwards-Trinity Plateau aquifer to back up its current supplies. Water from this source is not widely used because of low well yields and poor water quality. This source is currently used for manufacturing. This strategy assumes that seven new wells would be drilled to provide approximately 370 acre-feet per year. These wells are assumed to produce water from approximately 190 feet below the surface with elevated TDS levels. It is assumed that this water is blended with surface water. However, if it is determined that the water qualities of the two sources are incompatible, the groundwater may require advanced treatment. Costs for advanced treatment are not included. This strategy assumes that the new wells will be drilled within three miles of the City's existing infrastructure. This project includes 1,800 feet of 6-inch diameter well field collection piping and three miles of 8-inch transmission piping to connect to existing infrastructure.

Quantity, Reliability and Cost

The quantity and reliability of water from this source is expected to be approximately 40 gpm. Historical use indicates that the Edwards-Trinity Plateau may be a viable source but may contain high TDS. For this plan, the seven new wells are assumed to supply an additional 370 acre-feet per year. The reliability of the supply is considered to be medium because of water quantity and quality issues.

Environmental Factors

The blending of slightly brackish water with Junction's existing supplies may increase the TDS levels of treated wastewater from the City. It is expected the increase will not exceed current discharge limits. No other environmental impacts are identified.

Agricultural and Rural Impacts

Wells provide water for ranching, domestic and municipal supplies throughout the area. This strategy assumes sufficient groundwater rights would be obtained on a willing buyer-willing seller basis, which should mitigate potential impacts to agricultural and rural water users.

Impacts to Natural Resources and Key Parameters of Water Quality

Water quality in the Edwards-Trinity Plateau aquifer ranges from fresh to slightly saline in the outcrop areas, and brine water in subsurface portions. Water levels have remained relatively stable because recharge has generally kept pace with the relatively low amounts of pumping. No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

None identified.

Other Issues Affecting Feasibility

A significant challenge for this strategy is locating areas with sufficient well production where the water quality is good.

WUG:	**Kimble County Manufacturing**	**Capital Cost:**	$1,621,000
WMS Name:	**Develop Edwards-Trinity Aquifer Supplies**	**Annual Cost** (During Amortization):	$274 per acre-foot $0.84 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$46 per acre-foot $0.14 per 1,000 gal
WMS Yield:	500 acre-feet per year	**Implementation:**	2020
WMS Status:	Recommended		

Strategy Description

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 10 new wells would be drilled to provide approximately 500 acre-feet per year. These wells would produce water approximately 190 feet below the surface.

Quantity, Reliability and Cost

This strategy could meet Kimble County manufacturing water needs for consumptive use, but not for recirculated water. This strategy assumes that up to 500 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.

Environmental Factors

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 springflows and base flows of area rivers. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts

Wells provide water for ranching, industrial, domestic and municipal supplies throughout the area. This strategy assumes sufficient groundwater rights would be obtained on a willing buyer-willing seller basis, which should mitigate potential impacts to agricultural and rural water users.

Impacts to Natural Resources and Key Parameters of Water Quality

The water quality in the Edwards-Trinity Plateau aquifer ranges from fresh to slightly saline in the outcrop areas, and brine water in subsurface portions. Water levels have remained relatively stable because recharge has generally kept pace with the relatively low amounts of pumping over the extent of the aquifer. This strategy is not expected to impact key parameters of water quality.

No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

This strategy may compete with other Kimble County strategies for limited supplies. However, the strategies were sized with respect to the MAG for the Edwards-Trinity Plateau aquifer, so there should be no impacts to other strategies.

Other Issues Affecting Feasibility

The most significant challenge for this strategy is locating areas with sufficient well production and low potential for impacts on springflows. 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 needs calculation because the surface water supplies are limited to consumptive use only in the WAM. The actual amount of surface water available for manufacturing use for recirculation is greater.

WUG:	**Menard**	**Capital Cost:**	$3,287,000
WMS Name:	**Develop Hickory Aquifer Supplies**	**Annual Cost** (During Amortization):	$1,320 per acre-foot $4.05 per 1,000 gal
WMS Type:	Groundwater Development		
WMS Yield:	200 acre-feet per year	**Annual Cost** (After Amortization):	$160 per acre-foot $0.51 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description

The City of Menard has been actively seeking a groundwater source to add to 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 3,600 ft. The City is planning to drill one well near its existing storage tank to provide approximately 200 acre-feet per year. This well would produce water from approximately 3,600 feet below the surface.

Quantity, Reliability and Cost

The quantity and reliability of water from this source is expected to be approximately 620 gpm. Limited historical agricultural use indicates that the Hickory aquifer may be a viable source but elevated radionuclide concentrations will require advanced treatment. For the purpose 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. The one new well is assumed to supply an additional 200 acre-feet per year. The reliability of the supply is considered to be medium because of water quality issues. Capital costs for this strategy are estimated at $3.3 million.

Environmental Factors

The proposed well will produce water from the down-dip portion of the Hickory aquifer. Because of the 3,000 feet of overburden, there is no connection with the land surface and as a result, no impact is expected 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. Groundwater development from this source is expected to cause minimal environmental impacts, unless the water requires advanced treatment. If advanced treatment is required, impacts may be higher depending on the method used to dispose of the reject from the treatment process.

Agricultural and Rural Impacts

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.

Impacts to Natural Resources and Key Parameters of Water Quality

In Menard County, the water quality of the Hickory aquifer tends to be poor. The upper portion of the aquifer contains iron in excess of the State's secondary drinking water standards. Also, much of the water from the Hickory aquifer exceeds drinking water standards for radionuclides. For 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.

Impacts on Other Water Resources and Management Strategies

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. No impacts to other strategies or water resources were identified.

Other Issues Affecting Feasibility

The most significant challenge for this strategy is locating areas with sufficient well production where the water quality is good. For the purposes of this plan, this strategy assumes that water from the Hickory can meet primary drinking water standards in regards to radionuclides if blended with the City's existing water supply.

WUG:	**Midland County Other**	**Capital Cost:**	$24,557,000
WMS Name:	**Develop Pecos Valley Aquifer Supplies from Roark Ranch in Winkler County**	**Annual Cost** (During Amortization):	$738 per acre-foot $2.26 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$121 per acre-foot $0.37 per 1,000 gal
WMS Yield:	2,800 acre-feet per year	**Implementation:**	2020
WMS Status:	Recommended		

Strategy Description

Midland County Utility District is considering developing additional groundwater in conjunction with the Midland County Fresh Water District (FWD). This strategy would expand groundwater supplies from the Pecos Valley aquifer in Winkler County and would be transported by the existing Midland County FWD pipeline to the greater Midland area. This strategy is a recommended strategy for Midland County Utility District (County-Other).

Quantity, Reliability and Cost

At this time it is unclear how much water would be available through this strategy or how it will ultimately be transported. For planning purposes, the strategy was assumed to provide up to 2,800 acre-feet of additional water to County-Other in Midland County. It is assumed that fifteen new wells would be drilled in Winkler County and connected to the T-Bar infrastructure, if agreements can be reached with the Midland County Freshwater Supply District No. 1 and the City of Midland to provide this capacity in the transmission line from the T-Bar Well Field. For this strategy, no treatment is included. This supply is considered reliable, but the use of the T-Bar infrastructure may limit the supplies when Midland is using the full capacity of the system. The capital cost of this strategy is $24.6 million, not including the purchase of the land which is considered complete for the purposes of this plan. Further development of supply from this land may be possible beyond the quantity shown in this plan. However, at this time, not enough information is available for inclusion in the plan.

Environmental Factors

The aquifer is a proven groundwater source for municipal, industrial, and agricultural purposes. However, the long-term water quality is unknown. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts

Development of groundwater may divert water that was previously used for agricultural and rural purposes. However, this strategy involves groundwater rights that were obtained on a willing buyer – willing seller basis which minimizes the impacts to agriculture.

Impacts to Natural Resources and Key Parameters of Water Quality

The strategy proposes to utilize a sustainable level of groundwater that does not exceed the Modeled Available Groundwater (MAG). The impacts to natural resources are expected to be minimal. No impacts to water quality are expected.

Impacts on Other Water Resources and Management Strategies

This strategy could limit the ability to transport water from the expansion of the T-Bar Well Field during times of peak capacity.

Other Issues Affecting Feasibility

Since this strategy proposes to use the existing T-Bar ranch pipeline, agreements must be reached between all entities involved including the Midland County Fresh Water District, the Midland County Utility District, and the City of Midland.

WUG:	**Pecos City & Madera Valley WSC**	**Capital Cost:**	$43,107,000
WMS Name:	**Partner with Madera Valley WSC & Expand Pecos Valley Aquifer Supplies**	**Annual Cost** (During Amortization):	$427 per acre-foot $1.31 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$89 per acre-foot $0.27 per 1,000 gal
WMS Yield:	8,960 acre-feet per year	**Implementation:**	2030
WMS Status:	Recommended		

Strategy Description

The Madera Valley WSC has an existing well field and 10-inch transmission line for their own use. Pecos City is considering partnering with Madera Valley to expand the well field yield by an additional 6-8 MGD of average annual supply for both users from the Pecos Valley Aquifer. This strategy assumes the full 8 MGD is developed, all with ten new 650 gpm wells. The project also includes a 24-inch transmission line for Pecos City to connect to the expanded well field.

This strategy is subject to on-going negotiations between Madera Valley WSC and Pecos City and is contingent upon the two entities reaching mutually agreeable terms for the division of water and cost.

Quantity, Reliability and Cost

This strategy would increase the supply availability to Pecos City and Madera Valley WSC by an estimated 8,960 acre-feet per year. The amount of supply to each entity is dependent upon on-going negotiations between the two parties. The reliability of this supply is considered high. The estimated total capital investment required for both parties is $43.1 million.

Environmental Factors

The aquifer is a proven groundwater source for municipal, industrial and agricultural purposes. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts

This strategy is expected to have no impacts on agricultural or rural users.

Impacts to Natural Resources and Key Parameters of Water Quality

The water quality in the Pecos Valley aquifer is highly variable. However, since this is an expansion of an existing field that is currently used for municipal use, the water quality is anticipated to be good. No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

This strategy respects the MAG values in Reeves County, such that there is sufficient supplies for all recommended strategies.

Other Issues Affecting Feasibility

None identified.

WUG:	**Pecos County WCID #1**	**Capital Cost:**	$3,630,000
WMS Name:	**Develop Edwards-Trinity-Plateau Aquifer Supplies**	**Annual Cost** (During Amortization):	$1,224 per acre-foot $3.76 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$204 per acre-foot $0.63 per 1,000 gal
WMS Yield:	250 acre-feet per year	**Implementation:**	2020
WMS Status:	Recommended		

Strategy Description

Developing additional groundwater supplies is a recommended strategy to increase the reliability of Pecos County WCID's current system. For this planning purpose, it is assumed that Pecos County WCID #1 will drill two additional 150 gpm wells in the Edwards-Trinity Plateau aquifer to back up current supplies. The strategy also includes 6-inch collection piping and an elevated storage tank. The transmission line replacement is costed as part of a standalone project (see Transmission Pipeline, Pecos County WCID #1) and is therefore not included in here.

Quantity, Reliability and Cost

This strategy is expected to produce an additional 250 acre-feet per year from two additional wells. This source is already in use by the WCID and the reliability is considered high. The cost for the well field expansion is estimated at $3.6 million.

Environmental Factors

The aquifer is a proven groundwater source for municipal, industrial and agricultural purposes. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts

This strategy is expected to have no impacts on agricultural or rural users.

Impacts to Natural Resources and Key Parameters of Water Quality

Since this is an expansion of an existing field that is currently used for municipal use, the water quality is anticipated to be good. No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

This strategy is only for the well field expansion. A replacement and upsizing of the transmission line to connect this supply to the WCID's service area is also required and is discussed in a separate technical memorandum (Transmission Pipeline, Pecos County WCID#1) in the expanded use section of this appendix.

Other Issues Affecting Feasibility

None.

WUG:	**Reeves County Mining**	**Capital Cost:**	$17,465,000
WMS Name:	**Develop Pecos Valley Aquifer Supplies**	**Annual Cost** (During Amortization):	$173 per acre-foot $0.53 per 1,000 gal
WMS Type:	Groundwater Development		
WMS Yield:	10,400 acre-feet per year	**Annual Cost** (After Amortization):	$54 per acre-foot $0.17 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description

The Pecos Valley aquifer has been identified as a potential source of water for mining in Reeves County. Water from this source is highly variable, and typically hard. This strategy assumes that 75 new wells would need to be drilled to provide approximately 10,400 acre-feet per year. These wells would produce water from approximately 500 feet below the surface.

Quantity, Reliability and Cost

The quantity and reliability of water from this source is expected to be approximately 100 gpm. Historical use indicates that the Pecos Valley aquifer may contain high levels of chloride and sulfate, resulting from previous oil field activities. It is uncertain whether these constituents are present in the portion of the aquifer that lies within Reeves County. For this plan, the new wells are assumed to supply an additional 10,400 acre-feet per year. The reliability of the supply is considered to be medium because of aquifer and water quality properties. The total cost of the project will be approximately $17.5 million.

Environmental Factors

Environmental impacts are expected to be low.

Agricultural and Rural Impacts

This strategy would marginally reduce the amount of water available to other users but since there is sufficient MAG, impacts are expected to be limited. There are no agricultural or rural issues associated with this strategy.

Impacts to Natural Resources and Key Parameters of Water Quality

The water quality in the Pecos Valley aquifer in Reeves County is unknown. In other areas, the aquifer is characterized by high levels of chloride and sulfate in excess of secondary drinking standards. Further study is needed on the water quality in Reeves County. Use of this source is not expected to impact key parameters of water quality.

No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

No other water management strategies use water supplies from the Pecos Valley aquifer in Reeves County, therefore no other strategies will be impacted.

Other Issues Affecting Feasibility

None.

WUG:	**Robert Lee, Bronte**	**Capital Cost:**	$4,154,000
WMS Name:	**Develop Edwards-Trinity-Plateau Supplies in Nolan County**	**Annual Cost** (During Amortization):	$4,293 per acre-foot $13.17 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$400 per acre-foot $1.23 per 1,000 gal
WMS Yield:	75 acre-feet per year	**Implementation:**	NA
WMS Status:	Alternative		

Strategy Description

Robert Lee and Bronte are considering developing new groundwater wells in south central Nolan County, which is in Region G. These wells produce water from the Edwards Trinity aquifer. For the purposes of this strategy, it is assumed that five new wells and approximately 15 miles of 6-inch transmission pipeline would be needed.

Quantity, Reliability and Cost

This strategy will provide 75 acre-feet per year. The reliability of this strategy is considered to be low to medium since it is dependent on finding adequate water quality and quantity. Capital costs are estimated at $4.2 million.

Environmental Factors

There are no significant environmental issues associated with this strategy.

Agricultural and Rural Impacts

Robert Lee and Bronte are rural communities. Increased water security provided by this strategy will have a positive impact on the vitality of this rural community.

Impacts to Natural Resources and Key Parameters of Water Quality

None identified.

Impacts on Other Water Resources and Management Strategies

If Robert Lee is able to implement one of the alternative groundwater strategies in this plan, their need to purchase from Bronte may be reduced and Bronte may be able to develop smaller quantities of future water supply. Or if Bronte were to implement this strategy, it may reduce Robert Lee's need to find additional sources of water.

Other Issues Affecting Feasibility

Since the reliability of this supply is unknown, the City should consider other alternatives to meet long-term needs as well. Funding construction of these new wells will be a significant strain on the financial resources of the City.

WUG:	**Robert Lee**	**Capital Cost:**	$7,272,000
WMS Name:	**Develop Edwards-Trinity-Plateau Aquifer Supplies in Tom Green**	**Annual Cost** (During Amortization):	$3,756 per acre-foot $11.53 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$556 per acre-foot $1.71 per 1,000 gal
WMS Yield:	160 acre-feet per year	**Implementation:**	NA
WMS Status:	Alternative		

Strategy Description
The City of Robert Lee is currently investigating developing groundwater in far western Tom Green County in the Edwards-Trinity Plateau aquifer. For planning purposes, this strategy includes two new 100 gpm wells and a 15-mile pipeline to Robert Lee.

Quantity, Reliability and Cost
It is assumed that each well will produce approximately 100 gpm. The reliability of this strategy is medium due to uncertainty in locating supplies of adequate quality and quantity. The total cost of the project will be approximately $7,272,000.

Environmental Factors
Environmental impacts from this strategy are expected to be low. Groundwater development from this source should be evaluated for potential impacts on springflows and base flows of area rivers. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts
Robert Lee is a rural community. Increased water security provided by this strategy will have a positive impact on the vitality of this rural community.

Impacts to Natural Resources and Key Parameters of Water Quality
The water quality of this aquifer is uncertain, but Robert Lee is actively searching for well locations with good water quality. No significant impacts to water quality are expected from the implementation of this strategy. No impacts to natural resources were identified.

Impacts on Other Water Resources and Management Strategies
If Robert Lee is able to implement one of the alternative groundwater strategies in this plan, their need to purchase from Bronte may be reduced and Bronte may be able to develop smaller quantities of future water supply.

Other Issues Affecting Feasibility
Since the reliability of this supply is unknown, the City should consider other alternatives to meet long-term needs as well. Funding construction of these new wells will be a significant strain on the financial resources of the City.

WUG:	**Scurry County Manufacturing**	**Capital Cost:**	$677,000
WMS Name:	**Develop Other Aquifer Supplies**	**Annual Cost** (During Amortization):	$356 per acre-foot $1.09 per 1,000 gal
WMS Type:	Groundwater Development		
WMS Yield:	160 acre-feet per year	**Annual Cost** (After Amortization):	$56 per acre-foot $0.17 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description

The Other Aquifer (or local Dockum aquifer) has been identified as a potential source of water for manufacturing in Scurry County. This strategy assumes that five new wells would be drilled to provide approximately 160 acre-feet per year. These wells are assumed to produce water from approximately 200 feet below the surface.

Quantity, Reliability and Cost

It is assumed that each well will produce approximately 25 additional gpm of water. This equates to a total strategy yield of 160 acre-feet per year. The reliability of the supply is considered to be low to medium because of the unproven use of the source in this county.

The total cost of the project will be approximately $677,000.

Environmental Factors

Depending on the connection between the river alluvium and local streams, this strategy could impact streamflows. Reduced streamflows could have impacts to water quality and aquatic habitats.

Agricultural and Rural Impacts

This source is currently used for agricultural purposes. This strategy would marginally reduce the amount of water currently available to agricultural users. There are no other agricultural or rural issues associated with this strategy.

Impacts to Natural Resources and Key Parameters of Water Quality

The water quality in the Other Aquifer (or local Dockum formations) are generally poor, with freshwater in outcrop areas and brine in the subsurface portions. This is not an issue for manufacturing purposes. No impacts to key parameters of water quality are expected to occur as a result of this strategy.

No impacts to natural resources have been identified.

Impacts on Other Water Resources and Management Strategies

None identified.

Other Issues Affecting Feasibility

The biggest issue affecting the feasibility of this strategy will be to find an area where the production of the well will be sufficient.

WUG:	**Sonora**	**Capital Cost:**	$437,000
WMS Name:	**Develop Additional Edwards-Trinity-Aquifer Supplies**	**Annual Cost** (During Amortization):	$1,000 per acre-foot $3.07 per 1,000 gal
WMS Type:	Groundwater Development	**Annual Cost** (After Amortization):	$114 per acre-foot $0.35 per 1,000 gal
WMS Yield:	35 acre-feet per year	**Implementation:**	2020
WMS Status:	Recommended		

Strategy Description

The City has an existing well field in the Edwards-Trinity-Plateau Aquifer near Interstate 10. This strategy is to develop two additional 30 gpm, 420-ft depth wells in the same well field and associated collection piping. Additional transmission infrastructure was not included since it is an expansion of an existing facility.

Quantity, Reliability and Cost

Based on existing productivity of wells in the area, it is estimated that the new wells would yield an additional 35 acre-feet per year. The reliability of this strategy is expected to be high. Costs for the two additional wells and associated collection piping are estimated at $437,000.

Environmental Factors

The aquifer is a proven groundwater source for municipal, industrial, and agricultural purposes. It is unlikely that this strategy would cause subsidence.

Agricultural and Rural Impacts

Since this is a small expansion of an existing well field, no additional agricultural or rural impacts are anticipated.

Impacts to Natural Resources and Key Parameters of Water Quality

The strategy proposes to utilize a sustainable level of groundwater that does not exceed the Modeled Available Groundwater (MAG). The impacts to natural resources are expected to be minimal. No impacts to water quality are expected.

Impacts on Other Water Resources and Management Strategies

None identified.

Other Issues Affecting Feasibility

Since this is an expansion of the City's existing well field, no issues are anticipated that would affect the feasibility of the project.

APPENDIX C

C.5 DESALINATION

MWP:	**San Angelo**	**Capital Cost:**	$70,709,000
WMS Name:	**Desalination of Brackish Groundwater Supplies**	**Annual Cost** (During Amortization):	$1,062 per acre-foot $3.26 per 1,000 gal
WMS Type:	Treatment of New Groundwater	**Annual Cost** (After Amortization):	$615 per acre-foot $1.90 per 1,000 gal
WMS Yield:	11,200 acre-feet pear year	**Implementation:**	NA
WMS Status:	Alternative		

Strategy Description
This strategy assumes that supply from San Angelo's groundwater strategies in Schleicher and Pecos Counties is brackish and will require additional advanced treatment to meet drinking water standards. For planning purposes, the advanced treatment plant is assumed to be located near the proposed well field. This strategy is sized to treat 15 MGD acre-feet of raw brackish supplies. The advanced treatment processes associated with brackish water desalination result in around 25 percent losses, resulting in about 10 MGD (11,200 acre-feet) of finished water. For planning purposes, the brackish supplies are assumed to have a starting salinity of 5,000 TDS. Five 1,000-gpm deep brine injection wells were also included for concentrate disposal.

Quantity, Reliability and Cost
The treated supply made available through this strategy is estimated to be 10 MGD (11,200 acre-feet per year). It should be noted that this strategy involves supplies from other potentially feasible strategies for San Angelo and is therefore not additive. Because of the uncertainty involved with development of this source for municipal water use, the reliability of this strategy is considered moderate. The capital cost for this strategy is estimated at $70.8 million. This equates to $3.26 per thousand gallons during debt service for treatment of the brackish groundwater only. After the infrastructure is fully paid for, the price for treatment drops to $1.90 per thousand gallons.

Environmental Factors
The conceptual design for this project uses deep well injection for brine disposal. A properly designed and maintained facility should have minimal environmental impact. Construction of the treatment facility should have minimal environmental impact as well.

Agricultural and Rural Impacts
Since this strategy relies on brackish supplies that are not readily usable for agricultural or municipal users, competition for the water is expected to be minimal. Therefore, agricultural and rural impacts are expected to be minimal.

Impacts to Natural Resources and Key Parameters of Water Quality
The current conceptual design for this project uses deep well injection to dispose of the brine waste stream. If this were to change and the brine was released to a stream, impacts to the receiving water body would need to be evaluated.

Impacts on Other Water Resources and Management Strategies
Since this strategy relies on brackish supplies that cannot be used without significant treatment, impacts to other strategies will be minimal.

Other Issues Affecting Feasibility
None identified.

APPENDIX C

C.6 REGIONAL WATER MANAGEMENT STRATEGIES

WUGs:	**San Angelo, UCRA, BCWID #1**	**Capital Cost:**	N/A
WMS Name:	**Brush Control**	**Annual Cost** (During Amortization):	N/A
WMS Type:	Regional		
WMS Yield:	550 acre-feet pear year	**Annual Cost** (After Amortization):	$456 per acre-foot $1.40 per 1,000 gal
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description

Brush control has been identified as a potentially feasible water management strategy for Region F. It has the potential to enhance the existing supply from the region's reservoirs.

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 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. In 2011, the 82nd Legislature replaced the Brush Control Program with the Water Supply Enhancement Program (WSEP). The WSEP's purpose is to increase available surface and groundwater supplies through the selective control of brush species that are detrimental to water conservation. The WSEP considers priority watersheds across the State, the need for conservation within the territory of a proposed projection based on the State Water Plan, and if the Regional Water Planning Group has identified brush control as a strategy in the State Water Plan as part of their competitive grant, cost sharing program. Five species are eligible for funding from the WSEP:

- Juniper
- Mesquite
- Salt cedar
- Huisache*
- Carrizo cane*

**These are classified as other species of interest and are conditionally eligible.*

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 chainsaw to large bulldozers.

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 ongoing TSSWCB brush programs. Arsenal is the herbicide typically used for removal of salt cedar. These chemicals 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.

Prescribed burning is also used to control brush. Burning is conducted under prescribed conditions to specifically target desired effects. There are some limitations, however, burning rarely affects moderate to heavy stands of mature mesquite. Burning only top kills 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 fire 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.

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 ongoing 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.

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 is a potential water management. Predicting the amount of water that would be made available by implementing a brush control program is difficult, but some estimates have been made. For a watershed to be eligible for cost-share funds from the WSEP, a feasibility study must demonstrate increases in projected post-treatment water yield as compared to the pre-treatment conditions. Feasibility studies have been conducted and published for the following watersheds in Region F[2]:

- Lake Brownwood
- North Concho River (O.C. Fisher Lake)
- O.H. Ivie Reservoir lake basin (Lake Basin)
- O.H. Ivie Reservoir (Watershed, Upper Colorado River and Concho River)
- E.V. Spence (Upper Colorado River)
- Lake J.B. Thomas (Upper Colorado River)
- Twin Buttes Reservoir (including Lake Nasworthy)
- Upper Llano River, including South and North Llano Rivers and Junction City Lake

Twin Buttes Reservoir/Lake Nasworthy Brush Control Projects

Brush control projects are on-going 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 Brownwood Project

There are efforts to treat mesquite and juniper in the Lake Brownwood watershed. Lake Brownwood provides municipal, industrial and agricultural water supply to Brown County and surrounding areas.

O.H. Ivie Project

As of the writing of this plan, there is not currently an active brush control project in the O.H. Ivie watershed. However, a feasibility study has been completed and if funding was available, this project could be initiated. The Upper Colorado River Authority (UCRA) is the potential sponsor for this project.

These three projects have identified sponsors and are likely in Region F. However, others in the region may choose to pursue brush control and Region F supports those efforts and considers them consistent with this plan. The UCRA has expressed willingness to partner with other interested agencies and entities.

Although many studies have illustrated the benefits of brush control, it difficult to quantify the benefits in the context of regional water planning. This quantification is very important because in most areas where the program is 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 region's 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.

Based on anecdotal accounts and observations, almost everyone in the area from participating landowners to water supply and elected officials recognize the water producing value of the program. The Water Supply Enhancement Program (WSEP) annually publishes statewide water yield estimate projections that originate from computer models that have been in published brush control feasibility studies. The annual report published by the Texas State Soil and Water Conservation Board (TSSWCB) documents the results from the program and includes the extent of the completed brush work within the watershed along with status reviews to determine the brush density of treated acreage. 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.

The TSSWCB uses a competitive grant process to rank the most feasible projects, and allocates the WSEP cost-share funds according to the project that balances the most critical water conservation need with the highest projected water yield. Once the funding has been allocated to a project, a geospatial analysis is performed to determine the acreage that has the highest potential to yield water within the watershed. The analysis will subdivide each Project area into four priority zones – high, medium, low, and not eligible. Available funding will only be obligated for those landowners who are in the high priority zone. The TSSWCB then works through Soil and Water Conservation Districts (SWCDs) to provide technical and financial assistance to landowners. Cost-share funding is based on the actual cost and is not to exceed the average cost established in the project's implementation plan. Payments are determined by acreage times the cost-share rate times the actual cost to implement.

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. The landowners will be subjected to periodic reviews by their local SWCD or the TSSWCB to determine compliance. If a landowner is found out of compliance they will not be eligible for another WSEP contract for a period of ten years. It is important to note that any follow-up brush control is entirely the landowners' financial responsibility and they cannot receive any additional state funds for this follow-up brush control.

The Water Supply Enhancement Program for the State of Texas was not funded for 2019 but funds may be available in future years. If funding is available, Region F supports local sponsors partnering with the WSEP to implement brush control.

Quantity, Reliability, and Cost

The quantity of supply expected from this strategy is relatively small and is shown in Table C-12 below. There are no capital costs associated with this strategy, only annual operating costs. The supply from this strategy is considered to be of low reliability since brush must be continually treated to continue to provide additional supplies and must have rainfall to produce yield.

Table C- 12
Brush Control Quantities and Cost

Sponsor	Watershed	Estimated Acres Treated	Estimated Cost Per Acre (Sep 2018)	Annual Cost	Quantity (acre-feet per year)	Unit Cost ($/ac-ft)
UCRA	O.H. Ivie	1,000	$51	$51,000	60	$850
San Angelo	Twin Buttes Reservoir	586	$76	$44,000	90	$489
BCWID	Lake Brownwood	958	$163	$156,000	400	$390

Environmental Factors

The Texas Parks and Wildlife Department (TPWD) lists 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.[3] Region F suggests coordinating with TPWD and other state and federal agencies regarding any brush control program.

Agricultural and Rural Impacts

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.

Impacts to Natural Resources and Key Parameters of Water Quality

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.

Impacts on Other Water Resources and Management Strategies

If the program is adequately implemented and maintained, brush control could supplement existing supplies.

Other Issues Affecting Feasibility

The most significant factor regarding the feasibility of this strategy is ongoing funding for brush control projects. In 2019, no funding was made available for this program at all. Brush control is an ongoing process that must be constantly maintained for the project to be successful. Existing programs may provide funding for the initial clearing of brush but any necessary follow-up brush control is typically the landowner's financial responsibility. Further clarification is needed as to whether the landowner will be able to receive any additional state funds for ongoing brush control maintenance. 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 ongoing cooperation and financial contributions of individual landowners. Therefore, each program should be tailored to local conditions.

WUGs:	**Irrigation Users**	**Capital Cost:**	N/A
WMS Name:	**Weather Modification**	**Annual Cost** (During Amortization):	N/A
WMS Type:	Regional	**Annual Cost** (After Amortization):	$156 per acre-foot $0.48 per 1,000 gal
WMS Yield:	5,128 acre-feet per year		
WMS Status:	Recommended	**Implementation:**	2020

Strategy Description

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.[4] The cloud seeding process increases the availability of ice crystals, which bond with moisture in the atmosphere to form raindrops. This is accomplished by injecting a target cloud with artificial crystals, such as silver iodide, and is known as glaciogenic seeding. Hygroscopic seeding, or injecting calcium chloride into target clouds, is often used in tandem with glaciogenic seeding. Specially equipped aircraft release the seeding crystals into clouds as flares that are rich in super cooled droplets. The silver iodide crystals form water droplets from available moisture in the air. Droplets then collide with droplets transforming the ice crystal into a raindrop.

Weather modification is most often utilized as a water management strategy during the dry summers in West Texas, with the season beginning in March and ending in October. 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. However, during wet years, the amount of water produced by weather modification may be significant.

The amount of water made available to a specific entity from this strategy is difficult to quantify, yet there are regional benefits. Four 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
- Hail suppression

In Region F, there are two ongoing weather modification programs: the West Texas Weather Modification Association (WTWMA) project and the Trans Pecos Weather Modification Association (TPWMA) program.

West Texas Weather Modification Association (WTWMA) Project

The WTWMA began weather modification efforts in 1995. The intent of the rainfall enhancement program was to increase groundwater recharge, springflow, and runoff resulting in increased agricultural productivity and reduction in groundwater withdrawals. A side effect of the rain enhancement operations also include hail suppression but is not one of the main intents of the program. WTWMA has operated in eight counties covering an area of 6.6 million acres. In 2017, a total of 73 clouds were seeded as part of the WTMA's rain enhancement efforts in 24 operational days. WTWMA estimated a 10.2 percent increase in rainfall in the target area because of their operations.[5] Table C-13 shows a breakdown by county of the estimated increase in rainfall for the year 2017 from the annual report of the Texas Weather Modification Association.[6]

Table C- 13
Estimated Precipitation Increase for the Year 2017 due to WTWMA Activities

County	Inches (increase)	Rain Gage (season value)	% (increase)
Crockett	0.52	11.2	4.6%
Irion	2.21	14.77	15.0%
Reagan	1.35	12	11.3%
Schleicher	1.33	14.77	9.0%
Sterling	1.67	16.1	10.4%
Sutton	0.45	14.22	3.2%
Tom Green	2.39	13.42	17.8%
Average	**1.42**	**13.78**	**10.2%**

Data are from the West Texas Weather Modification Association.

Trans Pecos Weather Modification Association (TPWMA) Program

The TPWMA began operation in 2003. The TPWMA consists of the Ward County Irrigation District and other political entities from Culberson, Loving, Reeves, Ward and parts of Pecos County. 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. In 2016, TPWMA estimated a 4.7 percent increase in precipitation from cloud seeding.[7]

Table C-14 shows a breakdown by county of the estimated increase in rainfall for the year 2016 from the annual report of the Texas Weather Modification Association[8].

Table C- 14
Estimated Precipitation Increase for the Year 2016 due to TPWMA Activities

County	Inches (Increase)	Rain Gauge (season value)	% Increase
Reeves	0.48	9.01	5.3%
Pecos	0.33	6.9	4.8%
Ward	0.95	9.67	9.8%
Loving	0.37	11.44	3.2%
Average	**0.43**	**9.36**	**4.7%**

Data are from the Texas Weather Modification Association.

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. The eight counties in the WTWMA target area were evaluated for their increase in precipitation and recharge potential over a 10-year period (Jennings and Green, 2014)[9]. Analysis from 2004 to 2013 performed by Ruiz-Columbiè (2014)[10] which compared seeded clouds with non-seeded clouds resulted in precipitation increases of 8 to 20 percent or up to 2 inches per year. Rain gauges within and outside the target area provided confirmatory results.

For purposes of this plan, weather modification is a recommended strategy for irrigated agriculture for counties that currently participate in an active program. It is assumed that the increase in rainfall will offset irrigation water use. To determine the water savings associated with this strategy, an estimate of the increase in annual rainfall over the growing season is applied directly to the irrigated acreages. These savings are shown by county in Table C-15.

Table C- 15
Water Savings due to Precipitation Enhancement per County

Weather Modification Program	County	Irrigated Acreage (acres)	Coverage %	Annual Increase (feet)[a]	Water Savings (ac-ft/yr)	Cost ($)	Cost per Ac-Ft ($/ac-ft)
TPWMA	Pecos	12,887	30%	0.03	106	$580	$5.45
TPWMA	Reeves	8,138	100%	0.04	326	$366	$1.13
TPWMA	Ward	3,276	100%	0.08	259	$147	$0.57
WTWMA	Crocket	13	100%	0.10	1	$1	$0.47
WTWMA	Irion	923	100%	0.22	202	$42	$0.21
WTWMA	Reagan	8,098	100%	0.23	1,869	$364	$0.19
WTWMA	Schleicher	1,412	100%	0.20	275	$64	$0.23
WTWMA	Sterling	411	100%	0.12	48	$18	$0.39
WTWMA	Sutton	341	100%	0.10	34	$15	$0.45
WTWMA	Tom Green	19,604	45%	0.23	2,007	$882	$0.44

[a] Annual increase values based on 2016 State Report for the TPWMA and the 2017 Annual Report for the WTWMA.

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. However, during the drought of 2011, the WTWMA target area averaged a precipitation increase of 1.12 inches per year, the lowest of 2004-2013. Among the counties, the increase in precipitation was between 0.77 inches per year and 1.54 inches per year, resulting in half of the counties receiving over 1 inch of rainfall from cloud seeding.

The cost of operating Texas weather modification programs are approximately 4 to 5 cents per acre[11]. For the purposes of this plan, a cost of 4.5 cents per acre was applied. On average, this results in a cost of $0.48 per acre-foot of water supply.

Environmental Factors

Weather modification should have a positive impact on the environment due to the increased rainfall from storms. Possible benefits include improved wildlife habitat and landscapes. The chemicals used in weather modification should be sufficiently diluted to minimize any threat of contamination.

Agricultural and Rural Impacts

Weather modification has a positive impact on agriculture and ranching by increasing productivity. Dry land farm production, a common means of measuring the effects of rainfall enhancement, has increased in regions participating in rainfall enhancement. Another benefit of weather modification is hail suppression, which helps minimize damage from severe weather, but is not a primary goal of the TPWMA and WTWMA programs.

Dryland farming revenues can increase by $4.6 million for each additional one inch of rainfall created through weather modification (Johnson, 2014)[12].

Impacts to Natural Resources and Key Parameters of Water Quality

Increased rainfall over the target areas results increased aquifer recharge. Recharge efforts are ideal in the winter months when evapotranspiration is lowest, however no programs are known to have successfully attempted such seeding. The potential for groundwater recharge from weather modification is growing, however research methodology and seasonal climatic effects exclude recharge strategies from regional water planning presently.

No impacts to key parameters of water quality were identified for this strategy.

Impacts on Other Water Resources and Management Strategies

This strategy may reduce the demand for water from other water management strategies. Downwind impacts of increased precipitation to areas outside target areas is also an additional benefit.

Other 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. State funding for weather modification has been absent since 2002. Many of the programs that chose to contract out their operations instead of purchasing equipment with state funding have been discontinued. In addition, there is some local opposition to precipitation enhancement. This opposition has been slowly decreasing due to the TWMA’s continuing education outreach activities. Lastly, several weather modification programs have adjusted their target areas which limits continuous and reliable data for water planning regions.

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WUGs:	**Midland, San Angelo, Abilene**	**Capital Cost:**	$ TBD
WMS Name:	**West Texas Water Partnership**	**Annual Cost** (During Amortization):	$ TBD $ TBD
WMS Type:	Regional		
WMS Yield:	TBD	**Annual Cost** (After Amortization):	$ TBD $ TBD
WMS Status:	Recommended	**Implementation:**	NA

Strategy Description

The Cities of Midland, San Angelo, and Abilene have formed the West Texas Water Partnership (the Partnership) to evaluate long-term water supplies the Partnership could develop jointly. The Partnership is conducting a separate study to determine the most feasible water management strategies for these cities, but the results were not available at the writing of this Initially Prepared Plan. Additional information is anticipated before the publication of the Final Region F Water Plan.

Quantity, Reliability and Cost

Quantity, reliability, and cost will be evaluated after the specifics of the strategy are made available following the publication of the Region F Initially Prepared Plan.

Environmental Factors

Environmental factors will be evaluated after the specifics of the strategy are made available following the publication of the Region F Initially Prepared Plan.

Agricultural and Rural Impacts

Agricultural and rural impacts will be evaluated after the specifics of the strategy are made available following the publication of the Region F Initially Prepared Plan.

Impacts to Natural Resources and Key Parameters of Water Quality

Impacts to natural resources and key parameters of water quality will be evaluated after the specifics of the strategy are made available following the publication of the Region F Initially Prepared Plan.

Impacts on Other Water Resources and Management Strategies

Impacts on other water resources and water management strategies will be evaluated after the specifics of the strategy are made available following the publication of the Region F Initially Prepared Plan.

Other Issues Affecting Feasibility

Other issues affecting feasibility will be evaluated after the specifics of the strategy are made available following the publication of the Region F Initially Prepared Plan.

WUGs:	**Bronte, Ballinger, Winters, Robert Lee**	**Capital Cost:**	$115,443,000
WMS Name:	**Regional System from Lake Brownwood to Runnels and Coke Counties**	**Annual Cost** (During Amortization):	$3,904 per acre-foot $11.98 per 1,000 gal
WMS Type:	Regional	**Annual Cost** (After Amortization):	$1,005 per acre-foot $3.09 per 1,000 gal
WMS Yield:	2,802 acre-feet per year		
WMS Status:	Alternative	**Implementation:**	NA

Strategy Description

Lake Brownwood is one of the few surface water sources in Region F with a firm yield under WAM Run 3 with uncommitted supply. However, it is still susceptible to drought and has suffered in recent years. A conceptual design for a regional system providing water to the Cities of Bronte, Ballinger, Winters and Robert Lee was developed to evaluate the potential for water supply from this source. It is unclear if Brown County WID #1 would be willing to sell water to these users and an agreement would have to be reached between all parties.

Quantity, Reliability and Cost

This strategy would provide a total of 2,802 acre-feet per year to multiple users. The division of supply is shown below in Table C-16. This source is considered to be reliable. Capital costs are estimated at $115.6 million and are assumed to be split amongst the entities that would need to enter into a partnership to implement this strategy. The exact division of costs and water supply would be negotiated as part of the partnership to implement the proposed strategy.

Table C- 16
Supply to Each User (acre-feet per year)

Water User Group	Supply
Winters	729
Ballinger	1,345
Bronte	280
Robert Lee	448
Total	**2,802**

Environmental Factors

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 Impacts

Although Lake Brownwood is used for agricultural supplies, there are sufficient supplies under WAM Run 3 to meet irrigation demands as well as additional municipal demands. No impacts to agriculture are expected. Each participant 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 participants and the surrounding rural area.

Impacts to Natural Resources and Key Parameters of Water Quality

None identified.

Impacts on Other Water Resources and Management Strategies

Other strategies for Bronte, Ballinger, Winters, and Robert Lee.

Other Issues Affecting Feasibility

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 and BCWID may not be willing to sell a portion of their supply to these communities. 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.

WUGs:	**Bronte, Ballinger, Winters, Robert Lee**	**Capital Cost:**	$103,328,000
WMS Name:	**Regional System from Lake Ft. Phantom Hill to Runnels and Coke Counties**	**Annual Cost** (During Amortization):	$7,606 per acre-foot $23.34 per 1,000 gal
WMS Type:	Regional	**Annual Cost** (After Amortization):	$1,312 per acre-foot $4.03 per 1,000 gal
WMS Yield:	1,155 acre-feet per year	**Implementation:**	NA
WMS Status:	Alternative		

Strategy Description

Fort Phantom Hill Reservoir is located in Jones County in Region G. In 2013, the City of Clyde purchased a 2,500 acre-foot water right in Fort Phantom Hill Reservoir from an abandoned steam electric power generation facility. The City of Clyde amended the water right to expand its use for municipal supply and also secured an interbasin transfer to select counties including Runnels and Coke Counties. The City of Clyde does not currently receive any supply from the reservoir. For the purposes of this strategy, it is assumed that 1,750 acre-feet of water would be available to serve Ballinger, Bronte, Robert Lee, and Winters. This strategy includes the construction of a new intake on Lake Fort Phantom Hill and a new pipeline and associated infrastructure to connect to Winters, Ballinger, and Bronte. It was assumed that existing infrastructure from Bronte to Robert Lee could be used to convey supplies to Robert Lee.

Quantity, Reliability and Cost

Many watersheds throughout the State are over-appropriated, i.e. not all water rights can be fully met at all times. Thus, the yields from a water right are often less than the amount shown in the water right. This is also the case for Fort Phantom Hill Reservoir. Based on the yield analyses, the 1,750 acre-feet of water right would translate into 1,155 acre-feet of safe yield in 2020. The yield in the remaining decades is shown below in Table C-17. The division of supply is shown below in Table C-18. This source is considered to be reliable. Capital costs are estimated at $103.0 million and are assumed to be split amongst the entities that would need to enter into a partnership to implement this strategy. The exact division of costs would be negotiated as part of the partnership to implement the proposed strategy.

Table C- 17
Yield of Water Right at Full Purchase Amount

	2020	2030	2040	2050	2060	2070
Water Right Purchase Amount	1,750	1,750	1,750	1,750	1,750	1,750
Total WMS Quantity (Safe Yield)	1,155	1,114	1,074	1,033	993	952

Table C- 18
Potential Supply by User

Water User Group	Supply (%)	2020 (ac-ft)	2070 (ac-ft)
Winters	15.1%	175	143
Ballinger	43.3%	500	413
Bronte	30.3%	350	288
Robert Lee	11.3%	130	108
Total	**100%**	**1,115**	**952**

Environmental Factors

Since this supply is from an existing reservoir and water right, the environmental impacts are expected to be minimal. The disruption from the construction of the pipeline is expected to be minor and temporary. Specific environmental studies would be required to assess impacts at the intake location and along the pipeline. It is assumed that the pipeline would be routed to avoid environmentally sensitive areas, where possible.

Agricultural and Rural Impacts

Ballinger, Bronte, Winters and Robert Lee are rural communities. Having a sustainable water supply source will improve the vitality of the rural community. No agricultural impacts are expected.

Impacts to Natural Resources and Key Parameters of Water Quality

Since this strategy provides water from an existing reservoir and water right, no impacts to natural resources or water quality are expected.

Impacts on Other Water Resources and Management Strategies

This strategy utilizes water from Fort Phantom Hill Reservoir which is operated, maintained, and used by the City of Abilene. Coordination on use from this source would be needed to avoid impacting Abilene's water supplies.

Other Issues Affecting Feasibility

This strategy is dependent upon agreements between multiple parties that are outside the scope of regional water planning. The economic viability of this strategy will depend on the results of these agreements..

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