Volume II

Identification, Evaluation, and Selection of Water Management Strategies

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1 Water Management Strategies

Title 31 TAC 357.7(a)(7) requires that the regional water planning group evaluate all water management strategies determined to be potentially feasible. The guidelines list multiple types of strategies and numerous subtypes, including water conservation; drought management measures; reuse of wastewater; expanded use of existing facilities, including systems optimizations, conjunctive use, reallocation of storage to new uses, etc.; interbasin transfers; new supply development; and others. At the beginning of the 2006 planning cycle, the Brazos G RWPG identified approximately 25 water management strategies to be potentially feasible. For the 2016 Plan update, 48 strategies were identified to be potentially feasible. Many of these strategies were evaluated for the previous 2006 and 2011 Plans. Several strategies were re-evaluated due to changed conditions such as new hydrologic information or requests for further information. Costs for these strategies as shown in specific WUG and WWP plans have been updated to September 2013 prices.

Potential water supply strategy categories evaluated during preparation of the 2011 Plan are listed in Table 1.1-1. Within some of the 12 types of water management strategies listed in Table 1.1-1 there are a number of sub-options. For instance, in the section on New Reservoirs (Section 4), fourteen potential reservoir sites are evaluated.

Table 1.1-1. Potential Water Supply Categories

Section No. (Located in Volume II)	***Category Title***
2	Water Conservation
3	Wastewater Reuse
4	New Reservoirs
5	Acquisition of Existing Supplies
6	Acquisition of Existing Supplies
7	Management of Existing Supplies
8	Regional Water Supply Projects
9	Groundwater
10	Aquifer Storage and Recovery (ASR)
11	Brackish Groundwater
12	Miscellaneous Strategies
13	Additional Strategies

1.1 Evaluation of Strategies

The following sections contain an evaluation of each of the potential water management strategies. Each section is typically divided into five subsections: (1) Description of Option; (2) Available Yield; (3) Environmental Issues; (4) Engineering and Costing; and (5) Implementation Issues. Information in these sections was presented to the Brazos G RWPG at regularly scheduled public meetings and was used in evaluating strategies to meet water needs in the area.

1.2 Plan Development Criteria

It is the goal of the Brazos G RWPG to develop a plan to meet projected water needs within the Brazos G Area. The Brazos G RWPG has adopted a set of Plan Development Criteria that was used to evaluate whether a given strategy should be used to meet a projected shortage and ultimately be included in the Brazos G Regional Water Plan. The proposed strategies were developed by evaluating the water management strategies using the Plan Development Criteria and then matching strategies to meet projected shortages. This section discusses the evaluation criteria adopted by the planning group during plan development, and criteria to be met in formulation of the plan. The adopted plan elements will meet these criteria:

- Water Supply – Water supply must be evaluated with respect to quantity, reliability, and cost. The criteria for quantity are that the plan must be sufficient to meet all projected needs in the planning period. The criteria for reliability is that it meet municipal, industrial, and agricultural needs 100 percent of the time. The criteria for cost are that the projected cost be reasonable to meet the projected needs.
- Environmental Issues – Environmental considerations must be examined with respect to environmental water needs, wildlife habitat, cultural resources, and bays and estuaries. The criteria for environmental water flows and wildlife habitat are that stream conditions must meet permit requirements for diversions that currently have permits. For projects that require permit acquisition the project will provide adequate environmental instream flows for aquatic habitat. Projects should be sited to avoid known cultural resources, if possible. Flows to bays and estuaries should meet expected permit conditions. (It should be noted that the Brazos River does not have a well-defined estuary or bay system, so bay and estuary inflow requirements are expected to be low).
- Impacts on Other State Water Resources – The criteria recommend a follow-up study by the Brazos G RWPG if any significant impacts are anticipated on other state water resources.
- Threats to Agriculture and Natural Resources – The criteria requires that the planning group identify any potential impact, compare the impact to the proposed benefit of the plan, and make recommendations. With the exception of large projects that will affect large acreages, such as reservoir projects, the water management strategies evaluated will have no significant impact to the State's Agricultural resources.

- Equitable Comparison of Feasible Strategies – This is achieved by the equal application of criteria across different water development plans.
- Interbasin Transfers – The planning group may consider interbasin transfers as a supply option. The criteria require that the participating entities recognize and follow Texas Water Code requirements for expected permitting requirements.
- Impacts from Voluntary Redistribution – The criteria require that any potential third party social or economic impacts from voluntary redistribution of water rights be identified and described.
- Other Criteria – Texas Water Development Board (TWDB) allows the Brazos G RWPG to adopt other criteria. The Brazos G RWPG has not adopted any further criteria.

The following sections discuss the methods and procedures used to develop the information needed to evaluate the strategies and compare them to the criteria.

1.3 Engineering

A procedure was developed to maintain equal and consistent consideration of various design and cost variables across differing water management strategy options. These are planning level estimates only, and do not reflect detailed site-specific design work, nor any extensive optimization and selection of design variables. These procedures standardized the consideration of the following design and costing issues as closely as possible, given the varying scope and magnitude of differing projects. For each option, major cost components were determined at the outset. Estimates of volume of water and rate of delivery needed were developed from the supply-demand comparisons presented in Volume I, Chapter 4, if directly applicable. Volumes necessary to meet shortages were estimated, and both average annual and peak rates of projected delivery were calculated. Average annual rates were adjusted to reflect pump station downtime for maintenance activities. Transmission and treatment facilities were generally sized based on peak rates of delivery. Water source and delivery locations were determined, considering source and destination elevations, surrounding land use, and other geographic considerations. Further details on engineering factors considered are presented in the discussions of the various water management strategies presented in Volume II, Sections 2 through 13.

1.4 Cost Estimates

The cost estimates of this study are expressed in three major categories: (1) construction costs or capital (structural) costs, (2) other (non-structural) project costs, and (3) annual costs. All costs for these categories were estimated using the TWDB Unified Costing Model as required by the TWDB.

Construction costs are the direct costs incurred in constructing facilities, such as those for materials, labor, and equipment. "Other" project costs include expenses not directly associated with construction activities of the project, such as costs for engineering, legal counsel, land acquisition, contingencies, environmental studies and mitigation, and interest during construction. Capital costs and other project costs comprise the total project cost. Operation and maintenance, energy costs, purchase of wholesale water and debt service payments are examples of annual costs. Major components that may be part of a preliminary cost estimate are listed in Table 1.4-1. All costs represent September 2013 prices.

Table 1.4-1. Summary of Major Components Included in Preliminary Cost Estimates of Potential Water Supply Strategies

Capital Costs (Structural Costs)	*Other Project Costs (Non-Structural Costs)*
1. Pump Stations	1. Engineering (Design, Bidding and Construction Phase Services, Geotechnical, Legal, Financing, and Contingencies)
2. Pipelines	2. Land and Easements
3. Water Treatment Plants	3. Environmental - Studies and Mitigation
4. Water Storage Tanks	4. Interest During Construction
5. Off-Channel Reservoirs	***Annual Project Costs***
6. Well Fields	1. Debt Service
7. Dams and Reservoirs	2. Operation and Maintenance (excluding pumping energy)
8. Relocations	3. Pumping Energy Costs
9. Other Items	4. Purchase Water Cost (if applicable)

As previously mentioned, "other" (non-structural) project costs are costs incurred in a project that are not directly associated with construction activities. These include costs for engineering, legal counsel, financing, contingencies, land, easements, surveying and legal fees for land acquisition, environmental and archaeology studies, permitting, mitigation, and interest during construction. These costs are added to the capital costs to obtain the total project cost. A standard percentage applied to the capital costs is used to calculate a combined cost that includes engineering, financial, legal services, and contingencies.

Annual costs are those that the project owner can expect to incur if the project is implemented. These costs include repayment of borrowed funds (debt service), operation and maintenance costs of the project facilities, pumping power costs, and water purchase costs, when applicable.

Debt service is the estimated annual payment that can be expected for repayment of borrowed funds based on the total project cost, an assumed finance rate, and the finance period in years. As specified by the TWDB in Section 5.1.2 of Exhibit C, First Amended General Guidelines for Regional Water Plan Development (October 2012)[1], debt service for all projects was calculated assuming an annual interest rate of 5.5 percent and a

[1] Available for download at: http://www.twdb.texas.gov/waterplanning/rwp/planningdocu/2016/doc/current_docs/contract_docs/2012_exhC_1st_amended_gen_guidelines.pdf

repayment period of 40 years for large reservoir projects and 20 years for all other projects.

Operation and maintenance costs for dams, pump stations, pipelines, and well fields (excluding pumping power costs) include labor and materials required to operate the facilities and provide for regular repair and/or replacement of equipment. In accordance with TWDB guidelines, unless specific project data are available, operation and maintenance costs are calculated at 1 percent of the total estimated construction costs for pipelines, at 1.5 percent of the total estimated construction costs for dams and reservoirs, and at 2.5 percent for intake and pump stations. Water treatment plant operation and maintenance costs were based on treatment level and plant capacity. The operation and maintenance costs include labor, materials, replacement of equipment, process energy, building energy, chemicals, and pumping energy.

In accordance with TWDB guidelines, power costs are calculated on an annual basis using the appropriate calculated power load and a power rate of $0.09 per kilo-Watt-hour (kWh). The amount of energy consumed is based upon the pumping horsepower required.

The raw water purchase cost, if applicable, is included if the water supply option involves purchase of raw or treated water from an entity. This cost varies by source and by supplier.

A cost estimate summary for each individual option is presented with total capital costs, total project costs, and total annual costs. The level of detail is dependent upon the characteristics of each option. Additionally, the cost per unit of water involved in the option is reported as costs per acft and cost per 1,000 gallons of water developed. The individual option cost tables specify the point within the region at which the cost applies (e.g., raw water at the reservoir, treated water delivered to the WUG or WWP, or elsewhere as appropriate).

Numerous recommended water management strategies are included in plans for individual water user groups that are not analyzed to the exact level of detail as the separate water management strategies described in most of Volume II. These generally involve small interconnections between two neighboring systems or purchases of additional supplies from a wholesale water provider or adjacent water user group. These strategies are referred to as miscellaneous strategies and are summarized in Volume II, Section12.

Note that costs include only those infrastructure elements needed to develop, treat and transmit the water supply to the distribution system of the WUG or WWP. Distribution costs are not included in the cost estimates.

1.5 Methods Used to Investigate Environmental Effects of Proposed Regional Water Management Strategies

The Regional Water Planning Guidelines (31 TAC 357.7) require that each regional water management strategy includes an evaluation of environmental factors, specifically effects on environmental water needs, wildlife habitat, cultural resources, agricultural resources, upstream development on bays, estuaries, and arms of the Gulf of Mexico.

These factors were evaluated for each of the proposed water management strategies according to the level of description and engineering design information provided. Details regarding the methodology to investigate environmental water needs, instream flow needs, impact on bays and estuaries, and fish and wildlife habitat are generally included in the analysis of each strategy.

1.6 Agricultural Water Management Strategies

New firm water supplies often cannot be developed for irrigated agriculture, because the cost of development usually far exceeds the value of the water in irrigated production. The assumption is made that the available groundwater resources are already fully exploited. Brush control for water yield is the only potential new supply of water for irrigated agriculture, but a firm yield cannot be assigned to this practice. Without any firm supply of water, agricultural producers will have to reduce the irrigation and confined livestock demands through a variety of conservation and other management practices. Conservation practices were evaluated, specifically related to irrigation conservation and the savings of water that can be expected. The evaluation is presented in Volume II, Section 2.

1.7 Water Conservation and Drought Preparation

Water conservation recommendations are included in the plans for individual water user groups. Water conservation as a water management strategy for individual municipal water user groups was evaluated as per the description in Volume II, Section 2. For municipal water user groups, the Brazos G RWPG recommends a goal of a one-percent reduction per year (until the target rate of 140 gpcd is reached) in overall water demands, regardless of whether an entity reports a water supply need or not during the planning period. For Williamson County municipal water users, a target rate of 120 gpcd by Year 2070 is recommended. For conservation for non-municipal use (irrigation, manufacturing, steam electric, and mining), the Brazos G RWPG has recommended a target reduction in water demand of 3% by 2020, 5% by 2030, and 7% from 2040-2070 for entities with a water supply need (shortage) during the planning period. The plan presents a list of recommended BMPs in Volume II, Sections 2.1.2, 2.2.2, and 2.3.2. Costs and savings to be expected from various Best Management Practices (BMPs) are described, and recommended target reductions in per capita water use (gpcd) are presented. For irrigation conservation, specific costs, expected savings and conservation target recommended by the Brazos G RWPG are described in Volume II, Section 2.2. Little guidance exists for estimating water savings and costs for BMPs for non-municipal and non-irrigation uses, as water use under each of these categories is facility-specific.

While water conservation is a viable water management strategy that makes more efficient use of available supplies to meet projected water needs, drought management recommendations have not been made by the Brazos G RWPG as a water management strategy for specific WUG needs. The regional water plan is developed to meet projected water demands during a drought of severity equivalent to the drought of record. The purpose of the planning is to ensure that sufficient supplies are available to meet future water demands. Reducing water demands during a drought as a defined water management strategy does not ensure that sufficient supplies will be available to meet the projected water demands; but simply eliminates the demands. While the Brazos G RWPG encourages entities in the Brazos G Area to promote demand management during a drought, it should not be identified as a "new source" of supply. Recommending demand reductions as a water management strategy is antithetical to the concept of planning to meet projected water demands. It does not make more efficient use of existing supplies as does conservation, but instead effectively turns the tap off when the water is needed most. It is planning to not meet future water demands. When considering the costs of demand reduction during drought, the costs for drought management could be considered as the economic costs of not meeting the projected water demands, as summarized in Appendix H.

1.8 Funding and Permitting by State Agencies of Projects Not in the Regional Water Plan

Senate Bill 1 requires water supply projects to be consistent with approved regional water plans to be eligible for TWDB funding and to obtain TCEQ permits. Texas Water Code provides that the TCEQ shall grant an application to appropriate surface water, including amendments to existing permits, only if the proposed action addresses a water supply need in a manner that is consistent with an approved regional water plan. TCEQ may waive this requirement if conditions warrant.

For TWDB funding, the Texas Water Code states that the TWDB may provide financial assistance to a water supply project only after TWDB determines that the needs to be met by the project will be addressed in a manner that is consistent with the appropriate regional water plan. The TWDB may waive this provision if conditions warrant.

The Brazos G RWPG has considered the variety of actions and permit applications that may come before the TCEQ and the TWDB and does not want to unduly constrain projects or applications for small amounts of water that may not be included specifically in the adopted regional water plan. "Small amounts of water" is defined as involving no more than 1,000 acft/yr, regardless of whether the action is for a temporary or long term action. The Brazos G RWPG provides direction to TCEQ and TWDB regarding appropriations, permit amendments, and projects involving small amounts of water that will not have a significant impact on the region's water supply as follows: such projects are consistent with the regional water plan, even though not specifically recommended in the plan. However, many of the projects associated with these "small amounts of water" have been included where possible in the miscellaneous strategies Section 12.

The Brazos G RWPG also provides direction to the TWDB regarding financial assistance for repair and replacement of existing facilities, or to develop small amounts of water (less than 1,000 acft/yr). Water supply projects not involving the development of or connection to a new water source, or involving development of a new supply less than 1,000 acft/yr, are consistent with the regional water plan, even though not specifically mentioned in the adopted plan.

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2 Water Conservation

2.1 Municipal Water Conservation

Water conservation is defined as those methods and practices that either reduce the demand for water supply or increase the efficiency of the supply. Water facilities are used so that supply is conserved and made available for future use. Water conservation is typically a non-capital intensive alternative that any water supply entity can pursue.

Water supply entities and major water right holders that meet the following criteria are required by Texas Water Code and Texas Administrative Code statute to submit a Water Conservation Plan to the TCEQ:

- Entities who are requesting Texas Water Development Board (TWDB) financial assistance greater than $500,000
- Entities with 3,300 connections or greater
- Surface water right holders of:
  - Greater than 1,000 acft/year (non-irrigation)
  - Greater than 10,000 acft/year (irrigation)

The purpose of a water conservation plan is to establish strategies for reducing the volume of water used from a water supply source, reduce loss or waste of water, and maintain and improve the efficiency in the use of water. Water conservation plans must identify 5 and 10 year targets and goals for water use and water loss, including methods used to track progress in meeting targets and goals. Water conservation plans for Brazos G municipal water user groups, including the most common water conservation best management practices (BMPs) identified in the water conservation plans, are summarized in Volume I, Chapter 5.40.

The TWDB guidance and Texas Administrative Code 357.34(f)2 requires Regional Water Planning Groups to consider water conservation practices, including potentially applicable BMPs, for each water user group with an identified water need (shortage) in the regional water plan. For the 2016 Regional Water Plans, the TWDB has new requirements for water conservation content to be included in the Plans including directives for regional water planning groups to assess the highest level of water conservation and efficiencies achievable, report the resulting projected water use savings in gallons per capita per day, and develop conservation strategies based on this information. This write-up addresses the TWDB directives related to water conservation.

There are several water conservation resources that have been developed for use in developing the Regional Water Plans. The Water Conservation Implementation Task Force, created by Senate Bill 1094, provided guidance on Water Conservation Best Management Practices (BMPs). Additionally a GDS Associates Report provides guidance on expected water savings and costs associated with implementing water conservation best management practices.

2.1.1 Description of Strategy

For regional water planning purposes, municipal water use is defined as residential and commercial water use. Municipal water is primarily for drinking, sanitation, cleaning, cooling, fire protection, and landscape watering for residential, commercial, and institutional establishments. A key parameter for assessing municipal water use within a typical city or water service area is the number of gallons used per person per day (per capita water use). The objective of water conservation is to decrease the amount of water – measured in gallons per capita per day (gpcd) – that a typical person uses.

The Task Force recommends that a standardized methodology be used for determining gpcd municipal water use so as to allow consistent evaluations of the effectiveness of water conservation measures among Texas cities that are located in the different climates of Texas. The following were recommendations provided in the Task Force Report, some of which have been incorporated as requirements by TCEQ for water conservation plans submitted to the state:

- All public water suppliers that are required to prepare and submit water conservation plans should establish targets for water conservation, including specific goals for per capita water use and for water loss programs using appropriate water conservation BMPs.
- Municipal Water Conservation Plans required by the State shall include per capita water-use goals, with targets and goals established by an entity giving consideration to a minimum annual reduction of 1 percent in total gpcd, based upon a 5-year moving average, until such time as the entity achieves a total gpcd of 140 gpcd or less, or
- Municipal water use (gpcd) goals approved by regional water planning groups.

The current TWDB municipal water demand projections account for expected water savings due to implementation of the 1991 State Water-Efficient Plumbing Act. However, any projected water savings due to conservation programs over and above the savings associated with the 1991 Plumbing Act must be listed as a separate water management strategy. The projections assume that 100 percent of new construction includes water-efficient plumbing fixtures. Consequently, any water management strategy intended to replace inefficient plumbing fixtures installed prior to 1995 would constitute an acceleration of the effects of the 1991 Plumbing Act, but provide no additional long-term savings. Including a retrofit program as a water management strategy without first discounting the TWDB per capita water use reductions would double-count water savings, since those savings due to retrofits are already included in the base water demand projections.

In 2009, the Texas Legislature enacted House Bill (HB) 2667 establishing new minimum standards for plumbing fixtures sold in Texas beginning in 2014. HB 2667 clarifies and sets out the national standards of the American Society of Mechanical Engineers and American National Standards Institute by which plumbing fixtures will be produced and tested. This bill establishes a phase-in of high efficiency plumbing fixtures brought into Texas, which will allow manufacturers the time to change their production, at the same time allowing retailers the opportunity to turn over their inventory. HB 2667 creates an exemption for those manufacturers that volunteer to register their products with the

United States Environmental Protection Agency's WaterSense Program, which should result in additional water savings. This bill also repeals the TCEQ certification process for plumbing fixtures since the plumbing fixtures must meet national certification and testing procedures.

The TCEQ has promulgated rules to reflect this new change in law. The 2009 law requires that by January 2014, all toilets use no more than 1.28 gallons per flush (20% savings from the 1991 1.6 gallons per flush standard). Based upon an average frequency of per-person toilet use in households of 5.1 and a per-use savings of 0.32 gallons per use the supplementary savings of adopting high-efficiency toilets is 1.63 gpcd. This change is also reflected in Table 2.1-1.

Table 2.1-1. Standards for Plumbing Fixtures

Fixture	Standard
Toilets*	1.28 gallons per flush
Shower Heads	2.75 gallons per minute at 80 psi
Urinals	0.5 gallon per flush
Faucet Aerators	2.20 gallons per minute at 60 psi
Drinking Water Fountains	Shall be self-closing

*Bill 2667 of the 81st Texas Legislature, 2009

The TWDB has estimated that the effect of the new plumbing fixtures in dwellings, offices, and public places will be a reduction in per capita water use of approximately 20 gpcd, in comparison to what would have occurred with previous generations of plumbing fixtures.[1] The estimated water conservation effect of 20 gpcd was obtained from TWDB data shown in Table 2.1-2. The low flow plumbing fixtures effects that are already included in the water demand projections are deducted from the 20 gpcd plumbing fixtures potentials for municipal water demand reduction before additional conservation measures are suggested.

Table 2.1-2. Caption Water Conservation Potentials of Low Flow Plumbing Fixtures

Plumbing Fixture	Water Savings (gpcd)
Toilets and Showerheads	16.0
Additional Savings (High Efficiency Toilet)*	1.63
Faucet Aerators – 2.2 gallons per minute	2.0
Urinals – 1.0 gallon per minute	0.3
Drinking Fountains (self-closing)	0.1
Total	20.03 (~20 gpcd)

* TWDB, 2013

[1] "Water Conservation Impacts on Per Capita Water Use," Water Planning Information, Texas Water Development Board, Austin, Texas, 1992.

2.1.2 Brazos G Municipal Water Conservation Approach

The Brazos G Regional Water Planning Group (Brazos G RWPG) recommends additional water conservation beyond Plumbing Act savings for all municipal water user groups with per capita use above 140 gpcd in the TWDB base gpcd[2], regardless of whether or not the entity has needs. For these entities, the goal would be to reduce per capita use by 1% annually until the target is met, and then hold the 140 gpcd rate constant throughout the remainder of the planning period. This conservation can be achieved in a variety of ways, including using these BMPs identified by the Water Conservation Implementation Task Force:

1. System Water Audit and Water Loss,
2. Water Conservation Pricing,
3. Prohibition on Wasting Water,
4. Showerhead, Aerator, and Toilet Flapper Retrofit,
5. Residential Toilet Replacement Programs with Ultra-Low-Flow toilets,
6. Residential Clothes Washer Incentive Program,
7. School Education,
8. Water Survey for Single-Family and Multi-Family Customers,
9. Landscape Irrigation Conservation and Incentives,
10. Water-Wise Landscape Design and Conversion Programs,
11. Athletic Field Conservation,
12. Golf Course Conservation,
13. Metering of all New Connections and Retrofitting of Existing Connections,
14. Wholesale Agency Assistance Programs,
15. Conservation Coordinator,
16. Reuse of Reclaimed Water,
17. Public Information,
18. Rainwater Harvesting and Condensate Reuse,
19. New Construction Graywater,
20. Park Conservation, and
21. Conservation Programs for Industrial, Commercial, and Institutional Accounts.

The Brazos G RWPG does not recommend specific conservation BMPs for each municipal entity, as each entity should choose those conservation strategies that best fit their individual situation. However, based on a review of water conservation plans for Brazos G water user groups, the most common BMPs cited

[2] Typically based on 2011 water use, but may represent a different year based on revisions.

to assist in conserving water in the Brazos G region are shown bolded in the above list.

2.1.3 Available Supply

The available supply attributed to implementation of this strategy would be a 1% annual reduction in demand over and above that assumed in the TWDB water demand projections. All entities, in order to be in line with projections, will need to verify that their conservation planning measures are consistent with TCEQ standards and the TWDB projections. Beyond that, some communities with projected needs may be able to reduce or eliminate those needs with stronger conservation planning. Table 2.1-3 shows a comparison of TWDB baseline per capita rates for the 2016 Brazos G Plan to per capita rates with advanced conservation for Brazos G entities with per capita rates greater than 140 gpcd. Table 2.1-4 lists municipal WUGs with per capita use rates greater than 140 gpcd, and projected needs (shortages). The table also lists the additional water savings attributable to the Brazos G RWPG conservation recommendations[3].

[3] Additional savings represents savings beyond the 1991 Plumbing Act savings.

Table 2.1-3. Comparison of TWDB Baseline Per Capita Rates for the 2016 Brazos G Plan and Per Capita Rates With Advanced Conservation

		GPCD Board Projections without Advanced Conservation							GPCD Goal with Advanced Conservation					
		Base GPCD	Projected GPCD						Projected GPCD					
County	WUG	2011	2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
TAYLOR	ABILENE	169	169	167	165	164	162	160	157	142	140	140	140	140
SHACKELFORD	ALBANY	258	253	250	248	245	243	240	236	213	193	174	158	143
LEE	AQUA WSC	156	153	151	150	148	147	145	143	140	140	140	140	140
BELL	ARMSTRONG WSC	168	165	163	161	160	158	157	153	140	140	140	140	140
STONEWALL	ASPERMONT	250	245	243	240	238	235	233	228	207	187	169	153	140
CALLAHAN	BAIRD	153	150	148	147	146	144	143	140	139	135	135	135	135
WILLIAMSON	BARTLETT	181	177	176	174	172	170	169	165	150	140	140	140	140
BELL	BELL COUNTY-OTHER	162	159	157	156	154	153	151	148	140	140	140	140	140
BELL	BELL-MILAM FALLS WSC	142	139	139	139	139	139	139	134	130	128	126	126	126
BELL	BELTON	165	162	160	158	157	155	154	151	140	140	140	140	140
JOHNSON	BETHESDA WSC	197	193	191	189	187	185	184	180	163	147	140	140	140
BRAZOS	BRAZOS COUNTY-OTHER	142	139	139	139	139	139	139	131	130	130	129	128	128
STEPHENS	BRECKENRIDGE	161	158	156	155	153	152	150	147	140	140	140	140	140
ROBERTSON	BREMOND	174	171	169	167	165	164	162	159	144	140	140	140	140
WASHINGTON	BRENHAM	219	215	212	210	208	206	204	200	181	164	148	140	140
MCLENNAN	BRUCEVILLE-EDDY	174	171	169	167	165	164	162	159	144	140	140	140	140
WILLIAMSON	BRUSHY CREEK MUD	231	226	224	222	220	217	215	211	191	173	156	141	140
BRAZOS	BRYAN	168	165	163	161	160	158	157	153	140	140	140	140	140
JOHNSON	BURLESON	143	140	139	139	139	139	139	135	132	130	129	129	129
BURLESON	CALDWELL	197	193	191	189	187	185	184	180	163	147	140	140	140
ROBERTSON	CALVERT	152	149	147	146	145	143	142	140	137	135	135	134	134
MILAM	CAMERON	216	212	210	207	205	203	201	197	178	161	146	140	140
WILLIAMSON	CEDAR PARK	235	230	228	226	223	221	219	190	172	155	140	140	140
BOSQUE	CHILDRESS CREEK WSC	147	144	143	141	140	140	140	138	134	132	130	130	130
WILLIAMSON	CHISHOLM TRAIL SUD	174	171	169	167	165	164	162	159	144	140	140	140	140
EASTLAND	CISCO	168	165	163	161	160	158	157	153	140	140	140	140	140
JOHNSON	CLEBURNE	172	169	167	165	164	162	160	157	142	140	140	140	140
BOSQUE	CLIFTON	173	170	168	166	165	163	161	158	143	140	140	140	140
BRAZOS	COLLEGE STATION	177	173	172	170	168	167	165	162	146	140	140	140	140
LIMESTONE	COOLIDGE	156	153	151	150	148	147	145	143	140	140	140	139	139
CORYELL	CORYELL CITY WATER SUPPLY DISTRICT	154	151	149	148	146	145	144	141	140	140	140	140	140
MCLENNAN	CRAWFORD	191	187	185	183	182	180	178	174	158	143	140	140	140
HOOD	CRESSON	143	140	139	139	139	139	139	136	133	131	129	129	129
MCLENNAN	CROSS COUNTRY WSC	158	155	153	152	150	149	147	144	140	140	140	140	140
CALLAHAN	CROSS PLAINS	162	159	157	156	154	153	151	148	140	140	140	140	140
JOHNSON	CROWLEY	141	140	140	140	140	140	140	140	130	129	129	129	128
EASTLAND	EASTLAND	150	147	146	144	143	141	140	140	137	134	132	131	131
WILLIAMSON	FERN BLUFF MUD	190	186	184	183	181	179	177	174	157	142	140	140	140
HILL	FILES VALLEY WSC	146	143	142	140	139	139	139	137	133	131	129	129	129
BELL	FORT HOOD	215	211	209	207	204	202	200	196	178	161	145	140	140
JOHNSON	FORT WORTH	185	181	180	178	176	174	172	169	153	140	140	140	140
ROBERTSON	FRANKLIN	142	139	139	139	139	139	139	132	128	125	124	124	123
CORYELL	GATESVILLE	229	224	222	220	218	216	213	209	189	171	155	140	140
WILLIAMSON	GEORGETOWN	205	201	199	197	195	193	191	187	169	153	140	140	140
LEE	GIDDINGS	188	184	182	181	179	177	175	172	155	140	140	140	140
SOMERVELL	GLEN ROSE	200	196	194	192	190	188	186	183	165	149	140	140	140
YOUNG	GRAHAM	266	261	258	256	253	250	248	243	220	199	180	163	147
LIMESTONE	GROESBECK	149	146	145	143	142	140	139	139	137	134	132	132	132
MCLENNAN	HALLSBURG	141	140	140	140	140	140	140	133	128	124	124	123	123
HAMILTON	HAMILTON	162	159	157	156	154	153	151	148	140	140	140	140	140
JONES	HAMLIN	178	174	173	171	169	168	166	163	147	140	140	140	140
BELL	HARKER HEIGHTS	182	178	177	175	173	171	170	166	150	140	140	140	140
HASKELL	HASKELL	148	145	144	142	141	139	139	139	135	131	130	129	129
ROBERTSON	HEARNE	161	158	156	155	153	152	150	147	140	140	140	140	140

Table 2.1-3 (Concluded)

		GPCD Board Projections without Advanced Conservation							GPCD Goal with Advanced Conservation					
		Base GPCD	Projected GPCD						Projected GPCD					
County	WUG	2011	2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
MCLENNAN	HEWITT	165	162	160	158	157	155	154	151	140	140	140	140	140
HILL	HILLSBORO	200	196	194	192	190	188	186	183	165	149	140	140	140
KENT	JAYTON	164	161	159	158	156	154	153	150	140	140	140	140	140
LAMPASAS	KEMPNER	158	155	153	152	150	149	147	144	140	140	140	140	140
CORYELL	KEMPNER WSC	164	161	159	158	156	154	153	150	140	140	140	140	140
KNOX	KNOX CITY	195	191	189	187	185	184	182	178	161	146	140	140	140
LAMPASAS	LAMPASAS	154	151	149	148	146	145	144	141	139	136	135	135	135
LEE	LEXINGTON	169	166	164	162	161	159	158	154	140	140	140	140	140
BELL	LITTLE RIVER-ACADEMY	160	157	155	154	152	151	149	146	140	140	140	140	140
LAMPASAS	LOMETA	177	173	172	170	168	167	165	162	146	140	140	140	140
MCLENNAN	LORENA	154	151	149	148	146	145	144	141	140	139	138	138	137
JOHNSON	MANSFIELD	252	247	245	242	240	237	235	230	208	188	170	154	140
WILLIAMSON	MANVILLE WSC	148	145	144	142	141	139	139	139	136	135	134	134	134
FALLS	MARLIN	254	249	246	244	242	239	237	232	210	190	172	155	140
MCLENNAN	MART	142	139	139	139	139	139	139	133	129	126	124	124	124
MCLENNAN	MCGREGOR	146	143	142	140	139	139	139	137	133	129	128	127	127
PALO PINTO	MINERAL WELLS	155	152	150	149	147	146	144	142	140	139	137	137	137
JOHNSON	MOUNTAIN PEAK SUD	290	284	281	279	276	273	270	265	240	217	196	177	160
KNOX	MUNDAY	180	176	175	173	171	169	168	164	149	140	140	140	140
GRIMES	NAVASOTA	184	180	179	177	175	173	172	168	152	140	140	140	140
BELL	NOLANVILLE	212	208	206	204	202	200	198	194	175	158	143	140	140
MCLENNAN	NORTH BOSQUE WSC	235	230	228	226	223	221	219	215	194	176	159	144	140
WILLIAMSON	PFLUGERVILLE	155	152	150	149	147	146	144	142	140	140	140	140	140
PALO PINTO	POSSUM KINGDOM WSC	392	384	380	377	373	369	365	358	324	293	265	240	217
TAYLOR	POTOSI WSC	146	143	142	140	139	139	139	138	135	133	132	131	131
EASTLAND	RANGER	171	168	166	164	163	161	159	156	141	140	140	140	140
MCLENNAN	ROBINSON	181	177	176	174	172	170	169	165	150	140	140	140	140
FISHER	ROBY	175	172	170	168	166	165	163	160	145	140	140	140	140
MILAM	ROCKDALE	184	180	179	177	175	173	172	168	152	140	140	140	140
WILLIAMSON	ROUND ROCK	152	149	147	146	145	143	142	140	140	139	139	139	138
BELL	SALADO WSC	292	286	283	280	278	275	272	267	241	218	197	178	161
BURLESON	SNOOK	307	301	298	295	292	289	286	280	254	229	207	188	170
BURLESON	SOMERVILLE	170	167	165	163	162	160	158	155	140	140	140	140	140
MILAM	SOUTHWEST MILAM WSC	152	149	147	146	145	143	142	140	140	137	136	136	136
JONES	STAMFORD	237	232	230	228	225	223	221	217	196	177	160	145	140
PALO PINTO	STRAWN	182	178	177	175	173	171	170	166	150	140	140	140	140
NOLAN	SWEETWATER	153	150	148	147	146	144	143	140	138	135	134	134	134
WILLIAMSON	TAYLOR	157	154	152	151	149	148	146	143	140	140	139	139	139
BELL	TEMPLE	229	224	222	220	218	216	213	209	189	171	155	140	140
BRAZOS	TEXAS A & M UNIVERSITY	487	477	473	468	463	459	454	445	402	364	329	298	269
THROCKMORTON	THROCKMORTON	205	201	199	197	195	193	191	187	169	153	140	140	140
BOSQUE	VALLEY MILLS	184	180	179	177	175	173	172	168	152	140	140	140	140
JOHNSON	VENUS	174	171	169	167	165	164	162	159	144	140	140	140	140
MCLENNAN	WACO	220	216	213	211	209	207	205	201	182	164	149	140	140
BRAZOS	WELLBORN SUD	186	182	180	179	177	175	173	170	154	140	140	140	140
MCLENNAN	WEST	160	157	155	154	152	151	149	146	140	140	140	140	140
BELL	WEST BELL COUNTY WSC	149	146	145	143	142	140	139	138	134	131	131	130	130
HILL	WHITE BLUFF COMMUNITY WS	198	194	192	190	188	186	185	181	164	148	140	140	140
HILL	WHITNEY	180	176	175	173	171	169	168	164	149	140	140	140	140
WILLIAMSON	WILLIAMSON COUNTY MUD #10	196	192	190	188	186	185	183	179	162	146	140	140	140
WILLIAMSON	WILLIAMSON COUNTY MUD #11	185	181	180	178	176	174	172	169	153	140	140	140	140
WILLIAMSON	WILLIAMSON COUNTY MUD #9	188	184	182	181	179	177	175	172	155	140	140	140	140
WILLIAMSON	WILLIAMSON COUNTY-OTHER	148	145	144	142	141	139	139	139	135	134	133	133	133
MCLENNAN	WOODWAY	352	345	342	338	335	331	328	322	291	263	238	215	195

Table 2.1-4. Estimated Water Savings for WUGs with Recommended Conservation

County Name	Water User Group	Projected Water Needs						Additional Water Saved-W/Conservation (acft)*					
		2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
TAYLOR	ABILENE	-	(8,445)	(9,115)	(9,802)	(10,587)	(11,314)	710	2,331	2,246	2,045	2,040	2,067
SHACKELFORD	ALBANY	-	-	-	-	-	-	32	85	133	181	225	267
LEE	AQUA WSC	-	-	-	-	-	-	14	12	5	1	1	0
BELL	ARMSTRONG WSC	-	-	-	-	-	-	14	39	32	29	30	32
STONEWALL	ASPERMONT	-	-	-	-	-	-	13	30	48	66	82	95
CALLAHAN	BAIRD	-	-	-	-	-	-	6	-	-	-	-	-
WILLIAMSON	BARTLETT	(281)	(309)	(344)	(383)	(428)	(472)	12	40	61	62	68	73
BELL	BELL COUNTY-OTHER	-	-	(768)	(1,828)	(2,824)	(3,788)	14	62	73	94	117	138
BELL	BELTON	-	-	-	-	-	-	119	340	318	321	347	379
JOHNSON	BETHESDA WSC	(1,486)	(1,981)	(2,560)	(3,139)	(3,778)	(4,475)	126	410	763	1,018	1,138	1,271
STEPHENS	BRECKENRIDGE	-	-	-	-	-	-	30	51	29	17	15	15
ROBERTSON	BREMOND	-	-	-	-	-	-	6	20	22	23	23	25
WASHINGTON	BRENHAM	-	(217)	(400)	(605)	(780)	(928)	190	531	889	1,272	1,508	1,553
MCLENNAN	BRUCEVILLE-EDDY	-	-	-	-	-	-	11	33	38	36	38	40
WILLIAMSON	BRUSHY CREEK MUD	(877)	(1,204)	(1,170)	(1,150)	(1,146)	(1,145)	197	589	947	1,282	1,599	1,623
BRAZOS	BRYAN	(6,123)	(5,019)	(10,156)	(16,498)	(23,413)	(31,201)	493	1,573	1,616	1,697	1,899	2,143
BURLESON	CALDWELL	-	-	-	-	-	-	40	121	203	240	242	246
ROBERTSON	CALVERT	-	-	-	-	-	-	3	-	-	-	-	-
MILAM	CAMERON	-	-	-	-	-	-	58	163	269	389	448	464
WILLIAMSON	CEDAR PARK	(2,075)	(3,854)	(4,082)	(4,159)	(4,244)	(4,348)	1,149	3,048	5,001	6,657	8,166	8,521
WILLIAMSON	CHISHOLM TRAIL SUD	(2,392)	(3,577)	(5,070)	(6,685)	(8,512)	(10,401)	209	747	1,055	1,248	1,477	1,720
EASTLAND	CISCO	-	-	-	-	-	-	23	67	52	44	42	42
JOHNSON	CLEBURNE	-	-	-	-	(1,092)	(2,373)	207	685	736	749	809	883
BOSQUE	CLIFTON	-	-	-	-	-	-	21	74	77	71	71	71
BRAZOS	COLLEGE STATION	(4,973)	(8,024)	(7,372)	(7,673)	(8,085)	(8,401)	679	2,585	3,465	3,823	4,332	4,926
LIMESTONE	COOLIDGE	(72)	(12)	(38)	(70)	(105)	(140)	5	4	1	-	-	-
CORYELL	CORYELL CITY WATER SUPPLY DISTRICT	-	-	-	-	-	-	34	21	9	1	-	-
MCLENNAN	CRAWFORD	(5)	(3)	(3)	(3)	(5)	(7)	7	16	27	28	28	29
MCLENNAN	CROSS COUNTRY WSC	-	-	-	(138)	(139)	(141)	20	24	14	10	8	8
CALLAHAN	CROSS PLAINS	-	-	-	-	-	-	5	10	5	5	5	4
JOHNSON	CROWLEY	(9)	(12)	(17)	(23)	(29)	(35)	1	-	-	-	-	-
EASTLAND	EASTLAND	-	-	-	-	-	-	4	-	-	-	-	-
WILLIAMSON	FERN BLUFF MUD	(63)	(161)	(253)	(261)	(259)	(259)	63	161	253	261	259	259
BELL	FORT HOOD	-	-	-	-	-	-	293	842	1,376	1,946	2,134	2,133
JOHNSON	FORT WORTH	-	-	-	(759)	(1,238)	(1,573)	-	-	-	167	265	331
CORYELL	GATESVILLE	-	(629)	(1,406)	(2,356)	(3,152)	(3,995)	208	610	1,097	1,644	2,261	2,462
WILLIAMSON	GEORGETOWN	-	(2,194)	(6,695)	(11,781)	(17,840)	(24,121)	734	2,507	5,068	8,141	9,756	11,442
LEE	GIDDINGS	-	-	-	-	-	-	39	131	231	230	232	233
SOMERVELL	GLEN ROSE	-	-	-	-	(14)	(39)	24	73	128	167	172	178
YOUNG	GRAHAM	-	-	-	-	-	-	140	354	568	795	1,029	1,260

Table 2.1-4 (Continued)

County Name	Water User Group	Projected Water Needs						Additional Water Saved-W/Conservation (acft)*					
		2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
LIMESTONE	GROESBECK	(688)	(677)	(668)	(665)	(668)	(672)	2	-	-	-	-	-
HAMILTON	HAMILTON	-	-	-	-	-	-	18	32	20	14	13	13
JONES	HAMLIN	-	-	-	-	-	-	14	43	57	57	58	58
BELL	HARKER HEIGHTS	-	-	(938)	(1,496)	(1,974)	(3,170)	262	836	1,367	1,499	1,656	1,819
ROBERTSON	HEARNE	-	-	-	-	-	-	22	35	16	14	12	12
MCLENNAN	HEWITT	(87)	(237)	(211)	(204)	(216)	(231)	87	237	211	204	216	231
HILL	HILLSBORO	-	-	-	-	-	-	79	230	385	495	506	517
KENT	JAYTON	(92)	(91)	(89)	(89)	(88)	(88)	3	6	4	4	3	3
LAMPASAS	KEMPNER	(7)	(10)	(6)	(6)	(5)	(5)	7	10	6	6	5	5
CORYELL	KEMPNER WSC	(536)	(814)	(1,076)	(1,344)	(1,612)	(1,868)	94	225	211	209	219	232
KNOX	KNOX CITY	(48)	(83)	(118)	(154)	(190)	(226)	9	25	45	54	54	55
LAMPASAS	LAMPASAS	(49)	(148)	(227)	(318)	(414)	(505)	27	-	-	-	-	-
LEE	LEXINGTON	-	-	-	-	-	-	8	26	23	21	21	21
BELL	LITTLE RIVER-ACADEMY	-	(21)	(59)	(102)	(146)	(190)	12	19	13	11	11	11
LAMPASAS	LOMETA	-	-	-	-	-	-	7	21	26	27	28	29
MCLENNAN	LORENA	-	-	-	-	-	-	10	3	-	-	-	-
JOHNSON	MANSFIELD	(43)	(144)	(293)	(490)	(738)	(1,024)	43	144	293	490	738	1,024
FALLS	MARLIN	-	-	-	-	-	-	86	226	357	480	619	756
PALO PINTO	MINERAL WELLS	(1,931)	(1,884)	(1,816)	(1,803)	(1,735)	(1,616)	70	31	-	-	-	-
JOHNSON	MOUNTAIN PEAK SUD	-	-	-	-	-	-	34	99	184	288	413	555
KNOX	MUNDAY	(55)	(91)	(125)	(164)	(200)	(237)	8	26	36	37	36	37
GRIMES	NAVASOTA	-	-	-	-	-	-	55	158	238	229	231	235
BELL	NOLANVILLE	(72)	(444)	(858)	(1,330)	(1,758)	(2,188)	67	224	444	720	884	1,003
MCLENNAN	NORTH BOSQUE WSC	(14)	(146)	(265)	(385)	(507)	(628)	33	99	183	280	390	452
WILLIAMSON	PFLUGERVILLE	-	-	-	-	-	-	3	5	5	6	7	8
PALO PINTO	POSSUM KINGDOM WSC	(60)	(110)	(142)	(173)	(199)	(221)	53	126	198	271	342	410
EASTLAND	RANGER	-	-	-	-	-	-	15	46	39	37	36	36
MCLENNAN	ROBINSON	-	(346)	(720)	(1,109)	(1,511)	(1,909)	91	316	507	549	605	663
FISHER	ROBY	-	-	-	-	-	-	5	13	14	13	12	12
MILAM	ROCKDALE	-	-	-	-	-	-	43	128	198	195	200	207
WILLIAMSON	ROUND ROCK	(2,116)	(8,201)	(16,000)	(24,896)	(35,190)	(45,861)	513	117	-	-	-	-
BELL	SALADO WSC	-	-	-	-	(112)	(278)	97	255	431	624	830	1,044
BURLESON	SNOOK	-	-	-	-	-	-	11	26	42	59	76	91
BURLESON	SOMERVILLE	-	-	-	-	-	-	8	26	23	23	23	24
MILAM	SOUTHWEST MILAM WSC	-	-	-	-	-	-	33	-	-	-	-	-
JONES	STAMFORD	(1,834)	(1,865)	(1,885)	(1,910)	(1,932)	(1,951)	40	105	172	246	316	344
PALO PINTO	STRAWN	-	-	-	-	-	-	5	16	22	22	22	22
NOLAN	SWEETWATER	(1,349)	(1,390)	(1,410)	(1,474)	(1,527)	(1,576)	39	-	-	-	-	-
WILLIAMSON	TAYLOR	(13)	(14)	(16)	(18)	(20)	(21)	75	73	17	-	-	-
BELL	TEMPLE	-	-	(1,904)	(4,373)	(8,268)	(11,600)	914	2,740	5,015	7,724	10,771	11,850
BRAZOS	TEXAS A & M UNIVERSITY	-	-	-	-	-	-	416	942	1,418	1,869	2,289	2,670

Table 2.1-4 (Concluded)

County Name	Water User Group	Projected Water Needs						Additional Water Saved-W/Conservation (acft)*					
		2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
THROCKMORTON	THROCKMORTON	-	-	-	-	-	-	8	20	32	45	44	44
BOSQUE	VALLEY MILLS	-	-	-	-	-	(2)	10	31	48	47	48	48
JOHNSON	VENUS	(24)	(117)	(237)	(355)	(478)	(604)	30	90	115	127	140	156
MCLENNAN	WACO	-	-	-	-	-	(1,348)	1,462	4,033	6,781	9,781	11,940	12,554
BRAZOS	WELLBORN SUD	-	-	(202)	(625)	(1,216)	(1,867)	78	279	508	563	633	713
MCLENNAN	WEST	-	-	-	-	-	-	15	23	13	7	6	6
HILL	WHITE BLUFF COMMUNITY WS	-	-	-	-	-	-	24	63	103	125	128	132
HILL	WHITNEY	-	-	-	-	-	-	17	50	70	68	69	71
WILLIAMSON	WILLIAMSON COUNTY MUD #10	(61)	(181)	(352)	(489)	(587)	(688)	61	181	352	489	587	688
WILLIAMSON	WILLIAMSON COUNTY MUD #11	(35)	(103)	(193)	(233)	(278)	(326)	35	103	193	233	278	326
WILLIAMSON	WILLIAMSON COUNTY MUD #9	(37)	(128)	(263)	(319)	(382)	(448)	37	128	263	319	382	448
MCLENNAN	WOODWAY	-	(7)	(20)	(57)	(74)	(103)	208	512	832	1,180	1,541	1,906

* Note: This conservation is in addition to savings attributed to the 1991 Water Efficient Plumbing Fixtures Act.

2.1.4 Additional Advanced Conservation

While a goal of 140 gpcd or less was chosen as a standard for all WUGs in Region G, an additional advanced conservation goal of 120 gpcd was used for select WUGs in Williamson County. Rather than applying a 1% per year reduction until a gpcd of 140 or less was achieved, the annual reduction rate was calculated to bring the gpcd of each WUG to 120 by 2070 and that rate was applied over the planning period. The annual reduction rate and projected gpcd for each WUG are shown in Table 2.1-5. The additional water savings achieved above and beyond advanced conservation goals of 140 gpcd are shown in Table 2.1-6. A total savings of 17,909 acft/yr in 2070 is estimated for Williamson County.

Table 2.1-5. Projected Reduction Rates and Decadal GPCDs for Additional Advanced Conservation for selected WUGs in Williamson County

Participating WUG	Base GPCD	Annual Reduction Rate	Projected with Additional Advanced Conservation (GPCD)					
			2020	*2030*	*2040*	*2050*	*2060*	*2070*
BARTLETT	181	0.694%	170	159	148	138	129	120
BRUSHY CREEK MUD	231	1.104%	209	187	167	150	134	120
CHISHOLM TRAIL SUD	174	0.628%	164	154	145	136	128	120
WILLIAMSON COUNTY-OTHER	148	0.355%	143	138	134	129	124	120
GEORGETOWN	205	0.904%	189	173	158	144	131	120
ROUND ROCK	152	0.400%	147	141	135	130	125	120

Table 2.1-6. Estimated Water Savings for Reductions Identified for WUGs in Williamson County with Additional Advanced Conservation

Participating WUG	Estimated Water Savings (acft/yr)					
	2020	*2030*	*2040*	*2050*	*2060*	*2070*
BARTLETT	0	0	0	6	35	68
BRUSHY CREEK MUD	39	81	111	135	152	430
CHISHOLM TRAIL SUD	0	0	6	503	1,159	1,967
WILLIAMSON COUNTY-OTHER	0	0	56	567	1,432	2,594
GEORGETOWN	0	0	0	0	1,612	4,404
ROUND ROCK	0	0	1,060	2,825	5,310	8,446
Total	**39**	**81**	**1,234**	**4,036**	**9,700**	**17,909**

2.1.5 Environmental Issues

No substantial environmental impacts are anticipated, as water conservation is typically a non-capital intensive alternative that is not associated with direct physical impacts to the natural environment. A summary of the few potential environmental issues that might arise for this alternative are presented in Table 2.1-7.

Table 2.1-7. Environmental Issues: Municipal Water Conservation

Water Management Option	Municipal Water Conservation
Implementation Measures	Voluntary reduction, reduced diversions, changing water pricing, mandatory restrictions (landscaping ordinances, watering days), reducing unaccounted for water
Environmental Water Needs / Instream Flows	No substantial impact identified, assuming relatively low reduction in diversions and return flows; substantial reductions in municipal and industrial diversions from water conservation would potentially result in low to moderate positive impacts as more stream flow would be available for environmental water needs and instream flows
Bays and Estuaries	No substantial impact identified, assuming relatively low reduction in diversions and return flows
Fish and Wildlife Habitat	No substantial impact identified, assuming relatively low reductions in diversions and return flows; potential low to moderate positive impact to aquatic and riparian habitats with substantial reductions as more stream flow would be available to these habitats; potential moderate positive benefits from implementation of site-specific xeriscape landscaping
Cultural Resources	No substantial impacts anticipated.
Threatened and Endangered Species	No substantial impact identified, assuming relatively low reduction in diversions and return flows; potential low to moderate positive impact to aquatic and riparian threatened and endangered species (where they occur) with substantial diversion reductions
Comments	Assumes no substantial change in infrastructure with attendant landscape impacts; further assumes that infrastructure improvements which do occur will largely be in urbanized settings

2.1.6 Engineering and Costing

The TWDB requires that costs and water supply estimates be developed for each recommended water management strategy. However, the Task Force Report does not present methods for computing water savings and costs for each of the above BMPs, reducing the list of specific BMPs that can be used to compute costs and savings. Eleven of the twenty-one BMPs suggested by the Task Force and listed above were averaged to calculate program costs. These eleven BMPs included indoor practices, such as toilet retrofits, showerhead replacements, and clothes washer rebates, as well as outdoor conservation measures such as landscape incentives, rainwater harvesting and rain barrels. The Brazos G RWPG also considered water loss data provided by the TWDB for Brazos G entities and prepared costs of a pipeline replacement program to reduce water losses. Due to the high cost, the Brazos G RWPG did not specifically recommend pipeline replacement programs but supports it as a BMP that may be selected by municipal water user groups to reduce water use, as discussed in more detail below.

Based upon the costs obtained for the selected BMPs from the GDS Associates report[4] the cost per acft of water saved by implementing water conservation practices would range between $53 and $1,022 depending on which of the eleven BMPs were selected. An average cost of $496 per acre-foot is assumed in rural areas for purposes of assigning a cost to the water conservation strategy. An average cost of $474 and $470 per acre-foot was estimated for urban and suburban areas respectively. This is the cost associated with water savings above those already included in the TWDB water demand projections. The total program costs for municipal entities having per capita use greater than 140 gpcd in 2011 are presented in Table 2.1-8 and are based on the water savings presented in Table 2.1-4.Total Brazos G costs for water conservation are estimated at $5,378,087 in 2020 and increasing to $40,904,532 by 2070, with unit costs ranging from $470 to $496 per acft of water saved.

Table 2.1-8. Estimated Cost of Conservation to Achieve Water Savings Identified in Table 2.1-4

Water User Group	Costs of Water Savings*					
	2020	*2030*	*2040*	*2050*	*2060*	*2070*
ABILENE	$336,623	$1,104,672	$1,064,615	$969,390	$966,734	$979,948
ALBANY	$16,003	$42,127	$65,953	$89,590	$111,837	$132,492
AQUA WSC	$6,829	$5,718	$2,406	$618	$278	$162
ARMSTRONG WSC	$6,346	$18,348	$15,188	$13,609	$14,127	$14,792
ASPERMONT	$6,504	$15,029	$23,724	$32,932	$40,765	$47,354
BAIRD	$3,173	-	-	-	-	-
BARTLETT	$5,830	$18,658	$28,452	$29,092	$31,883	$34,058
BELL COUNTY-OTHER	$6,762	$30,916	$36,038	$46,618	$57,932	$68,629
BELTON	$55,986	$159,689	$149,042	$150,590	$162,667	$177,675
BETHESDA WSC	$59,177	$192,296	$357,847	$477,508	$533,580	$596,148
BRECKENRIDGE	$15,016	$25,378	$14,283	$8,313	$7,633	$7,624
BREMOND	$2,881	$9,157	$10,241	$10,685	$10,953	$11,838
BRENHAM	$94,145	$263,574	$441,051	$630,708	$747,825	$770,052
BRUCEVILLE-EDDY	$5,145	$15,388	$17,628	$16,969	$17,716	$18,610
BRUSHY CREEK MUD	$92,525	$276,227	$444,326	$601,392	$750,047	$761,359

[4] "Quantifying the Effectiveness of Various Water Conservation Techniques in Texas," Texas Water Development Board, prepared by GDS Associates, Austin, Texas, July 2003.

Table 2.1-8 (Continued)

Water User Group	Costs of Water Savings*					
	2020	2030	2040	2050	2060	2070
BRYAN	$233,851	$745,799	$766,035	$804,443	$900,310	$1,015,578
CALDWELL	$18,780	$56,522	$95,335	$112,547	$113,634	$115,282
CALVERT	$1,440	-	-	-	-	-
CAMERON	$29,006	$80,883	$133,608	$192,894	$222,241	$230,338
CEDAR PARK	-	$673,483	$1,321,567	$1,925,335	$1,937,258	$1,936,320
CHISHOLM TRAIL SUD	$98,166	$350,421	$494,775	$585,447	$692,758	$806,494
CISCO	$11,463	$33,426	$25,675	$21,629	$20,637	$20,637
CLEBURNE	$96,961	$321,130	$345,303	$351,235	$379,401	$414,341
CLIFTON	$10,205	$36,637	$38,226	$35,311	$35,166	$35,216
COLLEGE STATION	$321,615	$1,225,425	$1,642,442	$1,812,264	$2,053,396	$2,335,020
COOLIDGE	$2,502	$2,214	$621	-	-	$66
CORYELL CITY WATER SUPPLY DISTRICT	$15,817	$9,934	$4,231	$283	-	-
CRAWFORD	$3,242	$7,681	$12,789	$13,120	$13,322	$13,525
CROSS COUNTRY WSC	$9,228	$11,303	$6,449	$4,896	$3,931	$3,877
CROSS PLAINS	$2,369	$4,750	$2,631	$2,486	$2,311	$2,029
CROWLEY	$469	-	-	$181	$160	-
EASTLAND	$2,077	-	-	-	-	-
FERN BLUFF MUD	$29,403	$75,494	$118,517	$122,288	$121,350	$121,350
FORT HOOD	$137,245	$394,722	$645,330	$912,670	$1,001,051	$1,000,582
FORT WORTH	-	-	-	$78,276	$124,491	$155,145
GATESVILLE	$97,750	$286,113	$514,585	$771,162	$1,060,445	$1,154,452
GEORGETOWN	$344,326	$1,175,793	$2,376,874	$3,817,976	$4,575,506	$5,366,079
GIDDINGS	$19,176	$65,196	$114,817	$114,060	$114,869	$115,707
GLEN ROSE	$12,050	$36,451	$63,389	$82,613	$85,252	$88,240
GRAHAM	$69,343	$175,368	$281,897	$394,160	$510,323	$624,943
GROESBECK	$3,522	-	-	-	-	$5
HAMILTON	$8,825	$15,657	$9,705	$6,729	$6,233	$6,233
HAMLIN	$6,394	$20,227	$26,525	$26,738	$27,116	$27,366
HARKER HEIGHTS	$122,989	$392,267	$641,026	$703,240	$776,607	$853,016
HEARNE	$10,503	$16,293	$7,382	$6,444	$5,506	$5,506

Table 2.1-8 (Continued)

Water User Group	Costs of Water Savings*					
	2020	*2030*	*2040*	*2050*	*2060*	*2070*
HEWITT	$40,674	$111,188	$98,860	$95,498	$101,093	$108,545
HILLSBORO	$39,267	$114,266	$191,147	$245,305	$250,796	$256,413
JAYTON	$1,683	$3,133	$2,141	$2,141	$1,645	$1,645
KEMPNER	$3,216	$4,597	$3,017	$2,624	$2,175	$2,388
KEMPNER WSC	$44,241	$105,579	$99,117	$97,896	$102,790	$108,831
KNOX CITY	$4,335	$12,590	$22,470	$26,626	$26,743	$27,172
LAMPASAS	$12,459	-	-	-	-	-
LEXINGTON	$3,807	$12,899	$11,384	$10,568	$10,267	$10,248
LITTLE RIVER-ACADEMY	$5,503	$8,832	$6,060	$5,045	$4,941	$5,130
LOMETA	$3,338	$9,930	$12,391	$12,678	$13,157	$13,683
LORENA	$4,498	$1,450	-	-	$18	-
MANSFIELD	$20,081	$67,696	$137,417	$229,991	$346,010	$480,043
MARLIN	$40,333	$105,891	$167,336	$225,048	$290,278	$354,582
MINERAL WELLS	$34,739	$15,260	-	-	-	-
MOUNTAIN PEAK SUD	$15,966	$46,340	$86,199	$135,163	$193,731	$260,510
MUNDAY	$4,100	$12,793	$17,808	$18,140	$18,024	$18,296
NAVASOTA	$25,906	$73,939	$111,629	$107,182	$108,371	$110,093
NOLANVILLE	$31,501	$104,969	$208,031	$337,913	$414,432	$470,584
NORTH BOSQUE WSC	$15,579	$46,435	$85,732	$131,201	$182,773	$212,152
PFLUGERVILLE	$1,575	$2,191	$2,240	$2,813	$3,249	$3,712
POSSUM KINGDOM WSC	$26,130	$62,376	$98,262	$134,332	$169,773	$203,321
RANGER	$7,293	$22,670	$19,331	$18,339	$17,843	$17,843
ROBINSON	$42,815	$148,282	$237,744	$257,348	$283,564	$310,920
ROBY	$2,461	$6,476	$7,133	$6,637	$6,141	$6,141
ROCKDALE	$21,168	$63,641	$98,113	$96,767	$99,419	$102,896
ROUND ROCK	$240,748	$55,060	-	-	-	-
SALADO WSC	$45,338	$119,671	$201,992	$292,881	$389,490	$489,869
SNOOK	$5,254	$13,015	$20,682	$29,093	$37,506	$45,042
SOMERVILLE	$3,600	$12,079	$10,912	$10,776	$10,878	$11,173

Table 2.1-8 (Concluded)

Water User Group	Costs of Water Savings*					
	2020	2030	2040	2050	2060	2070
SOUTHWEST MILAM WSC	$16,195	-	-	-	-	-
STAMFORD	$18,661	$49,470	$80,756	$115,175	$148,312	$161,194
STRAWN	$2,367	$7,766	$10,919	$10,910	$10,949	$10,960
SWEETWATER	$19,112	-	-	-	-	-
TAYLOR	$35,322	$34,307	$7,795	-	-	-
TEMPLE	$433,105	$1,298,837	$2,376,991	$3,660,947	$5,105,344	$5,616,738
TEXAS A & M	$197,306	$446,413	$672,095	$885,715	$1,084,774	$1,265,612
THROCKMORTON	$3,810	$10,093	$16,082	$22,163	$21,667	$21,667
VALLEY MILLS	$4,964	$15,285	$24,035	$23,278	$23,609	$23,726
VENUS	$14,167	$42,387	$53,747	$59,395	$65,882	$73,353
WACO	$692,979	$1,911,441	$3,214,161	$4,636,431	$5,659,560	$5,950,518
WELLBORN SUD	$36,916	$132,294	$240,674	$266,767	$299,871	$338,053
WEST	$7,053	$10,847	$6,131	$3,292	$2,797	$2,919
WHITE BLUFF COMMUNITY WS	$12,066	$31,494	$50,907	$62,069	$63,646	$65,242
WHITNEY	$8,221	$24,741	$34,588	$33,676	$34,135	$35,186
WILLIAMSON COUNTY MUD #10	$28,790	$84,888	$164,908	$229,529	$275,123	$322,722
WILLIAMSON COUNTY MUD #11	$16,424	$48,391	$90,396	$109,405	$130,578	$153,104
WILLIAMSON COUNTY MUD #9	$17,349	$60,235	$123,352	$149,669	$179,092	$210,097
WOODWAY	$97,676	$240,256	$390,206	$553,223	$722,666	$894,110
Total Brazos G:	$4,841,756	$14,202,763	$21,875,416	$29,330,089	$35,150,363	$38,844,520

* Note: This conservation is in addition to savings attributed to the 1991 Water Efficient Plumbing Fixtures Act.

Table 2.1-9 Estimated Costs to Achieve Additional Advanced Conservation Costs for Select WUGs in Williamson County

Participating WUG	Estimated Additional Advanced Conservation Costs						
	Type	2020	2030	2040	2050	2060	2070
BARTLETT	Suburban	$0	$0	$0	$2,927	$16,431	$32,036
BRUSHY CREEK MUD	Suburban	$18,342	$37,853	$52,226	$63,131	$71,213	$201,693
CHISHOLM TRAIL SUD	Suburban	$0	$0	$3,037	$236,106	$543,669	$922,431
WILLIAMSON COUNTY-OTHER	Suburban	$0	$0	$26,294	$266,037	$671,598	$1,216,511
GEORGETOWN	Suburban	$0	$0	$0	$0	$756,076	$2,065,489
JONAH WATER SUD	Suburban	$0	$0	$0	$0	$0	$0
ROUND ROCK	Suburban	$0	$0	$497,240	$1,324,850	$2,490,465	$3,961,318
Total Brazos G:	Suburban	$18,342	$37,853	$578,797	$1,893,051	$4,549,452	$8,399,478

2.1.7 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 2.1-10, and the option meets each criterion.

Table 2.1-10. Caption Comparison of Municipal Water Conservation Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Variable, dependent on current per capita rate
2. Reliability	2. Variable, dependent on public acceptance
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. None or low impact
2. Habitat	2. No apparent negative impact
3. Cultural Resources	3. None
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. None or low impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• Not applicable

2.1.8 Water Loss Reduction

The TWDB provided results of their 2010 Water Loss Audit on December 5, 2011 for regional water planning groups to consider when developing the regional water plans (Texas Administrative Code §357.34 (f)(2)D). Furthermore, water management strategy evaluations for the 2016 Brazos G Plan are to take into account anticipated water losses associated with the each strategy when calculating the quantify of water delivered and treated, according to TWDB guidelines (Texas Administrative Code §357.34 (d)(3)A). The reported water losses include both real and apparent losses. Real Loss is water lost through distribution system leakage and line breaks; Apparent Loss includes water that was not read accurately by a meter, unauthorized consumption, including water taken by theft, and data analysis errors. The best opportunity for water savings for Brazos G entities is by implementing water management strategies to reduce Real Loss.

Municipal water entities seeking infrastructure replacement programs to reduce water loss may be eligible for state supported programs, including State Water Implementation Fund for Texas (SWIFT), which has been allocated $2 billion to make financing of water projects more affordable and provide consistent state financial assistance for development of water supply projects identified in the State Water Plan.

The Brazos G RWPG considered TWDB-provided water loss information for Brazos G entities and water conservation BMP for pipeline replacement for municipal entities that report real losses greater than 15% of water system input volume. Ninety-five (95) of the 234 reported entities, or 40%, report real losses exceeding 15%, as shown in Table 2.1-11. The real losses for these entities range from 15% to 99%[5]. For these entities, a water loss program as a water management strategy considered targeted annual replacement of 5% of a utility's existing water main lines. This would replace the entire existing distribution system (100%) in 20 years. Note that this does not deal with new distribution system infrastructure installed to accommodate growth and expansion of the system, but only with losses experienced from a utility's existing distribution system. Real loss information is also presented for Moffat WSC who had a reported real loss of 2% and requested inclusion of analysis of savings and costs associated with the infrastructure replacement program. The Brazos G RWPG supports Moffat WSC's interest in pipe replacement programs as a water conservation BMP.

Some water losses are still expected to occur from the replaced system due to aging, pipe joints, minor connection leaks, and other factors (estimated at 5% of existing system input). For this reason, the full 20-year pipe replacement program is assumed to provide a total water savings to achieve an ultimate real loss of 5% from a utility's existing distribution system after 20 years.

This total water savings is divided by 20 years to calculate the annual water savings expected with annual replacement of 5% of the existing water supply mains. This assumes that losses are distributed uniformly over the existing distribution system. In early years of a main replacement program, however, areas with higher loss rates would be identified and likely replaced first, depending upon coordination with other utilities (sewer, electric, gas, telecommunications) and the municipality's plans for pavement

[5] Ten entities report real losses exceeding 50%, which is likely erroneous data. Each entity should review the submitted data before utilizing this BMP.

replacement. Water savings, therefore, would actually be greater in the early years of the main replacement program because the larger loss areas of a system would be targeted and corrected earliest.

The cost of line replacement, at 5% of the utility's main lines annually, was estimated based on the Unified Costing Model Tool for Regional Water Planning with the following assumptions:

- Entities reporting < 32 connections per mile were assumed to be more rural in nature. The pipeline unit cost was assumed for 12" diameter replacement in soil in a rural environment at a cost of $35 per linear foot[6] (or $184,500 per mile).
- Entities reporting > 32 connections per mile were assumed to be more urban in nature. Pipeline unit cost was assumed for 16" diameter replacement in soil in an urban environment at a cost of $81 per linear foot[7] (or $427,680 per mile).

The total annual cost of pipe replacement varies from $18,480 to $128,019,936 depending on the utility and number of water main line miles reported. The annual unit costs for a 10-year program amortized over 20 years range from $12,710 per acft of water saved to more than $1.8 million per acft of water saved, based strictly upon the loss data and number of miles of pipe reported in data provided by the TWDB. Overall, as shown by this initial analysis, pipe replacement programs are generally more expensive than other water conservation BMPs. Note that the quality of much of these data, including System Input Volume (water supplied), is questionable and can lead to erroneous savings, annual replacement costs, and unit cost estimates. These data should be reviewed individually for each water user group for which this water management strategy is considered.

[6] The unit costs include installed cost of the pipeline and appurtenances, such as markers, valves, thrust restraint systems, corrosion monitoring and control equipment, air and vacuum valves, blow-off valves, erosion control, revegetation of rights-of-way, fencing and gates.

Table 2.1-11. Summary of Brazos G Water Loss Audit and Estimated Savings and Costs with Pipe replacement Program for WUGs with Real Loss Greater than 15%

UtilityName	Retail Pop Served 20,608,300	Main Line Miles	Service Connection Density/ml m Av = 46.6	Real Loss (gallons)	Real Loss/Input Volume	Total 20 Year Water Savings Needed to Achieve 5% Real Loss (gallons)	Annual Water Savings Needed to Achieve 5% Real Loss in 20 years (gallons)	Amount of Pipe (mi) to Be Replaced Annually to Achieve 100% Replacement in 20 years	Annual Cost ($)	Cost 10 Year Program ($)	Amortized Annual Cost of 10-Year Program ($)	Unit Cost ($ per acft saved)
439 WSC	6,459	60	36	55,305,900	17%	39,098,800	1,954,940	3	$1,283,040	$12,830,400	$1,073,639	$178,955
ARMSTRONG WSC	2,526	90	9	18,882,960	18%	13,617,010	680,851	4.5	$831,600	$8,316,000	$695,877	$333,043
BELL MILAM FALLS WSC	4,568	170	11	83,139,703	38%	72,138,925	3,606,946	8.5	$1,570,800	$15,708,000	$1,314,435	$118,746
BISTONE MUNICIPAL WATER SUPPLY	546	80	3	42,455,663	77%	39,707,248	1,985,362	4	$739,200	$7,392,000	$618,558	$101,522
BLAIR WSC	966	290	1	2,716,550	17%	1,935,750	96,788	14.5	$2,679,600	$26,796,000	$2,242,271	$7,548,974
BLOCK HOUSE MUD	5,505	17	129	38,269,190	16%	26,102,524	1,305,126	0.85	$363,528	$3,635,280	$304,198	$75,949
BLUEBONNET WSC	0	51	0	38,883,860	99%	36,910,060	1,845,503	2.55	$471,240	$4,712,400	$394,330	$69,625
BRANDON IRENE WSC	2,069	54	13	109,586,583	63%	100,955,833	5,047,792	2.7	$498,960	$4,989,600	$417,526	$26,953
BRUSHY CREEK MUD	19,630	63	100	266,990,000	25%	212,640,000	10,632,000	3.15	$1,347,192	$13,471,920	$1,127,321	$34,550
CADE LAKES WSC	444	12	12	15,616,970	66%	14,431,384	721,569	0.6	$110,880	$1,108,800	$92,784	$41,900
CEDAR CREEK WATER SYSTEM	4,086	83	16	25,234,185	23%	19,627,907	981,395	4.15	$766,920	$7,669,200	$641,754	$213,080
CEDAR SHORES WATER CORPORATION	636	7	30	2,177,773	23%	1,708,818	85,441	0.35	$64,680	$646,800	$54,124	$206,415
CEDRON CREEK RANCH WATER SUPPLY	283	9	11	2,584,632	33%	2,198,824	109,941	0.45	$83,160	$831,600	$69,588	$206,249
CEGO DURANGO WSC	870	119	3	11,731,736	23%	9,183,316	459,166	5.95	$1,099,560	$10,995,600	$920,104	$652,960
CENTRAL BOSQUE WSC	990	60	5	12,709,814	28%	10,459,109	522,955	3	$554,400	$5,544,000	$463,918	$289,065
CENTRAL WASHINGTON COUNTY WSC	2,049	96	7	11,197,540	19%	8,212,293	410,615	4.8	$887,040	$8,870,400	$742,269	$589,042
CHALK BLUFF WSC	3,438	47	24	26,438,133	22%	20,439,042	1,021,952	2.35	$434,280	$4,342,800	$363,403	$115,871
CHAPPELL HILL WSC	657	9	24	10,790,526	39%	9,390,526	469,526	0.45	$83,160	$831,600	$69,588	$48,294
CHATT WSC	864	83	3	33,215,779	98%	31,529,684	1,576,484	4.15	$766,920	$7,669,200	$641,754	$132,647
CITY OF ABBOTT	356	5	44	3,518,100	17%	2,500,774	125,039	0.25	$106,920	$1,069,200	$89,470	$233,159
CITY OF ASPERMONT	1,000	60	10	15,845,414	20%	11,884,014	594,201	3	$554,400	$5,544,000	$463,918	$254,406
CITY OF CALDWELL	4,104	45	42	64,011,917	26%	51,801,764	2,590,088	2.25	$962,280	$9,622,800	$805,229	$101,303
CITY OF CARBON	660	17	13	3,879,332	24%	3,075,580	153,779	0.85	$157,080	$1,570,800	$131,443	$278,523
CITY OF CEDAR PARK	57,533	320	59	714,613,800	19%	525,802,050	26,290,103	16	$6,842,880	$68,428,800	$5,726,076	$70,971
CITY OF CISCO	3,851	150	10	68,346,017	34%	58,312,349	2,915,617	7.5	$1,386,000	$13,860,000	$1,159,796	$129,619
CITY OF COMANCHE	4,482	250	7	34,416,433	21%	26,222,000	1,311,100	12.5	$2,310,000	$23,100,000	$1,932,993	$480,412
CITY OF FLORENCE	1,148	4	110	8,651,848	16%	5,905,980	295,299	0.2	$85,536	$855,360	$71,576	$78,981
CITY OF GEORGETOWN	51,000	360	58	1,421,950,800	29%	1,180,498,657	59,024,933	18	$7,698,240	$76,982,400	$6,441,836	$35,563
CITY OF GOREE	321	10	10	2,687,439	24%	2,138,804	106,940	0.5	$92,400	$924,000	$77,320	$235,596
CITY OF HARKER HEIGHTS	26,700	171	55	1,718,740,000	57%	1,568,923,500	78,446,175	8.55	$3,656,664	$36,566,640	$3,059,872	$12,710
CITY OF HASKELL	3,106	48	31	34,350,490	21%	26,243,615	1,312,181	2.4	$443,520	$4,435,200	$371,135	$92,163

Table 2.1-11 (Continued)

UtilityName	Retail Pop Served 20,608,300	Main Line Miles	Service Connection Density/ml m Av = 46.6	Real Loss (gallons)	Real Loss/Input Volume	Total 20 Year Water Savings Needed to Achieve 5% Real Loss (gallons)	Annual Water Savings Needed to Achieve 5% Real Loss in 20 years (gallons)	Amount of Pipe (mi) to Be Replaced Annually to Achieve 100% Replacement in 20 years	Annual Cost ($)	Cost 10 Year Program ($)	Amortized Annual Cost of 10-Year Program ($)	Unit Cost ($ per acft saved)
CITY OF ITASCA	1,875	9	69	13,057,987	21%	10,005,366	500,268	0.45	$192,456	$1,924,560	$161,046	$104,898
CITY OF JAYTON	285	20	14	9,308,474	28%	7,673,646	383,682	1	$184,800	$1,848,000	$154,639	$131,331
CITY OF KOSSE	487	19	13	4,380,090	26%	3,526,505	176,325	0.95	$175,560	$1,755,600	$146,907	$271,487
CITY OF LUEDERS	300	12	15	11,438,028	50%	10,301,120	515,056	0.6	$110,880	$1,108,800	$92,784	$58,700
CITY OF MALONE	264	2	63	1,787,971	18%	1,289,277	64,464	0.1	$42,768	$427,680	$35,788	$180,901
CITY OF MERKEL	2,842	29	42	24,456,910	24%	19,424,060	971,203	1.45	$620,136	$6,201,360	$518,926	$174,106
CITY OF MEXIA	10,080	85	32	89,787,530	21%	67,896,830	3,394,842	4.25	$785,400	$7,854,000	$657,217	$63,082
CITY OF MOUNT CALM	310	10	10	1,793,740	17%	1,250,305	62,515	0.5	$92,400	$924,000	$77,320	$403,017
CITY OF MUNDAY	1,300	16	23	28,210,530	34%	24,000,004	1,200,000	0.8	$147,840	$1,478,400	$123,712	$33,593
CITY OF OGLESBY	828	30	9	11,180,567	32%	9,425,497	471,275	1.5	$277,200	$2,772,000	$231,959	$160,382
CITY OF ROCKDALE	5,595	60	41	95,363,980	29%	79,078,071	3,953,904	3	$1,283,040	$12,830,400	$1,073,639	$88,481
CITY OF ROSCOE	1,271	20	27	17,121,050	32%	14,424,111	721,206	1	$184,800	$1,848,000	$154,639	$69,868
CITY OF RULE	636	11	30	9,138,950	35%	7,834,200	391,710	0.55	$101,640	$1,016,400	$85,052	$70,752
CITY OF TEHUACANA	307	12	14	1,584,128	16%	1,077,078	53,854	0.6	$110,880	$1,108,800	$92,784	$561,401
CITY OF TOLAR	954	10	32	6,730,624	24%	5,324,747	266,237	0.5	$92,400	$924,000	$77,320	$94,632
CITY OF WEINERT	177	9	11	6,329,702	39%	5,526,166	276,308	0.45	$83,160	$831,600	$69,588	$82,065
CITY OF WOODWAY	8,733	81	47	127,596,208	16%	87,227,939	4,361,397	4.05	$1,732,104	$17,321,040	$1,449,413	$108,289
COMANCHE COUNTY WSC BEATTIE	948	189	2	7,309,300	34%	6,239,200	311,960	9.45	$1,746,360	$17,463,600	$1,461,342	$1,526,413
DOG RIDGE WSC	4,428	6	246	36,809,990	20%	27,468,559	1,373,428	0.3	$128,304	$1,283,040	$107,364	$25,472
EAST BELL WSC	3,500	475	2	26,326,741	24%	20,880,234	1,044,012	23.75	$4,389,000	$43,890,000	$3,672,686	$1,146,298
ELM CREEK WSC	4,170	225	6	31,125,350	22%	23,946,900	1,197,345	11.25	$2,079,000	$20,790,000	$1,739,693	$473,448
FILES VALLEY WSC	3,024	206	5	44,783,005	22%	34,746,755	1,737,338	10.3	$1,903,440	$19,034,400	$1,592,786	$298,739
FORT BELKNAP WSC	6,156	750	3	42,284,630	23%	32,983,380	1,649,169	37.5	$6,930,000	$69,300,000	$5,798,978	$1,145,791
GAUSE WSC	1,015	24	14	7,689,850	34%	6,551,455	327,573	1.2	$221,760	$2,217,600	$185,567	$184,592
H & H WSC	1,593	48	11	7,294,789	16%	5,068,477	253,424	2.4	$443,520	$4,435,200	$371,135	$477,203
HILLTOP WSC	855	35	8	5,926,441	23%	4,613,311	230,666	1.75	$323,400	$3,234,000	$270,619	$382,291
HOG CREEK WSC	297	49	5	27,870,610	55%	25,345,046	1,267,252	2.45	$452,760	$4,527,600	$378,867	$97,419
JARRELL SCHWERTNER WSC	4,350	210	7	77,351,401	37%	66,878,673	3,343,934	10.5	$1,940,400	$19,404,000	$1,623,714	$158,223
JONAH WATER SUD	13,958	390	13	133,790,000	23%	104,311,500	5,215,575	19.5	$3,603,600	$36,036,000	$3,015,468	$188,396
KEMPNER WSC	14,908	360	14	500,038,950	33%	423,656,014	21,182,801	18	$3,326,400	$33,264,000	$2,783,509	$42,818
LAKESHORE WATER SYSTEM	1,428	27	18	12,103,585	42%	10,663,125	533,156	1.35	$249,480	$2,494,800	$208,763	$127,591
LCRA LOMETA REGIONAL WATER SYSTEM	2,769	223	4	66,622,694	45%	59,291,097	2,964,555	11.15	$2,060,520	$20,605,200	$1,724,229	$189,520

Table 2.1-11 (Concluded)

UtilityName	Retail Pop Served 20,608,300	Main Line Miles	Service Connection Density/mlm Av = 46.6	Real Loss (gallons)	Real Loss/Input Volume	Total 20 Year Water Savings Needed to Achieve 5% Real Loss (gallons)	Annual Water Savings Needed to Achieve 5% Real Loss in 20 years (gallons)	Amount of Pipe (mi) to Be Replaced Annually to Achieve 100% Replacement in 20 years	Annual Cost ($)	Cost 10 Year Program ($)	Amortized Annual Cost of 10-Year Program ($)	Unit Cost ($ per acft saved)
LEE COUNTY WSC	10,000	700	5	44,235,160	15%	29,723,653	1,486,183	35	$6,468,000	$64,680,000	$5,412,379	$1,186,684
LEROY TOURS GERALD WSC	1,557	35	14	8,580,250	18%	6,179,815	308,991	1.75	$323,400	$3,234,000	$270,619	$285,385
M & H WATER SUPPLY	135	2	23	3,101,874	47%	2,772,244	138,612	0.1	$18,480	$184,800	$15,464	$36,353
MARLOW WSC	480	29	7	9,988,863	39%	8,711,389	435,569	1.45	$267,960	$2,679,600	$224,227	$167,745
MOFFAT WSC	4,890	80	17	2,822,389	2%	14,767,143	738,357	4	$739,200	$7,392,000	$618,558	$272,981
MORTON VALLEY WSC	500	55	4	7,221,588	28%	5,933,338	296,667	2.75	$508,200	$5,082,000	$425,258	$467,092
MULTI-COUNTY WSC	3,576	400	3	15,115,000	18%	10,825,550	541,278	20	$3,696,000	$36,960,000	$3,092,788	$1,861,870
MURRAY HILL WATER SYSTEM	1,278	35	12	19,495,186	38%	16,952,231	847,612	1.75	$323,400	$3,234,000	$270,619	$104,035
MUSTANG VALLEY WSC	3,000	150	4	77,058,440	54%	69,887,690	3,494,385	7.5	$1,386,000	$13,860,000	$1,159,796	$108,151
NORTH HAMILTON HILL WSC	51	3	9	490,000	16%	340,000	17,000	0.15	$27,720	$277,200	$23,196	$444,612
NORTH MILAM WSC	1,348	154	4	26,652,715	42%	23,499,225	1,174,961	7.7	$1,422,960	$14,229,600	$1,190,723	$330,222
PENELOPE WSC	198	2	47	1,038,359	17%	735,469	36,773	0.1	$42,768	$427,680	$35,788	$317,119
POST OAK SUD	2,500	350	2	24,589,327	22%	18,936,577	946,829	17.5	$3,234,000	$32,340,000	$2,706,190	$931,335
PRAIRIE HILL WSC	2,004	523	1	22,346,605	35%	19,168,437	958,422	26.15	$4,832,520	$48,325,200	$4,043,820	$1,374,847
ROBERTSON COUNTY WSC	2,670	270	4	19,660,166	18%	14,238,293	711,915	13.5	$2,494,800	$24,948,000	$2,087,632	$955,532
ROCKY CREEK WATER SYSTEM	3,132	38	27	20,423,673	25%	16,328,844	816,442	1.9	$351,120	$3,511,200	$293,815	$117,265
ROSS WSC	2,388	69	12	13,997,560	18%	10,195,490	509,774	3.45	$637,560	$6,375,600	$533,506	$341,020
RRA TRUSCOTT GILLILAND WATER SYSTEM	202	90	1	5,713,936	48%	5,115,156	255,758	4.5	$831,600	$8,316,000	$695,877	$886,590
SANTO SUD	2,550	103	8	14,470,465	19%	10,599,760	529,988	5.15	$951,720	$9,517,200	$796,393	$489,644
SHACKELFORD WSC	2,616	220	4	24,387,320	34%	20,805,432	1,040,272	11	$2,032,800	$20,328,000	$1,701,033	$532,826
SHILOH WSC	585	21	9	5,638,906	34%	4,815,504	240,775	1.05	$194,040	$1,940,400	$162,371	$219,744
SOUTHWEST MILAM WSC	8,925	575	5	155,229,780	36%	133,469,733	6,673,487	28.75	$5,313,000	$53,130,000	$4,445,883	$217,082
STAFF WSC OLDEN AREA	1,569	40	14	12,096,116	38%	10,511,581	525,579	2	$369,600	$3,696,000	$309,279	$191,748
STEELE CREEK HARBOR	468	12	13	976,384	17%	690,263	34,513	0.6	$110,880	$1,108,800	$92,784	$876,004
STEPHENS REGIONAL SUD	3,132	250	6	19,998,858	19%	14,863,111	743,156	12.5	$2,310,000	$23,100,000	$1,932,993	$847,558
TRI COUNTY SUD	4,075	430	4	54,192,758	27%	44,293,602	2,214,680	21.5	$3,973,200	$39,732,000	$3,324,747	$489,178
TUSCOLA-TAYLOR COUNTY WCID 1	714	10	38	15,820,000	33%	13,409,500	670,475	0.5	$213,840	$2,138,400	$178,940	$86,965
WEST BELL COUNTY WSC	3,800	67	19	40,539,873	20%	30,276,261	1,513,813	3.35	$619,080	$6,190,800	$518,042	$111,509
WESTBOUND WSC CISCO SOURCE	2,400	850	1	24,120	98%	22,896	1,145	42.5	$7,854,000	$78,540,000	$6,572,175	$1,870,716,656
WHITE ROCK WSC 1	240	6	13	1,522,780	25%	1,216,280	60,814	0.3	$55,440	$554,400	$46,392	$248,575
WHITE ROCK WSC 2 FOREST GLADE	1,632	39	14	11,066,000	24%	8,751,200	437,560	1.95	$360,360	$3,603,600	$301,547	$224,562
WOODROW OSCEOLA WSC BLANTON WELL PLAN	2,046	100	7	9,586,471	16%	6,634,951	331,748	5	$924,000	$9,240,000	$773,197	$759,454
WOODROW OSCEOLA WSC PLEASANT VW	1,278	100	4	7,326,604	20%	5,516,585	275,829	5	$924,000	$9,240,000	$773,197	$913,417
Total (Region G Entities Evaluated for Water Loss Program)				**6,940,861,811**		**5,811,590,711**	**290,579,536**	**534.9**	**$114,020,016**	**$1,138,352,160**	**$95,256,546**	

2.2 Irrigation Water Conservation

2.2.1 Description of Strategy

Irrigation water use is the use of freshwater that is pumped from aquifers and/or diverted from streams and reservoirs of the planning area and applied directly to grow crops, orchards, and hay and pasture in the study area. Irrigation water is typically applied to land by: (1) flowing or flooding water down furrows; and (2) the use of sprinklers. When groundwater is used, irrigation wells are usually located within the fields to be irrigated. For surface water supplies, typically water is diverted from the source and conveyed by canals and pipelines to the fields. For both groundwater and surface water, the conservation objective is to reduce the quantity of water that is lost to deep percolation and evaporation between the originating points (wells in the case of groundwater, and stream diversion points in the case of surface water), and the irrigated crops in the fields. Thus, the focus is upon investments in irrigation application equipment, instruments, and conveyance facility improvements (canal lining and pipelines) to reduce seepage losses, deep percolation, and evaporation of water, and management of the irrigation processes to improve efficiencies of irrigation water use and reduce the quantities of water needed to accomplish irrigation.

2.2.2 Brazos G Irrigation Water Conservation Approach

The Brazos G RWPG recommends conservation for irrigation WUGs with projected irrigation water needs during the planning period from 2020 to 2070. A voluntary target is recommended for these irrigation entities with needs to reduce water demands by 3% by 2020, 5% by 2030, and 7% from 2040-2070. In the Brazos G Area, eighteen counties are projected to have irrigation needs (shortages) during the 2020 to 2070 planning period, as shown in Table 2.2-1. Irrigation shortages range from 3 acft/yr in Taylor County (2030) to almost 53,000 acft in Robertson County (2020). Generally, the shortages decrease over time except for Eastland and Knox County, where minimal increases in shortages are anticipated and Williamson County where the shortages remain constant. Most of the counties use both surface water and groundwater supplies to meet irrigation water demands. Palo Pinto solely receives surface water supplies for irrigation while Haskell and Stephenson rely on groundwater. Young County irrigation does not currently have surface or groundwater supplies.

Table 2.2-1. Projected Irrigation Water Demands, Supplies, and Needs (Shortages) in Counties Having Projected Irrigation Shortages

County	Projections (acft/yr)					
	2020	2030	2040	2050	2060	2070
Bell						
Irrigation Demand	2,205	2,174	2,147	2,117	2,086	2,058
Irrigation Existing Supply						
Groundwater	385	385	385	385	385	385
Surface water	540	541	541	542	542	543
Total Irrigation Supply	925	926	926	927	927	928
(Shortage)/ Surplus	(1,280)	(1,248)	(1,221)	(1,190)	(1,159)	(1,130)
Bosque						
Irrigation Demand	2,128	2,094	2,060	2,029	1,998	1,968
Irrigation Existing Supply						
Groundwater	1,460	1,460	1,460	1,460	1,460	1,460
Surface water	132	132	132	131	131	131
Total Irrigation Supply	1,592	1,592	1,592	1,591	1,591	1,591
(Shortage)/ Surplus	(536)	(502)	(468)	(438)	(407)	(377)
Brazos						
Irrigation Demand	26,050	24,791	23,594	22,459	21,374	20,438
Irrigation Existing Supply						
Groundwater	14,808	14,808	14,808	14,808	14,808	14,808
Surface water	350	310	270	230	190	151
Total Irrigation Supply	15,158	15,118	15,078	15,038	14,998	14,958
(Shortage)/ Surplus	(10,892)	(9,673)	(8,516)	(7,421)	(6,376)	(5,480)
Comanche						
Irrigation Demand	27,458	27,175	26,894	26,617	26,342	26,076
Irrigation Existing Supply						
Groundwater	21,597	21,597	21,597	21,597	21,597	21,597
Surface water	5,164	5,164	5,164	5,164	5,164	5,164
Total Irrigation Supply	26,761	26,761	26,761	26,761	26,761	26,761
(Shortage)/ Surplus	(697)	(414)	(133)	144	419	685

Table 2.2-1 (Continued)

County	Projections (acft/yr)					
	2020	2030	2040	2050	2060	2070
Eastland						
Irrigation Demand	6,819	6,829	6,837	6,840	6,843	6,850
Irrigation Existing Supply						
Groundwater	4,328	4,329	4,331	4,332	4,332	4,332
Surface water	77	76	76	76	75	75
Total Irrigation Supply	4,404	4,406	4,407	4,408	4,408	4,407
(Shortage)/ Surplus	(2,415)	(2,423)	(2,430)	(2,432)	(2,435)	(2,443)
Hamilton						
Irrigation Demand	507	504	495	471	448	436
Irrigation Existing Supply						
Groundwater	383	383	383	383	383	383
Surface water	54	53	51	50	49	47
Total Irrigation Supply	437	435	434	432	431	430
(Shortage)/ Surplus	(71)	(69)	(61)	(39)	(17)	(6)
Haskell						
Irrigation Demand	47,844	46,422	45,040	43,072	42,405	41,207
Irrigation Existing Supply						
Groundwater	45,619	44,034	41,843	42,007	43,087	43,087
Surface water	0	0	0	0	0	0
Total Irrigation Supply	45,619	44,034	41,843	42,007	43,087	43,087
(Shortage)/ Surplus	(2,225)	(2,388)	(3,197)	(1,065)	682	1,880
Hill						
Irrigation Demand	582	582	582	582	568	563
Irrigation Existing Supply						
Groundwater	405	405	405	405	405	405
Surface water	9	9	9	9	9	9
Total Irrigation Supply	414	414	414	414	414	414
(Shortage)/ Surplus	(168)	(168)	(168)	(168)	(154)	(149)

Table 2.2-1 (Continued)

County	Projections (acft/yr)					
	2020	2030	2040	2050	2060	2070
Knox						
Irrigation Demand	41,033	40,025	39,041	38,082	37,147	36,278
Irrigation Existing Supply						
Groundwater	37,752	34,368	30,412	28,693	31,103	31,103
Surface water	160	142	124	106	88	70
Total Irrigation Supply	37,912	34,510	30,536	28,799	31,191	31,173
(Shortage)/ Surplus	(3,122)	(5,516)	(8,506)	(9,284)	(5,957)	(5,106)
Lampasas County						
Irrigation Demand	387	382	377	372	370	366
Irrigation Existing Supply						
Groundwater	64	64	64	64	64	64
Surface water	103	103	103	103	103	103
Total Irrigation Supply	166	166	166	166	166	166
(Shortage)/ Surplus	(221)	(216)	(211)	(206)	(204)	(200)
McLennan						
Irrigation Demand	4,880	4,877	4,872	4,867	4,862	4,858
Irrigation Existing Supply						
Groundwater	1,158	1,158	1,158	1,158	1,158	1,158
Surface water	1,424	1,406	1,389	1,372	1,354	1,337
Total Irrigation Supply	2,581	2,564	2,547	2,529	2,512	2,495
(Shortage)/ Surplus	(2,299)	(2,313)	(2,325)	(2,338)	(2,350)	(2,363)
Nolan						
Irrigation Demand	7,413	7,217	7,024	6,842	6,663	6,497
Irrigation Existing Supply						
Groundwater	3,126	3,126	3,126	3,126	3,126	3,126
Surface water	40	40	40	40	40	40
Total Irrigation Supply	3,166	3,166	3,166	3,166	3,166	3,166
(Shortage)/ Surplus	(4,247)	(4,051)	(3,858)	(3,676)	(3,497)	(3,331)

Table 2.2-1 (Continued)

County	Projections (acft/yr)					
	2020	2030	2040	2050	2060	2070
Palo Pinto						
Irrigation Demand	3,138	3,097	3,063	3,022	2,981	2,944
Irrigation Existing Supply						
Groundwater	0	0	0	0	0	0
Surface water	550	550	550	550	550	550
Total Irrigation Supply	550	550	550	550	550	550
(Shortage)/ Surplus	(2,588)	(2,547)	(2,513)	(2,472)	(2,431)	(2,394)
Robertson						
Irrigation Demand	63,420	61,607	59,841	58,127	56,460	55,124
Irrigation Existing Supply						
Groundwater	9,896	9,996	10,096	10,144	10,144	10,144
Surface water	535	535	535	535	535	535
Total Irrigation Supply	10,431	10,531	10,631	10,679	10,679	10,679
(Shortage)/ Surplus	(52,989)	(51,076)	(49,210)	(47,448)	(45,781)	(44,445)
Stephens						
Irrigation Demand	116	115	113	112	111	110
Irrigation Existing Supply						
Groundwater	86	86	86	86	86	86
Surface water	0	0	0	0	0	0
Total Irrigation Supply	86	86	86	86	86	86
(Shortage)/ Surplus	(30)	(29)	(27)	(26)	(25)	(24)
Taylor						
Irrigation Demand	1,557	1,519	1,481	1,444	1,406	1,373
Irrigation Existing Supply						
Groundwater	500	500	500	500	500	500
Surface water	1,016	1,016	1,016	1,016	1,016	1,016
Total Irrigation Supply	1,516	1,516	1,516	1,516	1,516	1,516
(Shortage)/ Surplus	(41)	(3)	35	72	110	143

Table 2.2-1 (Concluded)

County	Projections (acft/yr)					
	2020	2030	2040	2050	2060	2070
Williamson						
Irrigation Demand	151	151	151	151	151	151
Irrigation Existing Supply						
Groundwater	13	13	13	13	13	13
Surface water	65	65	65	65	65	65
Total Irrigation Supply	79	79	79	79	79	79
(Shortage)/ Surplus	(72)	(72)	(72)	(72)	(72)	(72)
Young						
Irrigation Demand	51	50	48	47	45	44
Irrigation Existing Supply						
Groundwater	0	0	0	0	0	0
Surface water	0	0	0	0	0	0
Total Irrigation Supply	0	0	0	0	0	0
(Shortage)/ Surplus	(51)	(50)	(48)	(47)	(45)	(44)

NOTE: Positive values = surplus. Negative values (in parenthesis) = shortages.

The Task Force report[7] lists the following irrigation BMPs that may be used to achieve the recommended water savings:

1. Irrigation Scheduling,
2. Volumetric Measurement of Irrigation Water Use,
3. Crop Residue Management and Conservation Tillage,
4. On-Farm Irrigation Audit,
5. Furrow Dikes,
6. Land Leveling,
7. Contour Farming,
8. Conservation of Supplemental Irrigated Farmland to Dry-Land Farmland,
9. Brush Control/Management,
10. Lining of On-Farm Irrigation Ditches,
11. Replacement of On-Farm Irrigation Ditches with Pipelines,
12. Low-Pressure Center Pivot Sprinkler Irrigation Systems,
13. Drip/Micro-Irrigation Systems,
14. Gated and Flexible Pipe for Field Water Distribution Systems,
15. Surge Flow Irrigation for Field Water Distribution Systems,
16. Linear Move Sprinkler Irrigation Systems,
17. Lining of District Irrigation Canals,
18. Replacement of District Irrigation Canals and Lateral Canals with Pipelines,
19. Tailwater Recovery and Use Systems, and
20. Nursery Production Systems.

The Task Force report describes the above BMP methods and how they reduce irrigation water use; however, information regarding specific water savings and costs to install irrigation water saving systems is generally unavailable. The Task Force report does include water savings and costs for three irrigation water conservation BMPs: (1) furrow dikes; (2) low-pressure sprinklers (LESA); and (3) low-energy precision application systems (LEPA). These major irrigation water conservation techniques are described briefly below.

Furrow dikes are small mounds of soil mechanically installed a few feet apart in the furrow. These mounds of soil create small reservoirs that capture precipitation and hold it until it soaks into the soil instead of running down the furrow and out the end of the field. This practice can conserve (capture) as much as 100 percent of rainfall runoff, and furrow dikes are used to prevent irrigation runoff under sprinkler systems. This maintains high irrigation uniformity and increases irrigation application efficiencies. Capturing and

[7] Texas Water Development Board (TWDB) Report 362 Special Report, developed from work by the Water Conservation Implementation Task Force, Austin, Texas, November 2004.

holding precipitation that would have drained from the fields replaces required irrigation water. Furrow dikes have been demonstrated to be useful management tools on both irrigated and non-irrigated cropland. Use of furrow dikes can have water savings up to 12 percent of the gross quantity of water applied using sprinkler irrigation. Furrow dikes require special tillage equipment and cost $7 to $39 per acre to install.

Low-pressure sprinklers (LESA), with 90 percent application efficiency, improve irrigation application efficiency in comparison to conventional furrow irrigation by reducing water requirements per acre by between 10 and 25 percent. Low-pressure sprinklers spray water into the atmosphere above the crops as the sprinkler systems are moved across the fields. LEPA systems involve a sprinkler system that has been modified to discharge water directly into furrows at low pressure, thus reducing evaporation losses. When used in conjunction with furrow dikes, LEPA systems can accomplish the irrigation objective with less water than is required for the furrow irrigation and pressurized sprinkler methods. When used with furrow dike systems, the expected water savings from LEPA would range from 0.17 acft/acre to 0.30 acft/acre (a total reduction in water use of 16 to 37 percent). Use of LEPA and furrow dikes allows irrigation farmers to produce equivalent yields per acre at lower energy and labor costs. It has been demonstrated that LEPA systems improve production and profitability of irrigation farming. The barriers to installation are high capital costs; with no assurance (at the present time) that the water saved would be available to the irrigator who incurred the costs.

2.2.3 Available Yield

The Brazos G RWPG recommends that counties with projected irrigation needs (shortages) reduce their irrigation water demands by 3 percent by 2020, 5 percent by 2030, and 7 percent from 2040 to 2070 by using BMPs listed previously. A reduction in irrigation water demand subsequently reduces shortages for each decade, if water supplies remain constant. In 2070, with conservation reductions, the shortages are reduced between 7 percent for Young County to 50 percent for Knox County (Table 2.2-2). The maximum water savings expected by irrigation water conservation by implementing the schedule above amongst the eighteen counties is for Robertson County, with a recommended savings of 4,189 acft/yr in 2040.

Table 2.2-2. Projected Water Demands and Needs (Shortages) for Irrigation Users after Recommended Irrigation Water Conservation

Counties	2020	2030	2040	2050	2060	2070
Bell						
New Demand (after conservation)	2,139	2,065	1,997	1,969	1,940	1,914
Expected Conservation Savings	*66*	*109*	*150*	*148*	*146*	*144*
New Surplus (Shortage) (acft/yr)	(1,214)	(1,140)	(1,071)	(1,042)	(1,013)	(986)
Shortage Reduction w/ Conservation	5%	9%	12%	12%	13%	13%
Bosque						
New Demand (after conservation)	1,989	1,916	1,887	1,858	1,830	(473)
Expected Conservation Savings	*64*	*105*	*144*	*142*	*140*	*138*
New Surplus (Shortage) (acft/yr)	(473)	(398)	(324)	(295)	(267)	(239)
Shortage Reduction w/ Conservation	12%	21%	31%	32%	34%	37%
Brazos						
New Demand (after conservation)	25,269	23,551	21,942	20,887	19,878	19,007
Expected Conservation Savings	*782*	*1,240*	*1,652*	*1,572*	*1,496*	*1,431*
New Surplus (Shortage) (acft/yr)	(10,111)	(8,434)	(6,864)	(5,849)	(4,880)	(4,049)
Shortage Reduction w/ Conservation	7%	13%	19%	21%	23%	26%
Comanche						
New Demand (after conservation)	26,634	25,816	25,011	24,754	24,498	24,251
Expected Conservation Savings	*824*	*1,359*	*1,883*	*1,863*	*1,844*	*1,825*
New Surplus (Shortage) (acft/yr)	127	945	1,749	2,007	2,263	2,510
Shortage Reduction w/ Conservation	100%	100%	100%	100%	100%	100%
Eastland						
New Demand (after conservation)	6,614	6,488	6,358	6,361	6,364	6,371
Expected Conservation Savings	*205*	*341*	*479*	*479*	*479*	*480*
New Surplus (Shortage) (acft/yr)	(2,210)	(2,082)	(1,951)	(1,953)	(1,956)	(1,963)
Shortage Reduction w/ Conservation	8%	14%	20%	20%	20%	20%

Table 2.2-2 (Continued)

Counties	2020	2030	2040	2050	2060	2070
Hamilton						
New Demand (after conservation)	492	479	460	438	417	405
Expected Conservation Savings	*15*	*25*	*35*	*33*	*31*	*31*
New Surplus (Shortage) (acft/yr)	(55)	(44)	(27)	(6)	15	24
Shortage Reduction w/ Conservation	22%	37%	57%	86%	100%	100%
Haskell						
New Demand (after conservation)	46,409	44,101	41,887	40,057	39,437	38,323
Expected Conservation Savings	*1,435*	*2,321*	*3,153*	*3,015*	*2,968*	*2,884*
New Surplus (Shortage) (acft/yr)	(790)	(67)	(44)	1,951	3,651	4,765
Shortage Reduction w/ Conservation	65%	97%	99%	100%	100%	100%
Hill						
New Demand (after conservation)	565	553	541	541	528	524
Expected Conservation Savings	*17*	*29*	*41*	*41*	*40*	*39*
New Surplus (Shortage) (acft/yr)	(151)	(139)	(127)	(127)	(114)	(110)
Shortage Reduction w/ Conservation	10%	17%	24%	24%	26%	26%
Knox						
New Demand (after conservation)	39,802	38,024	36,308	35,416	34,547	33,739
Expected Conservation Savings	*1,231*	*2,001*	*2,733*	*2,666*	*2,600*	*2,539*
New Surplus (Shortage) (acft/yr)	(1,891)	(3,514)	(5,773)	(6,618)	(3,356)	(2,566)
Shortage Reduction w/ Conservation	39%	36%	32%	29%	44%	50%
Lampasas						
New Demand (after conservation)	375	363	351	346	344	340
Expected Conservation Savings	*12*	*19*	*26*	*26*	*26*	*26*
New Surplus (Shortage) (acft/yr)	(209)	(197)	(184)	(180)	(178)	(174)
Shortage Reduction w/ Conservation	5%	9%	13%	13%	13%	13%

Table 2.2-2 (Continued)

Counties	2020	2030	2040	2050	2060	2070
McLennan						
New Demand (acft/yr)	4,734	4,633	4,531	4,526	4,522	4,518
Expected Savings (acft/yr)	*146*	*244*	*341*	*341*	*340*	*340*
New (shortage)/surplus (acft/yr)	(2,152)	(2,069)	(1,984)	(1,997)	(2,010)	(2,023)
Shortage Reduction (acft/yr)	6%	11%	15%	15%	14%	14%
Nolan						
New Demand (after conservation)	7,191	6,856	6,532	6,363	6,197	6,042
Expected Conservation Savings	*222*	*361*	*492*	*479*	*466*	*455*
New Surplus (Shortage) (acft/yr)	(4,025)	(3,690)	(3,366)	(3,197)	(3,031)	(2,876)
Shortage Reduction w/ Conservation	5%	9%	13%	13%	13%	14%
Palo Pinto						
New Demand (after conservation)	3,044	2,942	2,849	2,810	2,772	2,738
Expected Conservation Savings	*94*	*155*	*214*	*212*	*209*	*206*
New Surplus (Shortage) (acft/yr)	(2,494)	(2,392)	(2,299)	(2,260)	(2,222)	(2,188)
Shortage Reduction w/ Conservation	4%	6%	9%	9%	9%	9%
Robertson						
New Demand (after conservation)	61,517	58,527	55,652	54,058	52,508	51,265
Expected Conservation Savings	*1,903*	*3,080*	*4,189*	*4,069*	*3,952*	*3,859*
New Surplus (Shortage) (acft/yr)	(51,086)	(47,995)	(45,021)	(43,379)	(41,829)	(40,586)
Shortage Reduction w/ Conservation	4%	6%	9%	9%	9%	9%
Stephens						
New Demand (after conservation)	113	109	105	104	103	102
Expected Conservation Savings	*3*	*6*	*8*	*8*	*8*	*8*
New Surplus (Shortage) (acft/yr)	(26)	(23)	(19)	(18)	(17)	(16)
Shortage Reduction w/ Conservation	12%	20%	30%	30%	31%	32%

Table 2.2-2 (Concluded)

Counties	2020	2030	2040	2050	2060	2070
Taylor						
New Demand (after conservation)	1,510	1,443	1,377	1,343	1,308	1,277
Expected Conservation Savings	*47*	*76*	*104*	*101*	*98*	*96*
New Surplus (Shortage) (acft/yr)	6	73	139	174	209	240
Shortage Reduction w/ Conservation	100%	100%	100%	100%	100%	100%
Williamson						
New Demand (after conservation)	146	143	140	140	140	140
Expected Conservation Savings	*5*	*8*	*11*	*11*	*11*	*11*
New Surplus (Shortage) (acft/yr)	(68)	(65)	(62)	(62)	(62)	(62)
Shortage Reduction w/ Conservation	6%	10%	15%	15%	15%	15%
Young						
New Demand (after conservation)	49	48	45	44	42	41
Expected Conservation Savings	*2*	*3*	*3*	*3*	*3*	*3*
New Surplus (Shortage) (acft/yr)	(49)	(48)	(45)	(44)	(42)	(41)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Total Brazos G Savings:	**7,072**	**11,481**	**15,656**	**15,208**	**14,858**	**14,514**

2.2.4 Environmental Issues

The irrigation water conservation methods described above have been developed and tested through public and private sector research, and have been adopted and applied within the region. Hundreds of LEPA systems have been installed and are in operation today, and experience has revealed no significant environmental issues associated with this water management strategy. This method improves water use efficiency without making significant changes to wildlife habitat. This method of application, when coupled with furrow dikes, reduces runoff of both applied irrigation water and rainfall. These actions results in the reduced transport of sediment, fertilizers, pesticides and other chemicals that have been applied to the crops. Thus, the proposed conservation practices are not anticipated to have significant potential adverse environmental effects, and may have potentially beneficial environmental effects.

2.2.5 Engineering and Costing

The Brazos G RWPG recommended irrigation water conservation as a water management strategy for irrigation needs, resulting in a total water savings of 7,072 acft/yr beginning in 2020, 15,656 acft/yr in 2040 and 14,514 acft/yr in 2070 as shown in Table 2.2-3. Brazos G recommends the use of furrow, LESA, and LEPA systems described above but supports flexibility for each WUG to voluntarily decide which of these or other options might serve them best. An average cost of implementing furrow dikes, LESA, and LEPA programs of $230 per acft/yr was used for water saved since the exact technology utilized by each WUG is unknown[8]. The total estimated cost of implementing these three BMPs for Brazos G entities is estimated to cost $3,600,926 in 2040 when largest water savings are expected to occur to $3,338,190 in 2070 as shown in Table 2.2-3.

Each of the three irrigation water conservation strategies described (furrow dikes, LESA, and LEPA) have the potential to increase water savings beyond the minimum recommended by the Brazos G RWPG; however, none of the strategies can accomplish water savings sufficient to meet all of the projected needs. Further studies are needed to consider other irrigation water conservation BMPs that can be applied to surface applications to increase their application efficiencies.

It may not be economically feasible for agricultural producers to pay for additional water supplies to meet projected irrigation water needs (shortages), even if such supplies were available. For example, in 2004, the estimated income for irrigated cotton remaining after other production expenses had been paid was about $68 per acre, and the income for wheat with high input management was about $65 per acre. At an application rate of about 1 acft/acre, the cost of water from other sources far exceeds these values. For example, costs for water management strategies (new reservoirs) considered to meet projected municipal needs *could range* between $481 per acft and $1,760 per acft for water supply at the reservoirs. The costs greatly exceed the income that would be realized from land irrigated with these water supplies.

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[8] Installing LESA or LEPA systems would incur a greater capital cost, and therefore higher annual costs, however both achieve a substantially higher water savings potential and therefore have more economical unit cost ($/acft) when compared to furrow dikes.

Table 2.2-3. Brazos G Irrigation Water Savings and Estimated Costs

Brazos G Irrigation WUG[1]	WATER SAVINGS WITH IRRIGATION WATER CONSERVATION (acft/yr)						Estimated Cost of Water Savings ($230 per acft)[2]					
	2020 (3%)	2030 (5%)	2040 (7%)	2050 (7%)	2060 (7%)	2070 (7%)	2020	2030	2040	2050	2060	2070
BELL COUNTY-IRRIGATION	66	109	150	148	146	144	$15,215	$25,001	$34,567	$34,084	$33,585	$33,134
BOSQUE COUNTY-IRRIGATION	64	105	144	142	140	138	$14,683	$24,081	$33,166	$32,667	$32,168	$31,685
BRAZOS COUNTY-IRRIGATION	782	1,240	1,652	1,572	1,496	1,431	$179,745	$285,097	$379,863	$361,590	$344,121	$329,052
COMANCHE COUNTY-IRRIGATION	824	1,359	1,883	1,863	1,844	1,825	$189,460	$312,513	$432,993	$428,534	$424,106	$419,824
EASTLAND COUNTY-IRRIGATION	205	341	479	479	479	480	$47,051	$78,534	$110,076	$110,124	$110,172	$110,285
HAMILTON COUNTY-IRRIGATION	15	25	35	33	31	31	$3,498	$5,796	$7,970	$7,583	$7,213	$7,020
HASKELL COUNTY-IRRIGATION	1,435	2,321	3,153	3,015	2,968	2,884	$330,124	$533,853	$725,144	$693,459	$682,721	$663,433
HILL COUNTY-IRRIGATION	17	29	41	41	40	39	$4,016	$6,693	$9,370	$9,370	$9,145	$9,064
KNOX COUNTY-IRRIGATION	1,231	2,001	2,733	2,666	2,600	2,539	$283,128	$460,288	$628,560	$613,120	$598,067	$584,076
LAMPASAS COUNTY-IRRIGATION	12	19	26	26	26	26	$2,670	$4,393	$6,070	$5,989	$5,957	$5,893
MCLENNAN COUNTY-IRRIGATION	146	244	341	341	340	340	$33,672	$56,086	$78,439	$78,359	$78,278	$78,214
NOLAN COUNTY-IRRIGATION	222	361	492	479	466	455	$51,150	$82,996	$113,086	$110,156	$107,274	$104,602
PALO PINTO COUNTY-IRRIGATION	94	155	214	212	209	206	$21,652	$35,616	$49,314	$48,654	$47,994	$47,398
ROBERTSON COUNTY-IRRIGATION	1,903	3,080	4,189	4,069	3,952	3,859	$437,598	$708,481	$963,440	$935,845	$909,006	$887,496
STEPHENS COUNTY-IRRIGATION	3	6	8	8	8	8	$800	$1,323	$1,819	$1,803	$1,787	$1,771
TAYLOR COUNTY-IRRIGATION	47	76	104	101	98	96	$10,743	$17,469	$23,844	$23,248	$22,637	$22,105
WILLIAMSON COUNTY-IRRIGATION	5	8	11	11	11	11	$1,042	$1,737	$2,431	$2,431	$2,431	$2,431
YOUNG COUNTY-IRRIGATION	2	3	3	3	3	3	$352	$575	$773	$757	$725	$708
Brazos G Total	7,072	11,481	15,656	15,208	14,858	14,514	$1,626,599	$2,640,527	$3,600,926	$3,497,773	$3,417,386	$3,338,190

[1]Conservation values applied only to those WUGs with needs by decade. Values assume 3% of demand reduction in 2020, 5% demand reduction in 2030 and

[2]Cost of water savings based on averaging cost to convert sprinkler systems (from TWDB 2000 irrigation survey) to Furrow Dikes ($308 per acft), LESA ($212

2.2.6 Implementation Issues

Irrigation demand reduction through water conservation is being implemented throughout the Brazos G Area and the State of Texas. The rate of adoption of efficient water-use practices is dependent upon public knowledge of the benefits, information about how to implement water conservation measures, and financing.

There is widespread public support for irrigation water conservation and it is being implemented at a steady pace, and as water markets for conserved water expand, this practice will likely reach its maximum potential. A major barrier to implementation of water conservation is financing. The TWDB has irrigation conservation programs that may provide funding to irrigators to implement irrigation BMPs that increase water use efficiency. Future planning efforts should consider the use of detailed studies to fully determine the maximum potential benefits of additional irrigation conservation.

This option is compared to the plan development criteria in Table 2.2-4 and meets most criteria.

Table 2.2-4. Comparison of Irrigation Conservation to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Firm Yield: Variable according to BMP selected.
2. Reliability	2. High reliability
3. Cost	3. High for internal use (based on BMP selected)
B. Environmental factors	
1. Environmental Water Needs	1. None or low impact
2. Habitat	2. None or low impact
3. Cultural Resources	3. No apparent negative impact
4. Bays and Estuaries	4. None
5. Threatened and Endangered Species	5. None
6. Wetlands	6. No cultural resources affected
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Feasible Strategies	• Standard analyses and methods used
F. Requirements for Interbasin Transfers	• None
Third Party Social and Economic Impacts from Voluntary Redistribution	• None

2.3 Industrial Water Conservation

2.3.1 Description of Strategy

Water uses for industrial purposes (manufacturing, steam-electric power generation, and mining) are primarily associated with manufacturing products, cleaning and waste removal, waste heat removal, dust control, landscaping, and mine dewatering. In the Brazos G Area, industrial water demands are assumed to be 322,733 acft/yr in 2020 and are projected to increase to 478,772 acft/yr in 2070 as shown in Table 2.3-1.

Manufacturing is a significant part of the Brazos G Area's economy, and industries use water as a component of the final product, for cooling, and cleaning/wash-down of parts and/or products. Regional industries that are major water users include food and kindred products, apparel, fabricated metal, machinery, and stone and concrete production. Manufacturing water demand is projected at 21,848 acft/yr in 2020 and expected to increase to 34,977 acft/yr by 2070. There are twelve (12) counties in the Brazos G Area with projected manufacturing needs: Bell, Bosque, Brazos, Burleson, Grimes, Fisher, Limestone, McLennan, Nolan, Washington, Williamson, and Young. In 2070, the estimated water needs are 12,135 acft/yr, which is 35% of the manufacturing water demand for the Brazos G Area.

In the Brazos G Area, the trends for steam-electric water demands are projected to increase each decade with a maximum demand of 362,386 acft/yr by 2070. Grimes, Limestone, Milam, Nolan, Robertson, and Somervell Counties comprise over 80 percent of the projected regional steam-electric water use in 2070. The increase in water demand is due to projected increases in population and manufacturing growth and estimated increases in fresh water use based on projected power generation capacities. The Brazos G Area steam-electric users are projected to receive around 90% of their water supplies from surface water sources in 2070. There are seven (7) counties in the Brazos G Area with projected steam-electric needs: Bell, Brazos, Grimes, Johnson, Limestone, Milam, and Robertson. In 2070, the estimated water needs are 139,187 acft/yr, which is 38% of the steam-electric water demand for the Brazos G Area.

Gross state product data released from the U.S. Department of Commerce shows mining economic outputs of $37.6 billion for 1999 and $29.9 billion for 2000.[9] The TWDB water demand projections for mining users is generally based on projected economic output, assuming that past and current water use trends remain constant over time. In the Brazos G Area, the mining water demands increase from 61,586 acft/yr in 2020 to 81,409 acft/yr by 2070. In 2070, the Brazos G Area mining users are projected to receive over 90% of their water supplies from groundwater sources. Thirty-five (35) of the thirty-seven counties in the Brazos G Area have projected mining needs over the planning period. In 2070, the estimated water needs are 64,577 acft, which is about 75% of the mining water demand for the Brazos G Area.

[9] TWDB, "Water Demand Methodology and Projections for Mining and Manufacturing," March 2003.

Table 2.3-1. Projected Water Demands, Supplies, and Needs (Shortages) for Industrial Uses

	Projections (acft/yr)					
	2020	*2030*	*2040*	*2050*	*2060*	*2070*
Manufacturing						
Demand	21,848	24,554	27,270	29,687	32,223	34,977
Existing Supply						
Groundwater	7,380	9,080	9,414	9,720	10,043	10,414
Surface water	19,251	20,221	21,163	22,047	22,939	24,007
Total Supply	26,631	29,302	30,577	31,766	32,981	34,421
Manufacturing Balance (All Brazos G)	4,783	4,748	3,307	2,079	758	(556)
Manufacturing Balance (Counties with Shortages)	(6,972)	(6,972)	(8,378)	(9,570)	(10,856)	(12,135)
Steam-Electric						
Demand	239,299	272,711	288,696	322,702	341,364	362,386
Existing Supply						
Groundwater	23,211	20,452	20,386	21,885	22,526	22,516
Surface water	264,127	251,408	238,736	226,048	213,359	200,683
Total Supply	287,338	271,860	259,122	247,933	235,886	223,199
Steam-Electric Balance (All Brazos G)	48,039	(851)	(29,574)	(74,769)	(105,478)	(139,187)
Steam-Electric Balance (Counties with Shortages)	(73,820)	(97,401)	(120,953)	(160,259)	(184,995)	(212,876)
Mining						
Demand	61,586	70,381	68,875	70,949	75,038	81,409
Existing Supply						
Groundwater	17,686	17,686	17,686	17,686	17,686	17,686
Surface water	3,455	3,055	2,655	2,255	1,855	1,455
Total Supply	21,141	20,741	20,341	19,941	19,541	19,141
Mining Balance (All Brazos G)	(40,445)	(49,640)	(48,534)	(51,008)	(55,497)	(62,268)
Mining Balance (Counties with Shortages)	(41,749)	(50,261)	(49,306)	(53,690)	(58,022)	(64,577)

Table 2.3-1 (Concluded)

	Projections (acft/yr)					
	2020	***2030***	***2040***	***2050***	***2060***	***2070***
Total Industrial						
Demand	322,733	367,646	384,841	423,338	448,625	478,772
Existing Supply						
Groundwater	48,278	47,218	47,485	49,291	50,255	50,616
Surface water	286,832	274,685	262,554	250,350	238,153	226,145
Total Supply	335,110	321,903	310,040	299,641	288,408	276,761
Total Industrial Balance (All Brazos G)	12,377	(45,743)	(74,801)	(123,697)	(160,217)	(202,011)
Total Industrial Balance (Counties with Shortages)	(122,541)	(154,634)	(178,638)	(223,520)	(253,872)	(289,588)

2.3.2 Brazos G Industrial Water Conservation Approach

The Brazos G RWPG recommends that counties with projected needs (shortages) for industrial users (manufacturing, steam electric, or mining) reduce those water demands by 3 percent by 2020, 5 percent by 2030, and 7 percent from 2040 to 2070 by using BMPs identified by the Water Conservation Implementation Task Force.

The Task Force report lists the following industrial BMPs that may be used to achieve the recommended water savings:[10]

1. Industrial Water Audit,
2. Industrial Water Waste Reduction,
3. Industrial Submetering,
4. Cooling Towers,
5. Cooling Systems (other than Cooling Towers),
6. Industrial Alternative Sources and Reuse and Recirculation of Process Water,
7. Rinsing/Cleaning,
8. Water Treatment,
9. Boiler and Steam Systems,
10. Refrigeration (including Chilled Water),
11. Once-Through Cooling,
12. Management and Employee Programs,
13. Industrial Landscape, and
14. Industrial Site Specific Conservation.

[10] Water Conservation Implementation Task Force, Report to the 79th Legislature, Texas Water Development Board,

The Task Force report describes the above BMP methods and how they reduce water use; however, information regarding specific water savings and costs to implement conservation programs is generally unavailable. Conservation savings and costs are by nature facility-specific. Since industrial entities are presented on a county basis and are not individually identified, identification of specific water management strategies is not a reasonable expectation.

2.3.3 Available Yield

The Brazos G RWPG recommends that counties with projected needs (shortages) for industrial users (manufacturing, steam electric, or mining) reduce those water demands by 3 percent by 2020, 5 percent by 2030, and 7 percent from 2040 to 2070 by using Best Management Practices identified by the Water Conservation Implementation Task Force.

For the 12 manufacturing users with projected needs, the total water savings after 7 percent water demand reduction in 2070 is 1,688 acft/yr (a 14% reduction in total regional manufacturing shortages) as shown in Table 2.3-2.

For the seven (7) steam-electric users with projected needs, the total water savings after 7 percent water demand reduction in 2070 is 14,307 acft/yr (a 7% reduction in total regional steam-electric shortages) as shown in Table 2.3-3. Nolan and Somervell Counties have significant increases in steam-electric demands during the planning period. It is assumed that with these new demands generating facilities will utilize the most water efficient means appropriate to produce power; therefore, no additional steam-electric conservation is recommended for Nolan and Somervell counties.

For the thirty five (35) mining users with projected needs, the total water savings after 7 percent water demand reduction in 2060 is 5,680 acft/yr (a 9% reduction in total regional mining shortages) as shown in Table 2.3-4.

Table 2.3-2. Projected Water Demands and Needs (Shortages) for Manufacturing Users Considering up to a 7 Percent Demand Reduction by 2040

Manufacturing Projections (acft/yr)						
	2020 (3%)	***2030 (5%)***	***2040 (7%)***	***2050 (7%)***	***2060 (7%)***	***2070 (7%)***
Bell						
New Demand (after conservation)	1,329	1,416	1,495	1,591	1,718	1,854
Expected Conservation Savings	41	75	112	120	129	140
New Surplus (Shortage) (acft/yr)	(832)	(919)	(998)	(1,094)	(1,221)	(1,357)
Shortage Reduction w/ Conservation	5%	8%	10%	10%	10%	9%
Bosque						
New Demand (after conservation)	2,657	2,905	3,136	3,388	3,682	4,001
Expected Conservation Savings	82	153	236	255	277	301
New Surplus (Shortage) (acft/yr)	(1,786)	(2,034)	(2,265)	(2,517)	(2,811)	(3,130)
Shortage Reduction w/ Conservation	4%	7%	9%	9%	9%	9%

Table 2.3.2 (Continued)

Manufacturing Projections (acft/yr)						
	2020 (3%)	*2030 (5%)*	*2040 (7%)*	*2050 (7%)*	*2060 (7%)*	*2070 (7%)*
Brazos						
New Demand (after conservation)	2,382	2,640	2,891	3,167	3,435	3,727
Expected Conservation Savings	74	139	218	238	259	281
New Surplus (Shortage) (acft/yr)	(1,646)	(537)	(791)	(1,065)	(1,334)	(1,626)
Shortage Reduction w/ Conservation	4%	21%	22%	18%	16%	15%
Burleson						
New Demand (after conservation)	135	153	170	189	206	224
Expected Conservation Savings	4	8	13	14	15	17
New Surplus (Shortage) (acft/yr)	4	(14)	(31)	(50)	(67)	(85)
Shortage Reduction w/ Conservation	100%	36%	29%	22%	19%	16%
Grimes						
New Demand (after conservation)	350	388	423	462	501	544
Expected Conservation Savings	11	20	32	35	38	41
New Surplus (Shortage) (acft/yr)	164	127	91	52	38	41
Shortage Reduction w/ Conservation	N/A	N/A	N/A	N/A	100%	100%
Fisher						
New Demand (after conservation)	218	242	264	288	312	339
Expected Conservation Savings	7	13	20	22	24	25
New Surplus (Shortage) (acft/yr)	(14)	(38)	(59)	(84)	(108)	(134)
Shortage Reduction w/ Conservation	33%	25%	25%	21%	18%	16%
Limestone						
New Demand (after conservation)	90	97	103	110	118	127
Expected Conservation Savings	3	5	8	8	9	10
New Surplus (Shortage) (acft/yr)	3	6	7	8	9	10
Shortage Reduction w/ Conservation	100%	N/A	100%	100%	N/A	N/A

Table 2.3.2 (Concluded)

Manufacturing Projections (acft/yr)						
	2020 (3%)	*2030 (5%)*	*2040 (7%)*	*2050 (7%)*	*2060 (7%)*	*2070 (7%)*
McLennan						
New Demand (after conservation)	4,934	5,438	5,927	6,468	7,005	7,586
Expected Conservation Savings	153	286	446	487	527	571
New Surplus (Shortage) (acft/yr)	(1,511)	(1,630)	(1,758)	(1,930)	(2,137)	(2,263)
Shortage Reduction w/ Conservation	9%	15%	20%	20%	20%	20%
Nolan						
New Demand (after conservation)	1,377	1,530	1,673	1,827	1,981	2,147
Expected Conservation Savings	43	81	126	138	149	162
New Surplus (Shortage) (acft/yr)	(838)	(991)	(1,134)	(1,288)	(1,442)	(1,608)
Shortage Reduction w/ Conservation	5%	8%	10%	10%	9%	9%
Washington						
New Demand (after conservation)	671	719	764	817	884	957
Expected Conservation Savings	21	38	58	62	67	72
New Surplus (Shortage) (acft/yr)	(41)	(89)	(134)	(187)	(254)	(326)
Shortage Reduction w/ Conservation	34%	30%	30%	25%	21%	18%
Williamson						
New Demand (after conservation)	2,283	2,557	2,820	3,105	3,372	3,662
Expected Conservation Savings	71	135	212	234	254	276
New Surplus (Shortage) (acft/yr)	60	125	201	223	243	265
Shortage Reduction w/ Conservation	100%	100%	100%	100%	100%	100%
Young						
New Demand (after conservation)	57	61	64	67	73	81
Expected Conservation Savings	2	3	5	5	6	6
New Surplus (Shortage) (acft/yr)	(23)	(22)	(20)	(20)	(19)	(19)
Shortage Reduction w/ Conservation	7%	13%	19%	20%	22%	24%
Total Savings	**454**	**849**	**1,320**	**1,436**	**1,557**	**1,688**

Table 2.3-3. Projected Water Demands and Needs (Shortages) for Steam-Electric Users Considering up to a 7% Percent Demand Reduction by 2040

Steam-Electric Projections (acft/yr)						
	2020 (3%)	*2030 (5%)*	*2040 (7%)*	*2050 (7%)*	*2060 (7%)*	*2070 (7%)*
Bell						
New Demand (after conservation)	4,093	4,687	5,398	6,384	7,586	9,014
Expected Conservation Savings	127	247	406	481	571	679
New Surplus (Shortage) (acft/yr)	(4,093)	(4,687)	(5,398)	(6,384)	(7,586)	(9,014)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Brazos						
New Demand (after conservation)	488	386	428	290	377	357
Expected Conservation Savings	15	20	32	22	28	27
New Surplus (Shortage) (acft/yr)	3,358	2,757	1,995	1,413	606	(94)
Shortage Reduction w/ Conservation	4%	21%	22%	18%	16%	15%
Grimes						
New Demand (after conservation)	30,807	31,502	32,234	34,094	36,884	39,902
Expected Conservation Savings	953	1658	2426	2566	2776	3003
New Surplus (Shortage) (acft/yr)	(13,970)	(14,665)	(15,396)	(17,256)	(20,046)	(23,064)
Shortage Reduction w/ Conservation	6%	10%	14%	13%	12%	12%
Johnson						
New Demand (after conservation)	6,790	6,650	6,510	6,510	6,510	6,510
Expected Conservation Savings	210	350	490	490	490	490
New Surplus (Shortage) (acft/yr)	(5,446)	(5,306)	(5,166)	(5,166)	(5,166)	(5,166)
Shortage Reduction w/ Conservation	4%	6%	9%	9%	9%	9%
Limestone						
New Demand (after conservation)	21,920	25,099	28,903	34,185	40,623	48,391
Expected Conservation Savings	678	1321	2176	2573	3058	3642
New Surplus (Shortage) (acft/yr)	756	(6,791)	(14,963)	(24,611)	(35,417)	(47,552)
Shortage Reduction w/ Conservation	N/A	16%	13%	9%	8%	7%

Table 2.3-3 (Concluded)

Steam-Electric Projections (acft/yr)						
	2020 (3%)	*2030 (5%)*	*2040 (7%)*	*2050 (7%)*	*2060 (7%)*	*2070 (7%)*
Milam						
New Demand (after conservation)	31,062	30,422	29,781	38,120	38,120	38,120
Expected Conservation Savings	961	1601	2242	2869	2869	2869
New Surplus (Shortage) (acft/yr)	3,848	1,711	2,285	(4,553)	(3,913)	(3,923)
Shortage Reduction w/ Conservation	N/A	N/A	N/A	39%	42%	42%
Robertson						
New Demand (after conservation)	16,937	28,861	33,026	43,695	45,694	47,784
Expected Conservation Savings	524	1519	2486	3289	3439	3597
New Surplus (Shortage) (acft/yr)	16,961	601	(8,000)	(23,105)	(29,540)	(36,067)
Shortage Reduction w/ Conservation	N/A	100%	24%	12%	10%	9%
Total Savings	**3,467**	**6,716**	**10,258**	**12,290**	**13,232**	**14,307**

Table 2.3-4. Projected Water Demands and Needs (Shortages) for Mining Users Considering up to a 7% Percent Demand Reduction by 2040

Mining Projections (acft/yr)						
	2020 (3%)	***2030 (5%)***	***2040 (7%)***	***2050 (7%)***	***2060 (7%)***	***2070 (7%)***
Bell						
New Demand (after conservation)	3,145	3,781	4,277	4,975	5,678	6,480
Expected Conservation Savings	97	199	322	374	427	488
New Surplus (Shortage) (acft/yr)	(3,145)	(3,781)	(4,277)	(4,975)	(5,678)	(6,480)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Bosque						
New Demand (after conservation)	1,913	1,967	1,760	1,741	1,705	1,694
Expected Conservation Savings	59	104	132	131	128	127
New Surplus (Shortage) (acft/yr)	(1,784)	(1,839)	(1,631)	(1,612)	(1,576)	(1,565)
Shortage Reduction w/ Conservation	3%	5%	8%	8%	8%	8%
Brazos						
New Demand (after conservation)	1,055	1,530	1,333	1,064	858	757
Expected Conservation Savings	33	81	100	80	65	57
New Surplus (Shortage) (acft/yr)	(1,055)	(1,530)	(1,333)	(1,064)	(858)	(757)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Burleson						
New Demand (after conservation)	965	1,827	1,406	1,023	638	398
Expected Conservation Savings	30	96	106	77	48	30
New Surplus (Shortage) (acft/yr)	(965)	(1,827)	(1,406)	(1,023)	(638)	(398)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Callahan						
New Demand (after conservation)	221	216	199	187	177	167
Expected Conservation Savings	7	11	15	14	13	13
New Surplus (Shortage) (acft/yr)	(221)	(216)	(199)	(187)	(177)	(167)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%

Table 2.3.4 (Continued)

Mining Projections (acft/yr)						
	2020 (3%)	*2030 (5%)*	*2040 (7%)*	*2050 (7%)*	*2060 (7%)*	*2070 (7%)*
Comanche						
New Demand (after conservation)	431	499	338	257	175	119
Expected Conservation Savings	13	26	25	19	13	9
New Surplus (Shortage) (acft/yr)	(404)	(473)	(311)	(230)	(149)	(93)
Shortage Reduction w/ Conservation	3%	5%	8%	8%	8%	9%
Coryell						
New Demand (after conservation)	1,465	1,018	457	338	370	406
Expected Conservation Savings	45	54	34	25	28	31
New Surplus (Shortage) (acft/yr)	(1,465)	(1,018)	(457)	(338)	(370)	(406)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Eastland						
New Demand (after conservation)	1,129	1,114	864	664	482	402
Expected Conservation Savings	35	59	65	50	36	30
New Surplus (Shortage) (acft/yr)	(1,129)	(1,114)	(864)	(664)	(482)	(402)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Falls						
New Demand (after conservation)	218	234	241	266	286	308
Expected Conservation Savings	7	12	18	20	21	23
New Surplus (Shortage) (acft/yr)	(218)	(234)	(241)	(266)	(286)	(308)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Fisher						
New Demand (after conservation)	395	382	334	291	254	221
Expected Conservation Savings	12	20	25	22	19	17
New Surplus (Shortage) (acft/yr)	(395)	(382)	(334)	(291)	(254)	(221)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%

Table 2.3.4 (Continued)

Mining Projections (acft/yr)						
	2020 (3%)	*2030 (5%)*	*2040 (7%)*	*2050 (7%)*	*2060 (7%)*	*2070 (7%)*
Grimes						
New Demand (after conservation)	313	572	438	316	194	119
Expected Conservation Savings	10	30	33	24	15	9
New Surplus (Shortage) (acft/yr)	(281)	(539)	(405)	(284)	(162)	(86)
Shortage Reduction w/ Conservation	3%	5%	8%	8%	8%	9%
Hamilton						
New Demand (after conservation)	381	224	94	0	0	0
Expected Conservation Savings	12	12	7	0	0	0
New Surplus (Shortage) (acft/yr)	(369)	(212)	(81)	13	13	13
Shortage Reduction w/ Conservation	3%	5%	8%	N/A	N/A	N/A
Haskell						
New Demand (after conservation)	90	87	77	69	61	55
Expected Conservation Savings	3	5	6	5	5	4
New Surplus (Shortage) (acft/yr)	(90)	(87)	(77)	(69)	(61)	(55)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Hill						
New Demand (after conservation)	1,585	1,131	721	375	405	358
Expected Conservation Savings	49	60	54	0	31	33
New Surplus (Shortage) (acft/yr)	(554)	(299)	(90)	0	(174)	(326)
Shortage Reduction w/ Conservation	8%	17%	38%	N/A	15%	26%
Hood						
New Demand (after conservation)	2,016	2,314	2,066	1,984	1,900	1,913
Expected Conservation Savings	62	122	156	149	143	144
New Surplus (Shortage) (acft/yr)	(792)	(1,090)	(843)	(760)	(676)	(689)
Shortage Reduction w/ Conservation	7%	10%	16%	16%	17%	17%

Table 2.3.4 (Continued)

Mining Projections (acft/yr)						
	2020 (3%)	*2030 (5%)*	*2040 (7%)*	*2050 (7%)*	*2060 (7%)*	*2070 (7%)*
Johnson						
New Demand (after conservation)	4,002	2,649	1,409	942	1,080	1,242
Expected Conservation Savings	124	139	106	71	81	94
New Surplus (Shortage) (acft/yr)	(1,140)	214	1,453	1,920	1,782	1,620
Shortage Reduction w/ Conservation	10%	N/A	N/A	N/A	N/A	N/A
Jones						
New Demand (after conservation)	232	222	203	185	170	157
Expected Conservation Savings	7	12	15	14	13	12
New Surplus (Shortage) (acft/yr)	(232)	(222)	(203)	(185)	(170)	(157)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Knox						
New Demand (after conservation)	15	14	13	13	13	13
Expected Conservation Savings	0	1	1	1	1	1
New Surplus (Shortage) (acft/yr)	(15)	(14)	(13)	(13)	(13)	(13)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Lampasas						
New Demand (after conservation)	192	210	224	243	266	291
Expected Conservation Savings	6	11	17	18	20	22
New Surplus (Shortage) (acft/yr)	(167)	(185)	(199)	(218)	(241)	(266)
Shortage Reduction w/ Conservation	3%	6%	8%	8%	8%	8%
Lee						
New Demand (after conservation)	3,085	6,925	7,223	7,723	8,281	8,957
Expected Conservation Savings	95.4	364.45	543.69	581.28	623.28	674.17
New Surplus (Shortage) (acft/yr)	(3,085)	(6,925)	(7,223)	(7,723)	(8,281)	(8,957)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%

Table 2.3.4 (Continued)

Mining Projections (acft/yr)						
	2020 (3%)	*2030 (5%)*	*2040 (7%)*	*2050 (7%)*	*2060 (7%)*	*2070 (7%)*
Limestone						
New Demand (after conservation)	10,007	9,429	9,174	9,615	10,049	10,625
Expected Conservation Savings	310	496	691	724	756	800
New Surplus (Shortage) (acft/yr)	(9,198)	(8,619)	(8,365)	(8,806)	(9,239)	(9,816)
Shortage Reduction w/ Conservation	3%	5%	8%	8%	8%	8%
McLennan						
New Demand (after conservation)	2,462	2,850	2,846	3,262	3,564	3,921
Expected Conservation Savings	76	150	214	246	268	295
New Surplus (Shortage) (acft/yr)	(2,188)	(2,576)	(2,572)	(2,989)	(3,290)	(3,647)
Shortage Reduction w/ Conservation	3%	6%	8%	8%	8%	7%
Milam						
New Demand (after conservation)	14	13	13	13	13	13
Expected Conservation Savings	0	1	1	1	1	1
New Surplus (Shortage) (acft/yr)	(14)	(13)	(13)	(13)	(13)	(13)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Nolan						
New Demand (after conservation)	218	211	186	166	147	131
Expected Conservation Savings	7	11	14	12	11	10
New Surplus (Shortage) (acft/yr)	(218)	(211)	(186)	(166)	(147)	(131)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Robertson						
New Demand (after conservation)	9,616	11,165	12,804	15,086	17,872	21,334
Expected Conservation Savings	297	588	964	1136	1345	1606
New Surplus (Shortage) (acft/yr)	589	(960)	(2,599)	(4,881)	(7,667)	(11,129)
Shortage Reduction w/ Conservation	N/A	38%	27%	19%	15%	13%

Table 2.3.4 (Continued)

Mining Projections (acft/yr)						
	2020 (3%)	*2030 (5%)*	*2040 (7%)*	*2050 (7%)*	*2060 (7%)*	*2070 (7%)*
Shackelford						
New Demand (after conservation)	545	710	519	411	305	226
Expected Conservation Savings	17	37	39	31	23	17
New Surplus (Shortage) (acft/yr)	(538)	(703)	(512)	(404)	(298)	(219)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Somervell						
New Demand (after conservation)	1,079	1,215	1,066	986	928	903
Expected Conservation Savings	33	64	80	74	70	68
New Surplus (Shortage) (acft/yr)	(374)	(510)	(361)	(281)	(223)	(198)
Shortage Reduction w/ Conservation	8%	11%	18%	21%	24%	26%
Stephens						
New Demand (after conservation)	4,912	4,884	4,146	3,557	3,029	2,579
Expected Conservation Savings	152	257	312	268	228	194
New Surplus (Shortage) (acft/yr)	(3,912)	(3,884)	(3,146)	(2,557)	(2,029)	(1,579)
Shortage Reduction w/ Conservation	4%	6%	9%	9%	10%	11%
Stonewall						
New Demand (after conservation)	566	547	476	415	361	314
Expected Conservation Savings	18	29	36	31	27	24
New Surplus (Shortage) (acft/yr)	(391)	(372)	(301)	(240)	(186)	(139)
Shortage Reduction w/ Conservation	4%	7%	11%	12%	13%	15%
Taylor						
New Demand (after conservation)	379	371	340	322	306	293
Expected Conservation Savings	12	20	26	24	23	22
New Surplus (Shortage) (acft/yr)	(379)	(371)	(340)	(322)	(306)	(293)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%

Table 2.3.4 (Concluded)

Mining Projections (acft/yr)						
	2020 (3%)	*2030 (5%)*	*2040 (7%)*	*2050 (7%)*	*2060 (7%)*	*2070 (7%)*
Throckmorton						
New Demand (after conservation)	188	181	159	140	123	108
Expected Conservation Savings	6	10	12	11	9	8
New Surplus (Shortage) (acft/yr)	(188)	(181)	(159)	(140)	(123)	(108)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Washington						
New Demand (after conservation)	552	823	654	500	347	246
Expected Conservation Savings	17	43	49	38	26	18
New Surplus (Shortage) (acft/yr)	(552)	(823)	(654)	(500)	(347)	(246)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Williamson						
New Demand (after conservation)	5,008	5,935	6,849	7,956	9,097	10,403
Expected Conservation Savings	155	312	515	599	685	783
New Surplus (Shortage) (acft/yr)	(4,593)	(5,520)	(6,433)	(7,541)	(8,682)	(9,988)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Young						
New Demand (after conservation)	181	262	182	140	98	68
Expected Conservation Savings	6	14	14	11	7	5
New Surplus (Shortage) (acft/yr)	(181)	(262)	(182)	(140)	(98)	(68)
Shortage Reduction w/ Conservation	3%	5%	7%	7%	7%	7%
Total Savings	**1,827**	**3,475**	**4,775**	**4,902**	**5,227**	**5,680**

2.3.4 Environmental Issues

The Task Force BMPs have been developed and tested through public and private sector research, and have been applied within the region. Such programs have been installed, and are in operation today, and are not expected to have significant environmental issues associated with implementation. For example, most BMPs improve water use efficiency without making significant changes to wildlife habitat. Thus, the proposed conservation practices are not anticipated to have significant potential adverse environmental effects, and may have potentially beneficial environmental effects.

2.3.5 Engineering and Costing

The Brazos G RWPG recommends implementing water conservation for industrial users (manufacturing, steam-electric, and mining) with projected needs amounting to a 3 percent water demand reduction by 2020, 5 percent by 2030, and 7 percent from 2040 to 2070. The 12 counties in the Brazos G Area with projected manufacturing shortages can save up to 1,688 acft/yr in 2070. The seven counties in the Brazos G Area with projected steam-electric shortages can save up to 14,307 acft in 2070. The 35 counties in the Brazos G Area with projected mining shortages can save up to 5,680 acft in 2070. Costs to implement BMPs vary from site to site and the Brazos G RWPG recognizes that industries will pursue conservation strategies that are economically feasible with water savings benefits. For this reason, it is impractical to evaluate the costs of implementing industrial water conservation strategies.

2.3.6 Implementation Issues

Demand reduction through water conservation is being implemented throughout the Brazos G Area. The rate of adoption of efficient water-using practices is dependent upon public knowledge of the benefits, information about how to implement water conservation measures, and financing.

There is public support for industrial water conservation; and, it is being implemented at a steady pace, and as water markets for conserved water expand, this practice will likely reach greater potentials. The TWDB has industrial water conservation programs including presentations and workshops for utilities who wish to train staff to develop local programs including water use site surveys, publications on industrial water reuse potential, and information on tax incentives for industries that conserve or reuse water. Future planning efforts should consider the use of detailed studies to fully determine the maximum potential benefits of mining conservation.

This option is compared to the plan development criteria in Table 2.3-5 and the option meets each criterion.

Table 2.3-5. Comparison of Industrial Conservation to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1 Quantity	1. Manufacturing Firm Yield: up to 1,688 acft/yr (2070) Steam-Electric Firm Yield: up to 14,307 acft/yr (2070) Mining Firm Yield: up to 5,680 acft/yr (2070)
2. Reliability and Cost	2. Good reliability.
3. Cost	3. Cost: Highly variable based on BMP selected and facility specifics.
B. Environmental factors	
1. Instream flows	1. None or low impact.
2. Bay and Estuary Inflows	2. None or low impact.
3. Wildlife Habitat	3. None or low impact.
4. Wetlands	4. None or low impact.
5. Threatened and Endangered Species	5. None.
6. Cultural Resources	6. No cultural resources affected.
7. Water Quality	7. None or low impact.
C. Impacts to State water resources	• No apparent negative impacts on water resources
D. Threats to agriculture and natural resources in region	• None
E. Recreational impacts	• None
F. Equitable Comparison of Strategies	• Standard analyses and methods used
G. Interbasin transfers	• None
H. Third party social and economic impacts from voluntary redistribution of water	• None
I. Efficient use of existing water supplies and regional opportunities	• Improvement over current conditions by reducing the rate of decline of local groundwater levels.
J. Effect on navigation	• None
K. Consideration of water pipelines and other facilities used for water conveyance	• None

3 Wastewater Reuse

3.1 Overview

Wastewater reuse would be defined as the types of projects that utilize treated wastewater effluent as a replacement for potable water supply, reducing the overall demand for fresh water supply. Wastewater reuse typically involves a capital project connecting the treatment plant discharge facilities to an individual area that has a relatively high, localized use that can be met with non-potable water. Examples most frequently include the irrigation of golf courses and other public lands and specific industries or industrial use areas. Few entities, if any, would be capable of utilizing their entire effluent capacity for reuse at present; long term, it is likely that increased pressure on water supplies will result in increased emphasis on reuse, with reused water approaching the quantity of effluent available. Downstream needs, both water rights and environmental instream uses, would have to be met. Any remaining flows after these needs are met could potentially be utilized. Virtually any water supply entity with a wastewater treatment plant could pursue a reuse alternative, provided that downstream water rights do not have a claim for the entire return flow. Current examples of existing reuse systems in the Brazos G Area include those of the cities of Abilene, Cleburne, Georgetown, Killeen and Round Rock. Many other smaller communities make their effluent available for irrigation purposes.

Wastewater reuse can be classified into two forms, defined by how the reuse water is handled:

1. Direct Reuse – Pipe treated wastewater directly from wastewater plant to place of use (also called “flange-to-flange”).
2. Indirect Reuse – Discharge treated wastewater to river, stream, or lake for subsequent diversion downstream (also called “bed and banks”).

3.1.1 Direct Reuse

All direct reuse water supply options assume that treated wastewater remains under the control (in pipelines or storage tanks) at all times from treatment to point of use by the entity treating the wastewater and/or supplying reuse water.

Wastewater reuse quality and system design requirements are regulated by TCEQ by 30 TAC §210. TCEQ allows two types of reuse as defined by the use of the water and the required water quality:

- Type 1 – Public or food crops generally can come in contact with reuse water; and
- Type 2 – Public or food crops cannot come in contact with reuse water.

Current TCEQ criteria for reuse water are shown in Table 3.1-1. Trends across the country indicate that criteria for unrestricted reuse water will likely tend to become more stringent over time. The water quality required for Type 1 reuse water is more stringent with lower requirements for oxygen demand (BOD_5 or $CBOD_5$), turbidity, and fecal coliform levels.

Table 3.1-1. TCEQ Quality Standards for Reuse Water

Parameter	Allowable Level
Type 1 Reuse	
BOD_5 or $CBOD_5$	5 mg/L
Turbidity	3 NTU
Fecal Coliform	20 CFU / 100 ml[1]
Fecal Coliform (not to exceed)	75 CFU / 100 ml[2]
Type 2 Reuse For a system other than a pond system	
BOD_5	20 mg/L
or $CBOD_5$	15 mg/L
Fecal Coliform	200 CFU / 100 ml[1]
Fecal Coliform (not to exceed)	800 CFU / 100 ml[2]
Type 2 Reuse For a pond system	
BOD_5	30 mg/L
Fecal Coliform	200 CFU / 100 ml[1]
Fecal Coliform (not to exceed)	800 CFU / 100 ml[2]

[1] geometric mean
[2] single grab sample

Two approaches were utilized to evaluate a broad range of potential reuse water supplies:

1. General evaluation of wastewater reuse for multiple water user groups with needs and potential wastewater sources.
2. Specific supply options for twelve water user groups with defined wastewater sources and identified needs.

The following potential wastewater reuse projects were evaluated as specific management strategies:

1. City of College Station;
2. City of Bryan;
3. City of Cleburne;
4. Waco WMARSS
    i. Waco East
    ii. Bellmead/Lacy-Lakeview;

   iii. Bull Hide Creek;
   iv. Flat Creek; and
   v. Waco North.
5. Bell County WCID No.1

3.1.2 Indirect Reuse

Indirect reuse is the discharge of treated wastewater to rivers, streams, or lakes for subsequent diversion downstream (also called “bed and banks”). Several water user groups within the Brazos G Area have applied for or have plans to apply for indirect reuse of municipal wastewater flows. For these entities, indirect reuse may be more economical than direct reuse options and/or enable a greater quantity of treated wastewater flows to be utilized as a replacement for potable water supplies.

Applications for indirect reuse are currently being evaluated on a case by case basis, and the requirements for indirect reuse are in the process of becoming better defined. Some relevant sections of the Texas Water Code are presented here in an effort to present the framework that is informing the current deliberations on indirect reuse. State water is defined in the Texas Water Code as:

> § 11.021. STATE WATER. (a) The water of the ordinary flow, underflow, and tides of every flowing river, natural stream, and lake, and of every bay or arm of the Gulf of Mexico, and the storm water, floodwater, and rainwater of every river, natural stream, canyon, ravine, depression, and watershed in the state is the property of the state.
>
> (b) Water imported from any source outside the boundaries of the state for use in the state and which is transported through the beds and banks of any navigable stream within the state or by utilizing any facilities owned or operated by the state is the property of the state.

Indirect reuse or “bed and banks” delivery is addressed in the Texas Water Code as:

> § 11.042. DELIVERING WATER DOWN BANKS AND BEDS. (a) Under rules prescribed by the commission, a person, association of persons, corporation, water control and improvement district, water improvement district, or irrigation district supplying stored or conserved water under contract as provided in this chapter may use the bank and bed of any flowing natural stream in the state to convey the water from the place of storage to the place of use or to the diversion point of the appropriator.
>
> (b) A person who wishes to discharge and then subsequently divert and reuse the person's existing return flows derived from privately owned groundwater must obtain prior authorization from the commission for the diversion and the reuse of these return flows. The authorization may allow for the diversion and reuse by the discharger of existing return flows, less carriage losses, and shall be subject to special conditions if necessary to protect an existing water right that was granted based on the use or availability of these return flows. Special conditions may also be provided to help maintain in stream uses and freshwater inflows to bays and estuaries. A person wishing to divert and reuse future increases of return flows

derived from privately owned groundwater must obtain authorization to reuse increases in return flows before the increase.

(c) Except as otherwise provided in Subsection (a) of this section, a person who wishes to convey and subsequently divert water in a watercourse or stream must obtain the prior approval of the commission through a bed and banks authorization. The authorization shall allow to be diverted only the amount of water put into a watercourse or stream, less carriage losses and subject to any special conditions that may address the impact of the discharge, conveyance, and diversion on existing permits, certified filings, or certificates of adjudication, in stream uses, and freshwater inflows to bays and estuaries. Water discharged into a watercourse or stream under this chapter shall not cause a degradation of water quality to the extent that the stream segment's classification would be lowered. Authorizations under this section and water quality authorizations may be approved in a consolidated permit proceeding.

(d) Nothing in this section shall be construed to affect an existing project for which water rights and reuse authorizations have been granted by the commission before September 1, 1997

Table 3.1-2 shows the Brazos G entities with indirect reuse applications currently filed with TCEQ.

Table 3.1-2. Current and Pending Indirect Reuse Applications Filed at TCEQ in Region G as of August 5, 2014

Owner	Water Right	Stream	County	Amount [acft/yr]	Use Type
City of Cleburne	4106 - Certificate of Adjudication	Nolan River	Johnson	5,760	Municipal, Industrial
City of Cleburne	4106 - Certificate of Adjudication	Nolan River	Johnson	240	Multiple Uses
City of Abilene	4266 - Permit	Deadman Creek	Jones, Shackelford	4,330	Irrigation
City of Abilene	4161 - Certificate of Adjudication	Clear Fork of the Brazos River	Multiple along the Clear Fork	25,690	Multiple Uses
Brazos River Authority	5730 - Permit	Colorado River	Williamson	25,000	Multiple Uses
Somervell County Water District	5744 - Permit	Paluxy River, Wheeler Branch	Somervell	5,000	Multiple Uses
City of Navasota	5748 - Permit	Cedar Creek	Grimes	430	Irrigation
Buhari Inc.	5771 - Permit	Buttonwillow Creek	Taylor	2	Irrigation
Burl G. Harris	5771 - Permit	Buttonwillow Creek	Taylor	18	Irrigation
City of Albany	5802 - Permit	Unnamed Tributary of North Fork Creek	Shackelford	50	Irrigation, Recreation

Table 3.1-2. Current and Pending Indirect Reuse Applications Filed at TCEQ in Region G as of August 5, 2014

Owner	Water Right	Stream	County	Amount [acft/yr]	Use Type
City of Waco	5840 - Permit	Brazos River	McLennan		Multiple Uses
City of Bryan	5912 - Permit	Brazos River	Brazos	14,282	Multiple Uses
City of College Station	5913 - Permit	Brazos River	Brazos	12,881	Multiple Uses
Brazos River Authority	5851 - Pending System Operation Permit	Varies	Multiple	Varies	Multiple Uses
City of Lubbock	5921 - Pending Permit		Multiple		
City of Lubbock	4146B - Pending Permit		Multiple		
River Place POA	5755-A Pending		Brazos		
Pecan Plantation Owners Association	12940 - Pending		Hood		
Decordova Bend Estates	12984 - Pending		Hood		
Sugartree, Inc	12995 - Pending		Parker		
Kenneth D. Harvick	12-3662B - Pending		Comanche		
PARR 4 CW, LLC	13066 - Pending		Parker		
Double Diamond, Inc	13075 - Pending		Johnson		
McMinn Ranches LTD	12-2822A - Pending		Comanche		
Randy Stephens	12-3505 - Pending		Comanche		
ALCOA Inc.	12-5803A - Pending		Milam		
Star Golf Partners, LTD	13096 - Pending		Williamson		
ALCOA Inc.		Little River	Bell	200	

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3.2 General Evaluation of Direct Reuse Potential for Multiple Water User Groups

3.2.1 Description of Option

Many water user groups with need have the potential to develop wastewater reuse projects, and a general evaluation of wastewater reuse potential was conducted for these entities. Figure 3.2-1 shows the county needs and the "Year 2070 Confirmed Discharge" for wastewater treatment plants with 1 MGD or greater treatment capacity. The "Year 2070 Confirmed Discharge" is the projected wastewater discharge into the receiving stream as reported by the entity responsible for the wastewater treatment plant. Some entities reported that they intended to utilize all 2070 wastewater effluent for reuse and therefore the confirmed discharge reported is zero. Figure 3.2-2 shows the municipal balance of individual water user groups.

3.2.2 Available Supply

The water supply from reuse that would be potentially available for any entity would be that portion of their wastewater effluent stream that is over and above any currently planned reuse and any commitments made to downstream water rights and environmental flows. Of this potential, the amount that can actually be recognized depends on the availability of suitable uses within an economical distance from the treatment plant. If individual high water use industrial plants or open land that benefits from irrigation, such as golf courses, are located relatively close to the plant, then reuse can provide a substantial benefit to water supplies.

In order to isolate those communities that may potentially benefit from a reuse program, information regarding each of the communities with both a projected need for additional water supply and a wastewater treatment plant (WWTP) proximate to need was gathered. Table 3.2-1 lists these water user groups, their projected need, approximate average effluent, and an assumed portion of the effluent that may be recoverable. If a WWTP with discharge over 1 MGD is proximate to the need it is listed in the table. Initially, the portion of effluent that may be recoverable was estimated as 25 percent of the current average effluent plus 50 percent of future effluent. A relatively low recoverable percentage was used because of the variability in effluent flows, variability in demand, and the large storage volumes that would likely be needed to match availability with demand. Entities were then contacted to verify this estimate and the assumed effluent recoverable adjusted based on feedback from entities. The difference between the potential supply and any confirmed 2070 discharges would be considered the amount available.

Several water user groups show a potential reuse amount greater than the projected need and could possibly meet their need in this manner. Utilization of this water source is contingent on whether a potential use for the wastewater effluent exists within an economical distance from the treatment plant.

Figure 3.2-1. Year 2070 Confirmed Discharges from WWTP and County Needs

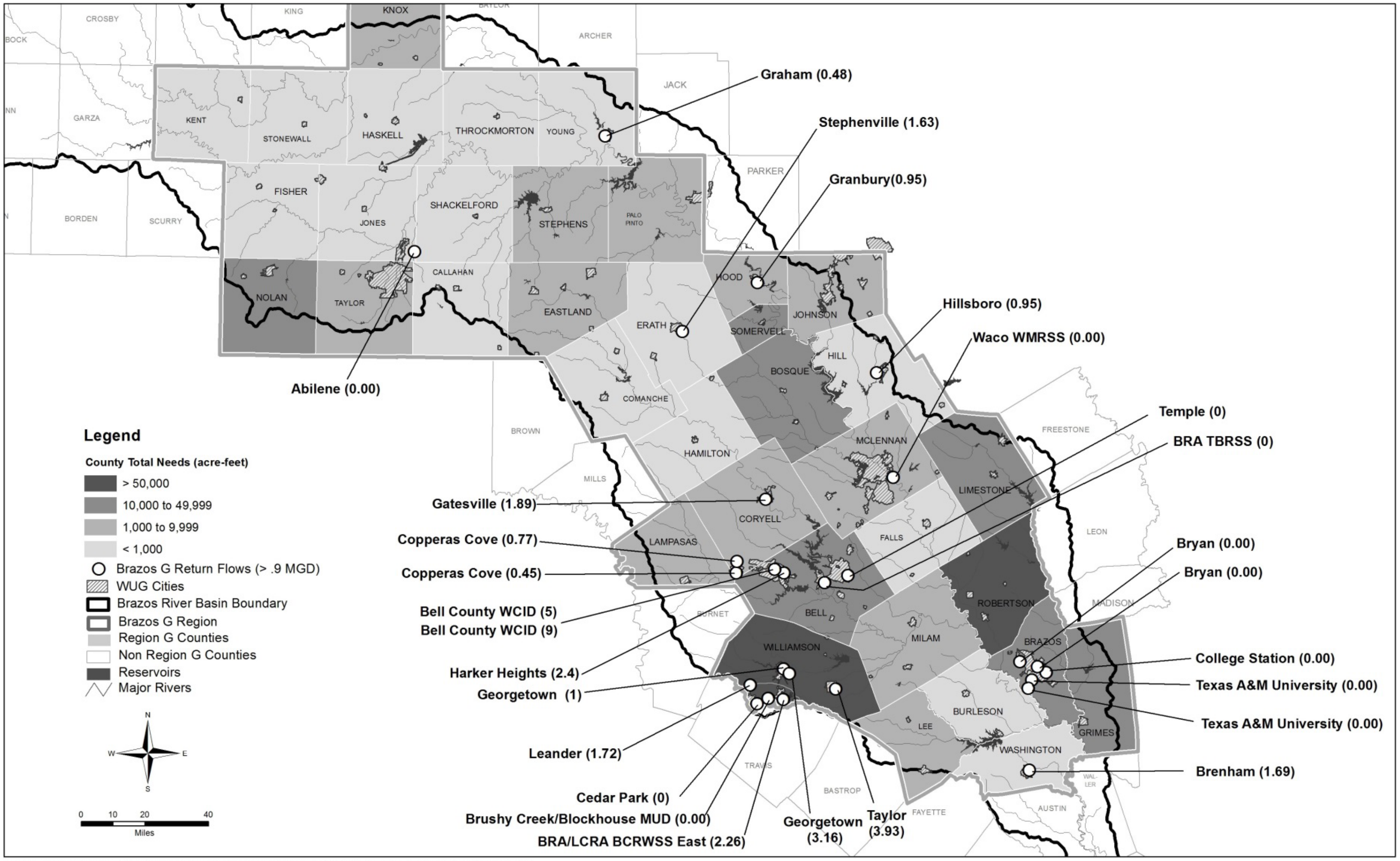

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Figure 3.2-2 Year 2070 Municipal Water User Group Needs

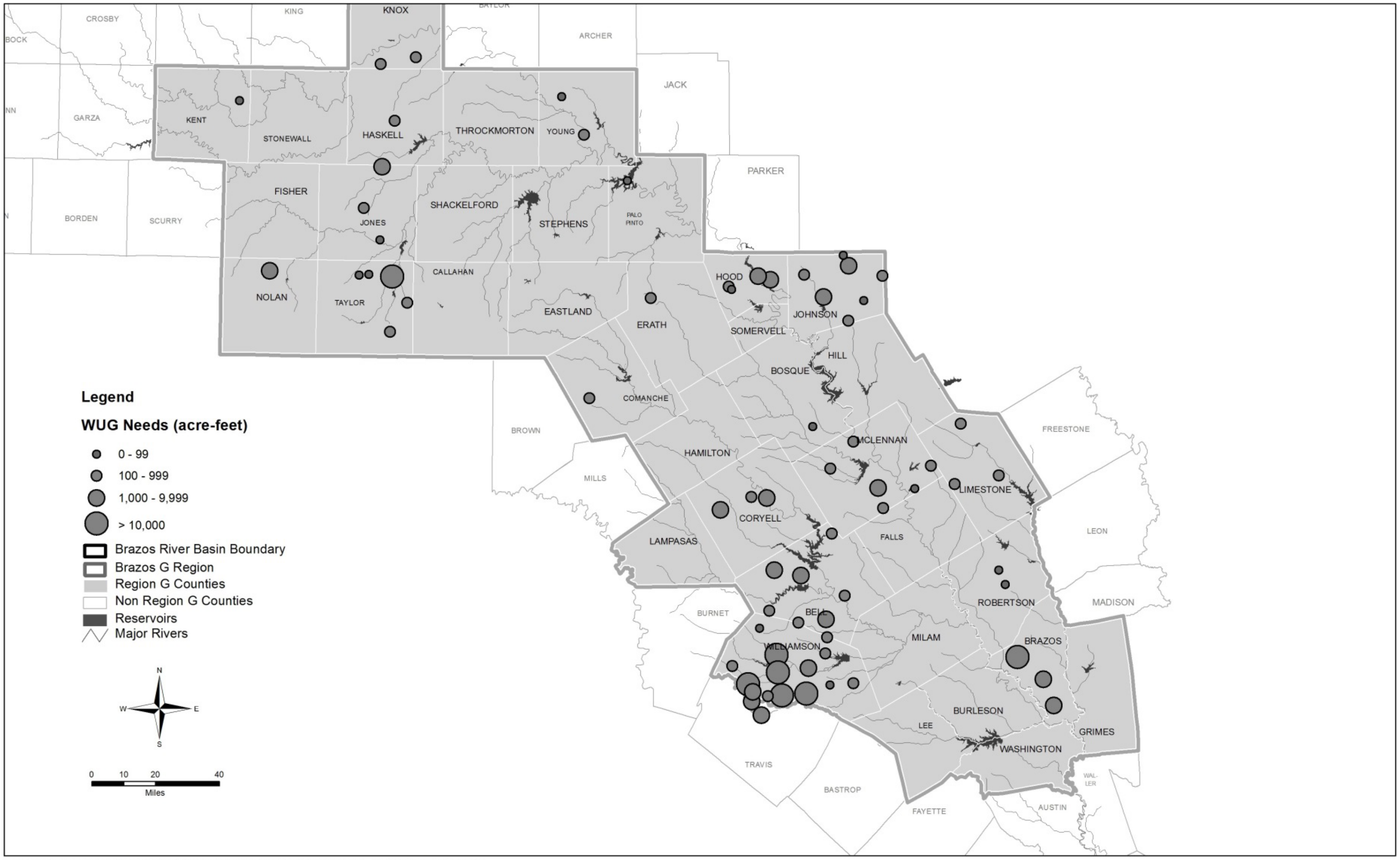

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Table 3.2-1. General Wastewater Reuse Potential

WUG	County	Proximate WW Treatment Facility Over 1 MGD	2070 Projected Need (acft/yr)	2070 Projected Need Percent of Demand	Current Reuse	2070 Maximum Available WWTP Effluent (acft/yr)	2070 Confirmed Reuse by owner (acft/yr)
Killeen	Bell	Bell County WCID#1	0	0%	N	30,811	17,360
Elm Creek WSC	Bell	City of Temple	181	22%	N	5,328	5,320
Nolanville	Bell	City of Harker Heights	1,185	49%	N	4,410	1,710
Bell County-Other	Bell	Bell County WCID#1	3,937	71%	N	30,811	17,360
Little River-Academy	Bell	BRA TBRSS	179	32%	N	26,794	26,790
Harker Heights	Bell	Bell County WCID#1	1,352	15%	N	30,811	17,360
Manufacturing	Bell	City of Temple	1,357	73%	N	5,328	5,320
Steam-Electric	Bell	City of Temple	9,693	100%	N	5,328	5,320
Irrigation	Bell	Bell County WCID#1	894	47%	N	30,811	17,360
Mining	Bell	Bell County WCID#1	6,480	100%	N	30,811	17,360
Temple	Bell	BRA TBRSS	1,488	6%	Y	26,794	26,790
Bryan	Brazos	City of Bryan	24,436	86%	Y	16,651	16,654
College Station	Brazos	City of College Station	3,475	10%	Y	16,008	16,005
College Station	Brazos	Texas A&M University	3,475	10%	Y	4,655	4,466
Manufacturing	Brazos	City of Bryan	1,835	49%	N	16,651	16,654
Mining	Brazos	City of Bryan	757	100%	N	16,651	16,654
Irrigation	Brazos	City of Bryan	3,891	20%	N	16,651	16,654
Gatesville	Coryell	City of Gatesville	1,533	32%	Y	3,244	1,123
Steam-Electric	Grimes	City of Bryan	23,064	58%	N	16,651	16,654
Cleburne	Johnson	City of Cleburne	1,850	22%	Y	7,658	0
Godley	Johnson	City of Godley	108	59%	N	0	0
Joshua	Johnson	Johnson County SUD	0	0%	N	1,467	0
Venus	Johnson	Johnson County SUD	379	39%	N	1,467	0
Steam-Electric	Johnson	City of Cleburne	5,166	79%	N	7,658	0
Hawley WSC	Jones	City of Abilene	33	7%	N	23,383	15,120
Anson	Jones	City of Abilene	421	104%	N	23,383	15,120
Mining	Jones	City of Abilene	157	100%	N	23,383	15,120
Mining	Lee	BRA/LCRA BCRWSS West	8,957	100%	N	4,394	1,857
Bellmead	McLennan	WMARSS	0	0%	Y	36,370	36,366
Chalk Bluff WSC	McLennan	WMARSS	0	0%	N	36,370	36,366

Table 3.2-1. General Wastewater Reuse Potential

WUG	County	Proximate WW Treatment Facility Over 1 MGD	2070 Projected Need (acft/yr)	2070 Projected Need Percent of Demand	Current Reuse	2070 Maximum Available WWTP Effluent (acft/yr)	2070 Confirmed Reuse by owner (acft/yr)
Hallsburg	McLennan	WMARSS	0	0%	N	36,370	36,366
Lacy Lakeview	McLennan	WMARSS	0	0%	Y	36,370	36,366
Mart	McLennan	WMARSS	244	55%	N	36,370	36,366
Riesel	McLennan	WMARSS	19	13%	N	36,370	36,366
North Bosque WSC	McLennan	WMARSS	175	22%	N	36,370	36,366
Robinson	McLennan	WMARSS	1,106	29%	N	36,370	36,366
West Brazos WSC	McLennan	WMARSS	216	48%	N	36,370	36,366
Irrigation	McLennan	WMARSS	2,023	45%	N	36,370	36,366
Manufacturing	McLennan	WMARSS	2,263	30%	N	36,370	36,366
Mining	McLennan	WMARSS	3,647	93%	N	36,370	36,366
Sweetwater	Nolan	City of Sweetwater	1,640	79%	Y	2,236	0
Steam-Electric	Robertson	City of Hearne	14,882	31%	Y	893	309
Abilene	Taylor	City of Abilene	7,177	32%	Y	23,383	15,120
Merkel	Taylor	City of Abilene	9	2%	Y	23,383	15,120
Mining	Taylor	City of Abilene	293	100%	N	23,383	15,120
Blockhouse MUD	Williamson	Blockhouse MUD	1,299	54%	Y	2,879	2,879
Brushy Creek MUD	Williamson	Brushy Creek MUD	225	7%	Y	2,448	2,448
Chisholm Trail SUD	Williamson	City of Georgetown	753	7%	N	11,541	6,720
Georgetown	Williamson	City of Georgetown	13,152	43%	Y	11,541	6,720
Granger	Williamson	City of Georgetown	190	66%	Y	11,541	6,720
Hutto	Williamson	BRA/LCRA BCRWSS West	12,477	93%	N	4,394	1,857
Jonah Water SUD	Williamson	City of Georgetown	2,737	58%	N	11,541	6,720
Leander	Williamson	City of Leander	27,698	81%	Y	3,334	1,409
Mining	Williamson	City of Georgetown	9,988	96%	N	11,541	6,720
Thrall	Williamson	City of Taylor	139	96%	N	4,893	489
Williamson C-O	Williamson	City of Leander	16,481	78%	N	3,334	1,409
Irrigation	Williamson	BRA/LCRA BCRWSS East	62	44%	N	50,528	21,359
Taylor	Williamson	City of Taylor	21	0%	N	4,893	489
Florence	Williamson	BRA TBRSS	92	61%	N	26,794	26,790

3.2.3 Environmental Issues

A summary of environmental issues is presented in Table 3.2-2.

3.2.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply would be expected to vary considerably between entities based on the upgrades required both in treatment and distribution. Therefore, general cost estimates were developed for varying wastewater reuse scenarios as described in Table 3.2-3. To provide more flexibility in the types of wastewater reuse applications possible, the scenarios assume the use of a type 1 wastewater effluent.

Table 3.2-2. Environmental Issues: General Wastewater Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations.
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows.
Bays and Estuaries	Possible low negative impact.
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows.
Cultural Resources	Possible low impact.
Threatened and Endangered Species	Possible variable impacts depending on habitat requirements for listed species.
Comments	Assumes needed infrastructure will be in urbanized areas.

Table 3.2-3. Wastewater Reuse Scenarios

Scenario #	Treatment	Distribution
1	Existing WWTP is achieving treatment that meets the Type 1 effluent requirements. Treatment upgrade includes only the addition of chlorine for distribution.	Treated wastewater is supplied to demand location(s) from central WWTP by addition of piping and pump station.
2	Existing WWTP is nearly achieving treatment that meets the Type 1 effluent requirements. Treatment upgrade includes tertiary treatment and chlorine.	Treated wastewater is supplied to demand location(s) from central WWTP by addition of piping and pump station.

Scenarios 1 and 2 include central storage at the wastewater plant with reuse water delivered to demand location on an as needed basis. An alternate delivery option not included here is a more decentralized reuse system with storage located at the point of use. Providing storage at the point of use may decrease required pipeline and pump station size because the water can be transported at a more uniform rate to fill storage tanks at the point of use. However, installation of storage tanks at the point of use may be problematic in highly urbanized areas or undesirable near high public use areas.

Cost estimates were developed for each of these scenarios with required facilities for each scenario shown in Table 3.2-4. The demand for reuse water used for irrigation of golf courses, parks, schools, crops, or other landscapes will vary seasonally. For planning purposes the application rates in Table 3.2-5 are assumed to determine the available project yield for varying sizes of wastewater reuse facilities. Reuse facilities are sized for the peak usage periods, and consequently, the average annual rate of usage may be considerably lower than the peak usage. For a reuse system with typical application rates, as shown in Table 3.2-5, the annual available project yield is 57 percent of the reuse system capacity. Available project yield may be higher than 57 percent of maximum capacity for systems supplying a large portion of the reuse water to industrial or other users that have a more uniform reuse water demand.

Table 3.2-4. Wastewater Reuse Scenarios 1, and 2 Required Distribution Facilities

Facility	Maximum Capacity (MGD)				Description
	0.5	1	5	10	
Pump Station, HP	127	248	1,209	2,332	Capacity to deliver maximum daily demand in 6 hours
Storage Tank, MG	0.5	1	5	10	Store one days treated reuse water at WWTP
Pipeline, Size in Inches (Length in Miles)	12 (2)	16 (2)	30 (3) 18 (2) 12 (1)	48 (4) 18 (3) 12 (2)	Capacity to deliver maximum daily demand in 6 hours
Available Project Yield, acft/yr (MGD)	319 (0.28)	638 (0.57)	3,193 (2.85)	6,385 (5.7)	Yield is 57 percent of maximum treatment capacity based on seasonal use shown in Table 3.1-7

Table 3.2-5. Wastewater Reuse Irrigation Application Rate

Use Level	Application Rate	Duration
Peak	1.25 in/week	4 months
Normal	0.75 in/week	3 months
Below Normal	0.25 in/week	5 months
Average	0.71 in/week	weighted
Average/Peak	0.71 / 1.25 = 0.57	

Irrigation water for landscapes such as golf courses and parks will generally be applied during periods when these areas are not being utilized, typically at night. Therefore, the distribution facilities are sized to deliver the total daily demand in a 6-hour period. Pumping facilities are sized to provide a residual pressure of 60 psi at the delivery point.

Table 3.2-6 shows annual cost of reuse water per 1,000 gallons for a range of project scenarios and capacities. Figure 3.2-3 expresses those costs graphically as an annual cost per acft. These costs are for general planning purposes and will vary significantly depending on the specific circumstances of an individual water user group. Table 3.2-7 and Table 3.2-8 show the total project capital costs and total operations and maintenance costs for reuse water supplies, respectively.

Table 3.2-6. General Wastewater Reuse Annual Cost of Water ($ per 1,000 gal available project yield)

Scenario	Capacity (MGD)			
	0.5	1	5	10
1	$3.43	$2.74	$1.69	$1.50
2	$7.38	$5.62	$3.40	$2.99
Debt Service (5.5 percent for 20 years)				

Figure 3.2-3. General Wastewater Reuse Annual Cost of Water ($ per acft available project yield)

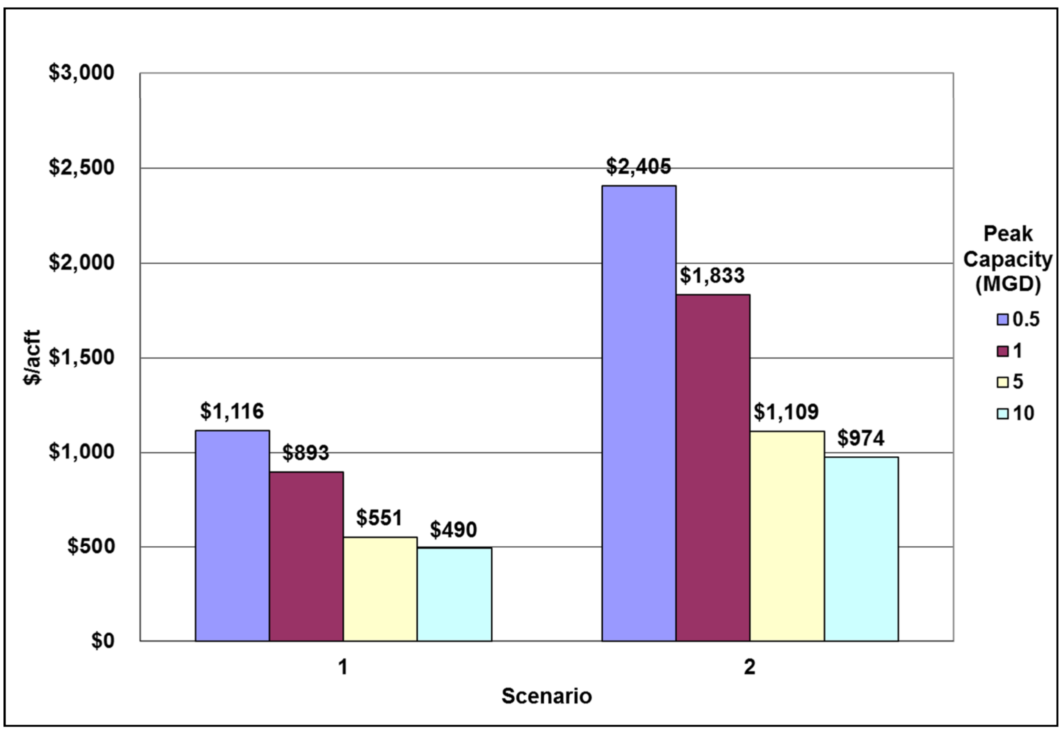

Table 3.2-7. General Wastewater Reuse Total Project Capital Cost ($ per gallon maximum capacity)

Scenario	Maximum Capacity (MGD)			
	0.5	1	5	10
1	$6.78	$5.30	$3.16	$1.58
2	$10.32	$7.83	$4.53	$2.27

Table 3.2-8. General Wastewater Reuse Total Operations and Maintenance Cost ($ per 1,000 gallons)

Scenario	Maximum Capacity (MGD)			
	0.5	1	5	10
1	$0.70	$0.61	$0.42	$0.36
2	$3.23	$2.47	$1.58	$1.39

The general wastewater reuse costs are utilized to develop the cost estimates for individual water user groups shown in Table 3.2-9. Cost Estimate Summaries: Reuse as a Water Management Strategy for Multiple Water User Groups. The reuse project maximum capacity (MGD) for each water user group was developed based on the "2070 Projected Need" and "2070 Potential Reuse," as shown in Table 3.2-1. A reuse scenario, as shown in Table 3.2-1, was applied to each water user group based on available information about existing wastewater treatment facilities proximate to the need.

Information for individual water user groups that have specific reuse water supply options are not included in Table 3.2-9; the individual options should be referenced for information on reuse options for these water user groups.

3.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.2-10, and the option meets each criterion. Each community that pursues wastewater reuse will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit restrictions,
- Potential users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas), and
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.

Table 3.2-9. Cost Estimate Summaries: Reuse as a Water Management Strategy for Multiple Water User Groups

WUG	County	Reuse Maximum Capacity (MGD)	Available Project Yield (MGD)	Scenario	Unit Cost ($/1000 gal)	Project Cost ($/gal)	Project Cost ($)
Killeen	Bell	See Individual Option					
Elm Creek WSC	Bell	0.1	0.057	2	$7.38	$10.32	$1,032,000
Nolanville	Bell	0.5	0.285	2	$7.38	$10.32	$5,162,000
Bell C-O	Bell	0.2	0.114	2	$7.38	$10.32	$2,065,000
Little River-Academy	Bell	0.2	0.114	2	$7.38	$10.32	$2,065,000
Harker Heights	Bell	See Individual Option					
Manufacturing	Bell	1	1	2	$5.62	$7.83	$7,834,000
Steam-Electric	Bell	7.5	7.5	2	$2.99	$2.27	$16,997,000
Irrigation	Bell	1	1	2	$5.62	$7.83	$7,834,000
Mining	Bell	5	5	2	$3.40	$4.53	$22,662,000
Temple	Bell	1	1	2	$5.62	$7.83	$7,834,000
Bryan	Brazos	See Individual Option					
College Station	Brazos	See Individual Option					
Manufacturing	Brazos	2	2	2	$3.40	$4.53	$9,065,000
Mining	Brazos	0.5	0.5	2	$7.38	$10.32	$5,162,000
Irrigation	Brazos	1	1	2	$5.62	$7.83	$7,834,000
Gatesville	Coryell	0.2	0.114	2	$7.38	$10.32	$2,065,000
Steam-Electric	Grimes	5	5	2	$3.40	$4.53	$22,662,000
Cleburne	Johnson	See Individual Option					
Godley	Johnson	0.1	0.057	2	$7.38	$10.32	$1,032,000
Joshua	Johnson	0.1	0.057	2	$7.38	$10.32	$1,032,000
Venus	Johnson	0.1	0.057	2	$7.38	$10.32	$1,032,000
Steam-Electric	Johnson	5	5	2	$3.40	$4.53	$22,662,000
Hawley WSC	Jones	0.1	0.057	2	$7.38	$10.32	$1,032,000
Anson	Jones	0.1	0.057	2	$7.38	$10.32	$1,032,000
Mining	Jones	0.1	0.057	2	$7.38	$10.32	$1,032,000
Mining	Lee	2	1.14	2	$3.40		
Bellmead	McLennan	See Individual Option					

Table 3.2-9. Cost Estimate Summaries: Reuse as a Water Management Strategy for Multiple Water User Groups

WUG	County	Reuse Maximum Capacity (MGD)	Available Project Yield (MGD)	Scenario	Unit Cost ($/1000 gal)	Project Cost ($/gal)	Project Cost ($)
Chalk Bluff WSC	McLennan	See Individual Option					
Hallsburg	McLennan	See Individual Option					
Lacy Lakeview	McLennan	See Individual Option					
Mart	McLennan	See Individual Option					
Riesel	McLennan	See Individual Option					
North Bosque WSC	McLennan	0.1	0.057	1	$3.43	$6.78	$678,000
Robinson	McLennan	0.2	0.114	1	$3.43	$6.78	$1,356,000
West Brazos WSC	McLennan	0.1	0.057	1	$3.43	$6.78	$678,000
Irrigation	McLennan	1	1	1	$2.74	$5.30	$5,297,000
Mining	McLennan	See Individual Option					
Manufacturing	McLennan	1	1	1	$2.74	$5.30	$5,297,000
Sweetwater	Nolan	0.5	0.285	1	$3.43	$6.78	$3,391,000
Steam-Electric	Robertson	0.2	0.2	2	$7.38	$10.32	$2,065,000
Merkel	Taylor	0.1	0.057	2	$7.38	$10.32	$1,032,000
Mining	Taylor	0.2	0.2	2	$7.38	$10.32	$2,065,000
Blockhouse MUD	Williamson	0.5	0.285	2	$7.38	$10.32	$5,162,000
Brushy Creek MUD	Williamson	0.5	0.285	2	$7.38	$10.32	$5,162,000
Chisholm Trail SUD	Williamson	1.	0.57	2	$5.62	$7.83	$7,834,000
Georgetown	Williamson	5	2.85	2	$3.40	$4.53	$22,662,000
Granger	Williamson	0.2	0.114	2	$7.38	$10.32	$2,065,000
Hutto	Williamson	0.5	0.285	2	$7.38	$10.32	$5,162,000
Jonah Water SUD	Williamson	1	0.57	2	$5.62	$7.83	$7,834,000
Leander	Williamson	1	0.57	2	$5.62	$7.83	$7,834,000
Mining	Williamson	5	5	2	$3.40	$4.53	$22,662,000
Thrall	Williamson	0.1	0.057	2	$7.38	$10.32	$1,032,000
Williamson C-O	Williamson	0.2	0.114	2	$7.38	$10.32	$2,065,000
Irrigation	Williamson	0.1	0.1	2	$7.38	$10.32	$1,032,000
Taylor	Williamson	0.1	0.057	2	$7.38	$10.32	$1,032,000
Florence	Williamson	0.1	0.057	2	$7.38	$10.32	$1,032,000

Table 3.2-10. Comparison of General Wastewater Reuse Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. Possible impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	Could offset the need for voluntary redistribution of other supplies

Reuse of reclaimed wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water customers may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- TPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

3.3 City of College Station Non-Potable Reuse

3.3.1 Description of Option

The City of College Station is currently applying reuse as a water supply from the Carters Creek WWTP for irrigation at Veterans Park and other customers. The City has obtained TCEQ Reclaimed Water Type 1 permits to utilize treated wastewater from the Lick Creek and Carters Creek WWTPs. The City is considering expanding the reuse system, and is conducting a strategy study to determine the most cost effective system. One option (called the Irrigation Option) is to provide 103 acft/yr irrigation supply to Post Oak Mall, Central Park and a planned Industrial Park are to the west of Carters Creek WWTP. Although average annual demand for these three facilities totals approximately 103 acft/yr, the reuse system must be sized to meet the peak irrigation demand during the summer months, which is about 0.25 MGD or 282 acft/yr.

The location of the current system and possible future expansion is shown in Figure 3.3-1. As shown on the map, Veterans Park, Adam Development, and Crescent Pointe are north of Carters Creek WWTP within the current service area; and, the Post Oak Mall, Central Park and a planned Industrial Park are to the west of Carters Creek WWTP. A summary of irrigation demand for existing and planned customers is included in Table 3.3-1.

3.3.2 Available Supply

The water supply that would be potentially available for College Station would be that portion of their wastewater effluent stream that has suitable uses within an economical distance from the treatment plant. The average daily effluent flow from the Carters Creek WWTP for the summer months of the year 2011 was 3,534 gpm (5.09 MGD).

College Station wastewater treatment plants include Carters Creek and Lick Creek WWTPs. The combined Year 2070 Estimated WWTP Effluent for these WWTP plants is 16,008 acft/yr (14.3MGD). Based on feedback from the WWTP operators the combined Year 2070 Confirmed WWTP Effluent for these WWTP is 0 acft/yr since the City is planning on reusing all of the treated wastewater.

Figure 3.3-1. College Station Non-Potable Reuse

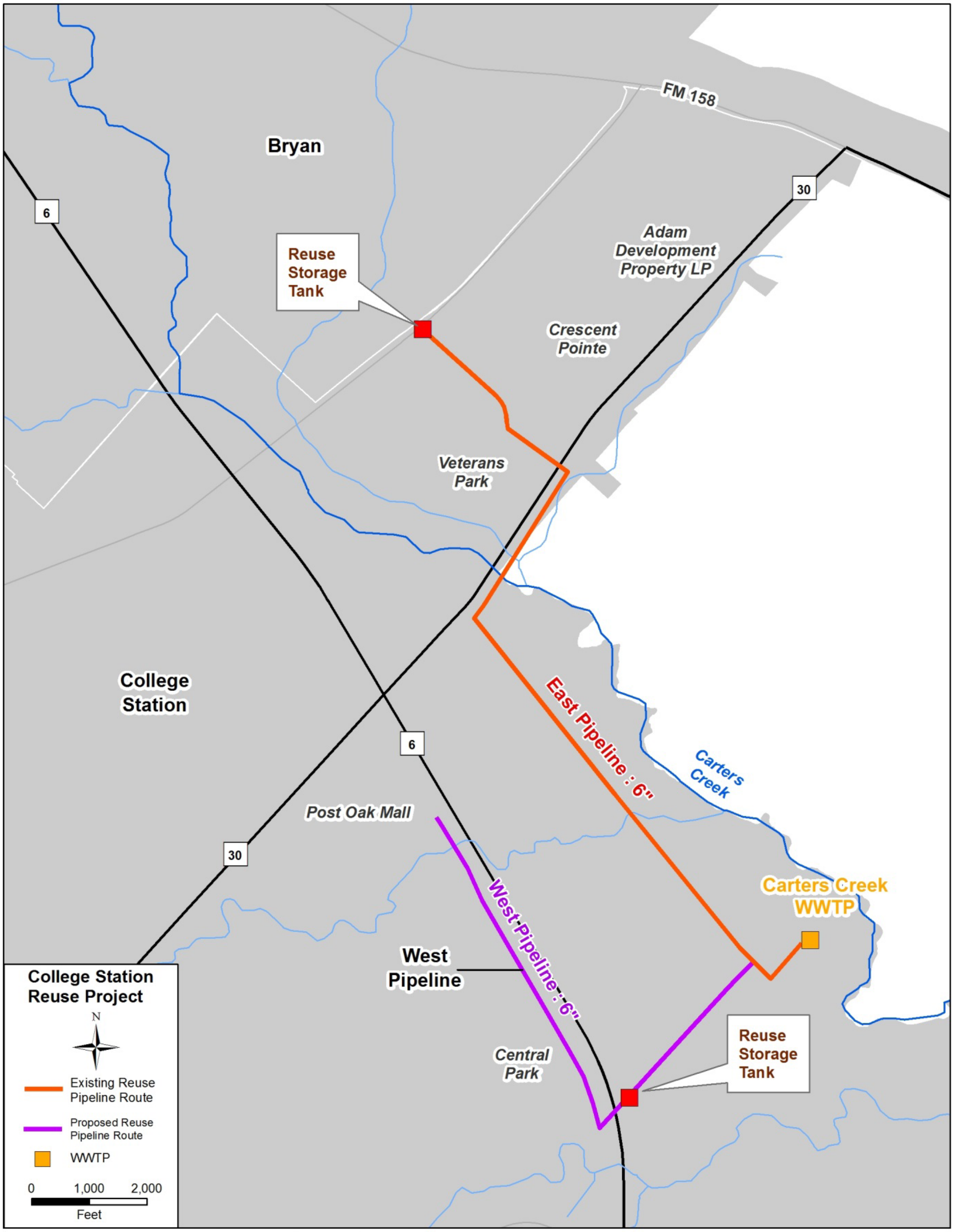

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Table 3.3-1. Water Reuse Demands for College Station Non-Potable Reuse Project

Reuse Customer	Current (acft/yr)	Proposed (acft/yr)
Veteran's Park	141	
Crescent Pointe	13	
Adam Development	56	
Central Park		57
Post Oak Mall		33
Planned Industrial Park		13
Total	209	103

3.3.3 Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows;
- Possible high negative impact to fish and wildlife habitat with substantially reduced stream flows; and
- Possible negative impact to threatened and endangered species depending on habitat and stream flow requirements.

A summary of environmental issues is presented in Table 3.3-2.

Table 3.3-2. Environmental Issues: College Station Non-Potable Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible variable impacts depending on habitat requirements for listed species.
Comments	Assumes needed infrastructure will be in urbanized areas

3.3.4 Engineering and Costing

The irrigation option will include a pump station at the wastewater treatment plant, a pipeline for customers west of Texas Hwy 6, and ground storage at the end of the pipeline to balance the daily supply and hourly demand. The distribution facilities are sized to deliver the total daily demand in a 6-hour period. Pumping facilities are sized to deliver the water to a ground storage tank near the irrigation demand. Distribution pumps and pipelines would draw water from the storage tank as needed. The required improvements to implement a wastewater reuse supply for College Station are summarized in Table 3.3-3. The total costs for expanding the reuse system are shown in Table 3.3-4. The unit cost of a reuse supply could potentially be decreased by the addition of other users within an economical distance from the WWTP(s).

Table 3.3-3. Required Facilities – College Station Reuse for Veterans Park Irrigation

Facility	Description
Treatment Upgrade	0.09 MGD, Scenario 1; existing WWTP meets type 1 reuse standards, requiring only the addition of chlorine for distribution
Pump Station(s)	Expansion of existing reuse pump station with dedicated pumps - 8 HP to deliver average demand of 0.09 MGD in 6 hours
Storage Tank	0.17; Store one days treated reuse water at the end of the pipeline
Pipeline	11,278 ft of 6-inch pipe
Available Project Yield	0.09 MGD (103 acft/yr)

3.3.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.3-5, and the option meets each criterion. Before pursuing wastewater reuse, College Station will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, and not committed under separate contracts.
- Potential other users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- Texas Pollutant Discharge Elimination System (TPDES) Storm Water Pollution Prevention Plan; and

- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

Table 3.3-4. Cost Estimate Summary: College Station Non-Potable Reuse

Item	Estimated Costs for Facilities
Transmission Pipeline (6 in dia., 2 miles)	$661,000
Transmission Pump Station(s) & Storage Tank(s)	$312,000
Storage Tanks (Other Than at Booster Pump Stations)	$231,000
Water Treatment Plant (0.1 MGD)	$16,000
Total Cost Of Facilities	**$1,220,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$394,000
Environmental & Archaeology Studies and Mitigation	$53,000
Surveying (17 acres)	$8,000
Interest During Construction (4% for 0.5 years with a 1% ROI)	$30,000
Total Cost Of Project	**$1,705,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$143,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$17,000
Water Treatment Plant (2.5% of Cost of Facilities)	$10,000
Pumping Energy Costs (35784 kW-hr @ 0.09 $/kW-hr)	$3,000
Total Annual Cost	**$173,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 2.725	**103**
Annual Cost of Water ($ per acft)	**$1,680**
Annual Cost of Water ($ per 1,000 gallons)	**$5.15**

Table 3.3-5. Comparison of College Station Non-Potable Reuse Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. Possible impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	Could offset the need for voluntary redistribution of other supplies

3.4 College Station Direct Potable Reuse

3.4.1 Description

The City of College Station is considering two options to utilize its treated wastewater for potable uses. One option that is described in Chapter 10.2 purifies the city's treated effluent and utilizes an aquifer storage and recovery (ASR) wellfield to store potable supplies for peaking demands. The second option described in this section, purifies the supplies and blends it back with the City's treated water sources for subsequent distribution. The concept for the City of College Station (College Station) Direct Potable Reuse project is to:

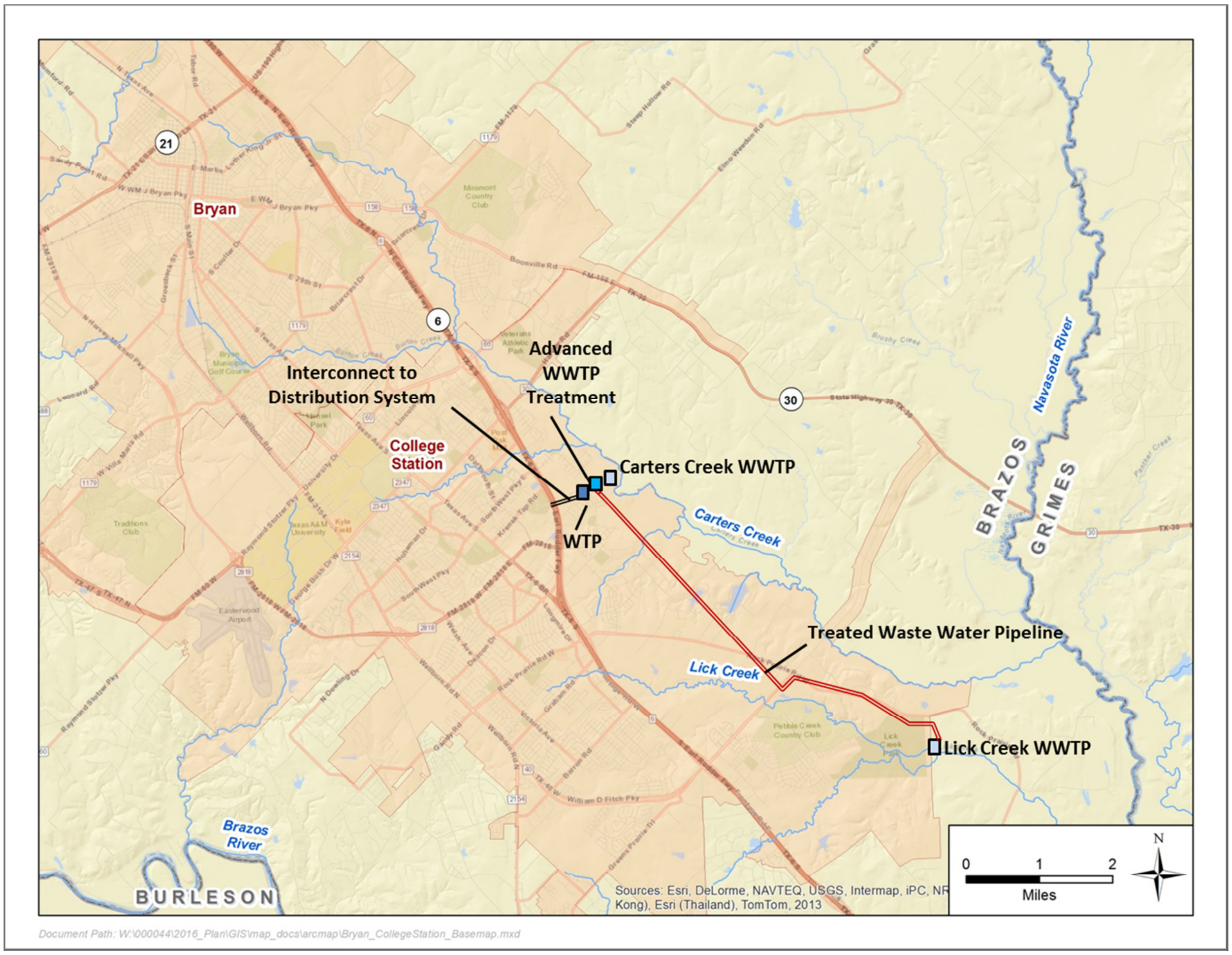
- Utilize existing wastewater effluent as the source of water for direct potable reuse. For 2005-2007, the average effluent discharges from Carters Creek WWTP and Lick Creek WWTP were 5.75 and 0.68 million gallons per day (MGD), respectively.
- A new Water Treatment Plant and Advance Wastewater Treatment Plant (AAWTP) would be located near the Carters Creek WWTP. Effluent from the much smaller Lick Creek WWTP would be transported to the AAWTP through a new pipeline.
- The AAWTP would treat the treated wastewater effluent with: (1) Low Pressure Membrane, (2) Reverse Osmosis, and (3) Oxidation before sending the water through a WTP as additional buffer and credit toward required log removal.

A schematic showing the location of the project is shown in Figure 3.4-1. New facilities required for this option are the pump station and wastewater transmission pipeline from Lick Creek WTP and Carters Creek WTP, advanced water treatment plant, interconnects between AAWTP, WTP and College Station's distribution system.

3.4.2 Available Yield

College Station wastewater treatment plants include Carters Creek and Lick Creek WWTPs. The combined Year 2070 Estimated WWTP Effluent for these WWTP plants is 16,008 acft/yr (14.3MGD). Based on feedback from the WWTP operators the combined Year 2070 Confirmed WWTP Effluent for these WWTP is 0 acft/yr since the City is planning on reusing all of the treated wastewater.

Figure 3.4-1. Location of College Station's Direct Potable Reuse Project



3.4.3 Environmental Issues

A summary of environmental issues is presented in Table 3.4-1.

Table 3.4-1. Environmental Issues: College Station Direct Potable Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible variable impacts depending on habitat requirements for listed species.
Comments	Assumes needed infrastructure will be in urbanized areas

3.4.4 Engineering and Costing

The major facilities required for these projects include:

- Pump Station at Lick Creek WTP,
- Advance Wastewater Treatment Plant,
- Water Treatment Plant;
- Transmission pipeline between AAWTP and distribution system, and
- Interconnect to existing distribution system.

Estimates were prepared for capital and project costs, annual debt service, operation and maintenance, power, land, and environmental mitigation. These costs are summarized in Table 3.4-2. The annual costs, including debt service, operation and maintenance, and power, is estimated to be $3,484 per acft for the College Station project.

3.4.5 Implementation

Implementation of the DPR water management strategy for College Station includes the following issues:

- Close coordination with TCEQ to define treatment criteria for expected 5.5 log removal cryptosporidium, 6 log removal giardia, 8 log removal virus after secondary/tertiary WWTP ;
- Acquiring permits from TCEQ for the Water Treatment Plant facilities construction and operations;
- Initial and operational cost; and
- Development of a management plan to efficiently use the reuse supply.
- Currently, several log removal required by TCEQ: 5.5 log crypto, 6 log giardia, 8 log virus (after secondary/tertiary WWTP) means that the city would need to provide additional treatment barriers beyond an AWWTP in order to achieve expected log removals. This analysis assumes construction of a new WTP to provide the additional log removals.

This water supply option has been compared to the plan development criteria, as shown in Table 3.4-3, and the option meets each criterion.

Table 3.4-2. Cost Estimate Summary: College Station DPR Project Option

Item	Estimated Costs for Facilities
Pump Stations	$2,747,000
Transmission Pipelines	$2,317,000
Advanced Wastewater Treatment Plant (5.5 MGD)	$23,100,000
Water Treatment Plant (5.5 MGD)	$11,337,000
Integration, Relocations, & Other	$250,000
TOTAL COST OF FACILITIES	**$39,751,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$13,797,000
Environmental & Archaeology Studies and Mitigation	$398,000
Land Acquisition and Surveying (47 acres)	$345,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,901,000
TOTAL COST OF PROJECT	**$56,192,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$4,702,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$94,000
Water Treatment Plant (2.5% of Cost of Facilities)	$4,853,000
Pumping Energy Costs (4463825 kW-hr @ 0.09 $/kW-hr)	$106,000
Purchase of Water (acft/yr @ $/acft)	$0
TOTAL ANNUAL COST	**$9,755,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 2	**2,800**
Annual Cost of Water ($ per acft)	**$3,484**
Annual Cost of Water ($ per 1,000 gallons)	**$10.69**

Table 3.4-3. Comparison of College Station DPR Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Does not fully shortages
2. Reliability	2. High reliability
3. Cost	3. High
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. None
3. Cultural Resources	3. None
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. None
C. Impact on Other State Water Resources	None
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered in an attempt to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

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3.5 City of Bryan Lake Bryan Reuse

3.5.1 Description of Option

The City of Bryan currently irrigates the Traditions Golf Course with Type 2 treated wastewater effluent from Thompson's Creek WWTP, a small package treatment plant located near the golf course with a capacity of 2.0 MGD. The City has two other WWTPs, Burton Creek and Still Creek, that produce effluent requiring additional treatment to meet Type 1 reuse water requirements. There are several parks, ball fields, and other green spaces dispersed throughout the City that could be irrigated with reuse water if the wastewater could be treated and distributed economically. However, these green spaces do not individually have large irrigation water demands and are located a significant distance from the existing wastewater treatment plant. Therefore, irrigation reuse options were not evaluated.

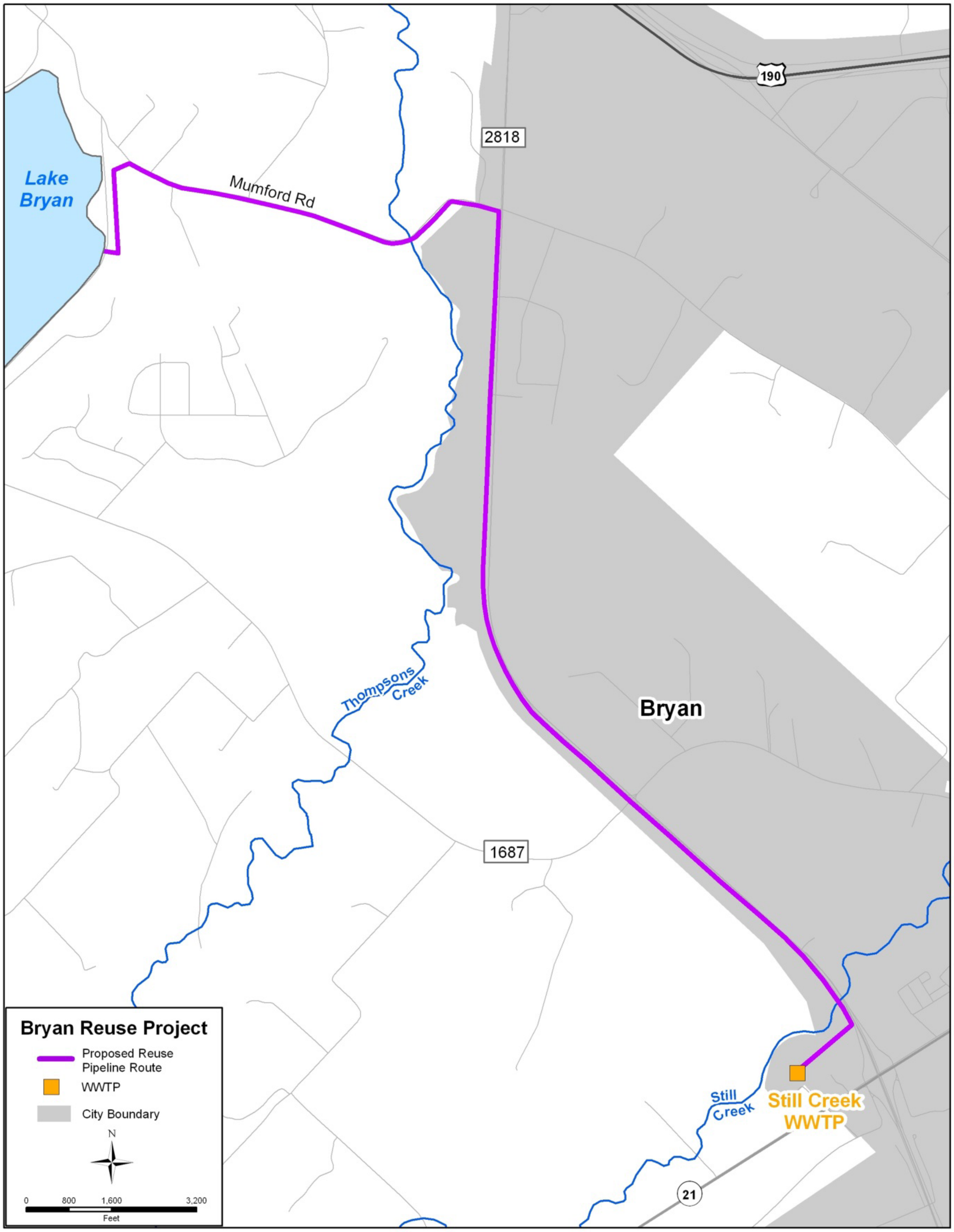
The City is considering two alternate reuse projects using treated supplies from Still Creek WWTP to either offset potable demand (Option 1) or as indirect potable reuse (Option 2). Option 1 consists of a reuse project to deliver Type 1 treated wastewater to Bryan Utilities Lake, a small lake associated with a power generation plant (Figure 3.5-1). The City has periodically supplied potable water to this lake for extended periods at a rate of up to 3,000 gpm (4.32 MGD). This option will replace a portion of this potable water demand with a wastewater reuse supply having a peak capacity of 1,500 gpm (2.16 MGD). Since Bryan Utilities Lake is used for recreational purposes, this option includes additional treatment at Still Creek WWTP to supply Type 1 reuse water to the lake. The reuse water supply will be delivered at a continuous daily rate during periods of demand, so no storage is required. The project yield is based on an average demand of 2.16 MGD for 3 months during each year.

Option 2 utilizes similar infrastructure to deliver treated effluent to Bryan Utilities Lake for blending and subsequent treatment to drinking water standards and combining it with existing groundwater supply. However, reuse supplies will be delivered at a uniform rate of 2.16 MGD. An advanced water treatment facility consisting of low pressure membranes, reverse osmosis and advanced oxidation would be constructed nearby to treat blended supplies from Bryan Utilities Lake. The location of the WTP has not been selected and would be subject to availability of land.

3.5.2 Available Supply

The water supply that would be potentially available for Bryan would be that portion of their wastewater effluent stream that has suitable uses within an economical distance from the treatment plant. The City of Bryan has confirmed that it plans to reuse all of its treated wastewater by 2070. The Still Creek WWTP Year 2070 Estimated WWTP Effluent is 3,557 acft/yr (3.17 MGD). The Burton Creek WWTP Year 2070 Estimated WWTP Effluent is 11,561 acft/yr (10.31 MGD).

Figure 3.5-1. Bryan Reuse Option 1 and Option 2



3.5.3 Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible impact to water quality in Bryan Utilities Lake and potential for release downstream of reuse water from Bryan Utilities Lake,
- Possible increased water quality to remaining stream flows;
- Possible high negative impact to fish and wildlife habitat with substantially reduced stream flows; and
- Possible negative impact to threatened and endangered species depending on habitat and stream flow requirements.

A summary of environmental issues is presented in Table 3.5-1.

Table 3.5-1. Environmental Issues: Bryan Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible variable impacts depending on habitat requirements for listed species.
Comments	Assumes needed infrastructure will be in urbanized areas

3.5.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply for Bryan's Option 1 are summarized in Table 3.5-2. Costs presented in Table 3.5-3 provide the total Option 1 costs for developing a wastewater reuse supply to Bryan Utilities Lake. The required improvements to implement a indirect potable reuse supply for Bryan's Option 2 are summarized in Table 3.5-4. Costs presented in Table 3.5-5 provide the total Option 2 costs for developing an indirect potable reuse supply. System integration costs are not included in the estimate.

Table 3.5-2. Required Facilities – Bryan Reuse Option 1

Facility	Description
Treatment Upgrade	2.16 MGD, Scenario 2; existing WWTP requires additional tertiary treatment to meet type 1 standards and addition of chlorine for distribution
Pump Station	174 hp; 2.16 MGD capacity to deliver peak capacity at uniform rate
Storage Tank	None
Pipeline	29,000 ft of 12-inch pipe
Available Project Yield	0.54 MGD (605 acft/yr), yield is 3 months per year of peak demand supplied to lake

Table 3.5-3. Cost Estimate Summary: Option 1 Reuse for Bryan Utilities Lake Supply

Item	Estimated Costs for Facilities
Transmission Pipeline (12 in dia., 6 miles)	$1,282,000
Transmission Pump Station(s) & Storage Tank(s)	$1,502,000
Wastewater Treatment Plant Upgrades	$2,942,000
Total Cost Of Facilities	**$5,726,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,940,000
Environmental & Archaeology Studies and Mitigation	$188,000
Land Acquisition and Surveying (34 acres)	$831,000
Interest During Construction (4% for 1 years with a 1% ROI)	$304,000
Total Cost Of Project	**$8,989,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$752,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$50,000
Water Treatment Plant (2.5% of Cost of Facilities)	$122,000
Pumping Energy Costs (128384 kW-hr @ 0.09 $/kW-hr)	$12,000
Total Annual Cost	**$936,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 4	605
Annual Cost of Water ($ per acft)	$1,547
Annual Cost of Water ($ per 1,000 gallons)	$4.75

Table 3.5-4. Required Facilities – Bryan Indirect Potable Reuse Option 2

Facility	Description
Treatment Upgrade	2.16 MGD, Scenario 2; existing WWTP requires additional tertiary treatment to meet type 1 standards and addition of chlorine for distribution
New WTP	2.3 MGD Advanced WTP (low pressure membranes, RO, advanced oxidation)
Pump Station	174 hp; 2.16 MGD capacity to deliver peak capacity at uniform rate
Intake & Pump Station	43 hp; 2.3 MGD capacity to deliver from Lake Bryan to Advanced WTP
Storage Tank	None
Pipeline	31,000 ft of 12-inch pipe
Available Project Yield	2.19 MGD (2,419 acft/yr)

Table 3.5-5. Cost Estimate Summary: Option 2 Indirect Potable Reuse for Bryan

Item	Estimated Costs for Facilities
Intake Pump Stations	$1,069,000
Transmission Pipeline (12 in dia., 6 miles)	$1,379,000
Transmission Pump Station(s) & Storage Tank(s)	$1,664,000
WWTP Improvements	$2,942,000
Advanced Water Treatment Plant (2.3 MGD)	$9,072,000
Total Cost Of Facilities	**$16,126,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$5,575,000
Environmental & Archaeology Studies and Mitigation	$232,000
Land Acquisition and Surveying (41 acres)	$1,454,000
Interest During Construction (4% for 1 years with a 1% ROI)	$819,000
Total Cost Of Project	**$24,206,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$2,026,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$82,000
Water Treatment Plant (2.5% of Cost of Facilities)	$1,579,000
Pumping Energy Costs (1418459 kW-hr @ 0.09 $/kW-hr)	$128,000
Purchase of Water (acft/yr @ $/acft)	$0
Total Annual Cost	**$3,815,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	2,419
Annual Cost of Water ($ per acft)	$1,577
Annual Cost of Water ($ per 1,000 gallons)	$4.84

3.5.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.5-6, and the option meets each criterion. The City of Bryan will select Option 1 or Option 2 as a reuse strategy.

Before pursuing wastewater reuse Option 1, Bryan will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit restrictions.
- Potential users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.
- Regulatory approval of a new discharge (permit) into Bryan Utilities Lake

Before pursuing indirect potable reuse Option 2, Bryan will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit restrictions.
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.
- Public acceptance and regulatory approval of this water management strategy
- Integration of surface water source into a groundwater system which may affect water quality and disinfection compatibility

Table 3.5-6. Comparison of Bryan Reuse Options to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Potentially produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. Potential impact

Table 3.5-6. Comparison of Bryan Reuse Options to Plan Development Criteria

Impact Category	Comment(s)
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	Could offset the need for voluntary redistribution of other supplies

Supply of indirect potable reuse would require a TCEQ discharge permit for returning treated effluent to Bryan Utilities Lake, as well as TCEQ approval of the new surface water supply from the lake. Approval of a TCEQ discharge permit would likely require water quality modeling of Bryan Utilities Lake to help determine effluent limits for dissolved oxygen, biochemical oxygen demand, ammonia-nitrogen and potentially other constituents. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- TPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

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3.6 City of Bryan – Miramont Reuse

3.6.1 Description of Option

In addition to the Lake Bryan reuse project options, the City of Bryan is also considering a reuse project to meet summer peaking needs of the Miramont Country Club from the Burton Creek WWTP. The Burton Creek WWTP is rated for 8 MGD with average daily flow of 5.6 MGD that can meet Type II reuse requirements. The Miramont uses three wells on the property to pump to onsite ponds which are used to irrigate the golf course, rights of way and landscaping. In the peak irrigation months, the Miramont is using approximately 1.6 MGD to irrigate and maintain pond levels. The Miramont's irrigation supply is currently backed up by the City's potable water system.

If Type I effluent is required for the golf course, the Burton Creek WWTP would require tertiary treatment.

3.6.2 Available Supply

The City of Bryan has confirmed that it plans to reuse all of its treated wastewater by 2070. The Burton Creek WWTP Year 2070 Estimated WWTP Effluent is 11,561 acft/yr (10.31 MGD).

3.6.3 Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows;
- Possible negative impact to fish and wildlife habitat with reduced stream flows; and
- Possible negative impact to threatened and endangered species depending on habitat and stream flow requirements.

A summary of environmental issues is presented in Table 3.6-1.

3.6.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply for the Miramont Country Club are summarized in Table 3.6-2. Project and annual costs are included in Table 3.6-3. The total project cost is estimated at $2,544,000 with an average annual cost of $245,000.

Table 3.6-1. Environmental Issues: Bryan Miramont Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible variable impacts depending on habitat requirements for listed species.
Comments	Assumes needed infrastructure will be in urbanized areas

Table 3.6-2. Required Facilities – Bryan Miramont Reuse

Facility	Description
Treatment Upgrade	Additional chlorine for distribution
Pump Station	60 hp pump station
Storage Tank	None
Pipeline	18,600 ft of 12-inch pipe
Available Project Yield	0.54 MGD (600 acft/yr), yield is 4 months per year of peak demand

Table 3.6-3. Cost Estimate Summary: Bryan Miramont Reuse Project

Item	Estimated Costs for Facilities
Pump Station (1.6 MGD)	$500,000
Transmission Pipeline (12 in dia., 4 miles)	$1,303,000
Total Cost Of Facilities	$1,803,000
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$566,000
Environmental & Archaeology Studies and Mitigation	$88,000
Interest During Construction (4% for 1 years with a 1% ROI)	$87,000
Total Cost Of Project	**$2,544,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$213,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$13,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$13,000
Pumping Energy Costs (67906 kW-hr @ 0.09 $/kW-hr)	$6,000
Total Annual Cost	**$245,000**
Available Project Yield (acft/yr)	**600**
Annual Cost of Water ($ per acft), based on a Peaking Factor of 3	**$408**
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 3	**$1.25**

3.6.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.6-4, and the option meets each criterion. Before pursuing wastewater reuse, the City of Bryan will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit requirements.
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.
- Public acceptance of this water management strategy

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- TPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel, and Marl permit for construction in state-owned streambeds.

Table 3.6-4. Comparison of Bryan Miramont Reuse Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. Potential impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	Could offset the need for voluntary redistribution of other supplies

3.7 City of Cleburne Reuse

3.7.1 Description of Option

The City of Cleburne obtains its water supply from Lake Pat Cleburne, Lake Aquilla, and groundwater from the Trinity Aquifer. Lake Pat Cleburne, which is owned and operated by the City, impounds runoff from Nolan Creek for storage and use. The city also has contracted with the Brazos River Authority (BRA) for water supply from Lake Aquilla (5,300 acft/yr), from the BRA System (4,700 acft/yr), and from the BRA System with a Lake Whitney diversion (5,000 acft/yr). The city owns and operates six wells that produce water from the Trinity Aquifer.

The City of Cleburne has embraced the beneficial use of reuse water as a viable water management strategy to meet anticipated future shortages. The city plans to reuse available wastewater supplies to help meet its projected deficit in the year 2070, and has filed a water rights application for 8,440 acre feet (7.5 MGD) with TCEQ to allow reuse of all authorized discharges, which would provide for the city's needs well beyond the current planning horizon.

3.7.2 Available Supply

The City currently supplies 1.2 MGD (1,344 acft/yr) of reuse water directly to a Brazos Electric Power Cooperative Plant located north of the city for use as cooling water. The City of Cleburne owns and operates the existing reuse water treatment facility located on the City's wastewater treatment plant site. The facility is rated for 2.5 MGD capacity and utilizes inclined plate clarification technology to produce a Type 1 effluent for use in unrestricted areas. A 16-inch diameter reuse water transmission line exists along the east side of the city to convey reuse water from the wastewater facility to the power plant and for irrigation at a sports complex.

The City intends to expand the existing reuse water treatment facilities and expand the existing east line to accommodate planned increases in reuse. A 40 acre wetland will also be constructed for additional polishing treatment. Other potential future uses for the east loop reuse line identified by the City of Cleburne include irrigation of a new golf course planned northeast of the city. The reuse projects considered for estimating costs associated with the east loop reuse line include average annual demands of 351 acft/yr, delivered for seasonal uses.

In addition to the expansion of the existing reuse line, the City is planning to develop a new West Loop Reclaimed Water Line and Pump Station to meet other identified non-potable water needs. This project would include a 16-inch diameter reclaimed water pipeline on the west side of the City (Figure 3.7-1), which would join the existing east reclaimed water line serving the Brazos Electric Power Plant (Steam Electric) to form a looped system. This new west loop line would supply reclaimed water for oil and gas development (Mining), irrigation use by Cleburne Municipal Golf Course and commercial facilities, and industrial use (Manufacturing) by the existing James Hardie manufacturing plant and others. This project would supply the City of Cleburne and Johnson County mining, manufacturing, steam electric and irrigation water through Cleburne. The West Loop will be sized to meet a peak daily capacity of 4.5 MGD. Demands for the reuse water are anticipated to increase from 3.3 MGD in 2020 to 5 MGD by 2050 as indicated in Table 3.7-1.

Table 3.7-1. Projected Reuse Demands for Cleburne Reuse Project

Reuse Customers	Year 2020	Year 2050
Brazos Electric Power Plant	1,344	1,344
James Hardie Manufacturing	1,030	3,192
Mining	840	560
Golf course, commercial irrigation	487	487
Sports Complex	17	17
Total Demand (acft/yr)	3,718	5,600

3.7.3 Environmental Issues

The City of Cleburne has filed a water rights application with TCEQ to reuse all effluent discharged pursuant to TPDES Permit No. 10006-001 and new outfall 003. The city is also in the process of amending its Chapter 210 Use of Reclaimed Water authorization to supply reuse water for irrigation to the sports complex facility planned east of the city, and to supplement industrial scenarios for fracking. Additional future reuse will require further amendment of the city's reuse authorization.

Expansion of the reuse water treatment facilities would involve relatively low environmental impacts:

- Reduced effluent discharges to the wastewater outfall could have a low impact on environmental water needs and instream flows.
- For potential future reuse within areas a reasonable distance from the existing reclaimed water pipeline, pipeline construction would be limited since available capacity in the existing 16-inch reclaimed water pipeline is currently underutilized.
- Reduced effluent discharges would reduce the BOD stream loading.

A summary of environmental issues is presented in Table 3.7-2.

Figure 3.7-1. Cleburne Reuse

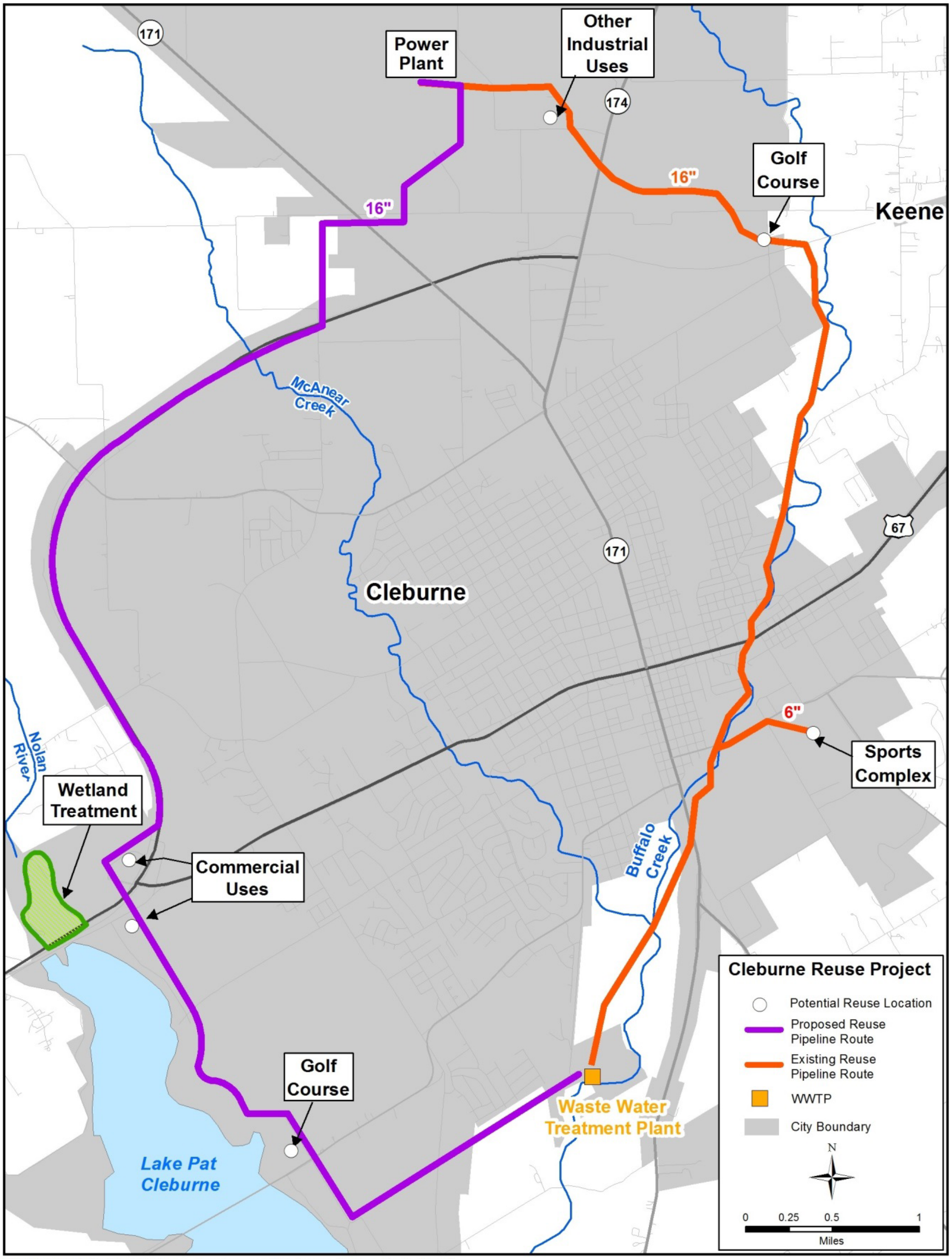

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Table 3.7-2. Environmental Issues: Cleburne Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible variable impacts depending on habitat requirements for listed species.
Comments	Assumes needed infrastructure will be in urbanized areas

3.7.4 Engineering and Costing

The facilities needed to provide reuse water for the proposed expansion of the existing reuse water system and the new west loop include the following:

- Construction of 10.7 mile 16-inch diameter west loop to deliver reuse water to additional and existing customers; and
- Expanded reuse water pump station.
- Construction of 40 acre wetland for polishing treatment

In keeping with the city's goal to maximize its use of reuse water, the additional expansion of the reuse water facilities may cost more than other alternatives that could be used to meet additional portions of the projected water shortage of 6,490 acft/yr in year 2070. As uses of reuse water increase over time, booster pump stations may also be required along the existing 16-inch reuse water line to allow for increased conveyance capacity. Estimated costs to expand the reuse water system as described above are summarized in Table 3.7-3. Total capital costs for the project are $14,059,000 with annual costs of $1,495,000. This translates to $736/ acft or $2.26/ thousand gallons.

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.7-4, and the option meets each criterion. Implementation of this strategy is relatively straightforward and will include the required permit and reuse authorization amendments mentioned previously in addition to right-of-way and easement acquisition for reuse water piping, authorization for creek and river crossings, and financing.

Table 3.7-3. Cost Estimate Summary Cleburne Reuse

Item	Estimated Costs for Facilities
Transmission Pipeline (16 in dia., 11 miles)	$5,617,000
Transmission Pump Station(s) & Storage Tank(s)	$1,243,000
Storage Tanks (Other Than at Booster Pump Stations)	$495,000
Wetlands Treatment (40 acres)	$1,102,000
Meter(s)	$122,000
Total Cost Of Facilities	**$8,579,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,722,000
Environmental & Archaeology Studies and Mitigation	$290,000
Land Acquisition and Surveying (68 acres)	$1,548,000
Interest During Construction (4% for 2 years with a 1% ROI)	$920,000
Total Cost Of Project	**$14,059,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$1,176,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$92,000
Water Treatment Plant (2.5% of Cost of Facilities)	$66,000
Pumping Energy Costs (1790333 kW-hr @ 0.09 $/kW-hr)	$161,000
Total Annual Cost	**$1,495,000**
Available Project Yield (acft/yr)	2,031
Annual Cost of Water ($ per acft)	$736
Annual Cost of Water ($ per 1,000 gallons)	$2.26

Table 3.7-4. Comparison of Cleburne Reuse Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. Potential impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	Could offset the need for voluntary redistribution of other supplies

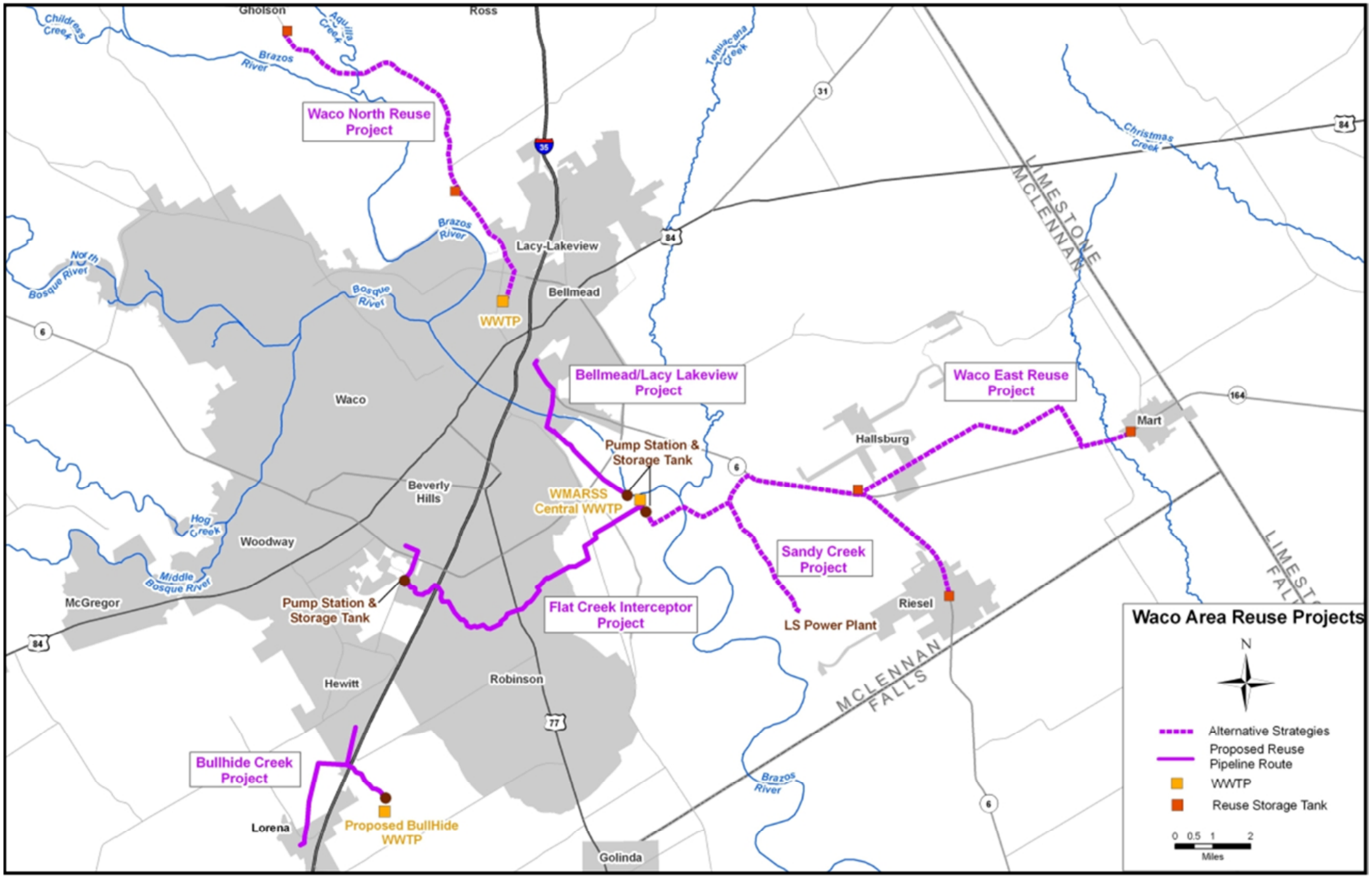
3.8 Waco WMARSS Reuse Projects

Since the 2011 Brazos G Regional Plan, Waco Metropolitan Area Regional Sewerage System (WMARSS) has constructed the Sandy Creek Energy Associates (SCEA) Project which provides 15,000 acft/yr of treated effluent from the WMARSS Central Wastewater Treatment Plant to the SCEA power plant. WMARSS continues to pursue the development of four wastewater reuse systems to supply reuse water to customers. These reuse systems are referred to as the Bellmead/Lacy Lakeview Project, Waco East Project (Cities of Hallsburg, Mart and Riesel), Flat Creek Interceptor Project and Bullhide (3.5MGD) through the Bullhide Creek and Bellmead/Lacy Lakeview reuse projects. Creek Project. Future projects would consider supplying an additional 3,920 acft/yr

Assuming simultaneous implementation of the other reuse projects, potential available supply from the Flat Creek Reuse Project would be 7,114 acft/yr in 2020, and the full 7,847 acft/yr (7 MGD) capacity sometime prior to 2030. The Year 2011 effluent from WMARSS was 25,355 acft/yr (22.6 MGD). The Year 2070 estimated effluent from WMARSS is 36,370 acft/yr (32.5 MGD). These options consists of integrated reuse projects to deliver Type 1 reuse water from the existing WMARSS Central Wastewater Treatment Plant located southeast of Waco along the Brazos River and from the Bull Hide WWTP.

Locations of each of the Waco reuse projects including treatment plants, proposed transmission pipelines, ground storage tanks, and pump stations are shown in Figure 3.8-1. Descriptions of each of the options are included in Sections 3.8.1 through 3.8.5

Figure 3.8-1. Locations of Waco Area Reuse Projects



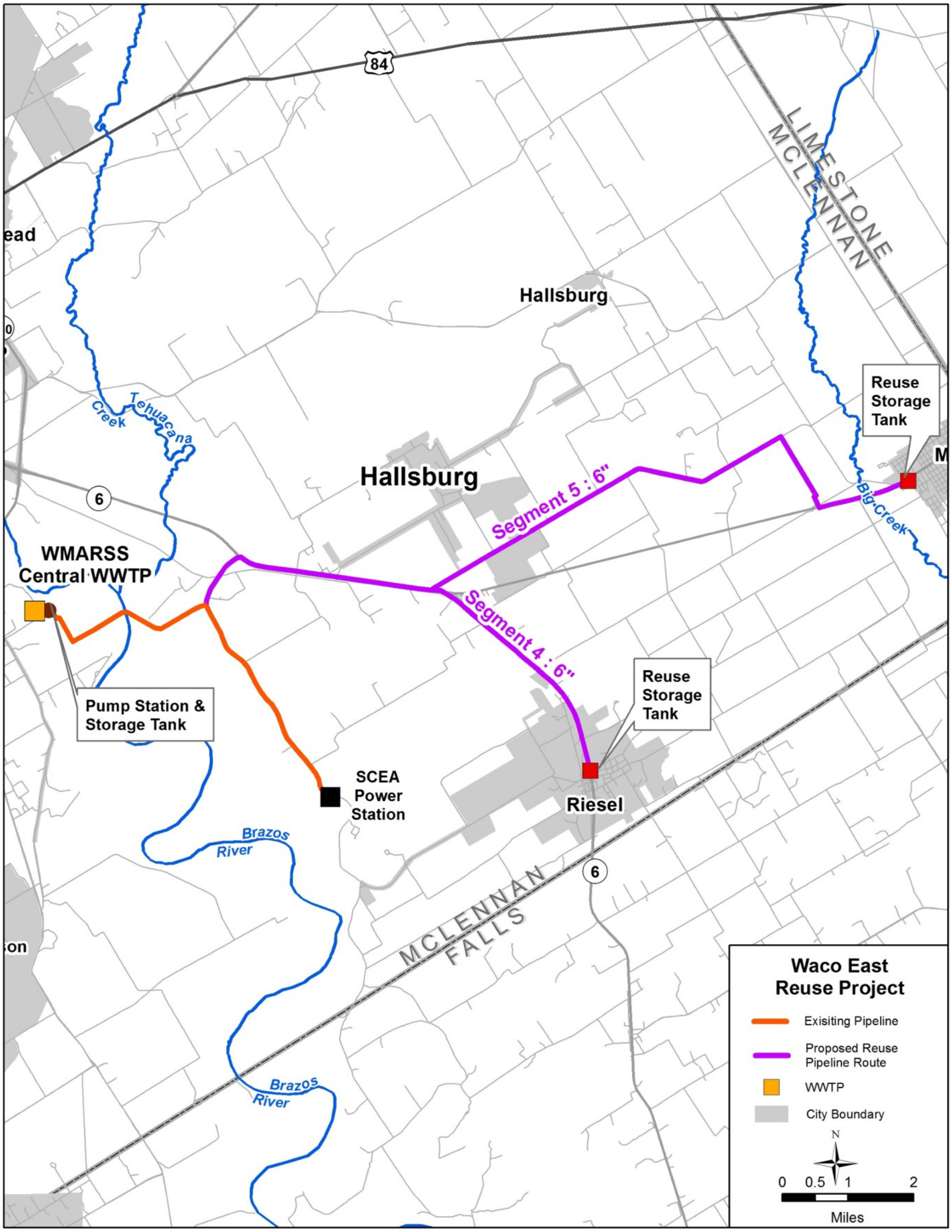
3.8.1 Waco East –Cities of Hallsburg, Mart, and Riesel Reuse

Description of Option

The City of Waco is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the City of Waco and potentially to other entities within the vicinity of Waco. Several water user groups in the vicinity of Waco showing a water supply need by the year 2070 may potentially be provided reuse water as part of this larger Waco reuse system. This option utilizes existing delivery of reuse supplies for cooling and other non-potable uses to the SCEA power station located on Lake Creek Reservoir (Figure 3.8-2) from the WMARSS wastewater treatment plant and a potential expansion to provide Type 1 reuses supplies to the Cities of Hallsburg, Mart, and Riesel.

The potential reuse water demand for the Cities of Hallsburg, Mart, and Riesel is estimated at 30 percent of each city's 2070 water demand for purposes of this option. This Type 1 reuse water may be utilized for landscape irrigation at existing or future parks, schools, ball fields, and other green spaces. Reuse water may also potentially supply existing or future industrial customers within these cities. For this option the transmission system to supply reuse water for these three cities also includes capacity to supply 900 acft/yr of reuse water for use by McLennan County-Mining entities within the vicinity of the reuse transmission pipelines. The amount of reuse water supplied to each entity for this option is summarized in Table 3.8-1.

Figure 3.8-2. Waco East Reuse Project



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Available Supply

The Year 2070 Estimated WWTP Effluent for WMARSS is 36,370 acft/yr (32.5 MGD). Based on feedback from the City of Waco the combined Year 2070 Confirmed WWTP Effluent for this WWTP is 0 acft/yr (0 MGD). Therefore, the 2070 Potential Reuse is the difference between the Estimated and Confirmed WWTP Effluent which is 36,370 acft/yr (32.5 MGD).

Table 3.8-1. Waco East Reuse Water Demand

Entity	2070 Demand (acft/yr)	Reuse Water Demand (acft/yr)	2070 Need (acft/yr)
Hallsburg	102	31	0
Mart	448	134	245
Riesel	144	43	19
McLennan County-Mining	3,921	900	3,647
Total		**1,108**	**3,911**

Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows;
- Possible negative impact to fish and wildlife habitat with reduced stream flows; and
- Possible negative impact to threatened and endangered species depending on habitat and stream flow requirements.

A summary of environmental issues is presented in Table 3.8-2.

Engineering and Costing

Many of the required improvements to implement a reuse supply for this option are shared between the multiple entities. These shared facilities include the upgraded treatment at the WMARSS treatment plant, pump stations, and transmission pipelines. The shared facilities are sized to supply the combined demand for the entities served by each improvement. To determine each entities share of the total improvement cost, the shared improvements are estimated separately and costs per acft of total supply are developed for each shared improvement.

Table 3.8-2. Environmental Issues: Waco East Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible variable impacts depending on habitat requirements for listed species.
Comments	Assumes needed infrastructure will be in urbanized areas

The total cost estimates for each entity include the cost of these shared improvements as annual costs based on the quantity supplied by the improvement to each entity. Due to the economy of scale, significant cost savings are realized by utilizing shared larger improvements for the treatment and delivery of reuse water to all entities supplied by the Waco East water supply option. The total project cost is estimated at $10,421,000 with an average annual cost of $1,090,000.

Table 3.8-3 details the required facilities for this project. The already constructed segment 1 is the initial pipeline segment that transmits reuse water from the WMARSS Central WWTP to other pipelines supplying the SCEA Power Station, Hallsburg, Mart, Riesel, and McLennan County-Mining. The Segment 1 improvements are assumed to be sized for the total demand for all these entities (17,120 acft/yr). Segment 2 is a 27-inch diameter pipeline from the end of Segment 1 to SCEA Power. Segments 1 and 2 have been constructed. Segment 3, 4, and 5 are sized to convey 1,108 acft/yr to the additional potential users of the reuse system. Storage and irrigation pumping are included for Hallsburg, Mart, and Riesel.

Table 3.8-3. Required Facilities – Waco East

Facility	Description
Pump Station	Three booster pump stations 60 hp, 28 hp and 23 hp to deliver 1.0 MGD to storage tanks located at Hallsburg, Mart, or Riesel
Storage Tank	0.1 MG; balancing storage
Pipeline	20,583 ft of 10-inch pipe; 65,337 ft of 6-inch pipe
Available Project Yield	1.0 MGD (1108 acft/yr); total yield for combined Hallsburg, Mart, and Riesel plus 900 acft/yr for McLennan County-Mining

Costs shown in Table 3.8-4 are based on the share of the reuse water and the infrastructure requirements to deliver the water to each entity. The treatment upgrades at WMARSS to supply a Type 1 reuse effluent are additional tertiary treatment and chlorine addition to provide a residual for distribution. Treatment Plant upgrades and O&M are passed to the additional reuse users through the treated reuse water costs of $54.44/acft.

Table 3.8-4. Cost Estimate Summary: WMARSS East Reuse Project

Item	Estimated Costs for Facilities
Transmission Pipeline (10 in dia., 16 miles)	$2,409,000
Transmission Pump Station(s) & Storage Tank(s)	$3,005,000
Storage Tanks (Other Than at Booster Pump Stations)	$552,000
Total Cost Of Facilities	**$5,966,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,968,000
Environmental & Archaeology Studies and Mitigation	$459,000
Land Acquisition and Surveying (100 acres)	$273,000
Interest During Construction (4% for 1 years with a 1% ROI)	$304,000
Total Cost Of Project	**$8,970,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$751,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$93,000
Pumping Energy Costs (659096 kW-hr @ 0.09 $/kW-hr)	$59,000
Purchase of Water (1108 acft/yr @ 54.44 $/acft)	$60,000
Total Annual Cost	**$963,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**1,108**
Annual Cost of Water ($ per acft)	**$869**
Annual Cost of Water ($ per 1,000 gallons)	**$2.67**

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.8-5, and the option meets each criterion. Before pursuing wastewater reuse, the Waco East entities will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit requirements.
- Potential users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- TPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel, and Marl permit for construction in state-owned streambeds.

Table 3.8-5. Comparison of Waco East Reuse Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. Potential impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	Could offset the need for voluntary redistribution of other supplies

3.8.2 WMARSS Bellmead/Lacy-Lakeview Reuse

Description of Option

WMARSS is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the Cities of Bellmead and Lacy-Lakeview. This option consists of an integrated reuse project to deliver Type 1 reuse water from the existing

WMARSS Central WWTP located southeast of Waco along the Brazos River. Treated reuse water would be transported to the industrial and municipal sectors of Bellmead and Lacy Lakeview. Locations of the WMARSS Central WWTP plant, and proposed transmission pipelines, ground storage tanks, and pump stations are shown in Figure 3.8-3.

The transmission system will be capable of delivering 2 MGD (2,242 acft/yr) of treated reuse water from the WMARSS Central WWTP. Supplies to the two cities are divided equally at 50% of the planned system capacity. This Type 1 reuse water may be utilized for landscape irrigation at existing or future parks, schools, ball fields, and other green spaces. Reuse water may also potentially supply existing or future industrial customers.

Available Supply

The planned capacity of the WMARSS Bellmead/Lacy Lakeview Reuse project is 2 MGD (2,242 acft/yr).

Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows;
- Possible negative impact to fish and wildlife habitat with substantially reduced stream flows; and
- Possible negative impact to threatened and endangered species depending on habitat and stream flow requirements.

A summary of environmental issues is presented in Table 3.8-6.

Figure 3.8-3. WMARSS Bellmead/Lacy-Lakeview Reuse

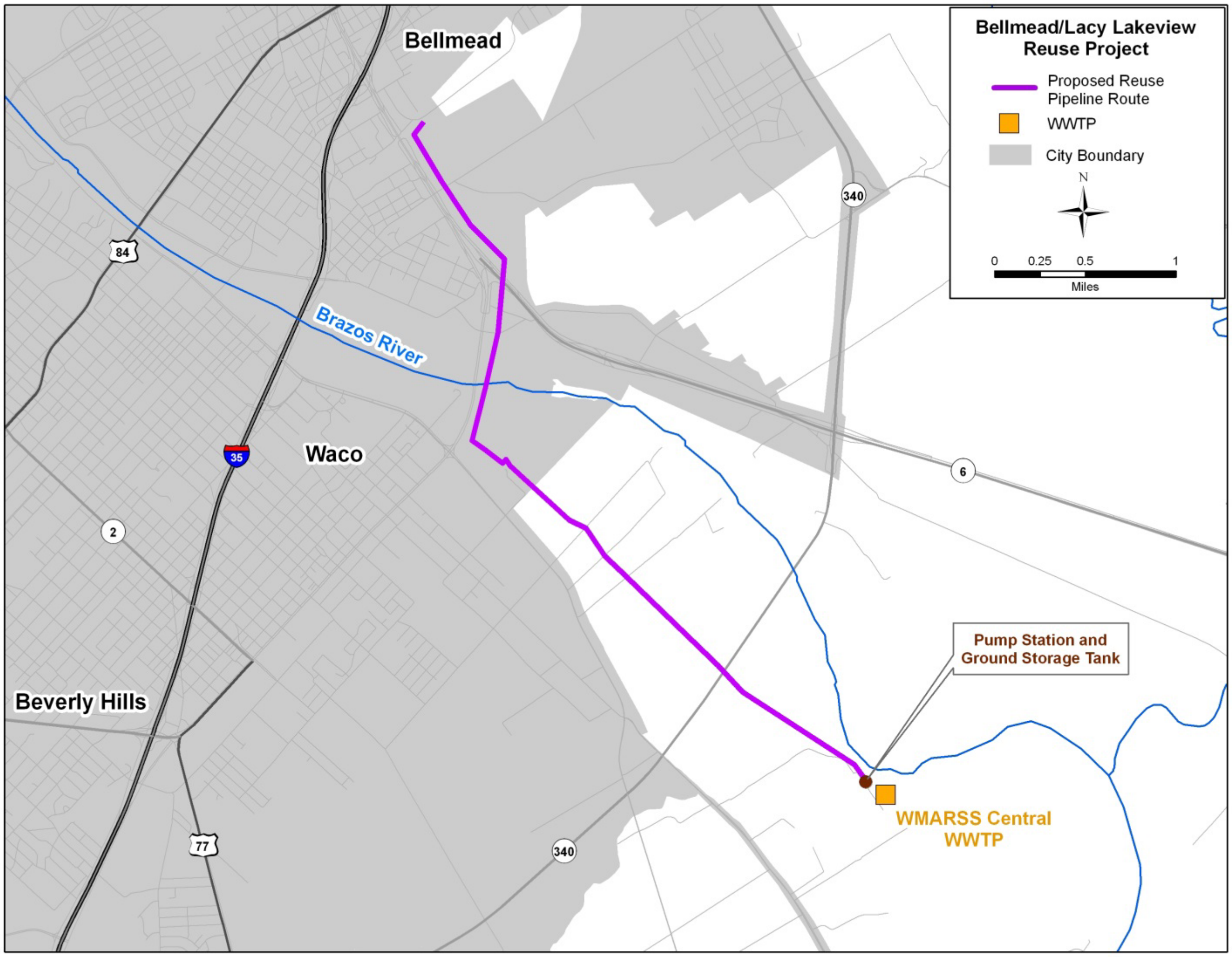


Table 3.8-6. Environmental Issues: WMARSS Bellmead/Lacy-Lakeview Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible negative impact to fish and wildlife habitat due to reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible variable impacts depending on habitat requirements for listed species.
Comments	Assumes needed infrastructure will be in urbanized areas

Engineering and Costing

The required improvements to implement a wastewater reuse supply for Bellmead and Lacy-Lakeview are summarized in Table 3.8-7. The project requires a 2 MGD pump station along with a 1.5 MG storage tank located at the WMARSS Central WWTP. A 5 mile, 12-inch diameter pipe would deliver the reuse supply to the Bellmead city limits. Distribution lines not included in this cost estimate would deliver supply to Lacy-Lakeview and customers of the two cities.

Table 3.8-7. Required Facilities – WMARSS Bellmead/Lacy-Lakeview Reuse

Facility	Description
Pump Stations	124 HP at WMARSS Central WWTP; 2 MGD capacity to deliver at uniform rate to Bellmead
Storage Tanks	1.5 MG; balancing storage at WMARSS Central WWTP
Pipelines	51,000 ft of 12-inch pipe; from WMARSS Central WWTP to I-35 Pump Station
Available Project Yield	2.0 MGD (2,240 acft/yr); total yield for all Bellmead/Lacy-Lakeview projects supplied

The total costs for developing a wastewater reuse supply for Bellmead and Lacy-Lakeview are shown in Table 3.8-8. The project will have an estimated total capital cost of $4,023,000 and an annual cost of $725,000. This cost translates to a $324 per acft or $0.99 per 1,000 gallons unit cost of the reuse water.

Table 3.8-8. Cost Estimate Summary: WMARSS Bellmead/Lacy Lakeview Reuse

Item	*Estimated Costs for Facilities*
Transmission Pipeline (12 in dia., 5 miles)	$1,612,000
Transmission Pump Station(s) & Storage Tank(s)	$1,071,000
Storage Tanks (Other Than at Booster Pump Stations)	$1,340,000
Total Cost Of Facilities	**$4,023,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,327,000
Environmental & Archaeology Studies and Mitigation	$139,000
Land Acquisition and Surveying (31 acres)	$83,000
Interest During Construction (4% for 1 years with a 1% ROI)	$196,000
Total Cost Of Project	**$5,768,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$483,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$56,000
Pumping Energy Costs (714391 kW-hr @ 0.09 $/kW-hr)	$64,000
Purchase of Water (2240 acft/yr @ 54.44 $/acft)	$122,000
Total Annual Cost	**$725,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**2,240**
Annual Cost of Water ($ per acft)	**$324**
Annual Cost of Water ($ per 1,000 gallons)	**$0.99**

Table 3.8-9. Comparison of WMARSS Bellmead/Lacy-Lakeview Reuse Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient for intended uses
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Reduces instream flows—possible low impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	Could offset the need for voluntary redistribution of other supplies

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

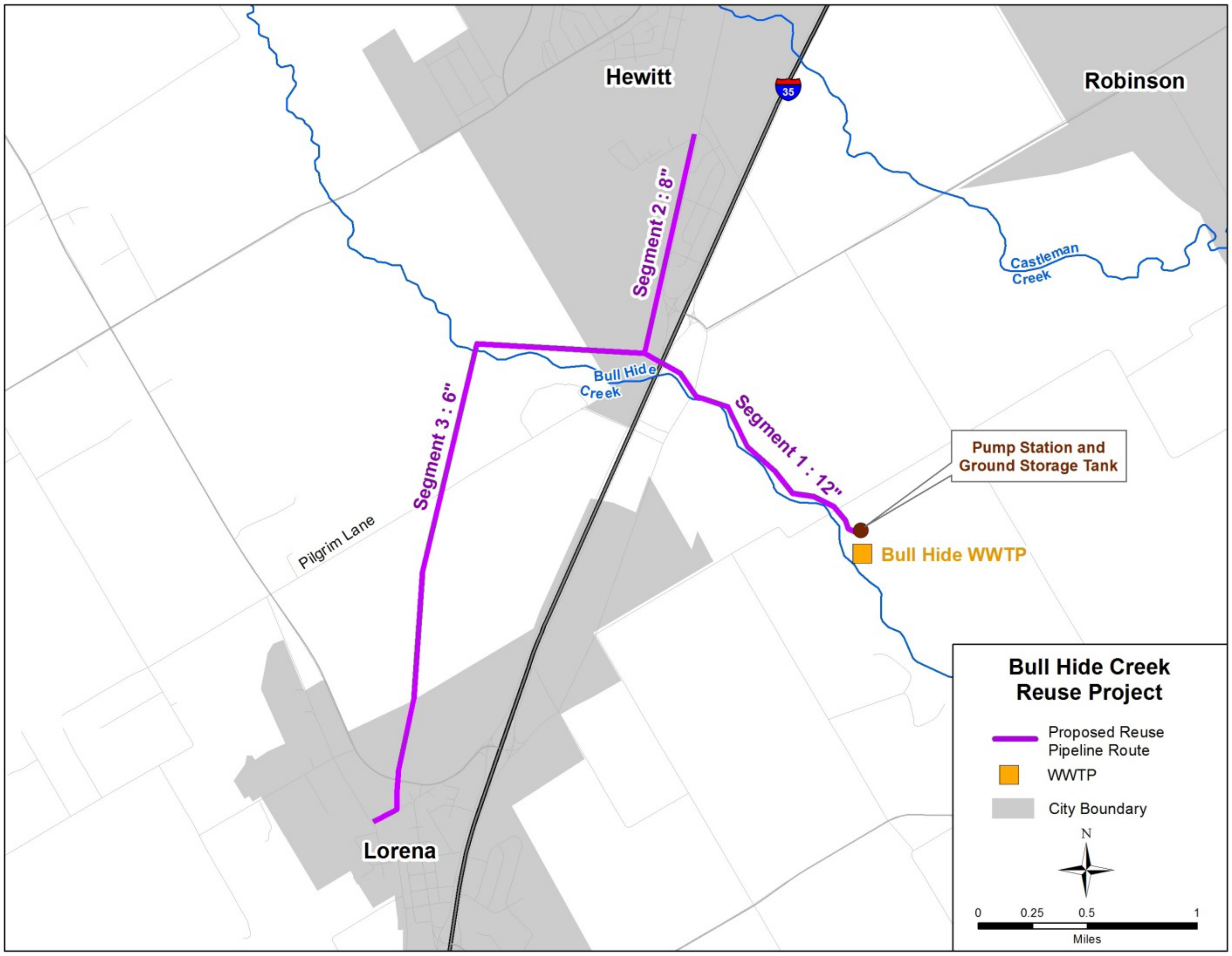
- TCEQ authorization to reuse domestic wastewater under 30 TAC Chapter 210 (“210 authorization”);
- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- TPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

3.8.3 WMARSS Bullhide Creek Reuse

Description of Option

WMARSS is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the Cities of Hewitt and Lorena. This option consists of an integrated reuse project to deliver Type 1 reuse water from the WMARSS Bull Hide Creek WWTP located approximately 1.2 miles southeast of I-35 on Bull Hide Creek. Treated reuse water from this satellite plant would be transported to the industrial and municipal sectors of Hewitt and Lorena. Locations of the proposed reuse treatment plant, transmission pipelines, ground storage tanks, and pump stations are shown in Figure 3.8-4.

Figure 3.8-4. WMARSS Bullhide Creek Reuse



The potential reuse water demand for the City of Hewitt and Lorena is based upon hydraulic constraints of the transmission system. The transmission system will be capable of delivering 1.5 MGD (1,681 acft/yr) of treated reuse water from the WMARSS Bull Hide Creek WWTP. The planned system provides Hewitt with 1,233 acft/yr (1.1 MGD) of reuse water and 448 acft/yr (0.4 MGD) of reuse water to Lorena. This Type 1 reuse water may be utilized for landscape irrigation at existing or future parks, schools, ball fields, and other green spaces. Reuse water may also potentially supply existing or future industrial customers.

Available Supply

The capacity for the WMARSS Bull Hide Creek WWTP is 1.5 MGD (1,681 acft/yr).

Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows;
- Possible negative impact to fish and wildlife habitat due to reduced stream flows; and
- Possible negative impact to threatened and endangered species depending on habitat and stream flow requirements.

A summary of environmental issues is presented in Table 3.8-10.

Table 3.8-10. Environmental Issues: WMARSS Bull Hide Creek Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible negative impact to fish and wildlife habitat due to reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible variable impacts depending on habitat requirements for listed species.
Comments	Assumes needed infrastructure will be in urbanized areas

Engineering and Costing

The required improvements to implement a wastewater reuse supply for Hewitt and Lorena are summarized in Table 3.8-11. The project requires a 1.5 MGD pump station along with a 1.5 MG storage tank located at the WMARSS Bull Hide Creek WWTP site. The transmission pipeline system is separated into three separate components. The first segment is a 12-inch pipe capable of transporting 1.5 MGD of reuse water from the proposed WWTP site. Segment 2 is an 8-inch pipe that splits of from the main line to provide reuse water to the City of Hewitt. Segment 2 is capable of delivering 1.1 MGD based on hydraulic constraints of the system. Segment 3 transports the remaining 0.4 MGD of reuse water through a 6-inch pipe to the City of Lorena.

Table 3.8-11. Required Facilities – WMARSS Bull Hide Creek Reuse

Facility	Description
Pump Stations	111 HP at WMARSS Bull Hide Creek WWTP; 1.5 MGD capacity to deliver at uniform rate to Hewitt and Lorena
Storage Tanks	1.5 MG; balancing storage at WMARSS Bull Hide Creek WWTP
Pipelines	Segment 1; 1.3 miles of 12-inch pipe; from proposed WMARSS Bull Hide Creek WWTP to Segment 2/Segment 3 intersection Segment 2; 1.0 mile of 8-inch pipe; from Segment 1 intersection to Hewitt Segment 3; 3.0 miles of 6-inch pipe from Segment 1 intersection to Lorena
Available Project Yield	1.5 MGD (1,681 acft/yr); total yield for all Hewitt and Lorena projects supplied

Costs presented in Table 3.8-12 provide the total option costs for developing a wastewater reuse supply for Hewitt and Lorena. The project will have an estimated total capital cost of $4,657,000 and an annual cost of $641,000. This cost translates to a $381 per acft or $1.17 per 1,000 gallons unit cost of the reuse water.

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.8-13, and the option meets each criterion. Before pursuing wastewater reuse, the WMARSS entities will need to investigate concerns that would include at a minimum:

- Amount and timing of treated effluent available.
- Potential users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment and transmission facilities to the ultimate points of end use.

Table 3.8-12. Cost Estimate Summary: WMARSS Bull Hide Creek Reuse

Item	Estimated Costs for Facilities
Transmission Pipeline (12 in dia., 5 miles)	$1,001,000
Transmission Pump Station(s) & Storage Tank(s)	$1,199,000
Storage Tanks (Other Than at Booster Pump Stations)	$968,000
Total Cost Of Facilities	**$3,168,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,059,000
Environmental & Archaeology Studies and Mitigation	$166,000
Land Acquisition and Surveying (39 acres)	$106,000
Interest During Construction (4% for 1 years with a 1% ROI)	$158,000
Total Cost Of Project	**$4,657,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$390,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$46,000
Water Treatment Plant (2.5% of Cost of Facilities)	$54,000
Pumping Energy Costs (652313 kW-hr @ 0.09 $/kW-hr)	$59,000
Purchase of Water (1681 acft/yr @ 54.44 $/acft)	$92,000
Total Annual Cost	**$641,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**1,681**
Annual Cost of Water ($ per acft)	**$381**
Annual Cost of Water ($ per 1,000 gallons)	**$1.17**

Table 3.8-13. Comparison of WMARSS Bull Hide Creek Reuse Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient for intended uses
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Reduces instream flows—possible low impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	Could offset the need for voluntary redistribution of other supplies

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- TCEQ authorization to reuse domestic wastewater under 30 TAC Chapter 210 (“210 authorization”);
- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- TPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

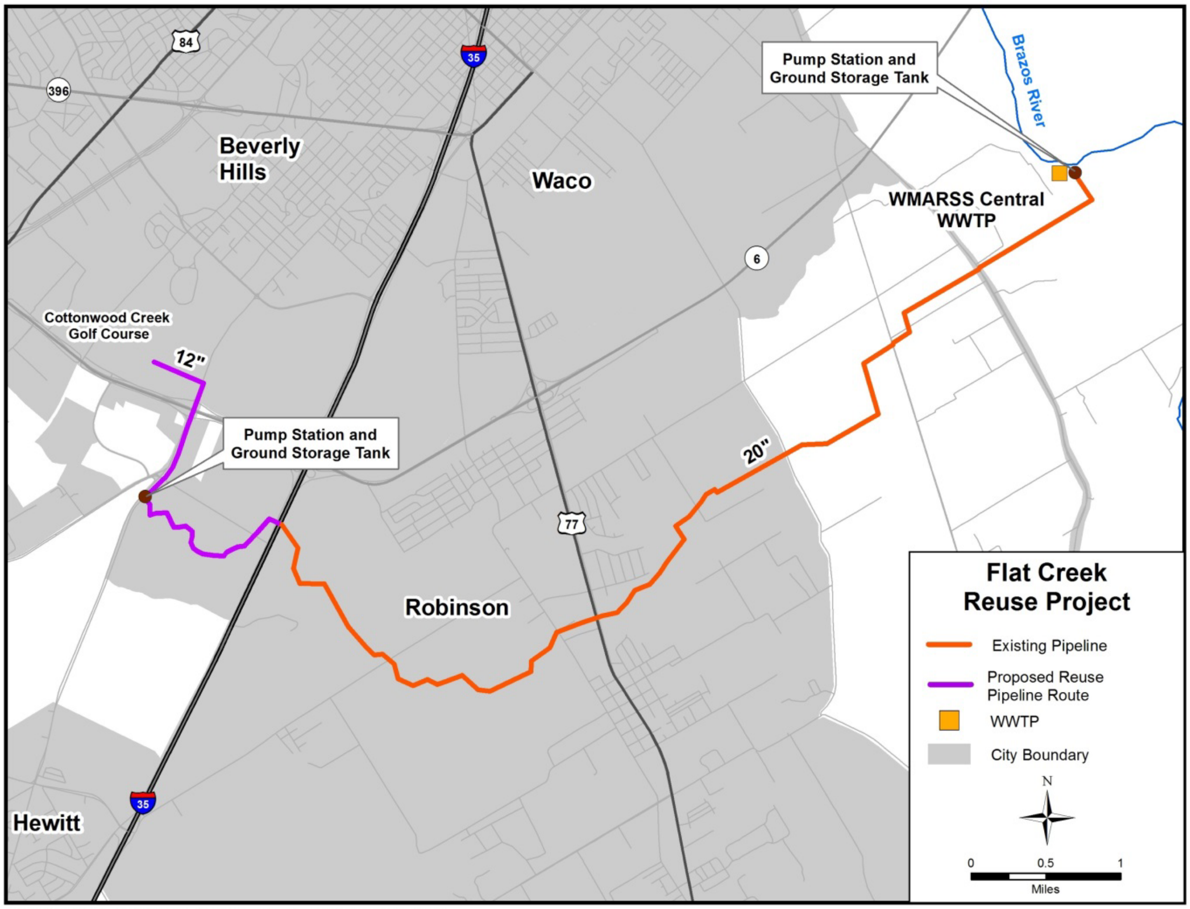
3.8.4 WMARSS Flat Creek Reuse

Description of Option

WMARSS is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the City of Waco. This option consists of an integrated reuse project to deliver Type 1 reuse water from the existing WMARSS Central WWTP located southeast of Waco along the Brazos River. Treated reuse water from the WMARSS Central WWTP would be transported to the industrial and municipal sectors of

Waco and the Cottonwood Creek Golf Course. Locations of the existing reuse treatment plant, and proposed transmission pipelines, ground storage tanks, and pump stations are shown in Figure 3.8-5. Approximately 42,000 feet of 20-inch diameter pipeline has been constructed extending from the WMARSS Central WWTP to Interstate I-35.

Figure 3.8-5. WMARSS Flat Creek Reuse



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The potential reuse water demand for the City of Waco is assumed to be the entire amount of available yield (7,847 acft/yr) from the WMARSS Central WWTP. This Type 1 reuse water may be utilized for landscape irrigation at existing or future parks, schools, ball fields, and other green spaces. Reuse water may also potentially supply existing or future industrial customers. Discussions with industrial customers indicate that public-private partnerships may be viable project funding option. The transmission system will be capable of delivering 7 MGD (7,847 acft/yr) of treated reuse water from the WMARSS Central WWTP.

Available Supply

The WMARSS system is contracted to supply 15,000 acft/yr (13.4 MGD) of the treated effluent from the WMARSS system to the SCEA Power Plant (Section 3.6.1). An additional 3,920 acft/yr (3.5 MGD) would be supplied through the Bullhide Creek and Bellmead/Lacy Lakeview reuse projects. The Year 2011 effluent from WMARSS was 25,355 acft/yr (22.62 MGD). The Year 2070 estimated effluent from WMARSS is 36,370 acft/yr (32.5 MGD). Assuming simultaneous implementation of the other reuse projects, potential available supply from the Flat Creek Reuse Project would be the full 7,847 acft/yr (7 MGD) capacity sometime by 2020.

Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows;
- Possible negative impact to fish and wildlife habitat due to reduced stream flows; and
- Possible negative impact to threatened and endangered species depending on habitat and stream flow requirements.

A summary of environmental issues is presented in Table 3.8-14.

Table 3.8-14. Environmental Issues: WMARSS Flat Creek Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible negative impact to fish and wildlife habitat due to reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible variable impacts depending on habitat requirements for listed species.
Comments	Assumes needed infrastructure will be in urbanized areas

Engineering and Costing

The required improvements to implement a wastewater reuse supply for Waco are summarized in Table 3.8-15. The project requires a 7 MGD pump station along with two 1.5 MG storage tanks located at the WMARSS Central WWTP. A 6,000 ft, 20-inch diameter pipe connects the existing pipeline to a 1 MG storage tank located west of I-35. Distribution lines to connect the 20-inch pipeline to industrial customers within the City of Waco are not included in this cost estimate. At the I-35 site, a 1500 gpm pump station would deliver up to 2 MGD of reuse water through a 6,720 ft, 12-inch diameter pipe to Cottonwood Creek Golf Course for irrigation purposes.

Table 3.8-15. Required Facilities – WMARSS Flat Creek Reuse

Facility	Description
Pump Stations	5000 gpm at WMARSS Central WWTP; 7 MGD capacity to deliver at uniform rate to Waco and Storage Tanks at I-35 Pump Station 1500 gpm at I-35 Site; 2 MGD capacity to deliver at uniform rate to Cottonwood Creek Golf Course
Storage Tanks	2, 1.5 MG tanks to provide balancing storage at WMARSS Central WWTP 1 MG tank to provide balancing storage at I-35 Pump Station
Pipelines	6,000 ft of 20-inch pipe; from WMARSS Central WWTP to I-35 Pump Station 6,720 ft of 12-in pipe; from I-35 Pump Station to Cottonwood Creek Golf Course
Available Project Yield	7.0 MGD (7,847 acft/yr); total yield for all Flat Creek projects supplied

Costs presented in Table 3.8-16 provide the total option costs for developing a wastewater reuse supply for Waco and Cottonwood Creek Golf Course. The project will have an estimated total capital cost of $8,802,000 and an annual cost of $1,875,000. This cost translates to a $239 per acft or $0.73 per 1,000 gallons unit cost of the reuse water, upon utilization of the full 7 MGD (7,847 acft/yr).

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.8-17, and the option meets each criterion. Before pursuing wastewater reuse, the WMARSS entities will need to investigate concerns that would include at a minimum:

- Amount and timing of treated effluent available.
- Potential users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.

Table 3.8-16. Cost Estimate Summary: WMARSS Flat Creek Reuse

Item	Estimated Costs for Facilities
Capital Costs	
Upgrade to WMARSS Intake & Pump Station (7 MGD)	$1,645,000
Two Ground Storage Tanks @ WMARSS (1.5 MG)	$1,936,000
Transmission Pipeline (20 in dia., 1 miles)	$672,000
Transmission Pipeline (12 in dia.,1.3 miles)	$453,000
Transmission Pump Station @ I-35 (2 MGD)	$1,226,000
Ground Storage Tank @ I-35 (1.0 MG)	$699,000
Total Cost Of Facilities	**$6,631,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,264,000
Environmental & Archaeology Studies and Mitigation	$72,000
Land Acquisition and Surveying (16 acres)	$88,000
Interest During Construction (4% for 1 years with a 1% ROI)	$317,000
Total Cost Of Project	**$9,371,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$784,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$93,000
Pumping Energy Costs (3384493 kW-hr @ 0.09 $/kW-hr)	$305,000
Purchase of Water (7847 acft/yr @ 54.44 $/acft)	$427,000
Total Annual Cost	**$1,609,000**
Available Project Yield (acft/yr)	**7,847**
Annual Cost of Water ($ per acft)	**$205**
Annual Cost of Water ($ per 1,000 gallons)	**$0.63**

Table 3.8-17. Comparison of Flat Creek Reuse Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient for intended uses
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Reduces instream flows—possible low impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	Could offset the need for voluntary redistribution of other supplies

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- TCEQ authorization to reuse domestic wastewater under 30 TAC Chapter 210 (“210 authorization”);
- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- TPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

3.8.5 Waco North – Chalk Bluff WSC and Gholson Reuse

Description of Option

The City of Waco is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the City of Waco and potentially to other entities within the vicinity of Waco. Several water user groups in the vicinity of Waco showing a water supply need by the year 2070 may potentially be provided reuse water as part of this larger Waco reuse system. This option consists of an integrated reuse project to deliver Type 1 reuse water from a new satellite wastewater reuse treatment plant located north of Waco and diverting wastewater from a collection main of the WMARSS. Treated reuse water from this satellite plant is transported to Chalk Bluff WSC and the City of Gholson. The new satellite reuse treatment plant and transmission pipeline locations are shown in Figure 3.8-6.

The potential reuse water demand for Chalk Bluff WSC and the City of Gholson is estimated at 30 percent of their 2070 water demand for purposes of this option. This Type 1 reuse water may be utilized for landscape irrigation at existing or future parks, schools, ball fields, and other green spaces. Reuse water may also potentially supply existing or future industrial customers. For this option the transmission system to supply reuse water for these entities also includes capacity to supply 811 acft/yr of reuse water for use by Mining entities within the vicinity of the reuse transmission pipelines. The amount of reuse water supplied to each entity for this option is summarized in Table 3.8-18.

Available Supply

The Year 2070 Estimated WWTP Effluent for WMARSS is 36,370 acft/yr (32.5 MGD). Based on feedback from the City of Waco the combined Year 2070 Confirmed WWTP Effluent Discharge for this WWTP is 0 acft/yr (0 MGD). Therefore, the 2070 Potential Reuse is the difference between the Estimated and Confirmed WWTP Effluent which is 36,370 acft/yr (32.5 MGD). The amount of reuse water available for Waco North reuse will be limited by the wastewater flow in the collector main feeding the new satellite reuse treatment plant.

Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows;
- Possible high negative impact to fish and wildlife habitat with substantially reduced stream flows; and
- Possible negative impact to threatened and endangered species depending on habitat and stream flow requirements.

A summary of environmental issues is presented in Table 3.8-19.

Figure 3.8-6. Waco North Reuse

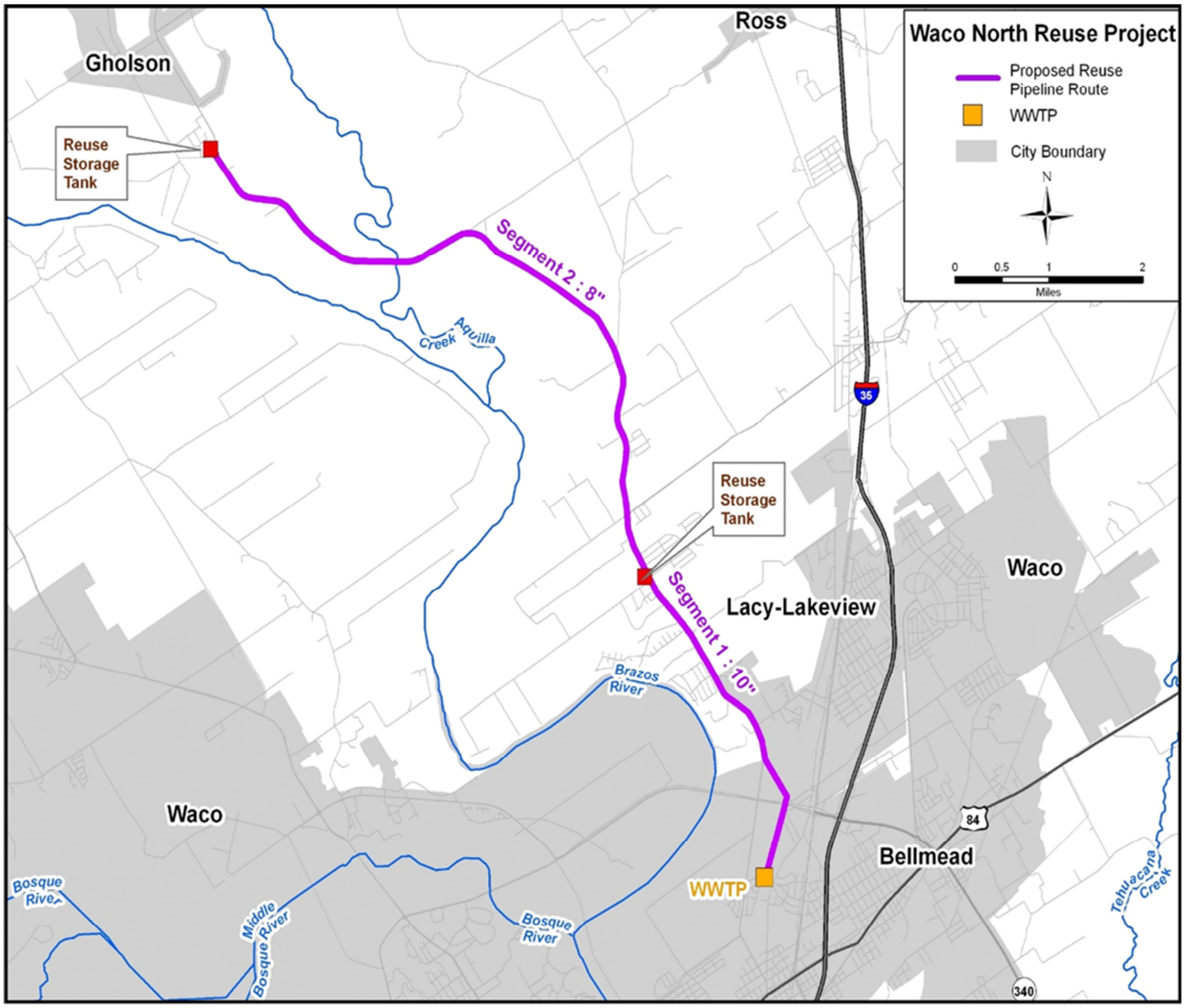


Table 3.8-18. Waco North Reuse Water Demand

Entity	2070 Demand (acft/yr)	Reuse Water Demand (acft/yr)	2070 Need (acft/yr)
Chalk Bluff WSC	244	73	0
Gholson	218	65	0
McLennan County Mining	4,216	811	3,647
Total		**1,120**	**3,647**

Table 3.8-19. Environmental Issues: Waco North Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible variable impacts depending on habitat requirements for listed species.
Comments	Assumes needed infrastructure will be in urbanized areas

Engineering and Costing

This option has a total capital cost of $15,430,000 and an annual cost of $3,390,000. Many of the required improvements to implement a reuse supply for this option are shared between the multiple entities. These shared facilities include the satellite reuse treatment plant in north Waco, pump stations, and transmission pipelines. The shared facilities are sized to supply the combined demand for the entities served by each improvement. A summary of costs is included in Segment 1 shown in Figure 3.8-6 is the initial pipeline segment that transmits reuse water from the satellite reuse treatment plant to Chalk Bluff WSC, McLennan County-Mining, and the Segment 2 pipeline supplying Gholson and Mining. The treatment upgrades to supply a Type 1 reuse effluent are a new satellite reuse treatment plant with a treatment capacity of 3 MGD. The satellite treatment plant is oversized by 2 MGD for this option to allow for additional reuse water demand in the vicinity of the new plant [1 MGD (1,120 acft/yr) demand for Waco North; 2 MGD (2,240 acft/yr) demand for others in the vicinity of reuse plant].

The required improvements to implement wastewater reuse supplies for Chalk Bluff WSC and Gholson are summarized in Table 3.8-21 through Table 3.8-23. Storage and irrigation pumping are included for Chalk Bluff WSC and Gholson.

Table 3.8-20The costs to develop the entire project are shown in Table 3.8-20. Due to the economy of scale, significant cost savings are realized by utilizing shared larger improvements for the treatment and delivery of reuse water to all entities supplied by the Waco North water supply option.

Segment 1 shown in Figure 3.8-6 is the initial pipeline segment that transmits reuse water from the satellite reuse treatment plant to Chalk Bluff WSC, McLennan County-Mining, and the Segment 2 pipeline supplying Gholson and Mining. The treatment upgrades to supply a Type 1 reuse effluent are a new satellite reuse treatment plant with a treatment capacity of 3 MGD. The satellite treatment plant is oversized by 2 MGD for this option to allow for additional reuse water demand in the vicinity of the new plant [1 MGD (1,120 acft/yr) demand for Waco North; 2 MGD (2,240 acft/yr) demand for others in the vicinity of reuse plant].

The required improvements to implement wastewater reuse supplies for Chalk Bluff WSC and Gholson are summarized in Table 3.8-21 through Table 3.8-23. Storage and irrigation pumping are included for Chalk Bluff WSC and Gholson.

Table 3.8-20. Cost Estimate Summary: WMARSS Waco North Reuse

Item	Estimated Costs for Facilities
Primary Pump Stations (1.1 MGD)	$863,000
Transmission Pipeline (10 in dia., 11 miles)	$2,235,000
Storage Tanks (Other Than at Booster Pump Stations)	$1,084,000
Two Water Treatment Plants (3 MGD and 3 MGD)	$11,248,000
Total Cost Of Facilities	**$15,430,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$5,289,000
Environmental & Archaeology Studies and Mitigation	$305,000
Land Acquisition and Surveying (65 acres)	$178,000
Interest During Construction (4% for 1 years with a 1% ROI)	$743,000
Total Cost Of Project	**$21,945,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$1,836,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$48,000
Water Treatment Plant (2.5% of Cost of Facilities)	$1,201,000
Pumping Energy Costs (3384493 kW-hr @ 0.09 $/kW-hr)	$305,000
Total Annual Cost	**$3,390,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**3,360**
Annual Cost of Water ($ per acft)	**$1,009**
Annual Cost of Water ($ per 1,000 gallons)	**$3.10**

Table 3.8-21. Required Facilities – Waco North

Facility	Description
WWTP	New 3 MGD satellite reuse WWTP
Pump Station	80 hp; 1.0 MGD capacity to deliver at uniform rate to storage tanks at Chalk Bluff WSC and Gholson with 25 psi residual pressure
Storage Tank	1 MG; balancing storage at new satellite reuse plant; 0.1 MG tanks for Gholson and Chalk Bluff WSC
Pipeline	18,434 ft of 10-inch pipe; 39,722 ft of 8-inch pipe
Available Project Yield	Total yield is 3 MGD: 1.0 MGD (1,120 acft/yr) delivered, and 2 MGD available at plant.

Table 3.8-22. Required Facilities – Chalk Bluff WSC

Facility	Description
Treatment Upgrade	Purchase 0.07 MGD treated reuse water from Waco
Pump Station	52 hp; 0.26 MGD capacity to deliver peak daily capacity in 6 hours at 60 psi; shared use of segment 1 pump station
Storage Tank	0.07 MG; Store one days treated reuse water at tank near Chalk Bluff WSC demand
Pipeline	Shared use of pipeline segment 1
Available Project Yield	0.07 MGD (73 acft/yr), yield is based on 30 percent of total year 2070 demand to be used for irrigation and/or industrial customers

Table 3.8-23. Required Facilities – Gholson

Facility	Description
Treatment Upgrade	Purchase 0.06 MGD treated reuse water from Waco
Pump Station	14 hp; 0.24 MGD capacity to deliver peak daily capacity in 6 hours at 60 psi; shared use of segment 1 pump station
Storage Tank	0.06 MG; Store one days treated reuse water at tank in Gholson
Pipeline	Shared use of pipeline segments 1 and 2
Available Project Yield	0.06 MGD (65 acft/yr), yield is based on 30 percent of total year 2070 demand to be used for irrigation and/or industrial customers

Costs presented in Table 3.8-20 provide the total option costs for developing a wastewater reuse supply for Chalk Bluff WSC, Gholson and Mining. The demand from McLennan County Mining is divided between pipeline Segments 1 and 2. Inclusion of the Mining shared use of these transmission facilities greatly decreases the unit cost for transmission of reuse water to Chalk Bluff WSC and Gholson. Without participation from Mining or other non municipal demand (irrigation, manufacturing) in this reuse water supply option, supplying the relatively small quantity of reuse water demanded by Chalk Bluff WSC and Gholson would likely not be economical.

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.8-24, and the option meets each criterion. Before pursuing wastewater reuse, the Waco North entities will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit requirements.
- Potential users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- TPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

Table 3.8-24. Comparison of Waco North Reuse Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. Potential impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	Could offset the need for voluntary redistribution of other supplies

3.9 Bell County WCID No.1 – Reuse

3.9.1 Description of Option

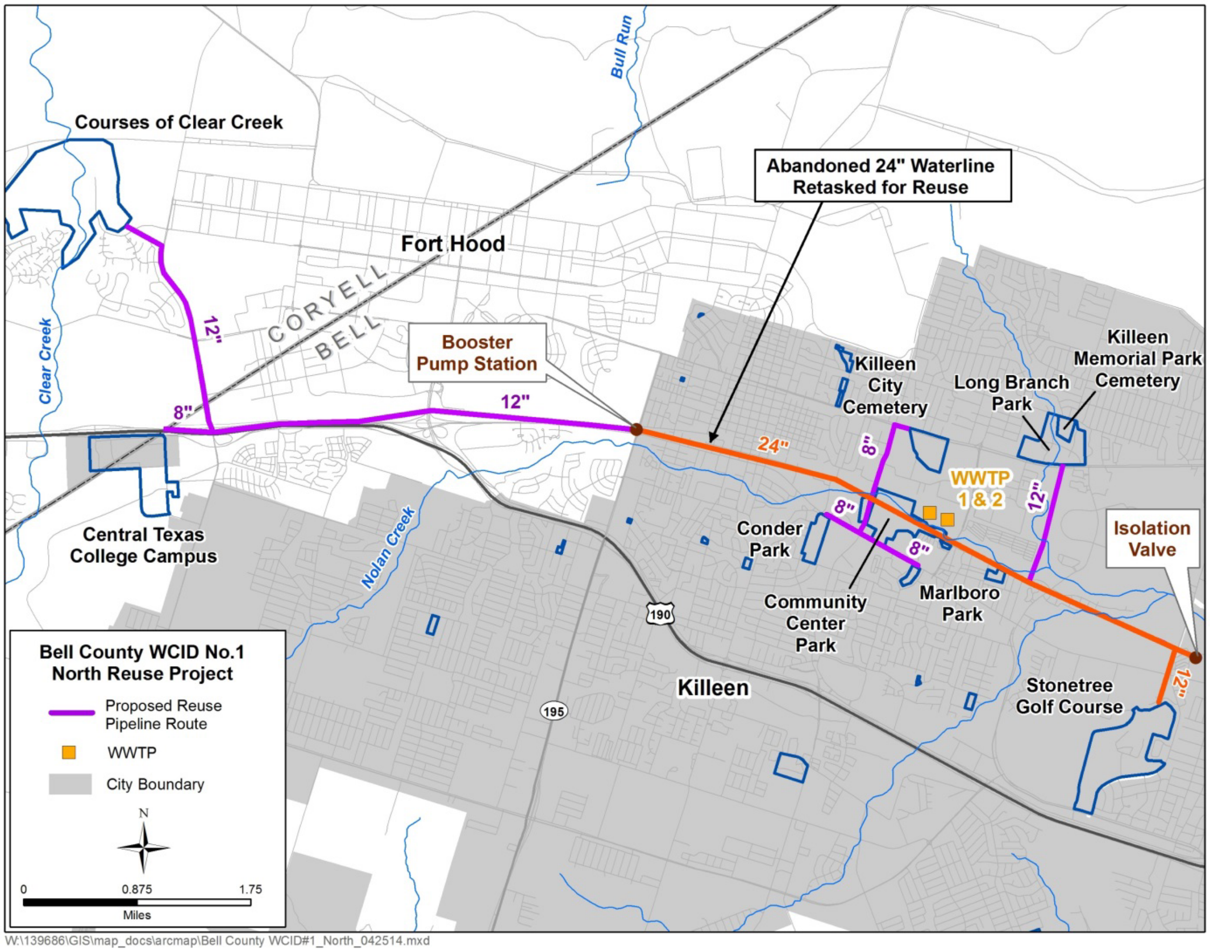
Bell County WCID does not currently provide any of its wastewater effluent as a reuse water supply. The District is pursuing TCEQ Reclaimed Water Type I permits to utilize treated wastewater from wastewater treatment plants (WWTP) 1 and 2 and the South WWTP. The District has evaluated several wastewater reuse options as part of its Master Plan update. The reuse portion of the Master Plan identifies both near-term potential customers as well as other future customers that would utilize the total available reuse supply generated through the District's regional wastewater system. The near-term potential projects are those that the District and the cities of Killeen and Harker Heights have identified for implementation within the next 20 years. The other potential demands are associated with future reuse projects at Fort Hood, and additional projects for Killeen, Harker Heights, and other communities in the US Highway 190 corridor.

The near-term potential customers will be served through two projects identified as the North Reuse Project and the South Reuse Project. The North Reuse Project consists of supplying treated wastewater from WWTPs 1 and 2 to potential customers for irrigation use at several municipal parks, two cemeteries in Killeen, the Courses of Clear Creek near Fort Hood, the Stonetree Golf Course, and the Central Texas College campus. Irrigation demands for the North project are shown in Table 3.9-1. An abandoned 24-inch diameter water line will be placed back into service as the main transmission of the North Reuse Project. The locations of the WWTPs, potential customers and proposed North Reuse Project facilities are shown in Figure 3.9-1. Although average annual demands total approximately 1,925 acft/yr, the reuse system must be sized to meet the peak irrigation demand during the summer months, which is about 3.03 MGD (3,394 acft/yr).

Table 3.9-1. Water Reuse Demands for Bell County WCID No. 1 North Reuse Project

Reuse Customer	Average Demand (MGD)	Peak Demand (MGD)
Courses at Clear Creek	0.47	0.82
Stonetree Golf Course	0.44	0.78
Community Center Ball Park	0.25	0.44
Long Branch Park	0.21	0.38
Central Texas College	0.11	0.19
Killeen City Cemetery	0.11	0.19
Conder Park	0.07	0.13
Memorial Park Cemetery	0.03	0.06
Marlboro Park	0.02	0.03
Total	**1.72**	**3.03**

Figure 3.9-1. Bell County WCID No. 1 North Reuse Project



The South project includes potential irrigation customers to be supplied from the South WWTP. A portion of the existing effluent discharge line will be used to deliver a portion of the reuse supply. The locations of the WWTP, potential customers and proposed South Reuse Project facilities are shown in Figure 3.9-2. Average annual demand for the South project is approximately 748 acft/yr, and peak irrigation demand is about 1.18 MGD or 1,318 acft/yr. Irrigation demands for the South project are shown in Table 3.9-2.

The long-term need for reuse supply is anticipated by the District to increase greatly in the future. Future reuse demands are associated with Fort Hood, and municipalities along the US Highway 190 corridor such as Harker Heights, Nolanville, Copperas Cove, and others. The North Reuse System would be expanded with new reuse transmission mains to serve these areas. Table 3.9-3 shows the future potential reuse demands.

3.9.2 Available Supply

The water supply that would be potentially available for the District would be that portion of their wastewater effluent stream that has suitable uses within an economical distance from the treatment plant. The District's three WWTP have a total rated capacity of 30

MGD. The average daily effluent flow from WWTP 1 and 2 is 13.2 MGD (14,784 acft/yr) of Type 1 effluent. The South WWTP facility is rated for 6 MGD capacity averaging about 4 MGD (4,480 acft/yr) of Type 1 effluent for use in unrestricted areas.

Figure 3.9-2. Bell County WCID No. 1 South Reuse Project

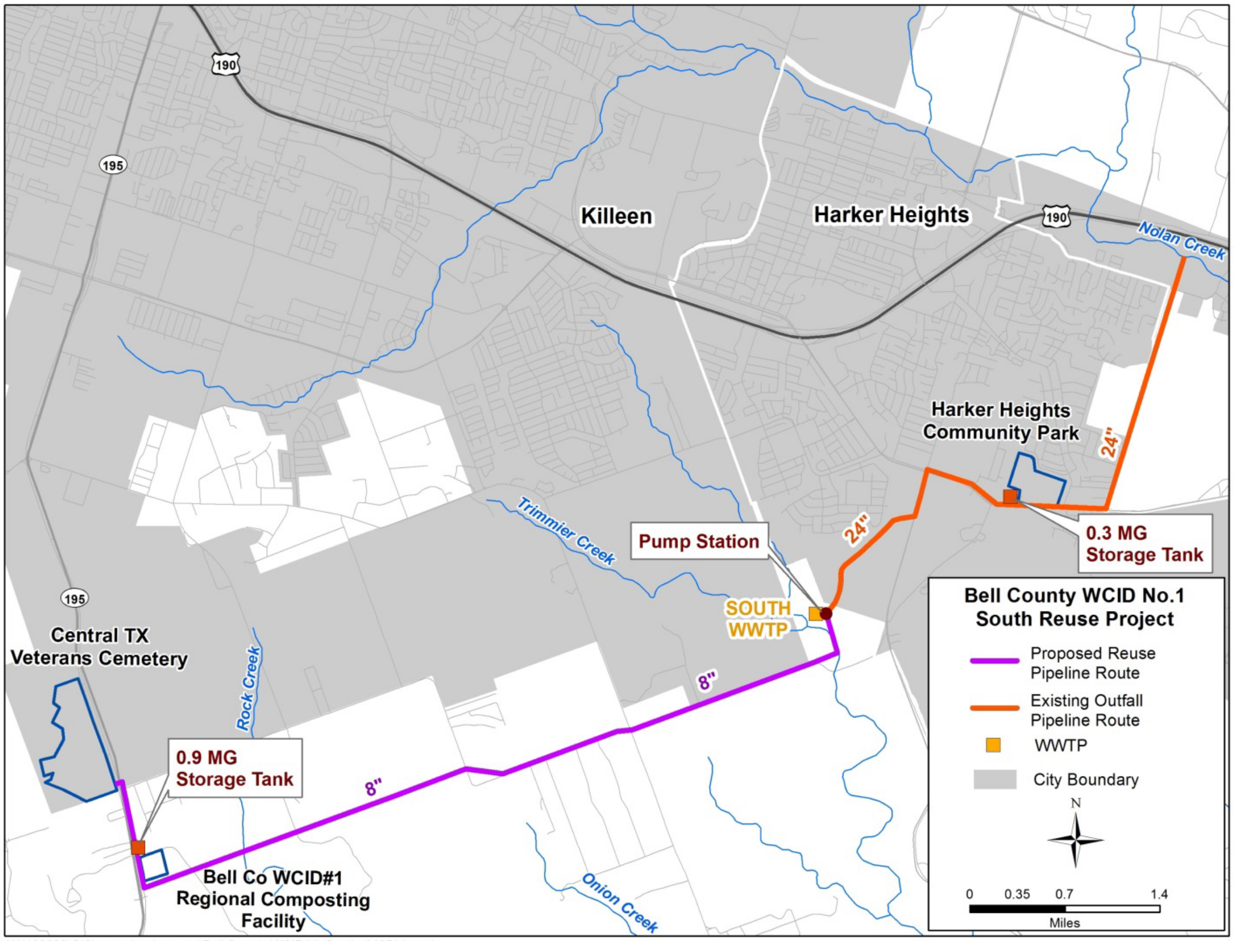


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Table 3.9-2. Water Reuse Demands for Bell County WCID South Reuse Project

Reuse Customer	Average Demand (MGD)	Peak Demand (MGD)
Central Texas State Veteran's Cemetery	0.48	0.85
Harker Heights Community Park	0.17	0.29
Composting Facility	0.02	0.03
Total	0.67	1.18

The Year 2070 Estimated WWTP Effluent for WWTP 1 and 2 is 26,880 acft/yr (24MGD) and 6,720 acft/yr (6 MGD) for the South WWTP. Since there is no current reuse, potentially all of this volume would be available for direct reuse. The currently proposed near term and future reuse projects could potentially use most of the year 2070 estimated WWTP effluent for the District.

Table 3.9-3. Other Potential Future Water Reuse Demands for Bell County WCID Reuse System

Reuse Customer	Average Demand (MGD)	Peak Demand (MGD)
Fort Hood		
Vehicle Wash	5.00	5.00
Dust Control	1.20	1.20
Irrigation	6.25	11.06
Site Cooling	0.50	0.50
Future Development (Stillhouse Hollow Lake residential and recreational areas)	0.75	1.33
Nolanville Irrigation	0.50	0.89
Lions Club Park	0.45	0.80
Bacon Ranch Park	0.38	0.67
Camacho Park	0.22	0.39
Timber Ridge Park	0.15	0.27
Maxdale Park	0.15	0.27
AA Lane Park	0.06	0.11
Stewart Park	0.05	0.09
Fowler Park	0.04	0.07
Phyllis Park	0.03	0.05
Fox Creek Park	0.03	0.05
Lions Neighborhood Park	0.02	0.04
Home and Hope Park	0.02	0.04
Pershing	0.02	0.04
Santa Rosa Park	0.02	0.04
Ira Cross Park	0.02	0.04
Other Killeen Areas	1.50	2.66
Other Harker Heights Areas	1.20	2.12
Total	18.6	27.7

3.9.3 Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows;
- Possible negative impact to fish and wildlife habitat with reduced stream flows; and
- Possible negative impact to threatened and endangered species depending on habitat and stream flow requirements.

A summary of environmental issues is presented in Table 3.9-4.

Table 3.9-4. Environmental Issues: Bell County WCID No. 1 North and South Reuse Projects

Implementation Measures	Development of additional distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible variable impacts depending on habitat requirements for listed species
Comments	Assumes needed infrastructure for the North project will be in urbanized areas and mostly rural areas for the South project

3.9.4 Engineering and Costing

The North Reuse Project will make use of an abandoned 24-inch diameter transmission line to convey treated reuse water to potential customers. New facilities will include storage at the WWTP, a pump station, booster station and branch pipelines. Irrigation water for golf courses, parks, ball fields and cemeteries will generally be applied during periods when these areas are not being utilized, typically at night. Existing storage at the golf courses will be used for irrigation. For reuse customers without storage, water will be delivered on an as needed basis. Therefore, facilities are sized to deliver the total daily demand in a 6-hour period for the customers without existing storage. Providing storage at the point of use may decrease required pipeline and pump station size because the water can be transported at a more uniform rate to fill storage tanks at the point of use.

The required improvements to implement a wastewater reuse supply for the North Reuse Project are summarized in Table 3.9-5.

Table 3.9-5. Required Facilities – Bell County WCID No. 1 North Reuse Project

Facility	Description
Treatment Upgrade	Existing WWTP meets Type 2 reuse standards, no additional treatment necessary
Pump Station(s)	Two pump stations - 339 hp and 143 HP to deliver peak demand of 3.9 MGD (Total pump capacity of 7.82 MGD to deliver portion for two golf courses with on-site storage in 18 hours and in 6 hours for other demand locations)
Storage Tank	0.9 MG at WWTP. 0.1 MG storage at booster station. Utilize existing storage at golf courses.
Pipeline	11,724 ft of 8-inch pipe 32,216 ft of 12-inch pipe
Available Project Yield	1.72 MGD (1,925 acft/yr).

Estimated costs for the North Reuse Project are summarized in Table 3.9-6. Total costs for the project are $12,146,000 with annual costs of $1,473,000. Annual costs include debt service estimated at 5.5% for 20 years, O&M for pipelines and pump stations and pumping energy. Annual unit costs are estimated to be $765/acft or $2.35/thousand gallons. The unit cost of a reuse water supply could potentially be decreased by the addition of other users within an economical distance from the WWTP(s).

The South Reuse Project will make use of a portion of the pressurized pipeline to the Nolan Creek outfall to convey treated reuse water to potential customers east of the South WWTP. New facilities will include a pump station, booster station and branch pipelines. Pumping facilities are sized to deliver the water to ground storage tanks near the irrigation demand. Distribution pumps and pipelines would draw water from the storage tanks as needed. The improvements required to implement a wastewater reuse supply for the South Reuse Project are summarized in Table 3.9-7.

Estimated costs for the South Reuse Project are summarized in Table 3.9-8. Total project costs for the project are $6,529,000 with annual costs of $696,000. Annual costs include debt service estimated at 5.5% for 20 years, O&M for pipeline and pump station and pumping energy. Annual unit costs are estimated at $930/acft or $2.86/thousand gallons. The unit cost of a reuse water supply could potentially be decreased by the addition of other users within an economical distance from the WWTPs.

Table 3.9-6. Cost Estimate Summary: Bell County WCID No. 1 North Reuse Project

Item	Estimated Costs for Facilities
Transmission Pipeline (8 - 12 in dia., 8 miles)	$3,506,000
Transmission Pump Station(s) & Storage Tank(s)	$3,769,000
Storage Tanks (Other Than at Booster Pump Stations)	$641,000
Disinfection (9 MGD)	$399,000
Total Cost Of Facilities	**$8,315,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,736,000
Environmental & Archaeology Studies and Mitigation	$324,000
Land Acquisition and Surveying (47 acres)	$360,000
Interest During Construction (4% for 1 years with a 1% ROI)	$411,000
Total Cost Of Project	**$12,146,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$1,016,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$128,000
Water Treatment Plant (2.5% of Cost of Facilities)	$240,000
Pumping Energy Costs (993113 kW-hr @ 0.09 $/kW-hr)	$89,000
Total Annual Cost	**$1,473,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 4	**1,925**
Annual Cost of Water ($ per acft)	**$765**
Annual Cost of Water ($ per 1,000 gallons)	**$2.35**

Table 3.9-7. Required Facilities – Bell County WCID No. 1 South Reuse Project

Facility	Description
Treatment Upgrade	Existing WWTP meets Type 1 reuse standards, add chlorine disinfection to the western pipeline and at the Harker Heights Community Park storage tank
Pump Station	Transmission and booster pump station - 134 hp to deliver peak demand of 0.9 MGD to a terminal storage tank
Storage Tanks	0.9 MG tank near the Veterans Cemetery and 0.3 MG tank near Harker Heights Community Park to store one day of treated reuse water.
Pipeline	35,187 ft of 8-inch pipe
Available Project Yield	0.67 MGD (748 acft/yr).

Table 3.9-8. Cost Estimate Summary: Bell County WCID No. 1 South Reuse Project

Item	Estimated Costs for Facilities
Transmission Pipeline (8 in dia., 7 miles)	$1,413,000
Transmission Pump Station(s) & Storage Tank(s)	$2,005,000
Storage Tanks (Other Than at Booster Pump Stations)	$927,000
Two Water Treatment Plants (0.9 MGD and 0.3 MGD)	$92,000
Total Cost Of Facilities	**$4,437,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,482,000
Environmental & Archaeology Studies and Mitigation	$184,000
Land Acquisition and Surveying (34 acres)	$205,000
Interest During Construction (4% for 1 years with a 1% ROI)	$221,000
Total Cost Of Project	**$6,529,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$546,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$65,000
Water Treatment Plant (2.5% of Cost of Facilities)	$55,000
Pumping Energy Costs (327793 kW-hr @ 0.09 $/kW-hr)	$30,000
Total Annual Cost	**$696,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 2	**748**
Annual Cost of Water ($ per acft)	**$930**
Annual Cost of Water ($ per 1,000 gallons)	**$2.86**

As identified in Table 3.9-9, the combined yield of the North and South Reuse Projects are 2,673 acft/yr with annual unit costs of $811/acft or $2.49 per thousand gallons.

3.9.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.9-10, and the option meets each criterion. Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;

- TPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel, and Marl permit for construction in state-owned streambeds.

Table 3.9-9. Total Yield and Cost for North and South Reuse Projects

Project	Average Yield (acft/yr)	Unit Cost	
		($/acft)	($/kgal)
North Reuse Project	1,925	$765	$2.35
South Reuse Project	748	$930	$2.86
Total	2,673	$811	$2.49

Table 3.9-10. Comparison of Bell County WCID No.1 North and South Reuse Projects to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Potentially important source reducing demand for potable supplies
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Reduces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. Potential impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	Could offset the need for voluntary redistribution of other supplies

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4 New Reservoirs

4.1 Brushy Creek Reservoir

4.1.1 Description of Option

The proposed Brushy Creek Reservoir will serve water supply, recreation and flood control purposes in the Big Creek watershed. The reservoir site is located in Falls County on Brushy Creek, which is a tributary to Big Creek. This watershed drains to the Brazos River. The proposed reservoir is located approximately 26 miles southeast of the City of Waco and 8 miles east of the City of Marlin (Figure 4.1-1). This project was suggested as a water management strategy in the 2001, 2006, and 2011 Brazos G Regional Water Plans. Other studies include the 1984 *Final Watershed Plan and Environmental Impact Statement for the Big Creek Watershed for Falls, Limestone, and McLennan Counties*[1] and the 2008 *Reservoir Site Protection Study*[2]. The proposed reservoir has a storage capacity of 6,560 acre-feet at the permitted conservation storage level of 380.5 feet above mean sea level (ft-msl). At conservation storage level the reservoir will inundate an area of approximately 697 acres. The land required to create the reservoir has already been acquired by the City of Marlin.

The Brushy Creek Reservoir is authorized by Certificate of Adjudication 12-4355, as amended. The certificate also authorizes New Marlin Reservoir and Marlin City Lake which impound 3,135 and 791 acre-feet of water, respectively. Marlin City Lake is used as a sedimentation basin. The City of Marlin is permitted to divert 4,000 acre-feet per year from New Marlin Reservoir and/or Brushy Creek Reservoir for municipal purposes. The certificate also authorizes diversions between October and April from the Brazos River at the rate of 2,000 acft/yr for municipal purposes and 2,000 acft/yr for industrial purposes. A continuous release of 0.1 cfs must be made from Brushy Creek Reservoir to maintain instream flows. Table 4.1-1 is a summary of the authorizations made by Certificate No. 12-4355.

[1] USDA, 1984. *Final Watershed Plan and Environmental Impact Statement for the Big Creek Watershed for Falls, Limestone, and McLennan Counties*. U.S. Department of Agriculture, Soil Conservation Service. July 1984.
[2] TWDB, 2008. *Reservoir Site Protection Study* – Chapter 5.3 Brushy Creek Reservoir. Technical Report 370. Prepared for the Texas Water Development Board by R. J. Brandes and R. D. Purkeypile of the R.J. Brandes Company. July 2008. Pg 46-53.

Figure 4.1-1. Brushy Creek Reservoir Location

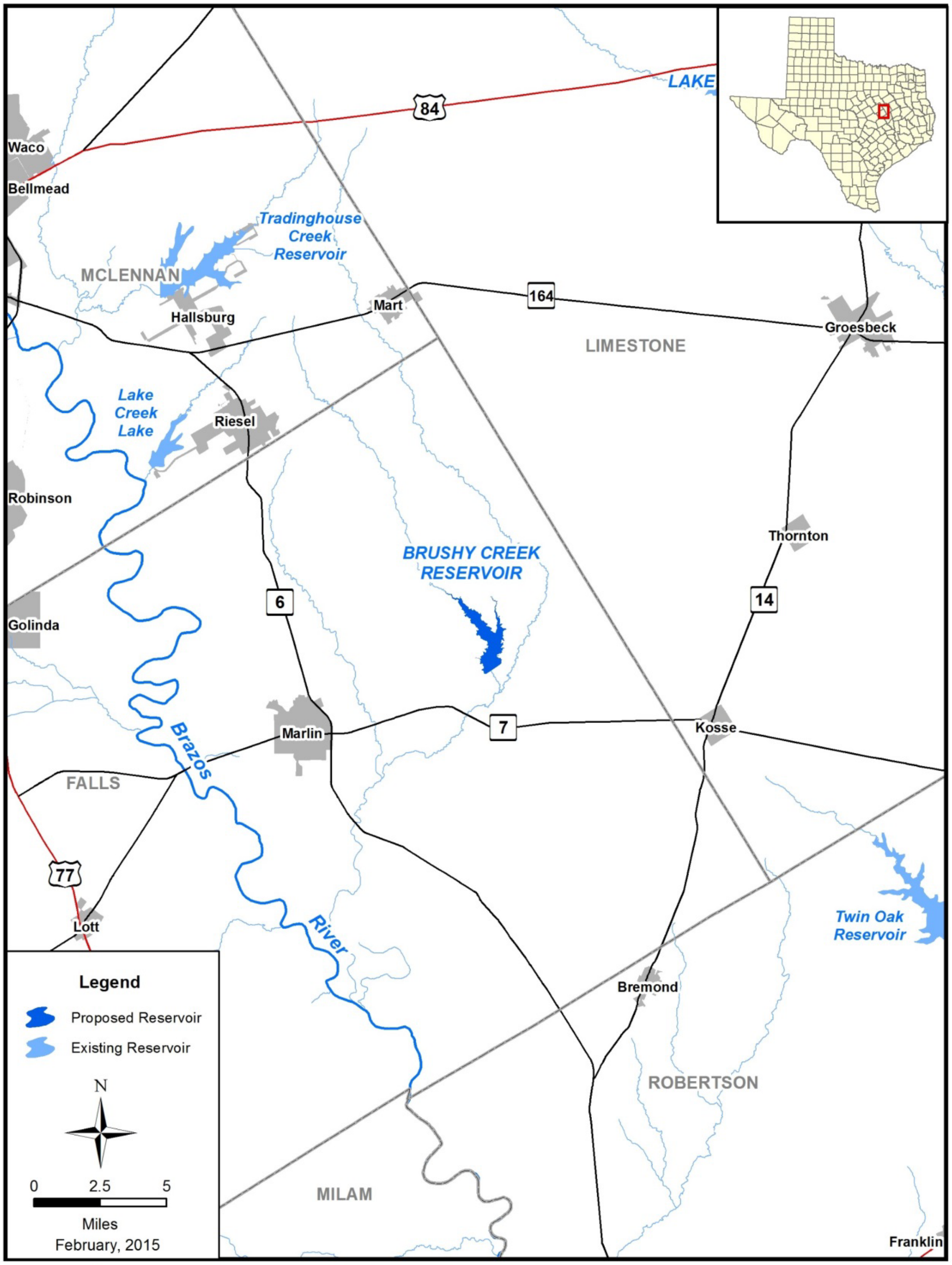

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Table 4.1-1. Summary of Authorizations for Certificate of Adjudication 12-4355

Source	Storage (acft)	Priority Date	Diversion (acft/year)	Use	Priority Date
New Marlin Reservoir	3,135	4/9/1948	1,500	Municipal	4/9/1948
Brushy Creek Reservoir	2,921	11/22/1982	1,500	Municipal	11/27/1956
	3,639	12/3/1990	1,000	Municipal	11/22/1982
Marlin City Lake	650	11/1/1976			
	141	11/22/1982			
Brazos River			2,000	Municipal	11/27/1956
			2,000	Industrial	11/27/1956

4.1.2 Available Yield

Water potentially available for impoundment in the proposed Brushy Creek Reservoir was estimated using the TCEQ Brazos WAM Run 3. The model utilizes a January 1940 through December 1997 hydrologic period of record and assumes no return flows and permitted storages and diversions for all water rights in the basin. The model computed the streamflow available for diversion into the Brushy Creek Reservoir without causing increased shortages to existing downstream rights. Firm yield was computed subject to the reservoir and diversion having to pass inflows to meet environmental flow standards associated with Senate Bill 3 (SB3).

The elevation-area capacity relationship for the reservoir is shown in Table 4.1-2.

The firm yield was computed for the authorized storage capacity of Brushy Creek Reservoir, which is 6,560 acre-feet, subject to a minimum required instream flow release of 0.1 cfs as specified in Special Condition G of Certificate of Adjudication 12-4355. Based on the premises and assumptions reflected in the model, the firm yield for Brushy Creek Reservoir is 1,450 acre-feet per year.

Figure 4.1-2 shows the simulated storage in Brushy Creek Reservoir assuming an annual diversion amount equal to the firm yield. The storage frequency curve for these conditions is presented in Figure 4.1-3.

Table 4.1-2. Elevation-Area-Capacity Relationship for Brushy Creek Reservoir

Elevation (feet)	Area (acres)	Capacity (acre-feet)
352	0	0
356	1	1
360	33	68
364	115	363
368	234	1,059
372	341	2,208
376	497	3,884
380	668	6,214
380.5*	697	6,560
384	896	9,296
388	1,065	13,119
392	1,310	17,868
394	1,431	20,608

* Authorized conservation pool elevation

Figure 4.1-2. Simulated Storage in Brushy Creek Reservoir

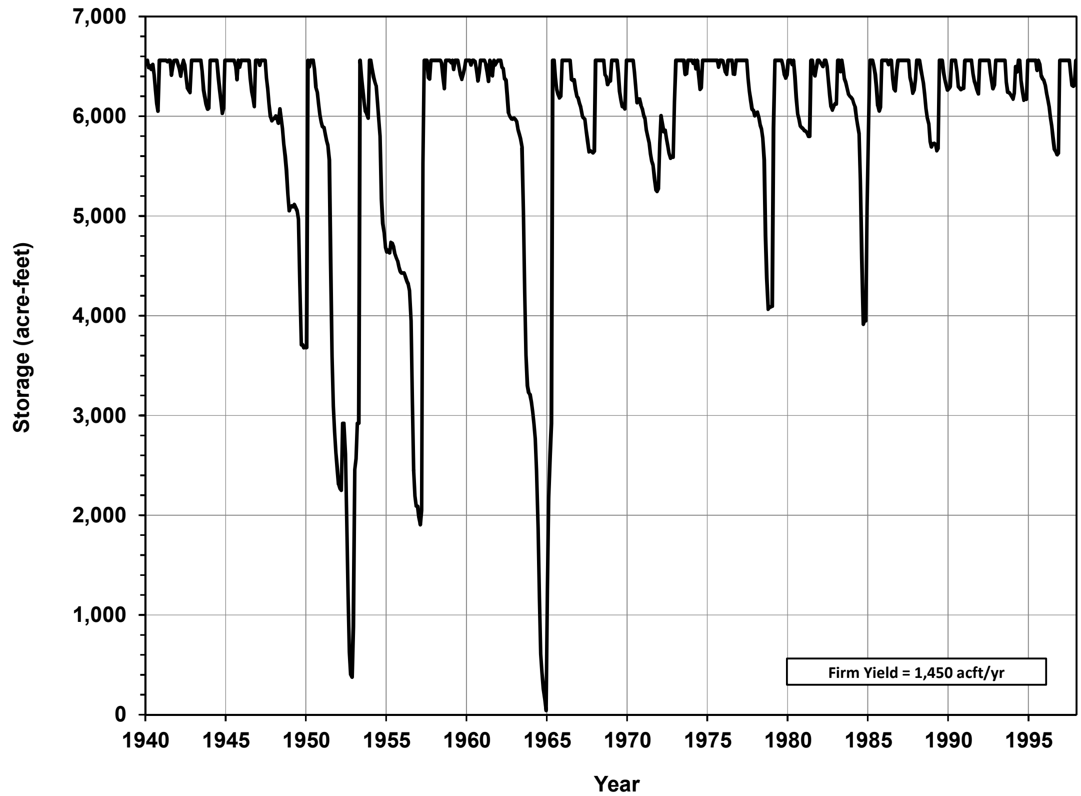
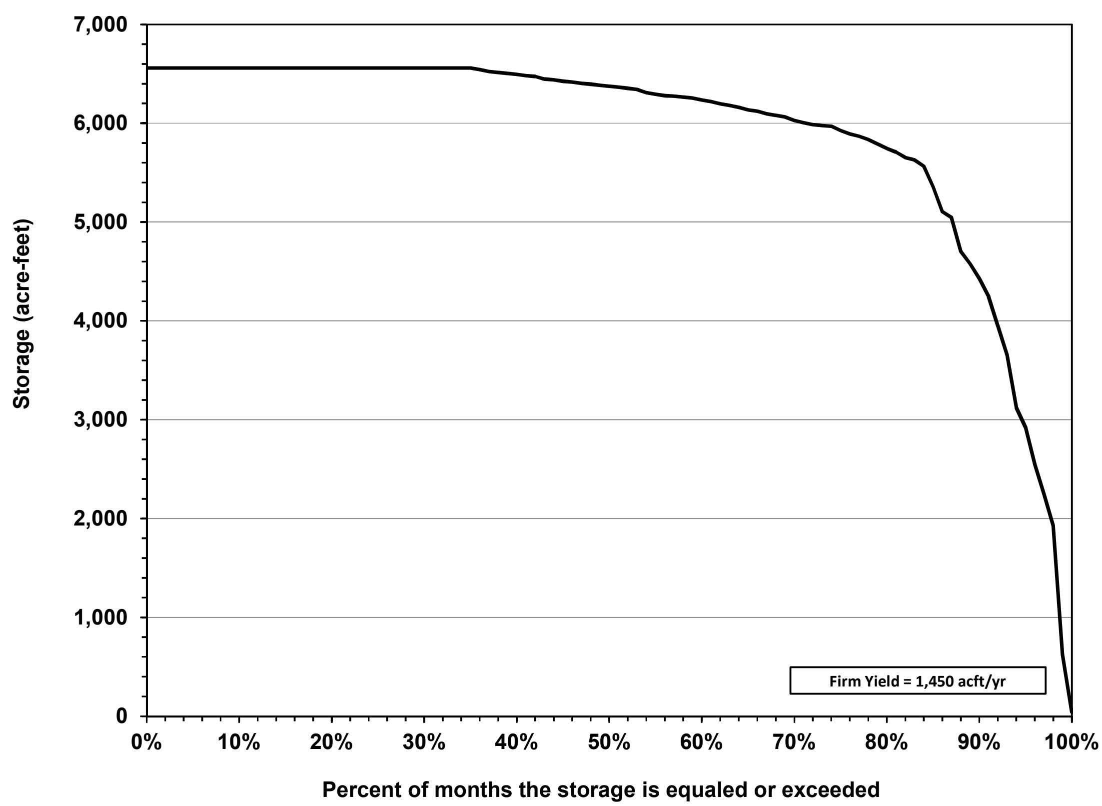


Figure 4.1-3. Storage Frequency Curve for Brushy Creek Reservoir



4.1.3 Environmental Issues

Existing Environment

The proposed Brushy Creek Reservoir site in Falls County lies within the Texas Blackland Prairies Ecological Region.[3] This region is characterized by gentle topography and black alkaline clay soils. Historically, the region was covered with native tall-grass prairies but today most of it has been converted to agriculture. The project area includes a vegetation type defined by Texas Parks and Wildlife (TPWD) as crops.[4] The climate of this area is characterized as subtropical humid, and is noted for its warm summers. On average, area precipitation ranges from 36 to 38 inches per year.

There are no major aquifers beneath the project site, however, the Trinity Aquifer is located five miles to the northwest and the Carrizo Aquifer is seven miles to the southeast of the proposed reservoir site.

Potential Impacts

Aquatic Environments including Bays and Estuaries

Construction of the Brushy Creek Reservoir project could reduce the quantity and variability of median monthly streamflows in Brushy Creek downstream of the reservoir (Table 4.1-3). Assuming annual diversions equal to the permitted amounts, these reductions could range from 2.2 cfs (52 percent) in June to 5.7 cfs (82 percent) in December. The highest percent reductions (>95 percent) could be from September through November. The lowest percent reduction occurs in May (14 percent). Figure 4.1-4 shows that without the reservoir, streamflow would likely cease 11% of the time. With the reservoir, streamflow will likely persist because a minimum release of 0.1 cfs is required to maintain instream flows. Without the required instream flow releases, streamflow would likely cease 40% of the time.

Changes in streamflow could impact instream and riparian biological communities by potentially affecting their reproductive cycles and changing the composition of species. Substantial reductions in streamflow during the summer months could result in higher temperatures and higher concentrations of contaminants.

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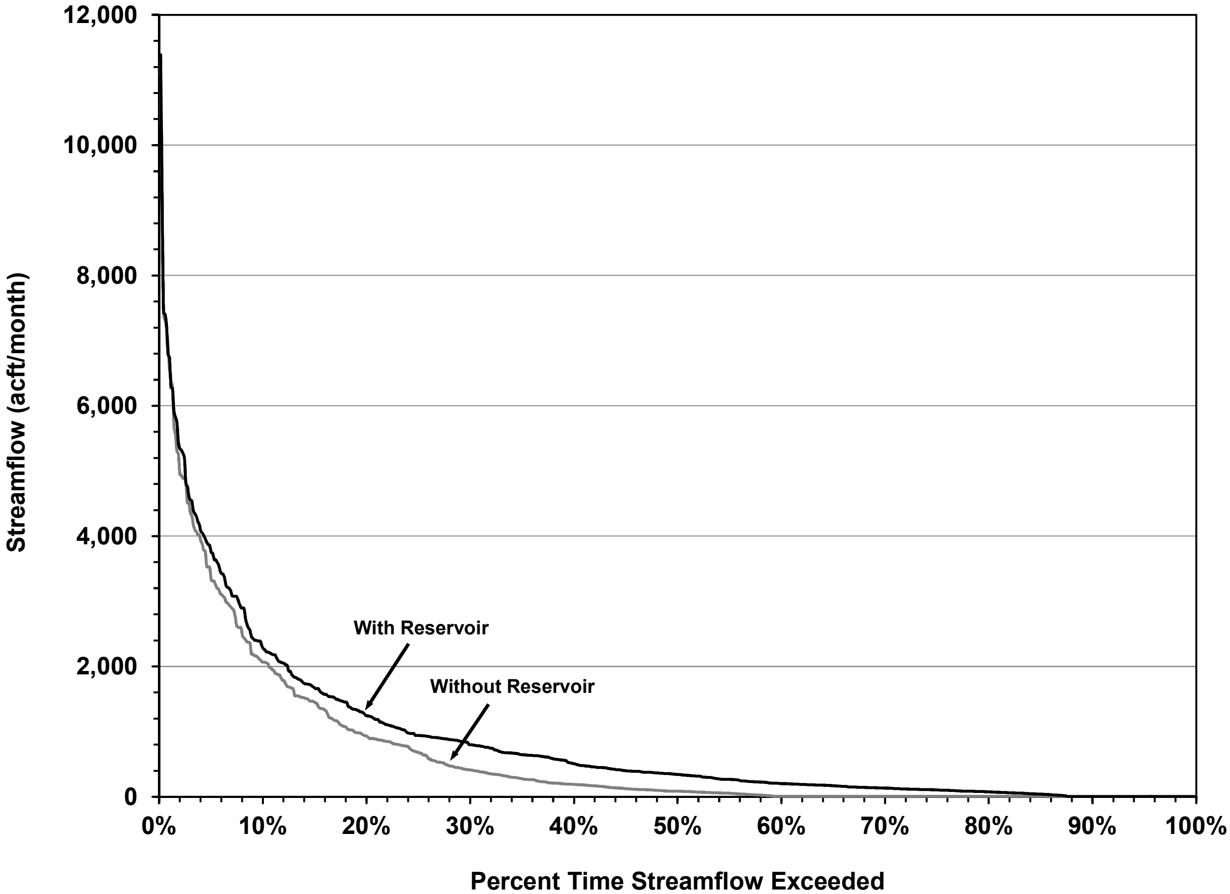
[3] Grifffith, Glenn, Sandy Bryce, James Omernik and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality and Environmental Protection Agency, Austin, Texas.

[4] McMahan, Craig A., Roy G. Frye and Kirby L. Brown. 1984. The Vegetation Types of Texas Including Cropland. Texas Parks and Wildlife Department, Austin, Texas.

Table 4.1-3. Median Monthly Streamflow for Brushy Creek Reservoir

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	7.7	2.6	5.1	66
February	6.6	3.0	3.7	55
March	7.2	3.5	3.7	51
April	6.7	3.0	3.7	55
May	15.6	13.4	2.2	14
June	11.0	5.3	5.7	52
July	4.1	1.5	2.6	63
August	3.7	1.6	2.2	58
September	2.4	0.1	2.3	96
October	2.6	0.1	2.5	96
November	3.3	0.1	3.2	97
December	7.0	1.3	5.7	82

Figure 4.1-4. Brushy Creek Reservoir Streamflow Frequency Comparison



Threatened & Endangered Species

The Brushy Creek Reservoir site would be located in Falls County, Texas. There are 22 species that are state or federally-listed as rare, threatened, or endangered that could potentially occur within Falls County (Table 4.1-4). This list contains 10 birds, 2 fish species, 3 mammals, 3 mollusks, and 4 reptiles. Two bird species that could potentially occur in the vicinity of the reservoir site are federally-listed as endangered. They are the whooping crane (*Grus americana*) and the interior least tern (*Sterna antillarum athalassos*). However because these two birds are seasonal migrants, they are not likely to be impacted by the proposed project. There are no areas of critical habitat designated within or near the project area.[5]

The information in Table 4.1-4 does not confirm nor deny the presence of the species in the project area. The project area may provide potential habitat to endangered or threatened species listed for Falls County. A survey of the project area may be required prior to project construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

[5] USFWS. Critical Habitat Portal. Accessed online at http://ecos.fws.gov/crithab/ May 29, 2014.

Table 4.1-4. Endangered, Threatened, and Species of Concern for Falls County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
BIRDS					
American peregrine falcon	*Falco peregrinus anatum*	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Artic peregrine falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL		Possible Migrant
Bald eagle	*Haliaeetus leucocephalu s*	Found primarily near rivers and large lakes.	DL	T	Possible Migrant
Henslow's Sparrow	*Ammodramus henslowii*	Wintering migrant found in weedy fields or cut-over areas.			Possible Migrant
Interior least tern	*Sterna antillarum athalassos*	Nests along sand and gravel bars in braided streams	LE	E	Possible Migrant
Sprague's pipit	*Anthus spragueii*	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C		Possible Migrant
Western burrowing owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna			Resident
White-faced Ibis	*Plegadis chihi*	Found in freshwater marshes and sloughs.		T	Potential Migrant
Whooping crane	*Grus americana*	Potential migrant	LE	E	Potential Migrant
Wood Stork	*Mycteria Americana*	Forages in prairie ponds, flooded pastures or ditches.		T	Potential Migrant
FISHES					
Sharpnose shiner	*Notropis oxyrhynchus*	Endemic to Brazos River drainage; large turbid river, with bottom a combination of sand, gravel, and clay-mud	LE		Resident

Table 4.1-4. Endangered, Threatened, and Species of Concern for Falls County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Smalleye shiner	*Notropis buccula*	Endemic to upper Brazos River system and its tributaries (Clear Fork and Bosque); medium to large prairie streams with sandy substrate and turbid to clear warm water	LE		Resident
MAMMALS					
Cave myotis bat	*Myotis velifer*	Roosts colonially in caves, rock crevices			Resident
Plains spotted skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas.			Resident
Red wolf	*Canis rufus*	Extirpated.	LE	E	Historic Resident
MOLLUSKS					
False spike mussel	*Quincuncina mitchelli*	Substrates of cobble and mud. Rio Grande, Brazos, Colorado and Guadalupe river basins. Not recorded from reservoirs.		T	Resident
Smooth pimpleback	*Quadrula houstonensis*	Small to moderate streams and rivers as well as moderate size reservoirs; mixed mud, sand, and fine gravel, tolerates very slow to moderate flow rates, Brazos, and Colorado River basins.	C	T	Resident
Texas fawnsfoot	*Truncilla macrodon*	Possibly found in rivers and larger streams, intolerant of impoundment. Brazos and Colorado River basins.	C	T	Resident
REPTILES					
Alligator snapping turtle	*Macrochelys temminckii*	Found in perennial water bodies and deep water of rivers and lakes.		T	Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	Wet or moist microhabitats			Resident

Table 4.1-4. Endangered, Threatened, and Species of Concern for Falls County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands.		T	Resident
Timber rattlesnake	*Crotalus horridus*	Floodplains, upland pine, deciduous woodlands, riparian zones.		T	Resident

TPWD, 2014. Annotated County List of Rare Species – Falls County revised 9/4/2014.
USFWS, Obtained from http://ecos.fws.gov/tess_public/reports/species-by-current-range-county?fips=48145 February 13, 2015.

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

Wildlife Habitat

The quality of wildlife habitat in the Brushy Creek area has been previously impacted due to aggressive brush eradication efforts and the conversion of native habitats into agricultural lands. The reservoir would inundate approximately 697 acres of land at conservation capacity.[6] Landcover of the reservoir area includes 44% Upland Deciduous Forest, 39% Agricultural Land, 10% Grassland and 7% Shrubland. Current aerial photography shows riparian and wooded areas along Brushy Creek within the proposed reservoir area.

Cultural Resources

A cultural resource surface survey of the Brushy Creek Reservoir area was conducted in 1978[7]. The study identified nine prehistoric cultural resource sites located in the area to be inundated by the reservoir. In April 2005, another cultural resource survey of the site

[6] TWDB. 2008. Reservoir Site Protection Study. Report 370.

[7] Nunley, 1978. *Archeological Survey of Portions of Big Creek Watershed, Falls, Limestone and McLennan Counties, Texas*. Nunley Multimedia Productions, Miscellaneous Papers, No. 2, Dallas.

was conducted by TRC Environmental Corporation[8]. The 2005 survey revisited these nine sites and identified 15 additional sites. The 24 sites contained primarily diagnostic projectile points, debris from the manufacture of chipped stone tools, and a few burned rocks. The survey area did not completely cover the footprint of the dam or the emergency spillway. The study found six sites that have the potential to contribute important information about the region. Their eligibility for inclusion in the National Register of Historic Places (NRHP) and/or as State Archeological Landmarks (SAL) still needs to be assessed. The other 18 cultural sites investigated in the study do not have sufficient potential to be considered for inclusion in the NRHP or for designation as SALs. Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Archeological and Historic Preservation Act (PL93-291), the National Historic Preservation Act (PL96-515), and the Texas Antiquities Code (Title 9, Chapter 191, Texas Natural Resource Code of 1977).

The development of this strategy would include potential changes to in-stream flows in and below Brushy Creek which could affect aquatic and other species, and loss of riparian and other existing habitat in the reservoir and dam area. Development of the reservoir would inundate existing habitat areas resulting in habitat loss for some species and producing new habitat for others. It is anticipated that any additional facilities needed such as pipelines and pump stations would be positioned to avoid impacts to known cultural resources, sensitive habitats, wetlands or stream crossings as much as reasonably possible.

Agricultural Impacts

The Brushy Creek Reservoir site contains approximately 185 acres of Pasture/Hay fields and 84 acres of cropland. These two agricultural land uses account for roughly 25 percent of the reservoir footprint.

4.1.4 Engineering and Costing

Due to the history of detailed studies on the Brushy Creek reservoir the cost estimate presented below in Table 4.1-5 contains a greater level of detail than the typical water management strategy evaluation that uses the Unified Regional Costing Tool. The proposed Brushy Creek Reservoir includes the construction of a rolled earth embankment, a principal spillway, and an emergency spillway. Table 4.1-5 shows the estimated costs for the Brushy Creek Reservoir, including the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and engineering services. The unit costs used in this study are based on the Reservoir Site Protection Study (TWDB, 2008) 2005 prices adjusted to September 2013 prices using a multiplier based on the Construction Cost Index (CCI). The price of land per acre is estimated as the percent between minimum and maximum land values for river properties in Falls County based on Texas Rural Land Value Trends developed by Texas A&M Real Estate Center. However, the inclusion of land prices in this cost estimate may

[8] TRC, 2006. *Cultural Resource Survey of the Proposed Brushy Creek Reservoir – Structure 19 Project Area, Falls County, Texas*. Technical Report 43211. Prepared for City of Marlin by J. M. Quigg, M. J. Archambeault, E. Schroeder, and P. M. Matchen of the TRC Environmental Corporation. July 2006.

be unnecessary since the City of Marlin has already purchased the land needed to build the reservoir for about $1 million.

Given these assumptions, the estimated cost of the project is $20.8 million (September 2013 prices). The annual costs of the project, which include debt service and operation and maintenance, are estimated to be $1.7 million. With a projected firm yield of 1,450 acre-feet per year by 2070, the annual unit cost of raw water will be $3.69 per 1,000 gallons ($1,202 per acre-foot). Without the floodwater component, the unit cost is $1.48 per 1,000 gallons ($481 per acre-foot).

Table 4.1-5. Cost Estimate Summary for Brushy Creek Off-Channel Reservoir

Item	Estimated Costs for Facilities
Dam and Reservoir (Conservation Pool 6,560 acft, 1,812 acres)	$5,283,000
Intake Pump Stations (1.4 MGD)	$1,456,000
Transmission Pipeline (12 in dia., 12 miles)	$2,612,000
Integration, Relocations, and Other	$3,957,000
TOTAL COST OF FACILITIES	**$13,308,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$4,527,000
Environmental & Archaeology Studies and Mitigation	$1,336,000
Land Acquisition and Surveying (77 acres)	$301,000
Interest During Construction (4% for 2 years with a 1% ROI)	$1,364,000
TOTAL COST OF PROJECT	**$20,836,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$1,005,000
Reservoir Debt Service (5.5 percent, 40 years)	$550,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$26,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$36,000
Dam and Reservoir (1.5% of Cost of Facilities)	$79,000
Pumping Energy Costs (524,421 kW-hr @ 0.09 $/kW-hr)	$47,000
TOTAL ANNUAL COST	**$1,743,000**

Table 4.1-5. Cost Estimate Summary for Brushy Creek Off-Channel Reservoir

Item	Estimated Costs for Facilities
Available Project Yield (acft/yr)	1,450
Unit Cost of Water with NRCS floodwater component ($ per acft)	$1,202
Annual Cost of Water with NRCS floodwater component ($ per 1,000 gallons)	$3.69
Unit Cost City Share 40% ($ per acft)	$481
Unit Cost City Share 40% ($ per 1,000 gallons)	$1.48

[1] Includes the dam, intake, and spillway tower.

4.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.1-6 and the option meets each criterion.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits have already been obtained;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- General Land Office Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 4.1-6. Evaluations of Brushy Creek Off-Channel Reservoir Option to Enhance Water Supplies

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	Negligible impact
2. Habitat	Negligible impact
3. Cultural Resources	Low impact
4. Bays and Estuaries	Negligible impact
5. Threatened and Endangered Species	Low impact
6. Wetlands	Negligible impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

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4.2 Cedar Ridge Reservoir

4.2.1 Description of Option

The proposed Cedar Ridge Reservoir was analyzed in the 2001 Plan at the Breckenridge Reservoir Reynolds Bend site, and in 2006 as the Breckenridge Reservoir Cedar Ridge site. In the 2011 Plan, the Cedar Ridge Reservoir dam site was moved to its current site in Shackelford County on the Clear Fork of the Brazos River about 40 miles north of the City of Abilene (City), as shown in Figure 4.2-1. Initially located further downstream and known as the Breckenridge Reservoir, this project was initially studied in 1971 by the Texas Water Development Board and most recently in 2009 for the City by Enprotec/ Hibbs & Todd (eHT) and HDR, Inc[1]. The proposed reservoir will contain approximately 227,127 acft of conservation storage and inundate 6,635 acres at the full conservation storage level of 1,489 ft-msl. The total drainage area at the Cedar Ridge Reservoir Site is approximately 2,748 sq. miles.

The water supply from this reservoir could be used to meet several municipal shortages in the area and is part of the water supply plan for the City. The City is actively pursuing the necessary permits and engineering required to implement this project. The information contained in this section is based on the water right permit application filed at the Texas Commission on Environmental Quality and the Clean Water Act, Section 404 permit filed with the U.S. Army Corps of Engineers, Ft. Worth District (USACE).

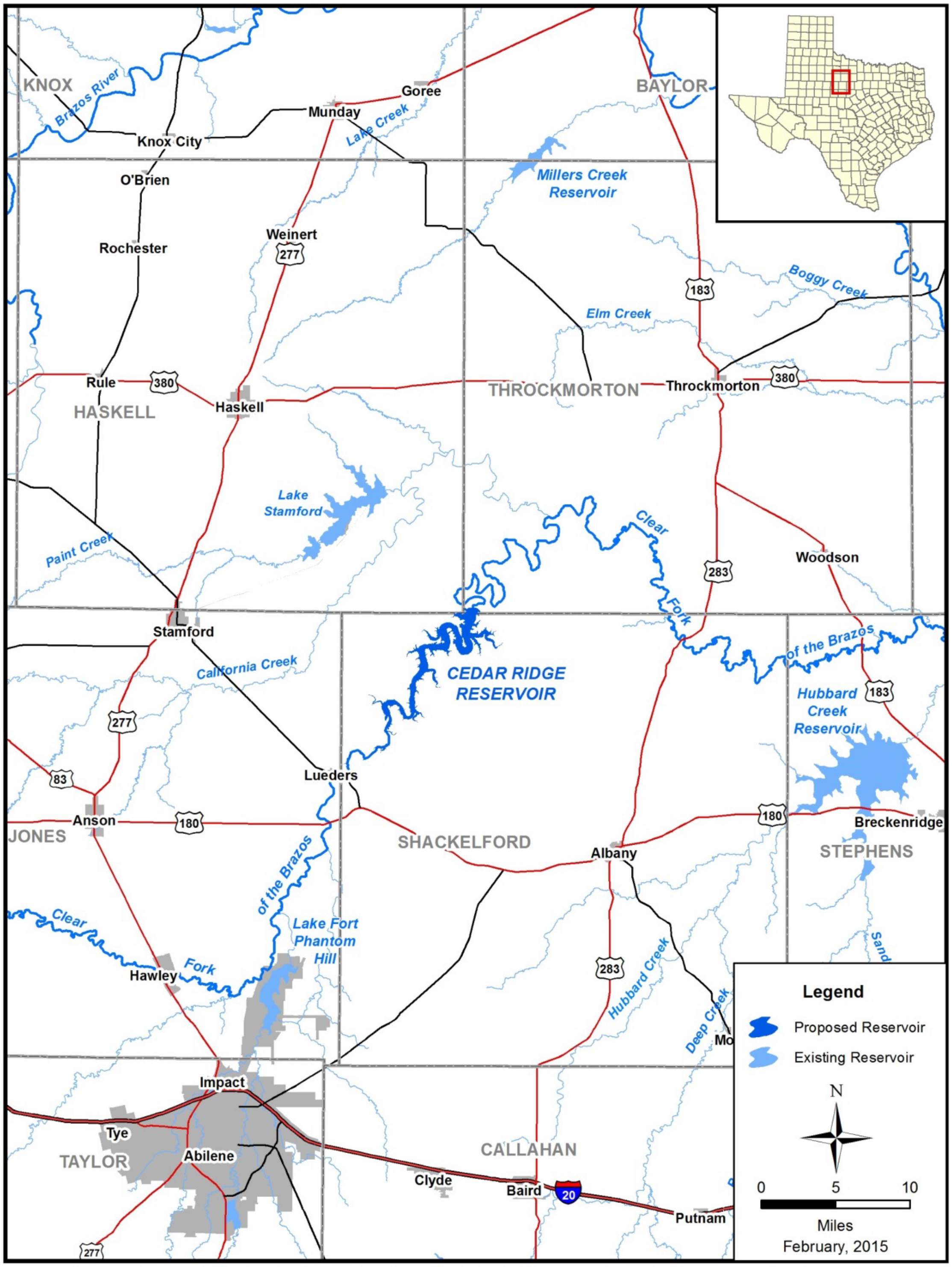
4.2.2 Available Yield

The City has applied for a water right permit with the TCEQ to divert up to 34,400 acft/yr of stored water from the reservoir for multi-purpose uses including: municipal, domestic, industrial, agriculture, livestock, steam-electric, mining, and recreation. This diversion was calculated to be the firm yield supply of the reservoir assuming permitted storages and diversions for all other senior water right holders in the Brazos basin for the 1940 to 1997 hydrologic period (TCEQ Brazos WAM Run 3) in accordance with an interlocal agreement with BRA which includes the subordination of Possum Kingdom Reservoir. However, since 1997 severe drought conditions have occurred in the upper Brazos Basin resulting in a new critical drought for the Clear Fork watershed. Therefore, the City conservatively plans for supplies from Cedar Ridge Reservoir to equal to the 1-year safe yield as calculated by the Brazos G Mini-WAM.

The Mini-WAM utilizes an updated January 1940 through June 2008 hydrologic period of record to account for the recent drought in the Upper Brazos Basin. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computes the streamflow available from the Clear Fork of the Brazos River without causing increased shortages to existing downstream rights. Safe

[1] Enprotec / Hibbs & Todd, HDR,Inc., "Updated Evaluations of Cedar Ridge Reservoir and Possum Kingdom Lake Water Supply Options for City of Abilene," November 2009.

Figure 4.2-1. Cedar Ridge Reservoir



L:\Project_Data\00044_BrazosG\GIS\Map_Docs\Task_04_WMS\WMS_Task_04_Existing_Supplies\Cedar_Ridge_Reservoir.mxd yield was computed subject to the reservoir having to pass inflows to meet Senate Bill 3 (SB3) environmental flow criteria and assuming subordination of Possum Kingdom Reservoir.

The calculated 1-year safe yield of the Cedar Ridge Reservoir for the 2016 Plan is 26,575 acft/yr, an increase of 3,195 acft/yr compared to the 2011 Plan 1-year safe yield of 23,380 acft/yr. The increase in safe yield can be attributed to the application of the SB3 environmental flow criteria compared to the Consensus Criteria for Environmental Flow Criteria (CCEFN) used in the 2011 Plan. The firm yield impact on Possum Kingdom Reservoir from the operation of Cedar Ridge Reservoir, as defined in the inter-local agreement between the Brazos River Authority, the City and the WCTMWD, has been determined to be 5,000 acft/yr.

Figure 4.2-2 illustrates the simulated Cedar Ridge Reservoir storage levels subject to the safe yield demand of 26,575 acft/yr for the 1940 to 2008 historical period. The storage trace reveals that the more recent drought beginning in the late 1990's is more severe than the drought of the 1950's.

Figure 4.2-3 illustrates the storage frequency of the simulated Cedar Ridge Reservoir subject to the safe yield demand. Simulated reservoir contents remain above half full more than 80 percent of the time and do not drop below 10 percent of capacity.

Figure 4.2-4 presents the changes in Clear Fork monthly median streamflows caused by impoundments in the reservoir considering pass throughs for downstream senior water rights and environmental needs in accordance with TCEQ environmental flow requirements Figure 4.2-4 shows that monthly median streamflows remain above 5 cfs for all months with the reservoir in place. Figure 4.2-5 compares the existing Clear Fork streamflow frequency characteristics for the full period of the analysis without the project to simulated streamflow characteristics with the project considering pass throughs for downstream senior water rights and environmental needs in accordance with TCEQ environmental flow requirements.

Figure 4.2-2. Cedar Ridge Reservoir Safe Yield Storage Trace

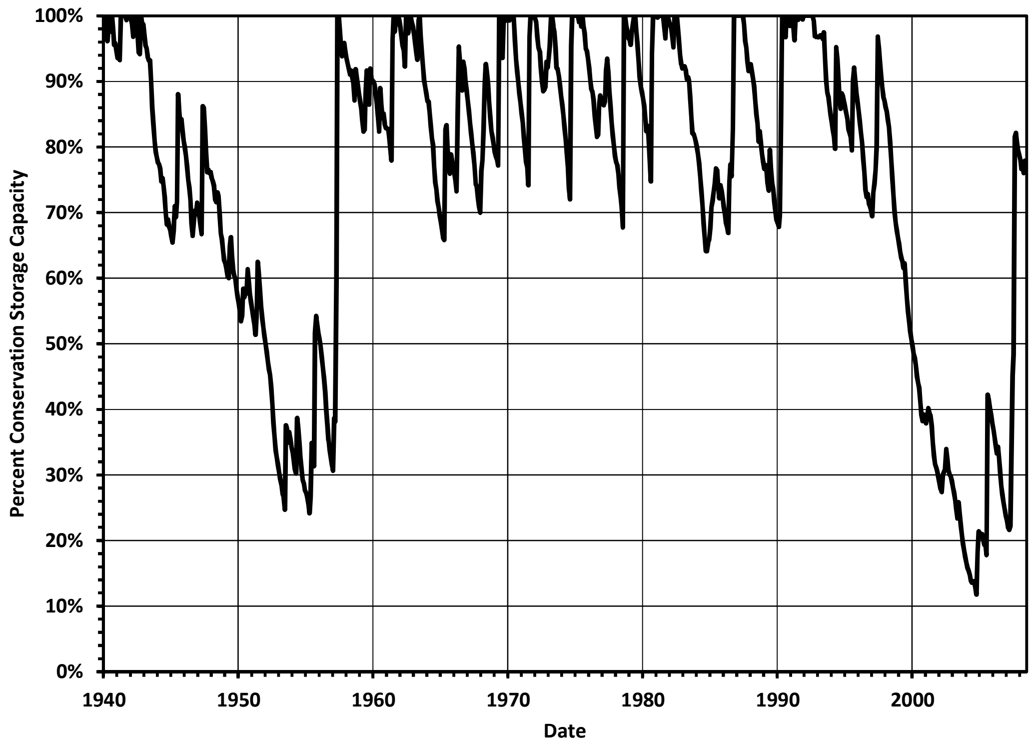


Figure 4.2-3. Cedar Ridge Reservoir Safe Yield Storage Frequency

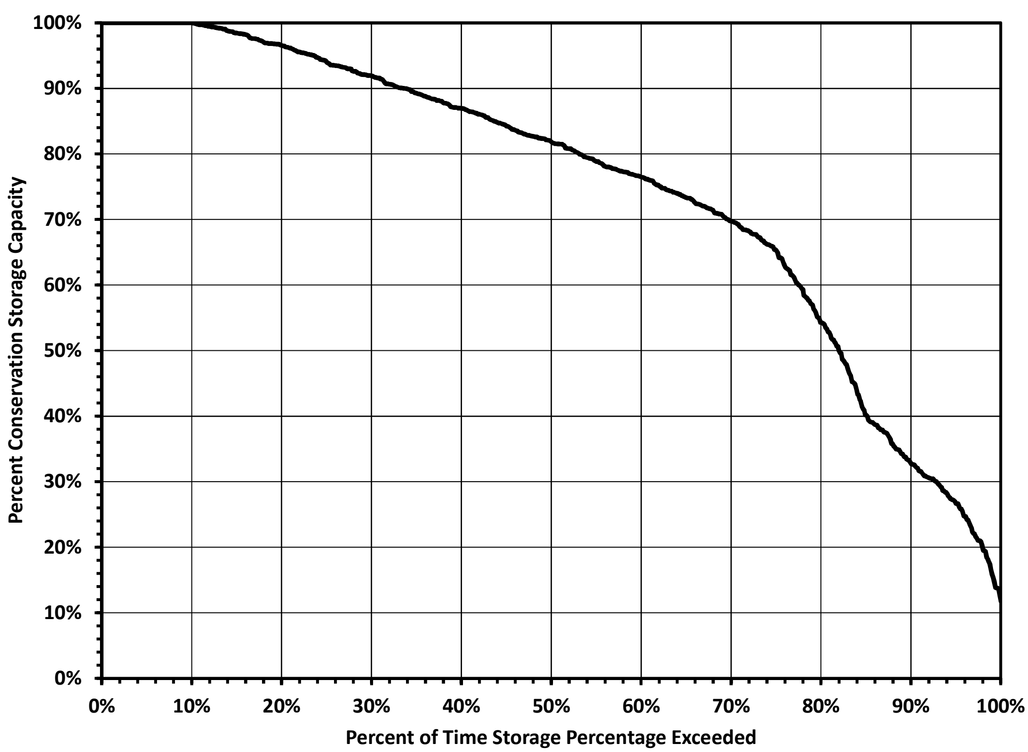


Figure 4.2-4. Cedar Ridge Reservoir Median Streamflow Comparison

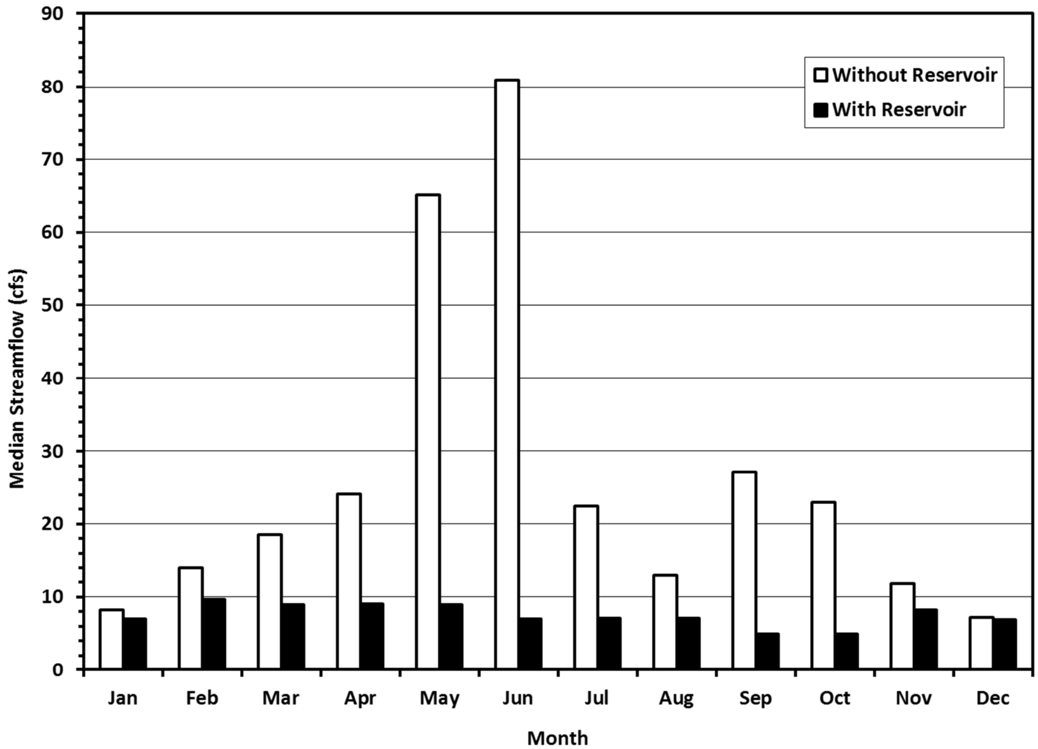
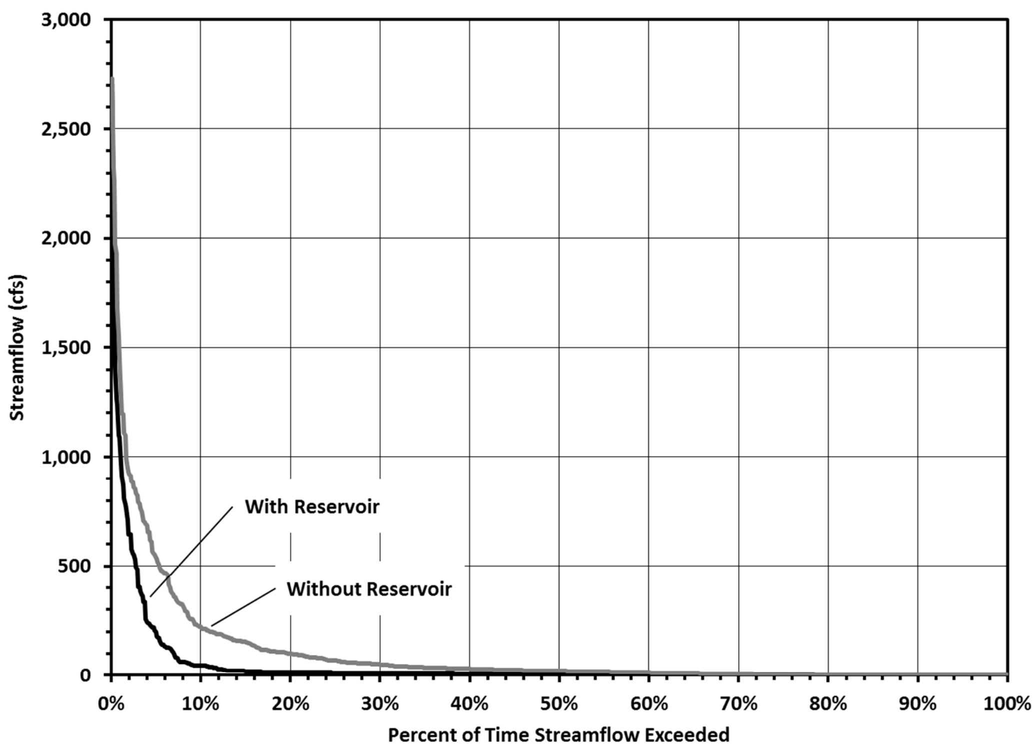


Figure 4.2-5. Cedar Ridge Reservoir Streamflow Frequency Comparison



4.2.3 Environmental Issues

The following environmental section focuses on providing a high level summary of environmental issues consistent with other water management strategies evaluated as part of the 2016 Brazos G plan. The information presented here is based on the City's TCEQ water right application and the USACE Section 404 permit application.

Existing Environment

The Cedar Ridge reservoir will inundate 6,635 acres at its conservation storage level of 1,489 ft-msl. The project will require an intake pump station, a water treatment plant expansion and a transmission pipeline of approximately 29 miles. Water diverted from this reservoir will be used to meet water supply shortages for the City and include existing and future customers.

Steep canyon walls are present throughout this area, ranging from 5 to 30 percent slopes with near vertical cliffs in some areas. Soils in the study area are predominantly loamy and clayey with clayey soils occurring primarily in the upstream portions of the study area. General soil map units in the project area include the Palopinto-Throck and Clairemont-Grandfield-Clearfork soil units.

No major or minor aquifers underlie the project area. The Trinity Aquifer lies south of the project area and consists of interbedded sandstone, sand, limestone, and shale of Cretaceous Age. The Seymour Aquifer is located west and north of the project area and is composed of isolated areas of alluvium.[2]

The climate in the study area is subtropical subhumid, with hot, dry summers and mild, dry winters. Temperatures range from an average low of 31°F in January to an average maximum of 97°F in July with a mean average temperature of 64oF.[3] The growing season is approximately 224 days and annual precipitation averages between 25 and 28 inches. Most precipitation occurs from April to October during thunderstorms of short duration and high intensity. Recurring droughts are common in this area and can last many years.

The project area lies within the Limestone Plains subregion of the portion of the Central Great Plains ecoregion in Texas[4] and within the vegetational area known as the Rolling Plains.[5] Although this subregion is principally covered by a mixed grass prairie dominated by grasses such as little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), and buffalograss (*Bouteloua dactyloides*), it also includes scattered trees such as honey mesquite (*Prosopis glandulosa*).

The dominant vegetation type found within the project area as mapped by the TPWD is mesquite brush, which covers approximately 61 percent of the conservation pool area of

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2 Texas Water Development Board (TWDB). 2010a. Major and Minor Aquifers of Texas; Maps online at http://www.twdb.state.tx.us/mapping/index.asp.

3 Handbook of Texas Online (HTO), s.v. "Shackelford County, Texas,". http://www.tshaonline.org/handbook/online/articles/SS/hcs8.htm.

4 Griffith, G. E., S. A. Bryce, J. M. Omernik, J. A.Comstock, A. C.Rogers, B.Harrison, and S. L. Hatch, and D. Bezanson. 2004. Ecoregions of Texas (color poster with map, descriptive text, and photographs): Reston, VA, U.S. Geological Survey.

5 Hatch, S. L., N. G. Kancheepuram, and L. E. Brown. 1990. Checklist of the Vascular Plants of Texas. Texas Agricultural Experiment Station. Texas A&M University, College Station.

Cedar Ridge Reservoir.[6] Plants commonly associated with this vegetation type include narrow-leaf yucca (*Yucca glauca*), purple pricklypear (*Opuntia macrocentra*), juniper (*Juniperus* spp.), red grama (*Bouteloua trifida*), Texas grama (*Bouteloua rigidiseta*), purple three-awn (*Aristida purpurea* var. *purpurea*), James' rushpea (*Caesalpinia jamesii*), and wild buckwheat (*Eriogonum* spp.).[7]

The mesquite-lotebush shrub vegetation type is also found within the project area. This vegetation type is dispersed relatively evenly along the reservoir site, covering approximately 39 percent of the conservation pool area. Commonly associated plants in this vegetation type include honey mesquite, yucca (Yucca spp.), fragrant sumac (*Rhus aromatica*), elbowbush (*Forestiera pubescens*), cane bluestem (*Bothriochloa barbinodis*), silver bluestem (*Bothriochloa laguroides* ssp. *torreyana*), Texas wintergrass (*Nassella leucotricha*), Engelmann's daisy (*Engelmannia peristenia*), and bitter rubberweed (*Hymenoxys odorata*).[8]

Permanent impacts will occur to all the current vegetation located within the conservation pool of the reservoir and some portions of the construction area. This vegetation will be impacted either by clearing at the dam site or inundation by the reservoir. Temporary impacts may also occur to the vegetation located outside of the conservation pool area but within the flood pool area. These areas will be inundated only occasionally for a few days as floods will be passed through an ungated spillway. Pipeline areas will primarily impact vegetation during construction and maintenance activities with some areas returning to their original states after the initial disturbance.

Potential Impacts

Aquatic Environments including Bays & Estuaries

With the construction of the new reservoir, the current floodplains along the Clear Fork and its major tributaries within the new reservoir's conservation pool area will be inundated. Although some stream and wetland functions would be impacted due to inundation by the conservation storage area, the creation, enhancement, and/or protection of aquatic habitat resulting from the new reservoir will replace some of the biological, chemical, and physical functions of the impacted resources and habitats.

The anticipated impact of this project would be lower variability in and reductions in the quantity of median monthly flows. Variability in flow is important to the instream biological community as well as riparian species and pass throughs for environmental needs are proposed to be in accordance with recently adopted TCEQ flow requirements. The TCEQ flow requirements for this segment of the Clear Fork were based, in part, on in-stream flow studies performed for the project to assure that adequate flows remained in the stream to maintain the existing biological community.

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6 McMahan, C. A., R. G. Frye, K. Brown. 1984. The Vegetation Types of Texas, Including Cropland. Wildlife Division, Texas Parks and Wildlife Department, Austin.

7 Ibid.

8 McMahan, C. A., R. G. Frye, K. Brown. 1984. The Vegetation Types of Texas, Including Cropland. Wildlife Division, Texas Parks and Wildlife Department, Austin.

Although there may be some impacts on the biological community in the immediate vicinity of the project site and downstream, this project would not have a substantial influence on total discharge in the Brazos River or to freshwater inflows to the Brazos River estuary. As a new reservoir Cedar Ridge Reservoir would be required to pass through environmental flows based on TCEQ's recently adopted environmental flow requirements.

Wildlife Habitat

The project area is located within the Kansan biotic province.[9] The Kansan Province is divided into three districts that include (from west to east) the short-grass plains, mixed-grass plains, and the mesquite plains. The project area is situated within the mesquite plains district. Within this district the typical vegetation community generally consists of clusters of mesquite and other shrubs interspersed with open areas of grasses. Common wildlife species found in the Kansan Biotic Province include the Great Plains toad (*Anaxyrus cognatus*), turkey vulture (*Cathartes aura*), scaled quail (*Callipepla squamata*), big brown bat (*Eptesicus fuscus*) and eastern collared lizard (*Crotaphytus collaris*) among others. Wildlife species inhabiting the project area utilize it to varying extents depending on their specific biologic needs.

Inundation of existing habitat by the reservoir will force non-aquatic species inhabiting these areas to relocate to surrounding suitable habitats unaffected by reservoir filling. Greater adverse impacts will occur to those wildlife species that currently utilize riparian habitats within the reservoir's footprint; however, similar habitats exist along upstream and downstream reaches of the Clear Fork, and additional riparian habitat will develop along portions of the reservoir shoreline subsequent to reservoir filling.

Threatened & Endangered Species

Table 4.2-1 lists the state and federally threatened, endangered, or otherwise rare species that could occur in Haskell, Jones, Shackelford, and Throckmorton Counties. This table includes the listing status of these taxa, as well as descriptions of suitable habitat for each species. Inclusion in this table does not mean that a species will occur within the project area but acknowledges the potential for its occurrence within one of the four counties in which the project area exists. On-site evaluations by qualified biologists would be required to confirm or deny the occurrence of sensitive species or habitats.

A search of the Texas Natural Diversity Database (TNDD)[10] identified the state threatened Brazos water snake as the only threatened or endangered species with documented occurrences within or near the new reservoir site. The plains spotted skunk (*Spilogale putorius interrupta*), a species of concern, was also documented in the vicinity of the new reservoir however, this species is not state or federally protected. While based on the best information available to TPWD, TNDD data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area.

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9 Blair, W. F. 1950. The biotic provinces of Texas. Texas Journal of Science 2:93–117.

10 Texas Parks and Wildlife Department (TPWD). 2010. Element occurrence records for Haskell, Jones, Shackelford, and Throckmorton Counties. Texas Natural Diversity Database, Texas Parks and Wildlife Department.

Listed species with the potential to occur within the project area are discussed in the following paragraphs. These species include two birds, the Whooping Crane (*Grus americana*) and the Interior Least Tern (*Sterna antillarum athalassos*). These birds are federally listed as endangered and could occur within the project and surrounding areas as seasonal migrants. During migration Whooping Cranes primarily utilize wetland areas as rest stops. Wetland habitat within the project area is limited and occurrences of this species would be limited to occasional migratory stops. The Interior Least Tern typically nests on bare or sparsely vegetated areas associated with streams or lakes, such as sand and gravel bars, beaches, islands, and salt flats. Occasional migrants of these species are possible within the new reservoir site.

Two fishes, the sharpnose shiner (*Notropis oxyrhynchus*) and the smalleye shiner (*N. buccula*) are small, slender minnows endemic to the Brazos River Basin.[11] Historically, these fishes existed throughout the Brazos River and several of its major tributaries; however, both species have experienced significant population declines. General habitat associations for both species include relatively shallow water with moderate currents flowing through broad, open sandy channels. Surveys of the Clear Fork performed within and downstream of the reservoir footprint indicate that suitable habitat for both the sharpnose and smalleye shiner is not present.

Two mussel species, the smooth pimpleback (*Quadrula houstonensis*) and the Texas fawnsfoot (*Truncilla macrodon*), are endemic to the Brazos River Basin and could potentially occur within or in the surrounding vicinity of the new reservoir footprint. The smooth pimpleback prefers small to moderate sized streams and rivers, as well as moderately sized reservoirs, and is typically found in substrates of mixed mud, sand and fine gravel in water flowing at a very slow to moderate rate.[12] While it is unlikely that the smooth pimpleback inhabits the reach of the Clear Fork to be impacted by the new reservoir, this species is known to tolerate impoundment.

The Texas fawnsfoot historically occurred in the Brazos and Colorado River drainages. Little is known pertaining to the preferred habitat of this species; however, it is known to be intolerant of impoundment.[13] Texas fawnsfoot specimens potentially occurring downstream of the new reservoir are not anticipated to be significantly impacted from the project, as this species has been reported to occur downstream of other impoundments along the Brazos River. Surveys of the project reach for mussels were conducted in 2009, 2010, and 2011. No live or recently dead specimens of either the smooth pimpleback or the Texas fawnsfoot were identified upstream, within, and downstream of the project reach.

The new reservoir could potentially cause adverse impacts to two state threatened reptile species. These species include the Texas horned lizard (*Phrynosoma cornutum*) and the Brazos water snake (*Nerodia harteri harteri*). The Texas horned lizard is a relatively small lizard that is known to occur in a variety of habitats including short-grass prairie,

11 Cross, F. B. 1953. A new minnow, Notropis bairdi buccula, from the Brazos River, Texas. Texas Journal of Science 5:252-259.

12 Howells, R. G., R. W. Neck, and H. D. Murray. 1996. Freshwater Mussels of Texas. Inland Fisheries Division, Texas Parks and Wildlife Department, Austin..

13 Ibid.

mesquite grasslands, shrublands, desert scrub, and desert grasslands.[14] Potentially suitable habitat for the Texas horned lizard is present both within and surrounding the reservoir footprint. As the Cedar Ridge Reservoir fills, Texas horned lizards inhabiting areas within the reservoir footprint would be displaced. Potential impacts to this state threatened lizard will likely be minimal given the estimated slow filling rate of the new reservoir and abundant suitable habitat immediately surrounding the project area.

Table 4.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Haskell, Jones, Shackelford and Throckmorton Counties

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
		BIRDS			
American peregrine falcon	*Falco peregrinus anatum*	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL	--	Possible Migrant
Baird's sparrow	*Ammodramus bairdii*	Found in shortgrass prairie with scattered low bushes and matted vegetation migratory in western part of state.	--	--	Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Ferruginous hawk	*Buteo regalis*	Open country primarily prairies, plains, and badlands nesting near water.	--	--	Possible Migrant
Black-capped vireo	*Vireo atricapilla*	Prefers oak-juniper woodlands with distinctive patchy, two-layered aspect; shrub and tree layer with open, grassy spaces.	LE	E	Possible Migrant
Interior least tern	*Sterna antillarum athalassos*	Nests along sand and gravel bars in braided streams	LE	E	Possible Migrant
Mountain plover	*Charadrius montanus*	Non-breeding, shortgrass plains and fields	--	--	Nesting/ Migrant

14 Price, A. H. 1990. Phrynosoma cornutum. Catalogue of American Amphibians and Reptiles. 469:1–7.

Table 4.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Haskell, Jones, Shackelford and Throckmorton Counties

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Piping plover	*Charadrius melodus*	A small pale shorebird of open sandy beaches and alkali flats, the Piping Plover is found along the Atlantic and Gulf coasts.	LT	T	Possible Migrant
Snowy plover	*Charadrius alexandriunus*	Potential migrant winters along coast	--	--	Possible Migrant
Sprague's pipit	*Anthus spragueii*	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Western burrowing owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna	--	--	Resident
Western snowy plover	*Charadrius alexandrines nivosus*	Potential migrant, winters along coast.	--	--	Possible Migrant
Whooping crane	*Grus americana*	Potential migrant	LE	E	Potential Migrant
FISHES					
Sharpnose shiner	*Notropis oxyrhynchus*	Endemic to Brazos River drainage. Found in large rivers.	LE	--	Resident
Smalleye shiner	*Notropis buccula*	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident
MAMMALS					
Black-footed ferret	*Mustela nigripes*	Extirpated, inhabited prairie dog towns.	LE	--	Historic Resident
Black-tailed prairie dog	*Cynomys ludovicianus*	Found on dry, flat, short grasslands.	--	--	Resident

Table 4.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Haskell, Jones, Shackelford and Throckmorton Counties

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Cave myotis bat	*Myotis velifer*	Roosts colonially in caves, rock crevices	--	--	Resident
Gray wolf	*Canis lupus*	Extirpated formerly known in western two-thirds of the state.	LE	E	Historic Resident
Pale Townsend's big-eared bat	*Corynorhinus townsendii pallescens*	Roosts in caves and old buildings. Hibernates in winter.	--	--	Resident
Plains spotted skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	Extirpated.	LE	E	Historic Resident
MOLLUSKS					
Smooth pimpleback	*Quadrula houstonensis*	Found in small to moderate streams and rivers as well as moderate sized reservoirs. Brazos and Colorado River basins.	C	T	Resident
Texas fawnsfoot	*Truncilla macrodon*	Found in rivers and larger streams, intolerant of impoundment.	C	T	Resident
REPTILES					
Brazos water snake	*Nerodia harteri*	Found in upper Brazos River drainage in shallow water with rocky bottoms.	--	T	Resident
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands.	--	T	Resident

Table 4.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Haskell, Jones, Shackelford and Throckmorton Counties

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
LE/LT=Federally Listed Endangered/Threatened DL=Federally Delisted C=Candidate for Federal Listing PT=Proposed Threatened E, T=State Listed Endangered/Threatened Blank = Considered rare, but no regulatory listing status TPWD, 2015. Annotated County List of Rare Species –Haskell County 9/4/2014, Jones County 9/4/2014, Shackelford County 9/4/2014, and Throckmorton County 9/4/2014. USFWS, 2015. Endangered Species List for Haskell, Jones, Shackelford and Baylor Counties, Texas. At http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action, February 18, 2015.					

The Brazos water snake is a highly aquatic, endemic Texas snake with a limited and patchy distribution along the upper Brazos River drainage in north-central Texas. Preferred habitat consists of shallow rocky riffles along the river that have a gently sloping rocky shoreline free of vegetation.[15] Investigation of the project area indicate that Brazos water snake populations and suitable habitat exist along the Clear Fork, both within and downstream of the proposed Cedar Ridge reservoir footprint. Potential impacts to the Brazos water snake from the construction of Cedar Ridge Reservoir include the inundation and loss of existing habitat along the Clear Fork. However, geologic investigations of the Cedar Ridge Reservoir shoreline indicate that there will be significant areas of rocky shoreline that will provide significant habitat after the reservoir fills. Based on the occurrence and populations of Brazos Water Snakes that have continued to reproduce in Possum Kingdom Lake since its initial filling in 1941, it is anticipated that the Brazos Water Snake will have suitable habitat to maintain viable populations in Cedar Ridge Reservoir.

Cultural Resources

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available GIS datasets provided by the Texas Historical Commission (THC), there are no National Register Properties, National Register Districts, State Historic Sites, cemeteries or historical markers located within or near the reservoir or pipeline project areas. The owner of the project is required to coordinate with the Texas Historical Commission regarding potential impacts to cultural resources.

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15 Scott, N. J., Jr., T. C. Maxwell, O. W. Thornton, Jr., L. A. Fitzgerald, and J. W. Flury. 1989. Distribution, habitat, and future of Harter's Water Snake, Nerodia harteri, in Texas. Journal of Herpetology 23:373-389.

The Texas Archeological Sites Atlas online database of the Texas Historical Commission (THC) was also consulted and background research was conducted to determine any previous cultural resources survey efforts as well as the locations of previously recorded historic and archaeological resources in the project area. Records indicate that eight previously recorded prehistoric archaeological sites were located within a 1-mile radius of the reservoir area.

The City conducted preliminary Phase 1A archeological surveys and historical evaluations, and the results and recommendations from these Phase 1A surveys were provided to the TCEQ in the Water Rights application submitted on August 17, 2011, and to the THC and USACE under separate cover. Phase 1B surveys, including trenching at selected alluvial terrace locations, were initiated in 2011 and completed in 2012. The findings of the Phase 1B surveys were provided to the USACE and THC in support of Section 404 Permit coordination in accordance with the requirements of Section 106 of the National Historic Preservation Act (NHPA). The City will also coordinate the findings of the archeological surveys with the THC and TCEQ in conjunction with the review of the project under the Antiquities Code of Texas.

The Phase 1A and 1B investigations identified 66 prehistoric sites, five historic sites, and four multicomponent sites. Four archeological sites located within the project area are recommended for further testing to determine their eligibility for listing in the National Register of Historic Places (NRHP) and designation as a State Archeological Landmark (SAL) by the City pending concurrence from the USACE and THC. Additionally, historical sites were evaluated and 62 architectural resources at five sites were recorded. Fifty-seven of the sites are associated with the proposed Hendrick River Ranch Historic District. Evaluation of the pre-historic and historic resources in the area of potential effect of the reservoir will be conducted and documented in accordance with standard practices for determination of NRHP and SAL eligibility and mitigation measures will be implemented, if necessary.

Specific project features such as pipelines generally have sufficient design flexibility to avoid most impacts or significantly mitigate potential impacts to geographically limited environmental and cultural resource sites. Field surveys conducted at the appropriate phase of development should be employed to minimize the impacts of project construction and operations on sensitive resources.

Threats to Natural Resources

Threats to natural resources include lower streamflows below the reservoir. However, due to the nutrient removal that will occur as a result of the new reservoir and a planned multi-level outlet, water quality downstream of the reservoir is anticipated to improve with respect to increasing dissolved oxygen concentrations, and lowering concentrations of any existing stream pollutants.

Agricultural Impacts

The Cedar Ridge Reservoir site contains approximately 35 acres of Pasture/Hay fields and 58 acres of cropland. These two agricultural land uses account for less than two percent of the reservoir footprint.

4.2.4 Engineering and Costing

The proposed Cedar Ridge Reservoir includes the construction of an earthen dam, principal spillway, emergency spillway, and appurtenant structures. eHT and HDR completed a study[16] in 2009 of the proposed Cedar Ridge Reservoir and estimated costs for the reservoir project. These costs were indexed to September 2013 dollars. Infrastructure required for the transmission of supplies from the reservoir was estimated using the TWDB unified costing model.

The capital cost of the project is estimated to be $163.5 million. This capital cost includes the construction of the dam, land acquisition and resolution of conflicts. Also included in this cost are facilities to deliver the water to the City through a 42-inch pipeline and for additional treatment capacity that would be needed by the City to fully utilize the Cedar Ridge supply. The total cost of the project is estimated to be $290.9 million and includes environmental permitting and mitigation, and technical services. A more detailed listing of the various components of the cost estimate is provided in Table 4.2-2. The annual project costs are estimated to be $27.4 million, which includes annual debt service, operation and maintenance, and an annual payment to the Brazos River Authority for lost yield in Possum Kingdom. The cost for the estimated 1-yr safe yield of 26,575 acft/yr translates to an annual unit cost of $3.16 per 1,000 gallons or $1,031 per acft.

16 eHT and HDR, Op. Cit., November 2009.

Table 4.2-2. Cost Estimate for Cedar Ridge Reservoir

Item	Estimated Costs for Facilities
Capital Cost	
Dam and Reservoir	$69,977,000
Intake Pump Stations (25 MGD)	$10,352,000
Transmission Pipeline (42 in dia., 29 miles)	$43,697,000
Water Treatment Plant Expansion (16.7 MGD)	$26,665,000
Integration, Relocations, & Other	$12,837,000
Total Cost Of Facilities	**$163,528,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$55,050,000
Environmental & Archaeological Studies and Mitigation	$26,614,000
Land Acquisition and Surveying (9,978 acres)	$18,036,000
Interest During Construction (4% for 3 years with a 1% ROI)	$27,640,000
Total Cost Of Project	**$290,868,000**
Debt Service (5.5 percent, 20 years)	$11,580,000
Reservoir Debt Service (5.5 percent, 40 years)	$9,503,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$969,000
Dam and Reservoir	$1,050,000
Water Treatment Plant	$2,667,000
Pumping Energy Costs ($0.09 kwh)	$1,574,000
Purchase of Water (5,000 acft/yr @ 65.65 $/acft)	$328,000
Total Annual Cost	**$27,398,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**26,575**
Annual Cost of Water ($ per acft)	**$1,031**
Annual Cost of Water ($ per 1,000 gallons)	**$3.16**

4.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.2-3, and the option meets each criterion.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permit (pending at TCEQ);
- U.S. Army Corps of Engineers Permit will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act) (pending at the USACE-SWF);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- Texas General Land Office Easement if State-owned land or water is involved; and
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions or other local landowner agreements;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Relocations or removal of residences, utilities, roads, or other structures.

Table 4.2-3. Comparison of Cedar Ridge Reservoir Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable to High
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impact
2. Habitat	2. High impact
3. Cultural Resources	3. Moderate impact based on surveys of site
4. Bays and Estuaries	4. Low impact due to distance from coast
5. Threatened and Endangered Species	5. Possible moderate impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	Potential impact on bottomland farms and habitat in reservoir area
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

4.3 Coryell County Off-Channel Reservoir

4.3.1 Description of Option

The Coryell County Off-Channel Reservoir (OCR) is a proposed new reservoir on a tributary adjacent to Cowhouse Creek and about four miles southeast of the Coryell-Hamilton County Line, as shown in Figure 4.3-1 and Figure 4.3-2. While there are no current water needs from entities in the county, the off-channel reservoir would provide water for projected future shortages.

The off-channel reservoir will impound diversions from Cowhouse Creek diversion site that is directly downstream of the proposed OCR dam location illustrated in Figure 4.3-2. The reservoir will consist of a 4,767 ft earthfill embankment dam on the Cowhouse Creek tributary stream with a crest elevation at 1,080 ft-msl. The dam will allow for a 5 ft vertical freeboard and create a conservation pool elevation of 1,075 ft-msl. At conservation pool elevation, the reservoir will have a storage capacity of 15,380 acft and inundate 445 surface acres. All flows from the small contributing drainage area to the OCR would be passed.

For the project to be economically feasible, the Brazos River Authority (BRA) would be required to subordinate their water rights at Lake Belton to the Coryell County Off-Channel Reservoir diversions from Cowhouse Creek. Without subordination, the unappropriated flows in Cowhouse Creek that are available for diversion would not be sufficient to maintain adequate water levels in the off-channel reservoir as no inflows will be impounded by the OCR.

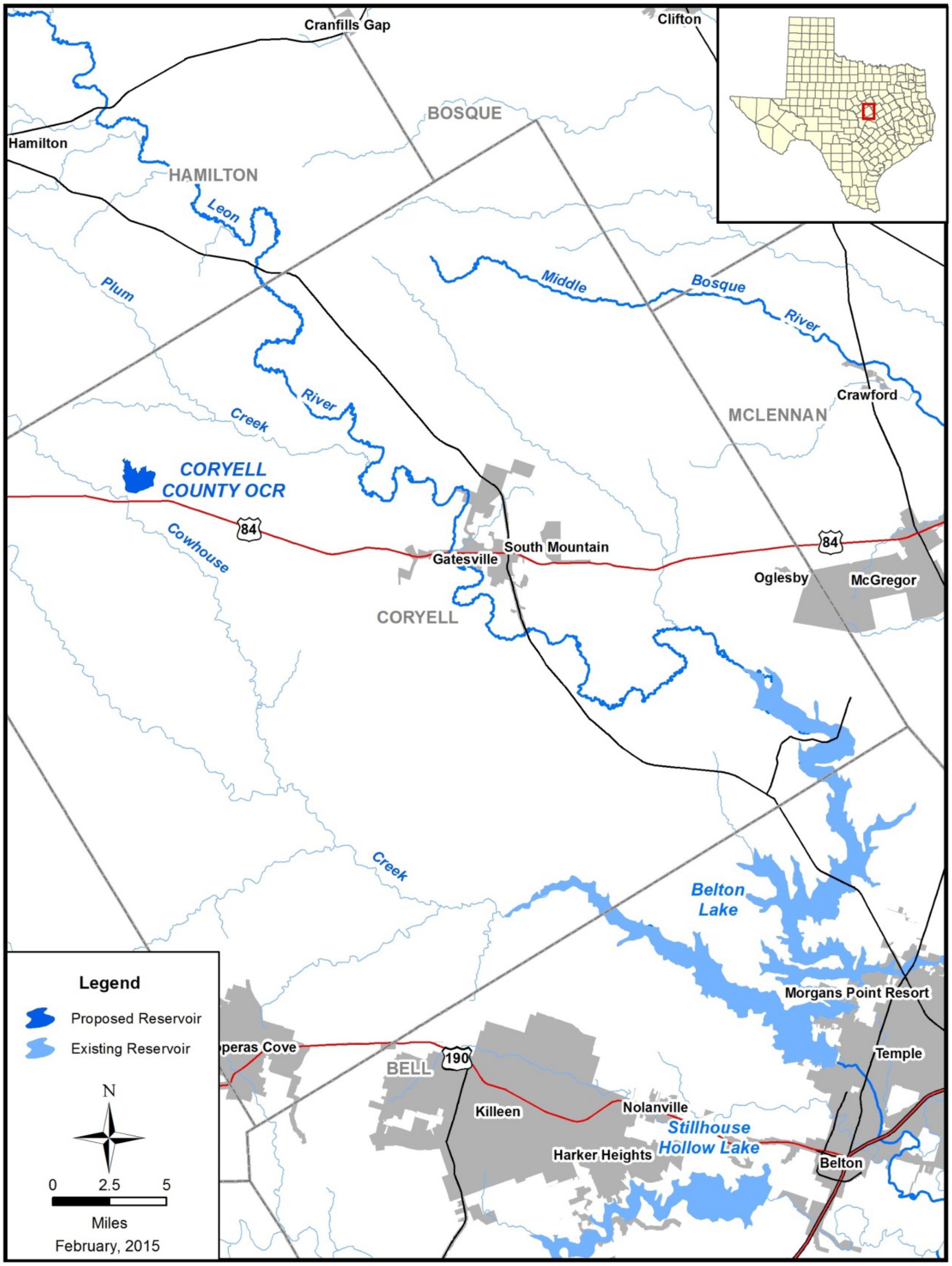
4.3.2 Available Yield

Water potentially available for impoundment in the proposed Coryell Off-Channel Reservoir was estimated using the TCEQ Brazos WAM Run 3. The model utilizes a January 1940 through December 1997 hydrologic period of record and assumes no return flows and permitted storages and diversions for all water rights in the basin. The model computed the streamflow available for diversion from Cowhouse Creek into the Coryell OCR without causing increased shortages to existing downstream rights. Firm yield was computed subject to the subordination agreement with Lake Belton. Firm yield was computed subject to the reservoir and Cowhouse Creek diversion having to pass inflows to meet environmental flow standards associated with Senate Bill 3 (SB3).

This strategy could potentially be provided supply under the BRA System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. If an entity other than the BRA were to sponsor and pursue this strategy, then an agreement with the BRA would be required to address concerns related to the potential subordination of the System Operation strategy.

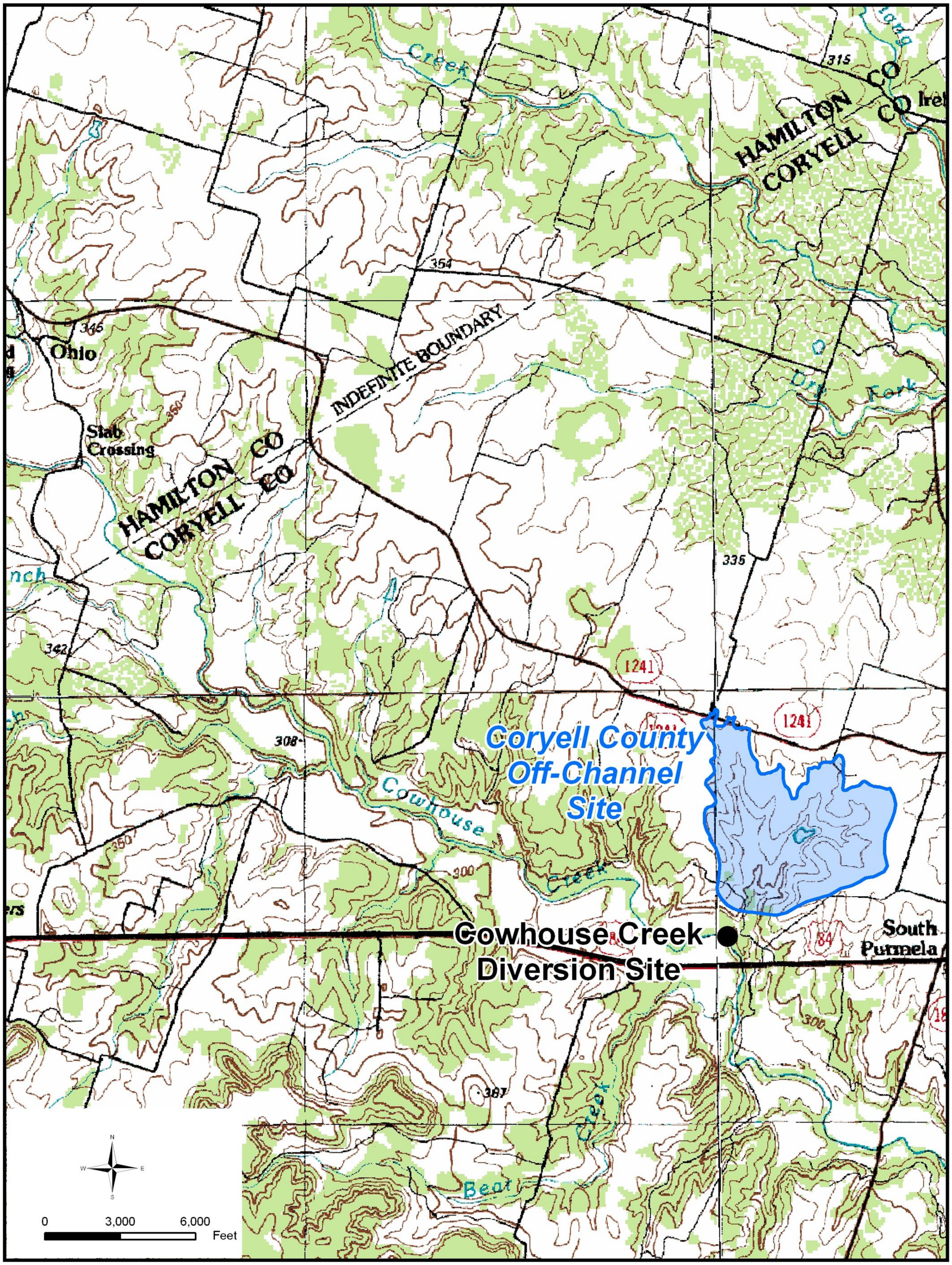
The firm yield of Lake Belton is 96,722 acft/yr which is less than its authorized diversion of 112,257 acft/yr. The WAM shows that when Lake Belton was subordinated to the Cowhouse Creek diversions for the OCR, there was minimal impact to the reservoir's ability to meet its authorized diversions. To estimate the yield impact from subordination, Lake Belton was modeled as being fully utilized in meeting BRA contracts. This approach to modeling Lake Belton produces a yield impact of 894 acft/yr due to subordination.

Figure 4.3-1. Coryell County Off-Channel Reservoir



L:\Project_Data\00044_BrazosG\GIS\Map_Docs\Task_04_WMS\WMS_Task_04_Existing_Supplies\Coryell_County_OCR.mxd

Figure 4.3-2. Coryell County Off-Channel Reservoir



A 675 ft, 36-inch diameter pipeline would be used to deliver streamflow from Cowhouse Creek to the off-channel reservoir. Due to the short pipeline length, it was assumed the diversion system would be capable of transmitting water at a velocity of 7 feet per second (49.5 cfs). A possible 2,985 acft of water could be diverted per month if the transmission system operated every day at full capacity. However, for the transmission system to be able to operate, streamflow in Cowhouse Creek must exceed the pumping capacity (49.5 cfs) by 0.5 cfs to maintain enough suction head at the intake to transmit water. Streamflow was estimated at the diversion site using a drainage area ratio with available USGS daily streamgage data from 1950 to 2014 at Cowhouse Creek near Pidcoke, TX. The estimated streamflow indicates that on average, only 5.3 days per month exceed the required streamflow of 50.0 cfs. Therefore, it is assumed that the transmission system will only operate 5.2 days per month and transfer a maximum of 510 acft/mo of flow from Cowhouse Creek. Figure 4.3-3 illustrates the annual diversion amount under firm yield conditions from Cowhouse Creek used to refill storage. On average, 3,703 acft/yr of water would be diverted.

The calculated firm yield of the Coryell County OCR is 3,135 acft/yr. Figure 4.3-4 and Figure 4.3-5 illustrates the simulated Coryell County OCR storage levels for the 1940 to 1997 historical period, subject to the firm yield of 3,135 acft/yr and assuming subordination of Lake Belton and delivery of Cowhouse Creek diversions via a 36-inch pipeline. Simulated reservoir contents remain above 80 percent capacity about 31 percent of the time and above 50 percent capacity about 64 percent of the time.

Figure 4.3-6 illustrates the change in streamflows in Cowhouse Creek caused by the project. The largest change in the Cowhouse Creek would be a decline in median streamflow of 9.21 cfs during February. Figure 4.3-7 llustrates the Cowhouse Creek streamflow frequency characteristics with the Coryell County OCR in place. There is little impact on flow frequencies due to the reservoir.

Figure 4.3-3. Coryell County Off-Channel Reservoir Firm Yield Diversions from Cowhouse Creek

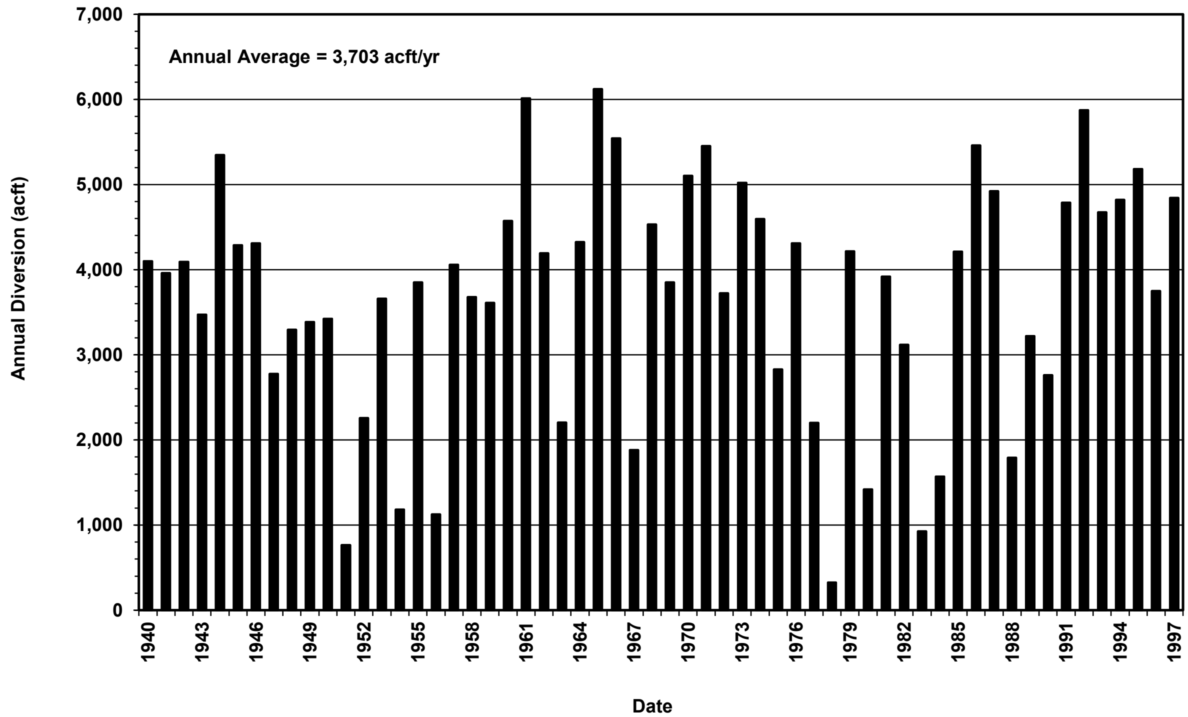


Figure 4.3-4. Coryell County Off-Channel Reservoir Storage Trace

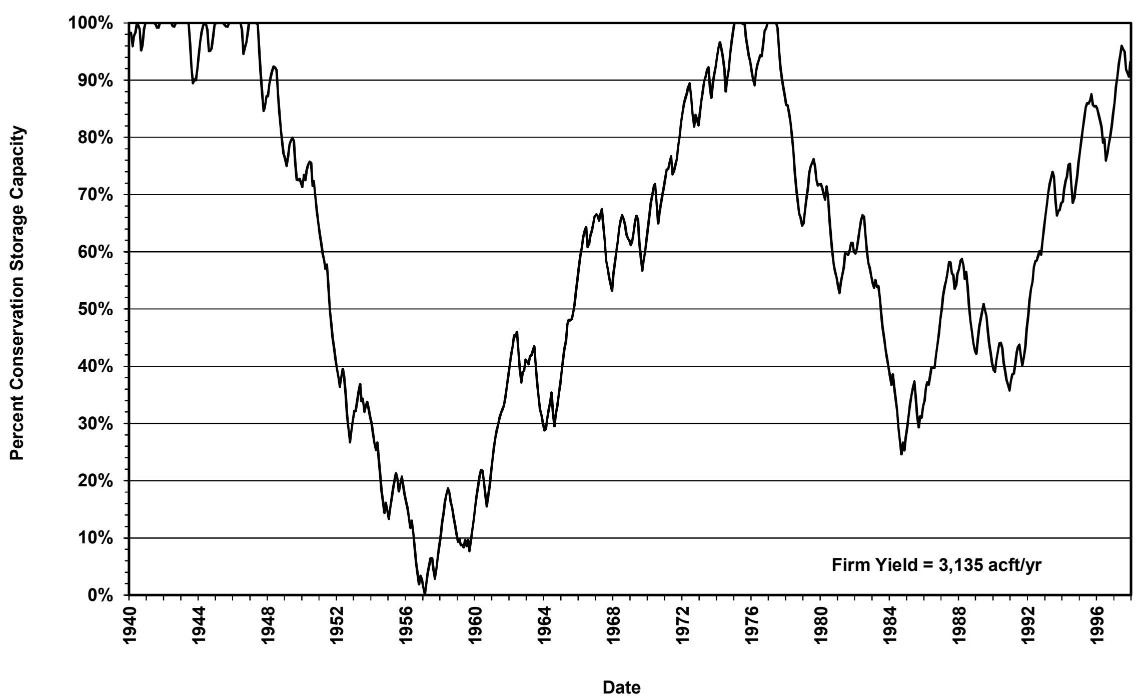


Figure 4.3-5. Coryell County Off-Channel Reservoir Storage Frequency at Firm Yield

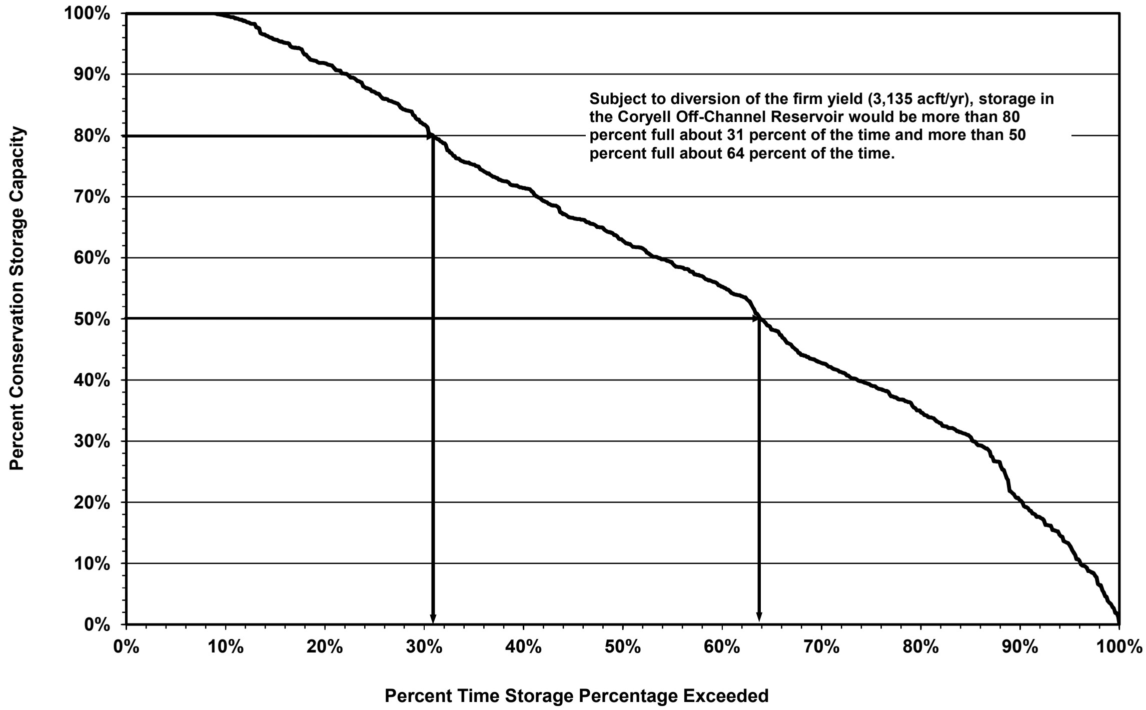


Figure 4.3-6. Cowhouse Creek Diversion Streamflow Comparisons

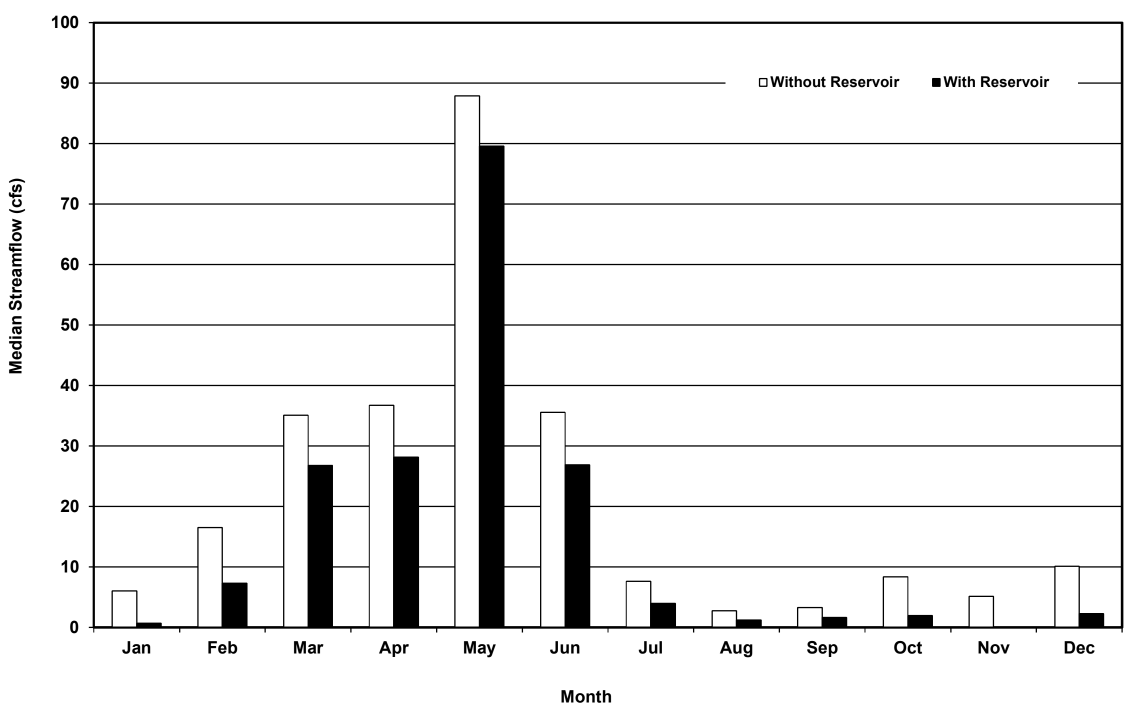
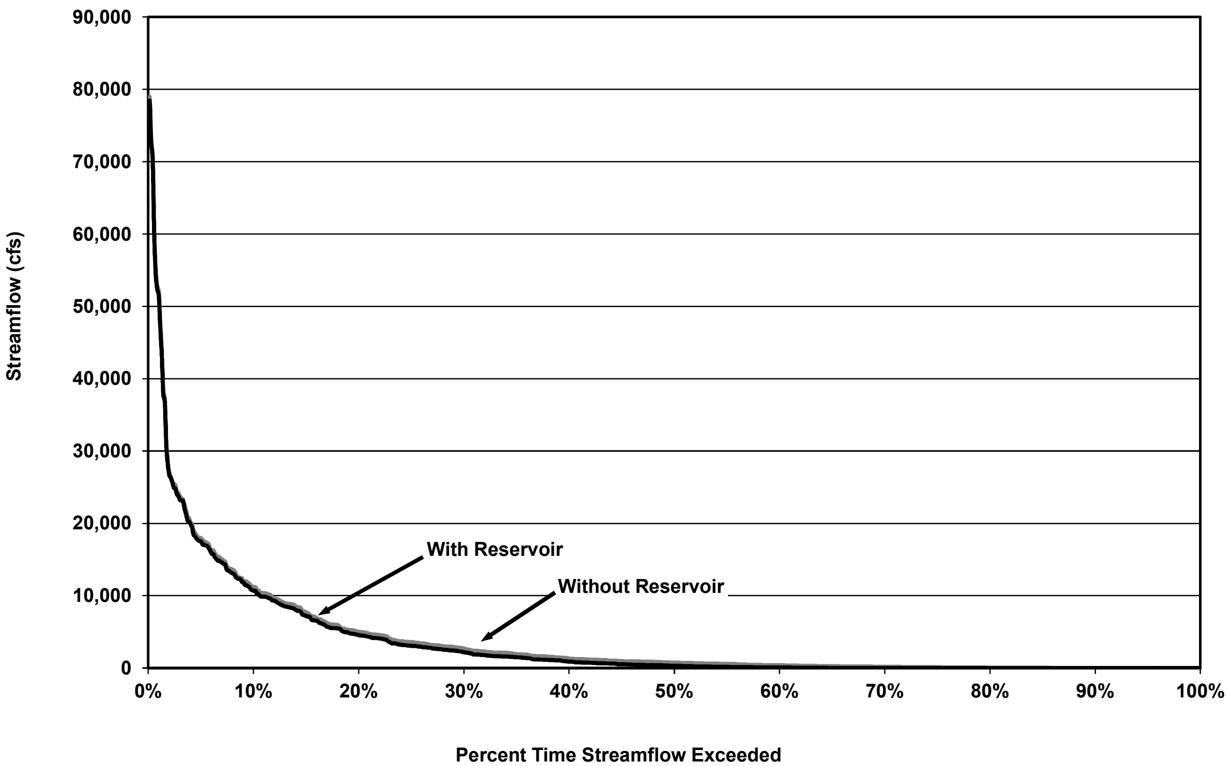


Figure 4.3-7. Cowhouse Creek Diversion Streamflow Comparisons



4.3.3 Environmental Issues

Existing Environment

The Coryell County OCR involves the construction of a pipeline to capture flood water from Cowhouse Creek, and dam construction and inundation of approximately 445 acres in a tributary east of Cowhouse Creek. The proposed OCR site is located in northwestern Coryell County. The site is situated on the ecotone between the Central Oklahoma/Texas Plains and the Edwards Plateau Ecoregions[1] and is within the Balconian biotic province.[2] This region is characterized by rolling to hilly topography, with interspersed grassland and woodland, and soils ranging from the deep, fertile, black soils of the Central Oklahoma/Texas Plains to the shallow, dry limestone of the Edwards Plateau. The climate in this area is characterized as subtropical humid with warm summers. Average annual precipitation is approximately 33 inches.[3] The Trinity Aquifer is the only major aquifer underlying the project area.[4]

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[1] Griffith, G.E., Bryce, S.A., Omernik, J.M., Comstock, J.A., Rogers, A.C., Harrison, B., Hatch, S.L., and Bezanson, D., 2004. Ecoregions of Texas. Reston, Virginia, U.S. Geological Survey.

[2] Blair, W.F., “The Biotic Provinces of Texas, “Tex. J. Sci. 2:93-117, 1950.

[3] The Dallas Morning News, 2008, “Texas Almanac 2008-2009.” Texas A&M University Press Consortium, College Station, Texas.

[4] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.

A Custom Soil Resource Report was completed for the Coryell County OCR site[5]. According to this report, five soil types underlie the project site. Doss-Real complex, 1-8 percent slopes, is the most abundant soil at 50% of the project area. These soils typically occupy backslopes of ridges. This soil is well drained, has a very low available water capacity and consists of clay loam to very gravelly clay loam. Wise clay loam soils occur within 30% of the project area. These soils are found on ridges, are well drained and have a low available water capacity. They are comprised of clay loam at the surface, underlain by silty clay loam and stratified very fine sandy loam to silty clay loam.

Nuff very stony silty clay loam, 2 to 6 percent slopes, which comprises approximately 11% of the reservoir area is typically found on the backslopes of ridges, is well drained and consists of a surface layer covered with cobbles, stones or boulders underlain by silty clay loam. Seawillow clay loam, 3 to 5 percent slopes, and Cisco fine sandy loam, 1 to 5 percent slopes, moderately eroded each occur in less than 7% of the project area. The Seawillow soils within the site occur on stream terraces, are well drained and consist of clay loam. Cisco soils in the project area are found on ridges, are well drained and have a moderate available water capacity. Fine sandy loam is found at the surface and below about 40 inches, and clay loam is present in the middle layers of these Cisco soils. Water areas comprise a little over one percent of the project area, and include existing stock tanks. None of the soils found within the project area are considered to be prime farmland soils.

Vegetation within the project area is primarily Silver Bluestem-Texas Wintergrass Grassland with a smaller area of Oak-Mesquite-Juniper Parks/Woods[6]. Silver bluestem-Texas wintergrass grasslands could include the following commonly associated plants: little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), Texas grama (*Bouteloua rigidiseta*), three-awn (*Aristida sp.*), hairy grama (*Bouteloua hirsute*), tall dropseed (*Sporobolus asper*), buffalograss (*Buchloe dactyloides*), windmillgrass (*Chloris verticillata*), hairy tridens (*Erioneuron pilosum*), tumblegrass (*Schedonnardus paniculatus*), western ragweed (*Ambrosia psilostachya*), broom snakeweed (*Gutierrezia sarothrae*), Texas bluebonnet (*Lupinus texensis*), live oak (*Quercus virginiana*), post oak (*Q. stellata*) and mesquite (*Prosopis glandulosa*). Commonly associated plants in the Oak-Mesquite-Juniper Parks/Woods include: post oak, Ashe juniper (*Juniperus ashei*), shin oak (*Q. sinuata*), Texas oak (*Q. buckleyi*), blackjack oak (*Q. marilandica*), live oak, cedar elm (*Ulmus crassifolia*), agarito (*Berberis trifoliolata*) , soapberry (*Sapindus saponaria*), sumac (*Rhus sp.*), hackberry (*Celtis reticulata*), Texas pricklypear (*Opuntia sp.*), Mexican persimmon (*Diospyros texana*), purple three-awn (*Aristida purpurea*), hairy grama, Texas grama, sideoats grama, curly mesquite (*Hilaria mutica*), and Texas wintergrass (*Stipa leucotricha*).

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[5] NRCS. "Custom Soil Resource Report for Coryell County, Texas – Coryell County Off-Channel Site. November 24, 2014.

[6] McMahan, C. A., R. G. Frye and K. L. Brown, " The Vegetation Types of Texas -- Including Cropland," Texas Parks and Wildlife Department - PWD Bulletin 7000-120. 1984.

Potential Impacts

Aquatic Environments including Bays and Estuaries

The potential impacts of this project were evaluated at Cowhouse Creek where water will be pumped and diverted to the project site. At the diversion site on Cowhouse Creek, it is anticipated that there would be a reduction in the quantity of median monthly flows as shown in Table 4.3-1. Median monthly flows are expected to be reduced in all months of the year with a low of a 9 percent reduction expected in May, when flows are typically high. November and January have the highest percent reductions (i.e. greater than 85 percent) in median monthly flows. A difference in variability of monthly flow conditions at the diversion point might also be expected. Variability in flow is important to the instream biological community as well as riparian species and a reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing suitability for others. Siting of the intake and pump station for this project should be situated as to result in minimal disturbance to existing area species.

Although there would be impacts in the immediate vicinity of the project site and downstream, it appears that this project, alone, would have minimal influence on total discharge in the Brazos River, resulting in a minimal influence on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects of this type may reduce freshwater inflows into the estuary.

Threatened & Endangered Species

A total of 23 species could potentially occur in Coryell County that are state- or federally-listed as threatened or endangered, federal candidates for listing, or exhibit sufficient rarity to be listed as a species of concern by the State (Table 4.3-2). This group includes ten birds, two fishes, one insect, three mammals, three mollusks, and three reptiles. Three bird species federally- listed as endangered could possibly occur within the project area. These include the black-capped vireo (*Vireo atricapilla*), golden-cheeked warbler (*Setophaga chrysoparia*) and whooping crane (*Grus americana*). The black-capped vireo and golden-cheeked warbler are only present in central Texas during the breeding season and have very specific habitat requirements. The whooping crane is a seasonal migrant that could pass through the project area.

Data from the TPWD Texas Natural Diversity Database[7] did not reveal any documented occurrences of listed species within the vicinity of the proposed Coryell OCR. However, these data are not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area**.** On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

[7] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, November 10, 2014.

Table 4.3-1. Median Monthly Streamflow: Cowhouse Creek Diversion Site

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	6.05	0.72	5.33	88%
February	16.54	7.33	9.21	56%
March	35.09	26.77	8.32	24%
April	36.75	28.17	8.58	23%
May	87.89	79.58	8.30	9%
June	35.56	26.90	8.65	24%
July	7.64	3.95	3.69	48%
August	2.78	1.24	1.53	55%
September	3.29	1.64	1.65	50%
October	8.38	1.94	6.44	77%
November	5.15	0.00	5.15	100%
December	10.10	2.29	7.81	77%

Wildlife Habitat

The primary impacts that would result from construction and operation of the proposed Coryell County OCR include conversion of approximately 445 acres of existing habitat within the conservation pool to open water. Projected wildlife habitat that will be impacted includes approximately 337 acres of Savanna Grassland, 76 acres of Ashe Juniper/Live Oak Shrubland, three acres of Ashe Juniper/Love Oak Slope Shrubland, one acre of Ashe Juniper Motte and Woodland, one acre of Ashe Juniper Slope Forest, seven acres of Oak/Hardwood Motte and Woodland, less than one acre of Oak/hardwood Slope Forest, 11 acres of Mesquite Shrubland, and seven acres of open water, primarily from existing stock tanks.[8] Siting of the raw water intake, pump station and raw water pipeline needed to complete the project should be located in an area that would result in minimal impacts to existing aquatic and terrestrial species. Impacts from the pipeline and associated appurtenances are anticipated to be low and primarily limited to the construction of these facilities and subsequent maintenance activities.

A number of vertebrate species could occur within the Coryell County OCR site including smaller mammals such as the eastern red bat (*Lasiurus borealis*), hispid cotton rat

[8] Texas Parks and Wildlife. Ecological Mapping Sytem GIS layer. Accessed at http://www.tpwd.state.tx.us/gis/data/ November 18, 2014.

(*Sigmodon hispidus*), white-footed mouse (*Peromyscus leucopus*), eastern fox squirrel (*Sciurus niger*), and woodland vole (*Microtus pinetorum*).[9] Reptiles and amphibians known from the county include the western rough green snake (*Opheodrys aestivus majalis*), Strecker's chorus frog (*Pseudacris streckeri*), Texas toad (*Bufo speciosus*), and Great Plains rat snake (*Elaphe guttata emoryi*) among others.[10] An undetermined number of bird species and a variety of fish species would also be expected to inhabit the various habitat types within the site, with distributions and population densities limited by the types and quality of habitats available.

Table 4.3-2. Endangered, Threatened, Candidate and Species of Concern Listed for Coryell County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
BIRDS					
American peregrine falcon	*Falco peregrinus anatum*	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Black-capped vireo	*Vireo atricapilla*	Occupies oak-juniper woodlands with a distinctive patchy, two-layered aspect. Migrant.	LE	E	Nesting/ Migrant
Golden-cheeked warbler	*Setophaga chrysoparia*	Found in juniper-oak woodlands; dependent on Ashe juniper for bark strips used in nest construction.	LE	E	Nesting/ Migrant
Mountain plover	*Charadrius montanus*	Non-breeding, shortgrass plains and fields	--	--	Migrant
Peregrine falcon	*Falco peregrinus*	Possible migrant. Subspecies not easily distinguishable so reference is made to species level.	DL	T	Possible Migrant
Sprague's pipit	*Anthus spragueii*	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Western burrowing owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna	--	--	Resident
Whooping crane	*Grus americana*	Potential migrant	LE	E	Potential Migrant

[9] Davis, William B. and David J. Schmidly. 1994. The Mammals of Texas. Texas Parks and Wildlife, Austin, Texas

[10] Dixon, James R., Amphibians and Reptiles of Texas. 1987, Texas A&M Press.

Table 4.3-2. Endangered, Threatened, Candidate and Species of Concern Listed for Coryell County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
FISHES					
Guadalupe bass	*Micropterus treculi*	Endemic to perennial streams of the Edwards Plateau region.	--	--	Resident
Smalleye shiner	*Notropis buccula*	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident
INSECTS					
Leon river winter stonefly	*Taenioptery x starki*	This species breeds in rivers using lotic environments.	--	--	Resident
MAMMALS					
Cave myotis bat	*Myotis velifer*	Colonial and cave-dwelling species. Also roosts in rock crevices and buildings.	--	--	Resident
Plains spotted skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	Extirpated.	LE	E	Historic Resident
MOLLUSKS					
False spike mussel	*Quincuncina mitchelli*	Substrates of cobble and mud. Rio Grande, Brazos, Colorado and Guadalupe river basins.	--	T	Resident
Smooth pimpleback	*Quadrula houstonensi s*	Freshwater mollusk found in small to moderate streams and rivers as well as moderate sized reservoirs. Brazos and Colorado River Basins.	C	T	Resident
Texas fawnsfoot	*Truncilla macrodon*	Found in rivers and larger streams, intolerant of impoundment.	C	T	Resident
PLANTS					
Texabama croton	*Croton alabamensis* var *texensis*	Texas endemic found in clay soils on rocky slopes in limestone canyons.	--	--	Resident
REPTILES					
Texas garter snake	*Thamnophis sirtalis annectens*	Found in wet or moist microhabitats which are preferred by this species.	--	--	Resident

Table 4.3-2. Endangered, Threatened, Candidate and Species of Concern Listed for Coryell County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands.	--	T	Resident
Timber rattlesnake	*Crotalus horridus*	Floodplains, upland pine, deciduous woodlands, riparian zones.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

TPWD, 2014. Annotated County List of Rare Species –Coryell County updated 9/4/2014.

USFWS, 2014. Species Lists from http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action?fips=48187, accessed October 6, 2014.

Cultural Resources

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available GIS datasets provided by the Texas Historical Commission (THC) for the 2011 Regional Water Plan, there are no National Register Properties, National Register Districts, cemeteries, or historical markers are located within or near the project area. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission regarding potential impacts to cultural resources.

Threats to Natural Resources

This project would likely increase adverse effects on streamflow below the diversion point along Cowhouse Creek. Decreased stream flow would contribute to declines in dissolved oxygen and higher temperatures during summer periods. Additional impacts would be expected to terrestrial species found within the proposed OCR area that would be displaced by the reservoir filling. The project is expected to have negligible impacts to the streamflow and water quality in the Brazos River.

Agricultural Impacts

The Coryell County OCR site contains approximately zero acres of Pasture/Hay fields and 25 acres of cropland. These two agricultural land uses account for less than three percent of the reservoir footprint.

4.3.4 Engineering and Costing

The potential off-channel reservoir project for Coryell County OCR project would require additional facilities to divert water from Cowhouse Creek to the OCR. The facilities required for implementation of the project include:

- Raw water intake and pump station at the Cowhouse Creek diversion site with a capacity of 37 MGD;
- 674 feet of raw water pipeline (36-inch diameter) from the pump station to the off-channel reservoir;
- Off-channel dam including spillway, intake tower, and 445 acres of land for the reservoir.

A summary of the total project cost in September 2013 dollars is presented in Table 4.3-3. The proposed Coryell County OCR project would cost approximately $42.2 million for surface water supply facilities. This includes the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The project costs also include the cost for the raw water facilities to convey surface water from the Cowhouse Creek diversion site to the off-channel reservoir. Costs associated with the transmission and treatment of raw water stored in the off-channel reservoir to future customers is not included. The annual project costs are estimated to be $4,405,000. This includes annual debt service, operation and maintenance, pumping energy costs, and purchase of water from BRA for compensation of yield impacts to Lake Belton.

The off-channel project will be able to provide raw water prior to treatment and transmission of treated water to entities in Coryell County at a unit cost of $1,405 per ac-ft or $4.31 per 1,000 gallons.

Compensation to BRA may be required if this strategy were developed by another entity other than BRA to compensate for any subordination of the System Operations strategy.

Table 4.3-3. Cost Estimate Summary for Coryell County Off-Channel Reservoir

Item	Estimated Costs for Facilities
Off-Channel Storage/Ring Dike[1] (Conservation Pool 15,380 acft, 445 acres)	$17,578,000
Channel Dam and Intake Pump Stations (33.7 MGD)	$10,204,000
Transmission Pipeline (36 in dia., 674 feet)	$131,000
TOTAL COST OF FACILITIES	**$27,913,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$9,763,000
Environmental & Archaeology Studies and Mitigation	$1,120,000
Land Acquisition and Surveying (451 acres)	$1,142,000
Interest During Construction (4% for 2 years with a 1% ROI)	$2,308,000
TOTAL COST OF PROJECT	**$42,246,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$1,211,000
Reservoir Debt Service (5.5 percent, 40 years)	$1,731,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$1,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$255,000
Dam and Reservoir (1.5% of Cost of Facilities)	$264,000
Pumping Energy Costs (9,817,556 kW-hr @ 0.09 $/kW-hr)	$884,000
Purchase of Water (894 acft/yr @ 65.65 $/acft)	$59,000
TOTAL ANNUAL COST	**$4,405,000**
Available Project Yield (acft/yr)	3,135
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	$1,405
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	$4.31

[1] Includes the dam, intake, and spillway tower.

4.3.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.3-4, and the option meets each criterion.

Table 4.3-4. Evaluations of Coryell County Off-Channel Reservoir Option to Enhance Water Supplies

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	1. Negligible impact
2. Habitat	2. Negligible impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Negligible impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

Implementation of the off-channel reservoir project will require permits from various state and federal agencies, land acquisition, and design and construction of the facilities. The project may also have an impact on the firm yield of Lake Belton, which may require mitigation with the Brazos River Authority in terms of a water supply contract in the amount of the firm yield impact. A summary of the implementation steps for the project is presented below.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- General Land Office Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.
- Coordination with BRA on any potential subordination agreements for the System Operations strategy.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

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4.4 City of Groesbeck Off-Channel Reservoir

4.4.1 Description of Option

The Groesbeck Off-Channel Reservoir is a proposed new reservoir adjacent to the Navasota River, northeast of the City of Groesbeck in Limestone County, as shown in Figure 4.4-1 and Figure 4.4-2. The City of Groesbeck uses surface water directly from the Navasota River and has water rights on the Navasota River that authorize diversion of 2,500 acft/yr and storage of 500 acft with a priority of June 1921. This water right is one of the more senior water rights in the Brazos River Basin.

The diversion point for the City of Groesbeck is just north (upstream) of the City and downstream (south) of Springfield Lake at Fort Parker. A natural spring occurs just below Springfield Lake that provides a base flow to the river just upstream of the City's diversion point during most years. However, during past drought periods the springflow has not been able to supply the City's water demand and the City has diverted stored water from Springfield Lake. Springfield Lake is owned by the TPWD for recreation purposes; however, Groesbeck's 500 acft storage right extends into the lake. During drought periods, when the flow in the Navasota River is not adequate to meet the City's water needs, the City siphons water from storage in Springfield Lake over the dam and into the downstream river channel. The City diverts the normal river flow and the water diverted from storage in Springfield Lake.

Springfield Lake was built in 1939 for the primary purpose of recreation. The lake is very shallow, originally storing about 3,100 acft over a surface area of 750 acres, making the average depth of the lake about 4 feet. Over the years, the lake has lost significant storage due to sedimentation. In 1991, the City of Groesbeck and the TPWD jointly participated in a project[1] to dredge the lake making the average lake depth approximately 4 feet over 500 acres. Groesbeck has relied on this storage during recent drought periods to meet their needs and has implemented water rationing in the City as recently as 1998.

A yield analysis of Springfield Lake was performed to determine what the reliable supply to Groesbeck would be with its diversion rights from the Navasota River and storage in Springfield Lake. The shallow depth of about four feet and effective surface area of 500 acres of Springfield Lake results in the reservoir being very inefficient. In comparison, net evaporation rates during the extended drought periods of the 1950s were as high as 4.2 feet annually, which would severely deplete the reservoir storage without any diversions by the City. The yield analysis showed that the firm yield of the City's water right, supplemented with storage from Springfield Lake, was less than 200 acft/yr.

The City of Groesbeck's water use in 2011 was 736 acft. The Brazos G WAM modeling results indicate that there is no reliable yield associated with the City's right. Thus, the

[1] Hunter & Associates, Inc., "A Plan for Dredging and Rehabilitation of Springfield Lake at Fort Parker, Limestone County, Texas," prepared for the City of Groesbeck and the Texas Parks and Wildlife Department, January 1991.

Figure 4.4-1. Groesbeck Off-Channel Reservoir

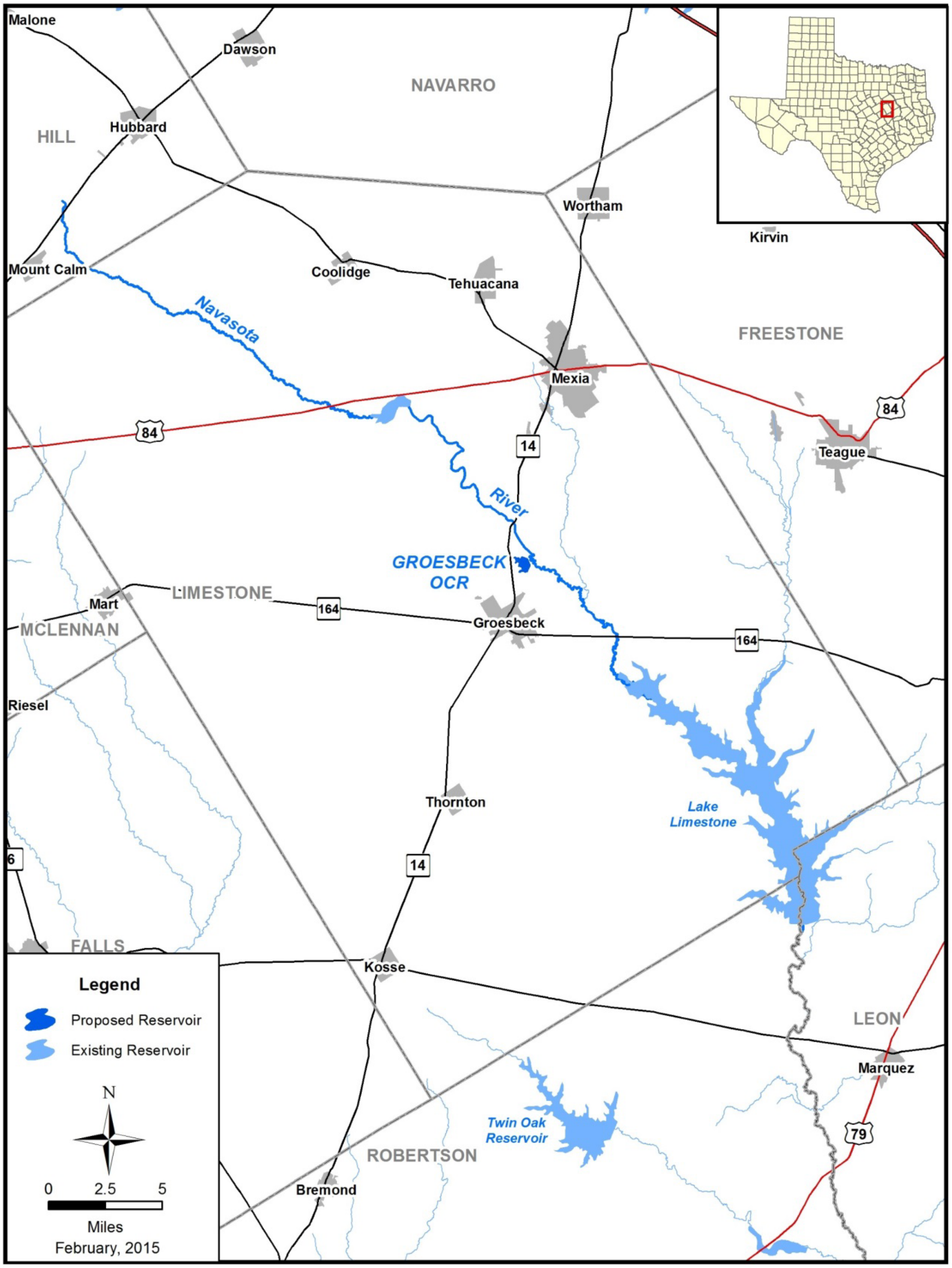

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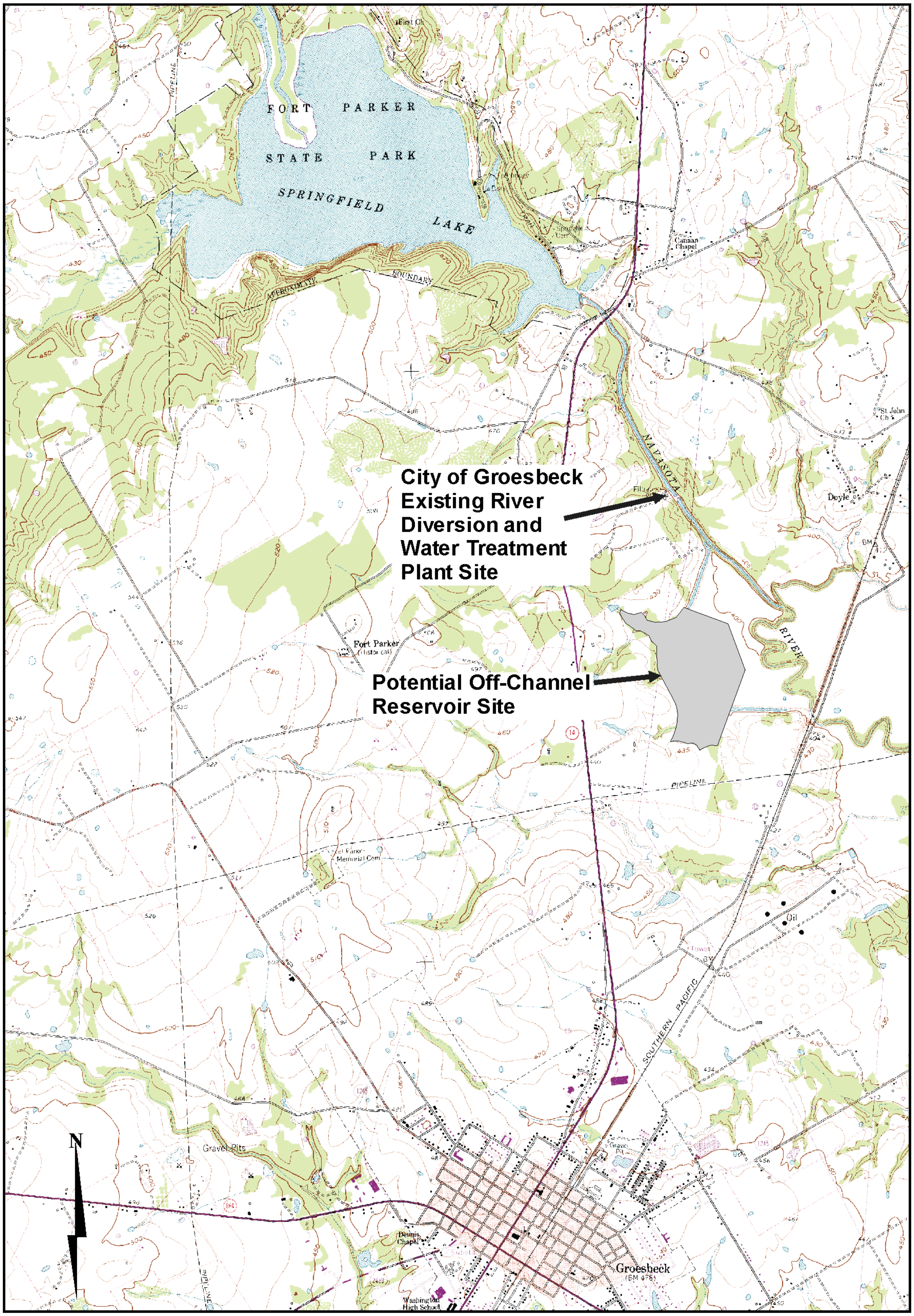
Figure 4.4-2. Groesbeck Off-Channel Reservoir



City can expect substantially less than the authorized diversion of 2,500 acft/yr. As the City's demands grow, additional storage or a supplemental supply of water will be needed.

Various alternatives to supplement the City's supply are available. These alternatives include construction of an off-channel reservoir along the Navasota River to store water for use during drought periods, development of groundwater in the Carrizo-Wilcox Aquifer east of the City, and purchase of water from Lake Limestone, located downstream of the City. The off-channel reservoir alternative appears to be an economical solution to provide the City with a firm water supply, as the storage can be developed near the City's existing river diversion and water treatment facilities. A potential off-channel storage site along the Navasota River is shown in Figure 4.4-2. The dam would be an earthfill embankment that would extend approximately 1,500 feet and provide a conservation storage capacity of 2,317 acft at an elevation 420 ft-msl; the reservoir would inundate 146 surface acres. The reservoir would impound flows diverted from the Navasota River. All flows from the small watershed above the reservoir would be passed.

The City's senior water right with a diversion of 2,500 acft/yr and a priority of June 1921 would be used to divert water from the Navasota River to the off-channel reservoir. The City would then divert water from the reservoir for municipal use. This will allow an increase in the City's current minimum annual diversion by providing an increase in storage of available flows for use during drought periods. Additionally, since the city's water right is senior to Lake Limestone, water would not need to be purchased from BRA to compensate for losses in Lake Limestone's yield from a subordination agreement. Any subordination agreement with the BRA is dependent on the BRA being able to successfully obtain the System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. A subordination agreement would have to be negotiated and acquired for this strategy to be implemented. The diversion amounts from the Navasota River into the off-channel reservoir will not exceed the original water right for the City. Any additional water diverted above the prior authorization could require subordination of BRA's Water Rights.

4.4.2 Available Yield

Water potentially available for impoundment in the proposed Groesbeck Off-Channel Reservoir was estimated using the TCEQ Brazos WAM Run 3 which assumes no return flows and permitted storages and diversions for all water rights in the basin. The model utilized a January 1940 through December 1997 hydrologic period of record. The model computed the streamflow available for diversion from the Navasota River into the Groesbeck Off-Channel Reservoir without causing increased shortages to existing downstream rights. The off-channel reservoir was also modeled such that it has no naturalized flow contributing from its own drainage area. Firm yield was computed subject to the reservoir and Navasota River diversion having to pass inflows to meet environmental flow standards associated with Senate Bill 3 (SB3).

A 24-inch diameter pipeline would be used to divert streamflow from the Navasota River to the off-channel reservoir. Assuming the pipeline would transmit water at a velocity of 5 feet per second (15.7 cfs), a possible 948 acft of water could be diverted per month if the transmission system operated every day at full capacity. However, for the transmission system to be able to operate, streamflow in the Navasota River must exceed the pumping capacity (15.7 cfs) by 0.5 cfs to maintain enough suction head at the intake to transmit water. Available USGS daily streamgage data from 1978 to 2014 for the Navasota River at Groesbeck indicates that on average, only 7.6 days per month exceed the required streamflow of 16.2 cfs. Therefore, it is assumed that the transmission system will only operate 7.6 days per month and transfer a maximum of 237 acft/mo of flow from the Navasota River. Figure 4.4-3 illustrates the annual diversion amount under firm yield conditions from the Navasota River used to refill storage. On average, 2,065 acft/yr of water would be diverted.

The calculated firm yield of the Groesbeck Off-Channel Reservoir is 1,755 acft/yr. Figure 4.4-4 illustrates the simulated Groesbeck Off-Channel Reservoir storage levels for the 1940 to 1997 historical period, subject to the firm yield of 1,755 acft/yr and based on delivery of Navasota River diversions via a 24-inch pipeline. Figure 4.4-5 shows the storage frequency associated with firm yield. Simulated reservoir contents remain above 80 percent capacity and 61 percent of the time and above 50 percent capacity about 86 percent of the time.

Figure 4.4-6 illustrates the change in streamflows in the Navasota River caused by the project. From July through November, there is little or no water available in the stream. During January through June and December, there are significant decreases in median streamflow from the implementation of the off-channel reservoir. The greatest reduction (>50 percent) would occur in December. Figure 4.4-7 also illustrates the Navasota River streamflow frequency characteristics with the Groesbeck Off-Channel Reservoir in place.

Figure 4.4-3. Groesbeck OCR Firm Yield Diversions from Navasota River

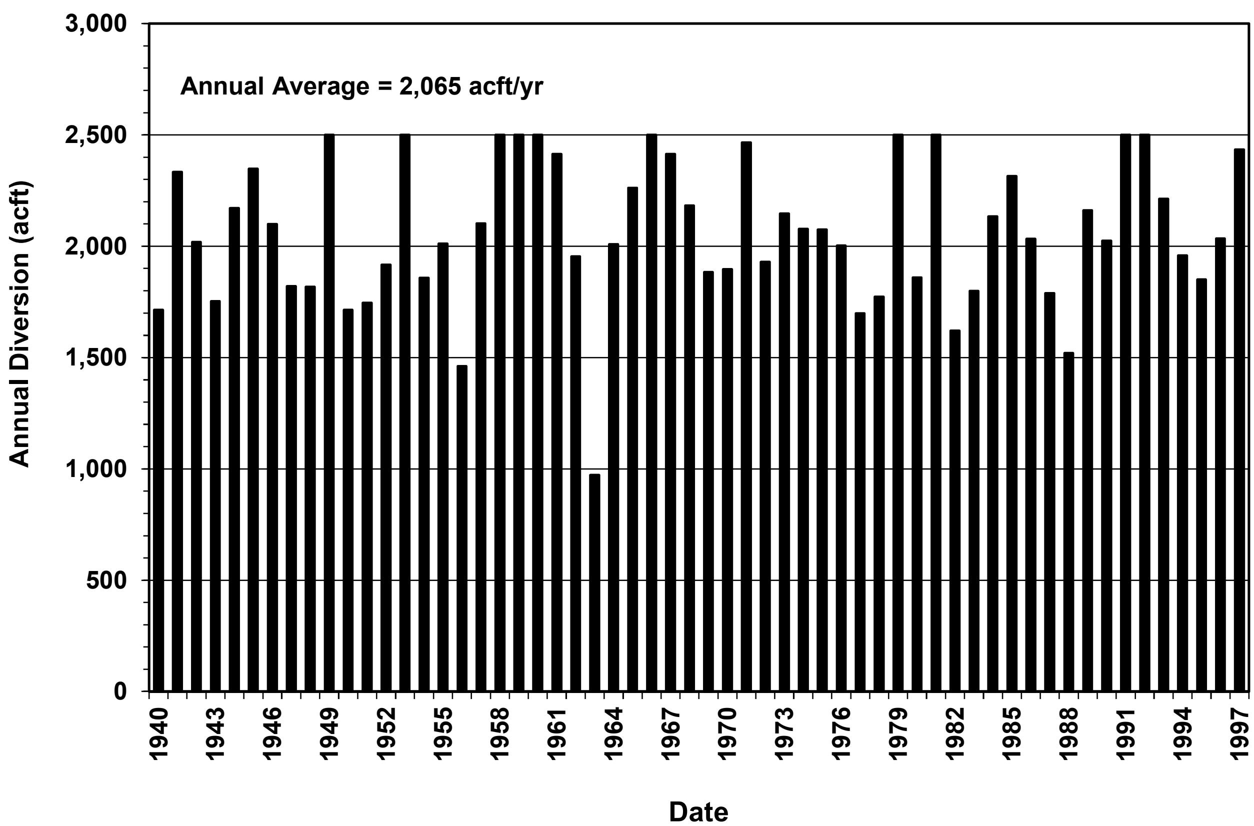


Figure 4.4-4. Groesbeck OCR Firm Yield Storage Trace

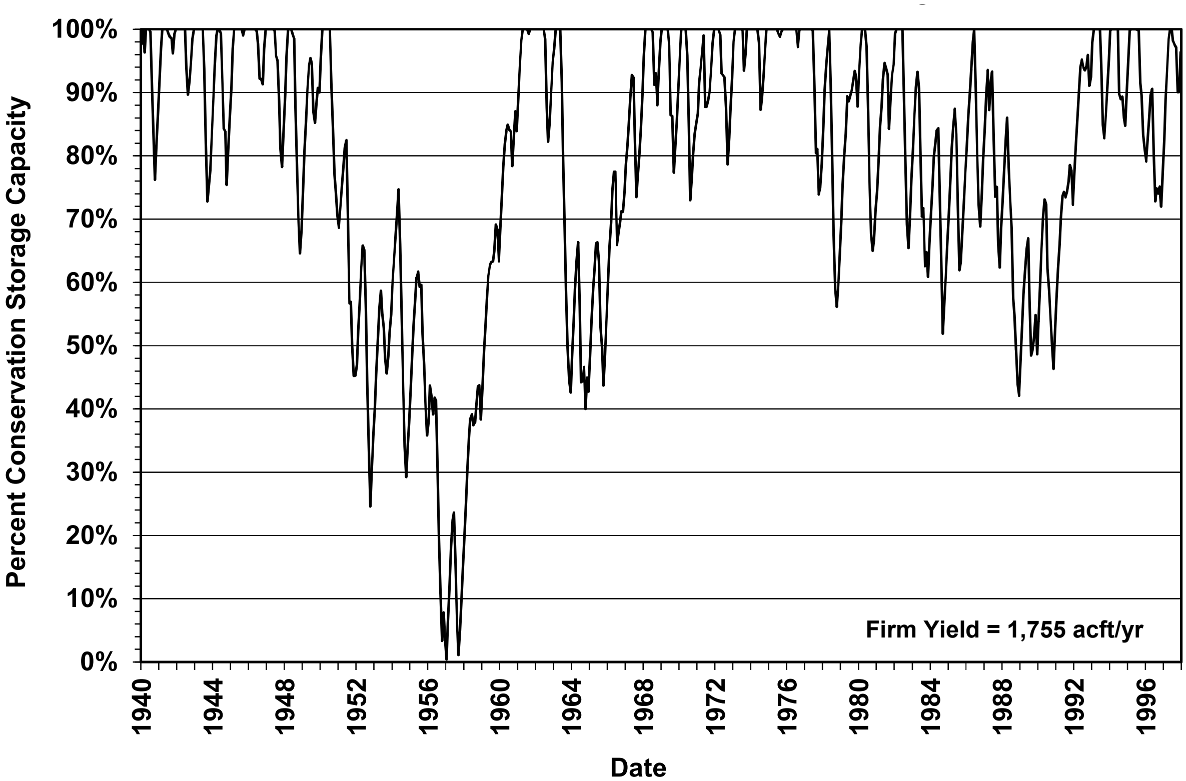


Figure 4.4-5. Storage Frequency at Firm Yield

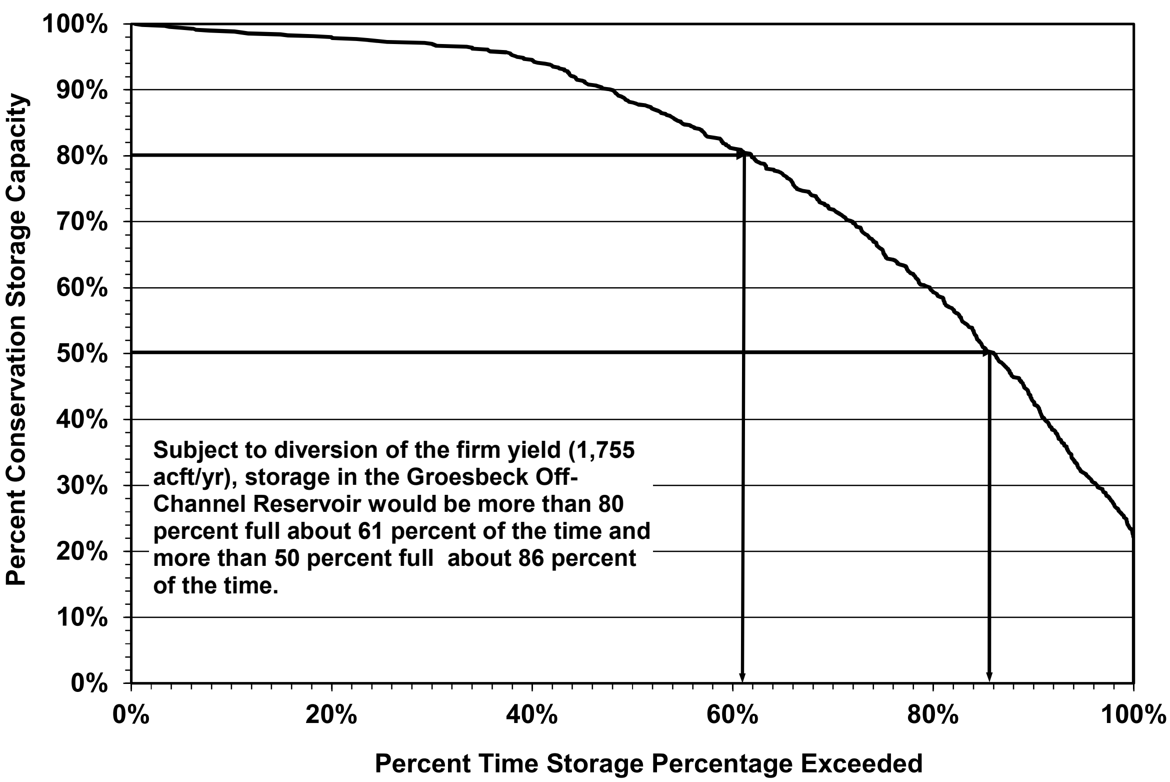


Figure 4.4-6. Navasota River Diversion - Median Streamflow Comparison

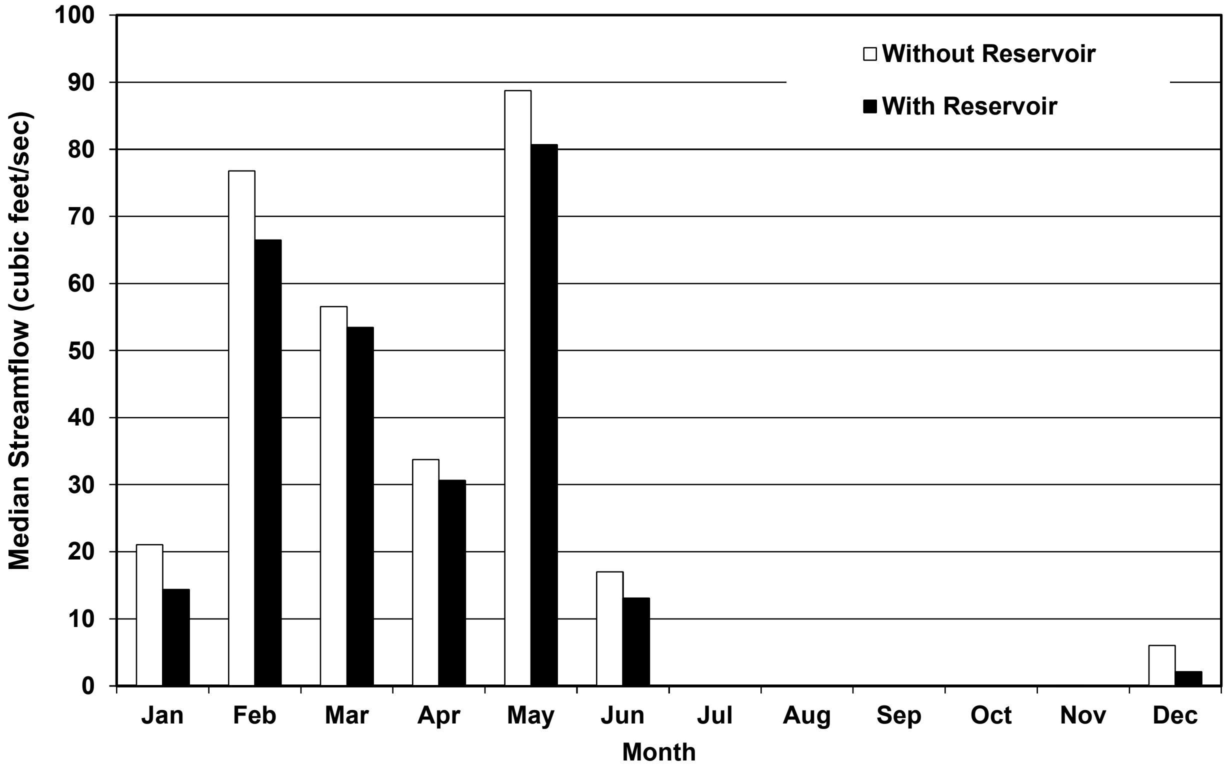
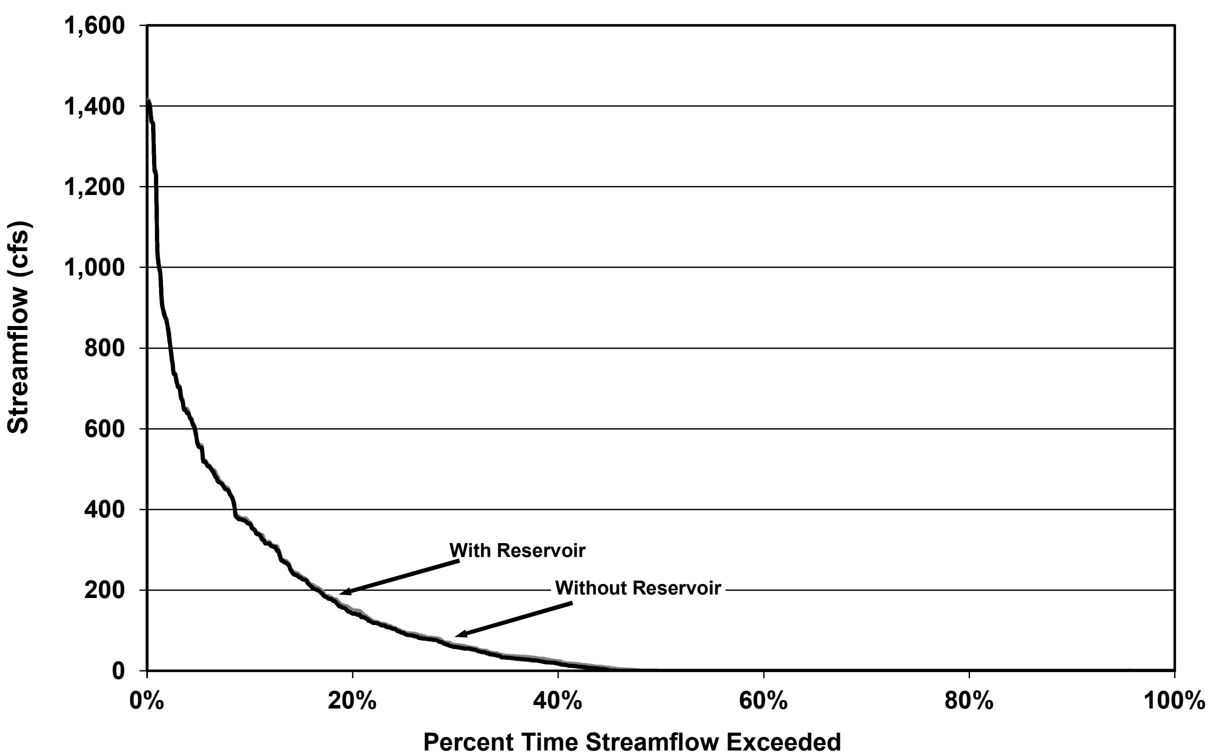


Figure 4.4-7. Navasota River Diversion- Streamflow Frequency Comparison



4.4.3 Environmental Issues

Existing Environment

The City of Groesbeck Off-Channel Reservoir site in Limestone County lies in the Blackland Prairies Vegetational Area.[2] This area is a rolling and well-dissected region that was historically a luxuriant tallgrass prairie dominated by little bluestem (*Schizachyrium scoparium* var. *frequens*), big bluestem (*Andropogon gerardii*), indiangrass (*Sorghastrum nutans*), and dropseeds (*Sporobolus* sp.). During the turn of the 20th century, the majority of the Blackland Prairie was cultivated for crops. Livestock production within this area has increased dramatically since the 1950s and now only about half of the area is used for cropland. Grazing pressure has caused an increase in grass species such as sideoats grama (*Bouteloua curtipendula*), hairy grama (*B. hirsuta*), Mead's sedge (*Carex meadii*), Texas Wintergrass (*Nassella leucotricha*) and buffalograss (*Buchloe dactyloides*). Common woody species of this area include mesquite (*Prosopis glandulosa*), huisache (*Acacia smallii*), oak (*Quercus* sp.) and elm (*Ulmus* sp.). Oak, elm, cottonwood (*Populus* sp.) and pecan are common larger tree species found along drainages in this area.

Based on vegetation types as defined by the Texas Parks and Wildlife Department (TPWD) the vegetation type that occurs within the project area is Elm-Hackberry Parks/ Woods.[3] Elm-Hackberry Parks/Woods could include the following commonly associated plants: mesquite (*Prosopis glandulosa*), post oak (*Quercus stellata*), woollybucket bumelia (*Sideroxylon lanuginosum*), honey locust (*Gleditsia triacanthos)*, coralberry (*Symphoricarpos orbiculatus*), pasture haw (*Crataegus spathulata*), elbowbush (*Forestiera pubescens*), Texas pricklypear (*Opuntia engelmannii* var. *lindheimeri*), tasajillo (Opuntia leptocaulis), dewberry (Rubus spp.), silver bluestem (Bothriochloa saccharoides), buffalograss (Buchloe dactyloides), western ragweed (Ambrosia cumanensis), giant ragweed (A. trifida), goldenrod (Solidago spp.), frostweed (Verbesina virginica), ironweed (Vernonia spp.), prairie parsley (Polytaenia nuttallii), and broom snakeweed (Gutierrezia sarothrae). Variations of this primary type may occur based on changes in the composition of woody and herbaceous species and the physiognomy of localized conditions and specific range sites.

The average annual precipitation for Limestone County is almost thirty-eight inches, and the temperatures range from an average low of 37° F in January to an average high of 96° in July. The average growing season lasts 255 days.4 No major or minor aquifer underlies the project area.[5]

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[2] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, Vegetational Areas of Texas, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.

[3] McMahan, C.A., R.F. Frye, and K.L. Brown, "The Vegetation Types of Texas Including Cropland," Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

[4] Ellen Maschino, "LIMESTONE COUNTY," Handbook of Texas Online (http://www.tshaonline.org/handbook/online/articles/hcl09), accessed November 17, 2014.

[5] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.

Soil units found within the proposed off-channel reservoir area include Axtell fine sandy loam, 1 to 3 percent slopes, Edge fine sandy loam, 2 to 5 percent slopes, Kaufman clay, occasionally flooded, Lavender-Rock outcrop complex, Silawa fine sandy loam, 5 to 12 percent slopes and Whitesboro loam, frequently flooded. Of these six soil types only one, Kaufman clay, occasionally flooded is considered to be a prime farmland soil. This soil type is found within 49 acres or approximately 33.5 percent of the project area. Current aerial photography of the OCR site shows agricultural activity in the eastern portion of the area.

Potential Impacts

Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated in two locations, at the proposed reservoir site and in the Navasota River where water will be pumped and diverted to the project site. The potential impacts of this project are very different in the two locations. In the diversion site on the Navasota River, minimal impacts are anticipated in terms of a reduction in variability or quantity of median monthly flows. But in the proposed project site, there would be a moderate reduction in variability and dramatic reductions in the quantity of median monthly flows. Variability in flow is important to the instream biological community as well as riparian species and a reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing suitability for others.

In the Navasota River, non-negligible reductions in streamflow would occur in January through June and December, as shown in Table 4.4-1. All other months would have little or no reduction in median monthly flow at the diversion. Because low-flows occur frequently without the project in place, the addition of this project would have minimal impact on these low-flow conditions. At the Navasota River diversion site, the 85 percent exceedance values would be 0.003 cfs without the project and zero cfs without the project.

Table 4.4-1. Median Monthly Streamflow: Navasota River Diversion Site

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	21.05	14.40	6.65	32%
February	76.77	66.47	10.29	13%
March	56.58	53.45	3.13	6%
April	33.75	30.63	3.12	9%
May	88.75	80.68	8.07	9%
June	17.01	13.08	3.92	23%
July	0.01	0.00	0.01	100%
August	0.00	0.00	0.00	100%
September	0.01	0.00	0.01	100%
October	0.02	0.00	0.02	100%

Table 4.4-1. Median Monthly Streamflow: Navasota River Diversion Site

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
November	0.04	0.00	0.04	100%
December	6.01	2.11	3.90	65%

Although there would be impacts in the immediate vicinity of the project site and downstream, it appears that this project, alone, would have minimal influence on total discharge in the Navasota or Brazos Rivers, in which case there would be minimal influence on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows into the estuary. As a new reservoir without a current operating permit, the Groesbeck Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

Threatened & Endangered Species

A total of 23 species which might occur in Limestone County are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed by the State as a species of concern (Table 4.4-2). This group includes 4 reptiles, 11 birds, 2 mammals, 3 mussels, 1 fish and 2 plant species. Two bird species which are federally-listed as endangered could possibly occur within the project area. These include the interior least tern (*Sterna antillarum athalassos*), and the whooping crane (*Grus americana*). Because the interior least tern, and whooping crane are only seasonal migrants that could pass through the project area, they are not anticipated to be directly affected by the proposed reservoir.

Data from the TPWD Texas Natural Diversity Database[6] did not reveal any documented occurrences of listed species within the vicinity of the proposed City of Groesbeck Off-Channel Reservoir. However these data are not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

[6] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, November 10, 2014.

Table 4.4-2. Endangered, Threatened, Candidate and Species of Concern Listed for Limestone County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
BIRDS					
American peregrine falcon	*Falco peregrinus anatum*	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Henslow's Sparrow	*Ammodramus henslowii*	Wintering individuals found in weedy fields with bunch grasses and brambles.	--	--	Migrant
Interior least tern	*Sterna antillarum athalassos*	Nests along sand and gravel bars in braided streams	LE	E	Resident
Peregrine falcon	*Falco peregrinus*	Possible migrant. Subspecies not easily distinguishable so reference is made to species level.	DL	T	Possible Migrant
Sprague's pipit	*Anthus spragueii*	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Western burrowing owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna	--	--	Resident
White-faced ibis	*Plegadis chihi*	Prefers freshwater marshes and irrigated rice fields.	--	T	Possible Migrant
Whooping crane	*Grus americana*	Potential migrant	LE	E	Possible Migrant
Wood stork	*Mycteria Americana*	Forages in prairie ponds, flooded fields and ditches.	--	T	Possible Migrant
FISHES					
Smalleye shiner	*Notropis buccula*	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident

Table 4.4-2. Endangered, Threatened, Candidate and Species of Concern Listed for Limestone County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
MAMMALS					
Plains spotted skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	Extirpated.	LE	E	Historic Resident
MOLLUSKS					
False spike mussel	*Quincuncina mitchelli*	Substrates of cobble and mud. Rio Grande, Brazos, Colorado and Guadalupe river basins.	--	T	Resident
Smooth pimpleback	*Quadrula houstonensis*	Freshwater mollusk found in small to moderate streams and rivers as well as moderate sized reservoirs. Brazos and Colorado River Basins.	C	T	Resident
Texas fawnsfoot	*Truncilla macrodon*	Found in rivers and larger streams, intolerant of impoundment.	C	T	Resident
PLANTS					
Navasota ladies'-tresses	*Spiranthes parksii*	Texas endemic found in openings in post oak woodlands in sandy loams along upland drainages or intermittent streams.	LE	E	Resident
Small-headed pipewort	*Eriocaulon koernickianum*	In east Texas found in post oak woodlands and xeric sandhill openings on wet acid sands of seeps and bogs.	--	--	Resident
REPTILES					
Alligator snapping turtle	*Macrochelys temminckii*	Found near perennial water bodies in swamps and bayous.	--	T	Resident

Table 4.4-2. Endangered, Threatened, Candidate and Species of Concern Listed for Limestone County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Texas garter snake	*Thamnophis sirtalis annectens*	Found in wet or moist microhabitats are preferred by this species.	--	--	Resident
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands.	--	T	Resident
Timber rattlesnake	*Crotalus horridus*	Floodplains, upland pine, deciduous woodlands, riparian zones.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

TPWD, 2014. Annotated County List of Rare Species –Limestone County updated 9/4/2014.

USFWS, 2014. Species Lists from http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action?fips=48187, accessed October 6, 2014.

Wildlife Habitat

Approximately 146 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 21 acres of floodplain hardwood forest, 33 acres of floodplain herbaceous vegetation, 7 acres of riparian hardwood forest, 30 acres of post oak motte and woodland areas, 13 acres of savanna grassland, 43 acres of crops and less than one acre of urban low intensity area.[7] Siting of the raw water intake, pump station and raw water pipeline needed to complete the project should be situated in a way that would result in minimal impacts to existing aquatic and terrestrial species. Impacts from this portion of the project are anticipated to be low and primarily limited to construction of these facilities and subsequent maintenance activities.

A number of vertebrate species could occur within the City of Groesbeck Reservoir site including smaller mammals such as the hispid cotton rat (*Sigmodon hispidus*), white-footed mouse (*Peromyscus leucopus*), eastern gray squirrel (*Sciurus carolinensis*), and common muskrat (*Ondatra zibethicus*).[8] Reptiles and amphibians known from the county include the central newt (*Notophthalmus viridescens louisianensis*), Strecker's chorus

[7] Texas Parks and Wildlife. Ecological Mapping Sytem GIS layer. Accessed at http://www.tpwd.state.tx.us/gis/data/ November 18, 2014.

[8] Davis, William B. and David J. Schmidly. 1994. The Mammals of Texas. Texas Parks and Wildlife, Austin, Texas.

frog (*Pseudacris streckeri*), red-eared slider (*Trachemys scripta elegans*), and western rough green snake (*Opheodrys aestivus aestivus*) among others.[9] An undetermined number of bird species and a variety of fish species would also be expected to inhabit the various habitat types within the site, with distributions and population densities limited by the types and quality of habitats available.

Cultural Resources

Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available GIS datasets provided by the Texas Historical Commission (THC) for the 2011 Regional Water Plan, there are no National Register Properties, National Register Districts, cemeteries, or historical markers located within the project area. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission regarding potential impacts to cultural resources.

A search of the Texas Archeological Sites Atlas database indicates that 27 archeological sites have been documented within the general vicinity of the proposed reservoir. Fifteen of these sites were recorded by the Texas Parks and Wildlife Department as part of a survey of Fort Parker in 1994. While all of these sites lie outside the limits of the proposed reservoir, it is possible that similar unrecorded sites could occur within the project's Area of Potential Effect. These sites represent a variety of historic and prehistoric site types. Prior to reservoir inundation, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL).

Threats to Natural Resources

Threats to natural resources include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely increase adverse effects on stream flow below the reservoir site, but the reservoir would trap sediment and/or dilute pollutants, providing some positive benefits to water quality downstream. These benefits could be offset by declines in dissolved oxygen through decreased flows and higher temperatures during summer periods. The project is expected to have negligible impacts to the stream flow and water quality in the Navasota and Brazos Rivers. No significant impacts to any listed threatened or endangered species is anticipated from this project.

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[9] Dixon, James R., Amphibians and Reptiles of Texas. 1987, Texas A&M Press.

Agricultural Impacts

The Groesbeck OCR site contains approximately 54 acres of Pasture/Hay fields and zero acres of cropland. These two agricultural land uses account for roughly 37 percent of the reservoir footprint.

4.4.4 Engineering and Costing

The potential off-channel reservoir project for the City of Groesbeck would require additional facilities to divert water from the Navasota River to the off-channel reservoir site. The facilities required for implementation of the project included:

- Raw water intake and pump station at the Navasota River diversion site with a capacity of 10.7 MGD;
- 5,280 feet of raw water pipeline (24-inch diameter) from the pump station to the off-channel reservoir;
- Pump station at the off-channel reservoir site with a capacity of 3 MGD;
- 3,500 feet of raw water pipeline (12-inch diameter) from the off-channel pump station to the water treatment plant; and
- Off-channel dam including spillway, intake tower, and 146 acres of land for the reservoir.

A summary of the total project cost is presented in Table 4.4-3. The proposed Groesbeck Off-Channel Reservoir project would cost approximately $11.9 million for surface water supply facilities. This includes the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The project cost also includes the cost for the raw water facilities to convey surface water from the Navasota River to the off-channel reservoir and back to the City's existing water treatment plant. The annual project costs are estimated to be $1,083,000. This includes annual debt service, operation and maintenance, and pumping energy costs.

The total annual cost reported in the 2011 Water plan was $991,000; the current plan costs are estimated at $1,083,000. The increase in 2016 estimated costs are due to the higher pumping energy costs and Inflation. The annual unit cost of water is $617 per acft ($1.89 per 1,000 gallons) in the current plan. Note that any subordination agreement would need to be negotiated with BRA and is dependent on the BRA successfully obtaining the System Operations permit from the TCEQ. Compensation could be required to BRA as part of the subordination agreement.

Table 4.4-3. Cost Estimate Summary for Groesbeck Off-Channel Reservoir

Item	Estimated Costs for Facilities
Off-Channel Storage/Ring Dike (Conservation Pool 2,317 acft, 146 acres)	$3,563,000
Intake Pump Stations (10.7 MGD & 3 MGD)	$3,528,000
Transmission Pipeline (24 in dia., 1 miles; 12 in dia., 0.5 miles)	$552,000
TOTAL COST OF FACILITIES	**$7,643,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,647,000
Environmental & Archaeology Studies and Mitigation	$420,000
Land Acquisition and Surveying (164 acres)	$419,000
Interest During Construction (4% for 2 years with a 1% ROI)	$780,000
TOTAL COST OF PROJECT	**$11,909,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$500,000
Reservoir Debt Service (5.5 percent, 40 years)	$370,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$6,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$88,000
Dam and Reservoir (1.5% of Cost of Facilities)	$53,000
Pumping Energy Costs (0.09 $/kW-hr)	$66,000
TOTAL ANNUAL COST	**$1,083,000**
Available Project Yield (acft/yr)	1,755
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	$617
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	$1.89

4.4.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.4-4, and the option meets each criterion.

Table 4.4-4. Evaluations of Coryell County Off-Channel Reservoir Option to Enhance Water Supplies

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	1. Negligible impact
2. Habitat	2. Negligible impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Negligible impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

Implementation of the off-channel reservoir project for the City of Groesbeck will require permits from various state and federal agencies, land acquisition, and design and construction of the facilities. The project may also have an impact on the firm yield of Lake Limestone, which may require mitigation with the Brazos River Authority in terms of a water supply contract in the amount of the firm yield impact. A summary of the implementation steps for the project is presented below.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;

- General Land Office Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.
- Coordination with BRA on any potential subordination agreement, subject to availability under the System Operations permit.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

4.5 Hamilton County Off-Channel Reservoir

4.5.1 Description of Option

A potential water management strategy for Hamilton County is a new off-channel reservoir (OCR) located in the southeast corner of Hamilton County as shown in Figure 4.5-1. The proposed reservoir will be located on South Fork Neils Creek and will contain approximately 49,849 acft of conservation storage and inundate 1,374 acres at the full conservation storage level of 1,080 ft-msl. All Natural inflows into the OCR are released downstream into South Fork Neils Creek and the reservoir is supplied from Leon River diversions. For the project to be economically feasible, the Brazos River Authority would be required to subordinate their water rights at Lake Belton to the diversions from the Leon River. Without subordination, the unappropriated flows available for diversion would not be sufficient enough to maintain adequate water levels in the OCR.

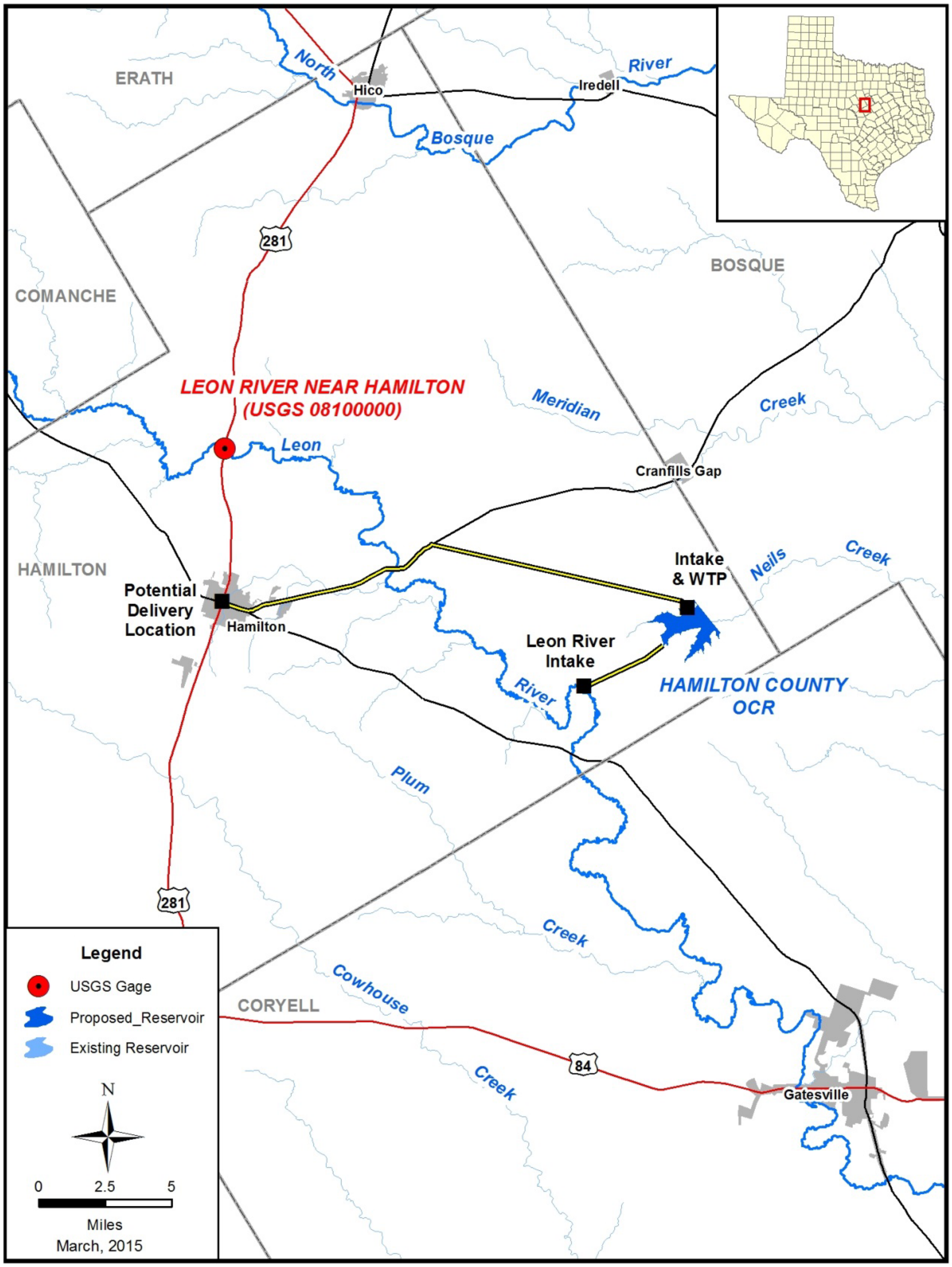
Raw water supplies from the OCR would be treated at a new water treatment facility located next to the OCR. The treated supplies would be delivered to customers within Hamilton County to meet County-Other needs. At this stage of the planning process, potential customers have not yet been identified; therefore, for planning purposes, the treated water is assumed to be delivered to the City of Hamilton, located near the center of the county.

4.5.2 Available Yield

Water potentially available for impoundment in the proposed Hamilton County OCR was estimated using the TCEQ Brazos WAM. The model utilized a January 1940 through December 1997 hydrologic period of record and assumes no return flows and permitted storages and diversions for all water rights in the basin. The OCR was also modeled such that it has no naturalized flow contributing from its own drainage area. The model computed the streamflow available for diversion from Leon River into the Hamilton County OCR without causing increased shortages to existing downstream rights. Firm yield was computed subject to the subordination agreement with Lake Belton and instream flow requirements associated with Senate Bill 3 (SB3).

The optimal Leon River diversion capacity was found to be 200 cfs. Daily gaged streamflow at the Leon River near Hamilton (USGS Gage 08100000) was available for the model simulation period. The location of the gage is shown in Figure 4.5-2. Recorded streamflows at the gage were used to estimate daily flows at the diversion site by adjusting for differences in contributing drainage areas between the two locations. Figure 4.5-2 provides a frequency of daily streamflows calculated at the Leon River diversion site. The frequency shows that streamflows are adequate to support the 200 cfs diversion approximately 20 percent of the time. This diversion constraint was included in the model simulation to more accurately estimate available flow for diversion from the Leon River.

Figure 4.5-1. Hamilton County Off-Channel Reservoir



L:\Project_Data\00044_BrazosG\GIS\Map_Docs\Task_04_WMS\WMS_Task_04_Existing_Supplies\Hamilton_County_OCR.mxd

The calculated firm yield of the Hamilton County OCR is 9,275 acft/yr, assuming subordination of Lake Belton. Without subordination, the firm yield is 1,875 acft/yr. Figure 4.5-3 illustrates the simulated Hamilton County OCR storage levels under the firm yield demand of 9,275 acft/yr. The simulated storage levels show that the critical drought for the OCR occurs in the 1980's. Figure 4.5-4 shows the simulated storage frequency of the OCR under the same firm yield demand. The frequency shows that the OCR would remain at the conservation pool capacity more than 20 percent of the time and above 90 percent full for about half of the simulation period. Figure 4.5-5 provides the annual diversion volumes from the Leon River that are impounded by the OCR. The average annual diversion over the entire model simulation period is 12,363 acft/yr.

Figure 4.5-6 and Figure 4.5-7 show the simulated monthly median streamflow and streamflow frequency at the Leon River diversion site with and without the project. The largest reduction in median monthly streamflow from implementing the project would occur in May with a reduction of 86 cfs or 33 percent. The streamflow frequency shows that there is not a significant reduction in monthly streamflows throughout the model simulation period with the project in place.

Figure 4.5-2. Daily Streamflow at Leon River Diversion Site

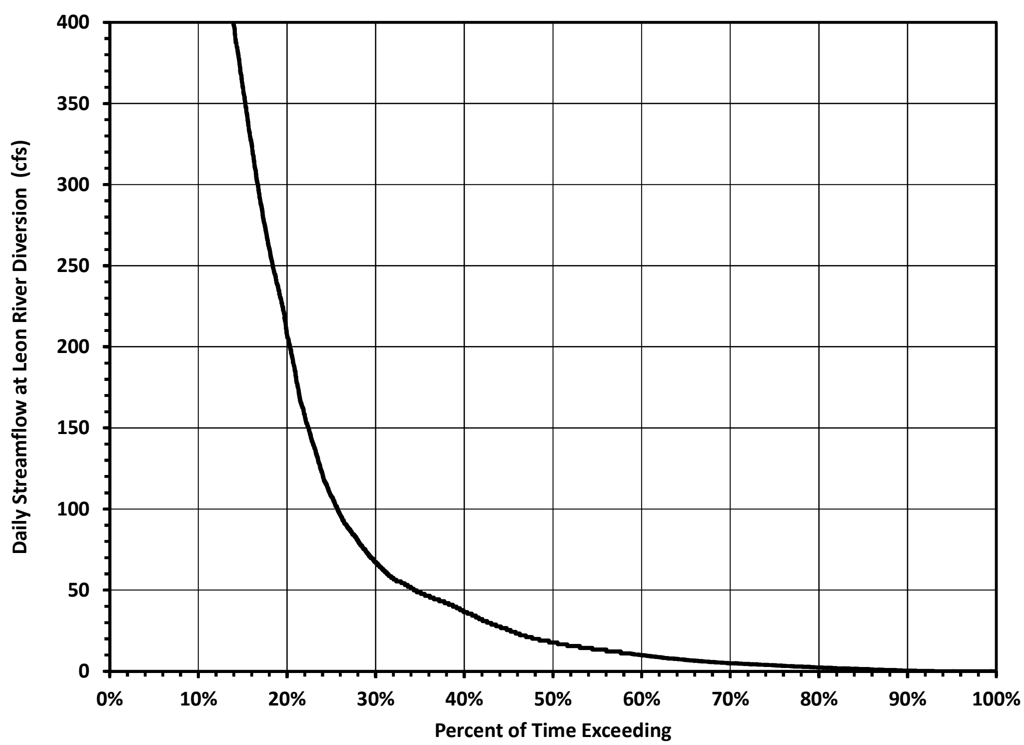


Figure 4.5-3. Hamilton County Reservoir Storage Frequency

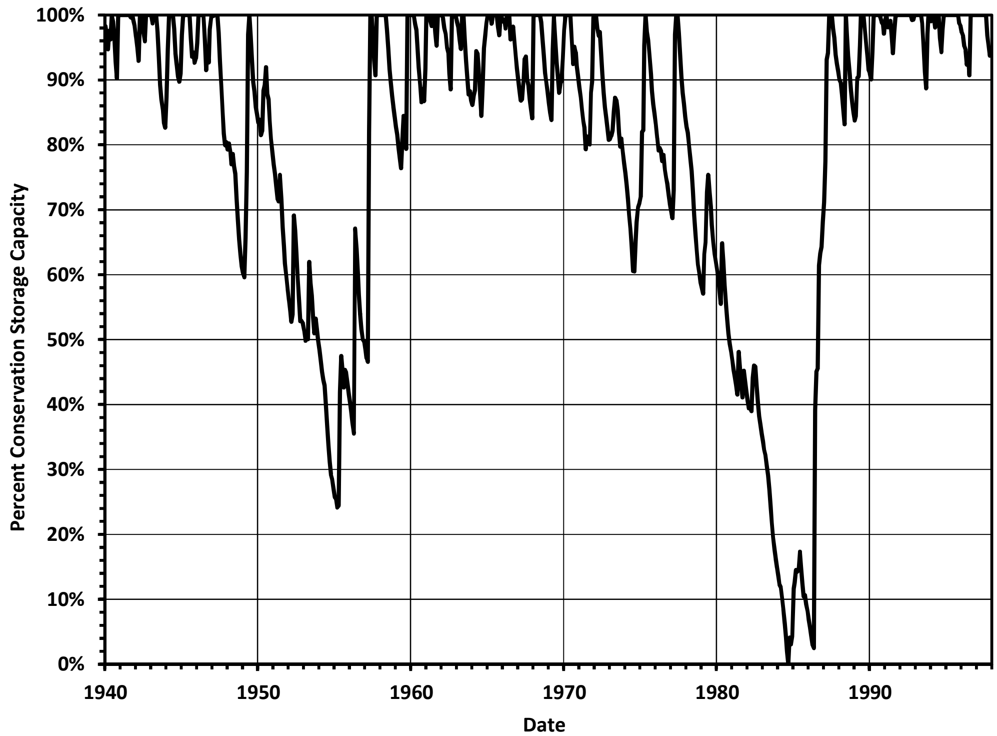


Figure 4.5-4. Hamilton County Reservoir Storage Frequency

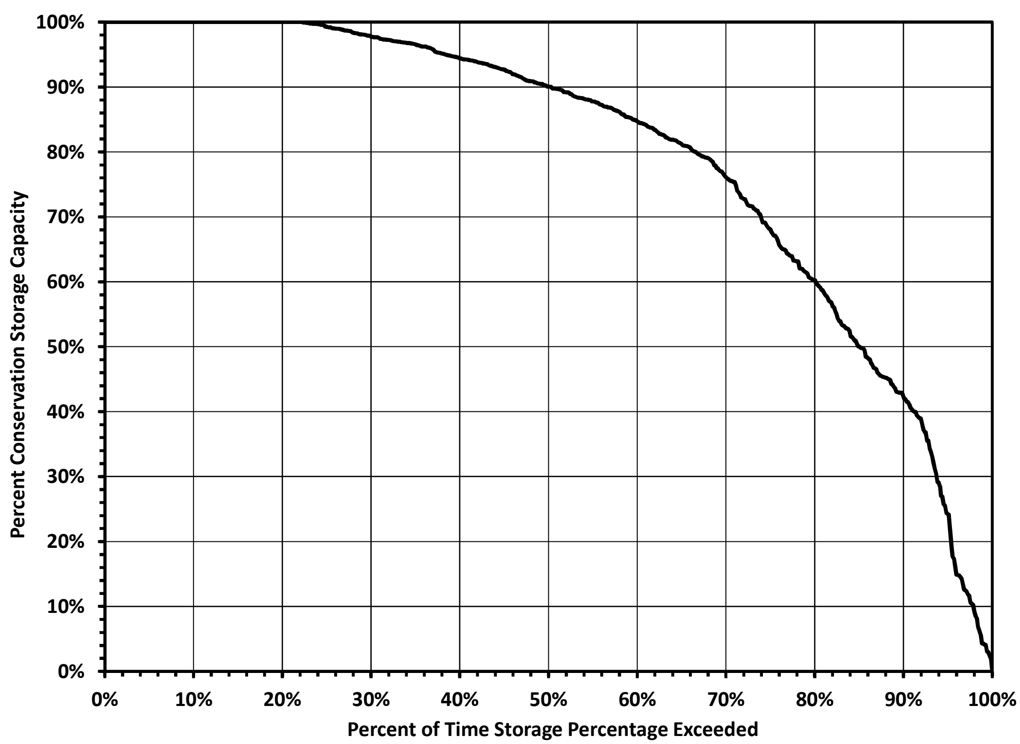


Figure 4.5-5. Annual Diversions from Leon River

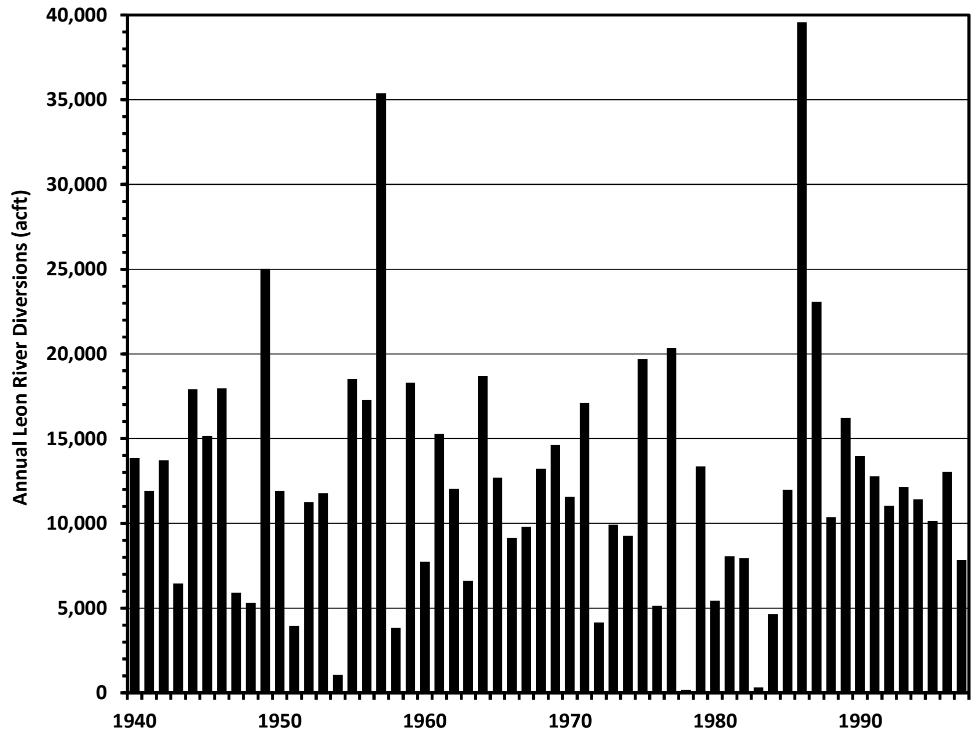


Figure 4.5-6. Leon River Simulated Monthly Median Streamflow with and without Diversion

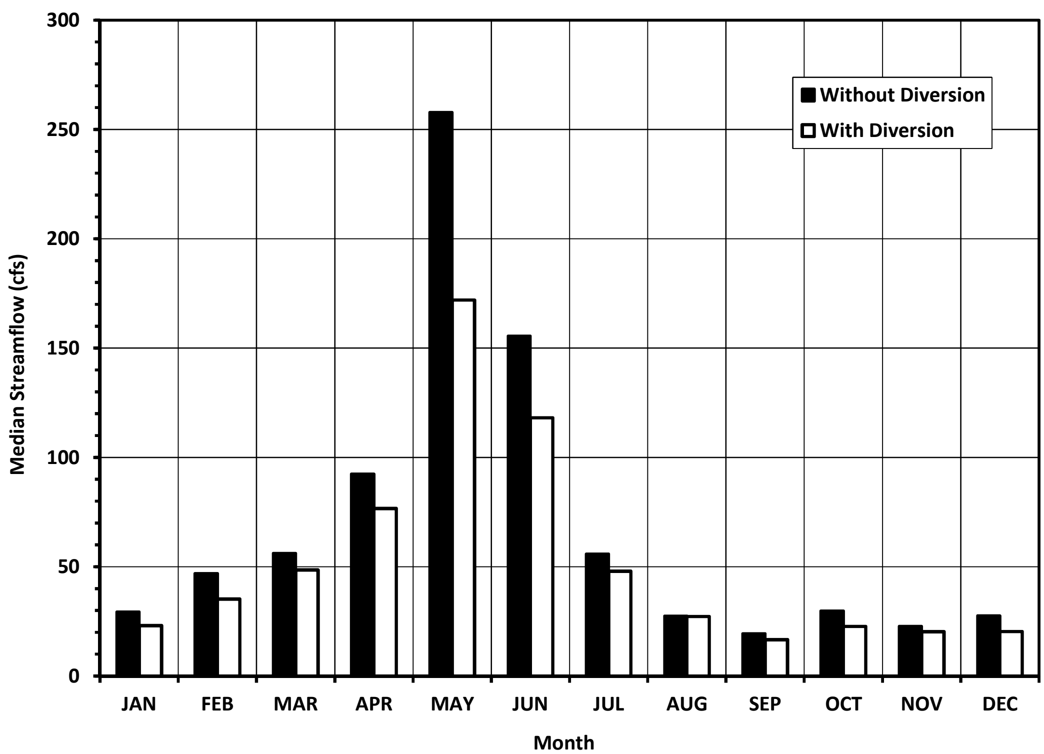
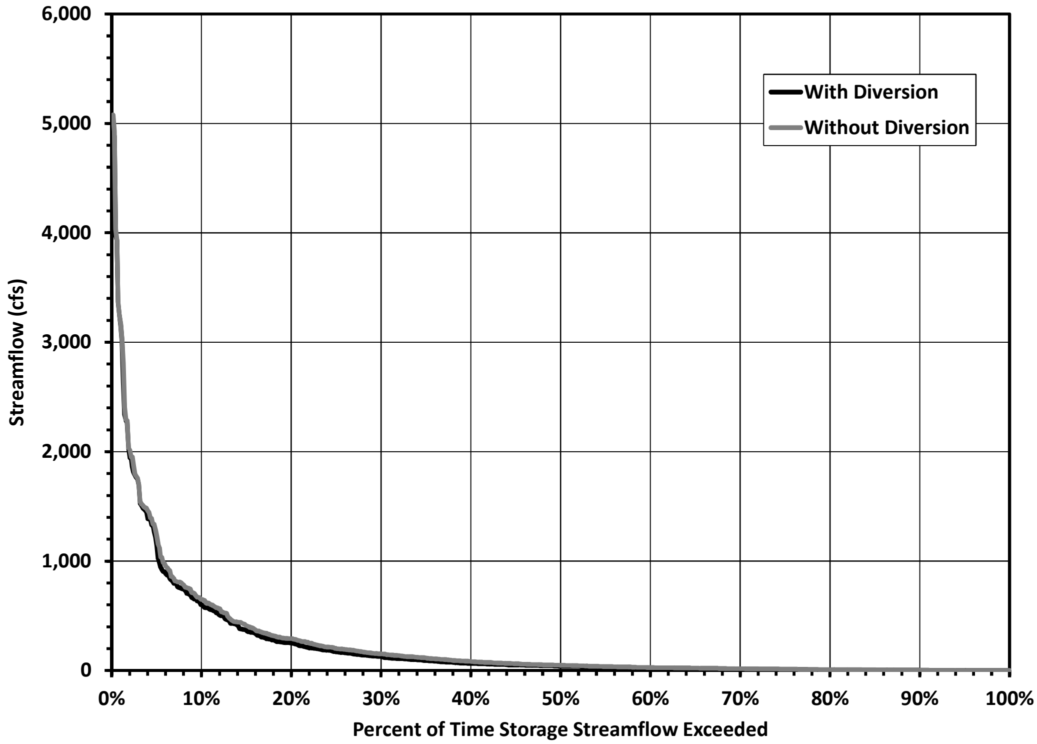


Figure 4.5-7. Leon River Simulated Streamflow Frequency with and without Diversion



4.5.3 Environmental Issues

Existing Environment

The Hamilton County OCR strategy involves the construction of an OCR along South Fork Neils Creek, an intake and pipeline from the Leon River to the OCR, a new water treatment plant and a transmission pipeline to the city of Hamilton. The proposed OCR site is located in eastern Hamilton County. The site is situated in the Cross Timbers Ecoregion[1] and is primarily located within the Balconian biotic province, with a small section on the western limits occurring within the Texan biotic province.[2] The Cross Timbers ecoregion is considered to be a transitional area found between prairie areas to the west and the forested hills of eastern Oklahoma and Texas. This area is used primarily for rangeland and pastureland, but some areas include forested sections. The mean annual precipitation of this area is 30-34 inches and the mean temperature ranges from 32 to 57 degrees Fahrenheit. The Trinity Aquifer is the only major aquifer underlying the project area.[3]

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[1] Griffith, G.E., Bryce, S.A., Omernik, J.M., Comstock, J.A., Rogers, A.C., Harrison, B., Hatch, S.L., and Bezanson, D., 2004. Ecoregions of Texas. Reston, Virginia, U.S. Geological Survey.

[2] Blair, W.F., “The Biotic Provinces of Texas, “Tex. J. Sci. 2:93-117, 1950.

[3] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.

A Custom Soil Resource Report was completed for the Hamilton County OCR site[4]. According to this report, sixteen soil types underlie the project site. Krum silty clay, 1 to 5 percent slopes, is the most abundant soil at 42% of the project area. These soils typically occupy the backslopes of ridges, and are well drained. They have a moderately available water capacity and consist of silty clay. Krum silty clay, 1 to 5 percent slopes is considered to be a prime farmland soil. Topsey clay loam, 1 to 5 percent slopes is the next most abundant soil type and is found in 12% of the project area. These soils which are found on ridges are well drained and considered to be prime farmland soils. All other soil types are included in 7% or less of the OCR area. Water areas comprise a little over two percent of the project area, and include a portion of South Fork Neils Creek and existing stock tanks.

Vegetation types which occur within the OCR area include Bluestem Grassland and Oak-Mesquite-Juniper Parks/Woods.[5] Bluestem Grassland areas include plants such as bushy bluestem (Andropogon glomeratus), slender bluestem (Schizachyrium tenerum), silver bluestem (Bothriochloa saccharoides), three awn (Aristida ssp.), buffalograss (Bouteloua dactyloides), southern dewberry (Rubus trivialis), live oak (*Quercus virginiana*), mesquite (*Prosopis glandulosa*), and baccharis (*Baccharis neglecta*). Commonly associated plants in the Oak-Mesquite-Juniper Parks/Woods vegetation type include: post oak (*Q stellata*), Ashe juniper (*Juniperus ashei*), shin oak (*Q. sinuata*), Texas oak (*Q. buckleyi*), blackjack oak (*Q. marilandica*), live oak, cedar elm (*Ulmus crassifolia*), agarito (*Berberis trifoliolata*) , soapberry (*Sapindus saponaria*), sumac (*Rhus sp.*), hackberry (*Celtis reticulata*), Texas pricklypear (*Opuntia sp.*), Mexican persimmon (*Diospyros texana*), purple three-awn (*A. purpurea*), curly mesquite (*Hilaria mutica*), and Texas wintergrass (*Stipa leucotricha*).

Vegetation found along the two project pipeline routes includes the two vegetation types described above in addition to areas of Silver Bluestem-Texas Wintergrass Grassland.[6] Silver bluestem-Texas Wintergrass Grasslands include the following commonly associated plants: little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), Texas grama (*Bouteloua rigidiseta*), hairy grama (*Bouteloua hirsute*), tall dropseed (*Sporobolus asper*), windmillgrass (*Chloris verticillata*), hairy tridens (*Erioneuron pilosum*), tumblegrass (*Schedonnardus paniculatus*), western ragweed (*Ambrosia psilostachya*), broom snakeweed (*Gutierrezia sarothrae*), Texas bluebonnet (*Lupinus texensis*), live oak, post oak and mesquite.

Potential Impacts

Aquatic Environments including Bays & Estuaries

The potential aquatic impacts of this project were evaluated at the Leon River where water will be diverted to the OCR site. Streamflow available for diversion from the Leon

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[4] NRCS. “Custom Soil Resource Report for Hamilton County, Texas – Hamilton Off-Channel Site. February 17, 2015.

[5] McMahan, C. A., R. G. Frye and K. L. Brown, “ The Vegetation Types of Texas -- Including Cropland,” Texas Parks and Wildlife Department - PWD Bulletin 7000-120. 1984.

[6] McMahan, C. A., R. G. Frye and K. L. Brown, “ The Vegetation Types of Texas -- Including Cropland,” Texas Parks and Wildlife Department - PWD Bulletin 7000-120. 1984.

River into the OCR are not anticipated to cause increased shortages to existing downstream rights or significant impact to existing aquatic species. The river diversion would be required to pass inflows which meet the environmental flow criteria for stream flow. However a difference in the variability of monthly flow conditions at the diversion point might also be anticipated. Variability in flow is important to the instream biological community as well as riparian species and a reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing suitability for others.

Because the OCR has no naturalized flow originating from its own drainage area, no environmental flow criteria pass-through requirements are needed for this site. However impacts to aquatic species within the OCR area would occur as habitats change from the existing intermittent stream condition to a reservoir environment.

Siting of the Leon River intake and pump station for this project should be situated as to result in minimal disturbance to existing area species. Although there would be impacts in the immediate vicinity of the project site and downstream, it appears that this project, alone, would have minimal influence on total discharge in the Brazos River, resulting in a minimal influence to freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects of this type may reduce freshwater inflows into the estuary.

Threatened & Endangered Species

A total of 20 species could potentially occur in Hamilton County that are state- or federally-listed as threatened or endangered, federal candidates for listing, or exhibit sufficient rarity to be listed as a species of concern by the State. This group includes ten birds, one fish, one insect, four mammals, three mollusks, and one reptile (Table 4.5-1). Three bird species federally- listed as endangered could possibly occur within the project area. These include the black-capped vireo (*Vireo atricapilla*), golden-cheeked warbler (*Setophaga chrysoparia*) and whooping crane (*Grus americana*). The black-capped vireo and golden-cheeked warbler are only present in central Texas during the breeding season and have very specific habitat requirements. Potential preferred habitat for these two species may occur within the project area. The whooping crane is a seasonal migrant that could pass through the project area.

Data from the TPWD Texas Natural Diversity Database[7] did not reveal any documented occurrences of listed species within the vicinity of the proposed Hamilton OCR. However documented occurrences of the smooth pimpleback mussel, a state threatened species, are located along the Leon River approximately two miles downstream of the project intake. Although based on the best information available to TPWD, these data do not provide a definitieve statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

[7] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, November 10, 2014.

Table 4.5-1. Endangered, Threatened, Candidate and Species of Concern Listed for Hamilton County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
BIRDS					
American peregrine falcon	*Falco peregrinus anatum*	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Black-capped vireo	*Vireo atricapilla*	Occupies oak-juniper woodlands with a distinctive patchy, two-layered aspect. Migrant.	LE	E	Nesting/ Migrant
Golden-cheeked warbler	*Setophaga chrysoparia*	Found in juniper-oak woodlands; dependent on Ashe juniper for bark strips used in nest construction. Migrant	LE	E	Nesting/ Migrant
Mountain plover	*Charadrius montanus*	Non-breeding, shortgrass plains and fields	--	--	Migrant
Peregrine falcon	*Falco peregrinus*	Possible migrant. Subspecies not easily distinguishable so reference is made to species level.	DL	T	Possible Migrant
Sprague's pipit	*Anthus spragueii*	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant

Table 4.5-1. Endangered, Threatened, Candidate and Species of Concern Listed for Hamilton County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Western burrowing owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna	--	--	Resident
Whooping crane	*Grus americana*	Potential migrant	LE	E	Potential Migrant
FISHES					
Smalleye shiner	*Notropis buccula*	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident
INSECTS					
Leon river winter stonefly	*Taeniopteryx starki*	This species breeds in rivers using lotic environments.	--	--	Resident
MAMMALS					
Cave myotis bat	*Myotis velifer*	Colonial and cave-dwelling species. Also roosts in rock crevices and buildings.	--	--	Resident
Gray wolf	*Canis lupus*	Extirpated, formerly known throughout the western two-thirds of the state in forests, brushlands, or grasslands.	LE	E	Historic Resident
Plains spotted skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	Extirpated.	LE	E	Historic Resident
MOLLUSKS					
False spike mussel	*Quincuncina mitchelli*	Substrates of cobble and mud. Rio Grande, Brazos, Colorado and Guadalupe river basins.	--	T	Resident

Table 4.5-1. Endangered, Threatened, Candidate and Species of Concern Listed for Hamilton County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Smooth pimpleback	*Quadrula houstonensis*	Freshwater mollusk found in small to moderate streams and rivers as well as moderate sized reservoirs. Brazos and Colorado River Basins.	C	T	Resident
Texas fawnsfoot	*Truncilla macrodon*	Found in rivers and larger streams, intolerant of impoundment.	C	T	Resident
REPTILES					
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

TPWD, 2015. Annotated County List of Rare Species –Hamilton County updated 9/4/2014.

USFWS, 2014. Species Lists from http://ecos.fws.gov/tess_public/reports/species-by-current-range-county?fips=48193, accessed February 18, 2015.

Wildlife Habitat

The primary impacts that would result from construction and operation of the proposed Hamilton OCR include conversion of approximately 1,374 acres of existing habitat within the conservation pool to open water. Projected wildlife habitat that will be impacted includes approximately 794 acres of Savanna Grassland that encompass 58% of the OCR area. An additional 30% of this area includes wood or forest areas and approximately four percent includes shrubland. Smaller percentages of row crops, urban herbaceous vegetation also occur within the OCR area.[8]

Siting of the raw water intake, pump station, and raw water pipeline to the OCR should be located as feasible in areas that would result in minimal impacts to existing aquatic and terrestrial species. The transmission pipeline to the City of Hamilton as currently planned includes approximately 18 miles of 72-in pipeline. The eastern half of this pipeline would occur within areas that are relatively undeveloped and the western portion primarily occurs within the right-of-way of existing roadways. The use of previously disturbed areas such as the right-of-way areas would reduce the impacts associated with the pipeline construction and maintenance. The transmission pipeline also crosses

[8] Texas Parks and Wildlife. Ecological Mapping Sytem GIS layer. Accessed at http://www.tpwd.state.tx.us/gis/data/ November 18, 2014.

numerous waterways including the Leon River and a number of creeks and tributaries. Best Management Practices utilized during construction activities would minimize impacts to the project area habitats and existing species. Impacts from the project pipelines and associated appurtenances are anticipated to be primarily limited to the construction of these facilities and subsequent maintenance activities.

A number of vertebrate species could occur within the Hamilton County OCR site including smaller mammals such as the eastern red bat (*Lasiurus borealis*), hispid cotton rat (*Sigmodon hispidus*), white-footed mouse (*Peromyscus leucopus*), and eastern fox squirrel (*Sciurus niger*).[9] Reptiles and amphibians known from the county include the Great Plains rat snake (*Elaphe guttata guttata*), western coachwhip (*Masticophis flagellum flagellum*), and Texas horned lizard (*Phrynosoma cornutum*) among others.[10] An undetermined number of bird species and a variety of fish species would also be expected to inhabit the various habitat types within the site, with distributions and population densities limited by the types and quality of habitats available.

Cultural Resources

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available GIS datasets provided by the Texas Historical Commission (THC), there are no National Register Properties, National Register Districts, or State Historic Sites located within or near the OCR or pipeline project areas. One cemetery occurs within the OCR area and 2 occur within one mile of the transmission pipeline. Twenty one historical markers occur within one mile of the transmission pipeline, all within the city limits of Hamilton. Avoidance of cultural resources located near the pipelines, water treatment plant and intake structure are probable with careful location of these facilities. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission regarding potential impacts to cultural resources.

Threats to Natural Resources

This project could possibly have adverse effects on stream flow below the diversion point along the Leon River. Decreased stream flow would contribute to declines in dissolved oxygen and higher temperatures during summer periods. The project is expected to have negligible impacts to the stream flow and water quality in the Brazos River. Additional impacts would be expected to terrestrial species found within the proposed OCR area that would be displaced by the reservoir filling. Impacts associated with the transmission pipelines and water treatment plants are anticipated to be limited to the construction of these facilities and continued maintenance of these areas.

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[9] Davis, William B. and David J. Schmidly. 1994. The Mammals of Texas. Texas Parks and Wildlife, Austin, Texas

[10] Dixon, James R., Amphibians and Reptiles of Texas. 1987, Texas A&M Press.

Agricultural Impacts

The Hamilton County Reservoir site does not contain Pasture/Hay fields or cultivated cropland. No impacts are expected for agricultural land use.

4.5.4 Engineering and Costing

The potential OCR project for Hamilton County would require additional facilities to divert water from the Leon River to the OCR site and to treat and transmit water from the OCR to the City of Hamilton. The facilities required for implementation of the project include:

- Raw water intake and pump station at the Leon River diversion site with a capacity of 200 cfs (129 MGD);
- 3 Miles of raw water pipeline (72-inch diameter) from the pump station to the OCR;
- OCR dam including spillway, intake tower, and 1,374 acres of land for the reservoir;
- A new 8.7 MGD water treatment plant, intake and pump station at the OCR Site;
- 18-mile, 24-in treated water pipeline to County-Other distribution lines.

A summary of the total project cost in September 2013 dollars is presented in Table 4.5-2. The proposed Hamilton Creek OCR project would cost approximately $153.8 million for surface water supply facilities. This includes the construction of the dam, land acquisition, environmental permitting and mitigation, and technical services. The project costs also include the cost for the raw water facilities to convey surface water from the Leon River diversion site to the OCR and the transmission and treatment water stored in the OCR to the distribution line. The annual project costs are estimated to be approximately $17.8 Million. This includes annual debt service, operation and maintenance, pumping energy costs, and purchase of water from BRA for compensation of yield impacts to Lake Belton. The OCR project would be able to provide 9,275 acft/yr of treated water at a unit cost of $1,923 per ac-ft or $5.90 per 1,000 gallons.

Table 4.5-3 provides a comparison of the plan to development criteria. The option meets each criterion.

Table 4.5-2. Cost Estimate Summary for Hamilton County Off-Channel Reservoir

Item	Estimated Costs for Facilities
Dam and Reservoir (Conservation Pool 49,849 acft, 1,374 acres)	$14,690,000
Leon River Channel Dam & Intake Pump Station (129 MGD)	$23,976,000
Leon River Diversion Pipeline (72 in dia., 3 miles)	$6,780,000
OCR Intake Pump Station (8.7 MGD)	$6,383,000
OCR Transmission Pipeline (24 in dia., 18 miles)	$16,302,000
Water Treatment Plant (8.7 MGD)	$28,963,000
TOTAL COST OF FACILITIES	**$97,094,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$32,829,000
Environmental & Archaeology Studies and Mitigation	$4,303,000
Land Acquisition and Surveying (1,776 acres)	$4,994,000
Interest During Construction (4% for 2 years with a 1% ROI)	$14,619,000
TOTAL COST OF PROJECT	**$153,839,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$10,342,000
Reservoir Debt Service (5.5 percent, 40 years)	$1,885,000
Operation and Maintenance	
Intakes and Pump Stations (2.5% of Cost of Facilities)	$990,000
Dam and Reservoir (1.5% of Cost of Facilities)	$220,000
Water Treatment Plant (2.5% of Cost of Facilities)	$2,896,000
Pumping Energy Costs (0.09 $/kW-hr)	$1,267,000
Purchase of Water (3,590 acft/yr @ 65.65 $/acft)	$236,000
TOTAL ANNUAL COST	**$17,836,000**
Available Project Yield (acft/yr)	9,275
Annual cost of Water ($ per acft)	$1,923
Annual cost of Water ($ per 1,000 gallons)	$5.90

Table 4.5-3. Evaluations of Hamilton County Off-Channel Reservoir Option to Enhance Water Supplies

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. High
B. Environmental factors	
1. Environmental Water Needs	Moderate impact
2. Habitat	Moderate impact
3. Cultural Resources	Low impact
4. Bays and Estuaries	Negligible impact
5. Threatened and Endangered Species	Low impact
6. Wetlands	Negligible impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

4.5.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.5-3 and the option meets each criterion.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits have already been obtained;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);

- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- General Land Office Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

4.6 Palo Pinto Off-Channel Reservoir

4.6.1 Description of Option

During the early 1980s and after the occurrence of low lake levels, the Palo Pinto County Municipal Water District No. 1 (District) became concerned about the capacity of Lake Palo Pinto. As a result, a volumetric survey of the lake was performed in 1985 by HDR, Inc. (HDR). This survey determined the reservoir's conservation capacity to be 27,650 acft or about 16,450 acft less than the authorized capacity of 44,100 acft. A second volumetric survey was conducted in 1988 by the Texas Water Development Board (TWDB). This survey confirmed the results of the 1985 survey and determined the reservoir's capacity to be 27,590 acft. This survey also determined the reservoir has an average conservation pool depth of only 12.5 feet. In the late 1980's the District became further concerned about the potential loss of water supply releases along the 16 miles of Palo Pinto Creek between Lake Palo Pinto and the District's channel reservoir on Palo Pinto Creek. The results of a 1989 channel loss study revealed that between 500 and 2,000 acft of water are lost annually to Palo Pinto Creek and the channel reservoir.

In 2004, the Brazos Electric Power Cooperative (BEPC) approached the District about their need for additional water. The District re-initiated previous investigations of alternatives to restore the capacity of Lake Palo Pinto and increase its yield. The District authorized a study to evaluate the feasibility of additional water supply options.[1] In 2006, the District undertook a subsurface geotechnical investigation to determine dam and reservoir feasibility of the Wilson Hollow off-channel reservoir site in addition to an environmental study to determine if endangered species were present.

In the 2001 Brazos G Regional Water Plan (2001 Plan), the Turkey Peak Reservoir was included as the Recommended Water Management Strategy (WMS) for the District. In the 2006 Brazos G Regional Water Plan (2006 Plan) and the 2007 State Water Plan, the Wilson Hollow (Off-channel Reservoir) Water Management Strategy (WMS) replaced the Turkey Peak Reservoir WMS as a recommended WMS due to its lower estimated cost in 2005. The Turkey Peak Reservoir was included in the 2006 Plan as an Alternative WMS. However, following the completion of the 2006 geotechnical and environmental studies (which determined that an endangered species was present at the Wilson Hollow site and that the project would also cost more than originally estimated due to geologic conditions), the District requested the Brazos G Regional Planning Group to approve the substitution of the Turkey Peak Reservoir WMS for the Wilson Hollow (Off-channel Reservoir) WMS as the recommended WMS in the State Water Plan. This substitution request was officially approved by the TWDB. The Palo Pinto Off-Channel Reservoir (Wilson Hollow Site) remains an alternative WMS to meet the needs of the District.

The proposed off-channel reservoir is located approximately 1.6 miles north of Lake Palo Pinto at Wilson Hollow, as shown in Figure 4.6-1 and Figure 4.6-2. The proposed dam would be an earthfill embankment that would extend approximately 1,550 feet and provide an initial conservation storage capacity of 10,000 acft with a surface area of 182

[1] HDR, Inc. "Reconnaissance Report for Off-Channel Reservoir Project for Palo Pinto County Municipal Water District No. 1", April 2005.

acres at an elevation of 1,088 ft-msl. This site can be expanded to store up to 22,000 acft depending on the growth of the District and the future needs of the BEPC.

The proposed off-channel reservoir would be filled by natural drainage and by pumping water from Lake Palo Pinto when it is spilling or nearly full. As shown in Figure 4.6-2, water would be pumped 2 miles via a 36-inch pipeline to the off-channel reservoir from Lake Palo Pinto at a new 28.4 MGD intake site located at the northeast corner of the lake. When the level of Lake Palo Pinto is lowered due to drought conditions, water would be released by gravity from the off-channel reservoir to Lake Palo Pinto to increase its supply capability. When both the off-channel reservoir and Lake Palo Pinto are at their conservation elevations, 1,088 ft-msl and 867 ft-msl respectively, the combined storage capacity in 2070 would be approximately 34,505 acft. This is less than the District's authorized storage capacity of Lake Palo Pinto of 44,100 acft.

4.6.2 Available Yield

Water potentially available for diversion to the proposed Lake Palo Pinto Off-Channel Reservoir was estimated using the Texas Water Development Board's (TWDB) reservoir operation model, SIMYLD-II. Using this model, Lake Palo Pinto and the proposed off-channel reservoir were evaluated as a reservoir system subject to a set of operational rules. These operational rules attempted to maintain Lake Palo Pinto above elevation 864 ft-msl for as long as possible while still meeting the municipal diversions of the District at the diversion dam located downstream of Lake Palo Pinto. The model utilized a January 1948 through December 2001 hydrologic period of record.[2,3] The water availability analysis was not updated for the 2016 Regional water plan, as no significant changes occurred requiring updating of the SIM-YLD model.

The additional yield available for the Lake Palo Pinto and off-channel reservoir system that may be attributed to the Lake Palo Pinto Off-Channel Reservoir is 3,110 acft/yr. Figure 4.6-3 shows that when operated with the proposed Off-channel Reservoir, the lake levels in Lake Palo Pinto are stabilized and more water is available in the drier years compared to Lake Palo Pinto operated independently. Figure 4.6-4 compares the storage in Lake Palo Pinto at existing conditions (standalone) with the storage when the lake is operated with the Off-Channel Reservoir. The 2070 safe yield (with a six month storage reserve) and the 2070 stand alone safe yield of Lake Palo Pinto was utilized to determine the additional available yield. While the most recent elevation-area-capacity relationship for Lake Palo Pinto is not incorporated into this analysis, the additional available yield associated with operating the Lake Palo Pinto and off-channel reservoir system would not change significantly by incorporating this information.

The yield analysis does not pass inflows to meet environmental flow standards associated with Senate Bill 3 (SB3) as these requirements do not apply to the proposed project. The combined storage of the off-channel reservoir and Lake Palo Pinto is less than the District's authorized storage in Lake Palo Pinto as described above; therefore,

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[2] HDR, Inc. "Yield Studies of Lake Palo Pinto and Turkey Peak Reservoir," Palo Pinto County Municipal Water District Number One, March 1986.

[3] HDR, Inc. "Yield Studies for Lake Palo Pinto and the Proposed Turkey Peak Reservoir," Palo Pinto County Municipal Water District Number One, June 2001.

the additional off-channel storage would replace lost storage authorized in the District's existing permit and be senior to the SB3 environmental flow standards.

Figure 4.6-1. Lake Palo Pinto Off-Channel Reservoir

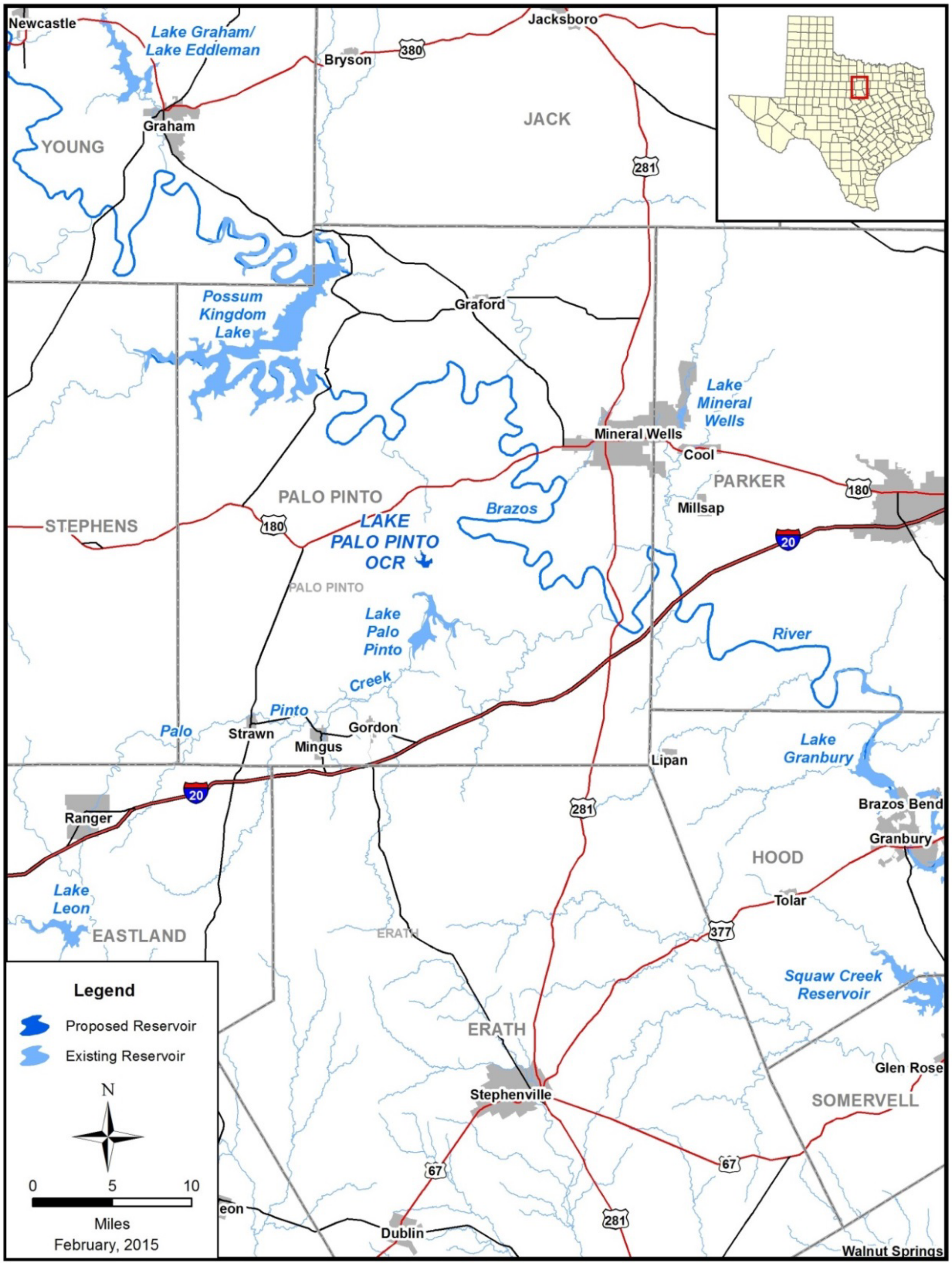
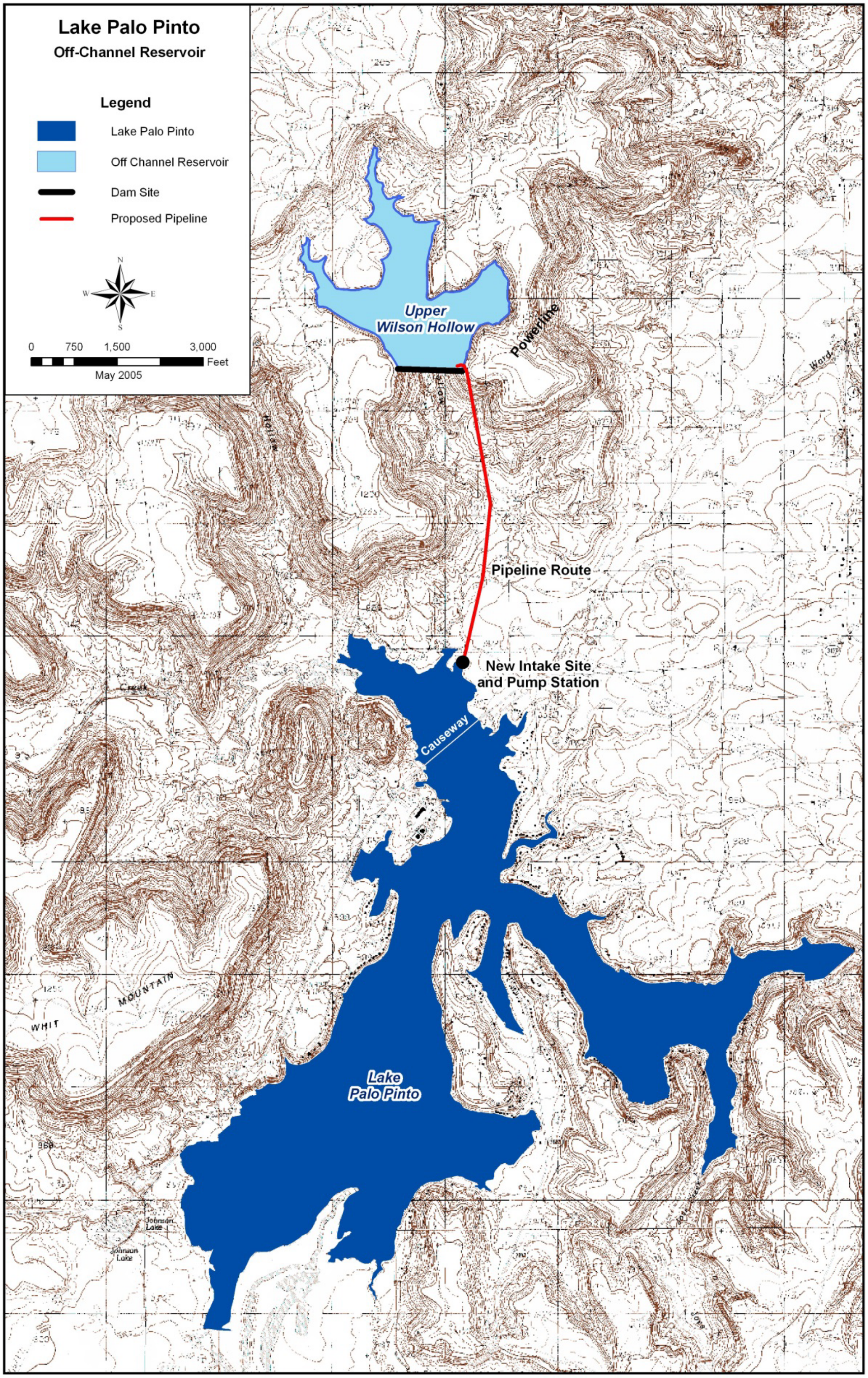


Figure 4.6-2. Lake Palo Pinto Off-Channel Reservoir



Since both the combined storage and diversion amounts for the Lake Palo Pinto and off-channel reservoir are within the limits of the District's existing water rights, and the off-channel reservoir is proximate to Lake Palo Pinto, this proposed project could be implemented within the existing water rights held by the District (storage capacity and diversion) and will have little or no change to streamflow beyond those already caused by the District's water rights when fully utilized.

Figure 4.6-3. Lake Palo Pinto Storage when Operated With Lake Palo Pinto Off-Channel Reservoir

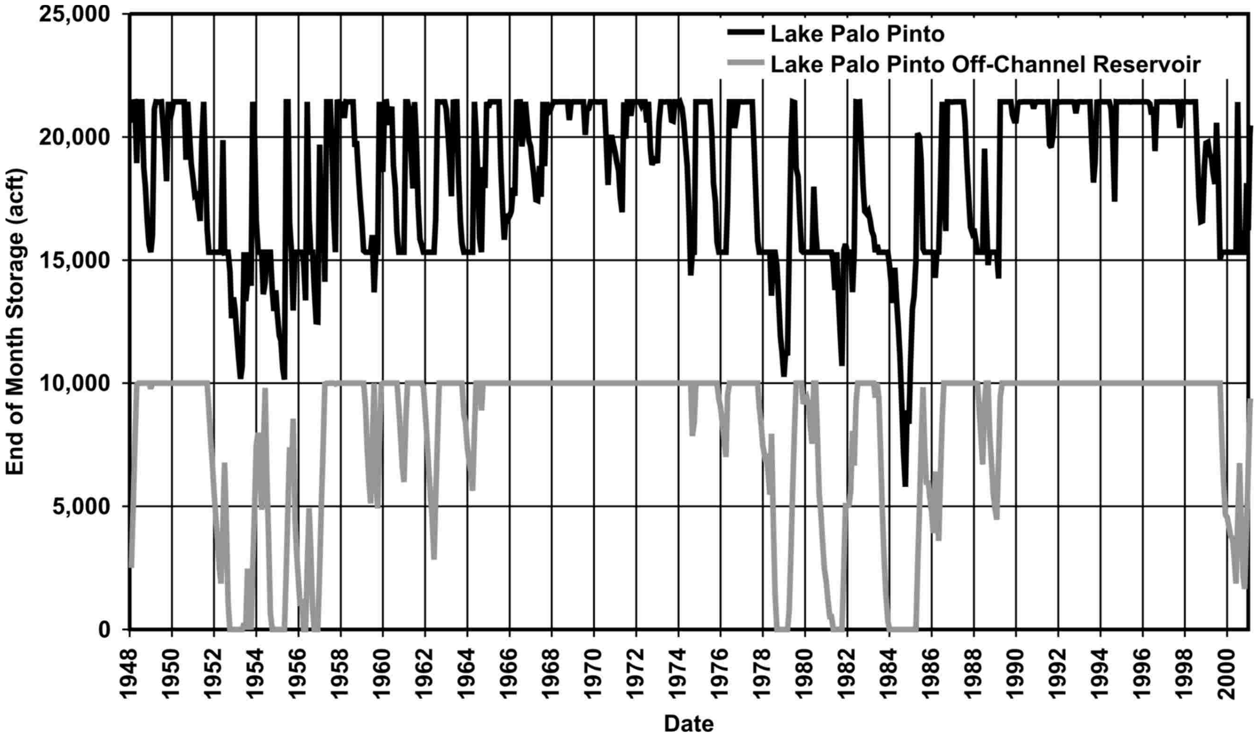
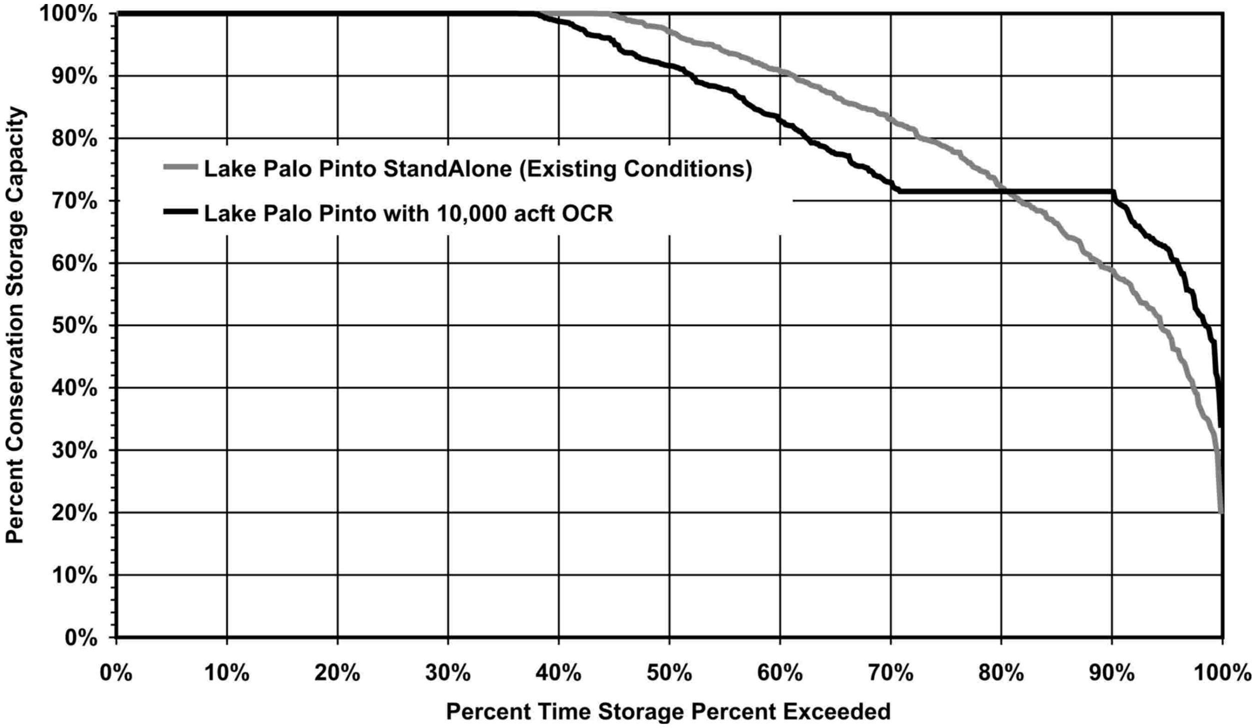


Figure 4.6-4. Comparison of Lake Palo Pinto Storage Frequency when Operated With and Without Lake Palo Pinto Off-Channel Reservoir



4.6.3 Environmental Issues

Existing Environment

The Lake Palo Pinto Off-Channel Reservoir (OCR) site in central Palo Pinto County is within the Cross Timbers and Prairies Vegetational Area.[4] This complex transitional area of prairie dissected by parallel timbered strips is located in north-central Texas west of the Blackland Prairies, east of the Rolling Plains, and north of the Edwards Plateau. The physiognomy of the region is oak and juniper woods and mixed grass prairie. Much of the native vegetation has been displaced by agriculture and development, and range management techniques, including fire suppression, have contributed to the spread of invasive woody species and grasses. Farming and grazing practices have also reduced the abundance and diversity of wildlife in the region.[5] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 28 and 32 inches.[6] No major or minor aquifers underlie the project area;

[4] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, Vegetational Areas of Texas, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.

[5] Telfair, R.C., "Texas Wildlife Resources and Land Uses," University of Texas Press, Austin, Texas, 1999.

[6] Larkin, T.J., and G.W. Bomar, "Climatic Atlas of Texas," Texas Department of Water Resources, Austin, Texas, 1983.

the Trinity Aquifer, a major aquifer consisting of interbedded sandstone, sand, limestone, and shale of Cretaceous Age, lies east and south of the project area.[7]

The physiography of the region includes hard sandstone, mud, and mudstone (undifferentiated), ceramic clay and lignite/coal, terraces, and flood-prone areas. The topography ranges from flat to rolling, and from steeply to moderately sloped, with local shallow depressions in flood-prone areas along waterways.[8]

A Custom Soil Resource Report was completed for the Lake Palo Pinto OCR site.[9] According to this report, two soil types underlie the project site. Shatruce gravelly sandy loam, 12 to 50 percent slopes, very rubbly, is the most abundant soil at over 98% of the project area. This soil typically occupies ridges, is well drained, and has low available water capacity. It consists of gravelly sandy loam underlain by clay. The other soil found within the project area is Set-Palopinto complex, 8 to 40 percent slopes, extremely stony, which occurs within 2% of the project area. These soils are found on ridges, shoulders and backslope areas; are well drained and have a moderate to very low available water capacity. They are comprised of stony clay with clay, silty clay or bedrock underneath. Neither of these soil types is considered to be a prime farmland soil.

The major vegetation type surrounding the entirety of the proposed project area consists of the Ashe Juniper Parks/Woods.[10] Variations of this primary vegetation type may involve changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. The proposed OCR lies within the Wilson Hollow Canyon north of Lake Palo Pinto along a second-order stream, Wilson Creek, a minor headwater tributary to the reservoir. The canyon cross section is V-shaped with steep slopes variably incised into a sandstone escarpment composed of Turkey Creek Sandstone.[11] The lower half of the canyon is typically obstructed or braided by accumulations of relatively unsorted sediment ranging in size from silty sand to boulders. Dry pools, or short stream reaches exhibiting features such as bank undercutting and thin algal crusts on rocks, were observed at numerous locations along the canyon.

The irregular, relatively steep canyon slopes that cap the escarpment are densely wooded throughout the canyon with post oak (*Quercus stellata*), blackjack oak (*Q. marylandica*) and Ashe juniper (*Juniperus ashei*) with Texas ash (*Fraxinus texana*), scrub oak (*Q. sinuata*), and honey mesquite (*Prosopis glandulosa*) also present in small numbers. Woodlands on the steeper slopes generally have open canopies and relatively dense ground covers of small junipers, oaks, *Opuntia* cacti, and grasses. Where the

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[7] Texas Water Development Board (TWDB), Major and Minor Aquifers of Texas; Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.

[8] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., “Land Resources of Texas.” Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.

[9] NRCS. “Custom Soil Resource Report for Palo Pinto County, Texas – Lake Palo Pinto Off-Channel Site. December 8, 2014.

[10] McMahan, C.A., R.F. Frye, and K.L. Brown, “The Vegetation Types of Texas,” Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

[11] Bureau of Economic Geology (BEG). 1972. Geologic Atlas of Texas, Abilene Sheet. The University of Texas at Austin. Austin, Texas.

slopes are less steep (and the trees more mature) a primarily post oak forest with a closed canopy and open understory has developed. Post and blackjack oaks account for at least 70% of the canopy coverage in the canyon, with ashe juniper accounting for most of the remainder. The riparian zone is not well developed or defined, generally corresponding to the canyon bottom floodway. This area is characterized by deep colluvial soils (i.e., a loose deposit of rocky materials that accumulate at the base of slopes by force of gravity and erosion) and more gentle slopes than are present on the valley walls. Overstory and shrub vegetation along the floodway includes post oak, blackjack oak, scrub oak, live oak (*Q. virginiana*), hackberry (*Celtis laevigata*), cedar elm, green ash (*F. pennslyvanica*), Texas ash, pecan (*Carya illinoiensis*), cottonwood (*Populus deltoides*), honey mesquite, Ashe juniper, prairie sumac (*Rhus lanceolata*), yaupon (*Ilex vomitoria*), prickley pear (*Opuntia lindheimeri*), pencil cactus (*O. leptocaulis*), buttonbush (*Cephalanthus occidentalis*), American beautyberry (*Callicarpa americana*), and greenbriar (*Smilax* spp.). Although numerous large trees are present, the floodway vegetation commonly consists of a mosaic of shrubby thickets of small Ashe junipers or saplings of the dominant tree species, and clearings where a variety of grasses dominated ground cover.

Potential Impacts

Inundation of the OCR area would impact terrestrial species currently or occasionally using the area by removing existing habitat. This project would reduce stream flow below the reservoir site during storm events but would increase stream flow when water is released to Lake Palo Pinto, affecting aquatic species.

Threatened & Endangered Species

A total of 15 species could potentially occur in Palo Pinto County that are state- or federally-listed as threatened or endangered, federal candidates for listing, or exhibit sufficient rarity to be listed as a species of concern by the State (Table 4.6-1). This group includes two reptiles, eight birds, two mammals, one mollusk, and two fish species. Inclusion in this table does not mean that a species will occur within the study area but only acknowledges the potential for its occurrence in Palo Pinto County. On-site evaluations by qualified biologists are required to confirm the occurrence of sensitive species or habitats.

The Migratory Bird Treaty Act protects most bird species, including, but not limited to, cranes, ducks, geese, shorebirds, hawks, and songbirds. Migratory bird pathways, stopover habitats, wintering areas, and breeding areas may occur within and adjacent to the project area, and may be associated with wetlands, ponds, shorelines, riparian corridors, fallow fields and grasslands, and woodland and forested areas. If the off-channel option is employed, reservoir construction would remove some habitats utilized by certain migratory bird species, however it would create more habitats for others. This transition from a terrestrial to an aquatic ecosystem would allow time for migratory species to acclimate to the altered condition within the project area and encourage the movement of non-aquatic species to similar areas nearby.

Table 4.6-1. Endangered, Threatened, Candidate and Species of Concern Listed for Palo Pinto County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
BIRDS					
American peregrine falcon	*Falco peregrinus anatum*	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Black-capped vireo	*Vireo atricapilla*	Occupies oak-juniper woodlands with a distinctive patchy, two-layered aspect. Migrant.	LE	E	Nesting/ Migrant
Golden-cheeked warbler	*Setophaga chrysoparia*	Found in juniper-oak woodlands; dependent on Ashe juniper for bark strips used in nest construction. Migrant	LE	E	Nesting/ Migrant
Interior least tern	*Sterna antillarum athalassos*	Nests along sand and gravel bars in braided streams	LE	E	Resident
Mountain plover	*Charadrius montanus*	Non-breeding, shortgrass plains and fields	--	--	Migrant
Peregrine falcon	*Falco peregrinus*	Possible migrant. Subspecies not easily distinguishable so reference is made to species level.	DL	T	Possible Migrant
Piping Plover	*Charadrius melodus*	Migrant shorebird in Texas.	T	--	Migrant
Red knot	*Calidris canutus rufa*	Migratory species within Texas.	PT	--	Possible Migrant

Table 4.6-1. Endangered, Threatened, Candidate and Species of Concern Listed for Palo Pinto County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Sprague's pipit	*Anthus spragueii*	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Western burrowing owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna	--	--	Resident
Whooping crane	*Grus americana*	Potential migrant	LE	E	Potential Migrant
FISHES					
Guadalupe bass	*Micropterus treculi*	Endemic to perennial streams of the Edwards Plateau region.	--	--	Resident
Sharpnose shiner	*Notropis oxyrhynchus*	Endemic to Brazos River drainage. Found in large rivers.	LE	--	Resident
Smalleye shiner	*Notropis buccula*	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident
MAMMALS					
Gray wolf	*Canis lupus*	Extirpated formerly known in western two-thirds of the state.	LE	E	Historic Resident
Plains spotted skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	Extirpated.	LE	E	Historic Resident
MOLLUSKS					
Texas fawnsfoot	*Truncilla macrodon*	Found in rivers and larger streams, intolerant of impoundment.	C	T	Resident

Table 4.6-1. Endangered, Threatened, Candidate and Species of Concern Listed for Palo Pinto County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
REPTILES					
Brazos water snake	*Nerodia harteri*	Found in upper Brazos River drainage in shallow water with rocky bottoms.	--	T	Resident
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

TPWD, 2014. Annotated County List of Rare Species –Palo Pinto County updated 9/4/2014.

USFWS, 2014. Species Lists from http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action?fips=48187, accessed October 6, 2014.

Five bird species federally listed as threatened or endangered may occur in the project vicinity. These include the black-capped vireo, golden-cheeked warbler, interior least tern, piping plover, and whooping crane. These bird species are all seasonal migrants that could pass through the project area. The black-capped vireo only nests in dense underbrush in semi-open woodlands having distinct upper and lower stories. The interior least tern typically nests on bare or sparsely vegetated areas associated with streams or lakes, such as sand and gravel bars, beaches, islands, and salt flats. Unvegetated bars within wide river channels or open flats along lake or reservoir shorelines are preferred and provide nesting habitat and access to adjacent open water for feeding.

The piping plover is a migrant shorebird in Texas that prefers open sandy beaches. The whooping crane spends the winter on the Texas Coast at Aransas National Wildlife Refuge near Rockport, and breeds in the wetlands of Wood Buffalo National Park in northern Canada. Whooping cranes occasionally utilize wetlands as an incidental rest stop during their migration throughout the central portion of Texas. Habitat elements particularly attractive to the black-capped vireo, interior least tern, piping plover and whooping crane do not appear to be present on or adjacent to this potential reservoir site, although migrants are possible.

Of the aforementioned federally-listed avian species, the golden-cheeked warbler (GCW) does utilize the proposed reservoir site for nesting, as the juniper-oak woodland habitats on the canyon slopes and the riparian floodplain along Wilson Creek is representative of fairly high quality GCW habitat. Several detailed presence/absence field surveys of the Wilson Hollow canyon was conducted by qualified biologists in March-May 2006. A total of 139 GCW detections including observations of 121 males, 7 females and 11 juveniles were made during 7 site visits totaling slightly over 40 hours of total survey time.[12] Fifty-eight of the GCW observations or 42% of the birds sighted during the study were recorded within the boundaries of the reservoir survey area. Between 12 and 14 individual GCW territories were mapped across the Wilson Hollow study area with most extending beyond the boundary of the study area.[13]

Avian species listed by the State of Texas as endangered or threatened include the peregrine falcon and bald eagle. The peregrine falcon includes two subspecies which migrate across the state from more northern breeding areas in the U.S. and Canada to winter along the coast. Bald eagles are listed as threatened in Texas and occur as winter migrants. The majority of nesting bald eagle pairs currently reported are found along major rivers and near reservoirs in eastern Texas. Bald eagles are opportunistic predators, feeding primarily on fish captured in the shallow water of both lakes and streams or scavenged food sources. These birds may utilize tall trees near perennial water as roosting or nesting sites. Although the bald eagle could use the nearby reservoirs (Lake Palo Pinto or Possum Kingdom Reservoir) for foraging or nesting, the species has not been reported in the region. It is not expected that either bird species would be directly affected by the proposed Lake Palo Pinto Off-Channel Reservoir site.

The Texas horned lizard, a state threatened species, and the plains spotted skunk, a state species of concern, are possible inhabitants of the reservoir site or its adjacent upland pastures. Texas horned lizards inhabit deserts and grasslands in semi-arid to arid landscapes with sparse vegetation and gravelly soils. Their habitat must contain a stable population of harvester ants, which make up the majority of its diet. They typically inhabit relatively flat, open areas with light ground vegetation cover but can be found in elevations up to 6,000 ft on a variety of soil types. This species could be displaced within the areas that will be gradually inundated. Relocation would then be possible into similar and acceptable habitat available adjacent to the project area. The plains spotted skunk is generally found in open fields, prairies, and croplands. Vegetation within the project area generally consists of moderately dense mixed deciduous woodlands in the canyons, with pastures or pecan orchards in the floodplains. It is expected that if the plains spotted skunk is present in the proposed reservoir area, the gradual transition to an aquatic system could displace these species. However, the project area is rural, and similar suitable habitats exist adjacent to the project area; therefore, it is anticipated that the spotted skunk could relocate to those areas if necessary.

The gray wolf and red wolf are two state and federally listed endangered mammals which historically lived in Palo Pinto County. These two species are now considered to be extinct within this region of the state.

The Brazos water snake, a state threatened species, and the sharpnose shiner and the smalleye shiner, are aquatic species endemic to the Brazos River Basin. The Brazos water snake is usually found in shallow rocky riffle areas along river channels that have a gently sloping rocky shoreline free of vegetation and in reservoir environments with similar habitat characteristics. Occurrences of the Brazos water snake have been documented twice by Texas Parks and Wildlife Department (TPWD) near Palo Pinto

[12] Ladd, Clifton and Amanda Aurora. Endangered Species Survey Summary for the Golden-Cheeked Warbler. Loomis Austin, 2006.

[13] Ibid.

Creek. The two species of fish are listed as endangered by the U.S. Fish and Wildlife Service (USFWS) due to the decline of suitable habitat resulting from the construction of dams along the Brazos River and several of its major tributaries. General habitat associations for these sympatric fish species include relatively shallow water of moderate currents flowing through broad and open sandy channels. No evidence of persistent water was observed in Wilson Creek; therefore, the occurrence of either the Brazos water snake or the two cyprinid species is highly unlikely.

Freshwater mussels are sensitive barometers of environmental quality. When terrestrial or aquatic ecological conditions degrade or are modified, native unionid mussels (Family Unionidae) are often the first organisms to decline or vanish. The Texas fawnsfoot, listed as threatened by the state and a species of concern by USFWS, is known only in the Brazos River downstream of Possum Kingdom Lake. The lack of permanent water in Wilson Creek would preclude this species or other freshwater mussels from inhabiting the study area.

A search of the Texas Natural Diversity Database for Wilson Hollow and the immediate vicinity[14] revealed no documented occurrences of endangered or threatened species within or near the proposed Lake Palo Pinto Off-Channel Reservoir site. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area.

Wildlife Habitat

Palo Pinto County is included in the Texan Biotic Province as delineated by Blair[15] and modified by TPWD. This province includes bands of prairie and woodland that begin in South Central Texas and run north to Kansas. The Texan Biotic Province constitutes a broad ecotone between the forests in the eastern portion of this region and the western grasslands. Although varied, the vertebrate community within the area of the proposed reservoir includes no true endemic species. The wildlife habitat types of the study area coincide closely with the major plant community types present. The mountains and associated vegetation areas within Palo Pinto County are similar to that of the Edwards Plateau; therefore the wildlife habitats and species of the study area represent a mixture of those typical of the surrounding areas. Siting of the raw water intake, pump station and raw water pipeline needed to complete the project should be located in an area that would result in minimal impacts to existing aquatic and terrestrial species. Impacts from the pipeline and associated appurtenances are anticipated to be low and primarily limited to the construction of these facilities and subsequent maintenance activities.

Within this province, western species tend to encroach into open habitats, and eastern species intrude along the many wooded drainageways extending through the landscape. Typical mammals of this province include the Virginia opossum (*Didelphis virginiana*), fox squirrel (*Sciurus niger*), and fulvous harvest mouse (*Reithrodontomys fulvescens*). The Gulf Coast toad (*Bufo valliceps*), gray treefrog (*Hyla versicolor/chrysosceles*) and

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14 Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, Received 10/03/2014.

15 Blair, W. Frank. 1950. "The Biotic Provinces of Texas," Texas Journal of Science 2 (1):93-117.

southern leopard frog (*Rana sphenocephala*) are typical anuran species found in this province.

Cultural Resources

A review of available GIS datasets provided by the Texas Historical Commission (THC) for the 2011 Regional Plan revealed that there are no National Register Properties, National Register Districts, cemeteries, or historical markers located within or near the project area.

However a search of the Texas Archeological Sites Atlas database indicates that 99 archeological sites have been documented within the general vicinity of the proposed OCR. Researchers from the University of Texas recorded 49 of these sites as part of the Village Bend archeological survey in 1980. These sites, which lie outside the currently proposed reservoir, represent a variety of historic and prehistoric site types.

Prior to reservoir inundation, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any other cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archeological and Historic Preservation Act (PL93-291).

Threats to Natural Resources

This project would reduce stream flow below the reservoir site during storm events but would increase stream flow when water is released to Lake Palo Pinto. As the reservoir would trap and/or dilute pollutants, it would provide some positive benefits to water quality immediately downstream. Dissolved oxygen levels would be maintained by the installation of a multi-level outlet tower at the new reservoir which would always release water from the top 30 feet of the reservoir conservation pool. The project is expected to have negligible impacts to total discharge downstream and overall water quality in the Brazos River.

A series of avian surveys conducted by Loomis-Austin[16] indicated the wooded ravine and riparian floodplain areas in the Wilson Hollow canyon and close proximity are currently used by the federally protected golden-cheeked warbler, with a total of 139 individuals being observed during March, April and May 2006.

Agricultural Impacts

The Lake Palo Pinto OCR site does not contain Pasture/Hay fields or cultivated cropland. No impacts are expected for agricultural land use.

[16] Ladd, Clifton and Amanda Aurora. Endangered Species Survey Summary for the Golden-Cheeked Warbler. Loomis Austin, 2006.

4.6.4 Engineering and Costing

Cost estimates for the Lake Palo Pinto Off-Channel Reservoir were originally prepared by HDR, Inc. in April, 2005 for the District.[17] For consistency with the regional water planning guidelines, these costs were adjusted to September 2013 prices using a ratio derived from Engineering News Record Construction Cost Indexes. The estimated construction cost of the Lake Palo Pinto Off-Channel Reservoir is approximately $34.7 million. This includes the construction of the dam, land acquisition, resolution of conflicts, geotechnical investigation, environmental permitting and mitigation, and technical services.

The annual costs are estimated to be $3 million; this includes annual debt service, operation and maintenance, and pumping energy costs. The cost for the estimated increase in system yield of 3,110 acft/yr translates to an annual unit cost of raw water of $3.01 per 1,000 gallons, or $980/acft. A summary of the cost estimate is provided in Table 4.6-2.

4.6.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.6-3, and the option meets each criterion.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- General Land Office Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,

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[17] HDR, Inc. "Reconnaissance Report for Off-Channel Reservoir Project for Palo Pinto County Municipal Water District No. 1", April 2005.

- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 4.6-2. Cost Estimate Summary for Lake Palo Pinto Off-Channel Reservoir

Item	Estimated Costs for Facilities
Off Channel Storage/Ring Dike (Conservation Pool 10,000 acft, 182 acres)	$11,075,000
Intake Pump Stations (28.4 MGD)	$9,205,000
Transmission Pipeline (2 miles)	$1,712,000
Integration, Relocations, and Other	$425,000
TOTAL COST OF FACILITIES	**$22,417,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$7,760,000
Environmental & Archaeology Studies and Mitigation	$941,000
Land Acquisition and Surveying (199 acres)	$966,000
Interest During Construction (4% for 2 years with a 1% ROI)	$2,270,000
Pumping Costs to Fill Initial Reservoir	$331,170
TOTAL COST OF PROJECT	**$34,685,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$1,407,000
Reservoir Debt Service (5.5 percent, 40 years)	$1,114,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$17,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$230,000
Dam and Reservoir (1.5% of Cost of Facilities)	$166,000
Pumping Energy Costs (1,265,017 kW-hr @ 0.09 $/kW-hr)	$114,000
TOTAL ANNUAL COST	**$3,048,000**
Available Project Yield (acft/yr)	**3,110**
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	**$980**
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	**$3.01**

Table 4.6-3. Evaluations of Lake Palo Pinto Off-Channel Reservoir Option to Enhance Water Supplies

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	1. Negligible impact
2. Habitat	2. Negligible impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Moderate impact
6. Wetlands	6. Negligible impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4.7 Little River Off-Channel Reservoir

4.7.1 Description of Option

The Little River Off-Channel Reservoir (OCR) is a proposed new reservoir on Pin Oak Creek, a tributary to the Little River. The reservoir site is located in Milam County, east of the City of Cameron, as shown in Figure 4.7-1 and would impound water from the Pin Oak Creek watershed. The dam would be an earthfill embankment that would extend approximately 3.8 miles across the Pin Oak Creek valley and provide a conservation storage capacity of 155,812 acft at an elevation 400 ft-msl; the reservoir would inundate 4,343 surface acres. Two options were considered for augmenting supplies in the OCR. The first option is to divert and impound streamflow from the Little River. The second option is to divert and impound available streamflow from the main stem of the Brazos River.

4.7.2 Available Yield

Water potentially available for impoundment in the proposed Little River OCR was estimated using the TCEQ Brazos WAM. The model utilized a January 1940 through December 1997 hydrologic period of record with permitted storages and diversions for all surface water rights in the basin. The model computed the streamflow available for impoundment from Pin Oak Creek and diversion from the Little River or Brazos River into the Little River OCR without causing increased shortages to downstream rights. Firm yield was computed subject to the reservoir and supplemental diversions having to pass inflows to meet environmental flow standards associated with Senate Bill 3 (SB3).

This strategy could potentially provide supply under the BRA System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. If an entity other than the BRA were to sponsor and pursue this strategy, then an agreement with the BRA would be required to address concerns related to the potential subordination of the System Operation strategy.

Various maximum diversion capacities associated with potential pipeline sizes (64-inch, 72-inch, 90-inch, 108-inch, and 120-inch, 144-inch and parallel 120-inch diameter pipelines) were evaluated. The greatest incremental benefit in yield occurs with the 108-inch pipeline size for the Little River diversion and the 144-inch pipeline size for the Brazos River diversion. The calculated firm yield of the Little River OCR is 34,625 acft/yr with the Little River diversions and 56,150 acft/yr with the Brazos River diversion.

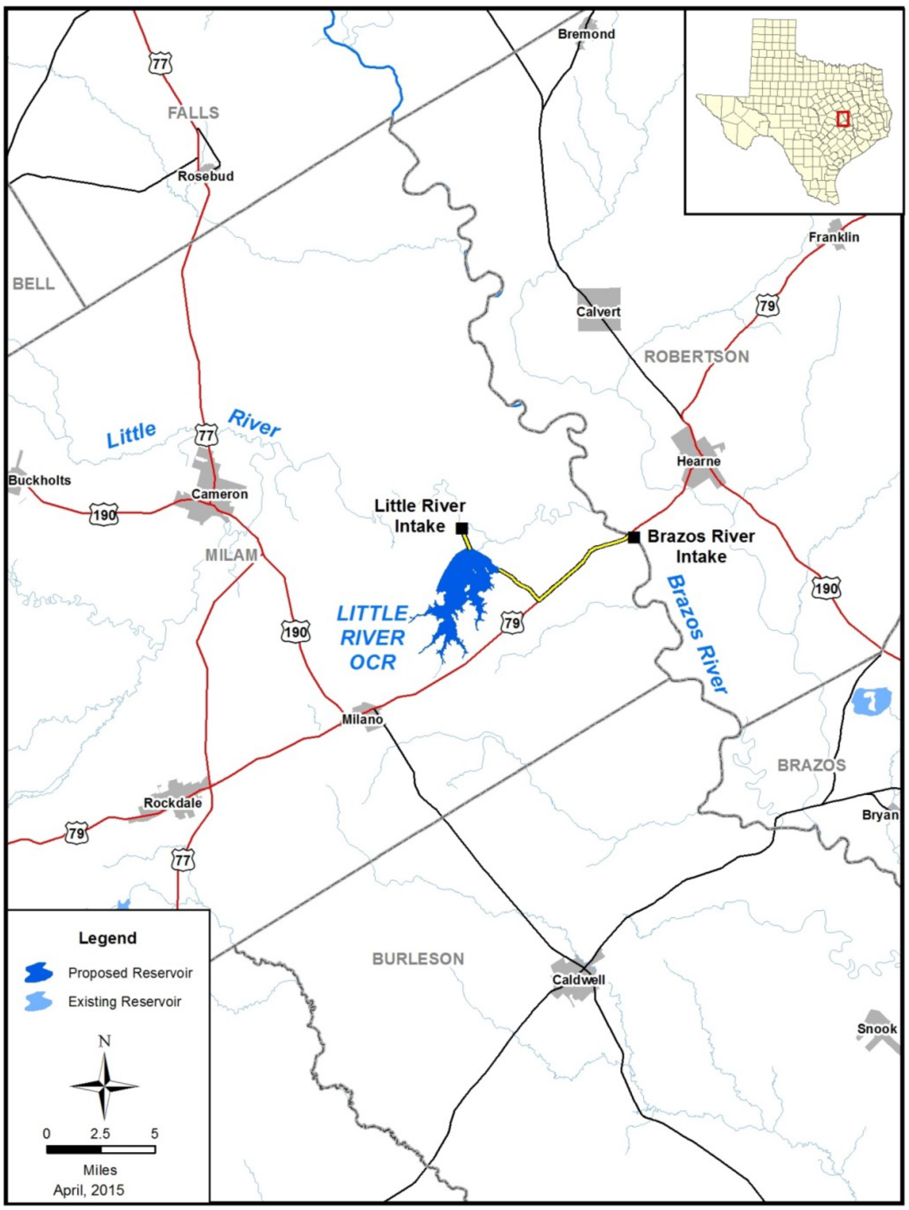
Figure 4.7-2 illustrates the simulated Little River Off-Channel Reservoir storage contents for the 1940 to 1997 historical period, subject to the firm yield of 34,625 acft/yr and based on delivery of Little River diversions via a 108-inch pipeline. Figure 4.7-3 shows that simulated reservoir contents remain above 80 percent capacity about 78 percent of the time and above 50 percent capacity about 94 percent of the time.

Figure 4.7-4 and Figure 4.7-5 illustrate the changes in streamflows at the reservoir location and the Little River caused by the project . There are significant changes in streamflow at the reservoir location due to the project; however, there are minimal changes in Little River streamflow due to the project. The largest decline in monthly median streamflow on the

Little River (47 cfs; 27% reduction) occurs in October. Figure 4.7-6 and Figure 4.7-7 also illustrate the streamflow frequency characteristics at the reservoir location and the Little River with the project in place. There is little difference in streamflow on the Little River with the project because the Little River diversion would be required to pass substantial inflows in order to satisfy senior water rights and/or environmental flow requirements.

Figure 4.7-8, Figure 4.7-9, Figure 4.7-10, Figure 4.7-11, Figure 4.7-12, and Figure 4.7-13 provide the same model simulation results for the Brazos River diversion option. Streamflows at the OCR would be reduced to amounts almost identical to those for the Little River diversion option. Streamflow reductions at the Brazos River diversion site are minimal as shown in Figure 4.7-11 and Figure 4.7-13 .

Figure 4.7-1. Little River Off-Channel Reservoir



L:\Project_Data\00044_BrazosG\GIS\Map_Docs\Task_04_WMS\WMS_Task_04_Existing_Supplies\Little_River_OCR.mxd

Figure 4.7-2. Little River OCR with Little River Diversion - Firm Yield Storage Trace

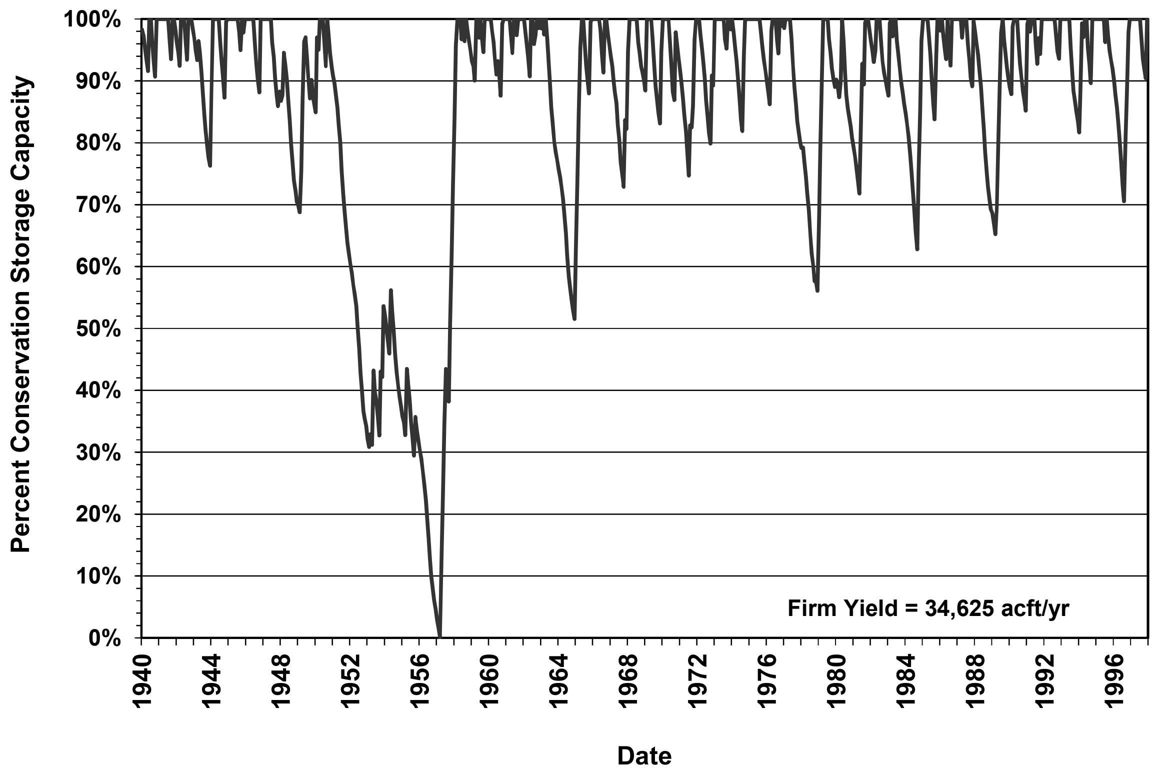


Figure 4.7-3. Little River OCR with Little River Diversion – Firm Yield Storage Frequency

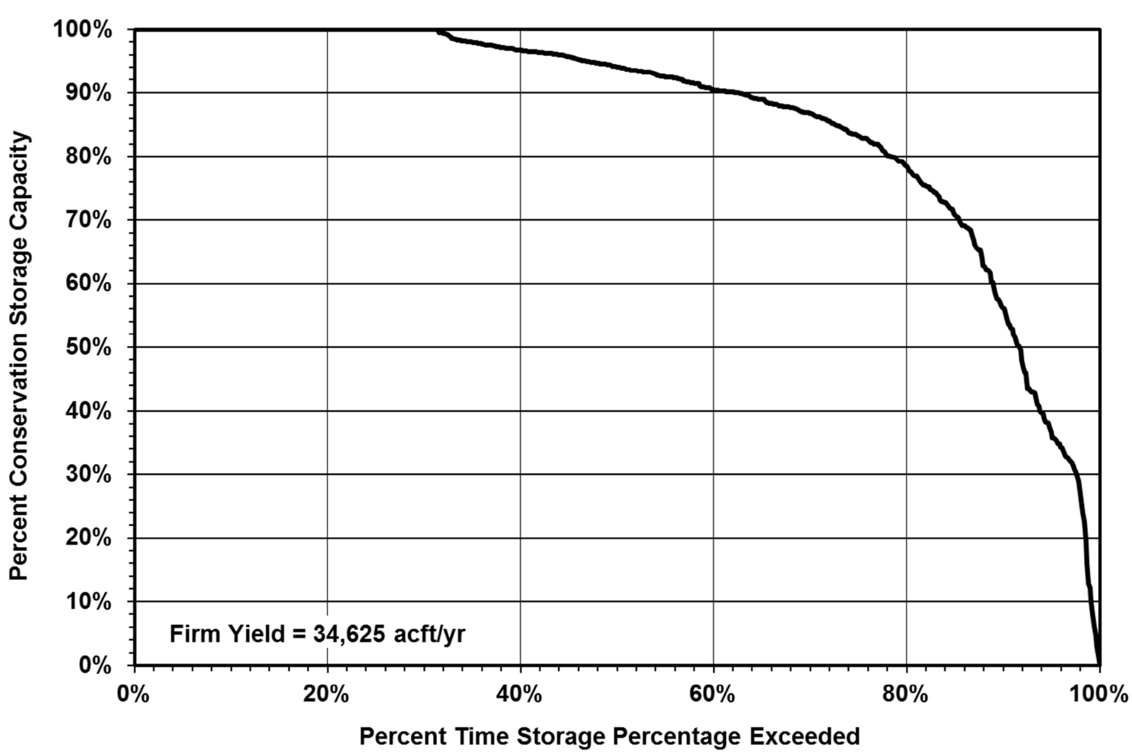


Figure 4.7-4. Little River OCR with Little River Diversion - Median Streamflow Comparison

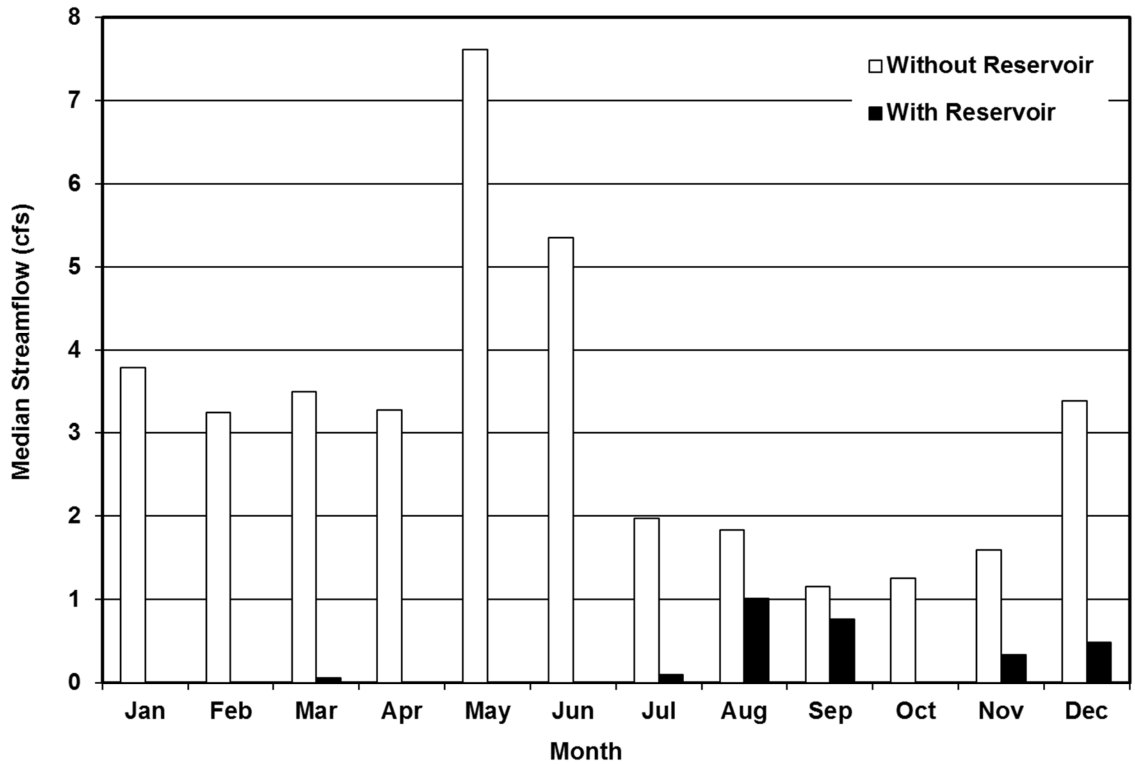


Figure 4.7-5. Little River Diversion - Median Streamflow Comparison

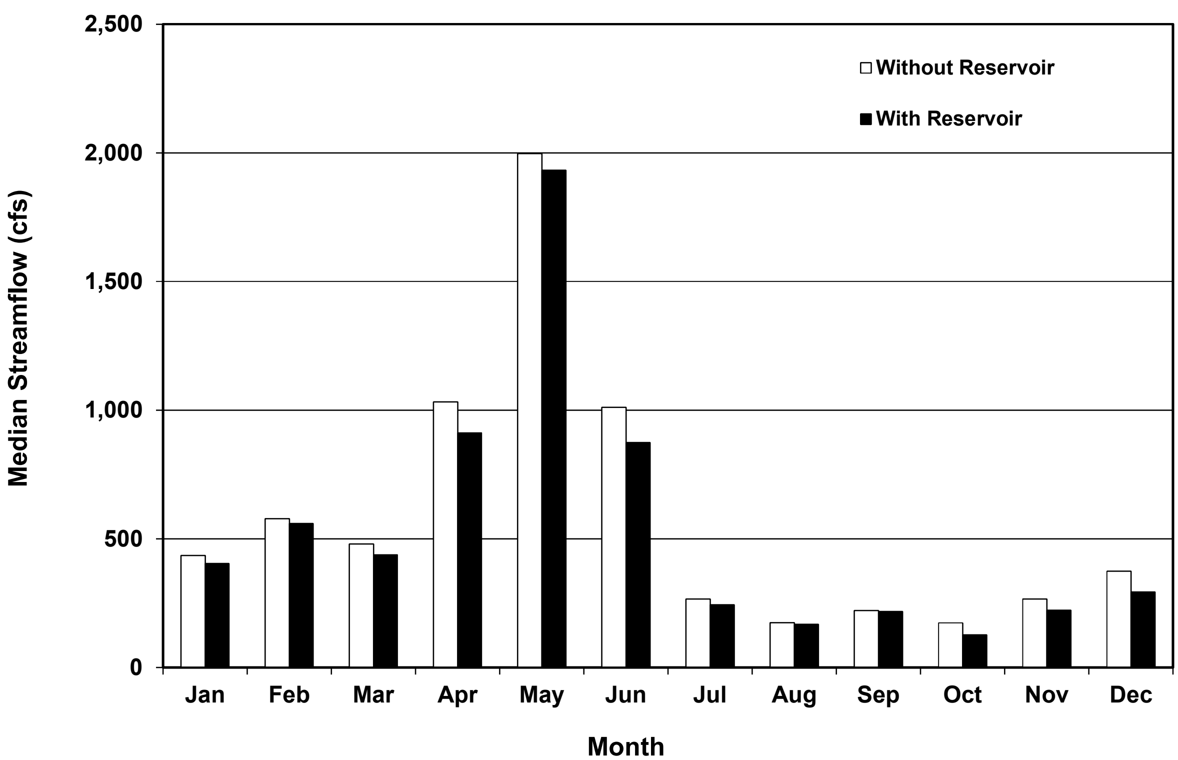


Figure 4.7-6. Little River OCR with Little River Diversion - Streamflow Frequency Comparison

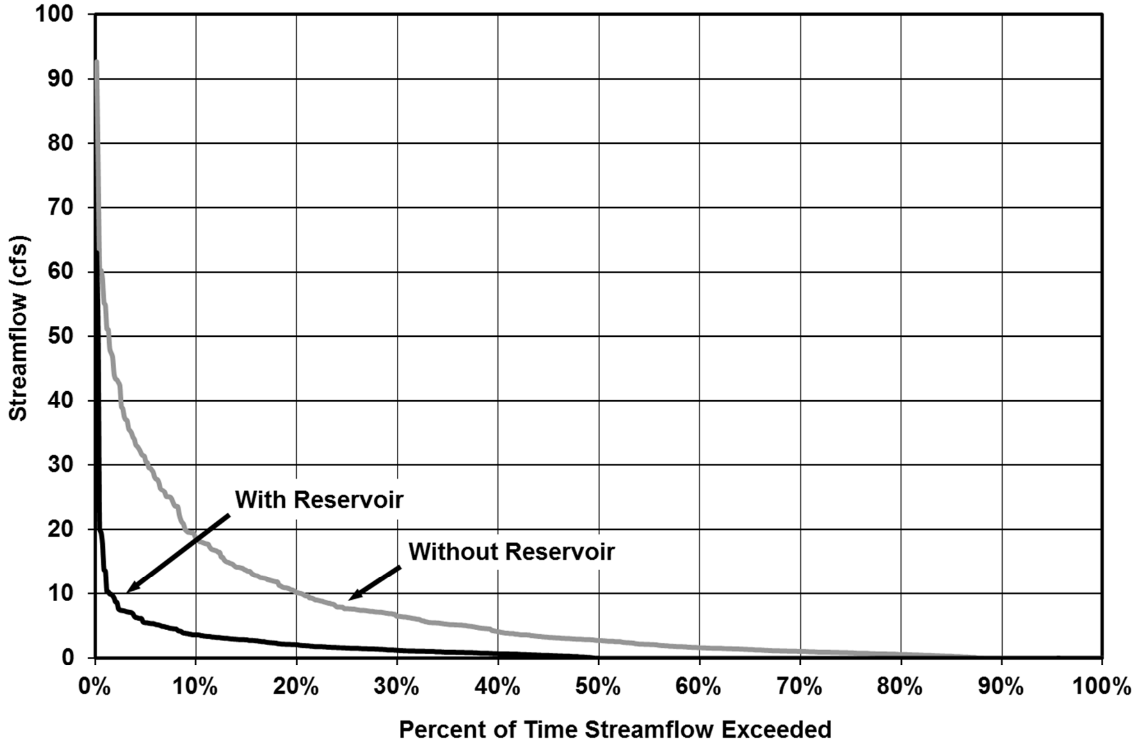


Figure 4.7-7. Little River Diversion - Streamflow Frequency Comparison

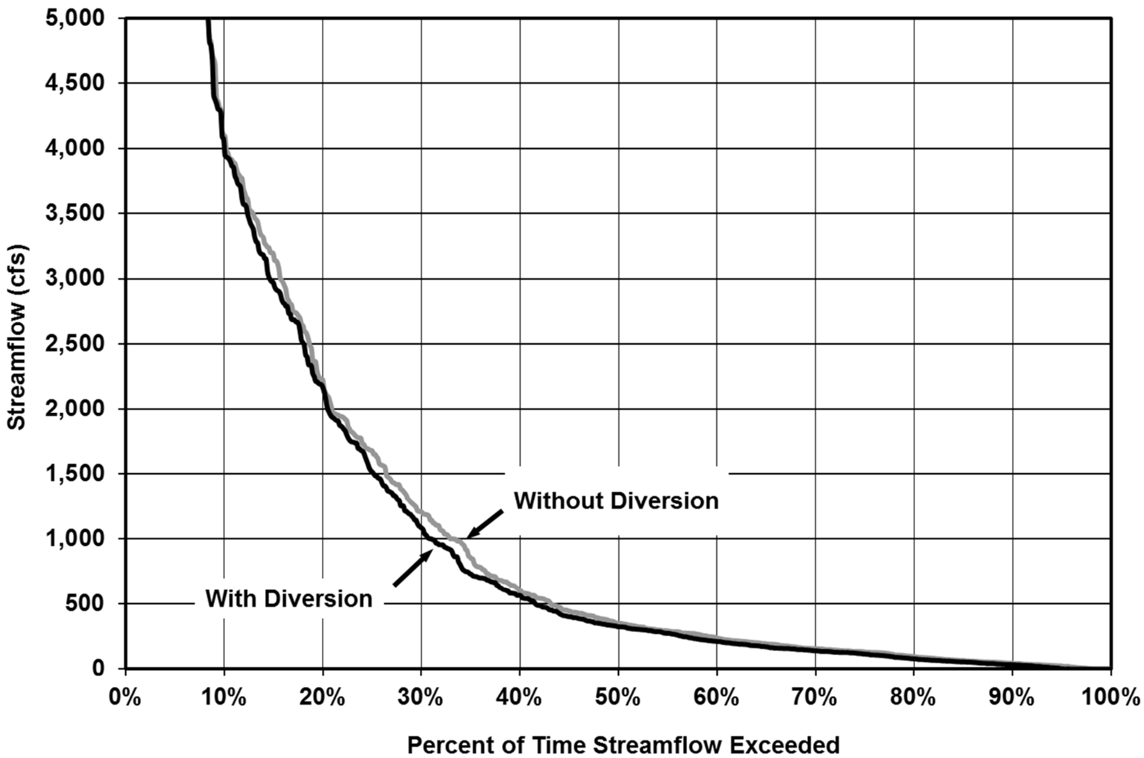


Figure 4.7-8. Little River OCR with Brazos River Diversion - Firm Yield Storage Trace

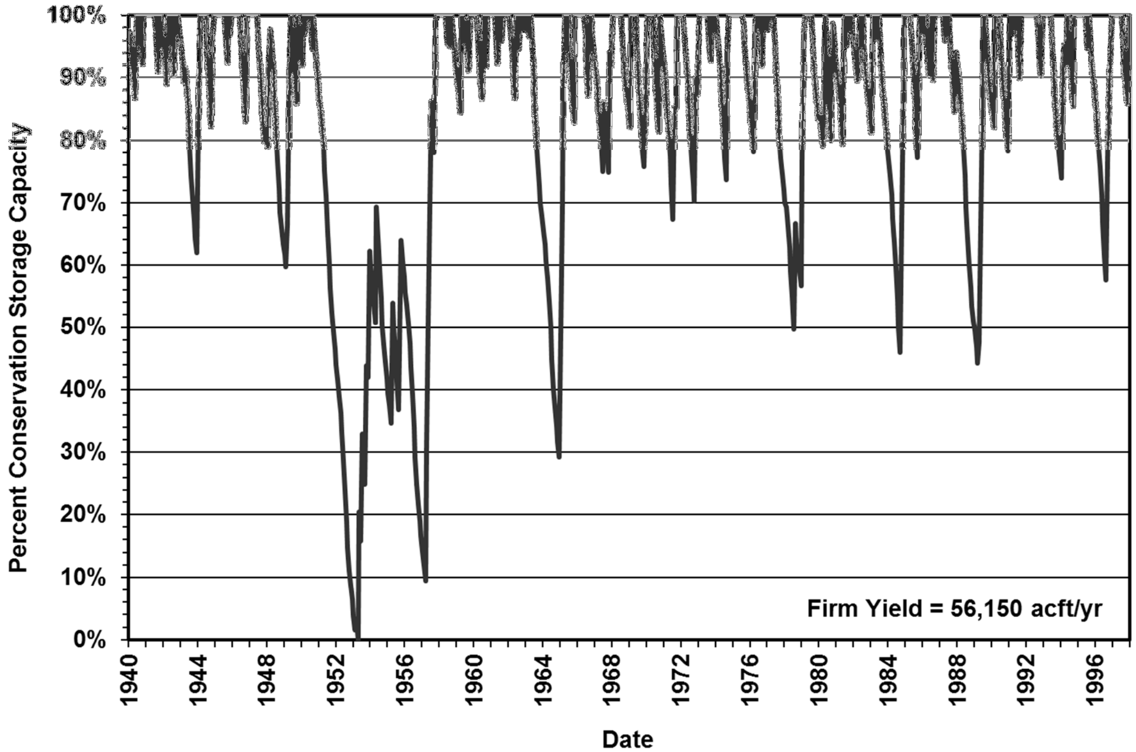


Figure 4.7-9. Little River OCR with Brazos River Diversion – Firm Yield Storage Frequency

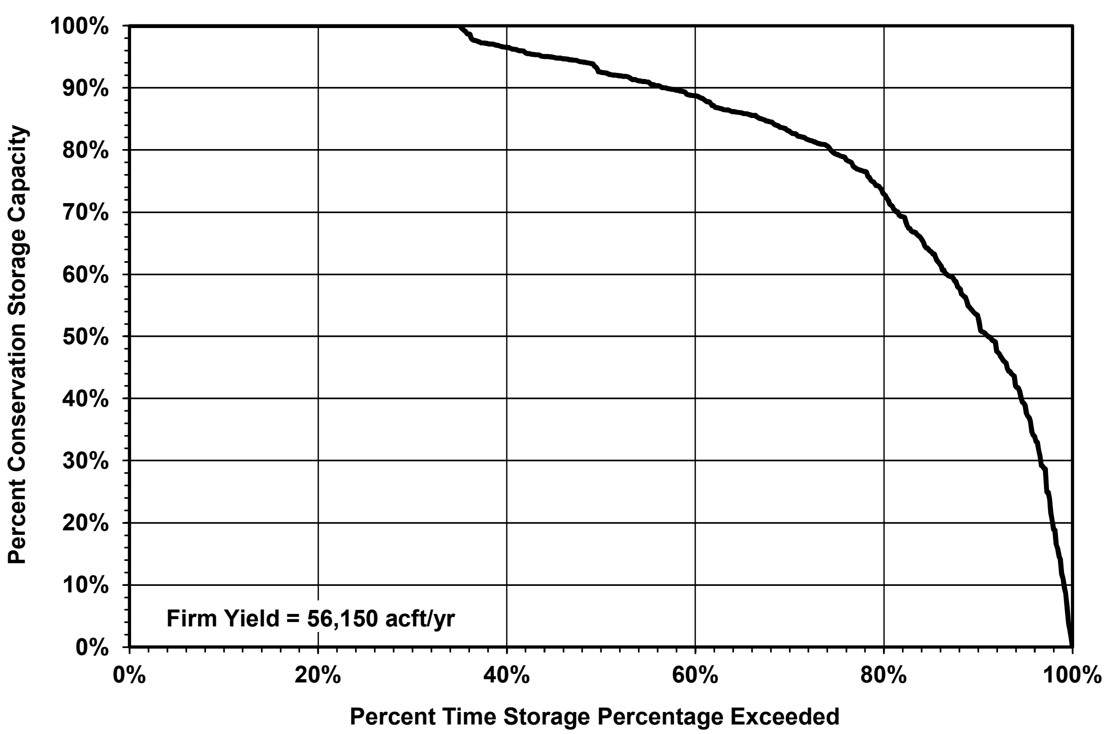


Figure 4.7-10. Little River OCR with Brazos River Diversion - Median Streamflow Comparison

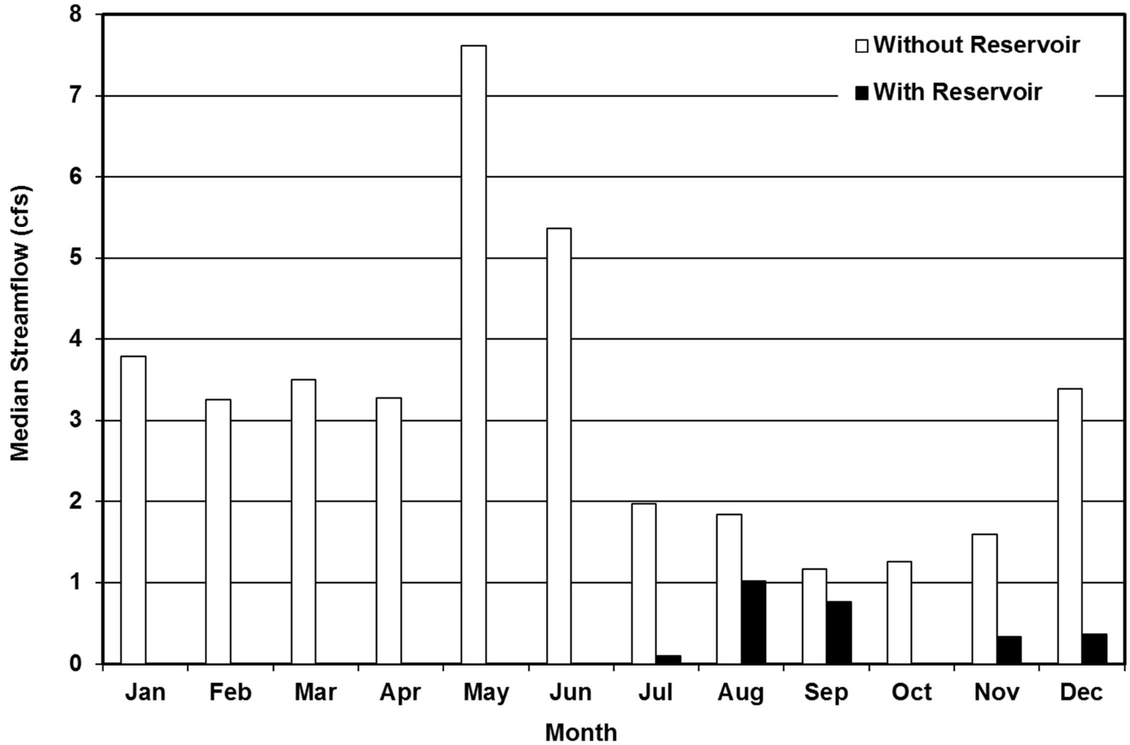


Figure 4.7-11. Brazos River Diversion - Median Streamflow Comparison

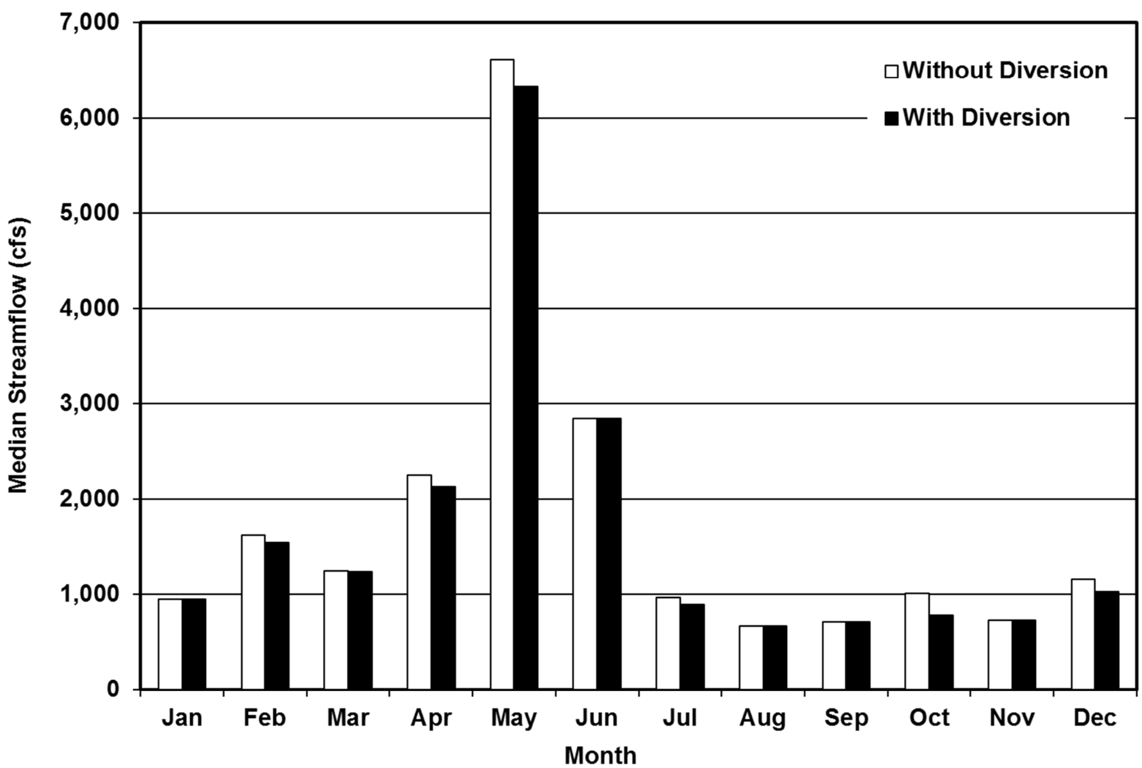


Figure 4.7-12. Little River OCR with Brazos River Diversion - Streamflow Frequency Comparison

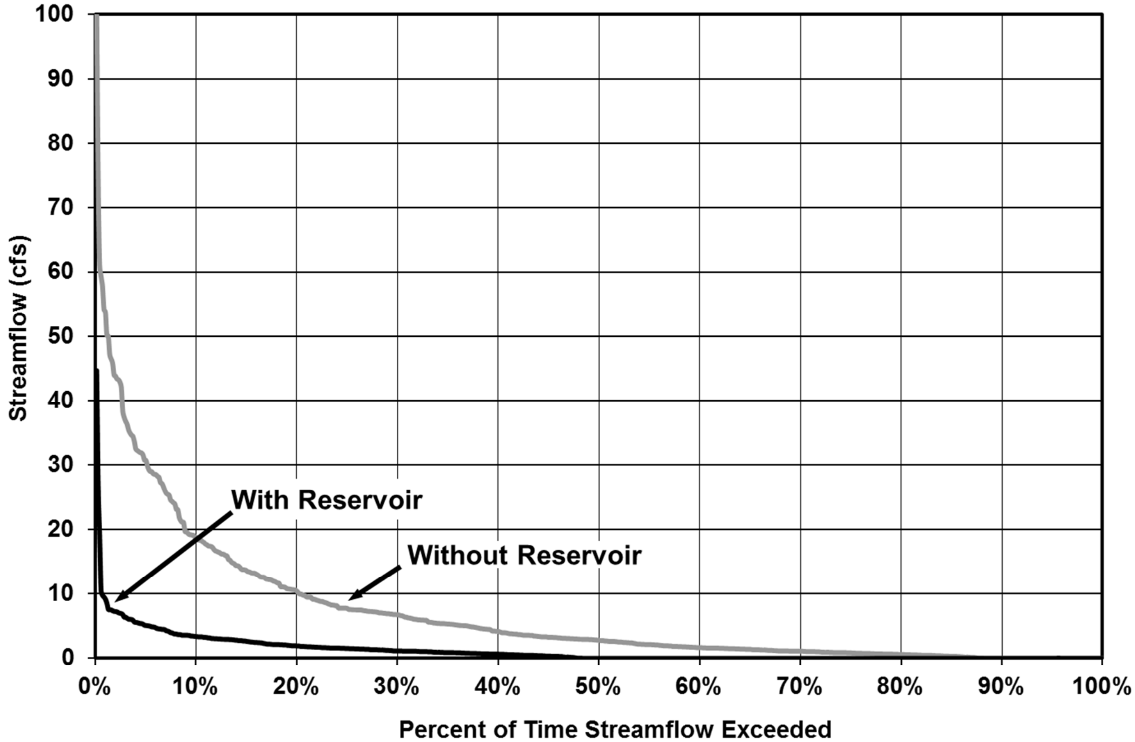
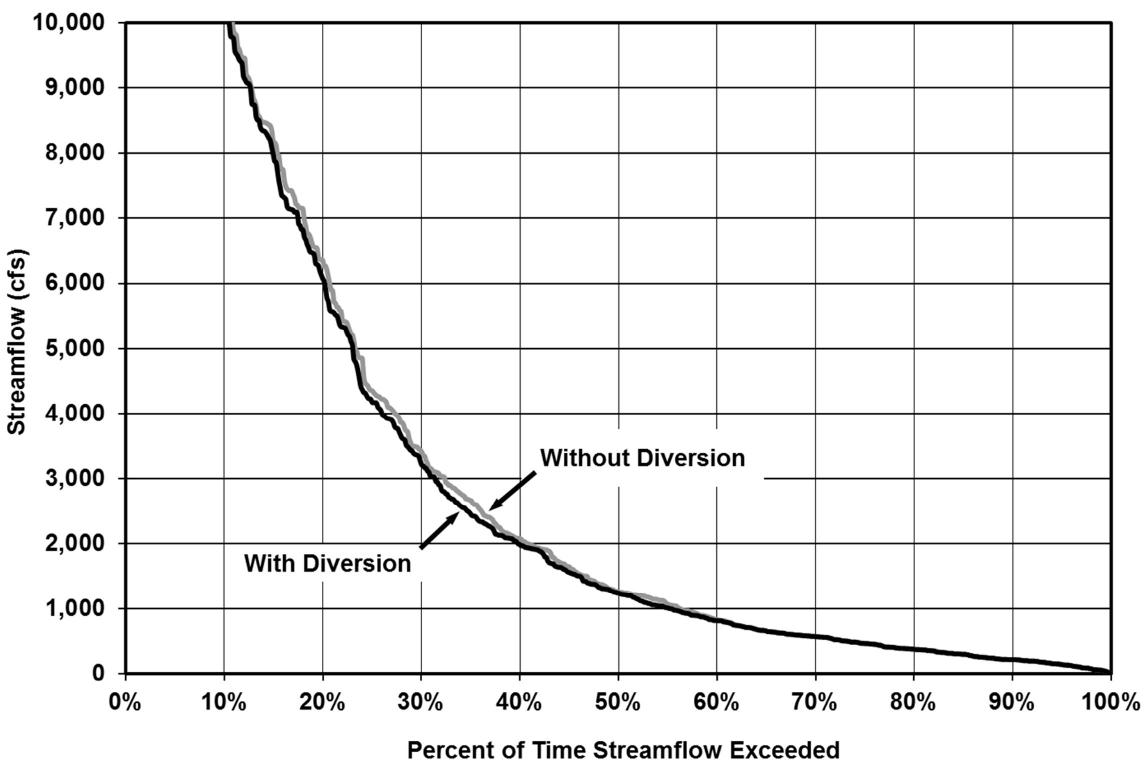


Figure 4.7-13. Brazos River Diversion - Streamflow Frequency Comparison



4.7.3 Environmental Issues

Existing Environment

The project includes the construction of an off-channel reservoir (OCR), intake structure and pump station on the Little River or Brazos River, transmission pipeline from the intake structure to the OCR, and transmission pipeline from the OCR to Granger Lake in Williamson County. The Little River Off-Channel Reservoir site in Milam County is located within the Post Oak Savannah Ecological Region.1 This region is characterized as a narrow, highly irregular oak belt that consists of intermingled forest, woodland, and savannah. It is located between the Pine-Hardwood Forest to the east, Blackland Prairies to the west, and the Coastal Prairie and South Texas Brushlands to the south. The western half of the transmission pipeline occurs within the Blackland Prairie Ecological Region. The original physiognomy of the Post Oak Savannah Ecological Region included medium to tall broad-leaved deciduous trees and some needle-leaved evergreens. The climate within this area is temperate with a temperature range of 39° F to 96° and a rainfall average of thirty-five inches.2 The Carrizo-Wilcox Aquifer is the only major aquifer underlying the OCR project area.3 The Queen City and Brazos River Alluvium minor aquifers are to the north and east of the OCR project area, respectively.

The physiography of the region includes ceramic clay and lignite/coal, recharge sands, expansive clay mud, and flood-prone areas. The topography is flat to rolling with local escarpments, with local shallow depressions in flood-prone areas along waterways.4

A Custom Soil Resource Report was completed for the Little River OCR site.5 According to this report, fourteen soil types are found within the project area. The most frequent soil found is Padina fine sand, 1 to 8 percent slopes, which comprises approximately 35% of the project area. Padina soils are found on the backslopes and summits of ridges and are well drained. Other larger areas of soils include Edge fine sandy loam, 2 to 5 percent slopes, moderately eroded which covers 23% of the project area, and Uhland loam, frequently flooded which includes 16.3%. Edge fine sandy loam soils are located on ridges and are well drained, while Uhland loam soils are located on floodplains and are moderately well drained.

The remaining eleven soil types occupy a total of only 25% of the project area. Five of the soil types found within the project area are considered to be prime farmland soils. These soils comprise 13.7% of the total project area and include Rader loamy fine sand, 1 to 3 percent slopes, Minerva loamy fine sand, 1 to 5 percent slopes, Gause loamy fine

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[1] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, Vegetational Areas of Texas, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.

2 Cecil Harper, Jr., and Vivian Elizabeth Smyrl, "MILAM COUNTY," Handbook of Texas Online (http://www.tshaonline.org/handbook/online/articles/hcm13), accessed November 25, 2014. Uploaded on June 15, 2010.

[3] Texas Water Development Board (TWDB), Major and Minor Aquifers of Texas; Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.

[4] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., “Land Resources of Texas.” Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.

[5] NRCS. “Custom Soil Resource Report for Milam County, Texas – Little River Off-Channel Site. November 25, 2014.

sand, 1 to 3 percent slopes, Frio silty clay, 0 to 1 percent slopes, occasionally flooded, and Travis loamy fine sand, 1 to 3 percent slopes.

Three major vegetation types occur within the proposed reservoir and its pipeline to Williamson County: Crops, Post Oak Woods/Forest, and Post Oak Woods, Forest, and Grassland Mosaic.6 Variations of these primary types may occur within the project area based on changes in the composition of woody and herbaceous species and the physiognomy of localized conditions and specific range sites. Post Oak Woods/Forest, and Post Oak Woods, Forest, and Grassland Mosaic could include the following commonly associated plants: blackjack oak (Quercus marilandica), eastern redcedar (Juniperus virginiana), mesquite (Prosopis glandulosa), black hickory (Carya texana), live oak (Q. virginiana), sandjack oak (Q. incana), cedar elm (Ulmus crassifolia), hackberry (Celtis spp.), yaupon (Ilex vomitoria), American beautyberry (Callicarpa americana), hawthorn (Crataegus spp.), supplejack (Berchemia scandens), trumpet creeper (Campsis radicans), dewberry (Rubus spp.), coralberry (Symphoricarpos orbiculatus), little bluestem (Schizachyrium scoparium var. scoparium), silver bluestem (Bothriochloa saccharoides), sand lovegrass (Eragrostis trichodes), beaked panicum (Panicum anceps), three-awn (Aristida spp.), spranglegrass (Chasmanthium sessiliflorum), and tickclover (Desmodium spp.). Crops include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

Potential Impacts

Aquatic Environments including Bays and Estuaries

The potential aquatic impacts of the reservoir portion of this project were evaluated in mussel population. Siting of the intake and pump station for this project should be situated as to result in minimal disturbance to existing area aquatic species.

Although there would be biological impacts in the immediate vicinity of the OCR project site and downstream, it is not likely that this project, alone, would have a substantial influence on total discharge in the Brazos River, in which case there would be minimal influence on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows into the estuary. As a new reservoir without a current operating permit, the Little River Off-Channel Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

Threatened and Endangered Species

A total of 48 species could potentially occur within in Milam or Williamson Counties that are state- or federally-listed as threatened or endangered, federal candidates for listing, or exhibit sufficient rarity to be listed as a species of concern by the state. This group includes 5 amphibians, 5 reptiles, 14 birds, 3 mammals, 4 fish species, 4 insects, 3 crustaceans, 2 arachnids, 4 mollusks, and 4 plant species (Table 4.7-1). The information in this table does not confirm nor deny the presence of the species in the project area.

[38] McMahan, C.A., R.F. Frye, and K.L. Brown, “The Vegetation Types of Texas,” Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

The project area may provide potential habitat to endangered or threatened species listed for either project county. A survey of the project area may be required prior to project construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

A search of the Texas Natural Diversity Database revealed documented occurrences of Navasota ladies'-tresses an endangered species and Park's jointweed, a species of concern, within two miles of the proposed Little River Off-Channel Reservoir (as noted on representative 7.5-minute quadrangle map(s) that include the project site). These data are not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or two locations, at the proposed reservoir site and in the Little River and Brazos River where water will be pumped and diverted to the project site.

The potential impacts of the OCR part of the project are very different at the two locations. At the diversion site on the Little River or Brazos River, very little impact is predicted in terms of a reduction in flow variability or quantity of median monthly flows. But in the proposed reservoir project site, there would be dramatic reductions in both flow variability and the quantity of median monthly flows. Variability in flow is important to the instream biological community as well as riparian species and a reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing suitability for others.

Because of the number of months with zero flow values, this project is anticipated to have substantial impacts on the instream biological community at the proposed reservoir site; however, there would be minimal impacts at the Little River or Brazos River diversion sites. However the Texas Parks & Wildlife Department (TPWD) has identified the Little River from the confluence with the Brazos River in Milam County upstream to the confluence of the Leon and Lampasas rivers in Bell County (Texas Commission on Environmental Quality designated stream segment 1213) as an ecologically significant stream segment on the basis of high water quality/exceptional aquatic life and high aesthetic value, with high aquatic life use, and a unique community including a thriving mussel population. Siting of the intake and pump station for this project should be situated as to result in minimal disturbance to existing area aquatic species.

Table 4.7-1. Endangered, Threatened, Candidate and Species of Concern Listed for Milam and Williamson Counties

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
AMPHIBIANS					
Georgetown salamander	*Eurycea naufragia*	Endemic species known from springs and waters in and around Georgetown Texas.	T	--	Resident
Houston toad	*Anaxyrus houstonensis*	Endemic species found in sandy substrate near pools.	LE	E	Resident
Jollyville Plateau salamander	*Eurycea tonkawae*	Known from springs and waters of caves north of the Colorado River.	T	--	Resident
Salado Springs salamander	*Eurycea chisholmensis*	Endemic species found in surface springs and subterranean waters of Salado Springs.	T	--	Resident
Southern crawfish frog	*Lithobates areolatus areolatus*	Found in abandoned crawfish holes and small mammal burrows.	--	--	Resident
ARACHNIDS					
Bandit Cave spider	*Cicurina bandida*	Very small subterrestrial, subterranean obligate spider.	--	--	Resident
Bone Cave harvestman	*Texella reyesi*	Small, blind, cave-adapted harvestman endemic to several caves in Travis and Williamson Counties.	LE	--	Resident
BIRDS					
American peregrine falcon	*Falco peregrinus anatum*	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Black-capped vireo	*Vireo atricapilla*	Prefers oak-juniper woodlands with distractive patchy shrub and tree layer with open grassy spaces.	LE	E	Migrant
Golden-cheeked Watbler	*Setophaga chrysoparia*	Found in juniper-oak woodlands. Nesting in late March to early summer.	LE	E	Migrant

Table 4.7-1. Endangered, Threatened, Candidate and Species of Concern Listed for Milam and Williamson Counties

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Henslow's Sparrow	*Ammodramus henslowii*	Wintering individuals found in weedy fields with bunch grasses and brambles.	--	--	Migrant
Interior least tern	*Sterna antillarum athalassos*	Nests along sand and gravel bars in braided streams	LE	E	Potential Migrant
Mountain plover	*Charadrius montanus*	Nests on high plains or shortgrass prairie.	--	--	Potential Migrant
Peregrine falcon	*Falco peregrinus*	Possible migrant. Subspecies not easily distinguishable so reference is made to species level.	DL	T	Possible Migrant
Piping Plover	*Charadrius melodus*	Small shorebird, migrant in Texas	LT	T	Possible Migrant
Sprague's pipit	*Anthus spragueii*	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Western burrowing owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna	--	--	Resident
Whooping crane	*Grus americana*	Potential migrant	LE	E	Possible Migrant
Wood stork	*Mycteria Americana*	Forages in prairie ponds, flooded fields and ditches.	--	T	Possible Migrant
CRUSTACEANS					
An amphipod	*Stygobromus russelli*	Found in subterranean waters, usually in caves and limestone aquifers.	--	--	Resident
Bifurcated cave amphipod	*Stygobromus bifurcates*	Found in cave pools.	--	--	Resident
Ezell's cave amphipod	*Stygobromus flagellates*	Only known from artesian wells.	--	--	Resident

Table 4.7-1. Endangered, Threatened, Candidate and Species of Concern Listed for Milam and Williamson Counties

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
FISHES					
Blue sucker	*Cycleptus elongates*	Found in larger portions of major rivers in Texas.	--	T	Resident
Guadalupe bass	*Micropterus treculi*	Endemic to perennial streams of the Edwards Plateau region.	--	--	Resident
Sharpnose shiner	*Notropis oxyrhynchus*	Endemic to Brazos River drainage. Found in large rivers.	LE	--	Resident
Smalleye shiner	*Notropis buccula*	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident
INSECTS					
A mayfly	*Pseudocentro ptiloides morihari*	Distinguished by aquatic larval stage with adults generally found in shoreline vegetation.	--	--	Resident
Coffin Cave mold beetle	*Batrisodes texanus*	Small cave-adapted beetle found in small Edwards Limestone caves in Travis and Williamson counties.	LE	--	Resident
Leonora's dancer damselfly	*Argia leonorae*	Found in small streams and seepages of south central and western Texas.	--	--	Resident
Tooth Cave ground beetle	*Rhadine Persephone*	Small cave-adapted beetle found in small Edwards Limestone caves in Travis and Williamson counties.	LE	--	Resident
MAMMALS					
Cave myotis bat	*Myotis velifer*	Colonial and cave-dwelling species. Also roosts in rock crevices and buildings.	--	--	Resident

Table 4.7-1. Endangered, Threatened, Candidate and Species of Concern Listed for Milam and Williamson Counties

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Plains spotted skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	Extirpated.	LE	E	Historic Resident
MOLLUSKS					
Creeper (squawfoot)	*Strophitus undulates*	Found in small to large streams in Colorado, Guadalupe, and San Antonio river basins.	--	--	Resident
False spike mussel	*Quincuncina mitchelli*	Substrates of cobble and mud. Rio Grande, Brazos, Colorado and Guadalupe river basins.	--	T	Resident
Smooth pimpleback	*Quadrula houstonensis*	Freshwater mollusk found in small to moderate streams and rivers as well as moderate sized reservoirs. Brazos and Colorado River Basins.	C	T	Resident
Texas fawnsfoot	*Truncilla macrodon*	Found in rivers and larger streams, intolerant of impoundment.	C	T	Resident
PLANTS					
Bristle nailwort	*Paronychia setacea*	Flowering vascular plant endemic to eastern south central Texas in sandy soils.	--	--	Resident
Elmendorf's onion	*Allium elmendorfii*	Texas endemic found in grassland openings in oak woodlands on deep, loose, well-drained sands.	--	--	Resident
Navasota ladies'-tresses	*Spiranthes parksii*	Texas endemic found in openings in post oak woodlands in sandy loams along upland drainages or intermittent streams.	LE	E	Resident

Table 4.7-1. Endangered, Threatened, Candidate and Species of Concern Listed for Milam and Williamson Counties

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Parks' jointweed	*Polygonella parksii*	Texas endemic primarily found on deep, loose sand blowouts in Post Oak Savanna landscapes.	--	--	Resident
REPTILES					
Alligator snapping turtle	*Macrochelys temminckii*	Found near perennial water bodies in swamps and bayous.	--	T	Resident
Spot-tailed earless lizard	*Holbrookia lacerate*	Found in moderately open prairie-brushland in fairly flat areas free of vegetation or other obstruction including disturbed areas.	--	--	Resident
Texas garter snake	*Thamnophis sirtalis annectens*	Found in wet or moist microhabitats are preferred by this species.	--	--	Resident
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands.	--	T	Resident
Timber rattlesnake	*Crotalus horridus*	Floodplains, upland pine, deciduous woodlands, riparian zones.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

TPWD, 2014. Annotated County List of Rare Species –Milam County updated 9/4/2014 and Williamson County updated 12/11/2014.

USFWS, 2014. Species Lists from http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.accessed Feb. 16, 2015.

Wildlife Habitat

The primary impacts that would result from construction and operation of the proposed Little River OCR include conversion of approximately 4,343 acres of existing habitat within the conservation pool to open water. Larger areas of habitat that will be impacted include approximately 1,693 acres of Savanna Grassland, 1,589 acres of Post Oak Motte and Woodland, 356 acres of floodplain herbaceous vegetation and 326 acres of floodplain hardwood forest. These areas together comprise 91% of the project area. Twelve additional vegetation types make up the remainder of this area.[7] Siting of the raw water intake, pump station and raw water pipeline needed to complete the OCR project should be located in an area that would result in minimal impacts to existing aquatic and terrestrial species. Impacts from the OCR pipeline and associated appurtenances are anticipated to be low and primarily limited to the construction of these facilities and subsequent maintenance activities.

A number of vertebrate species could occur within the Little River OCR site including smaller mammals such as the eastern red bat (*Lasiurus borealis*), hispid cotton rat (*Sigmodon hispidus*), white-footed mouse (*Peromyscus leucopus*), eastern fox squirrel (*Sciurus niger*), and swamp rabbit (*Sylvilagus aquaticus*).[8] Reptiles and amphibians known from Milam County include the central newt (*Notophthalmus viridescens louisianensis*), red-eared slider (*Trachemys scripta elegans*), Texas toad (*Bufo speciosus*), and Great Plains rat snake (*Elaphe guttata emoryi*) among others.[9] An undetermined number of bird species and a variety of fish species would also be expected to inhabit the various habitat types within the site, with distributions and population densities limited by the types and quality of habitats available.

The transmission pipeline to Williamson County will include a distance of approximately 45 miles and terminate at Granger Lake. The majority of this pipeline route as now planned will occur along right-of-way areas of existing roadways or within agricultural areas. The use of previously disturbed areas for the pipeline will reduce the potential impacts of this portion of the proposed project. Wooded areas occur near the origin of this pipeline at the OCR and pipeline construction and maintenance activities in this area will impact existing habitats and species that utilize the habitat types within Milam County. In addition, because this pipeline crosses a number of streams and tributaries of the Brazos River Basin the use of Best Management Practices during construction is needed in order to minimize impacts to existing aquatic species in these areas.

Cultural Resources

Based on the review of available GIS datasets provided by the Texas Historical Commission (THC) for the 2011 Regional Water Plan, there are no National Register Properties, National Register Districts, or historical markers within or near the OCR or within half a mile of the transmission pipeline to Williamson County. One cemetery, the Pin Oak Cemetery is located within the OCR area and eight additional cemeteries occur within half a mile of the transmission pipeline route.

A search of the Texas Archeological Sites Atlas database indicates that 31 archeological sites have been documented within the general vicinity of the proposed reservoir. Nineteen of these sites were recorded by private individuals or by university research programs for academic purposes. All of these sites lie outside the currently proposed

[7] Texas Parks and Wildlife. Ecological Mapping Sytem GIS layer. Accessed at http://www.tpwd.state.tx.us/gis/data/ November 18, 2014.

[8] Davis, William B. and David J. Schmidly. 1994. The Mammals of Texas. Texas Parks and Wildlife, Austin, Texas

[9] Dixon, James R., Amphibians and Reptiles of Texas. 1987, Texas A&M Press.

reservoir location. These sites represent a variety of historic and prehistoric site types. Prior to reservoir inundation, the project area must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archeological and Historic Preservation Act (PL93-291).

Threats to Natural Resources

Threats to natural resources were identified and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased adverse effects on stream flow below the reservoir site, but the reservoir would trap sediment and/or dilute pollutants, providing some positive benefits to water quality downstream. These benefits could be offset by declines in dissolved oxygen through decreased flows and higher temperatures immediately downstream of the reservoir during summer periods. The project is expected to have negligible impacts to the stream flow and water quality in the Little and Brazos Rivers.

Agricultural Impacts

The Little River OCR site contains approximately 1,297 acres of Pasture/Hay fields and 0.04 acres of cropland. These two agricultural land uses account for roughly 30 percent of the reservoir footprint.

4.7.4 Engineering and Costing

A summary of the project costs is presented in Table 4.7-2 and Table 4.7-3 for the two options. The cost estimate for the OCR is $40.2 million. The total project is estimated to cost $138.5 million for construction of the dam, reservoir, river intake and pump station, and raw water pipeline from the Little River to the reservoir site. For the Brazos River diversion option, the total project cost is greater than the Little River diversion option as a result of the larger pipeline size and intake pump station and estimated to be $248.8 million.

The annual project costs are estimated to be $11.5 million and $23.2 million, respectively; this includes annual debt service, operation and maintenance, and pumping energy costs. The cost for the estimated firm yield of 34,625 acft/yr of the Little River diversion option translates to an annual unit cost for raw water of $1.02 per 1,000 gallons, or $333/acft. The cost for the estimated firm yield of 56,150 acft/yr of the Brazos River diversion option translates to an annual unit cost for raw water of $1.27 per 1,000 gallons, or $413/acft.

Table 4.7-2. Cost Estimate Summary for Little River Off-Channel Reservoir with Little River Diversion and Brazos River Diversion

Item	Little River Diversion	Brazos River Diversion
Dam and Reservoir (155,812 acft; 4,340 acres)	$40,210,000	$40,210,000
Intake Pump Stations	$22,158,000	$41,819,000
Transmission Pipeline	$3,312,000	$63,180,000
Integration, Relocations, & Other	$798,000	$798,000
TOTAL COST OF FACILITIES	**$66,478,000**	**$146,007,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$23,102,000	$47,943,000
Environmental & Archaeology Studies and Mitigation	$17,219,000	$17,392,000
Land Acquisition and Surveying	$17,439,000	$17,622,000
Interest During Construction (4% for 4 years with a 1% ROI)	$14,299,000	$19,797,000
TOTAL COST OF PROJECT	**$138,537,000**	**$248,761,000**
ANNUAL COST		
Debt Service (5.5 percent, 20 years)	$3,116,000	$12,339,000
Reservoir Debt Service (5.5 percent, 40 years)	$6,313,000	$6,313,000
Operation and Maintenance		
Pipeline and Storage Tanks (1% of Cost of Facilities)	$33,000	$632,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$554,000	$1,045,000
Dam and Reservoir (1.5% of Cost of Facilities)	$603,000	$603,000
Pumping Energy Costs (0.09 $/kW-hr)	$913,000	$2,256,000
TOTAL ANNUAL COST	**$11,532,000**	**$23,188,000**
Available Project Yield (acft/yr)	34,625	56,150
Annual Cost of Water ($ per acft)	$333	$413
Annual Cost of Water ($ per 1,000 gallons)	$1.02	$1.27

Supplies developed and stored in the Little River OCR could potentially be used to meet needs in Williamson County as early as 2030 and Milam County starting in 2050. For the Little River diversion option, a 48 inch diameter, 45 mile pipeline will be used to convey raw water to a water treatment plant near Lake Granger in Williamson County (Figure 4.7-14). For the Brazos River diversion option, the pipeline would need to be increased to a 60 inch diameter to handle the additional yield. Table 4.7-3 includes a summary of the project costs to deliver supplies. Total unit cost for the storage, delivery and treatment of supplies is for the Little River diversion option is $1,043/acft and $1,038/acft for the Brazos River diversion option.

Compensation to BRA may be required if this strategy were developed by another entity other than BRA to compensate for any subordination of the System Operations strategy.

Figure 4.7-14. Pipeline Routing from Little River OCR to East Williamson County

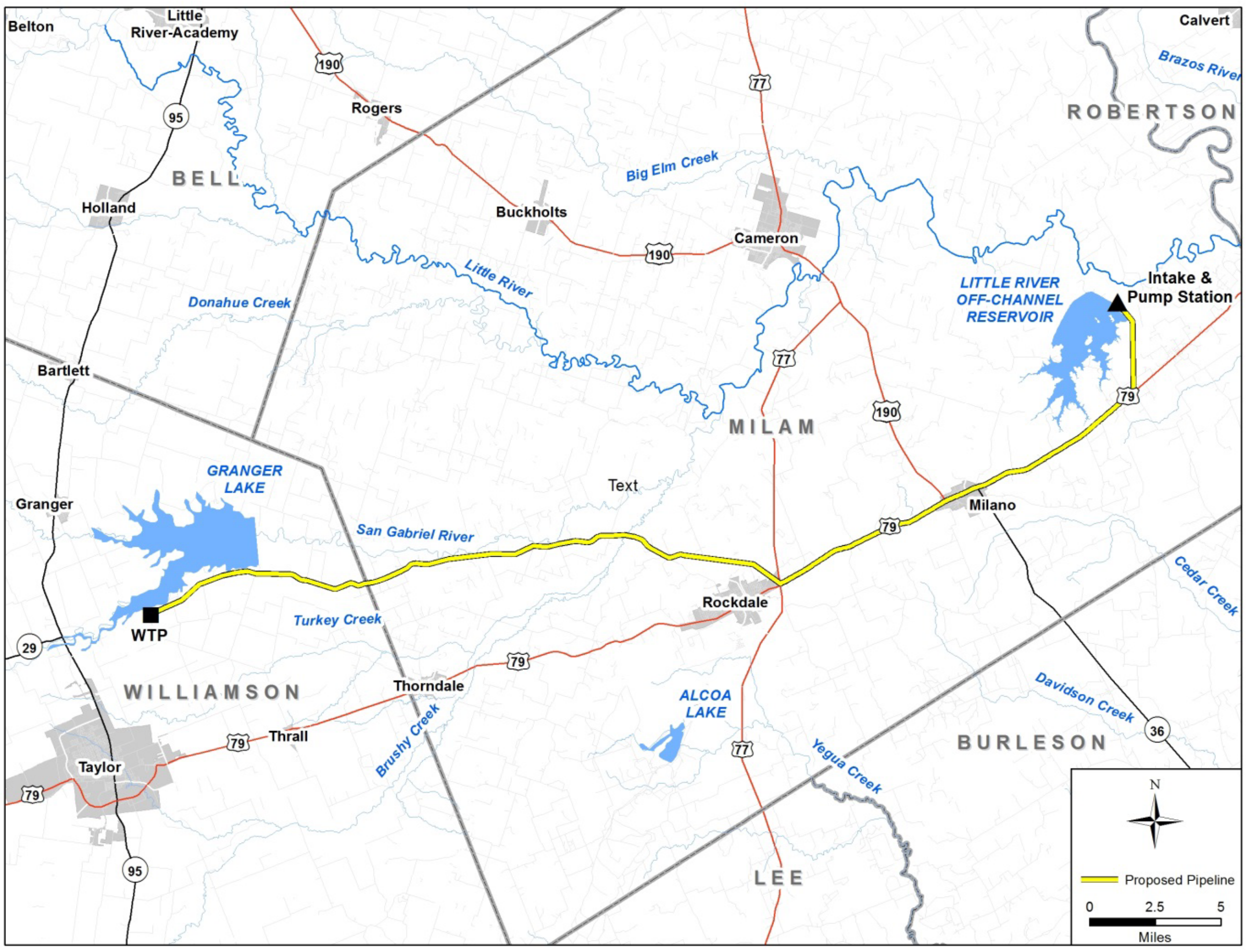

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Table 4.7-3. Cost Estimate Summary for Delivery of Little River OCR supplies to East Williamson County for Little River and Brazos River Diversion Options

Item	Little River Diversion	Brazos River Diversion
Intake Pump Stations	$11,860,000	$14,061,000
Transmission Pipeline (48 in dia., 45 miles)	$68,555,000	$87,052,000
Water Treatment Plant (32.5 MGD)	$45,752,000	$71,165,000
TOTAL COST OF FACILITIES	**$126,167,000**	**$172,278,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$40,731,000	$55,945,000
Environmental & Archaeology Studies and Mitigation	$1,198,000	$1,238,000
Land Acquisition and Surveying (291 acres)	$1,267,000	$1,311,000
Interest During Construction (4% for 2 yrs with a 1%ROI)	$5,928,000	$8,078,000
TOTAL COST OF PROJECT	**$175,291,000**	**$238,850,000**
ANNUAL COST		
Debt Service (5.5 percent, 20 years)	$14,668,000	$19,987,000
Operation and Maintenance		
Pipeline and Storage Tanks (1% of Cost of Facilities)	$686,000	$871,000
Intake and Pump Stations (2.5% of Cost of Facilities)	$297,000	$352,000
Water Treatment Plant	$4,575,000	$7,117,000
Pumping Energy Costs (0.09 $/kW-hr)	$2,095,000	$3,091,000
Purchase of Water (65.65 $/acft)	$2,273,000	$3,686,000
TOTAL ANNUAL COST	**$24,594,000**	**$35,104,000**
Available Project Yield (acft/yr)	34,625	56,150
Annual Cost of Water ($ per acft)	$710	$625
Annual Cost of Water ($ per 1,000 gallons)	$2.18	$1.92

4.7.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.7-4, and the option meets each criterion.

Table 4.7-4. Comparison of Little River Off-Channel Reservoir Project to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low to moderate impact
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Negligible impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

This Implementation of the Little River Off-Channel Reservoir will require permits from various state and federal agencies, land acquisition, and design and construction of the facilities. A summary of the implementation steps for the project is presented below.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- General Land Office Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.
- Coordination with BRA on any potential subordination agreements for the System Operations strategy.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

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4.8 Main Stem Off-Channel Reservoir

4.8.1 Description of Option

The Main Stem Off-Channel Reservoir (OCR) strategy could potentially provide supply under the BRA System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. If an entity other than the BRA were to sponsor and pursue this strategy, then an agreement with the BRA would be required to address concerns related to the potential subordination of the System Operation strategy.

Fourteen (14) sites along the Brazos River between Lake Waco and Lake Somerville were identified as possible locations for an OCR project. The OCR would impound diversions of unappropriated streamflow from the Brazos River. The locations of the 14 identified sites are shown in Figure 4.8-1. Each site was evaluated based on conservation storage capacity, storage efficiency (in order to minimize losses from evaporation), and potential conflicts.

Of the 14 identified sites, the two most favorable sites were selected for yield and cost analyses to determine the preferred site. The two sites selected were the Little River and Milam County OCR sites. These two sites would divert and store water from the Brazos River and deliver supplies to Lake Granger for treatment and inclusion in the BRA system operations supplies. The Milam County OCR is located about 5 miles west of Calvert as shown in Figure 4.8-1. The OCR would provide a conservation storage capacity of 55,133 acft and inundate 1,507 surface acres. Figure 4.8-2 provides the proposed pipeline route for diversions of unappropriated streamflow from the Brazos River.

The Little River OCR as described in Volume II, Chapter 4.7 is a proposed new reservoir on Beaver Creek, a tributary to the Little River. The reservoir site is located in Milam County, east of the City of Cameron, as shown in Figure 4.8-1. The difference in this option is that the project would divert unappropriated streamflow from the Brazos River rather than the Little River during periods when flow is in excess of downstream needs. The dam would be an earthfill embankment that would extend approximately 1-mile across the Beaver Creek valley and provide a conservation storage capacity of 155,812 acft at an elevation 400 ft-msl; the reservoir would inundate 4,343 surface acres. Figure 4.8-2 provides the proposed pipeline route for diversions from the Brazos River.

Figure 4.8-1. Locations of Identified Brazos Main Stem OCR Sites

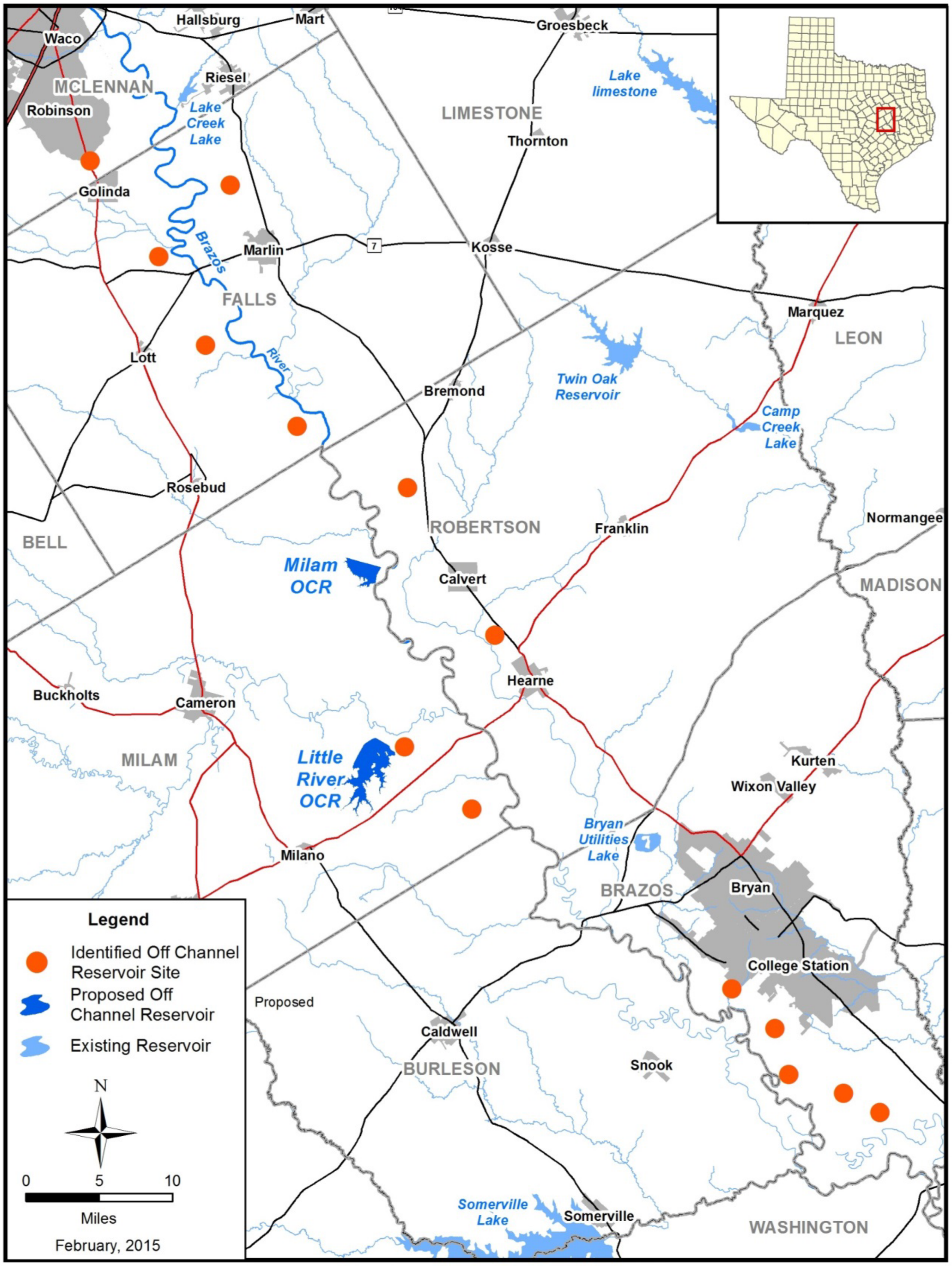

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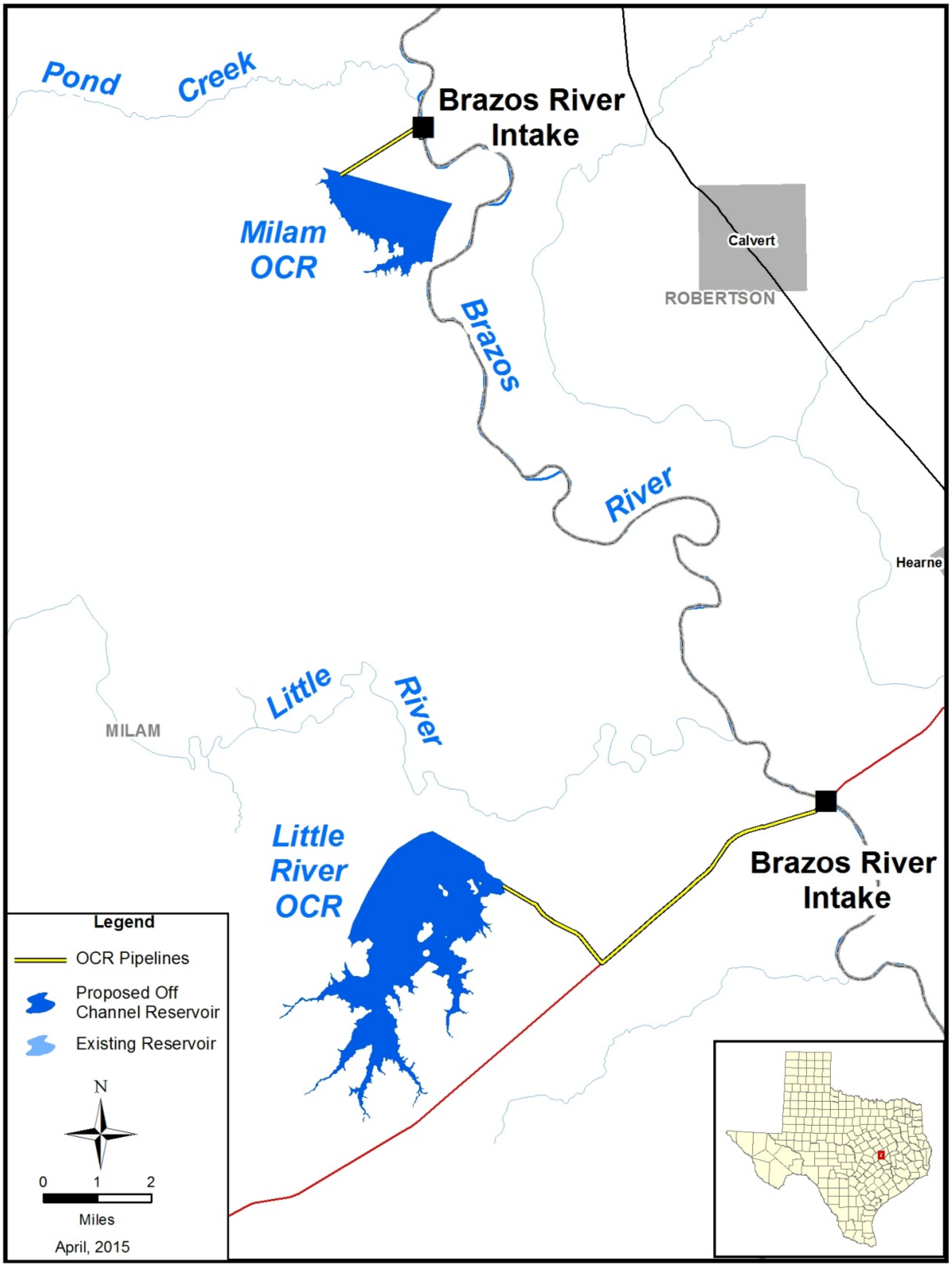
Figure 4.8-2. Location of Milam and Little River OCR Sites and Diversion Pipeline Routes



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Available Yield

Water potentially available for impoundment in the Milam County and Little River OCR was estimated using the TCEQ Brazos WAM which assumes permitted storages and diversions for all surface water rights in the basin. The model utilizes a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to all diversions and impoundments having to pass streamflows to meet environmental flow standards associated with Senate Bill 3 (SB3). The model computed streamflow available for impoundment without causing increased shortages to downstream rights.

Various maximum diversion capacities associated with potential pipeline sizes ranging from 64-inch to parallel 120-inch diameters were evaluated. The greatest incremental benefit in yield occurs with an 84-inch pipeline size for the Milam County OCR diversion and a 144-inch pipeline size for the Little River OCR diversion. The calculated firm yield of the Milam County OCR is 19,600 acft/yr and the firm yield of the Little River OCR is 56,150 acft/yr. Because of the greater yield and smaller unit cost (See Section 4.8.3) of the Little River OCR, it was chosen as the preferred OCR site. Therefore, environmental and implementation issues associated with the Milam County OCR were not evaluated.

4.8.2 Environmental Issues

Environmental issues associated with the implementation of the Little River OCR, Brazos River pipeline, and transmission pipeline to Lake Granger are included the Little River OCR water management strategy located in Volume II, Chapter 4.7.

Agricultural Impacts

The Milam OCR site contains approximately 350 acres of Pasture/Hay fields and 636 acres of cropland. These two agricultural land uses account for roughly 65 percent of the reservoir footprint.

4.8.3 Engineering and Costing

Cost estimates for the two selected main stem OCR sites were prepared using the TWDB uniform costing model. If an entity other than BRA were to sponsor these projects, then an agreement with the BRA may be required to address concerns related to potential subordination of the BRA's water rights. The Milam County OCR is estimated to have a total project of cost $104.4 million for construction of the dam, reservoir, river intake and pump station, and raw water pipeline from the Brazos River to the reservoir site. The annual project costs are estimated to be $11.1 million; this includes annual debt service, operation and maintenance, and pumping energy costs. A summary of the project costs is presented in Table 4.8-1. The cost for the estimated firm yield of 19,600 acft/yr translates to an annual unit cost for raw water of $1.74 per 1,000 gallons, or $567/acft.

Table 4.8-1. Cost Estimate Summary for Milam County Off-Channel Reservoir with Diversions from Brazos River

Item	Estimated Costs for Facilities
Off-Channel Storage/Ring Dike (Conservation Pool 55,133 acft, 1,507 acres)	$44,328,000
Intake Pump Stations (124.4 MGD)	$17,203,000
Transmission Pipeline (84 in dia., 2 miles)	$5,447,000
Integration, Relocations, & Other	$3,000,000
TOTAL COST OF FACILITIES	**$69,978,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$24,220,000
Environmental & Archaeology Studies and Mitigation	$68,000
Land Acquisition and Surveying (1,536 acres)	$200,000
Interest During Construction (4% for 3 years with a 1% ROI)	$9,920,000
TOTAL COST OF PROJECT	**$104,386,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$3,195,000
Reservoir Debt Service (5.5 percent, 40 years)	$4,126,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$54,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$430,000
Dam and Reservoir (1.5% of Cost of Facilities)	$665,000
Pumping Energy Costs (0.09 $/kW-hr)	$2,647,000
TOTAL ANNUAL COST	**$11,117,000**
Available Project Yield (acft/yr)	**19,600**
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	**$567**
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	**$1.74**

A cost estimate for the proposed Little River OCR with scalping from the Brazos River was made utilizing available mapping and information. The total project cost is estimated at $248.8 million for construction of the dam, reservoir, river intake and pump station, and raw water pipeline from the Brazos River to the reservoir site. The annual project costs are estimated to be $23.2 million; this includes annual debt service, operation and maintenance, and pumping energy costs. A summary of the project costs is presented in Table 4.8-2. The cost for the estimated firm yield of 56,150 acft/yr translates to an annual unit cost for raw water of $1.27 per 1,000 gallons, or $417/acft. Costs for delivering raw water supplies from the Little River OCR to Lake Granger including treatment are presented in Volume II, Chapter 4.7.

Table 4.8-2. Cost Estimate Summary for Little River Off-Channel Reservoir with Diversions from Brazos River

Item	Estimated Costs for Facilities
Dam and Reservoir (Conservation Pool 155,812 acft; 4,340 acres)	$40,210,000
Channel Dam & Intake Pump Stations (365 MGD)	$41,819,000
Transmission Pipeline (144 in dia., 8 miles)	$63,180,000
Integration, Relocations, & Other	$798,000
TOTAL COST OF FACILITIES	**$146,007,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$47,943,000
Environmental & Archaeology Studies and Mitigation	$17,392,000
Land Acquisition and Surveying (4,394 acres)	$17,622,000
Interest During Construction (4% for 4 years with a 1% ROI)	$19,797,000
TOTAL COST OF PROJECT	**$248,761,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$12,339,000
Reservoir Debt Service (5.5 percent, 40 years)	$6,313,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$632,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$1,045,000
Dam and Reservoir (1.5% of Cost of Facilities)	$603,000
Pumping Energy Costs (0.09 $/kW-hr)	$2,256,000
TOTAL ANNUAL COST	**$23,188,000**
Available Project Yield (acft/yr)	**56,150**
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	**$413**
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	**$1.27**

4.8.4 Implementation Issues

Implementation issues associated with the Little River OCR, Brazos River pipeline, and transmission pipeline to Lake Granger are included the Little River OCR water management strategy located in Volume II, Chapter 4.7.

4.9 Meridian Off-Channel Reservoir

4.9.1 Description of Option

The City of Meridian, located along the banks of the North Bosque River in Bosque County, has been planning for the implementation of a surface water supply since the early 1980s.[1] Bosque County has experienced rapid declines in Trinity Aquifer groundwater levels. As a result, a surface water supply is needed to supplement the existing groundwater supply. The City of Meridian was one of eight regional participants in the Lake Bosque project in the 1980s. When the decision was made to no longer pursue the Lake Bosque project, the City began to evaluate other surface water supply options. In 1995, the City of Meridian joined with the City of Clifton to perform a regional water supply study[2] for the two cities. The results of the study recommended the implementation of a joint regional project near Clifton and a treated water pipeline to Meridian. At the conclusion of the study, the City of Clifton voted to pursue the project while the City of Meridian decided to pursue other options. In 1998, the City of Meridian, in cooperation with the Brazos River Authority, performed a feasibility study[3] of long-term water supply alternatives for Meridian. As part of this study, diversion of water from the North Bosque River with off-channel storage near Meridian was evaluated, as well as a reservoir on Meridian Creek and demineralization of water from Lake Whitney. Of these three options, the results showed that diversion of water from the North Bosque River with off-channel storage was the most economical future surface water supply for the City. The location of the potential river diversion and off-channel dam and reservoir is presented in Figure 4.9-1.

In order for the project to provide a sufficient yield to be cost effective, the City of Waco would likely subordinate their water right at Lake Waco to the Meridian Off-Channel Reservoir diversions from the North Bosque River. Without subordination, the unappropriated flows in the North Bosque River would not be sufficient enough to maintain adequate water levels in the off-channel reservoir for a viable project.

4.9.2 Available Yield

Water potentially available for impoundment in the proposed Meridian Off-Channel Reservoir was estimated using the TCEQ Brazos WAM Run 3 which assumes no return flows and permitted storages and diversions for all water rights in the basin. The model utilized a January 1940 through December 1997 hydrologic period of record. The model computed the streamflow available for diversion from the North Bosque River into the Meridian Off-Channel Reservoir without causing increased shortages to downstream water rights. Firm yield was calculated subject to a priority calls agreement with Lake Waco.

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[1] HDR, Inc., "Water Supply Alternatives for Bosque County," The County of Bosque, May 1982.

[2] HDR, Inc., "Regional Water Supply Study, City of Clifton, City of Meridian, and Texas Water Development Board," August 1995

[3] HDR, Inc., "Long-Term Water Supply for the City of Meridian, Feasibility Study," Prepared for the City of Meridian and Brazos River Authority, August 1998.

The calculated firm yield of the Meridian Off-Channel Reservoir is 615 acft/yr. Firm yield was computed subject to the reservoir and North Bosque River diversion having to pass inflows to meet environmental flow standards associated with Senate Bill 3 (SB3). A 2.5 mile, 12-inch pipeline would be used to divert streamflow from the North Bosque River to the off-channel reservoir. The yield of the off-channel reservoir project at Meridian is a function of river flow, diversion rate, and reservoir storage. The project was proposed to have a maximum diversion rate of 4 cfs from the North Bosque River and 1,400 acft of storage in the off-channel reservoir.

4.9.3 Environmental Issues

The Meridian Off-channel Reservoir Project includes the diversion of water from the North Bosque River into an off-channel reservoir (OCR). Environmental concerns associated with this water management strategy include inundation of areas from the development of the off-channel reservoir, impacts associated with the construction of the channel dam, raw water intake, pump station, water treatment plant, and associated piping facilities, and reduction of flow in the Bosque River below the reservoir due to the diversion of water.

Depending on their final location, the raw water transmission pipeline to the OCR and the treated water lines to Meridian could cross the North Bosque River. Avoidance and minimization measures, such as horizontal directional drilling, construction best management practices (BMPs), and avoiding perennial and/or sensitive aquatic habitats when locating the intake and dam would reduce potential impacts to aquatic species.

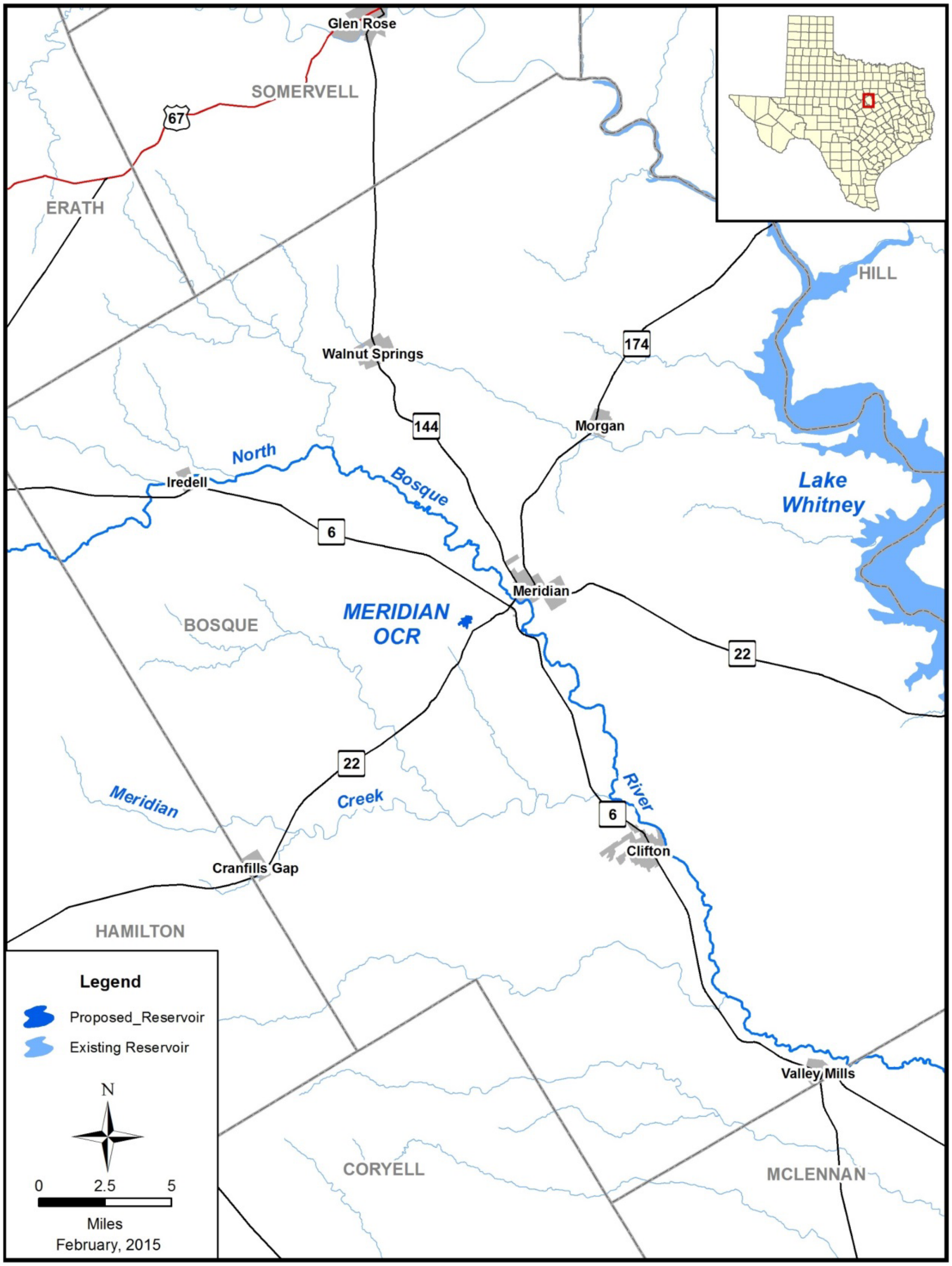
Coordination with the U.S. Army Corps of Engineers would be required for construction within waters of the U.S. Impacts from this proposed project resulting in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities unless there are significant impacts to the aquatic environment by other project components.

The proposed project would occur in the Cross Timbers Ecoregion of Texas.[4] This ecoregion is a transitional area between the original prairie regions to the west and the low mountains or hills of eastern Oklahoma and Texas. The project area includes two major vegetation types as defined by Texas Parks and Wildlife (TPWD),[5] including Bluestem Grassland and Oak-Mesquite-Juniper Parks/Woods. Bluestem Grassland commonly includes plants such as bushy bluestem (*Andropogon glomeratus*), slender bluestem (*Schizachyrium tenerum*), little bluestem (*Schizachyrium scoparium*), buffalograss (*Bouteloua dactyloides*), southern dewberry (*Rubus trivialis*), live oak (*Quercus virginiana*), mesquite (*Prosopis pubescens*) and huisache (*Acacia farnesiana*). Oak-Mesquite-Juniper Parks/Woods associated plants include post oak (*Q. stellata*), Ashe juniper (*Juniperus ashei*), shin oak (*Q. havardii*), blackjack oak (*Q. marilandica*), cedar elm (*Ulmus crassifolia*), Mexican persimmon (*Diospyros texana*), purple three-awn (*Aristida purpurea*), sideoats grama (*Bouteloua curtipendula*) and curly mesquite (*Hilaria belangeri*).

[4] Grifffith, Glenn, Sandy Bryce, James Omernik and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality and Environmental Protection Agency, Austin, Texas.

[5] McMahan, Craig A., Roy G. Frye and Kirby L. Brown. 1984. The Vegetation Types of Texas Including Cropland. Texas Parks and Wildlife Department, Austin, Texas.

Figure 4.9-1. Meridian Off-Channel Reservoir Location



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The species listed by the United States Fish and Wildlife Service (USFWS), or Texas Parks and Wildlife Department (TPWD), as endangered, threatened, federal candidates or state species of concern in Bosque County are listed in Table 4.9-1. There are no areas of critical habitat designated within or near the project area.[6]

Table 4.9-1. Endangered, Threatened, and Species of Concern for Bosque County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
BIRDS					
American peregrine falcon	*Falco peregrinus anatum*	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Artic peregrine falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL		Possible Migrant
Bald eagle	*Haliaeetus leucocephalu s*	Found primarily near rivers and large lakes.	DL	T	Possible Migrant
Black-capped vireo	*Vireo atricapilla*	Oak-juniper woodlands with distinctive patchy, two-layered aspect.	LE	E	Possible Migrant
Golden-cheeked warbler	*Setophaga chrysoparia*	Juniper-oak woodlands; dependent on Ashe juniper for long fine bark strips.	LE	E	Possible Migrant
Interior least tern	*Sterna antillarum athalassos*	Nests along sand and gravel bars in braided streams	LE	E	Resident
Mountain plover	*Charadrius montanus*	Non-breeding, shortgrass plains and fields			Nesting/ Migrant
Sprague's pipit	*Anthus spragueii*	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C		Possible Migrant
Western burrowing owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna			Resident
Whooping crane	*Grus americana*	Potential migrant	LE	E	Potential Migrant
FISHES					

[6] USFWS. Critical Habitat Portal. Accessed online at http://ecos.fws.gov/crithab/ May 29, 2014.

Table 4.9-1. Endangered, Threatened, and Species of Concern for Bosque County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Guadalupe bass	*Micropterus treculi*	Endemic to perennial streams of the Edwards Plateau region. Introduced in Nueces River system.			Resident
Sharpnose shiner	*Notropis oxyrhynchus*	Endemic to Brazos River drainage; large turbid river, with bottom a combination of sand, gravel, and clay-mud	LE		Resident
Smalleye shiner	*Notropis buccula*	Endemic to upper Brazos River system and its tributaries (Clear Fork and Bosque); medium to large prairie streams with sandy substrate and turbid to clear warm water	LE		Resident
MAMMALS					
Cave myotis bat	*Myotis velifer*	Roosts colonially in caves, rock crevices			Resident
Plains spotted skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas.			Resident
Red wolf	*Canis rufus*	Extirpated.	LE	E	Historic Resident
MOLLUSKS					
False spike mussel	*Quincuncina mitchelli*	Substrates of cobble and mud. Rio Grande, Brazos, Colorado and Guadalupe river basins. Not recorded from reservoirs.		T	Resident
Smooth pimpleback	*Quadrula houstonensis*	Small to moderate streams and rivers as well as moderate size reservoirs; mixed mud, sand, and fine gravel, tolerates very slow to moderate flow rates, Brazos, and Colorado River basins.	C	T	Resident
Texas fawnsfoot	*Truncilla macrodon*	Possibly found in rivers and larger streams, intolerant of impoundment. Brazos and Colorado River basins.	C	T	Resident
REPTILES					

Table 4.9-1. Endangered, Threatened, and Species of Concern for Bosque County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Brazos water snake	*Nerodia harteri*	Upper Brazos River drainage; in shallow water with rocky bottom and on rocky portions of banks		T	Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	Wet or moist microhabitats			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands.		T	Resident
Timber rattlesnake	*Crotalus horridus*	Floodplains, upland pine, deciduous woodlands, riparian zones.		T	Resident
TPWD, 2014. Annotated County List of Rare Species – Bosque County revised 9/4/2014. USFWS, Obtained from http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action?fips=48035 August 19, 2014					
LE/LT=Federally Listed Endangered/Threatened DL=Federally Delisted C=Candidate for Federal Listing E, T=State Listed Endangered/Threatened Blank = Considered rare, but no regulatory listing status					

The project area may provide potential habitat to endangered or threatened species found in Bosque County. A survey of the project area may be required prior to reservoir, pipeline and facility construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Based on existing habitat types, the following threatened or endangered species have the potential to occur within or near the project area.

Peregrine Falcon (*Falco peregrinus*), including the American peregrine falcon (*F. p. anatum*) subspecies — This state threatened species is a possible migrant in the project area. They utilize a wide range of habitats during migration, including urban areas and landscape edges such as lakes or large river shores.

Bald Eagle (*Haliaeetus leucocephalus*) — The bald eagle is a state-listed threatened species that could occur as a migrant near larger aquatic resources. Although they breed primarily in the eastern half of the state, they could potentially occur in this region of Texas during the winter along rivers or large lakes.

Black-capped vireo (*Viro atricapilla*) — The black-capped vireo is an endangered species that could occur as a migrant within the project area. This small bird requires the presence of oak-juniper woodlands with a distinctive patchy, two-layered aspect. Habitat which could be utilized by this species occurs within the project area. This species has been documented in the past as occurring in Meridian State Park which is located west of the City of Meridian. Potential habitat for this species may occur within the project area.

Golden-cheeked warbler (*Setophaga chrysoparia*) — The golden-cheeked warbler is found as a migrant in juniper-oak woodlands and is dependent on Ashe juniper trees for long fine bark strips used for nesting. This avian species has been documented in Meridian State Park which is located west of the City of Meridian. Potential habitat for this species may occur within the project area.

Interior Least Tern (*Sterna antillarum athalassos*) — The interior least tern is federally listed as endangered. This species prefers to nest on sandbars, islands, salt flats, and bare or sparsely vegetated sand, shell, and gravel beaches that are associated with braided streams, rivers and reservoirs.

Whooping Crane (*Grus americana*) — The whooping crane is a federally listed endangered species which only occurs in this part of Texas during migration. Whooping cranes use a variety of habitats during migration, including croplands for feeding and large, marshy palustrine wetlands for roosting. Although few large wetland areas occur near the project area, the whooping crane could also potentially occur in surrounding cropland habitat during migration.

Two fish species, the sharpnose shiner (*Notropis oxyrhynchus*) and smalleye shiner (*Notropis buccula*) have been recently listed as endangered by the USFWS.[7] These two minnows are native to the arid prairie streams of Texas and are considered to be in danger of extinction. The USFWS has designated approximately 623 miles of the Upper Brazos River Basin and the upland areas extending beyond the river channel by 98 feet on each side as critical habitat for these two fish.

Red wolf (*Canis rufus*) is an endangered species that is extirpated within Texas.

False spike mussel (*Quincuncina mitchelli*) — The false spike mussel is a state threatened species. This freshwater mollusk occurs in rivers or streams with substrates of sand, mud and gravel. However no living specimens have been documented in reservoirs suggesting an intolerance of impoundment.

Smooth pimpleback (*Quadrula houstonensis*) — The smooth pimpleback is a federal candidate for listing and is state threatened. This freshwater mollusk exists in small to moderate streams and rivers with slow flow rates, as well as moderate size reservoirs

[7] USFWS. 2014. *Sharpnose Shiner and Smalleye Shiner Protected under the Endangered Species Act*. News Release, August 4, 2014.

with substrates of mixed mud, sand and fine gravel in the Brazos and Colorado River basins.

Texas fawnsfoot (*Truncilla macrodon*) — The Texas fawnsfoot mussel is a federal candidate for listing and is state threatened. This mussel is found in rivers and larger streams of the Brazos and Colorado River basins and is intolerant of impoundment.

Brazos water snake (*Nerodia harteri*) is a state threatened species found in the upper Brazos River drainage in shallow water with rocky bottoms or banks.

Texas horned lizard (*Phrynosoma cornutum*) — The Texas horned lizard is a state-listed threatened species and is present throughout much of the state. They exist in open, arid, and semi-arid regions with sparse vegetation, which includes grass, cactus, scattered brush and scrubby trees. This species could potentially occur in areas with this type of vegetation.

Timber rattlesnake (*Crotalus horridus*) — This is a state threatened species that occurs in swamps, floodplains, upland pine and deciduous woodlands, riparian zones and abandoned farmland. This species could potentially occur in areas of abandoned farmland or riparian areas.

No designated critical habitat for the endangered black-capped vireo or golden-cheeked warbler occurs within the project area. Populations of the endangered smalleye and sharpnose shiner occur within the upper Brazos River basin above Lake Whitney. Although these shiner species were once found throughout the Brazos River and several of its major tributaries within the watershed, they are currently restricted almost entirely to the contiguous river segments of the upper Brazos River basin in north-central Texas.[8]

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available geographic information systems (GIS) datasets provided by the Texas Historical Commission (TAC), there are several national register properties and historical markers, and a large cemetery located along the potential pipeline route. No cultural resource sites occur within the reservoir area.

Based on a review of soils, geology, and aerial photographs, there is a high probability for undocumented significant cultural resources within the alluvial deposits and terrace formations associated with waterways, specifically the intermittent and perennial aquatic resources. The probability of pipelines crossing areas which may include cultural resources increases near waterways and associated landforms.

The development of this strategy would include potential changes to in-stream flows due to increased diversions which could affect aquatic and other species, and loss of riparian and other habitat near the channel dam and water intake. Development of the OCR would inundate existing habitat areas resulting in habitat loss for some species and producing new habitat for others. Impacts resulting from the construction and maintenance of the associated pipelines, pump stations or water treatment facilities are anticipated to be minimal if avoidance measures are implemented. It is anticipated that

[8] USFWS Ecological Services. Sharpnose and smalleye shiners. Accessed online at http://www.fws.gov/southwest/es/arlingtontexas/shiner.htm, on May 29, 2014.

the pipelines, pump stations and other necessary facilities will be positioned to avoid impacts to known cultural resources, sensitive habitats, wetlands or stream crossings as much as reasonably possible.

Agricultural Impacts

The Meridian OCR site does not contain Pasture/Hay fields or cultivated cropland. No impacts are expected for agricultural land use.

4.9.4 Engineering and Costing

The proposed off-channel reservoir project includes facilities to divert water from the North Bosque River, off-channel dam and reservoir on a small tributary to the North Bosque River, water treatment plant, and associated piping facilities. The facilities required for implementation of the project included:

- Channel dam on the North Bosque River near the City of Meridian;
- Raw water intake and pump station (4 cfs);
- 25,000 feet of raw water pipeline (12-inch diameter) from the pump station to the off-channel reservoir and from the off-channel reservoir to an existing water pipeline;
- Off-channel dam including spillway, intake tower, and 63 acres of land for the reservoir;
- Water Treatment Plant (1.3 MGD); and
- 1,200 feet of treated water pipelines (8-inch diameter) from water treatment plant to City of Meridian.

A summary of the total project cost in September 2013 dollars is presented in Table 4.9-2. The proposed Meridian Off-Channel Reservoir project would cost approximately $21.7 million for surface water supply facilities. This includes construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The project costs also include the cost for the raw water facilities to convey surface water from the North Bosque River diversion site to the off-channel reservoir. Costs associated with the transmission of treated water to future customers is not included. The annual project costs are estimated to be $2,436,000. This includes annual debt service, operation and maintenance, and pumping energy costs.

The off-channel project will be able to provide raw water prior to treatment and transmission of treated water to a site near the North Bosque river adjacent to the City of Meridian at a unit cost of $3,961 per acft or $12.15 per 1,000 gallons.

4.9.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.9-3, and the option meets each criterion. Implementation of the off-channel reservoir project for the City of Meridian will require permits from various state and federal agencies, land acquisition, and design and construction of the facilities. A summary of the implementation steps for the project is presented below.

It will be necessary to obtain these permits:

a. TCEQ Water Right and Storage permit.

b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for reservoir and pipelines imparting wetlands and navigable water of the United States.

c. TPWD Sand, Gravel, and Marl permit for construction of the channel dam.

d. NPDES Storm Water Pollution Prevention Plan.

e. General Land Office (GLO) easement for use of the state-owned streambed; and

f. Section 404 certification from the TCEQ related to the Clean Water Act.

Permitting, at a minimum, will require these studies:

a. Assessment of changes in instream flows in the North Bosque River.

b. Habitat mitigation plan.

c. Environmental studies.

d. Cultural resource studies and mitigation.

Land will need to be acquired through either negotiations or condemnation.

Table 4.9-2. Cost Estimate Summary for Meridian Off-Channel Reservoir

Item	Estimated Costs for Facilities
Dam and Reservoir (Conservation Pool 1,400 acft, 63 acres)	$3,919,000
Channel Dam & Intake Pump Stations (2.6 MGD)	$3,884,000
Transmission Pipeline (12 in dia., 5 miles)	$1,161,000
Water Treatment Plant (1.3 MGD)	$5,626,000
TOTAL COST OF FACILITIES	**$14,590,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$5,048,000
Environmental & Archaeology Studies and Mitigation	$353,000
Land Acquisition and Surveying (108 acres)	$291,000
Interest During Construction (4% for 2 years with a 1% ROI)	$1,420,000
TOTAL COST OF PROJECT	**$21,702,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$1,308,000
Reservoir Debt Service (5.5 percent, 40 years)	$378,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$12,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$97,000
Dam and Reservoir (1.5% of Cost of Facilities)	$59,000
Water Treatment Plant	$563,000
Pumping Energy Costs (212,958 kW-hr @ 0.09 $/kW-hr)	$19,000
TOTAL ANNUAL COST	**$2,436,000**
Available Project Yield (acft/yr)	615
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	$3,961
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	$12.15

Table 4.9-3. Evaluations of Meridian Off-Channel Reservoir Option to Enhance Water Supplies

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	1. Negligible impact
2. Habitat	2. Negligible impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Negligible impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4.10 Lake Creek Reservoir

4.10.1 Description of Option

A potential water management strategy for North Central Texas Municipal Water Authority (NCTMWA) is a new reservoir located on Lake Creek in the southeast corner of Knox County as shown in . This strategy has the potential to supply 14,500 acft of raw water. The Lake Creek Reservoir strategy is an alternative to the Millers Creek Augmentation WMS which was the highest ranked strategy in the 2011 Brazos G RWP but may not have adequate supplies for project development according to a recent HDR study. The proposed Lake Creek diversion site for the Millers Creek Augmentation WMS is shown in for comparison purposes.

The proposed Lake Creek Reservoir will contain approximately 58,560 acft of conservation storage and inundate 2,866 acres at the full conservation storage level of 1,400 ft-msl. The reservoir would impound Lake Creek streamflow and diversions from the Brazos River. Almost all of the streamflow originating in Lake Creek must be passed downstream for senior water rights at Possum Kingdom Reservoir. A subordination agreement with Possum Kingdom Reservoir would allow for these inflows to be impounded by the Lake Creek Reservoir, thus significantly increasing the yield of the project. Any subordination agreement with the BRA is dependent on the BRA being able to successfully obtain the System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. A subordination agreement would have to be negotiated and acquired for this strategy to be implemented as presented in this section.

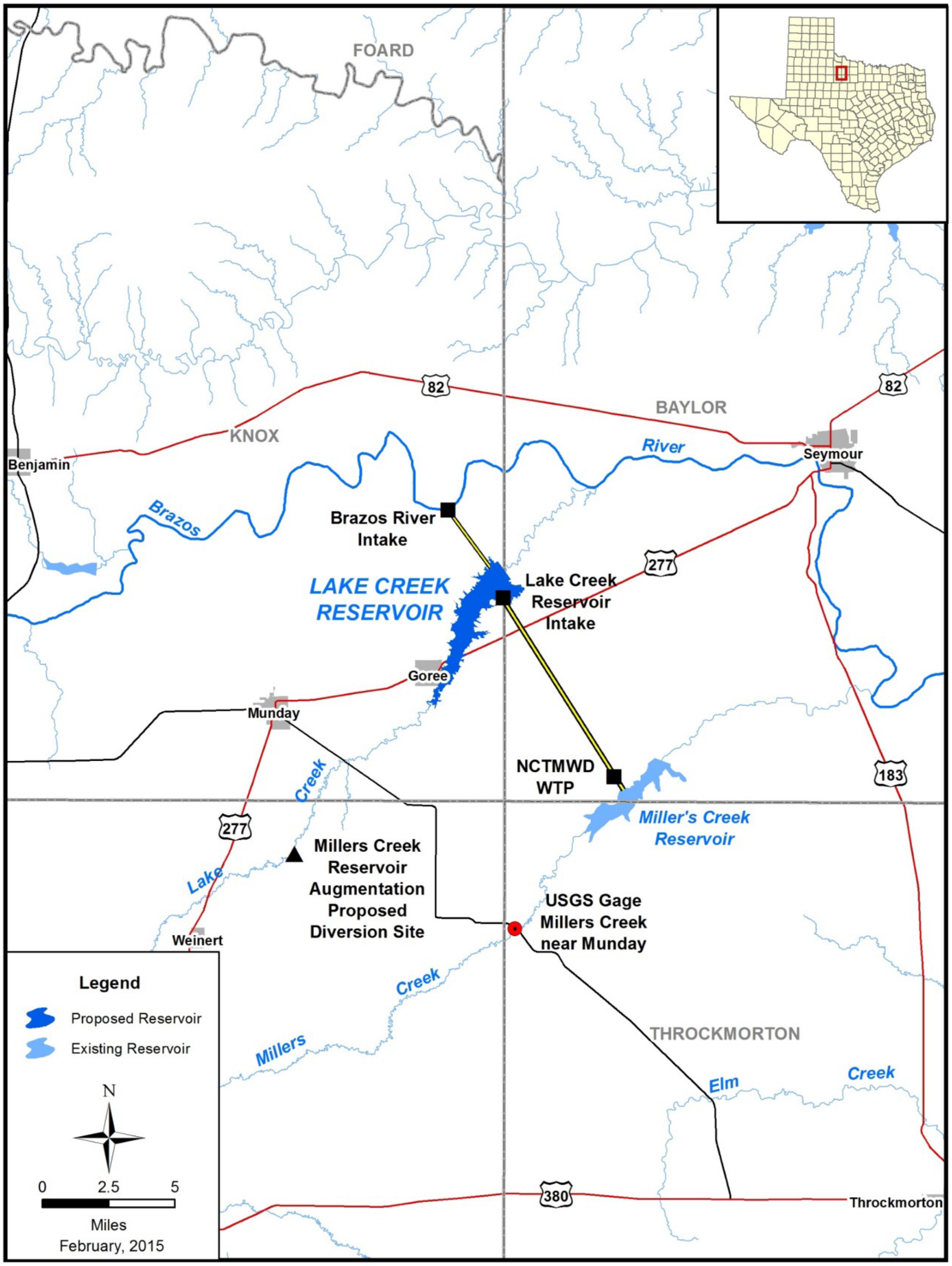
Diversions from the Brazos River would be transported through a 3-mile, 120-in pipeline to the reservoir for impoundment. Due to water quality concerns in the main stem of the Brazos River, diversions would only occur during flood flow periods. A subordination agreement with Possum Kingdom Reservoir for the Brazos River diversions would not substantially increase the yield of the project because during flood flow times, when diversion would occur, unappropriated flow is typically available. Therefore, a subordination agreement with Possum Kingdom Reservoir is recommended only for the impoundment of natural inflows in the Lake Creek Reservoir and not for diversions from the Brazos River.

Stored water in the reservoir would be transported to the NCTMWD WTP or Millers Creek Reservoir via an 8-mile, 30-in pipeline. NCTMWD would have the operational flexibility to treat the supplies or discharge the raw water into Millers Creek Reservoir if storage is available. A 13.6 MGD expansion of the WTP would also be required to treat the additional raw water supplied by the project.

4.10.2 Available Yield

Water potentially available for impoundment in the proposed Lake Creek Reservoir was estimated using the TCEQ Brazos WAM Run 3 which assumes no return flows and permitted storages and diversions for all water rights in the basin. The model utilizes a January 1940 through December 1997 hydrologic period of record and includes the

Figure 4.10-1. Lake Creek Reservoir



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Senate Bill 3 (SB3) environmental flow criteria. The model computed the streamflow available for impoundment with Possum Kingdom Reservoir subordination and diversions from the Brazos River without causing increased shortages to existing downstream rights.

The calculated firm yield of the Lake Creek Reservoir project is 14,500 acft/yr. Figure 4.10-2 provides the individual contributions to the total firm yield from junior reservoir impoundments, the Possum Kingdom subordination (subject to BRA obtaining the System Operations permit) and the Brazos River diversions. Without the subordination agreement or Brazos River diversions, the project would only be able to provide 1,400 acft/yr of firm yield. The Brazos River diversions provide the greatest contribution to the firm yield (11,000 acft/yr) and are required to make the project economically feasible. The subordination agreement would result in a 1,600 acft yield impact to Possum Kingdom Reservoir. Figure 4.10-3 provides the annual volumes of reservoir impoundments and Brazos River diversion for the model simulation period. Any subordination agreement with the BRA is dependent on the BRA being able to successfully obtain the System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. A subordination agreement would have to be negotiated and acquired for this strategy to be implemented as presented in this section.

Figure 4.10-2. Lake Creek Reservoir Firm Yield Components

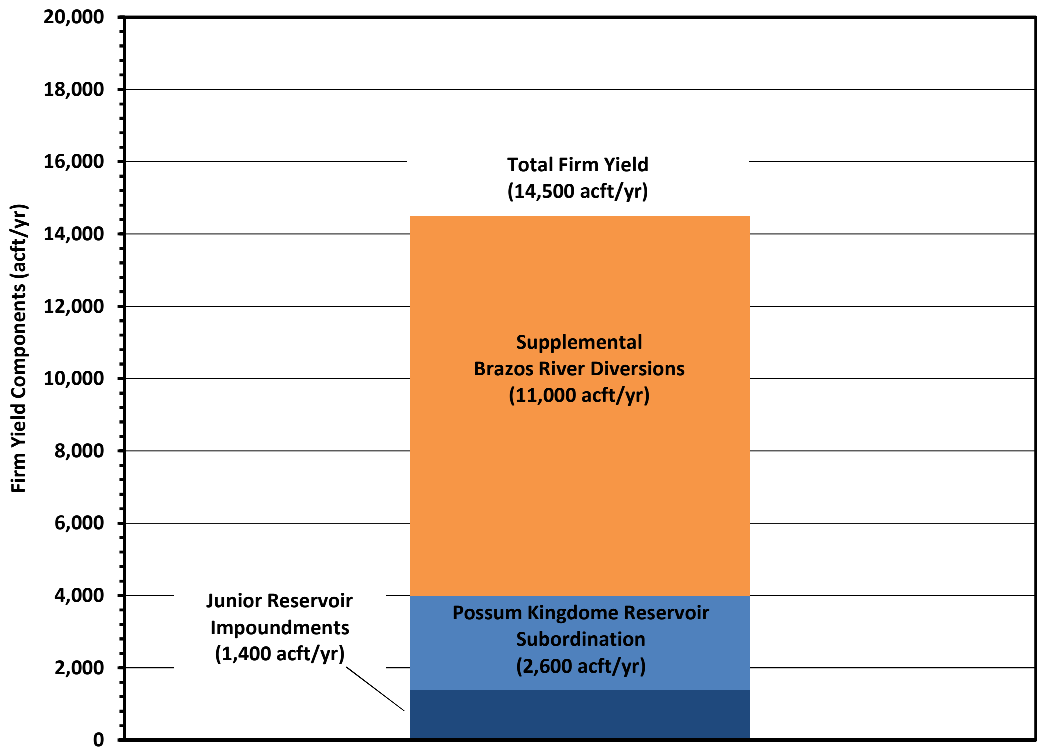


Figure 4.10-3. Annual Lake Creek Impoundments and Brazos River Diversions

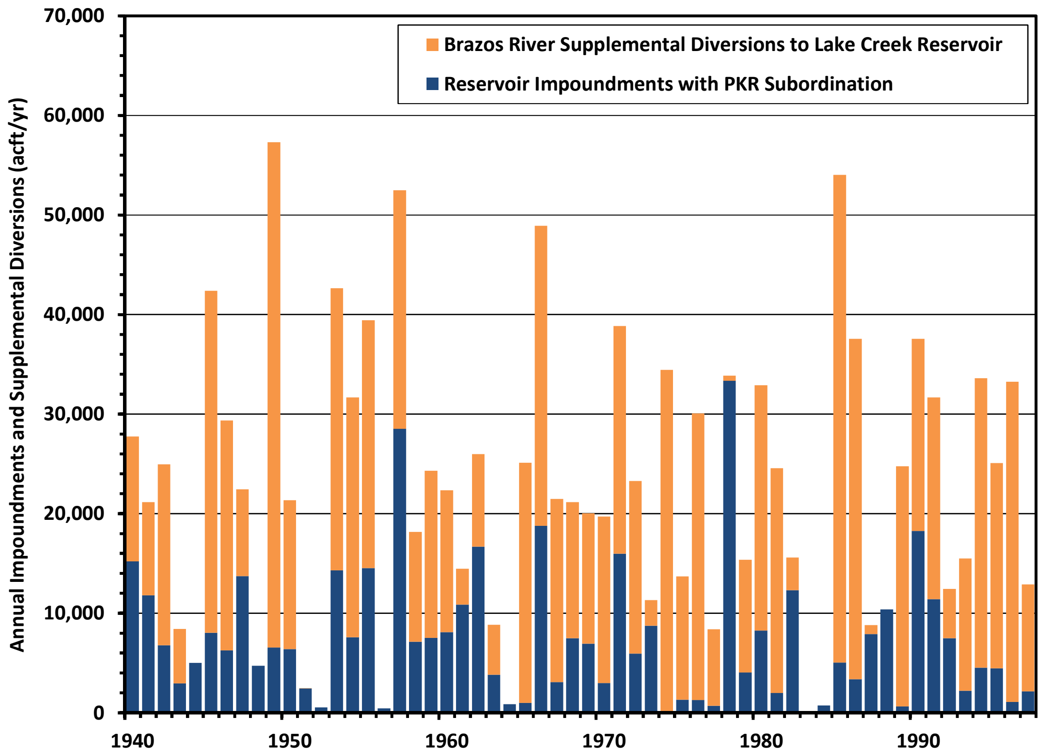


Figure 4.10-4 illustrates the storage trace of Lake Creek Reservoir for the 57 year model simulation period under the firm yield demand of 14,500 acft/yr. Figure 4.10-5 provides a frequency of the storage in Lake Creek Reservoir under the firm yield demand. The storage frequency reveals that the reservoir remains full almost 20 percent of the time and over half full approximately 85 percent of the time.

Figure 4.10-6 presents the monthly changes in the Lake Creek median streamflow values from reservoir impoundments. Even though the reservoir would only be able to impound flows in excess of that required for downstream senior water rights and environmental needs, median streamflow values are reduced to zero for all months.

Figure 4.10-7 compares the existing Lake Creek streamflow frequency characteristics without the project to simulated streamflow characteristics with Lake Creek Reservoir in place. For times when flows are less than the upper quartile, there are minimal reductions from the project because streamflows without the project are less than 6 cfs. There is a more pronounced reduction in streamflows during periods when flows are in the upper quartile because the reservoir has more frequent opportunities to impound significant streamflows.

Figure 4.10-8 and Figure 4.10-9 provide similar median streamflow statistics and streamflow frequency for the Brazos River at the diversion site. The figures reveal that the greatest reduction in streamflows occurs during the month of May and June when flood flows typically occur the most.

Figure 4.10-4. Lake Creek Reservoir Firm Yield Storage Trace

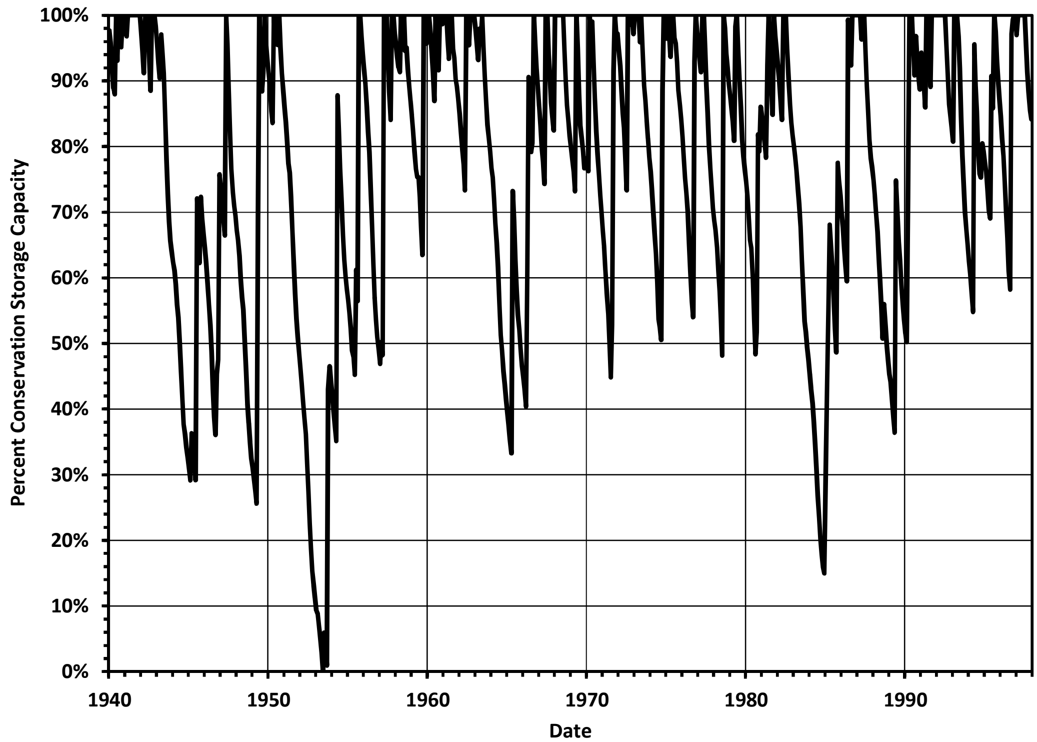


Figure 4.10-5. Lake Creek Reservoir Firm Yield Storage Frequency

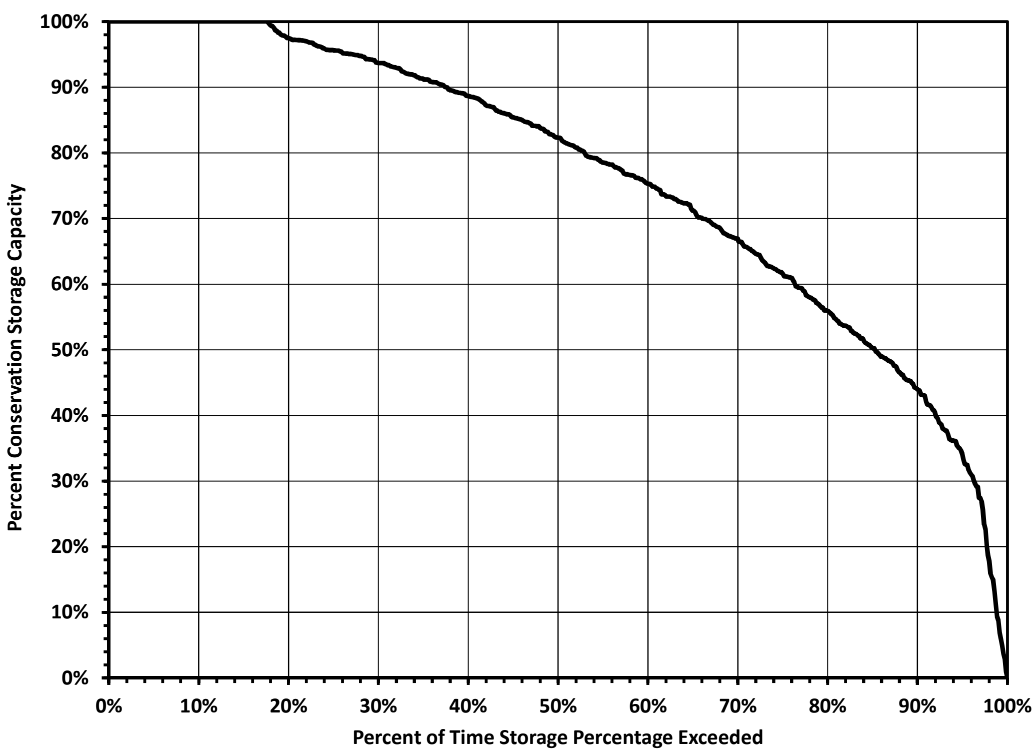


Figure 4.10-6. Lake Creek Reservoir Median Streamflow Comparison

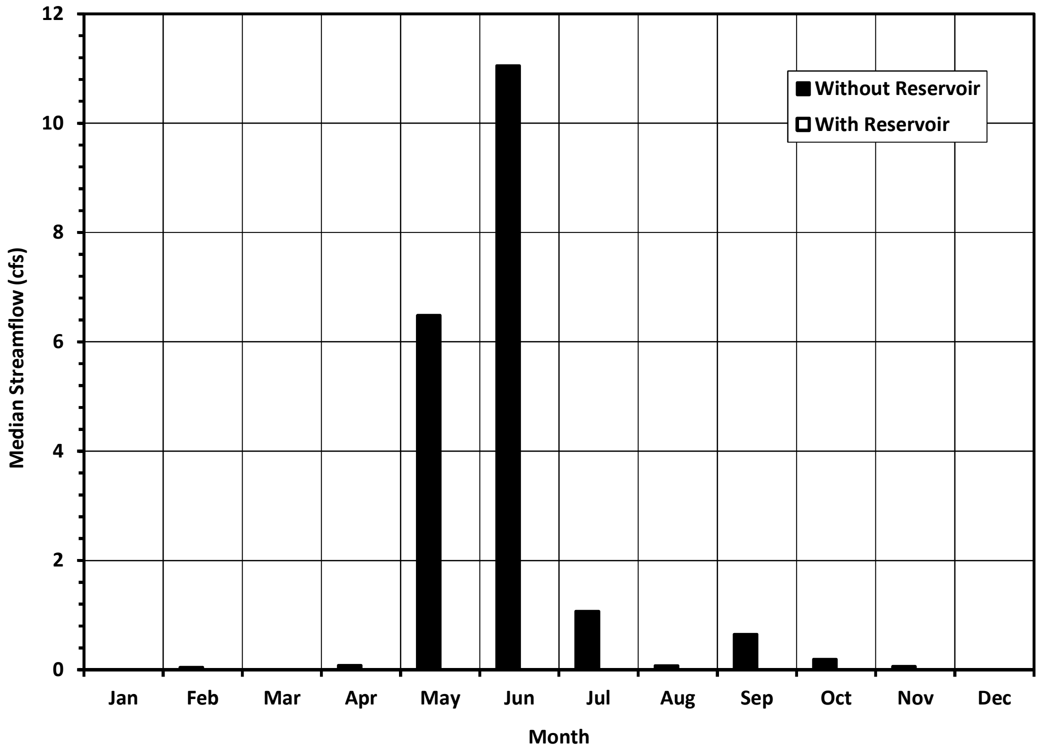


Figure 4.10-7. Lake Creek Reservoir Streamflow Frequency Comparison

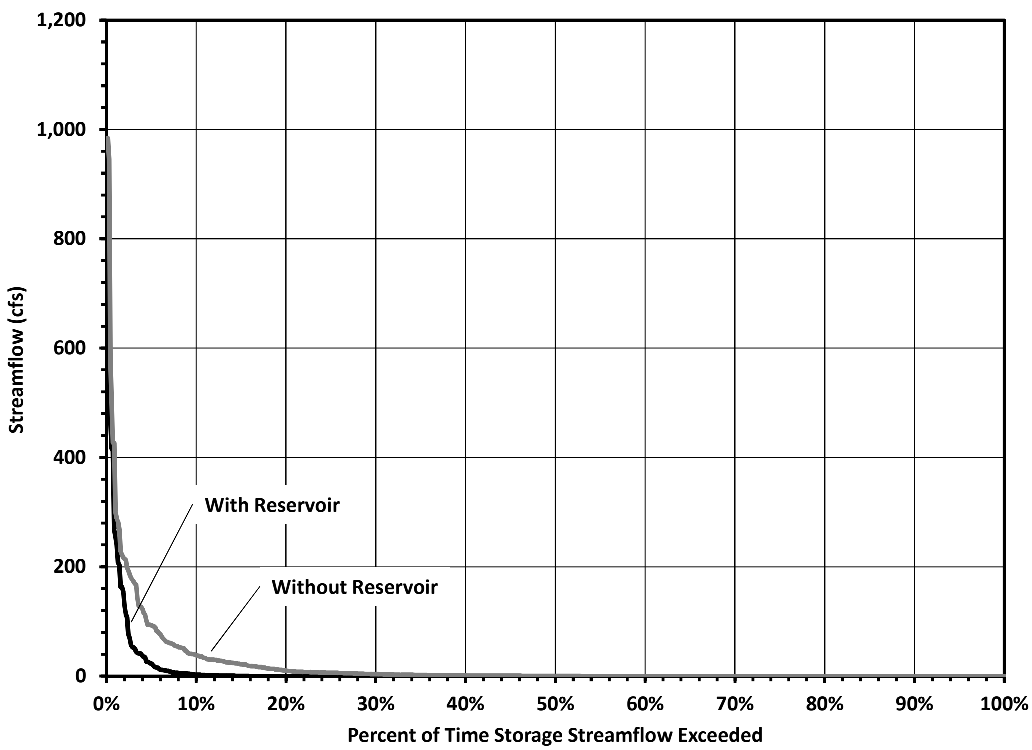


Figure 4.10-8. Brazos River Diversion Median Streamflow Comparison

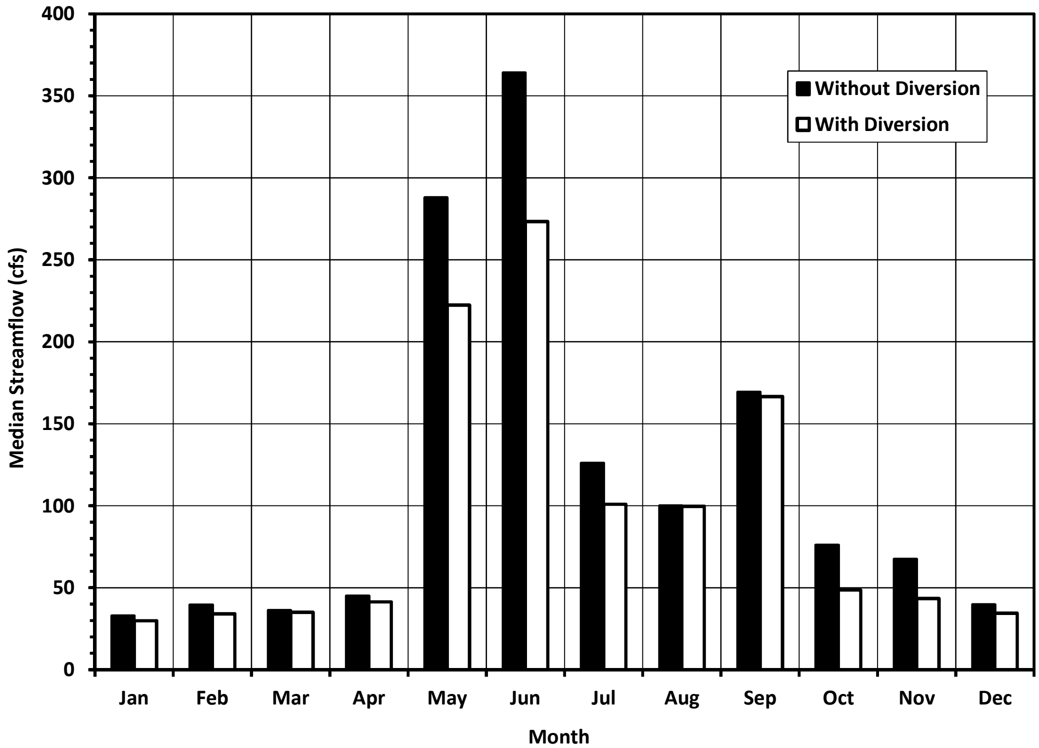
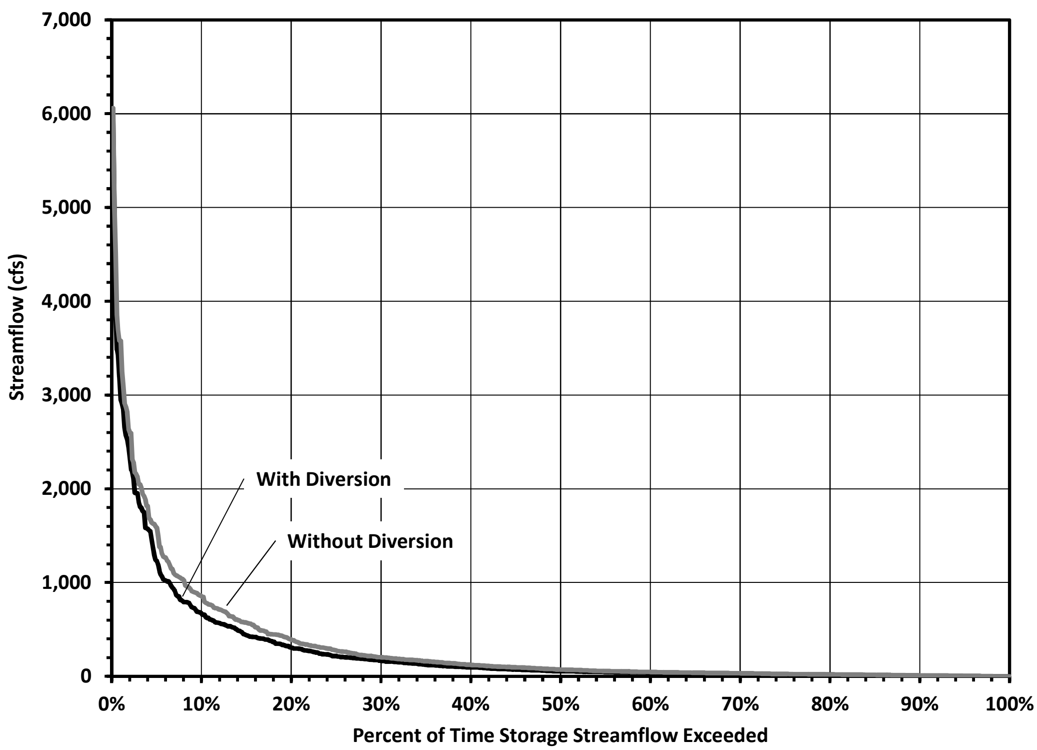


Figure 4.10-9. Brazos River Diversion Streamflow Frequency Comparison



4.10.3 Environmental Issues

The proposed Lake Creek Reservoir (LCR) project will consist of three components. These include: 1) an on-channel reservoir on Lake Creek, 2) an intake and pump station at the Brazos River and associated pipeline to Lake Creek Reservoir to provide supplemental diversions to the reservoir, and 3) an intake and pipeline from Lake Creek Reservoir to the existing water treatment plant (WTP) located near Millers Creek Reservoir which will be expanded.

The proposed project would occur in the Central Great Plains Ecoregion of Texas. The majority of this ecoregion is now cropland, but once included either grassland or a mixed transitional prairie. The project area includes two major vegetation types as defined by Texas Parks and Wildlife (TPWD), the majority type includes crops, however smaller portions of Mesquite/Saltcedar Brush/Woods occur along the margins of rivers and other drainages. Plants commonly found within the Mesquite/Saltcedar Brush/Woods vegetation type include Creosotebush (Larrea tridentata), cottonwood (Populus ssp.), desert willow (Chilopsis linearis), common buttonbush (Cephalanthus occidentalis), whitethorn acacia (Acacia constricta), lotebush (Ziziphus obtusifolia), Johnsongrass (Sorghum halepense), bushy bluestem (Andropogon glomeratus), and Mexican devil-weed (Leucosyris spinosa). Table 4.10-1 lists the threatened, endangered, and candidate or species of concern that may occur in Knox, or Baylor counties according to the U.S. Fish and Wildlife Service (USFWS), and county lists of rare species published by the Texas Parks and Wildlife Department (TPWD) online in the “Annotated County Lists of Rare Species.” Inclusion in Table 4.10-1 does not mean that a species will occur within the project area, but only acknowledges the potential for its occurrence in the project area counties.

Two fish species, the sharpnose shiner (Notropis oxyrhynchus) and smalleye shiner (Notropis buccula) have been recently listed as endangered by the USFWS. These two minnows are native to the arid prairie streams of Texas and are considered to be in danger of extinction. The USFWS has designated approximately 623 miles of the Upper Brazos River Basin and the upland areas extending beyond the river channel by 98 feet on each side as critical habitat for these two fish. These areas occur within the counties of Baylor, Crosby, Fisher, Garza, Haskell, Kent, King, Knox, Stonewall, Throckmorton and Young. In addition TPWD has identified a number of stream segments throughout the state as ecologically significant on the basis of biological function, hydrologic function, riparian conservation, exceptional aquatic life uses, and/or threatened or endangered species. The segment of the Brazos River, located within the project area, is listed by TPWD as an Ecologically Significant River and Stream Segment.

Potential impacts to these species could occur from the construction and operation of the intake and pump station proposed along the Brazos River intended to provide supplemental diversion to Lake Creek Reservoir. Appropriate site selection and screening technology must be considered during the project system design as part of the overall effort to avoid or minimize potential impacts to aquatic species. Coordination with USFWS would be required for listed species within the project area. No other species listed by USFWS are anticipated to be adversely effected by the proposed project.

Table 4.10-1. Important Species Habitat or Known to Occur in Baylor and Knox Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
BIRDS								
American peregrine falcon	*Falco peregrinus anatum*	0	3	0	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	0	2	0	Migrant throughout the state.	DL		Possible Migrant
Baird's Sparrow	*Ammodramus bairdii*	0	1	0	Found in shortgrass prairie with scattered low bushes and matted vegetation migratory in western part of state.			Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	0	2	0	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Ferruginous Hawk	*Buteo regalis*	0	1	0	Open country primarily prairies, plains, and badlands nesting near water.			Possible Migrant
Interior least tern	*Sterna antillarum athalassos*	0	3	0	Nests along sand and gravel bars in braided streams	LE	E	Resident
Mountain plover	*Charadrius montanus*	0	1	0	Non-breeding, shortgrass plains and fields			Nesting/ Migrant
Piping Plover	*Charadrius melodus*	0	2	0	A small pale shorebird of open sandy beaches and alkali flats, the Piping Plover is found along the Atlantic and Gulf coasts.	LT	T	Possible Migrant
Snowy plover	*Charadrius alexandrinus*	0	1	0	Potential migrant winters along coast			Possible Migrant

Table 4.10-1. Important Species Habitat or Known to Occur in Baylor and Knox Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Sprague's pipit	*Anthus spragueii*	0	1	0	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C		Possible Migrant
Western burrowing owl	*Athene cunicularia hypugaea*	0	1	0	Open grasslands, especially prairie, plains and savanna			Resident
Western snowy plover	*Charadrius alexandrines nivosus*	0	1	0	Potential migrant, winters along coast.			Possible Migrant
White-faced Ibis	*Plegadis chihi*	0	2	0	Prefers freshwater marshes and irrigated fields.		T	Resident
Whooping crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Potential Migrant
FISHES								
Sharpnose shiner	*Notropis oxyrhynchus*	1	1	1	Endemic to Brazos River drainage. Found in large rivers.	LE		Resident
Smalleye shiner	*Notropis buccula*	1	1	1	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE		Resident
MAMMALS								
Black-footed ferret	*Mustela nigripes*	0	3	0	Extirpated, inhabited prairie dog towns.	LE		Historic Resident
Black-tailed prairie dog	*Cynomys ludovicianus*	1	1	0	Found on dry, flat, short grasslands.			Resident
Cave myotis bat	*Myotis velifer*	0	1	0	Roosts colonially in caves, rock crevices			Resident

Table 4.10-1. Important Species Habitat or Known to Occur in Baylor and Knox Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Gray wolf	*Canis lupus*	0	3	0	Extirpated formerly known in western two-thirds of the state.	LE	E	Historic Resident
Pale Townsend's big-eared bat	*Corynorhinus townsendii pallescens*	0	1	0	Roosts in caves and old buildings. Hibernates in winter.			Resident
Plains spotted skunk	*Spilogale putorius interrupta*	1	1	1	Prefers wooded, brushy areas.			Resident
Red wolf	*Canis rufus*	0	3	0	Extirpated.	LE	E	Historic Resident
Texas kangaroo rat	*Dipodomys elator*	1	2	2	Associated with scattered mesquite shrubs and short grasses.		T	Resident
PLANTS								
Correll's wild-buckwheat	*Eriogonum correllii*	0	1	0	Occurs on clay mound, caprock and rocky ledges on caliche substrates.			Resident
REPTILES								
Brazos water snake	*Nerodia harteri*	1	2	2	Found in upper Brazos River drainage in shallow water with rocky bottoms.		T	Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands.		T	Resident

Table 4.10-1. Important Species Habitat or Known to Occur in Baylor and Knox Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

TPWD, 2014. Annotated County List of Rare Species –Knox County 1/22/2014, and Baylor County 1/22/2014.
USFWS, 2014. Endangered Species List for Baylor and Knox Counties, Texas. http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action, August 9, 2014.

Construction of the water transmission pipelines located between the Brazos River and LCR and from LCR to the WTP near Millers Creek Reservoir would include the clearing and removal of woody vegetation. Surveys for protected species should be conducted within the proposed construction corridors where preliminary evidence indicates their existence. State threatened species, including the Texas horned lizard (Phrynosoma cornutum), and Brazos water snake (Nerodia harteri) are dependent on shrubland or riparian habitat. Because the majority of pipeline construction will occur in previously disturbed areas such as croplands the destruction of potential habitat utilized by terrestrial species will be minimized.

Although suitable habitat for several state threatened species may exist within the project area, no significant impact to these species is anticipated due to limited area that will be impacted by the project, the abundance of similar habit nearby and these species ability to relocate to those areas if necessary. The presence or absence of potential habitat does not confirm the presence or absence of a listed species. No species specific surveys were conducted in the project area for this report.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available GIS datasets provided by the Texas Historical Commission (THC), there are no National Register Properties, National Register Districts, cemeteries, or historical markers located within the project area. However there is a high probability for undocumented significant cultural resources to occur within the alluvial deposits and terrace formations associated with waterways, specifically the intermittent and perennial aquatic resources. A review of archaeological resources in the proposed project area should be conducted during the project planning phase.

Specific project features, such as pump stations, and pipelines generally have sufficient design flexibility to avoid most impacts or significantly mitigate potential impacts to geographically limited environmental and cultural resource sites. Field surveys conducted at the appropriate phase of development should be employed to minimize the impacts of project construction and operations on sensitive resources.

Taking into consideration that the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the THC regarding impacts to cultural resources. The project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding any impacts to waters of the United States or wetlands.

Agricultural Impacts

The Lake Creek Reservoir site contains approximately zero acres of Pasture/Hay fields and 203 acres of cropland. These two agricultural land uses account for roughly seven percent of the reservoir footprint.

4.10.4 Engineering and Costing

In addition to the new reservoir, the potential Lake Creek Reservoir project for NCTMWA would require additional facilities to divert water from the Brazos River to the Reservoir Site on Lake Creek and from the Reservoir to the water treatment plant at Millers Creek Reservoir. The facilities required for implementation of the project include:

- A raw water intake and pump station at the Brazos River diversion site with a capacity of 400 cfs (258 MGD);
- 3-mile, 120-inch pipeline from the pump station to Lake Creek Reservoir;
- On-channel dam including spillway, intake tower, and 2,866 acres of land for the reservoir;
- 13.6 MGD intake and pump ptation at lake Creek Reservoir;
- 8-mile, 30-in pipeline to NTMWD WTP and Millers Creek Reservoir; and,
- 13.6 MGD expansion of the NTMWD WTP.

A summary of the total project cost in September 2013 dollars is presented in Table 4.10-2. The estimated total project cost for the proposed Lake Creek Reservoir project is $193.5 million. This cost includes land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $18.7 million. This includes annual debt service, operation and maintenance, pumping energy costs, and purchase of water from BRA for compensation of yield impacts to Possum Kingdom. The off-channel project will be able to provide treated water at a unit cost of $1,308 per ac-ft or $4.01 per 1,000 gallons. Note that any subordination agreement would need to be negotiated with BRA and is dependent on the BRA successfully obtaining the System Operations permit from the TCEQ.

Table 4.10-2. Cost Estimate for Lake Creek Reservoir

Item	Estimated Costs for Facilities
Dam and Reservoir	$46,255,000
Brazos River Intake Pump Station & Channel Dam (258 MGD)	$23,232,000
Brazos River Transmission Pipeline (120 in dia., 3 miles)	$16,382,000
Lake Creek Reservoir Intake Pump Station (13.6 MGD)	$2,876,000
Lake Creek Transmission Pipeline (30 in dia., 8 miles)	$6,778,000
Water Treatment Plant Expansion (13.6 MGD)	$22,940,000
TOTAL COST OF FACILITIES	**$118,463,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$40,304,000
Environmental & Archaeological Studies and Mitigation	$5,428,000
Land Acquisition and Surveying (3,012 acres)	$5,562,000
Interest During Construction (4% for 4 years with a 1% ROI)	$23,767,000
TOTAL COST OF PROJECT	**$193,524,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$9,245,000
Reservoir Debt Service (5.5 percent, 40 years)	$5,175,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$884,000
Dam and Reservoir	$694,000
Water Treatment Plant	$2,294,000
Pumping Energy Costs ($0.09 kwh)	$564,000
Purchase of Water (1,600 acft/yr @ 65.65 $/acft)	$105,000
Total Annual Cost	**$18,961,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**14,500**
Annual Cost of Water ($ per acft)	**$1,308**
Annual Cost of Water ($ per 1,000 gallons)	**$4.01**

4.10.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.10-3, and the option meets each criterion.

Table 4.10-3. Comparison of Lake Creek Reservoir Project to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable to High
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impact
2. Habitat	2. High impact
3. Cultural Resources	3. High impact
4. Bays and Estuaries	4. Low impact due to distance from coast
5. Threatened and Endangered Species	5. Possible moderate impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	Potential impact on bottomland farms and habitat in reservoir area
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

Implementation of the reservoir project will require permits from various state and federal agencies, land acquisition, and design and construction of the facilities. The project may also have an impact on the firm yield of Possum Kingdom, which may require mitigation with the Brazos River Authority in terms of a water supply contract in the amount of the firm yield impact. A summary of the implementation steps for the project is presented below.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;

- Texas General Land Office Easement if State-owned land or water is involved; and
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.
- Coordination with BRA on any potential subordination agreement, subject to availability under the System Operations permit.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions or other local landowner agreements;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

4.11 South Bend Reservoir

4.11.1 Description of Option

The South Bend Reservoir is a proposed reservoir with the dam located in Young County immediately downstream from the confluence of the main stem Brazos River and the Clear Fork of the Brazos River, as shown in Figure 4.11-1. The reservoir would capture flow from both streams, with an estimated capacity of up to 771,604 acft from the 13,168 square mile drainage area. The dam would be an earthfill embankment that would extend approximately 2.8 miles across the Brazos River at an elevation of 1,090 ft-msl and inundate 29,877 surface acres.

There are some water-short entities in the area that could benefit from the construction of the reservoir, but the majority of the water would have its greatest usefulness as part of the BRA System. Some of the water-short entities in the area would include Tolar and Fort Belknapp WSC. Other non-municipal shortages identified in the area include mining in Stephens County.

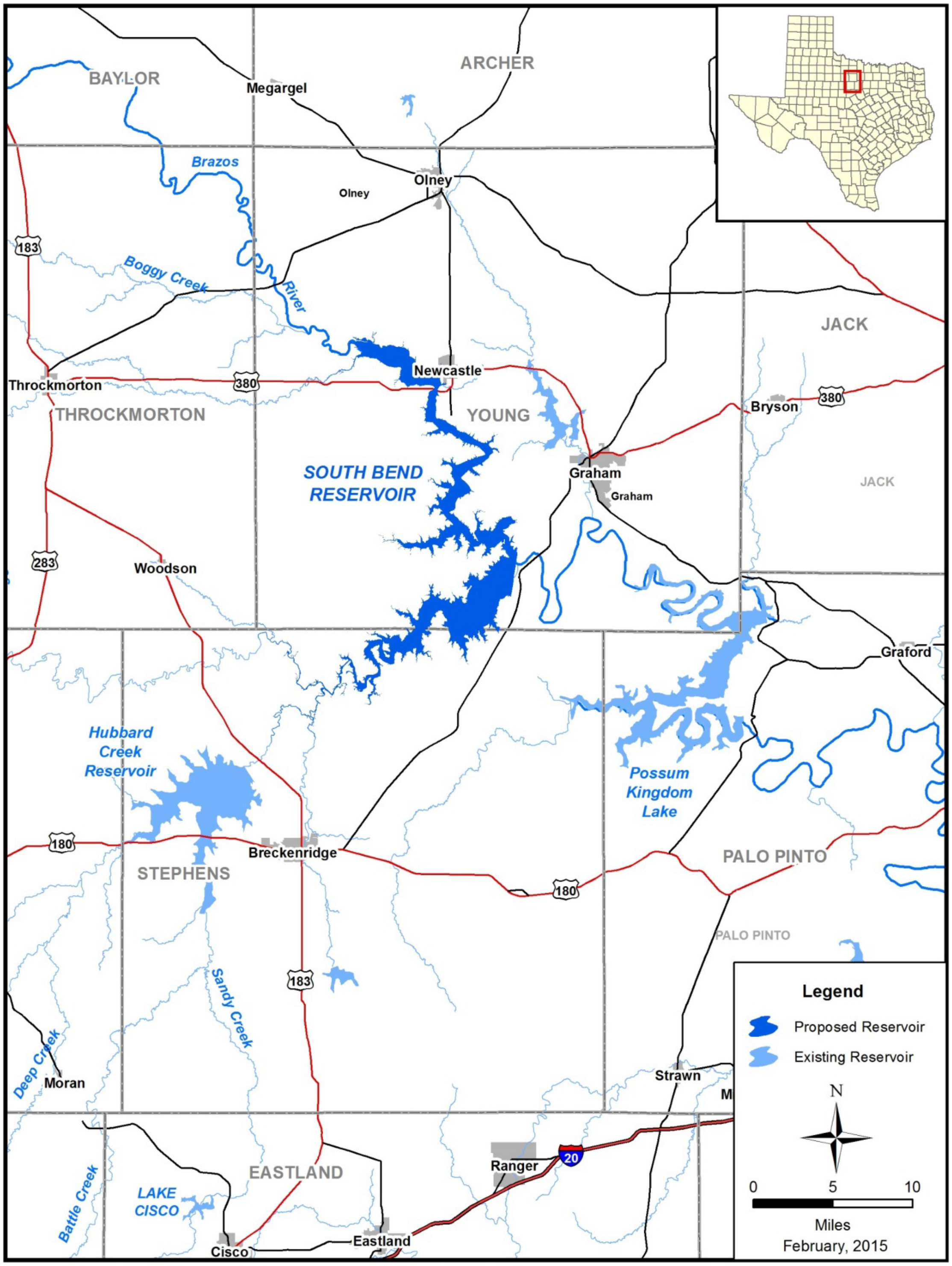
4.11.2 Available Yield

Water potentially available for impoundment in the proposed South Bend Reservoir was estimated using the TCEQ Brazos WAM Run 3. The TCEQ WAM assumes no return flows and permitted storages and diversions for all water rights in the basin. The model utilized a January 1940 through December 1997 hydrologic period of record and computed the streamflow available from the Brazos River for impoundment in the South Bend Reservoir without causing increased shortages to downstream rights. Firm yield was computed subject to the reservoir and Brazos River depletions having to pass inflows to meet environmental flow standards associated with Senate Bill 3 (SB3).

Since the South Bend Reservoir is of a significant size and geographically close to Possum Kingdom Reservoir, it was analyzed both as a stand alone reservoir and acting as part of a system with Possum Kingdom Reservoir. The stand alone firm yield of South Bend Reservoir is 62,100 acft/yr. Preliminary analysis indicates that 34,300 acft/yr of additional supply could be made available by operating South Bend as part of the BRA system in conjunction with Possum Kingdom Reservoir. The results presented in the remainder of this section are for the stand alone yield scenario of South Bend Reservoir.

Figure 4.11-2 illustrates simulated South Bend Reservoir storage levels for the 1940 to 1997 historical period, subject to the firm yield in South Bend Reservoir of 62,100 acft/yr and authorized diversions from Possum Kingdom Reservoir (230,750 acft/yr). Figure 4.11-3 shows the storage frequency of South Bend Reservoir associated with the firm yield demand of 62,100 acft/yr. Simulated reservoir contents in South Bend remain above 80 percent capacity about 40 percent of the time and above 50 percent capacity about 70 percent of the time.

Figure 4.11-1. South Bend Reservoir Location



L:\Project_Data\00044_BrazosG\GIS\Map_Docs\Task_04_WMS\WMS_Task_04_Existing_Supplies\South_Bend_Res.mxd

Figure 4.11-2. South Bend Reservoir Firm Yield Storage Trace

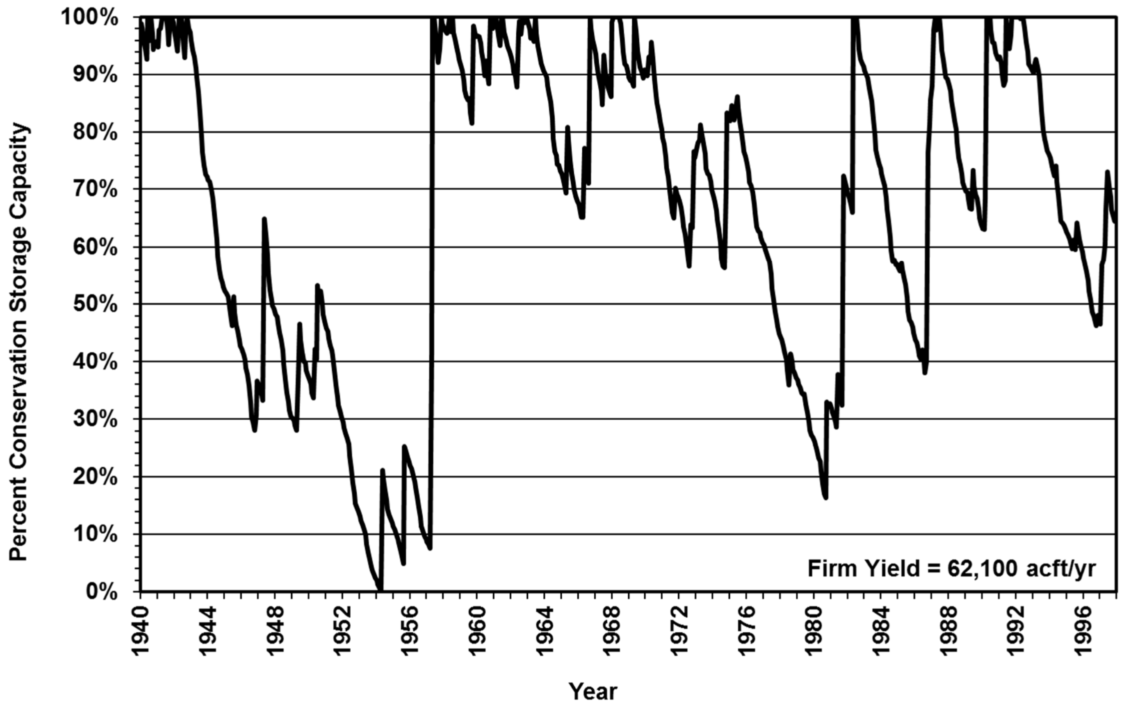


Figure 4.11-3. Storage Frequency at Firm Yield

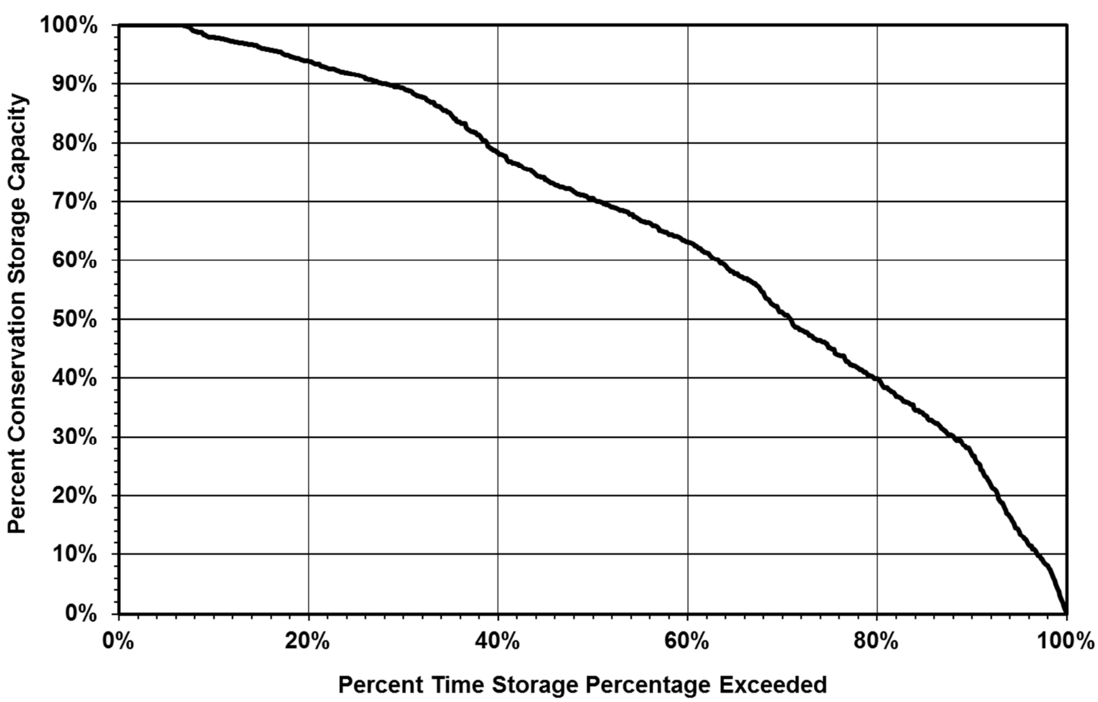


Figure 4.11-4 illustrates the changes in Brazos River streamflows at the South Bend Reservoir Dam caused by impounding the unappropriated waters of the Brazos and Clear Fork of the Brazos Rivers. The greatest change in flow would occur in the spring and summer months of May and June. The largest decline occurs in June, where the median streamflow is reduced by 189 cfs. During the winter months, there would be little change in streamflow because the reservoir would rarely be able to impound flows in excess of those required for downstream senior water rights and environmental needs. Figure 4.11-5 also illustrates the Brazos River streamflow frequency characteristics with the South Bend Reservoir in place.

Figure 4.11-4. Monthly Median Streamflow at Proposed South Bend Reservoir Dam

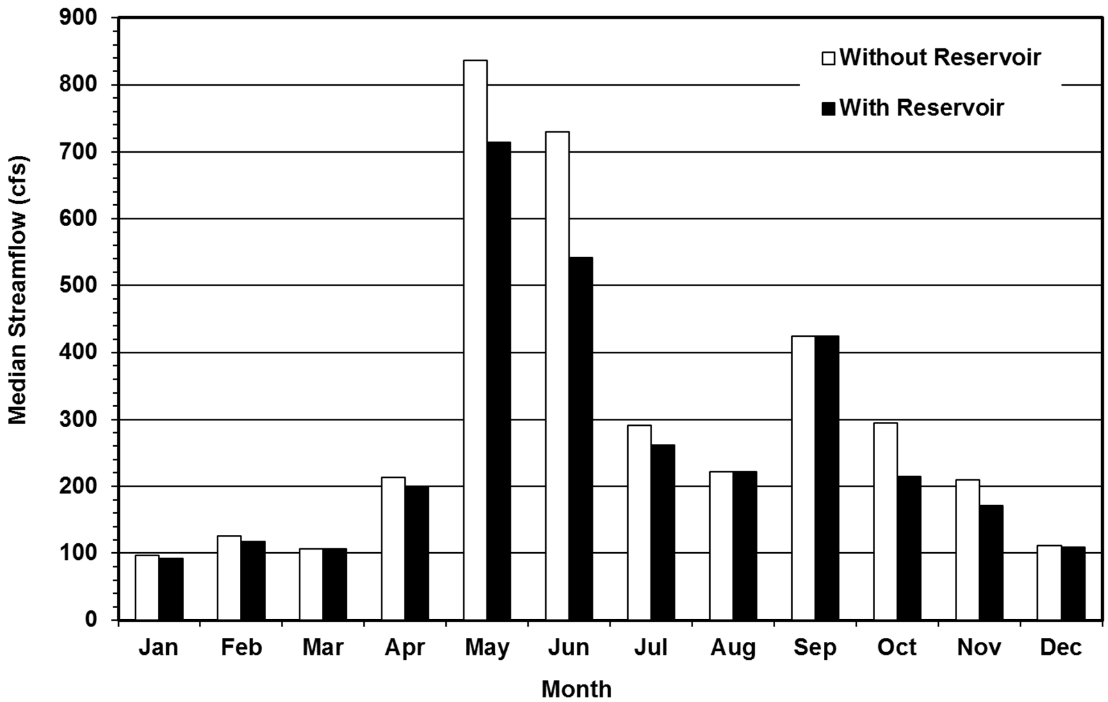
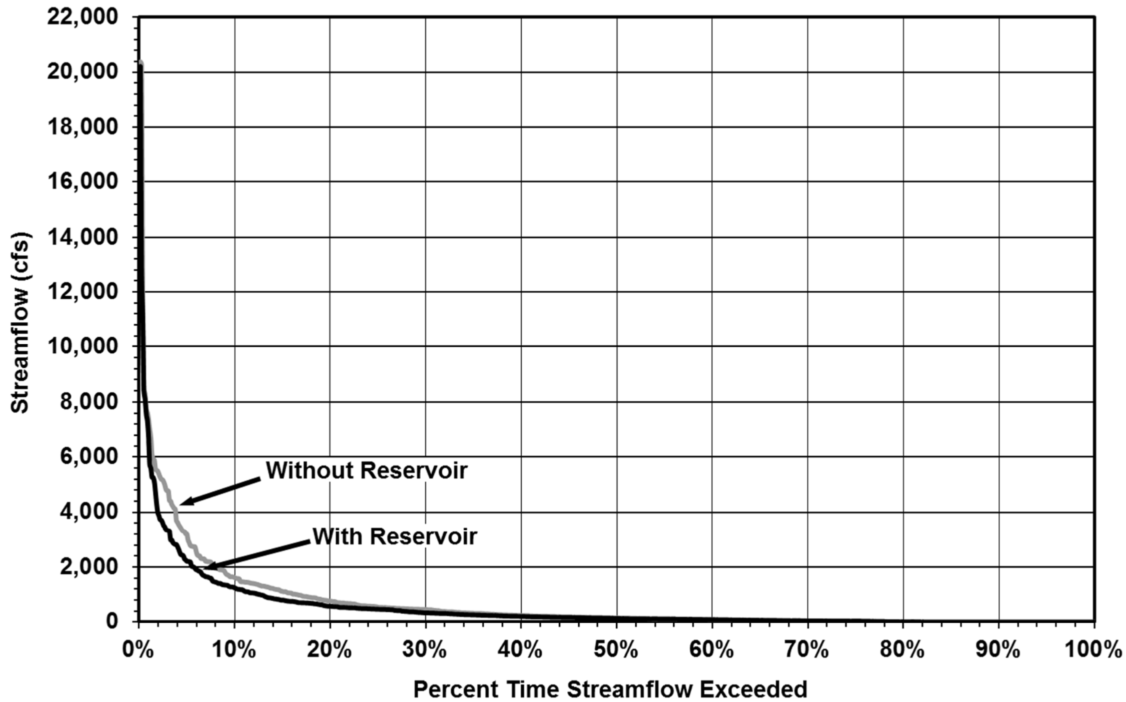


Figure 4.11-5. Streamflow Frequency at Proposed South Bend Reservoir Dam



4.11.3 Environmental Issues

Existing Environment

The South Bend Reservoir site in Stephens and Young Counties is within the Cross Timbers and Prairies Ecological Region, a complex transitional area of prairie dissected by two parallel timbered strips extending from north to south.[1] This region is located in north-central Texas west of the Blackland Prairies, east of the Rolling Plains, and north of the Edwards Plateau and Llano Uplift. The physiognomy of the region is oak and juniper woods and mixed grass prairie. Much of the native vegetation has been displaced by agriculture and development, and range management techniques—including fire suppression—have contributed to the spread of invasive woody species and grasses. Farming and grazing practices have also reduced the abundance and diversity of wildlife in the region.[2] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 26 and 32 inches.[3] The

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[1] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, Vegetational Areas of Texas, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.

[2] Telfair, R.C., "Texas Wildlife Resources and Land Uses," University of Texas Press, Austin, Texas, 1999.

[3] Larkin, T.J., and G.W. Bomar, "Climatic Atlas of Texas," Texas Department of Water Resources, Austin, Texas, 1983.

project area lies between the Seymour and Trinity major aquifers, but is underlain by no major or minor aquifers.[4]

The region lies within the North-Central Plains physiographic region which includes elevations between 900 and 3,000 feet above sea level. Bedrock includes limestones, sandstones, and shales. Where shale bedrock prevails, meandering rivers traverse stretches of local prairie. In areas of harder bedrock, hills and rolling plains dominated. Local areas of hard sandstones and limestones cap steep slopes severly dissected near rivers. [5] The predominant soil associations in the project area are the Shatruce-Exray-Loving, Lincoln-Westola-Padgett, and Clearfork-Wheatwood associations in Young County[6] and the Clearfork-Clairemont and Bastrop-Minwells, associations in Stephens County[7]. The Shatruce-Exray-Loving association ranges from very shallow to moderately deep soils on ridges. These soils, primarily support rangeland, typically have a surface of fine, sandy loam underlain by clay, clay loam, and sandstone. The Lincoln-Westola-Padgett association consists of very deep loamy and clayey soils formed in alluvial sediments on the Brazos River flood plain. Soils in this map unit are generally used as pasture, rangeland or cropland. The Clearfork-Wheatwood soil association very deep loamy soils formed in alluvium on the Clearfork of the Brazos River flood plain. These soils are typically used as cropland and pasture. The Clearfork-Clairemont association consists of very deep, nearly level and very gently sloping, loamy soils underlain by clayey and loamy alluvial sediments, on flood plains. The Bastrop-Minwells association consists of very deep, nearly level and very gently sloping, loamy soils underlain by loamy and gravelly alluvial sediments, on stream terraces.

Four major vegetation types occur within the general vicinity of the proposed project: Mesquite (*Prosopis glandulosa*)-Lotebush (*Ziziphus obtusifolia*) Shrub (and Mesquite brush), Post Oak (*Quercus stellata*) Parks/Woods, Live Oak (*Q. virginiana*)-Mesquite-Ashe Juniper (*Juniperus ashei*) Parks, and crops.[8] Variations of these primary types may occur based on changes in the composition of woody and herbaceous species and the physiognomy of localized conditions and specific range sites.

Mesquite-Lotebush Brush/Shrub could include the following commonly associated plants: yucca (*Yucca* spp.), skunkbush sumac (*Rhus trilobata*), agarito (*Berberis trifoliolata*), elbowbush (*Forestiera pubescens*), juniper, tasajillo (*Opuntia leptocaulis*), cane bluestem (*Bothriochloa barbinodis*), silver bluestem (*Bothriochloa saccharoides*), little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), Texas grama (*Bouteloua rigidiseta*), sideoats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua*

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[4] Texas Water Development Board (TWDB), *Aquifers*, http://www.twdb.texas.gov/groundwater/aquifer/index.asp accessed December 1, 2014.

[5] Wermund, E.G., Physiographic Map of Texas, Bureau of Economic Geology, University of Texas, Austin, Texas, 1996. Accessed online at http://www.beg.utexas.edu/UTopia/images/pagesizemaps/physiography.pdf on November 25, 2014.

[6] NRCS, 2009. Soil Survey of Young County, Texas. Accessed online http://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/texas/TX503/0/Young.pdf December 2, 2014.

[7] NRCS, 1994. Soil Survey of Stephens County, Texas. Accessed online http://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/texas/TX429/0/stephens_texas.pdf December 2, 2014.

[8] McMahan, C.A., R.F. Frye, and K.L. Brown, “The Vegetation Types of Texas,” Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

hirsuta), red grama (*Bouteloua trifida*), tobosagrass (*Pleuraphis mutica*), buffalograss (*Buchloe dactyloides*), Texas wintergrass (*Nasella leucotricha*), purple three-awn (*Aristida purpurea*), Engelmann daisy (*Engellmania pinnatifida*), broom snakeweed (*Gutierrezia sarothrae*), and bitterweed (*Hymenoxys odorata*).

Commonly associated plants of Post Oak Parks/Woods are blackjack oak (*Q. marilandica*), eastern redcedar (*J. virginiana*), mesquite, black hickory (*Carya texana*), live oak, sandjack oak (*Q. incana*), cedar elm (*Ulmus crassifolia*), hackberry (*Celtis* spp.), yaupon (*Ilex vomitoria*), poison oak (*Toxicodendron pubescens*), American beautyberry (*Callicarpa americana*), hawthorn (*Crataegus* spp.), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus* sp.), coralberry (*Symphoricarpos orbiculatus*), little bluestem, silver bluestem, sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida* spp.), sprangle-grass (*Chasmanthium sessiliflorum*), and tickclover (*Desmodium* spp.).

Commonly associated plants of Live Oak-Mesquite-Ashe Juniper, found chiefly on level to gently rolling uplands and ridge tops of the Edwards Plateau, are Texas oak, shin oak (*Q. havardii*), cedar elm, netleaf hackberry (*Celtis laevigata*), flameleaf sumac (*Rhus lanceolata*), agarito, Mexican persimmon (*Diospyros texana*), Texas pricklypear (*Opuntia engelmannii*), kidneywood (*Eysenhardtia texana*), saw greenbrier (*Smilax bona-nox*), Texas wintergrass, little bluestem, curly mesquite (*Hilaria belangeri*), Texas grama, Hall's panicgrass (*Panicum hallii*), purple three-awn, hairy tridens (*Erioneuron pilusum*), cedar sedge (Carex *planostachys*), two-leaved senna (*Senna roemeriana*), mat euporbia (*Chamaesyce serpens*), and rabbit tobacco (*Evax prolifera*).

Crops consist of cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals. This vegetation type may also portray grassland associated with crop rotations.

Potential Impacts

Aquatic Environments including Bays & Estuaries

The anticipated impact of this project would be minimal influence on the variability of monthly flows but substantial reductions in quantity of median monthly flows at the project site. The minimal reduction in variability of monthly flow values would probably not have much impact on the instream biological community or riparian species. The decrease in monthly median flow values would range from 0 cfs (0 percent) in August and September to 188 cfs (26 percent) in June, as shown in Table 4.11-1. The highest reductions (>20 percent) would occur in June and October. Despite relatively large differences in median flow values, this project would have no effect on the frequency of low-flow conditions; the 65 percent exceedance value would be approximately 65 cfs without the proposed reservoir in place and 62 cfs with the proposed reservoir. The reductions in flow that would occur with this project in place may have moderate impacts on the instream biological community since the highest reductions would occur in the summer when water temperatures are high.

Because this site is in the upper portion of the watershed, there would be a greater probability of impacts in the Brazos River than with a similar-sized project further downstream where flows are higher. However, additional downstream inflows would limit the extent of such impacts from this project. Alone, this project would not be expected to have a substantial influence on freshwater inflows to the Brazos River estuary, but the cumulative impact of multiple projects may reduce freshwater inflows to the estuary. As a new reservoir without a current operating permit, the South Bend Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

Table 4.11-1. Caption Median Monthly Streamflow at South Bend Reservoir Dam

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	97.2	92.0	5.2	5%
February	125.3	117.4	7.9	6%
March	106.0	106.0	0.0	0%
April	213.7	198.3	15.5	7%
May	836.5	714.7	121.7	15%
June	729.9	541.5	188.4	26%
July	291.9	261.4	30.6	10%
August	221.4	221.4	0.0	0%
September	424.8	424.8	0.0	0%
October	294.8	215.0	79.7	27%
November	209.5	171.0	38.5	18%
December	111.6	109.0	2.5	2%

Threatened & Endangered Species

A total of 18 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4.11-2). This group includes 13 birds, two fish, one plant, and two reptile species. Six bird species federally-listed as threatened, endangered, potentially threatened or candidate for listing could occur in the project area. These include the black-capped vireo (Vireo atricapillus), golden-cheeked warbler (Dendroica chrysoparia), interior least tern (Sterna antillarum athalassos), red knot (Calidris canutus rufa), Sprague's pipit (Anthus spragueii) and whooping crane (Grus americana). The black-capped vireo and golden-cheeked warbler are potential residents who could be present in the project area during nesting season and could be affected by the proposed reservoir. The interior least tern is a potential resident who nests along braided streams and could be affected by the proposed reservoir. The red knot, Sprague's pipit, and whooping crane are all migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir. The sharpnose shiner (Notropis oxyrhincus) and smalleye shiner (Notropis buccula) are federally-listed endangered fish which potentially occur in the project area.

A search of the Texas Natural Diversity Database9 maintained by the Texas Parks and Wildlife Department (TPWD) revealed the documented occurrence of two colonial water bird rookeries within the vicinity of the proposed South Bend Reservoir (as noted on representative 7.5-minute quadrangle maps that include the project site). One rookery is located less than one mile north of the project site; the other is located within five miles east of the proposed reservoir site. These data are not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations would be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

Table 4.11-2. Table Endangered, Threatened, Candidate and Species of Concern Listed for Young and Stephens County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
		BIRDS			
American peregrine falcon	Falco peregrinus anatum	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	Falco peregrinus tundrius	Migrant throughout the state.	DL	--	Possible Migrant
Baird's Sparrow	Ammodramus bairdii	Migratory in western half of State. Shortgrass prairie with scattered low bushes.	--	--	Possible Migrant
Bald eagle	Haliaeetus leucocephalus	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Black-capped Vireo	Vireo atricapilla	Oak-juniper woodlands with a distinctive patchy aspect. Shrub and tree layer with open, grassy space and foliage to ground.	LE	E	Nesting
Golden-cheeked Warbler	Setophaga chrysoparia	Juniper-oak woodlands; dependent on mature Ashe juniper for fine long bark strips.	LE	E	Nesting
Interior least tern	Sterna antillarum athalassos	Nests along sand and gravel bars in braided streams	LE	E	Resident
Mountain plover	Charadrius montanus	Breeding nests on high plains or shortgrass prairie. Nonbreeding – shortgrass plains and bare dirt.	--	--	Migrant
Peregrine falcon	Falco peregrinus	Possible migrant. Subspecies not easily distinguishable so reference is made to species level.	DL	T	Possible Migrant

[9] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, *Element of Occurrence Records*, November 24, 2014.

Table 4.11-2. Table Endangered, Threatened, Candidate and Species of Concern Listed for Young and Stephens County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Red knot	Calidris canutus rufa	Migratory species within Texas.	PT	--	Possible Migrant
Sprague's pipit	Anthus spragueii	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Western burrowing owl	Athene cunicularia hypugaea	Open grasslands, especially prairie, plains and savanna. Nests and roosts in abandoned burrows	--	--	Resident
Whooping crane	Grus americana	Potential migrant	LE	E	Potential Migrant
FISHES					
Sharpnose shiner	Notropis oxyrhynchus	Endemic to Brazos River drainage. Found in large rivers.	LE	--	Resident
Smalleye shiner	Notropis buccula	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident
PLANTS					
Glen Rose yucca	Yucca necopina	Texas endemic; grasslands on sandy soils and limestone outcrops.	--	--	Resident
REPTILES					
Brazos water snake	Nerodia harteri	Upper Brazos River drainage; in shallow water with rocky bottom and on rocky portions of banks.	--	T	Resident
Texas Horned Lizard	Phrynosoma cornutum	Varied, sparsely vegetated uplands.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status
TPWD, 2014. Annotated County List of Rare Species –Stephens County updated 9/4/2014 and Young County updated 9/4/2014. Accessed online http://tpwd.state.tx.us/landwater/land/maps/gis/ris/endangered_species/ November 25, 2014.

USFWS, 2014. Species Lists for Young and Stephens Counties from http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action?fips=48503, accessed November 25, 2014.

Wildlife Habitat

Approximately 29,877 acres are estimated to be inundated by the reservoir. Based on TPWD's Ecological Mapping Systems of Texas data[10], the largest habitat components that would be affected include approximately 9,850 acres of mesquite shrubland, approximately 7,300 acres of floodplain hardwood forest, 3,500 acres of cropland, 1,850 acres of savanna grassland and 1,900 acres of post oak woodland. The remaining affected acreage is divided among a variety of vegetation types.

A number of vertebrate species would be expected to occur within the vicinity of the South Bend Reservoir site as indicated by county occurrence records.[11] These include 11 species of frogs and toads, seven species of turtles, 12 species of lizards and skinks, and 24 species of snakes. Additionally, 78 species of mammals could occur within the site or surrounding region[12] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

Cultural Resources

A search of the Texas Historical Commission's online database for the 2011 Regional Water Plan indicated that one historical marker for Old Donnell Mill is located within the footprint for the proposed reservoir. At least two cemeteries, the Hill Cemetery and the Peveler Cemetery, are mapped within the proposed reservoir site.

A search of the Texas Archeological Sites Atlas database indicated that approximately 700 archeological sites have been documented within or in close proximity to the proposed reservoir. In 1987-88, Texas A&M University conducted a survey of South Bend Reservoir as it was then proposed, recording 673 archeological sites. The investigators recommended that 18 percent of the prehistoric sites and 21 percent of the historic sites warranted further testing to determine their eligibility for inclusion in the National Register of Historic Places or as State Archeological Landmarks. Prior to reservoir inundation, these sites must be reassessed relative to their eligibility for inclusion in the National Register of Historic Places or as State Archeological Landmarks. Additionally, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted for any areas within the proposed reservoir that were not included in the previous survey to determine if cultural resources are present. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places or as State Archeological Landmarks. Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (Title 9, Chapter 191, Texas Natural Resource Code of 1977),

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[10] TPWD, 2014. Ecological Mapping Systems of Texas – Great Plains and Cross Timbers Ecological Areas.

[11] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," http://wfscnet.tamu.edu/tcwc/Herps_online/CountyRecords.htm accessed September 2, 2009.

[12] Davis, W.B., and D.J. Schmidly, "The Mammals of Texas – Online Edition," Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

the National Historic Preservation Act (PL96-515), and the Archeological and Historic Preservation Act (PL93-291).

Threats to Natural Resources

Threats to natural resources include lower streamflows, declining water quality, and reduced inflows to reservoirs. This project would contribute to seasonally lower streamflows downstream of the reservoir site and potentially affect water quality through decreased flows.

Agricultural Impacts

The South Bend Reservoir site contains approximately zero acres of Pasture/Hay fields and 3,034 acres of cropland. These two agricultural land uses account for roughly 10 percent of the reservoir footprint.

4.11.4 Engineering and Costing

A cost estimate for the proposed South Bend Reservoir was made in 1991. This estimate was updated for the 2011 Brazos G Regional Water Plan and now to September 2013 prices for the current plan. The cost details are shown in Table 4.11-3. The total project costs are estimated to be $504,509,000. The cost for the estimated increase in system yield of 62,100 acft/yr, translates to an annual unit cost of raw water at the reservoir of $1.73 per 1,000 gallons, or $563 per acft. The annual project costs are estimated to be $35 million; this includes annual debt service, and operation and maintenance costs.

Table 4.11-3. Cost Estimate Summary for South Bend Reservoir

Item	Estimated Costs for Facilities
Dam and Reservoir (Conservation Pool 771,604 acft, 29,877 acres)	$121,520,000
Integration, Relocations, & Other	$51,909,000
TOTAL COST OF FACILITIES	**$173,429,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$60,700,000
Environmental & Archaeology Studies and Mitigation	$102,717,000
Land Acquisition and Surveying (59,754 acres)	$105,705,000
Interest During Construction (4% for 4 years with a 1% ROI)	$61,958,000
TOTAL COST OF PROJECT	**$504,509,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$6,685,000
Reservoir Debt Service (5.5 percent, 40 years)	$26,463,000
Operation and Maintenance	
Dam and Reservoir (1.5% of Cost of Facilities)	$1,823,000
TOTAL ANNUAL COST	**$34,971,000**
Available Project Yield (acft/yr)	62,100
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	$563
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	$1.73

4.11.5 Implementation Issues

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- General Land Office Easement if State-owned land or water is involved; and,
    - Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.
    - Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
    - Wildlife habitat mitigation plan that may require acquisition and management of additional land;
    - Flow releases downstream to maintain aquatic ecosystems;and
    - Assessment of impacts on Federal- and State-listed endangered and threatened species.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

This water supply option has been compared to the plan development criteria, as shown in Table 4.11-4, and the option meets each criterion.

Table 4.11-4. Evaluations of South Bend Reservoir Option to Enhance Water Supplies

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	1. Negligible impact
2. Habitat	2. Negligible impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Negligible impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

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4.12 Throckmorton Reservoir

4.12.1 Description of Option

A potential water management strategy for the City of Throckmorton is a new reservoir located approximately 3 miles northwest of the city as shown in Figure 4.12-1. The proposed reservoir will be located on the North Elm Creek and will contain approximately 15,900 acft of conservation storage and inundate 1,161 acres at the full conservation storage level of 1,345 ft-msl. The contributing drainage area is approximately 82 square miles.

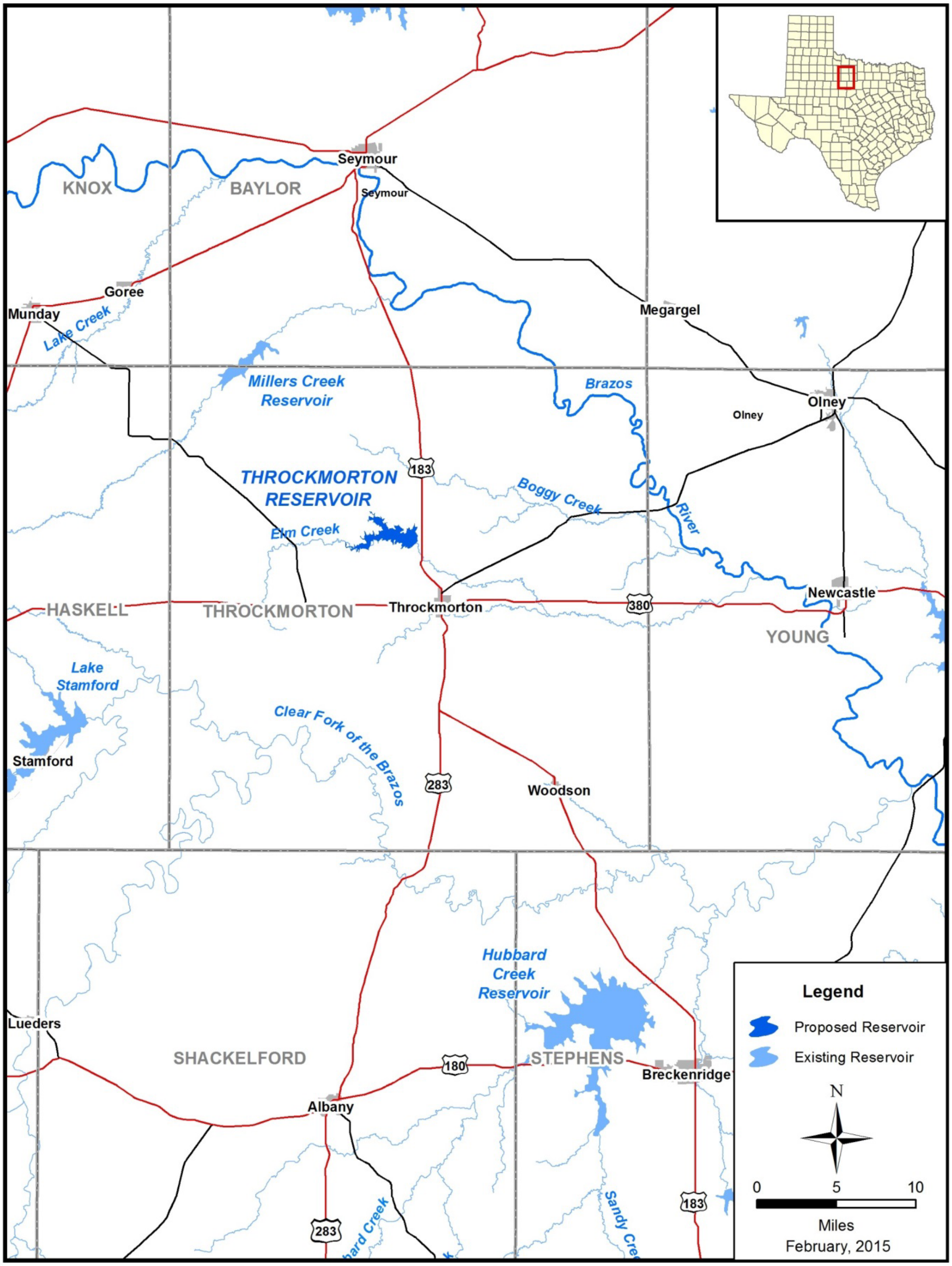
4.12.2 Available Yield

Water potentially available for impoundment in the proposed Throckmorton Reservoir was estimated using a version of the TCEQ WAM Run 3. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions associated with TCEQ WAM Run 3. The model computed the streamflow available from North Elm Creek without causing increased shortages to existing downstream rights. Safe yield was computed subject to the reservoir and North Elm Creek diversion having to pass inflows to meet environmental flow standards associated with Senate Bill 3 (SB3).

The calculated safe yield of Throckmorton Reservoir is 3,540 acft/yr, assuming subordination of Possum Kingdom Reservoir. According to the Brazos WAM, channel losses between Throckmorton Reservoir and Possum Kingdom Lake are about 18%. The firm yield of Possum Kingdom is reduced by an estimated 2,390 acft/yr. This strategy has been evaluated with a subordination agreement with BRA for Possum Kingdom Reservoir. Any subordination agreement with the BRA is dependent on the BRA being able to successfully obtain the System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. A subordination agreement would have to be negotiated and acquired for this strategy to be implemented as presented in this section.

Figure 4.12-2 illustrates the simulated Throckmorton Reservoir storage levels for the 1940 to 1997 historical period, subject to the safe yield of 3,540 acft/yr. Figure 4.12-3 shows that simulated reservoir contents remain above 80 percent capacity about 46 percent of the time and above 50 percent capacity above 84 percent of the time. Figure 4.12-4 illustrates the changes in North Elm Fork streamflows caused by impounding unappropriated water. The largest changes would be declines in median streamflow of 24 cfs during May and 21.8 cfs during June. Streamflow is reduced significantly in all months. Figure 4.12-5 also illustrates the North Elm Creek streamflow frequency characteristics with the Throckmorton Reservoir in place.

Figure 4.12-1. Throckmorton Reservoir



L:\Project_Data\00044_BrazosG\GIS\Map_Docs\Task_04_WMS\WMS_Task_04_Existing_Supplies\Throckmorton_Res.mxd

Figure 4.12-2. Throckmorton Reservoir Firm Yield Storage Trace

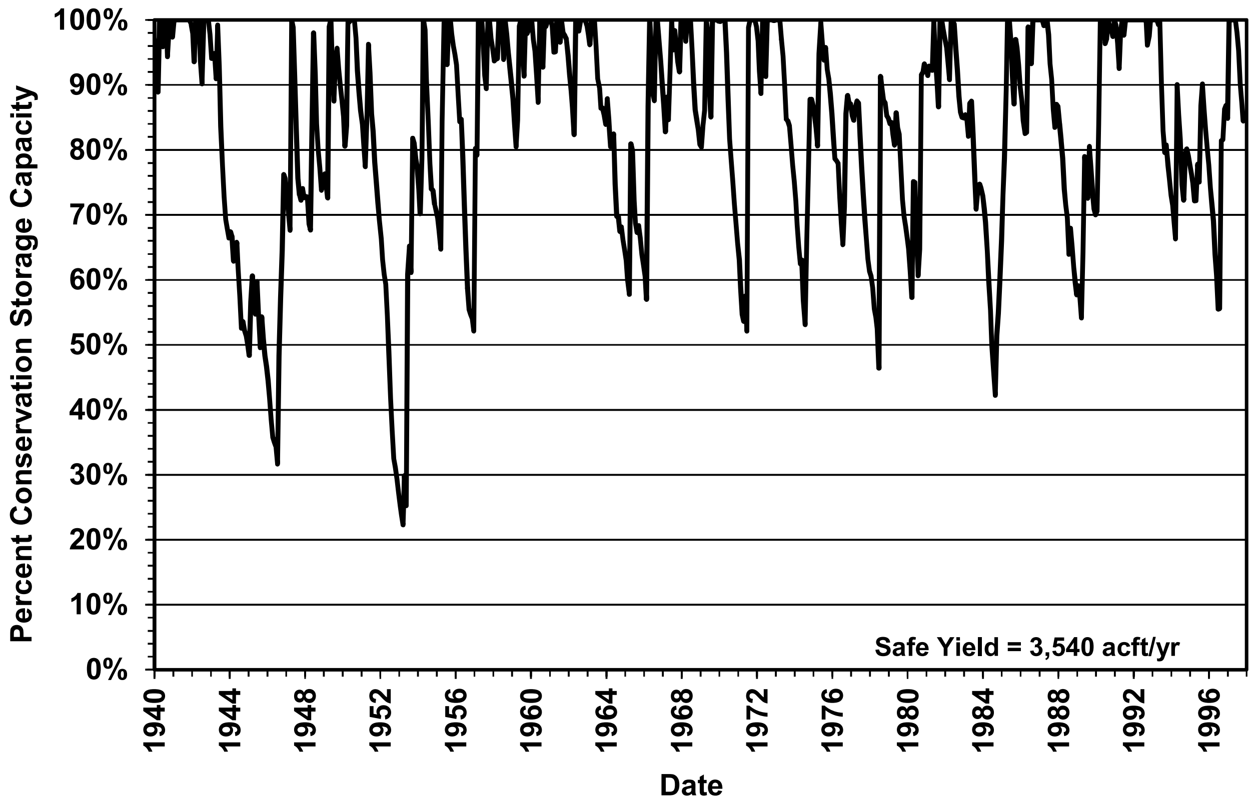


Figure 4.12-3. Storage Frequency at Safe Yield

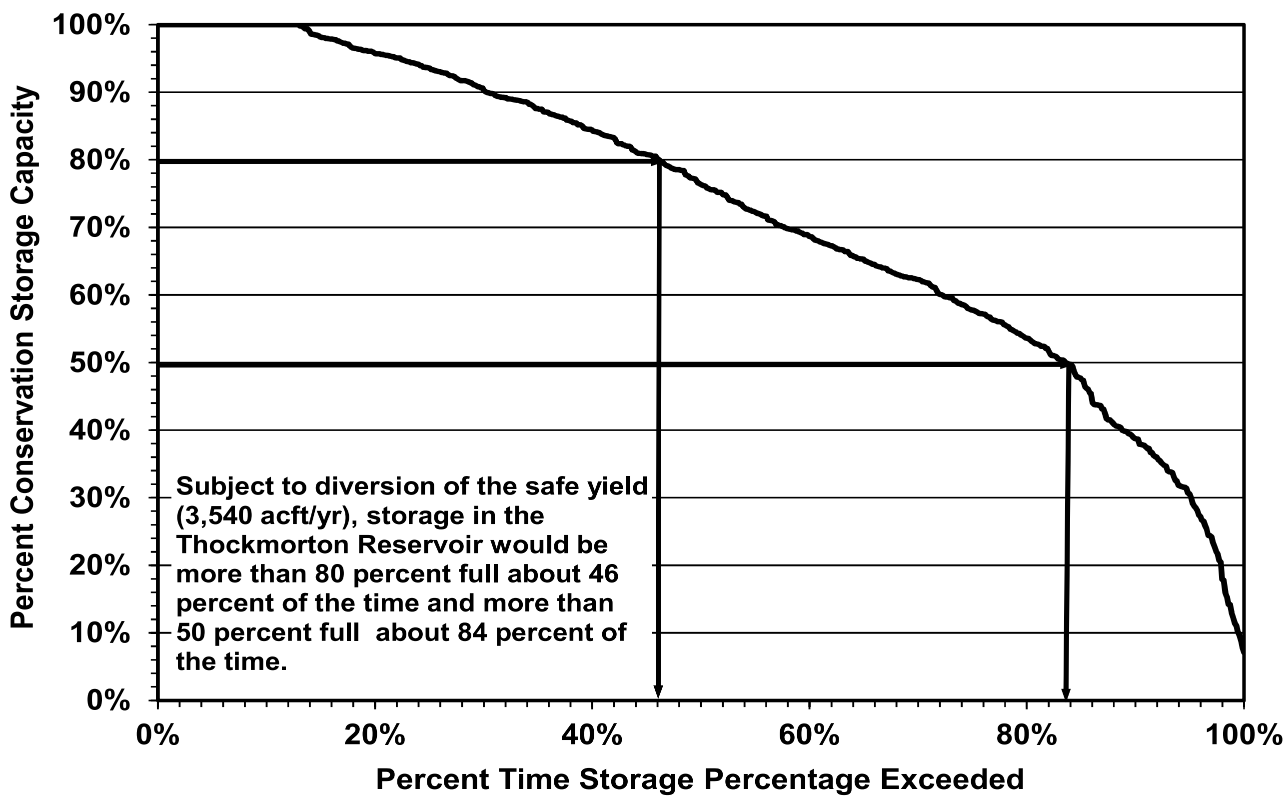


Figure 4.12-4. North Elm Fork Diversion - Median Streamflow Comparison

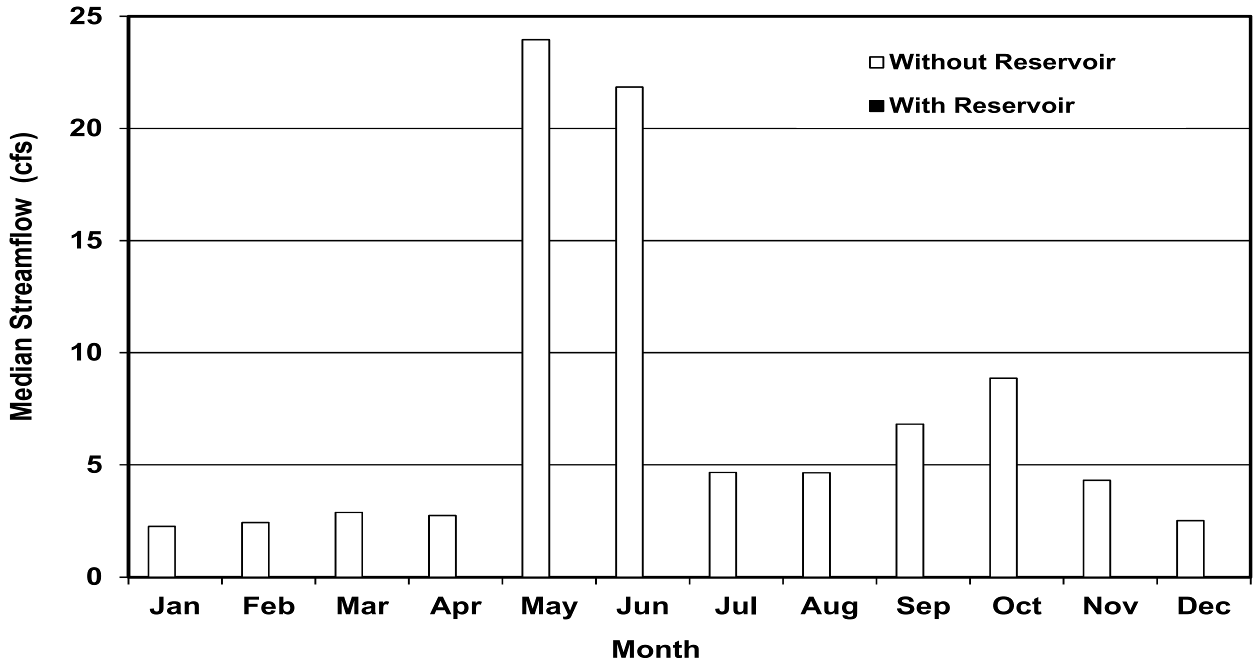
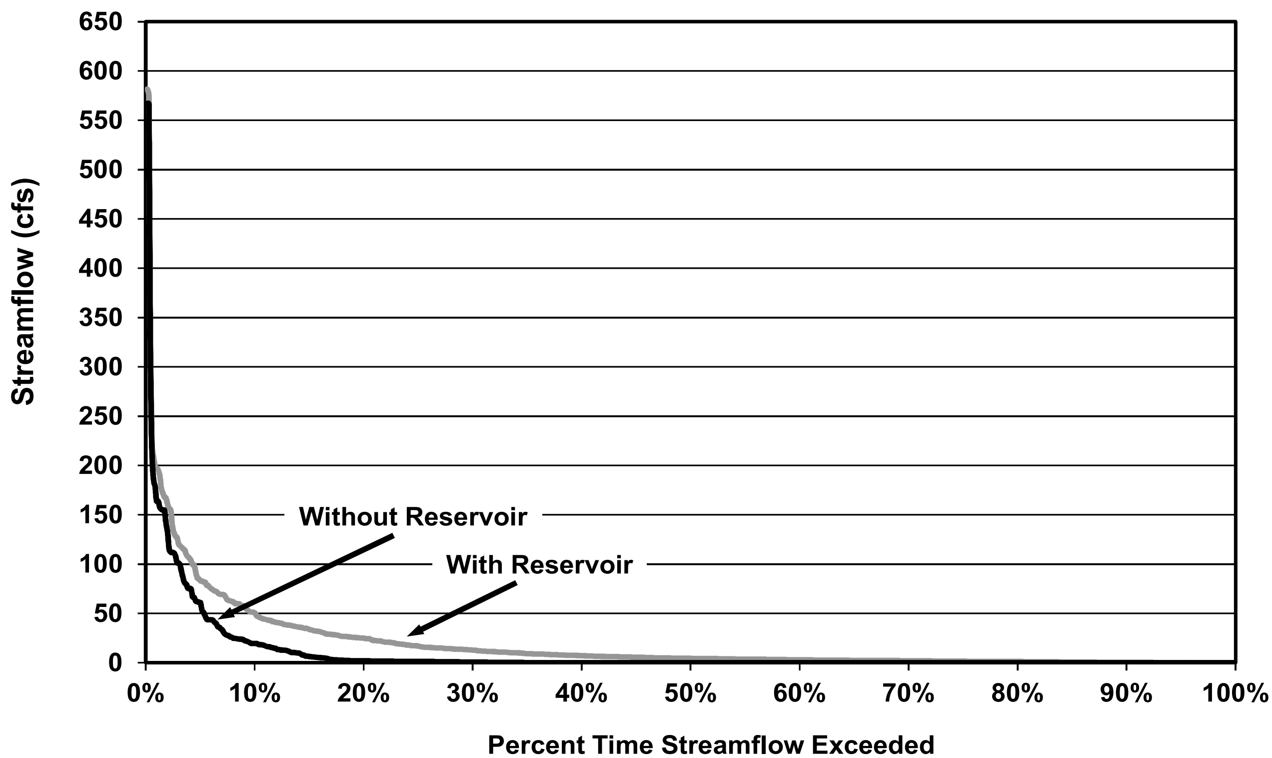


Figure 4.12-5. North Elm Fork Diversion- Streamflow Frequency Comparison



4.12.3 Environmental Issues

Existing Environment

The Throckmorton Reservoir site in Throckmorton County is within the Rolling Plains Ecological Region[1]. This region is located east of the High Plains, west of the Cross Timbers and Prairies, and north of the Edwards Plateau. It is characterized by nearly level to rolling topography, soft prairie sands and clays, and alternating woodlands and prairies. The physiognomy of the region varies from open, short to tall, scattered to dense grasslands to savannahs with bunch grasses. Most of the plains are rangeland, but cultivated crops are important in certain localities. Poor range management practices of the past have increased the density of invasive woody plant species and have decreased the value of the land for cattle production. Farming and grazing practices have also reduced the abundance and diversity of wildlife in the region[2]. The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation is approximately 27 inches.[3]

The Seymour aquifer, an unconsolidated sand and gravel aquifer, is the only major aquifer in the county, but does not underlie the proposed reservoir site.[4] The aquifer consists of Quaternary-age, alluvial sediments unconformably overlying Permian-age rocks. Water is contained in isolated patches of alluvium as much as 360 feet thick. Water ranges from fresh to slightly saline. Most of the groundwater pumped from the aquifer (about 90%) is used for irrigation, with the remainder used primarily for municipal supply.[5]

The region lies within the North-Central Plains physiographic region which includes elevations between 900 and 3,000 feet above sea level. Bedrock includes limestones, sandstones, and shales. Where shale bedrock prevails, meandering rivers traverse stretches of local prairie. In areas of harder bedrock, hills and rolling plains dominated. Local areas of hard sandstones and limestones cap steep slopes severly dissected near rivers.[6] The predominant soil types in the project area are the Clearfork silty clay loam, occasionally flooded and Lueders-Throck complex, 1-8 percent slopes, extremely stony. The Clearfork silty clay loams are very deep, well drained soils present on floodplains on draws. These soils are considered prime farmland soils. The Lueders-Throck complex soils are soils are generally found on hillslopes on ridges and are derived from gravelly residuum weathered from limestone. These soils are well drained and are not considered prime farmland. Other soils comprise a smaller portion of the project area. These include Leeray clay, 0 to 1 percent slopes, Lueders cobbly loam, 1 to 5 percent slopes, Lueders-Springcreek complex, 1 to 8 percent slopes, very stony, Nukrum clay

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[1] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, Vegetational Areas of Texas, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.
[2] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.
[3] Texas Almanac, 2008. Texas Almana 2008-2009. The Dallas Morning News Inc., Dallas, TX 2008.
[4] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.texas.gov/groundwater/aquifer/major.asp, accessed November 25, 2004.
[5] TWDB, *Seymour Aquifer*, http://www.twdb.texas.gov/groundwater/aquifer/majors/seymour.asp, accessed November 25, 2014.
[6] Wermund, E.G., *Physiographic Map of Texas*, Bureau of Economic Geology, University of Texas, Austin, Texas, 1996. Accessed online at http://www.beg.utexas.edu/UTopia/images/pagesizemaps/physiography.pdf on November 25, 2014.

loam, 1 to 3 percent slopes, Nuvalde clay loam, 0 to 1 percent slopes, Nuvalde clay loam, 1 to 3 percent slopes, Owens-Harpersville complex, 8 to 45 percent slopes, extremely bouldery, Owens-Lueders complex, 5 to 30 percent slopes, extrememly bouldery, Rowden clay loam, 0 to 2 percent slopes, Rowena clay loam, 0 to 1 percent slopes, Sagerton clay loam, moist, 1 to 3 percent slopes, Speck silty clay loam, 0 to 2 percent slopes, Springcreek clay loam, 1 to 3 percent slopes, and Throck silty clay loam, 1 to 5 percent slopes. Of these soils, approximately 46 percent are considered to be prime farmland soils.[7]

Two major vegetation types occur within the general vicinity of the proposed project: Mesquite (*Prosopis glandulosa*)–Lotebush Shrub, and crops.[8] Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Mesquite-Lotebush Shrub could include the following commonly associated plants: yucca (*Yucca* spp.), skunkbush sumac (*Rhus trilobata*), agarito (*Berberis trifoliolata*), elbowbush (*Forestiera angustifolia*), juniper, tasajillo (*Opuntia leptocaulis*), cane bluestem (*Bothriochloa barbinodis*), silver bluestem (*Bothriochloa saccharoides*), little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), Texas grama (*Bouteloua rigidiseta*), sideoats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua hirsuta*), red grama (*Bouteloua trifida*), tobosagrass (*Pleuraphis mutica*), buffalograss (*Buchloe dactyloides*), Texas wintergrass (*Nasella leucotricha*), purple three-awn (*Aristida purpurea*), Engelmann daisy (*Engellmania peristena*), broom snakeweed (*Gutierrezia sarothrae*), and bitterweed (*Hymenoxys odorata*). Crops include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

Potential Impacts

Aquatic Environments including Bays and Estuaries

The anticipated impact of this project would be minimal reduction in variability and substantial reductions in quantity of median monthly flows. The reduction in variability of monthly flow values would probably not have much impact on the instream biological community or riparian species. However, there would be a reduction in the quantity of median monthly flows downstream of the project ranging from 2.3 cfs in January to 24 cfs in May, as shown in Table 4.12-1. The highest reductions (>10 cfs) would occur in May and June, and all months would have significant reductions in flow. This project would also result in a higher frequency of low-flow conditions. Without the project, the monthly flow would be less than 0.71 cfs only 15 percent of the time (85 percent exceedance value), and would be less than 0.71 cfs 90 percent of the time with the project in place. These reductions in flow would have substantial impacts on the instream biological community, especially since the greatest reductions are predicted for

[7] Natural Resources Conservation Service, *Custom Soil Resource Report for Throckmorton County, Texas*, United States Department of Agriculture, Natural Resources Conservation Service, in cooperation with Texas Agricultural Experiment Station, November 25, 2014.
[8] McMahan, C.A., R.F. Frye, and K.L. Brown, *The Vegetation Types of Texas*, Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

the summer months when flows are already historically low and water chemistry conditions are the most stressful for aquatic species (e.g., high temperatures and high nutrient growth).

Although there would be biological impacts in the immediate vicinity of the project site and downstream, it is not likely that this project, alone, would have a substantial influence on total discharge in the Brazos River or to freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflow to the estuary. As a new reservoir without a current operating permit, the Throckmorton Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

Table 4.12-1. Median Monthly Streamflow: North Elm Creek Diversion Site

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	2.3	0.0	2.3	100%
February	2.4	0.0	2.4	100%
March	2.9	0.0	2.9	100%
April	2.7	0.0	2.7	100%
May	24.0	0.0	24.0	100%
June	21.8	0.0	21.8	100%
July	4.7	0.0	4.7	100%
August	4.7	0.0	4.7	100%
September	6.8	0.0	6.8	100%
October	8.9	0.0	8.9	100%
November	4.3	0.0	4.3	100%
December	2.5	0.0	2.5	100%

Threatened & Endangered Species

A total of 14 species potentially occur within Throckmorton County that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4.12-2). This group includes 12 birds and two fishes. The least tern (*Sterna antillarum)*, piping plover (*Charadrius melodus*), red knot (*Calidris canutus rufa*), Sprague's pipit (*Anthus spragueii*), and whooping crane (*Grus Americana*) are federally-listed threatened, endangered, candidate or potentially threatened bird species potentially occurring in the project area. The least tern is a potential resident who nests along braided streams and could be affected by the proposed reservoir. The piping plover, red knot, Sprague's pipit, and whooping crane are all migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir. The sharpnose shiner (*Notropis oxyrhincus*) is a federally-listed endangered fish potentially occur in the project area.

No documented occurrences of any state or federally listed threatened, endangered, or candidate species or species of concern were revealed within at least 2.5 miles of the proposed Throckmorton Reservoir during a search of the Texas Natural Diversity Database[9] maintained by TPWD (as noted on representative 7.5 minute quadrangle map(s) that include the project site). This data is not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

Table 4.12-2. Endangered, Threatened, Candidate and Species of Concern Listed for Palo Pinto County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
BIRDS					
American Peregrine Falcon	*Falco peregrinus anatum*	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL	--	Possible Migrant
Baird's Sparrow	*Ammodramus bairdii*	Shortgrass prairie with scattered low bushes; mostly migrant in western half of State.	--	--	Possible Migrant
Bald Eagle	*Haliaeetus leucocephalus*	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Least Tern	*Sterna antillarum*	Interior population. Nests along sand and gravel bars in braided streams	LE	E	Resident
Mountain Plover	*Charadrius montanus*	Nests on high plains or shortgrass prairie, on ground in shallow depression. Non-breeding in shortgrass plains and bare, dirt fields.	--	--	Migrant
Peregrine Falcon	*Falco peregrinus*	Possible migrant. Subspecies not easily distinguishable so reference is made to species level.	DL	T	Possible Migrant
Piping Plover	*Charadrius melodus*	Migrant shorebird in Texas.	T	--	Possible Migrant

[9] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, *Element of Occurrence Records*, November 24, 2014.

Table 4.12-2. Endangered, Threatened, Candidate and Species of Concern Listed for Palo Pinto County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Red Knot	*Calidris canutus rufa*	Migratory species within Texas.	PT	--	Possible Migrant
Sprague's Pipit	*Anthus spragueii*	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Western Burrowing Owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna, sometimes in vacant lots near human habitation. Uses abandoned burrows.	--	--	
Whooping Crane	*Grus americana*	Potential migrant	LE	E	Potential Migrant
FISHES					
Sharpnose shiner	*Notropis oxyrhynchus*	Endemic to Brazos River drainage. Found in large rivers.	LE	--	Resident
Smalleye shiner	*Notropis buccula*	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

TPWD, 2014. Annotated County List of Rare Species –Throckmorton County updated 9/4/2014.

USFWS, 2014. Species Lists from http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action?fips=48447, accessed November 18, 2014.

Wildlife Habitat

Approximately 1,160 acres are estimated to be inundated by the reservoir. Utilizing Ecological Mapping Systems of Texas data[10], the projected wildlife habitat that will be impacted includes dominantly mixed grass prairie (approximately 760 acres), mesquite shrubland (approximately 470 acres), native invasive mesquite shrubland (approximately 430 acres), floodplain herbaceous vegetation (approximately 255 acres), and row crops (approximately 250 acres). Other wildlife habitat types that would be impacted include riparian herbaceous vegetation, native invasive juniper shrubland, floodplain hardwood forest, native invasive juniper woodland, marsh and barren land.

[10] Texas Parks & Wildlife Department (TPWD), "Ecological Mapping Systems of Texas," https://drive.google.com/folderview?id=0B32g5sG2VKbgbl9oOGlneUdMZjA&usp=sharing accessed November 21, 2014.

A number of vertebrate species would be expected to occur within Throckmorton County near the proposed reservoir site including many game and non-game animals. These include 11 species of frogs and toads, 6 species of turtles, 10 species of lizards and skinks, and 24 species of snakes. Additionally, 78 species of mammals could occur within the site or surrounding region [11] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

Cultural Resources

A search of the Texas Historical Commission's online database for the 2011 Regional Water Plan identified no mapped cemeteries, historical markers, National Register of Historic Places sites or districts or State historic sites within the proposed reservoir site. A search of the Texas Archeological Sites Atlas database indicated that no archeological sites have been documented within the general vicinity of the proposed reservoir. However, the area has never been surveyed by a professional archeologist and the absence of documented sites may reflect the lack of investigation rather than the absence of archeological sites. Prior to reservoir inundation the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archeological and Historic Preservation Act (PL93-291).

Threats to Natural Resources

Threats to natural resources include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased adverse effects on stream flow below the reservoir site as a reduction in the quantity of median monthly flow is projected downstream, but the reservoir would also trap sediment and/or dilute pollutants, providing some positive benefits to water quality immediately downstream. These benefits could be offset by declines in dissolved oxygen through decreased flows and higher temperatures during summer periods. The project is expected to have negligible impacts to total discharge downstream and overall water quality in the Brazos River.

Agricultural Impacts

The Throckmorton reservoir site contains approximately 180 acres of Pasture/Hay fields and zero acres of cropland. These two agricultural land uses account for roughly 8 percent of the reservoir footprint.

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[11] Davis, W.B., and D.J. Schmidly, *The Mammals of Texas – Online Edition*, Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

4.12.4 Engineering and Costing

Construction of the Throckmorton Reservoir project will cost approximately $28 million. This includes the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $2.13 million; this includes annual debt service and operation and maintenance. The cost for the available project safe yield of 3,540 acft/yr translates to an annual unit cost of raw water of $1.85 per 1,000 gallons, or $601/acft. A summary of the cost estimate is provided in Table 4.12-3. Costs shown herein are for raw water supply at the reservoir and do not include transmission, local distribution, or treatment costs. These costs include compensation to BRA for impacts of subordination of Possum Kingdom Reservoir to Throckmorton Reservoir. Note that any subordination agreement would need to be negotiated with BRA and is dependent on the BRA successfully obtaining the System Operations permit from the TCEQ.

Table 4.12-3. Cost Estimate Summary for Throckmorton Reservoir

Item	Estimated Costs for Facilities
Dam and Reservoir (Conservation Pool 15,900 acft; 1,161 acres)	$14,970,000
TOTAL COST OF FACILITIES	**$14,970,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$5,240,000
Environmental & Archaeology Studies and Mitigation	$2,940,000
Land Acquisition and Surveying (2,322 acres)	$3,056,000
Interest During Construction (4% for 2 years with a 1% ROI)	$1,835,000
TOTAL COST OF PROJECT	**$28,041,000**
ANNUAL COST	
Reservoir Debt Service (5.5 percent, 40 years)	$1,747,000
Operation and Maintenance	
Dam and Reservoir (1.5% of Cost of Facilities)	$225,000
Purchase of Water (2.390 acft/yr @ 65.65 $/acft)	$157,000
TOTAL ANNUAL COST	**$2,129,000**
Available Project Yield (acft/yr)	3,540
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	$601
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	$1.85

4.12.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.12-4, and the option meets each criterion.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- General Land Office Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.
- Coordination with BRA on any potential subordination agreement, subject to availability under the System Operations permit.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 4.12-4. Evaluations of Throckmorton Reservoir Option to Enhance Water Supplies

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impact
2. Habitat	2. High impact
3. Cultural Resources	3. High impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Potential impact on bottomland farms and habitat in the reservoir area
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4.13 Turkey Peak Dam – Lake Palo Pinto Enlargement

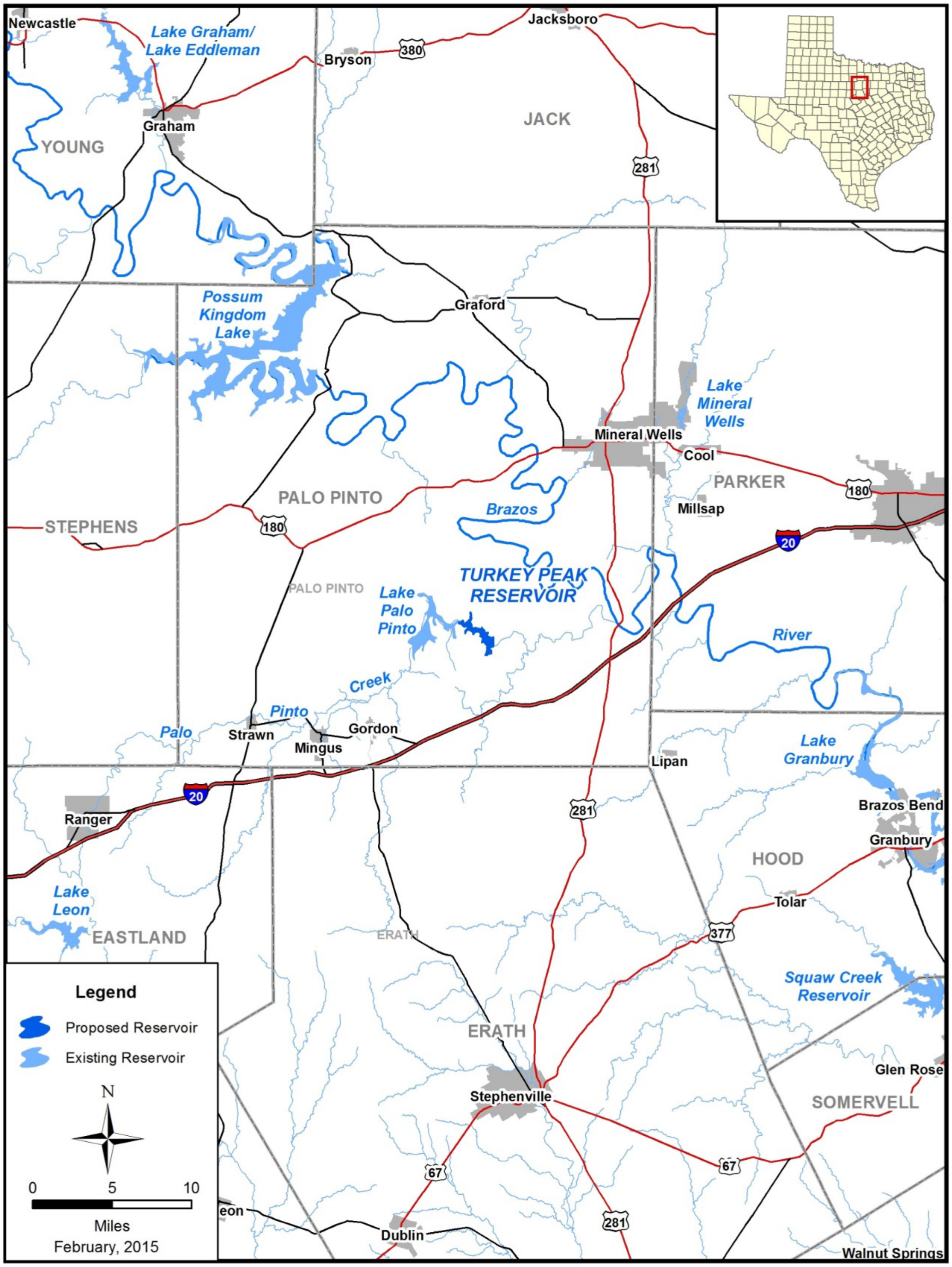
4.13.1 Description of Option

The Lake Palo Pinto dam was initially constructed in 1963 and 1964 with a conservation pool level of 863.0 feet above mean sea level (ft-msl) and deliberate impoundment began in April 1964. In 1966 the conservation storage level was raised four feet to 867.0 ft-msl. In the early 1980s, the Palo Pinto County Municipal Water District No. 1(District) became concerned about the capacity of Lake Palo Pinto and in 1985, a volumetric survey of Lake Palo Pinto was performed. This survey determined the reservoir's conservation capacity to be 27,650 acft or about 63 percent of its authorized storage. In 2007, an additional volumetric survey was performed by the Texas Water Development Board and this survey determined the reservoir's capacity to be 27,215 acft (about 62 percent of its authorized storage of 44,100 acft). Based on the June 2007 TWDB survey, Lake Palo Pinto's conservation pool currently inundates 2,176 acres at its conservation level and has an average depth of only 12.5 feet. The Turkey Peak Project project is currently being pursued by the District to recover the lost storage in Lake Palo Pinto as authorized under Certificate of Adjudication 12-4031.

The proposed Turkey Peak Project is located on Palo Pinto Creek immediately downstream of Lake Palo Pinto, as shown in Figure 4.13-1. The proposed reservoir is located approximately 2 miles northwest of the City of Santo, just upstream from the bridge over Palo Pinto Creek on FM4. The conservation capacity of Turkey Peak Project is 22,577 acft and covers 648 acres, resulting in an average reservoir depth of 35 ft.

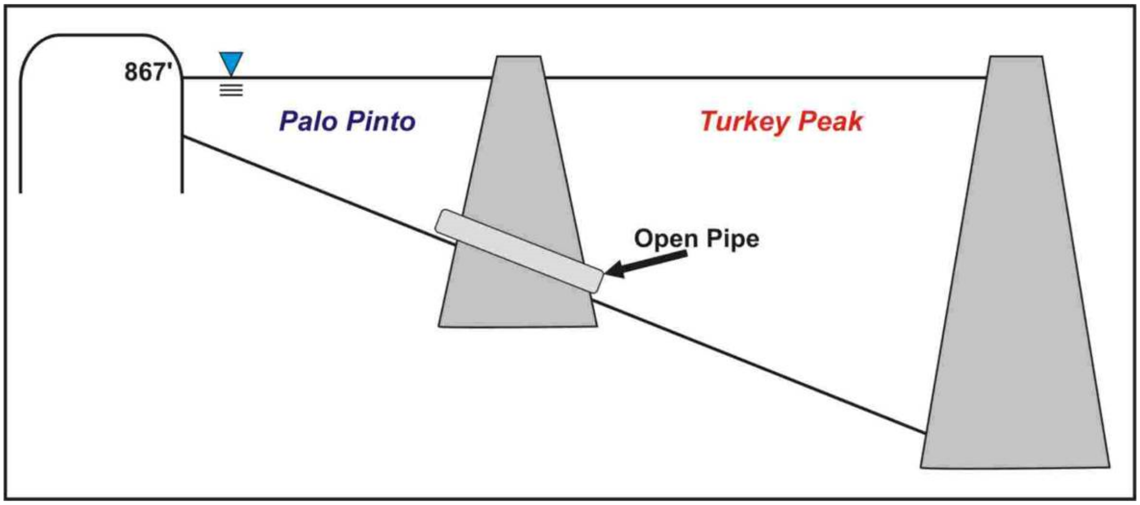
The normal pool elevation of the Turkey Peak Project will be 867 ft-msl, the same as Lake Palo Pinto. A portion of the existing dam and spillway at Lake Palo Pinto will be removed and the two reservoir pools will be connected above an elevation of 863 ft-msl. Below this elevation a pipe will connect both pools as shown in Figure and the two pools can be operated either as a single reservoir or as separate reservoirs. The combined Turkey Peak/Palo Pinto Reservoir will initially contain approximately 49,792 acft of conservation storage and inundate 2,824 acres at its conservation storage level of 867 ft-msl.

Figure 4.13-1. Location of Turkey Peak Project



L:\Project_Data\00044_BrazosG\GIS\Map_Docs\Task_04_WMS\WMS_Task_04_Existing_Supplies\Turkey_Peak_Reservoir.mxd

Figure 4.13-2. Combined Turkey Peak/Palo Pinto Reservoir



The Turkey Peak Project will increase storage by 83 percent (as compared to Lake Palo Pinto), while only inundating an additional 20 percent of the surface area of the existing Lake Palo Pinto. Because Turkey Peak Project is significantly deeper than Lake Palo Pinto, there is a 695 acre reduction (20 percent) in the surface area of the combined reservoirs when compared to raising the conservation level of Lake Palo Pinto by 5.5 feet (and storing 44,100 acft, its current permit authorization). This results in a significant reduction in reservoir evaporation between the two alternative configurations. The District selected the Turkey Peak project instead of the Lake Palo Pinto Off-Channel Reservoir project because of lower unit water costs and to avoid an endangered species (Golden-cheeked Warbler).

The District has completed feasibility and preliminary design studies of the project. Efforts are currently underway for the District to secure an amendment to their surface water permit for Lake Palo Pinto (Certificate of Adjudication 12-4031A) for the impoundment of Turkey Peak Project. A draft permit was issued by the TCEQ in March of 2015. The District is moving forward with the required permitting activities associated with a Section 404 permit of the Clean Water Act.

4.13.2 Available Yield

Water potentially available for impoundment in the proposed Turkey Peak/Palo Pinto Reservoir was estimated using the TCEQ Brazos WAM which assumes no return flows and permitted storages and diversions for all water rights in the basin. The model utilizes a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to the reservoir having to pass inflows to meet environmental flow standards associated with Senate Bill 3 (SB3).

The reservoir was modeled by combining the current storage capacity of Lake Palo Pinto (27,650 acft) with the proposed storage capacity of Turkey Peak project (22,577 acft). Because this project is being pursued to recover lost storage in Lake Palo Pinto and to increase the reliability of the supply as currently authorized by the District's Certificate of Adjudication, the additional storage provided by Turkey Peak Project was modeled at the

Lake Palo Pinto priority date of July 3, 1962, which is consistent with the draft water right permit.

The District operates using a 6-month safe yield, which for the combined project is 16,900 acft/yr. The 2070 stand-alone 6-month safe yield of Lake Palo Pinto is 8,800 acft/yr. Therefore, the additional safe yield attributed to Turkey Peak Project in 2070 is 8,100 acft/yr.

Figure 4.13-3 shoes simulated Turkey Peak/Palo Pinto Reservoir storage levels for the 1940 to 1997 historical period, subject to the 6-month safe yield demand of 16,900 acft/yr. Figure 4.13-3 illustrates the storage frequency of the combined reservoir under the same 6-month safe yield demand. Simulated contents remain full almost 20 percent of the time and above 80 percent full more than half of the time.

Figure 4.13-2. Turkey Peak/Palo Pinto Reservoir Storage Trace

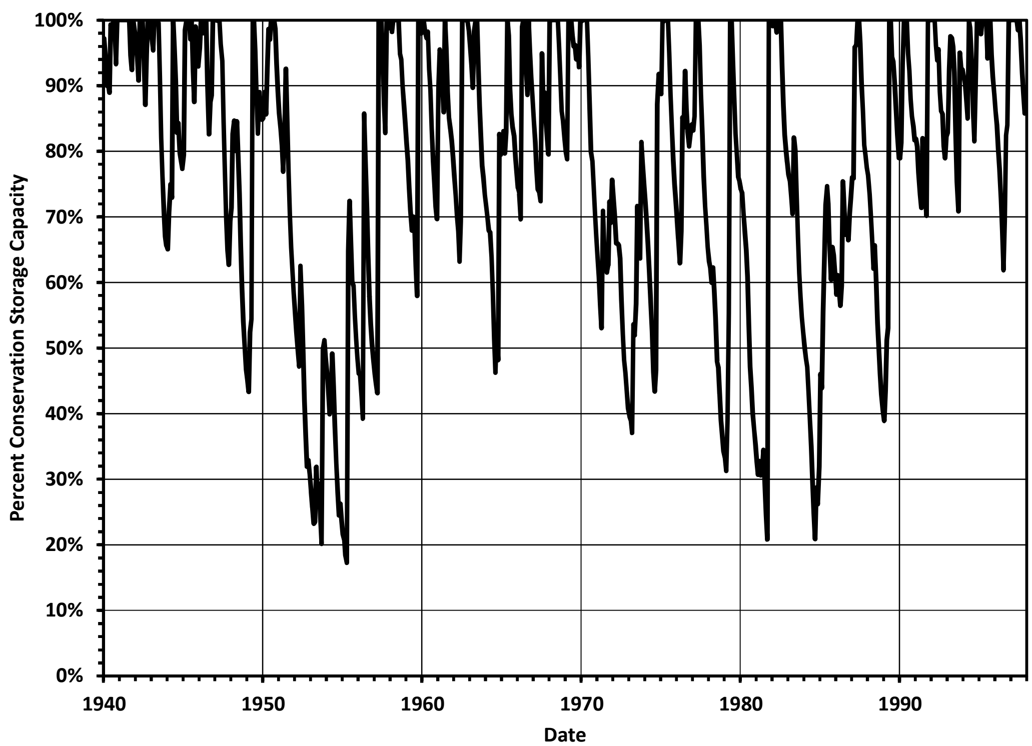
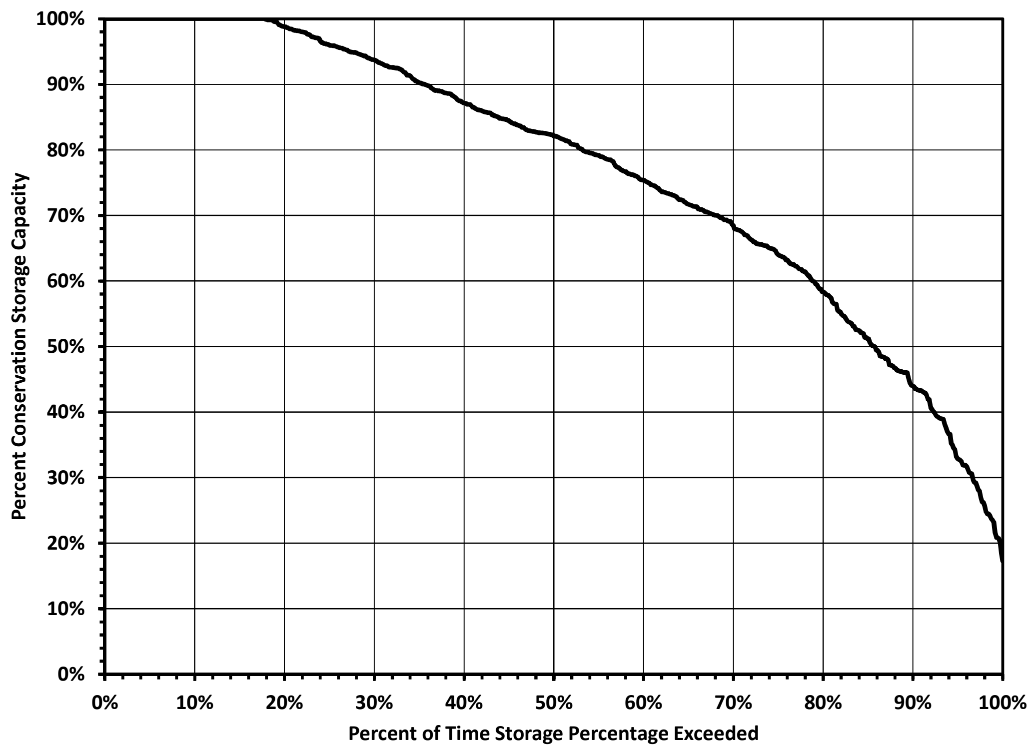


Figure 4.13-3. Turkey Peak/Palo Pinto Reservoir Storage Frequency



The draft Turkey Peak permit contains an environmental flow provision based on SB3 Brazos environmental flow standards that applies only to the diversion of water that occurs from inflows in the additional 7 square miles of drainage area captured by the new dam. However, because the District is not seeking any additional appropriation of state water in the permit, the impact of the project on the flows downstream is negligible when evaluated with the Brazos WAM.

4.13.3 Environmental Issues

Existing Environment

The Turkey Peak Project site in Palo Pinto County is within the Cross Timbers Ecoregion.1 This complex transitional area of prairie dissected by parallel timbered strips is located in north-central Texas west of the Texas Blackland Prairies Ecoregion, east of the Central Plains Ecoregion and north of the Edwards Plateau Ecoregion. The physiognomy of the Cross Timbers Ecoregion is oak and juniper woods, and mixed grass prairie. Much of the native vegetation has been displaced by agriculture and development. Range management techniques, including fire suppression, have contributed to the spread of invasive woody species and grasses within this area. Farming and grazing practices have also reduced the abundance and diversity of wildlife

[1] Griffith, G.E., Bryce, S.A., Omernik, J.M., Comstock, J.A., Rogers, A.C., Harrison, B., Hatch, S.L., and Bezanson, D., 2004, Ecoregions of Texas (color poster with map, descriptive text, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:2,3000,000).

in the region.[2] The climate within this area is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 28 and 32 inches.[3] No major or minor aquifers underlie the project area, however the Trinity Aquifer, a major aquifer consisting of interbedded sandstone, sand, limestone, and shale of Cretaceous Age, lies east and south of the project area.[4]

The physiography of the region includes hard sandstone, mud, and mudstone (undifferentiated), ceramic clay and lignite/coal, terraces, and flood-prone areas. The topography ranges from flat to rolling, and from steeply to moderately sloped, with local shallow depressions in flood-prone areas along waterways.[5] The predominant soil associations in the project area are the Bosque-Santo and Bonti-Truce-Shatruce associations. Bosque-Santo soils are deep, nearly level to gently sloping, loamy soils, typically found on flood plains. Bonti-Truce-Shatruce soils are moderately deep and deep, gently sloping to steep, loamy, stony, and bouldery upland soils.[6]

The dominant vegetation types found within the project area as mapped by the TPWD are Ashe Juniper Parks/Woods and Oak-Mesquite-Juniper Parks/Woods.[7] Variations of these primary types occur within the region, which reflect changes in the composition of woody and herbaceous species and physiognomy. Ashe Juniper Parks/Woods, which occur principally on the slopes of hills in Palo Pinto County, usually include the following commonly associated plants: live oak (*Quercus virginiana*), Texas oak (*Q. texana*), cedar elm (*Ulmus crassifolia*), mesquite (*Prosopis glandulosa*), agarito (*Mahonia trifoliolata*), tasajillo (*Opuntia leptocaulis*), western ragweed (*Ambrosia cumanensis*), scurfpea (*Psoralea* spp.), little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), Texas wintergrass (*Nasella leucotricha*), silver bluestem (*Bothriochloa saccharoides*), hairy tridens (*Erioneuron pilosum*), tumblegrass (*Schedonnardus paniculatus*), and red three-awn (*Aristida purpurea* var. *longiseta*).

Oak-Mesquite-Juniper Parks/Woods, which occur as associations or as a mixture of individual (woody) species stands on uplands, generally include the following commonly associated plants: post oak (*Q. stellata*), Ashe juniper (*Juniperus ashei*), shin oak (*Q. sinuata* var. *breviloba*), Texas oak, blackjack oak (Q. marilandica), live oak, cedar elm, agarito, soapberry (*Sapindus saponaria*), sumac (*Rhus* spp.), hackberry (*Celtis* spp.), Texas pricklypear (*Opuntia engelmannii* var. *lindheimeri*), Mexican persimmon (*Diospyros texana*), purple three-awn (*Aristida purpurea*), hairy grama (*Bouteloua*

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[2] Telfair, R.C., “Texas Wildlife Resources and Land Uses,” University of Texas Press, Austin, Texas, 1999.

[3] Larkin, T.J., and G.W. Bomar, “Climatic Atlas of Texas,” Texas Department of Water Resources, Austin, Texas, 1983.

[4] Texas Water Development Board (TWDB), Major and Minor Aquifers of Texas; Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.

[5] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., “Land Resources of Texas.” Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.

[6] Moore, J.D., *Soil Survey of Palo Pinto County, Texas*, United States Department of Agriculture, Soil Conservation Service, in cooperation with Texas Agricultural Experiment Station, 1981.

[7] McMahan, C.A., R.F. Frye, and K.L. Brown, “The Vegetation Types of Texas,” Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

hirsuta), Texas grama (*B. texana*), curly mesquite (*Hilaria belangeri*), and Texas wintergrass (*Nassella leucotricha*).

Potential Impacts

Aquatic Environments including Bays & Estuaries

Currently there is no requirement for pass throughs of environmental flows from Lake Palo Pinto. However the draft permit issued by TCEQ for the Turkey Peak project would assure base flows in Palo Pinto Creek as base flow requirements between 1 and 4 cfs are included in the draft permit in accordance with recently adopted TCEQ environmental flow requirements. Therefore only minimal differences in streamflow frequencies in Palo Pinto Creek are anticipated. This project will not have a substantial influence on total discharge in downstream locations on the Brazos River including freshwater inflows to the Brazos River estuary.

Threatened & Endangered Species

A total of 20 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4.13-1). This group includes two reptiles, eleven birds, three mammals, one mollusk, and three fish species. Inclusion in this table does not mean that a species will occur within the study area but only acknowledges the potential for its occurrence in Palo Pinto County. On-site evaluations by qualified biologists are required to confirm the occurrence of sensitive species or habitats.

The Migratory Bird Treaty Act protects most bird species, including, but not limited to, cranes, ducks, geese, shorebirds, hawks, and songbirds. Migratory bird pathways, stopover habitats, wintering areas, and breeding areas may occur within and adjacent to the project area, and may be associated with wetlands, ponds, shorelines, riparian corridors, fallow fields and grasslands, and woodland and forested areas. Although reservoir construction would remove some habitats utilized by certain migratory bird species, it would create more habitats for others. It is anticipated that the reservoir would reach its full capacity in one to three years. This transition from terrestrial to aquatic habitat would allow time for migratory species to acclimate to the altered condition within the project area and movement of non-aquatic species to similar areas nearby.

Four bird species federally listed as threatened or endangered may occur in the project vicinity. These include the black-capped vireo (*Vireo atricapillus*), golden-cheeked warbler (*Dendroica chrysoparia*), interior least tern (*Sterna antillarum athalassos*), and whooping crane (Grus americana). These bird species are all seasonal migrants that could pass through the project area. The black-capped vireo only nests in dense underbrush in semi-open woodlands having distinct upper and lower stories. The interior least tern typically nests on bare or sparsely vegetated areas associated with streams or lakes, such as sand and gravel bars, beaches, islands, and salt flats. Unvegetated bars within wide river channels or open flats along lake or reservoir shorelines are preferred and provide nesting habitat and access to adjacent open water for foraging for this tern. The main whooping crane flock nests in Canada and migrates annually to their wintering grounds in and around the Aransas National Wildlife Refuge near Rockport on the Texas coast. Whooping cranes occasionally utilize wetlands as an incidental rest stop during this migration. Habitat elements particularly attractive to the black-capped vireo, interior least tern, and whooping crane do not appear to be present on or adjacent to the proposed reservoir site, although migrants are possible.

The golden-cheeked warbler is the only federally-listed avian species with potential to utilize the proposed reservoir site for nesting. Juniper-oak woodlands found on canyon slopes may provide the isolated woodland habitat of deciduous oaks and mature junipers required by this migratory songbird. A detailed field survey for this species was conducted by qualified personnel in March–May 2006, and no sightings or detections of the warbler were documented.[8] This survey and habitat assessment concluded that the Turkey Peak study area lacked the appropriate habitat for the golden-cheeked warbler, and that the Turkey Peak Project area was not likely to support this species.[9]

Avian species listed by the State of Texas as endangered or threatened include the peregrine falcon (*Falco peregrinus*) and bald eagle (*Haliaeetus leucocephalus*). The peregrine falcon includes two subspecies which migrate across the state from more northern breeding areas in the U.S. and Canada to winter along the coast. Bald eagles are listed as threatened in Texas and occur as winter migrants. The majority of nesting bald eagle pairs currently reported are found along major rivers and near reservoirs in eastern Texas. Bald eagles are opportunistic predators, feeding primarily on fish captured in the shallow water of both lakes and streams or scavenged food sources. These birds may utilize tall trees near perennial water as roosting or nesting sites. Although the bald eagle could use either Lake Palo Pinto or Possum Kingdom Reservoir for foraging or nesting, the species has not been reported in the region. It is not expected that either bird species would be directly affected by the proposed reservoir construction at the Turkey Peak site.

The Texas horned lizard (*Phrynosoma cornutum*), Texas fawnsfoot mussel (*Truncilla macrodon*), and Brazos water snake (*Nerodia harteri*), all state threatened species, and the plains spotted skunk (*Spilogale putorius interrupta*), a species of concern, are possible inhabitants of the reservoir site or its adjacent upland pastures. Texas horned lizards inhabit deserts and grasslands in semi-arid to arid landscapes with sparse vegetation and gravelly soils. Their habitat must contain a stable population of harvester ants, the primary prey of the horned lizard, which make up the majority of its diet. Patchy environments that contain bare areas mixed with patches of vegetation are ideal to attract harvester ants and Texas horned lizards. This species could be displaced within the areas that will be gradually inundated. Relocation would then be possible into similar and acceptable habitat available adjacent to the project area.

Several species of freshwater mussels including the Texas fawnsfoot (*Truncilla macrodon*) have been listed as threatened by the state of Texas. This species is currently considered a candidate by the USFWS. The Texas fawnsfoot has been documented within the Brazos River Basin although it is generally thought to prefer large to medium streams or rivers which are not representative of Palo Pinto Creek. No Texas

[8] Ladd, Clifton and Amanda Aurora. Endangered Species Survey Summary for the Golden-Cheeked Warbler. Loomis Austin, 2006.

[9] Ibid.

fawnsfoot specimens (live or dead) were identified during mussel surveys conducted in 2009 of the project reach downstream of the existing Lake Palo Pinto dam.

The Brazos water snake (Nerodia harteri) is limited in range to the Brazos River drainage, and is usually found in riffle areas along the riverbank. Possible suitable habitat for this species occurs along Palo Pinto Creek within the reservoir area; however, comparable habitat occurs downstream of the proposed dam site. Occurrences of the endemic Brazos water snake have been documented by TPWD near Palo Pinto Creek. Surveys for the Brazos water snake along Palo Pinto Creek within the Turkey Peak Project site and downstream were undertaken in 2009 and there were no sightings of this species. Adverse impacts to this snake are not anticipated as it has been documented to persist along rocky shorelines in reservoirs, such as in Possum Kingdom.

The plains spotted skunk (*Spilogale putorius interrupta*) is generally found in open fields, prairies, and croplands. Vegetation within the project area generally consists of moderately dense mixed deciduous woodlands in the canyons, with pastures or pecan orchards in the floodplains. It is expected that if the plains spotted skunk is present in the project area, the gradual transition to an aquatic system could displace these species. However, the project area is rural, and similar suitable habitats exist adjacent to the project area; therefore, it is anticipated that the spotted skunk could relocate to those areas if necessary.

The gray wolf (*Canis lupus*) and red wolf (*Canis rufus*) are two state and federally listed endangered mammals which historically lived in Palo Pinto County. These two species are now considered to be extinct within this region of the state.

The sharpnose shiner (*Notropis oxyrhynchus*) and the smalleye shiner (*Notropis buccula*) are two small, slender minnows endemic to the Brazos River Basin that are federally listed as endangered. Historically, these sympatric fish existed throughout the Brazos River and several of its major tributaries. The population of each species within the Upper Brazos River drainage which occurs upstream of Possum Kingdom Reservoir is apparently stable, while the population within the middle and lower segments of the Brazos River Basin may exist only in remnant areas of suitable habitat. General habitat associations for both species include relatively shallow water of moderate currents flowing through broad and open sandy channels. Typical habitat is similar for both species and includes the often saline and turbid water of the Upper Brazos River. The last documented occurrence of the smalleye shiner within the lower segment of the Brazos River was recorded near the confluence of Palo Pinto Creek and the Brazos River in 1953. The stored water released from the existing Lake Palo Pinto is fresh and does not provide the saline water quality conditions needed by both species. Additionally, the existing channel dam constructed in the mid 1960's would likely restrict upstream movement of these minnows. The study area lies downstream of any recently recorded occurrences for these species; therefore the occurrence of either cyprinid species is unlikely.

Information received from the TPWD Texas Natural Diversity Database[10] revealed no documented occurrences of endangered or threatened species within or near the

[10] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, Received 10/04/2014.

proposed Turkey Peak Project. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area.

Based on the lack of suitable habitat for listed endangered or threatened species, the degree of previous land modification, and the anticipated gradual transition of the area into an aquatic system, this project is unlikely to have an adverse effect on any listed threatened or endangered species.

Wildlife Habitat

Palo Pinto County is included in the Texan Biotic Province as delineated by Blair and modified by TPWD. [11] This province includes bands of prairie and woodland that begin in South Central Texas and run north to Kansas. The Texan Biotic Province constitutes a broad ecotone between the forests in the eastern portion of this region and the western grasslands. Although varied, the vertebrate community within the area of the proposed reservoir includes no true endemic species. The wildlife habitat types of the study area coincide closely with the major plant community types present. The mountains and associated vegetation areas within Palo Pinto County are similar to that of the Edwards Plateau; therefore the wildlife habitats and species of the study area represent a mixture of those typical of the surrounding areas.

Within this province, western species tend to encroach into open habitats, and eastern species intrude along the many wooded drainageways extending through the landscape. Mammals typical of this province include the Virginia opossum (*Didelphis virginiana*), eastern mole (*Scalopus aquaticus*), fox squirrel (Sciurus niger), Louisiana pocket gopher (*Geomys breviceps*), fulvous harvest mouse (*Reithrodontomys fulvescens*), white-footed mouse (*Peromyscus leucopus*) and swamp rabbit (*S. aquaticus*). Animals typical of grasslands of this province include the thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), hispid pocket mouse (*Chaetodipus hispidus*), and black-tailed jackrabbit (*Lepus californicus*).

Typical anuran species to the Texan Biotic Province include the Hurter's spadefoot (*Scaphiopus holbrookii hurteri*), Gulf Coast toad (*Bufo valliceps*), green treefrog (*Hyla cinerea*), bullfrog (*Rana catesbeiana*), southern leopard frog (*Rana sphenocephala*) and eastern narrowmouth toad (*Microhylla carolinensis*).

According to TPWD geographic information system (GIS) data, 84 percent of the habitat which will be inundated by the project includes forest or woodland areas, 6 percent is grassland, approximately 4 percent is shrubland, and the remaining 6 percent includes herbaceous vegetation, open water and urban areas.[12]

Cultural Resources

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National

[11] Blair, W. Frank. 1950. “The Biotic Provinces of Texas,” Texas Journal of Science 2 (1):93-117, modified by TPWD GIS lab.

[12] TPWD. 2014. Texas Ecological Systems GIS mapping layers.

Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available GIS datasets provided by the Texas Historical Commission (THC), there are no National Register Properties, National Register Districts, State Historic Sites, cemeteries or historical markers located within or near the reservoir project area. The owner or controller of the project would be required to coordinate with the Texas Historical Commission regarding potential impacts to cultural resources.

The Texas Archeological Sites Atlas online database of the Texas Historical Commission (THC) was also consulted and background research was conducted to determine any previous cultural resources survey efforts as well as the locations of previously recorded historic and archaeological resources in the project area. Records indicate that eight previously recorded prehistoric archaeological sites were located within a 1-mile radius of the reservoir area.

In addition a Phase IA cultural resource assessment was conducted for the proposed development of the Turkey Peak Project site in January 2009. This research revealed that there were no previously documented archeological sites found within the proposed reservoir area. Phase 1B surveys, including trenching at selected alluvial terrace locations, were initiated in 2010. The findings of the Phase 1B surveys were provided to the USACE and THC in support of Section 404 Permit coordination in accordance with the requirements of Section 106 of the National Historic Preservation Act (NHPA). The District will also coordinate the findings of the archeological surveys with the THC and TCEQ in conjunction with the review of the project under the Antiquities Code of Texas.

The Phase 1B investigations recorded two prehistoric localities, 13 prehistoric sites, and one historic site. Nine sites are recommended for further testing to determine eligibility for listing in the National Register of Historic Places (NRHP) and designation as a State Archeological Landmark (SAL). Five sites are recommended as not eligible for NRHP listing or SAL designation. The evaluation of the pre-historic and historic resources in the area of potential effect of the reservoir will be conducted and documented in accordance with standard practices for determination of NRHP and SAL eligibility and mitigation measures will be implemented, if necessary.

Threats to Natural Resources

The Turkey Peak Project will have little adverse effect on stream flow below the reservoir site and will meet TCEQ environmental flow requirements included in the water rights permit. In addition the reservoir would trap and/or dilute pollutants, providing some positive benefits to water quality immediately downstream. Dissolved oxygen levels on Palo Pinto Creek are expected to be slightly improved as the project includes plans to construct a multi-level outlet tower which will always release water to Palo Pinto Creek from the top 10 to 15 feet of the reservoir pool. Current conditions include an existing outlet pipe at Lake Palo Pinto at a fixed elevation of 835 ft-msl which is 32 feet below conservation level. The project is expected to have negligible impacts to total discharge downstream and overall water quality in the Brazos River or Brazos River estuary.

Agricultural Impacts

The Turkey Peak Reservoir site does not contain Pasture/Hay fields or cultivated cropland. No impacts are expected for agricultural land use.

Table 4.13-1. Endangered, Threatened, Candidate and Species of Concern Listed for Palo Pinto County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
		BIRDS			
American peregrine falcon	*Falco peregrinus anatum*	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Black-capped vireo	*Vireo atricapilla*	Prefers oak-juniper woodlands with distinctive patchy, two-layered aspect; shrub and tree layer with open, grassy spaces.	LE	E	Possible Migrant
Golden-cheeked warbler	*Setophaga chrysoparia*	Prefers juniper-oak woodlands with Ashe juniper for nesting.	LE	E	Possible Migrant
Interior least tern	*Sterna antillarum athalassos*	Nests along sand and gravel bars in braided streams	LE	E	Possible Migrant
Mountain plover	*Charadrius montanus*	Non-breeding, shortgrass plains and fields	--	--	Nesting/ Migrant
Piping plover	*Charadrius melodus*	A small pale shorebird of open sandy beaches and alkali flats, the Piping Plover is found along the Atlantic and Gulf coasts.	LT	T	Possible Migrant
Sprague's pipit	*Anthus spragueii*	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Western burrowing owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna	--	--	Resident

Table 4.13-1. Endangered, Threatened, Candidate and Species of Concern Listed for Palo Pinto County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Whooping crane	*Grus americana*	Potential migrant	LE	E	Potential Migrant
		FISHES			
Guadalupe bass	*Micropterus treculii*	Endemic to perennial streams of the Edward's Plateau region.	--	--	Resident
Sharpnose shiner	*Notropis oxyrhynchus*	Endemic to Brazos River drainage. Found in large rivers.	LE	--	Resident
Smalleye shiner	*Notropis buccula*	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident
		MAMMALS			
Gray wolf	*Canis lupus*	Extirpated formerly known in western two-thirds of the state.	LE	E	Historic Resident
Plains spotted skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	Extirpated.	LE	E	Historic Resident
		MOLLUSKS			
Texas fawnsfoot	*Truncilla macrodon*	Found in rivers and larger streams, intolerant of impoundment.	C	T	Resident
		REPTILES			
Brazos water snake	*Nerodia harteri*	Found in upper Brazos River drainage in shallow water with rocky bottoms.	--	T	Resident

Table 4.13-1. Endangered, Threatened, Candidate and Species of Concern Listed for Palo Pinto County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
PT=Proposed Threatened
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

TPWD, 2015. Annotated County List of Rare Species –Palo Pinto County 9/4/2014.

USFWS, 2015. Endangered Species List for Palo Pinto County, Texas. At http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action, February 19, 2015.

4.13.4 Engineering and Costing

Cost estimates for the Turkey Peak/Palo Pinto Reservoir were originally prepared by HDR, Inc. in 2013 as part of a preliminary design study and those costs were updated for this study to reflect current September 2013 costs. The capital cost, approximately $48.3 million, are associated with the relocation of FM 4, the construction of a new bridge and road at the existing dam and spillway at Lake Palo Pinto and the construction of the new dam and spillways along with modifications to the existing dam and spillway. The total project cost is approximately $91.4 million (Table 4.13-2). This includes the costs for construction, land acquisition, resolution of conflicts, environmental permitting and mitigation, engineering, mapping and surveying, utility relocations, design, TxDOT plan review, and construction phase services. However, the District has already financed approximately $8 million in preliminary engineering studies and legal assistance associated with permit acquisitions. Therefore, the total remaining project costs are estimated to be $83.4 million. The 6-month safe yield of 8,100 acft/yr from the project would provide raw water to the District at a unit cost of $749 per acft or $2.30 per 1,000 gallons.

Table 4.13-2. Cost Estimate for Turkey Peak Project

Item	Estimated Costs for Facilities
Capital Cost	
Dam and Reservoir	$48,257,000
Integration, Relocation, & Other	$8,622,000
Total Cost Of Facilities	**$48,256,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$16,890,000
Environmental & Archaeological Studies and Mitigation	$8,767,000
Fees Paid by District for Completed Studies and Legal Assistance	($8,000,000)
Land Acquisition and Surveying (9,978 acres)	$8,767,000
Interest During Construction (4% for 3 years with a 1% ROI)	$8,683,000
Total Remaining Cost Of Project	**$83,363,000**
Debt Service (5.5 percent, 20 years)	$1,076,000
Reservoir Debt Service (5.5 percent, 40 years)	$4,394,000
Operation and Maintenance	
Dam and Reservoir	$595,000
Pumping Energy Costs ($0.09 kwh)	$0
Total Annual Cost	**$6,065,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**8,100**
Annual Cost of Water ($ per acft)	**$749**
Annual Cost of Water ($ per 1,000 gallons)	**$2.30**

4.13.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.13-3, and the option meets each criterion.

The District is actively implementing this project with plans showing construction beginning in 2017-2018. A summary of the planned implementation steps for the project follows.

- Complete on going geotechnical investigations required for final design.
- Complete final design of the project.
- Initiate and complete land acquisition for the project.
- Receive all necessary permits required for construction.

- Secure additional state funding to implement the project.
- Begin construction of the project.

Potential Regulatory Requirements:

- Finalize the Texas Commission on Environmental Quality Water Right and Storage permits;
- Finalize the U.S. Army Corps of Engineers Permit for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- Texas General Land Office Easement if State-owned land or water is involved; and
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions or other local landowner agreements;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 4.13-3. Comparison of Turkey Peak Project to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Low impact due to distance from coast
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	Low to none
D. Threats to Agriculture and Natural Resources	Low to none
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

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4.14 Peach Creek Off-Channel Reservoir

4.14.1 Description of Option

The proposed Peach Creek Off-Channel Reservoir (OCR) is located on Peach Creek, a tributary of the Navasota River in the Brazos County, about 10 miles southeast of the Bryan-College Station area (Figure 4.14-1). The total reservoir storage capacity at a normal pool elevation of 240 feet-msl is 14,641 acft and the reservoir will inundate approximately 1,045 acres of land. The contributing drainage area is approximately 17 square miles. The project is proposed with a diversion from the Navasota River through a 60-inch pipeline and 1,400 HP pump station with a 100 cfs capacity to supplement local runoff from the Peach Creek watershed. The Navasota River diversion has a drainage area of 1,933 square miles. The reservoir is a potential source of water supply for Brazos County.

4.14.2 Available Yield

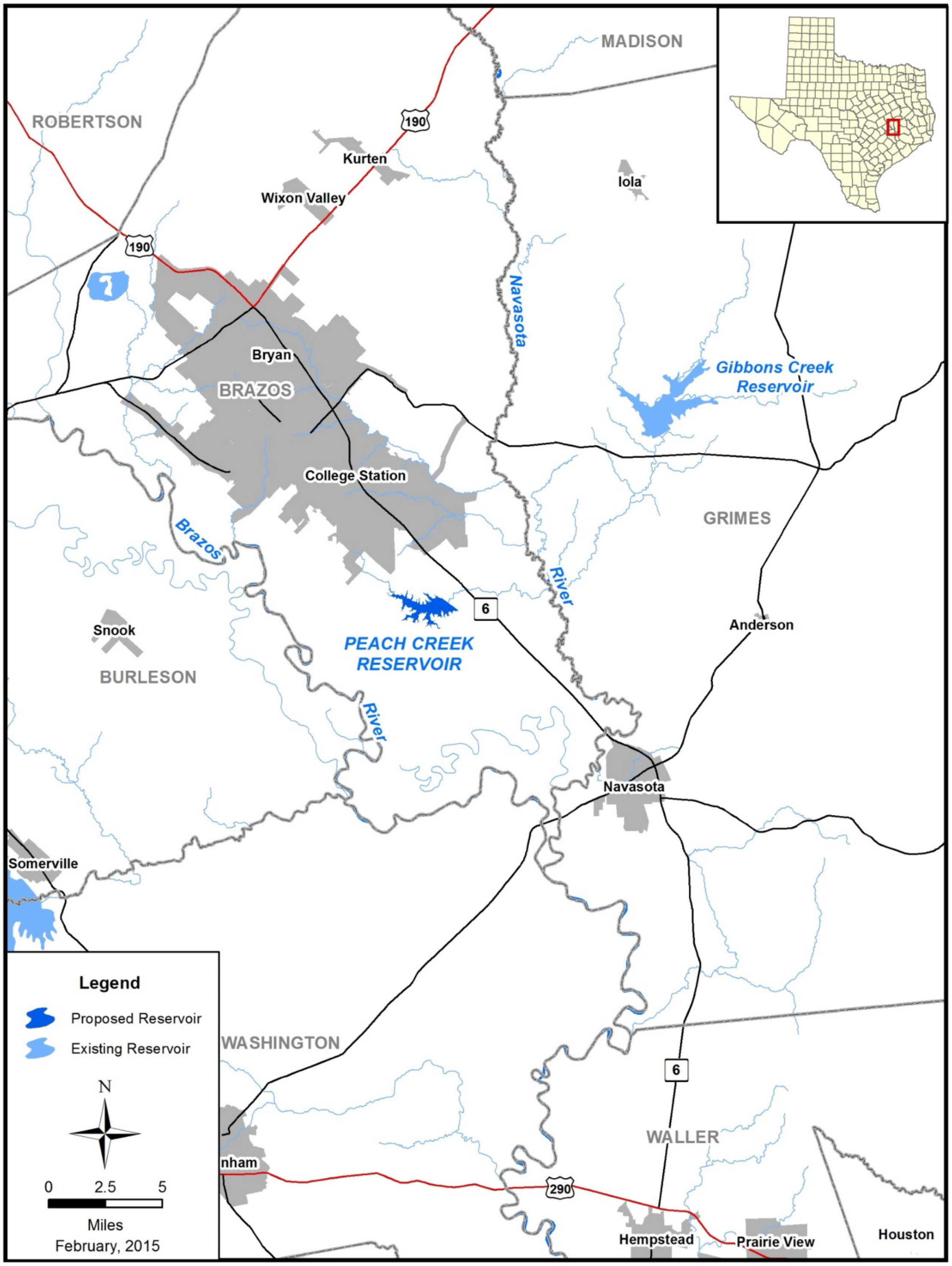
Water potentially available for impoundment in the proposed Peach Creek OCR was estimated using the TCEQ Brazos WAM Run 3 which assumes no return flows and permitted storages and diversions for all water rights in the basin. The model utilizes a January 1940 through December 1997 hydrologic period of record. The model computed the streamflow available for diversion from the Navasota River into the Peach Creek OCR without causing increased shortages to downstream rights. Firm yield was computed subject to the reservoir and Navasota River diversion having to pass inflows to meet environmental flow standards associated with Senate Bill 3 (SB3).

The calculated firm yield of the Peach Creek OCR is 4,240 acft/yr. This yield is obtained by assuming that unappropriated flows in the Navasota River are available for pumping at a maximum rate of 100 cfs through a 60-inch diameter pipeline. The firm yield of the reservoir may increase if water is purchased from Lake Limestone to supplement local runoff with a larger pumping capacity. The 2011 Region G plan also reported a firm yield of 4,240 acft/yr.

Figure 4.14-2 illustrates the simulated Peach Creek OCR storage contents for the 1940 to 1997 historical period, subject to the firm yield of 4,240 acft/yr and based on delivery of Navasota River diversions via a 60-inch pipeline. Figure 4.14-3 shows the storage frequency associated with firm yield. Simulated reservoir contents remain above 80 percent capacity about 80 percent of the time and above 50 percent capacity about 95 percent of the time.

Figure 4.14-4 and Figure 4.14-5 illustrate the changes in Peach Creek and Navasota River streamflows caused by the project. There is about a 50 percent reduction in median streamflows in Peach Creek and minimal changes in the Navasota River streamflow due to the project. Figure 4.14-6 and Figure 4.14-7 illustrate the streamflow frequency characteristics with the Peach Creek Reservoir in place.

Figure 4.14-1. Peach Creek Off-Channel Reservoir



L:\Project_Data\00044_BrazosG\GIS\Map_Docs\Task_04_WMS\WMS_Task_04_Existing_Supplies\Peach_Creek_Reservoir.mxd

Figure 4.14-2. Peach Creek Off-Channel Reservoir Firm Yield Storage Trace

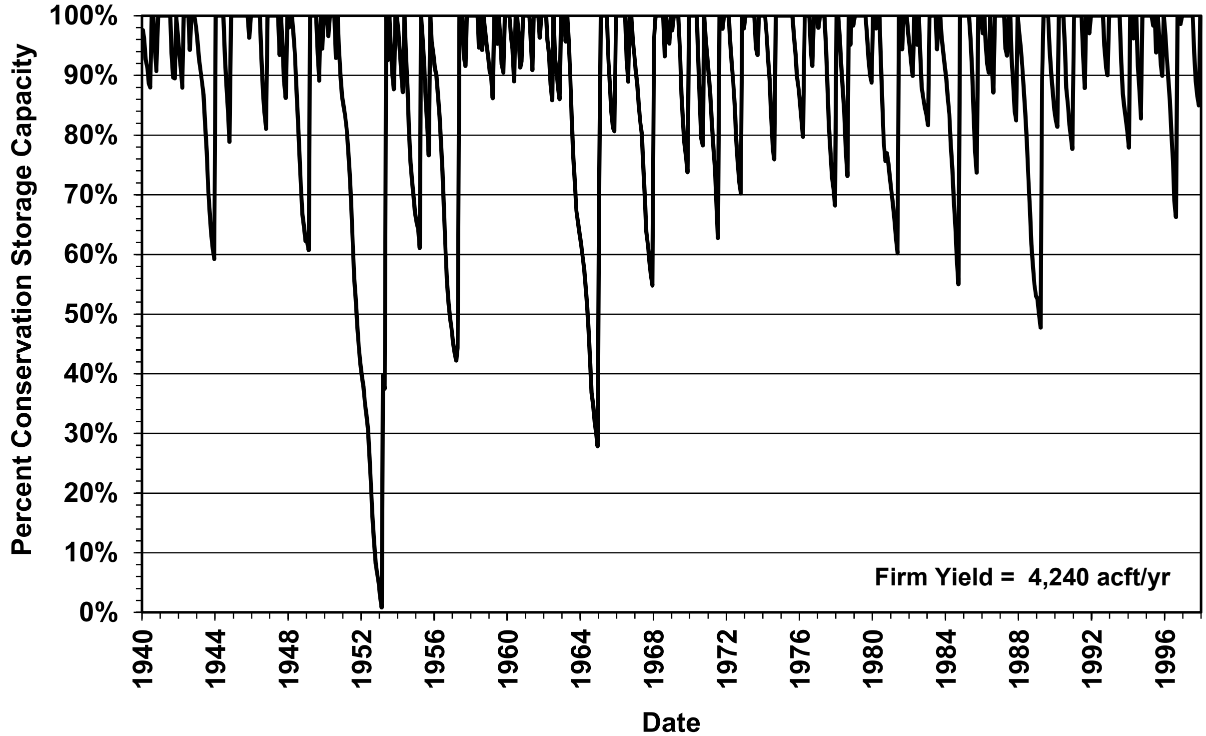


Figure 4.14-3. Peach Creek Storage Frequency at Firm Yield

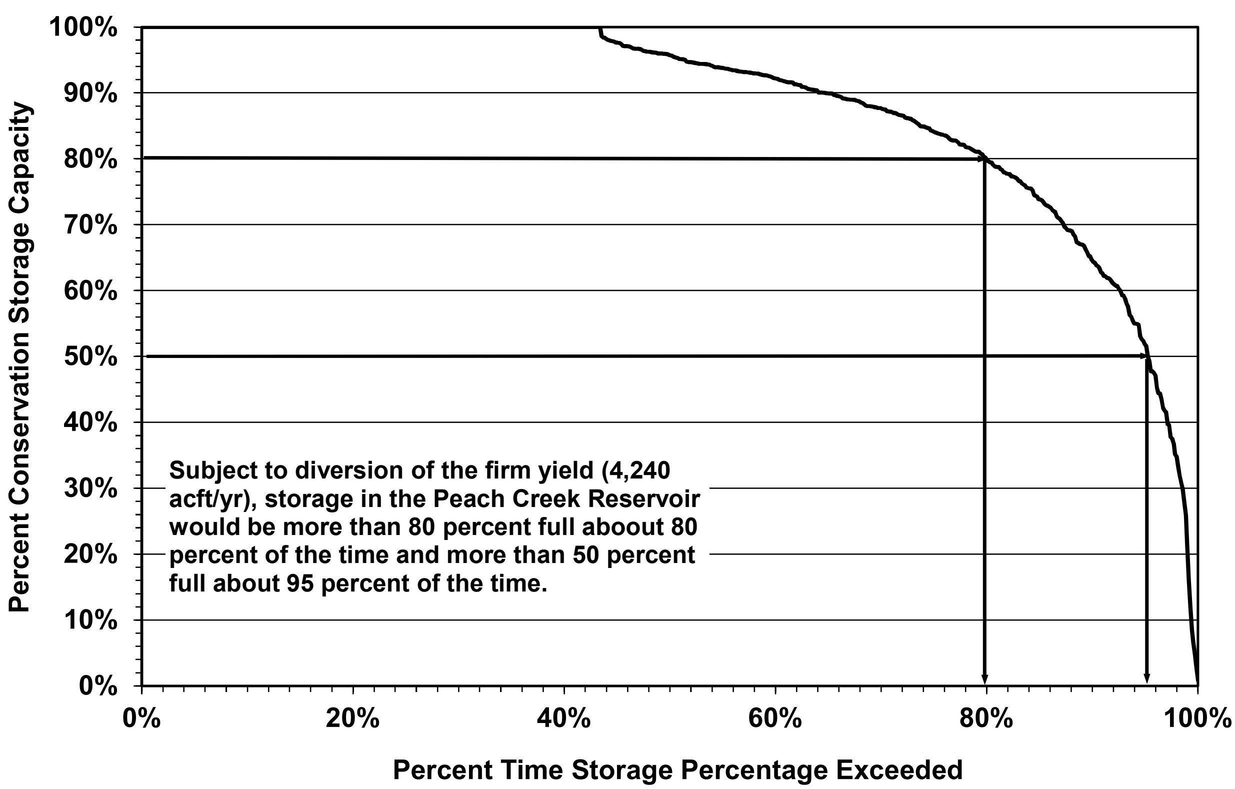


Figure 4.14-4. Peach Creek Median Streamflow Comparison

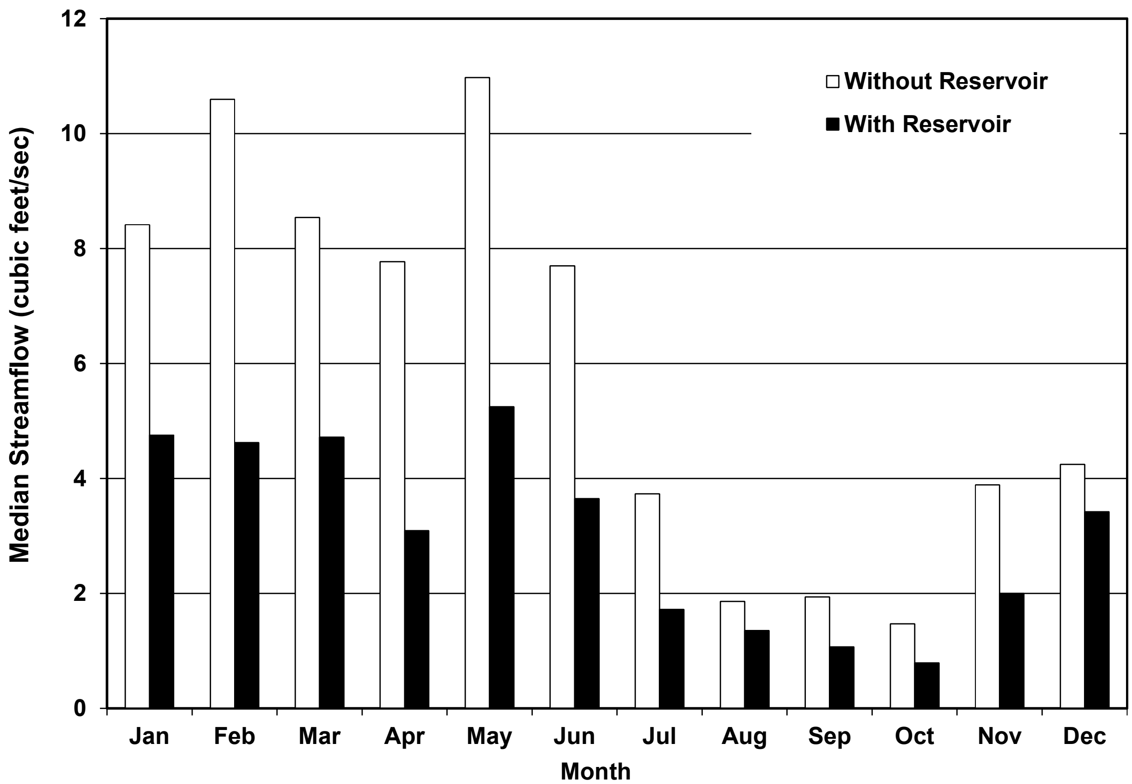


Figure 4.14-5. Navasota River Diversion Median Streamflow Comparison

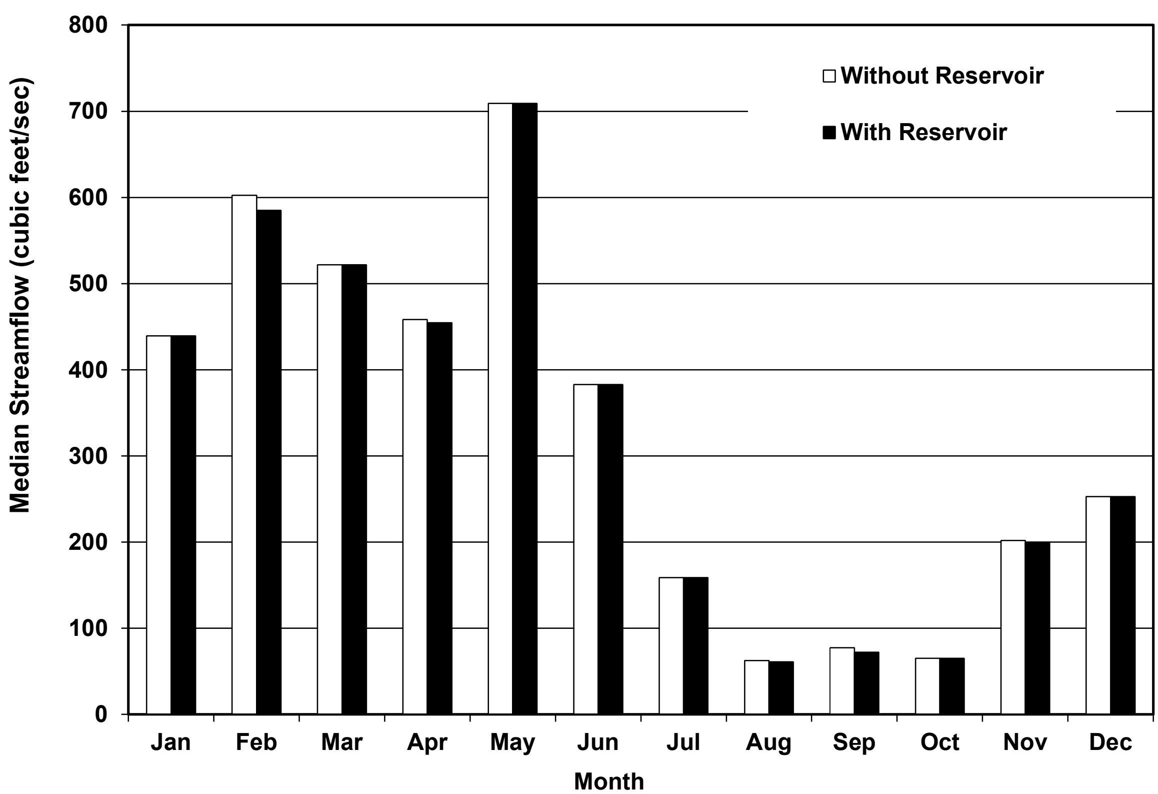


Figure 4.14-6. Peach Creek Reservoir Streamflow Frequency Comparison

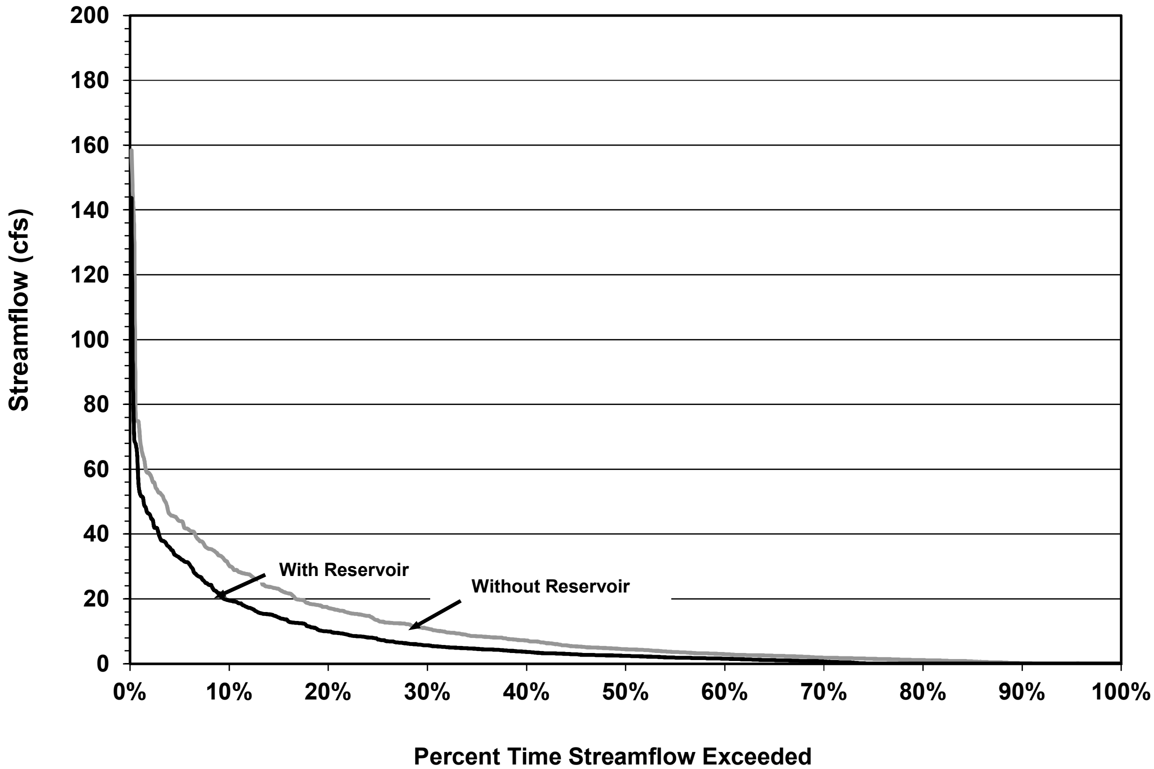
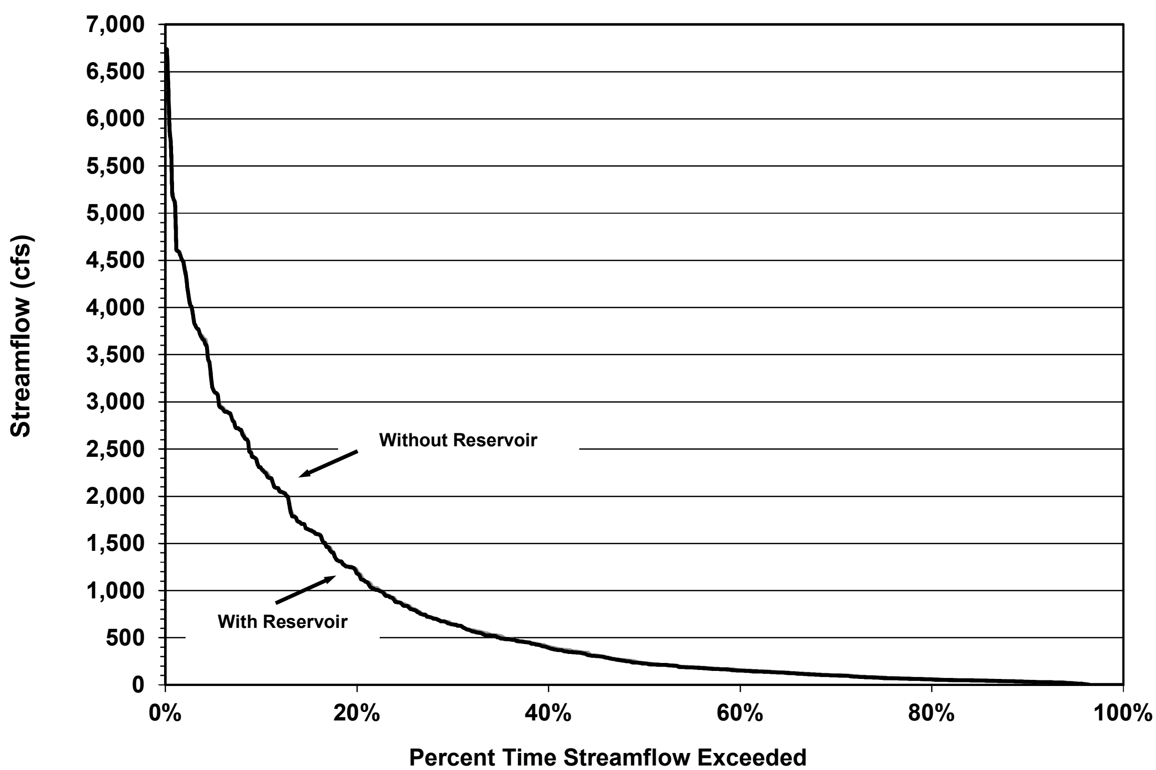


Figure 4.14-7. Navasota River Streamflow Frequency Comparison



4.14.3 Environmental Issues

Existing Environment

The Peach Creek OCR site in Brazos County is within the Post Oak Savannah Vegetational Area.[1] This area is characterized as a narrow, highly irregular oak belt that consists of intermingled forest, woodland, and savannah. It is located between the East Texas Pine-Hardwood Forest to the east, Blackland Prairies to the west, and the Gulf Prairies and Marshes, and South Texas Plains to the south. The original physiognomy of the region included medium to tall broad-leaved deciduous trees and some needle-leaved evergreens. In the northern and eastern areas, these trees are interspersed with open areas of grasses and forbs, however in the southern and western areas, areas of trees are often found clumped or in solid stands. The shallow, nearly impervious clay pan of the Post Oak Savannah region causes the soil to be arid.[2] The climate within this area is characterized as subtropical humid, with warm summers and an average annual precipitation which ranges between 36 and 40 inches.[3] Aquifers which underlie the area include the Queen City, Sparta, and Yegua Jackson minor aquifers. A major aquifer, the Gulf Coast, lies south of the project area but does not underlie it.[4]

The physiography of the region includes sand and mud with lignite and bentonite, and flood-prone areas. The topography is low to moderately rolling with local shallow depressions in flood-prone areas along waterways.[5]

A Custom Soil Resource Report was completed for the Peach Creek OCR site.[6] According to this report, eleven soil types underlie the project site. Sandow loam, frequently flooded, is the most abundant soil at 32% of the project area. These soils typically occupy floodplains. This soil is moderately well drained, has a moderate available water capacity and consists of loam underlain by stratified loamy sand to clay loam. Burlewash fine sandy loam, 5 to 8 percent slopes soils occur within 31% of the project area. These soils are found on ridges, are well drained and have a low available water capacity. They are comprised of fine sandy loam at the surface, underlain by clay and bedrock.

Uhland loam, frequently flooded, which comprises approximately 17% of the reservoir area is typically found on floodplains, is moderately well drained and consists of loam underlain by clay loam. Burlewash fine sandy loam, 1 to 5 percent slopes and Singleton fine sandy loam, 1 to 3 percent slopes each occur in less than 9% of the project area. Burlewash fine sandy loam and Singleton fine sandy loam soils are found on ridges and

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[1] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, *Vegetational Areas of Texas*, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960

[2] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.

[3] Larkin, T.J., and G.W. Bomar, *Climatic Atlas of Texas*, Texas Department of Water Resources, Austin, Texas, 1983.

[4] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.

[5] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., *Land Resources of Texas*, Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.

[6] NRCS. "Custom Soil Resource Report for Brazos County, Texas – Peach Creek Off-Channel Site. December 3, 2014.

include fine sandy loam over clay and bedrock. The remaining six soil types comprise approximately 3.3 percent of the project area. Two of the soil types found within the project area, Chazos loamy fine sand, 1 to 5 percent slopes and Rader fine sandy loam, 0 to 2 percent slopes are considered to be prime farmland soils. Soils designated as prime farmland soils make up less than two percent of the project area.

The major vegetation type which occurs within the proposed project is Post Oak Woods/Forest.[7] Areas of Post Oak Woods/Forest could include the following commonly associated plants: blackjack oak (*Quercus marilandica*), eastern redcedar (*Juniperus virginiana*), mesquite (*Prosopis glandulosa*), black hickory (*Carya texana*), live oak (*Q. virginiana*), sandjack oak (*Q. incana*), cedar elm (*Ulmus crassifolia*), hackberry *(Celtis* spp.), yaupon (*Ilex vomitoria*), American beautyberry (*Callicarpa americana*), hawthorn (*Crataegus* spp.), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus* spp.), coralberry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium* var. *scoparium*), silver bluestem (*Bothriochloa saccharoides*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida* spp.), spranglegrass (*Chasmanthium sessiliflorum*), and tickclover (*Desmodium* spp.). Variations of this primary type may occur based on changes in the composition of woody and herbaceous species in the area and the physiognomy of localized conditions and specific range sites.

Potential Impacts

Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated in two locations, at the proposed reservoir site and in the Navasota River where water will be pumped and diverted to the project site. The potential impacts of this project would differ in the two locations. In the diversion site on the Navasota River, very little impact is predicted in terms of a reduction in flow variability or reduction in the quantity of median monthly flows. At the proposed reservoir site, there would be lower flow variability and substantial reductions in quantity of median monthly flows. Variability in flow is important to the instream biological community as well as riparian species and a reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing suitability for others. Siting of the intake and pump station for this project should be situated as to result in minimal disturbance to existing area species.

The reductions in median monthly flows at the project site would range from 0.7 cfs (46 percent) in October to 6.0 cfs (56 percent) in February, as shown in Table 4.14-1. The greatest reductions (>50 percent) would occur in February and April through July. December has the lowest percent reduction (19 percent) at the proposed reservoir site. In the Navasota River, the reduction in median monthly flows would range from 0 cfs in January, March, May through July, October, and December to 17.7 cfs (3 percent) in February, as shown in Table 4.14-2. There would be virtually no reduction in seven months of the year. September would have consequential decreases in median monthly flow. This project would also result in a higher frequency of low-flow conditions at the project site. Without the project, the monthly flows would be less than 0.68 cfs only 15

[7] McMahan, C.A., R.F. Frye, and K.L. Brown, *The Vegetation Types of Texas*, Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

percent of the time (85 percent exceedance value), but the monthly flows would be 0 cfs for 25 percent of the time with the project in place. The 85 percent exceedance value would be 47 and 46 cfs in the Navasota River without and with the project, respectively. These reductions in flow at the project site would have substantial impacts on the instream biological community, particularly during the summer months when streams are more susceptible to a reduction in water quality conditions (e.g., high temperatures and high nutrient growth).

Although there would be biological impacts in the immediate vicinity of the project site and downstream, this project, alone, would have little impact on total discharge in the Navasota and Brazos Rivers and minimal influence on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows into the estuary. As a new reservoir without a current operating permit, the Peach Creek Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

Table 4.14-1. Median Monthly Streamflow: Peach Creek Off-Channel Reservoir

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	8.4	4.8	3.7	43%
February	10.6	4.6	6.0	56%
March	8.5	4.7	3.8	45%
April	7.8	3.1	4.7	60%
May	11.0	5.2	5.7	52%
June	7.7	3.7	4.0	53%
July	3.7	1.7	2.0	54%
August	1.9	1.4	0.5	27%
September	1.9	1.1	0.9	45%
October	1.5	0.8	0.7	46%
November	3.9	2.0	1.9	49%
December	4.2	3.4	0.8	19%

Table 4.14-2. Median Monthly Streamflow: Navasota River Diversion Site

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	489.2	489.2	0.0	0%
February	662.4	662.4	0.0	0%
March	534.2	534.2	0.0	0%
April	466.9	463.0	3.9	1%
May	716.2	714.4	1.8	0%
June	391.1	391.1	0.0	0%
July	156.4	144.4	12.1	8%
August	61.0	61.0	0.0	0%
September	77.3	70.8	6.5	8%
October	90.6	83.1	7.5	8%
November	204.5	188.4	16.1	8%
December	256.6	255.7	0.9	0%

Threatened & Endangered Species

A total of 31 species could potentially occur in Brazos County that are state- or federally-listed as threatened or endangered, federal candidates for listing, or exhibit sufficient rarity to be listed as a species of concern by the State (Table 4.14-3). This group includes one amphibian, three reptiles, three insects, nine birds, three mammals, three fish, three mollusks, and five plant species. Two bird species, one amphibian, two fishes, two mammals, and one plant species federally-listed as threatened or endangered could occur (or historically occurred) in the project county. These include the interior least tern (*Sterna antillarum athalassos*), whooping crane (*Grus americana*), Houston toad (*Bufo houstonensis*), sharpnose shiner (*Notropis oxyrhynchus*), smalleye shiner (*Notropis buccula*), Louisiana black bear (*Mustela nigripes*), red wolf (*Canis rufus*), and Navasota ladies'-tresses (*Spiranthes parksii*). The interior least tern and whooping crane are seasonal migrants that could pass through the project area, but are not anticipated to be directly affected by the project. The Houston toad prefers deep sands for burrowing and upland ponds and depressions for breeding. Navasota Ladies'-tresses generally occur on upland margins of intermittent, minor tributaries in association with post oak, blackjack oak, and yaupon. Although historically occurring, populations of the black bear and red wolf no longer occur within the region.

A search of the Texas Natural Diversity Database8 revealed numerous documented occurrences of the endangered Navasota ladies'-tresses near the project area, in addition to occurrences of Texas meadow-rue (Thalictrum texanum), a state species of concern. This data is not a representative inventory of rare resources or sensitive sites. Although based on the best information available to the Texas Parks and Wildlife Department (TPWD), these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats. Coordination with TPWD and U.S. Fish and Wildlife Service (USFWS) regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Table 4.14-3. Endangered, Threatened, Candidate and Species of Concern Listed for Brazos County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
		AMPHIBIANS			
Houston toad	*Anaxyrus houstonensis*	Endemic species found in sandy substrate near pools.	LE	E	Resident
		BIRDS			
American peregrine falcon	*Falco peregrinus anatum*	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Henslow's Sparrow	*Ammodramus henslowii*	Wintering individuals found in weedy fields with bunch grasses and brambles.	--	--	Migrant
Interior least tern	*Sterna antillarum athalassos*	Nests along sand and gravel bars in braided streams	LE	E	Resident
Peregrine falcon	*Falco peregrinus*	Possible migrant. Subspecies not easily distinguishable so reference is made to species level.	DL	T	Possible Migrant

[8] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, October 3, 2014.

Table 4.14-3. Endangered, Threatened, Candidate and Species of Concern Listed for Brazos County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Sprague's pipit	*Anthus spragueii*	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Whooping crane	*Grus americana*	Potential migrant	LE	E	Possible Migrant
Wood stork	*Mycteria Americana*	Forages in prairie ponds, flooded fields and ditches.	--	T	Possible Migrant
FISHES					
Blue sucker	*Cycleptus elongates*	Found in larger portions of major rivers in Texas.	--	T	Resident
Sharpnose shiner	*Notropis oxyrhynchus*	Endemic to Brazos River drainage. Found in large rivers.	LE	--	Resident
Smalleye shiner	*Notropis buccula*	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident
INSECTS					
A mayfly	*Procloeon texanum*	Found in Oklahoma and Texas. Mayflies are distinguished by their aquatic larval stage; adults generally found in bankside vegetation.	--	--	Resident
Gulf Coast clubtail	*Gomphus modestus*	Found in medium rivers with moderate gradient and streams with silty sand or rocky bottoms.	--	--	Resident
Smoky shadowfly	*Neurocordulia molesta*	Found in rivers and sometimes larger streams with rock or logs to which the larvae cling.	--	--	Resident
MAMMALS					

Table 4.14-3. Endangered, Threatened, Candidate and Species of Concern Listed for Brazos County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Louisiana black bear	*Ursus americanus luteolus*	Possible as transient in bottomland hardwoods and inaccessible forested areas.	LT	T	Possible transient
Plains spotted skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	Extirpated.	LE	E	Historic Resident
MOLLUSKS					
False spike mussel	*Quincuncina mitchelli*	Substrates of cobble and mud. Rio Grande, Brazos, Colorado and Guadalupe river basins.	--	T	Resident
Smooth pimpleback	*Quadrula houstonensis*	Freshwater mollusk found in small to moderate streams and rivers as well as moderate sized reservoirs. Brazos and Colorado River Basins.	C	T	Resident
Texas fawnsfoot	*Truncilla macrodon*	Found in rivers and larger streams, intolerant of impoundment.	C	T	Resident
PLANTS					
Branched gay-feather	*Liatric cymosa*	Texas endemic found on somewhat barren grassland openings in post oak woodlands.	--	--	Resident
Bristle nailwort	*Paronychia setacea*	Flowering vascular plant endemic to eastern south central Texas in sandy soils.	--	--	Resident
Navasota ladies'-tresses	*Spiranthes parksii*	Texas endemic found in openings in post oak woodlands in sandy loams along upland drainages or intermittent streams.	LE	E	Resident
Small-headed pipewort	*Eriocaulon koernickianum*	Found in East Texas post-oak woodlands and xeric sandhill openings on permanently wet acid sands of upland seeps and bogs.	--	--	Resident

Table 4.14-3. Endangered, Threatened, Candidate and Species of Concern Listed for Brazos County

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Texas meadow-rue	*Thalictrum texanum*	Texas endemic primarily found in woodlands and woodland margins on soils with a surface layer of sandy loam but also occurs on prairie pimple mounds.	--	--	Resident
PLANTS					
Texas windmill grass	*Chloris texensis*	Texas endemic grass found in sandy to sandy loam soils in relatively bare areas in coastal prairie grassland remnants and roadsides.	--	--	Resident
REPTILES					
Alligator snapping turtle	*Macrochelys temminckii*	Found near perennial water bodies in swamps and bayous.	--	T	Resident
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands.	--	T	Resident
Timber rattlesnake	*Crotalus horridus*	Floodplains, upland pine, deciduous woodlands, riparian zones.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

TPWD, 2014. Annotated County List of Rare Species –Brazos County updated 9/4/2014.

USFWS, 2014. Species Lists from http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action?fips=48187, accessed October 6, 2014.

Wildlife Habitat

The primary impacts that would result from construction and operation of the proposed Peach Creek OCR include conversion of approximately 1,045 acres of existing habitat within the conservation pool to open water. Projected wildlife habitat that will be impacted includes approximately 442 acres of Post Oak Motte and Woodland, 427 acres of Floodplain Hardwood Forest, 85 acres of Floodplain and Riparian Herbaceous Vegetation, 80 acres Savanna Grassland, and minor amounts of row crops, barren areas, mesquite shrubland, juniper woodland and urban areas.[9] Siting of the raw water

[9] Texas Parks and Wildlife. Ecological Mapping Sytem GIS layer. Accessed at http://www.tpwd.state.tx.us/gis/data/ November 18, 2014.

intake, pump station and raw water pipeline needed to complete the project should be located in an area that would result in minimal impacts to existing aquatic and terrestrial species. Impacts from the pipeline and associated appurtenances are anticipated to be low and primarily limited to the construction of these facilities and subsequent maintenance activities.

A number of vertebrate species could occur within the Peach Creek OCR site including smaller mammals such as the eastern red bat (*Lasiurus borealis*), hispid cotton rat (*Sigmodon hispidus*), white-footed mouse (*Peromyscus leucopus*), eastern fox squirrel (*Sciurus niger*), and woodland vole (*Microtus pinetorum*).[10] Reptiles and amphibians known from the county include the western rough green snake (*Opheodrys aestivus majalis*), Strecker's chorus frog (*Pseudacris streckeri*), Texas toad (*Bufo speciosus*), and Great Plains rat snake (*Elaphe guttata emoryi*) among others.[11] An undetermined number of bird species and a variety of fish species would also be expected to inhabit the various habitat types within the site, with distributions and population densities limited by the types and quality of habitats available.

Cultural Resources

A review of available GIS datasets provided by the Texas Historical Commission (THC) for the 2011 Regional Water Plan revealed that there are no National Register Properties, National Register Districts, cemeteries, or historical markers located within or near the project area.

However a search of the Texas Archeological Sites Atlas database indicated that 126 archeological sites have been documented within the general vicinity of the proposed reservoir. Prewitt and Associates, Inc. recorded 23 of these sites in 1981 as part of an archeological survey of proposed reservoir alternatives. Researchers from the University of Texas documented 26 of these sites as part of a preliminary investigation of the area proposed for Millican Lake in 1973. An additional 22 sites have been recorded during surveys on behalf of the Texas Municipal Power Agency in advance of various electrical transmission lines and proposed lignite mines. Thirteen sites have been recorded during surveys of proposed facilities for Texas A&M University. The sites recorded on behalf of the Texas Municipal Power Agency and Texas A&M University lie outside the currently proposed reservoir location. The sites documented in the area represent a variety of historic and prehistoric site types. Prior to reservoir inundation, the project must be coordinated with the THC and a cultural resources survey must be conducted to determine if these sites or any other cultural resources are present within the conservation pool. Any cultural resources identified during this survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archeological and Historic Preservation Act (PL93-291).

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[10] Davis, William B. and David J. Schmidly. 1994. The Mammals of Texas. Texas Parks and Wildlife, Austin, Texas

[11] Dixon, James R., Amphibians and Reptiles of Texas. 1987, Texas A&M Press.

Threats to Natural Resources

Threats to natural resources include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased adverse effects on stream flow below the reservoir site, but the reservoir would trap sediment and/or dilute pollutants, providing some positive benefits to water quality downstream. These benefits could be offset by declines in dissolved oxygen through decreased flows and higher temperatures immediately downstream during summer periods. Additional impacts would be expected to terrestrial species found within the proposed OCR area that would be displaced by the reservoir filling. The project is expected to have negligible impacts to stream flow and water quality in the Navasota and Brazos Rivers.

Agricultural Impacts

The Peach Creek OCR site contains approximately 103 acres of Pasture/Hay fields and zero acres of cropland. These two agricultural land uses account for roughly ten percent of the reservoir footprint.

4.14.4 Engineering and Costing

Construction of the Peach Creek Reservoir project will cost approximately $66.9 million. This includes the construction of the dam, pumping facilities, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $6.1 million; this includes annual debt service and operation and maintenance. The cost for the available project yield of 4,240 acft/yr translates to an annual unit cost of raw water of $4.40 per 1,000 gallons, or $1,435/acft. A summary of the cost estimate is provided in Table 4.14-4. Costs shown herein are for raw water supply at the reservoir and include no subordination, transmission, local distribution, or treatment costs.

Table 4.14-4. Cost Estimate Summary for Peach Creek Off-Channel Reservoir

Item	Estimated Costs for Facilities
Off-Channel Storage/Ring Dike (Conservation Pool 14,641 acft, 1,045 acres)	$20,977,000
Channel Dam & Intake Pump Stations (68 MGD)	$9,750,000
Transmission Pipeline (60 in dia., 4 miles)	$8,254,000
TOTAL COST OF FACILITIES	**$38,981,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$13,231,000
Environmental & Archaeology Studies and Mitigation	$5,092,000
Land Acquisition and Surveying (1,075 acres)	$5,174,000
Interest During Construction (4% for 2 years with a 1% ROI)	$4,374,000
TOTAL COST OF PROJECT	**$66,852,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$2,165,000
Reservoir Debt Service (5.5 percent, 40 years)	$2,554,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$83,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$244,000
Dam and Reservoir (1.5% of Cost of Facilities)	$315,000
Pumping Energy Costs (8,035,066 kW-hr @ 0.09 $/kW-hr)	$723,000
TOTAL ANNUAL COST	**$6,084,000**
Available Project Yield (acft/yr)	4,240
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	$1,435
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	$4.40

4.14.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.14-4, and the option meets each criterion.

Implementation of the OCR project will require permits from various state and federal agencies, land acquisition, and design and construction of the facilities. The project may also have an impact on the firm yield of Navasota River, which may require mitigation with the Brazos River Authority in terms of a water supply contract in the amount of the firm yield impact. A summary of the implementation steps for the project is presented below.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- General Land Office Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

Environmental impact or assessment studies;

- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;

- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 4.14-5. Evaluations of Peach Creek Off-Channel Reservoir Option to Enhance Water Supplies

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	1. Negligible impact
2. Habitat	2. Negligible impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Negligible impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

5 Acquisition of Existing Supplies

5.1 Lake Aquilla Augmentation

5.1.1 Description of Option

Lake Aquilla is located southwest of the City of Hillsboro in Hill County. The reservoir is owned by the U.S. Army Corps of Engineers (USACE) and is part of the Brazos River Authority (BRA) System. The reservoir provides water for the cities of Hillsboro, Cleburne and Milford and for Brandon-Irene WSC, Files Valley WSC, and Lake Whitney Water Company. The yield of Lake Aquilla will not be able to completely supply the future needs of these entities. Options to supplement supplies at Lake Aquilla are being evaluated and include both reallocation of flood pool to conservation pool storage, as well as building pipelines between Lake Whitney and Cleburne and Lake Aquilla. The City of Cleburne has contracts with the BRA totaling 9,700 acre-feet per year with a Lake Whitney diversion location, but does not currently have the infrastructure to access this water. A proposed pipeline option would allow Cleburne access to its Lake Whitney water and could supplement other Lake Aquilla water users as well. The total supply for the project will be 14,700 acft/yr (9,700 acft/yr for the City of Cleburne and up to 5,000 acft/yr for others). The supplemental water for the project will come from a combination of existing BRA rights and the BRA System Operation Permit, pending approval at the Texas Commission on Environmental Quality.

The City of Cleburne has also looked at developing the 9,700 acre-feet per year of undeveloped water supply from Lake Whitney contracted to the City through the BRA without a partnership with the Aquilla Water Supply district. The project would require a deep water intake, diversion pump station to take water out of Lake Whitney, an advanced water treatment facility for the Lake Whitney water, blending tanks, a booster pump station, and a pipeline to connect the Lake Whitney supply to the existing Barkman Pipeline for delivery to Cleburne, and all associated appurtenances for a fully functional and operational water supply delivery and treatment system. This project would supply the City of Cleburne and Johnson County mining, manufacturing, steam electric, and irrigation water though Cleburne.

The main stem of the Brazos River in the vicinity of Lake Whitney has relatively high levels of total dissolved solids (TDS). From 1993 to 2006, Lake Whitney averaged about 845 mg/L TDS, while water in Lake Aquilla averaged about 228 mg/L TDS. The relatively high salt concentration in the main stem water will need to be mitigated either by blending with better quality water (such as Lake Aquilla water) or have the salt concentration reduced by advanced treatment.

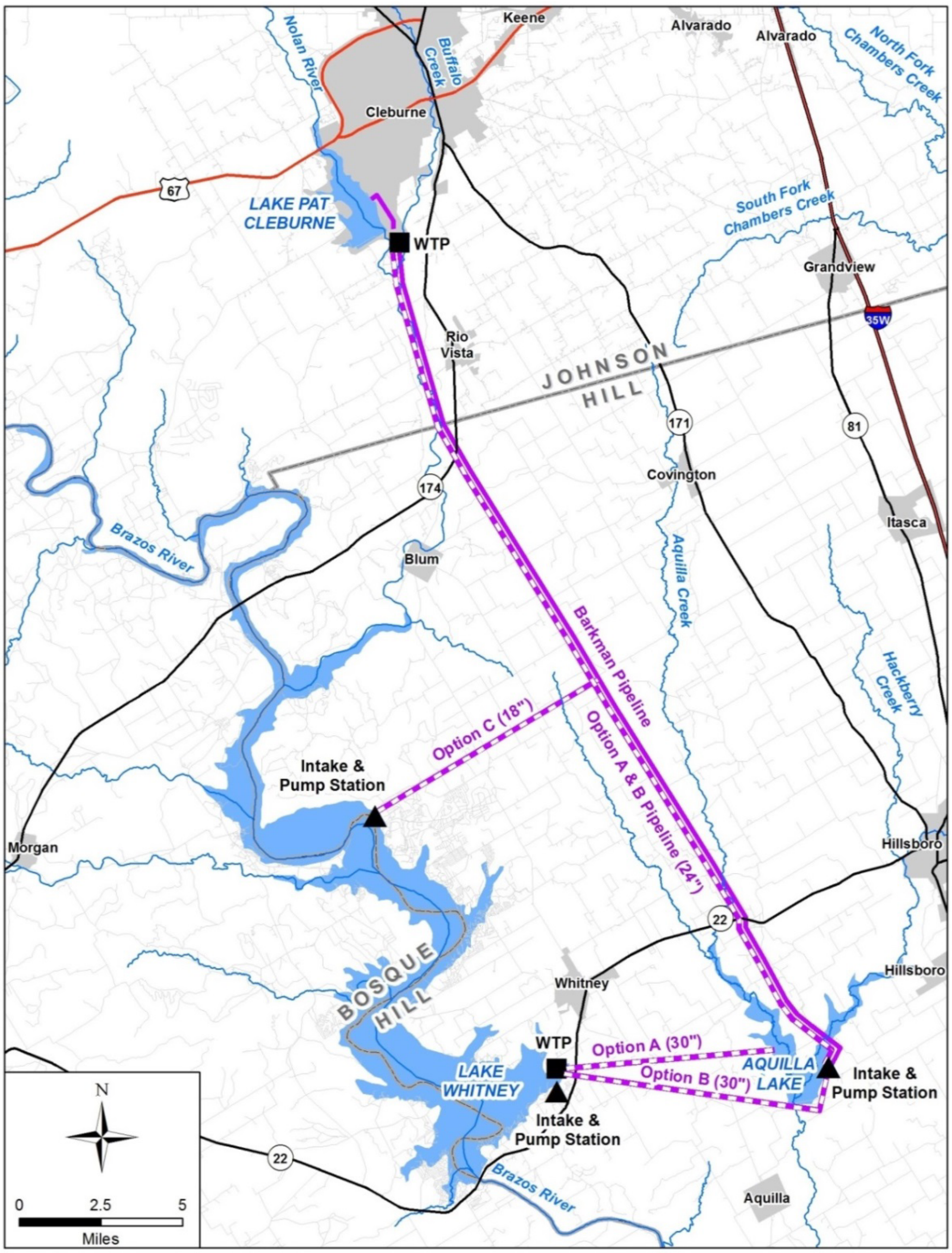
Three options have been considered for this strategy (Figure 5.1-1) as described below.

- Option A takes 14,700 acft/yr from Lake Whitney, treats the water to remove TDS, and discharges the water into Lake Aquilla.

- Option B is similar to Option A except that instead of discharging the water into Lake Aquilla the water is taken to the existing intake structures and pump stations owned by the City of Cleburne and the Aquilla Water Supply District.
- Option C would be a strategy for Cleburne only that delivers up to 9,700 acft/yr directly into the existing Barkman pipeline.

All options include advanced treatment to remove dissolved solids from a portion of the water from Lake Whitney. Approximately 70 to 85 percent of the water will need to be treated to remove sufficient salt loads to maintain acceptable water quality.

Figure 5.1-1. Lake Aquilla Augmentation Options A, B and C



5.1.2 Available Yield

The yield from Lake Aquilla without this strategy is estimated to be 13,315 acft/yr in 2020 and 12,099 ac-ft/yr in 2070. This project would provide 14,700 acft/yr of additional supply to the area, with 9,700 acft/yr going to the City of Cleburne and potentially 5,000 acft/yr for others (Options A & B). Water would come from a combination of stored water from Lake Whitney, releases from upstream BRA reservoirs, and coordinated operation of run-of-the-river supplies authorized under the System Operation Permit.

The main source of Cleburne's existing water supply is Lake Pat Cleburne which has 5,760 acre-feet per year of adjudicated municipal water rights. The certificate of adjudication was amended in January 2002 to authorize the City to use the bed and banks of Lake Pat Cleburne to deliver 5,300 acre-feet per year of water from Lake Aquilla and 4,700 acre-feet per year of water from Lake Whitney.

It is estimated that the yield of Lake Pat Cleburne will decrease by about 0.32 MGD between 2020 to the year 2070. The supply available from Lake Aquilla may decrease significantly over the same period. If the yield of Lake Aquilla decreases as indicated by previous analyses, Cleburne (and other holders of contracts for water from the Lake) will not be able to divert the full contracted amount as a reliable supply. To meet the existing and long-term water supply need it will be necessary to develop the Lake Whitney BRA contracted water supply. This strategy could potentially be provided supply under the BRA System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. If an entity other than the BRA were to sponsor and pursue this strategy, then an agreement with the BRA would be required to address concerns related to the potential subordination of the System Operation strategy.

5.1.3 Environmental Issues

For Option A, the primary environmental concern with transporting water from Lake Whitney to Lake Aquilla is the high TDS content of the Brazos River main stem. In addition to the TDS content of the main stem of the Brazos River, there exists the possibility that changes in water temperature or salinity along with other factors could trigger golden algae blooms in Lake Aquilla. A recent study indicated that high levels of salinity, sulfate and chloride were found to have the greatest influence on golden alga distribution and bloom formation in inland waters. Treatment of the water to remove TDS before its discharge into Lake Aquilla may be sufficient to address this issue. However additional studies will be required to evaluate the potential impact of blending the treated water in Lake Aquilla. If these studies indicate that blending water in Lake Aquilla would result in an unacceptable environmental impact, then Option B should be selected. Option B and the Cleburne only option would eliminate any potential TDS impacts to Lake Aquilla.

Another potential concern is the return of reject brine water resulting from the TDS treatment to Lake Whitney. Lake Whitney is a very large reservoir with more than 550,000 acft of storage and a significant amount of flow-through due to hydropower operations. As a result, the return of reject brine water to this reservoir is anticipated to have minimal impact on the existing water quality. Additional studies may be required to verify this assumption. If it is determined that the reject brine water cannot be returned to the reservoir, deep-well injection or evaporation ponds could be used to dispose of this product. However, the addition of either of these options will result in increased costs to the project and additional environmental concerns.

The specific locations of facilities and pipeline routes have not been identified at this time. It is anticipated that pipelines, pump stations and other necessary facilities will be positioned to avoid impacts to known cultural resources, sensitive habitats, wetlands or stream crossings.

The species listed by the United States Fish and Wildlife Service (USFWS), or Texas Parks and Wildlife Department (TPWD), as endangered, threatened, federal candidates or state species of concern in Bosque, Hill or Johnson counties are listed in Table 5.1-1. There are no areas of critical habitat designated within or near the project area.

The project area may provide potential habitat to endangered or threatened species found in Bosque, Hill or Johnson counties. A survey of the project area may be required prior to pipeline and facility construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Based on existing habitat types, the following threatened or endangered species have the potential to occur within or near the project area.

- Peregrine Falcon (Falco peregrinus), including the American peregrine falcon (F. p. anatum) subspecies — This state threatened species is a possible migrant in the project area. They utilize a wide range of habitats during migration, including urban areas and landscape edges such as lakes or large river shores.

Table 5.1-1. Endangered, Threatened, and Species of Concern for Bosque, Hill and Johnson Counties

Common Name	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
			BIRDS			
American peregrine falcon	2	2	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Artic peregrine falcon	1	0	Migrant throughout the state.	DL		Possible Migrant
Bald eagle	2	2	Found primarily near rivers and large lakes.	DL	T	Possible Migrant
Black-capped vireo	3	3	Oak-juniper woodlands with distinctive patchy, two-layered aspect.	E	E	Possible Migrant
Golden-cheeked warbler	3	3	Juniper-oak woodlands; dependent on Ashe juniper for long fine bark strips.	E	E	Possible Migrant
Henslow's sparrow	1	0	Found in weedy fields or cut-over areas			Possible Migrant

Table 5.1-1. Endangered, Threatened, and Species of Concern for Bosque, Hill and Johnson Counties

Common Name	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Interior least tern	3	1	Nests along sand and gravel bars in braided streams	E	E	Resident
Mountain plover	1	0	Non-breeding, shortgrass plains and fields			Nesting/ Migrant
Sprague's pipit	1	0	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C		Possible Migrant
Western burrowing owl	1	0	Open grasslands, especially prairie, plains and savanna			Resident
White-faced Ibis	2	0	Prefers freshwater marshes, sloughs, and irrigated rice fields, but will attend brackish and saltwater habitats.		T	Resident
Whooping crane	3	3	Potential migrant	E	E	Potential Migrant
Wood stork	2	0	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX		T	Migrant
			FISHES			
Guadalupe bass	1	0	Endemic to perennial streams of the Edwards Plateau region. Introduced in Nueces River system.			Resident
Sharpnose shiner	3	0	Endemic to Brazos River drainage; large turbid river, with bottom a combination of sand, gravel, and clay-mud	PE		Resident
Smalleye shiner	3	0	Endemic to upper Brazos River system and its tributaries (Clear Fork and Bosque); medium to large prairie streams with sandy substrate and turbid to clear warm water	PE		Resident

Table 5.1-1. Endangered, Threatened, and Species of Concern for Bosque, Hill and Johnson Counties

Common Name	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
MAMMALS						
Cave myotis bat	1	0	Roosts colonially in caves, rock crevices			Resident
Gray wolf	3	0	Extirpated; formerly known throughout the western two-thirds of the state.	E	E	Historic Resident
Plains spotted skunk	1	0	Prefers wooded, brushy areas.			Resident
Red wolf	3	0	Extirpated.	E	E	Historic Resident
MOLLUSKS						
False spike mussel	2	2	Substrates of cobble and mud. Rio Grande, Brazos, Colorado and Guadalupe river basins. Not recorded from reservoirs.		T	Resident
Smooth pimpleback	2	2	Small to moderate streams and rivers as well as moderate size reservoirs; mixed mud, sand, and fine gravel, tolerates very slow to moderate flow rates, Brazos, and Colorado River basins.	C	T	Resident
MOLLUSKS						
Texas fawnsfoot	2	1	Possibly found in rivers and larger streams, intolerant of impoundment. Brazos and Colorado River basins.	C	T	Resident
REPTILES						
Brazos water snake	2	0	Upper Brazos River drainage; in shallow water with rocky bottom and on rocky portions of banks		T	Resident
Texas Garter Snake	1	1	Wet or moist microhabitats			Resident

Table 5.1-1. Endangered, Threatened, and Species of Concern for Bosque, Hill and Johnson Counties

Common Name	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Texas Horned Lizard	2	2	Varied, sparsely vegetated uplands.		T	Resident
Timber rattlesnake	2	2	Floodplains, upland pine, deciduous woodlands, riparian zones.		T	Resident

TPWD, 2014. Annotated County List of Rare Species – Bosque, Hill and Johnson Counties revised 4/28/2014.
USFWS, 2013. Endangered Species List for Texas. http://www.fws.gov/southwest/es/ES_ListSpecies.cfm accessed online May 29, 2014.
E=Endangered
T=Threatened
PE =Proposed Endangered
C=Federal candidate
DL=Delisted

- Bald Eagle (Haliaeetus leucocephalus) — The bald eagle is a state-listed threatened species that could occur as a migrant near major aquatic resources. Although they breed primarily in the eastern half of the state, they could potentially occur in this region of Texas during the winter and migration along rivers or large lakes.
- Black-capped vireo (Viro atricapilla) — The black-capped vireo is an endangered species that could occur as a migrant within the project area. This small bird requires the presence of oak-juniper woodlands with a distinctive patchy, two-layered aspect.
- Golden-cheeked warbler (Setophaga chrysoparia) — The golden-cheeked warbler is found as a migrant in juniper-oak woodlands and is dependent on Ashe juniper trees for long fine bark strips used for nesting.
- Interior Least Tern (Sterna antillarum athalassos) — The interior least tern is federally listed as endangered. This species prefers to nest on sandbars, islands, salt flats, and bare or sparsely vegetated sand, shell, and gravel beaches that are associated with braided streams, rivers and reservoirs.
- Whooping Crane (Grus americana) — The whooping crane is a federally listed endangered species which only occurs in this part of Texas during migration. Whooping cranes use a variety of habitats during migration, including croplands for feeding and large, marshy palustrine wetlands for roosting. Although few large wetland areas occur within the project area, the whooping crane could also potentially occur in surrounding cropland habitat during migration.
- Texas horned lizard (Phrynosoma cornutum) — The Texas horned lizard is a state-listed threatened species and is present throughout much of the state. They exist in open, arid, and semi-arid regions with sparse vegetation, which includes

grass, cactus, scattered brush and scrubby trees. This species could potentially occur in areas with this type of vegetation.

- Timber rattlesnake (Crotalus horridus) — The timber rattlesnake is a state threatened species that occurs in swamps, floodplains, upland pine and deciduous woodlands, riparian zones and abandoned farmland. This species could potentially occur in areas of abandoned farmland or riparian areas.
- False spike mussel (Quincuncina mitchelli) — The false spike mussel is a state threatened species. This freshwater mollusk occurs in rivers or streams with substrates of sand, mud and gravel. However no living specimens have been documented in reservoirs suggesting an intolerance of impoundment.
- Smooth pimpleback (Quadrula houstonensis) — The smooth pimpleback is a federal candidate for listing and is state threatened. This freshwater mollusk exists in small to moderate streams and rivers with slow flow rates, as well as moderate size reservoirs with substrates of mixed mud, sand and fine gravel in the Brazos and Colorado River basins.
- Texas fawnsfoot (Truncilla macrodon) — The Texas fawnsfoot mussel is a federal candidate for listing and is state threatened. This mussel is found in rivers and larger streams of the Brazos and Colorado River basins and is intolerant of impoundment.

No designated critical habitat for the endangered black-capped vireo or golden-cheeked warbler occurs within the project area. Populations of the endangered smalleye and sharpnose shiner occur within the upper Brazos River basin above Lake Whitney. Although these shiner species were once found throughout the Brazos River and several of its major tributaries within the watershed, they are currently restricted almost entirely to the contiguous river segments of the upper Brazos River basin in north-central Texas.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available geographic information systems (GIS) datasets, there are no national register properties, national register district properties, or historical markers located within a 0.5-mile buffer of the proposed pipeline routes, pump stations or other facilities. Several small cemeteries are located within the areas proposed for the pipeline routes and should be avoided during the siting of pipelines, pump stations or other facilities.

Impacts resulting from this project would include changes in salinity of the water within either Lake Whitney or Lake Aquilla, or impacts from the construction and maintenance of the associated pipelines, pump stations or water treatment facilities. If no additional high TDS water is added to Lake Aquilla or no reject brine water is returned to Lake Whitney impacts to aquatic species from this project would be anticipated to be minor and associated with the water intake facilities. Changes in TDS levels could result in additional environmental impacts to aquatic species. In Option A, water delivered into Lake Aquilla is expected to be withdrawn almost immediately by users resulting in little expected change in Lake Aquilla elevations.

Impacts from pipelines, pump stations and water treatment facilities would be anticipated to include temporary construction impacts and maintenance activities if their siting is based on the avoidance of impacts to cultural resources, sensitive habitats, wetlands, or stream crossings.

The project is expected to have low to medium impacts to environmental flows and no impacts to bays and estuaries.

5.1.4 Engineering and Costing

Options A, B and C were evaluated to determine required infrastructure and costs to develop water supplies from Lake Whitney. All strategies include pretreatment of Lake Whitney water before it is discharged to Lake Aquilla or delivered to the Barkman pipeline. Option A requires an intake and pump station at Lake Whitney, approximately 7 miles of 30-inch pipe, membrane treatment facilities, and a discharge structure in Lake Aquilla. Reject water from membrane treatment is returned to Lake Whitney. The total project cost for Option A with delivery to Lake Aquilla and Cleburne is $79.6 million with total annual costs of $13.6 million.

Option B is similar to Option A, except that instead of discharging into Lake Aquilla an additional 5.6 miles of pipeline carries water to a common delivery point near the existing intake and pump stations for the City of Cleburne and the Aquilla Water Supply District. Facilities include an intake and pump station on Lake Whitney, membrane treatment facilities, 12.6 miles of 30-inch pipe, and a connection for water users. The total capital cost for Option B is $88.2 million with total annual costs of $15.3 million. A summary of the costs for Options A and B is provided in Table 5.1-2.

Option A appears to be the more cost-effective of the two options. In addition, because the water will be delivered to Lake Aquilla, customers will be able to access the water anywhere a suitable intake can be located in the reservoir. Costs for Option B, which only has one location for delivery to customers, are higher. However, delivery of supplies from Lake Aquilla to users may require additional infrastructure assuming Option A configuration compared to Option B that delivers to existing transmission systems. Environmental concerns may also cause Option B to be the preferred option. Additional studies will be required before finalizing the delivery option.

To deliver full contracted supplies to Cleburne, a 31 mile, 24-inch diameter pipeline paralleling the existing Barkman Pipeline will be required. The delivery system based on Option A configuration will include a new 10 mgd intake and pump station at Aquilla and a booster pump station with a total project cost of $51.3 million. A summary of the costs are shown in Table 5.1-3. Delivery to Cleburne through a parallel pipeline using Option B configuration is slightly less due to direct infrastructure connection and another intake on Aquilla is not required. Total project costs for delivery to Cleburne using Option B is $43.2 million.

Table 5.1-2. Cost Estimate for Lake Aquilla Augmentation Options A & B

Item	Option A	Option B
Whitney Raw Water Intake and Pump Stations (20 MGD)	$15,304,000	$15,304,000
RO Desalination Treatment (11 MGD)	$27,157,000	$27,157,000
Concentrate Disposal (4.6 MGD, 18 in. dia. 5000 ft)	$2,233,000	$2,233,000
Transmission Pump Station(s) & Storage Tank(s)	$4,744,000	$5,581,000
Transmission Pipeline	$6,521,000	$11,665,000
TOTAL COST OF FACILITIES	**$55,959,000**	**$61,940,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$19,260,000	$21,096,000
Land Acquisition and Surveying	$1,715,000	$2,211,000
Interest During Construction (4% for 1 years with a 1% ROI)	$2,693,000	$2,984,000
TOTAL COST OF PROJECT	**$79,627,000**	**$88,231,000**
ANNUAL COST		
Debt Service (5.5 percent, 20 years)	$6,663,000	$7,383,000
Operation and Maintenance		
Intake, Pipeline, Pump Station	$589,000	$661,000
Water Treatment Plant	$5,142,000	$5,142,000
Pumping Energy Costs ($0.09 kwh)	$1,221,000	$2,093,000
TOTAL ANNUAL COST	**$13,615,000**	**$15,279,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**14,700**	**14,700**
Annual Cost of Water ($ per acft)	**$926**	**$1,039**
Annual Cost of Water ($ per 1,000 gallons)	**$2.84**	**$3.19**

Table 5.1-3. Cost Estimate for Parallel Pipeline from Lake Aquilla to the City of Cleburne for Options A & B

Item	Option A	Option B
New Aquilla Lake Intake and Pump Station (10 MGD)	$8,580,000	$2,791,000
Transmission Pipeline (24 in. dia, 31.2 miles)	$23,057,000	$23,057,000
Booster Pump Station (13.4 MGD)	$4,279,000	$4,279,000
TOTAL COST OF FACILITIES	**$35,916,000**	**$30,127,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$11,418,000	$9,392,000
Land Acquisition and Surveying	$2,199,000	$2,199,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,734,000	$1,460,000
TOTAL COST OF PROJECT	**$51,267,000**	**$43,178,000**
ANNUAL COST		
Debt Service (5.5 percent, 20 years)	$4,290,000	$3,613,000
Operation and Maintenance		
Intake, Pipeline, Pump Station	$552,000	$552,000
Pumping Energy Costs($0.09 kwh)	$826,993	$826,993
TOTAL ANNUAL COST	**$5,668,993**	**$4,991,993**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**9,700**	**9,700**
Annual Cost of Water ($ per acft)	**$584**	**$515**
Annual Cost of Water ($ per 1,000 gallons)	**$1.79**	**$1.58**

A separate Engineering and Costing analysis was completed for Option C, the Cleburne only option. Based on preliminary examination of the Lake Whitney reservoir topography, an intake and pump station from Lake Whitney could be located on the eastern shore of the lake. Other diversion locations may be evaluated and other future take points identified. Lake Whitney water would be treated at an advanced water treatment plant located on the eastern shore. The water would not be disinfected to meet drinking water standards, but the TDS and chlorides would be reduced to match the target water quality in Lake Pat Cleburne and Lake Aquilla. The partially treated water would then be blended with Lake Aquilla water in the Barkman pipeline and pumped to the City's treatment plant or Lake Pat Cleburne. Future options may include full treatment at the take point. The total capital cost for Phase I of the Lake Whitney to Cleburne only project is $46.7 million with total annual costs of $6.5 million. A summary of the costs for this option is provided in Table 5.1-4. Compensation to BRA may be required if this strategy were developed by another entity other than BRA to compensate for any subordination of the System Operations strategy.

Table 5.1-4. Cost Estimate for Phase I Lake Whitney Diversion to Cleburne Only

Item	Estimated Costs for Facilities
Raw Water Intake and Pump Stations (4.2 MGD)	$16,188,000
Storage and Transfer Tanks (3 @ 0.5 MGD)	$1,079,000
Transfer Pumps (1.9 MGD)	$570,000
Pre-Treatment MU/UF (1.75 MGD)	$2,098,000
RO Desalination Treatment (1.75 MGD)	$3,268,000
Concentrate Disposal (0.5 MGD)	$4,197,000
Transmission Pipeline (18 in dia, 8 miles)	$4,872,000
TOTAL COST OF FACILITIES	**$32,272,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$11,052,000
Permitting (404, mitigation, Bed & Banks etc.)	$1,145,000
Land Acquisition and Surveying	$629,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,578,000
TOTAL COST OF PROJECT	**$46,676,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$3,906,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$498,000
Water Treatment Plant	$1,937,000
Pumping Energy Costs ($0.09 kwh)	$45,000
Purchase of Water (2,128 acft/yr @ 65.65 $/acft)	$140,000
TOTAL ANNUAL COST	**$6,526,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**2,128**
Annual Cost of Water ($ per acft)	**$3,067**
Annual Cost of Water ($ per 1,000 gallons)	**$9.41**

5.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 5.1-5, and the option meets each criterion.

A summary of the implementation steps for the project is presented below.

- Agreement between BRA and the City of Cleburne on pipeline route, delivery point, and cost sharing.
- Pilot study to evaluate RO treatment of Lake Whitney water.
- Agreement with USACE for discharge into Lake Aquilla (Option A).
- Analysis of potential impact of blending Lake Whitney water in Lake Aquilla and disposal of brine reject.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- Texas General Land Office Easement if State-owned land or water is involved; and
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.
- Coordination with BRA on any potential subordination agreements for the System Operations strategy.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions or other local landowner agreements;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 5.1-5. Comparison of Transportation of Raw Water from Lake Whitney to Lake Aquilla to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low to medium impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Low impact due to distance from coast
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	Possible negative impacts on state water resources from water quality changes; no effect on navigation
D. Threats to Agriculture and Natural Resources	Low to none
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

5.2 Potential Purchase and Use of Water from Possum Kingdom Reservoir

5.2.1 Description of Option

The City of Abilene is evaluating potential sources of raw water to supplement their existing surface water supplies. Little rainfall and record low reservoir inflows over the last decade have driven Texas deeper and deeper into drought conditions. Particularly in West Texas, cities and towns are evaluating new sources to plan for their future water needs. One such possibility for Abilene is purchasing water from the Brazos River Authority (BRA) under the System Operations Permit from Possum Kingdom Reservoir. Note that the BRA System Operations Permit is pending at TCEQ and the viability of this strategy is dependent upon BRA obtaining the permit satisfactorily. This alternative has been explored in varying detail several times over the last 25 years. A general study was last performed in 2008 by HDR, Inc. (HDR), in conjunction with Enprotec/Hibbs & Todd, Inc. (eHT), and Lockwood, Andrews, and Newnam, Inc. (LAN)[1]. The 2008 study concluded that it is feasible to use Possum Kingdom Lake as a source of raw water supply for the City of Abilene. However, the report identified the preferred alternative is Cedar Ridge Reservoir (see chapter 4.2 of this report for more information). No new major study of the Possum Kingdom to Abilene option has been performed since the 2008 Report.

On March 10, 2005, Abilene entered into an Interlocal Agreement with the BRA and the West Central Texas Municipal Water District (WCTMWD) to address existing and future water supplies. With regards to the Possum Kingdom to Abilene strategy, the Interlocal Agreement provides the City of Abilene and/or the WCTMWD the option to purchase up to 20,000 acre-feet (acft) per year of BRA System Water, diverted from Possum Kingdom Reservoir, pending the approval of the BRA Systems Operation Permit (Application No. 5851). The first option was for a period of 10-years from the March 10, 2005 effective date of the Interlocal Agreement, at no cost. The City of Abilene, the WCTMWD and the BRA amended the original agreement on March 9, 2015, to extend the original agreement. If exercised once the BRA Systems Operations Permit is approved, the option to purchase would be converted into a standard, long-term water purchase agreement with the BRA. For more information on the BRA Systems Operations Permit and the potential supply available to Abilene, see Chapter 7.11 of this volume.

5.2.2 Available Yield – Possum Kingdom Reservoir

Possum Kingdom Reservoir lies approximately 80 miles east of Abilene, predominantly in Palo Pinto, Stephens, and Young Counties. The reservoir was created with BRA's construction of Morris Sheppard Dam in 1941. According to the BRA, Possum Kingdom Reservoir has a current conservation capacity of approximately 540,000[2] acre feet and a conservation surface area of 16,716 acres with 230,750 acft/yr available as water supply

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[1] *Evaluation of Cedar Ridge Reservoir and Possum Kingdom Lake Water Supply Options for the City of Abilene.* HDR, Inc. Enprotec/Hibbs & Todd, Inc. Prepared for the City of Abilene. April 2008.

[2] http://www.brazos.org/pkHome.asp

in the Brazos River Basin. Normal pool level is approximately 1,000 feet above mean sea level (ft-msl). There are approximately 219 miles of shoreline encompassing the long and meandering reservoir. The reservoir is a major component of BRA's basin-wide water supply system.

Morris Sheppard Dam was originally constructed with a hydroelectric power plant capable of generating 22,500 kilowatts of electrical energy from two turbine units that are no longer in use.

5.2.3 Water Quality

Possum Kingdom Reservoir historically has had elevated levels of chlorides, sulfates and total dissolved solids (TDS) due to naturally occurring salt springs in the upper reaches of the Brazos River Basin. These constituents are typically much higher than other area lakes and also higher than current Federal and State drinking water standards. Table 5.2-1shows median concentrations of chlorides, sulfates, and TDS in Possum Kingdom Reservoir for the 1996 to 2001 period in comparison to maximum limits allowed by current Texas drinking water standards (Texas Administrative Code 30 TAC §290.118(b)).

Table 5.2-1. Possum Kingdom Reservoir Water Quality (1996 – 2001)

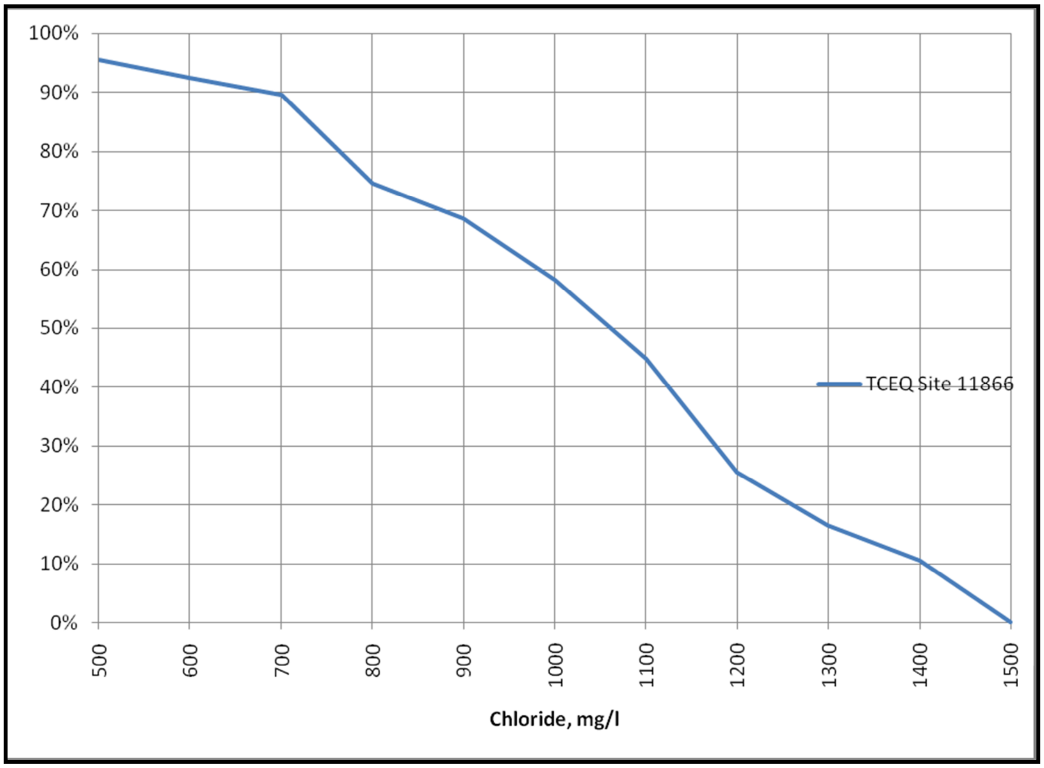
Constituent	Median Concentration (mg/l)	Texas Drinking Water Standard (mg/l)
Chlorides	909	300
Sulfates	369	300
Total Dissolved Solids	1,894	1,000

Chloride data from September 1997 to July 2007, measured at TCEQ sampling site #11866 located in the lower body of the lake near Johnson Bend, are presented in Figure 5.2-1. This figure shows that the median chloride level increased to about 1,060 mg/L during this recent timeframe. With the secondary contaminant level for chlorides in Texas currently set at 300 milligrams per liter (mg/L), the data indicate that any water treatment facility processing this supply source for potable water use must include demineralization to achieve secondary drinking water standards.

5.2.4 Water Treatment Facilities

Prior water planning efforts reviewed various treatment and conveyance scenarios for delivering Possum Kingdom water to the City of Abilene. While the option of expanding the City's existing WTPs is feasible, there appear to be several benefits to implementing a new plant near the lake. First, there are a number of communities located along the Possum Kingdom – Abilene corridor that could potentially take advantage of this project and purchase water from the City of Abilene. A second benefit of strategically locating the plant next to the lake is the ability to return brackish reject water from the treatment process back into the lake, an option that is not economically available at other potential plant locations. Alternate waste disposal methods, such as deep well injection and evaporation ponds would be significantly more expensive than a direct discharge. Lastly, treating the water prior to transmission eliminates conveyance of the reject water component (approximately 25% of the raw water volume) over a distance of nearly 80 miles. As the quantity of water to be conveyed reduces, so too can the diameter of the pipeline. Savings would be realized in the lower material cost of the smaller pipe diameter with less corrosion protection, and the lower energy costs associated with pumping the reduced quantity of water.

Figure 5.2-1. Exceedance Frequencies for Chloride Concentrations, Possum Kingdom Lake (TCEQ Site 11866: 1997 to 2007)



Treatment Objectives and Process Description

The finished water quality from the proposed WTP must meet Federal Primary and Secondary Standards, and Texas Commission on Environmental Quality (TCEQ) standards from its Chapter 290 – Public Drinking Water, Subchapter D: Rules and Regulations for Public Water Systems and Subchapter F: Drinking Water Standards. For this water source, a conventional treatment process would address potability and bacteriological quality requirements, but would not effectively remove the dissolved solids. Reverse Osmosis (RO) is considered to be an effective advanced treatment step for a water source of this quality. Several RO facilities are currently successfully treating the raw water from Possum Kingdom Lake, one of which has since the early 1980s.

With the inclusion of a RO treatment train, the volume of concentrated brine waste, or reject water, must be recognized. Current operating data for a plant on Possum Kingdom Lake operated by the Possum Kingdom Water Supply Corporation (PKWSC) indicate approximately 23% of the total raw water is brackish reject water that is disposed of back into the Lake. Given the above, and allowing an additional 3% water consumption for other process water uses within the WTP, results in a total 26% reduction from gross raw water to net finished water. If the total 20,000 acre-feet of option water were to be utilized, the raw water supply, waste, and net potable water produced would be proportioned as shown in Table 5.2-2. Taking into account these factors, a potential potable supply for Abilene of 14,800 acft/yr would return approximately 5,200 acft/yr of the 20,000 acft/yr diversion back to Possum Kingdom.

Table 5.2-2. Gross/Waste/Net Volumes

Component	Acft/yr	MGD
Total Raw Water Supply	20,000	17.85
RO Reject & Waste	5,200	4.65
Net Potable Water	14,800	13.20

The proposed WTP process is anticipated to consist of a conventional treatment train with coagulation/sedimentation and micro-filtration in advance of the RO membranes to remove the larger particulates and achieve a partial level of treatment. A portion of the filtered water from the conventional treatment train can be blended with the RO permeate to attain the desired finished water quality, thereby optimizing the RO equipment capacity. A preliminary schematic diagram of the treatment process is presented as Figure 5.2-2, and the primary process flow streams are summarized in Table 5.2-3. This summary is based on use of the total 20,000 acft of supply; alternate, lower capacity scenarios would be proportioned commensurately.

Process wastewater from the treatment process, predominantly consisting of RO reject water, will have significantly elevated levels of chloride, sulfate, and TDS, and must be disposed of properly. Based on recent Possum Kingdom Lake water quality data, the water treatment volumes described above, and a projected dissolved solids removal rate of 95%, the range of concentrations of these constituents in the waste stream has been estimated as follows:

- Chloride 1,990 to 3,636 mg/L
- Sulfate 1,330 to 2,070 mg/L
- TDS 5,635 to 8,675 mg/L

Figure 5.2-2. Preliminary WTP Flow Schematic

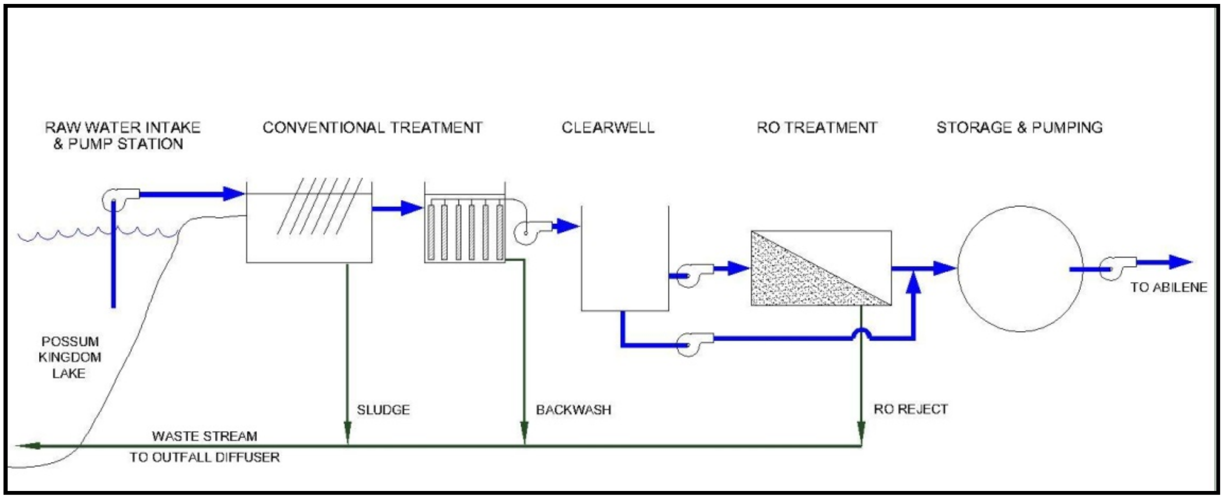


Table 5.2-3. Preliminary WTP Process Summary

Process Stream	Flow Rate (MGD)	% Raw	Blend Stream (MGD)	Blend Ratios
Conventional Train Feed	17.85	100%		
Filtered Water to Blend	-1.96	11%	1.96	14.85%
Backwash & Process Water	-0.54	3%		
Net, RO Feed Water	15.35	89%		
RO reject	-4.11	23%		
Net, RO Permeate	11.24	67%	11.24	85.15%
Total Finished Water	13.20	78%	13.20	

The most cost effective means of disposal is to return the brine flow back into the lake. Other disposal methods such as evaporation ponds or deep well injection entail significant capital and/or operation and maintenance costs, and are not preferable for this project. Disposal of the waste stream in Possum Kingdom Lake will require a discharge permit and approval by TCEQ. A preliminary analysis of the impact of this discharge on the water quality of the lake with respect to TCEQ criteria was performed. This analysis projects the not-to-exceed effluent discharge concentrations for chloride, sulfate, and TDS to be 4,300 mg/L, 1,200 mg/L, and 10,000 mg/L, respectively, indicating that the anticipated sulfate levels in the waste stream would require additional analysis in order to be permitted by the TCEQ. The analysis is based on a simplified dispersion model, however, and it might be possible to use more complex techniques to show that enhanced dispersion or diffusion would allow higher concentrations If not, additional treatment may be required to reduce brine concentrations to acceptable levels.

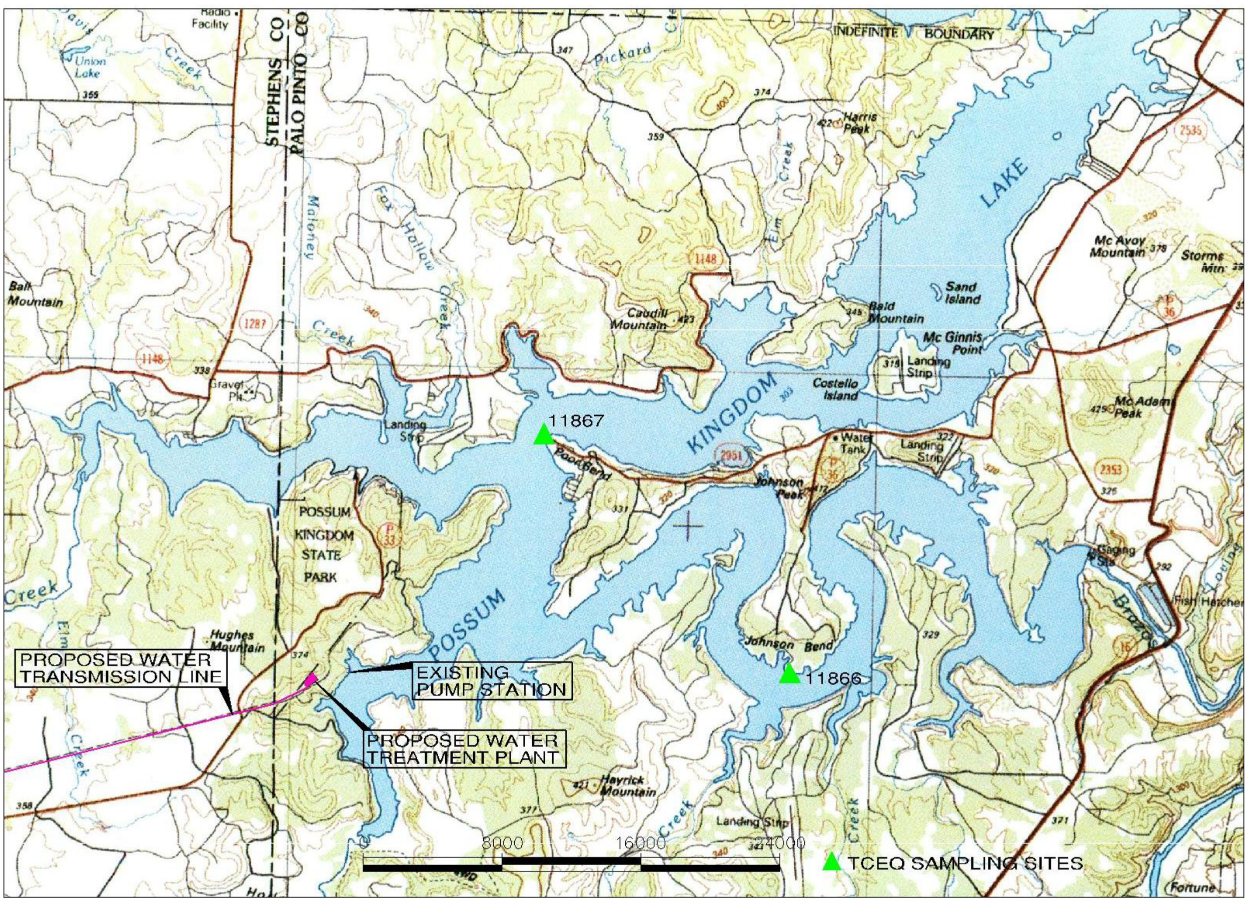
Water Treatment Plant Siting

The destination of water delivery favors a WTP site on the southwest side of Possum Kingdom Lake. The most cost-effective option for the proposed raw water intake and pumping facility appears to be the joint use of the existing BRA West Central Brazos (WCB) Water Distribution System intake located in this area. Fortunately, there appear to be many suitable locations for siting of the proposed WTP near the existing intake site. Much of the land adjacent to Park Road 33 and Pump Station Road is owned by the BRA. Advantages of this particular area include the following:

- Level or slightly rolling terrain,
- Minimal clearing required,
- Close proximity to electricity,
- Close proximity to intake structure,
- BRA owned property, and
- Considerable distance to existing homes.

A map of the general area in the vicinity of the WCB intake, showing the relationship of the potential site location and transmission line is presented in Figure 5.2-3.

Figure 5.2-3. Proposed WTP Site and Existing Intake Area Map



Raw Water Intake

The proposed WTP intake must be sized and configured to convey the required volume of raw water from the lake to the WTP site. The intake should be in close proximity to the WTP site, have reasonable access to electrical power and roads, and be configured for operation over a conservatively-projected range of lake levels. The existing WCB pump station, with the appropriate capacity upgrades, appears to be adequate. This intake site is located on the Little Caddo Creek arm on the southwest portion of the lake. The intake is situated at the end of Pump Station Road which intersects Park Road 33 approximately 2.5 miles southwest of the Possum Kingdom State Park entrance. The WCB intake condition should be assessed to determine if only modifications and additions were needed to adequately serve as the intake and raw water pump station for this project.

Expansion or additional use of the WCB intake will require coordination with and approval from the BRA. The City would need to work with the BRA to determine the extent of necessary improvements, determine joint-use versus separate facilities, and develop a lease agreement that addresses operation and maintenance responsibilities and allocation of costs. BRA has indicated that it would support the City's efforts if joint-use of the existing intake is implemented.

In general, principal modifications to the WCB intake would include raw water pumps installed in the existing structure, discharge piping and control valving, a pipe bridge to the structure, electrical and controls for the pumps, and a motor control center (MCC) building to support the City's pumping infrastructure. Based on the August 7, 2007, excerpt of the Freese & Nichols, Inc. "Assessment of Funding Requirements for the BRA Repair and Replacement Fund" pertaining to the WCB intake, several other capacity and Operation & Maintenance (O&M) improvements have been identified for implementation over the next several years. It is assumed that, if the City of Abilene pursues this option, the City would need to participate in the cost of improvements to shared components of the facility and any necessary improvements based on condition assessment of the structure at the time the strategy is implemented.

Water Availability

The supply for this strategy is dependent on the BRA securing the BRA Systems Operation permit from the TCEQ, The BRA Systems Operation Water Management strategy and associated water availability are discussed in detail in Chapter 7.10 of this report. That analysis shows that when this demand for the City of Abilene is included as part of the Systems Operations scenario there is sufficient water available from Possum Kingdom as part of Systems Operations to meet this demand with 100% reliability.

5.2.5 Treated Water Transmission

As presented above, the net finished potable water production associated with a 20,000 acft raw water supply volume is projected to be 14,800 acft, or 13.20 MGD. The transmission system is sized to convey this volume with a potential 5% downtime, resulting in an effective transmission capacity of 13.91 MGD, or 9,660 gpm. The system would begin at a high service pump station at the WTP site, and include booster stations at strategic locations to convey the water to Abilene. The point of delivery is Abilene's distribution system on the northeast side of the City.

The layout and configuration of the transmission system requires that consideration be given to topography, system hydraulics, easement/right-of-way issues, and constructability. The terrain is somewhat challenging in that a wide range of elevations are encountered from a lake level of 1000 feet above mean sea level to a high point at approximately 1,950 feet above mean sea level. The character of the surface and sub-surface soils will have a direct impact on the cost of construction.

Formations expected to be encountered in trenching range from the most stubborn limestone and sandstone to more moderate soils such as mudstone and shale to the most forgiving soils like sand and alluvium. A preliminary geological review of the project corridor suggests that approximately half of the pipeline length is limestone or sandstone. The other half is a combination of mainly mudstone, shale, alluvium, and deposits.

The evaluated transmission pipeline alignment is shown in Figure 5.2-4 (System Layout). The proposed alignment follows the alignment of existing water transmission facilities, with the intent to utilize existing easements and minimize new easement acquisition. The proposed route would utilize two existing easements that could provide right-of-way for approximately half of the length of the transmission pipeline. One easement was first established by the Texas Pacific Oil Company, Inc., later acquired by the Kerr-McGee Company, and was most recently acquired by the BRA. This easement contains an existing 36" pipeline which is still used for secondary recovery operations in oil fields located west of Breckenridge and in some areas south of Eliasville. BRA has incorporated this facility into their WCB system. This easement, with some limitations, could be used up to a point between US Highway 180 and State Highway 717, northeast of Breckenridge. Based on correspondence with the BRA, the existing easements on several of the parcels along this route will require landowner approval for additional pipelines to be installed and/or easement rights to be assigned. The second easement, owned by the WCTMWD, begins at Hubbard Creek Reservoir and generally runs southwest toward Abilene. It is a 100 foot-wide easement containing two existing raw water lines. One line runs down the center of the easement and the other lies approximately 30 feet to the north. The route of the proposed transmission line between the BRA/WCB easement and the WCTMWD easement avoids the developed fringes east and south of Breckenridge, and the southern extremities of Hubbard Creek Reservoir. Total length of the transmission pipeline would be about 77 miles. A preliminary hydraulic analysis was performed for the transmission system route to size piping, locate and determine operating requirements for pump stations, and review pipe pressure conditions. Figure 5.2-5 presents hydraulic profiles for the proposed route, and display the ground profile, and hydraulic grade line (HGL). The analysis indicates that a 36" transmission line will be required to efficiently convey the treated water volume of 14,800 acft/yr. Three booster pump stations, in addition to the intake and high service pump station will provide sufficient energy to overcome the elevation changes throughout the proposed pipeline route. Operating conditions for the pump stations are summarized in Table 5.2-4.

Each pump station would include a 750,000 gallon ground storage tank for pump suction and flow balancing. The topography along the last quarter of the corridor favors the provision of an "elevated" ground storage tank at the high point in the system that would allow gravity feed into the City.

Figure 5.2-4. System Layout for the Possum Kingdom to Abilene Water Supply Option

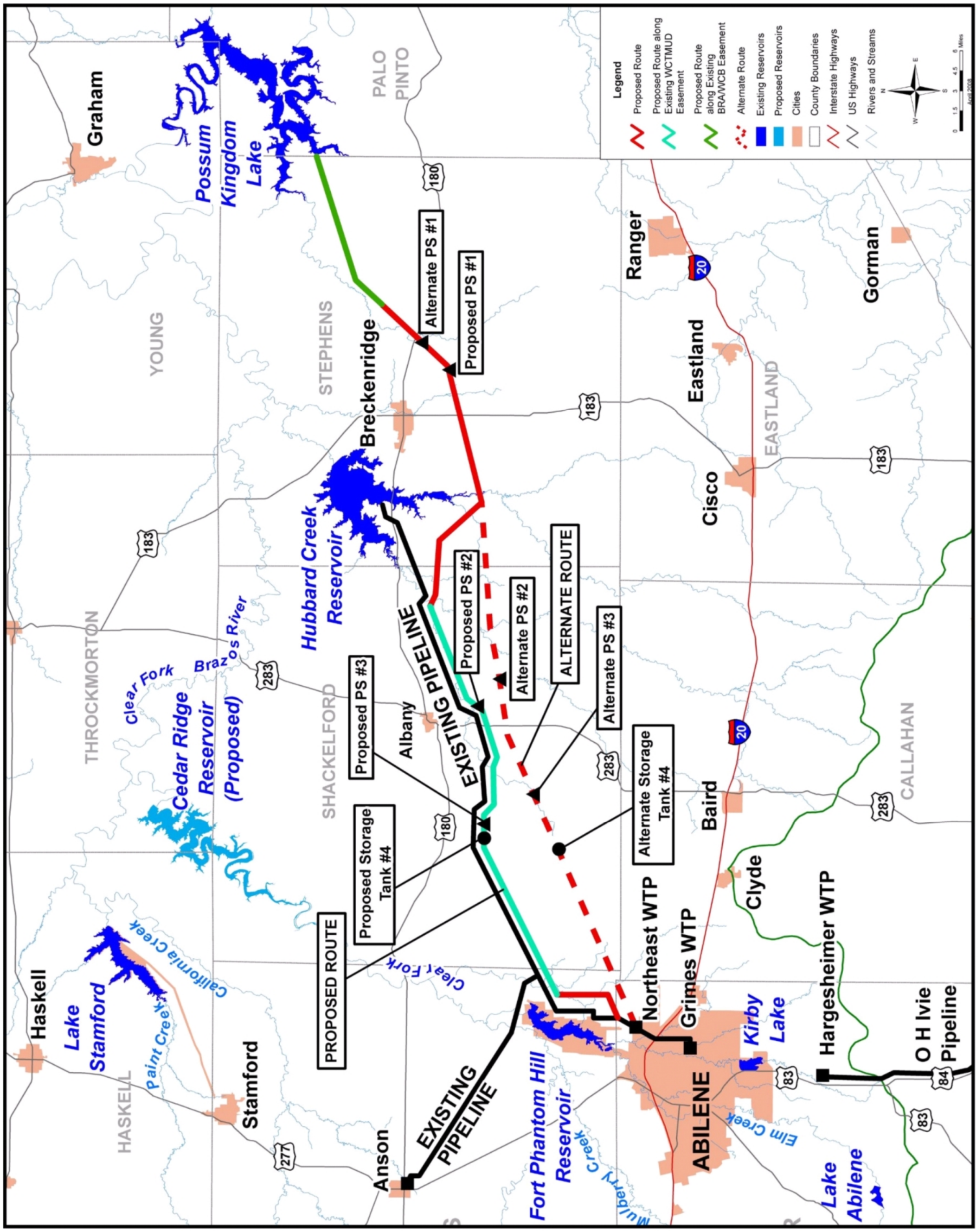


Figure 5.2-5. Hydraulic Profile of Transmission System Route

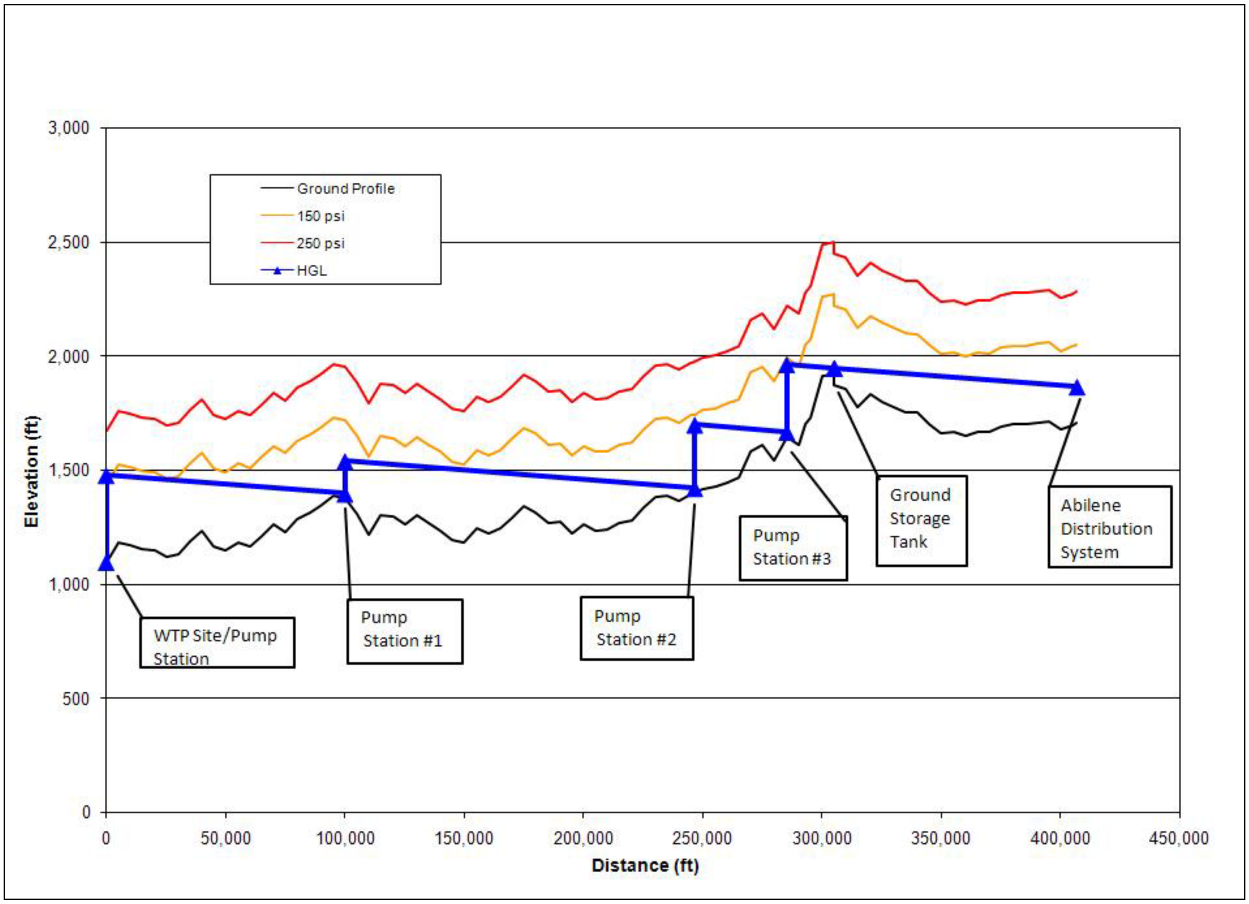


Table 5.2-4. Transmission System Pump Station Requirements

Facility	Station Capacity (gpm)	Discharge Pressure (psi)	Power (HP)
WTP Pump Station	9,700	180	1495
Booster PS #1	9,700	72	626
Booster PS #2	9,700	108	921

5.2.6 Environmental Issues

Existing Environment

The proposed management strategy would include the addition of a new water treatment plant and upgrading of an existing pump station on the southwest side of Possum Kingdom Reservoir, an approximately 77 mile pipeline system used to convey the water to Abilene, and the addition of three booster pump stations and four storage tanks. The proposed pipeline will connect to Abilene's existing distribution system located on the northeast side of the City.

The primary environmental issues related to this project are the development of a new pipeline route, addition of three new pump stations and four storage tanks, development of new brackish water treatment facilities, disposal of brackish reject water, and integration into the existing pipeline system.

The proposed route includes a total length of approximately 77 miles, and follows the alignment of existing water transmission facilities for approximately half of its route. The use of existing right-of-way (ROW) areas would result in minimal vegetation clearing for those areas and minimize the amount of habitat which would be impacted by the pipeline.

The development of the three booster pump stations and four 750,000 gallon ground storage tanks, and the addition of upgrades to the existing intake and pump station located at Possum Kingdom Reservoir will impact relatively small areas of existing habitat.

Plans to process the brackish water found in Possum Kingdom Reservoir at a new water treatment plant could result in the reintroduction of the brackish reject water into the lake. Possible impacts to existing species found near or within Possum Kingdom Reservoir should be carefully evaluated if this option is selected. Alternative methods suggested for the disposal of brackish reject water include deep well injection or the use of evaporation ponds. Either of these alternate methods would be expected to have a more limited impact on existing area species.

Project Overview

The project area is located in the North-Central Plains Physiographic Province.[3] This area is locally characterized by limestones, sandstones and shales arranged in low north-south ridges. The geologic structure within this area is tilted to the west, with elevation levels ranging from 900 to 3,000 feet above mean sea level.

Vegetation and Wildlife Habitats

The study area encompasses two vegetational areas; the western portion of the project is located within the Rolling Plains vegetational area and the eastern portion within the Cross Timbers and Prairies vegetational area.[4] The Rolling Plains vegetational area is located between the High Plains, and Cross Timbers and Prairies vegetational areas of northern Texas and contains areas of nearly level to rolling plain with moderate to rapid surface drainage. The original prairie vegetation found within the Rolling Plains Vegetational Area included medium-tall grassland with a sparse shrub cover. The dominant vegetation currently found includes native grasses such as little bluestem (Schizachyrium scoparium var. frequens), blue grama (Bouteloua gracilis), sideoats grama (B. curtipendula), indiangrass (Sorghastrum nutans), sand bluestem (Andropogon gerardii var. paucipilus), and various forbes.

[3] Bureau of Economic Geology. 1996. Physiographic Map of Texas. University of Texas at Austin, Austin, Texas.

[4] Hatch, S.L., N.G. Kancheepuram, and L.E. Brown. 1990. Checklist of the Vascular Plants of Texas. Texas Agricultural Experiment Station. Texas A&M University, College Station.

Within areas of sandier soils with broad rolling relief you will find shin oak (Quercus sinuata var. breviloba) grasslands, with additional groups of various oaks occurring in the mixed grass prairie. In areas containing clay and clay loam soils the predominant vegetation is the mesquite savannah grasslands. These usually occur on flat to gently rolling lands and are characterized by an open canopy of larger mesquite (Prosopis glandulosa) trees, a mid-story composed of shrubs such as lotebush (Zizyphus obtusifolia), succulents including prickly pears (Opuntia spp.), and ephedra (Ephedra spp.), and an understory of grasses and forbs.

Historically these natural communities were maintained by a combination of severe weather events, drought and fire. Invasion of the rangeland areas in this region by annual and perennial forbs, legumes, and woody species has been facilitated by historic livestock grazing practices and a lack of naturally occurring fire in the area. The Cross Timbers and Prairies vegetational area is a transitional area between the Blackland Prairies to the east and the Rolling Plains to the west. The original climax vegetation of this area was primarily composed of grasses such as big bluestem (Andropogon gerardii var. gerardii), little bluestem, indiangrass, switchgrass (Panicum virgatum), and Canada wild rye (Elymus canadensis). At one time this area also contained significant amounts of forbes such as western ragweed (Ambrosia psilostachya), littlesnout sedge (Carex microrhyncha), heath aster (Aster ericoides), gayfeathers (Liatris spp.) and sageworts (Artemisia spp.).

As a result of historical misuse and cultivation, the uplands within this area now contain scrub oak (Quercus sp.), mesquite, and Ashe juniper (Juniperus ashei), with mid- and short-grass understories. Hardwoods such as pecan (Carya illinoensis), oak, and elm (Ulmus sp.) are the traditional primary bottomland trees, but have commonly been invaded by mesquite.

Faunal species found within the project area include those suited to a semi-arid environment. Riparian zones located along the Brazos River, and streams and their tributaries contain important wildlife habitat for the region and support populations of white-tailed deer (Odocoileus virginianus) and Rio Grande turkeys (Meleagris gallopavo intermedia). Bobwhites (Colinus virginianus), scaled quail (Callipepla squamata), mourning dove (Zenaida macroura), and a variety of song birds, small mammals, waterfowl, shorebirds, reptiles, and amphibians are found in this region. Mammals which occur principally in the plains area of Texas include the Texas kangaroo rat (Dipodomys elator), Texas mouse (Peromyscus attwateri), prairie vole (Microtus ochrogaster), and plains pocket mouse (Perognatus flavescents).[5] Larger mammals found in the region include the coyote (Canis latrans), and ringtail (Bassariscus astusus). Bison (Bos bison), and black-footed ferrets (Mustela nigripes) are historically associated with this area.

County-Listed Species

In Jones, Taylor, Shackelford, Stephens, Young, and Palo Pinto counties there may occur fourteen state-listed endangered or threatened species and ten federally-listed endangered or threatened wildlife species, according to the county lists of rare species produced by the U.S. Fish and Wildlife Service and Texas Parks and Wildlife

[5] Davis, W. B. and D. J. Schmidly. 1994. The Mammals of Texas. Texas Parks and Wildlife Department, Austin, TX

Department. A list of these species, their preferred habitat and potential occurrence in the six county areas is provided in Table 5.2-5.

Inclusion in Table 5.2-5 does not imply that a species will occur within the project area, but only acknowledges the potential for occurrence in the project area counties. A more intensive field reconnaissance would be necessary to confirm and identify specific suitable habitat that may be present in the project area.

The proposed projects occur primarily in areas which have been previously developed and used for farming and ranching activities for an extended period of time. Because a large portion of the pipeline is planned to be constructed within existing easements disturbance within these areas due to construction of the pipeline route and other facilities needed for this project is anticipated to have minimal effect on the existing environment. Although the use of deep well injection methods or evaporation ponds for disposal of the brackish reject water is not anticipated to impact existing terrestrial species, impacts from the disposal of this water into Possum Kingdom Reservoir or surface water streams should be carefully monitored in order to minimize any impacts this may have on aquatic species. Impacts to any federally listed threatened or endangered species, its habitat, or designated habitat, or to any state endangered species would depend on the specific location of the pipeline route and the disposal option chosen for the brackish reject water. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning. The presence or absence of potential habitat within an area does not confirm the presence or absence of a listed species. No species specific surveys were conducted in the project area for this report.

Table 5.2-5. Endangered, Threatened, and Species of Concern for Jones, Palo Pinto, Taylor, Shackelford, Stephens, and Young Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
				BIRDS				
American peregrine falcon	Falco peregrinus anatum	0	2	0	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	Falco peregrinus tundrius	0	1	0	Migrant throughout the state.	DL	--	Possible Migrant
Baird's sparrow	Ammodramus bairdii	0	1	0	Migratory in western half of the state. Found in shortgrass prairie with scattered low bushes and matted vegetation.	--	--	Possible Migrant
Bald eagle	Haliaeetus leucocephalus	0	2	0	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Black-capped vireo	Vireo atricapilla	0	3	0	Occupies oak-juniper woodlands with a distinctive patchy, two-layered aspect. Migrant.	LE	E	Nesting/ Migrant

Table 5.2-5. Endangered, Threatened, and Species of Concern for Jones, Palo Pinto, Taylor, Shackelford, Stephens, and Young Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Ferruginous hawk	Buteo regalis	0	1	0	Prefers open county, primarily prairies, plains and badlands. Resident in northwester high plains, migrant in western 2/3 of Texas.	--	--	Possible Migrant
Golden-cheeked warbler	Setophaga chrysoparia	0	3	0	Found in juniper-oak woodlands; dependent on Ashe juniper for bark strips used in nest construction. Migrant	LE	E	Nesting/ Migrant
Interior least tern	Sterna antillarum athalassos	0	3	0	Nests along sand and gravel bars in braided streams	LE	E	Resident
Mountain plover	Charadrius montanus	0	1	0	Non-breeding, shortgrass plains and fields	--	--	Migrant
Peregrine falcon	Falco peregrinus	0	2	0	Possible migrant. Subspecies not easily distinguishable so reference is made to species level.	DL	T	Possible Migrant
Piping plover	Charadrius melodus	0	2	0	Migrant shorebird in Texas.	T	--	Migrant
Red knot	Calidris canutus rufa	0	1	0	Migratory species within Texas.	PT	--	Possible Migrant
Snowy plover	Charadrius alexandrines	0	1	0	Potential migrant that winters along the coast.	--	--	Possible Migrant
Sprague's pipit	Anthus spragueii	0	1	0	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Western burrowing owl	Athene cunicularia hypugaea	0	1	0	Open grasslands, especially prairie, plains and savanna	--	--	Resident
Western snowy plover	Charadrius alexandrines nivosus	0	1	0	Potential migrant that winters along the coast.	--	--	Potential Migrant
Whooping crane	Grus americana	0	3	0	Potential migrant	LE	E	Potential Migrant
				FISHES				
Guadalupe bass	Micropterus treculi	0	1	0	Endemic to perennial streams of the Edwards Plateau region.	--	--	Resident
Sharpnose shiner	Notropis oxyrhynchus	0	3	0	Endemic to Brazos River drainage. Found in large rivers.	LE	--	Resident

Table 5.2-5. Endangered, Threatened, and Species of Concern for Jones, Palo Pinto, Taylor, Shackelford, Stephens, and Young Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Smalleye shiner	Notropis buccula	0	3	0	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident
MAMMALS								
Black-footed ferret	Mustela nigripes	0	3	0	Extirpated in the state, small areas of reintroduced individuals.	LE	--	Historic Resident
Black-tailed prairie dog	Cynomys ludovicianus	0	1	0	Found in dry, flat, short grasslands with low, relatively sparse vegetation.	--	--	Resident
Cave myotis bat	Myotis velifer	0	1	0	Colonial and cave-dwelling species which also roosts in rock crevices, old buildings, and other areas.	--	--	Resident
Gray wolf	Canis lupus	0	3	0	Extirpated formerly known in western two-thirds of the state.	LE	E	Historic Resident
Plains spotted skunk	Spilogale putorius interrupta	1	1	1	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	Canis rufus	0	3	0	Extirpated.	LE	E	Historic Resident
Texas kangaroo rat	Dipodomys elator	0	2	0	Normally associated with scattered mesquite shrubs and sparse, short grasses in areas underlain by firm clay soils.	--	T	Resident
MOLLUSKS								
Smooth pimpleback	Quadrula houstonensis	0	2	0	Found in small to moderate streams and rives as well as moderate sized reservoirs. Brazos and Colorado River basins.	C	T	Resident
Texas fawnsfoot	Truncilla macrodon	0	2	0	Found in rivers and larger streams, intolerant of impoundment.	C	T	Resident
PLANTS								
Glen Rose yucca	Yucca necopina	0	1	0	Texas endemic found in grasslands on sandy soils and limestone outcrops.	--	--	Resident

Table 5.2-5. Endangered, Threatened, and Species of Concern for Jones, Palo Pinto, Taylor, Shackelford, Stephens, and Young Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
				REPTILES				
Brazos water snake	Nerodia harteri	0	2	0	Found in upper Brazos River drainage in shallow water with rocky bottoms.	--	T	Resident
Spot-tailed earless lizard	Holbrookia laceratat	0	1	0	Found in central and southern Texas and adjacent Mexico in moderately open prairie-brushland.	--	--	Resident
Texas Horned Lizard	Phrynosoma cornutum	1	2	2	Varied, sparsely vegetated uplands.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

TPWD, 2014. Annotated County List of Rare Species –Palo Pinto, Jones, Shackelford, Stephens, and Young Counties updated 9/4/2014, Taylor County updated 5/25/2011,

USFWS, 2014. Species Lists from http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action?fips=48187, etc., accessed December 9, 2014.

Wetland Areas

Potential wetland impacts are expected to include pipeline crossings of rivers, and streams, and areas near existing reservoirs. The additional pump stations, storage tanks, water treatment plant, and water transmission pipeline systems should be sited in such a way as to avoid or minimize impacts to these sensitive resources. Potential impacts can be minimized by right-of-way selection and appropriate construction methods, including erosion controls and revegetation procedures. Compensation for net losses of wetlands would be required where impacts are unavoidable.

Cultural Resources

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available GIS datasets provided by the Texas Historical Commission (THC), there are no National Register Properties, National Register Districts or historical markers listed near any of the proposed project areas. Several small cemeteries occur near the pipeline route; however they should be avoided by careful siting during project design.

A cultural resource survey of the proposed WTP, storage tanks and pump station sites along with the pipeline route for the project will need to be performed in a manner consistent with requirements of the Texas Antiquities Commission.

Summary of Overall Possible Impacts

Because of the relatively small areas involved, construction and maintenance of the additional pump stations, storage tanks and wastewater treatment plant are not expected to result in substantial environmental impacts. Use of the proposed pipeline route would substantially reduce the amount of impact to existing habitats by utilizing already disturbed easement areas.

Where environmental resources (e.g., endangered species habitat and cultural resource sites) could be impacted by infrastructure, adjustments in facility siting and pipeline alignment should generally be sufficient to avoid or minimize adverse effects. Mitigation requirements would vary depending on the impacts, but could possibly include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

5.2.7 Engineering and Costing

Project cost projections were prepared using the TWDB Unified Costing Model. Cost tables were updated to September 2013 with energy cost set at $0.09 per kWh, to be consistent with State regional water planning efforts. Cost projections were prepared for the Possum Kingdom option using the proposed alignment described above. The Cost summary is included in Table 5.2-6.

Operating and maintenance production costs are projected based on the 14,800 acft per year water needs. The total project cost for treatment and delivery of 14,800 acft of potable Possum Kingdom Lake water to the City of Abilene (using the alignment cost in Table 5.2-6) is $269,334,000. The associated debt service and annual operating cost are projected at $38,271,000, yielding a finished water cost of $2,586 per acft, or $7.93 per thousand gallons.

Table 5.2-6. Cost Estimate for Possum Kingdom to Abilene Water Supply Project

Item	Estimated Costs for Facilities
Intake Pump Stations (18.2 MGD)	$3,868,000
Transmission Pipeline (36 in dia., 77 miles)	$83,847,000
Transmission Pump Station(s) & Storage Tank(s)	$15,392,000
Storage Tanks (Other Than at Booster Pump Stations)	$1,667,000
Two Water Treatment Plants (18.2 MGD and 12.1 MGD)	$83,098,000
TOTAL COST OF FACILITIES	**$187,872,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$61,563,000
Environmental & Archaeology Studies and Mitigation	$1,984,000
Land Acquisition and Surveying (192 acres)	$295,000
Interest During Construction (4% for 2 years with a 1% ROI)	$17,620,000
TOTAL COST OF PROJECT	**$269,334,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$22,538,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$877,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$426,000
Water Treatment Plant	$10,897,000
Pumping Energy Costs (24576268 kW-hr @ 0.09 $/kW-hr)	$2,212,000
Purchase of Water (20000 acft/yr @ 65.65 $/acft)	$1,313,000
Easement and Intake Lease	$8,000
TOTAL ANNUAL COST	**$38,271,000**
Available Project Yield (acft/yr)	**14,800**
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	**$2,586**
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	**$7.93**

5.2.8 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 5.2-7, and the option meets each criterion.

Table 5.2-7. Comparison of Potential Purchase and Use of Water from Possum Kingdom Reservoir to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible Impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not Applciable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

The participating entities must negotiate a regional water service contract to build and operated the system and to equitably share costs. This would probably include the need for a cost of service study.

Requirements specific to pipelines needed to link existing sources to users will include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the U.S. for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

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6 Conjunctive Use

6.1 Lake Granger Augmentation

6.1.1 Description of Option

Rapid population growth and development in Williamson County require additional water supplies throughout the planning period. The total need for new supplies in Williamson County is about 19,700 acft/yr in the year 2020, increasing to about 167,200 acft/yr by year 2070. Much of the increased demand is in the southwestern portion of the county in and adjoining the Cities of Round Rock, Leander and Georgetown. This alternative will add 53,361 acft/yr (7,096 from Phase I in 2070 + 46,265 acft/yr from Phase II[1]) by augmenting the long-term firm yield of Lake Granger with groundwater pumped from the Trinity Aquifer and the Carrizo-Wilcox Aquifer. In the initial phase of the project, water from the Trinity Aquifer in eastern Williamson County would be blended with treated water from the East Williamson County Regional Water Treatment Plant (EWCRWTP). In the second phase of the project, additional groundwater would be developed from the Carrizo-Wilcox Aquifer in areas east of Williamson County, in Milam, Lee and Burleson Counties. At this time, specific locations for these supplies have not been identified. For the purposes of this plan, it is assumed that these supplies will come from Milam County.

Facilities for Phases 1 and 2 are depicted in Figure 6.1-1 and Figure 6.1-2, respectively. Conceptual designs for the various components of these projects are based on studies performed for the Brazos River Authority in 2005[1], 2009[2] and 2014[3]. Two alternatives have been studied previously for the second phase of the project. In the first alternative, referred to as the Comingling Option, Carrizo-Wilcox Aquifer water is first pumped into Lake Granger and comingled with natural runoff in the reservoir. The comingled water is subsequently diverted and all of the water is treated at the EWCRWTP. In the second alternative, referred to here as the Bypass Option, groundwater is blended with treated Lake Granger water rather than comingling the water in the reservoir. Because of concerns about blending groundwater in Lake Granger and the additional cost and treatment capacity associated with treating the blended water, current Brazos River Authority planning assumes that the Bypass Option will be used rather than the Comingling Option. The Comingling Option produces a more consistent water quality to the customers than does the Bypass Option.

As an alternative or complement to using blended Trinity Aquifer and Lake Granger water, the Trinity Aquifer could be used for aquifer storage and recovery (ASR). Treated

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[1] Parsons Brinkerhoff Quade and Douglas, Inc. and Espey Consultants: Williamson County Water Supply Plan Groundwater Procurement, Implementation and Costs, prepared for the Brazos River Authority, July 2005.

[2] R.W. Harden and Associates and Freese and Nichols, Inc.: Assessment of the Use of Trinity Groundwater in Williamson County, Texas, prepared for the Brazos River Authority, July 2009.

[3] R.W. Harden and Associates and Freese and Nichols, Inc.: Results of Test Hole Drilling and Conceptual Design of Permanent Facilities, Trinity Aquifer, Williamson County, prepared for the Brazos River Authority, November 2014.

surface water could be stored in the Trinity Aquifer during times of low demand or high flows and recovered for use at a later date. Pending further study ASR is not included as an option in Phase I at this time.

6.1.2 Available Yield

Using the Brazos G WAM, the firm yield of Lake Granger is projected to decline from a yield of 17,017 acft/yr in the year 2020 to 14,192 acft/yr by 2070. Reservoir sedimentation is depleting conservation storage from its original permitted volume of 65,500 acft to a projected volume at year 2070 of 36,271 acft.

Water from the Trinity Aquifer in the Lake Granger area is relatively high in dissolved solids. Phase I envisions blending Trinity Aquifer water with treated water from the EWCRWTP to reduce dissolved solids concentration. A ratio of 2 parts Lake Granger water to 1 part Trinity Aquifer water should meet drinking water standards. As a result, the amount of water available from the Trinity Aquifer is limited by the yield of Lake Granger. Table 6.1-1 shows the potential supply from the first phase of this project, which ranges from about 8,500 acft/yr of additional supply in 2020 to about 7,100 acft/yr in 2070.

This strategy could potentially be provided supply under the BRA System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. If an entity other than the BRA were to sponsor and pursue this strategy, then an agreement with the BRA would be required to address concerns related to the potential subordination of the System Operation strategy.

Table 6.1-1. Potential Supply from First Phase of Lake Granger Augmentation Project (Values in acft/yr)

Source	2020	2030	2040	2050	2060	2070
Granger Lake Firm Yield	17,017	16,452	15,887	15,322	14,757	14,192
Amount of Trinity Aquifer Groundwater	8,509	8,226	7,944	7,661	7,379	7,096
Total	25,526	24,678	23,831	22,983	22,136	21,288

* assumes a 2:1 mixing ratio of Granger to Trinity water

Figure 6.1-1. Phase I – Conjunctive Use with Trinity Aquifer

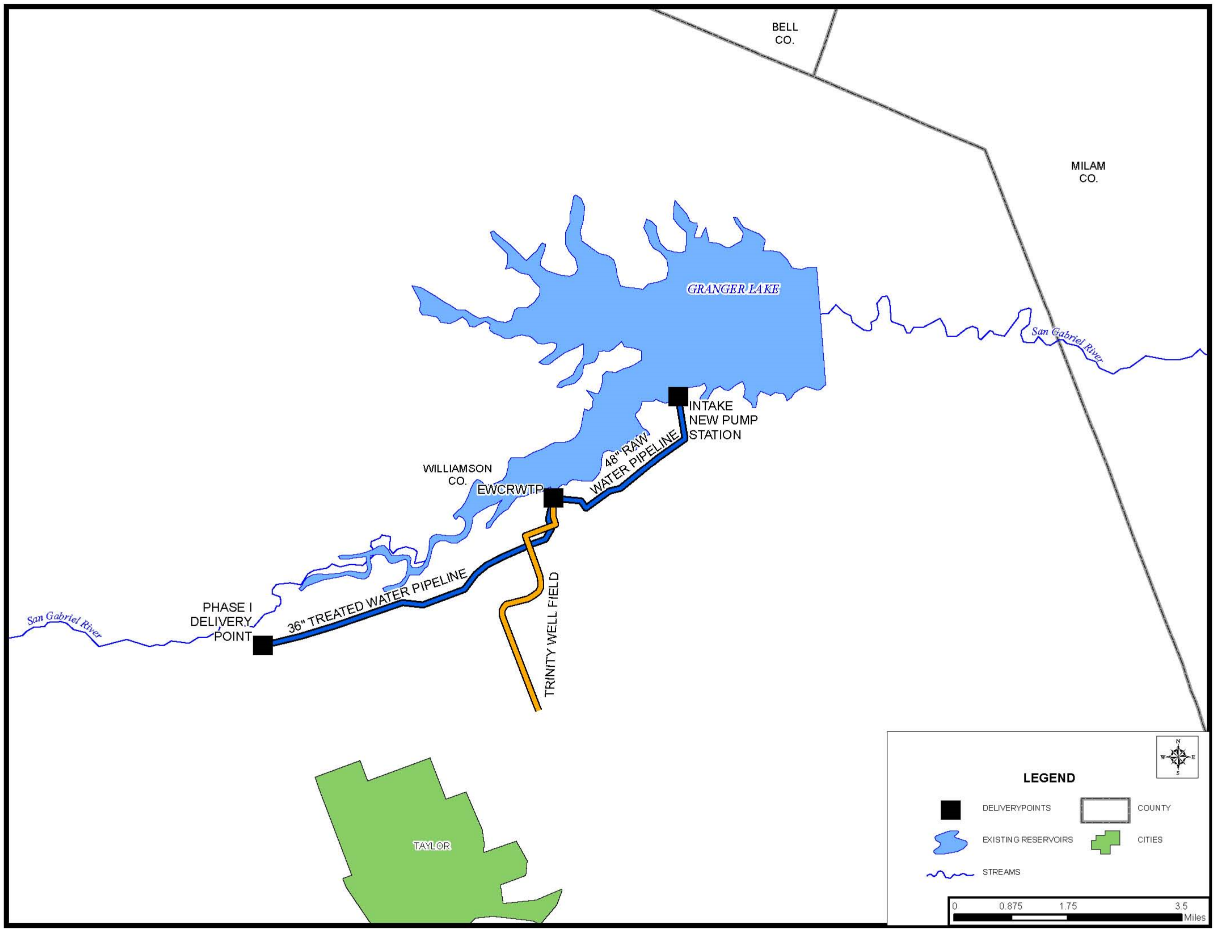
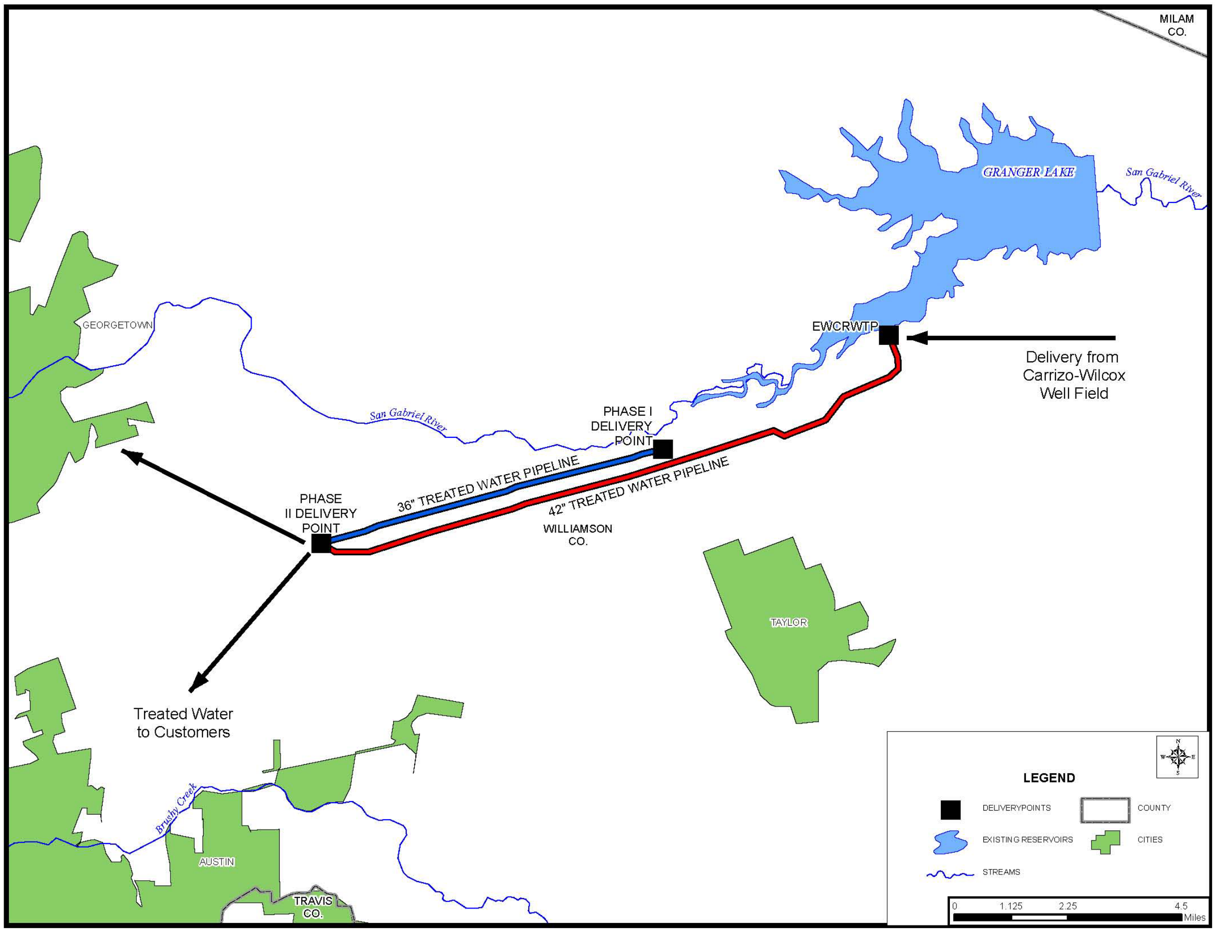


Figure 6.1-2. Phase II – Conjunctive Use with Carrizo-Wilcox Aquifer



The second phase of the project calls for overdrafting Lake Granger during times of high flow, utilizing interruptible surface water from BRA System Operations. Surface water supplies will be supplemented by water from the Carrizo-Wilcox Aquifer when interruptible water from Lake Granger is not available.

The conjunctive use project would develop a total supply of 53,361 acft/yr (7,096 acft/yr from Phase I in 2070 plus 46,265 acft/year from Phase II). A portion of the water from Phase II is used to firm up the 19,840 acft/yr of permitted diversions out of Lake Granger, of which only 14,192 acft/yr are firm in 2070 without the conjunctive use project. EWCRWTP customers and other water utilities in the distribution system are likely candidates for this additional water supply.

The Brazos G WAM was utilized to simulate operations of Lake Granger supplemented with the groundwater pumping. In the WAM, it was assumed that all of the demand (less the Trinity Aquifer water from Phase I) was taken from Lake Granger when the reservoir was full and spilling. When the reservoir is less than full, demands on the reservoir are reduced as the storage declines and the remainder of the demand is met by pumping from the Carrizo-Wilcox Aquifer. Figure 6.1-3 shows the storage trace for Lake Granger modeled with these assumptions. Based on these assumptions, the average pumping from the Carrizo-Wilcox Aquifer is 28,118 acft/yr with a maximum pumping of 51,831 acft/yr (Figure 6.1-4).

Figure 6.1-3. Lake Granger Storage – 2070 Conditions

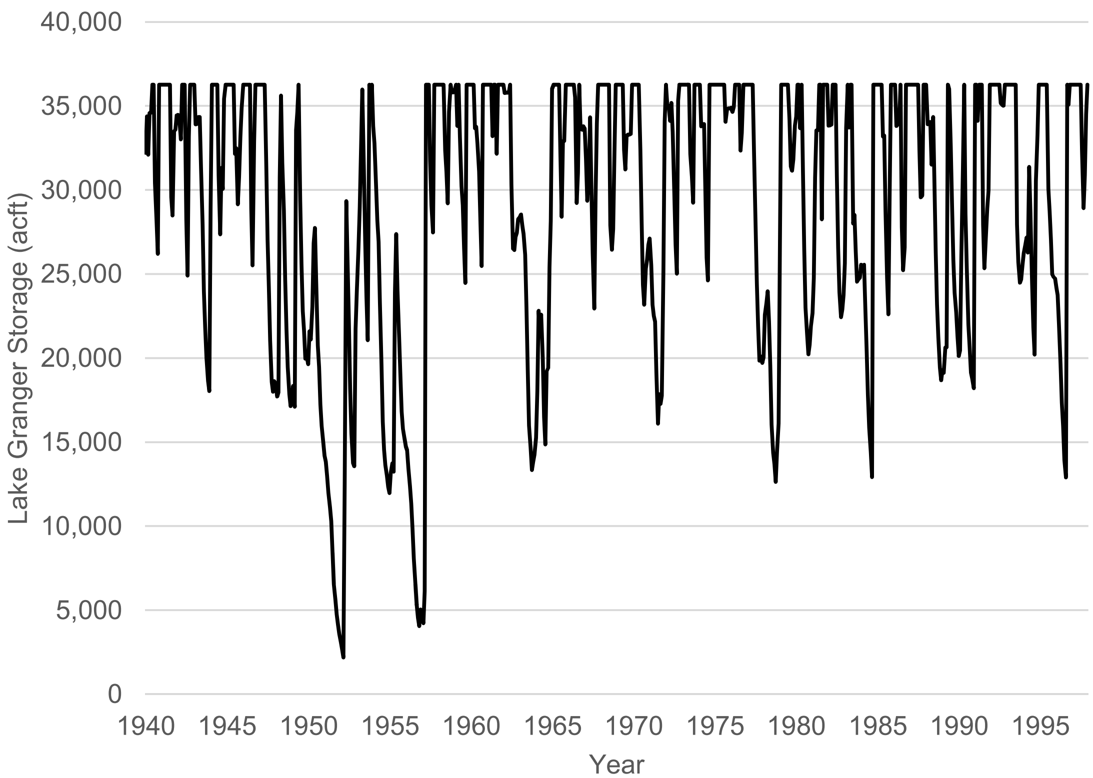
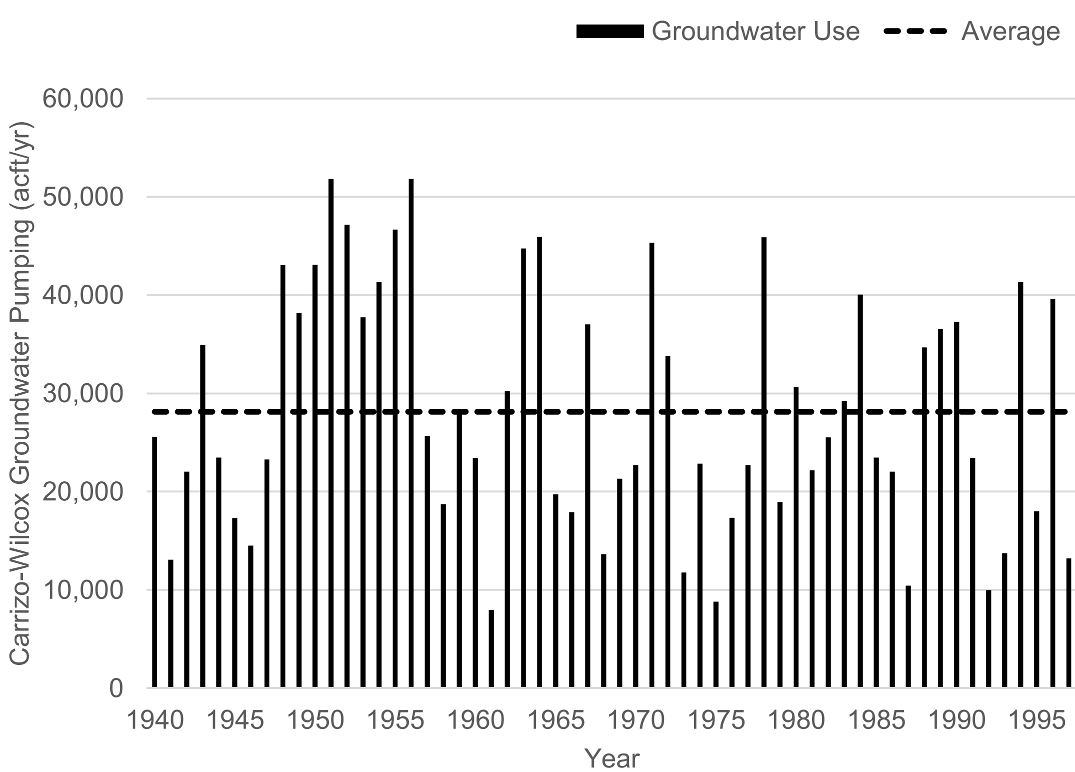


Figure 6.1-4. Annual Carrizo-Wilcox Pumping – 2070 Conditions



A review of groundwater availability for the Trinity Aquifer in Williamson County and the Carrizo-Wilcox Aquifer in Milam County shows that existing demands are equal to are greater than the Modeled Available Groundwater (MAG). Thus, the groundwater supply for the Lake Granger Augmentation Project may not be available as presented.

6.1.3 Environmental Issues

Environmental impacts could include:

- Possible reduction in flood releases to the San Gabriel River downstream of Lake Granger
- Possible moderate impacts on riparian corridors depending on specific locations of pipelines
- Possible low impacts on instream flows due to slight decrease in groundwater discharges from the Carrizo-Wilcox Aquifer

A summary of environmental issues is presented in Table 6.1-2.

Table 6.1-2. Environmental Issues: Groundwater/Surface Water Conjunctive Use (Lake Granger Augmentation)

Water Management Option	Groundwater/Surface Water Conjunctive Use
Implementation Measures	Construction of well fields, collection systems, pump stations, pipelines, and expansion of existing water treatment plant
Environmental Water Needs/Instream Flows	Possible impacts on instream flows
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Possible moderate impacts on riparian corridors and upland habitats depending on specific locations of pipelines
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible low impact
Comments	Assume institutional transfer agreements among water rights owners, suppliers, and users

6.1.4 Engineering and Costing

Facilities for this option are shown in Figures 6.1-1 and 6.1-2, and Table 6.1-3 and Table 6.1-4. For costing purposes, it is assumed that in Phase I potable water supply will be delivered to a point just north of the City of Taylor. In Phase II, delivery would be extended to a point between the Cities of Taylor and Georgetown.

For Phase I, the Trinity Aquifer well field is assumed to require four wells located near the EWCRWTP. Because there is little current use from the Trinity Aquifer in this area, one test well was drilled in 2013 to verify productivity and water quality. Based on the results, it is concluded that the Trinity Aquifer near the EWCRWTP has greater productivity and a lower concentration of dissolved minerals than projected from the information available in the last plan. Other facilities include a well field collection system, cooling towers (the water will most likely be hot), expansions to the EWCRWTP, and a 3.7-mile 36-inch treated water pipeline from EWCRWTP to an existing customer delivery point. This option also required a larger intake structure in Lake Granger, a new pump station and a 3.8-mile 48-inch raw water pipeline that have already been built by BRA.

Conceptual designs and costs for the various components of these projects are based on studies performed for the Brazos River Authority between 2005 and 2014. The construction costs were updated to September 2013 prices and reformatted to be consistent with Brazos G practices. No evaluation was made to determine consistency of these costs with results from Unified Costing Tool, which is used by all regional planning groups.

The total capital costs for Phase I is $59.4 million as shown in Table 6.1-3. Additional costs for professional services, land acquisition, well mitigation, and interest during construction add $25.7 million for a total project cost of $85.1 million. Annual debt service on this principal amount, calculated on the basis of 5.5 percent interest for 20-year debt is $7.1 million. Operation and maintenance costs for pumping, transmission, and treatment to deliver a total annual supply of 25,526 acft (17,017 acft from Lake Granger in 2020 plus 8,509 acft from the Trinity Aquifer), as well as groundwater leasing and surface water purchase contracts must be accounted for to arrive at a unit cost of produced water. These additional costs of $7.8 million added to the annual debt service gives a total annual cost for the full project of $14.9 million. For Phase I, the unit cost of water is $584 per acft/yr or $1.79 per 1,000 gallons.

Phase II will provide an additional 46,265 acft/yr of supply. The location of the well field for Phase II has not been identified. For the purposes of this study, it is assumed that the well field will be located in Milam County, although all or part of the required well field may be located in Burleson, Lee or other counties to the east of Williamson County. Carrizo-Wilcox groundwater will be gathered by a well-field collection system and transported by parallel 36-inch and 48-inch pipelines (built in phases) to a blending facility near the EWCRWTP. An additional 42-inch treated water pipeline will be built from the blending facility to the Phase I delivery point. Two parallel 38-inch and 42-inch pipelines (also built in phases) would deliver the water to a new customer delivery point between the cities of Taylor and Georgetown. Customers such as Chisholm Trail Special Utility District, Georgetown or Round Rock would need to build treated water pipelines to the delivery point.

The Phase II total capital cost is $360.6 million as shown in Table 6.1-4. Additional costs for professional services, land acquisition, well mitigation, and interest during construction add $276.5 million for a total project cost of $637.1 million. Annual debt service on this principal amount is $53.3 million. Annual costs for the new supply of 46,265 acft/yr, as well as groundwater leasing, regulatory groundwater withdrawal fees, and surface water purchase contracts must be accounted for to arrive at a unit cost of produced water. These additional costs of $21.2 million added to the annual debt service gives a total annual cost for the full project of $74.5 million. For Phase II, the unit cost of water is $1,611 per acft/yr or $4.94 per 1,000 gallons. Compensation to BRA may be required if this strategy were developed by another entity other than BRA to compensate for any subordination of the System Operations strategy.

Table 6.1-3. Cost Estimate Summary for Phase I of Lake Granger Augmentation

Item	Estimated Costs for Facilities
Trinity Aquifer Well Field (4 wells)	$24,369,000
EWCRWTP Expansions (12.5 MGD)	$28,670,000
Treated water pipeline (36 in. dia., 3.7 miles)	$4,453,000
Transmission Pump Station(s)	$1,925,000
TOTAL COST OF FACILITIES	**$59,417,000**
Engineering, Legal Costs and Contingencies	$20,573,000
Environmental & Archaeology Studies and Mitigation	$713,000
Land Acquisition and Surveying (37 acres)	$219,000
Interest During Construction (1.5 years)	$4,248,000
TOTAL COST OF PROJECT	**$85,170,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$7,127,000
Operation and Maintenance	$5,050,000
Pumping Energy Costs (13233294 kW-hr @ 0.09 $/kW-hr)	$1,191,000
Purchase of Water (25,526 acft/yr @ $60.50/acft)	$1,544,000
TOTAL ANNUAL COST	**$14,912,000**
Available Project Yield (acft/yr)	**25,526**
Annual Cost of Water ($ per acft)	**$584**
Annual Cost of Water ($ per 1,000 gallons)	**$1.79**

Table 6.1-4. Cost Estimate Summary for Phase II of Lake Granger Augmentation

Item	Estimated Costs for Facilities
Carrizo-Wilcox Well Field (30 wells)	$33,848,000
Pipeline from Well Field to EWCRWTP (36 & 48 in. dia. each 44 miles)	$128,311,000
Blending Facility	$9,993,000
EWCRWTP Expansions (83 MGD)	$83,485,000
Treated water pipeline from delivery to customers (various dia., 68 miles)	$68,617,000
Transmission Pump Stations	$33,895,000
Treated water storage	$2,417,000
TOTAL COST OF FACILITIES	**$360,566,000**
Engineering, Legal Costs and Contingencies	$116,765,000
Environmental & Archaeology Studies and Mitigation	$4,322,000
Land and/or Groundwater Rights Acquisition	$100,000,000
Land Acquisition and Surveying	$4,371,000
Interest During Construction (3 years)	$51,033,000
TOTAL COST OF PROJECT	**$637,057,000**
ANNUAL COST	
Debt Service for Infrastructure (5.5 percent, 20 years)	$53,309,000
Operation and Maintenance	$10,990,000
Pumping Energy Costs (@ 0.09 $/kW-hr)	$5,725,000
Annual Cost to Purchase Water (Assumed $60.50 per acft)	$2,799,000
Annual Groundwater Permitting Cost (Assumed $60.50 per acft)	$1,701,000
TOTAL ANNUAL COST	**$74,524,000**
Available Project Yield (acft/yr)	**46,265**
Annual Cost of Water ($ per acft)	**$1,611**
Annual Cost of Water ($ per 1,000 gallons)	**$4.94**

6.1.5 Implementation Issues

Early significant activity toward implementation of this startegy has been accomplished by the Brazos River Authority via its ownership of Lake Granger water supply, application for a systems operation permit, ownership of the existing water treatment plant on Lake Granger, and pursuit of nearby groundwater supplies. Developing a suitable approach to the evaluated level of groundwater pumping requires additional cooperative agreements with local groundwater districts and landowners. However, for purposes of regional planning, both Phase 1 and 2 projects overdraft the groundwater supply, which is inconsistent with required procedures as implemented by the TWDB.

This water supply option has been compared to the plan development criteria, as shown in Table 6.1-5.

Potential Regulatory Requirements:

- Requirements for permits to use surface water and groundwater, as well as for pipeline construction, will require permits as follow:
- Local groundwater district pumping permits as needed.
- TCEQ water rights permit (pending) for BRA System Operations (Phase II)
- U.S. Army Corps of Engineers Section 404 permits for pipeline stream crossings, discharges of fill into wetlands and waters of the U.S. for construction, and other activities
- NPDES Stormwater Pollution Prevention Plans
- TP&WD Sand, Shell, Gravel, and Marl permit for construction in state-owned stream beds

Table 6.1-5. Comparison of Lake Granger Augmentation to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. Uncertain, dependent on acquiring groundwater
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low to moderate impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Low to None
E. Equitable Comparison of Strategies Deemed Feasible	• No. Groundwater availability does not consider MAG as other Options do
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

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6.2 Oak Creek Reservoir

6.2.2 Description of Option

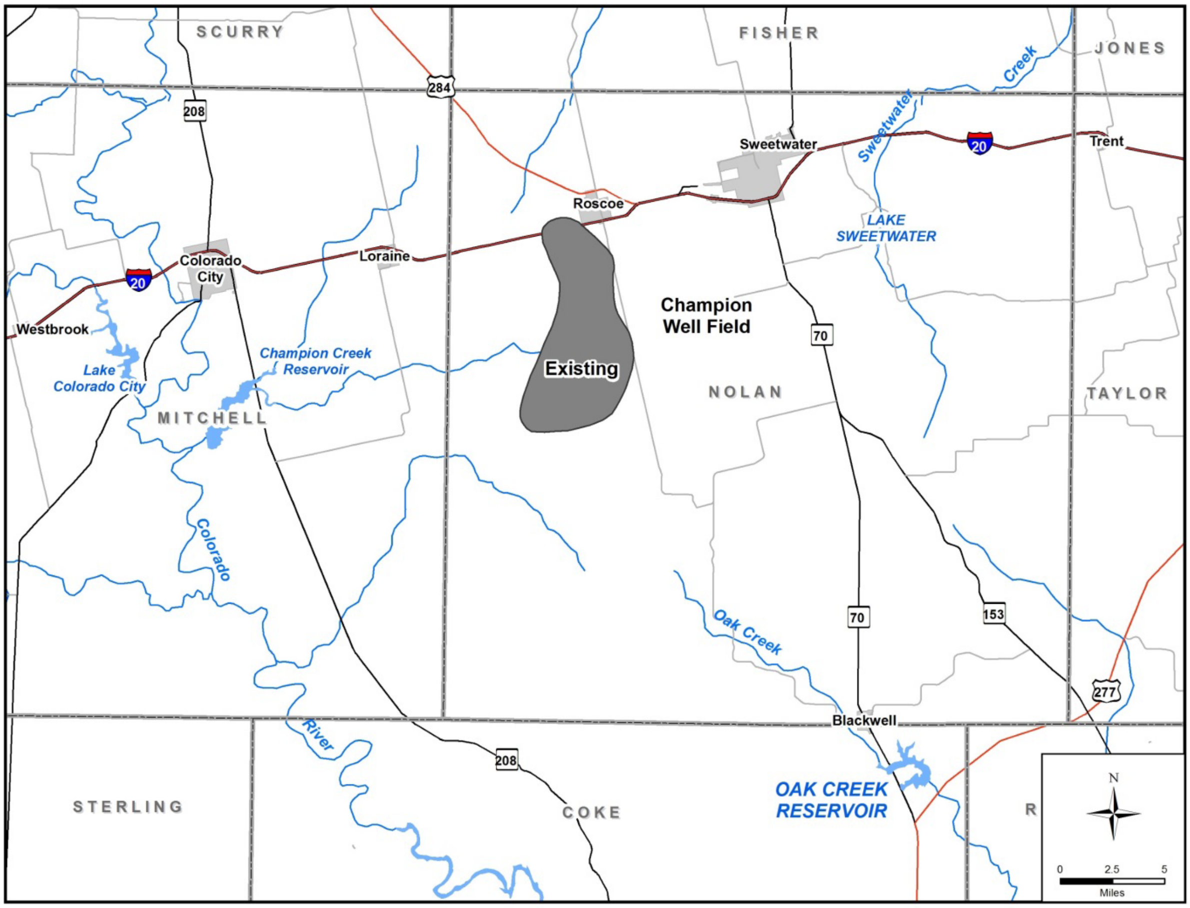
The City of Sweetwater (Sweetwater) utilizes water supplies from the Oak Creek Reservoir in Coke County and the Champion Well Field in Nolan County. The wells are in the Dockum Aquifer. Prior to the drought beginning in 1998, the primary water supply was Oak Creek Reservoir and supplemental supplies from Lake Sweetwater, Lake Trammel and about eight wells in the Champion Well Field. Because of the 1998-2007 drought, the water supplies from the lakes diminished and finally disappeared. As a result, the City installed about 35 new wells in the Champion Well Field on an emergency basis. During the later part of the drought, groundwater from the Champion Well Field was the sole source of supply. Six more wells were added in the Summer of 2014, bringing the current well capacity for Sweetwater to a total of 4,142 acft/yr.

To assess the long-term groundwater supplies from the Champion Well Field and in the general vicinity, a study was conducted for the Brazos G Regional Water Planning Group by HDR, Inc. (HDR). This study was partly funded by Sweetwater and consisted of: (1) developing a local groundwater model for western Nolan and eastern Mitchell Counties, (2) evaluating four potential groundwater pumping scenarios in the vicinity of the Champion Well Field with the groundwater model, and (3) evaluating the performance of wells in the Champion Well Field.

Studies of Oak Creek Reservoir by Water Planning Groups in Region F and K have concluded that there is no firm yield for Sweetwater when considering existing senior downstream surface water rights. These studies have noted the feasibility of subordinating downstream rights from Oak Creek Reservoir in the Colorado River Basin to increase local supplies.

The conjunctive management concept for Sweetwater is to use Oak Creek Reservoir and Champion Well Field as parallel supplies. Both the reservoir and the well field will contribute on an average month, but either may be over-drafted when the other supply is low. The long term average of groundwater use must remain within the MAG even though it may be surpassed in any given year. This strategy will not involve any new facilities but will be composed of an operational strategy to balance supplies. The locations of Champion Well Field, Oak Creek Reservoir and Sweetwater are shown in Figure 6.2-1.

Figure 6.2-1. Existing Champion Well field and Oak Creek Reservoir Locations



6.2.3 Available Yield

The Champion Well field has a capacity of 4,142 acft/yr after the 2014 expansion. However, the availability to Sweetwater has been limited by MAG restrictions to 2,535 acft/yr. An analysis of Sweetwater's demands and water supply contracts shows the peak demand during the planning period is 4,116 acft/yr in 2070. While Champion well field has sufficient capacity to meet annual demands, it is limited by available groundwater. The city also utilizes water supplies from the Oak Creek Reservoir and can purchase yield through subordination agreements, however, they cannot rely on this supply during times of drought.

At least three Water Availability Model (WAM) simulations have been made for the Oak Creek basin by consultants for Region F. They are known as the Basin WAM, Run 3, and Mini-WAM. The first two simulations have a daily time step and end in 1998, thus they miss recent periods of drought. The Mini-WAM has monthly time intervals and ends in 2014. A result comparison of the Mini-WAM for Oak Creek Reservoir with historical results showed a reasonable match. For these reasons, the data from the Mini-WAM were used in this conjunctive use analysis.

A study was conducted to balance the use of groundwater and surface water to limit depletion of available groundwater. Three strategies were used to meet the maximum need of 4,116 acft per year during the planning period without exceeding the long term MAG of 2,535 acft/yr and assuming subordination of downstream rights to Oak Creek Reservoir. The water level in Oak Creek Reservoir was used to determine the proportion of supply coming from each source. Strategy 1 relied on Oak Creek Reservoir as a primary source and utilized Champion Well Field only when needed to supplement supply. This involved the utilization of ground water when the reservoir dropped to 25% capacity. Figure 6.2-2 shows the temporal distribution of annual diversions and annual pumpage to meet 2070 demands. This figure shows that, the worst drought condition for this conjunctive water management strategy since 1940 would have been for 2010-2014 conditions.

While Strategy 1 is a plausible operation scenario for the conjunctive use of Oak Creek and Champion well field, the aggressive utilization of surface water prevents Oak Creek from full recovery after periods of drought. Figure 6.2-3 shows the storage trace for Oak Creek assuming Strategy 1 was utilized under 2070 demands and 1940-2014 hydrologic conditions. The long term groundwater average use for Strategy 1 is 1,201 acft/yr, which is significantly less than the available supply for Sweetwater despite over drafting the MAG 18 of the 74 years.

Figure 6.2-2. Strategy 1 Distribution of Water Sources for Sweetwater for 2070 Demands with 1940-2014 Hydrologic Conditions

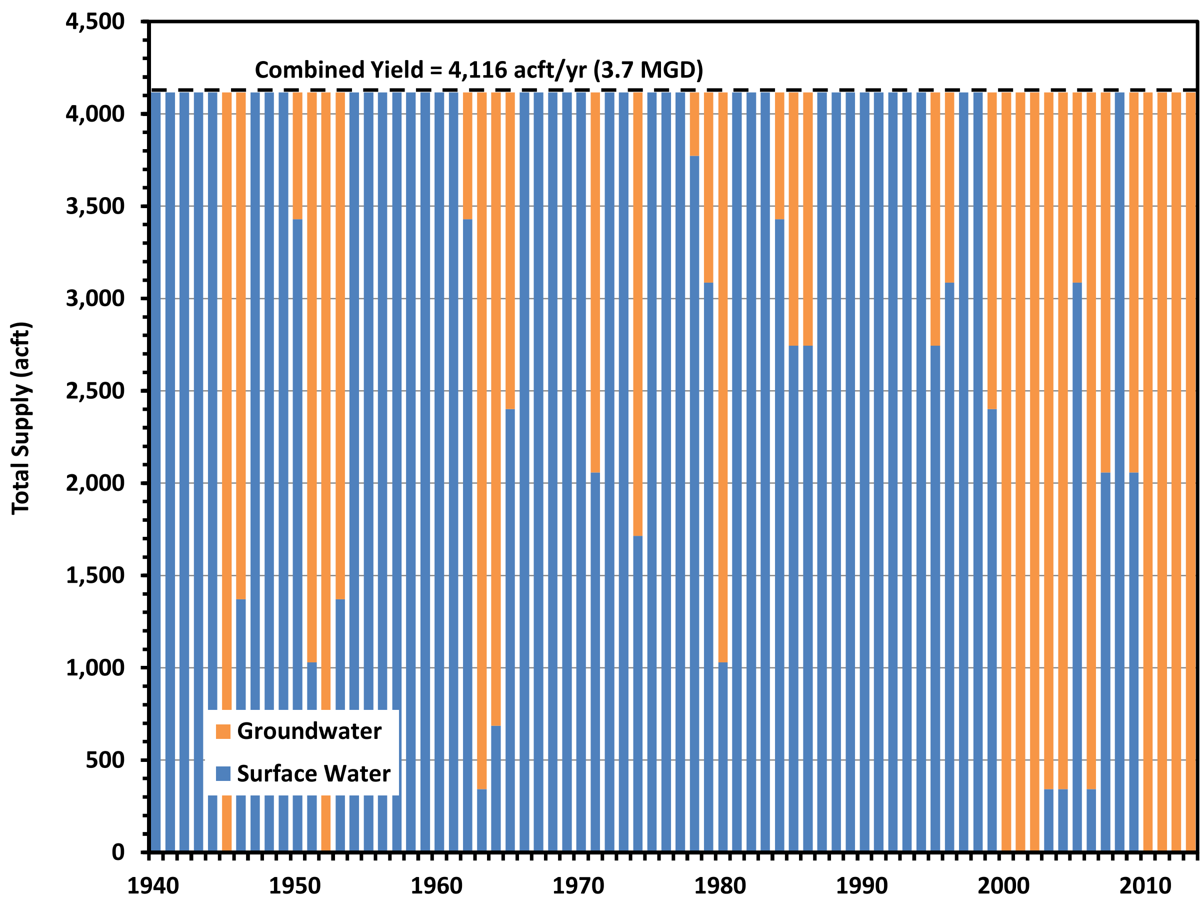
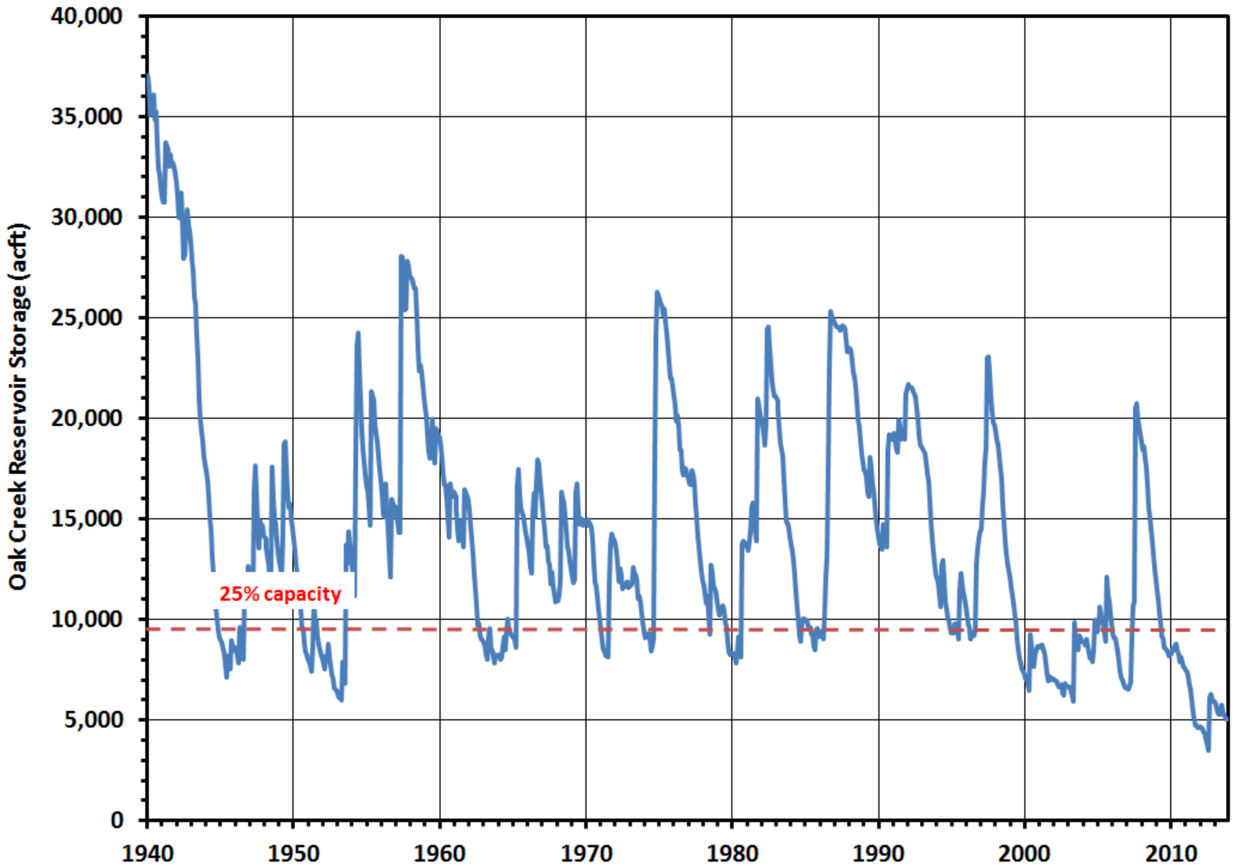


Figure 6.2-3. Strategy 1 Storage Trace for Oak Creek with 2070 Demands and 1940-2014 Hydrologic Conditions



Strategy 2 attempts to maximize the use of Champion Well Field while keeping the long term groundwater use at or below the MAG limit. In this scenario, Oak Creek was used as the sole source of supply only when the reservoir was at 57% or above. Figure 6.2-4 shows the temporal distribution of annual diversions and annual pumpage to meet 2070 demands. The long term average groundwater use for this strategy is 2,531 acft/yr which is still less than the MAG of 2,535 acft/yr despite overdrafting 41 of the 74 years. The storage trace (Figure 6.2-4) for Oak Creek Reservoir under this strategy shows that the reservoir can recover when groundwater is used more frequently.

Figure 6.2-4. Strategy 2 Distribution of Water Sources for Sweetwater for 2070 Demands with 1940-2014 Hydrologic Conditions

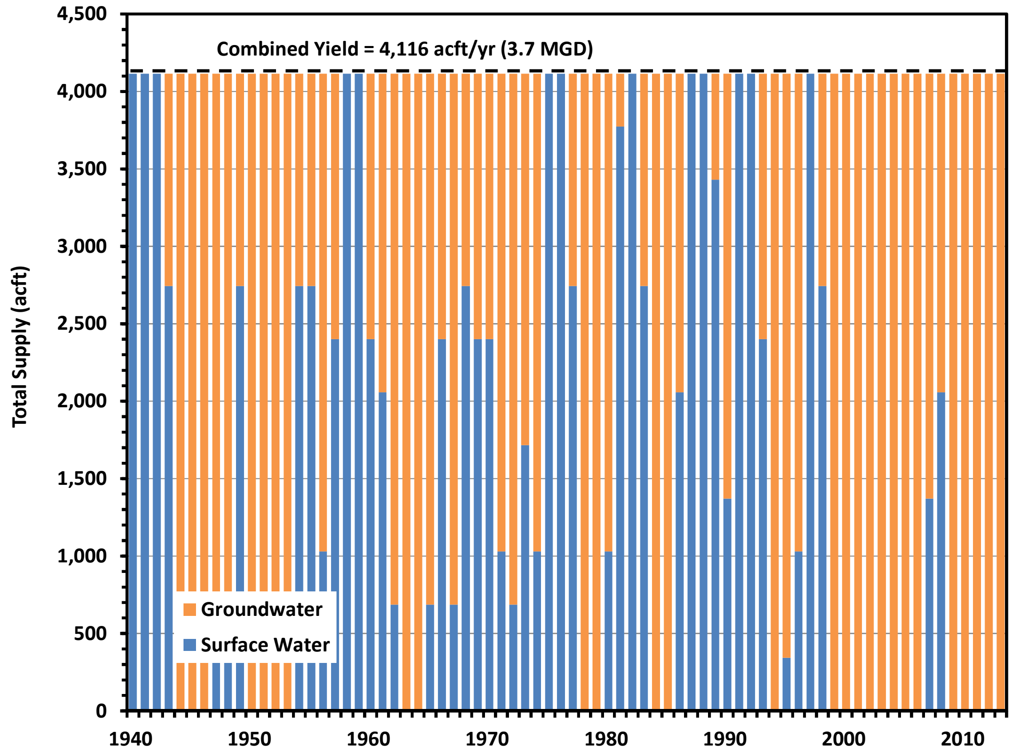
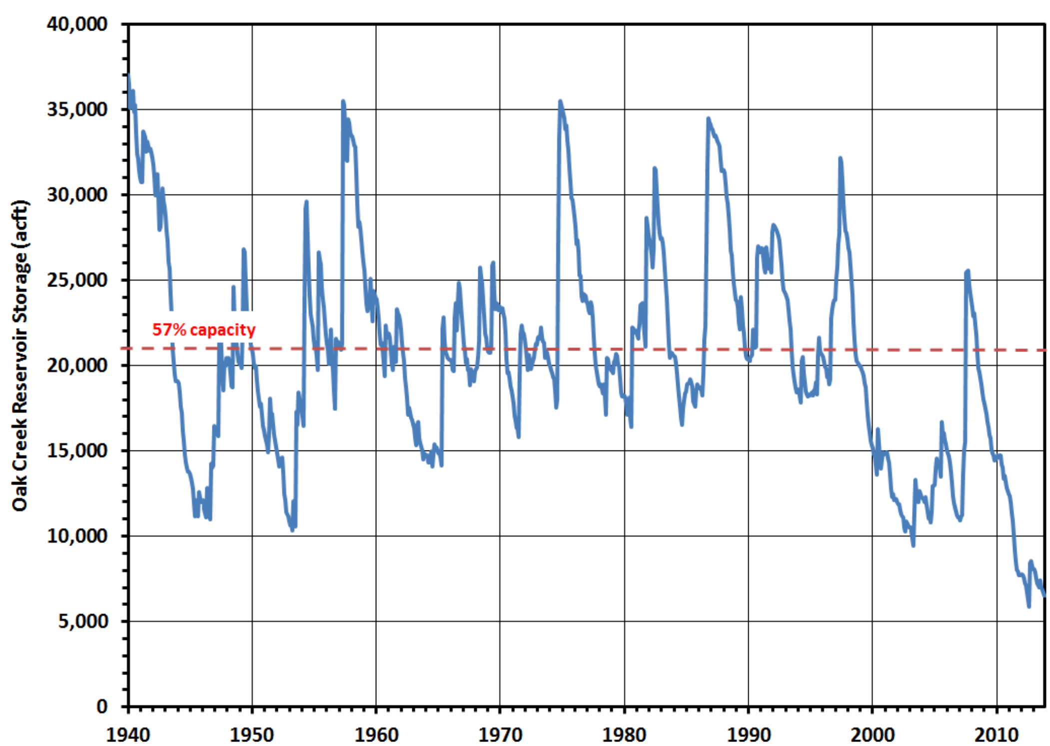


Figure 6.2-5. Strategy 2 Storage Trace for Oak Creek with 2070 Demands and 1940-2014 Hydrologic Conditions



The first two strategies show that while the needs can be met with either source set as a primary supply, relying too heavily on surface water can keep the reservoir from recovering and relying too heavily on groundwater will cause overdrafting of the MAG an undesirable number of years. A third strategy was considered that attempted to keep the long term averages of groundwater use and surface water use roughly equivalent. For this strategy, about 50% of the supply came from Oak Creek Reservoir and about 50% came from Groundwater for non-drought conditions. If in any given month, the reservoir dropped below 25% full, then groundwater was used as a sole source. Otherwise, the supply is a blend of the two sources. Figure 6.2-6 shows the temporal distribution of annual diversions and annual pumpage to meet 2070 demands. The long term average groundwater use for this strategy is 2,046 acft/yr which is still less than the MAG of 2,535 acft/yr and the MAG was only overdrafted 12 out of 74 years. The storage trace (Figure 6.2-7) for Oak Creek Reservoir under this strategy shows that while the reservoir does not fully recover, it remains at a higher level than in Strategy 1.

Figure 6.2-6. Strategy 3 Distribution of Water Sources for Sweetwater for 2070 Demands with 1940-2014 Hydrologic Conditions

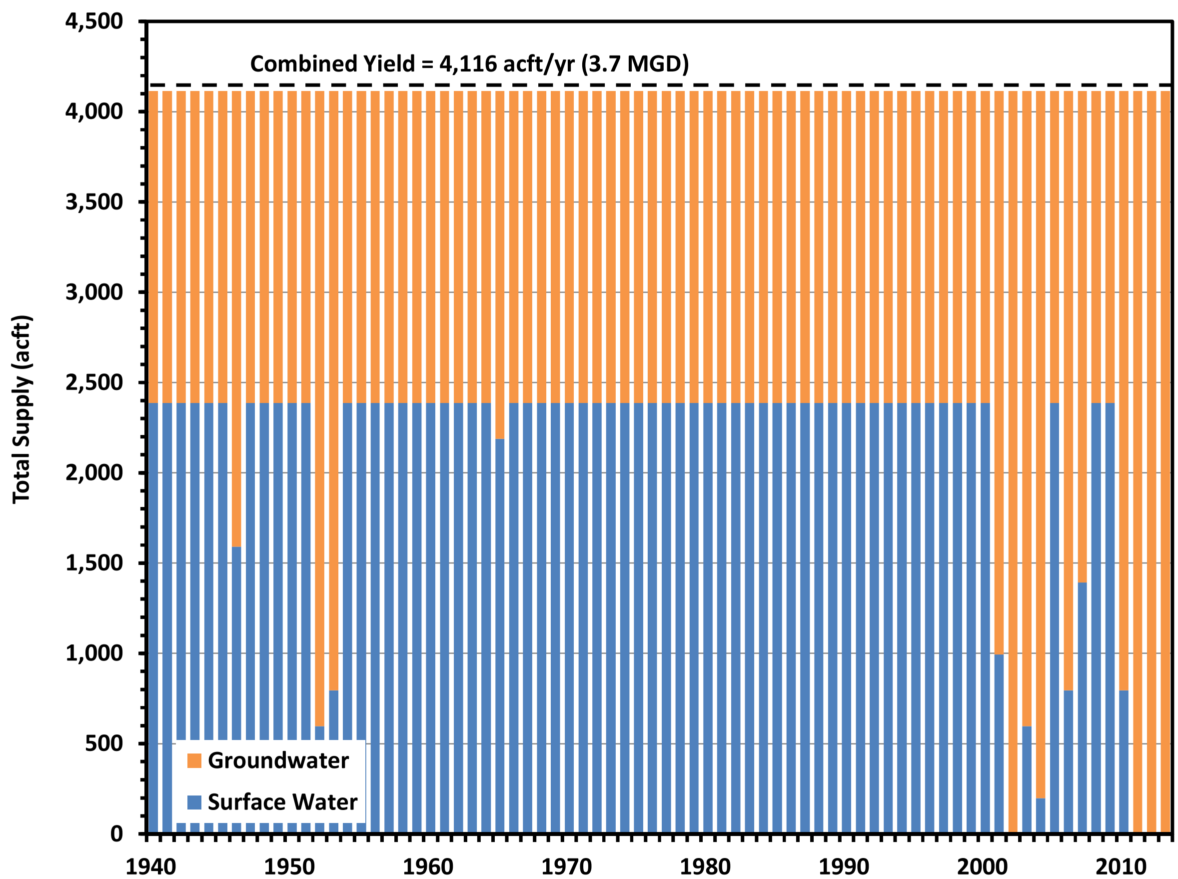
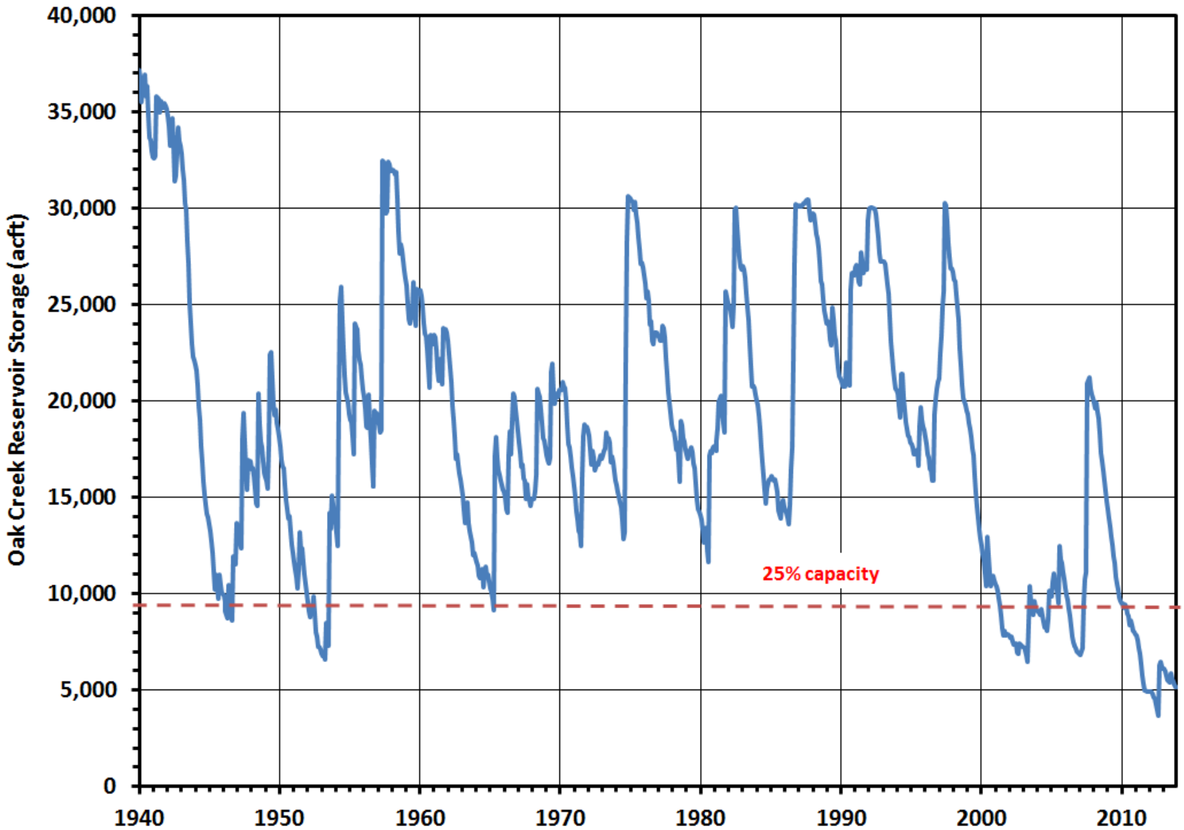


Figure 6.2-7. Strategy 3 Storage Trace for Oak Creek with 2070 Demands and 1940-2014 Hydrologic Conditions



6.2.4 Environmental Issues

There will be no new environmental impacts associated with this strategy. No wells, pipelines or other infrastructure will be built for this strategy.

Implementation Issues

Development of this water management strategy requires the subordination of the senior water rights that are downstream of Oak Creek Reservoir.

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7 Management of Existing Supplies

7.1 Lake Belton to Lake Stillhouse Hollow Pipeline

7.1.1 Description of Option

A pipeline is proposed to connect Lake Belton to Lake Stillhouse Hollow (Figure 7.1-1) to supplement supplies from Lake Stillhouse Hollow and Lake Georgetown. Lake Belton is on the Leon River in Bell and Coryell Counties. Lake Stillhouse Hollow is on the Lampasas River in Bell County. Both reservoirs are located near the Cities of Killeen, Belton and Temple. The reservoirs are owned by the U.S. Army Corps of Engineers and are part of the Brazos River Authority system. The reservoirs provide water for the Cities of Temple, Belton, Killeen, Gatesville, Copperas Cove, Lampasas and a number of other water supply districts and corporations in the area. In addition, Lakes Stillhouse Hollow and Georgetown are connected by the Williamson County Regional Raw Water Pipeline, which transfers water from Lake Stillhouse Hollow to Lake Georgetown to be used in the Williamson County area. Table 7.1-1 summarizes storage and diversion information for the reservoirs.

The Belton to Stillhouse Hollow pipeline project is primarily designed to delay the need for development of new sources of water by making use of surplus Lake Belton water in the decades prior to 2070. With the implementation of this pipeline, the combined supplies from the three reservoirs can meet existing contract demands until about 2060. For the purposes of this plan, the proposed pipeline was assumed to transfer up to 30,000 acft/yr to Lake Stillhouse Hollow. From Stillhouse Hollow, some of the Lake Belton water could be transferred to Lake Georgetown via the existing Williamson County Regional Raw Water Pipeline. The Belton to Stillhouse Hollow Pipeline will allow the BRA to operate these three lakes as a system, increasing the reliability of the supplies to the area.

The locations of facilities and a pipeline route for this project are not available for this plan. It is expected that the intake and pump station will be located in deep water near the Lake Belton Dam. The outlet structure in Lake Stillhouse Hollow would most likely be located somewhere on the north shore of the lake in the downstream part of the reservoir.

Figure 7.1-1. Connection between Lakes Belton and Stillhouse Hollow

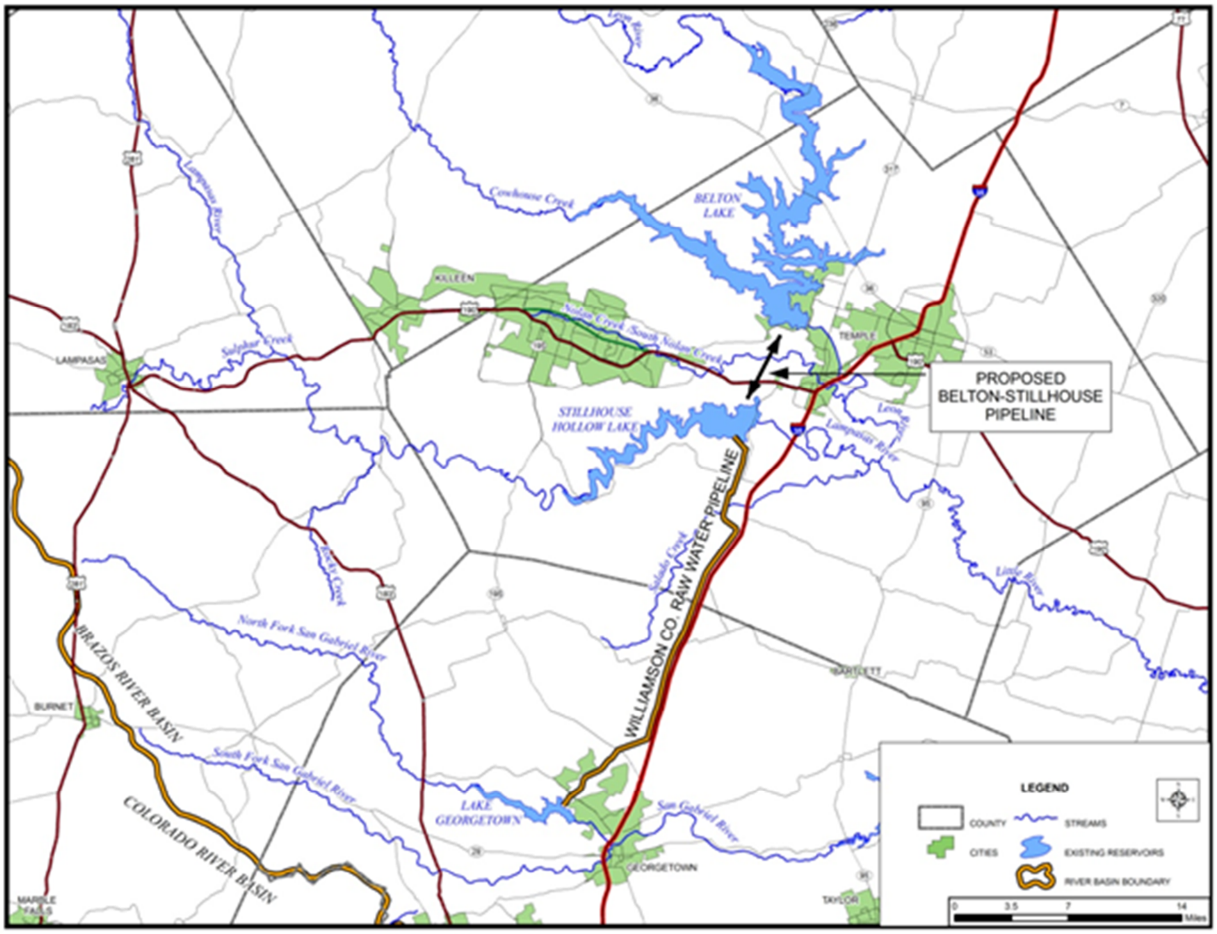


Table 7.1-1. Diversion and Storage Data for Lakes Belton, Stillhouse Hollow and Georgetown

Reservoir Name	Water Right	Authorized Storage (acft)	Authorized Priority Diversion (acft/yr)	Priority Date
Belton	CA 12-5160	457,600	100,257	12/16/1963
Stillhouse Hollow	CA 12-5161	235,700	67,768	12/16/1963
Georgetown	CA 12-5162	37,100	13,610	2/12/1968

CA – Certificate of Adjudication

7.1.2 Available Yield

The project is expected to deliver up to 30,000 acft/yr from Lake Belton to Lake Stillhouse Hollow. The primary benefit of the pipeline will be the delay in developing expensive new sources of water to meet anticipated future demands. The supply for this project is authorized under the existing BRA water rights for Lakes Belton and Stillhouse

Hollow, although some of the supply could also come from the proposed System Operation Permit.

Figure 7.1-2 shows simulated storage traces for Lake Stillhouse Hollow operating under 2070 sedimentation conditions with and without the Belton to Stillhouse Hollow pipeline. Figure 7.1-3 shows the exceedance frequency for the same data. Figures 7.1-4 and 7.1-5 shows a simulated 2070 conditions storage trace and exceedance frequency for Lake Georgetown, respectively. Storage traces were simulated using the Brazos Water Availability Model (WAM) Run 3 with Senate Bill 3 environmental flows. Demands for these analyses are proportional to the Brazos River Authority (BRA) contracts assigned to Lakes Belton, Stillhouse Hollow and Georgetown, with demands totaling 83,800 acft/yr, 25,400 acft/yr and 50,800 acft/yr, respectively. Under this strategy the demands at Lake Georgetown are being met by water pumped from Lake Stillhouse Hollow through the Williamson County Regional Raw Water Line that connects Lake Stillhouse to Lake Georgetown and and from Lake Belton through the Lake Belton to Lake Stillhouse Hollow pipeline. Pumping is initiated from Lake Belton when Lake Stillhouse Hollow has less than 130,000 acft in storage. Note that without the proposed pipeline there would be insufficient supplies to meet demands during a repeat of the 1950s drought. Figures 7.1-6 and 7.1-7 show the storage traces and exceedance frequencies for Lake Belton, respectively. Without the pipeline, over 50,000 acft of water is in storage at Lake Belton's lowest point in the simulation. The proposed Belton to Stillhouse Hollow pipeline would allow the BRA to use the uncommitted supplies from this storage to meet demands at the other two reservoirs.

7.1.3 Environmental Issues

The intake and discharge structures could have low to moderate environmental impacts depending on the final location of the structures. The pipeline route is expected to avoid sensitive areas, so the construction and operation of the pipeline is expected to have low environmental impacts.

Figures 7.1-3 to 7.1-7 show that the pipeline has a minimal impact on the frequency of time that these reservoirs are full and spilling. This is because pumping does not occur until Lake Stillhouse Hollow has been drawn down significantly. Because the frequency and volume of spills are about the same with and without the pipeline, the project has minimal impact on instream flows or bays and estuaries.

Lakes Belton and Stillhouse Hollow are located in adjacent watersheds on tributaries of the Little River that join a short distance below the reservoirs. Both reservoirs are expected to have similar biological communities and water quality. There are no anticipated impacts associated with blending water for the two reservoirs, although this may need to be verified by studies.

Figure 7.1-2. Lake Stillhouse Hollow Storage under 2070 Conditions With and Without Proposed Belton to Stillhouse Pipeline

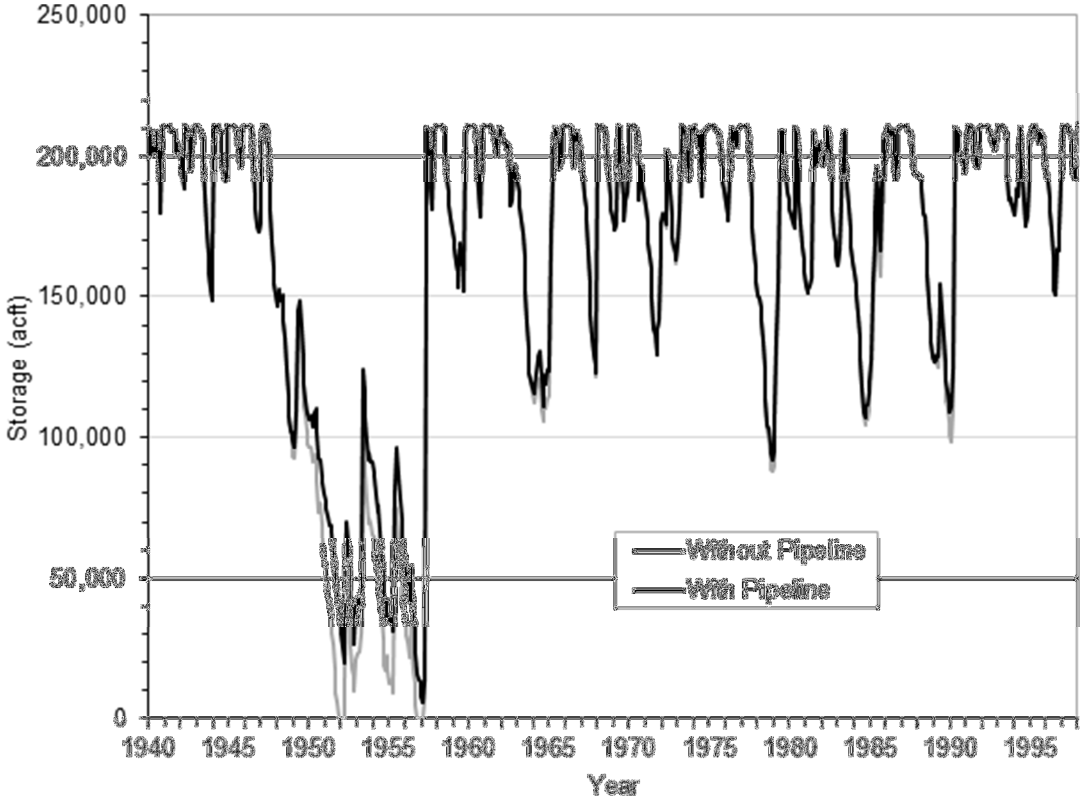


Figure 7.1-3. Lake Stillhouse Hollow Storage Exceedance Frequency under 2070 Conditions With and Without Proposed Belton to Stillhouse Pipeline

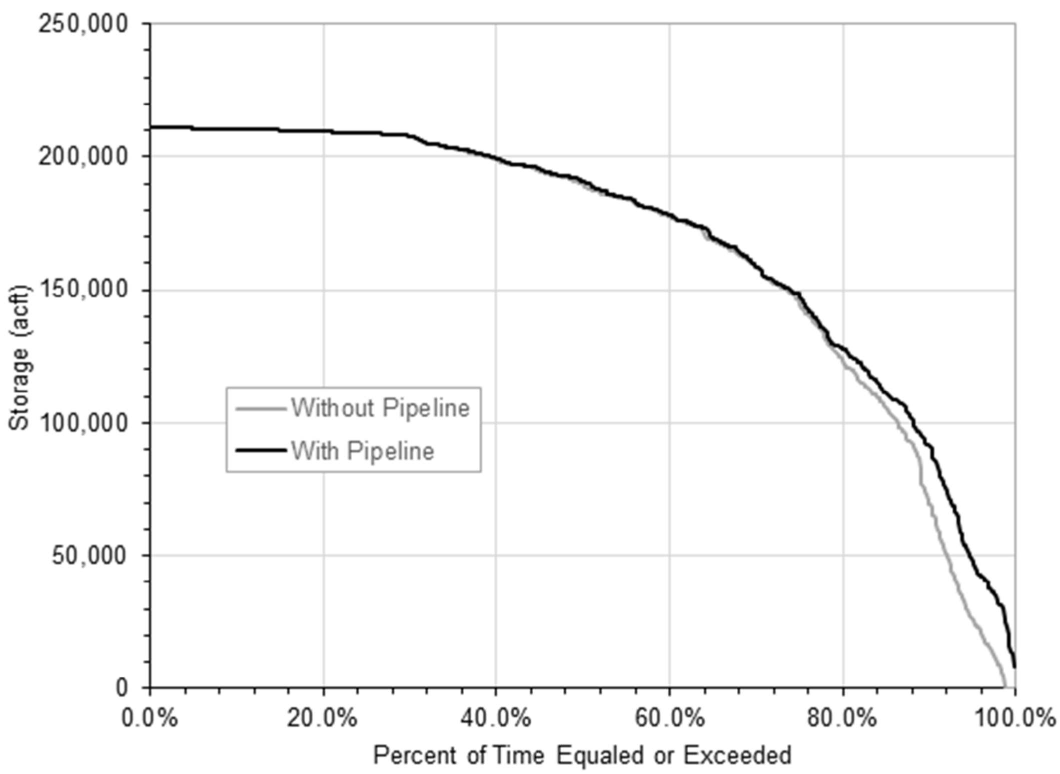


Figure 7.1-4. Lake Georgetown Storage under 2070 Conditions With and Without Proposed Belton to Stillhouse Pipeline

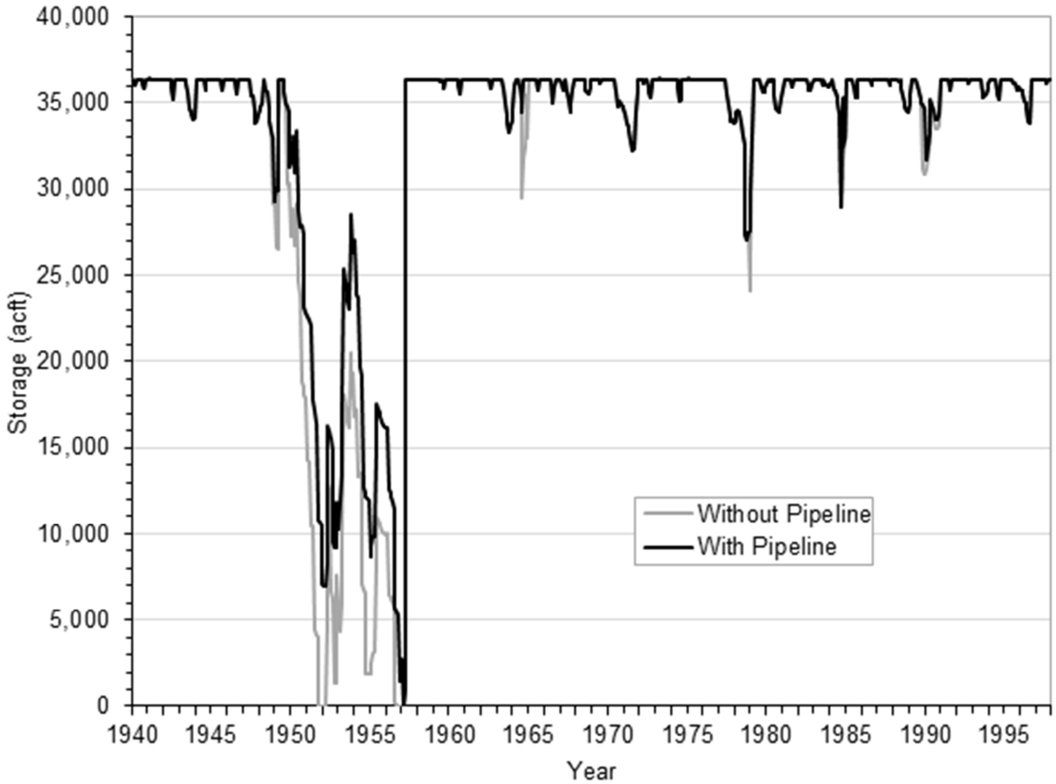


Figure 7.1-5. Lake Georgetown Storage Exceedance Frequency under 2070 Conditions With and Without Proposed Belton to Stillhouse Pipeline

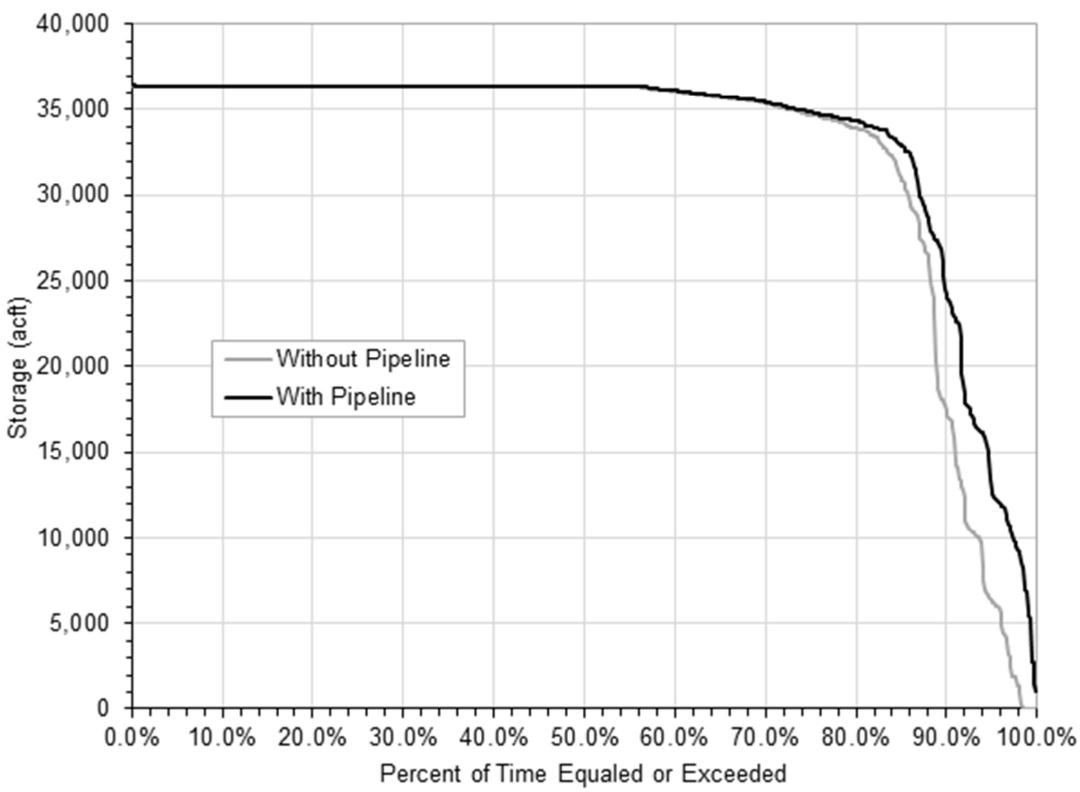


Figure 7.1-6. Lake Belton Storage under 2070 Conditions with and without Proposed Belton to Stillhouse Pipeline

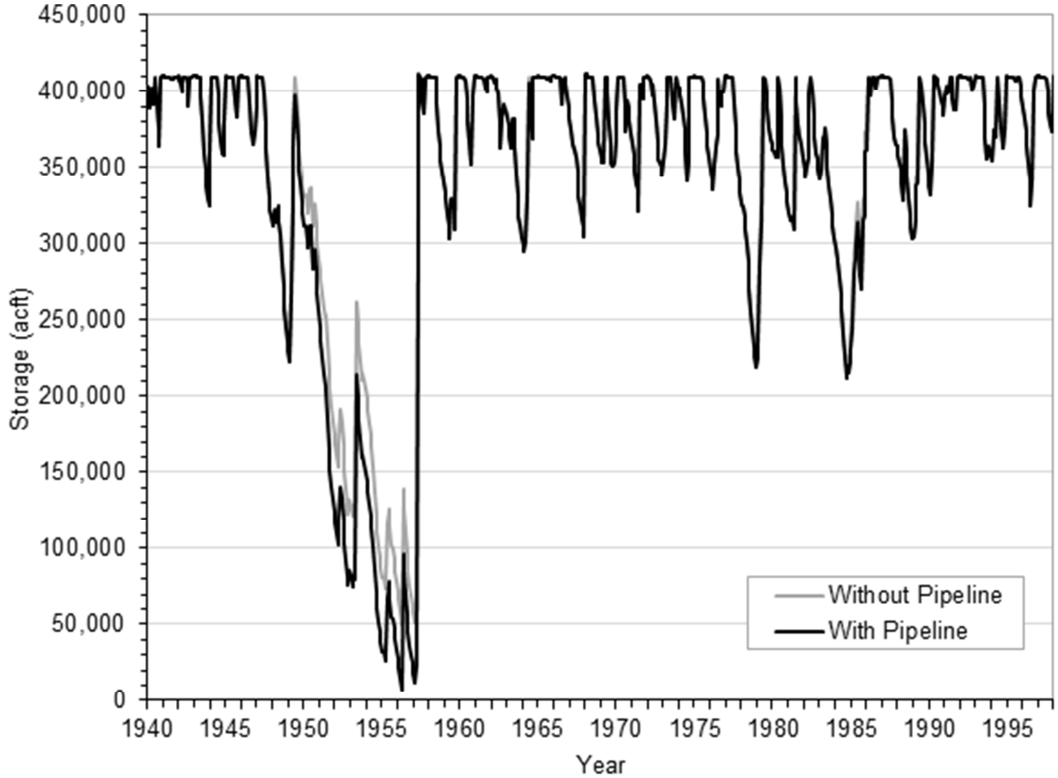
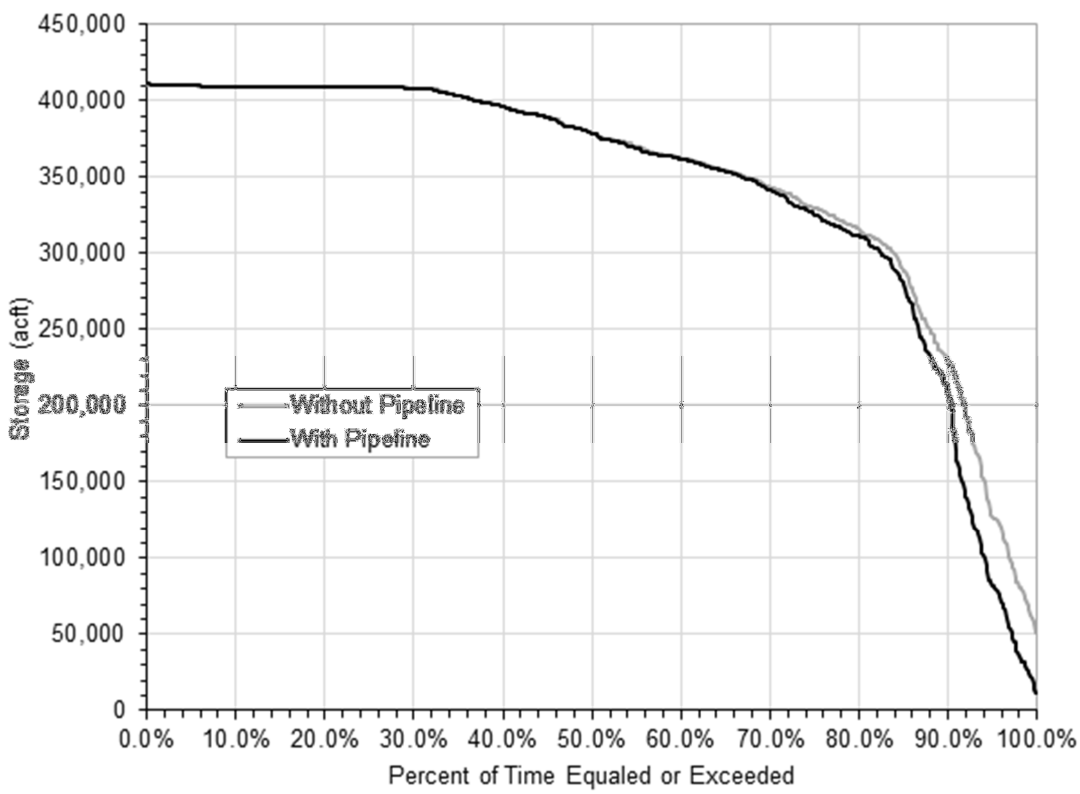


Figure 7.1-7. Lake Belton Storage Exceedance Frequency under 2070 Conditions With and Without Proposed Belton to Stillhouse Pipeline



7.1.4 Engineering and Costing

For the purposes of this plan, it is assumed that the pipeline will be about 7 miles long with a diameter of 48 inches. Table 7.1-2 summarizes the costs for this option. About 12 percent of the pipeline route is assumed to be in a relatively urbanized area. The intake structure and pump station are assumed to be located near the Lake Belton Dam and the discharge structure is located on the north shore of Lake Stillhouse Hollow in the lower portion of the lake. Using these assumptions, the estimated capital cost of the pipeline is about $27.4 million. Total project costs, including engineering, contingencies, permitting, mitigation and interest during construction are an additional $10.7 million for a total project cost of $38.1 million. Annual costs, including debt service, power cost and operation and maintenance are approximately $4.6 million per year. The resulting unit costs are $154 per acre-foot or $0.47 per thousand gallons.

7.1.5 Implementation Issues

This water supply options have been compared to the plan development criteria, as shown in Table 7.1-3, and the option meets each criterion. Implementation steps for the project are presented below.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act)
- Texas Commission on Environmental Quality administered Texas Pollution Discharge Elimination System (TPDES) Permit and Storm Water Pollution Prevention Plan
- General Land Office Easement if State-owned land or water is involved
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if State-owned streambeds are involved
- Agreement with USCOE for discharge into Lake Stillhouse Hollow.

State and Federal Permits may require the following studies and plans:

- Possible analysis of potential impact of blending Lake Belton water in Lake Stillhouse Hollow.
- Environmental impact or assessment studies
- Wildlife habitat mitigation plan that may require acquisition and management of additional land
- Flow releases downstream to maintain aquatic ecosystems
- Assessment of impacts on Federal- and State-listed endangered and threatened species

- Cultural resources studies in coordination with the Texas Historical Commission to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging

Land Acquisition Issues:

- Land acquired for the project could include market transactions or other local landowner agreements
- Additional acquisition of rights-of-way and/or easements may be required
- Possible relocations or removal of residences, utilities, roads, or other structures

Table 7.1-2. Estimated Costs for the Lake Belton to Lake Stillhouse Hollow Pipeline

Item	Estimated Costs
Capital Costs	
Intake & Pump Station (33 MGD)	$17,006,000
Pipeline (6.8 mi, 48 in. dia.)	$10,290,000
Discharge Structure	$104,000
Total Capital Cost	$27,400,000
Engineering, Legal Costs and Contingencies	$8,944,000
Environmental & Archeological Studies and Mitigation	$438,000
Interest During Construction (12 months)	$1,287,000
Total Project Cost	$38,069,000
Annual Costs	
Debt Service (5.5 percent, 20 years)	$3,186,000
Electricity ($0.09 kWh)	$781,000
Operation & Maintenance	$647,000
Total Annual Cost	$4,614,000
Available Project Yield (acft/yr)	30,000
Annual Cost of Water ($ per acft)	$154
Annual Cost of Water ($ per 1,000 gallons)	$0.47

Table 7.1-3. Comparison of Lake Belton to Lake Stillhouse Hollow Pipeline to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low to medium impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Low impact due to distance from coast
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	Possible negative impacts on state water resources from water quality changes; no effect on navigation
D. Threats to Agriculture and Natural Resources	Low to none
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

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7.2 Brushy Creek Regional Utility Authority System

7.2.1 Description of Option

The Lower Colorado River Authority (LCRA) owns and operates five reservoirs which, along with Lake Austin, are known as the Highland Lakes. Two of the Highland Lakes, Lakes Buchanan and Travis, are water supply reservoirs and have dedicated conservation storage. The other four reservoirs in the Highland Lakes chain are constant level lakes and are not considered water supply reservoirs. The LCRA, which supplies water primarily in the Colorado River Basin (Region K), has contracts with two cities in Williamson County to supply raw water from Lake Travis. These contracts include 18,000 acft/yr of raw water to the City of Cedar Park, and 24,000 acft/yr of raw water to the City of Leander. The City of Round Rock has a contract with BRA for supply 20,928 acft/yr of raw water from the LCRA. Until recently, infrastructure was not in place to transport this water to Round Rock.

The cities of Round Rock, Cedar Park and Leander have entered into agreements to participate in the Brushy Creek Regional Utility Authority (BCRUA) that would ultimately provide 105.8 MGD of treated water capacity and 141.7 MGD of raw water. Portions of this project have been constructed. This project will provide peaking capacity for system demands including 15 MGD to Cedar Park, 40.8 MGD to Round Rock and 50 MGD to Leander. Although, the system will be designed for peaking capacity, average annual supplies from this project will be approximately 50 percent of the peaking capacity. In addition, the project will provide 23 MGD of raw water to Cedar Park's existing water treatment plant, 12 MGD to Leander's water treatment plan, and 0.9 MGD to the Twin Creeks golf course.

The BCRUA will utilize an existing 17 MGD, expandable to 30 MGD, interim floating intake structure located near the Cedar Park WTP, until a deep water 141.7 MGD intake structure can be constructed near Volente. The deep water intake will provide physical access to Lake Travis water during a severe drought. The floating intake conveys raw water through a new pipeline to the regional water treatment plant, with initial and ultimate capacities of 17 MGD and 105.8 MGD, respectively, which is located near the western edge of Cedar Park and Leander. Treated water is delivered to Cedar Park (15 MGD), Leander (50 MGD) and Round Rock (40.8 MGD). The general locations of the facilities are shown in Figure 7.2-1. The allocation of capacity for the proposed regional system is detailed in *Table 7.2-1*.

7.2.2 Available Yield

Under the provisions of HB 1437[1] and by agreement between the Brazos River Authority (BRA) and LCRA, 25,000 acft/yr of stored water in the Highland Lakes can be sold by LCRA (through the BRA) to entities in Williamson County in addition to the existing contracts with Cedar Park and Leander. Current contracts commit 21,528 acft/yr. However, the 25,000 acft/yr available under HB 1437 does not meet the 2070 needs in Williamson County. Uncommitted stored water exists in the Highland Lakes that would

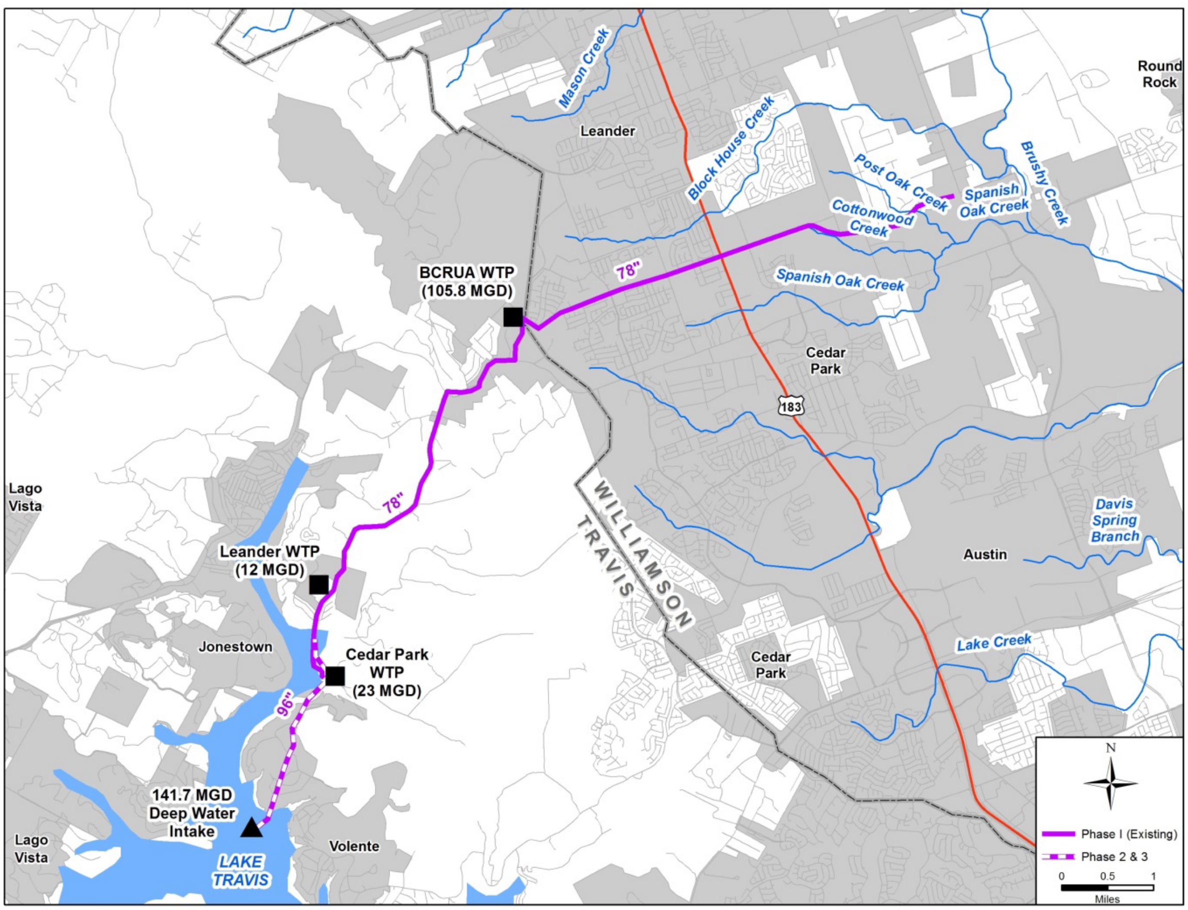
[1] House Bill 1437, 76th Session, Texas Legislature.

be sufficient to meet a large portion of Williamson County's projected 2070 shortages. However, for Williamson County to acquire this water, either HB 1437 has to be amended by the legislature to allow the sale of additional water, or other administrative measures such as a TCEQ interbasin transfer permit would be required to deliver any quantity above 25,000 acft/yr.

HB 1437 also provides that a 25 percent surcharge be added to the cost of water from the Colorado River basin delivered to Williamson County to pay for development of replacement supplies in the Colorado River Basin. This is subject to an adjustment by the LCRA Board of Directors.

Several entities have already committed to purchase the original 25,000 acft/yr designated by HB 1437. Table 7.2-2 presents the projected allocation of water under the original 25,000 acft/yr, and an additional allocation of water of 42,000 acft/yr. This plan assumes that the City of Round Rock will obtain the portion of the HB 1437 water currently allocated to Georgetown. Cedar Park and Leander would obtain additional supply above the original HB 1437 amount.

Figure 7.2-1. Brushy Creek Regional Utility Authority System



L:\Project_Data\00044_BrazosG\GIS\Map_Docs\General\BCRUA.mxd

Table 7.2-1. Brushy Creek Regional Utility Authority System Participation with Peaking Capacity

	Cedar Park	*Round Rock*	*Leander*	*Total*
Treated Water Allocation (MGD)	*15*	*40.8*	*50*	*105.8*
Treated Water Allocation (%)	*14.18%*	*38.56%*	*47.26%*	*100%*
With Deep Water Intake (MGD)	*38.9*	*40.8*	*62*	*141.7*
Deep Water Intake Allocation (%)	*27.45%*	*28.79%*	*43.76%*	*100%*

Table 7.2-2. Allocation of New Highland Lakes Supply in Williamson County

Entity	Previous (2010) HB 1437 Allocation (acft/yr)	Current HB 1437 Allocation (acft/yr)	Additional Highland Lakes Supply (acft/yr)	Current Allocation + Additional Highland Lakes Supply (acft/yr)
Cedar Park	0	0	18,000	18,000
Chisholm Trail SUD[1]	2,540	0	0	0
Liberty Hill	600	600	0	600
Round Rock	11,444	20,928	0	24,400
Leander	0	0	24,000	24,000
Georgetown	6,944	0	0	0
Unallocated	3,472	3,472	0	0
Total	25,000	25,000	42,000	67,000

[1] Chisholm Trail SUD and Georgetown have merged.

7.2.3 Environmental

This alternative includes the construction of a new deep water intake structure on Lake Travis and connection to an existing transmission pipeline to Williamson County. The project contains an intake assembly at the mouth of the Sandy Creek arm of Lake Travis, a maintenance building in the Village of Volente, a pump station adjacent to Sandy Creek Park and a tunneled pipeline from the deep water intake assembly to the pump station and from there to existing Phase 1 facilities on Trails End Road.

The proposed project is not anticipated to impact land use, density, or type of development beyond that already planned in the BCRUA Regional Water system within the project area. Permanent land use impacts in the project area would be limited to the pump station and intake assembly sites. The pump station site is located adjacent to a LCRA public park and an existing industrial facility (the City of Cedar Park WTP). The park will be able to remain open to park users during construction, and the proposed site does not limit any waterfront access to park users. The proposed maintenance building site is located within the Village of Volente. Construction of the intake assembly would have minimal impacts to area recreational use with the exception of a restricted area which is required around a raw water intake. The pipeline will be bored underground resulting in minimal disturbance to area land use.

Environmental issues for the proposed Regional Surface Water Supply to Williamson County from Lake Travis are described below. An Environmental Assessment submitted to the Brushy Creek Regional Utility Authority was completed for this project in March 2014. The project occurs within the Cross Timbers and Prairies vegetational area[2] and is within the Balconian biotic province.[3] Vegetation within the project area is defined as Live Oak-Ashe Juniper Parks by the Texas Parks and Wildlife Department.[4] Chiefly found on level to gently rolling uplands and ridge tops of the Edwards Plateau, this vegetation type commonly includes trees such as live oak (*Quercus virginiana*), Texas oak (*Q. buckleyi*), shin oak (*Q. havardii*), cedar elm (*Ulmus crassifolia*), and netleaf hackberry (*Celtis reticulata*) in addition to other species including saw greenbrier (*Smilax bona-nox*), little bluestem (*Schizachyrium scoparium*), curly mesquite (*Hilaria belangeri*) and Texas grama (*Bouteloua rigidiseta*). Vegetation impacts would include the clearing of small areas for the construction of the pump station, maintenance building and a portion of the temporary construction easement for construction of the pump station building and tunnel shaft. The raw water pipeline would be tunneled instead of open-cut to avoid vegetation clearing, crossing waters of the U.S., and impacts to endangered species habitat found along the pipeline alignment.

The pipeline would occur underneath or adjacent to Lake Travis and would not impact any existing rivers creeks or tributaries. The deep location of the water intake structure would have minimal impact to existing aquatic resources within the lake. The Federal Emergency Management Administration (FEMA) oversees the delineation of 100-year floodplain zone on the flood insurance rate maps (FIRMs) across the United States. The term 100-year flood refers to areas that have a one percent chance of flooding in any given year. The FEMA 100-year floodplain zones within the project fall along the perimeter of Lake Travis. A small portion of the proposed project including the water intake structure occurs within this zone.

The delineation of wetlands by the National Wetland Inventory indicates that within the project area, the perimeter of Lake Travis is delineated as palustrine, emergent, persistent, seasonally flooded, and diked. Coordination with the U.S. Army Corps of Engineers would be required for construction within waters of the U.S. Impacts from this proposed project resulting in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

The TCEQ 2012 *Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d)* states that Lake Travis (Segment 1404) is fully supporting of its designated uses and contains no water quality concerns.

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[2] Gould, F.W. 1975. The Grasses of Texas. Texas A&M University Press. College Station, Texas.

[3] Blair, W.F., “The Biotic Provinces of Texas, “Tex. J. Sci. 2:93-117, 1950.

[4] McMahan, C. A., R. G. Frye and K. L. Brown, “ The Vegetation Types of Texas -- Including Cropland,” Texas Parks and Wildlife Department - PWD Bulletin 7000-120. 1984.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available Geographic Information System (GIS) datasets, there are no cemeteries, historical markers, national register properties or national register districts located within a one-mile buffer of the proposed project area.

A review of archaeological resources in the proposed project area should be conducted during project planning. The owner or controller of the project will be required to coordinate with the Texas Historical Commission regarding impacts to cultural resources.

Species listed by U.S. Fish and Wildlife Service (USFWS), and the Texas Parks and Wildlife Department (TPWD), as endangered, threatened, or species of concern in Travis County are listed in Table 7.2-3. The Texas Natural Diversity Database (TXNDD), maintained by TPWD, which documents the occurrence of rare species within the state, was included in this project area analysis. TXNDD shows documented occurrences of the endangered Black-capped vireo and Golden-cheeked warbler within a one mile buffer of the project area.

The project area may provide potential habitat to endangered or threatened species found in Travis County. A survey of the project area may be required prior to construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Based on existing project area habitat types, the following endangered or threatened species have the potential to occur within or near the project area.

Table 7.2-3. Endangered, Threatened and Candidate Species Listed for Travis County, Texas

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
		AMPHIBIANS			
Austin Blind Salamander	*Eurycea waterlooensis*	Barton Springs; water-filled subterranean caverns	C	--	Resident
Barton Springs Salamander	*Eurycea sosorum*	Spring outflows of Barton Springs	LE	E	Resident
Jollyville Plateau salamander	*Eurycea tonkawae*	Known from springs and waters of some caves north of the Colorado River	T	--	Resident
		ARACHNIDS			
Bandit Cave spider	*Cicurina bandida*	Very small, subterrestrial oblígate spider.	--	--	Resident

Table 7.2-3. Endangered, Threatened and Candidate Species Listed for Travis County, Texas

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Bee Creek Cave harvestman	*Texella reddelli*	Small, blind cave-adapted harvestman endemic to a few caves in Travis and Williamson Counties	LE	--	Resident
Bone Cave harvestman	*Texella reyesi*	Small, blind cave-adapted harvestman endemic to a few caves in Travis and Williamson Counties.	LE	--	Resident
Tooth Cave pseudoscorpion	*Tartarocreagris texana*	Small, cave-adapted pseudoscorpion known from small limestone caves of the Edwards Plateau	LE	--	Resident
Tooth Cave spider	*Leptoneta myopica*	Very small, cave-adapted, sedentary spider	LE	--	Resident
Warton's cave meshweaver	*Cicurina wartoni*	Very small, cave-adapted spider	C	--	Resident
		BIRDS			
American peregrine falcon	*Falco peregrinus anatum*	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Artic peregrine falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	Found primarily near rivers and large lakes.	DL	T	Possible Migrant
Black-capped Vireo	*Vireo atricapilla*	Oak-juniper woodlands with patchy shrub/tree layer and open, grassy spaces; nests from March to late summer	LE	E	Resident
Golden-cheeked Warbler	*Setophaga chrysoparia*	Juniper-oak woodlands with mature Ashe junipers (cedar); nests from March to early summer	LE	E	Resident
Least tern	*Sterna antillarum athalassos*	Nests along sand and gravel bars in braided streams	LE	E	Resident
Mountain plover	*Charadrius montanus*	Non-breeding, shortgrass plains and fields	--	--	Nesting/ Migrant

Table 7.2-3. Endangered, Threatened and Candidate Species Listed for Travis County, Texas

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Peregrine Falcon	*Falco peregrinus*	Possible migrant	DL	T	Possible migrant
Sprague's pipit	*Anthus spragueii*	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Western burrowing owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna	--	--	Resident
Whooping crane	*Grus americana*	Potential migrant	LE	E	Potential Migrant
		FISHES			
Guadalupe bass	*Micropterus treculi*	Endemic to perennial streams of the Edwards Plateau region.	--	--	Resident
Smalleye shiner	*Notropis buccula*	Endemic to the upper Brazos River system and its tributaries	PE	--	Resident
		INSECTS			
Kretschmarr Cave mold beetle	*Texamaurops reddelli*	Small, cave-adapted beetle found in Edwards Limestone caves of the Jollyville Plateau	LE	--	Resident
Leonora's dancer damselfly	Argia leonorae	Found in south central and western Texas in small streams and seepages.	--	--	Resident
Rawson's metalmark	Calephelis rawsoni	Found in moist areas I shaded limestone outcrops in central Texas.	--	--	Resident
Tooth Cave blind rove beetle	*Cylindropsis* sp.1	Collected from Tooth Cave.	--	--	Resident
Tooth Cave ground beetle	*Rhadine persephone*	Small, cave-adapted beetle found in small Edwards Limestone caves in Travis and Williamson counties	LE	--	Resident
		MAMMALS			
Cave myotis bat	*Myotis velifer*	Roosts colonially in caves, rock crevices	--	--	Resident

Table 7.2-3. Endangered, Threatened and Candidate Species Listed for Travis County, Texas

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Plains spotted skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	Extirpated.	LE	E	Historic Resident
		MOLLUSKS			
Creeper (squawfoot)	*Strophitus undulates*	Small to large streams. Colorado, Guadalupe, and San Antonio River basins.	--	--	Resident
False spike mussel	*Quincuncina mitchelli*	Substrates of cobble and mud. Rio Grande, Brazos, Colorado and Guadalupe river basins.	--	T	Resident
Smooth pimpleback	*Quadrula houstonensis*	Found in small to moderate streams and rivers	C	T	Resident
Texas fatmucket	*Lampsilis bracteata*	Streams and rivers on sand, mud and gravel, Colorado and Guadalupe River basins.	C	T	Resident
Texas fawnsfoot	*Truncilla macrodon*	Possibly found in rivers and larger streams, intolerant of impoundment	C	T	Resident
Texas pimpleback	*Quadrula petrina*	Mud, gravel and sand substrates, Colorado and Guadalupe river basins	C	T	Resident
		PLANTS			
Basin bellflower	*Campanula reverchonii*	Texas endemic found on loose gravel, and rock outcrops on open slopes.	--	--	Resident
Boerne bean	*Phaseolus texensis*	Endemic to rocky canyons in eastern and southern Edwards Plateau.	--	--	Resident
Bracted twist-flower	*Streptanthus bracteatus*	Texas endemic found on shallow, well-drained gravelly clays and clay loams over limestone in oak juniper woodlands	C	--	Resident

Table 7.2-3. Endangered, Threatened and Candidate Species Listed for Travis County, Texas

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Correll's false dragon-head	*Physostegia correllii*	Found in wet, silty clay loams on streamsides and roadside drainage ditches.	--	--	Resident
Texabama croton	*Croton alabamensis* var *texensis*	Texas endemic found in loamy clay soils on rocky slopes in forested limestone canyons.	--	--	Resident
Warnock's coral-root	*Hexalectric warnockii*	In leaf litter and humus in oak-juniper woodlands on shaded lopes and intermittent, rocky creekbeds in canyons.	--	--	Resident
REPTILES					
Spot-tailed earless lizard	*Holbrookia lacerata*	Moderately open prairie-brushland.	--	--	Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	Wet or moist microhabitats	--	--	Resident
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands.	--	T	Resident

LE – Federally listed as Endangered
E—State Listed as Endangered
T – State listed as Threatened
DL—Federally delisted Endangered/Threatened
C – Candidate for Federal Listing
Source: US Fish & Wildlife Service, Last updated: January 21, 2014. Accessed March 14, 2014 online at http://www.fws.gov/southwest/es/ES_ListSpecies.cfm
TPWD, Travis County– last revised 03/31/2014

- Bald eagle (*Haliaeetus leucocephalus*) — The bald eagle is a state-listed threatened species that could occur as a migrant near major aquatic resources. Although they breed primarily in the eastern half of the state, they could potentially occur in this region of Texas during the winter and during migration along rivers or large lakes. The vegetation on the intake site and in surrounding areas has been modified for residential development which is not a preferred habitat for this species. No impacts to this species are anticipated from this project.
- The Golden-cheeked warbler (Setophaga chrysoparia) (GCWA) —The Golden-cheeked warbler is a small endangered songbird found in Juniper-oak woodlands with mature Ashe junipers (cedar). This species nests from March to early summer in the project area. The proposed pump station site at Sandy Creek

Park is located in the Balcones Canyonlands Conservation Plan (BCCP) Permit Area adjacent to the BCCP Wheless Preserve. This site is mapped as Zone 1: Confirmed GCWA habitat in the BCCP Section 10(a)(1)(B) permit. The Deep Water Intake Site (Proposed Maintenance Building Site) lies within areas considered to be "unconfirmed habitat" and "not known to be habitat". However the small size of this area makes it unlikely to be regularly utilized by GCWA during the nesting season. The location of the tunnel shaft/Phase 1 connection is in existing ROW in a largely developed, disturbed, and fragmented area, and does not have the requisite structure, density, and tree species to be considered potential GCWA habitat. As a result of this data BCRUA has agreed to participate in the BCCP for GCWA, and will participate in the BCCP for the final acreage of permanent and temporary disturbance for GCWA. Participation will occur after final design of the project but prior to construction.

- Black-capped vireo (*Vireo atricapilla*) —This endangered species prefers oak-juniper woodlands with patchy shrub/tree layer and open, grassy spaces and nests from March to late summer within the project area. Confirmed habitat for this species does not occur within the area of the intake site or the pump station site and the general landform of these sites were inconsistent with areas regularly utilized by this species. In addition the location of the tunnel shaft/Phase 1 connection is in existing right-of-way in a largely developed, disturbed, and fragmented area which is not consistent with the TPWD description of preferred habitat for this species. No impacts to this species would result from the pipelines due to the boring method used. No impacts to the Black-capped vireo are anticipated as a result of this project; however participation by the BCRUA in the BCCP for GCWA would afford any necessary mitigation for impacts to this species.
- Least Tern (*Sterna antillarum athalassos*)--The location of the proposed project does not appear to contain suitable habitat for the endangered least tern because the tern normally utilizes minimally altered or disturbed areas near rivers, lakes, and reservoirs. No effects to the least tern are anticipated as a result of the proposed project.
- Peregrine Falcon (*Falco peregrinus*), including the American peregrine falcon (*F. p.anatum*) subspecies — This state threatened species is a possible migrant. They utilize a wide range of habitats during migration, including urban areas and landscape edges such as lakes or large river shores. No effects to the peregrine falcon are anticipated from the proposed project.
- Whooping Crane (Grus americana) — The Whooping Crane is a federally listed endangered species which occurs in Texas only during migration. Whooping cranes use a variety of habitats during migration, including croplands for feeding and large, marshy wetlands for roosting. The proposed project is situated on the banks of the Colorado River; however, the project is within an area highly disturbed by residential development and boat traffic which is not habitat this species prefers. No effects to the whooping crane are anticipated as a result of the proposed project.

- Texas horned lizard (*Phrynosoma cornutum*) — The Texas horned lizard is a state-listed threatened species and is present throughout much of the state. They exist in open, arid, and semi-arid regions with sparse vegetation, which includes grass, cactus, scattered brush and scrubby trees. This species could potentially occur in areas with this type of vegetation within the project area although this type of habitat is not common. Impacts to this species would be minimized by the existence of areas of similar habitat nearby and the limited amount of surface construction within the project area. No impacts are anticipated to this species by the project.

The project area does not include suitable habitat for any of the spring, cave or karst dwelling species listed for Travis County. However, the project could have a low negative impact on terrestrial species like the plains spotted skunk, Texas garter snake and Texas horned lizard by causing these species to relocate to less suitable habitat areas or to compete with other species for remaining habitat. The river water intake has a low potential to have a negative impact on mollusks and other aquatic species although the deep location precludes the occurrence of most species. The pipelines, pump station and maintenance station are anticipated to have a nominal impact on all species due to the small area of construction impact and permanent maintenance.

7.2.4 Engineering and Costing

The project is planned in three phases. The first phase is under construction; and, the final phase is to be completed by 2025.

The first phase of the project provides 30 MGD of treated water. Total projected costs for Phase I is $143,751,150. The major facilities constructed as Phase I of this project are:

- Construction of 17 MGD floating raw water pump station;
- Raw water transmission pipeline from Lake Travis to Regional Water Treatment Plant;
- Construction of a new 17 MGD water treatment plant; and
- Treated water transmission pipelines to Cedar Park, Leander and Round Rock.

Remaining facilities to be designed and constructed as part of Phase I include the expansion of the raw water intake and WTP to 30 MGD.

The second phase will be constructed to provide a treated water capacity of 70 MGD. Total projected cost for Phase II is $219,396,780. The major facilities planned for Phase II of the project are:

- Construction of a new deep water intake near Volente;
- Raw water transmission tunnels from the deep water intake; and
- Expansion of the regional water treatment plant to 40 MGD that is to be constructed in Phase I.

The third and final phase of the project will increase the deep water intake capacity and regional water treatment plant to meet ultimate needs by 2050. Total projected costs for Phase III are $48,801,500. Major facilities include:

- Increase deep water intake capacity to 141.7 MGD; and
- Expansion at the regional water treatment plant by 35.8 MGD, for total capacity of 105.8 MGD.

Costs for the regional system and the share of the facilities costs have been developed from the BCRUA Regional Water Supply Project Environmental Assessment, March 2014. Table 7.2-4 summarizes the costs for Phase II and Phase III based on September 2013 prices.

7.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 7.2-5, and the option meets each criterion.

The transfer of water from Lake Travis to Williamson County in excess of the 25,000 acft/yr specified in HB 1437 would constitute an interbasin transfer, but would be exempted from interbasin transfer rules if supplied to Cedar Park. TCEQ permit amendments might be needed to add a point of diversion at Lake Travis.

Requirements Specific to Pipelines

1. Necessary permits:
   - A. U.S. Army Corps of Engineers Section 404 dredge and fill permit for stream crossings and lake intake impacting wetlands or navigable water of the United States.
   - B. GLO Sand and Gravel Removal permits.
   - C. TPWD Sand, Gravel and Marl permit for construction in state-owned streambeds.
2. Right-of-way and easement acquisition.
3. Crossings:
   - A. Highways and Railroads.
   - B. Creeks and Rivers.
   - C. Other Utilities.
4. Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

Table 7.2-4. Summary of Costs for BCRUA Water Supply Project (Phases II- III)

Item	Estimated Costs for Facilities	Cedar Park	Round Rock	Leander[3]
Deep Water Intake and Pump Station (141.7 MGD)	$82,687,000	$22,700,000	$23,808,000	$36,179,000
Raw Water Pipeline	$36,546,000	$10,033,000	$10,523,000	$15,990,000
Water Treatment Plant	$90,173,000	$12,784,000	$34,774,000	$42,615,000
Relocations & Other	$14,396,000	$3,952,000	$4,145,000	$6,299,000
TOTAL COST OF FACILITIES	**$223,802,000**	**$49,469,000**	**$73,250,000**	**$101,083,000**
Engineering, Legal Costs and Contingencies	$74,882,000	$16,535,000	$24,521,000	$33,826,000
Land Acquisition and Surveying	$5,515,000	$1,306,000	$1,741,000	$2,468,000
Interest During Construction (3 years)[1]	$10,648,000	$2,356,000	$3,483,000	$4,809,000
TOTAL PROJECT COST	**$314,847,000**	**$69,666,000**	**$102,995,000**	**$142,186,000**
ANNUAL COSTS				
Debt Service (5.5 percent, 20 years)[1]	$26,346,000	$5,830,000	$8,618,000	$11,898,000
Operation and Maintenance				
Intake, Pipeline, Pump Station	$2,432,000	$668,000	$700,000	$1,064,000
Water Treatment Plant	$11,066,000	$1,569,000	$4,267,000	$5,230,000
Pumping Energy Costs (@$0.09/kW-hr)	$17,549,000	$4,715,000	$6,391,000	$6,443,000
Purchase of Water ($157.5/acft)	$3,938,000	$0	$3,843,000	$95,000
Purchase of Water ($126/acft)	$5,292,000	$2,268,000	$0	$3,024,000
TOTAL ANNUAL COST	**$66,623,000**	**$15,050,000**	**$23,819,000**	**$27,754,000**
Available Project Yield (acft/yr)[2] with a peaking factor of 1.8	**67,000**	**18,000**	**24,400**	**24,600**
Annual Cost of Water ($ per acft)	**$994**	**$836**	**$976**	**$1,128**
Annual Cost of Water ($ per 1,000 gallons)	**$3.05**	**$2.57**	**$3.00**	**$3.46**

Costs developed from BCRUA Regional Water Supply Project Environmental Assessment. March 2014.

1 - Calculated by phase and then summarized.

2 -Yield is limited to the available supply from the Highland Lakes. Treated capacity is 105.8 MGD.

3 – Leander will receive 24,000 acft/yr from the project and wheel another 600 acft/yr for Liberty Hill

Table 7.2-5. Comparison of Lake Travis Supply to Williamson County Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	Low to none
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Sales from LCRA to Cedar Park are exempted from interbasin transfer requirements
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

7.3 Control of Naturally Occurring Salinity

7.3.1 Characterization of Salinity in the Brazos River

Sources

Natural salt pollution has been recognized as the most serious and widespread water quality problem in the Brazos River Basin. No other pollution source, man-made or natural, has had the impact of the natural salt sources located in the upper basin. However, as the Brazos River flows to the Gulf, inflows from tributaries decrease the concentration of dissolved minerals and salts, which in turn improves the quality of water.

The primary sources of the natural salt pollution in the Brazos River Basin are northwest of the City of Abilene, principally in the watersheds of the Salt and Double Mountain Forks of the Brazos River, which are within the Brazos G Area (Figure 7.3-1).

A substantial part of the salt load in the Brazos River is contributed by Croton Creek and Salt Croton Creek, according to various reports.[1,2,3,4,5,6,7] The natural salt pollution producing area is a semi-arid region of salt and gypsum encrusted hills and canyon-like stream valleys. The area is studded with salt springs and seeps. The highly erodible floodplain material in this region is continually washed away as the streams cut their way down to rock or other impervious base. This bedrock provides a cap over a brine aquifer that underlies this entire region of Texas and parts of Arkansas, Oklahoma, and Kansas. In areas where the erosion process has continued for centuries, the streambed has spread out to form large flats. Wherever there is a joint of fracture in the stream bedrock material, the highly mineralized water seeps to the surface under artesian pressure. Massive salt flats, often 400 to 500 acres in size, are formed by this process. Salt and other minerals are also leached out of the adjacent floodplain material that surrounds the salt flats and streams. The Brazos River receives a tremendous salt load when local rainfall is sufficient to dissolve the deposited salt and wash it out of the salt flats.

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[1] Blank, H.R, "Sources of Salt Water Entering the Upper Brazos River," Report, Project 99, Texas A&M Research Foundation, 1955.

[2] Blank, H.R., "Supplementary Report on Sources of Salt Water entering the Upper Brazos Basin," Project 99, Texas A&M University Research Foundation, 1956.

[3] Baker, R.C., Hughes, L.S., Yost, I.D., "Natural Sources of Salinity in the Brazos River, Texas, with Particular Reference to the Salt Croton and Croton Creek Basins, U.S," 1962.

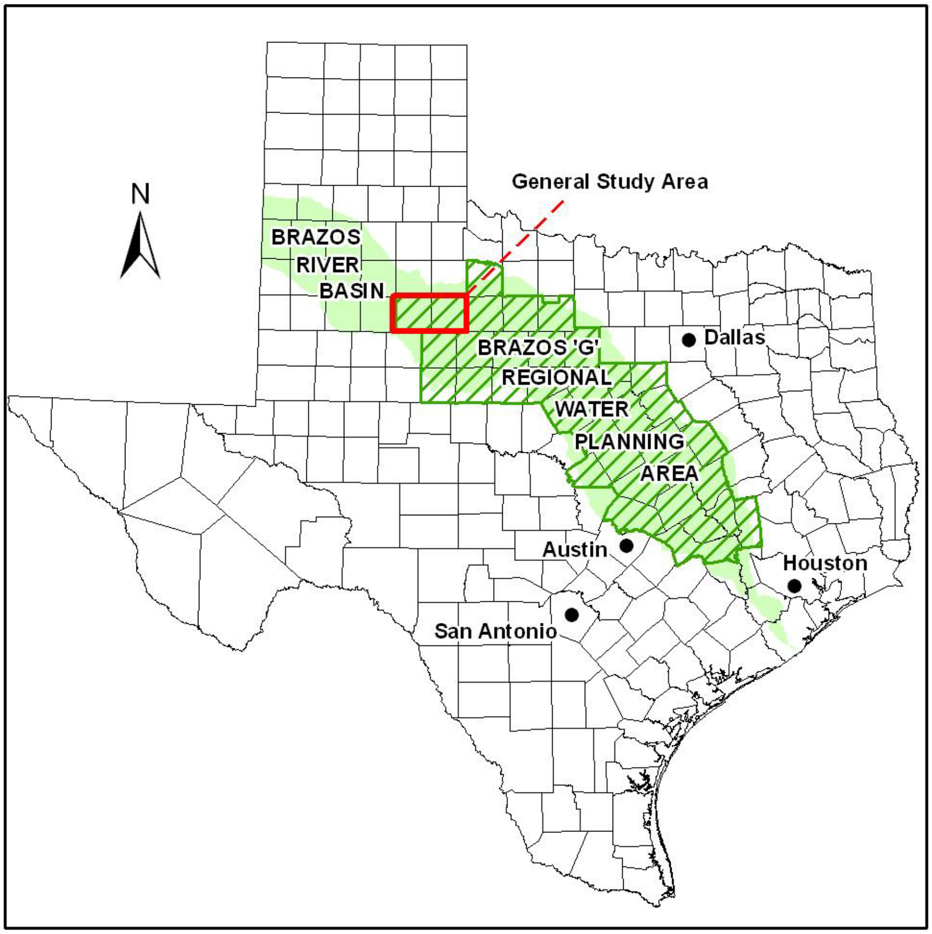
[4] Mason-Johnson & Associates, "Dove Creek Salt Study, Stonewall County, Texas," 1955.

[5] U.S. Army Corps of Engineers Fort Worth District, "Natural Salt Pollution Control Study, Brazos River Basin, Texas," Volumes 1-4, 1973.

[6] U.S. Army Corps of Engineers, Fort Worth District, "Brazos Natural Salt Pollution Control, Brazos River Basin, Texas, Design Memorandum No. 1, General Phase 1 – Plan Formulation," 1983.

[7] Ganze, C.K., and Wurbs, R.A., "Compilation and Analysis of Monthly Salt Loads and Concentrations in the Brazos River Basin," Civil Engineering Department, Texas A&M University, 1989.

Figure 7.3-1. Salinity Control Study Area



Quantification

Salinity in the Brazos River Basin is quantified in terms of concentrations or loads of total dissolved solids (TDS), chlorides (Cl), and sulfates (SO_4). Chlorides and sulfates are primary constituents of the TDS measured in the Basin. The US Geological Survey (USGS) conducted a water quality monitoring program in the Brazos River Basin during the 1964 through 1986 water years. Ganze and Wurbs (1989)[8] and Wurbs et. al. (1993)[9] prepared statistical summaries of the salinity data collected at 26 of the 39 USGS water quality monitoring stations having monthly data for at least 3 years during the monitoring period, excerpted from Wurbs et. al. (1993). The 26 gages were chosen based on their record durations and their locations, which are mapped in Figure 7.3-2. This section highlights data and findings from the Ganze and Wurbs (1989) and Wurbs et. al. (1993) studies.

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[8] Ganze, C.K. and , R.A. Wurbs, "Compilation and Analysis of Monthly Salt Loads and Concentrations in the Brazos River Basin," Prepared for U.S. Army Corps of Engineers Forth Worth District under Contract DACW63-88-M-0793, January 1989.

[9] Wurbs, R.A., A.S. Karama, I. Saleh, and C.K. Ganze, "Natural Salt Pollution and Water Supply Reliability in the Brazos River Basin," Texas Water Resources Institute, 1993.

Table 7.3-2 is excerpted from Wurbs et. al. (1993) and provides the period-of-record mean discharges along with the TDS, Cl, and SO_4 loads and concentrations at the 26 gages. The Possum Kingdom and Whitney gages are located downstream of the respective reservoirs, and the salinity concentration data from these gages provide an indication of the quality of the water released from the reservoirs. Table 7.3-3, also excerpted from Wurbs et. al. (1993), lists the mean discharges and TDS, Cl, and SO_4 loads at 12 of the 26 gages based on available data from the 1964 through 1986 period. The table provides data from similar time periods to facilitate comparisons.

The data in that much of the salinity in the watershed originates above the Seymour gage. A decrease in concentration with distance down the main stem of the Brazos is evident, as tributaries having lower salinity concentrations join the main stem. Based on the data in Table 7.3-3, the mean TDS load in the main stem at Seymour for the 1964 through 1986 period was approximately 41% of the mean load at Richmond, while the mean discharge at Seymour was only approximately 3.9% of the mean discharge at Richmond.

Wurbs et. al. (1993) showed that salinity concentrations vary significantly over time. Table 7.3-4 lists concentration ranges at the Seymour and Richmond gages reported by Wurbs et. al. (1993). Wurbs et. al. (1993) found that, of the main stem gages at Seymour, Possum Kingdom, Whitney, College Station, and Richmond, the Seymour gage showed the greatest variability in monthly mean salinity concentrations over time and that streamflow regulation by Possum Kingdom Lake, Lake Granbury, and Lake Whitney dampen fluctuations in salinity concentrations at downstream gages.

Table 7.3-1. Selected USGS Streamflow Gaging and Water Quality Sampling Stations

USGS Station Number	Station Name	Drainage Area (sq mile)	Period Covered by Annual Data (water year)	Period Covered By Monthly Data (water year)
08080500	Double Mountain Fork Brazos River Near Aspermont	8,796	1949-51, 57-86	1964-86
08081000	Salt Fork Brazos River Near Peacock	4,619	1950-51, 65-86	1965-86
08081200	Croton Creek Near Jayton	290	1962-86	1966-86
08081500	Salt Croton Creek near Aspermont	64	1969-77	1969-77
08082000	Salt Fork Brazos River near Aspermont	5,130	1949-51, 57-82	1964-82
08082180	North Croton Creek near Knox City	251	1966-86	1966-86
08082500	Brazos River at Seymour	15,538	1960-86	1964-86
08083240	Clear Fork Brazos River at Hawley	1,416	1968-79, 82-84	1968-79, 82-84
08085500	Clear Fork River at Fort Griffin	3,988	1950-51, 68-76, 79, 82-84	1968-76, 79, 82-84
08086500	Hubbard Creek Near Breckenridge	1,089	1956-66, 68-75	1968-75

Table 7.3-1. Selected USGS Streamflow Gaging and Water Quality Sampling Stations

USGS Station Number	Station Name	Drainage Area (sq mile)	Period Covered by Annual Data (water year)	Period Covered By Monthly Data (water year)
08087300	Clear Fork Brazos River at Eliasville	5,697	1962-82	1964-82
08088000	Brazos River near South Bend	22,673	1942-48, 78-81	1978-81
08088600	Brazos River at Morris Sheppard Dam near Graford	27,190	1942-86	1964-86
08090800	Brazos River near Dennis	25,237	1971-86	1971-86
08092600	Brazos River at Whitney Dam near Whitney	27,189	1949-86	1964-86
08093360	Aquilla Creek above Aquilla	255	1980-82	1980-82
08093500	Aquilla Creek near Aquilla	308	1968-81	1968-81
08098290	Brazos River near Highbank	30,436	1968-79, 81-86	1968-79, 81-86
08104500	Littler River near Little River	5,228	1965-73, 80-86	1965-73, 80-86
08106500	Little River at Cameron	7,065	1960-86	1964-86
08109500	Brazos River near College Station	39,599	1962-83	1967-83
08110000	Yegua Creek near Somerville	1,009	1962-66	1964-66
08110325	Navasota River Above Groesbeck	239	1968-86	1968-86
08111000	Navasota River near Bryan	1,454	1959-81	1964-81
08114000	Brazos River at Richmond	45,007	1946-86	1964-86
08116650	Brazos River near Rosharon	45,339	1969-80	1969-80

Source: Wurbs, R.A., A.S. Karama, I. Saleh, and C.K. Ganze, “Natural Salt Pollution and Water Supply Reliability in the Brazos River Basin,” Texas Water Resources Institute, 1993.

Figure 7.3-2. Selected USGS Water Quality Monitoring Stations

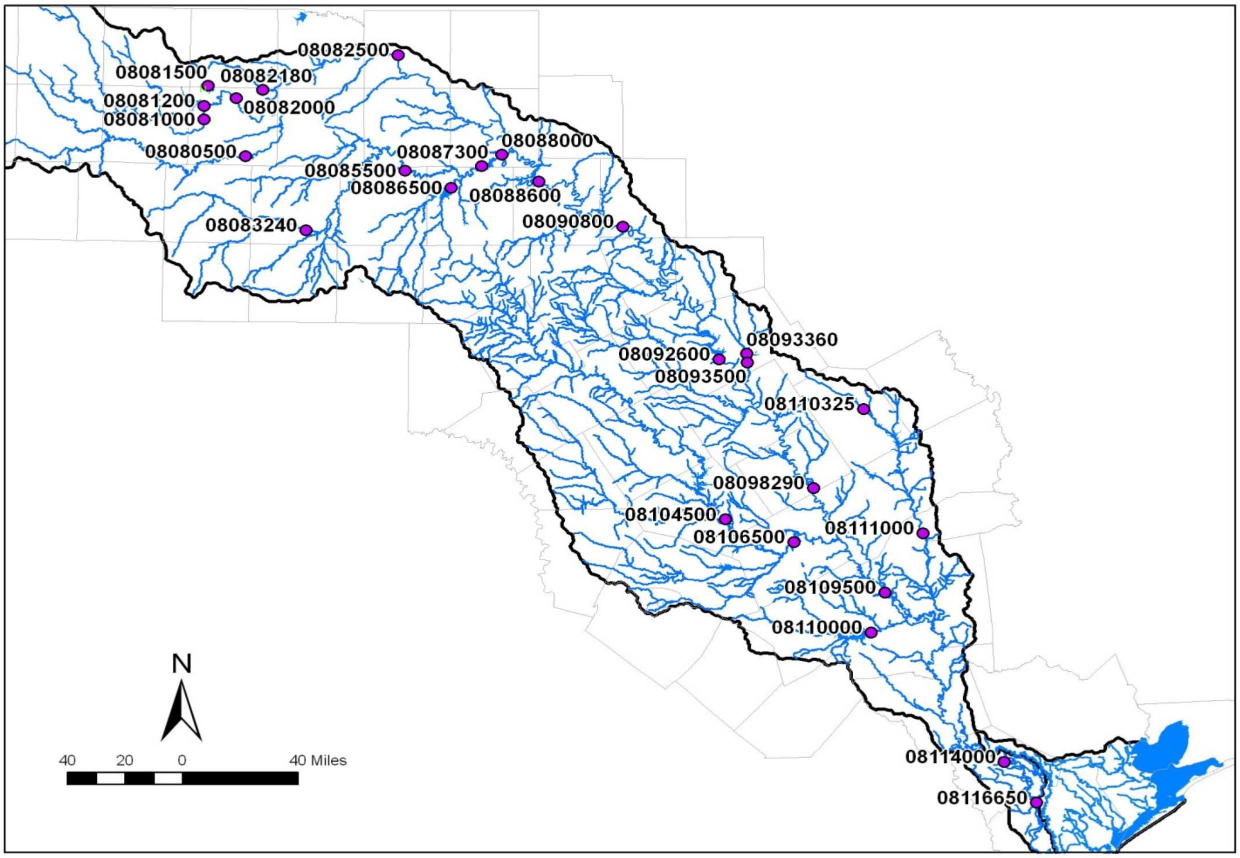


Table 7.3-2. Mean Discharges, Loads, and Concentrations for Period-of-Record

USGS Station Number	Abbreviated Station Name	Tributary	Years of Record	Mean Discharge (cfs)	Load (tons/day)			Concentration (mg/L)		
					TDS	Cl	SO_4	TDS	Cl	SO_4
08080500	Aspermont	Double Mountain Fork	33	147	562	136	218	1,353	324	510
08081000	Peacock	Salt Fork	24	43	680	334	83	5,317	2,585	657
08081200	Jayton	Croton Creek	24	13	237	96	58	6,321	2,487	1,617
08081500	Aspermont	Salt Croton Creek	9	4	673	388	27	56,923	32,856	2,273
08082000	Aspermont	Salt Fork	29	81	1,887	942	217	8,606	4,153	989
08082180	Knox City	North Croton Creek	21	17	216	82	60	4,723	1,786	1,323

Table 7.3-2. Mean Discharges, Loads, and Concentrations for Period-of-Record

USGS Station Number	Abbreviated Station Name	Tributary	Years of Record	Mean Discharge (cfs)	Load (tons/day)			Concentration (mg/L)		
					TDS	Cl	SO_4	TDS	Cl	SO_4
08082500	Seymour	Main Stem	27	292	2,638	1,018	447	3,356	1,295	569
08083240	Hawley	Clear Fork	15	46	235	51	94	1,893	411	759
08085500	Fort Griffin	Clear Fork	15	151	391	105	116	961	258	286
08086500	Breckenridge	Hubbard Creek	19	93	73	25	4	268	91	20
08087300	Eliasville	Clear Fork	21	319	614	201	148	715	234	172
08088000	South Bend	Main Stem	11	760	2,601	996	561	1,261	486	274
08088600	Possum Kingdom	Main Stem	45	836	2,959	1,127	636	1,299	493	279
08090800	Dennis	Main Stem	19	892	3,103	1,205	622	1,291	501	259
08092600	Whitney	Main Stem	38	1,376	3,174	1,120	633	856	302	171
08093360	Aquilla	Aquilla Creek	3	55	35	2	10	236	14	69
08093500	Aquilla	Aquilla Creek	14	147	102	6	29	257	14	73
08098290	Highbank	Main Stem	18	2,530	4,154	1,287	772	609	189	113
08104500	Little River	Little River	16	912	768	79	61	313	32	25
08106500	Cameron	Little River	26	1,544	1,094	129	126	263	31	30
08109500	College Station	Main Stem	22	4,364	5,315	1,379	944	452	117	80
08110000	Somerville	Yegua Creek	5	252	114	20	33	167	30	48
08110325	Groesbeck	Navasota River	19	161	56	9	6	131	22	13
08111000	Bryan	Navasota River	23	600	232	61	38	144	38	23

Table 7.3-2. Mean Discharges, Loads, and Concentrations for Period-of-Record

USGS Station Number	Abbreviated Station Name	Tributary	Years of Record	Mean Discharge (cfs)	Load (tons/day)			Concentration (mg/L)		
					TDS	Cl	SO_4	TDS	Cl	SO_4
08114000	Richmond	Main Stem	41	6,545	6,140	1,431	1,020	351	81	58
08116650	Rosharon	Main Stem	12	7,305	6,462	1,491	1,004	328	76	51

Source: Wurbs, R.A., A.S. Karama, I. Saleh, and C.K. Ganze, "Natural Salt Pollution and Water Supply Reliability in the Brazos River Basin," Texas Water Resources Institute, 1993.

Table 7.3-3. Mean Discharges, Loads, and Concentrations for Comparable Time Periods

USGS Station Number	Abbreviated Station Name	Tributary	Years of Record	Mean Discharge (cfs)	Load (tons/day)			Concentration (mg/L)		
					TDS	Cl	SO_4	TDS	Cl	SO_4
08080500	Aspermont	Double Mountain Fork	1964-86	126	580	153	209	1,540	416	548
08081000	Peacock	Salt Fork	1965-86	40	684	339	81	5,782	2,830	698
08081200	Jayton	Croton Creek	1964-86	13	225	93	53	6,391	2,541	1,591
08081500	Aspermont	Salt Croton Creek	1969-77	4	676	425	33	56,923	32,856	2,273
08082000	Aspermont	Salt Fork	1964-82	60	1,660	1,094	219	12,407	6,066	1,235
08082180	Knox City	North Croton Creek	1966-86	17	211	80	58	4,723	1,786	1,323
08082500	Seymour	Main Stem	1964-86	269	2,601	1,074	504	3,591	1,482	696
08088600	Possum Kingdom	Main Stem	1964-86	686	2,795	111	571	1,512	601	309
08092600	Whitney	Main Stem	1964-86	1,230	3,075	1,134	591	928	342	178
08106500	Cameron	Little River	1964-86	1,481	1,024	123	119	256	31	30
08109500	College Station	Main Stem	1964-83	4,529	5,348	1,368	938	438	112	77

Table 7.3-3. Mean Discharges, Loads, and Concentrations for Comparable Time Periods

USGS Station Number	Abbreviated Station Name	Tributary	Years of Record	Mean Discharge (cfs)	Load (tons/day)			Concentration (mg/L)		
					TDS	Cl	SO_4	TDS	Cl	SO_4
08114000	Richmond	Main Stem	1964-86	6,868	6,267	1,466	1,030	339	79	56

Source: Wurbs, R.A., A.S. Karama, I. Saleh, and C.K. Ganze, "Natural Salt Pollution and Water Supply Reliability in the Brazos River Basin," Texas Water Resources Institute, 1993.

Table 7.3-4. Ranges in Monthly Mean Salinity Concentration for Water Years 1964 through 1986

Abbreviated Station Name	Tributary	Con-stituent	Minimum Monthly Mean Concen-tration (mg/L)[1]	Date of Minimum Monthly Mean Concen-tration (mg/L)[1]	Maximum Monthly Mean Concen-tration (mg/L)[1]	Date of Maximum Monthly Mean Concen-tration (mg/L)[1]	Ratio of Maximum to Minimum
Seymour	Main Stem	TDS	618	Aug 1964	15,400	May 1984	24.92
Seymour	Main Stem	Cl	190	Jun 1975	7,740	May 1984	40.74
Seymour	Main Stem	SO_4	112	Nov 1963	2,225	Mar 1976	19.87
Richmond	Main Stem	TDS	153	Nov 1984	978	Oct 1978	6.39
Richmond	Main Stem	Cl	28	Nov 1984	355	Oct 1978	12.68
Richmond	Main Stem	SO_4	24	Dec 1965	185	Oct 1963	7.71

[1] Source: Wurbs, R.A., A.S. Karama, I. Saleh, and C.K. Ganze, "Natural Salt Pollution and Water Supply Reliability in the Brazos River Basin," Texas Water Resources Institute, 1993.

Based on arithmetic averages of the monthly mean concentrations for each month of the year in the 1964 through 1986 analysis period, Wurbs et. al. (1993) also found that seasonal fluctuations in salinity concentrations were greater at the Seymour gage than at the gages located below the reservoirs. The month having the maximum average monthly mean concentrations of all three salinity parameters at Seymour is February. Table 7.3-5 lists the range of the arithmetic averages of the monthly mean concentrations at the Seymour, Whitney, and Richmond gages. Of the three gages listed in, the variation is least at the Whitney gage, which is likely due to the effects of the reservoir. With regard to trends over time, Wurbs et al. (1993) found that any trends or long term changes in salinity concentrations are very small relative to the random variability in the data.

Table 7.3-5. Range of Arithmetic Averages of Monthly Mean Salinity Concentrations for Each Month of the Year for Water Years 1964 through 1986

Abbreviated Station Name	Tributary	Con-stituent	Minimum Average Monthly Mean Concen-tration (mg/L)[1]	Month Having Minimum Average Monthly Mean Concen-tration (mg/L)[1]	Maximum Average Monthly Mean Concen-tration (mg/L)[1]	Month Having Maximum Average Monthly Mean Concen-tration (mg/L)[1]	Ratio of Maximum to Minimum
Seymour	Main Stem	TDS	3,240	Sep	10,600	Feb	3.27
Seymour	Main Stem	Cl	1,310	Sep	4,650	Feb	3.55
Seymour	Main Stem	SO_4	701	Sep	1,620	Feb	2.31
Whitney	Main Stem	TDS	880	Jul	996	Jan	1.13
Whitney	Main Stem	Cl	321	Jul	374	Jan	1.17
Whitney	Main Stem	SO_4	167	Jul	194	Dec	1.16
Richmond	Main Stem	TDS	335	May	546	Aug	1.63
Richmond	Main Stem	Cl	78	May	158	Aug	2.03
Richmond	Main Stem	SO_4	55	May	95	Aug	1.73

[1] Source: Wurbs, R.A., A.S. Karama, I. Saleh, and C.K. Ganze, “Natural Salt Pollution and Water Supply Reliability in the Brazos River Basin,” Texas Water Resources Institute, 1993.

Effects of Salinity on Usability of Water

TDS concentration-duration curves at the Seymour, Possum Kingdom, Whitney, College Station, and Richmond gages based on the 1964 through 1986 water year (1964 through 1983 for the College Station gage) monthly mean data are plotted in Figure 7.3-3 through Figure 7.3-7.

Figure 7.3-3. TDS Concentration-Duration Curve at Seymour

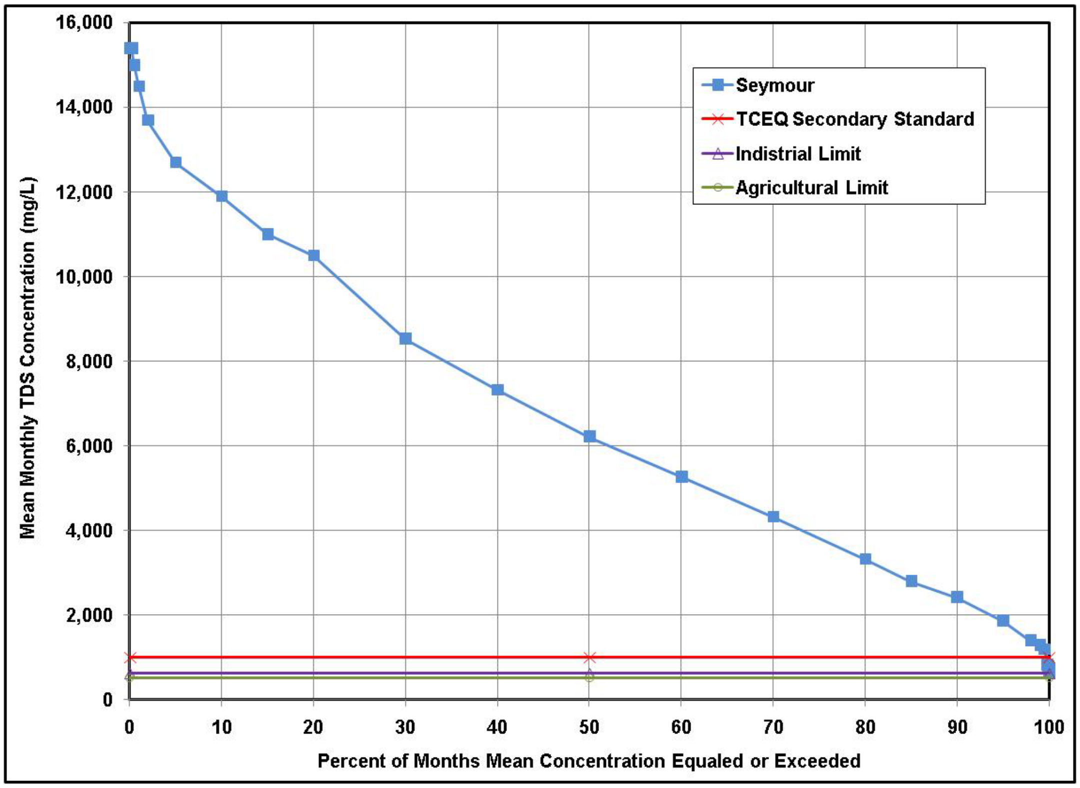


Figure 7.3-4. TDS Concentration-Duration Curve at Possum Kingdom

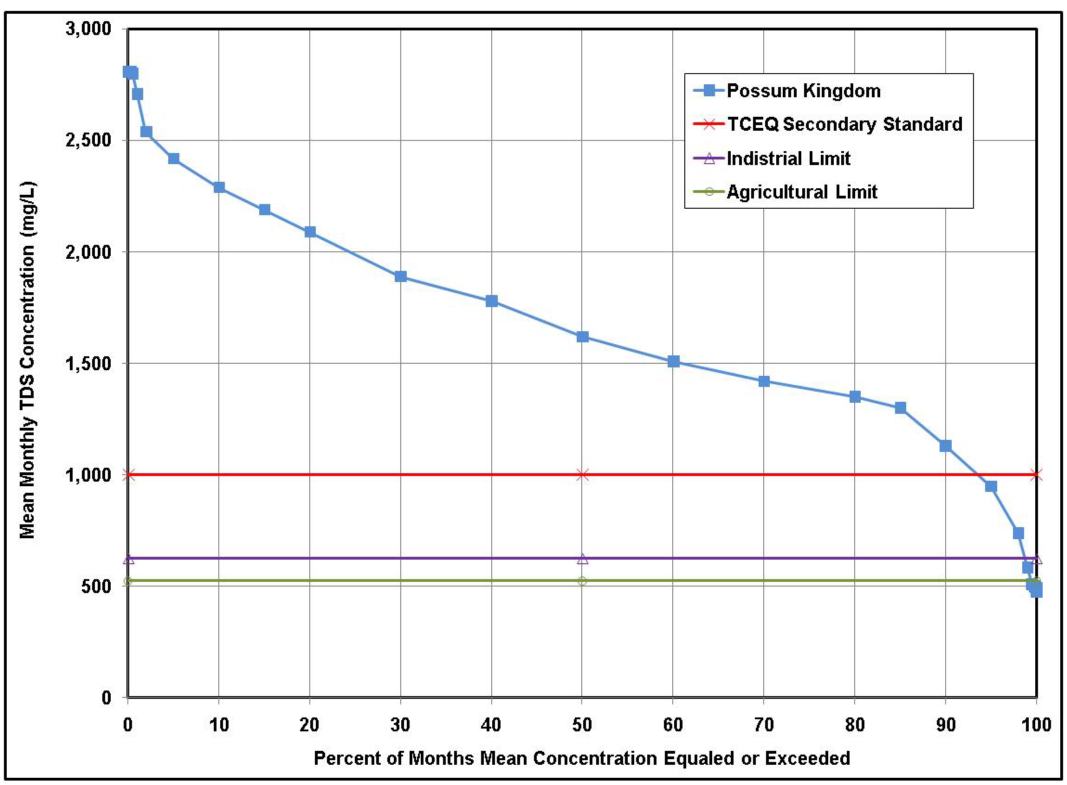


Figure 7.3-5. TDS Concentration-Duration Curve at Whitney

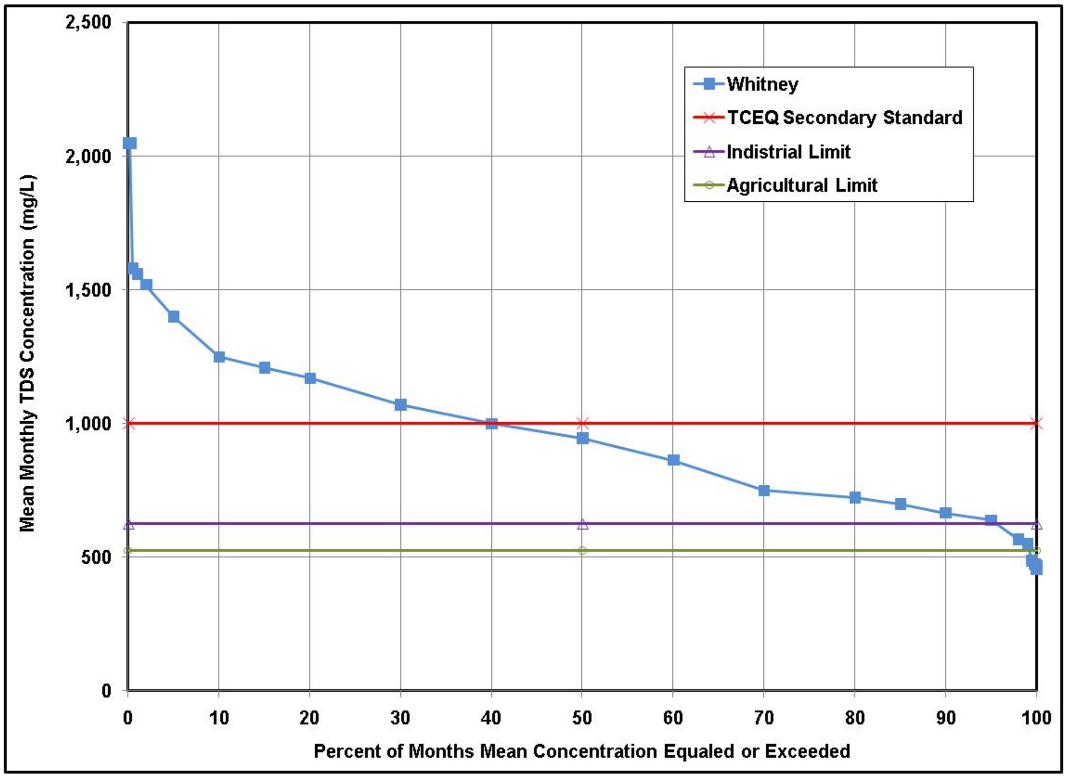


Figure 7.3-6. TDS Concentration-Duration Curve at College Station

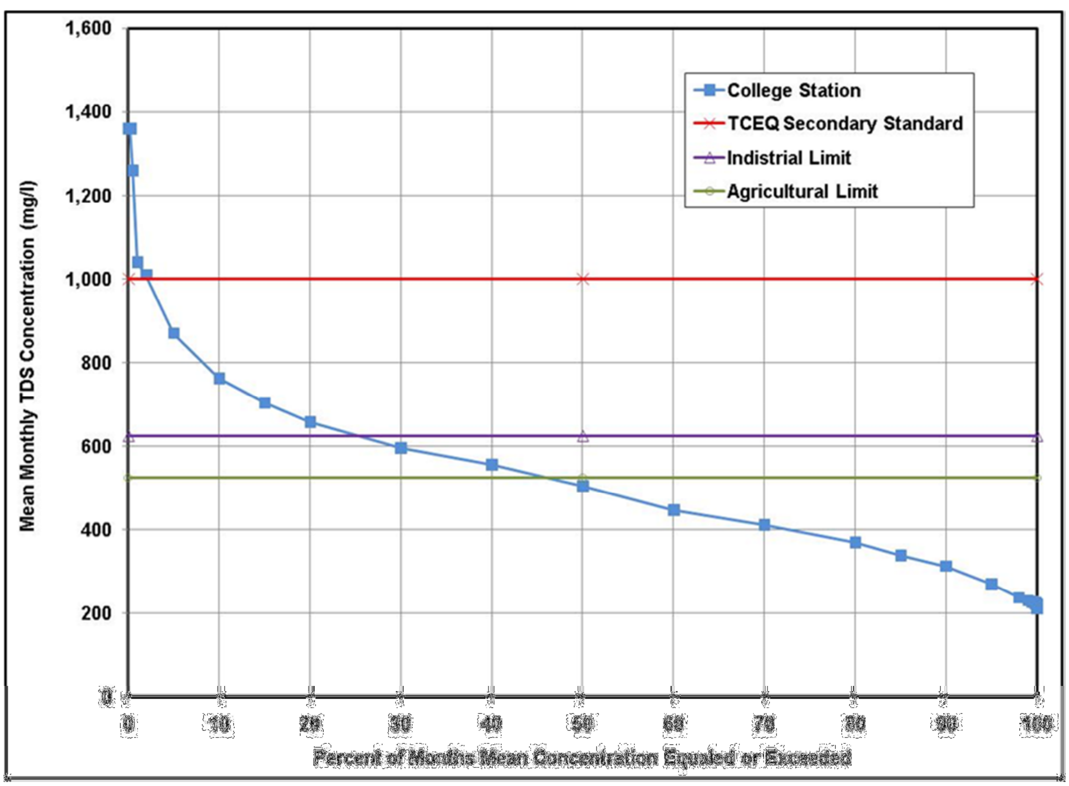
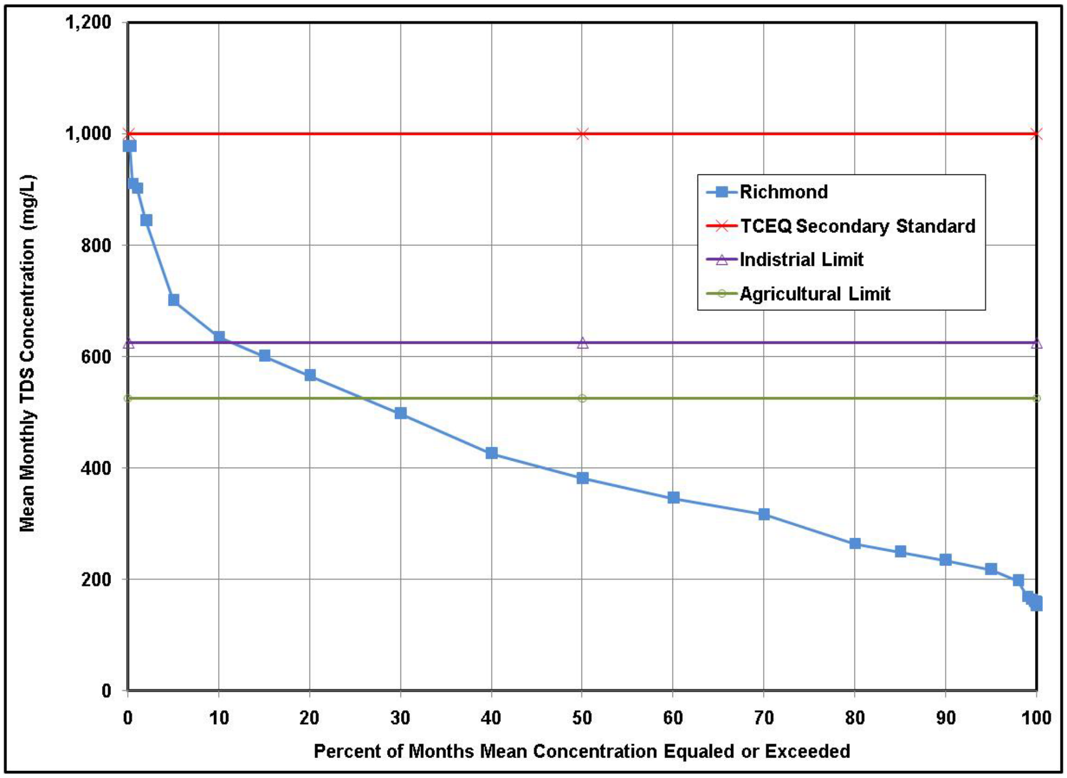


Figure 7.3-7. TDS Concentration-Duration Curve at Richmond



Comparison of the salinity concentration frequencies to requirements for municipal, agricultural, and industrial use provide insight into the usability of the water in the Brazos without desalination treatment.

The TCEQ secondary drinking water standard for TDS is 1,000 mg/L. Figure 7.3-2 indicates that concentrations at the Seymour gage equaled or exceeded the TDS limit in 99.7% of the study period months. Further downstream, below Possum Kingdom Lake and Lake Whitney, concentrations equaled or exceeded the TDS limit in 93.6% and 40.0% of the months, respectively. At College Station, concentrations equaled or exceeded the TDS limit in 2.2% of the months. Finally, at the Richmond gage, the downstream-most gage in the study (92 river miles above the Gulf of Mexico), concentrations remained less than the TDS limit.

Table 7.3-6 provides permissible TDS limits for classes of irrigation water, as presented by Fipps.[10] The table shows that at TDS concentrations above 525 mg/L, leaching is recommended to flush accumulated salts below the active root zone. Table 7.3-7 provides irrigation water quality guidelines published by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). The NRCS guidelines indicate that irrigation water can be used without restriction, or without expectation of related problems, if TDS concentrations are below 450 mg/L and that with concentrations ranging from 450 mg/L to 2,000, use is slightly to moderately restricted. Additional information on the effects of salinity on the suitability of water for irrigation is

[10] Fipps, G. “Irrigation Water Quality Standards and Salinity Management Strategies,” Texas A&M Agricultural Research and Extension Center, April 2003.

provided by Hem.[11] Assuming a desirable TDS concentration of less than 525 mg/L for irrigation use, Figure 7.3-3 through Figure 7.3-7 indicate that TDS levels in the Brazos River at the Seymour, Possum Kingdom, Whitney, College Station, and Richmond gages equaled or exceeded the desirable level in 100%, 99.4%, 99.2%, 46.2%, and 26.0% of the months in the analysis period, respectively.

Table 7.3-6. Permissible TDS Limits for Classes of Irrigation Water

Classes of Water	TDS Concentration (mg/L)	Comment
Class 1, Excellent	175	
Class 2, Good	175-525	
Glass 3, Permissible	525-1,400	Leaching needed if used.
Class 4, Doubtful	1,400-2,100	Good drainage needed and sensitive plants will have difficulty obtaining stands.
Class 5, Unsuitable	2,100	Good drainage needed and sensitive plants will have difficulty obtaining stands.

Source: Fipps, G., "Irrigation Water Quality Standards and Salinity Management Strategies," Texas A&M Agricultural Research and Extension Center, April 2003.

Table 7.3-7. Irrigation Water Quality Guidelines

Degree of Restriction on Use	TDS Concentration (mg/L)
None	< 450
Slight to Moderate	450 – 2,000
Severe	> 2,000

Source: Ayers, R.S., and D.W. Westcot, "Water Quality for Agriculture," Food and Agricultural Organization of the United Nations, Irrigation and Drainage Paper No. 29, rev. 1, 1985, as cited in U.S. Department of Agriculture Natural Resources Conservation Service. Part 623 National Engineering Handbook, Chapter 2, "Irrigation Water Requirements," 1993.

Water quality requirements for industrial usage vary widely depending upon the industrial process.[12] A 625 mg/L TDS limit is assumed here. The limit is derived from a desirable chloride concentration for water used in cooling towers of less than 200 mg/L. Based on the USGS water quality data, mean chloride concentration as a percentage of mean TDS concentration in the Brazos River ranges from 23% at Richmond to 41% at Seymour. Using the midpoint of this range, 32%, as a representative percentage of TDS that is chloride, a 200 mg/L chloride limit equates to a 625 mg/L TDS limit (200/.32 = 625). Figure 7.3-3 through Figure 7.3-7 indicate that TDS levels in Brazos at Seymour, Possum Kingdom, Whitney, College Station, and Richmond gages equaled or exceeded this concentration in 100%, 98.7%, 95.6%, 25.4%, and 11.5% of the months in the analysis period, respectively.

[11] Hem, J.D., "Study and Interpretation of the Chemical Characteristics of Natural Water," United States Geological Survey Water Supply Paper 2254, Third Edition, 1989.

[12] Ibid.

7.3.2 Description of Salinity Control Project

Three salinity control project options were studied in the 2001 Brazos G Regional Water Plan. All three options included brine recovery well fields that penetrate the saline aquifer, lowering the piezometric surface of the water table, thereby eliminating brine springs and seeps in the area. Option 1 involved disposal of the recovered brine in a deep well injection system. Option 2 involved disposal of the brine in Kiowa Peak Reservoir, which would serve as a permanent impoundment for the recovered brine. Option 3, which has evolved into the project studied further herein, would convey the recovered brine to a brine utilization and management complex (BUMC) where it would be converted into marketable sodium chloride (NaCl) salt products. Stonewall, Garza, and Kent Counties have formed a local government corporation called the Salt Fork Water Quality (SFWQ) Corporation to work on advance planning for the project in cooperation with the Brazos River Authority.

The currently proposed project configuration is shown in Figure 7.3-8. Key project components are located in Kent and Stonewall counties and include three brine recovery well fields, a brine conveyance pipeline, and the BUMC. The brine recovery well fields would be located adjacent to salt springs contributing flows to Salt Croton Creek (Dove Creek Salt Flat / Panther Canyon Area), Croton Creek (Short Croton Salt Flat), and Salt Creek. Test wells have been drilled in all three well fields. A test well at the Salt Creek field is currently producing brine that is being sold to Oxy-Permian Corporation.[13] Six-inch spur and 12-inch trunk lines would convey the brine from the well fields to the BUMC, which would employ solar evaporation ponds to recover the salt from solution. A total of approximately 37.5 miles of 12-inch line and 17.5 miles of 6-inch line would be installed. The pipe material would be carbon steel with epoxy coating. Three pump stations, located in the vicinity of the well fields, would be included in the transmission system. The BUMC would be located in Kent County approximately 16 miles southwest of Jayton and 29 miles north of Snyder. Costing and environmental information are also included in the present evaluation for a rail spur running along State Highway 208 from the BUMC to the BNSF Railroad line in Snyder. The rail spur would facilitate long distance shipping of salt products. Although the rail spur is preliminarily evaluated herein, the associated initial capital costs and potential benefits of access to a broader geographical market compared to trucking are still under consideration.

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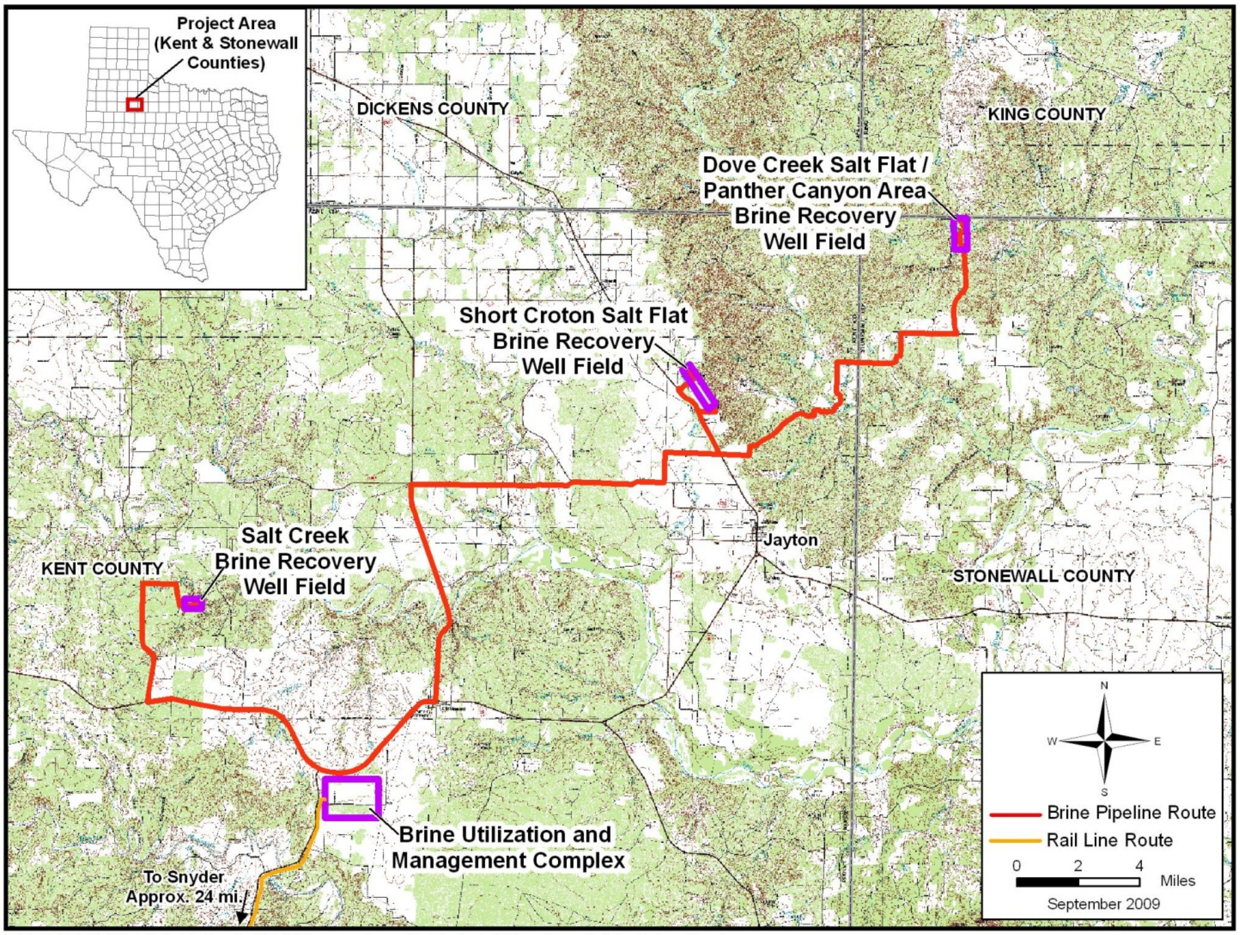
[13] Rodgers, R.W., "Natural Chloride Salt Pollution Control in the Upper Brazos River Basin," prepared for the Salt Fork Water Quality District, Stonewall, Kent, and Garza Counties, Texas, 2008.

Figure 7.3-8. Project Layout Map



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Most of the brine pumped from the well fields would be evaporated to make salt. There is a possibility that some fresh water could be condensed as a byproduct. Brine that is not evaporated would be used in liquid form as "ten-pound brine" for oil and gas operations. Sales of salt and liquid brine would produce revenues to help cover annual costs.

As an alternative configuration of the proposed project, the feasibility of using smaller evaporation units closer to the recovery wells is being evaluated by the SFWQ Corporation. Salt would be collected from these units and shipped by truck. A second variation of the project would include, in addition to the previously described components, capturing brine in North Croton Creek and piping it to a disposal reservoir in the Wichita River basin.[14] The U.S. Army Corps of Engineers' salinity control project in the Wichita River Basin includes the existing Truscott Brine Disposal Lake and project plans have included the Crowell Brine Lake. As information for the two variations of the project has not been developed in comparable detail to the components previously described, these variations are not evaluated further herein.

[14] Denny, K. and J. Dougherty, Verbal communication, September 2009.

7.3.3 Evaluation of the Potential Effectiveness of the Salinity Control Project

Modeling Approach

The approach to evaluating the potential effectiveness of the salinity control project involved modeling TDS concentrations in the Brazos River Basin for the hydrologic, water use, and reservoir operating policies of the 2070 Brazos G Water Availability Model (WAM). Model simulations were developed to represent conditions with and without the salinity control project, and the resulting TDS concentration frequency data were compared. Work by Wurbs and Lee (2009)[15] provided salinity input data used in the modeling.

Brazos WAM WRAP-SALT Input File

Wurbs and Lee (2009)[16] used the USGS 1964-1986 sampling data to develop a TDS budget for the Brazos Basin. The budget provided estimates of TDS loads and concentrations that Wurbs and Lee then applied in preparing an input file for the WRAP-SALT[17] software. WRAP-SALT is the salinity modeling component of the Water Rights Analysis Package (WRAP).[18] The program computes loads and concentrations of conservative water quality constituents based on scenarios of water use, reservoir operating policies, and salinity control measures. The Brazos WAM is implemented with the WRAP-SIM component of WRAP and provides the water quantity data that are necessary for execution of WRAP-SALT. The Wurbs and Lee (2009) input file is designed for use with the various versions of the Brazos WAM.

Table 7.3-8 provides a summary of the Wurbs and Lee (2009) TDS budget. Water volumes, TDS loads, and TDS concentrations of inflows to the Brazos River system and losses from the system are summarized in the table by their mean values over the 1964 through 1986 water year period. The inflow values are summarized at five control points representing five USGS gaging stations, and the losses are summarized at the three major main stem reservoirs (Possum Kingdom, Granbury, and Whitney). The losses represent removal of salinity from the system that is not associated with a particular water management practice.

Wurbs and Lee (2009) used the TDS budget in developing the WRAP-SALT input file. The 197,402 tons/month mean net TDS inflow less losses in Table 7.3-8 is the mean TDS load of the river flows at the Richmond gage as entered in the WRAP-SALT input file. The actual mean load at the Richmond gage (Table 7.3-10) for the 1964 through 1986 water year period was approximately 6,800 tons/month less than the load entered into the model. Of this difference, approximately 4,900 tons/month is accounted for by

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[15] Wurbs, R.A. and C. Lee, "Salinity Budget and WRAP Salinity Simulation Studies of the Brazos River/Reservoir System," Texas Water Resources Institute Technical Report No. 352, July 2009.

[16] Ibid.

[17] Wurbs, R.A, "Salinity Simulation with WRAP," Texas Water Resources Institute Technical Report No. 317, July 2009.

[18] Wurbs, R.A, "Water Rights Analysis Package (WRAP) Modeling System Reference Manual," Texas Water Resources Institute Technical Report No. 255, August 2008.

the change in reservoir storage, and approximately 1,900 is accounted for by water supply diversions from Lake Granbury. These loads are not subtracted out of the load entered into the input file because the software computes the actual values of these loads for the water management strategies being modeled.

Components of the total Basin load are introduced at various locations throughout the Basin in the salinity simulation based on information provided by the Brazos WAM WRAP-SALT input file. The salinity computations are carried out from upstream to downstream. TDS loads entering the system at the Seymour control point and inflow concentrations entering at the Cameron control point define upstream boundaries of the salinity simulation. These boundaries are the loads and concentrations associated with total regulated flows at the Seymour and Cameron control points, respectively. The Little River is the largest low salinity tributary of the Brazos River. Although the Brazos WAM contains control points located upstream of the boundaries and computes water quantities above these points, the salinity simulation does not extend above the Seymour gage on the Brazos River and the Cameron gage on the Little River.

In addition to defining the boundary conditions, the WRAP-SALT input file defines the TDS concentrations for incremental inflows that occur throughout the Basin below the boundaries. The incremental inflow concentrations are defined at several control points. These concentrations are then automatically repeated by the model at all control points located above the given control point until a control point is encountered for which a different incremental inflow concentration is defined. Thus, incremental inflow concentrations are applied to all incremental inflows entering the model below the upstream boundaries.

Table 7.3-8. TDS Budget Summary

Location	Brazos WAM Control Point ID	USGS Station Number	Mean Volume (acft / month)	Mean Load (tons / month)	Mean Load (percentage)	Mean Concen-tration (mg/L)
Inflows Entering the River System						
Brazos River at Seymour	BRSE11	08082500	16,215	79,127	34.9	3,589
Brazos River at Morris Sheppard Dam near Graford	SHGR26	08088600	33,153	31,828	14.1	706
Brazos River near Whitney (Aquilla) Below Whitney Dam	BRAQ33	08092600/ 08093100	43,077	18,485	8.2	316
Little River at Cameron	LRCA58	08106500	89,374	31,134	13.7	256
Brazos River at Richmond	BRRI70	08114000	251,443	65,956	29.1	193
Subtotal			**432,262**	**226,530**	**100.0**	**385**

Table 7.3-8. TDS Budget Summary

Location	Brazos WAM Control Point ID	USGS Station Number	Mean Volume (acft / month)	Mean Load (tons / month)	Mean Load (percentage)	Mean Concen-tration (mg/L)
Losses Leaving the Reservoir System						
Lake Possum Kingdom	515531		2,383	19,331	66.4	5,966
Lake Granbury	515631		2,222	6,694	23.0	2,216
Lake Whitney	515731		2,233	3,103	10.6	1,022
Subtotal			**6,838**	**29,128**	**100.0**	**3,140**
Total Net Inflows Less Losses						
Brazos River Basin Total			**440,100**	**197,402**		**330**
Source: Wurbs, R.A. and C. Lee, "Salinity Budget and WRAP Salinity Simulation Studies of the Brazos River/Reservoir System," Texas Water Resources Institute Technical Report No. 352, July 2009.						

Table 7.3-9 is excerpted from Wurbs and Lee (2009) and lists the locations at which TDS is input to the system, and describes how these inputs are defined. The Seymour boundary consists of a series of TDS loads for each month of the simulation period. The loads are combined in WRAP-SALT with the WAM regulated flow output to compute the concentrations at the boundary. The observed loads from the 1964 through 1986 dataset at the Seymour gage are adopted for that time period in the input file. Because the Brazos WAM simulation period extends from 1940 to 1997, loads were synthesized for the 1940 through 1939 and 1987 through 1997 periods. Wurbs and Lee (2009) synthesized the missing data by interpolating loads for the Brazos WAM naturalized flows from the observed loads and flows in the 1964 through 1986 dataset. This approach differs from simply developing a load-discharge regression equation from the observed data and using that equation to compute the load for the given naturalized flow. The approach used involves interpolating loads from the observed load-discharge data points after they have been ranked in order of increasing discharge. While these data do generally show increasing load with increasing discharge, for a given pair of data points the greater discharge point may not be associated with a larger load. Wurbs and Lee (2009) note that compared to a regression equation, the interpolation method preserves some of the variability of the observed discharge-load data.

Table 7.3-9. TDS Data in WRAP-SALT Input File

Control Point ID	Control Point Location	Input File Data
BRSE11	Brazos River at Seymour	Load series for total regulated flows
SHGR26	Brazos River at Morris Sheppard Dam near Graford	Concentration series for incremental inflows
BRAQ33	Brazos River near Whitney (Aquilla) Below Whitney Dam	Concentration series for incremental inflows
LRCA58	Little River at Cameron	Constant 256 mg/L for total regulated flows
BRRI70	Brazos River at Richmond	Concentration series for incremental inflows
BRGM73	Brazos River at Gulf of Mexico	Constant 339 mg/L for incremental inflows

Source: Wurbs, R.A. and C. Lee, “Salinity Budget and WRAP Salinity Simulation Studies of the Brazos River/Reservoir System,” Texas Water Resources Institute Technical Report No. 352, July 2009.

At the Cameron boundary, a constant TDS concentration of 256 mg/L is established for regulated flows. This concentration is applied to the regulated flow at this control point in each month of the simulation. The 256 mg/L value is equal to the 1964 through 1986 mean concentration at the Cameron gage.

In addition to the two upstream boundaries, TDS inputs are defined at the Graford gage, Whitney gage, Richmond gage, and at the Basin outlet at the Gulf of Mexico. The inputs at the Graford, Whitney, and Richmond gages are defined with time series of TDS concentrations for incremental inflows. The time series provide the incremental inflow concentrations for each month of the simulation period. The series consist of the 1964 through 1986 observed concentrations along with synthesized data for the remainder of the period. Similar to the synthesized loads at the Seymour gage, concentrations of incremental inflows were synthesized by linear interpolation of load-discharge datasets developed from the salinity budget.

A constant incremental inflow TDS concentration is defined at the basin outlet at the Gulf of Mexico. This constant value is applied for all months of the simulation period and is equal to the 1964 through 1986 mean concentration at the Richmond gage of 339 mg/L.

The TDS budget summarized in Table 7.3-8 shows losses from the system that are not associated with a particular water management practice. To account for these losses in the WRAP-SALT simulations, the input file includes coding to reduce inflow loads to the Lake Possum Kingdom, Granbury, and Whitney control points by 17.42%, 6.59%, and 3.00% respectively. These losses are not repeated at any other control points.

The WRAP-SALT simulation requires as input initial storage contents and TDS concentrations for each reservoir located below the upstream boundaries. In both the Brazos WAM and the salinity simulation, all reservoirs are assumed to be full at the beginning of the simulation period. Possum Kingdom Lake, Lake Granbury, and Lake

Whitney are assigned initial TDS concentrations of 1,626 mg/L, 1,302 mg/L, and 1,062 mg/L, respectively. These values are the mean 1964 through 1986 TDS concentrations for each lake as computed in the salinity budget. Reservoirs upstream of Possum Kingdom, Granbury, and Whitney are assigned initial TDS concentrations of 800 mg/L, 400 mg/L, and 300 mg/L respectively. Reservoirs upstream of the Brazos River at the Gulf of Mexico and below Whitney are assigned initial TDS concentrations of 250 mg/L.

Brazos WAM WRAP-SALT Input File

Wurbs and Lee (2009) used WRAP-SALT with the input file described in the previous section to assess the salinity reduction that would be achieved by construction of salinity control impoundments on Croton Creek, Salt Croton Creek, and North Croton Creek. The impoundment project has been previously studied by the U.S. Army Corps of Engineers.[19,20] Wurbs and Lee (2009) modeled the impacts of the impoundments by assuming that all flows and loads entering the system above the impoundments would be removed. A similar approach was used in the present study to assess the effects of the groundwater pumping salinity control project.

Table 7.3-10 provides a summary of loads and discharges at USGS gages in the upper Brazos River Basin prepared by Wurbs and Lee (2009). Not all the gages listed in Table 7.3-10 have complete water year 1964 through 1986 records. The table therefore provides 1969 through 1977 means that are based on measured data as well as 1964 through 1986 means that are based on records which were filled as necessary by regression analysis.

To model the affects of the salinity control impoundments, Wurbs and Lee (2009) reduced TDS loads at the Seymour gage in the WRAP-SALT input file using the information provided in Table 7.3-10. In doing so, the authors assumed that all discharges and loads entering above the impoundments would be removed. The Seymour gage is the upstream boundary for the salinity calculations on the Brazos River and therefore it follows that the effects of the impoundments, which lie upstream of this location, would be entered in the model at Seymour. Wurbs and Lee (2009) reduced the naturalized flow volumes by 12.7% and the TDS loads by 41.8%, which are the 1962 through 1968 average volume and load contributions of the impounded tributaries.

Figure 7.3-9 shows the location of the proposed brine recovery well fields in relation to major brine springs and USGS stream gages. Previous work has indicated that the proposed brine recovery well system will reduce the TDS loads in the Brazos River above Possum Kingdom Lake by 41%.[21] If the Dove Creek Salt Flat / Panther Canyon Area well field eliminated the TDS load from Salt Croton Creek and the Short Croton Salt Flat well field eliminated the TDS load from Croton Creek, an average of 901 tons per day would be eliminated from the system, based on the 1964 through 1986 mean TDS loads (Table 7.3-10 and Figure 7.3-9). The TDS load of Salt Creek is approximately 10%

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19 U.S. Army Corps of Engineers Fort Worth District, "Natural Salt Pollution Control Study, Brazos River Basin, Texas," Volumes 1-4, 1973.

20 U.S. Army Corps of Engineers, Fort Worth District, "Brazos Natural Salt Pollution Control, Brazos River Basin, Texas, Design Memorandum No. 1, General Phase 1 – Plan Formulation," 1983.

21 James, W.P., "Water Quality Improvement along the Brazos River," prepared for the Salt Fork Water Quality District, Stonewall, Kent, and Garza Counties, Texas, Open-file Report, 2007.

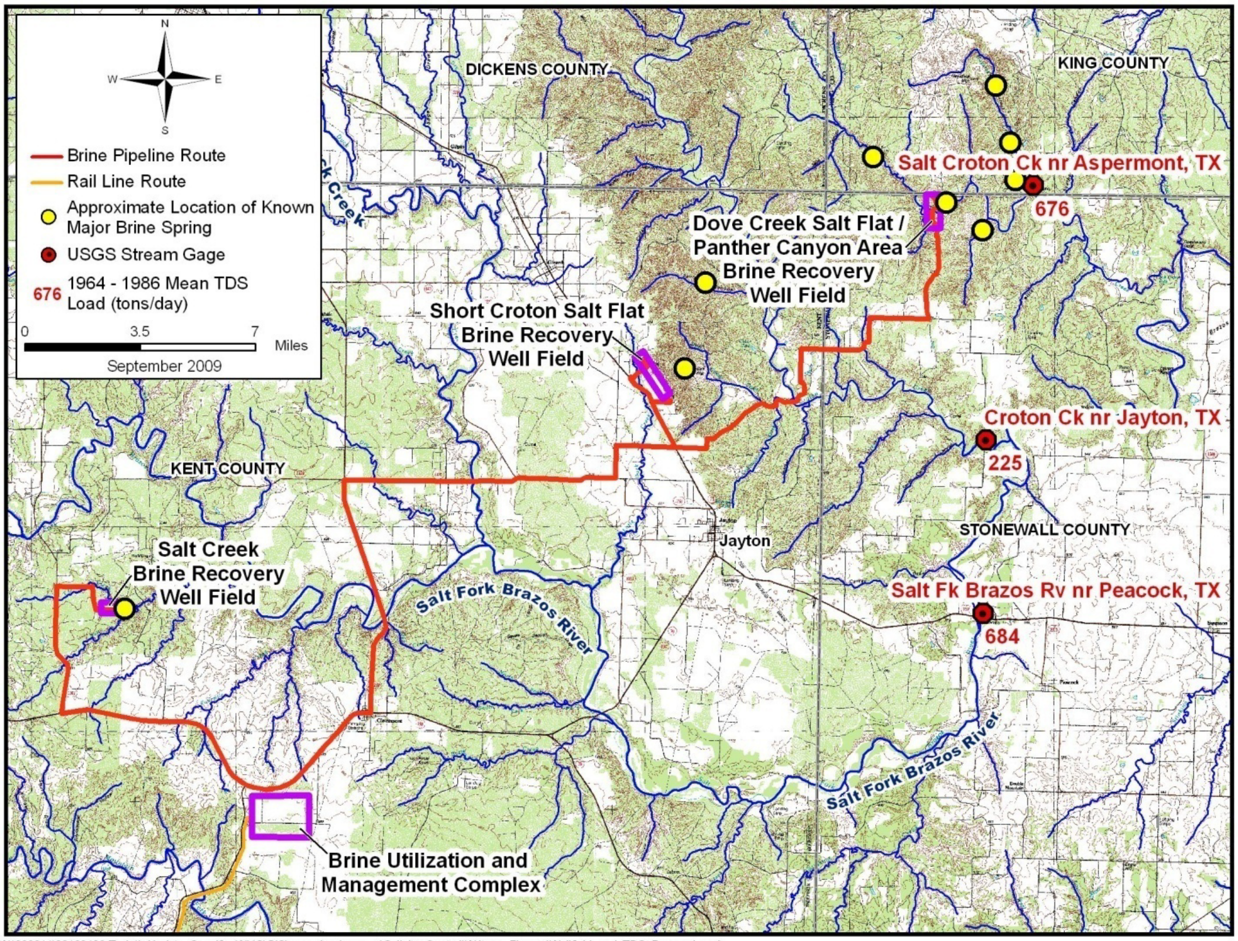
of the load of the Salt Fork of the Brazos River near Peacock[22], or approximately 68 tons per day based on the 1964 through 1986 mean load at the gage near Peacock (Table 7.3-10 and Figure 7.3-9). If the Salt Creek well field eliminated this load, the total mean TDS load eliminated by the project would be approximately 969 tons per day, which is approximately 37% of the 1964 through 1986 mean load of the Brazos River at Seymour. This value agrees reasonably well with the reported 41% load reduction. A WRAP-SALT input file representing conditions with the well fields in place was therefore developed that includes a provision to multiply the TDS loads at the Seymour boundary by a factor of 0.60 for a 40% reduction.

Table 7.3-10. Flows and Loads in the Upper Brazos River Basin

USGS Gaging Station	*USGS Station Number*	*Mean Flow (cfs)*	*Mean Load (tons / day)*	*Mean Concen-tration (mg/L)*	*Mean Flow (%)*	*Mean Load (%)*
October 1968 through September 1977 (Water Year 1969 through 1977)						
Salt Fork of Brazos River near Peacock	08081000	41	594	5,380	16.3	22.1
Croton Creek near Jayton	08081200	12	200	6,030	4.8	7.4
Salt Croton Creek near Aspermont	08081500	4	673	56,920	1.6	25.0
Salt Fork of Brazos River near Aspermont	08082000	63	1,548	9,090	25.1	57.5
North Croton Creek near Knox City	08082180	11	163	5,400	4.4	6.2
Brazos River at Seymour	08082500	251	2,693	3,980	100.0	100.0
October 1963 through September 1986 (Water Year 1964 through 1986)						
Salt Fork of Brazos River near Peacock	08081000	40	684	5,780	14.9	26.3
Croton Creek near Jayton	08081200	13	225	6,540	4.8	8.7
Salt Croton Creek near Aspermont	08081500	5	676	54,560	1.9	26.0
Salt Fork of Brazos River near Aspermont	08082000	62	1,660	10,000	23.0	63.8
North Croton Creek near Knox City	08082180	17	211	4,720	6.3	8.1
Brazos River at Seymour	08082500	269	2,601	3,590	100.0	100.0
Source: Wurbs, R.A. and C. Lee, "Salinity Budget and WRAP Salinity Simulation Studies of the Brazos River/Reservoir System," Texas Water Resources Institute Technical Report No. 352, July 2009.						

[22] Rodgers, R.W., "Natural Chloride Salt Pollution Control in the Upper Brazos River Basin," prepared for the Salt Fork Water Quality District, Stonewall, Kent, and Garza Counties, Texas, 2008.

Figure 7.3-9. Well Fields and TDS Loads



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It has been proposed that a total groundwater pumping rate of 500 gallons per minute (gpm) would effectively lower the piezometric surface on the brine aquifer such that the Dove Creek Salt Flat / Panther Canyon Area springs will cease to flow.[23] If the other two well fields were pumped at a similar rate, the total rate of groundwater pumping would be approximately 1% of the discharge of the Brazos River at Seymour. Given that a portion of this discharge would be lost to natural process in the channel between the springs and the Seymour gage, it was assumed for modeling purposes that the flow removed by the well fields would constitute an inconsequential fraction of the total discharge of the Brazos River at Seymour, and therefore the discharge at Seymour was not reduced in the model. As further justification for this assumption, the well pumping rate required to sufficiently lower the water table would likely exceed the total spring discharge. This would mean that the flow volume reduction in the upper Brazos River due to the project would be less than the total well pumping rate.

Several assumptions are inherent in the modeling approach described above. The approach assumes that the groundwater flows eliminated by the well fields provide the

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[23] James, W.P., "Chloride Concentration in the Possum Kingdom Reservoir," prepared for the Salt Fork Water Quality District, Stonewall, Kent, and Garza Counties, Texas, Open-file Report, 2005 cited in Rodgers, R.W., "Natural Chloride Salt Pollution Control in the Upper Brazos River Basin," prepared for the Salt Fork Water Quality District, Stonewall, Kent, and Garza Counties, Texas, 2008.

only salinity sources to the receiving creeks and that any salt stored in the system would be flushed out within a finite time period. Previous work by others has indicated that significant improvement in water quality of the Brazos River would occur within three to five years of implementation of the brine recovery well system, depending on the amount of rainfall that occurs in the watershed.[24] It was also assumed that brine discharges from existing desalination plants do not contribute a significant amount of additional salinity to the system; desalination discharges were therefore not explicitly modeled.

Two other assumptions in the approach are highlighted by Wurbs and Lee (2009). First, the approach assumes that there are no natural salinity losses occurring between the sources and the Seymour gage. Second, the WRAP-SALT program assumes that salinity load losses due to flow volume losses in the channel are linearly proportional to the volume losses. Wurbs and Lee (2009) note that underestimation of natural load losses would tend to cause overestimation in the effectiveness of salinity control measures.

The first assumption noted by Wurbs and Lee (2009) appears to be reasonable, as the sum of the mean 1964 through 1986 TDS loads at the Double Mountain Fork of the Brazos River near Aspermont (USGS gage 08080500), the Salt Fork of the Brazos River near Aspermont (USGS Gage 08082000), and North Croton Creek near Knox City (USGS Gage 08082180) is 2,451 tons per day (580 tons per day plus 1,660 tons per day plus 211 tons per day from Table 7.3-3 and Table 7.3-10), while the mean load at the Brazos River at Seymour (USGS Gage 08082500) is about 6% greater at 2,601 tons/day. If the load at Seymour were less than the sum of the loads at these three gages, it would be a clear indication that significant losses do occur. With regard to the second assumption noted by Wurbs and Lee (2009), study of the relationship between flow and salinity load losses is beyond the scope of this planning level study.

Comparison of Model-Predicted TDS Concentrations With and Without Salinity Control Project

The WRAP-SALT input files representing conditions with and without the salinity control project were executed with the 2070 version of the Brazos G WAM, which models reservoirs at their projected year 2070 capacity. Table 7.3-11 and Table 7.3-12 and Figure 7.3-10 through Figure 7.3-15 summarize the results of the WRAP-SALT analysis at key locations in the Brazos River Basin. The tables and figures provide concentration duration curves for regulated outflows from the Seymour, Bryan, and Richmond model control points and reservoir storage concentrations at Possum Kingdom Lake, Lake Granbury, and Lake Whitney. The concentration-duration curves are based on the monthly concentration output for the 696 months of the 1940 through 1997 Brazos WAM simulation period.

Table 7.3-11 and Table 7.3-12 provide monthly mean TDS concentrations at each location, computed as the arithmetic average of the concentrations for the 696 simulation periods. The last row in Table 7.3-12 lists the percent reductions in the monthly mean concentrations that result from the project. The reduction percentages show that the effects of the project are most pronounced at the upstream model limit (Seymour), and

[24] James, W.P., "Water Quality Improvement along the Brazos River," prepared for the Salt Fork Water Quality District, Stonewall, Kent, and Garza Counties, Texas, Open-file Report, 2007.

diminish with distance downstream. Wurbs and Lee (2009) explain that this is due to the effects of load losses in the channel and reservoirs.[25] The 40% reduction in mean TDS concentration at Seymour is expected, as the load reduction at this point is established as a model boundary condition. Reductions in mean concentrations of 29% to 24% are computed at the three reservoirs. Further down the basin, the reduction in mean concentration decreases to 11% at Bryan and 9% at Richmond.

Table 7.3-13 lists exceedance frequencies without and with the salinity control project for applicable water quality limits discussed in Section 7.3. The data are based on the model-predicted concentration-duration curves presented in Table 7.3-11 and Table 7.3-12 and Figure 7.3-10 through Figure 7.3-15. The water quality limits are plotted in Figure 7.3-10 through Figure 7.3-15 for comparison to the concentration-duration curves. The effects of the project are demonstrated by the reduction in the percentage of months in which a water quality limit is exceeded. For example, the percentage of months in which the TCEQ secondary TDS standard is equaled or exceeded in Lake Whitney is reduced by approximately 28% (36.2% - 8.5% = 27.7%). Of the locations shown in Table 7.3-13, Lake Whitney is the location with the greatest reduction in time exceeding the TCEQ standard. The greatest reduction in time exceeding the agricultural and industrial limits is also seen in Lake Whitney, where 9% and 21% reductions, respectively, are computed.

[25] Wurbs, R.A. and C. Lee, "Salinity Budget and WRAP Salinity Simulation Studies of the Brazos River/Reservoir System," Texas Water Resources Institute Technical Report No. 352, July 2009.

Table 7.3-11. Model-Predicted TDS Concentration-Duration Curves Without Project

Percent Equaled or Exceeded	Seymour (mg/L)	Possum Kingdom Lake (mg/L)	Lake Granbury (mg/L)	Lake Whitney (mg/L)	Bryan (mg/L)	Richmond (mg/L)
0.01	19,603	4,324	24,290	2,998	2,028	2,124
0.05	19,603	4,324	24,290	2,998	2,028	2,124
0.1	19,603	4,324	24,290	2,998	2,028	2,124
0.2	18,998	3,959	17,635	2,779	1,995	2,117
0.5	17,045	3,364	6,146	2,232	1,896	1,973
1	14,952	3,333	4,427	1,862	1,823	1,718
2	13,948	3,228	3,378	1,668	1,718	1,473
5	12,485	2,669	2,659	1,542	1,439	1,164
10	11,259	2,427	2,213	1,337	1,164	895
15	10,458	2,236	1,991	1,234	1,011	750
20	9,723	2,121	1,820	1,165	882	660
30	8,140	2,020	1,592	1,036	716	544
40	7,225	1,899	1,438	975	586	439
50	6,044	1,776	1,316	906	468	346
60	4,948	1,662	1,158	841	320	290
70	4,083	1,532	991	778	216	234
80	2,984	1,328	795	712	164	189
85	2,606	1,213	613	653	145	160
90	2,112	1,015	300	590	110	134
95	1,566	719	0	472	78	104
98	601	364	0	199	45	72
99	0	163	0	70	23	44
99.5	0	27	0	2	10	27
99.8	0	0	0	0	5	2
99.9	0	0	0	0	3	0

Table 7.3-11. Model-Predicted TDS Concentration-Duration Curves Without Project

Percent Equaled or Exceeded	Seymour (mg/L)	Possum Kingdom Lake (mg/L)	Lake Granbury (mg/L)	Lake Whitney (mg/L)	Bryan (mg/L)	Richmond (mg/L)
99.95	0	0	0	0	1	0
99.99	0	0	0	0	0	0
100	0	0	0	0	0	0
Mean	**6,398**	**1,751**	**1,374**	**936**	**551**	**449**

Table 7.3-12. Model-Predicted TDS Concentration-Duration Curves With Project

Percent Equaled or Exceeded	Seymour (mg/L)	Possum Kingdom Lake (mg/L)	Lake Granbury (mg/L)	Lake Whitney (mg/L)	Bryan (mg/L)	Richmond (mg/L)
0.01	11,762	2,883	13,488	2,397	2,045	2,124
0.05	11,762	2,883	13,488	2,397	2,045	2,124
0.1	11,762	2,883	13,488	2,397	2,045	2,124
0.2	11,399	2,700	10,363	2,182	1,998	2,079
0.5	10,227	2,413	4,557	1,702	1,871	1,812
1	8,971	2,322	3,461	1,611	1,808	1,602
2	8,369	2,176	2,573	1,213	1,718	1,326
5	7,491	1,813	1,856	1,099	1,341	1,005
10	6,755	1,654	1,559	969	1,049	816
15	6,275	1,589	1,472	911	887	673
20	5,834	1,510	1,361	865	787	591
30	4,884	1,426	1,157	799	614	465
40	4,335	1,359	1,041	748	507	387
50	3,626	1,272	948	693	380	317
60	2,968	1,183	867	646	275	266
70	2,450	1,092	757	609	191	220

Table 7.3-12. Model-Predicted TDS Concentration-Duration Curves With Project

Percent Equaled or Exceeded	Seymour (mg/L)	Possum Kingdom Lake (mg/L)	Lake Granbury (mg/L)	Lake Whitney (mg/L)	Bryan (mg/L)	Richmond (mg/L)
80	1,790	964	591	552	154	183
85	1,563	891	452	515	134	160
90	1,267	751	218	478	108	136
95	940	559	0	406	81	104
98	360	274	0	215	42	61
99	0	84	0	128	20	39
99.5	0	5	0	4	7	19
99.8	0	0	0	0	4	2
99.9	0	0	0	0	2	0
99.95	0	0	0	0	1	0
99.99	0	0	0	0	0	0
100	0	0	0	0	0	0
Mean	**3,839**	**1,241**	**1,000**	**715**	**493**	**408**
Percent Reduction in Mean	**40**	**29**	**27**	**24**	**11**	**9**

Figure 7.3-10. Model-Predicted TDS Concentration-Duration Curve at Seymour

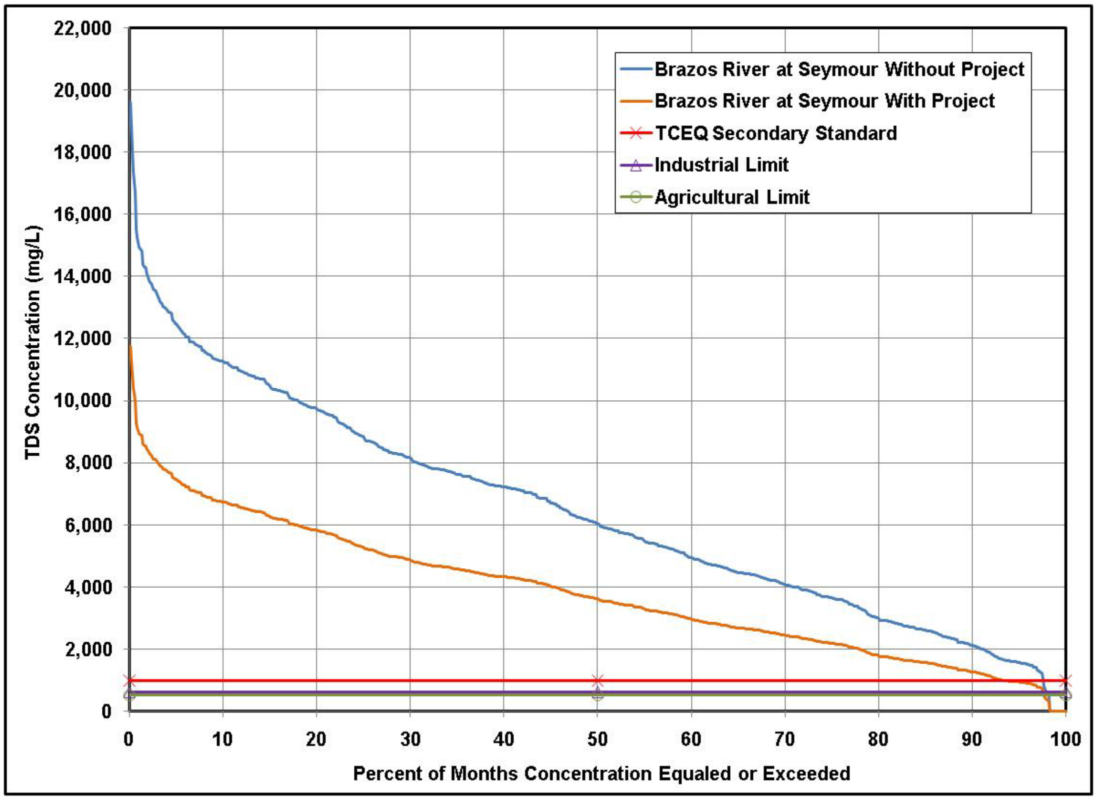

Figure 7.3-11. Model-Predicted TDS Concentration-Duration Curve at Possum Kingdom Lake

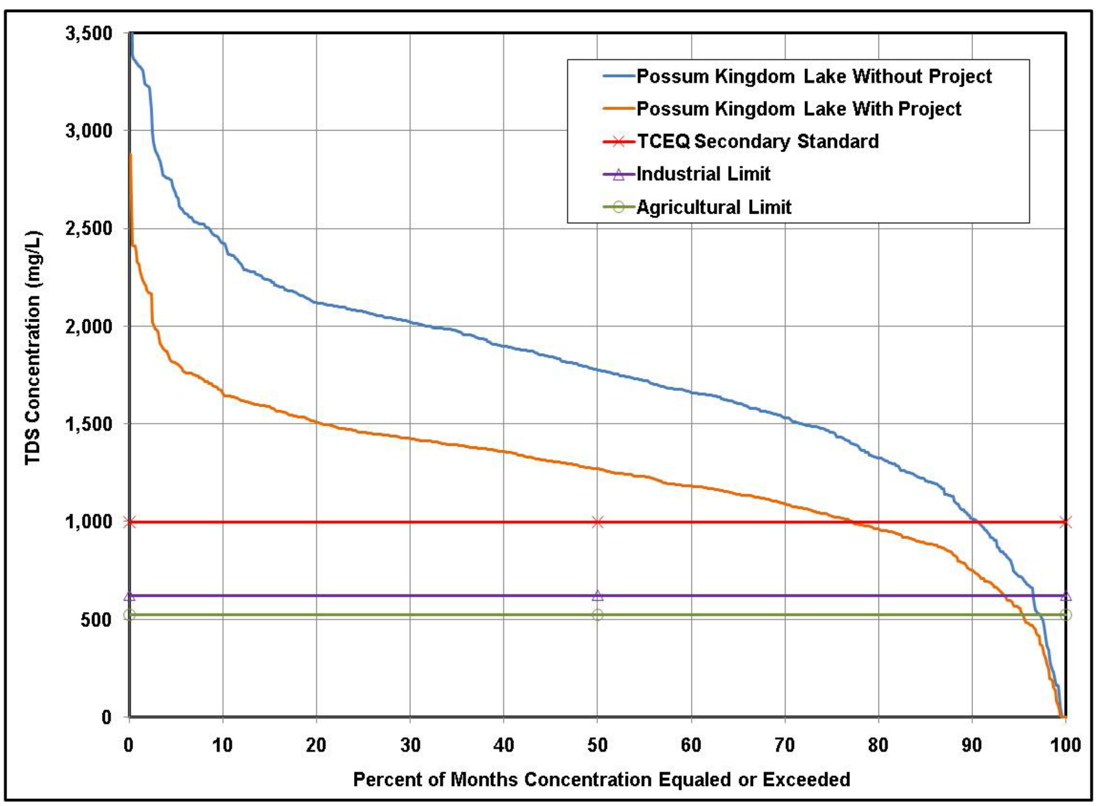

Figure 7.3-12. Model-Predicted TDS Concentration-Duration Curve at Lake Granbury

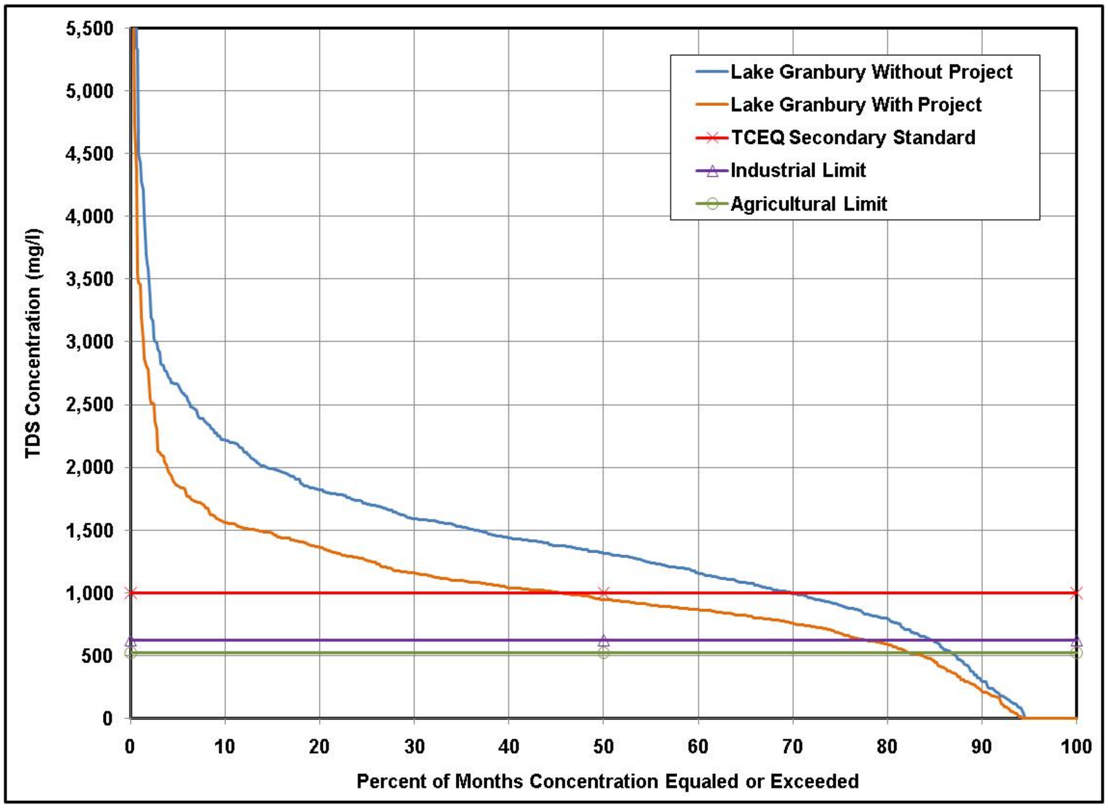

Figure 7.3-13. Model-Predicted TDS Concentration-Duration Curve at Lake Whitney

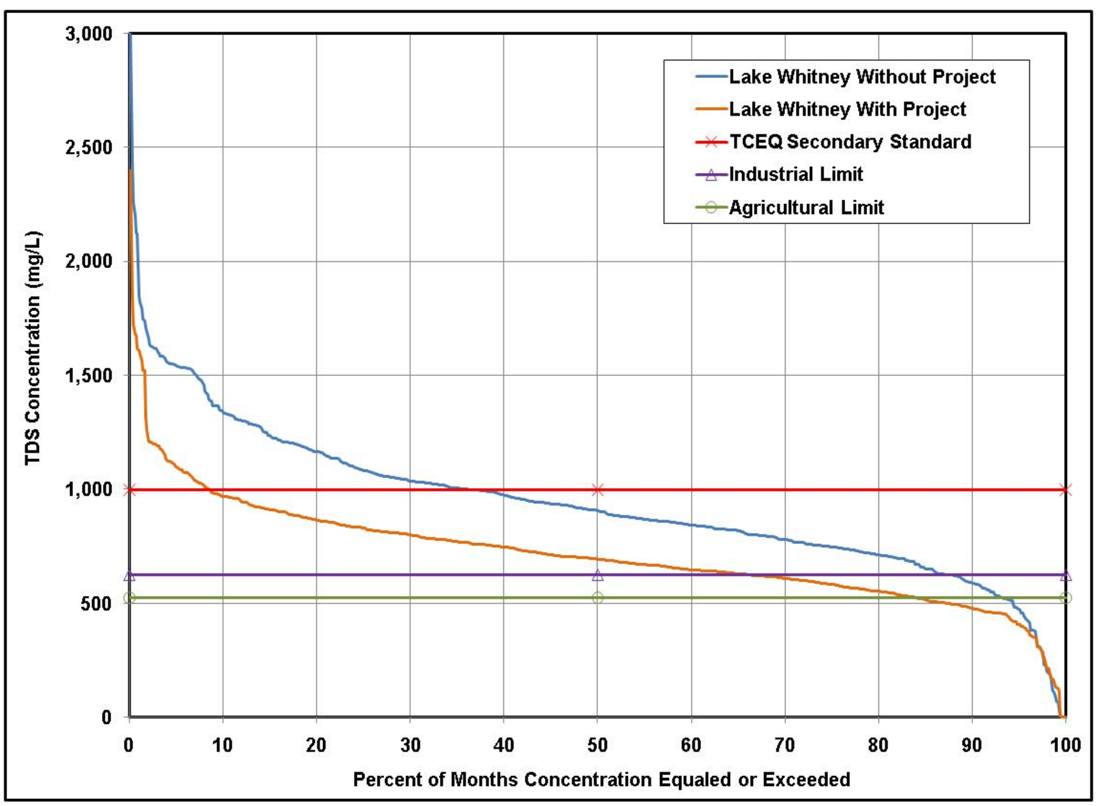

Figure 7.3-14. Model-Predicted TDS Concentration-Duration Curve at Lake Bryan

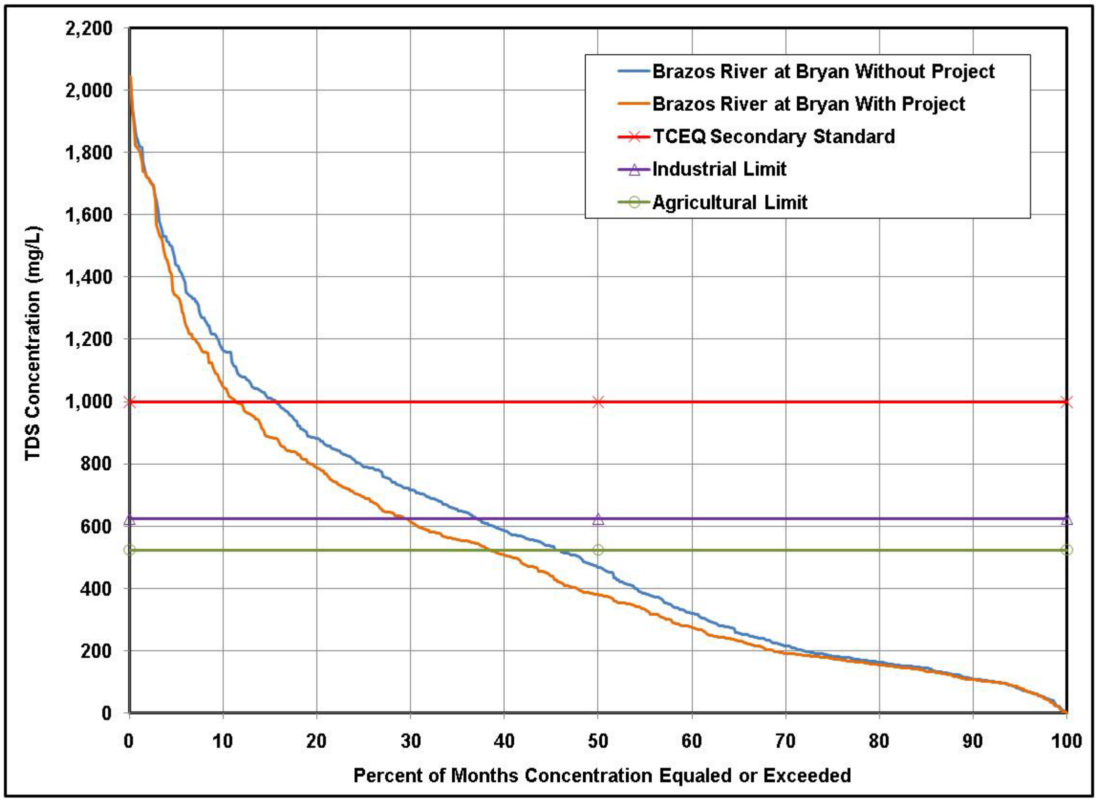

Figure 7.3-15. Model-Predicted TDS Concentration-Duration Curve at Richmond

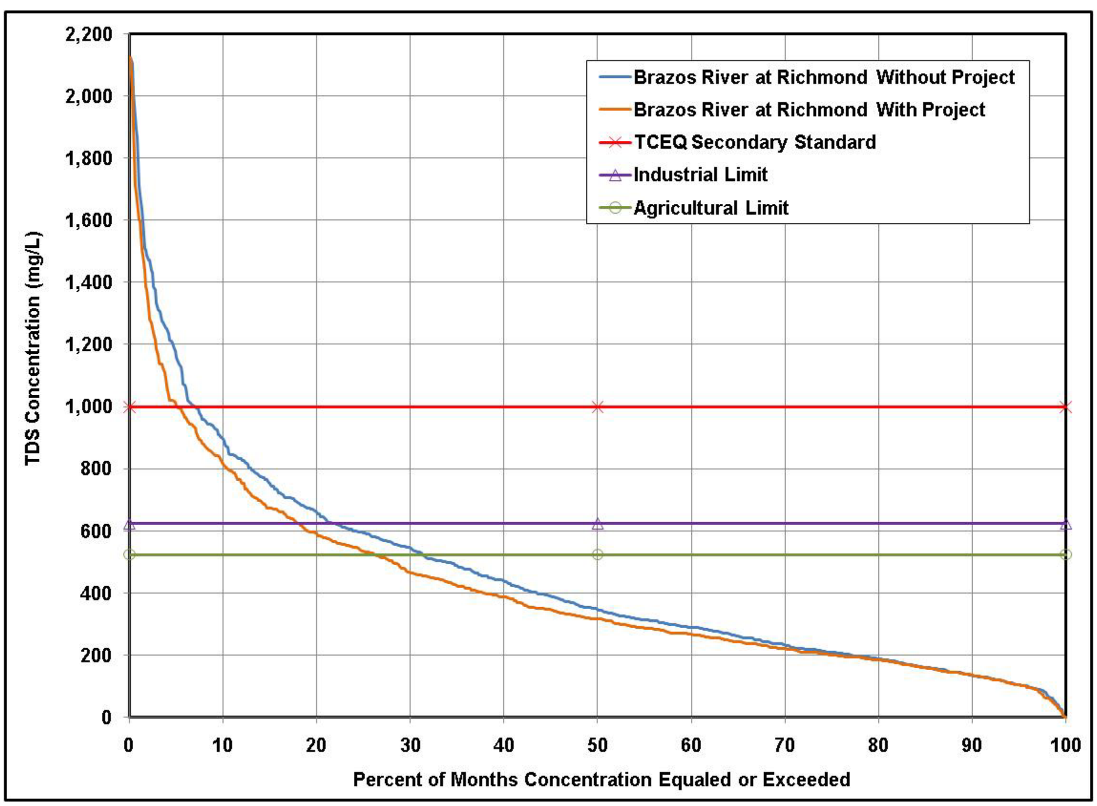

Table 7.3-13. Model-Predicted Exceedance Frequencies for Applicable Water Quality Limits Without and With Project

Application	TDS Concentration Limit (mg/L)	Percentage of Months in Which TDS Concentration Limit was Equaled or Exceeded					
		Seymour	Possum Kingdom Lake	Lake Granbury	Lake Whitney	Bryan	Richmond
Without Project							
TCEQ Secondary Standard	1,000	97.6	90.5	69.9	36.2	15.6	7.0
Agricultural	525	98.1	97.2	86.7	93.1	45.4	31.3
Industrial	625	97.9	96.5	84.6	87.2	37.1	21.6
With Project							
TCEQ Secondary Standard	1,000	93.2	77.3	45.5	8.5	11.4	5.1
Agricultural	525	97.7	95.4	82.2	83.9	38.2	26.1
Industrial	625	97.6	93.4	77.6	65.9	29.3	17.9

The TDS concentration frequency results for the without project scenario can be compared to the concentration frequency curves developed by Wurbs et. al.[26] from the stream gage data. Differences between these two frequency datasets result from both the modeling methodology and the difference between the water use and reservoir storage scenario in the 2070 Brazos G WAM, and conditions that actually existed during the 1964 through 1986 data collection period. The 1964 through 1986 dataset shows that the TCEQ standard was equaled or exceeded 99.7%, 93.6%, 40.0%, and 0% of the time at Seymour, below Possum Kingdom Lake, below Lake Whitney, and at Richmond respectively. In the model results, the TCEQ standard is exceeded 97.6%, 90.5%, 36.2% and 7.0% of the time at comparable locations. Although the exceedence frequencies for the observed and modeled datasets are different (as would be expected), the relative similarities in the frequencies provide some confidence that the model produces reasonable results.

[26] Wurbs, R.A., A.S. Karama, I. Saleh, and C.K. Ganze, "Natural Salt Pollution and Water Supply Reliability in the Brazos River Basin," Texas Water Resources Institute, 1993.

Integration with Other Water Management Strategies

This strategy is recommended for the Brazos River Authority as part of their main stem system. The implementation of this strategy would benefit the BRA and its main stem customers the most by reducing the salt concentration in the Brazos River and the BRA main stem supply reservoirs.

7.3.4 Environmental Issues

The proposed project area is located in the upper Brazos River Basin east of the Llano Estacado Region within portions of Kent, King, and Stonewall counties in north-central Texas. The primary environmental issues related to the development of the salt control water management option is the construction of the brine pipeline, development of the brine well fields, evaporation facilities and pump stations, and creation of the railroad spur and its amenities.

Environmental Setting

The study area is located in the Southwestern Tablelands Ecological Region as designated by the Texas Parks and Wildlife Department (TPWD).[27] This region is characterized by canyons, mesas, badlands, and dissected river breaks. Little cropland occurs within this area, with much of the region consisting of sub-humid grassland and semiarid rangeland. Vegetation within this area is characterized by grama-buffalograss with some mesquite-buffalograss in the southeast portion of the Region, juniper-scrub oak-midgrass savannah on escarpment bluffs, and midgrass prairie with low oak brush along portions of some rivers. This region is bordered on the south by the Edwards Plateau Ecological Region and on the west by the High Plains Ecological Region.

The study area is located in the Rolling Plains Vegetational area.[28] This area is characterized gently rolling hills with rangelands that are dissected by streams and rivers which flow from west to east. Vegetation within this area is characterized by mixed and short grass prairies, shinnery oak grasslands, and mesquite savannah grasslands. Within this area redberry juniper, mesquite, and Eastern red cedar are considered aggressive invasive species.

The original prairie vegetation found within the Rolling Plains Vegetational Area included medium-tall grassland with a sparse shrub cover. The dominant vegetation within this area is native grasses including little bluestem (*Schizachyrium scoparium* var. *frequens*), blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), Indiangrass (*Sorghastrum nutans*), and sand bluestem (*Andropogon gerardii* var. *paucipilus*), and various forbes. Within areas of sandier soils with broad rolling relief you will find shin oak (*Quercus sinuata* var. *breviloba*) grasslands, with additional groups of various oaks occurring in the mixed grass prairie. In areas containing clay and clay loam soils the predominant vegetation is the mesquite savannah grasslands. These usually occur on flat to gently rolling lands and are characterized by an open canopy of larger mesquite trees, a midstory composed of shrubs such as lotebush (*Zizyphus obtusifolia*),

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[27] Texas Parks and Wildlife Department, 2005.

[28] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, "Vegetational areas of Texas," TX Agri. Ext. Serv. L-492.

succulents including prickly pears (*Opuntia* spp.) and ephedra, and an understory of grasses and forbs. Bottomland areas found along larger streams contain American elm (*Ulmus Americana*), button willow (*Cephalanthus occidentalis*), pecan (*Carya illinoensis*) and cottonwood (*Populus* spp.). Historically these natural communities were maintained by a combination of severe weather events, drought and fire. Invasion of the rangeland areas in this region by annual and perennial forbs, legumes, and woody species has been facilitated by historic livestock grazing practices and a lack of naturally occurring fire in the area. The limestone ridges and steep terrains of this area produce a greater diversity of woody plants and wildlife habitat than would normally be expected within this area.

The natural region of the proposed project area, as described by TPWD in the Vegetation Types of Texas, indicates that along the proposed brine pipeline route vegetation is generally characterized as mesquite-lotebush shrub and mesquite-lotebush brush.[29] Pockets of Harvard Shin Oak-mesquite brush are also found within the area, along with limited areas of crops. The majority of land found near the project area is currently used as rangeland with limited areas of dryland and irrigated crops and pastures. Land use is expected to remain primarily rural in the future. Because of the heavy salt contamination found in the area of the proposed brine wells, this portion of the project has no current landuse application.

Faunal species found within the project area include those suited to a semi-arid environment. Riparian zones along the Brazos River, and streams and their tributaries contain important wildlife habitat for the region and support populations of white-tailed deer (*Odocoileus virginianus*) and Rio Grande turkeys (*Meleagris gallopavo intermedia*). Bobwhites (*Colinus virginianus*), scaled quail (*Callipepla squamata*), mourning dove (*Zenaida macroura*), and a variety of song birds, small mammals, waterfowl, shorebirds, reptiles, and amphibians are found in this region. Mammals which occur principally in the plains area of Texas include the Texas kangaroo rat (*Dipodomys elator*), Texas mouse (*Peromyscus attwateri*), prairie vole (*Microtus ochrogaster*), plains pocket mouse (*Perognatus flavescents*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), and three species of pocket gopher (*Geomys* sp.). Larger mammals include the coyote (*Canis latrans*), ringtail (*Bassariscus astusus*), ocelot (*Felis pardalis*), and collared peccary (*Tayassu tajacu*). Bison (*Bos bison*), and black-footed ferrets (*Mustela nigripes*) are historically associated with this area.

Threatened & Endangered Species

The Endangered Species Act of 1973 (et seq.) is designed to protect plant and animal resources from the adverse effects of development. To comply with this act, federal agencies are required to assess the proposed project area to determine if any threatened or endangered species or critical habitats for these species are present. Table 7.3-14 lists plant, wildlife and fish species possibly found within Kent, King, and Stonewall counties that are considered by U.S Fish and Wildlife Service (FWS) or the Texas Parks and Wildlife Department (TPWD) to be endangered, threatened or rare. The primary sources used to develop this list were the annotated county lists provided by the TPWD for the three-county project area.

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[29] Texas Parks and Wildlife Department, “The Vegetation Types of Texas,” Austin, Texas, 1984.

Twenty-two threatened, endangered or rare species have either been reported from this area or have some possibility of occurrence. Inclusion in Table 7.3-14 does not mean that a species will occur within the project area, but only acknowledges the potential for occurrence in the three project area counties. The following paragraphs present distributional data concerning each federally listed or state-listed endangered or threatened species, along with a brief evaluation of the potential for the species to occur within the project area.

Table 7.3-14. Threatened, Endangered and Rare Species of Kent, King, and Stonewall Counties, Texas

Species Name		Occurrence in County	Federal Status	State Status
BIRDS				
Peregrine Falcon (*Falco peregrinus*)	American Peregrine Falcon (*Falco peregrinus anatum*)	Year round resident and local breeder in west Texas.	DL	T
	Arctic Peregrine Falcon (*Falco peregrinus tundrius*)	Potential migrant.	DL	___
Baird's Sparrow (*Ammodramus bairdii*)		Found in shortgrass prairie with scattered low bushes and matted vegetation.	___	___
Bald Eagle (*Haliaeetus leucocephalus*)		Found primarily near seacoasts, rivers, and large lakes; nests in tall trees or on cliffs near water; communally roosts in winter.	DL	T
Ferruginous Hawk (*Buteo regalis*)		Lives in open country, primarily prairies, plains, and badlands; nests in tall trees along streams or on steep slopes, cliff ledges, river-cut banks, hillsides, power line towers.	___	___
Mountain Plover (*Charadrius montanus*)		Breeding species: nests on high plains or shortgrass prairie, on ground in shallow depression; nonbreeding: shortgrass plains and bare, dirt (plowed) fields; primarily insectivorous.	___	___
Snowy Plover (*Charadrius alexandrinus*)		Formerly an uncommon breeder in the Panhandle; potential migrant.	___	___
Western Burrowing Owl (*Athene cunicularia hypugaea*)		Open grasslands, especially prairie, plains, and savanna, sometimes in open areas such as vacant lots near human habitation or airports; nests and roosts in abandoned burrows and man-made structures.	___	___
Western Snowy Plover (*Charadrius alexandrines nivosus*)		Uncommon breeder in the Panhandle; potential migrant which winters along the coast.	___	___
Whooping Crane (*Grus americana*)		Potential migrant; winters in and around Aransas National Wildlife Refuge and migrates to Canada for breeding.	LE	E
FISHES				

Table 7.3-14. Threatened, Endangered and Rare Species of Kent, King, and Stonewall Counties, Texas

Species Name	Occurrence in County	Federal Status	State Status
Sharpnose shiner (*Notropis oxyrhynchus*)	Endemic to Brazos River drainage, found in large turbid rivers with a bottom composed of a combination of sand, gravel and clay-mud.	C	—
Smalleye shiner (*Notropis buccula*)	Endemic to upper Brazos river system and its tributaries (Clear Fork and Bosque), found in medium to large prairie streams with sandy substrate and turbid to clear warm water.	C	—
MAMMALS			
Black-footed Ferret (*Mustela nigripes*)	Extirpated in Texas; former inhabitant of prairie dog towns in the general area.	LE	—
Black-tailed Prairie Dog (*Cynomys ludovicianus*)	Prefers dry, flat, short grasslands with low, relatively sparse vegetation, including areas overgrazed by cattle; lives in large family groups.	—	—
Cave Myotis Bat (*Myotis velifer*)	Roosts colonially in caves, rock crevices, old buildings, carports, under bridges, nests; roosts in clusters of up to thousands of individuals; hibernates in limestone caves of Edwards Plateau and gypsum caves of Panhandle during winter; opportunistic insectivore.	—	—
Gray wolf (*Canis lupus*)	Extirpated; formerly known throughout the western two-thirds of the state.	LE	E
Pale Townsend's big-eared bat (*Corynorhinus townsendii pallescens*)	Roosts in caves, abandoned mine tunnels and old buildings, hibernates in groups during winter.	—	—
Plains Spotted Skunk (*Spilogale putorius interrupta*)	Catholic in habitat; open fields, prairies, croplands, fence rows, farmyards, forest edges, and woodlands; prefers wooded, brushy areas and tallgrass prairie.	—	—
Texas kangaroo rat (Dipodomys elator)	Mostly in association with scattered mesquite shrubs and sparse, short grasses in areas underlain by firm clay soils; along fencerows adjacent to cultivated fields/roads; burrows into soil with openings usually at base of mesquite or shrub.	—	T
REPTILES			
Brazos water snake *(Nerodia harteri)*	Upper Brazos River drainage; in shallow water with rocky bottom and on rocky portions of banks.	—	T
Texas Horned Lizard (*Phrynosoma cornutum*)	Open, arid and semi-arid regions with sparse vegetation, which could include grass, cactus, scattered brush or scrubby trees.	—	T

Status Key: LE Federal Endangered LT Federal Threatened DL Federal Delisted C Federal Candidate Species
E State Endangered T State Threatened -- Rare, but with no regulatory listing status
TPWD County Species Lists revised 6/24/2009.

Two species listed in Table 7.3-14 are considered endangered by both the FWS and TPWD. These are the Whooping Crane (*Grus Americana*) and the grey wolf (*Canis lupus*). The grey wolf is considered extirpated in Texas and subsequently will not occur within the project area. Portions of North Texas including the Panhandle lie within the migratory corridor the whooping cranes follow in route to and from their nesting grounds in Wood Buffalo National Park in northwestern Canada. This species is known to stop during migration at locations in Oklahoma, Kansas, and Nebraska. There have been only a few scattered confirmed ground sightings of whooping cranes within Texas with the exception of their salt marsh wintering grounds along the Texas Coastal Bend. Although these birds might occur as possible vagrants during migration periods, the likelihood of incidence within the project area is remote.

The black-footed ferret (*Mustela nigripes*), federally listed as endangered, is considered extirpated in Texas due to the decline of available shortgrass prairie habitat and reduction in the black-tailed prairie dog (*Cynomys ludovicianus*) population, a species that the ferret is heavily dependent on for survival. Although their historic range included the High Plains, Rolling Plains and Trans-Pecos regions of North America, the last reported Texas sightings of the black-footed ferret were on the western edge of the Texas Panhandle in Dallam County in 1953 and Bailey County in 1963.[30] This species is not expected to be impacted by the proposed project.

Historically, the smalleye shiner and the sharpnose shiner, both federal species of concern, were found throughout the Brazos River Watershed and several of its major tributaries. They are considered at this time to be stable in the upper Brazos River Basin, but their number has declined in the middle and lower reaches of the Basin. The most serious issues threatening these species are the effects of impoundments and degradation of water quality. Current information indicates that the shiner population within the Upper Brazos drainage upstream of Possum Kingdom Reservoir is apparently stable, whereas the population within the Lower Brazos River Basins may only exist in remnant areas of suitable habitat, or may be completely extirpated.

These two cyprinid species evolved to prosper in the saline and turbid conditions naturally occurring in the Brazos River Basin. The salinity control project proposed for the Upper Brazos River would convert the natural saline waters to a quality possibly available for human consumption, and would modify the waters chemical characteristics thought to be conducive to preferred shiner habitat.

After a review of the habitat requirements for each listed species, it is expected that this project will have no adverse effect on any federally listed threatened or endangered species, its habitat, or designated habitat, nor would it adversely affect any state endangered species. Although suitable habitat for the state threatened Texas horned lizard may exist within the project area, no impact to this species is anticipated due to the small area utilized by the wells and new desalinization water plant, and the abundance of similar habit near the project area. The presence or absence of potential habitat does not confirm the presence or absence of a listed species. No species specific surveys were conducted in the project area for this report.

[30] Davis, W. B. and D. J. Schmidly,. “The Mammals of Texas,” Texas Parks and Wildlife Department, Austin, Texas, 1994.

Solar Salt Production Facility Impacts

Solar salt production would utilize the brine removed from the existing brine aquifer in Stonewall and Kent Counties. Shallow wells located along the Dove, Short Croton, and Salt Creeks would pump the brine along a 55 mile pipeline to a proposed solar salt facility located in Kent County approximately 16 miles southwest of Jayton and 29 miles north of Snyder. There the brine would be processed by solar evaporation in a series of ponds to a final crystalline salt product which would then be marketed. Modern solar salt plants can produce a pure salt product that is more than 99.7% NaCl (dry basis). Solar salt sales in the United States have increased by 50% over the last twenty years to include 5.9 million tons in 2004.[31] Factors influencing the suitability of the area for this type of production include land cost, soil type, rainfall amounts, wind velocity and direction, susceptibility to flooding, possible endangered species habitat, availability of workers, and ease of transportation of products.

Possible Pipeline Impacts

A number of streams in the Upper Brazos River Basin would be crossed by the proposed pipeline corridor. The brine transport system would involve the construction of a 55 mile long pipeline which would extend through portions of Kent, Stonewall and King Counties.

The brine pipeline would begin at the Salt Creek Brine Recovery Well Field and follow Ranch Road (RR) 1081 south for approximately 6 miles, it would then turn east along U.S. Highway (US) 380 for approximately 7 additional miles and intersect with a connection to the solar salt facility. The pipeline would then continue east for approximately 5 additional miles along US 380, turn north along State Highway (SH) 208 for 7 miles, and then travel east paralleling RR 2320 and Farm to Market (FM) 1228 for 11 additional miles. A small portion of Kent County Roads (CR) 165 and 161 are then followed before the pipeline turns in a northwesterly direction along SH 70 for about 5 miles, terminating at the Short Croton Salt Flat Brine Recovery Well Field. From the intersection of SH 70 and CR 160 the pipeline travels northwest along CR 160, CR 350 and unnamed roadways for approximately 14 miles terminating at the Dove Creek Salt Flat/ Panther Canyon Area Brine Recovery Well Field in Stonewall County.

In general, the brine pipeline would traverse flat to gently rolling terrain and occasional surface areas designated as 100-year floodplains. Wetlands which are located within the pipeline right-of-way could potentially be affected by this project, and floodplains could possibly suffer a temporary change in drainage patterns. Potential wetland impacts are expected to primarily include pipeline stream and river crossings, which can be minimized by right-of-way selection and appropriate construction methods, including erosion controls and revegetation procedures. This pipeline could potentially traverse approximately eighteen stream crossings, a number of which are unnamed tributaries. Major water bodies crossed by this pipeline could include Salt Creek, T-O Creek, Duck Creek, Little Duck Creek, Croton Creek, and the Salt Fork Brazos River. Impacts to wetlands from construction possibly include destruction or alteration of vegetation/habitat along the right-of-way (ROW) and within the well field areas. Compensation for net losses of wetlands would be required where impacts are unavoidable.

[31] Salt Institute. Solar Salt Production. 2004

There are no state or national parks, forest, wildlife refuges, natural areas, wild or scenic rivers, or other similar preserves within the proposed project area. Habitat studies and surveys for protected species and cultural resources may need to be conducted at the proposed well sites, pump locations, the desalination facility, and along all pipeline or railroad spur routes.

A review of the Texas Historical Commission Texas Historic Sites Atlas database indicated that there are no National Register Properties within the project area, however two historical markers and the Clairemont Cemetery are listed within one mile of the proposed brine pipeline. These sites should be easily avoided by adjustment of the pipeline location if necessary.

7.3.5 Engineering and Costing

Table 7.3-15 and Table 7.3-16 summarize estimated costs for the brine collection and transmission system and the BUMC, respectively. The capital costs, engineering costs, and land acquisition costs were provided by the SFWQ Corporation's consultants, other costs were estimated for preparation of the regional water plan. Environmental and Archaeology Studies and Mitigation costs were estimated as being equal to the land acquisition costs. A two-year construction period was assumed for computing interest during construction.

The operation and maintenance costs in Table 7.3-15 and Table 7.3-16 are zero. The SFWQ Corporation's consultants have prepared a pro forma analysis indicating that revenue from salt sales would cover well field, pipeline, and BUMC operation and maintenance costs. It is anticipated that once the project was constructed, a salt company would operate and maintain the facilities and generate sufficient revenue such that operation and maintenance costs to the public would be zero. The SFWQ Corporation's consultants have also assumed that right of way costs for the brine transmission pipeline would be negligible; the pipeline would run within existing county road right of ways and the counties are participants in the project.

Overall, the estimated combined capital cost for the brine collection and transmission system and the BUMC is $111,057,000. The estimated combined total project cost for the brine collection and transmission system and the BUMC is $172,652,000, and the estimated combined annual cost is $14,447,000.

Table 7.3-15. Cost Estimate Summary for Brine Collection and Transmission System

Item	Estimated Costs for Facilities
Collection Wells	$1,161,000
Gathering Lines and Appurtenances	$221,000
Brine Transmission Pipeline (carbon steel with epoxy coating)	$18,540,000
Pump Stations, Emergency Generators, Gate Valves, Etc.	$871,000
Electrical Power Infrastructure	$335,000
TOTAL COST OF FACILITIES	**$21,128,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$6,468,000
Environmental & Archaeology Studies and Mitigation	$2,994,000
Land Acquisition and Surveying (164 acres)	$2,994,000
Interest During Construction (4% for 2 years with a 1% ROI)	$2,351,000
TOTAL COST OF PROJECT	**$35,935,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$3,007,000
Operation and Maintenance	$0
TOTAL ANNUAL COST	**$3,007,000**

Table 7.3-16. Cost Estimate Summary for Brine Utilization and Management Complex

Item	Estimated Costs for Facilities
Equipment, Machinery, Site Work, and Onsite Rail	$32,513,000
Rail Extension to BNSF Tracks at Snyder	$32,372,000
Solar Ponds	$24,335,000
Electrical Power Infrastructure	$709,000
TOTAL COST OF FACILITIES	**$89,929,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$31,475,000
Environmental & Archaeology Studies and Mitigation	$3,184,000
Land Acquisition and Surveying (164 acres)	$3,184,000
Interest During Construction (4% for 2 years with a 1% ROI)	$8,945,000
TOTAL COST OF PROJECT	**$136,717,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$11,440,000
Operation and Maintenance	$0
TOTAL ANNUAL COST	**$11,440,000**

Impacts Comparison of Desalination Costs With and Without Salinity Control Project

This section reviews the effectiveness of the salinity control project in reducing desalination costs in the Brazos River Basin. The cost of municipal desalination treatment with and without the salinity control project is compared to the cost of implementing the project.

Although the TCEQ TDS secondary standard is 1,000 mg/L, the costs presented herein assume that the desalination is implemented to reduce TDS concentrations to 500 mg/L. Actual acceptable TDS limits for water supply systems are case specific. Systems that have not historically been exposed to TDS concentrations as high as 1,000 mg/L may be subject to corrosion issues with introduction of water having a 1,000 mg/L TDS concentration. The 500 mg/L treatment level was assumed as a limit that would generally be acceptable for new supplies.

Concentration-duration curves for TDS based on WRAP-SALT modeling with the 2070 Brazos G WAM are presented in Table 7.3-11 and Table 7.3-12 and Figure 7.3-10 through Figure 7.3-15. The tables and figures compare TDS concentrations of regulated outflows from the Seymour, Bryan, and Richmond model control points and reservoir storage TDS concentrations at Possum Kingdom Lake, Lake Granbury, and Lake Whitney with and without the salinity control project. TDS is an indicator of the levels of chlorides and dozens of other dissolved ions that would be removed by the salinity control project and desalination treatment. The with-project concentration-duration curves are representative of a point in the future when the benefits of the project are fully realized and residual salt has been washed from the upland stream beds and from downstream lakes.

The estimated costs of desalination treatment at Seymour, Possum Kingdom Lake, Lake Granbury, Lake Whitney, Bryan, and Richmond with and without implementing the salinity control project are included in Table 7.3-17 through Table 7.3-22 the desalination cost estimates are based upon producing 10 MGD of treated water and the 90th percentile (10% equaled or exceeded) and 50th percentile (median) TDS concentrations at each location as shown by the concentration-duration curves. The desalination costs reflect the impact of TDS on both the plant capital and the operating and maintenance costs. Capital costs are based on the 90th percentile TDS concentrations and operating and maintenance costs are based on the 50th percentile TDS concentrations. Surface water must undergo conventional treatment prior to desalination. For the purpose of comparing treatment costs for various TDS concentrations, values shown are for the desalination component only. Costs common to conventional water treatment plants are omitted. Omitted costs include intakes, pump stations, conventional pretreatment, clearwell storage, and others.

The project will benefit water quality but will also have an impact on the available supply to entities required to desalinate as part of the treatment of water from the main stem of the Brazos River. Influent TDS levels affect the water recovery rates at desalination water treatment plants, expressed as a percentage of influent recovered for use. Estimates of the increased recovery rates result in an increase in recovered water of approximately 2,475 acft/yr[32].

Based on the cost estimates shown in Table 7.3-17 through Table 7.3-22, the largest estimated desalination treatment unit costs savings resulting from the project would occur at Seymour. The estimated total annual cost of desalination treatment at Seymour without the salinity control project is $11,284,000, or $1,007 per acft on a unit cost basis. With the salinity control project, the estimated annual cost of desalination at Seymour is $9,531,000, or $851 per acft on a unit cost basis. The estimated desalination treatment savings at Seymour as a result of implementing the salinity control project on a unit cost basis is $156 per acft. At Possum Kingdom Reservoir, Lake Granbury, and Lake Whitney, the estimated desalination treatment savings as a result of implementing the salinity control project on a unit cost basis is $85, $86, and $115 per acft, respectively. Downstream of the Lakes, at Bryan and Richmond, the estimated desalination treatment savings as a result of implementing the salinity control project on a unit cost basis is $40 and $45 per acft, respectively.

[32] SFWQ Corporation letter dated August 24, 2015.

The cost of desalination treatment for current municipal contracts and water rights in the Brazos River can be compared to the salinity control project cost in order to determine the cost effectiveness of implementing the project. Table 7.3-23 includes the Brazos River Authority contract amounts and TCEQ Water Rights for municipal use between Seymour and the Gulf of Mexico as listed in the Brazos G WAM input data file. The contracts and rights total to 505,988 acft per year. Table 7.3-23 also includes the unit cost of desalination treatment with and without the project and the increase in municipal supply due to project. The total annual cost to desalinate water contracted or permitted for municipal use without the project is estimated to be $198,450,000. With the project, the total annual cost of desalination treatment is estimated to be $172,797,000. Therefore, implementation of the project results in reduced annual desalination costs of $25,653,000.

Table 7.3-17. Cost Estimate Summary for Desalination at Seymour with and without Implementation of Salinity Control Project

Item	No Salinity Control	With Salinity Control	Cost Difference
90th Percentile TDS	11,259	6,755	
50th Percentile TDS	6,044	3,626	
% of Water Desalinated	100%	94%	
CAPITAL COST			
RO Desalination Plant (10 MGD)[1]	$27,924,000	$25,222,000	$2,702,000
Concentrate Disposal	$11,182,000	$8,287,000	$2,895,000
TOTAL COST OF FACILITIES	**$39,106,000**	**$33,509,000**	**$5,597,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$13,687,000	$11,728,000	$1,959,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,848,000	$1,584,000	$264,000
TOTAL COST OF PROJECT	**$54,641,000**	**$46,821,000**	**$7,820,000**
ANNUAL COST			
Debt Service (5.5 percent, 20 years)	$4,572,000	$3,918,000	$654,000
Operation and Maintenance			
Desalination Water Treatment Plant	$6,243,000	$5,218,000	$1,025,000
Concentrate Disposal	$469,000	$395,000	$74,000
TOTAL ANNUAL COST	**$11,284,000**	**$9,531,000**	**$1,753,000**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$1,007**	**$851**	**$156**
Annual Cost of Water ($ per 1,000 gallons)	**$3.09**	**$2.61**	**$0.48**

[1] For comparison purposes of treatment costs for various TDS concentrations, costs shown are for desalination component only. Costs common to conventional water treatment plants are omitted. Omitted costs include intake, pump stations conventional pretreatment, clearwell storage, and others.

Table 7.3-18. Cost Estimate Summary for Desalination at Possum Kingdom Lake with and without Implementation of Salinity Control Project

Item	No Salinity Control	With Salinity Control	Cost Difference
90th Percentile TDS	2,427	1,654	
50th Percentile TDS	1,776	1,272	
% of Water Desalinated	81%	72%	
CAPITAL COST			
RO Desalination Plant[1]	$20,918,000	$18,574,000	$2,344,000
Concentrate Disposal	$6,422,000	$5,334,000	$1,088,000
TOTAL COST OF FACILITIES	**$27,340,000**	**$23,908,000**	**$3,432,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$9,569,000	$8,368,000	$1,201,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,292,000	$1,130,000	$162,000
TOTAL COST OF PROJECT	**$38,201,000**	**$33,406,000**	**$4,795,000**
ANNUAL COST			
Debt Service (5.5 percent, 20 years)	$3,197,000	$2,795,000	$402,000
Operation and Maintenance			
Desalination Water Treatment Plant	$3,994,000	$3,493,000	$501,000
Concentrate Disposal	$306,000	$254,000	$52,000
TOTAL ANNUAL COST	**$7,497,000**	**$6,542,000**	**$955,000**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$669**	**$584**	**$85**
Annual Cost of Water ($ per 1,000 gallons)	**$2.05**	**$1.79**	**$0.26**

[1] For comparison purposes of treatment costs for various TDS concentrations, costs shown are for desalination component only. Costs common to conventional water treatment plants are omitted. Omitted costs include intake, pump stations conventional pretreatment, clearwell storage, and others.

Table 7.3-19. Cost Estimate Summary for Desalination at Lake Granbury with and without Implementation of Salinity Control Project

Item	No Salinity Control	With Salinity Control	Cost Difference
90th Percentile TDS	2,213	1,559	
50th Percentile TDS	1,316	948	
% of Water Desalinated	79%	70%	
CAPITAL COST			
RO Desalination Plant[1]	$20,384,000	$18,075,000	$2,309,000
Concentrate Disposal	$5,504,000	$4,234,000	$1,270,000
TOTAL COST OF FACILITIES	**$25,888,000**	**$22,309,000**	**$3,579,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$9,061,000	$7,808,000	$1,253,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,224,000	$1,055,000	$169,000
TOTAL COST OF PROJECT	**$36,173,000**	**$31,172,000**	**$5,001,000**
ANNUAL COST			
Debt Service (5.5 percent, 20 years)	$3,027,000	$2,608,000	$419,000
Operation and Maintenance			
Desalination Water Treatment Plant	$3,876,000	$3,393,000	$483,000
Concentrate Disposal	$262,000	$202,000	$60,000
TOTAL ANNUAL COST	**$7,165,000**	**$6,203,000**	**$962,000**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$640**	**$554**	**$86**
Annual Cost of Water ($ per 1,000 gallons)	**$1.96**	**$1.70**	**$0.26**

[1] For comparison purposes of treatment costs for various TDS concentrations, costs shown are for desalination component only. Costs common to conventional water treatment plants are omitted. Omitted costs include intake, pump stations conventional pretreatment, clearwell storage, and others.

Table 7.3-20. Cost Estimate Summary for Desalination at Lake Whitney with and without Implementation of Salinity Control Project

Item	No Salinity Control	With Salinity Control	Cost Difference
90th Percentile TDS	1,337	969	
50th Percentile TDS	906	693	
% of Water Desalinated	65%	51%	
CAPITAL COST			
RO Desalination Plant[1]	$16,836,000	$13,439,000	$3,397,000
Concentrate Disposal	$3,980,000	$2,540,000	$1,440,000
TOTAL COST OF FACILITIES	**$20,816,000**	**$15,979,000**	**$4,837,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$7,285,000	$5,593,000	$1,692,000
Interest During Construction (4% for 1 years with a 1% ROI)	$984,000	$756,000	$228,000
TOTAL COST OF PROJECT	**$29,085,000**	**$22,328,000**	**$6,757,000**
ANNUAL COST			
Debt Service (5.5 percent, 20 years)	$2,434,000	$1,868,000	$566,000
Operation and Maintenance			
Desalination Water Treatment Plant	$3,146,000	$2,493,000	$653,000
Concentrate Disposal	$190,000	$121,000	$69,000
TOTAL ANNUAL COST	**$5,770,000**	**$4,482,000**	**$1,288,000**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$515**	**$400**	**$115**
Annual Cost of Water ($ per 1,000 gallons)	**$1.58**	**$1.23**	**$0.35**

[1] For comparison purposes of treatment costs for various TDS concentrations, costs shown are for desalination component only. Costs common to conventional water treatment plants are omitted. Omitted costs include intake, pump stations conventional pretreatment, clearwell storage, and others.

Table 7.3-21. Cost Estimate Summary for Desalination at Bryan with and without Implementation of Salinity Control Project

Item	No Salinity Control	With Salinity Control	Cost Difference
90th Percentile TDS	1,164	1,049	
50th Percentile TDS	468	380	
% of Water Desalinated	60%	55%	
CAPITAL COST			
RO Desalination Plant[1]	$15,611,000	$14,402,000	$1,209,000
Concentrate Disposal	$1,693,000	$1,270,000	$423,000
TOTAL COST OF FACILITIES	**$17,304,000**	**$15,672,000**	**$1,632,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$6,057,000	$5,485,000	$572,000
Interest During Construction (4% for 1 years with a 1% ROI)	$818,000	$741,000	$77,000
TOTAL COST OF PROJECT	**$24,179,000**	**$21,898,000**	**$2,281,000**
ANNUAL COST			
Debt Service (5.5 percent, 20 years)	$2,023,000	$1,832,000	$191,000
Operation and Maintenance			
Desalination Water Treatment Plant	$2,908,000	$2,676,000	$232,000
Concentrate Disposal	$81,000	$60,000	$21,000
TOTAL ANNUAL COST	**$5,012,000**	**$4,568,000**	**$444,000**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$447**	**$408**	**$40**
Annual Cost of Water ($ per 1,000 gallons)	**$1.37**	**$1.25**	**$0.12**

[1] For comparison purposes of treatment costs for various TDS concentrations, costs shown are for desalination component only. Costs common to conventional water treatment plants are omitted. Omitted costs include intake, pump stations conventional pretreatment, clearwell storage, and others.

Table 7.3-22. Cost Estimate Summary for Desalination at Richmond with and without Implementation of Salinity Control Project

Item	No Salinity Control	With Salinity Control	Cost Difference
90th Percentile TDS	895	816	
50th Percentile TDS	346	317	
% of Water Desalinated	47%	41%	
CAPITAL COST			
RO Desalination Plant[1]	$12,478,000	$11,045,000	$1,433,000
Concentrate Disposal	$1,693,000	$1,270,000	$423,000
TOTAL COST OF FACILITIES	**$14,171,000**	**$12,315,000**	**$1,856,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$4,960,000	$4,310,000	$650,000
Interest During Construction (4% for 1 years with a 1% ROI)	$670,000	$582,000	$88,000
TOTAL COST OF PROJECT	**$19,801,000**	**$17,207,000**	**$2,594,000**
ANNUAL COST			
Debt Service (5.5 percent, 20 years)	$1,657,000	$1,440,000	$217,000
Operation and Maintenance			
Desalination Water Treatment Plant	$2,311,000	$2,043,000	$268,000
Concentrate Disposal	$81,000	$60,000	$21,000
TOTAL ANNUAL COST	**$4,049,000**	**$3,543,000**	**$506,000**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$361**	**$316**	**$45**
Annual Cost of Water ($ per 1,000 gallons)	**$1.11**	**$0.97**	**$0.14**

[1] For comparison purposes of treatment costs for various TDS concentrations, costs shown are for desalination component only. Costs common to conventional water treatment plants are omitted. Omitted costs include intake, pump stations conventional pretreatment, clearwell storage, and others.

Table 7.3-23. Cost Estimate Summary for the Total Annual Cost of Desalination Treatment within the Brazos River Basin

Strategy	Municipal Use[1] (acft/yr)	Unit Cost of Desalination Treatment ($/acft/yr)		Total Annual Cost of Desalination Treatment ($/yr)		Annual Desalination Cost Savings With Project	Increase in Desalinated Municipal Supply[2] (acft/yr)
		Without Salinity Control Project	With Salinity Control Project	Without Salinity Control Project	With Salinity Control Project		
Seymour to Above Possum Kingdom Lake	0	$1,007	$851	$0	$0	$0	0
Possum Kingdom Lake to Above Lake Granbury	3,298	$669	$584	$2,207,000	$1,926,000	$281,000	41.6
Lake Granbury to Above Lake Whitney	35,644	$640	$554	$22,799,000	$19,738,000	$3,061,000	281.6
Lake Whitney to Above Bryan	18,975	$515	$400	$9,774,000	$7,592,000	$2,182,000	808.3
Bryan to Above Richmond	19,935	$447	$408	$8,919,000	$8,129,000	$790,000	444.6
Richmond to Gulf of Mexico	428,136	$361	$316	$154,751,000	$135,412,000	$19,339,000	899.1
Total	505,988			$198,450,000	$172,797,000	$25,653,000	2475.2

1 Includes Brazos River Authority Contract amounts and TCEQ Water Rights for municipal use.
2 Resulting from increase in recovery rates for Desal WTP

Comparing the desalination cost savings to the total annual cost of the project, $14,447,000, shows that the project is cost effective. The cost savings exceed the annual costs by approximately $11,206,000. Additional benefits (although not quantified here) would accrue for industrial users and irrigation users. Furthermore, as the amount of water contracted or permitted for municipal use increases in the future, the desalination costs savings due to the project as computed in Table 7.3-23 would increase, while the project cost would not.

The results of the present desalination cost evaluation are subject to the modeling assumptions utilized. In particular, it is important to note that the benefits of reduced desalination treatment costs will only be fully realized at a point in the future when the effects of the salinity control project are fully realized and residual salt has been washed from upland stream beds and from downstream lakes.

7.3.6 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 7.3-24 and the option meets each criterion.

Table 7.3-24. Evaluation of Salinity Control Project to Enhance Water Supplies

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Increased water recovery rate for desalination
2. Reliability	2. Not a reliable water supply, although does increase reliable usage of existing and future main stem supplies.
3. Cost	3. Not applicable
B. Environmental factors	
1. Environmental Water Needs	1. Low to moderate impact
2. Habitat	2. Moderate to high impact on some species
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Negligible impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• Beneficial impact on water quality in much of the Brazos River Basin; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Overall positive impact on agriculture and natural resources
E. Equitable Comparison of Strategies Deemed Feasible	• Not considered for water supply. Possible significant benefit on basin water quality.
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

The salinity control project will increase the usability of Brazos River water throughout the Brazos G and Region H Areas. Distribution of project costs to beneficiaries will not be straightforward. A summary of the implementation steps for the project is presented below.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- General Land Office Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Other project issues include the following:

- Acquisition of additional land for mitigation;
- Cultural resources mitigation, including possibly extensive data recovery;
- Acquisition of rights-of-way and easements;
- Crossings of roads, railroads, creeks, rivers and other utilities; and
- Possible relocations, including residences and other structures, affected utilities and roads, etc.

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7.4 Gibbons Creek Reservoir Expansion

The Texas Municipal Power Agency (TMPA) owns and operates Gibbons Creek Reservoir in Grimes County, 20 miles east of Bryan/College Station near the town of Carlos (Figure 7.4-1). The reservoir is used to provide cooling water to the Gibbons Creek Steam-electric Station, a lignite coal-fired power plant. TMPA holds Certificate of Adjudication (CA) 12-5311 and Amendment 12-5311A for impoundment of 32,084 acre-feet (acft) of water at the normal maximum operating level. TMPA is authorized to divert, circulate, and re-circulate as much water as necessary, of which not more than 9,740 acre-feet per year (acft/yr) may be consumptively used, for industrial (forced evaporative cooling and power plant operation) purposes. TMPA also holds Certificate of Adjudication 12-5307 for diversion from the Navasota River for subsequent use in Gibbons Creek Reservoir. As flows are not always available to the Navasota diversion right, TMPA has contracted with the Brazos River Authority (BRA) to provide 3,600 acft/yr (4,800 maximum in one year) from Lake Limestone.

TMPA is considering the possibility of raising the level of Gibbons Creek Reservoir in order to secure additional supply for future power plant expansions. Gibbons Creek Dam is a 1.25-mile long earthen embankment constructed across the confluence of Gibbons and Sulphur Creeks. This water supply option involves increasing the reservoir storage capacity and the firm yield from the reservoir by raising the elevation of the conservation pool by 4 feet from elevation 247 ft-msl to elevation 251 ft-msl. This would increase the storage in Gibbons Creek Reservoir from 27,425 acft to 39,197 acft, based on the elevation-storage capacity relationship for the reservoir developed by the TWDB in 2009.

Raising the reservoir would involve increasing the effective dam crest elevation by installing a parapet wall along the upstream face, modifying the emergency spillway, modifying or replacing the spillway gates, and modifying the spillway piers. Engineering considerations for this project are discussed in Section 7.4-4.

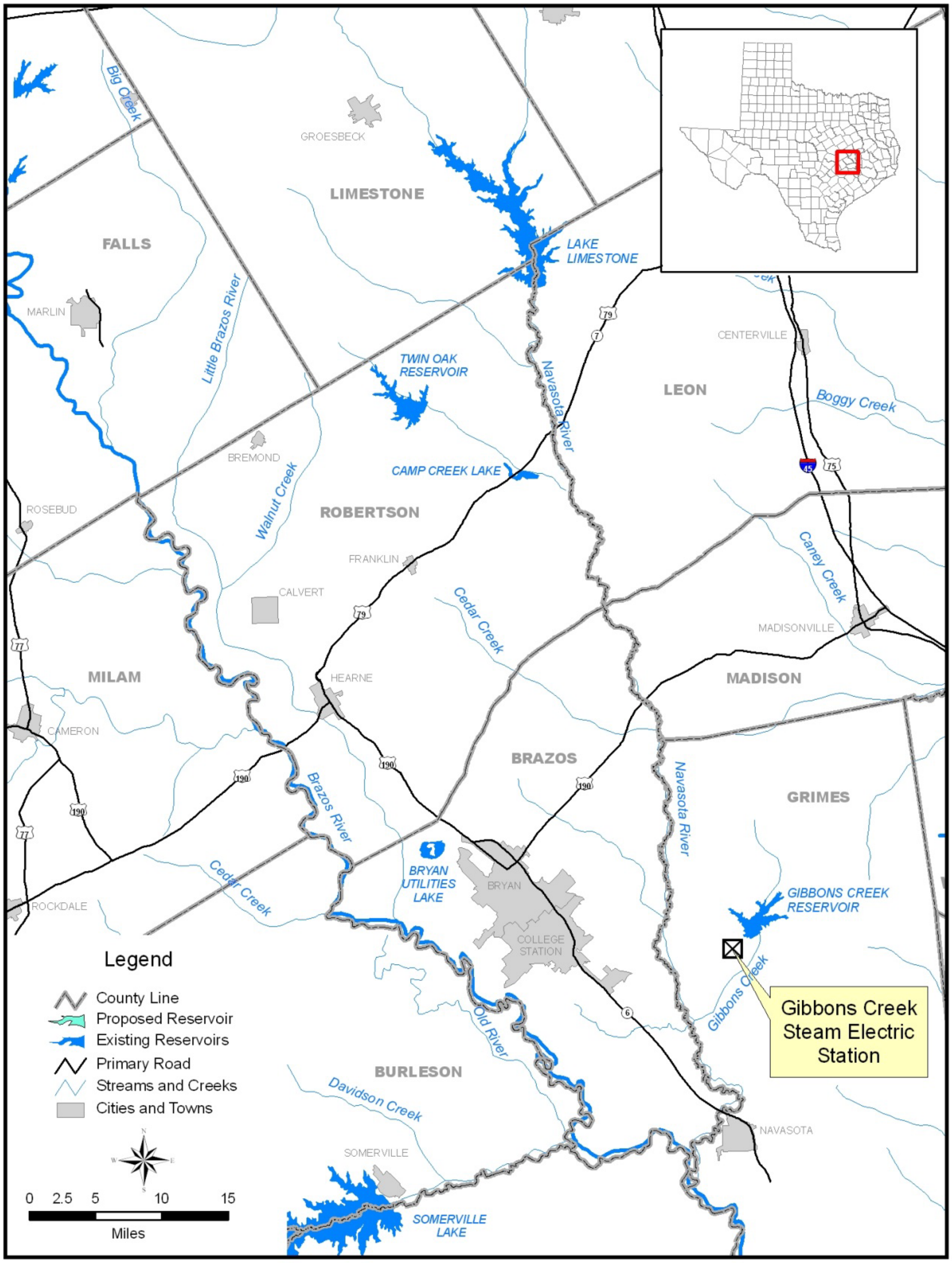
7.4.1 Available Yield

TMPA is currently studying this strategy for increasing their supply out of Gibbons Creek Reservoir. The following information is summarized from a May 2005 technical memorandum developed as part of TMPA's ongoing study efforts. The existing Gibbons Creek Reservoir was evaluated under three alternative water supply scenarios including:

- Water available from the Gibbons Creek watershed only;
- Water available from the Gibbons Creek watershed, supplemented with diversions from the Navasota River under CA 12-5307; and
- Water available from the Gibbons Creek watershed, supplemented with diversions from the Navasota River and releases from Lake Limestone.

For each of these scenarios, the TCEQ Brazos WAM was modified to implement the current restrictions defined in the certificates of adjudication, as well as reflect TMPA's current infrastructure. Under CA 12-5307, the total permitted annual diversion from the

Figure 7.4-1. Gibbons Creek Reservoir



Navasota River is limited to 6,000 acft. The releases from Lake Limestone were limited to a maximum 1 year volume of 4,800 acft in accordance with the BRA contract. The total monthly diversion rate from both sources was limited to a combined 1,400 acft per month, which is the approximate capacity of the Navasota River Diversion Facility. Firm yield was computed subject to the reservoir having to pass inflows to meet environmental flow standards associated with Senate Bill 3 (SB3).

For the analysis of the existing system, the reservoir was first modeled under a strict application of the water rights as included in the TCEQ model. The reservoir was operated under its currently authorized consumptive use of 9,740 acft/yr with no critical operating level in the reservoir defined. Therefore, the water level in the reservoir was allowed to drop without any restrictions that might otherwise be implemented in the actual management of the system. These model simulations attempted to maintain the reservoir at its existing conservation capacity of 27,425 acft at an elevation of 247 ft-msl.

As shown in Figure 7.4-2 and Figure 7.4-3, the authorized use from the reservoir is not firm under all three scenarios. Furthermore, in each simulation the reservoir water level drops below elevation 243 ft-msl, which is the estimated critical operating level for the steam-electric plant. The TMPA has determined that this is the minimum level to which the reservoir can drop and still maintain efficient cooling properties. The reservoir stays full approximately 40% of the time with water from its drainage area only, but when supplemented with water from the Navasota River and Lake Limestone releases, the reservoir maintains its 27,425 acft impoundment approximately 60% of the time.

A second set of model runs were developed to simulate the existing system with critical operating levels imposed. For these runs, the reservoir was operated under a firm yield basis while not allowing the water level to drop below elevation 243 ft-msl when subjected to each of the three previously described scenarios. The storage traces and frequency plots for these model runs are provided in Figure 7.4-4 and Figure 7.4-5. The yields for each simulation are also shown in these figures and reveal that the permitted consumptive use of 9,740 acft/yr is not firm under any of the three operating scenarios. These yields represent the amount that could be reliably consumed on an annual basis from the reservoir without dropping below the critical operating level of 243 ft-msl. The reservoir stays full approximately 58% to 67% of the time with the yields ranging from 1,355 acft/yr when water is obtained from the reservoir’s watershed only, to a maximum of 2,475 acft/yr when the BRA Lake Limestone contract is utilized in conjunction with the Navasota River diversion right.

This alternative strategy evaluated the firm yield increase provided by raising the conservation pool level of Gibbons Creek Reservoir 4 feet and increasing the storage capacity by approximately 12,000 acft to 39,197 acft at elevation 251 ft-msl. The firm yield of the raised reservoir would be increased to 5,080 acft/yr, which is less than the permitted consumptive use of 9,740 acft/yr. As shown in Figure 7.4-6 and Figure 7.4-7, the authorized consumptive use is not firm under all three scenarios.

Figure 7.4-2. Gibbons Creek Reservoir Firm Yield Storage Trace at Existing Capacity with No Critical Operating Limit Imposed

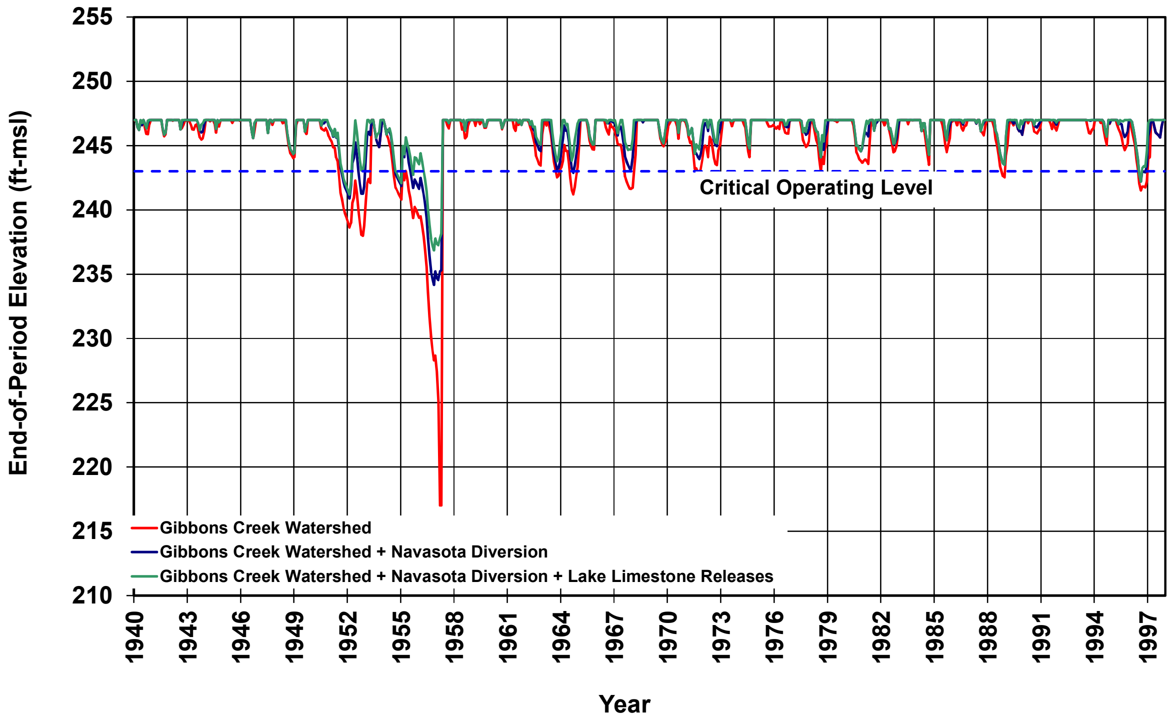
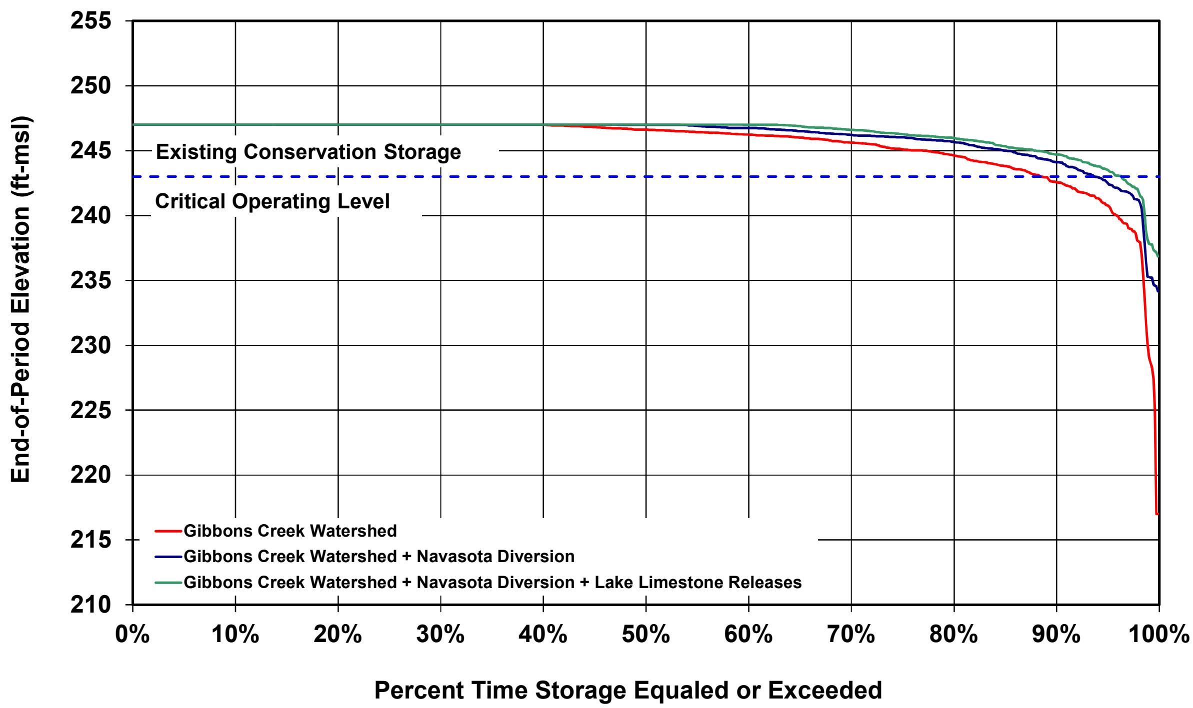


Figure 7.4-3. Gibbons Creek Storage Frequency at Firm Yield at Existing Capacity with No Critical Operating Limit Imposed



7.4. Gibbons Creek Reservoir Firm Yield Storage Trace at Existing Capacity with Critical Operating Limit Imposed

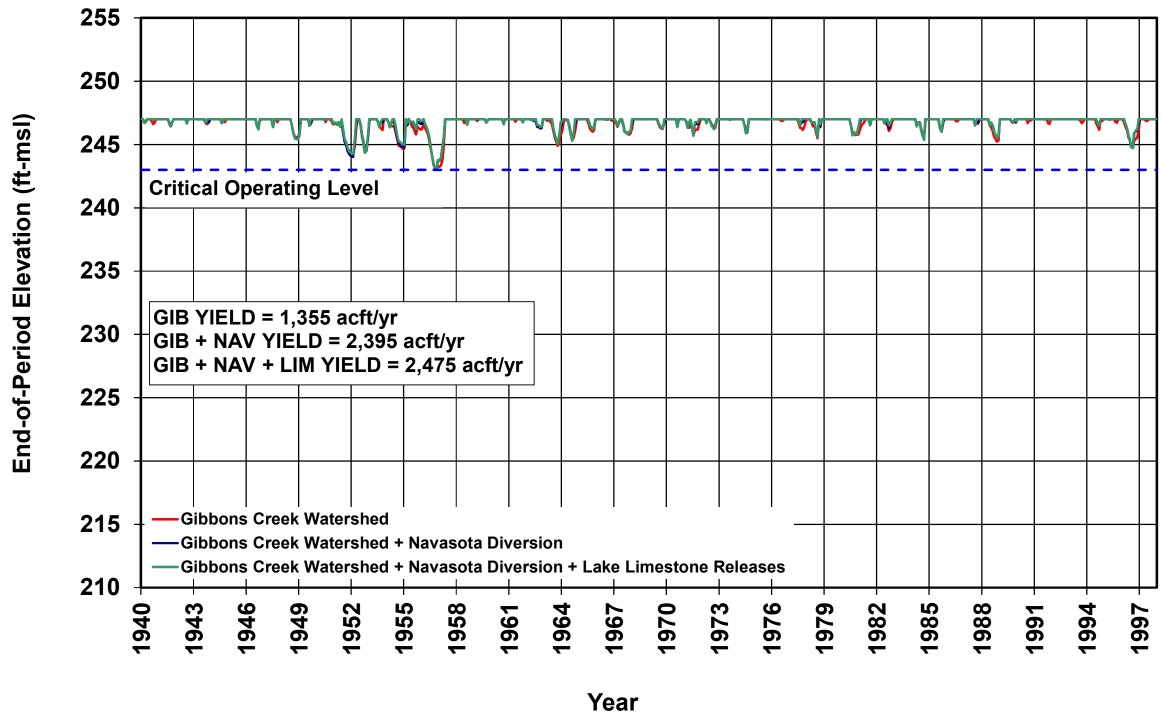


Figure 7.4-5. Gibbons Creek Storage Frequency at Firm Yield at Existing Capacity with Critical Operating Limit Imposed

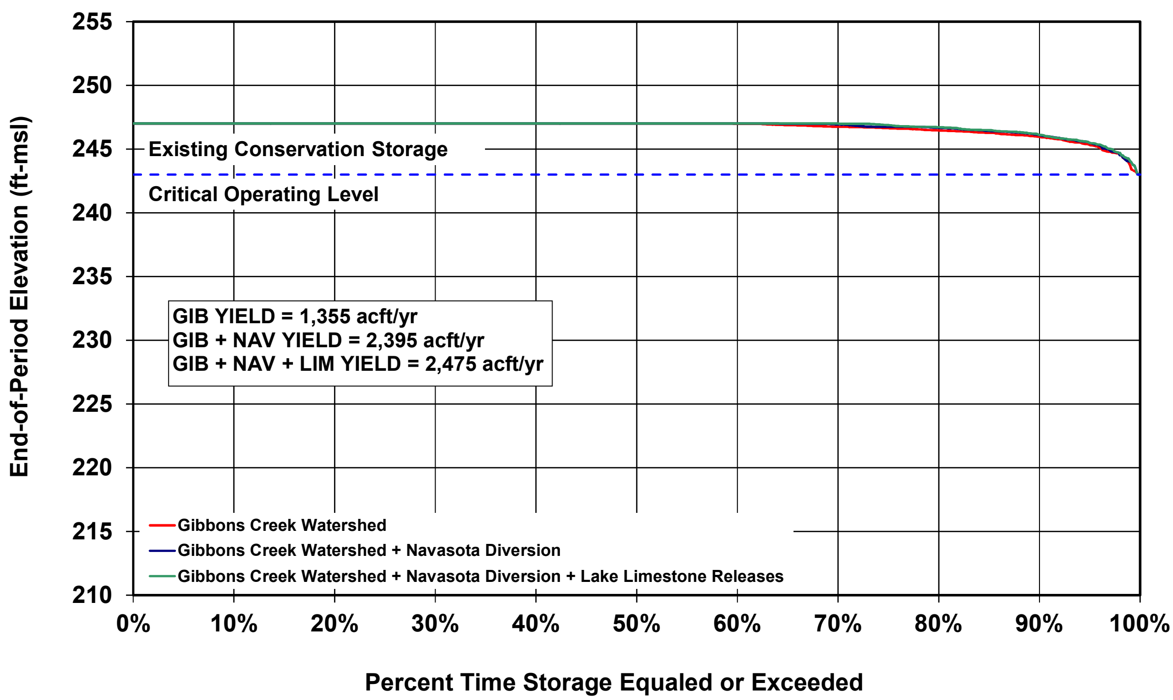


Figure 7.4-6. Gibbons Creek Reservoir Firm Yield Storage Trace at Proposed Capacity with Critical Operating Limit Imposed

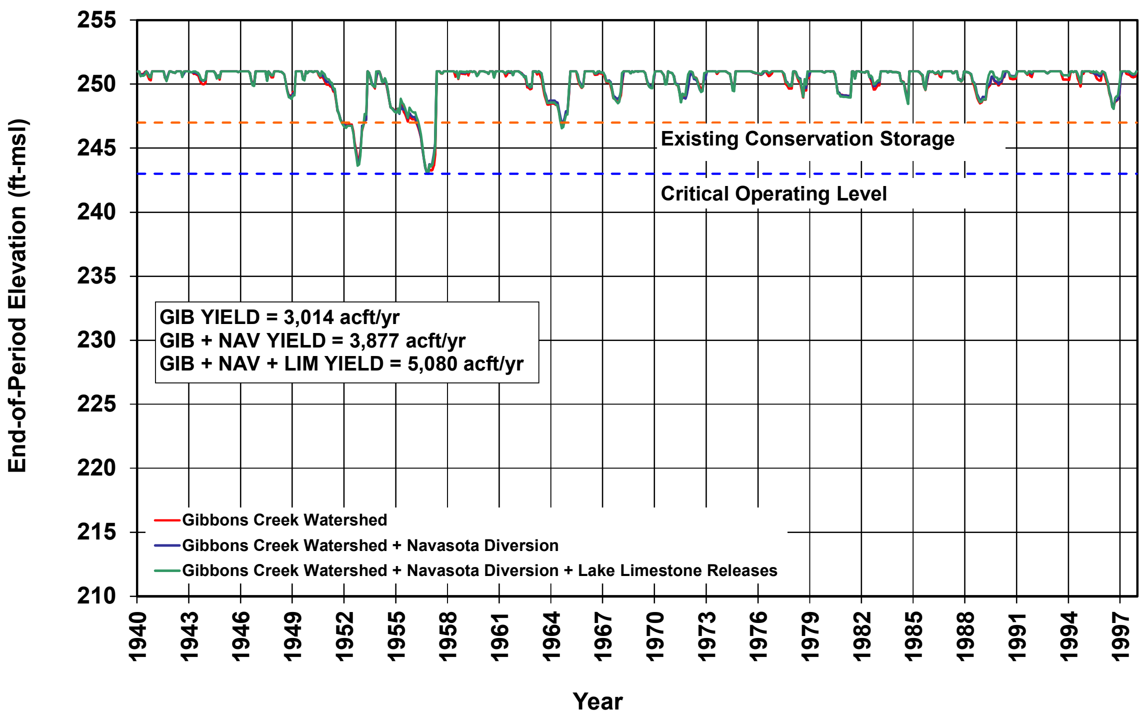
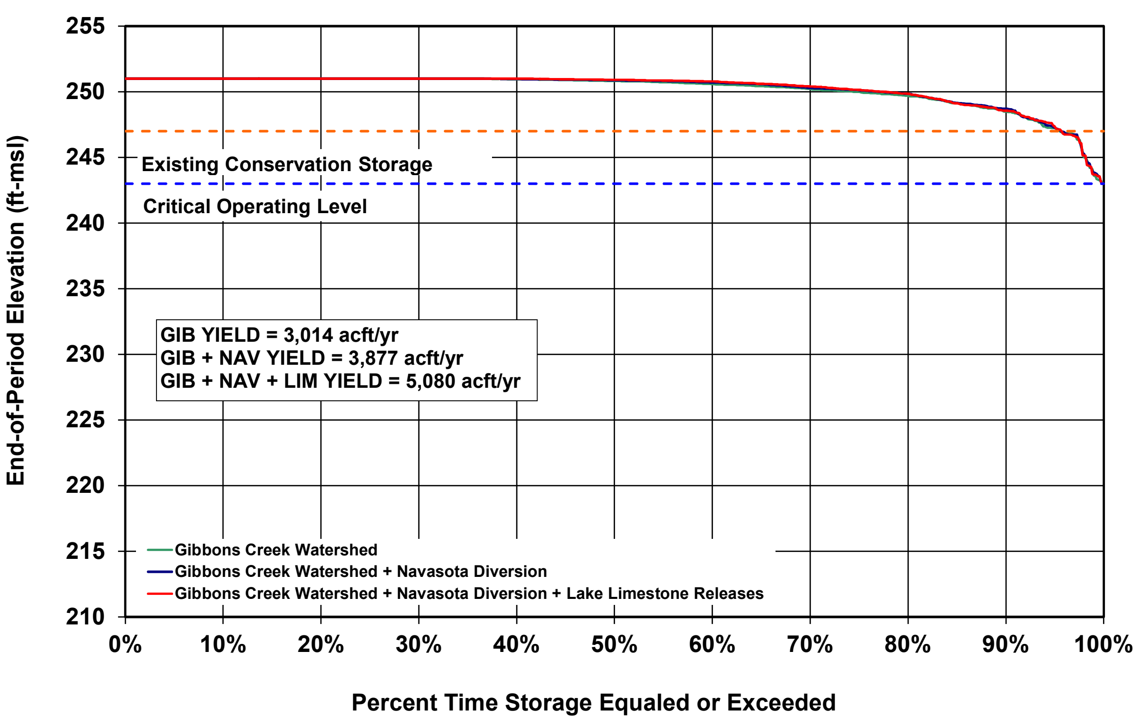


Figure 7.4-7. Gibbons Creek Storage Frequency at Firm Yield at Proposed Capacity with Critical Operating Limit Imposed



7.4.2 Environmental Issues

Existing Environment

The Gibbons Creek Reservoir expansion project involves raising the level of the reservoir 4 feet, from elevation 247 ft-msl to elevation 251 ft-msl. This change would increase the storage capacity of the reservoir and inundate forested habitat at several locations around the reservoir's current perimeter. The existing reservoir lies within the Post Oak Savannah Vegetational Area[1] and is within the Texan biotic province.[2] The reservoir is within the Interior Coastal Plain Physiographic Province, which is characterized by parallel ridges and valleys of unconsolidated sands and muds with an elevation range from 300 to 800 meters.[3] The climate is characterized as subtropical humid, with warm summers. Average annual precipitation is approximately 42-44 inches.[4]

Gibbons Creek Reservoir is located within the Texas Claypan Area. [5] Soils in the project area formed on nearly level to sloping plains dissected by perennial streams and their tributaries. Large floodplains and stream terraces are associated with meandering river systems. Over most of the area, soils have well-developed, clayey, subsoil horizons with sandy and loamy surface textures. Woodtell, Edge, Crockett and Straber soils occur on interstream divides and ridges, and Tabor soils are on stream terraces. Padina and Silstid soils have sandy surface layers more than 20 inches thick. Edge-Tabor-Silstid series soils are present in the project area.

Vegetation within the project area includes post oak woods, forest and grassland mosaic, and pine-hardwood forests.[6] Post oak woods, forest and grassland mosaic could include the following commonly associated plants: Blackjack oak (*Quercus marilandica*), eastern redcedar (*Juniperus viginiana*), mesquite (*Prosopis glandulosa*), black hickory (*Carya texana*), live oak (*Q. fusiformis*), sandjack oak (*Q. incana*), cedar elm (*Ulmus crassifolia*), hackberry (*Celtis reticulata*), yaupon (*Ilex vomitoria*), poison oak (*Rhus toxicodendron-radicans*), American beautyberry (*Callicarpa americana*), hawthorn (*Crateagus texana*), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus trivialis*), coral-berry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida purpurea*), sprangle-grass (*Chasmanthium latifolium*), and tickclover (*Desmodium paniculatum*).

Commonly associated plants in the pine-hardwood forest include: shortleaf pine (*Pinus echinata*), water oak (*Quercus nigra*), winged elm (*Ulmus alata*), beech (Fagus spp.), and magnolia (*Magnolia spp.*). Understory plants include American beautyberry

[1] Gould, Frank W. 1975. The Grasses of Texas. Texas A&M University Press, College Station, Texas.

[2] Blair, W.F., "The Biotic Provinces of Texas", Tex. J. Sci. 2:93-117, 1950.

[3] Bureau of Economic Geology. 1996. Physiographic Map of Texas. The University of Texas, Austin, Texas.

[4] Texas Water Development Board (TWDB). *Precipitation Polygon GIS Layer*.

[5] USDA – NRCS, 2008. *General Soil Map of Texas*, generated from the NRCS STATSGO 2004 database, September 25, 2008.

[6] McMahan, C. A., R. G. Frye and K. L. Brown, "The Vegetation Types of Texas -- Including Cropland", Texas Parks and Wildlife Department - PWD Bulletin 7000-120, 1984.

(*Callicarpa americana*), flowering dogwood (*Cornus florida*), yaupon (*Ilex vomitoria*), and sassafras (*Sassafras officinale*). Groundcovers such as poison ivy (*Toxicodendron radicans*), greenbriar (*Smilax spp.*), and blackberry (*Rubus spp.*) are common within the area.

Potential Impacts

Aquatic Environments including Bays & Estuaries

While not presented in the modeling simulation provided by TMPA, it is anticipated that there would be a slight reduction in the quantity of median monthly flows below the dam. Since a significant portion of the inflow into the reservoir comes from supplemental sources on the Navasota River and TMPA generally operates to keep the reservoir full, maximizing spills, the reductions are expected to be negligible.

Threatened & Endangered Species

A total of 29 species that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern could potentially occur within the vicinity of Gibbons Creek Reservoir. This group includes ten birds, two fishes, four mammals, five mollusks, four reptiles, and four plant species (Table 7.4-1). Three bird species federally-listed as threatened or endangered could possibly occur within the project area. These include the Interior Least Tern, Red-cockaded Woodpecker and Whooping Crane. The Interior Least Tern and Red-Cockaded Woodpecker may breed and forage within the vicinity of the site but have very specific habitat requirements. The Whooping Crane is a seasonal migrant that could pass through the project area. The federally-threatened Louisiana black bear is possible in the area as a transient in bottomland hardwoods and large tracts of inaccessible forest land; the federally-endangered red wolf has been extirpated. One plant species of potential occurrence, the Navasota ladies' tresses, is federally endangered. This plant species has restricted habitats requiring sandy soils and openings in post oak woodlands. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

Table 7.4-1. Endangered, Threatened, Candidate and Species of Concern Listed for Grimes County

Scientific Name	Common Name	Federal/State Status	Potential Occurrence
BIRDS			
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/SOC	Migrant
Haliaeetus leucocephalus	Bald Eagle	DL/T	Resident
Ammodramus henslowii	Henslow's Sparrow	SOC	Resident
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant
Falco peregrinus	Peregrine Falcon	DL/T	Migrant
Picoides borealis	Red-Cockaded Woodpecker	LE/E	Resident
Plegadis chihi	White-Faced Ibis	T	Resident
Grus Americana	Whooping Crane	LE/E	Migrant
Mycteria americana	Wood Stork	T	Migrant
FISHES			
Cycleptus elongates	Blue Sucker	T	X
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
MAMMALS			
Ursus americanus luteolus	Louisiana Black Bear	LT/T	Transient
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E	Extirpated
Myotis austroriparius	Southeastern Myotis Bat	SOC	X
MOLLUSKS			
Quincuncina mitchelli	False Spike Mussel	T*	X
Tritogonia verrucosa	Pistolgrip	SOC	X

Table 7.4-1. Endangered, Threatened, Candidate and Species of Concern Listed for Grimes County

Scientific Name	Common Name	Federal/State Status	Potential Occurrence
Arcidens confragosus	Rock Pocketbook	SOC	X
Quadrula houstonensis	Smooth Pimpleback	T*	X
Truncilla macrodon	Texas Fawnsfoot	T*	X
REPTILES			
Macrochelys temminckii	Alligator Snapping Turtle	T	X
Pituophis ruthveni	Louisiana Pine Snake	C//T	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X
PLANTS			
Liatris cymosa	Branched Gay-Feather	SOC	X
Agalinis navasotensis	Navasota False Foxglove	SOC	X
Spiranthes parksii	Navasota Ladies'-Tresses	LE/E	X
Thalictrum texanum	Texas Meadow-Rue	SOC	X

X = Occurs in county; * Nesting migrant; may nest in the county.

LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be Delisted (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-Delisted Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

TPWD, Annotated County List of Rare Species for Grimes County, January 2010.

E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; T*--Imminent listing by State as Threatened; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Wildlife Habitat

The primary impact that would result from increasing the conservation level of Gibbons Creek Reservoir includes the conversion of existing habitats and land uses of approximately 160 acres surrounding the existing reservoir to open water. Post oak woods/forest and grassland, and pine-hardwood areas between elevations 247 and 251 ft-msl would be permanently inundated. This area is currently within the existing flood pool of Gibbons Creek Reservoir.

A number of vertebrate species could occur within the project area, as indicated by county occurrence records.[7] These include 55 reptile and amphibian species which include salamanders, frogs and toads, turtles, lizards and skinks, snakes, and the American alligator. Additionally, approximately 54 species of mammals could occur within the site or surrounding region,[8] as well as an undetermined number of bird species. A variety of fish and invertebrate species likely inhabit the existing reservoir, but distributions and population densities may be limited by the types and quality of habitats available.

Cultural Resources

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available GIS datasets from the Texas Historical Commission (THC), no historic markers, cemeteries, or historic places are within the proposed additional reservoir inundation area.

Threats to Natural Resources

This project would alter the habitat along the current boundary of Gibbons Creek Reservoir from primarily a bottomland hardwood system to an impounded system. Bottomland hardwoods are extensive in the project area and are important habitats for a variety of species including migratory birds. Additional impacts would be expected to terrestrial wildlife, potentially including some threatened or endangered species, which would be displaced during additional reservoir filling.

Agricultural Resources

There is no agricultural use land within the expanded footprint of the reservoir expansion.

7.4.3 Engineering and Costing

Increasing the conservation pool level of Gibbons Creek Reservoir by 4 feet would necessitate raising the top of dam elevation in order to safely pass the probable maximum flood. Given the increasing storage with increasing reservoir pool elevation, it was assumed that the top of dam would need to be raised 3 feet. Detailed flood

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[7] Texas A&M University (TAMU), “County Records for Amphibians and Reptiles,” Accessed online http://wfscnet.tamu.edu/tcwc/Herps_online/CountyRecords.htm December 2, 2009.

[8] Davis, W.B., and D.J. Schmidly, “The Mammals of Texas – Online Edition,” Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

hydrology and hydraulic analyses would be required to refine the top of dam elevation. The dam would be raised using a concrete parapet wall along the upstream edge of the dam crest. The road on top of the dam crest would not be raised. The downstream face of this wall would be shaped to serve as a traffic barrier for vehicles driven on the dam crest. The existing soil cement slope protection along the upstream face of the wall that is disturbed by construction and would need to be replaced with lean concrete or cement-treated materials. Repairs to the road along the top of the dam and repaving it with a single chip-seal coat would complete the dam crest work.

The entire “footprint” of the emergency spillway would be raised 4 feet using earth fill to keep the frequency of engagement the same. A portion of the overflow crest would be protected using some form of armor, such as concrete pavers or gabions. The remainder of the raised and disturbed area would be revegetated using a turf reinforcement mat and native grasses. An existing boat ramp and associated park facilities in the vicinity of the emergency spillway would also need to be relocated to higher ground.

Two possible approaches exist for raising the service spillway gates 4 feet, including 1) either modify and strengthen the existing gates, or 2) replace the gates entirely. In either case, modifications would be required to the trunnion and trunnion anchorage in order to resist the additional loads, and new hoists and hoist platforms would likely be necessary to lift the additional weight of the gates. Because the tops of the existing gates were previously raised approximately 2 feet and the lower portions of the existing gates are likely not designed to handle any additional hydrostatic loads, 4 feet would be added to the bottom of the gates rather than the top. To perform the modification, the gates would be rotated 4 feet open and new skin plates, vertical purlins, horizontal girders, and radial struts would be added to the bottom of the gates. New hoist brackets would also be added to the bottom of the gates. With this approach the existing portions of the gates would carry essentially the same hydrostatic loads as before. Due to the new geometry, however, it is likely that additional diagonal braces will be required above the existing top radial struts. Such gate modifications are complicated and the costs would likely be equivalent to simply replacing the existing gates.

The hot canal and weir system that is used to return hot water from the power plant to the middle fork of the reservoir would also need to be raised. The concrete walls for the weir and wing walls would be scabbed onto and raised 4 feet. Concrete buttresses of some form would probably be required to stabilize the higher walls. The canal levees would be raised 4 feet using local earth fill material.

The estimated capital costs for the major construction items associated with expanding Gibbons Creek Reservoir are listed in Table 7.4-2. The total construction cost is estimated to be $8,323,000. Considering other costs such as engineering, legal, and financing, the total project cost of expanding Gibbons Creek Reservoir is estimated to be $12,979,000, with an annual cost (debt service and O&M) of $934,000 based on 5.5 percent interest and 40-year financing. The project would provide an additional firm yield of 2,605 acft/yr of water, for an annual unit cost of $359/acft.

7.4.4 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 7.4-3, and the option meets each criterion.

Implementation of the Gibbons Creek Reservoir Expansion project will require permits from various state and federal agencies, land acquisition, and design and construction of the facilities. Funding of the project will require a substantial commitment from a non-federal sponsor. The number of constraints to implement this expansion project would be significantly reduced as compared to the development of a new reservoir because of existing land ownership and the nature of the project. A summary of the implementation steps for the project is presented below.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permit (re-authorization);
- TCEQ Water Right and Storage permit (re-authorization);
- TCEQ Dam Safety Program permit for construction of the dam and spillway modifications;
- U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for reservoirs impacting wetlands or navigable waters of the U.S;
- NPDES Storm Water Pollution Prevention Plan administered by TCEQ;
- Section 401certification from the TCEQ related to the Clean Water Act.

State and Federal Permits may require the following studies and plans:

Environmental impact or assessment studies;

- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;

- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

The TMPA owns land to elevation 250 ft-msl and flood easement to elevation 255 ft-msl surrounding the reservoir. Land will need to be acquired to elevation 251 ft-msl and additional flood easement may need to be acquired above elevation 255 ft-msl through either negotiations or condemnation from multiple landowners.

Table 7.4-2. Cost Estimate Summary for Gibbons Creek Reservoir Expansion

Item	Estimated Costs for Facilities
Raise Dam Crest	$1,172,000
Modify Emergency Spillway	$2,372,000
Modify Service Spillway	$2,365,000
Modify Hot Canal Weir and Levees	$1,583,000
Relocate Boat Ramp and Park Facilities	$74,000
Unlisted Design Items (10%)	$757,000
TOTAL COST OF FACILITIES	**$8,323,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,913,000
Environmental & Archaeology Studies and Mitigation	$893,000
Interest During Construction (4% for 2 years with a 1% ROI)	$850,000
TOTAL COST OF PROJECT	**$12,979,000**
ANNUAL COST	
Reservoir Debt Service (5.5 percent, 40 years)	$809,000
Operation and Maintenance	$125,000
TOTAL ANNUAL COST	**$934,000**
Available Project Yield (acft/yr)	**2,605**
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	**$359**
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	**$1.10**

Table 7.4-3. Evaluations of Gibbons Creek Reservoir Expansion Option to Enhance Water Supplies

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. No impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Minimal impact on habitat in reservoir area
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

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7.5 Millers Creek Reservoir Augmentation

7.5.1 Description of Strategy

Augmentation of Millers Creek Reservoir was studied for the 2006 and 2011 Brazos G Regional Water Plan. The 2011 Plan evaluated 4 options:

- Diverting water from nearby Lake Creek to Millers Creek Reservoir via a canal,
- Diverting water from nearby Lake Creek to Millers Creek Reservoir via a pipeline,
- Construction of a new dam and reservoir on Millers Creek downstream of the existing reservoir,
- Construction of the new reservoir with the canal diversion from Lake Creek.

The current evaluation updates the yields and costs for these four options. It should be noted that assumptions regarding the computation of naturalized flows in Millers and Lake Creeks have been updated from those utilized in the 2006 and 2011 Brazos G Regional Water Plans. The previous plans used the TCEQ WAM methodology which applies a drainage area ratio to incremental naturalized flows at the Brazos River near South Bend (USGS 8088000). Figure 7.5-1 illustrates the incremental drainage area shaded in tan used to estimate flows at Millers Creek Reservoir. Naturalized flows at the Brazos River at Seymour (USGS 8082500), Millers Creek near Munday (USGS 8082700) and Clear Fork Brazos River near Eliasville (USGS 8087300) are subtracted from the South Bend gage and a drainage area ratio of 0.18 is applied to the incremental naturalized flows to calculate naturalized flow at Millers Creek Reservoir. Table 7.5-1 lists the drainage areas for the TCEQ WAM incremental drainage area and Millers Creek Reservoir.

The previous plans calculate naturalized flow at the Lake Creek diversion site in a similar fashion. Naturalized flows at the North Cotton Creek near Knox City (USGS 8082180), Salt Fork Brazos River near Aspermont (USGS 8082000) and Double Mountain Fork of the Brazos River near Aspermont (USGS 8080500) are subtracted from naturalized flows at the Brazos River near Seymour gage (USGS 8082500) to compute incremental drainage area flows. This incremental drainage area is shaded in green in Figure 7.5-1. A drainage area ratio of 0.12 is applied to the incremental naturalized flows at Seymour to calculate flows historically occurring at the Lake Creek diversion site. Table 7.5-1 lists the drainage areas for the TCEQ WAM incremental drainage area and the Lake Creek diversion site.

Figure 7.5-1. WAM Incremental Drainage Areas used to Calculate Naturalized Flows at Millers Creek Reservoir and Lake Creek Diversion Site

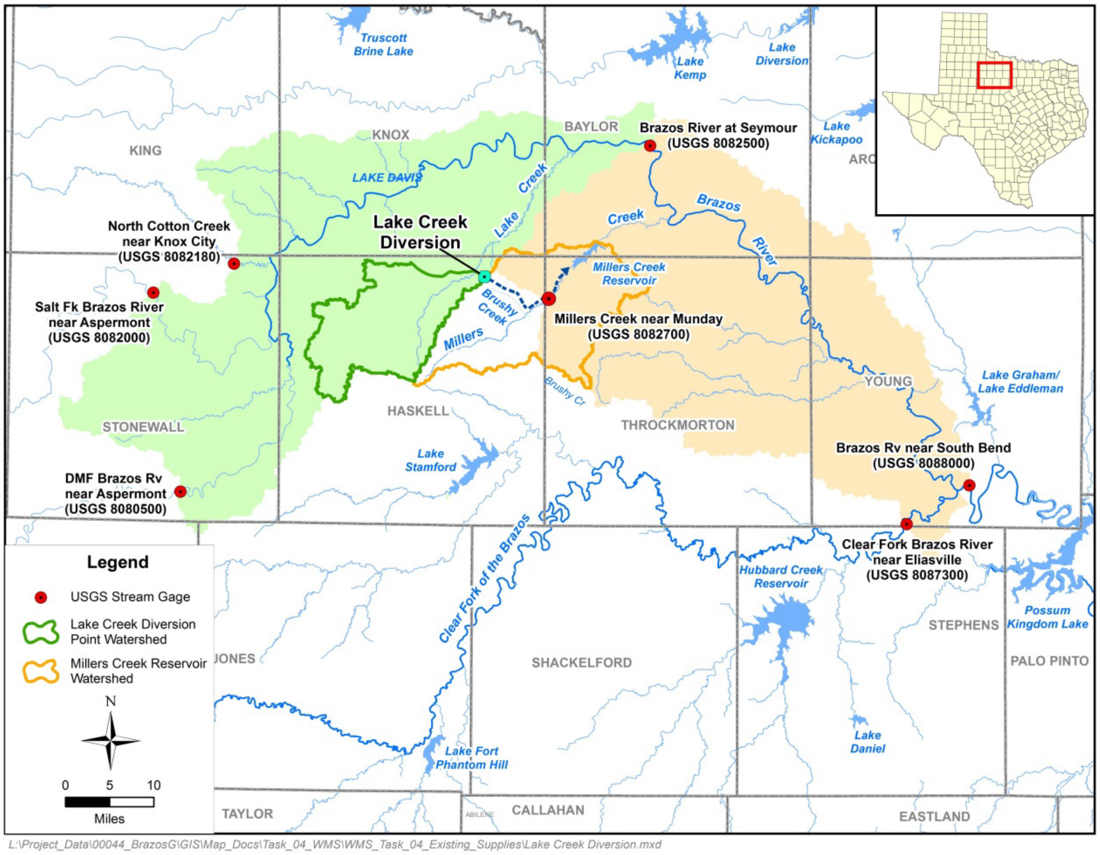

Table 7.5-1. Drainage Areas used to Translate Naturalized Flows to Millers Creek Reservoir and Lake Creek Diversion Site

Watershed	Drainage Area (sq-mi)
Millers Creek Reservoir	
Millers Creek nr Munday Gage	104
Millers Creek Reservoir	239
TCEQ WAM Incremental (tan)	1,319
Lake Creek Diversion Site	
Millers Creek nr Munday Gage	104
Lake Creek Diversion Site	167
TCEQ WAM Incremental (blue)	1,352

The TCEQ WAM methodology overestimate naturalized flows because of the large discrepancy between the incremental drainage areas and the much smaller Millers Creek Reservoir and Lake Creek diversion site drainage areas. Low flows translated from a significantly larger watershed on the main stem of a river to a smaller watershed on a tributary tend to be overestimated. In addition, large pulse events that occur on the main stem may not be present in the tributary watershed, therefore, potentially creating false pulse events at Millers Creek Reservoir and the Lake Creek diversion site. From a flow volume standpoint, flows translated from the Millers Creek near Munday gage are considered to be more representative of actual flows occurring at Millers Creek Reservoir and the Lake Creek diversion site and are used for all water availability analysis in Section 7.5. This assumption results in significant decreases in firm yield for the augmentation options when compared to the previous plans.

7.5.2 Canal Option

Description of Option

Millers Creek Reservoir is located in Baylor and Throckmorton Counties approximately 14 miles southwest of the City of Seymour. Lake Creek flows parallel to Millers Creek and the Millers Creek Reservoir. In an effort to increase the yield of the reservoir, streamflow is diverted from Lake Creek through a grass-lined canal into Brushy Creek, which flows into Millers Creek and eventually into Millers Creek Reservoir, as shown in Figure 7.5-2.

The maximum monthly depletion from Lake Creek, assuming the Lake Creek diversion is the most senior in the basin, was computed to be approximately 700 cfs. Therefore, the grass-lined canal was sized to accommodate a 700 cfs flow rate at a 0.05 percent slope. The canal bottom width would be 90 feet and the maximum top width would be 287 feet; the flow depth would be 2.8 feet. The proposed locations of the canal and Lake Creek channel dam are shown on Figure 7.5-3. The proposed canal length is 1.8 miles from Lake Creek to Brushy Creek. The topography in the area is such that there is a topographic 'high' between Lake Creek and Brushy Creek and therefore, a massive volume of earth cut would be needed to construct the grass-lined canal. It is anticipated that about 40 percent of the excess fill would be disposed of on-site, adjacent to the canal creating 5-feet high, 120-feet wide berms along the top of the canal.

The approximately 8-feet high channel dam would be an earthfill embankment to impound runoff from the Lake Creek watershed. The dam embankment would extend approximately 5,000 feet across Lake Creek at an elevation of 1,477 ft-msl. When full, the lake formed by the dam would periodically inundate approximately 360 acres.

Figure 7.5-2. Canal Option: Lake Creek Diversion to Millers Creek Reservoir

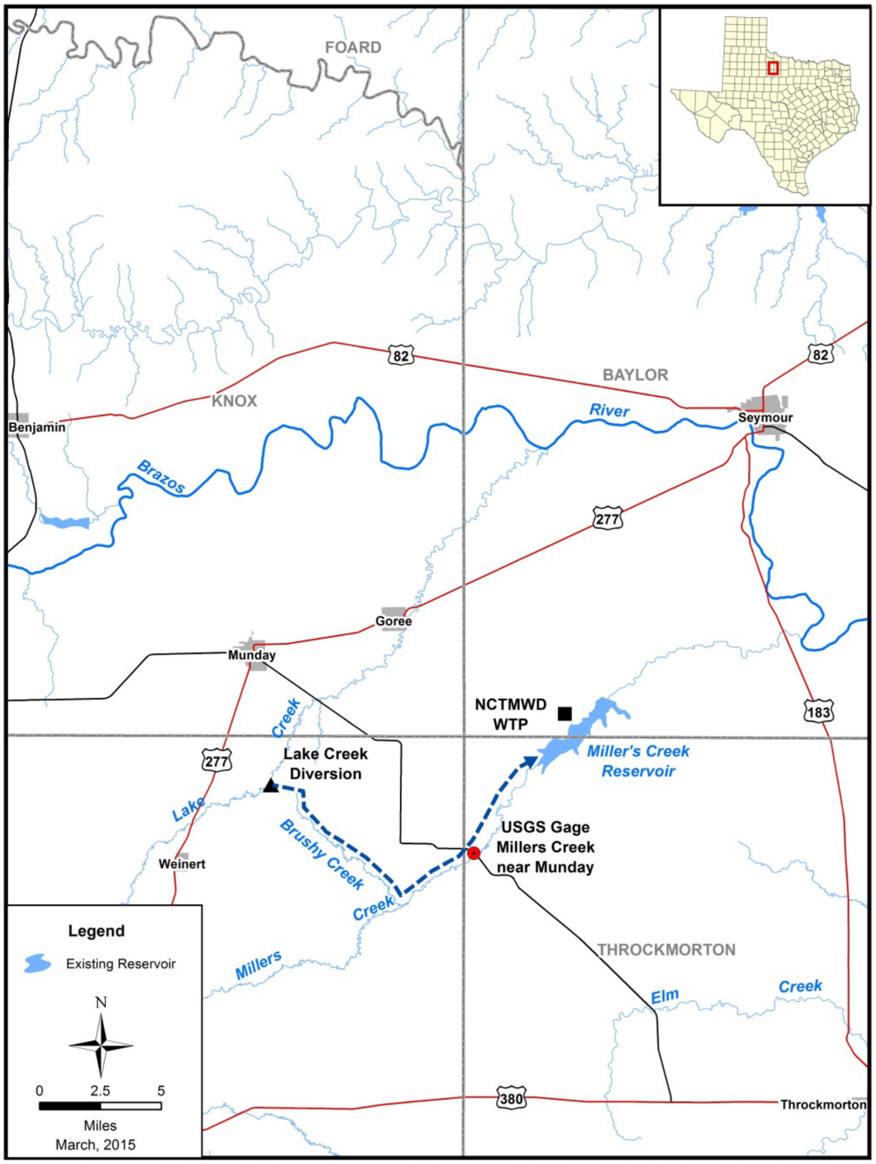

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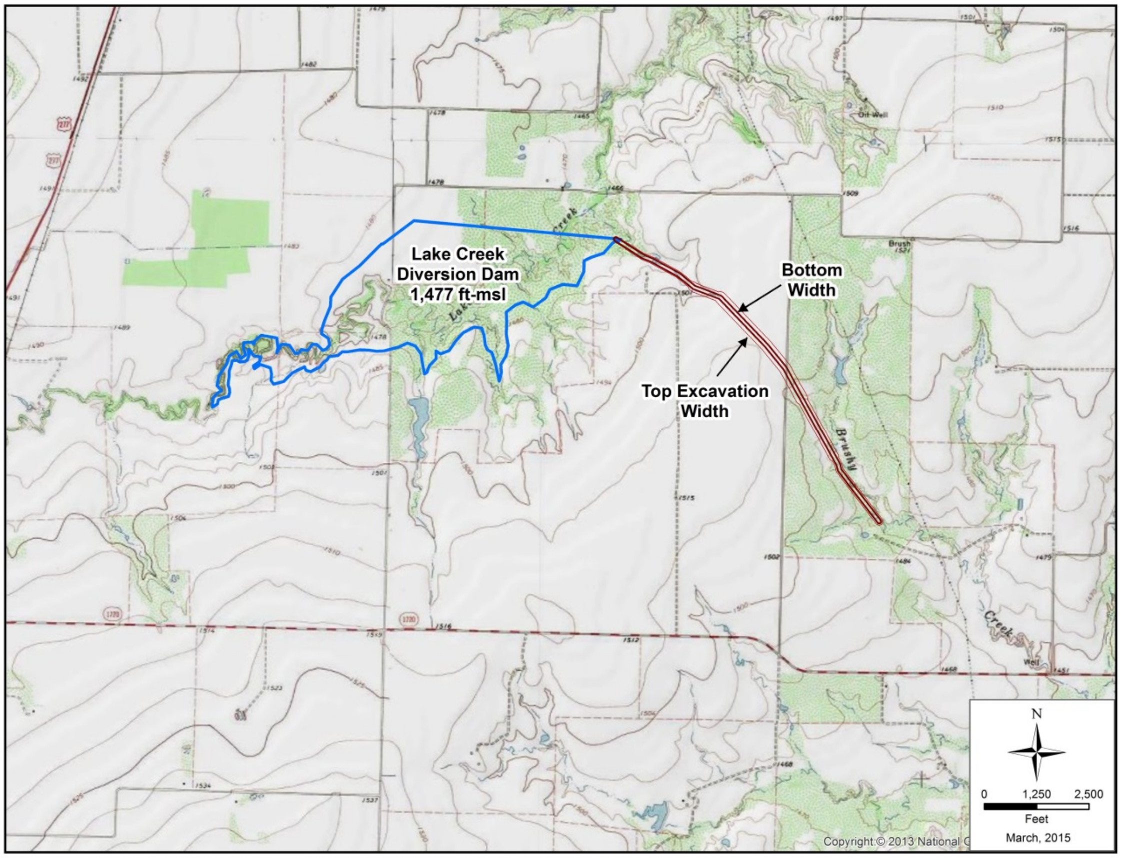
Figure 7.5-3. Lake Creek Diversion Dam and Canal to Brushy Creek



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Available Yield

Water potentially available for impoundment into the Millers Creek Reservoir was estimated using the TCEQ Brazos WAM with the modification to naturalized flow calculations at Millers and Lake Creeks. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to permitted storages and diversions. The model computed the streamflow available for diversion from Lake Creek into the Millers Creek Reservoir without causing increased shortages to existing downstream rights. Firm yield was computed subject to the Lake Creek diversion having to pass streamflows to meet Senate Bill 3 (SB3) environmental flow criteria and assuming subordination of Possum Kingdom Reservoir.

The 2020 firm yield of Millers Creek Reservoir is 3,000 acft/yr. The calculated firm yield of the Millers Creek Reservoir with the Lake Creek diversion is 3,775 acft/yr. Therefore, the Lake Creek diversion increases the current firm yield of the Millers Creek Reservoir over that of the existing reservoir alone by 775 acft/yr. Based on a delivery factor of 0.572 (from the TCEQ WAM) for water flowing from Millers Creek reservoir to Possum Kingdom Reservoir, the yield impact on Possum Kingdom Reservoir due to the canal diversion and subordination was estimated to be 443 acft/yr for costing purposes. Any subordination agreement with the BRA is dependent on the BRA being able to successfully obtain the System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. A subordination agreement would have to be negotiated and acquired for this strategy to be implemented as presented in this section.

Figure 7.5-4 illustrates the simulated Millers Creek Reservoir storage levels for the 1940 to 1997 historical period, subject to the firm yield of 775 acft/yr. The storage trace shows that the critical drought of record occurs in 1978. **Figure** 7.5**-**5 illustrates the storage frequency of Millers Creek Reservoir with the Canal diversion subject to the same firm yield demand. Simulated reservoir contents remain above 80 percent capacity 94 percent of the time and above the 50 percent capacity 78 percent of the time.

Figure 7.5-6 illustrates the changes in Lake Creek median monthly streamflows caused by the project. The maximum monthly median streamflow without the canal diversions occurs in July and the months from November through March have a median streamflow value of zero. The addition of the canal diversion reduces the monthly median streamflow values to zero for all months. Figure 7.5-7 also illustrates the Lake Creek streamflow frequency characteristics with and without the project in place. In Lake Creek, the percentage of time that no flows would be present increases from 55 percent of the time to 79 percent of the time.

Figure 7.5-4. Millers Creek Reservoir Firm Yield Storage Trace with Canal Diversion

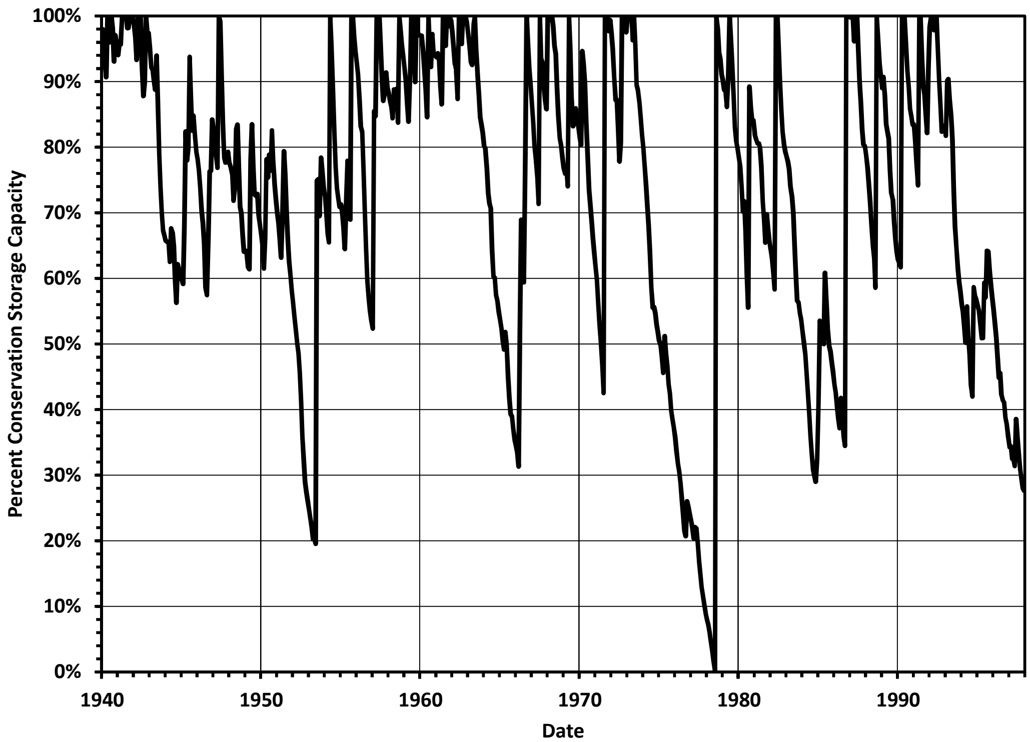


Figure 7.5-5. Millers Creek Reservoir Firm Yield Storage Frequency with Canal Diversion

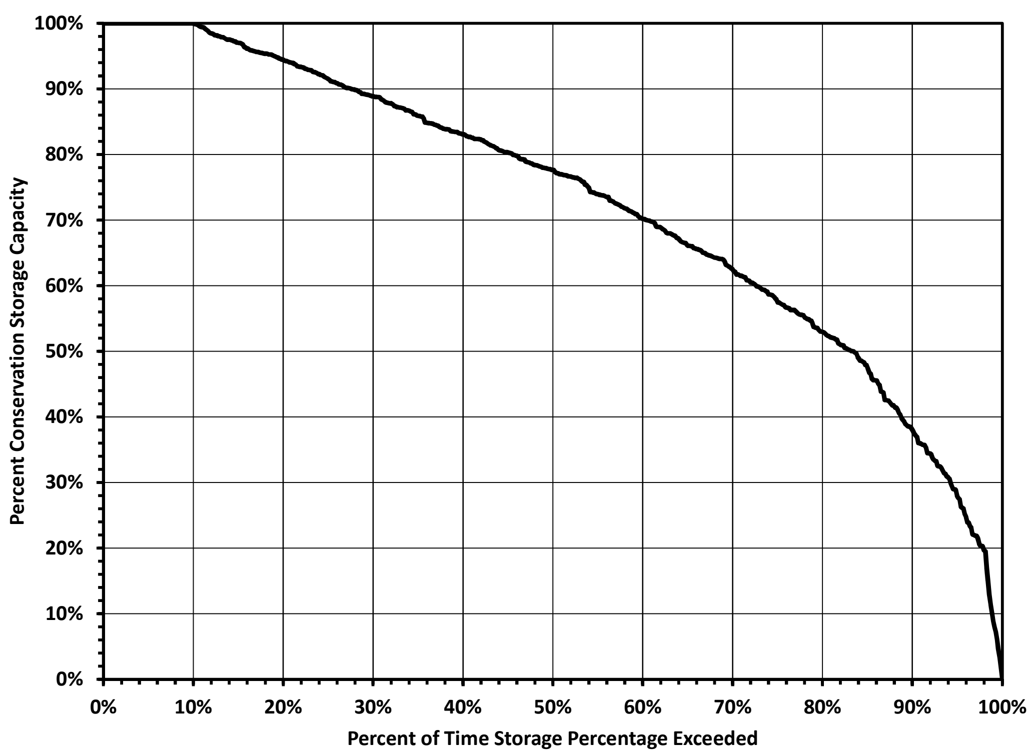


Figure 7.5-6. Comparison of Median Monthly Streamflow below Lake Creek Diversion Point With and Without Canal Diversion

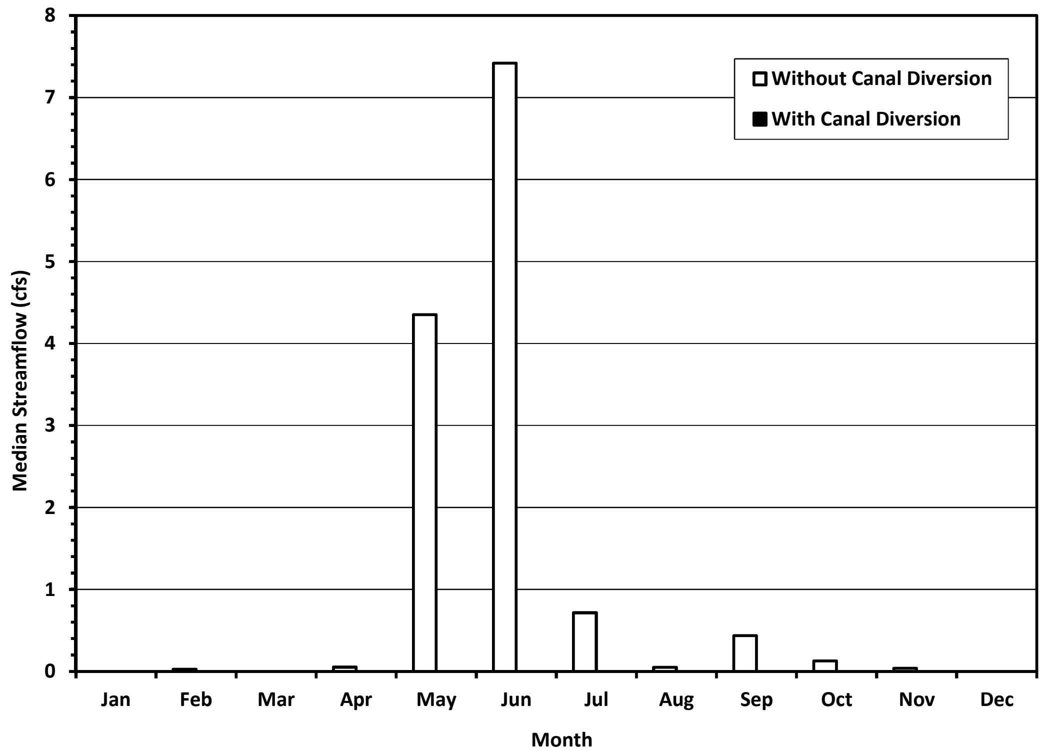
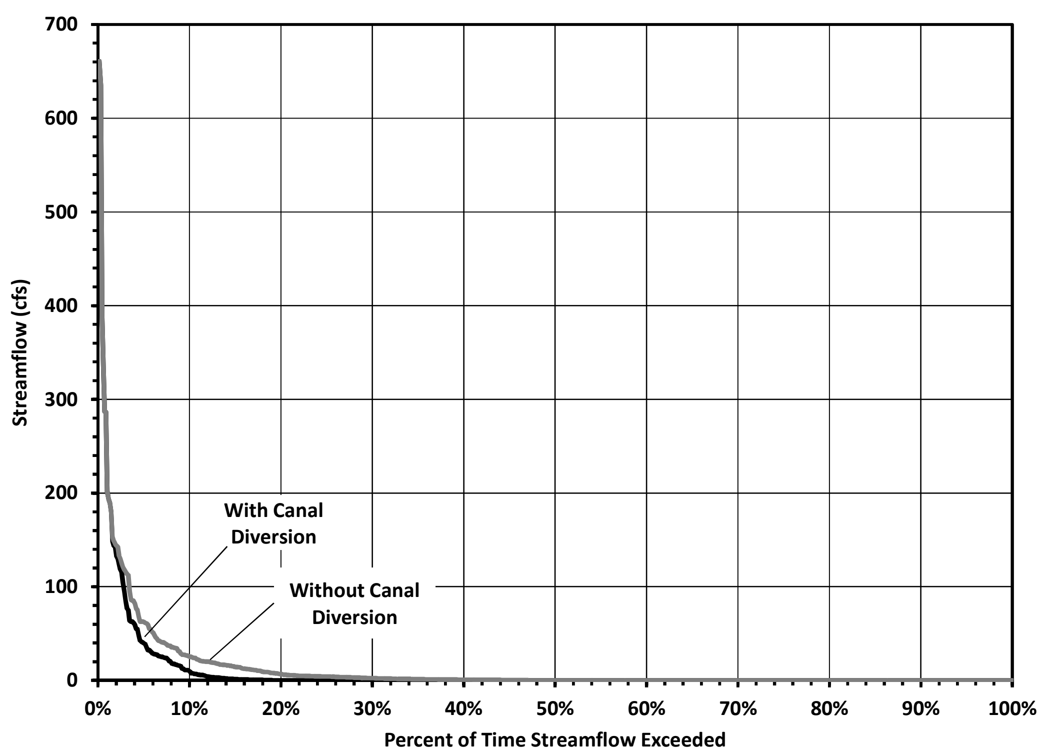


Figure 7.5-7. Comparison of Streamflow Frequency below Lake Creek Diversion Point With and Without Canal Diversion



Environmental Issues

The environmental issues associated with the four options for augmenting Millers Creek reservoir are discussed together in Section 7.5.6.

Engineering and Costing

The total estimated project cost for the channel dam and grass lined canal is $25.5 million. The annual project costs are estimated to be $1.86 million; this includes annual debt service, operation and maintenance, and annual payment to the Brazos River Authority for lost yield in Possum Kingdom Reservoir. A summary of the project costs is presented in Table 7.5-2. The cost for the estimated additional firm yield increase of 775 acft/yr translates to an annual unit cost for raw water of $7.38 per 1,000 gallons, or $2,405/acft.

Table 7.5-2. Cost Estimate for Augmentation of Millers Creek Reservoir (Canal Option)

Item	Estimated Costs for Facilities
Capital Cost	
Lake Creek Channel Dam, Reservoir, and Canal	$16,382,000
Total Cost Of Facilities	**$16,382,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$5,734,000
Environmental & Archaeological Studies and Mitigation	$844,000
Land Acquisition and Surveying (491 acres)	$869,000
Interest During Construction (4% for 2 years with a 1% ROI)	$1,668,000
Total Cost Of Project	**$25,497,000**
Reservoir Debt Service (5.5 percent, 40 years)	$1,589,000
Operation and Maintenance	
Dam and Reservoir	$246,000
Purchase of Water (443 acft/yr @ 65.65 $/acft)	$29,000
Total Annual Cost	**$1,864,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**775**
Annual Cost of Water ($ per acft)	**$2,405**
Annual Cost of Water ($ per 1,000 gallons)	**$7.38**

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 7.5-3 and the option meets each criterion.

Table 7.5-3. Comparison of Augmentation of Millers Creek Reservoir (Canal Option) to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet some needs
2. Reliability	2. Reasonable
3. Cost	3. High
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low to moderate impact
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Low impact due to distance from coast
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	Low to None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality (TCEQ) Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- TCEQ administered Texas Pollutant Discharge Elimination System (TPDES) Storm Water Pollution Prevention Plan;
- General Land Office (GLO) Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department (TPWD) Sand, Shell, Gravel and Marl permit if State-owned streambed is involved.

State and Federal Permits may Require the Following Studies and Plans:

- Environmental impact or assessment studies;

- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

7.5.3 Pipeline Option

Description of Option

Another option for augmenting Millers Creek Reservoir previously studied[1] and included in the 2006 and 2011 Brazos G Plan is to divert water from Lake Creek through a 2-mile, 24-inch pipeline into Brushy Creek, which flows into Millers Creek and eventually into Millers Creek Reservoir. The pipeline would follow the same route as the canal shown in Figure 7.5-2.

Available Yield

The increase in Millers Creek Reservoir yield that could potentially be obtained with the pipe diversion was estimated using the TCEQ Brazos WAM with the modification to naturalized flow calculations at Millers and Lake Creeks. Subordination of Possum Kingdom Reservoir to both Millers Creek Reservoir and the Lake Creek diversion was assumed. The capacity of the 24-inch pipe was assumed to be approximately 10 cfs or 7,200 acft/yr.

The firm yield of Millers Creek Reservoir with the pipeline diversion was computed to be 3,700 acft/yr, which is an increase of 700 acft/yr over the 2020 firm yield of 3,000 acft/yr for the reservoir with no augmentation. Based on a delivery factor for water flowing from Millers Creek reservoir to Possum Kingdom Reservoir of 0.572 (from the TCEQ WAM), the yield impact on Possum Kingdom Reservoir due to the pipe diversion and subordination was assumed to be 400 acft/yr for costing purposes. Any subordination agreement with the BRA is dependent on the BRA being able to successfully obtain the System Operation permit (See Section 7.12), currently pending at the Texas Commission

[1] Freese & Nichols, Inc, "West Central Brazos River Basin Regional Water Treatment and Distribution Facility Plan," August 2004.

on Environmental Quality. A subordination agreement would have to be negotiated and acquired for this strategy to be implemented as presented in this section.

Figure 7.5-8 illustrates the changes in Lake Creek median monthly streamflows caused by the project. The maximum monthly median streamflow without the canal diversions occurs in June and the months from July through April have a median streamflow value of less than 1 cfs. The addition of the canal diversion reduces the monthly median streamflow values to zero except for May and June. Figure 7.5-9 also illustrates the Lake Creek streamflow frequency characteristics with and without the project in place.

Figure 7.5-8. Comparison of Median Monthly Streamflow below Lake Creek Diversion Point With and Without Pipeline Diversion

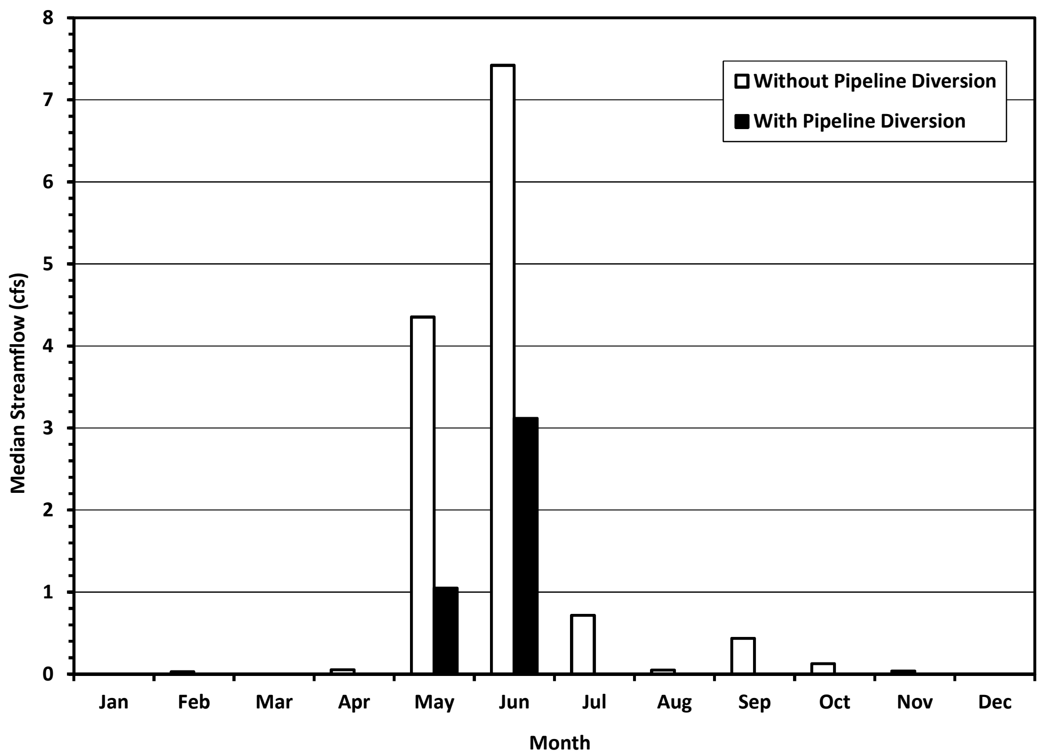
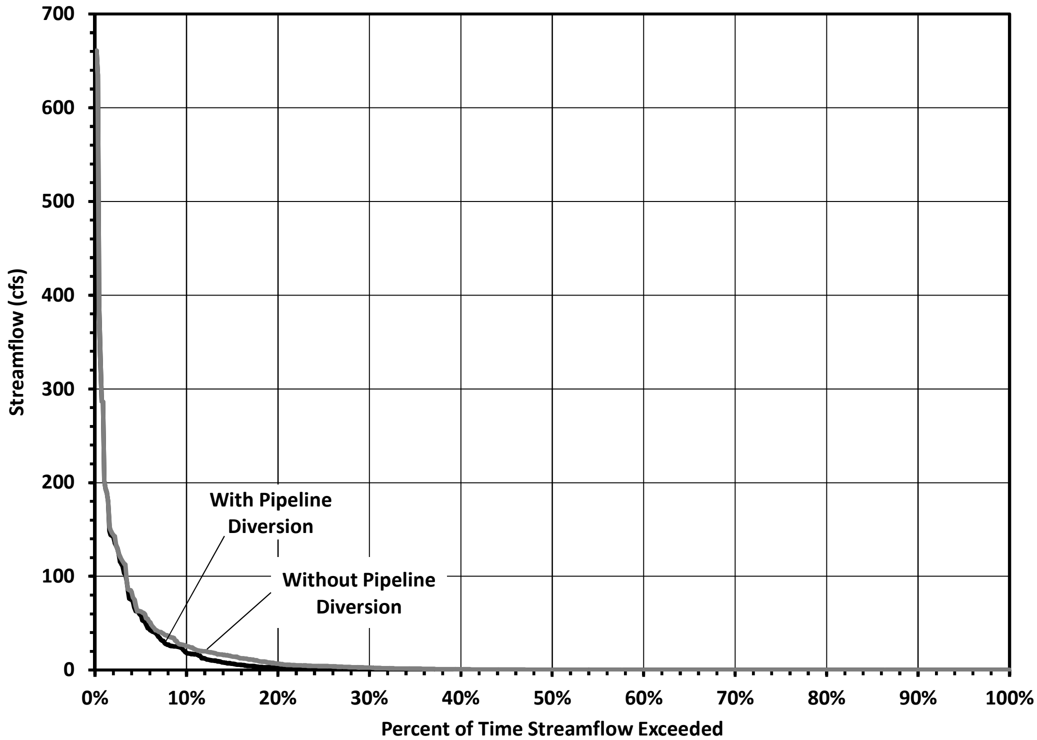


Figure 7.5-9. Comparison of Streamflow Frequency below Lake Creek Diversion Point With and Without Pipeline Diversion



Environmental Issues

The environmental issues associated with the four options for augmenting Millers Creek reservoir are discussed together in Section 7.5.6.

Engineering and Costing

The total estimated project cost is $13.7 million for the diversion weir, intake canal, pipeline, and pump station. The annual project costs are estimated to be $1.16 million, including annual debt service, operation and maintenance, and annual payment to the Brazos River Authority for lost yield in Possum Kingdom. Note that any subordination agreement would need to be negotiated with BRA and is dependent on the BRA successfully obtaining the System Operations permit from the TCEQ. A summary of the project costs is presented in Table 7.5-4. The cost for the estimated increase in Millers Creek Reservoir firm yield of 700 acft/yr translates to an annual unit cost for raw water of $5.10 per 1,000 gallons, or $1,661 per acft.

Table 7.5-4. Cost Estimate for Augmentation of Millers Creek Reservoir (Pipeline Option)

Item	Estimated Costs for Facilities
Capital Cost	
Lake Creek Channel Dam and Intake Canal)	$5,113,000
Intake Pump Stations (6.5 MGD)	$2,887,000
Transmission Pipeline (24 in dia., 2 miles)	$1,682,000
Total Cost Of Facilities	**$9,682,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$3,049,000
Environmental & Archaeological Studies and Mitigation	$44,000
Land Acquisition and Surveying (491 acres)	$61,000
Interest During Construction (4% for 2 years with a 1% ROI)	$849,000
Total Cost Of Project	**$13,685,000**
Debt Service (5.5 percent, 20 years)	$554,000
Reservoir Debt Service (5.5 percent, 40 years)	$395,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$89,000
Dam and Reservoir	$66,000
Pumping Energy Costs (0.09 $/kW-hr)	$33,000
Purchase of Water (443 acft/yr @ 65.65 $/acft)	$26,000
Total Annual Cost	**$1,163,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**700**
Annual Cost of Water ($ per acft)	**$1,661**
Annual Cost of Water ($ per 1,000 gallons)	**$5.10**

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 7.5-5 and the option meets each criterion.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality (TCEQ) Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- TCEQ administered Texas Pollutant Discharge Elimination System (TPDES) Storm Water Pollution Prevention Plan;
- General Land Office (GLO) Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department (TPWD) Sand, Shell, Gravel and Marl permit if State-owned streambed is involved.

State and Federal Permitting Requirements:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.
- Coordination with BRA on any potential subordination agreement, subject to availability under the System Operations permit.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 7.5-5. Comparison of Augmentation of Millers Creek Reservoir (Pipeline Option) to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet some needs
2. Reliability	2. Reasonable
3. Cost	3. High
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low to moderate impact
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Low impact due to distance from coast
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	Low to None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

7.5.4 New Dam and Reservoir

Description of Option

Freese, Nichols and Endress Consulting Engineers evaluated three locations for the Millers Creek Reservoir dam in a study completed in 1967.[2] The existing dam is located roughly at the upstream-most site considered in the study. The downstream-most location evaluated in the study is approximately four miles downstream of the existing dam. Construction of a new dam at this location is evaluated herein. 7.5 shows the locations of the existing and proposed dams. The drainage area at the new dam location is 291.5 sq. mi., an approximate increase of 52 sq. mi. over that at the existing dam.

A normal pool elevation of 1,316 ft-msl was assumed for the current evaluation of the new reservoir. The Freese, Nichols and Endress study identified 1,316 ft-msl as the most feasible normal pool elevation due to the presence of oil well heads that would be

[2] Freese, Nichols and Endress Consulting Engineers, "Engineering Report and Feasibility Study for Millers Creek Water Supply Facilities," Prepared for North Central Texas Municipal Water Authority, January 1967.

inundated at higher normal pool elevations. The study also noted that preliminary borings indicated the presence of a natural rock spillway at this elevation. The normal pool elevation of the existing reservoir is 1,334 ft-msl and its dam would be left in place with construction of the new reservoir. Spills and releases from the existing reservoir would be captured by the new reservoir. The surface area and storage volume of the new reservoir with a normal pool at 1,316 ft-msl would be 2,541 acres and 46,645 acft based on the USGS 1:24,000 scale quadrangle maps for the area. The capacity of the existing reservoir was computed by the Texas Water Development Board to be 29,171 acft based on a hydrographic survey conducted in 1993.[3] The new reservoir would provide an approximately 160% increase over the surveyed storage of the existing reservoir. The capacity of the existing reservoir in the 2020 Brazos G WAM, which models existing reservoirs at their current year 2020 capacity, is 22,126 acft.

Preliminary design parameters for the dam were identified in the Freese, Nichols and Endress study. The study recommends an earthen embankment dam with 3:1 downstream side slopes, and upstream side slopes of 3:1 below the normal pool elevation and 2:1 above the normal pool elevation. The study recommends a 20-foot embankment top width. A core trench having 1:1 side slopes and 20-foot bottom width extending to impervious material is also recommended by the study. The study recommends protection of the upstream face of the dam with 8 inches of gravel and 24 inches of riprap.

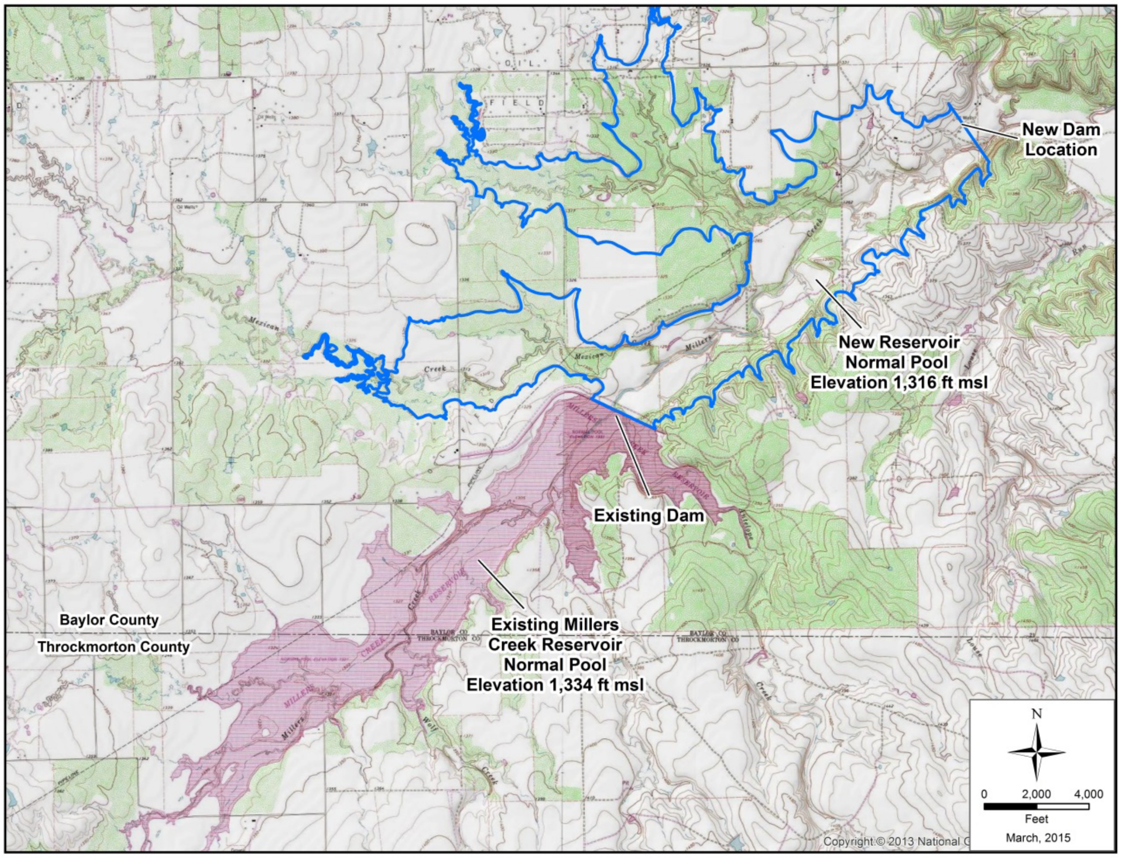
Available Yield

The firm yield that would be available with construction of the new reservoir was estimated using the TCEQ Brazos WAM with the modification to naturalized flow calculations at Millers and Lake Creeks. Subordination of Possum Kingdom Reservoir to both the existing and new Millers Creek reservoirs was assumed for the firm yield calculation. The model computed the streamflow available for impoundment from Millers Creek without causing increased shortages to existing downstream rights. Firm yield was computed subject to the impoundments in the new reservoir having to pass streamflows to meet Senate Bill 3 (SB3) environmental flow criteria.

The calculated firm yield of the new reservoir is 1,000 acft/yr, with the subordination and priority assumptions noted above. Along with a computed 300 acft/yr increase in the firm yield of the existing reservoir due to the subordination of Possum Kingdom Reservoir, the total increase in firm yield that would result from implementing this project is 1,300 acft/yr. Based on a delivery factor of 0.572, the yield impact on Possum Kingdom Reservoir was estimated to be 744 acft/yr for costing purposes. Figure 7.5-10 shows the simulated storage levels of the new reservoir for the 1940 to 1997 historical period, subject to the firm yield of 1,000 acft/yr. The new reservoir experiences long drawdown periods because it is reliant on spills from the existing reservoir for storage recovery. Figure 7.5-11 shows the storage frequency of the new reservoir under the firm yield demand. The frequency shows that reservoir storage is less than half full for a majority of the simulation period.

[3] Texas Water Development Board, “Hydrographic Survey of Miller’s Creek Reservoir,” Prepared for North Central Texas Municipal Water Authority, March 2003.

7.5. New Reservoir Below Millers Creek Reservoir



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The effects of the new reservoir on streamflow in Millers Creek below the new reservoir were computed from the model simulation results. In Millers Creek, the simulated median monthly streamflow below the dam is reduced to zero for all months. It should be noted that the only month with a median monthly streamflow greater than zero without the new reservoir is May with a median streamflow of 0.1 cfs. Figure 7.5-12 illustrates Millers Creek streamflow frequency characteristics with and without the project in place. The frequency characteristics for Millers Creek Reservoir are compared to those downstream of the existing reservoir computed for conditions as they currently exist, without the new reservoir, diversion from Lake Creek, or subordination of Possum Kingdom Reservoir.

Figure 7.5-10. New Reservoir Storage Trace

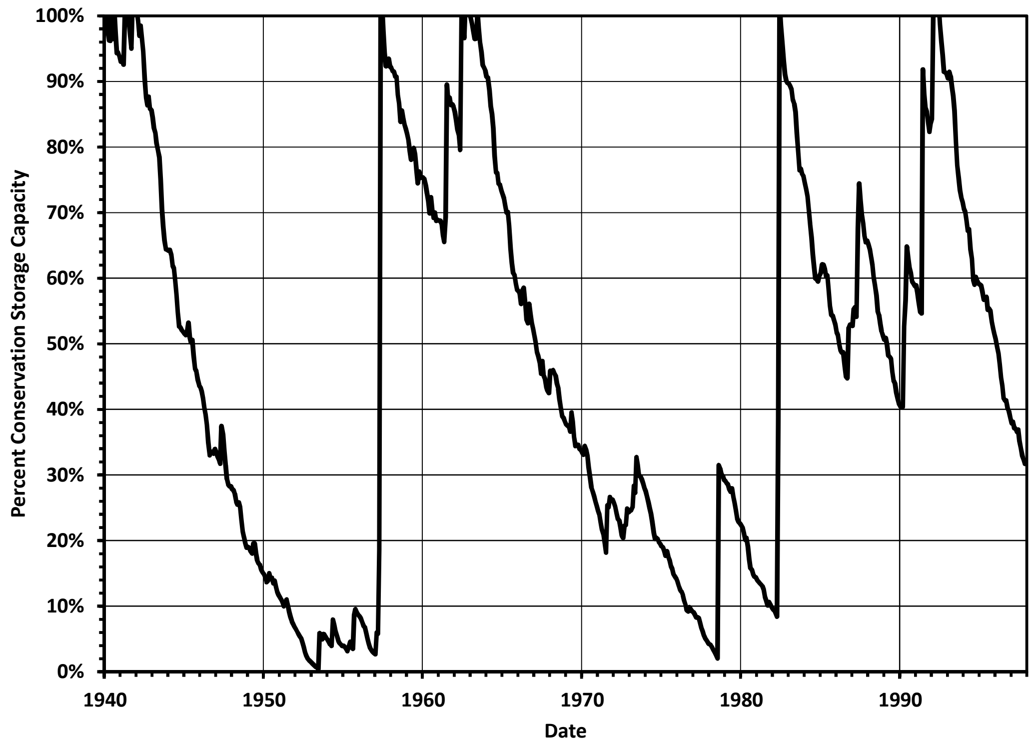


Figure 7.5-11. New Reservoir Storage Frequency

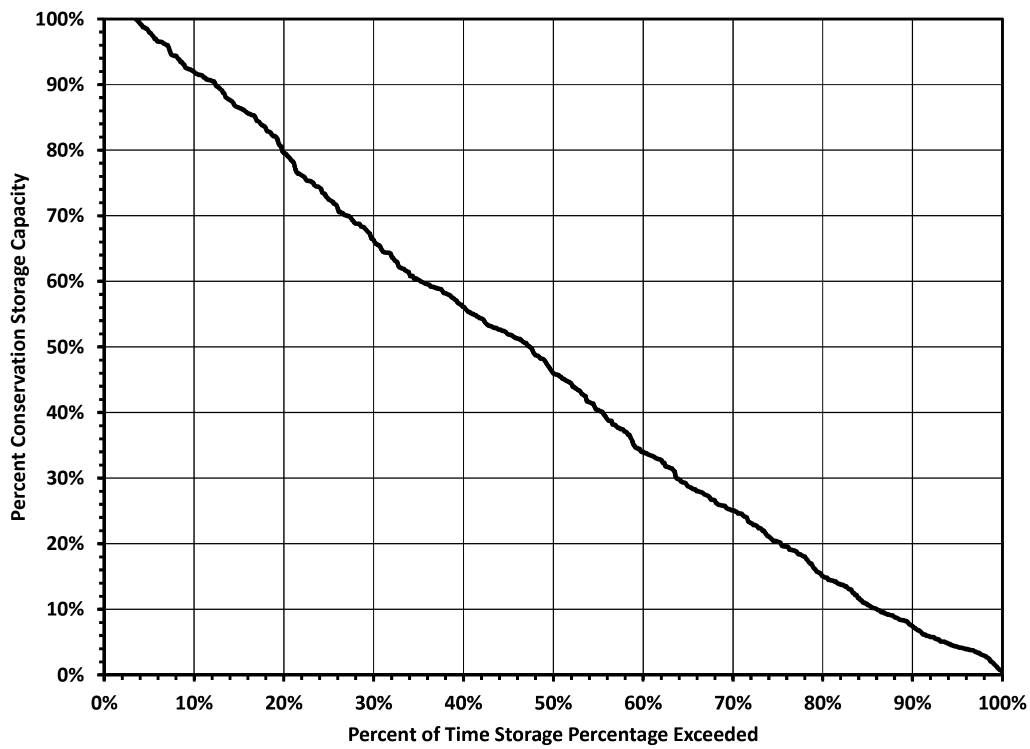
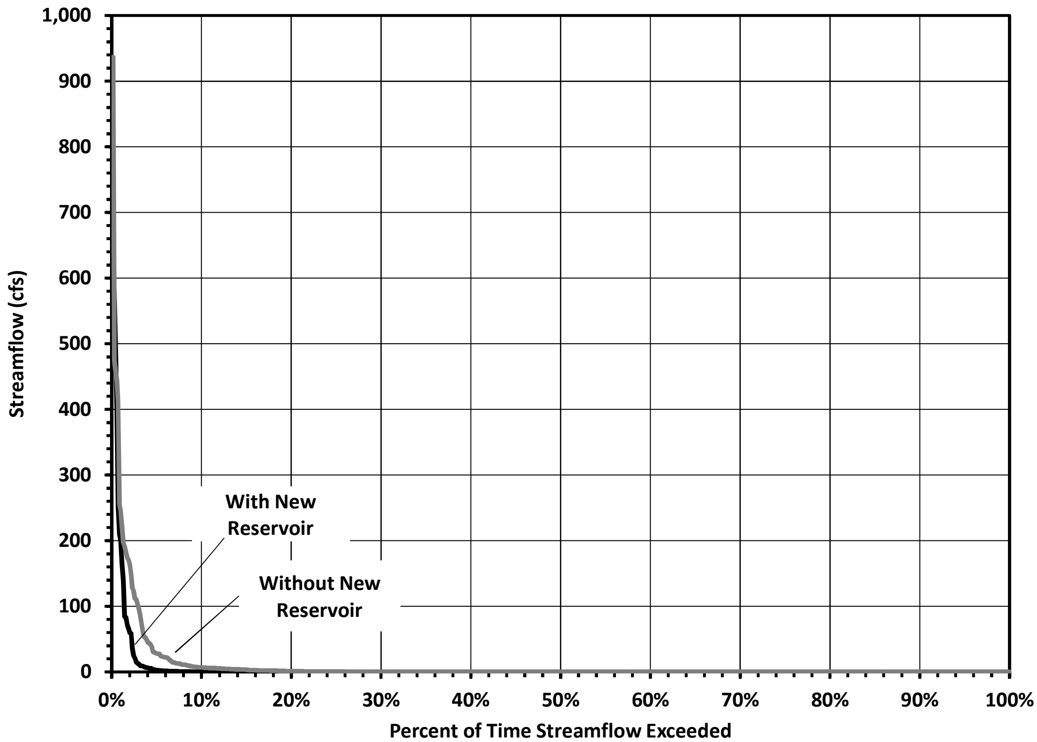


Figure 7.5-12. Comparison of Millers Creek Streamflow Frequency With and Without New Reservoir



Environmental Issues

The environmental issues associated with the four options for augmenting Millers Creek reservoir are discussed together in Section 7.5.6.

Engineering and Costing

Table 7.5-6 summarizes estimated costs for the new dam and reservoir. The total estimated project cost for the new dam and reservoir is $74.4 million. The annual project costs are estimated to be $5.30 million; this includes annual debt service, operation and maintenance, and annual payment to the Brazos River Authority for lost yield in Possum Kingdom Reservoir. The cost for the estimated additional firm yield increase of 1,300 acft/yr translates to an annual unit cost for raw water of $12.50 per 1,000 gallons, or $4,073 per acft.

Table 7.5-6. Cost Estimate for Augmentation of Millers Creek Reservoir (New Reservoir Option)

Item	Estimated Costs for Facilities
Capital Cost	
New Dam and Reservoir	$39,554,000
Integration, Relocations, & Other	$514,000
Total Cost Of Facilities	**$40,068,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$14,024,000
Environmental & Archaeological Studies and Mitigation	$6,524,000
Land Acquisition and Surveying (3,795 acres)	$6,713,000
Interest During Construction (4% for 2 years with a 1% ROI)	$7,070,000
Total Cost Of Project	**$74,399,000**
Debt Service (5.5 percent, 20 years)	$64,000
Reservoir Debt Service (5.5 percent, 40 years)	$4,589,000
Operation and Maintenance	
Dam and Reservoir	$593,000
Purchase of Water (744 acft/yr @ 65.65 $/acft)	$49,000
Total Annual Cost	**$5,295,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**1,300**
Annual Cost of Water ($ per acft)	**$4,073**
Annual Cost of Water ($ per 1,000 gallons)	**$12.50**

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 7.5-7, and the option meets each criterion.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality (TCEQ) Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- TCEQ administered Texas Pollutant Discharge Elimination System (TPDES) Storm Water Pollution Prevention Plan;

- General Land Office (GLO) Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department (TPWD) Sand, Shell, Gravel and Marl permit if State-owned streambed is involved.

State and Federal Permits may require the Following Studies and Plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 7.5-7. Comparison of Augmentation of Millers Creek Reservoir (New Dam and Reservoir Option) to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet some needs
2. Reliability	2. Reasonable
3. Cost	3. High
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impact
2. Habitat	2. Moderate impact
3. Cultural Resources	3. Moderate impact
4. Bays and Estuaries	4. Low impact due to distance from coast
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	Low to None. Some loss of crop land is expected in the inundation area of the new reservoir.

E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

7.5.5 Combined Canal Diversion with New Dam and Reservoir

Description of Option

This option combines the canal diversion from Lake Creek to the existing Miller's Creek Reservoir described in Section 7.5.2 with the new dam and reservoir described in Section 7.5.4. The design features of the two strategies would be the same as previously described. Water diverted from Lake Creek would first be used to fill the existing reservoir and then passed through the existing reservoir to fill the new reservoir.

Available Yield

The yield of the reservoir system, including the existing Millers Creek Reservoir, new reservoir, and Lake Creek diversion canal was computed with the TCEQ Brazos WAM with the modification to naturalized flow calculations at Millers and Lake Creeks. The firm yield simulations include the subordination of Possum Kingdom Reservoir to the existing and new Millers Creek Reservoirs and the canal diversions. Firm yield was computed subject to the impoundments in the new reservoir and canal diversions having to pass streamflows to meet Senate Bill 3 (SB3) environmental flow criteria.

The computed firm yield of Millers Creek Reservoir with the canal diversions is 3,775 acft/yr as noted in Section 7.5.2. Under this demand on Millers Creek Reservoir, the new reservoir firm yield was computed to be 1,650 acft/yr. Therefore, the combined firm yield of the existing reservoir and new reservoir with the canal diversion and subordination assumptions is 5,425 acft/yr, which is an increase of 2,425 acft/yr from the 2020 firm yield of 3,000 acft for the existing Millers Creek Reservoir.

When the canal option and new reservoir option are modeled separately, the firm yield sum is 2,075 acft/yr (1,300 acft/yr from the new reservoir and 775 acft/yr from the canal diversions). When the two options are combined, the system operations increases the combined firm yield by 350 acft/yr to 2,425 acft/yr. Based on a delivery factor of 0.572, the yield impact on Possum Kingdom Reservoir was estimated to be 1,387 acft/yr for costing purposes. Figure 7.5-13 shows the simulated storage levels of the new reservoir for the 1940 to 1997 historical period, subject to the firm yield demand of 1,650 acft/yr. Figure 7.5-14 illustrates the storage frequency of the new reservoir under the same firm yield demand. The storage trace and frequency figures show that the simulated new reservoir levels have large fluctuations and they are below half full almost 40 percent of the time.

Figure 7.5-13. New Reservoir Storage Trace at Firm Yield with Canal Diversion

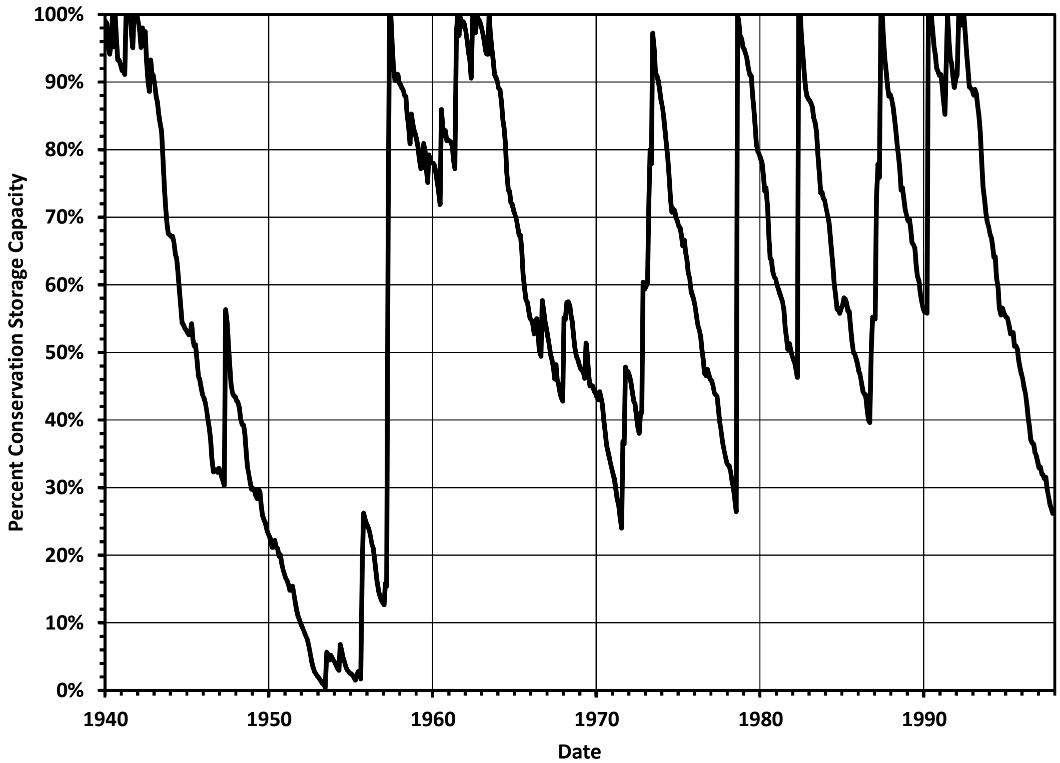
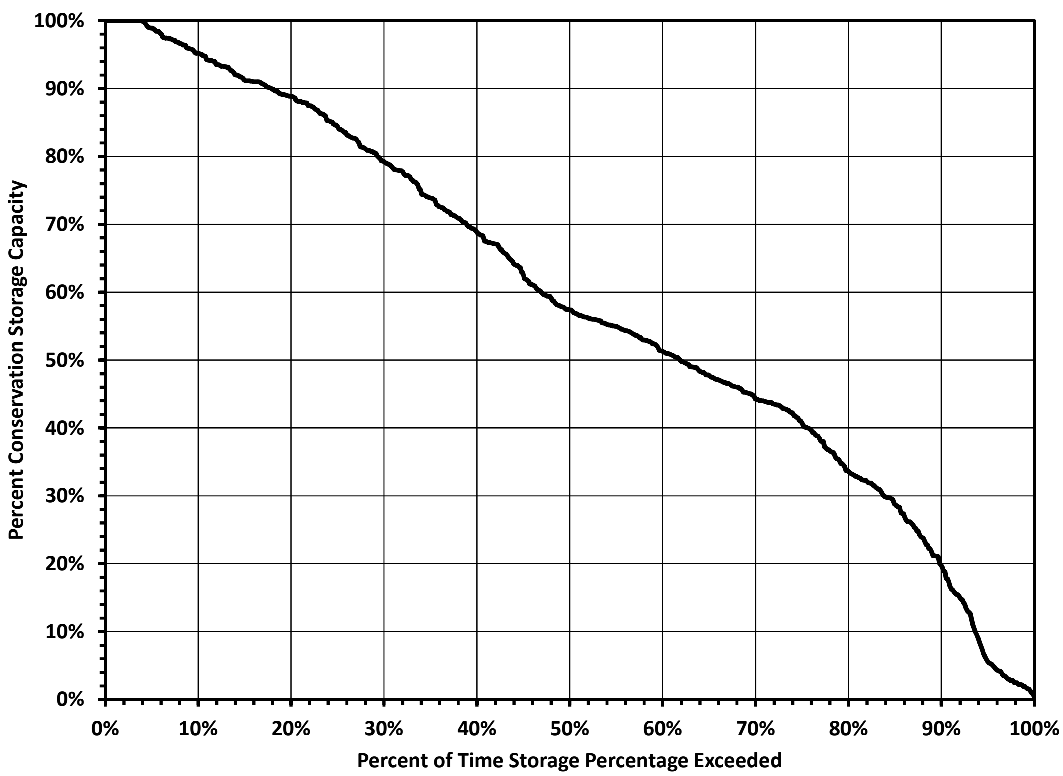


Figure 7.5-14. New Reservoir Storage Frequency at Firm Yield with Canal Diversion



The simulated changes in Lake Creek from the canal diversions show that the median monthly streamflow is reduced to zero for all months similar to the reduction in streamflow as described in Section 7.5.2 and shown in Figure 7.5-6. In Millers Creek, the model-computed median monthly streamflow below the dam is reduced to zero for all months. It should be noted that the only month with a median monthly streamflow greater than zero without the new reservoir is May with a median streamflow of 0.1 cfs.

Figure 7.5-15 and Figure 7.5-16 illustrate the Lake Creek and Millers Creek streamflow frequency characteristics with the project in place. In Lake Creek, the model-computed frequency with the combined projects is slightly reduced from the stand alone canal diversion frequency presented in Section 7.5.2 and shown in Figure 7.5-7. This reduction in streamflow is from additional storage available in the new reservoir allowing canal diversions to be made more often. The frequency characteristics for Millers Creek Reservoir are compared to those downstream of the existing reservoir computed for conditions as they currently exist, without the new reservoir, diversion from Lake Creek, or subordination of Possum Kingdom Reservoir.

Figure 7.5-15. Comparison of Streamflow Frequency below Lake Creek Diversion Point with and without New Reservoir and Canal Diversion

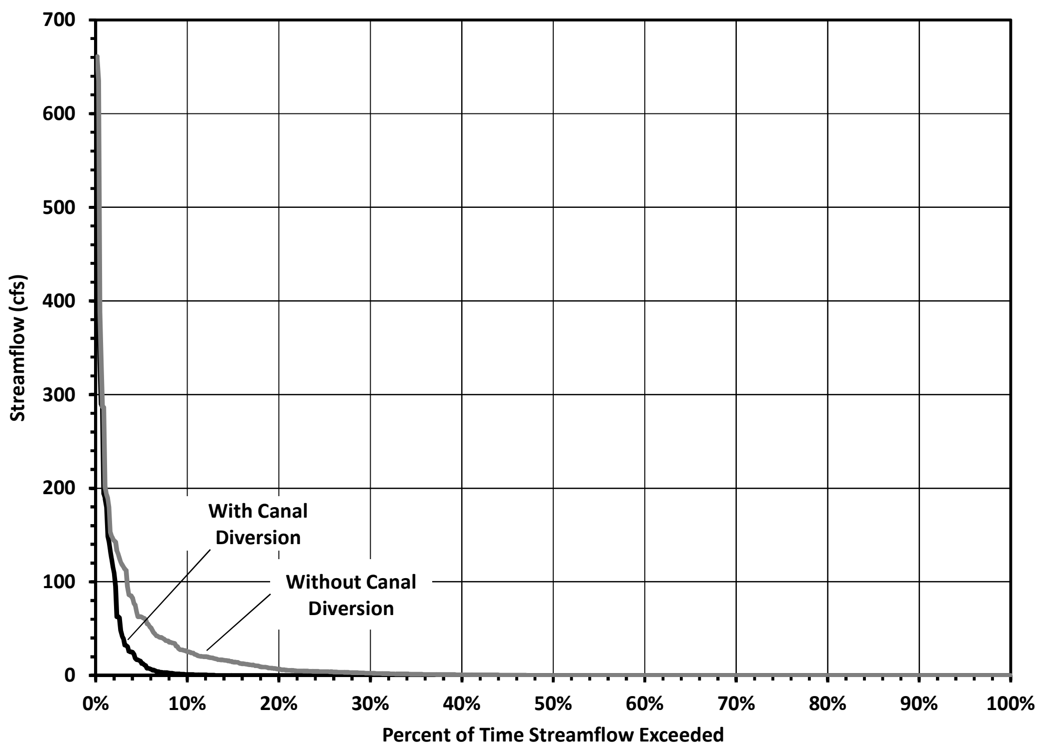
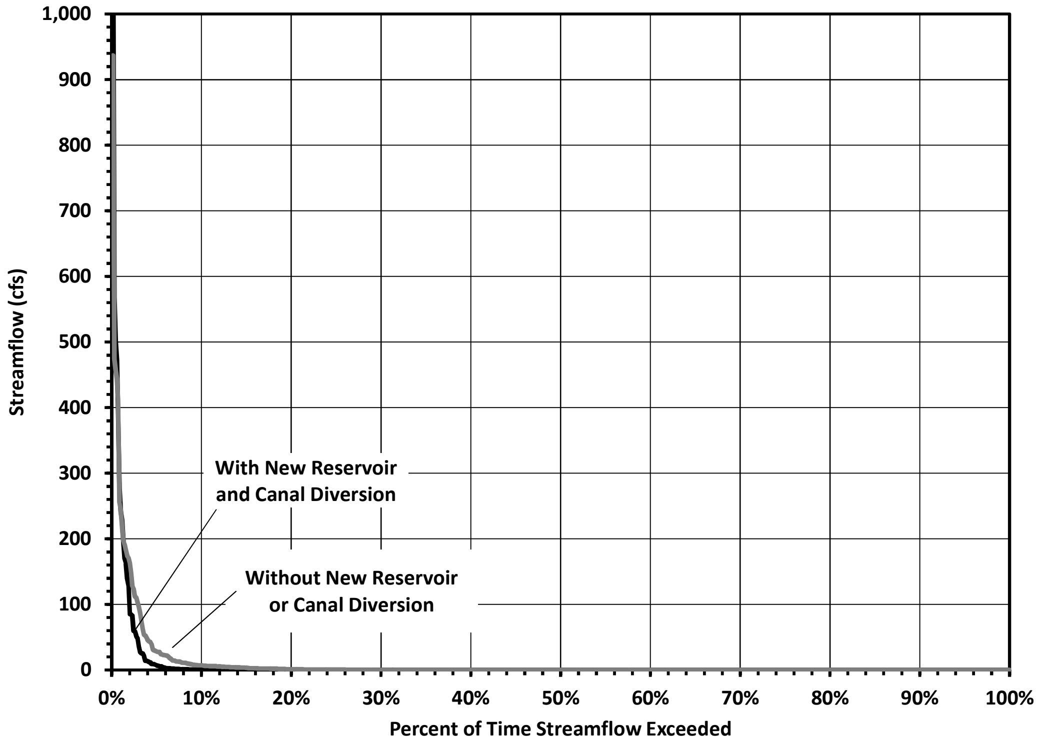


Figure 7.5-16. Comparison of Millers Creek Streamflow Frequency With and Without New Reservoir and Canal Diversion



Environmental Issues

The environmental issues associated with the four options for augmenting Millers Creek reservoir are discussed together in Section 7.5.6.

Engineering and Costing

Table 7.5-8 summarizes estimated costs for the new dam and reservoir with the canal diversion. The total estimated project cost for the combined canal diversion and new dam and reservoir project is $99.9 million. The annual project costs are estimated to be $7.17 million; this includes annual debt service, operation and maintenance, and annual payment to the Brazos River Authority for lost yield in Possum Kingdom Reservoir. The cost for the estimated additional firm yield increase of 2,425 acft/yr translates to an annual unit cost for raw water of $9.07 per 1,000 gallons, or $2,958 per acft.

Table 7.5-8. Cost Estimate for Augmentation of Millers Creek Reservoir (Combined Canal Diversion with New Dam and Reservoir Option)

Item	Estimated Costs for Facilities
Capital Cost	
New Dam and Reservoir	$39,554,000
Lake Creek Channel Dam, Reservoir, and Canal	$16,382,000
Integration, Relocations, & Other	$514,000
Total Cost Of Facilities	**$56,450,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$19,758,000
Environmental & Archaeological Studies and Mitigation	$7,368,000
Land Acquisition and Surveying (4,286 acres)	$7,582,000
Interest During Construction (4% for 3 years with a 1% ROI)	$8,738,000
Total Cost Of Project	**$99,896,000**
Debt Service (5.5 percent, 20 years)	$64,000
Reservoir Debt Service (5.5 percent, 40 years)	$6,178,000
Operation and Maintenance	
Dam and Reservoir	$839,000
Purchase of Water (1,387 acft/yr @ 65.65 $/acft)	$91,000
Total Annual Cost	**$7,172,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**2,425**
Annual Cost of Water ($ per acft)	**$2,958**
Annual Cost of Water ($ per 1,000 gallons)	**$9.07**

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 7.5-9, and the option meets each criterion.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality (TCEQ) Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);

- TCEQ administered Texas Pollutant Discharge Elimination System (TPDES) Storm Water Pollution Prevention Plan;
- General Land Office (GLO) Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department (TPWD) Sand, Shell, Gravel and Marl permit if State-owned streambed is involved.

State and Federal Permits may Require the Following Studies and Plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 7.5-9. Comparison of Augmentation of Millers Creek Reservoir (Combined Canal Diversion with New Dam and Reservoir Option) to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet some needs
2. Reliability	2. Reasonable
3. Cost	3. High
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impact
2. Habitat	2. Moderate impact
3. Cultural Resources	3. Moderate impact
4. Bays and Estuaries	4. Low impact due to distance from coast
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	Low to None. Some loss of crop land is expected in the inundation area of the new reservoir.
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

7.5.6 Environmental Issues

This water management strategy involves four possible scenarios: 1) a diversion dam which will divert water from Lake Creek through a grass-lined canal into Brushy Creek and subsequently into Millers Creek Reservoir; 2) the use of a pipeline instead of a canal to carry the diverted water from Lake Creek to Brushy Creek; 3) development of a new reservoir below Millers Creek Reservoir with no associated Lake Creek diversion; and 4) development of both the new reservoir and diversion of water from Lake Creek via a canal.

Both the Millers Creek Reservoir Augmentation Site, diversion canal and the new reservoir site lie within the Rolling Plains Ecological Region[4]. This region is located east of the High Plains, west of the West Cross Timbers and North Central Prairie, and north of the Edwards Plateau. It is characterized by nearly level to rolling topography, soft prairie sands and clays, juniper breaks, and midgrass prairie. The physiognomy of the

[4] Gould, F.W., G. O. Hoffman, and C.A. Rechenthin, 1960. Vegetational areas of Texas. College Station (TX): Texas A&M University Agricultural Experiment Station. Report L-492.

region varies from open, short to tall, scattered to dense grasslands to savannahs with bunch grasses. Most of the plains are rangeland, but dry-land and irrigated crops are considered increasingly important. Poor range management practices in the past have caused an increase in the density of invasive plant species and subsequently decreased the value of the land for cattle production. Farming and grazing practices have also reduced the abundance and diversity of wildlife in the region.[5] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average precipitation ranges between 24 and 26 inches.[6]

The Seymour Aquifer, an unconsolidated sand and gravel aquifer, is the only major aquifer in the project area. It is formed by alluvial deposits in twenty counties in north central Texas. The Seymour aquifer consists mainly of the scattered erosional remnants of the Seymour Formation of Pleistocene age, which consists of clay, silt, sand, and gravel, that were deposited by eastward-flowing streams. The aquifer generally has less than 100 feet of saturated thickness, but it is an important source of water for domestic, municipal, and irrigation needs.[7]

The physiography of the region includes recharge sand, undissected red beds, loose surficial sand, flood prone areas, and severely eroded land.[8] Three major vegetation types occur within the general vicinity of the project area: Mesquite - Lotebush Shrub, Mesquite-Saltcedar Brush/Woods, and Crops.[9] Variations in these primary types occur with changes in the composition of woody and herbaceous species and localized conditions.

Mesquite-Lotebush Shrub vegetational areas include the following commonly associated plants: mesquite (*Prosopis glandulosa*), lotebush (*Ziziphus obtusifolia*), yucca (*Yucca* spp.), skunkbush sumac (*Rhus trilobata*), agarito (*Berberis trifoliolata*), elbowbush (*Forestiera angustifolia*), tasajillo (*Opuntia leptocaulis*), cane bluestem (*Bothriochloa barbinodis*), silver bluestem (*Bothriochloa saccharoides*), little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), Texas grama (*Bouteloua rigidiseta*), sideoats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua hirsuta*), red grama (*Bouteloua trifida*), tobosagrass (*Pleuraphis mutica*), buffalograss (*Buchloe dactyloides*), Texas wintergrass (*Nasella leucotricha*), purple three-awn (*Aristida purpurea*), Engelmann daisy (*Engellmania peristena*), broom snakeweed (*Gutierrezia sarothrae*), and bitterweed (*Hymenoxys odorata*).

Commonly associated plants of Mesquite-Saltcedar Brush/Woods are mesquite, saltcedar (*Tamarix* sp.), creosotebush (*Larrea tridentata*), cottonwood (*Populus deltoides*), desert willow (*Chilopsis linearis*), giant reed (*Arundo donax*), seepwillow

[5] Telfar, Roy C. 1999. Vegetation Areas of Texas: concepts and Commentary. Journal of the Botanical Institute of Texas 3 (1).

[6] Larkin, T.J. and Bomar, G.W., 1983, Climatic atlas of Texas: Texas Water Development Board Limited Publication 192, 151 p.

[7] Ashworth, John B and Janie Hopkins. 1995. Aquifers of Texas. Texas Water Development Board, Report 345. Austin, Texas.

[8] Kier, R. S., L.E. Garner, and L.F. Brown, Jr. 1977. Land Resources of Texas [map]. Bureau of Economic Geology, University of Texas. Austin, Texas.

[9] McMahan, Craig A., Roy G. Frye and Kirby L. Brown. 1984. The Vegetation Types of Texas Including Cropland. Texas Parks and Wildlife Department, Austin, Texas.

(*Baccharis* sp.), common buttonbush (*Cephalanthus occidentalis*), whitethorn acacia (*Acacia constricta*), Australian saltbush (*Atriplex semibaccata*), fourwing saltbush (*Atriplex canescens*), wolfberry (*Lycium berlandieri*), tasajillo, guayacan (*Guaiacum angustifolium*), alkali sacaton (*Sporobolus airoides*), Johnsongrass (*Sorghum halepense*), saltgrass (*Distichlis spicata*), cattail (*Typha* spp.), bushy bluestem (*Andropogon glomeratus*), and chino grama (*Bouteloua ramosa*). Crop vegetational areas include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

Potential Impacts

Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated from areas near the existing Millers Creek Reservoir, and the Lake Creek diversion point. The diversion would occur at an impoundment created by construction of a channel dam on Lake Creek. Water would then be diverted from the Lake Creek impoundment via a canal or pipeline to Brushy Creek which supplies water to Millers Creek and Millers Creek Reservoir. Under a third option, a new dam and reservoir would be constructed downstream of the existing Miller's Creek Reservoir, providing additional storage for diverted flows to Millers Creek. A fourth option would include construction of the diversion canal along with the new reservoir, providing additional storage of flows from both Millers Creek and the Lake Creek diversion.

The streamflow statistics presented in the previous sections show that median monthly flows in Millers Creek and Lake Creek will decrease as a result of implementing any of the four options. The most significant impacts in Millers Creek would occur with construction of the new dam and reservoir either with or without the canal diversion. Implementation of either of these options would reduce the median monthly flows for all months to zero based on the simulation results. In Lake Creek, the largest impact would occur for construction of the new dam and reservoir with the diversion canal. Under this scenario, the median monthly flow would be reduced to zero for all months.

Although there would be impacts in the immediate vicinity of the project site and downstream, it appears that any of the four options would have minimal influence on total discharge in the Brazos River, in which case there would be minimal influence on freshwater inflows to the Brazos River estuary.

Endangered, Threatened, Candidate and Species of Concern

A total of 28 animal species could potentially occur within the vicinity of the project that are state or federally listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern according to county lists of rare species provided by the U.S. Fish and Wildlife Service (USFWS) and the Texas Parks and Wildlife Department (TPWD) (Table 7.5-10). Listed species include two reptiles, 15 birds, eight mammals, one freshwater mussel, and two fish species. Inclusion in this table does not mean that a species will occur within the project area, but only acknowledges the potential for its occurrence in the project area counties.

Two bird species, two fish species, and three mammal species which are federally-listed as endangered could occur (or historically occurred) in the project area. The bird species include the interior least tern (*Sterna antillarum athalassos*), and whooping crane (*Grus americana*). These birds are seasonal migrants that could pass through the project area. The sharpnose shiner (*Notropis oxyrhynchus*) and smalleye shiner (*Notropis buccula*) have been recently listed as endangered by the USFWS.[10] These two minnows are native to the arid prairie streams of Texas and are considered to be in danger of extinction. The USFWS has designated approximately 623 miles of the Upper Brazos River Basin and the upland areas extending beyond the river channel by 98 feet on each side as critical habitat for these two fish. These areas of the Upper Brazos River Basin occur within the counties of Baylor, Crosby, Fisher, Garza, Haskell, Kent, King, Knox, Stonewall, Throckmorton and Young. Mammal species which are federally listed include the gray wolf (*Canis lupus*), red wolf (*Canis rufus*), and black-footed ferret (*Mustela nigripes*). Both the gray wolf and red wolf are considered to be extirpated within the project counties. Although the black-footed ferret (*Mustela nigripes*) historically occurred in the area, there have been no confirmed reports of this species in Texas since 1963.[11] These listed species are not anticipated to be adversely affected by the proposed reservoir or diversion canal.

There are eight additional species which are listed as threatened by the state of Texas within the project counties. These include the American peregrine falcon (*Falco peregrinus anatum*), bald eagle (*Haliaeetus leucocephalus*), piping plover (*Charadrius melodus*), white-faced ibis (*Plegadis chihi*), Texas kangaroo rat (*Dipodomys elator*), Texas fawnsfoot (*Truncilla macrodon*), Brazos water snake (*Nerodia harteri*), and Texas horned lizard (*Phrynosoma cornutum*). The four state threatened bird species are migrants within the project area and are not anticipated to be adversely affected by the project. The Texas fawnsfoot, a freshwater mussel species is found in rivers and larger streams and is intolerant of impoundment. The Brazos water snake is known to inhabit rocky areas along waterways within the Brazos River Basin. Changes in aquatic habitat within the project area could potentially affect these species. The Texas kangaroo rat lives on clay soils supporting sparse, short grasses and small scattered mesquite bushes and the Texas horned lizard is normally found in varied and sparsely vegetated uplands. Although suitable habitat for the state threatened Texas kangaroo rat and Texas horned lizard may exist within the project area, no impacts to these species are anticipated due to the abundance of similar habit near the project area and the ability of this species to move to those areas. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats. No species specific surveys were conducted in the project area for this report.

Wildlife Habitat

The Lake Creek diversion area would include an eight-foot high channel dam to impound runoff from this watershed. When full, this area would periodically inundate

[10] USFWS. 2014. *Sharpnose Shiner and Smalleye Shiner Protected under the Endangered Species Act*. News Release, August 4, 2014.

[11] Campbell, Linda. 1995. Endangered and Threatened Animals of Texas. Texas Parks and Wildlife Department, Endangered Resources Branch. Austin, Texas.

approximately 360 acres of wildlife habitat. The diversion area is located within an area that is currently used for cropland.

Table 7.5-10. Important Species Having Habitat or Known to Occur in Baylor, Haskell and Throckmorton Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
				BIRDS				
American peregrine falcon	*Falco peregrinus anatum*	0	2	0	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	0	1	0	Migrant throughout the state.	DL	--	Possible Migrant
Baird's sparrow	*Ammodramus bairdii*	0	1	0	Found in shortgrass prairie with scattered low bushes and matted vegetation migratory in western part of state.	--	--	Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	0	2	0	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Ferruginous hawk	*Buteo regalis*	0	1	0	Open country primarily prairies, plains, and badlands nesting near water.	--	--	Possible Migrant
Interior least tern	*Sterna antillarum athalassos*	0	3	0	Nests along sand and gravel bars in braided streams	LE	E	Resident
Mountain plover	*Charadrius montanus*	0	1	0	Non-breeding, shortgrass plains and fields	--	--	Nesting/ Migrant
Piping plover	*Charadrius melodus*	0	2	0	A small pale shorebird of open sandy beaches and alkali flats, the Piping Plover is found along the Atlantic and Gulf coasts.	LT	T	Possible Migrant

Table 7.5-10. Important Species Having Habitat or Known to Occur in Baylor, Haskell and Throckmorton Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Red knot	*Calidris canutus rufa*	0	1	0	Migratory species within Texas.	PT	--	Possible Migrant
Snowy plover	*Charadrius alexandriunu s*	0	1	0	Potential migrant winters along coast	--	--	Possible Migrant
Sprague's pipit	*Anthus spragueii*	0	1	0	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Western burrowing owl	*Athene cunicularia hypugaea*	1	1	1	Open grasslands, especially prairie, plains and savanna	--	--	Resident
Western snowy plover	*Charadrius alexandrines nivosus*	0	1	0	Potential migrant, winters along coast.	--	--	Possible Migrant
White-faced Ibis	*Plegadis chihi*	0	2	0	Prefers freshwater marshes and irrigated fields.	--	T	Resident
Whooping crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Potential Migrant
FISHES								
Sharpnose shiner	*Notropis oxyrhynchus*	1	3	3	Endemic to Brazos River drainage. Found in large rivers.	LE	--	Resident
Smalleye shiner	*Notropis buccula*	1	3	3	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident
MAMMALS								

Table 7.5-10. Important Species Having Habitat or Known to Occur in Baylor, Haskell and Throckmorton Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Black-footed ferret	*Mustela nigripes*	0	3	0	Extirpated, inhabited prairie dog towns.	LE	--	Historic Resident
Black-tailed prairie dog	*Cynomys ludovicianus*	1	1	1	Found on dry, flat, short grasslands.	--	--	Resident
Cave myotis bat	*Myotis velifer*	0	1	0	Roosts colonially in caves, rock crevices	--	--	Resident
Gray wolf	*Canis lupus*	0	3	0	Extirpated formerly known in western two-thirds of the state.	LE	E	Historic Resident
Pale Townsend's big-eared bat	*Corynorhinus townsendii pallescens*	0	1	0	Roosts in caves and old buildings. Hibernates in winter.	--	--	Resident
Plains spotted skunk	*Spilogale putorius interrupta*	1	1	1	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	0	3	0	Extirpated.	LE	E	Historic Resident
Texas kangaroo rat	*Dipodomys elator*	1	2	2	Associated with scattered mesquite shrubs and short grasses.	--	T	Resident
MOLLUSKS								
Texas fawnsfoot	*Truncilla macrodon*		2		Found in rivers and larger streams, intolerant of impoundment.	C	T	Resident
REPTILES								

Table 7.5-10. Important Species Having Habitat or Known to Occur in Baylor, Haskell and Throckmorton Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Brazos water snake	*Nerodia harteri*	1	2	2	Found in upper Brazos River drainage in shallow water with rocky bottoms.	--	T	Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
PT=Proposed Threatened
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

TPWD, 2014. Annotated County List of Rare Species –Haskell County 9/4/2014, Throckmorton County 9/4/2014 and Baylor County 1/22/2014.
USFWS, 2014. Endangered Species List for Haskell, Throckmorton and Baylor Counties, Texas. http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action, September 19, 2014.

The ROW for the diversion canal connecting Lake Creek with Brushy Creek (that will transport diverted water to Millers Creek) is estimated to be approximately 1.8-miles long with a maximum top width of 287 feet. This would result in approximately 63 acres of impact to wildlife habitat. Vegetation found within the diversion canal ROW includes areas used for cropland and rangeland. Utilization of areas already impacted by agricultural uses generally reduces the overall habitat loss impact on species found within the project area. Impacts resulting from the use of a pipeline to transport the water from the diversion area rather than a canal would be fewer due to the fact that it would be buried and include only maintained ROW areas.

The addition of the new reservoir site below the existing Millers Creek Reservoir would involve the loss of approximately 2,541 acres of additional wildlife habitat at the normal pool elevation and approximately four stream miles of riparian habitat. Vegetation types found within this site include portions of Mesquite-Lotebush Shrub, Mesquite-Saltcedar Brush/Woods and Crop areas.

A number of vertebrate species would be expected to occur within the general vicinity of the project site as indicated by county occurrence records.[12] These include one species of salamander, five species of frogs and toads, three species of turtles, five species of lizards and skinks, and 17 species of snakes. Mammals expected to occur within the

[12] Dixon, James R. and R. Kathryn Vaughan. 1998. *Amphibians and Reptiles of Texas Counties Checklist*. Texas A & M University, College Station, Texas.

project area include the coyote (*Canis latrans*), common raccoon (*Procyon lotor*), white-tailed deer (*Odocoileus virginianus*), Texas mouse (*Peromyscus attwateri*), and plains pocket gopher (*Geomys bursarius*) among others.[13] A variety of bird and fish species would be expected to inhabit the site, with distributions and population densities limited by the types and quality of habitats available.

Cultural Resources

A review of the Texas Historical Commission Texas Historic Sites Atlas data base indicated that there are no National Register Properties, National Register Districts, State Historic Sites, Historical Markers, or cemeteries listed near any of the proposed project areas. A search of the Texas Archeological Sites Atlas database indicates that three archeological sites have been documented within the general vicinity of the proposed diversion canal. These sites, which lie outside the current project alignment, were recorded as prehistoric habitation sites. Two of these sites (41KX95 and 41HK1) were recommended for further testing in 1973. Prior to construction of the diversion canal or the new reservoir area, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any cultural resources are present within the area. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archeological and Historic Preservation Act (PL93-291). Taking into consideration that the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the THC regarding impacts to cultural resources. The project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding any impacts to waters of the United States or wetlands.

Natural Resource Potential Impacts

Potential impacts to natural resources include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would have an impact associated with lower stream flows and a possible resulting impact on water quality. Millers Creek Reservoir would have an increase in median monthly inflow that would enhance water quality and offset a decline in water levels. Riparian habitat currently within the reservoir area would be inundated, and areas of terrestrial habitat would be impacted by the canal or pipeline construction and maintenance activities.

Specific project features such as canals and pipelines generally have sufficient design flexibility to avoid most impacts or significantly mitigate potential impacts to geographically limited environmental and cultural resource sites. Field surveys conducted at the appropriate phase of development should be employed to minimize the impacts of project construction and operations on sensitive resources.

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[13] Davis, William B., and David J. Schmidly. 1994. The Mammals of Texas. Texas Parks and Wildlife, Austin, Texas.

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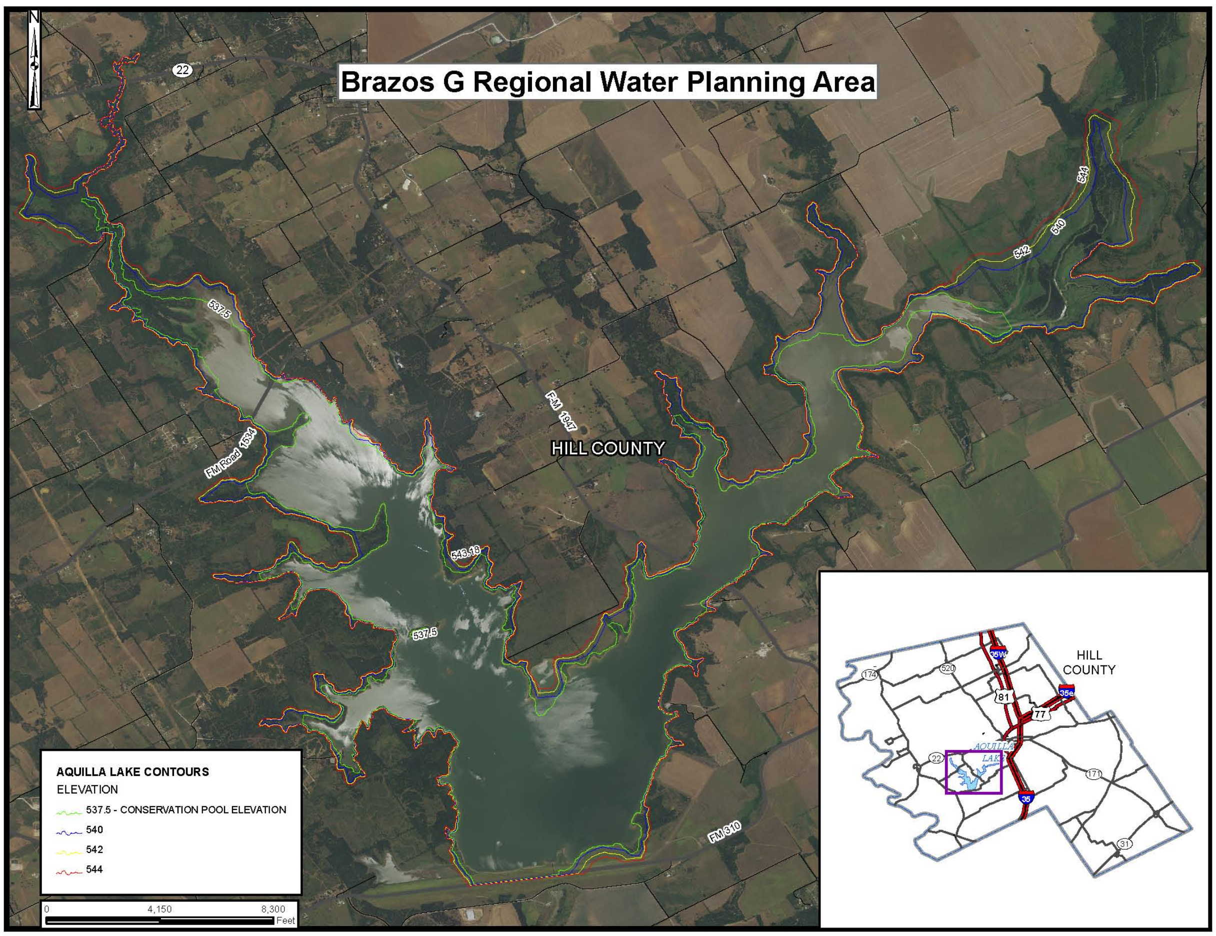
7.6 Lake Aquilla Storage Reallocation

7.6.1 Description of Option

Figure 7.6-1 is an aerial map of Lake Aquilla showing the water surface area at the four alternative pool elevations discussed in this section. According to a March 2008 volumetric survey, Aquilla Lake has 44,566 acre-feet of storage and a surface area of 3,066 acres at the current conservation elevation of 537.5 feet[1]. The flood storage in the reservoir extends up to elevation 556.0 feet (Table 7.6-1)

Figure 7.6-1. Aerial Map of Lake Aquilla with Elevation Contours



1 Texas Water Development Board, Volumetric Survey of Aquilla Lake March 2008 Survey, April 2009.

Table 7.6-1. Lake Aquilla Characteristics[2]

Owner	U.S. Army Corps of Engineers
Water Supply Contract	
Owner	Brazos River Authority
Storage amount	52,400 acft
Texas Water Right	
Number	CA 12-5158
Owner	Brazos River Authority
Diversion	13,896 acft/yr
Storage	52,400 acft at elevation 537.5 ft-msl
Priority date	October 25, 1976
Flood Pool	
Top elevation	556 ft
Storage[3]	93,634 acft
Conservation Pool	
Top elevation	537.5 ft
Surface area	3,066 ac
Storage	44,566ac-ft
Sediment Pool[1]	
Top elevation	503 ft
Storage	106 ac-ft

7.6.2 Available Yield

As part of this plan, the TCEQ Brazos WAM was used to calculate yields for Lake Aquilla under the following four scenarios:

- Existing – Current conservation storage elevation of 537.5 ft-msl
- Scenario 1 – Raise conservation elevation to 540.0 feet, an increase of 2.5 ft-msl
- Scenario 2 – Raise conservation elevation to 542.0 feet, an increase of 4.5 ft-msl
- Scenario 3 – Raise conservation elevation to 544.0 feet, an increase of 6.5 ft-msl

[2] Certificate of Adjudication 12-5158

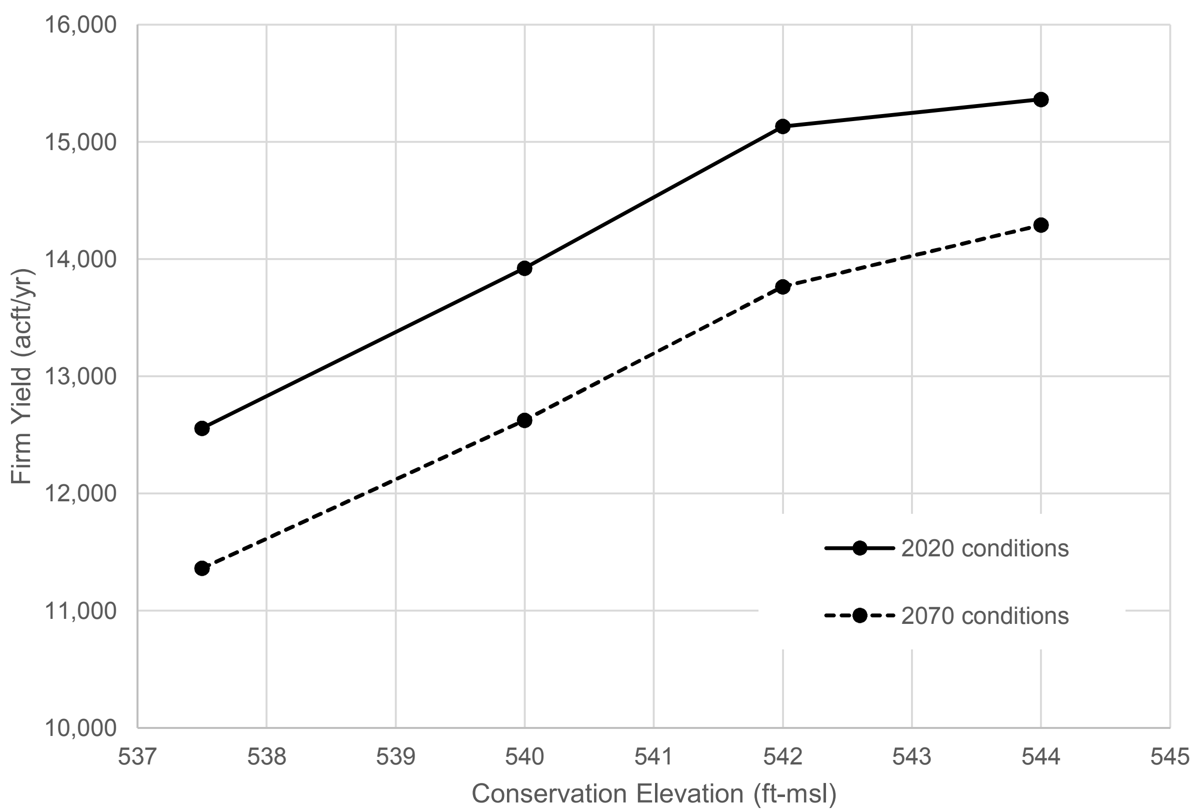
[3] Based on original volumetric survey, October 1983

Figure 7.6-1 shows the elevation contours for the four proposed conservation storage elevations. Table 7.6-2 is a summary of the yield studies. Figure 7.6-2 shows the relationship of yield to conservation storage elevation.

Table 7.6-2. Comparison of Firm Yield of Lake Aquilla with Flood Storage Reallocation using Brazos G WAM for 2020 and 2070 Conditions

Scenario	Top of Conservation Elevation (feet)	2020 Conditions			2070 Conditions		
		Storage (acft)	Firm Yield (acft/yr)	Yield Increase (acft/yr)	Storage (acft)	Firm Yield (acft/yr)	Yield Increase (acft/yr)
Existing	537.50	43,174	12,556		37,374	11,361	
Scenario 1	540.00	51,267	13,922	1,366	45,467	12,624	1,263
Scenario 2	542.00	58,258	15,131	2,575	52,458	13,764	2,403
Scenario 3	544.00	66,748	15,362	2,806	60,948	14,290	2,929

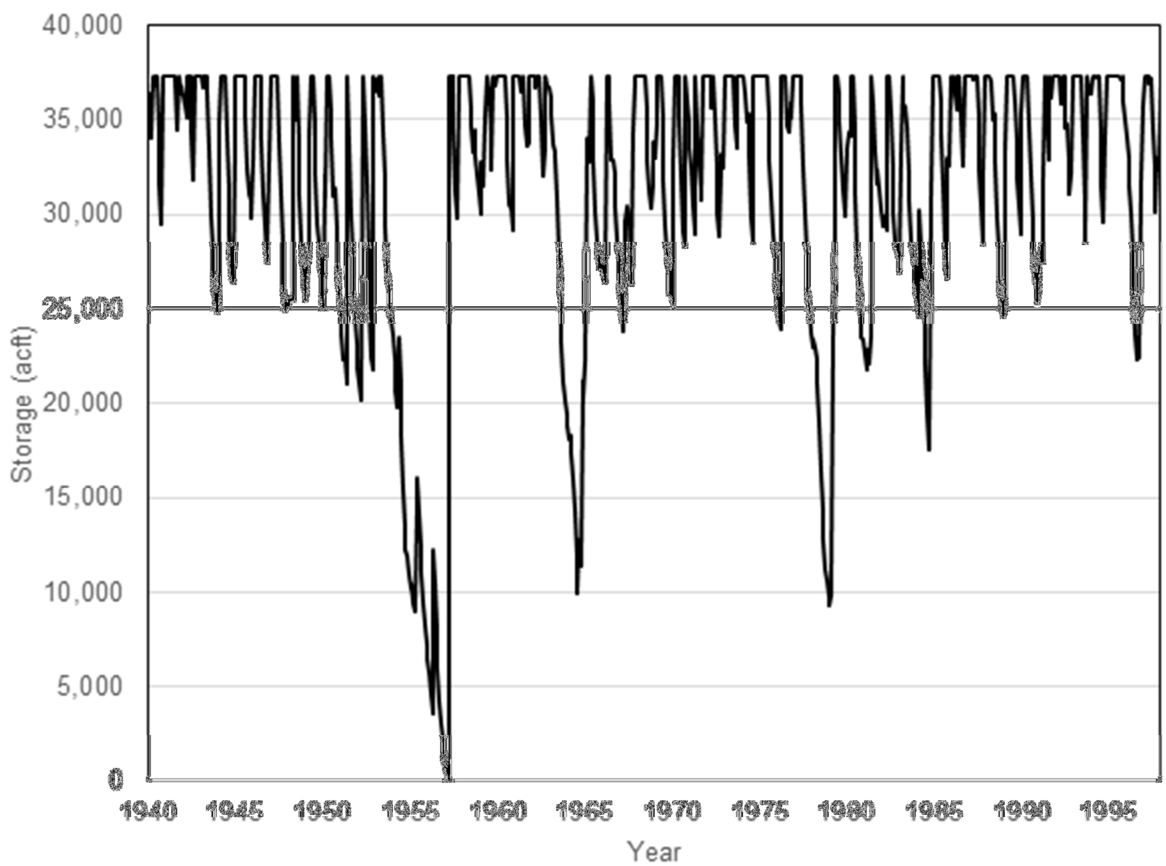
Figure 7.6-2. 2020 and 2070 Yield vs. Storage Elevation for Lake Aquilla



Currently the USACE has the authority to reallocate at its own discretion up to 50,000 acre-feet or 15 percent of the total flood storage, whichever is less. The yield increase of the reservoir with the discretionary authority is about 2,400 acft/yr declining only slightly by 2070. Additional reallocation of flood storage to conservation storage requires the approval of the U.S. Congress. Scenario 1 is within the discretionary authority of the USACE. Since raising the conservation pool 4.5 feet to 542 ft-msl (i.e., Scenario 2) will reallocate 15,073 acft, this amount corresponds to the discretionary authority, and therefore would not require congressional approval[4]. Scenario 3 is well above the discretionary authority and would require the approval of Congress.

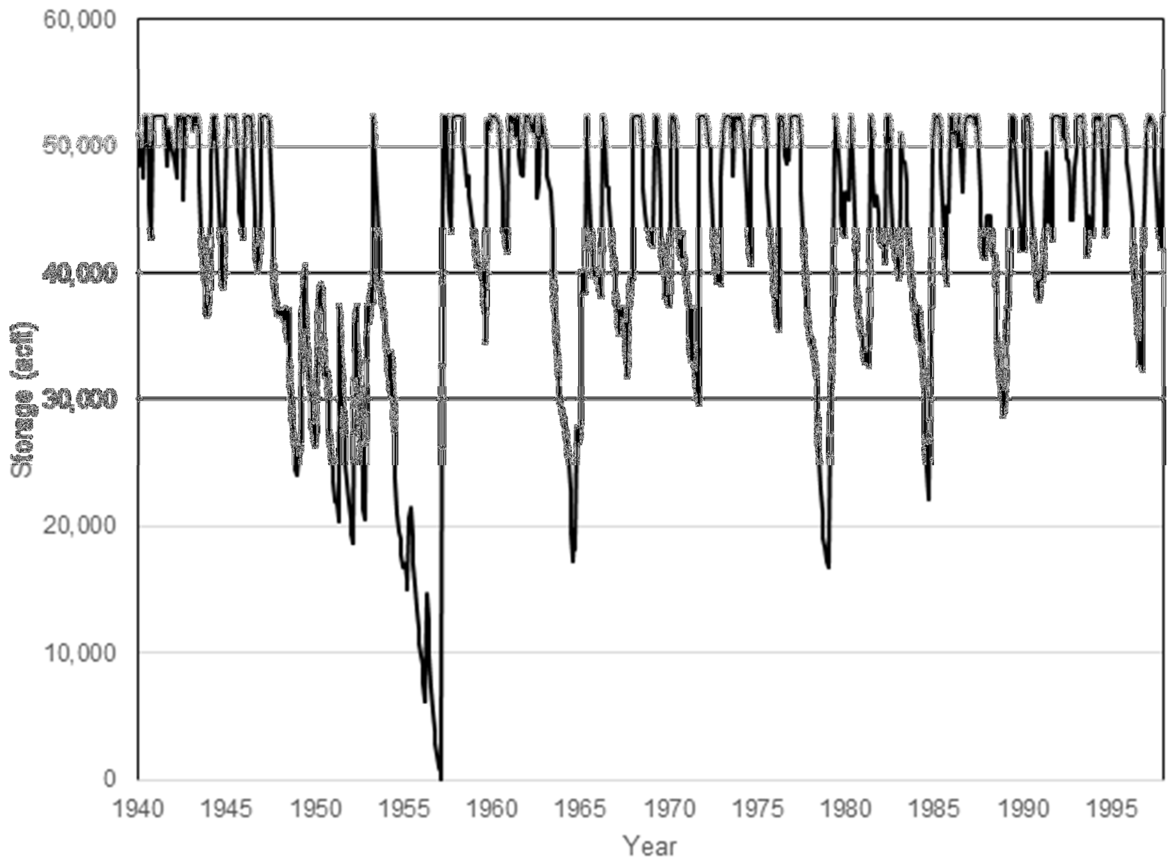
By 2070 the estimated storage of Lake Aquilla decreases to 37,374 acre-feet. The calculated firm yield in 2070 from the Brazos G WAM at the current conservation storage of elevation of 537.5 feet is 11,361 acre-feet. In Scenario 2 (elevation 542.0 feet) the yield of Lake Aquilla is 13,764, resulting in 2,403 acre-feet of additional yield in 2070. This is a 21% increase over the existing scenario yield. Figure 7.6-3 and Figure 7.6-4 show the storage trace in the year 2070 for Lake Aquilla under existing conditions and with Scenario 2, respectively. This strategy could potentially be provided supply under the BRA System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. If an entity other than the BRA were to sponsor and pursue this strategy, then an agreement with the BRA would be required to address concerns related to the potential subordination of the System Operation strategy.

Figure 7.6-3. 2070 Lake Aquilla Storage Trace, Current Conservation Elevation (537.5 ft-msl)



[4] United States Army Corps of Engineers, Middle Brazos Systems Assessment, Phase II Aquilla, Water Supply Reallocation Report and Environmental Assessment, DRAFT version, December 2014.

Figure 7.6-4. 2070 Lake Aquilla Storage Trace, Alternative 2 (Conservation Elevation at 542 ft-msl)



7.6.3 Environmental Issues

The greatest impact on the environment from the reallocation of storage in Lake Aquilla is the loss of terrestrial habitat due to higher lake levels.

Table 7.6-3 compares the water surface area at conservation under current conditions to the three storage alternatives described above. In Alternative 3, the maximum reallocation scenario considered for this strategy, the reservoir will inundate an additional 947 acres at conservation. All of the land up to the flood pool elevation around Lake Aquilla is owned by the USACE. The USACE manages the area around the lake as a wildlife management area.

Wetlands and bottomland hardwoods located in the upper reaches of the lake will be impacted by raising the conservation elevation. Endangered and threatened species reported in Hill County include the whooping crane, black-capped vireo, and golden-cheeked warbler. Species which are candidates for listing are the smalleye shiner and sharpnose shiner. The USCOE did not encounter any habitats that appeared suitable for the black-capped vireo or golden-cheeked warbler in the affected area. It is possible that whooping cranes may temporarily use the affected habitat during their annual migration but an encounter would be rare. The USCOE did not find evidence of either the smalleye shiner or sharpnose shiner within the study area.

Table 7.6-3. Comparison of Water Surface Areas with Reallocation

Scenario	Elevation (feet)	Surface Area (ac)	Change in Surface Area (ac)
Existing	537.5	3,066	-
Alternative 1	540.0	3,388	322
Alternative 2	542.0	3,613	547
Alternative 3	544.0	4,013	947

7.6.4 Engineering and Costing

Scenario 2 approximately restores original reservoir capacity and is selected for evaluation. The cost of minor improvements to Lake Aquilla dam is included in the cost estimate. Studies on the slope stability, seepage, and geotechnical aspects of the project have already been conducted and so are not included in the estimate. The total project costs for the reallocation of storage to an elevation of 542 ft-msl is $21.9 million. Detailed costs are shown in Table 7.6-4.

Very few recreational facilities are located at Lake Aquilla, so the reallocation of flood storage will have a low impact on recreation. Other infrastructure that may be affected and needing relocation are utility lines, petroleum pipelines and roads. Another cost is the mitigation of the loss of terrestrial habitat, which is potentially high for this project.

Table 7.6-4. Cost Estimate Summary for Lake Aquilla Pool Reallocation

Item	Estimated Costs for Facilities
Improvements to Dam	$1,901,000
Relocation	$1,773,000
TOTAL COST OF FACILITIES	**$3,674,000**
Engineering, Legal Costs and Contingencies	$1,286,000
Environmental & Archaeology Studies and Mitigation	$898,000
Real Estate	$0
Storage Allocation	$14,180,000
Slope Stability, Seepage and Geotechnical Studies	$0
Water Rights Permit from TCEQ	$1,000,000
Administrative Cost for USACE Storage Reallocation Process	$588,000
Interest During Construction (12 months)	$261,000
TOTAL COST OF PROJECT	**$21,887,000**
ANNUAL COSTS	
Debt Service (5.5 percent, 20 years)	$1,831,000
Operation and Maintenance	$244,000
TOTAL ANNUAL COST	**$2,075,000**
Available Project Yield (acft/yr)	**2,400**
Annual Cost of Water ($ per acft)	**$865**
Annual Cost of Water ($ per 1,000 gallons)	**$2.65**

7.6.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 7.6-5, and the option meets each criterion. Seepage related concerns have been expressed about Lake Aquilla dam in the past. A dam safety evaluation completed in August 2013 found that embankment stability has not been much of an issue and that seepage appears well controlled by measures implemented as part of the USACE's Risk Management Plan and is currently being monitored with a system of piezometers, relief wells and collection weirs. The habitat lost to inundation will have to be mitigated. Mitigation property has not yet been identified. If Alternative 3 is chosen, Congressional authorization for the project will be required. A summary of the implementation steps for the project is presented below.

Potential Regulatory Requirements

- Texas Commission on Environmental Quality (TCEQ) Water Right and Storage permits; potentially dependent on the granting of the BRA System Operations permit
- U.S. Army Corps of Engineers (USACE) Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act)
- USACE Section 404 permits for pipeline stream crossings, discharges of fill into wetlands and waters of the U.S. for construction, and other activities
- TCEQ administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan
- Texas General Land Office Easement if State-owned land or water is involved
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if a state-owned streambed is involved

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies
- Wildlife habitat mitigation plan that may require acquisition and management of additional land
- Flow releases downstream to maintain aquatic ecosystems
- Assessment of impacts on Federal- and State-listed endangered and threatened species
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resources recovery and cataloging, which would require coordination with the Texas Historical Commission

Land Acquisition Issues

- Land acquired for reservoir and/or mitigation plans could include market transactions or other local landowner agreements
- Additional acquisition of rights-of-way and/or easements may be required
- Possible relocations or removal of residences, utilities, roads, or other structures

Table 7.6-5. Comparison of Reallocation of Storage in Lake Aquilla Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low (540 ft) to moderate (544 ft) impacts on bottomland hardwood and fish and wildlife resources. Lake sedimentation may create significant amounts of shallow wetlands that might benefit migratory water fowl.
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Low impact due to distance from coast
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low (540 ft) to moderate (544 ft) impacts on wetlands
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

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7.7 Lake Granger Reallocation

7.7.1 Description of Option

Reservoirs owned by the United States Army Corps of Engineers (USACE) typically serve multiple functions, including flood control, water supply and recreation. Most USACE reservoirs contain a significant amount of storage dedicated to flood control. This flood control storage is used to temporarily hold flood waters in the top few feet of the reservoir to reduce flooding downstream. It is possible to increase the available water supply from these reservoirs by changing some of the flood control storage to the reservoir storage dedicated to water supply, or conservation storage. This process is commonly called reallocation. The USACE has the authority to reallocate at its own discretion up to 50,000 acre-feet or 15 percent of the total flood storage, whichever is less. Additional reallocation of flood storage to conservation storage requires the approval of the U.S. Congress. The Brazos River Authority (BRA) and the USACE have been continuing an evaluation of the feasibility of reallocating storage in several federal reservoirs. This section evaluates reallocation in Lake Granger as a potential water management strategy.

Lake Granger is located in Williamson County, Texas approximately seven miles east of the City of Granger and 10 miles northeast of Taylor (Figure 7.7-1). The Flood Control Act of 1953 authorized the construction of Granger Lake for flood control, water conservation, fish and wildlife habitat, and recreation. Construction of Granger Dam began in 1972 and it began impounding the San Gabriel River in the Brazos River Basin in 1980. The original conservation storage capacity was 65,500 acft at elevation 504 ft-msl, but has since been reduced by sedimentation to 51,822 acft (Table 7.7-1). The total storage in Lake Granger is approximately 230,522 acft, with 77.5% of the storage reserved for flood control, and 22.5% for water supply (Table 7.7-1).

Lake Granger was intended to be one of three lakes on the San Gabriel River. However, the proposed South Fork Lake was never constructed. Granger Dam was originally designed to support a conservation pool elevation of 512 ft-msl, so that when the South Fork Lake was completed the conservation pool at Lake Granger could be raised eight feet above its current level. This unique history makes Lake Granger an appealing option for reallocation because it requires few dam improvements and relocations, and the USACE already owns the necessary real estate.

Figure 7.7-1. Map of Lake Granger showing Contour at 510 ft

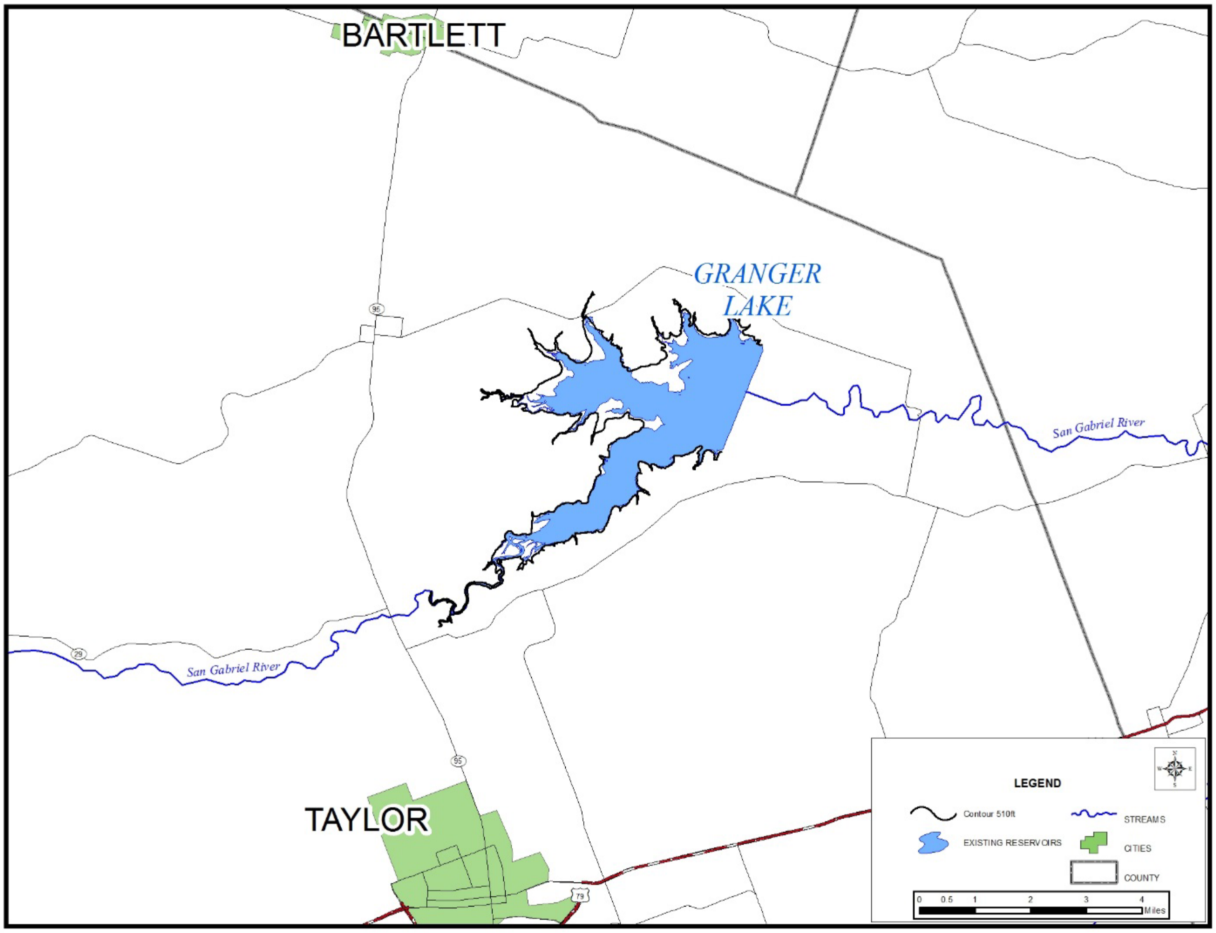

Table 7.7-1. Lake Granger Characteristics

Owner	U.S. Army Corps of Engineers
Water Supply Contract	
Owner	Brazos River Authority
Storage amount	65,500 acft
Texas Water Right	
Number	CA 12-5163
Owner	Brazos River Authority
Diversion	19,840 acft/yr
Storage	65,500 acft
Priority date	February 12, 1968
Flood Pool[1]	
Top elevation	528 ft-msl
Storage	178,700 acft
Conservation Pool[2]	
Top elevation	504 ft-msl
Surface area	4,159 ac
Storage	51,822 acft
Inactive Storage[3]	
Storage	0 acft

1. Based on original 1980 survey. Represents volume of flood pool only (i.e., volume between 504 ft-msl and 528 ft-msl assuming no sedimentation in flood pool).
2. Based on 2013 TWDB volumetric survey. Represents volume from 528 ft-msl and below.
3. Based on 2013 TWDB volumetric survey. Invert elevation (outlet works) at 457 ft-msl,

7.7.2 Available Supply

The Brazos Water Availability Model (WAM) Run 3 with Senate Bill 3 environmental flows was used to calculate yields for Lake Granger under the following two scenarios:

Existing – Current conservation storage elevation of 504.0 ft-msl

Scenario 2 – Raise conservation elevation to 510.0 ft-msl, an increase of 6 feet, which corresponds to the maximum discretionary authority of the USACE.

Figure 7.7-1 shows the surface area of the reservoir after reallocation. Table 7.7-2 is a summary of the firm yield analyses. The current storage in Lake Granger is expected to decrease from 47,917 to 36,271 acre-feet by 2070 due to sedimentation. Based on the WAM, the estimated firm yield in 2070 at the current conservation storage of elevation of 504.0 feet is 11,810 acre-feet per year. In Scenario 2 (elevation 510.0 feet), the yield of Lake Granger is 13,750 acre-feet per year, resulting in 1,940 acre-feet of additional yield in 2070, or a 16% increase over the existing scenario yield. This strategy could potential be provided supply under the BRA System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. If an entity other than the BRA were to sponsor and pursue this strategy, then an agreement with the BRA would be required to address concerns related to the potential subordination of the System Operation strategy.

Table 7.7-2. Storage Capacities and Yields for Existing and Reallocation Scenarios in Lake Granger

Scenario	Top of Conservation Elevation (feet)	2020 conditions			2070 conditions		
		Storage (acft)	Firm Yield (acft/yr)	Yield Increase (acft/yr)	Storage (acft)	Firm Yield (acft/yr)	Yield Increase (acft/yr)
Existing	504.00	47,971	15,290	0	36,271	11,810	0
Scenario 2	510.00	77,976	16,860	1,570	66,276	13,750	1,940

7.7.3 Environmental Issues

In Scenario 2, which corresponds to the maximum discretionary authority of the USACE, the reservoir will inundate an additional 1,586 acres at the new conservation elevation. Most of the private property around the lake consists of farm fields, but there is wildlife habitat in the floodplain above the lake and in other government property around the lake which would be adversely affected by the pool raise. The impacts could be significant due to the lack of available habitat in this area. Although Golden Cheeked Warblers habitat is found in Williamson County, it is unlikely to find adequate habitat around Lake Granger for the Warbler or other threatened and endangered species. A more detailed study of the expected habitat loss needs to be conducted in order to determine mitigation requirements. According to the Phase I Information Paper, there are currently 98 known cultural resources sites at Lake Granger. These sites need to be evaluated to determine if they are eligible for inclusion in the National Register of Historic Places. A complete survey of impacted cultural resources needs to be conducted to determine the full extent of cultural resources within the flood pool of Lake Granger.

7.7.4 Engineering and Costing

Table 7.7-3 summarizes the estimated cost for this option. The dam improvements costs include minor improvements to Granger Dam to store the additional capacity as well as slope stability, seepage and geotechnical studies. There are very few recreational facilities located at Lake Granger, so the reallocation of flood storage will have a low impact on recreation. The USACE owns the land up to 533 ft-msl, which is above the top of the flood pool at 528 ft-msl, so the real estate costs are zero. The estimated cost for water supply storage was based on the updated investment cost of the reallocated flood control storage as a proportion of the additional storage to total useable storage, which is 30,005 acft (15 percent increase). The updated total investment cost for Lake Granger was estimated to be about $123,013,000, so the increase in cost for water supply storage was estimated to be $18,452,000. The estimate for annual operation and maintenance cost is based on a 3-year average (2013-2015) operation and maintenance bill for the BRA based on 7.7% of the total usable storage. The reallocation will provide the BRA with 34% of the storage, so the increase in their O&M bill is expected to be about $609,000 per year. The total project costs for the reallocation of storage to an elevation of 510 ft-msl is $28.7 million. Given a yield of 1,940 acft/yr and a cost of $3,011,000 per year, the annual cost of water is $1,552 per acre-foot ($4.76 per 1,000 gallons).

Table 7.7-3. Cost Estimate Summary for Reallocation of Storage in Lake Granger

Item	Estimated Costs
Capital Costs	
Improvements to Dam	$3,300,000
Relocations	$354,000
Total Capital Cost	$3,654,000
Engineering, Legal Costs and Contingencies	$1,279,000
Environmental & Archaeology Studies and Mitigation	$893,000
Real Estate	$0
Storage Reallocation (15 percent)	$18,452,000
Water Rights Permit from TCEQ	$1,500,000
Administrative Cost for USACE Storage Reallocation Process	$2,585,000
Interest During Construction (12 months)	$347,000
Total Project Cost	$28,710,000
Annual Costs	
Debt Service (5.5 percent, 20 years)	$2,402,000
Operation and Maintenance	$609,000
Total Annual Cost	$3,011,000
Available Project Yield (acft/yr)	1,940
Annual Cost of Water ($ per acft)	$1,552
Annual Cost of Water ($ per 1,000 gallons)	$4.76

7.7.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 7.7-4, and the option meets each criterion.

Table 7.7-4. Comparison of Reallocation of Storage in Lake Granger Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low to moderate impacts possible
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Low impact due to distance from coast
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	Low to none
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal shortages
F. Requirements for Interbasin Transfers	None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

7.7.6 Potential Regulatory Requirements

Implementation of reallocation of storage in Lake Granger will require several steps including a detailed reallocation study performed by the U.S. Army Corps of Engineers and authorization from the U.S. Congress. An outline of the reallocation process is provided below:

1. Local sponsor requests the U.S. Army Corps of Engineers perform a reallocation study. Indicate local interest, purpose, financial capability, etc.
2. Reallocation studies are performed in two phases and follow the General Investigation Process consisting of a Reconnaissance Report and a Feasibility Study. Specific funding would be required for a reallocation study. A reallocation study includes the following:

   a. Define existing project
   b. Define current and projected water supply needs
   c. Alternative solutions considered
   d. Analysis of alternatives
      i. Reallocation of flood control storage
      ii. Raise top of flood control pool
      iii. Reallocate existing conservation pool/power pool
      iv. Hydropower compensation and other hydropower issues
      v. Other
      vi. No action
      vii. Screening of alternatives
      viii. Selection rationale and selection of a plan
   e. Selected plan
      i. Value of storage reallocation
      ii. Impacts of reallocation
      iii. Public involvement
      iv. Environmental impacts
      v. Hydropower compensation and other hydropower issues
   f. Recommended plan
3. NEPA Compliance
4. U.S. Army Corps of Engineers Headquarter Approval of Reallocation Study
5. Authorization from U.S. Congress
6. U.S. Army Corps of Engineers and Local Sponsor execute water supply contract based on Water Supply Storage Reallocation
7. Water Rights Permits from TCEQ, potentially dependent on the granting of the BRA System Operations permit

7.8 Lake Stillhouse Hollow Reallocation

7.8.1 Description

Reservoirs owned by the United States Army Corps of Engineers (USACE) typically serve multiple functions, including flood control, water supply and recreation. Most USACE reservoirs contain a significant amount of storage dedicated to flood control. This flood control storage is used to temporarily hold flood waters in the top few feet of the reservoir to reduce flooding downstream. It is possible to increase the available water supply from these reservoirs by changing some of the flood control storage to the reservoir storage dedicated to water supply, or conservation storage. This process is commonly called reallocation. The USACE has the authority to reallocate at its own discretion up to 50,000 acre-feet or 15 percent of the total flood storage, whichever is less. Additional reallocation of flood storage to conservation storage requires the approval of the U.S. Congress. The Brazos River Authority (BRA) and the USACE have been continuing an evaluation of the feasibility of reallocating storage in several federal reservoirs. This section evaluates reallocation in Lake Stillhouse Hollow as a potential water management strategy.

Lake Stillhouse Hollow is located in Bell County, Texas approximately five miles southwest of the City of Belton and impounds the Lampasas River in the Brazos River Basin. The location of Lake Stillhouse Hollow is shown in Figure 7.8-1. The reservoir was completed in 1968 by the U.S. Army Corps of Engineers (USACE) for the primary purpose of flood control, but it also provides fish and wildlife habitat, recreation and is a major municipal water source for Bell County and nearby communities. Additionally, a pipeline connects Lake Stillhouse to Lake Georgetown to augment the supply of Georgetown in dry years. The original conservation storage capacity was 235,700 acft at elevation 622 ft-msl, but has since been reduced by sedimentation to 227,825 acft (Table 7.8-1). The total storage in Lake Stillhouse Hollow is approximately 622,525 acft, with 63.4% of the storage reserved for flood control, and 36.6% for water supply (Figure 7.8-1).

Figure 7.8-1. Map of Lake Stillhouse Hollow showing Contour at 629 ft

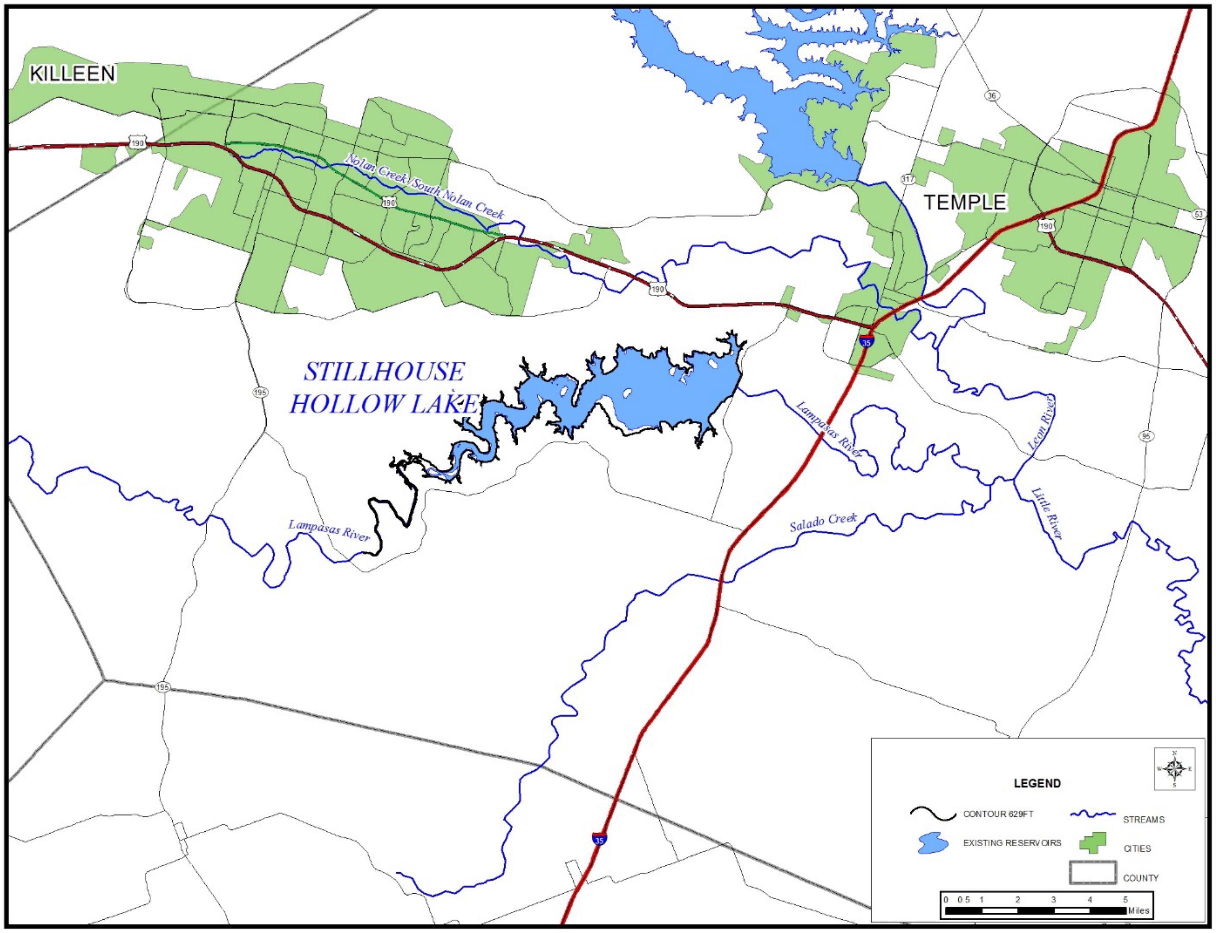

Table 7.8-1. Lake Stillhouse Hollow Characteristics

Owner	U.S. Army Corps of Engineers
Water Supply Contract	
Owner	Brazos River Authority
Storage amount	235,700 acft
Texas Water Right	
Number	CA 12-5161
Owner	Brazos River Authority
Diversion	67,768 acft/yr
Storage	235,700 acft between 569 ft and 622 ft-msl
Priority date	December 16, 1963
Flood Pool1	
Top elevation	666 ft-msl
Storage	394,700 acft
Conservation Pool2	
Top elevation	622 ft-msl
Surface area	6,484 ac
Storage	227,825 acft

1. Based on original 1968 survey. Represents volume of flood pool only (i.e., volume between 622 ft-msl and 666 ft-msl assuming no sedimentation in flood pool).
2. Based on 2005 TWDB volumetric survey. Represents volume from 622 ft-msl and below.

7.8.2 Available Supply

The Brazos Water Availability Model (WAM) Run 3 with Senate Bill 3 environmental flows was used to calculate yields for Lake Stillhouse Hollow under the following two scenarios:

- Existing – Current conservation storage elevation of 622.0 ft-msl
- Scenario 2 – Raise conservation elevation to 629.0 ft-msl, an increase of 7 feet, which corresponds to the maximum discretionary authority of the USACE.

Figure 7.8-1 shows surface area of the reservoir with reallocation. Table 7.8-2 is a summary of the firm yield analyses. The storage in Lake Stillhouse Hollow is expected to decrease to 214,045 acre-feet by 2070. Based on the assumptions reflected in the WAM, the estimated firm yield in 2070 at the existing conservation storage of elevation of 622.0

feet is 61,156 acre-feet per year. In Scenario 2 (elevation 629.0 feet), the yield of Lake Stillhouse Hollow is 63,799 acre-feet per year, resulting in 2,643 acre-feet of additional yield in 2070, or a 4% increase over the existing scenario yield. This strategy could potentialy be provided supply under the BRA System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. If an entity other than the BRA were to sponsor and pursue this strategy, then an agreement with the BRA would be required to address concerns related to the potential subordination of the System Operation strategy.

Table 7.8-2. Storage Capacities and Firm Yields for Existing Storage and Flood Pool Storage Reallocation in Lake Stillhouse Hollow

Scenario	Top of Conservation Elevation (feet)	2020 conditions			2070 conditions		
		Storage (acft)	Firm Yield (acft/yr)	Yield Increase (acft/yr)	Storage (acft)	Firm Yield (acft/yr)	Yield Increase (acft/yr)
Existing	622.00	224,645	62,033	0	214,045	61,156	0
Scenario 2	629.00	272,100	64,775	2,742	261,500	63,799	2,643

* Scenario 2 corresponds to USACE's maximum discretionary authority to reallocate

7.8.3 Environmental Issues

In Scenario 2, which corresponds to the maximum discretionary authority of the USACE, the reservoir will inundate an additional 750 acres at the new conservation elevation. Mitigation would be required for impacted wetlands along the main river channel. A pool raise would impact juvenile woody species and grasslands. Lake Stillhouse Hollow contains habitat for the Golden Cheeked Warbler[1]. A more detailed study of the expected habitat loss needs to be conducted in order to determine mitigation requirements. According to the Phase I Information Paper, there are currently 47 known cultural resources sites at Lake Stillhouse Hollow. Of these, 3 have been determined eligible for inclusion in the National Register of Historic Places (NRHP), 14 have been found ineligible, and 30 have yet to be evaluated. The remaining sites need to be evaluated to determine if they are eligible for inclusion in the NRHP. A complete survey of impacted cultural resources needs to be conducted to determine the full extent of cultural resources within the flood pool of Lake Stillhouse Hollow.

7.8.4 Engineering and Costing

Table 7.8-3 summarizes the estimated cost for this option. There are numerous recreational facilities at Lake Stillhouse Hollow, so the cost of relocations is higher than at Lakes Aquilla, Granger or Whitney. The dam improvements costs include minor improvements to Stillhouse Hollow Dam to store the additional capacity as well as slope stability, seepage and geotechnical studies. The USACE owns the land up to 671 ft-msl, which is above the top of the flood pool at 666 ft-msl, so the real estate costs are zero. The estimated cost for water supply storage was based on the updated investment cost

[1] Information Paper (Feasibility Scoping Meeting Documentation) for Brazos River Basin Systems Assessment Interim Feasibility Study Phase I, July 2008.

of the reallocated flood control storage as a proportion of the additional storage to total useable storage (47,455 acft / 595,500 acft or 8 percent). The updated total investment cost for Lake Granger was estimated to be around $171,600,000, so the increase in cost for water supply storage was estimated to be $13,728,000. The estimate for annual operation and maintenance cost is based on a 3-year average (2013-2015) operation and maintenance bill for the BRA based on 34% of the total usable storage (usable storage is the conservation storage plus flood storage). The reallocation will provide the BRA with 42% of the storage, so the increase in their O&M bill is expected to be around $51,000 per year. The total project costs for the reallocation of storage to an elevation of 629 ft-msl is $36.6 million. Given a yield of 2,643 acft/yr and a cost of $3,110,000 per year, the annual cost of water is $1,177 per acre-foot ($3.61 per 1,000 gallons).

Table 7.8-3. Cost Estimate Summary for Reallocation of Storage in Lake Stillhouse Hollow

Item	Estimated Costs
Capital Costs	
Improvements to Dam	$1,100,000
Relocations	8,905,000
Total Capital Cost	10,005,000
Engineering, Legal Costs and Contingencies	$3,502,000
Environmental & Archaeology Studies and Mitigation	$2,445,000
Real Estate	$0
Storage Reallocation (8%)	$13,728,000
Water Rights Permit from TCEQ	$1,500,000
Administrative Cost for USACE Storage Reallocation Process	$4,601,000
Interest During Construction (12 months)	$772,000
Total Project Cost	$36,553,000
Annual Costs	
Debt Service (5.5 percent, 20 years)	$3,059,000
Operation and Maintenance	$51,000
Total Annual Cost	**$3,110,000**
Available Project Yield (acft/yr)	2,643
Annual Cost of Water ($ per acft)	$1,177
Annual Cost of Water ($ per 1,000 gallons)	$3.61

[1] Based on estimates to address potential constraints for pool reallocation stated in Information Paper (FSM Documentation) for Brazos River Basin Systems Assessment Interim Feasibility Study Phase I, July 2008.

7.8.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 7.8-4, and the option meets each criterion.

Table 7.8-4. Comparison of Reallocation of Storage in Lake Stillhouse Hollow Option to Plan Development Criteria

Impact Category		Comment(s)	
A.	Water Supply		
1.	Quantity	1.	Sufficient to meet needs
2.	Reliability	2.	High reliability
3.	Cost	3.	Reasonable
B.	Environmental factors		
1.	Environmental Water Needs	1.	Low impact
2.	Habitat	2.	Low to moderate impacts possible
3.	Cultural Resources	3.	Low to moderate impact
4.	Bays and Estuaries	4.	Low impact due to distance from coast
5.	Threatened and Endangered Species	5.	Low impact
6.	Wetlands	6.	Low to moderate impacts possible
C.	Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation	
D.	Threats to Agriculture and Natural Resources	Low to none	
E.	Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal shortages	
F.	Requirements for Interbasin Transfers	None	
G.	Third Party Social and Economic Impacts from Voluntary Redistribution	None	

7.8.6 Potential Regulatory Requirements

Implementation of reallocation of storage in Lake Stillhouse Hollow will require several steps including a detailed reallocation study performed by the U.S. Army Corps of Engineers and authorization from the U.S. Congress. An outline of the reallocation process is provided below:

Local sponsor requests the U.S. Army Corps of Engineers perform a reallocation study. Indicate local interest, purpose, financial capability, etc.

Reallocation studies are performed in two phases and follow the General Investigation Process consisting of a Reconnaissance Report and a Feasibility Study. Specific funding would be required for a reallocation study. A reallocation study includes the following:

1) Define existing project
2) Define current and projected water supply needs
    i) Alternative solutions considered

- ii) Analysis of alternatives
  - (1) Reallocation of flood control storage
  - (2) Raise top of flood control pool
  - (3) Reallocate existing conservation pool/power pool
  - (4) Hydropower compensation and other hydropower issues
  - (5) Other
  - (6) No action
  - (7) Screening of alternatives
  - (8) Selection rationale and selection of a plan
- iii) Selected plan
  - (1) Value of storage reallocation
  - (2) Impacts of reallocation
  - (3) Public involvement
  - (4) Environmental impacts
  - (5) Hydropower compensation and other hydropower issues
- iv) Recommended plan

3) NEPA Compliance
4) U.S. Army Corps of Engineers Headquarter Approval of Reallocation Study
5) Authorization from U.S. Congress
6) U.S. Army Corps of Engineers and Local Sponsor execute water supply contract based on Water Supply Storage Reallocation
7) Water Rights Permits from TCEQ, potentially dependent on the granting of the BRA System Operations permit

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7.9 Lake Whitney Reallocation

7.9.1 Description of Option

Lake Whitney is a major impoundment located on the Brazos River approximately 30 miles north of the City of Waco in Hill and Bosque Counties. The location of Lake Whitney is shown in Figure 7.9-1. Lake Whitney was completed in 1951 by the U.S. Army Corps of Engineers for the primary purposes of flood control, water conservation, and production of hydroelectric power. The total storage in Lake Whitney is 1,999,500 acft, making it the largest reservoir in the Brazos River Basin. The vast majority of storage in Lake Whitney is for flood control, comprising 1,372,400 acft (68.6 percent of the total reservoir storage). The original conservation storage capacity was 627,100 acft at elevation 533 ft-msl, but it has since been reduced by sedimentation to 554,203 acft. The capacity below elevation 520 ft-msl is reserved for power head and sediment storage, and has a capacity of 320,711 acft according to the most recent survey (Figure 7.9-1). In 1972, the top of the power pool was raised from 520 ft-msl to 533ft-msl, and the top of power head reserve was raised from 510 ft-msl to 520 ft-msl, making 248,000 acft of storage available to hydropower[1]. In 1982, approximately 20 percent of the hydropower storage (50,000 acft) was reallocated to water conservation storage. A water right was issued to the Brazos River Authority (BRA) that authorizes the BRA to divert and use 18,336 acft/yr from the water conservation storage (Table 7.9-1).

Hydroelectric power generation from Lake Whitney is administered through the Southwestern Power Administration (SWPA), a federal agency. The SWPA has contracted with the Brazos Electric Power Cooperative to provide annual energy in the amount of 1,200 kWh per kilowatt of peaking power, with the energy not to exceed 200 kWh per kilowatt in any one month, or 600 kWh per kilowatt during four consecutive months. Whitney provides 30,000 kWh of peaking power. For purposes of this plan, the monthly energy demands were assumed to be 6,000,000 kWh in July and August, 2,000,000 kWh in June and September, and 2,500,000 kWh in each of the eight other months, for a total of 36,000,000 kWh per year.

The potential for reallocation of the hydropower storage and inactive storage at Lake Whitney to water conservation storage has been studied in various forms in the past and is an option for developing additional water supply in the Brazos River Basin[2]. The conversion of storage to water supply purposes at Lake Whitney can produce a significant supply of water that could be utilized by a number of entities throughout the Brazos River Basin. Potential users include entities in Bosque County and Johnson County, as well as entities downstream in Region H.

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[1] Whitney Reservoir Section 216 Initial Appraisal Report. Prepared by the U.S. Army Corps of Engineers. December 2014.

[2] Texas Water Resources Institute, “Reservoir/River System Reliability Considering Water Rights and Water Quality,” Texas A&M University, March 1994.

Figure 7.9-1. Map of Lake Whitney

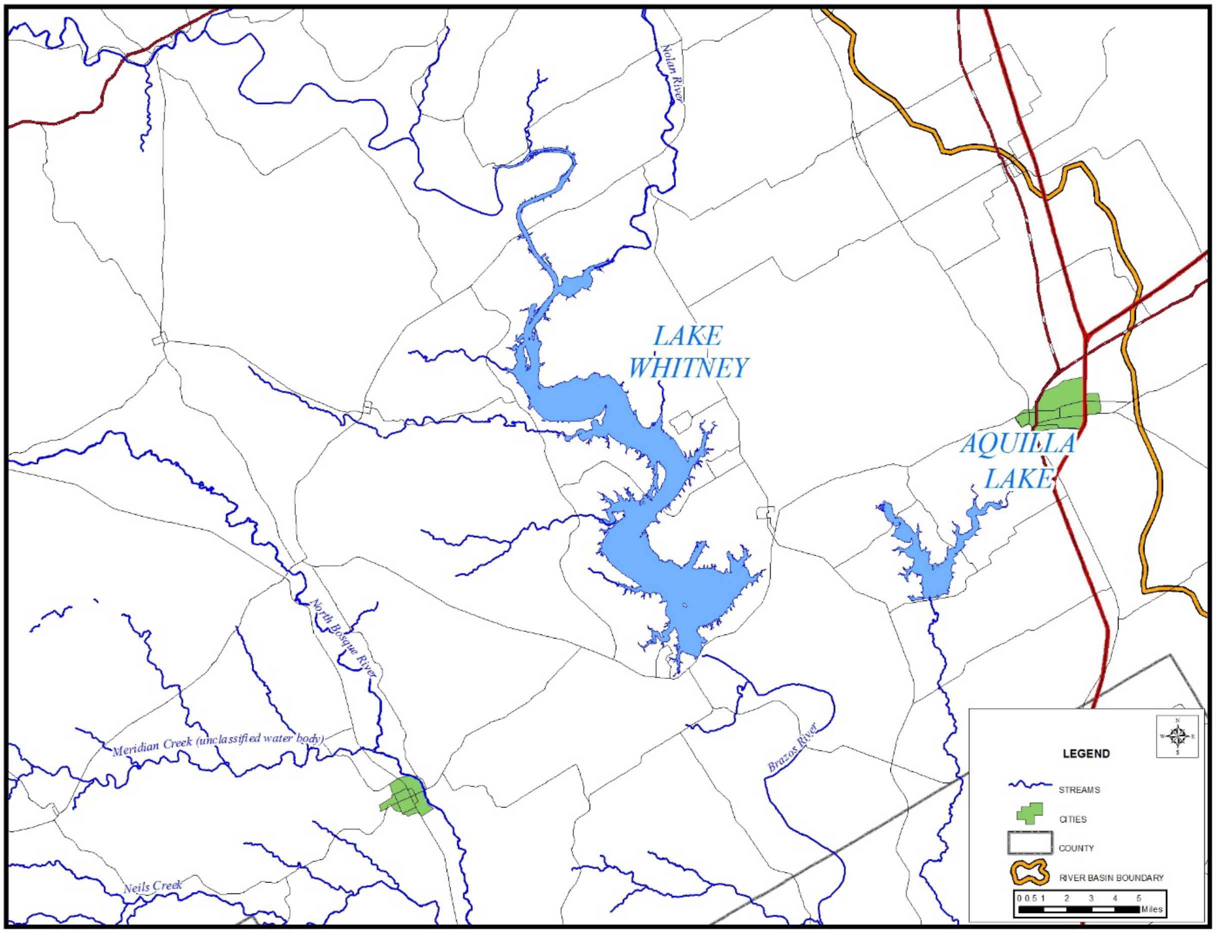

Table 7.9-1. Lake Whitney Characteristics

Owner	U.S. Army Corps of Engineers
Water Supply Contract	
Owner	Brazos River Authority
Storage amount	50,000 acft
Texas Water Right	
Number	CA 12-5157
Owner	Brazos River Authority
Diversion	18,336 acft/yr
Storage	50,000 acft between 520 ft and 533 ft-msl
Priority date	August 30, 1982
Flood Pool1	
Top elevation	571 ft
Storage	1,372,400 acft
Conservation Pool2	
Top elevation	533 ft
Surface area	23,220 ac
Storage	554,203 acft
Inactive Storage3	
Top elevation	520 ft
Storage	320,711 acft

[1]. Based on original 1959 survey. Represents volume of flood pool only (i.e., volume between 533ft and 571ft assuming no sedimentation in flood pool).
[2]. Based on 2005 TWDB volumetric survey. Represents volume from 533ft and below.
[3]. Based on 2005 TWDB volumetric survey. Capacity from 520ft and below is reserved for sediment and power-head storage space.

7.9.2 Available Supply

The firm yield for the reallocation of Lake Whitney was estimated using the Brazos Water Availability Model (WAM) Run 3 with Senate Bill 3 environmental flows. The sedimentation conditions for Lake Whitney were updated to projected storage capacities in 2020 and 2070, while all other reservoirs in the basin remained at their original permitted storage amounts. The WAM simulates streamflows, reservoir operations, and existing water rights for the historical period of 1940-1997. This evaluation does not consider converting flood storage to water supply storage at Lake Whitney, but rather evaluates the reallocation of hydropower storage and a portion of the inactive storage in Lake Whitney to water supply storage. This reallocation could produce a considerable firm yield. The increase in firm yield for reallocation of the hydropower storage in Lake Whitney was found to be 20,842 acft/yr for 2070 conditions (Table 7.9-2). This is in addition to the 18,336 acft/yr already permitted from the reservoir for a total firm yield of 39,178 acft/yr. If ten feet of previously inactive storage were reallocated to water supply, the increase in yield would be 73,125 acft/yr, for a total yield of 91,461 acft/yr (Table 7.9-2). This strategy could potentialy be provided supply under the BRA System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. If an entity other than the BRA were to sponsor and pursue this strategy, then an agreement with the BRA would be required to address concerns related to the potential subordination of the System Operation strategy.

Table 7.9-2. Storage Capacities and Firm Yields for Existing, Hydropower Reallocation, and Hydropower plus Inactive Storage Reallocation

Bottom of Conservation Elevation (feet)	Top of Conservation Elevation (feet)	2020 conditions			2070 conditions		
		Storage (acft)	Firm Yield (acft/yr)	Yield Increase (acft/yr)	Storage (acft)	Firm Yield (acft/yr)	Yield Increase (acft/yr)
520.00	533.00	50,000	18,336	0	50,000	18,336	0
520.00	533.00	231,084	39,866	21,530	226,999	39,178	20,842
510.00	533.00	351,448	93,376	75,040	341,301	91,461	73,125

7.9.3 Environmental Issues

Reallocation of hydroelectric and inactive storage in Lake Whitney will reduce hydroelectric generation and downstream streamflows and may have an impact on reservoir pool levels. The evaluation summarized in Table 7.9-3 was based on a wide range of natural resource databases on threatened and endangered species, and on riparian (stream bank) and littoral (lake side) habitats.

The reallocation of hydroelectric storage in Lake Whitney could possibly have moderate impacts on environmental water needs/instream flows in the Brazos River below the reservoir. Potential effects on aquatic and riparian habitats could result from reduction in stream flow, particularly in the summer months when flows are naturally lower and oxygen depletion in the water is greater. Reduced releases may increase the downstream concentration of pollutants from wastewater treatment plants and other sources, potentially impairing water quality in the stream. Seasonally reduced flows downstream from Lake Whitney could also adversely affect riparian vegetation and habitat, including bottomland hardwoods and wetlands. Changes in reservoir pool elevations could have possible low impacts on bank vegetation, wildlife habitat, and cultural resources sites. These issues will be evaluated closely by federal permitting agencies including the U.S. Army Corps of Engineers (for wetlands permitting), and the Federal Energy Regulatory Commission (for hydroelectric permitting).

Table 7.9-3. Environmental Issues: Lake Whitney Reallocation

Water Management Options	Implementation Measures	Environmental Water Needs / Instream Flows	Bays and Estuaries	Fish and Wildlife Habitat	Cultural Resources	Threatened and Endangered Species
Reallocation of Hydroelectric Storage to Conservation Storage in Lake Whitney	Reduced Hydroelectric Discharges to Brazos River below Lake Whitney1	Possible Moderate Impacts on Brazos River below Lake Whitney1	Possible Low Impacts	Possible Moderate Impacts on Brazos River Segment below Lake Whitney2	Possible Low Impacts	Negligible Impacts
1. Assumes decrease in average annual instream flows below Lake Whitney as a result of reduced hydroelectric generation. Does not account for cumulative effects of decreased regional stream flows.						
2. Impacts would be variable depending on resulting change in flows. Adverse impacts would be possible for bottomland hardwood forests and wetlands						

This preliminary identification of environmental issues is based on an evaluation of the general characteristics of the water management options. Site specific investigations of the potentially affected environments would be necessary to provide detailed evaluations of possible habitat and cultural resources impacts from the reallocation. A quantitative estimate of magnitude and seasonal distribution of the reduced downstream flows implied in the reallocation would be needed to assess the effects on environmental water needs/instream flow and on fish and wildlife in the Brazos River below Lake Whitney.

7.9.4 Engineering and Costing

Development of the firm yield from reallocation of storage in Lake Whitney will not require major facilities for implementation. However, implementation of this alternative requires a detailed evaluation of various issues that will require mitigation of adverse impacts. In addition to these costs, a detailed U.S. Army Corps of Engineers reallocation study is required. The final cost for implementation of this alternative will be dependent on the results of that study.

Table 7.9-4 summarizes the estimated cost for this option. The estimated cost for water supply storage in Lake Whitney is the maximum of two numbers: 1) the updated investment cost of the reallocated hydropower storage as a proportion of the reallocated storage to total useable storage (198,000 acft / 1,554,600 acft or 12.7 percent), or 2) the amount of money needed to compensate for lost hydropower benefits. The updated total investment cost for Lake Whitney was estimated to be $202,622,000, so the increase in cost for water supply storage was estimated to be $25,733,000. This corresponds to the first number referred to above. The impact to hydroelectric power generation will vary from year to year depending on hydrologic conditions. Based on the WAM simulations and diversions of the firm yield from the reservoir, the impact to hydroelectric power generation may be as much as 75 percent of the annual power generation amount. The mitigation cost for the reduction in hydroelectric power generation was based on a replacement cost of $0.09 per kWh, which results in an annual cost of $2,430,000. This amount is converted from an annual value to a present value of $76,359,000 by assuming a 50 year planning horizon and an inflation rate of 2%. This corresponds to the second number referred to above. Because $76 million is much larger than $26 million, the cost for hydropower compensation was taken as the cost for reallocated storage. The total annual cost for this reallocation strategy is estimated to be $7,527,000, which based on the increase in firm yield of 20,842 acft/yr, results in a unit cost of raw water of $361 per acft ($1.11 per 1,000 gallons). Compensation to BRA may be required if this strategy were developed by another entity other than BRA to compensate for any subordination of the System Operations strategy.

Table 7.9-4. Cost Estimate Summary for Reallocation of Hydropower Storage in Lake Whitney

Item	Estimated Costs
Capital Costs	
Improvements to Dam	$3,800,000
Relocations	$0
Total Capital Cost	$3,800,000
Engineering, Legal Costs and Contingencies	$1,330,000
Environmental & Archaeological Studies and Mitigation	$3,117,000
Real Estate	$0
Storage Reallocation	$76,359,000
Slope Stability, Seepage and Geotechnical Studies	$234,000
Water Rights Permit from TCEQ	$1,500,000
Administrative Cost for USACE Storage Reallocation Process	$3,608,000
Interest During Construction (12 months)	$476,000
Total Project Cost	$89,948,000
Annual Costs	
Debt Service (5.5 percent for 20 years)	$7,527,000
Hydropower Generation Compensation ($0.09/kWh)	$0
Operation and Maintenance	$79,000
Total Annual Cost	$7,527,000
Available Project Yield (acft/yr)	$20,842
Annual Cost of Water ($ per acft)	$361
Annual Cost of Water ($ per 1,000 gallons)	$1.11

7.9.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 7.9-5, and the option meets each criterion.

Table 7.9-5. Comparison of Lake Whitney Reallocation Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Significant quantity available for regional use or in Region H
2. Reliability	2. High reliability
3. Cost	3. Low
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impacts possible downstream
2. Habitat	2. Moderate impacts possible
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	No threats to agriculture; possible changes in downstream flows
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

7.9.6 Potential Regulatory Requirements

Implementation of reallocation of storage in Lake Whitney will require several steps including a detailed reallocation study performed by the U.S. Army Corps of Engineers and authorization from the U.S. Congress. An outline of the reallocation process is provided below:

1. Local sponsor requests the U.S. Army Corps of Engineers perform a reallocation study. Indicate local interest, purpose, financial capability, etc.
2. Reallocation studies are performed in two phases and follow the General Investigation Process consisting of a Reconnaissance Report and a Feasibility Study. Specific funding would be required for a reallocation study. A reallocation study includes the following:
   a. Define existing project

   b. Define current and projected water supply needs
   c. Alternative solutions considered
   d. Analysis of alternatives
      i. Reallocation of flood control storage
      ii. Raise top of flood control pool
      iii. Reallocate existing conservation pool/power pool
      iv. Hydropower compensation and other hydropower issues
      v. Other
      vi. No action
      vii. Screening of alternatives
      viii. Selection rationale and selection of a plan
   e. Selected plan
      i. Value of storage reallocation
      ii. Impacts of reallocation
      iii. Public involvement
      iv. Environmental impacts
      v. Hydropower compensation and other hydropower issues
   f. Recommended plan
3. NEPA Compliance
4. U.S. Army Corps of Engineers Headquarter Approval of Reallocation Study
5. Authorization from U.S. Congress
6. U.S. Army Corps of Engineers and Local Sponsor execute water supply contract based on Water Supply Storage Reallocation
7. Water Rights Permits from TCEQ
8. Coordination with BRA on any potential subordination agreements for the System Operations strategy.

7.10 BRA Sediment Reduction Program

7.10.1 Description of Option

The protection of already developed water supplies is a key element of water supply planning. Because Region G's inventory of suitable sites for new reservoirs is limited, extending the life of existing reservoirs in the region through sediment control strategies could be a cost effective way to maintain supplies. Over time sediment accumulation can significantly reduce storage capacity and reliability of water supplies. For BRA reservoirs in Region G, there is a projected reduction in reservoir capacity of almost 313,000 acre-feet, or 6,254 acre-feet per year over the 50-year planning period from 2020 to 2070 (Table 7.10-1). The lost storage causes a loss in firm yield of 700 acre-feet per year over the same period.

The BRA and the Little River-San Gabriel Soil and Water Conservation District developed a Watershed Protection Plan for Lake Granger and the San Gabriel River to identify and implement strategies that reduce sediment loading to the lake[1]. The results from a 1999 study of Lake Granger indicate that a combination of conversion of highly erodible cropland to grassland and employment of terracing, minimum tillage, and contour farming had the potential to reduce sediment loads by 20%, and that soil control dams would reduce loads by an additional 7%[2]. The Little River-San Gabriel Soil and Water Conservation District (SWCD) received funding to provide assistance to participants implementing these BMPs on agricultural lands. There are also watershed protection plans in place for Lakes Granbury[3], Belton[4], and Stillhouse Hollow[5].

7.10.2 Available Yield

Sediment production rates in Region G vary considerably due to land use, soil types and topography. Estimates of reservoir capacities for years 2020 and 2070, based on reservoir drainage area and sedimentation rate, are presented in Table 7.10-1. The sedimentation rates in column 2 Table 7.10-1 reported in the BRA Water Management Plan6, and were used to develop the projected capacities used in the water availability modeling (WAM) for regional water planning. The rates in column 3 are normalized by a

1 Lake Granger and San Gabriel River Watershed Protection Plan. Developed by Brazos River Authority. November 2011.

2 Assessment of Flow and Sediment Loadings and BMP Analyses for Lake Granger. USDA - Natural Resources Conservation Service. Prepared in Cooperation with the Brazos River Authority. May 1999.

3 Lake Granbury Watershed Protection Plan. Prepared by Brazos River Authority and Espey Consultants, Inc. for the U.S. Environmental Protection Agency and Texas Commission on Environmental Quality. July 2010.

4 Watershed Protection Plan for the Leon River below Proctor Lake and above Belton Lake. Prepared by Parsons Water and Infrastructure Inc. and the Brazos River Authority for the Stakeholders of the Leon River Watershed. December 2010.

5 Lampasas River Watershed Protection Plan. Prepared by L. Prcin, R. Srinivasan, and P. Casebolt for the Lampasas River Watershed Partnership. July 2010.

6 Brazos River Authority, Water Management Plan for Water Use Permit No. 5851, Appendix G-2. Updated May 2014.

time-weighted contributing drainage area. Because the water yield of a reservoir is affected by the reservoir storage volume, reservoirs experiencing higher sedimentation rates will experience more rapid reduction in firm yield over time than reservoirs with lower sedimentation rates. The projected reservoir yields over the planning period are also shown in Table 7.10-1. Reservoirs with higher sedimentation rates, and therefore greater yield reductions over time, include Lakes Limestone, Granbury, Granger, and Aquilla.

Lake Limestone was chosen for a more detailed evaluation in this plan because it has a relatively high loss in yield, the highest sedimentation rate per square mile, and a large ratio of yield lost to capacity lost (Table 7.10-1). Two sediment reduction best management practices (BMPs) are considered for the Lake Limestone watershed:

1. BMP 1 - conversion of cropland to grassland, and
2. BMP 2 - establishment of filter strips.

The USDA-NRCS Conservation Reserve Program facilitates the conversion of cropland to grassland by providing financial incentives for farmers to retire lands from growing annual crops and establish perennial pastures (grass or hay). It is assumed that the conversion extends throughout the 50-year project planning horizon. Filter strips are vegetated areas, typically 50 feet wide, on the edge of fields that trap sediment from the runoff water before it enters streams or lakes. BMP 2 develops one acre of filter strip for every 20 acres of cropland, for a total management unit of 21 acres. For the purposes of this plan, this BMP is assumed to require reinstallation every five years throughout the 50 year planning horizon, with one acre of filter strip per 21 acres of participating cropland[7].

Table 7.10-1. Estimated Sedimentation Rates, Projected Capacities and Firm Yields

Reservoir	Sedimentation Rate	Sedimentation Rate	Capacities (acft)			Yields (acft/yr)		
	(acft/yr)	(acft/yr/sq mi)	2020	2070	% Lost	2020	2070	% Lost
Aquilla	116	0.46	43,174	37,374	13%	13,315	12,099	9%
Belton	393	0.16	430,976	411,325	5%	98,562	96,722	2%
Georgetown	7	0.03	36,799	36,449	1%	11,743	12,003	-2%
Granbury	724	0.50	116,703	80,503	31%	64,712	53,310	18%
Granger	234	0.48	47,971	36,271	24%	17,017	14,192	17%
Possum Kingdom	2588	0.22	501,520	372,120	26%	230,750	224,692	3%
Limestone	614	1.28	196,965	166,265	16%	65,364	55,677	15%
Proctor	101	0.10	53,639	48,589	9%	17,742	16,957	4%
Somerville	355	0.35	141,069	123,319	13%	41,308	38,910	6%
Stillhouse Hollow	212	0.16	224,645	214,045	5%	66,230	66,195	0%
Whitney	910	0.45	540,553	495,053	8%	18,336	18,366	0%

There are approximately 11,700 acres of cultivated crops in the Lake Limestone watershed. Assuming a 25% adoption rate for both BMPs, means there are 2,925 acres available for BMP implementation. The expected annual sediment reduction rate for BMP 1 is 21.1% [7,8], and it is 17.5% for BMP 2 [7,8]. Given these assumptions, an average of 32 acft/yr of sediment is trapped by BMP 1 plus 27 acft/yr from BMP 2 for a total of 59 acft/yr, assuming the BMPs are adopted by different eligible areas. This translates to a reduced sedimentation rate of 555 acft/yr instead of the current 614 acft/yr (Table 7.10-2), so the projected capacity in 2070 would be 169,215 acft instead of 166,265 acft. This extra capacity increases the 2070 firm yield of Lake Limestone to 56,565 acft/yr, an increase of 888 acft/yr.

7.10.3 Environmental Factors

Scouring flows, which increase with land clearing and over-grazing, can cause enough sedimentation to eliminate the habitat of mussels, minnows and other sensitive organisms. The control of sediment by NRCS structures and BMPs can have water quality benefits for downstream streams and lakes.

7.10.4 Engineering and Cost

The capital costs for BMP 1 include $174.61 per acre for establishment of a perennial hay crop plus $16.50 per acre compensation for foregone income from crop production during the first year. The operation and maintenance costs for BMP 1 include annual payments of $26.54 per acre to compensate participants for lost income plus $21.06 per acre as incentive to convert cropland to grassland. The capital costs for BMP 2 include $15,797 every five years for educational programming and $133.75 per 21 acres every five years for seedbed establishment throughout the 50 year planning period. These costs are converted to present value assuming an interest rate of 2.11% [7]. The operation and maintenance costs for BMP 2 include annual payments of $43.39 per 21 acres to compensate participants for lost income plus $21.06 per 21 acres as incentive for implementing this BMP.

The total project cost for the implementation of these two BMPs is estimated to be over one millions dollars (Table 7.10-2). The project is expected to prevent 59 acft of sediment per year from entering Lake Limestone, which translates to an increase in firm yield of 888 acft/yr by 2070. Given these assumptions, the annual cost of water is $324 per acre-foot (Table 7.10-2). The analysis presented here provides planning-level estimates of yields and costs for a hypothetical sediment reduction program in the Lake Limestone watershed. Prior to implementation, any sediment reduction program would need a more in-depth analysis involving site-specific modeling and costs to gain more confidence in the estimates. The uncertainties associated with this strategy make it difficult to perform a more meaningful analysis at this time.

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[7] Evaluating the Economics of Best Management Practices for Tarrant Regional Water District's Eagle Mountain Lake Watershed. By J. Johnson. Texas Water Resources Institute Technical Report No. 407. September 2011.

[8] Lee, T., M.E. Rister, B. Narashimhan, R. Srinivasan, D. Andrew, M.R. Ernst (2010). Evaluation and Spatially-Distributed Analyses of Proposed Cost-Effective BMPs for Reducing Phosphorous Level in Cedar Creek Reservoir, Texas. Transactions of the ASABE. Vol 53(5): 1619-1627.

Funding opportunities for agricultural BMPs include the Environmental Quality Incentives Program (EQIP) administered by the NRCS, the Water Quality Management Plan (WQMP) Program administered by the TSSWCB, and the Federal Clean Water Act Section 319(h) Nonpoint Source Grants.

Table 7.10-2. Cost Estimate Summary for Lake Limestone Sediment Reduction Strategy

Item	Estimated Costs
Capital Costs	
Conversion of Cropland to Grass/Hay	$558,000
Establishment of Filter Strips	$225,000
Total Capital Cost	**$783,000**
Engineering, Legal Costs and Contingencies	$274,000
Interest During Construction (6 months)	$18,000
Total Project Cost	**$1,075,000**
Annual Costs	
Debt Service (5.5 percent, 20 years)	$90,000
Operation and Maintenance	$148,000
Program Coordination	$50,000
Total Annual Cost	**$288,000**
Available Project Yield (acft/yr)	**888**
Annual Cost of Water ($ per acft)	**$324**
Annual Cost of Water ($ per 1,000 gallons)	**$1.00**

7.10.5 Implementation Issues

The control of sediment by NRCS structures and BMPs can have water quality and yield benefits for downstream reservoirs.

There is some concern that implementation of erosion and sedimentation control measures would reduce net farm incomes[9], but this can be addressed through a properly designed compensation scheme. Appropriate annual compensation payments to farmers for lost productivity need to be considered in cost estimates for BMP implementation.

[9] White and Pantenheimer (1980). Economic impacts of erosion and sedimentation control plans: case studies of Pennsylvania dairy farms. Journal of Soil and Water Conservation 35(2): 76-78.

Further analyses need to be conducted to identify priority areas of implementation within Region G. Measuring the effectiveness of BMP implementation can be difficult in watersheds with large drainage areas. Other implementation issues include maintaining stakeholder participation and financing BMP implementation and control structure rehabilitation. As shown in Table 7.10-3, this water management strategy has been compared to the plan development criteria. It is likely that a robust and vigilant implementation effort would be needed to adequately address sedimentation concerns in Region G and prolong the life of BRA reservoirs.

Table 7.10-3. Comparison of BRA Sediment Reduction Program to Plan Development Criteria

Impact category	Comment(s)
A. Water Supply	
1. Quantity	1. Uncertain.
2. Reliability	2. Uncertain. Varies depending on area.
3. Cost	3. Reasonable
B. Environmental Factors	
1. Environmental Water Needs	1. Low impact.
2. Habitat	2. Positive impact.
3. Cultural Resources	3. Low impact.
4. Bays and Estuaries	4. Low impact.
5. Threatened and Endangered Species	5. Low impact.
6. Wetlands	6. Low impact.
C. Impact on Other State Water Resources	Positive impacts on state water resources and navigation.
D. Threats to Agriculture and Natural Resources	Low to none.
E. Equitable Comparison of Strategies Deemed Feasible	Done.
F. Requirements for Interbasin Transfers	Not applicable.
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None.

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7.11 Brazos River Authority System Operation of Reservoirs

7.11.1 Description of Option

The Brazos River Authority (BRA) has submitted to the Texas Commission on Environmental Quality (TCEQ) water rights permit application 5851 requesting additional appropriation of water that could be made available through system operation of the BRA's existing water rights and reservoirs. The application requested an appropriation of up to 421,449 acft/yr of firm supply. The BRA also requests authorization to use up to 90,000 acft/yr of its firm supply to produce, along with other unappropriated flows, an interruptible supply of up to 670,000 acft/yr for appropriation. By conventional definition, at least 75 percent of an interruptible supply is available at least 75 percent of the time. An initial draft permit was released by the TCEQ on December 1, 2008. A draft permit has been issued and proceedings have initiated before the State Office of Administrative Hearings to resolve protestants' concerns. As of this time there is no formal decision that has been made available to incorporate into the 2016 Brazos G Regional Water Plan (2016 Plan). This option presents the latest information available from the draft management plan associated with the draft permit application.

The Brazos G RWPG evaluated the BRA System Operations (Sys-Ops) as a potential water management strategy for the 2016 Plan.

The evaluation was completed through two tasks:

a. Incorporate the BRA System Operation into the Brazos WAM used to evaluate Water Management Strategies for the 2016 Plan and determine the maximum amount that could be made available under the constraints of existing contractual obligations and likely operations under the proposed BRA management plan.

b. Determine the additional water supply that would be made available by the BRA System Operation to Water User Groups (WUGs) with needs that could potentially utilize the additional supply.

7.11.2 Available Yield

The water requested in the BRA water rights permit application was the maximum amount of water that could be developed by the BRA System if all of the water were utilized (diverted) near the Gulf of Mexico. Diverting all water supply from the BRA System (both existing and new appropriations) near the Gulf maximizes the supply available by (a) allowing all BRA reservoirs to contribute and make releases, and (b) maximizes the area contributing flows (uncontrolled runoff and wastewater return flows, that originate downstream of the BRA reservoirs. Under this hypothetical operation (diverting all supply near the Gulf), uncontrolled flow originating downstream of the BRA reservoirs is diverted during wet times, and firmed up by releases from storage in the upstream BRA reservoirs during dry times. In this fashion, a total "system" yield can be developed that is substantially greater than the sum of the individual reservoir yields.

The BRA currently holds multiple contracts to supply water to cities, districts, irrigators and industry throughout the Brazos River Basin. Many of these contracts are supplied proximate to the BRA's reservoirs, or through lakeside diversions. This reduces the efficiency of the BRA System because (a) not every BRA reservoir can contribute releases to every contractual diversion location, and (b) diversion of the contracts from the basin upstream of the Gulf reduces the opportunity to utilize flows contributed by the basin downstream of the reservoir system. Because of this constraint, the total amount of water that the BRA could realize through system operation of its reservoirs is less than the amount stated in the permit application.

The Brazos WAM (Run 3 assumptions) was utilized to determine the availability of water for the BRA Sys-Ops strategy. This version of the Brazos WAM, included assumptions specific to the BRA management plan and associated modeling of Sys-Ops. One of the included assumptions was the use of BRA sourced return flows, consistent with those in the Management Plan. These assumptions include modeling of BRA contracts at aggregated locations throughout the basin, and use of the SB3 e-flow standards for the Brazos Basin. The aggregated contracts were updated from those in the management plan to be consistent with what is being accounted for in the analysis in this 2016 Plan.

Two known future demands that are contingent on the Sys-Ops supply were added to the model. One was for 14,800 acft/yr (consumptive, 20,000 total) out of Possum Kingdom tied to the Possum Kingdom to Abilene water management strategy. The second was for the expansion of the nuclear facilities at Comanche Peak with additional 90,152 acft diversion out of Lake Granbury for Luminant. Note that 76,120 acft of this diversion is considered Sys-Ops water with the remaining being the reallocation of existing Luminant – BRA contracts. The remaining water available from the BRA System (after supplying current contractual commitments aggregated throughout the basin) was then determined at the Brazos River near Rosharon control point, at the lower end of the Brazos Basin. The analysis performed for the Brazos G RWPG evaluates the effects of the BRA System Operations and includes only the Brazos River at near Rosharon system diversion location.

During the model simulations, the BRA contracts are met first from the BRA System, followed by the remaining amount that could be met at the Rosharon diversion. This would be the maximum amount that could be realized by the BRA under the agency's current contractual commitments. If the BRA's contractual commitments change in the future, the availability of water from the BRA System would also change accordingly. All simulations assume as permitted reservoir sedimentation conditions. The Allens Creek Reservoir project was included in the BRA Sys-Ops analysis, as it is permitted, but not constructed, and is included as part of the pending application on file at the TCEQ. Results of the water availability analysis are shown in Table 7.11-1. The availability of interruptible supply was not evaluated for this update of the 2016 Brazos G Plan.

Table 7.11-1. Water Availability from BRA System Operations (acft/yr)

	2016 BGRWP
Existing BRA Contracts	696,719
Supplies from System Operation	
Abilene at Possum Kingdom	14,800
Luminant	76,120
Diversions at Richmond/Rosharon	114,750
With Allens Creek[1] as part of system	41,650
Total Sys Ops Yield Supply	247,320
[1] Allens Creek Reservoir has a stand-alone lakeside demand of 99,650 acft/yr	

Utilization of the BRA System Operations as a Water Management Strategy for Specific WUGs in the Brazos G Area

Water available from BRA System Operations represents a new supply of water that could be utilized to meet future needs in the Brazos G Region without construction of new reservoirs. As part of the 2016 Sys-Ops analysis, WUGs with projected needs were identified in counties adjacent to the main stem of the Brazos River. Table 7.11-2 lists these potential WUGs that could be met from Sys-Ops. Figure 7.11-1 shows the counties with Brazos G Area Needs for BRA System Operations considerations. A meeting with BRA was initiated to discuss the applicability of meeting these needs with Sys-Ops. Region H consultants were also present at the meeting and requested 25,000 acft of Sys-Ops water be available to Region H for planning purposes.

Selected WUG with Needs

The development of the individual WUG and WWP plans will result in a discreet set of WUGs that are planned to use Sys-Ops water to meet future needs. Once these have been identified a final availability analysis will need to be run to confirm that these needs can be met by Sys-Ops while not causing impacts to existing BRA contracts or the other future demands described in this section. It is likely that the final set of WUGs / WWPs that will have Sys-Ops as part of their plan will be different than those presented in the table. Costs associated with connecting WUGs / WWPs to the Sys-Ops supply will be addressed in the miscellaneous strategies and presented in the respective Chapter 5 WUG and WWP tables.

Figure 7.11-1. Brazos G Area Needs by County for BRA System Operations Consideration

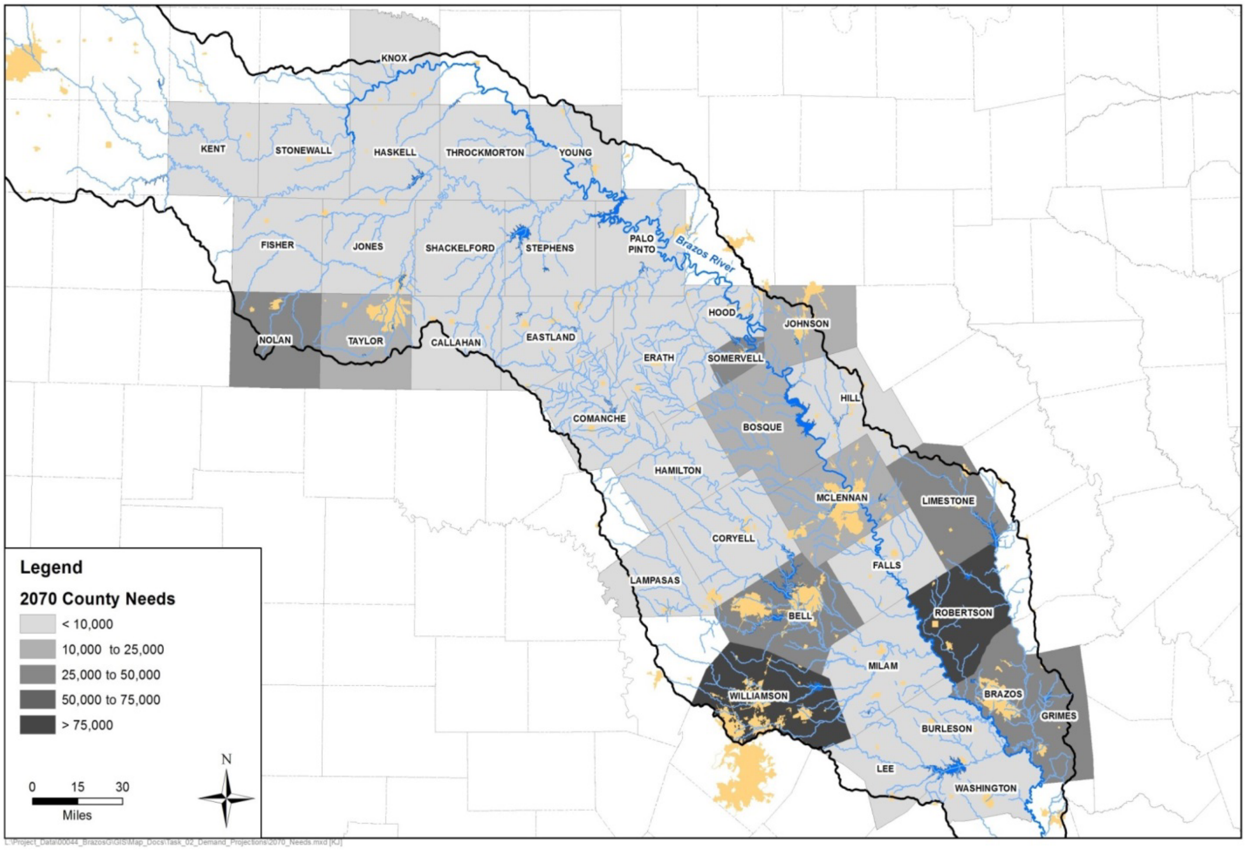


Table 7.11-2. Potential WUGs for Sys-Ops Availability

WUG	2020	2030	2040	2050	2060	2070
ABILENE	14,800	14,800	14,800	14,800	14,800	14,800
SOMERVELL COUNTY-SE	90,152	90,152	90,152	90,152	90,152	90,152
MCLENNAN CO - MINING				1,050	1,050	1,050
MCLENNAN CO - IRRIGATION	1,200	1,200	1,200	1,200	1,200	1,200
ROBERTSON CO - SE				2,000	4,000	6,000
ROBERTSON CO - MINING		1,000	2,600	5,000	7,700	11,200
ROBERTSON CO - IRRIGATION	33,500	29,000	25,000	25,000	29,000	35,600
BURLESON CO - MINING	250	1,100	700	300		
BRAZOS CO – MINING	1,100	1,600	1,400	1,100	900	800
BRAZOS CO – IRRIGATION	10,200	8,500	6,900	5,800	4,800	3,900
ROUND ROCK					22,000	22,000
WILLIAMSON COUNTY-OTHER	5,000	10,000	10,000	15,000	15,000	20,000
TOTAL	**156,202**	**157,352**	**152,752**	**161,402**	**190,602**	**206,702**

Summary of Hydrologic Findings Concerning the Proposed BRA System Operations

The proposed BRA System Operations appropriation would add a considerable amount of firm supply to the Brazos River Basin that could be used in the Brazos G Area, but also in adjacent regions where the BRA supplies water, most notably Region H (Houston area). New proposed water management strategies may be impacted negatively by the BRA System Operations, but only to the extent that priority limits availability to the new options.

The BRA System Operations could negatively affect the yields of several proposed water management strategies that are considered for the 2016 Plan. The proposed BRA System Operations appropriation would be granted with a priority date senior to any of these proposed reservoir projects, and would have a priority call on inflows. However, any of these proposed reservoirs could be operated in conjunction with the BRA System, and the resulting increase in supply to the Brazos River Basin would be greater than that obtained from the projects operated on a stand-alone basis with a priority senior to the proposed BRA appropriation.

7.11.3 Environmental Issues

Unlike the typical implementation of a large surface water reservoir, the proposed BRA System Operations appropriation requires no environmental permits because the reservoirs already exist. However, instream flow restrictions likely to be placed on the new appropriation could limit supplies that could be developed by the project. Figure 7.11-2 illustrates average streamflows by month in the Brazos River at the Richmond gage, both with and without the proposed BRA System appropriation. Figure 7.11-3. illustrates the expected Brazos River streamflow frequencies at this location. The figures indicate that with the proposed BRA appropriation, as modeled with the majority of the proposed appropriation diverted from the lower basin, streamflows would generally be greater up to the point of diversion. However, flows into the Gulf of Mexico would generally decrease.

A summary of environmental issues for the BRA System Operations is presented in Table 7.11-3.

Figure 7.11-2. Monthly Distribution of Streamflow at Brazos River at Gulf of Mexico Control Point with and without BRA System Operations

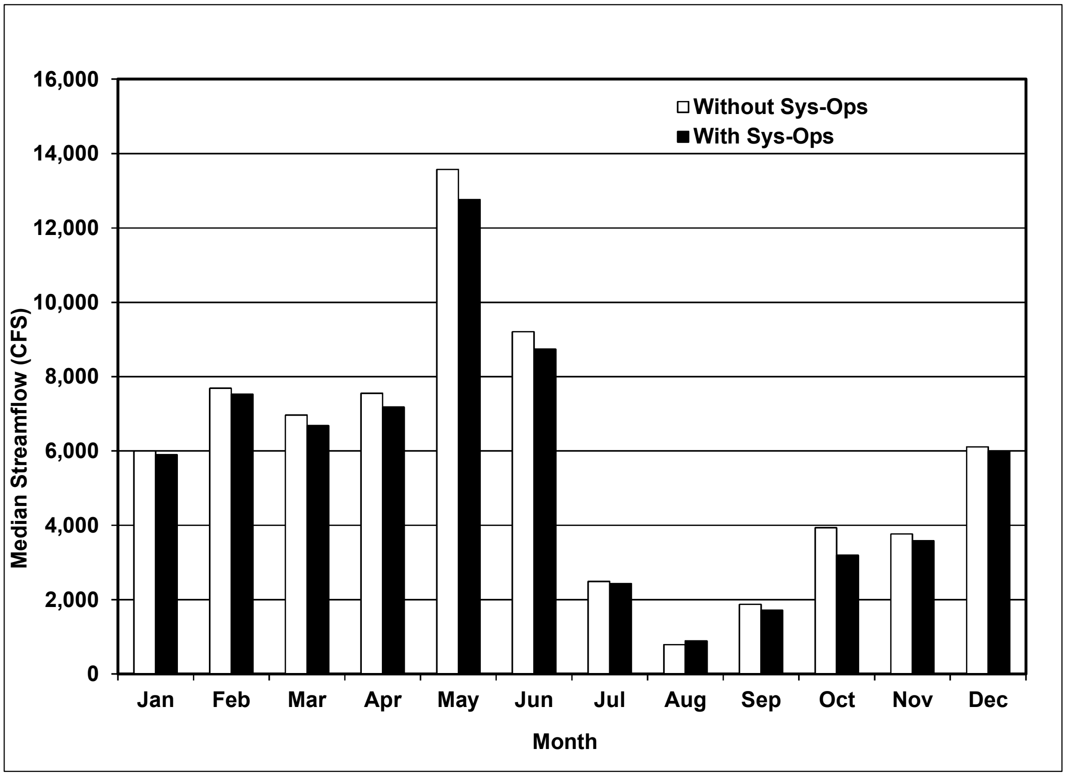


Figure 7.11-3. Frequency Distribution of Streamflow at Brazos River at Gulf of Mexico Control Point with and without BRA System Operations

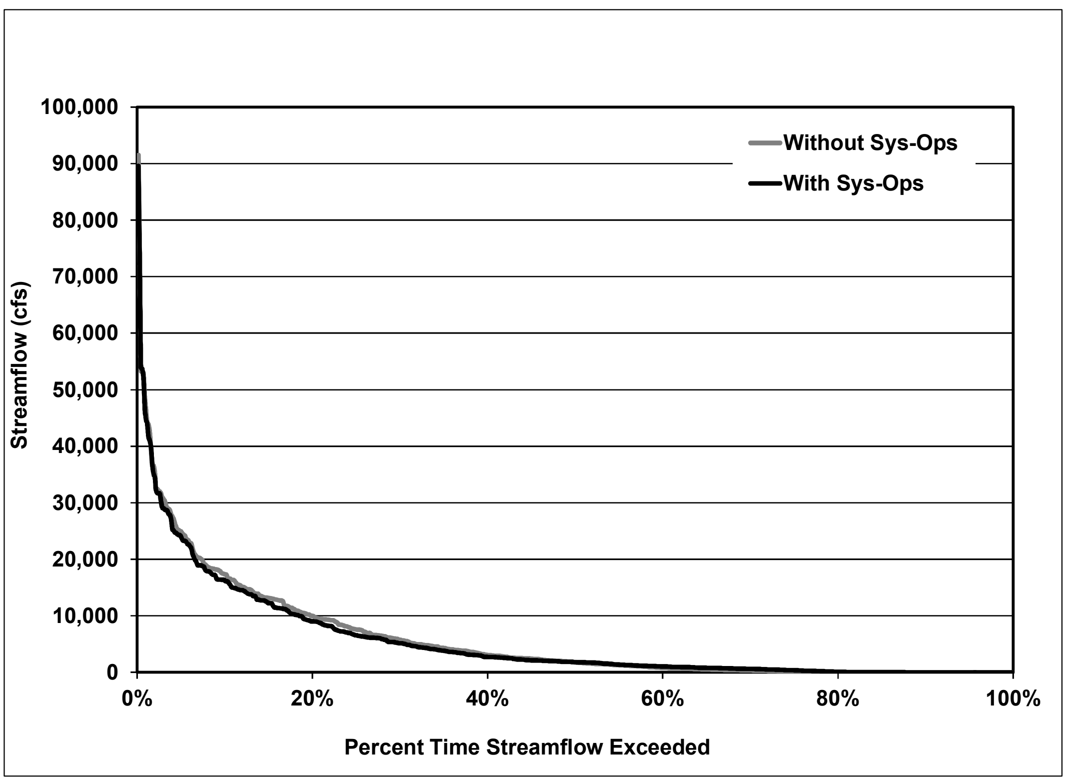


Table 7.11-3. Environmental Issues: BRA System Operations

Water Management Option	BRA System Operations
Implementation Measures	Each entity receiving the supply would have a water supply contract with the BRA.
Environmental Water Needs / Instream Flows	Possible low impacts. The primary sources of water are existing stored water and unappropriated flows diverted just upstream of the Gulf.
Bays and Estuaries	Possible low impact from reduced inflows to the Gulf.
Fish and Wildlife Habitat	Potential Impacts include constructing and maintaining easements for new pipelines or pump stations. Extent of impacts dependent on location and size of projects.
Cultural Resources	Possible low impact.
Threatened and Endangered Species	Potential Impacts include constructing and maintaining easements for new pipelines or pump stations. Extent of impacts dependent on location and size of projects.
Comments	Assumes infrastructure is needed to distribute purchased water to the entity in need.

7.11.4 Implementation Issues

It will be necessary to obtain these permits:

a. TCEQ Water Right permit;

b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for reservoirs and pipelines impacting wetlands or navigable waters of the U.S;

c. TPWD Sand, Gravel, and Marl Permit for construction in state owned streambeds;

d. NPDES Storm Water Pollution Prevention Plan;

e. GLO easement for use of the state-owned streambed; and

f. Section 404 certification from the TCEQ related to the Clean Water Act.

Permitting, at a minimum, will require these studies:

a. Assessment of changes in instream flows in the Brazos River.

b. Habitat mitigation plan.

c. Environmental studies of potential impact on endangered species.

d. Cultural resource studies and mitigation.

Land will need to be acquired through either negotiations or condemnation for pipeline and other facilities.

This water supply option has been compared to the plan development criteria, as shown in Table 7.11-4, and the option meets each criterion.

Table 7.11-4. Comparison of BRA System Operations to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Low impact due to distance from coast
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

8 Regional Water Supply Projects

8.1 Bosque County Regional Project

8.1.1 Description of Option

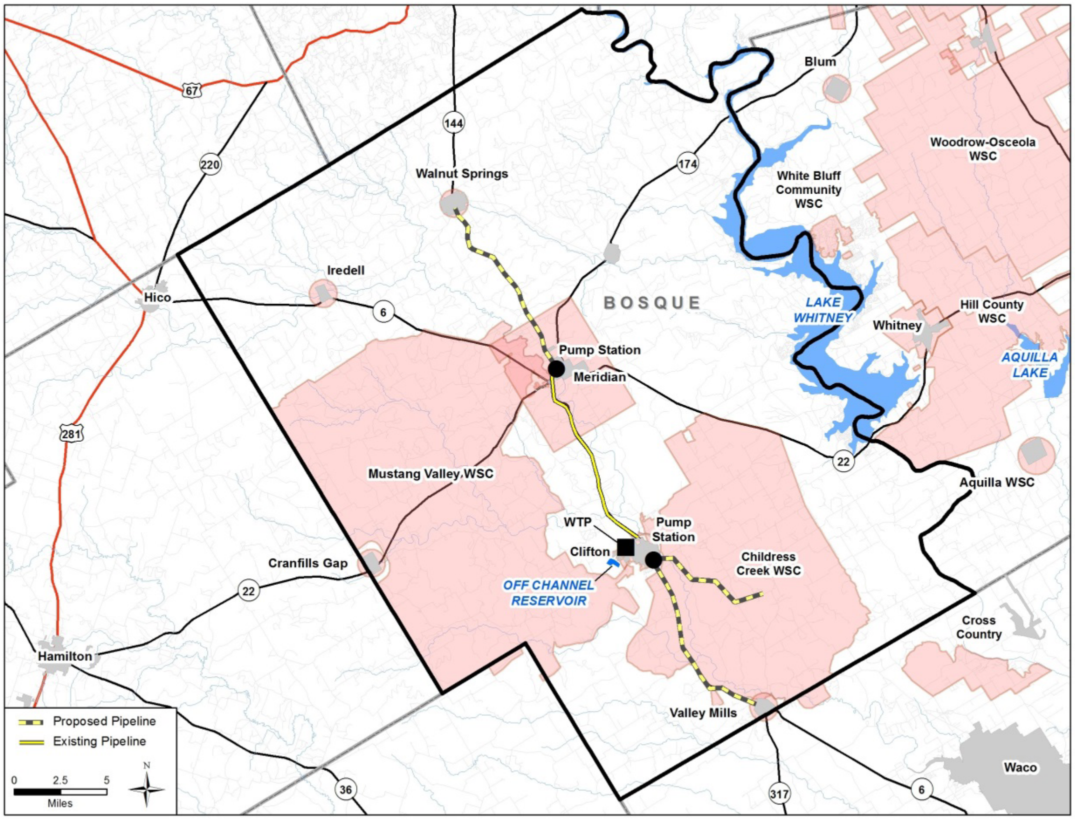
The Bosque County Regional Project has been a recommended water management strategy in both the 2006 and 2011 the regional water plans to address municipal water needs in Bosque County. Groundwater reliability remains a significant concern for the WUGs due to the large groundwater declines anticipated with the Desired Future Conditions (DFC) as developed by the groundwater districts for the Trinity Aquifer in Groundwater Management Area 8 (GMA-8). The project was originally identified through a jointly sponsored study[1] by the Brazos River Authority, Texas Water Development Board, and the Cities of Clifton and Meridian to determine the regional water needs and to evaluate existing and proposed water facilities.

The project envisioned the City of Clifton expanding its water system to provide treated surface water to the cities of Meridian, Valley Mills, Walnut Springs, and Childress Creek Water Supply Corp. (WSC). Bosque County Manufacturing demands could also be partially supplied through this project. The project would consist of expansion of the Clifton off-channel reservoir (OCR), expansion of Clifton's water treatment plant (WTP), and treated water transmission systems to nearby utilities. The 500 acft Clifton OCR was constructed in 1998 as the initial phase of the project with subsequent phases to increase it up to 2,000 acft of storage to meet local and regional water needs.

Figure 8.1-1 shows the planned interconnection of the four water utilities with the regional facility at Clifton. An 11 mile, 8-inch diameter water transmission pipeline has been recently constructed between Clifton and Meridian.

[1] Carter-Burgess, "Bosque County Regional Water Treatment and Distribution Facilities Plan," Final Report to the Brazos River Authority, March 2004.

Figure 8.1-1. Interconnection of Bosque County Systems



8.1.2 Available Yield

The City of Clifton holds two water rights on the North Bosque River. The first right with a priority date of March 14, 1963 allows the City to divert 600 acft for municipal use from the river. The second water right dated December 13, 1996 allows the City to divert and impound 2,000 acft/yr from the North Bosque River at a maximum rate of 12 cfs. Lake Waco rights are subordinated to Clifton's rights through the 1994 Windup Agreement between BRA and former Lake Bosque project participants. The Windup Agreement provides for 3,340 acft.yr for Clifton and Meridian from North Bosque River watershed to be senior to rights in Lake Waco.

A previous yield analysis2 for the Clifton OCR on the North Bosque River subject to instream flow conditions is included in Table 8.1-1.

[2] HDR, February 1997. City of Clifton Water Supply Plan. Preliminary Engineering Report

Table 8.1-1. Summary of Clifton OCR Yield

Reservoir Capacity (acft)	Yield (acft/yr)
500	730
1,150	1,133
2,000	1,523

The yield of the City of Clifton's surface water system (Bosque River diversion into an off-channel reservoir) is currently 730 acft/yr, but future enlargement of the reservoir could increase the yield up to 1,523 acft/yr. Based on projected demands, Clifton would have up to 1,070 acft/yr of supply available to sell in 2070 if its current water treatment plant were expanded and the reservoir were enlarged. This strategy, as formulated, would provide a total of 1,070 acft/yr to the five WUGS (203 acft/yr to Childress WSC; 224 acft/yr to Meridian; 182 acft/yr to Valley Mills; 64 acft/yr to Walnut Springs; and 397 acft/yr to Clifton. New water supplies for WUGs could also be used to meet Bosque County Manufacturing demands. Ongoing groundwater level declines in the Trinity Aquifer could result in a practical reduction in groundwater supplies to any of these entities in the future, necessitating either rehabilitation or replacement of existing wells or implementation of this water supply strategy.

8.1.3 Environmental

The Bosque County Regional Project includes an expansion of the existing Clifton off-channel reservoir and water treatment plant, and the construction of several treated water transmission pipelines and associated accoutrements. Expansion of the City of Clifton water system would allow this system to provide treated surface water to the cities of Meridian, Valley Mills, Walnut Springs and Childress Creek. Environmental concerns associated with this water management strategy include impacts from expansion of the water treatment plant and ground storage tanks, inundation of habitat resulting from the expansion of the existing reservoir, and impacts from the construction of pump stations and transmission pipelines.

With numerous miles of treated water transmission pipelines, four crossings of jurisdictional waters would occur. These crossings include two intermittent tributary streams and two perennial streams including the North Bosque River, and Neils Creek. Impacts to these waters from pipelines would be temporary and occur during construction. Any potential impacts to these areas would be restorable. Avoidance and minimization measures, such as horizontal directional drilling, construction best management practices (BMPs), and avoiding perennial and/or sensitive aquatic habitats would reduce potential impacts to these areas.

Coordination with the U.S. Army Corps of Engineers would be required for construction within waters of the U.S. Impacts from this proposed project resulting in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for

Utility Line Activities unless there are significant impacts to the aquatic environment by other project components.

The Texas Parks & Wildlife Department (TPWD) has identified a number of stream segments throughout the state as ecologically significant on the basis of biological function, hydrologic function, riparian conservation, exceptional aquatic life uses, and/or threatened or endangered species. Neils Creek is considered to be ecologically significant based on high aesthetic value for an ecoregion stream, high water quality, and diverse benthic macroinvertebrate community.[3]

The proposed project would occur in the Cross Timbers Ecoregion of Texas.[4] This ecoregion is a transitional area between the original prairie regions to the west and the low mountains or hills of eastern Oklahoma and Texas. The project area includes two major vegetation types as defined by Texas Parks and Wildlife (TPWD),[5] including Bluestem Grassland and Oak-Mesquite-Juniper Parks/Woods. Bluestem Grassland commonly includes plants such as bushy bluestem (*Andropogon glomeratus*), slender bluestem (*Schizachyrium tenerum*), little bluestem (*Schizachyrium scoparium*), buffalograss (*Bouteloua dactyloides*), southern dewberry (*Rubus trivialis*), live oak (*Quercus virginiana*), mesquite (*Prosopis pubescens*) and huisache (*Acacia farnesiana*). Oak-Mesquite-Juniper Parks/Woods associated plants include post oak (*Q. stellata*), Ashe juniper (*Juniperus ashei*), shin oak (*Q. havardii*), blackjack oak (*Q. marilandica*), cedar elm (*Ulmus crassifolia*), Mexican persimmon (*Diospyros texana*), purple three-awn (*Aristida purpurea*), sideoats grama (*Bouteloua curtipendula*) and curly mesquite (*Hilaria belangeri*).

The species listed by the United States Fish and Wildlife Service (USFWS), or Texas Parks and Wildlife Department (TPWD), as endangered, threatened, federal candidates or state species of concern in Bosque County are listed in Table 8.1-2. There are no areas of critical habitat designated within or near the project area.[6]

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[3] TPWD, "Ecologically Significant River and Stream Segments," http://www.tpwd.state.tx.us/landwater/water/environconcerns/water_quality/sigsegs/index.phtml accessed February 6, 2014.

[4] Grifffith, Glenn, Sandy Bryce, James Omernik and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality and Environmental Protection Agency, Austin, Texas.

[5] McMahan, Craig A., Roy G. Frye and Kirby L. Brown. 1984. The Vegetation Types of Texas Including Cropland. Texas Parks and Wildlife Department, Austin, Texas.

[6] USFWS. Critical Habitat Portal. Accessed online at http://ecos.fws.gov/crithab/ May 29, 2014.

Table 8.1-2. Endangered, Threatened, and Species of Concern for Bosque County

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
BIRDS								
American peregrine falcon	Falco peregrinus anatum	0	2	0	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Artic peregrine falcon	Falco peregrinus tundrius	0	1	0	Migrant throughout the state.	DL		Possible Migrant
Bald eagle	Haliaeetus leucocephalus	1	2	2	Found primarily near rivers and large lakes.	DL	T	Possible Migrant
Black-capped vireo	Vireo atricapilla	1	3	3	Oak-juniper woodlands with distinctive patchy, two-layered aspect.	LE	E	Possible Migrant
Golden-cheeked warbler	Setophaga chrysoparia	1	3	3	Juniper-oak woodlands; dependent on Ashe juniper for long fine bark strips.	LE	E	Possible Migrant
Interior least tern	Sterna antillarum athalassos	1	3	1	Nests along sand and gravel bars in braided streams	LE	E	Resident
Mountain plover	Charadrius montanus	1	1	1	Non-breeding, shortgrass plains and fields			Nesting/ Migrant
Sprague's pipit	Anthus spragueii	1	1	1	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C		Possible Migrant
Western burrowing owl	Athene cunicularia hypugaea	1	1	1	Open grasslands, especially prairie, plains and savanna			Resident
Whooping crane	Grus americana	1	3	3	Potential migrant	LE	E	Potential Migrant
FISHES								
Guadalupe bass	Micropterus treculi	1	1	1	Endemic to perennial streams of the Edwards Plateau region. Introduced in Nueces River system.			Resident

Table 8.1-2. Endangered, Threatened, and Species of Concern for Bosque County

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Sharpnose shiner	Notropis oxyrhynchus	1	3	3	Endemic to Brazos River drainage; large turbid river, with bottom a combination of sand, gravel, and clay-mud	LE		Resident
Smalleye shiner	Notropis buccula	1	3	3	Endemic to upper Brazos River system and its tributaries (Clear Fork and Bosque); medium to large prairie streams with sandy substrate and turbid to clear warm water	LE		Resident
MAMMALS								
Cave myotis bat	Myotis velifer	0	1	0	Roosts colonially in caves, rock crevices			Resident
Plains spotted skunk	Spilogale putorius interrupta	1	1	1	Prefers wooded, brushy areas.			Resident
Red wolf	Canis rufus	0	3	0	Extirpated.	LE	E	Historic Resident
MOLLUSKS								
False spike mussel	Quincuncina mitchelli	1	2	2	Substrates of cobble and mud. Rio Grande, Brazos, Colorado and Guadalupe river basins. Not recorded from reservoirs.		T	Resident
Smooth pimpleback	Quadrula houstonensis	1	2	2	Small to moderate streams and rivers as well as moderate size reservoirs; mixed mud, sand, and fine gravel, tolerates very slow to moderate flow rates, Brazos, and Colorado River basins.	C	T	Resident

Table 8.1-2. Endangered, Threatened, and Species of Concern for Bosque County

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Texas fawnsfoot	Truncilla macrodon	1	2	1	Possibly found in rivers and larger streams, intolerant of impoundment. Brazos and Colorado River basins.	C	T	Resident
REPTILES								
Brazos water snake	Nerodia harteri	1	2	2	Upper Brazos River drainage; in shallow water with rocky bottom and on rocky portions of banks		T	Resident
Texas Garter Snake	Thamnophis sirtalis annectens	1	1	1	Wet or moist microhabitats			Resident
Texas Horned Lizard	Phrynosoma cornutum	1	2	2	Varied, sparsely vegetated uplands.		T	Resident
Timber rattlesnake	Crotalus horridus	1	2	2	Floodplains, upland pine, deciduous woodlands, riparian zones.		T	Resident
TPWD, 2014. Annotated County List of Rare Species – Bosque County revised 4/28/2014. USFWS, Obtained from http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action?fips=48035 August 19, 2014								
LE/LT=Federally Listed Endangered/Threatened DL=Federally Delisted C=Candidate for Federal Listing E, T=State Listed Endangered/Threatened Blank = Considered rare, but no regulatory listing status								

The project area may provide potential habitat to endangered or threatened species found in Bosque County. A survey of the project area may be required prior to pipeline and facility construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Based on existing habitat types, the following threatened or endangered species have the potential to occur within or near the project area.

- Peregrine Falcon (*Falco peregrinus*), including the American peregrine falcon (*F. p.anatum*) subspecies — This state threatened species is a possible migrant in the project area. They utilize a wide range of habitats during migration, including urban areas and landscape edges such as lakes or large river shores.

- Bald Eagle (*Haliaeetus leucocephalus*) — The bald eagle is a state-listed threatened species that could occur as a migrant near larger aquatic resources. Although they breed primarily in the eastern half of the state, they could potentially occur in this region of Texas during the winter along rivers or large lakes.

- Black-capped vireo (*Viro atricapilla*) — The black-capped vireo is an endangered species that could occur as a migrant within the project area. This small bird requires the presence of oak-juniper woodlands with a distinctive patchy, two-layered aspect. Habitat which could be utilized by this species occurs within the project area. This species has been documented in the past as occurring in Meridian State Park which is located west of the City of Meridian.

- Golden-cheeked warbler (*Setophaga chrysoparia*) — The golden-cheeked warbler is found as a migrant in juniper-oak woodlands and is dependent on Ashe juniper trees for long fine bark strips used for nesting. This avian species has been documented in Meridian State Park which is located west of the City of Meridian.

- Interior Least Tern (*Sterna antillarum athalassos*) — The interior least tern is federally listed as endangered. This species prefers to nest on sandbars, islands, salt flats, and bare or sparsely vegetated sand, shell, and gravel beaches that are associated with braided streams, rivers and reservoirs.

- Whooping Crane (*Grus americana*) — The whooping crane is a federally listed endangered species which only occurs in this part of Texas during migration. Whooping cranes use a variety of habitats during migration, including croplands for feeding and large, marshy palustrine wetlands for roosting. Although few large wetland areas occur within the project area, the whooping crane could also potentially occur in surrounding cropland habitat during migration.

- Two fish species, the sharpnose shiner (Notropis oxyrhynchus) and smalleye shiner (Notropis buccula) have been recently listed as endangered by the USFWS.7 These two minnows are native to the arid prairie streams of Texas and are considered to be in danger of extinction. The USFWS has designated approximately 623 miles of the Upper Brazos River Basin and the upland areas extending beyond the river channel by 98 feet on each side as critical habitat for these two fish.

- Red wolf (Canis rufus) is an endangered species that is extirpated within Texas.

- False spike mussel (*Quincuncina mitchelli*) — The false spike mussel is a state threatened species. This freshwater mollusk occurs in rivers or streams with

[7] USFWS. 2014. Sharpnose Shiner and Smalleye Shiner Protected under the Endangered Species Act. News Release, August 4, 2014.

substrates of sand, mud and gravel. However no living specimens have been documented in reservoirs suggesting an intolerance of impoundment.

- Smooth pimpleback (*Quadrula houstonensis*) — The smooth pimpleback is a federal candidate for listing and is state threatened. This freshwater mollusk exists in small to moderate streams and rivers with slow flow rates, as well as moderate size reservoirs with substrates of mixed mud, sand and fine gravel in the Brazos and Colorado River basins.
- Texas fawnsfoot (*Truncilla macrodon*) — The Texas fawnsfoot mussel is a federal candidate for listing and is state threatened. This mussel is found in rivers and larger streams of the Brazos and Colorado River basins and is intolerant of impoundment.
- Brazos water snake (*Nerodia harteri*) is a state threatened species found in the upper Brazos River drainage in shallow water with rocky bottoms or banks.
- Texas horned lizard (*Phrynosoma cornutum*) — The Texas horned lizard is a state-listed threatened species and is present throughout much of the state. They exist in open, arid, and semi-arid regions with sparse vegetation, which includes grass, cactus, scattered brush and scrubby trees. This species could potentially occur in areas with this type of vegetation.
- Timber rattlesnake (*Crotalus horridus*) — This is a state threatened species that occurs in swamps, floodplains, upland pine and deciduous woodlands, riparian zones and abandoned farmland. This species could potentially occur in areas of abandoned farmland or riparian areas.
- Golden-cheeked warbler (*Setophaga chrysoparia*) — The golden-cheeked warbler is found as a migrant in juniper-oak woodlands and is dependent on Ashe juniper trees for long fine bark strips used for nesting. This avian species has been documented in Meridian State Park which is located west of the City of Meridian.
- Interior Least Tern (*Sterna antillarum athalassos*) — The interior least tern is federally listed as endangered. This species prefers to nest on sandbars, islands, salt flats, and bare or sparsely vegetated sand, shell, and gravel beaches that are associated with braided streams, rivers and reservoirs.
- Whooping Crane (*Grus americana*) — The whooping crane is a federally listed endangered species which only occurs in this part of Texas during migration. Whooping cranes use a variety of habitats during migration, including croplands for feeding and large, marshy palustrine wetlands for roosting. Although few large wetland areas occur within the project area, the whooping crane could also potentially occur in surrounding cropland habitat during migration.

- Two fish species, the sharpnose shiner (*Notropis oxyrhynchus*) and smalleye shiner (*Notropis buccula*) have been recently listed as endangered by the USFWS.[8] These two minnows are native to the arid prairie streams of Texas and are considered to be in danger of extinction. The USFWS has designated approximately 623 miles of the Upper Brazos River Basin and the upland areas extending beyond the river channel by 98 feet on each side as critical habitat for these two fish.
- Red wolf (*Canis rufus*) is an endangered species that is extirpated within Texas.
- False spike mussel (*Quincuncina mitchelli*) — The false spike mussel is a state threatened species. This freshwater mollusk occurs in rivers or streams with substrates of sand, mud and gravel. However no living specimens have been documented in reservoirs suggesting an intolerance of impoundment.
- Smooth pimpleback (*Quadrula houstonensis*) — The smooth pimpleback is a federal candidate for listing and is state threatened. This freshwater mollusk exists in small to moderate streams and rivers with slow flow rates, as well as moderate size reservoirs with substrates of mixed mud, sand and fine gravel in the Brazos and Colorado River basins.
- Texas fawnsfoot (*Truncilla macrodon*) — The Texas fawnsfoot mussel is a federal candidate for listing and is state threatened. This mussel is found in rivers and larger streams of the Brazos and Colorado River basins and is intolerant of impoundment.
- Brazos water snake (*Nerodia harteri*) is a state threatened species found in the upper Brazos River drainage in shallow water with rocky bottoms or banks.
- Texas horned lizard (*Phrynosoma cornutum*) — The Texas horned lizard is a state-listed threatened species and is present throughout much of the state. They exist in open, arid, and semi-arid regions with sparse vegetation, which includes grass, cactus, scattered brush and scrubby trees. This species could potentially occur in areas with this type of vegetation.
- Timber rattlesnake (*Crotalus horridus*) — This is a state threatened species that occurs in swamps, floodplains, upland pine and deciduous woodlands, riparian zones and abandoned farmland. This species could potentially occur in areas of abandoned farmland or riparian areas.

No designated critical habitat for the endangered black-capped vireo or golden-cheeked warbler occurs within the project area. The majority of the pipeline for this project will occur in previously disturbed areas such as existing road right-of-way or crop areas, therefore no impacts to these avian species is anticipated from the project.

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[8] USFWS. 2014. Sharpnose Shiner and Smalleye Shiner Protected under the Endangered Species Act. News Release, August 4, 2014.

Populations of the endangered smalleye and sharpnose shiner occur within the upper Brazos River basin above Lake Whitney. Although these shiner species were once found throughout the Brazos River and several of its major tributaries within the watershed, they are currently restricted almost entirely to the contiguous river segments of the upper Brazos River basin in north-central Texas.[9]

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available geographic information systems (GIS) datasets provided by the Texas Historical Commission (TAC), there are four national register properties, eight cemeteries, 17 historical markers, and a total of 20 archeological survey areas within one mile of the proposed pipelines, pump stations or other facilities.

Based on a review of soils, geology, and aerial photographs, there is a high probability for undocumented significant cultural resources within the alluvial deposits and terrace formations associated with waterways, specifically the intermittent and perennial aquatic resources. The probability of pipelines crossing areas which may include cultural resources increases near waterways and associated landforms.

Increasing the amount of water stored by the existing reservoir would inundate a limited amount of habitat; however this action is not anticipated to result in significant impacts to area species due to the abundance of similar habitat located nearby. Impacts resulting from the construction and maintenance of the associated pipelines, pump stations or water treatment facilities are anticipated to be minimal if avoidance measures are implemented. It is anticipated that the pipelines, pump stations and other necessary facilities will be positioned to avoid impacts to known cultural resources, sensitive habitats, wetlands or stream crossings as much as reasonably possible.

8.1.4 Engineering and Costing

The City of Clifton is the primary supplier used for the Bosque County Regional Project to interconnect its system into a regional and community system. The following facilities would be needed to connect the City of Clifton to Childress WSC, Valley Mills, Meridian and Walnut Springs:

- Enlargement of off-channel storage;
- Expansion Clifton's Water Treatment Plant and Ground Storage;
- Treated Water Pump Station at Clifton and Meridian; and
- Treated Water Transmission Pipelines.

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[9] USFWS Ecological Services. Sharpnose and smalleye shiners. Accessed online at http://www.fws.gov/southwest/es/arlingtontexas/shiner.htm, on May 29, 2014.

The channel dam, off-channel reservoir, and water treatment facilities would form the hub of the regional water system. At Clifton, a central pump station would be built. From here separate pipelines would connect to distribution points in the Childress WSC and Valley Mills, and to a pump station at Meridian. From the Meridian pump station, treated water would be pumped to a distribution point in the Meridian and Walnut Springs systems.

In January 2013, HDR evaluated the costs to expand the Clifton OCR and expand the WTP capacity to 2 million gallons per day (MGD). The off-channel reservoir is designed for staged construction with an initial capacity of 500 acre-feet. Increasing the height of the zoned earthfill dam will increase the storage capacity of the off-channel reservoir. Due to limited availability of on-site borrow material, off-site borrow material will need to be imported to increase the height of the dam. Additional geotechnical studies will be required to investigate the strength and water retention ability of the higher elevation abutments and to determine if pressure grouting will be required. The cost estimate includes modifications to appurtenant structures including the intake tower and emergency spillway to accommodate the increased capacity and height of the off-channel reservoir. No improvements are required for the intake pump station or raw water pipeline. Similarly, upgrades to clearwell storage and the finished water pipeline are not required for expansion of the water supply system.

The water treatment plant is also designed for expansion with a current treatment capacity of 1 MGD. The water treatment plant building is sized to accommodate the equipment required to increase the capacity of the plant to 2 MGD. The principal cost to expand the water treatment plant is the purchase of two additional modular package units. Improvements will also be required to increase the capacity of the chemical feed systems, construct appropriate access platforms, and connect the new treatment units to the plant piping system and plant SCADA and control system.

The costs for four participating communities in Bosque County to connect to the City of Clifton's water system are summarized in Table 8.1-3. The capital and other project costs have been estimated using TWDB's Unified Costing Model for Regional Planning. The total project cost, including capital, engineering, legal costs, contingencies, environmental studies, land acquisition and surveying, for the regional interconnections is $21.8 million. These costs were determined based on dedicated infrastructure to each entity and shared infrastructure costs based on prorated supplies.

Taking into consideration debt service on a 40-year loan for the OCR expansion and 20 year debt service on all other capital costs, operation and maintenance costs, and pumping energy costs, the total annual costs are $2.4 million and by entity: Childress, $532,000; Valley Mills, $477,000; Meridian, $403,000; Walnut Springs, $371,000; and Clifton, $652,000.

Table 8.1-3. Cost Estimate Summary: Bosque County Regional Project

Item	Estimated Costs for Facilities	Childress Creek WSC	Valley Mills	Meridian	Walnut Springs	Clifton
Off-Channel Reservoir Expansion	$8,082,000	$1,533,000	$1,375,000	$1,692,000	$483,000	$2,999,000
Primary Pump Stations	$67,000	$13,000	$11,000	$14,000	$4,000	$25,000
Transmission Pipeline (6 in dia., 28 miles)	$3,614,000	$903,000	$1,335,000	$0	$1,377,000	$0
Transmission Pump Station(s) & Storage Tank(s)	$1,864,000	$674,000	$176,000	$214,000	$800,000	$0
Water Treatment Plant (2 MGD)	$1,000,000	$190,000	$170,000	$209,000	$60,000	$371,000
TOTAL COST OF FACILITIES	**$14,627,000**	**$3,313,000**	**$3,067,000**	**$2,129,000**	**$2,724,000**	**$3,395,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$4,939,000	$1,114,000	$1,007,000	$745,000	$885,000	$1,188,000
Environmental & Archaeology Studies and Mitigation	$735,000	$166,000	$154,000	$107,000	$137,000	$171,000
Land Acquisition and Surveying (188 acres)	$403,000	$91,000	$85,000	$59,000	$75,000	$94,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,088,000	$246,000	$228,000	$158,000	$203,000	$253,000
TOTAL COST OF PROJECT	**$21,792,000**	**$4,930,000**	**$4,541,000**	**$3,198,000**	**$4,024,000**	**$5,101,000**
Debt Service (5.5 percent, 20 years)	$863,000	$195,000	$180,000	$127,000	$159,000	$202,000
Reservoir Debt Service (5.5 percent, 40 years)	$716,000	$162,000	$149,000	$105,000	$132,000	$168,000
Operation and Maintenance						
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$79,000	$24,000	$17,000	$5,000	$32,000	$1,000
Dam and Reservoir (1.5% of Cost of Facilities)	$121,000	$23,000	$21,000	$25,000	$7,000	$45,000
Water Treatment Plant (2.5% of Cost of Facilities)	$637,000	$121,000	$108,000	$133,000	$38,000	$236,000
Pumping Energy Costs (213654 kW-hr @ 0.09 $/kW-hr)	$20,000	$7,000	$2,000	$8,000	$3,000	$0
TOTAL ANNUAL COST	**$2,436,000**	**$532,000**	**$477,000**	**$403,000**	**$371,000**	**$652,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1.5	**1,070**	**203**	**182**	**224**	**64**	**397**
Annual Cost of Water ($ per acft)	**$2,277**	**$2,621**	**$2,621**	**$1,799**	**$5,797**	**$1,642**
Annual Cost of Water ($ per 1,000 gallons)	**$6.99**	**$8.04**	**$8.04**	**$5.52**	**$17.79**	**$5.04**

8.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 8.1-4, and the option meets each criterion.

The participating entities must negotiate a regional water service contract to build and operated the system and to equitably share costs. This would probably include the need for a cost of service study.

Requirements specific to pipelines needed to link existing sources to users will include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the U.S. for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

Table 8.1-4. Comparison of Bosque County Interconnections Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. High
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

8.2 East Williamson County Water Supply Project

8.2.1 Description of Option

Central Texas Water Supply Corporation (WSC) and Lone Star Regional Water Authority (RWA) are pursuing a water supply transmission system to deliver supplies from Lake Granger to meet growing demands in Bell and Williamson Counties. The Lone Star RWA was created by the 82nd Legislature and authorized to design, finance, construct and operate wholesale water and wastewater infrastructure projects for public and private retail water providers. Member entities of Lone Star RWA include Sonterra MUD, CL&L MUD, Jarrell, and Williamson County.

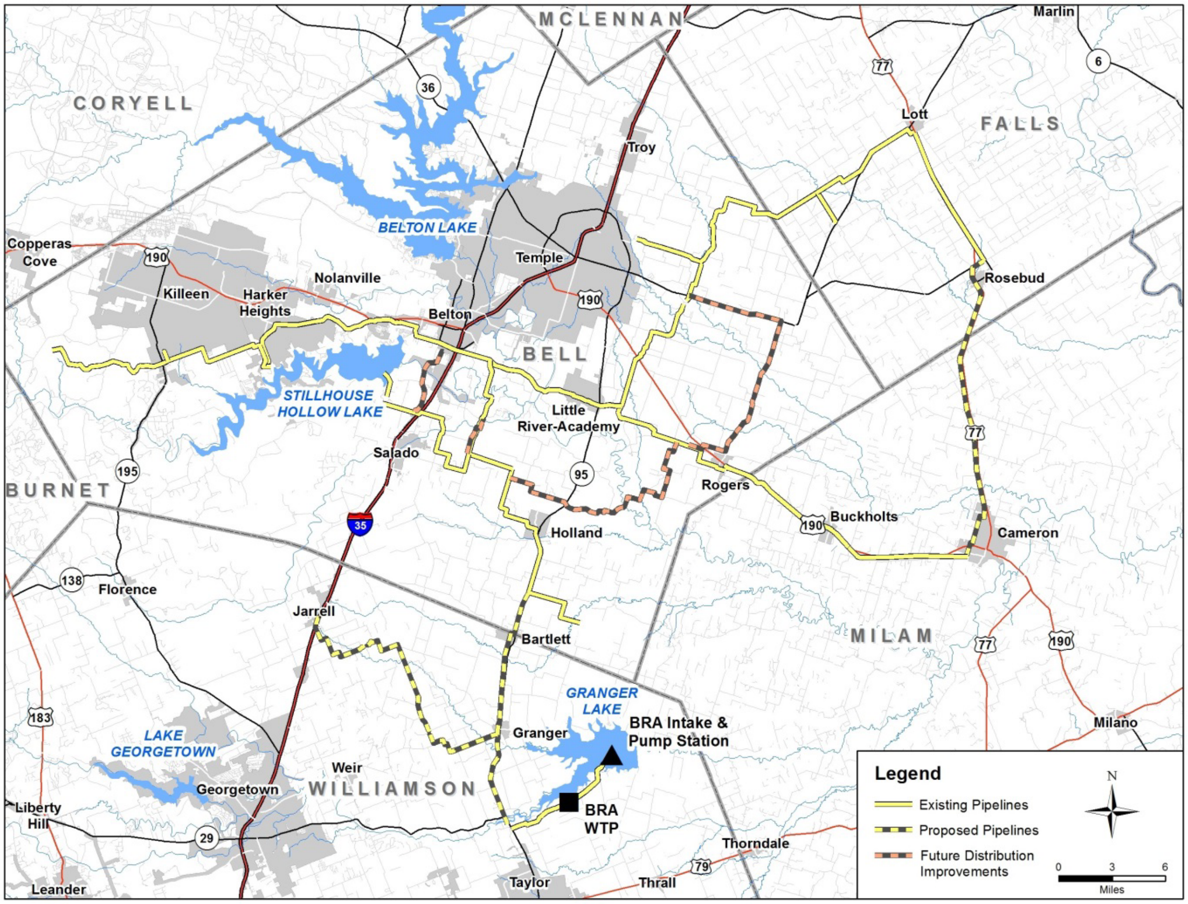
Central Texas WSC provides water to a number of water supply corporations and cities in Bell, Williamson, Milam and Lampasas Counties. The Central Texas WSC obtains water under contract with the Brazos River Authority (BRA) from Lake Stillhouse Hollow, and Trinity Aquifer.

The East Williamson County Water Supply Project is a transmission system to convey treated water from the Brazos River Authority treatment plant at Lake Granger to area water user groups. This infrastructure strategy utilizes current supplies and new supplies that may be delivered at Lake Granger.

Treated supplies from BRA's WTP at Lake Granger will be delivered to Lone Star RWA and Central Texas WSC customers as indicated in Figure 8.2-1 which includes existing and proposed transmission systems. The proposed transmission system will connect to the existing delivery pipeline near Circleville and deliver supplies northwest to Jarrell and north to Bartlett to connect with Central Texas WSC existing infrastructure. A new 8-IN diameter pipeline will be required on the east side of Central Texas WSC's system from Pettibone east to Cameron and north along SH 77 to Rosebud.

The transmission infrastructure will be designed with a 2.0 peaking factor. Lone Star RWA and Central Texas WSC will contract with BRA for 8,400 acft/yr (7.5 mgd) of Lake Granger supplies. Water User Groups that would receive supplies include: Jonah Water SUD, City of Jarrell, City of Granger, Bell-Milam Falls WSC, Williamson County-Other and entities served by Central Texas WSC.

Figure 8.2-1. East Williamson County Water Supply Project



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8.2.2 Available Supply

The supply for the East Williamson County Water Supply Project is treated Lake Granger water from the 13 MGD East Williamson County Regional Water Treatment Plant (WTP) located near the City of Taylor. The City of Taylor originally built and operated the WTP and sold it to Brazos River Authority in 2004. A new intake and WTP expansion have recently expanded the capacity from 5.5 MGD to 13 MGD to provide for increasing regional demands. Customers currently served through this system include Taylor, Hutto, Thrall, Noack WSC and Jonah Water SUD.

Lake Granger has a projected yield of 14,192 acft/yr under 2070 sediment conditions. The City of Taylor holds a 13,000 acft/yr contract from BRA for this supply. Based on the city's projected demand in 2070, 8,400 acft/yr of supply could be available for sale under this contract. Alternatively, this strategy could be supplied by other potential new supplies developed and delivered to Lake Granger including Lake Granger Augmentation strategy as described in Section 6.1, Lake Granger ASR (Section 10.4) and Little River Off-Channel Reservoir (Section 4.7).

8.2.3 Environmental Issues

There would be limited environmental impacts along the transmission system route, provided all terms and conditions of the permits are met. Environmental impacts could include:

- Possible minor impacts to riparian corridors, depending on location of pipelines
- Other possible minor impacts from pipeline development

The impacts of pipeline development will be minimized to the extent possible by following existing roadway corridors and by avoiding environmentally sensitive areas where feasible. A summary of environmental issues is presented in Table 8.2-1. No adverse impacts to federally-listed threatened or endangered species are anticipated.

Table 8.2-1. Environmental Issues: East Williamson County Water Supply Project

Water Management Option	East Williamson County Water Supply Project
Implementation Measures	Water treatment plant expansion, pump stations, and pipelines
Environmental Water Needs/Instream Flows	Negligible impact.
Bays and Estuaries	Negligible impact.
Fish and Wildlife Habitat	Possible minor impacts on riparian corridors, depending on specific location of pipelines.
Cultural Resources	Possible low impact.
Threatened and Endangered Species	Possible low impact.

8.2.4 Engineering and Costing

Cost estimates were prepared using the TWDB Unified Costing Model. Cost tables were updated to September 2013 with energy cost set at $0.09 per kWh, to be consistent with State regional water planning efforts. Cost projections were prepared using the proposed facilities and alignment described above. The cost summary is included in Table 8.2-2.

The transmission system is sized with a 2.0 peaking factor. Operating and maintenance and energy costs are projected based on the average annual operation of 8,400 acft per year. Entities would need to contract for treated supplies at the BRA WTP. The purchase cost for treated supplies is included in the total annual costs. The total project cost for treatment and delivery of 8,400 acft of potable water to the project participants is $42,127,000. The associated debt service and annual operating cost are projected at $9,855,000, yielding a finished water cost of $1,173 per acft, or $3.60 per thousand gallons.

Table 8.2-2. Cost Estimate Summary for East Williamson County Water Project

Item	Estimated Costs for Facilities
Intake Pump Stations (10 MGD)	$2,772,000
Transmission Pipeline (49 miles)	$19,318,000
Transmission Pump Station(s) & Storage Tank(s)	$6,832,000
TOTAL COST OF FACILITIES	**$28,922,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$9,157,000
Environmental & Archaeology Studies and Mitigation	$1,276,000
Land Acquisition and Surveying (310 acres)	$1,347,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,425,000
TOTAL COST OF PROJECT	**$42,127,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$3,525,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$412,000
Pumping Energy Costs (4929824 kW-hr @ 0.09 $/kW-hr)	$444,000
Purchase of Water (8400 acft/yr @ 651.7 $/acft)	$5,474,000
TOTAL ANNUAL COST	**$9,855,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 2	**8,400**
Annual Cost of Water ($ per acft)	**$1,173**
Annual Cost of Water ($ per 1,000 gallons)	**$3.60**

8.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 8.2-3, and the option meets each criterion.

Potential Regulatory Requirements:

Implementation of this water management strategy will require the following permits for pipeline construction:

- U.S. Army Corps of Engineers Section 404 permit for pipeline stream crossings and discharges of fill into wetlands and waters of the U.S. during construction.

- Stream crossings could be authorized under Nationwide Permit 12 (NWP-12), Utility Line Activities, if all terms and conditions are met, which is likely.

- A TPDES General Permit for Construction Activity is required for construction activities that disturb more than one acre, and a Storm Water Pollution Prevention Plan is required for any project that disturbs five acres or more.
- TP&WD Sand, Shell, Gravel, and Marl permits for construction in state-owned stream beds may be required.
- Appropriate permits have been and will be obtained for TxDOT highway crossings.

Table 8.2-3. Comparison of East Williamson County Water Supply Project to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient
2. Reliability	2. High reliability
3. Cost	3. Relatively high, but reasonable for a county-wide system
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Negligible impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Done
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

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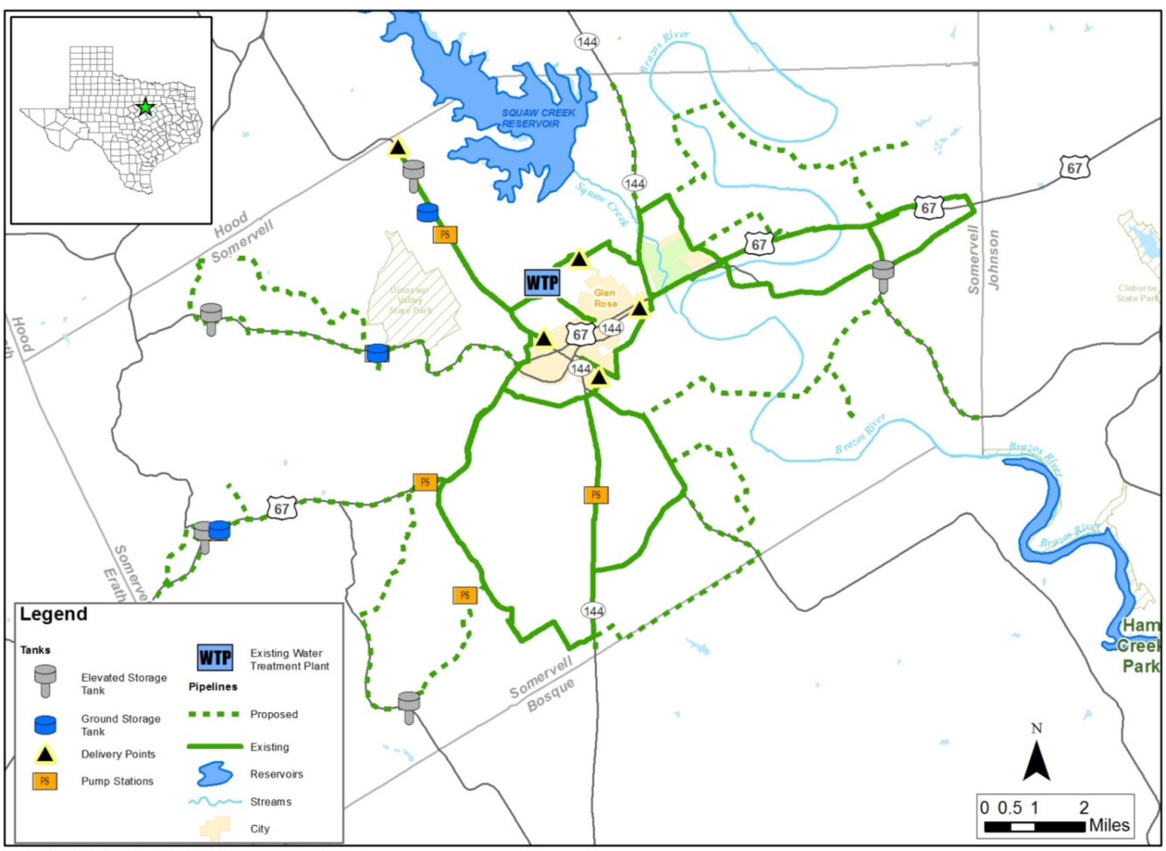
8.3 Somervell County Water Supply Project

8.3.1 Description of Option

The Somervell County Water District (SCWD) completed the first part of their surface water supply system in October 2011. Previously, Somervell County obtained all of its water from the Trinity Aquifer, which was not able to sustain current and future uses. SCWD is currently supplying water to the City of Glen Rose and Comanche Peak Steam Electric Station as wholesale customers and to many retail commercial and residential customers in the county. The components of the project that have been completed include the Paluxy River channel dam and reservoir, the raw water pump station, a 36-inch raw water pipeline, the 4,118 acre-foot off-channel Wheeler Branch Reservoir, a 2.5 MGD membrane filtration water treatment plant, two treated water pump stations and elevated storage tanks, and part of the distribution piping system. A 1.25 MGD water treatment plant expansion and additional distribution system piping will allow SCWD to deliver water to more commercial and residential customers within Somervell County. The SCWD plans to complete the project by 2035. When complete, the project will provide 2,000 acre-feet per year of surface water supplies to water users in Somervell County. Figure 8.3-1 shows SCWD's the existing and proposed infrastructure and major delivery points.

Figure 8.3-1. Proposed Phases of the Somervell County Water Supply Project



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8.3.2 Available Supply

The Somervell County Water District has a water right for 2,000 acre-feet per year from the Wheeler Branch Reservoir, which is operated in conjunction with a channel dam on the Paluxy River (CA-12-5744)[1]. The District has an agreement with the Brazos River Authority (BRA) that makes the 2,000 acre-feet per year available on a reliable basis by subordinating BRA's water right in Lake Whitney (CA 12-5157). The existing components of the Somervell County Water Supply Project provide1,400 acre-feet per year. The planned water treatment plant expansion in 2016 will allow the SCWD to use the full yield of the project[2].

8.3.3 Environmental Issues

There would be limited environmental impacts along the water distribution system route, provided all terms and conditions of the permits are met. Environmental impacts could include:

- Possible minor impacts to riparian corridors, depending on location of pipelines
- Other possible minor impacts from pipeline development

The impacts of pipeline development will be minimized to the extent possible by following existing roadway corridors and by avoiding environmentally sensitive areas where feasible. A summary of environmental issues is presented in Table 8.3-1. Suitable habitat for the black-capped vireo, golden-cheeked warbler, and the whooping crane were not observed in the proposed construction areas, and no adverse impacts to federally-listed threatened or endangered species are anticipated[2].

Table 8.3-1. Environmental Issues: Somervell County Water Supply Project

Water Management Option	Somervell County Water Supply Project
Implementation Measures	A 1.25 MGD water treatment plant expansion, pump stations, ground and elevated storage tanks, and pipelines (approx. 75 miles)
Environmental Water Needs/Instream Flows	Negligible impact.
Bays and Estuaries	Negligible impact.
Fish and Wildlife Habitat	Possible minor impacts on riparian corridors, depending on specific location of pipelines.
Cultural Resources	Possible low impact.
Threatened and Endangered Species	Possible low impact.
Water Management Option	Somervell County Water Supply Project

[1] Certificate of Adjudication 12-5744

[2] Somervell County Water District, Engineering Feasibility Report Phase 5, 6, 8a, and 8b Distribution System. Prepared for TWDB by Freese and Nichols, Inc. Updated March 2013.

8.3.4 Engineering and Costing

Figure 8.3-1 shows the facilities included in the Somervell County Water Project. Water from Wheeler Branch Reservoir is treated at the water treatment plant below the dam and distributed to the county by a system of pump stations, ground and elevated storage tanks, and pipelines. Completed phases include a 2.5 MGD water treatment plant and high service pump station, a raw water pump station, 2 booster pump stations, 4 ground storage tanks, 2 elevated tanks, and 75 miles of pipeline ranging from 6 inches to 18 inches in diameter. Future phases will include expanding the water treatment plant and high service pump station to 3.75 MGD, 3 booster pump stations, 2 ground storage tanks, 3 elevated tanks, and 75 miles of pipeline ranging from 6 inches to 12 inches in diameter.

Financing was identified as a possible implementation issue in the 2011 Plan. To date, the phases of the Somervell County Water Supply Plan that have been built have been financed through multiple loan requests, including: TWDB's Water Infrastructure Fund (WIF) construction loan ($9.4 million), WIF rural loan ($9.5 million), Economically Distressed Areas Program (EDAP) Rural State Water Plan Grant ($9.5 million), EDAP State Water Plan Grant ($1.3 million), and the EDAP State Water Plan Loan ($1.3 million), among others.

Table 8.3-2 summarizes the capital costs for the phases that have yet to be constructed (i.e., Phases 7A and 9 through 17), which total $23,017,000 in September 2013 dollars. Contingencies, professional services, land costs, and interest during construction will add $12,232,000, for a total project cost of $35,249,000. With 5.5 percent interest and 20-year bonds, the annual debt service is $2,950,000. Operation and maintenance costs for pumping, transmission and treatment add $606,000 per year, for a total annual cost of $3,556,000 for delivery of 600 acre-feet. All costs are for retail, as opposed to wholesale, facilities. The cost of treated water delivered is $5,928 per acre-foot, or $18.20 per thousand gallons. The development of a new surface water supply and retail distribution system in a rural area results in relatively high costs per unit of water. The cost for this strategy is especially high because it is calculated by dividing the total cost for the remainder of the project by the total amount of water made available by the remainder of the project. The WTP expansion in Phase 7A increases the total supply by 600 acft/yr because 1,400 acft/yr was made available by earlier phases and the water right limits the project to 2000 acft/yr. The costs of Phases 9-17 are associated with a retail distribution system in a rural area where the density of customers is low. Considering the entire project (Phases 1-17) and the full permitted amount of water (2,000 acft/yr), the annual cost of water is around $12.89 per thousand gallons.

Table 8.3-2. Cost Estimate Summary for Somervell County Water Supply Project Phases 7A & 9-17

Item	Estimated Cost for Facilities
Water Treatment Plant Expansion (1.25 MGD)	$895,000
High Service Pump Station Expansion	$90,000
6" Pipe	$2,336,000
8" Pipe	$7,203,000
12" Pipe	$6,400,000
Boring and Casing	$684,000
Horizontal Directional Drilling	$475,000
Pavement Repair	$142,000
Pressure Reducing Valve	$95,000
Ground Storage Tanks	$895,000
Elevated Storage Tanks	$3,265,000
Pump Stations	$537,000
TOTAL COST OF FACILITIES	**$23,017,000**
Engineering, Legal Costs and Contingencies	$6,905,000
Environmental & Archaeology Studies and Mitigation	$1,853,000
Land Costs	$2,282,000
Interest During Construction (1 year)	$1,192,000
TOTAL COST OF PROJECT	**$35,249,000**
ANNUAL COST	
Debt Service (5.5 percent for 20 years)	$2,950,000
Operation and Maintenance	$529,000
Energy Costs (852,700 kWh @ $0.09/kWh)	$77,000
TOTAL ANNUAL COST	**$3,556,000**
Available Project Yield (acft/yr)	**600**
Annual Cost of Water ($ per acft)	**$5,928**
Annual Cost of Water ($ per 1,000 gallons)	**$18.20**

Notes:

1. All costs are for retail facilities

2. Total project yield is 2000 acft/yr; 1400 acft/yr provided by other phases

8.3.5 Implementation Issues

Four sites with potentially significant cultural resources were identified in the vicinity of the proposed pipeline route[3]. The Somervell County Water District plans to preserve all four sites by completely avoiding each site and following the recommendations specified in the report. No impact to cultural resources is expected. Financing will continue to be an implementation issue, and financing vehicles similar to those used to fund the first part of the project are expected to be used to complete the project. Table 8.3-3 compares this water management strategy to the plan development criteria.

Table 8.3-3. Comparison of Somervell County Water Supply Project to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Relatively high, but reasonable for a county-wide system
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Done
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

[3] An Archaeological Survey of the Proposed Somervell County Water District Pipeline Route. Prepared by AR Consultants, Inc. for Somervell County Water District. January 2012.

Potential Regulatory Requirements:

Implementation of this water management strategy will require the following permits for pipeline construction:

- U.S. Army Corps of Engineers Section 404 permit for pipeline stream crossings and discharges of fill into wetlands and waters of the U.S. during construction.
    - Stream crossings could be authorized under Nationwide Permit 12 (NWP-12), Utility Line Activities, if all terms and conditions are met, which is likely.
- A TPDES General Permit for Construction Activity is required for construction activities that disturb more than one acre, and a Storm Water Pollution Prevention Plan is required for any project that disturbs five acres or more.
- TP&WD Sand, Shell, Gravel, and Marl permits for construction in state-owned stream beds may be required.
- Appropriate permits have been and will be obtained for TxDOT highway crossings.

8.4 West Central Brazos Water Distribution System

8.4.1 Description of Option

The West Central Brazos Water Distribution System (WCBWDS) is a relatively unused system that could potentially provide raw water to a large portion of the upper Brazos River Basin area. The WCDWDS pipeline facilities, which are owned by the Brazos River Authority (BRA), consist of an intake and pump station east of Breckenridge. The facilities currently provide raw water for municipal, irrigation and mining purposes to the area west of Possum Kingdom.

The BRA has received requests from numerous area water suppliers interested in purchasing raw water from Possum Kingdom Lake that could be conveyed through the WCBWDS facilities. Albany, Breckenridge, Eastland County WSD, and West Central Texas MWD have all expressed interest in obtaining water from the BRA. As part of the West Central Brazos Study[1], a hydraulic analysis of the WCBWDS was conducted and improvements were identified to move water to different participants. Three scenarios were evaluated: 1) existing demands, 2) short-term requests, and 3) long-term requests. These amounts from the West Central Brazos Study are shown in Table 8.4-1.

The hydraulic study found that with pump station improvements and some additional pipeline capacity, the WCBWDS facilities could have sufficient capacity to serve the existing customers and the near-term request for water. With the addition of a booster station and a 27-inch parallel pipeline, the facilities could serve additional supply to West Central Texas MWD, Eastland County WSD, the City of Graham, and the City of Albany. The WCBWDS pipeline could provide water to 20 or more entities.

For the 2016 Plan, the transport of water from Possum Kingdom Lake using the WCBWDS is being considered by several west Texas entities including many from the 2004 study referred to as the Midway Group whose participants included: Fort Griffin SUD (formerly Shackelford WSC), Stephens Regional SUD, the City of Throckmorton and the City of Breckenridge. The Midway Group provides much of the water in Shackelford, Stephens and Throckmorton Counties. Primary water sources for the group include Hubbard Creek Reservoir, Lake Daniel, Lake Throckmorton and a contract with the City of Albany, which receives water from Hubbard Creek Reservoir and Lake McCarty. The Water User Groups (WUGs) participating in the Midway Group have access to sufficient supplies to meet TWDB demand projections (demand projections for Fort Griffin SUD were not estimated by the TWDB because it is not a WUG), but are limited in their capability to accommodate demands that are substantially greater than TWDB projections. Additionally, encountering a drought worse than the drought of record could reduce available supplies to less than projected demands. To meet potential needs of the Midway Group, this strategy proposes to transport water from Possum Kingdom Lake to the Stephens Regional SUD water treatment facility near Breckenridge via the WCBWDS, and distributed using existing facilities, upgraded proposed facilities and new

[1] Freese and Nichols, *West Central Brazos River Basin Regional Water Treatment and Distribution Facility Plan*, August 2004.

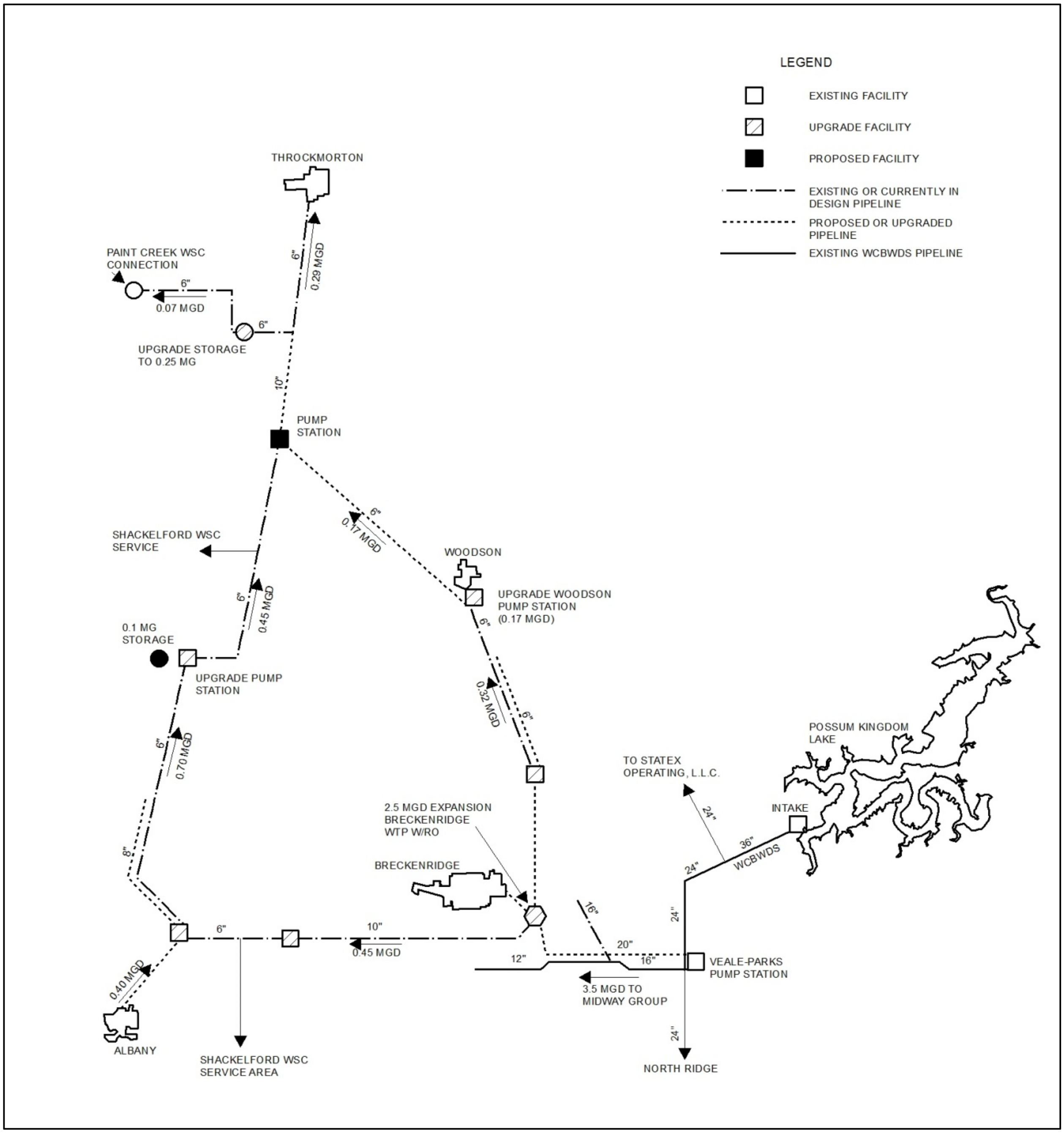
facilities to increase supplies and service currently unserved areas. Figure 8.4-1 presents a general schematic of the proposed improvements required for this strategy.

Table 8.4-1. Demands for WCBWDS Hydraulic Analyses

Water User	Demand (MGD)	Cumulative Demand (MGD)
Existing Demands	2.12	2.12
Near-Term	6.42	8.54
Fort Griffin SUD[1]		
Breckenridge[1]		
Stephens Regional SUD[1]		
Throckmorton[1]		
Mining		
Long-Term	18.96	27.50
Albany		
WCTMWD		
Eastland County WSD		
Graham		
Stephens Regional SUD		

1 – Entities have not requested additional water from BRA

Figure 8.4-1. Schematic of Midway Group Interconnections Using the WCBWDS Facilities (Not to Scale)



8.4.2 Available Yield

This strategy assumes that the Midway Group participants would contract with the BRA for a total raw water supply of 2,000 acft/yr. This strategy would be provided supply under the BRA System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. The System Operations permit would need to be successfully obtained by the BRA before this strategy could be implemented. Assuming 30 percent of this supply is lost as reject water during treatment (desalination), the available treated supply is approximately 1,400 acft/yr. The total projected demand for the group is about 1,600 acft/yr for the planning period.

The WCBWDS would be used to move the 2,000 acft/yr of water from Possum Kingdom Lake to the regional water treatment plant. Hydraulic analyses of this pipeline found that a new 20-inch pipeline and some pump station improvements were needed to meet the peak demands of the BRA's current customers and the Midway Group. To treat the water, the existing water treatment plant at Breckenridge would be expanded with a 2.5 MGD microfiltration and reverse osmosis facility. Alternatively, a new water treatment plant could be built solely for treating water from Possum Kingdom Lake. The reject water could possibly be discharged to evaporation beds, brine disposal well, , or by other means. Details of the proposed upgrades are shown in Figure 8.4-1 and available supplies to each participant are discussed below.

- **Throckmorton County.** This strategy proposes to supply the City of Throckmorton with 193 acft/yr by upgrading Fort Griffin SUD's planned expansion into Throckmorton County and utilizing existing and new water lines in the Stephens Regional SUD system. This is sufficient to meet the City's full demands of 182 acft/yr in 2020.
- **Shackelford County.** Of the remaining supply, approximately 250 acft/yr of treated water would be provided to Fort Griffin SUD, 400 acft/yr to Stephens Regional SUD and 550 acft/yr to Breckenridge to supplement current contracted supplies. The water for Fort Griffin SUD would be taken south of Breckenridge and transported through the Fort Griffin SUD's system to a proposed in-line pump station along Highway 180. The water would then be conveyed to the WSC's office pump station where it could be blended with water from the City of Albany and transported to an existing booster pump station near Fort Griffin. From there, water would be distributed to Fort Griffin SUD's customers and the City of Throckmorton. This scenario requires approximately 11.5 miles of upgrades to existing or planned water lines, upgrades of 5 pump stations and several new facilities. Some of these improvements are already proposed to serve retail customers of Fort Griffin SUD.
- **Stephens County.** Stephens Regional SUD would take treated water directly from the new regional water treatment plant. New connections to their existing distribution facilities would be needed. Some upgrades to Stephens Regional SUD system as shown in Figure 8.4-1 are also necessary to move water to Throckmorton and expand service to retail customers. These improvements include nearly 13 miles of new 6-inch pipeline and upgrades to Stephens Regional SUD's two existing pump stations. No additional improvements are proposed for the existing Breckenridge facilities.

8.4.3 Environmental Issues

The environmental impacts are expected to be low for the transmission improvements and system upgrades. Most of the upgrades are to existing or proposed pipelines. It is assumed that new pipelines can be routed around environmentally sensitive areas, as needed. Environmental impacts for the reject water from the treatment facility could be low to moderate, depending on the selected disposal method. Further study is needed on the disposal options and potential impacts. There would be minimal impacts to Possum Kingdom Lake from this strategy. The quantity of water represents a small amount of the total yield of the reservoir, and would have little impact on water levels or downstream flows. A summary of environmental issues is presented in Table 8.4-2.

Table 8.4-2. Environmental Issues: Midway Group Option using the WCBWDS

Water Management Option	Midway Group Option using the WCBWDS
Water Management Option	Infrastructure improvements to supply water from Possum Kingdom Lake to entities in Stephens, Shackelford and Throckmorton Counties (Midway Group).
Implementation Measures	Upgrading of existing pipelines and pump stations to move water from a regional water treatment plant near Breckenridge to users in a 3-county area. Includes 2.5 MGD expansion of water treatment plant with microfiltration to treat brackish water from Possum Kingdom Lake.
Environmental Water Needs / Instream Flows	Negligible impacts to Possum Kingdom Lake. Potential impacts to water quality if brine effluent is discharged to surface water streams.
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Negligible impact from upgrade of infrastructure since most of the infrastructure is in place. Possible low to moderate impacts if brine effluent is discharged to surface water streams.
Cultural Resources	Negligible impact
Threatened and Endangered Species	Low to moderate impacts to threatened or endangered species depending on specific locations of pipelines and disposal option of brine effluent.
Comments	Impacts from brine discharge will be evaluated and mitigated during the permitting process

8.4.4 Engineering and Costing

Facilities required for the Midway Option using the WCBWDS to deliver treated water to its customers in Stephens, Shackelford, and Throckmorton Counties include:

- Water treatment plant expansion (with microfiltration)
- Pump station upgrades
- Transmission pipeline, and
- Elevated storage tank upgrades

The total project costs for this strategy are estimated at $21.2 million, which includes upgrades to the WCBWDS pipeline and a 2.5 MGD water treatment facility. The cost for treated water would be $7.65 per 1,000 gallons. The capital and annual costs are shown in Table 8.4-3. Water would be purchased from the BRA at the system rate at the time the contract is enacted. This water supply is dependent on the BRA successfully obtaining the System Operations permit.

Table 8.4-3. Estimated Cost for the Midway Group Interconnections

Item	Estimated Costs
Capital Costs	
Intake and Pump Station Improvements	$1,284,000
Upgrade existing and new Transmission Pipeline (31 miles)	$5,791,000
Water Treatment Plant (2.5 MGD)	$7,619,000
Total Capital Cost	$14,694,000
Engineering, Legal Costs and Contingencies	$4,853,000
Environmental & Archeological Studies and Mitigation	$493,000
Land Acquisition and Surveying (12 acres)	$53,000
Interest During Construction (1.5 years)	$1,055,000
Total Project Cost	$21,148,000
Annual Costs	
Debt Service (5.5 percent, 20 years)	$1,770,000
Operation and Maintenance	$1,475,000
Pumping Energy Costs (@ $0.09/kWh)	$135,000
Purchase of Water (2000 acft/yr @ $54.50/acft)	$109,000
Total Annual Cost	$3,489,000
Available Project Yield (acft/yr)	1,400
Annual Cost of Water ($ per acft)	$2,492
Annual Cost of Water ($ per 1,000 gallons)	$7.65

8.4.5 Implementation Issues

Stephens Regional SUD received $5.8 million in total TWDB assistance through the DWSRF program to construct a surface water treatment plant near the City of Breckenridge and water lines to connect four of the districts pressure planes. The District currently purchases treated water from Breckenridge through a contract that will expire in 2015. The District has entered into a raw water purchase agreement with the Brazos River Authority to buy water from Possum Kingdom Reservoir.

This water supply option has been compared to the plan development criteria, as shown Table 8.4-4 the option meets each criterion. A major issue facing this option is that full participation of the identified entities may be critical to having an economically feasible project. Utilization of the WCBWDS will require infrastructure improvements that will need to be financed by the water users. Significant increases in the cost of water associated with the infrastructure improvements and water purchase can impede implementation, especially for smaller entities with limited financial resources.

The other major implementation issues are potential water quality concerns associated with the treatment and disposal of the elevated salts in the water from Possum Kingdom Lake. The Midway Group Regional WTP is proposed to treat Possum Kingdom water using reverse osmosis (or other comparable method). This will generate a brine reject stream that will require disposal. Options considered include discharge to the Brazos River, deep well injection, oil field flooding, or evaporation ponds. Depending on the disposal option, the cost of disposal and the time needed to obtain necessary permits will vary. For any discharge to state waters, a Texas Pollutant Discharge Elimination System Permit would be needed. This permit is issued by TCEQ and requires demonstration of no to low impacts to the water quality of the receiving stream. Permits for deep well injection are granted by the TCEQ for municipal and manufacturing wastes or by the Railroad Commission of Texas for oil and gas operations. The permitting process through TCEQ for deep well injection can be costly and take several years. Options for salt water disposal through the oil and gas industry either by injection or oil field flood are likely to be easier to implement, but these options require willing oil/gas participation with appropriate facilities. One implementation issue associated with evaporation ponds or drying beds is available space. For small-scale projects, this may be an option, but large scale projects will generate considerable amounts of brine requiring significant area for effective evaporation.

Mitigation requirements would vary depending on impacts. Mitigation is expected to be negligible for the infrastructure improvements. Mitigation requirements associated with the disposal of the brine effluent are unknown.

Table 8.4-4. Caption Comparison of Midway Group Interconnections to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	Requires approval of the BRA System Operations permit at TCEQ
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Moderate
B. Environmental factors	
1. Environmental Water Needs	1. Possible low to moderate impact, depending on disposal method for brine effluent
2. Habitat	2. Low impact possible where new pipelines are constructed
3. Cultural Resources	3. Possible low impact
4. Bays and Estuaries	4. No substantial impact
5. Threatened and Endangered Species	5. Possible low to moderate impact, depending on disposal method for brine effluent
6. Wetlands	6. Low impact possible where new pipelines are constructed
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	No apparent negative impacts on agriculture or natural resources
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet demand
F. Requirements for Interbasin Transfers	No interbasin water transfer required
G. Third Party Social and Economic Impacts from Voluntary Redistribution	No anticipated third party impacts

9 Groundwater

9.1 Regional Groundwater for Bryan

9.1.1 Description of Option

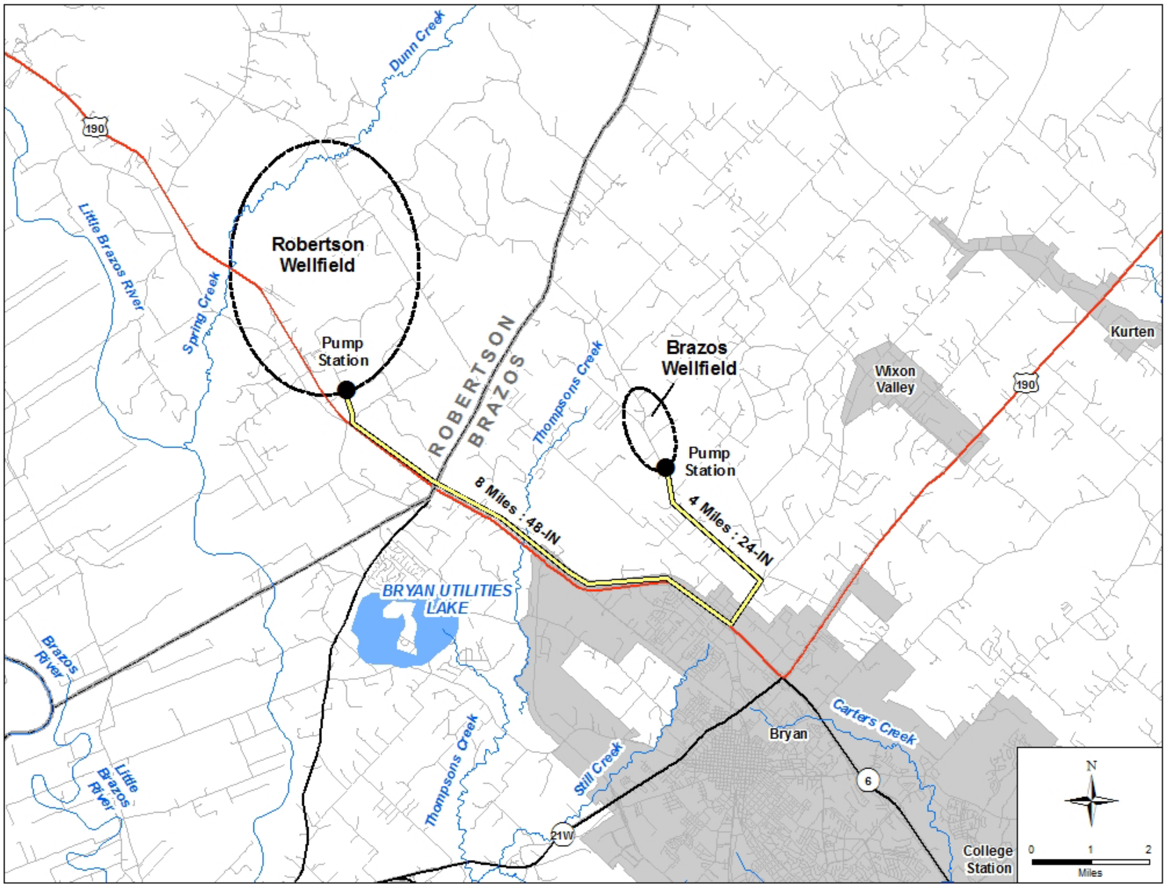
The City of Bryan (Bryan) currently supplies all of its customers with water from the Sparta and Simsboro Aquifers in Brazos County. In 2070, Bryan has been allocated 19,398 acft from the Carrizo-Wilcox Aquifer and 769 acft from the Sparta Aquifer through 1this regional planning process. Bryan is projected to grow significantly over the planning period and the needs can no longer be met solely by groundwater within Brazos County. Estimated water needs for the Bryan ranges from a surplus of about 300 acft/yr in 2030 to a shortage of about 24,400 acft/yr in in 2070. A review of the MAG for the Carrizo-Wilcox in Brazos County shows no availability until 2040 and then increasing to about 5,700 acft/yr in 2070. A review of the MAG for the Carrizo-Wilcox in Robertson County shows groundwater availability to increase from about 19,600 acft/yr in 2020 to about 20,700 acft/yr in 2070.

To meet the future needs in the Bryan, two well fields are proposed, one in Robertson County and an expansion of the Bryan's current well field in Brazos County. The Robertson County well field project contains an ultimate build out with Simsboro wells northwest of the existing Bryan well field in Brazos County. The Robertson well field can meet the needs until 2050. Then, the Brazos County well field would be expanded with new Simsboro wells. Figure 9.1-1. Locations of planned Bryan well fields and facilities illustrates the proposed regional groundwater system for the Bryan.

9.1.2 Available Yield

The new production wells in Brazos and Robertson Counties produce water from the Simsboro Formation of the Carrizo-Wilcox. According to hydrogeologic information of the area, the Simsboro wells are capable of producing 2,000 gpm and are 2,500 ft deep in Robertson County and 2,800 ft in Brazos County. The TWDB has determined that the Modeled Available Groundwater (MAG) for the Carrizo-Wilcox Aquifer in Brazos and Robertson Counties is 57,169 and 46,583 acft/yr in 2070, respectively. On the basis of projections of existing demands in Brazos County, there is no MAG Constrained availability until 2040. When the project would come online in 2050, the MAG constrained availability is 7,010 acft/yr by 2050 and increases to 10,209 acft/yr iby 2070. In Robertson County, the MAG constrained availability in Robertson County is 20,738 acft/yr in 2070.

Figure 9.1-1. Locations of planned Bryan well fields and facilities



9.1.3 Environmental Issues

The Brazos and Robertson Counties for the Bryan Project involves the development of a new well field in Robertson County and the expansion of an existing well field in Brazos County, associated well collection pipelines and pumps, upgrades to an existing water treatment plant and a transmission pipeline. The Robertson County well field will include 14 Simsboro Aquifer wells, and the Brazos County existing well field will add five Simsboro wells to the existing number.

This report section discusses the potential impacts to environmental and cultural resources known to exist within the proposed project area.

The project area occurs in the Post Oak Savannah Vegetational Area.[1] Common woody species of the Post Oak Savannah Vegetational Area include post oak (*Quercus stellata*), blackjack oak (*Q. marilandica*), and species of hickory (*Carya* sp.). Grasses of this area commonly include little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*) and switchgrass (*Panicum virgatum*).

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[1] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.

Vegetation types as described by TPWD[2] within the project area includes Post Oak Woods/Forest, Post Oak Woods-Forest and Grassland Mosaic, and Other Native and Introduced Grasses areas. Descriptions of these vegetation types closely follow those included in the Post Oak Vegetational Area above. No agricultural impacts are expected as pipelines and well locations will avoid affecting cropland.

Construction of the pipelines, pump stations and wells would involve the disturbance of existing habitat. The proposed transmission pipeline would require a construction corridor and maintenance corridor after completion. Significant portions of this pipeline are located along existing rights-of-way, fencerows, and other disturbed areas including cropland, which would reduce their overall vegetative impact. Herbaceous habitats would recover quickly from impacts and would experience low negative impacts. Outside the maintained right-of-way, land use would not be anticipated to change due to pipeline construction. However any impacts to woody vegetation would be permanent due to required pipeline, pump and well maintenance activities.

The transmission pipeline would cross several waterbodies within the project area including Peach, Thompsons and Campbells Creeks, and Thompsons Branch which is a tributary of Thompsons Creek. Appropriate Best Management Practices (BMPs) used during pipeline construction would help minimize impacts from these pipeline construction activities. National Wetland Inventory (NWI) maps show wetlands occurring along the transmission pipeline and within the well field areas. The Brazos well field mapped areas include primarily freshwater ponds, however the Robertson County well field contains numerous occurrences of several types of wetland areas including freshwater ponds, freshwater emergent wetlands, forested/shrub wetlands and a freshwater lake. A ground survey wetland delineation would be required to determine which of these and other features would be affected by the project and to what extent. This delineation would document the locations of streambeds, stream widths, quality and type of water bodies, types of aquatic vegetation, presence of special aquatic resources and areas of jurisdictional Waters of the U.S. likely to be disturbed during construction. Coordination with the U.S. Army Corps of Engineers would be required for construction within waters of the U.S. Impacts from the proposed project resulting in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

Concerns associated with the development of the two well field areas include changes in water levels in the two aquifers drawn upon and potential impacts to the surrounding streams, wetlands and existing water wells found near the well fields from lowered water levels. The possibility exists that water levels in the aquifers, affected by the new wells, could affect the habitat within the area. Waters of the U.S. found within the two project area well field areas include Wickson Creek in Brazos County, and Walker, Spring, Peach, Dunn and Campbells Creeks in Robertson County.

The 2012 Texas Integrated Report - Texas 303(d) List identifies the water bodies in or bordering Texas for which effluent limitations are not stringent enough to implement water quality standards, and for which the associated pollutants are suitable for measurement by maximum daily load. The most recent 303(d) List includes segments of

[2] McMahan, Craig A, Roy G. Frye and Kirby L. Brown. 1984. *The Vegetation Types of Texas including Cropland*. Texas Parks and Wildlife, Austin, Texas.

Carters Creek which is categorized as 5a for bacteria. Category 5a indicates that a Total Maximum Daily Load study is underway, scheduled, or will be scheduled for one or more parameters. Spring, Campbells, Thompsons, Still and Wickson Creeks are listed as 5b for bacteria. Category 5b indicates that a review of the standards for one or more parameters will occur before a management strategy is selected. Thompsons Creek is also listed for depressed dissolved oxygen with a category of 5c which means that additional data will be collected and/or evaluated for one or more parameters before a management strategy is selected. Potential impacts to existing water quality are not anticipated from this project.

Plant and animal species listed by the U.S. Fish and Wildlife Service (USFWS) and Texas Parks and Wildlife Department (TPWD) as endangered, threatened or rare in the project area are presented in Table 9.1-1. Inclusion in this table does not mean that a species will occur within the project area, but only acknowledges the potential for its occurrence in the project area counties. No USFWS designated critical habitat areas occur near the project area.

Table 9.1-1. Endangered, Threatened, and Species of Concern for Brazos and Robertson Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
				AMPHIBIANS				
Houston toad	*Anaxyrus houstonensis*	0	3	0	Endemic species found in sandy substrate near pools.	LE	E	Resident
				BIRDS				
American peregrine falcon	*Falco peregrinus anatum*	0	2	0	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	0	1	0	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	0	2	0	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Wintering migrant found in weedy fields with a key component of bare ground for running and walking	--	--	Migrant

Table 9.1-1. Endangered, Threatened, and Species of Concern for Brazos and Robertson Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Interior least tern	*Sterna antillarum athalassos*	0	3	0	Nests along sand and gravel bars in braided streams	LE	E	Resident
Peregrine falcon	*Falco peregrinus*	0	2	0	Possible migrant. Subspecies not easily distinguishable so reference is made to species level.	DL	T	Possible Migrant
Sprague's pipit	*Anthus spragueii*	0	1	0	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Whooping crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Potential Migrant
Wood stork	*Mycteria americana*	0	2	0	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX	--	T	Migrant
				FISHES				
Blue sucker	*Cycleptus elongates*	0	2	0	Found in larger portions of major rivers in Texas.	--	T	Resident
Sharpnose shiner	*Notropis oxyrhynchus*	0	3	0	Endemic to Brazos River drainage. Found in large rivers.	LE	--	Resident
Smalleye shiner	*Notropis buccula*	0	3	0	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident

Table 9.1-1. Endangered, Threatened, and Species of Concern for Brazos and Robertson Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
INSECTS								
A mayfly	*Procloeon texanum*	0	1	0	Found in Oklahoma and Texas. Mayflies are distinguished by their aquatic larval stage; adults generally found in bankside vegetation.	--	--	Resident
Gulf Coast clubtail	*Gomphus modestus*	0	1	0	Found in medium rivers with moderate gradient and streams with silty sand or rocky bottoms.	--	--	Resident
Smoky shadowfly	*Neurocordulia molesta*	0	1	0	Found in rivers and sometimes larger streams with rock or logs to which the larvae cling.	--	--	Resident
MAMMALS								
Louisiana black bear	*Ursus americanus luteolus*	0	2	0	Possible as transient in bottomland hardwoods and inaccessible forested areas.	LT	T	Possible transient
Plains spotted skunk	*Spilogale putorius interrupta*	1	1	1	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	0	3	0	Extirpated.	LE	E	Historic Resident
MOLLUSKS								

Table 9.1-1. Endangered, Threatened, and Species of Concern for Brazos and Robertson Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
False spike mussel	*Quincuncina mitchelli*	0	2	0	Substrates of cobble and mud. Rio Grande, Brazos, Colorado and Guadalupe river basins.	--	T	Resident
Smooth pimpleback	*Quadrula houstonensis*	0	2	0	Freshwater mollusk found in small to moderate streams and rivers as well as moderate sized reservoirs. Brazos and Colorado River Basins.	C	T	Resident
Texas fawnsfoot	*Truncilla macrodon*	0	2	0	Found in rivers and larger streams, intolerant of impoundment.	C	T	Resident
PLANTS								
Branched gay-feather	*Liatric cymosa*	1	1	1	Texas endemic found on somewhat barren grassland openings in post oak woodlands.	--	--	Resident
Bristle nailwort	*Paronychia setacea*	0	1	0	Flowering vascular plant endemic to eastern south central Texas in sandy soils.	--	--	Resident
Large-fruited sand-verbena	*Abronia macrocarpa*	0	3	0	Texas endemic restricted to sparse herbaceous vegetation in deep, drained sands in openings in Post oak woodlands and blowouts.	LE	E	Resident

Table 9.1-1. Endangered, Threatened, and Species of Concern for Brazos and Robertson Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Navasota ladies'-tresses	*Spiranthes parksii*	0	3	0	Texas endemic found in opening in post oak woodlands in sandy loams along upland drainages or intermittent streams.	LE	E	Resident
Panicled indigobush	*Amorpha paniculata*	0	1	0	A stout shrub up to 9 feet tall that grows in acid seep forests, peat bogs, wet floodplain forests and seasonal wetlands on the edge of saline prairies.	--	--	Resident
Parks' jointweed	*Polygonella parksii*	0	1	0	Texas endemic, primarily found on deep, loose, sand blowouts in Post Oak Savannas.	--	--	Resident
Sandhill woolywhite	*Hymenopappus carrizoanus*	0	1	0	Texas endemic found in disturbed or open areas in grasslands and post oak woodlands on deep sands.	--	--	Resident
Small-headed pipewort	*Eriocaulon koernickianum*	0	1	0	Found in East Texas post-oak woodlands and xeric sandhill openings on permanently wet acid sands of upland seeps and bogs.	--	--	Resident
Texas meadow-rue	*Thalictrum texanum*	0	1	0	Texas endemic primarily found in woodlands and woodland margins on soils with a surface layer of sandy loam but also occurs on prairie pimple mounds.	--	--	Resident

Table 9.1-1. Endangered, Threatened, and Species of Concern for Brazos and Robertson Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Texas windmill grass	*Chloris texensis*	0	1	0	Texas endemic grass found in sandy to sandy loam soils in relatively bare areas in coastal prairie grassland remnants and roadsides.	--	--	Resident
REPTILES								
Alligator snapping turtle	*Macrochelys temminckii*	0	2	0	Found in perennial water bodies near deep running water.	--	T	Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands.	--	T	Resident
Timber rattlesnake	*Crotalus horridus*	1	2	2	Floodplains, upland pine, deciduous woodlands, riparian zones.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

TPWD, 2014. Annotated County List of Rare Species –Brazos County updated 9/4/2014, and Robertson County updated 9/4/2014.

USFWS, 2014. Species Lists from http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action?fips=48187, accessed October 1, 2014.

9.1.4 Engineering and Costing

The envisioned Robertson County groundwater project will be developed in phases as necessary to meet growing needs. At ultimate build out there will be 14 Simsboro wells, collector pipelines, and well pumps and motors, and a transmission line that delivers the groundwater to the Bryan's existing raw water pipelines. In 2050, a local well field in Brazos County is proposed to supplement the Bryan's supply with 5 additional Simsboro wells. A transmission line and pump station from this well field will supply this water to existing raw water pipelines at the same point as the Robertson well field. The raw water from both well fields will be treated for disinfection and cooling within the Bryan before distribution. When completed, this combined regional project will have a maximum capacity of 24,438 acft/yr for the Bryan. The major facilities required for this strategy are:

- Simsboro wells
- Well field collection pipeline(s)
- Transmission pipeline/pump stations
- Upgrade to existing Water Treatment Plant

The approximate locations of these facilities are displayed in Figure 9.1-1.

The Robertson County Simsboro wells were assumed to be 2,500 feet deep and have a rated capacity of 2,000 gpm. Power costs were estimated by calculating the horsepower needed to operate the wells and pump stations to deliver raw water from the well fields to an interconnect with the existing infrastructure. Costs were included for leasing property necessary to obtain groundwater permits, and for anticipated third party well mitigation activities to compensate for lowered pumping levels in existing wells.

Based on these assumptions, it is estimated that the water obtained through the Robertson county well field to Bryan will have a unit cost that ranges from $258 per acft to $936 per acft (Table 9.1-2).

The Brazos County Simsboro wells were assumed to be 2,800 feet deep and have a rated capacity of 2,000 gpm. Power costs were estimated by calculating the horsepower needed to operate the wells and pump station to deliver the raw water to the tie in with the existing infrastructure. Costs were included for leasing property necessary to obtain groundwater permits, and for anticipated third party well mitigation activities to compensate for lowered pumping levels in existing wells.

Based on these assumptions, it is estimated that the water obtained through the Brazos County well field to Bryan will have a unit cost that ranges from $210 per acft to $517 per acft (Table 9.1-3).

Table 9.1-2. Cost Estimate Summary for Robertson Well Field for Bryan

Cost Estimate Summary Water Supply Project Option September 2013 Prices Robertson for Bryan						
	Estimated Cost for Facilities by Decade					
Item	2020	2030	2040	2050	2060	2070
CAPITAL COST						
Well Fields (Wells, Pumps, and Piping)	$7,061,000	$0	$0	$0	$11,769,000	$14,123,000
Transmission Pipeline (48 in dia., 8 miles)	$14,876,000	$0	$0	$0	$0	$0
Intake Pump Stations (33.1 MGD)	$3,921,000	$0	$0	$0	$0	$0
Water Treatment Plant	$155,000	$0	$0	$0	$259,000	$311,000
TOTAL COST OF FACILITIES	**$26,013,000**	**$0**	**$0**	**$0**	**$12,028,000**	**$14,434,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$8,361,000	$0	$0	$0	$4,210,000	$5,052,000
Environmental & Archaeology Studies and Mitigation	$378,769	$0	$0	$0	$0	$0
Signing Bonus and Holding Fees (14,933 acres @ $300 per Acre)	$3,705,000	$0	$0	$0	$0	$0
Interest During Construction (4% for 2 years with a 1% ROI)	$2,693,000	$0	$0	$0	$1,137,000	$1,365,000
TOTAL COST OF PROJECT	**$41,150,769**	**$0**	**$0**	**$0**	**$17,375,000**	**$20,851,000**
ANNUAL COST						
Debt Service (5.5 percent, 20 years)	$2,831,000	$2,831,000	$0	$0	$1,195,000	$2,630,000
Operation and Maintenance						
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$259,000	$259,000	$259,000	$259,000	$377,000	$518,000
Water Treatment Plant (2.5% of Cost of Facilities)	$4,000	$4,000	$4,000	$4,000	$10,000	$18,000
Pumping Energy Costs (@ 0.09 $/kW-hr)	$257,000	$257,000	$257,000	$257,000	$567,000	$940,000
Production Fee ($125/acft)	$521,739	$521,739	$521,739	$521,739	$1,391,304	$2,315,625
Groundwater District Export Fee ($8.71/acft)	$36,000	$36,000	$36,000	$36,000	$97,000	$161,000
TOTAL ANNUAL COST	**$3,908,739**	**$3,908,739**	**$1,077,739**	**$1,077,739**	**$3,637,304**	**$6,582,625**
Available Project Yield (acft/yr), based on a Peaking Factor of 2	4,174	4,174	4,174	4,174	11,130	18,525
Annual Cost of Water ($ per acft)	$936	$936	$258	$258	$327	$355
Annual Cost of Water ($ per 1,000 gallons)	$2.87	$2.87	$0.79	$0.79	$1.00	$1.09

Table 9.1-3. Cost Estimate Summary for Brazos Well Field for Bryan

Cost Estimate Summary Water Supply Project Option September 2013 Prices Local Brazos for Bryan			
	Estimated Cost for Facilities by Decade		
Item	2050	2060	2070
CAPITAL COST			
Well Fields (Wells, Pumps, and Piping)	$11,769,000	$0	$0
Transmission Pipeline (24 in dia., 4 miles)	$3,100,000	$0	$0
Intake Pump Stations (10.3 MGD)	$2,385,000	$0	$0
Water Treatment Plant	$246,000	$0	$0
TOTAL COST OF FACILITIES	**$17,500,000**	**$0**	**$0**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$5,970,000	$0	$0
Environmental & Archaeology Studies and Mitigation	$163,000	$0	$0
Signing Bonus and Holding Fees (4,480 acres @ $300 per Acre)	$1,182,600	$0	$0
Interest During Construction (4% for 2 years with a 1% ROI)	$1,563,000	$0	$0
TOTAL COST OF PROJECT	**$26,378,600**	**$0**	**$0**
ANNUAL COST			
Debt Service (5.5 percent, 20 years)	$1,815,000	$1,815,000	$0
Operation and Maintenance			
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$173,000	$173,000	$173,000
Water Treatment Plant (2.5% of Cost of Facilities)	$6,000	$6,000	$6,000
Pumping Energy Costs (@ 0.09 $/kW-hr)	$270,000	$270,000	$270,000
Production Fee ($125/acft)	$739,125	$739,125	$739,125
Groundwater District Export Fee ($8.71/acft)	$52,000	$52,000	$52,000
TOTAL ANNUAL COST	**$3,055,125**	**$3,055,125**	**$1,240,125**
Available Project Yield (acft/yr)	5,913	5,913	5,913
Annual Cost of Water ($ per acft)	$517	$517	$210
Annual Cost of Water ($ per 1,000 gallons)	$1.59	$1.59	$0.64

9.1.5 Implementation Issues

Implementation of the Regional Simsboro Plan with well fields in Brazos and Robertson Counties option could involve limited conflicts with other planned water supply projects. The development of groundwater in the Carrizo-Wilcox Aquifer in the Brazos G Water Planning Region must address several issues. Major issues include:

- Acquisition of water rights from land owners,
- Exposure to groundwater conservation district rules that may reduce groundwater production if drawdown exceeds allowable limits,
- Changes in regulations by groundwater conservation districts,
- Changes in the MAG,
- Impact on:
    - Endangered and threatened wildlife species,
    - Water levels in the aquifer,
    - Baseflow in streams, and
    - Wetlands.
- Substantial drawdown in existing wells, and
- Competition with others in the area for groundwater.

This water supply option has been compared to the plan development criteria, as shown in Table 9.1-4, and the option meets each criterion.

Table 9.1-4. Comparison of Bryan Regional Groundwater Option to Plan Development Criteria

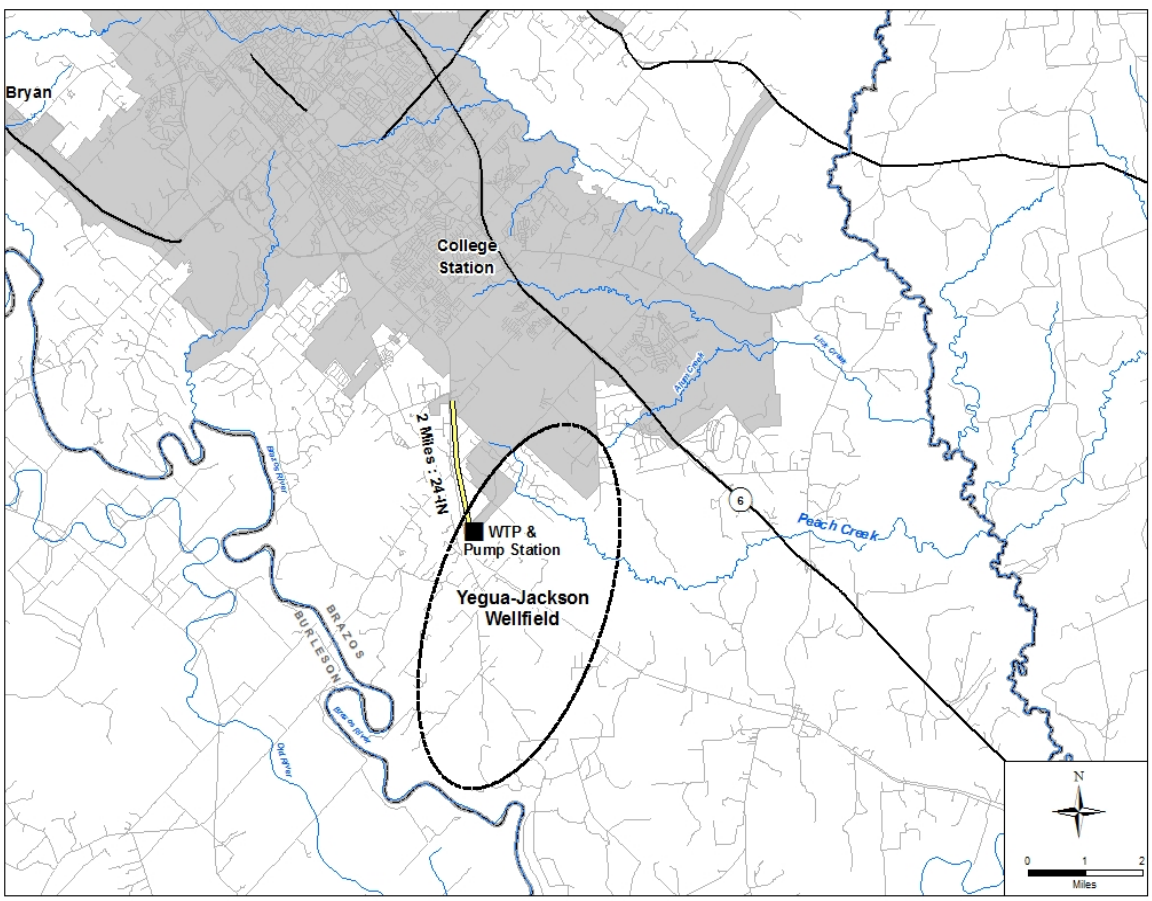
Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Meets Demands
2. Reliability	2. High
3. Cost	3. Low to Moderate
B. Environmental factors	
1. Environmental Water Needs	1. None
2. Habitat	2. None
3. Cultural Resources	3. None
4. Bays and Estuaries	4. None
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. None
C. Impact on Other State Water Resources	None
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered in an attempt to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

9.2 Local Groundwater for College Station

9.2.1 Description of Option

The City of College Station (College Station) currently supplies all of its customers with groundwater from the Sparta, Carrizo and Simsboro Aquifers in Brazos County. In 2070, College Station has been allocated 14,144 acft of Carrizo-Wilcox Aquifer and 545 acft from the Sparta Aquifer through this regional planning process. College Station is projected to more than double in population over the planning period and the needs can no longer be met with existing well fields. The range of estimated water needs for College Station ranges from about 4,300 acft/yr in 2020 to 3,500 acft/yr in 2070. A review of the MAG for the Carrizo-Wilcox shows no availability until 2040 and then increasing to about 5,700 acft/yr in 2070. The long-term availability from the Sparta and Queen City Aquifers is less than 800 acft/yr. The only aquifer in Brazos County capable of meeting this need is the Yegua-Jackson, which has a remaining availability of nearly 5,800 acft/yr. With constraints by the MAG, a Yegua-Jackson well field is proposed in Brazos County. The proposed project contains an ultimate build out of twenty 400 gpm Lower Jackson wells south of College Station. Figure 9.2-1 illustrates the proposed Local Groundwater strategy for College Station.

Figure 9.2-1. Location of College Station well field and facilities



9.2.2 Available Yield

The Yegua-Jackson in Brazos County has modeled available supply which could be used by College Station. According to hydrogeologic information in the area, the Yegua-Jackson wells are capable of producing 400 gpm and are about 1,500 ft deep. The TWDB has determined that the Modeled Available Groundwater (MAG) for the Yegua-Jackson Aquifer in Brazos County is 7,071 acft/yr in 2070. After allowance for existing groundwater production, the MAG constrained availability is 5,754 acft/yr over the planning period. To meet the 2070 needs for college station, 5,565 acft/yr of this supply is available for development.

9.2.3 Environmental Issues

The Local Groundwater Strategy for College Station Project involves the development of a new well field in Brazos County utilizing water from the Yegua-Jackson Aquifer, a well collection pipeline, pump stations, a water treatment plant and a transmission pipeline. The well field will include a total of 20 wells. This report section discusses the potential impacts to environmental and cultural resources known to exist within the proposed project area.

The project area occurs in the Post Oak Savannah Vegetational Area.[3] Common woody species of this area include post oak (*Quercus stellata*), blackjack oak (*Q. marilandica*), and species of hickory (*Carya* sp.). Grasses of this area normally include little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*) and switchgrass (*Panicum virgatum*).

Vegetation types as described by TPWD[4] within the project area include Post Oak Woods/Forest and a small area designated as crops. The Post Oak Woods/Forest vegetation type closely follows the species descriptions included for the Post Oak Vegetational Area above. No agricultural impacts are expected as pipelines and well locations will avoid affecting cropland.

Construction of the collection and transmission pipelines, pump stations and wells would involve the disturbance of existing habitat. The proposed transmission pipeline would require a construction corridor and maintenance corridor after completion. Significant portions of this pipeline are located along existing rights-of-way, fencerows, and other disturbed areas, which would reduce their overall vegetative impact. Herbaceous habitats would recover quickly from impacts and would experience low negative impacts. Outside the maintained right-of-way, land use would not be anticipated to change due to pipeline construction. However any impacts to woody vegetation would be permanent due to required pipeline, pump and well maintenance activities.

The well field area includes sections of several creeks including Franks, Cedar, and Boggy Creeks which flow into the Brazos River, and Peach and Alum Creeks which flow into the Navasota River. Appropriate Best Management Practices (BMPs) used during pipeline construction would help minimize impacts from these pipeline construction

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[3] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.

[4] McMahan, Craig A, Roy G. Frye and Kirby L. Brown. 1984. *The Vegetation Types of Texas including Cropland*. Texas Parks and Wildlife, Austin, Texas.

activities. National Wetland Inventory (NWI) maps show a number of wetlands occurring along the transmission pipeline and within the well field area. The well field area includes numerous freshwater ponds, a freshwater emergent wetland, two freshwater forested/shrub wetlands and a freshwater lake. A ground survey wetland delineation would be required to determine which of these and other features would be affected by the project and to what extent. This delineation would document the locations of streambeds, stream widths, quality and type of water bodies, types of aquatic vegetation, presence of special aquatic resources and areas of jurisdictional Waters of the U.S. likely to be disturbed during construction. Coordination with the U.S. Army Corps of Engineers would be required for construction within waters of the U.S. Impacts from the proposed project resulting in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

Concerns associated with the development of the well field include changes in water levels in the Yegua-Jackson Aquifer and potential impacts to the surrounding streams, wetlands and existing water wells found near the well field from lowered water levels. The possibility exists that water levels in the aquifers, affected by the new wells, could also affect the habitat within the area.

The 2012 Texas Integrated Report - Texas 303(d) List identifies the water bodies in or bordering Texas for which effluent limitations are not stringent enough to implement water quality standards, and for which the associated pollutants are suitable for measurement by maximum daily load. The most recent 303(d) List includes the Navasota River below Lake Limestone which has been designated by the Texas Commission on Environmental Quality (TCEQ) as Segment 1209. This segment is listed as including a category 5b for bacteria. Category 5b indicates that a review of the standards for one or more parameters will occur before a management strategy is selected. Potential impacts to existing water quality are not anticipated from this project.

Plant and animal species listed by the U.S. Fish and Wildlife Service (USFWS) and Texas Parks and Wildlife Department (TPWD) as endangered, threatened or rare in the project area are presented in Table 9.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Brazos County. Inclusion in this table does not mean that a species will occur within the project area, but only acknowledges the potential for its occurrence in the project area counties. No USFWS designated critical habitat areas occur near the project area and no significant impacts to any listed species are anticipated from this project.

Although suitable habitat for the state threatened Texas Horned Lizard (*Phrynosoma cornutum*) may exist within the project area, no significant impact to this species is anticipated due to limited area that will be impacted by the project, the abundance of similar habit near the project area and the ability to relocate to those areas if necessary. The presence or absence of potential habitat does not confirm the presence or absence of a listed species. No species specific surveys were conducted in the project area for this report.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). A review of Geographic Information System (GIS) shapefiles provided by the

Texas Historical Commission reveals that there are no National Register Properties, National Register Districts, State Historic Sites, cemeteries, or historical markers within the transmission pipeline route or well field area. However, several archeological surveys have occurred adjacent to and within the project area which indicate that the probability exists for cultural resources to be present. An archeological survey of the project area should be undertaken to more accurately determine actual impacts to cultural resources.

Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction. If the project will affect waters of the United States or wetlands, the project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to these resources.

Table 9.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Brazos County

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
AMPHIBIANS								
Houston toad	*Anaxyrus houstonensis*	0	3	0	Endemic species found in sandy substrate near pools.	LE	E	Resident
BIRDS								
American peregrine falcon	*Falco peregrinus anatum*	0	2	0	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	0	1	0	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	0	2	0	Primarily found near waterbodies.	DL	T	Nesting/ Migrant

Table 9.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Brazos County

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Wintering migrant found in weedy fields with a key component of bare ground for running and walking	--	--	Migrant
Interior least tern	*Sterna antillarum athalassos*	0	3	0	Nests along sand and gravel bars in braided streams	LE	E	Resident
Peregrine falcon	*Falco peregrinus*	0	2	0	Possible migrant. Subspecies not easily distinguishable so reference is made to species level.	DL	T	Possible Migrant
Sprague's pipit	*Anthus spragueii*	0	1	0	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Whooping crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Potential Migrant
Wood stork	*Mycteria americana*	0	2	0	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX	--	T	Migrant
FISHES								
Blue sucker	*Cycleptus elongates*	0	2	0	Found in larger portions of major rivers in Texas.	--	T	Resident

Table 9.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Brazos County

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Sharpnose shiner	*Notropis oxyrhynchus*	0	3	0	Endemic to Brazos River drainage. Found in large rivers.	LE	--	Resident
Smalleye shiner	*Notropis buccula*	0	3	0	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident
INSECTS								
A mayfly	*Procloeon texanum*	0	1	0	Found in Oklahoma and Texas. Mayflies are distinguished by their aquatic larval stage; adults generally found in bankside vegetation.	--	--	Resident
Gulf Coast clubtail	*Gomphus modestus*	0	1	0	Found in medium rivers with moderate gradient and streams with silty sand or rocky bottoms.	--	--	Resident
Smoky shadowfly	*Neurocordulia molesta*	0	1	0	Found in rivers and sometimes larger streams with rock or logs to which the larvae cling.	--	--	Resident
MAMMALS								

Table 9.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Brazos County

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Louisiana black bear	*Ursus americanus luteolus*	0	2	0	Possible as transient in bottomland hardwoods and inaccessible forested areas.	LT	T	Possible transient
Plains spotted skunk	*Spilogale putorius interrupta*	1	1	1	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	0	3	0	Extirpated.	LE	E	Historic Resident
MOLLUSKS								
False spike mussel	*Quincuncina mitchelli*	0	2	0	Substrates of cobble and mud. Rio Grande, Brazos, Colorado and Guadalupe river basins.	--	T	Resident
Smooth pimpleback	*Quadrula houstonensis*	0	2	0	Freshwater mollusk found in small to moderate streams and rivers as well as moderate sized reservoirs. Brazos and Colorado River Basins.	C	T	Resident
Texas fawnsfoot	*Truncilla macrodon*	0	2	0	Found in rivers and larger streams, intolerant of impoundment.	C	T	Resident
PLANTS								

Table 9.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Brazos County

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Branched gay-feather	*Liatric cymosa*	1	1	1	Texas endemic found on somewhat barren grassland openings in post oak woodlands.	--	--	Resident
Bristle nailwort	*Paronychia setacea*	0	1	0	Flowering vascular plant endemic to eastern south central Texas in sandy soils.	--	--	Resident
Navasota ladies'-tresses	*Spiranthes parksii*	0	3	0	Texas endemic found in opening in post oak woodlands in sandy loams along upland drainages or intermittent streams.	LE	E	Resident
Small-headed pipewort	*Eriocaulon koernickianum*	0	1	0	Found in East Texas post-oak woodlands and xeric sandhill openings on permanently wet acid sands of upland seeps and bogs.	--	--	Resident
Texas meadow-rue	*Thalictrum texanum*	0	1	0	Texas endemic primarily found in woodlands and woodland margins on soils with a surface layer of sandy loam but also occurs on prairie pimple mounds.	--	--	Resident

Table 9.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Brazos County

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Texas windmill grass	*Chloris texensis*	0	1	0	Texas endemic grass found in sandy to sandy loam soils in relatively bare areas in coastal prairie grassland remnants and roadsides.	--	--	Resident
REPTILES								
Alligator snapping turtle	*Macrochelys temminckii*	0	2	0	Found in perennial water bodies near deep running water.	--	T	Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands.	--	T	Resident
Timber rattlesnake	*Crotalus horridus*	1	2	2	Floodplains, upland pine, deciduous woodlands, riparian zones.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

TPWD, 2014. Annotated County List of Rare Species –Brazos County updated 9/4/2014.

USFWS, 2014. Species Lists from http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action?fips=48187, accessed October 1, 2014.

Field surveys conducted at the appropriate phase of development should be employed to minimize the impacts of construction and operations on sensitive resources. Specific project features, such as well fields, pump stations, water treatment plants and pipelines generally have sufficient design flexibility to avoid most impacts or significantly mitigate potential impacts to geographically limited environmental and cultural resource sites.

9.2.4 Engineering and Costing

The envisioned Yegua-Jackson groundwater project for the College Station will be developed in phases as necessary to meet growing needs. At ultimate build out, in 2030, there will be 20 new wells along with collector pipelines, pump stations, a WTP and a transmission line that delivers the groundwater to the existing distribution system. The water treatment plant will provide disinfection before distribution. When completed, the new well field will have a maximum capacity of 6,400 acft/yr for College Station. The major facilities required for this strategy are:

- Yegua-Jackson wells
- Well field collection pipeline(s)
- Transmission pipeline/pump stations
- Water Treatment Plant for disinfection.

The approximate locations of these facilities are displayed in Figure 9.2-1.

The Yegua-Jackson wells are estimated to be 1,500 ft deep and have an estimated capacity of 400 gpm. Costs included leasing the property necessary to obtain groundwater permits, and for anticipated third party well mitigation activities to compensate for lowered pumping levels in existing wells. Power costs were estimated by calculating the horsepower needed to operate the wells and to lift the yield from the well field and to transmit the water to the existing distribution system. Based on these assumptions, it is estimated that the water obtained through the Yegua-Jackson well field to College Station will have a unit cost that ranges from to $656 per acft/yr in 2020 to $221 per acft/yr after debt service (Table 9.2-2).

Table 9.2-2. Cost Estimate Summary for Yegua-Jackson Well Field for College Station

Cost Estimate Summary Water Supply Project Option September 2013 Prices Yegua-Jackson for College Station						
	Estimated Cost for Facilities by Decade					
Item	2020	2030	2040	2050	2060	2070
CAPITAL COST						
Well Fields (Wells, Pumps, and Piping)	$13,709,000	$3,427,000	$0	$0	$0	$0
Transmission Pipeline (24 in dia., 2 miles)	$1,947,000	$0	$0	$0	$0	$0
Intake Pump Stations (10.3 MGD)	$2,418,000	$0	$0	$0	$0	$0
Water Treatment Plant	$228,000	$0	$0	$0	$0	$0
TOTAL COST OF FACILITIES	**$18,302,000**	**$3,427,000**	**$0**	**$0**	**$0**	**$0**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$6,308,000	$1,199,000	$0	$0	$0	$0
Environmental & Archaeology Studies and Mitigation	$304,000	$0	$0	$0	$0	$0
Signing Bonus and Holding Fees (4,200 acres @ $300 per Acre)	$1,260,000	$0	$0	$0	$0	$0
Interest During Construction (4% for 2 years with a 1% ROI)	$1,833,000	$324,000	$0	$0	$0	$0
TOTAL COST OF PROJECT	**$28,007,000**	**$4,950,000**	**$0**	**$0**	**$0**	**$0**
ANNUAL COST						
Debt Service (5.5 percent, 20 years)	$1,927,000	$2,268,000	$341,000	$0	$0	$0
Operation and Maintenance						
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$181,000	$215,000	$215,000	$215,000	$215,000	$215,000
Water Treatment Plant (2.5% of Cost of Facilities)	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000
Pumping Energy Costs (@ 0.09 $/kW-hr)	$213,000	$266,000	$266,000	$266,000	$266,000	$266,000
Production Fee ($125/acft)	$556,522	$695,652	$695,652	$695,652	$695,652	$695,652
Groundwater District Export Fee ($8.71/acft)	$39,000	$48,000	$48,000	$48,000	$48,000	$48,000
TOTAL ANNUAL COST	**$2,922,522**	**$3,498,652**	**$1,571,652**	**$1,230,652**	**$1,230,652**	**$1,230,652**
Available Project Yield (acft/yr), Assuming a Peaking Factor of 2	4,452	5,565	5,565	5,565	5,565	5,565
Annual Cost of Water ($ per acft)	$656	$629	$282	$221	$221	$221
Annual Cost of Water ($ per 1,000 gallons)	$2.01	$1.93	$0.87	$0.68	$0.68	$0.68

9.2.5 Implementation Issues

Implementation of the Local Groundwater Plan for College Station with a Yegua-Jackson option could involve limited conflicts with other planned water supply projects. The development of groundwater in the Yegua-Jackson Aquifers in the Brazos G Water Planning Region must address several issues. Major issues include:

- Acquisition of water rights from land owners,
- Exposure to groundwater conservation district rules that may reduce groundwater production if drawdown exceeds allowable limits,
- Changes in regulations by groundwater conservation districts,
- Changes in the MAG,
- Impact on:
    - Endangered and threatened wildlife species,
    - Water levels in the aquifer,
    - Baseflow in streams, and
    - Wetlands.
- Substantial drawdown in existing wells, and
- Competition with others in the area for groundwater.

This water supply option has been compared to the plan development criteria, as shown in Table 9.2-3, and the option meets each criterion.

Table 9.2-3. Comparison of College Station Local Groundwater Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Meets Demands
2. Reliability	2. High
3. Cost	3. Low to Moderate
B. Environmental factors	
1. Environmental Water Needs	1. None
2. Habitat	2. None
3. Cultural Resources	3. None
4. Bays and Estuaries	4. None
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. None
C. Impact on Other State Water Resources	None
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered in an attempt to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

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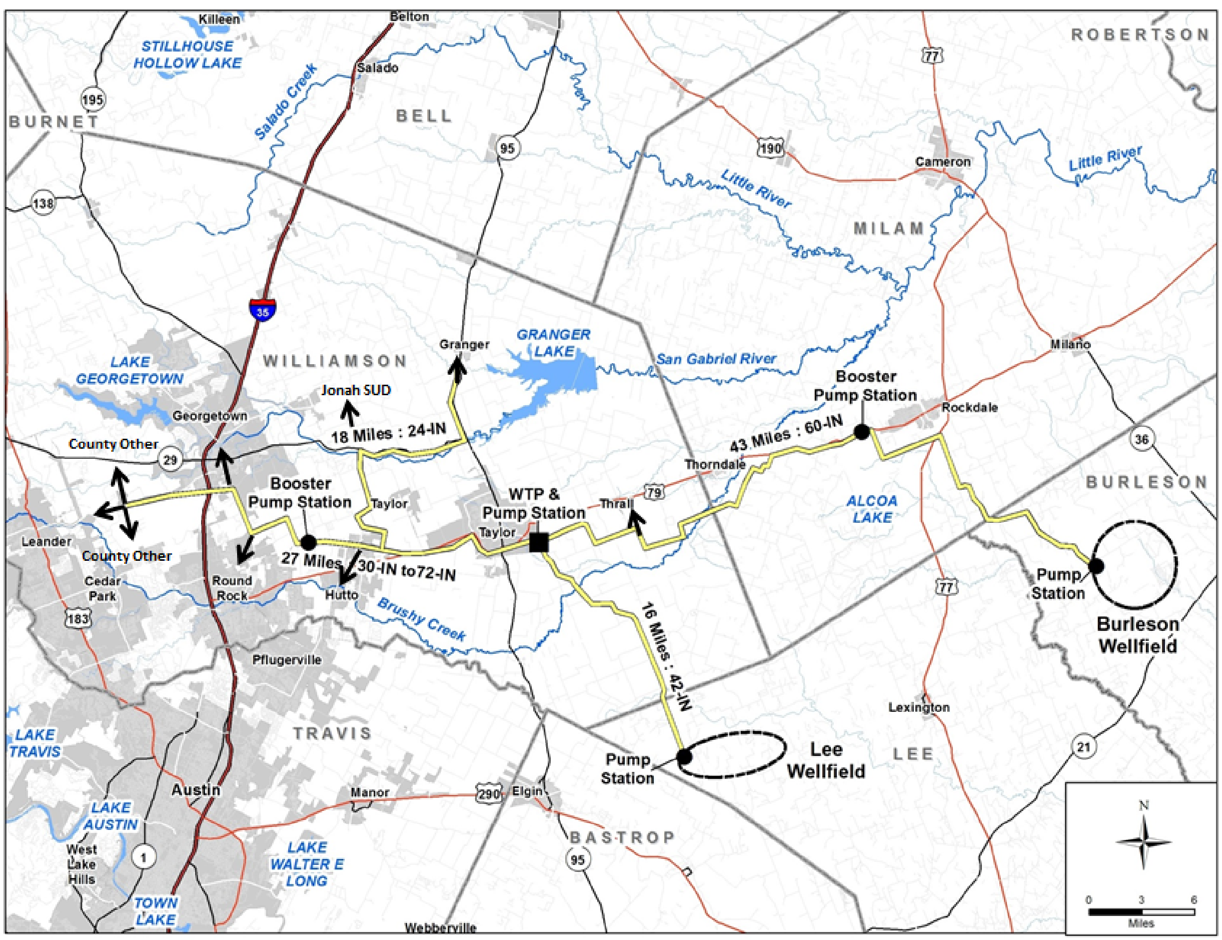
9.3 Regional Groundwater for Williamson County

9.3.1 Description of Option

Williamson County currently meets approximately 37 percent of municipal demands with groundwater and 63 percent with surface water. The TWDB has projected the county's population to grow significantly over the planning period and the future shortages cannot be met with local groundwater. By 2070, Williamson County has approximately 130,000 acft/yr of unmet need and essentially no available groundwater due to MAG restrictions. To meet some of the future needs in Williamson County, two well fields are proposed in Burleson and Lee Counties. At build-out, the Burleson County well field project includes ten 1,500 gpm Carrizo wells and fourteen 2,500 gpm Simsboro wells. The Lee County well field at buildout includes seven 1,000 gpm Carrizo wells and eleven 1,500 gpm Simsboro wells to supplement the supply. Raw water pipelines from the two well fields will meet at a new WTP south of Taylor. After treatment, pump stations and pipelines will deliver the water through a shared distributions system to meet needs in Thrall, Granger, Jonah SUD, Hutto, Round Rock, Georgetown, and Williamson County Other. Figure 9.3-1 illustrates the proposed Regional Groundwater System for Williamson County.

Figure 9.3-1. Location of Regional Williamson County Well Fields and Facilities



9.3.2 Available Yield

The Carrizo-Wilcox wells will tap from both the Simsboro and Carrizo formations for the Burleson and Lee Counties well fields. According to hydrogeologic maps of the area, the Carrizo wells are capable of producing 1,500 gpm and are 1,500 ft deep. The deeper Simsboro wells in the area are capable of producing 2,500 gpm each at an average depth of 2,000 ft. Approximately 30 percent of the groundwater will be developed from the Carrizo formation and 70 percent from the Simsboro. The TWDB has determined that the MAG for the Carrizo-Wilcox aquifer, which includes both the Carrizo and Simsboro formations, in Burleson County increases from 23,249 in 2020 to 38,701 acft/yr in 2070. For Lee County, the MAG increases from 24,023 in 2020 to 27,380 acft/yr in 2070 After allowance for existing groundwater production from the Carrizo-Wilcox Aquifer in Burleson County, the MAG constrained availability ranges from19,442 acft/yr in 2020 and 34,894 acft/yr in 2070. In Lee County, the MAG constrained availability ranges from12,977acft/yr in 2020 and 16,334 acft/yr in 2070

9.3.3 Environmental Issues

The Regional Groundwater for Williamson County Project involves the development of two new well fields, one each in Lee and Burleson Counties, associated well collection pipelines and pumps, a new water treatment plant and a shared distribution pipeline system. The Burleson County well field will include ten Carrizo Aquifer wells and fourteen Simsboro Aquifer wells, and the Lee County well field will include seven Carrizo wells and eleven Simsboro wells. This report section discusses the potential impacts to environmental and cultural resources known to exist within the proposed project area.

The western portion of the project area includes land in the Cross Timbers and Prairies vegetational area, the central portion occurs within the Blackland Prairie vegetational area and the eastern end including the well fields occurs in the Post Oak Savannah vegetational area.[5] The Cross Timbers and Prairies vegetational area includes rolling to hilly areas which are deeply dissected causing rapid surface drainage. Differences in soils and topography within this area result in sudden changes in vegetation cover. Tall grasses in this area predominantly include little bluestem (*Schizachyrium scoparium* var. *frequens*), big bluestem (*Andropogon gerardii*), indiangrass (*Sorghastrum nutans*), and Texas wintergrass (*Nassella leucotricha*). Common woody species of the Post Oak Savannah vegetational area include post oak (*Quercus stellata*), blackjack oak (*Q. marilandica*), and species of hickory (*Carya* sp.). Grasses of the Post Oak Savannah commonly include little bluestem, indiangrass and switchgrass (*Panicum virgatum*).

The Blackland Prairies vegetational area includes a rolling and well-dissected vegetational area that was historically a luxuriant tallgrass prairie dominated by little bluestem, big bluestem, indiangrass, and dropseeds (*Sporobolus* sp.). During the turn of the 20th century, the majority of the Blackland Prairie was cultivated for crops. Livestock production within this area has increased dramatically since the 1950s and now only about half of the area is used for cropland. Grazing pressure has caused an increase in grass species such as sideoats grama (*Bouteloua curtipendula*), hairy grama (*B. hirsuta*), Mead's sedge (*Carex meadii*), Texas wintergrass and buffalograss (*Buchloe*

[5] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.

dactyloides). Common woody species of this area include mesquite (*Prosopis glandulosa*), huisache (*Acacia smallii*), oak (*Quercus* sp.) and elm (*Ulmus* sp.). Oak, elm, cottonwood (*Populus* sp.) and pecan are common along drainages. No agricultural impacts are expected as pipelines and well locations will avoid affecting cropland.

Construction of the pipelines, pumps and wells would involve the disturbance of existing habitat. The proposed shared distribution system pipeline would require a construction corridor and maintenance corridor after completion. Special attention would have to be directed to areas of pipeline construction that occur within areas of karst habitat and the Edwards Aquifer recharge zone. Significant portions of the pipeline segments are located along existing rights-of-way, fencerows, and other disturbed areas including cropland, which would reduce their overall vegetative impact. Herbaceous habitats would recover quickly from impacts and would experience low negative impacts. Outside the maintained right-of-way, land use would not be anticipated to change due to pipeline construction. However any impacts to woody vegetation would be permanent due to required pipeline, pump and well maintenance.

The proposed pipeline would cross numerous waterbodies including several tributaries of the San Gabriel River and Brushy, Mustang and Yegua Creeks. Appropriate Best Management Practices (BMPs) used during pipeline construction would help minimize impacts from project construction activities. National Wetland Inventory (NWI) maps show wetlands which occur along the shared distribution pipeline and within the well field areas. A ground survey wetland delineation would be required to determine which of these and other features would be affected by the project and to what extent. This delineation would document the locations of streambeds, stream widths, quality and type of water bodies, types of aquatic vegetation, presence of special aquatic resources and areas of jurisdictional Waters of the U.S. likely to be disturbed during construction. Coordination with the U.S. Army Corps of Engineers would be required for construction within waters of the U.S. Impacts from the proposed project resulting in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

Concerns associated with the development of the two well field areas include changes in water levels in the two aquifers and potential impacts to the surrounding streams, wetlands or existing water wells near the well fields. The possibility exists that water levels in the aquifers, affected by the new wells, could affect the habitat within the area. Waters of the U.S. found within the two project well field areas include several tributaries of Yegua Creek in Lee County, and Hooker Creek and Second Davidson Creek in Burleson County.

The 2012 Texas Integrated Report - Texas 303(d) List identifies the water bodies in or bordering Texas for which effluent limitations are not stringent enough to implement water quality standards, and for which the associated pollutants are suitable for measurement by maximum daily load. This list includes segments of Brushy Creek and Middle Yegua Creek for elevated bacteria levels. These listed segments are classified as 5b, which means a review of standards for one or more parameters will be conducted before a management strategy for this segment is selected; including the possible revision to the water quality standards.

Plant and animal species listed by the U.S. Fish and Wildlife Service (USFWS) and Texas Parks and Wildlife Department (TPWD) as endangered, threatened or rare in the project area are presented in Table 9.3-1. Inclusion in this table does not mean that a species will occur within the project area, but only acknowledges the potential for its occurrence in the project area counties. In addition to these county lists, the Texas Natural Diversity Database (TXNDD) was reviewed for recorded occurrences of listed or rare species within or near the project area. This database included documented occurrences of two endangered cave species, the Coffin Cave mold beetle (*Batrisodes texanus*), and Bone Cave harvestman (*Texella reyesi*) near the western terminus of the shared pipeline adjacent to IH 35. These endangered cave species and others occur within the karst areas of central Texas. The endangered Golden-cheeked warbler (*Setophaga chrysoparia*) has been documented within two miles of the western terminus of the distribution pipeline. In addition, the Texas garter snake (*Thamnophis sirtalis annectens*) and mountain plover (*Charadrius montanus*), both species of concern, show occurrences near the project pipeline system. Species of concern are considered to be rare, but are not protected by USFWS or TPWD.

Although suitable habitat for two state threatened species including the Texas Horned Lizard (*Phrynosoma cornutum*), and timber rattlesnake (*Crotalus horridus*) may exist within the project area, no significant impact to these species is anticipated due to limited area that will be impacted by the project, the abundance of similar habit near the project area and these species ability to relocate to those areas if necessary. The presence or absence of potential habitat does not confirm the presence or absence of a listed species. No species specific surveys were conducted in the project area for this report.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). A review of Geographic Information System (GIS) shapefiles provided by the Texas Historical Commission reveals that there are no National Register Properties or National Register Districts or historical markers within 500 feet of the proposed pipeline route or well field areas. However five cemeteries occur within the two well field areas, and eight more occur along the shared distribution pipeline. In addition, numerous archeological surveys have occurred adjacent to and within the project area which indicate that a high probability exists for cultural resources to be present. An archeological survey of the project area should be undertaken to more accurately determine actual impacts to cultural resources.

Table 9.3-1. Endangered, Threatened, Candidate and Species of Concern Listed for Burleson, Lee, Milam and Williamson Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
				AMPHIBIANS				
Georgetown salamander	*Eurycea naufragia*	1	2	2	Endemic species known from springs and waters in and around Georgetown in Williamson County Texas.	T	--	Resident
Houston toad	*Anaxyrus houstonensis*	0	3	0	Endemic species found in sandy substrate near pools.	LE	E	Resident
Jollyville Plateau salamander	*Eurycea tonkawae*	0	2	0	Known from springs and waters of some caves north of the Colorado River.	T	--	Resident
Salado Springs salamander	*Eurycea chisholmensis*	0	2	0	Endemic species found in surface springs and subterranean waters of the Salado Springs system along Salado Creek.	T	--	Resident
				ARACHNIDS				
Bandit Cave spider	*Cicurina bandida*	1	1	1	Very small subterrestrial, subterranean obligate.	--	--	Resident
Bone Cave harvestman	*Texella reyesi*	1	3	3	Small blind cave-adapted harvestman endemic to a few caves in Travis and Williamson counties.	LE	--	Resident
				BIRDS				
American peregrine falcon	*Falco peregrinus anatum*	0	2	0	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	0	1	0	Migrant throughout the state.	DL	--	Possible Migrant

Table 9.3-1. Endangered, Threatened, Candidate and Species of Concern Listed for Burleson, Lee, Milam and Williamson Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Bald eagle	*Haliaeetus leucocephalus*	0	2	0	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Black-capped vireo	*Vireo atricapilla*	0	3	0	Occupies oak-juniper woodlands with a distinctive patchy, two-layered aspect. Migrant.	LE	E	Nesting/ Migrant
BIRDS								
Golden-cheeked warbler	*Setophaga chrysoparia*	1	3	3	Found in juniper-oak woodlands; dependent on Ashe juniper for bark strips used in nest construction. Migrant	LE	E	Nesting/ Migrant
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Wintering migrant found in weedy fields with a key component of bare ground for running and walking	--	--	Migrant
Interior least tern	*Sterna antillarum athalassos*	0	3	0	Nests along sand and gravel bars in braided streams	LE	E	Resident
Mountain plover	*Charadrius montanus*	0	1	0	Non-breeding, shortgrass plains and fields	--	--	Migrant
Piping plover	*Charadrius melodus*	0	2	0	Migrant shorebird in Texas.	T	--	Migrant
Sprague's pipit	*Anthus spragueii*	0	1	0	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant
Western burrowing owl	*Athene cunicularia hypugaea*	0	1	0	Open grasslands, especially prairie, plains and savanna	--	--	Resident

Table 9.3-1. Endangered, Threatened, Candidate and Species of Concern Listed for Burleson, Lee, Milam and Williamson Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Whooping crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Potential Migrant
Wood stork	*Mycteria americana*	0	2	0	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX	--	T	Migrant
CRUSTACEANS								
An amphipod	*Stygobromus russelli*	1	1	1	Found in subterranean waters, usually in caves and limestone aquifers within 10 counties of the Edwards Plateau.	--	--	Resident
Bifurcated cave amphipod	*Stygobromus bifurcates*	1	1	1	Found in cave pools.	--	--	Resident
CRUSTACEANS								
Ezell's cave amphipod	*Stygobromus flagellates*	0	1	0	Known only from artesian wells.	--	--	Resident
FISHES								
Blue sucker	*Cycleptus elongates*	0	2	0	Found in larger portions of major rivers in Texas.	--	T	Resident
Guadalupe bass	*Micropterus treculi*	0	1	0	Endemic to perennial streams of the Edwards Plateau region.	--	--	Resident

Table 9.3-1. Endangered, Threatened, Candidate and Species of Concern Listed for Burleson, Lee, Milam and Williamson Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Sharpnose shiner	*Notropis oxyrhynchus*	0	3	0	Endemic to Brazos River drainage. Found in large rivers.	LE	--	Resident
Smalleye shiner	*Notropis buccula*	0	3	0	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident
INSECTS								
A mayfly	*Procloeon distinctum*	0	1	0	Mayflies are distinguished by their aquatic larval state with the adult stage generally found in shoreline vegetation.	--	--	Resident
A mayfly	*Pseudocentroptiloides morihari*	0	1	0	Mayflies are distinguished by their aquatic larval state with the adult stage generally found in shoreline vegetation.	--	--	Resident
Coffin Cave mold beetle	*Batrisodes texanus*	1	3	3	Resident, a small cave-adapted beetle found in small Edwards Limestone caves in Travis and Williamson counties.	LE	--	Resident
Leonora's dancer damselfly	*Argia leonorae*	0	1	0	Found in south central and western Texas in small streams and seepages.	--	--	Resident
INSECTS								

Table 9.3-1. Endangered, Threatened, Candidate and Species of Concern Listed for Burleson, Lee, Milam and Williamson Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Tooth Cave ground beetle	*Rhadine Persephone*	1	3	3	Resident, small, cave-adapted beetle found in small Edwards Limestone caves in Travis and Williamson counties.	LE	--	Resident
MAMMALS								
Cave myotis bat	*Myotis velifer*	0	1	0	Roosts colonially in caves, rock crevices	--	--	Resident
Louisiana black bear	*Ursus americanus luteolus*	0	2	0	Possible as transient in bottomland hardwoods and inaccessible forested areas.	LT	T	Possible transient
Plains spotted skunk	*Spilogale putorius interrupta*	1	1	1	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	0	3	0	Extirpated.	LE	E	Historic Resident
MOLLUSKS								
Creeper (squawfoot)	*Strophitus undulates*	0	1	0	Small to large streams. Colorado, Guadalupe, and San Antonio River basins.	--	--	Resident
False spike mussel	*Quincuncina mitchelli*	0	2	0	Substrates of cobble and mud. Rio Grande, Brazos, Colorado and Guadalupe river basins.	--	T	Resident

Table 9.3-1. Endangered, Threatened, Candidate and Species of Concern Listed for Burleson, Lee, Milam and Williamson Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Smooth pimpleback	*Quadrula houstonensis*	0	2	0	Freshwater mollusk found in small to moderate streams and rivers as well as moderate sized reservoirs. Brazos and Colorado River Basins.	C	T	Resident
Texas fawnsfoot	*Truncilla macrodon*	0	2	0	Found in rivers and larger streams, intolerant of impoundment.	C	T	Resident
PLANTS								
Branched gay-feather	*Liatric cymosa*	0	1	0	Texas endemic found on somewhat barren grassland openings in post oak woodlands.	--	--	Resident
Bristle nailwort	*Paronychia setacea*	0	1	0	Flowering vascular plant endemic to eastern south central Texas in sandy soils.	--	--	Resident
Elmendorf's onion	*Allium elmendorfii*	0	1	0	Texas endemic found on grassland openings in oak woodlands on deep, loose, well-drained sands.	--	--	Resident
Green beebalm	*Monarda viridissima*	0	1	0	Endemic perennial herb. Found in well-drained sandy soils in opening of post oak woodlands.	--	--	Resident

Table 9.3-1. Endangered, Threatened, Candidate and Species of Concern Listed for Burleson, Lee, Milam and Williamson Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Navasota ladies'-tresses	*Spiranthes parksii*	0	3	0	Texas endemic found in opening in post oak woodlands in sandy loams along upland drainages or intermittent streams.	LE	E	Resident
Parks' jointweed	*Polygonella parksii*	0	1	0	Texas endemic, primarily found on deep, loose, sand blowouts in Post Oak Savannas.	--	--	Resident
Shinner's sunflower	*Helianthus occidentalis ssp. Plantagineus*	0	1	0	Primarily found in prairies on the Coastal Plain.	--	--	Resident
REPTILES								
Alligator snapping turtle	*Macrochelys temminckii*	0	2	0	Found in perennial water bodies near deep running water.	--	T	Resident
Spot-tailed earless lizard	*Holbrookia lacerata*	1	1	1	Moderately open prairie-brushland.	--	--	Resident
REPTILES								
Texas Garter Snake	*Thamnophis sirtalis annectens*	1	1	1	Wet or moist microhabitats	--	--	Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands.	--	T	Resident
Timber rattlesnake	*Crotalus horridus*	1	2	2	Floodplains, upland pine, deciduous woodlands, riparian zones.	--	T	Resident

Table 9.3-1. Endangered, Threatened, Candidate and Species of Concern Listed for Burleson, Lee, Milam and Williamson Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County

LE/LT=Federally Listed Endangered/Threatened
DL=Federally Delisted
C=Candidate for Federal Listing
E, T=State Listed Endangered/Threatened
Blank = Considered rare, but no regulatory listing status

TPWD, 2014. Annotated County List of Rare Species –Burleson County updated 9/4/2014, Milam County updated 9/4/2014, Lee County updated 4/28/2014, and Williamson County updated 9/4/2014.
USFWS, 2014. Species Lists from http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action?fips=48187, accessed September 25, 2014.

Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction. If the project will affect waters of the United States or wetlands, the project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to these resources.

Field surveys conducted at the appropriate phase of development should be employed to minimize the impacts of construction and operations on sensitive resources. Specific project features, such as well fields, pump stations and pipelines generally have sufficient design flexibility to avoid most impacts or significantly mitigate potential impacts to geographically limited environmental and cultural resource sites.

9.3.4 Engineering and Costing

The envisioned Burleson and Lee County groundwater projects will be developed in phases as necessary to meet growing needs. At build-out, the Burleson County well field project includes ten 1,500 gpm Carrizo wells and fourteen 2,500 gpm Simsboro wells. The Lee County well field at buildout includes seven 1,000 gpm Carrizo wells and eleven 1,500 gpm Simsboro wells to supplement the supply. Other facilities include well field collection pipelines, a transmission line and pump stations to deliver the raw groundwater to a shared WTP/distribution system. For purposes of this study, both well fields are started at the beginning of the project to meet the 2020 needs. Additional wells, pump station expansions, and water treatment plant expansions will be added as demand increases. The shared water treatment plant will provide disinfection and cooling before the water enters the shared distribution system. Because the Thrall connection is between the Burleson County well field and the WTP, the water will be treated within the Town of Thrall before distribution. When completed, the Burleson County well field will have a maximum capacity of 34,894 acft/yr and the Lee county well field will have a maximum capacity of 16,344 acft/yr. These capacities deplete nearly all of the remaining groundwater availability under the MAG and projected local demands. The combined capacity in 2070 for the Regional Williamson County groundwater strategy is 51,238 acft/yr for WUGs throughout Williamson County. The major facilities required for this strategy are:

- Wells
- Well field collection pipeline(s)
- Transmission Pipeline/Pump Stations
- Shared Water Treatment Plant/ Pump Stations
- Shared Distribution system for multiple WUG's

The approximate locations of these facilities are displayed in Figure 9.3-1. Location of Regional Williamson County

For the Burleson County component of this Regional Groundwater Strategey, approximately 70 percent of the supply will be coming from the Simsboro wells and 30 percent from the Carrizo. Power costs were estimated by calculating the horsepower needed to operate the wells and pump the water from the well field to the WTP. Costs were included for leasing property necessary to obtain groundwater permits, and for anticipated third party well mitigation activities to compensate for lowered pumping levels in existing wells. Based on these assumptions, it is estimated that the water obtained through the Burleson county well field excluding the shared pipeline and associated pump stations will have a unit cost that ranges from $258 per acft/yr to $1,670 per acft/yr (Table 9.3-2).

For the Lee County component Approximately approximately 70 percent of the supply will be coming from the Simsboro wells and 30 percent from the Carrizo. Power costs were estimated by calculating the horsepower needed to operate the wells and to pump the water to the WTP. Costs were included for leasing property necessary to obtain groundwater permits, and for anticipated third party well mitigation activities to compensate for lowered pumping levels in existing wells. Based on these assumptions, it is estimated that the water obtained through the Lee County well field excluding the shared pipeline and associated pump stations will have a unit cost that ranges from $246 per acft/yr to $899 per acft/yr (Table 9.3-3).

The shared pipeline will range from a 72-in pipe leaving the WTP to a 30-in pipe 27 miles to the west between Georgetown and Leander. An 18–mile 24-inch pipeline will split from the main trunk west of Taylor and deliver supply to Jonah SUD and Granger. Water will be delivered through smaller distribution pipes throughout the system to various Williamson County Other sites depending on locational needs. The overall project cost for this system which is divided amongst participating WUGs based on 2070 utilization is $123,257,000 with an annual cost in 2020 of $14,828,000 assuming a 20-year debt service (Table 9.3-4).

Costs for each Individual WUG are based on the percent participation in the project during that decade and an upfront capital contribution to the 2020 and 2030 debt service based on 2070 participation for Georgetown and Round Rock who do not have needs until 2050 but will be benefiting from the shared infrastructure once their systems come online. Table 9.3-5 shows the capital, project, annual and unit costs for each WUG along with the percent of supply going to that WUG for each decade.

Table 9.3-2. Cost Estimate Summary for Burleson County Well Field Component of the System

Item	Estimated Cost for Facilities by Decade					
	2020	2030	2040	2050	2060	2070
CAPITAL COST						
Well Fields (Wells, Pumps, and Piping)	$8,958,000	$3,771,000	$1,417,000	$6,124,000	$23,104,000	$0
Transmission Pipeline (60 in dia., 43 miles)	$85,637,000	$0	$0	$0	$0	$0
Intake Pump Stations (62.3 MGD)	$6,770,000	$0	$0	$0	$0	$0
Water Treatment Plant	$286,000	$114,000	$57,000	$171,000	$743,000	$0
TOTAL COST OF FACILITIES	**$101,651,000**	**$3,885,000**	**$1,474,000**	**$6,295,000**	**$23,847,000**	**$0**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$31,296,000	$1,359,750	$515,900	$2,203,250	$8,346,450	$0
Environmental & Archaeology Studies and Mitigation	$1,243,000	$0	$0	$0	$0	$0
Signing Bonus and Holding Fees (14,933 acres @ $300 per Acre)	$6,978,800	$0	$0	$0	$0	$0
Interest During Construction (4% for 2 years with a 1% ROI)	$9,882,000	$368,000	$140,000	$595,000	$2,254,000	$0
TOTAL COST OF PROJECT	**$151,050,800**	**$5,612,750**	**$2,129,900**	**$9,093,250**	**$34,447,450**	**$0**
ANNUAL COST						
Debt Service (5.5 percent, 20 years)	$10,393,000	$10,779,000	$533,000	$773,000	$2,996,000	$2,370,000
Operation and Maintenance						
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$1,014,000	$1,052,000	$1,066,000	$1,127,000	$1,358,000	$1,358,000
Water Treatment Plant (2.5% of Cost of Facilities)	$7,000	$10,000	$11,000	$15,000	$34,000	$34,000
Pumping Energy Costs (0.09 $/kW-hr)	$261,000	$366,000	$379,000	$418,000	$585,000	$585,000
Production Fee ($125/acft)	$950,000	$1,350,000	$1,500,000	$2,150,000	$4,362,000	$4,362,000
Groundwater District Export Fee ($8.71/acft)	$66,000	$94,000	$105,000	$150,000	$304,000	$304,000
TOTAL ANNUAL COST	**$12,691,000**	**$13,651,000**	**$3,594,000**	**$4,633,000**	**$9,639,000**	**$9,013,000**
Available Project Yield (acft/yr)	7,600	10,800	12,000	17,200	34,894	34,894
Annual Cost of Water ($ per acft)	$1,670	$1,264	$300	$269	$276	$258
Annual Cost of Water ($ per 1,000 gallons)	$5.12	$3.88	$0.92	$0.83	$0.85	$0.79

Table 9.3-3. Cost Estimate Summary for Lee County Well Field Component of the System

Item	Estimated Cost for Facilities by Decade					
	2020	2030	2040	2050	2060	2070
CAPITAL COST						
Well Fields (Wells, Pumps, and Piping)	$6,069,000	$1,417,000	$2,326,000	$2,326,000	$6,069,000	$3,743,000
Transmission Pipeline (42 in dia., 16 miles)	$20,002,000	$0	$0	$0	$0	$0
Intake Pump Stations (29.2 MGD)	$4,102,000	$0	$0	$0	$0	$0
Water Treatment Plant	$168,000	$34,000	$67,000	$67,000	$168,000	$101,000
TOTAL COST OF FACILITIES	**$30,341,000**	**$1,451,000**	**$2,393,000**	**$2,393,000**	**$6,237,000**	**$3,844,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$9,619,250	$507,850	$837,550	$837,550	$2,182,950	$1,345,400
Environmental & Archaeology Studies and Mitigation	$532,136	$0	$0	$0	$0	$0
Signing Bonus and Holding Fees (11,470 acres @ $300 per Acre)	$3,266,800	$0	$0	$0	$0	$0
Interest During Construction (4% for 2 years with a 1% ROI)	$3,064,000	$138,000	$227,000	$227,000	$590,000	$364,000
TOTAL COST OF PROJECT	**$46,823,186**	**$2,096,850**	**$3,457,550**	**$3,457,550**	**$9,009,950**	**$5,553,400**
ANNUAL COST						
Debt Service (5.5 percent, 20 years)	$3,222,000	$3,366,000	$382,000	$476,000	$858,000	$1,002,000
Operation and Maintenance						
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$302,000	$316,000	$339,000	$362,000	$423,000	$460,000
Water Treatment Plant (2.5% of Cost of Facilities)	$4,000	$5,000	$7,000	$9,000	$13,000	$16,000
Pumping Energy Costs (0.09 $/kW-hr)	$144,000	$173,000	$206,000	$239,000	$320,000	$369,000
Production Fee ($125/acft)	$600,000	$700,000	$950,000	$1,200,000	$1,800,000	$2,042,000
Groundwater District Export Fee ($8.71/acft)	$42,000	$49,000	$66,000	$84,000	$125,000	$142,000
TOTAL ANNUAL COST	**$4,314,000**	**$4,609,000**	**$1,950,000**	**$2,370,000**	**$3,539,000**	**$4,031,000**
Available Project Yield (acft/yr)	4,800	5,600	7,600	9,600	14,400	16,334
Annual Cost of Water ($ per acft)	$899	$823	$257	$247	$246	$247
Annual Cost of Water ($ per 1,000 gallons)	$2.76	$2.53	$0.79	$0.76	$0.75	$0.76

Table 9.3-4. Cost Estimate Summary for Shared Distribution Pipeline

Item	Estimated Costs for Facilities
Intake Pump Stations (91.5 MGD)	$15,992,000
Transmission Pipeline (72 in dia., 46 miles)	$65,582,000
Transmission Pump Station(s) & Storage Tank(s)	$8,234,000
TOTAL COST OF FACILITIES	**$89,808,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$28,139,000
Environmental & Archaeology Studies and Mitigation	$1,143,000
Interest During Construction (4% for 1 years with a 1% ROI)	$4,167,000
TOTAL COST OF PROJECT	**$123,257,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$10,310,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$1,261,000
Pumping Energy Costs (36189826 kW-hr @ 0.09 $/kW-hr)	$3,257,000
TOTAL ANNUAL COST	**$14,828,000**

Table 9.3-5. Cost Estimate Summary for Individual WUGs

Georgetown	2020*	2030*	2040	2050	2060	2070
Capital Costs	$27,634,000	$0	$0	$692,000	$4,148,000	$497,000
Project Costs	$37,372,000	$0	$0	$1,000,000	$5,992,000	$719,000
Annual Costs	$3,096,000	$3,096,000	$0	$651,000	$1,590,000	$1,444,000
Unit Costs ($/acft)	N/A	N/A	N/A	$342	$250	$227
% of Project	0.0%	0.0%	0.0%	8.0%	13.8%	12.9%
Granger	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Capital Costs	$827,000	$50,000	$31,000	$54,000	$110,000	$15,000
Project Costs	$1,119,000	$73,000	$45,000	$78,000	$160,000	$22,000
Annual Costs	$172,000	$162,000	$61,000	$51,000	$42,000	$43,000
Unit Costs ($/acft)	$1,522	$1,339	$459	$345	$249	$226
% of Project	1.3%	0.9%	0.8%	0.6%	0.4%	0.4%
Hutto	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Capital Costs	$54,314,000	$1,526,000	$1,274,000	$2,699,000	$6,660,000	$978,000
Project Costs	$73,454,000	$2,205,000	$1,841,000	$3,899,000	$9,621,000	$1,412,000
Annual Costs	$7,674,000	$8,253,000	$2,508,000	$2,538,000	$2,554,000	$2,838,000
Unit Costs ($/acft)	$3,402	$2,244	$458	$342	$251	$227
% of Project	25.0%	28.6%	33.0%	31.1%	22.1%	25.4%
Jonah Water SUD	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Capital Costs	$11,915,000	$314,000	$182,000	$496,000	$1,332,000	$214,000
Project Costs	$16,113,000	$454,000	$263,000	$717,000	$1,924,000	$310,000
Annual Costs	$1,869,000	$1,784,000	$358,000	$467,000	$511,000	$622,000
Unit Costs ($/acft)	$2,466	$2,354	$457	$342	$251	$227
% of Project	8.4%	5.9%	4.7%	5.7%	4.4%	5.6%
Round Rock	**2020***	**2030***	**2040**	**2050**	**2060**	**2070**
Capital Costs	$60,814,000	$0	$0	$1,323,000	$9,128,000	$1,095,000
Project Costs	$82,244,000	$0	$0	$1,911,000	$13,186,000	$1,581,000
Annual Costs	$6,813,000	$6,813,000	$0	$1,244,000	$3,500,000	$3,177,000
Unit Costs ($/acft)	N/A	N/A	N/A	$342	$251	$227
% of Project	0.0%	0.0%	0.0%	15.2%	30.3%	28.5%
Thrall	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Capital Costs	$605,000	$37,000	$23,000	$40,000	$81,000	$11,000
Project Costs	$818,000	$53,000	$33,000	$58,000	$117,000	$16,000
Annual Costs	$126,000	$119,000	$45,000	$38,000	$31,000	$32,000
Unit Costs ($/acft)	$1,518	$1,337	$455	$345	$250	$230
% of Project	0.9%	0.7%	0.6%	0.5%	0.3%	0.3%
Williamson Co. Other	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Capital Costs	$57,457,000	$3,409,000	$2,357,000	$3,385,000	$8,624,000	$1,034,000
Project Costs	$77,705,000	$4,925,000	$3,405,000	$4,889,000	$12,458,000	$1,494,000
Annual Costs	$10,534,000	$11,123,000	$4,639,000	$3,183,000	$3,307,000	$3,002,000
Unit Costs ($/acft)	$1,811	$1,354	$458	$342	$251	$227
% of Project	64.4%	63.9%	60.9%	39.0%	28.7%	26.9%

*Note: The debt service costs for 2020 and 2030 were also applied at 2070 ratios to Georgetown and Round Rock

9.3.5 Implementation Issues

Implementation of the Regional Groundwater Strategy for Williamson County with a Carrizo-Wilcox option in Burleson and Lee Counties involve conflicts with other planned water supply projects.

The development of groundwater in the Carrizo-Wilcox Aquifers in the Brazos G Water Planning Region must address several issues. Major issues include:

- Competition with others in the area for groundwater.
- Acquisition of water rights from land owners,
- Exposure to groundwater conservation district rules that may reduce groundwater production if drawdown exceeds allowable limits,
- Changes in regulations by groundwater conservation districts,
- Changes in the MAG,
- Impact on:
  - Endangered and threatened wildlife species,
  - Water levels in the aquifer,
  - Baseflow in streams, and
  - Wetlands.
- Substantial drawdown in existing wells,

This water supply option has been compared to the plan development criteria, as shown in Table 9.3-6, and the option meets each criterion.

Table 9.3-6. Comparison of Williamson County Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Only Partly Meets Demands
2. Reliability	2. Moderate to High
3. Cost	3. Moderate
B. Environmental factors	
1. Environmental Water Needs	1. None
2. Habitat	2. None
3. Cultural Resources	3. None
4. Bays and Estuaries	4. None
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. None
C. Impact on Other State Water Resources	None
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered in an attempt to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

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10 Aquifer Storage and Recovery (ASR)

10.1 City of Bryan ASR

10.1.1 Description

The City of Bryan (Bryan) currently has 12 water supply wells in the Simsboro and Sparta Aquifers with a combined permitted supply of 33,540 acft/yr. Eleven of these wells are permitted under historical use with an annual permitted production amount of 28,702 acft/yr. The current capacity of these wells is limited to 20,167 acft/yr. According to the City of Bryan's engineering consultant, the total current annual water supply based on permitted amounts meets the City's annual supply needs until 2056; however, pumping capacity from these wells prevents them from meeting the maximum day demands beyond 2040. Additionally, the Brazos County Modeled Available Groundwater (MAG) developed for the City of Bryan only allows for a supply of 16,792 acft/yr in 2020. Although the MAG allowable supply increases over time (maxing out at the pumping capacity of 20,167 acft/yr by 2040), the supply is not enough to meet demands beyond 2030.

Using TWDB methodology, the calculated total water supply, total water demand and water balance (surplus and shortage) is presented in Table 10.1-1 by decade. This analysis shows Bryan will need an additional 24,435 acft/yr by 2070. A groundwater strategy that is described in Section 9.1 will provide 5,100 acft/yr from the Carrizo Aquifer in Brazos County beginning in 2050. Remaining supplies will be developed by the ASR strategy

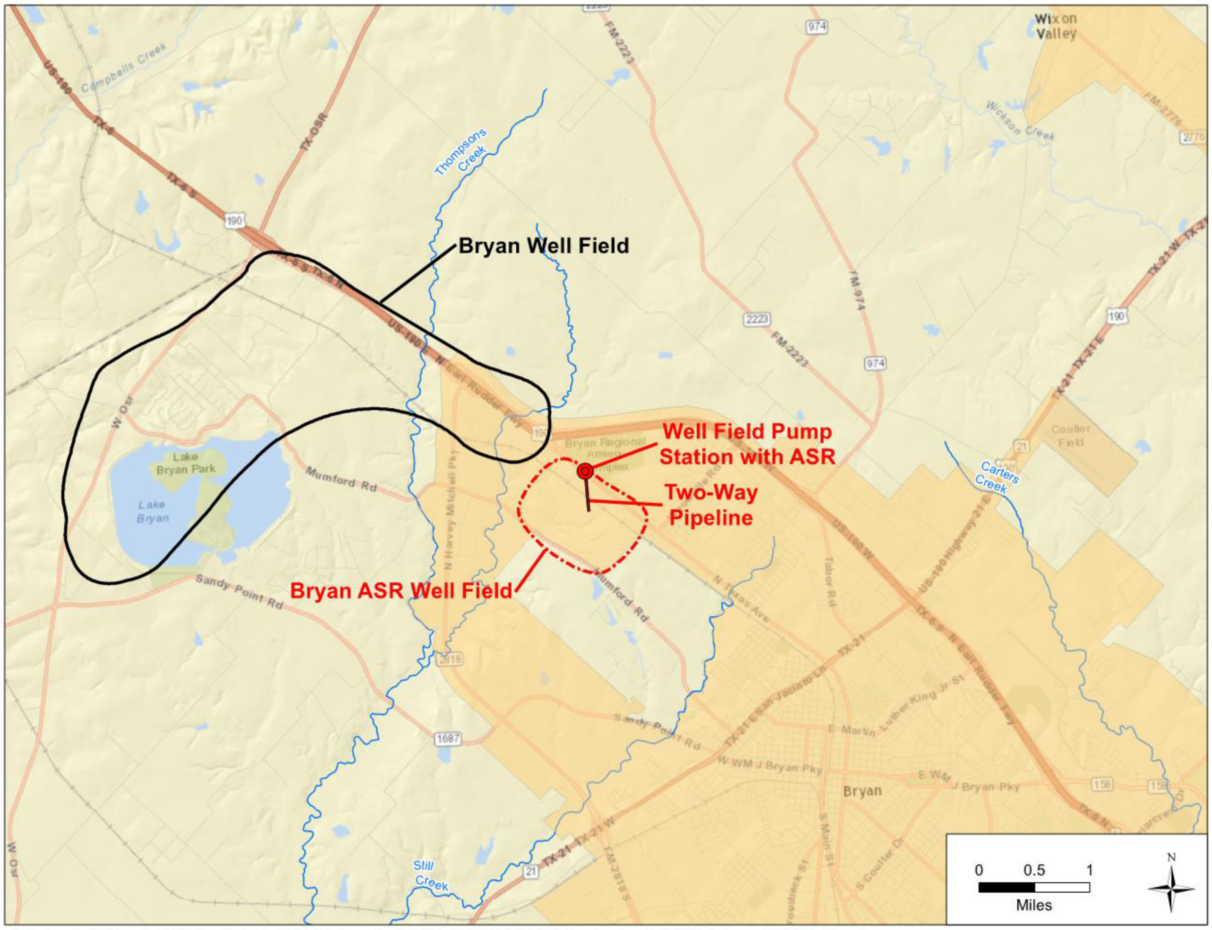
An ASR conjunctive use strategy was developed to meet demands out to 2070 that includes ASR and production wells. A spreadsheet model was developed that simulates the storage and use of ASR water to determine when ASR wells and additional productions wells are needed over time.

The ASR aspect of this conjunctive use strategy would fully utilize the MAG or well capacities by pumping at the allowable rate or capacities year round. During times when water demand is less than the amount of water being produced from the production wells, the excess water would be directed from the City's Well Field Pump Station to a new ASR well field for aquifer storage. This water would be recovered from the ASR wells when Bryan's demand exceeds the allowable use from the MAG. The recovered water would be delivered back to the Well Field pump station for cooling and disinfection and then into the distribution system. Additional production wells are added over time according to the modeling. The model was also used to determine when each of the ASR wells in the proposed ASR well field would need to come online.

This conjunctive use strategy requires four new ASR wells and four recovery wells.. The ASR strategy will produce 19,839 acft/yr The modeling of the strategy is discussed further in Section 10.1.2.

In addition to the wells required for this strategy, two-way pipelines between the ASR well field and the Well Field Pump Station, an ASR pump station at Well Field Pump Station, and an interconnect into the storage tanks are needed. A map showing the locations of the well fields is shown in Figure 10.1-1. For the purposes of this strategy, the target aquifer for storing the water is the brackish water zone of the Simsboro unit of the Wilcox Group.

Figure 10.1-1. Bryan's Existing Well Field and Proposed ASR Well Field



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Table 10.1-1. Bryan's Water Supply and Demand

Year	Total Supply	Total Demand	Balance
2020	16,792	19,634	-2,841
2030	19,294	18,990	304
2040	20,167	24,084	-3,917
2050	20,167	30,345	-10,178
2060	20,167	37,058	-16,891
2070	20,167	44,602	-24,435

Units are in acft/yr

10.1.2 Modeling and Available Supply

A probabilistic model was developed that simulates water demand over the available hydrologic record (1948 to 2014) to determine when ASR water may be stored or used. This model was used to determine how much water could be stored over time starting in 2020 and then adding production and ASR wells so as not to completely deplete the ASR supply out to 2070.

The first step in developing the model was to determine a relationship between current water demand and hydrologic conditions to simulate the monthly variations in demand. Water production data from 2000 to 2014 was converted to per capita demand and related to variables including precipitation, evaporation, and temperature. Evaporation was found to be the best indicator of water demand when considering each variable individually. The relationship was improved slightly by adding precipitation. Different relationships were then developed for each season or month to further improve the prediction.

Evaporation was the best indicator, but records from TWDB in the region are only available back to 1954. It was important to include the 1950's drought in the simulation; therefore, temperature data was used to extend the record. A relationship between evaporation and temperature was developed using all available data from 1954 to 2014. This relationship was used to extend the evaporation time series back to 1948.

Figure 10.1-2 shows a scatter plot of the production-based demand versus the final modeled demand based on the relationship developed between per capita demand and evaporation and precipitation for monthly values from 2000 to 2014.

Using the demand relationship that was developed, per capita water demand was predicted on a monthly time step from 1948 to 2014 using the available and extended evaporation and precipitation data. The Region G population projections were applied to the predicted monthly per capita water demands. Each decade was simulated over the entire period of record to determine the likelihood of ASR storage or use. It was found that water is likely to accumulate given 2020 and 2030 demands. By 2040, ASR water would likely be used at a greater rate than could be accumulated without adding additional supply. This agrees with the deficit predictions shown in Table 10.1-1.

To determine how much water is likely to be available through ASR over time as population increases, the median value of ASR storage or use on an annual basis was extracted for each of the simulated decades. These median storage/use values were applied to each decade from 2020 to 2070, and values between each decade were linearly interpolated. The cumulative volume was then calculated over time applying an unrecoverable (loss) factor of 10 percent. This analysis was used to determine how long the ASR supply would last given the MAG predicted supplies. Next, additional production wells and ASR wells were added to the strategy when needed to avoid depleting the supply and/or creating deficits. The resulting graph of cumulative supply is shown in Figure 10.1-3. The inflection points at 2030, 2040, and 2050 indicate when increases in the MAG allowed for additional pumping.

Figure 10.1-2. Fit of Demand Model

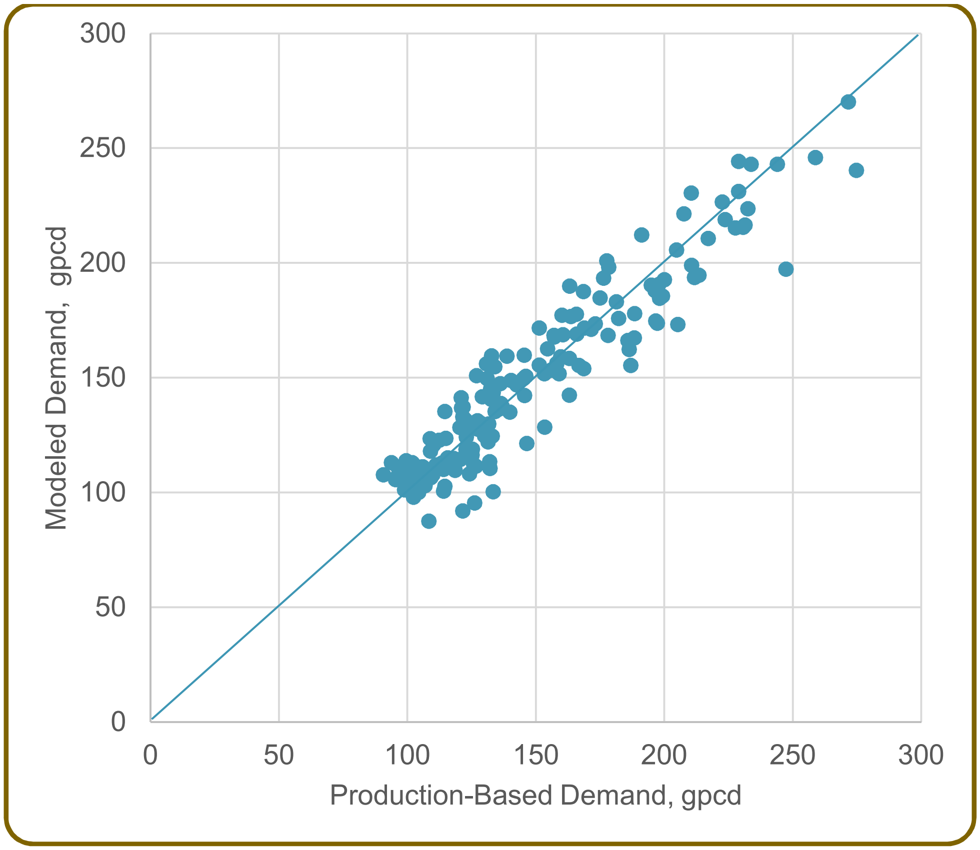
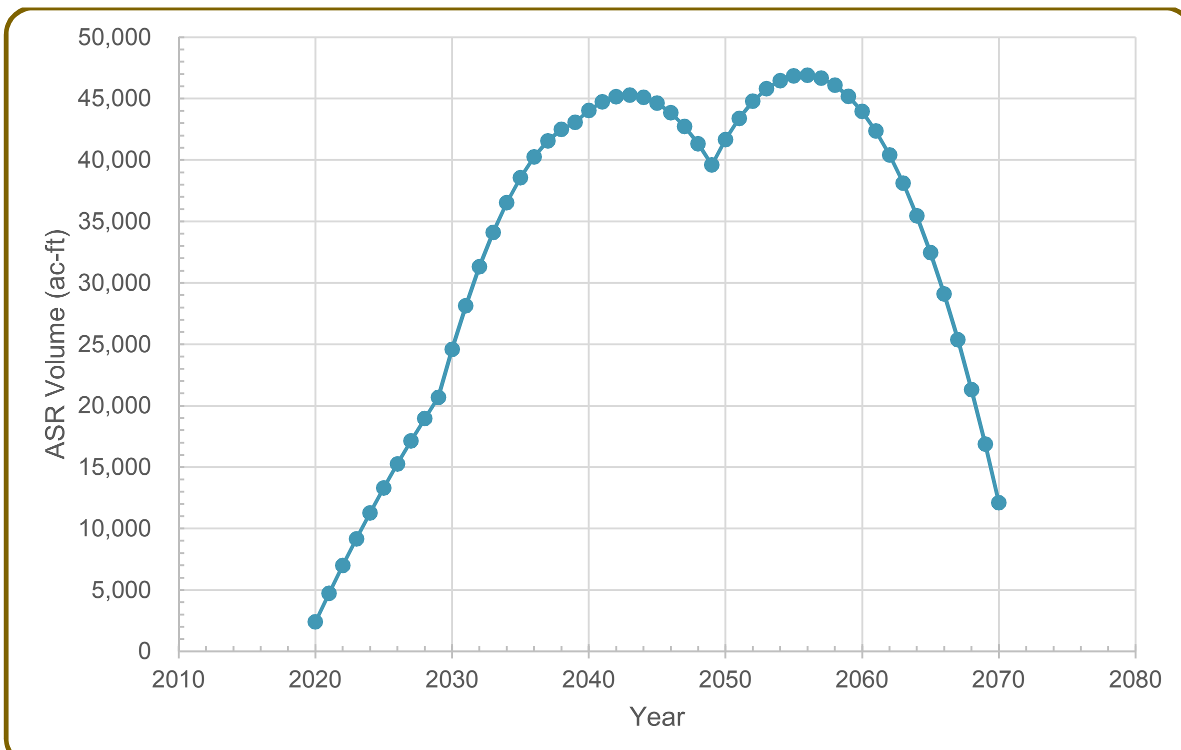


Figure 10.1-3. Time series Plot of ASR Recoverable Volume

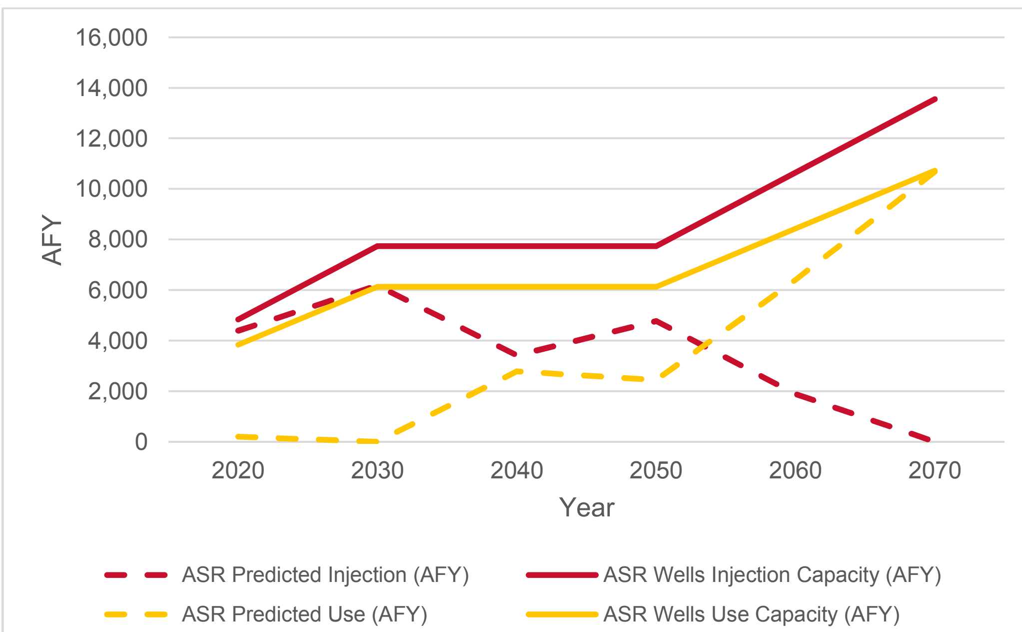


10.1.3 Infrastructure Timing

The modeling results show that by starting ASR in 2020, Bryan's current water production well infrastructure is sufficient until 2050. It is recommended that Bryan construct two new production wells in Brazos County by 2050. Each new well is assumed to have a rated capacity of 3,000 gpm. Actual production assumes that the wells need to meet a maximum day factor of 2 and that the wells are 95 percent reliable.

Results from the modeling were used to determine the timing of ASR wells. For each simulated decade, the maximum annual amount stored and used was compared to the total ASR injection and use capacities, respectively. The ASR injection capacity is assumed to be 60 percent of the rated production capacity of the well. The use capacity assumes the same factors as for the production wells. Figure 10.1-4shows the model predicted ASR injection and ASR use versus the ASR injection capacity and ASR use capacity. Predicted ASR use decreases each decade that additional production is recommended and increases in other decades. Predicted ASR injection follows opposite trends. To meet the predicted ASR injection and ASR use needs, Bryan should begin storing ASR water using Well #10 and one new ASR well by or before 2020. Then one new ASR well is needed each in 2030, 2060, and 2070. Additionally, piloting of Well #10 as an ASR well should begin as soon as possible.

Figure 10.1-4. ASR Injection, Capacity and Use Curves over Time



10.1.4 ASR Aquifer

The target area for ASR wells near Bryan is over the Carrizo-Wilcox aquifer. Major water-bearing formations in the Carrizo-Wilcox consist of the Carrizo Sands and Simsboro Formation. The wells would be installed in the Simsboro, which is 450 ft thick. Bryan's current wells are in the Sparta and Simsboro and are about 600 and 2,800 ft deep, respectively. High capacity Simsboro wells typically yield up to 3,000 gallons per minute (gpm). The water temperature for Simsboro wells in this locale is about 115 deg F and requires cooling before discharging into the distribution system.

The groundwater supply for the ASR project is currently permitted with the Brazos Valley Groundwater Conservation District.

10.1.5 Environmental Issues

Environmental issues for the proposed City of Bryan ASR Project are described below. This project includes the pumping of existing production wells nearly year round and utilizing any excess water for aquifer storage. This water would be recovered, disinfected and distributed later when needed for public use. This project would include the development of an ASR well field, additional well field distribution and collection pipelines, a new two-way transmission pipeline, a water treatment plant for disinfection and an interconnect. Implementation of this project would require field surveys by qualified professionals to document vegetation/habitat types, waters of the U.S. including wetlands, and cultural resources that may be impacted. Where impacts to protected species habitat or significant cultural resources cannot be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. The project sponsor would also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to wetland areas and compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

The pipelines and wells needed for the ASR project's well field would occur in close proximity to Still Creek and a tributary of Still Creek which includes several small stock ponds/impoundment areas. Coordination with the U.S. Army Corps of Engineers would be required for construction within any waters of the U.S. Any impacts from this proposed project which would result in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

The project occurs within the East Central Texas Plains Ecoregion[1] and lies within the Texan Biotic Province.[2] Vegetation types within the City of Bryan ASR well field area and transmission pipelines as described by the Texas Parks and Wildlife Department (TPWD)[3] include urban and other areas. These areas include portions of the city and wooded areas adjacent to cleared pasture areas. Avoidance of riparian areas near the creeks, impounded areas or heavily wooded areas would help minimize potential impacts to existing area species from project construction activities.

Table 10.1-2 lists state listed endangered or threatened species, and federally listed endangered or threatened species along with species of concern that may occur in Brazos County. This information comes from the county lists of rare species published online by the Texas Parks and Wildlife Department (TPWD). Inclusion in this table does not mean that a species will occur within the project area, but only acknowledges the

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[1] Griffith Glenn, Sandy Bryce, James Omernik, and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality.

[2] Blair, W. Frank. 1950. The Biotic Provinces of Texas. Texas Journal of Science 2(1):93-117.

[3] McMahan, Craig A., Roy G. Frye and Kirby L. Brown. 1984. The Vegetation Types of Texas. Wildlife Division, Texas Parks and Wildlife Department, Austin, Texas.

potential for its occurrence in the project area county. Because the project will use previously allocated water from existing wells to inject into the aquifer no significant impacts to existing stream flows or aquatic species are anticipated. Potential impacts to listed species within the project area are anticipated to include disturbance of existing habitat resulting from the construction of well fields and their associated pipelines, transmission pipelines and a new water treatment plant. However most of these disturbances would be minimized by the small areas generally required for well field and pipeline construction. After construction is completed the majority of the disturbed areas will return to their previous habitat types excluding areas where maintenance activities are required.

Table 10.1-2. Endangered, Threatened, and Species of Concern for Brazos County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
AMPHIBIANS					
Houston toad	Anaxyrus houstonensis	Endemic species found in sandy substrate, water in pools.	LE	E	Resident
Southern crawfish frog	Lithobates areolatus areolatus	A species found in abandoned crawfish holes and small mammal burrows in moist meadows and river flood plains.	--	--	Resident
BIRDS					
American peregrine falcon	Falco peregrinus anatum	Resident and local breeder in West Texas. Migrant across the state.	DL	T	Possible Migrant
Arctic peregrine falcon	Falco peregrinus tundrius	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	Haliaeetus leucocephalus	Found primarily near rivers and large lakes, migrant.	DL	T	Possible Migrant
Henslow's sparrow	Ammodramus henslowii	Wintering individuals found in weedy or cut-over areas.	--	--	Possible Migrant
Interior least tern	Sterna antillarum athalassos	Nests along sand and gravel bars in braided streams	LE	E	Resident
Sprague's pipit	Anthus spragueii	Migrant in Texas in winter. Strongly tied to native upland prairie.	C	--	Migrant
Whooping crane	Grus americana	Potential migrant	LE	E	Potential Migrant
FISH					

Table 10.1-2. Endangered, Threatened, and Species of Concern for Brazos County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
Blue sucker	Cycleptus elongatus	Found in larger portions of major rivers usually in channels and flowing pools with a moderate current.	--	T	Resident
Sharpnose shiner	Notropis oxyrhynchus	Endemic to Brazos River Drainage. Found in large rivers with a bottom of sand, gravel, and clay-mud.	LE	--	Resident
Smalleye shiner	Notropis buccula	Endemic to upper Brazos River system and its tributaries.	LE	--	Resident
INSECTS					
Gulf coast clubtail	Gomphus modestus	Found in medium rivers in streams with silty sand or rocky bottoms.	--	--	Resident
Smoky shadowfly	Neurocordulia molesta	Found in rivers and sometimes large streams. Larvae cling to rocks or logs.	--	--	Resident
MAMMALS					
Louisiana black bear	Ursus americanus luteolus	Possible as transient, found in bottomland hardwoods and large tracts of inaccessible forested areas.	LT	T	Potential Resident
Plains spotted skunk	Spilogale putorius interrupta	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	Canis rufus	Extirpated.	LE	E	Historic Resident
MOLLUSKS					
False spike mussel	Quadrula mitchelli	Possibly extirpated in Texas, probably found in medium to large rivers.	--	T	Historic Resident
Smooth pimpleback	Quadrula houstonensis	Found in small to moderate streams and rivers and moderate size reservoirs.	--	--	Resident
Texas fawnsfoot	Truncilla macrodon	Possibly occurs in rivers and larger streams and is intolerant of impoundment. Brazos and Colorado River basins.	C	T	Resident
PLANTS					

Table 10.1-2. Endangered, Threatened, and Species of Concern for Brazos County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
Branched gay-feather	Liatris cymosa	Texas endemic found in somewhat barren grassland openings in post oak woodlands on tight soils.	--	--	Resident
Bristle nailwort	Paronychia setacea	Endemic to eastern southcentral Texas, occurring in sandy soils.	--	--	Resident
Navasota ladies'-tresses	Spiranthes parksii	Texas endemic found in openings in post oak woodlands in sandy loams.	LE	E	Resident
Small-headed pipewort	Eriocaulon koenickianum	In East Texas in post-oak woodlands and xeric sandhill openings on permanently wet acid sands of upland seeps and hillside seepage bogs.	--	--	Resident
Texas meadow-rue	Thalicrum texanum	Texas endemic mostly found in woodlands and woodland margins on sandy loam.	--	--	Resident
Texas windmill-grass	Chloris texensis	Texas endemic found in sandy to sandy loam soils in relatively bare areas in coastl prairie grassland remnants.	--	--	Resident
REPTILES					
Alligator snapping turtle	Macrochelys temminckii	A species found in perennial water bodies in deep water of rivers, canals, lakes and oxbows.		T	Resident
Texas horned lizard	Phrynosoma cornutum	Varied, sparsely vegetated uplands.	--	T	Resident
Timber rattlesnake	Crotalus horridus	Floodplains, upland pine, deciduous woodlands, riparian zones.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL, PDL=Federally Delisted/Proposed for Delisting
T/SA=Listed as Threatened by Similarity of Appearance
E, T=State Listed Endangered/Threatened
Blank= Species of concern, but no regulatory listing status
Source: TPWD, 2014. Annotated County List of Rare Species – Brazos County revised 12/11/2014.

A survey of the project area would be required prior to project construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291).

Based on the review of publically available Geographic Information System (GIS) records obtained from the Texas Historical Commission, there are no State Historic Sites, National Register Properties or Districts, or cemeteries within the project area. However five historical markers occur near the proposed pipeline route from the ASR well field to the Tabor Road pump station. A review of archaeological resources in the proposed project area should be conducted during the project planning phase. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction.

10.1.6 Engineering and Costing

This ASR conjunctive use strategy recommends a total of four recovery wells and four storage and recovery (ASR) wells. The timing of the recovery and ASR wells is summarized in Table 10.1-3.

Table 10.1-3. Timing of ASR Wellfield Infrastructure

Year	Recovery Wells	ASR Wells
2020		1
2030		1
2040		
2050	1	
2060	1	1
2070	2	1

Available records indicate that the ASR wells in the Simsboro, where proposed, would average about 3,200 ft deep. A typical injection and recovery rate is estimated to be 1,800 gpm and 3,000 gpm, respectively. The well field design has the wells spaced about 1,320 ft apart.

The major facilities required for these projects include:

- Pump station,
- Pipeline,
- ASR and Recovery wells,

- Collector pipelines, and
- Cooling and Disinfection water treatment, and
- Interconnect.

Estimates were prepared for capital and project costs, annual debt service, operation and maintenance, power, land, and environmental mitigation. These costs are summarized in Table 10.1-4. The annual costs, including debt service, operation and maintenance, and power, is estimated to be $385 per acft.

Table 10.1-4. Cost Estimate Summary: City of Bryan ASR Project Option

Item	Estimated Costs for Facilities
Pump Station	$2,425,000
Transmission Pipelines	$4,032,000
Well Fields (Wells, Pumps, and Piping)	$29,516,000
Water Treatment Plant (Cooling & Disinfection)	$5,123,000
TOTAL COST OF FACILITIES	**$41,096,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$14,182,000
Environmental & Archaeology Studies and Mitigation	$111,000
Interest During Construction (4% for 1 yrs with a 1% ROI)	$1,9239,000
TOTAL COST OF PROJECT	**$57,328,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 yrs)	$4,797,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$396,000
Water Treatment Plant	$1,691,000
Pumping Energy Costs	$761,000
TOTAL ANNUAL COST	**$7,645,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1.94	**19,839**
Annual Cost of Water ($ per acft)	**$385**
Annual Cost of Water ($ per 1,000 gallons)	**$1.18**

10.1.7 Implementation

Implementation of the ASR conjunctive use water management strategy for Bryan includes the following issues:

- Acquiring permits from TCEQ for ASR construction and operations;
- Initial cost; and
- Development of a management and implementation of plan to efficiently balance utilization of production and ASR wells.

This water supply option has been compared to the plan development criteria, as shown in Table 10.1-5, and the option meets each criterion.

Table 10.1-5. Comparison of Bryan ASR Conjunctive Use Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Adequate supply with other strategies to meet needs
2. Reliability	2. High reliability
3. Cost	3. Low
B. Environmental factors	
1. Environmental Water Needs	1. None
2. Habitat	2. None
3. Cultural Resources	3. None
4. Bays and Estuaries	4. None
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. None
C. Impact on Other State Water Resources	None
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered in an attempt to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

10.2 City of College Station ASR

10.2.1 Description

The concept for the City of College Station (College Station) ASR project is to:

- Utilize existing wastewater effluent as the source of water for ASR. For 2005-2007, the average effluent discharges from Carters Creek WWTP and Lick Creek WWTP were 5.75 and 0.68 million gallons per day (MGD), respectively.
- A new Advance Water Treatment Plant (AWTP) would be located near the Carters Creek WWTP. Effluent from the much smaller Lick Creek WWTP would be transported to the AWTP through a new pipeline.
- The AWTP would treat the treated wastewater effluent with: (1) Low Pressure Membrane, (2) Reverse Osmosis, and (3) Oxidation before the water would be recharged into the aquifer.
- Recovered water would be disinfected before being delivered to the existing potable water distribution system.
- New Sparta and Queen City ASR wells would be located southeast of the AWTP. The Sparta and Queen City wells would be about 1,700 and 2,500 ft deep, respectively. An estimated 16 wells would be required at 8 sites.
- The recharge cycle of ASR would occur from October to March. Recovery would occur from April to September to supplement summer peaking demands.

A schematic showing the location of the project is shown in Figure 10.2-1. New facilities required for this option are the ASR wells, well field distribution and collection pipelines, pump station and wastewater transmission pipeline from Lick Creek WTP and Carters Creek WTP, advanced water treatment plant, interconnects between AWTP and the ASR well field and the AWTP and College Station's distribution system, and a two-way pipeline between the AWTP and the ASR well field.

Brazos G projected water supplies and demands are illustrated in Figure 10.2-2. For purposes of this ASR project, an assumed supply of 5.5 MGD of treated wastewater would be made available for storage in the ASR project during the months of October to March and recovery would be at a rate up to 5.0 MGD during April to September.

Figure 10.2-1. Location of College Station's ASR Project

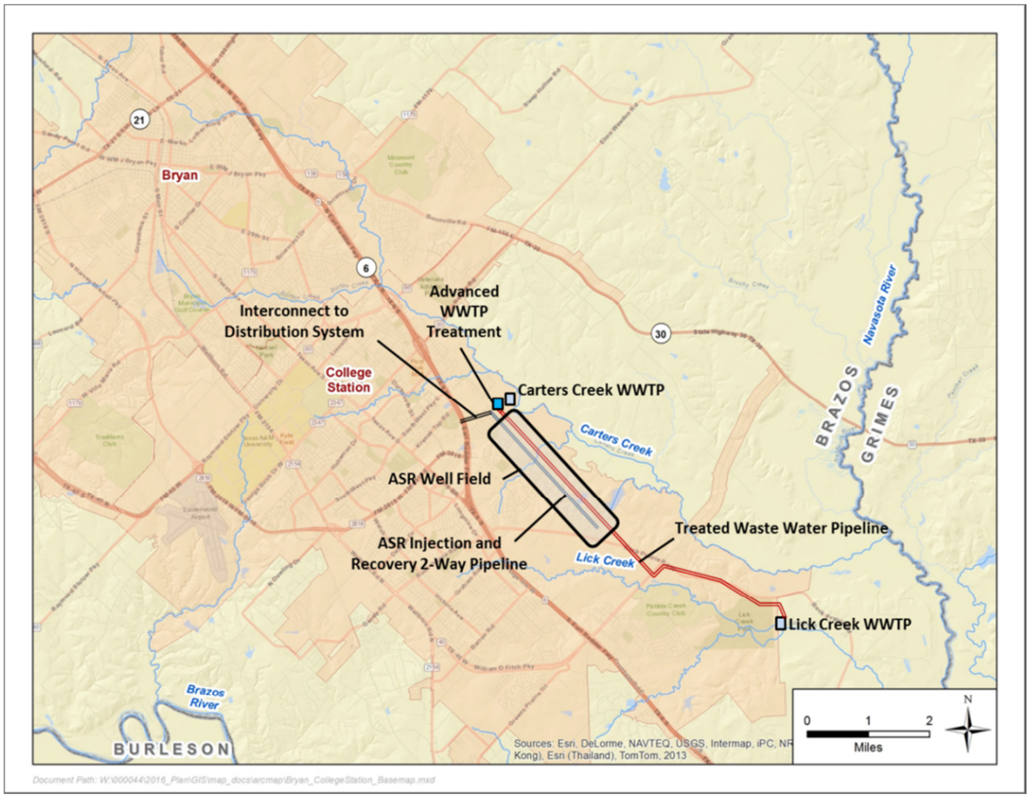
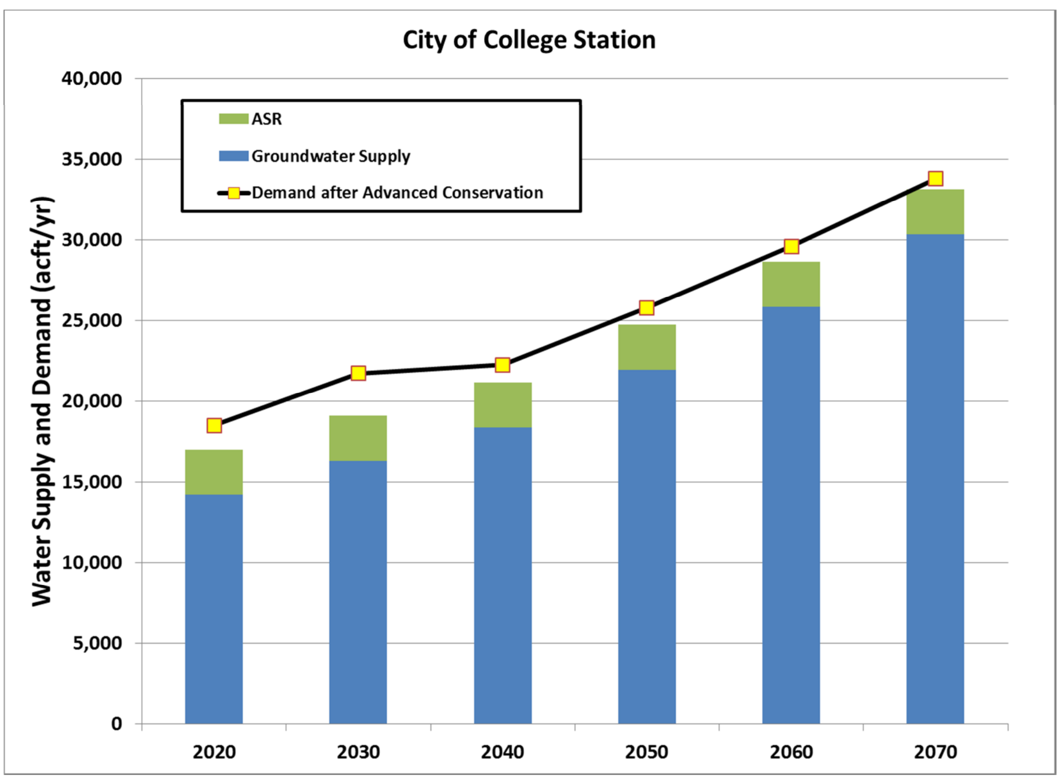


Figure 10.2-2. Water Supplies and Demand for College Station



10.2.2 Available Yield

The target area for ASR wells in College Station's project area has four minor and major aquifers, including, from youngest to oldest: Jackson-Yegua, Sparta, Queen City and Carrizo-Wilcox. Water-bearing formations in the Carrizo-Wilcox consist of the Carrizo Sands and Simsboro Formation. A geologic profile showing the approximate depth and thickness of the geologic formations is shown in Figure 10.2-3. The Jackson Group and Yegua Formation, called the Jackson-Yegua Aquifer, are the shallowest, but rather poor productivity limits well capacity. The Sparta Sands are about 250 ft thick and extends from about 1,450 to 1,700 ft below land surface. The Queen City Sands appear to be about 425 ft thick and range in depth from about 1,800 to 2,225 ft. The Carrizo Sands appear to be about 100 ft thick. The Simsboro is estimated to be about 450 ft thick and extend from about 4,500 to 4,950 ft below land surface.

Electric geophysical logs[1] for a geologic cross-section suggest that the Sparta and Queen have rather extensive sands with fresh to brackish water. Electric geophysical logs[2] for another geologic cross-section provide picks for the Simsboro Formation. These logs suggest that the water quality in the Simsboro is brackish to saline. Native groundwater temperatures at these depths for the Sparta, Queen City, and Simsboro at these locations are about 95, 105, and 150 deg F, respectively. For purposes of this study, the Sparta and Queen City Aquifers were selected for the storage because of depths and native groundwater temperature. This approach allows two wells to be constructed at each well site. Average well yields for both formations are estimated to be 300 gpm. One advantage of this well field is that there are few, if any, water wells in the target water-bearing zones.

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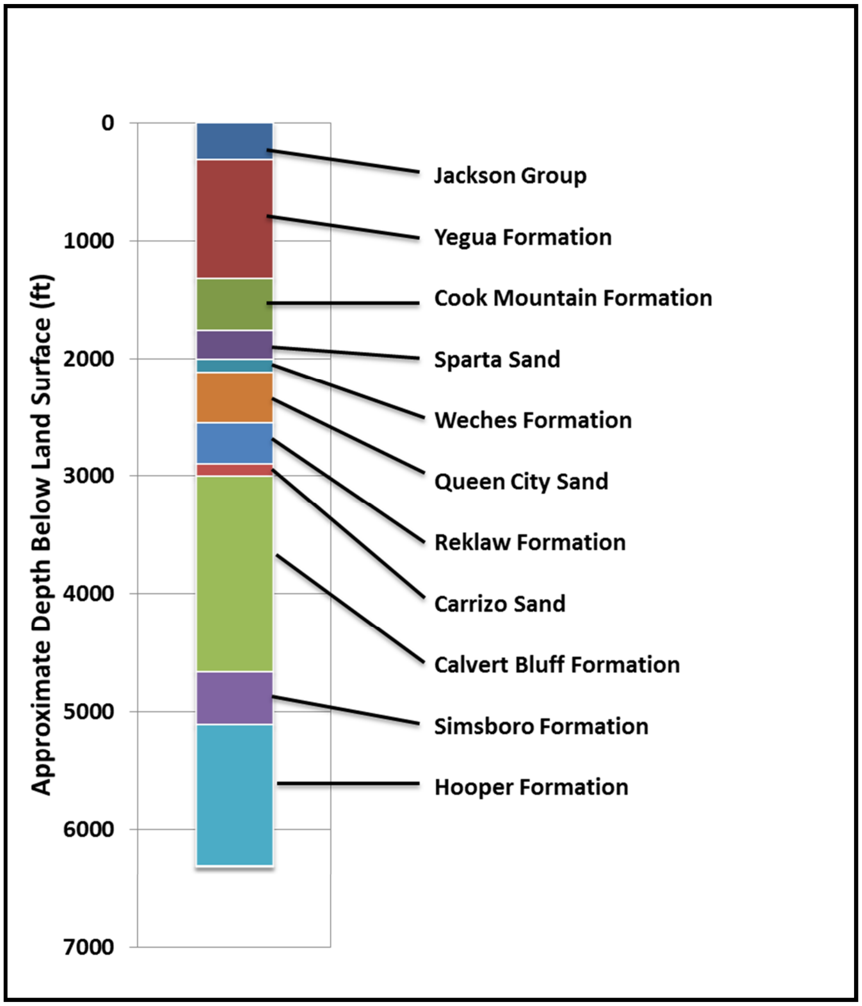
[1] Follett, C.R., 1974, Ground-water resources of Brazos and Burleson Counties, Texas: Texas Water Development Board Report 185.

[2] Thorkildsen, D., and Price, R.D., 1991, Ground-water resources of the Carrizo-Wilcox Aquifer in the Central Texas Region: Texas Water Development Board Report 332.

Figure 10.2-3. Geologic Profile in Target Area for ASR Well



10.2.3 Environmental Issues

Environmental issues for the proposed College Station ASR Project are described below. This project includes the development of an ASR well field, additional well field distribution and collection pipelines, a pump station and wastewater transmission pipeline, an advanced water treatment plant, and interconnects to existing transmission pipelines. The water source for this project would be existing wastewater effluent from local wastewater treatment plants which would be treated at a new AWTP planned near the existing Carters Creek WWTP. In addition effluent water from the Lick Creek WWTP would be transported through a pipeline to the new AWTP for treatment and injection into the ASR wells. Recovered water from the ASR would be treated before delivery to the existing water distribution system. Implementation of this project would require field surveys by qualified professionals to document vegetation/habitat types, waters of the U.S. including wetlands, and cultural resources that may be impacted. Where impacts to protected species habitat or significant cultural resources cannot be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. The project sponsor would also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to wetland areas and compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

The pipelines and wells needed for the ASR project well field would occur in close proximity to Carters, Bee, Lick and Alum Creeks. Coordination with the U.S. Army Corps of Engineers would be required for construction within any waters of the U.S. Any impacts from this proposed project which would result in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

The project occurs within the East Central Texas Plains Ecoregion[3] and lies within the Texan Biotic Province.[4] Vegetation types within the ASR well field area and transmission pipelines as described by the Texas Parks and Wildlife Department (TPWD)[5] include Post Oak Woods, Forest, and Post Oak Woods, Forest and Grassland Mosaic areas. These areas include portions which have been developed or disturbed and now include homes, business, and farms. Avoidance of riparian areas near the creeks or heavily wooded areas would help minimize potential impacts to existing area species from project construction activities.

Table 10.2-1 lists state listed endangered or threatened species, and federally listed endangered or threatened species along with species of concern that may occur in Brazos County. This information comes from the county lists of rare species published online by the TPWD. Inclusion in this table does not mean that a species will occur within the project area, but only acknowledges the potential for its occurrence in the project area county.

Table 10.2-1. Endangered, Threatened, and Species of Concern for Brazos County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
AMPHIBIANS					
Houston toad	Anaxyrus houstonensis	Endemic species found in sandy substrate, water in pools.	LE	E	Resident
Southern crawfish frog	Lithobates areolatus areolatus	A species found in abandoned crawfish holes and small mammal burrows in moist meadows and river flood plains.	--	--	Resident
BIRDS					

3 Griffith Glenn, Sandy Bryce, James Omernik, and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality.

4 Blair, W. Frank. 1950. The Biotic Provinces of Texas. Texas Journal of Science 2(1):93-117.

5 McMahan, Craig A., Roy G. Frye and Kirby L. Brown. 1984. The Vegetation Types of Texas. Wildlife Division, Texas Parks and Wildlife Department, Austin, Texas.

Table 10.2-1. Endangered, Threatened, and Species of Concern for Brazos County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
American peregrine falcon	Falco peregrinus anatum	Resident and local breeder in West Texas. Migrant across the state.	DL	T	Possible Migrant
Arctic peregrine falcon	Falco peregrinus tundrius	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	Haliaeetus leucocephalus	Found primarily near rivers and large lakes, migrant.	DL	T	Possible Migrant
Henslow's sparrow	Ammodramus henslowii	Wintering individuals found in weedy or cut-over areas.	--	--	Possible Migrant
Interior least tern	Sterna antillarum athalassos	Nests along sand and gravel bars in braided streams	LE	E	Resident
Sprague's pipit	Anthus spragueii	Migrant in Texas in winter. Strongly tied to native upland prairie.	C	--	Migrant
Whooping crane	Grus americana	Potential migrant	LE	E	Potential Migrant
FISH					
Blue sucker	Cycleptus elongatus	Found in larger portions of major rivers usually in channels and flowing pools with a moderate current.	--	T	Resident
Sharpnose shiner	Notropis oxyrhynchus	Endemic to Brazos River Drainage. Found in large rivers with a bottom of sand, gravel, and clay-mud.	LE	--	Resident
Smalleye shiner	Notropis buccula	Endemic to upper Brazos River system and its tributaries.	LE	--	Resident
INSECTS					
Gulf coast clubtail	Gomphus modestus	Found in medium rivers in streams with silty sand or rocky bottoms.	--	--	Resident
Smoky shadowfly	Neurocordulia molesta	Found in rivers and sometimes large streams. Larvae cling to rocks or logs.	--	--	Resident
MAMMALS					

Table 10.2-1. Endangered, Threatened, and Species of Concern for Brazos County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
Louisiana black bear	Ursus americanus luteolus	Possible as transient, found in bottomland hardwoods and large tracts of inaccessible forested areas.	LT	T	Potential Resident
Plains spotted skunk	Spilogale putorius interrupta	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	Canis rufus	Extirpated.	LE	E	Historic Resident
MOLLUSKS					
False spike mussel	Quadrula mitchelli	Possibly extirpated in Texas, probably found in medium to large rivers.	--	T	Historic Resident
Smooth pimpleback	Quadrula houstonensis	Found in small to moderate streams and rivers and moderate size reservoirs.	--	--	Resident
Texas fawnsfoot	Truncilla macrodon	Possibly occurs in rivers and larger streams and is intolerant of impoundment. Brazos and Colorado River basins.	C	T	Resident
PLANTS					
Branched gay-feather	Liatris cymosa	Texas endemic found in somewhat barren grassland openings in post oak woodlands on tight soils.	--	--	Resident
Bristle nailwort	Paronychia setacea	Endemic to eastern southcentral Texas, occurring in sandy soils.	--	--	Resident
Navasota ladies'-tresses	Spiranthes parksii	Texas endemic found in openings in post oak woodlands in sandy loams.	LE	E	Resident
Small-headed pipewort	Eriocaulon koenickianum	In East Texas in post-oak woodlands and xeric sandhill openings on permanently wet acid sands of upland seeps and hillside seepage bogs.	--	--	Resident
Texas meadow-rue	Thalicrum texanum	Texas endemic mostly found in woodlands and woodland margins on sandy loam.	--	--	Resident

Table 10.2-1. Endangered, Threatened, and Species of Concern for Brazos County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
Texas windmill-grass	Chloris texensis	Texas endemic found in sandy to sandy loam soils in relatively bare areas in coastl prairie grassland remnants.	--	--	Resident
REPTILES					
Alligator snapping turtle	Macrochelys temminckii	A species found in perennial water bodies in deep water of rivers, canals, lakes and oxbows.		T	Resident
Texas horned lizard	Phrynosoma cornutum	Varied, sparsely vegetated uplands.	--	T	Resident
Timber rattlesnake	Crotalus horridus	Floodplains, upland pine, deciduous woodlands, riparian zones.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL, PDL=Federally Delisted/Proposed for Delisting
T/SA=Listed as Threatened by Similarity of Appearance
E, T=State Listed Endangered/Threatened
Blank= Species of concern, but no regulatory listing status
Source: TPWD, 2014. Annotated County List of Rare Species – Brazos County revised 12/11/2014.

Because the project will use treated existing wastewater effluent to inject into the aquifer no significant impacts to existing stream flows or aquatic species are anticipated. Potential impacts to listed species within the project area are anticipated to include disturbance of existing habitat resulting from the construction of well fields and their associated pipelines, transmission pipelines and a new water treatment plant. However most of these disturbances would be minimized by the small areas generally required for well field and pipeline construction. After construction is completed the majority of the disturbed areas will return to their previous habitat condition excluding the AWTP site or areas where maintenance activities are required.

A survey of the project area would be required prior to project construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291).

Based on the review of publicly available Geographic Information System (GIS) records obtained from the Texas Historical Commission, there are no State Historic Sites, National Register Properties or Districts, cemeteries or Historical Markers within the project area. A review of archaeological resources in the proposed project area should be conducted during the project planning phase. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction

10.2.4 Engineering and Costing

Available records indicate that the ASR well depths in the Sparta and Queen City in an area southeast of College Station would average about 1,700 and 2,225 ft. A typical recharge and recovery rate is estimated to be 300 gpm. For a 5.5 MGD injection rate, 8 Sparta and 8 Queen City wells would be required. The well field design has the wells spaced about 1,000 ft apart.

The major facilities required for these projects include:

- Pump Station at Lick Creek WTP,
- Advance Water Treatment Plant,
- Pump Station at AWTP for distribution to ASR wells and existing distribution system,
- ASR well field,
- Collector pipelines,
- Transmission pipeline between AWTP and distribution system, and
- Interconnect to existing distribution system.

Estimates were prepared for capital and project costs, annual debt service, operation and maintenance, power, land, and environmental mitigation. These costs are summarized in Table 10.2-2. The annual costs, including debt service, operation and maintenance, and power, is estimated to be $3,069 per acft for the College Station project.

Table 10.2-2. Cost Estimate Summary: College Station ASR Project Option

Item	Estimated Costs for Facilities
Pump Stations	$2,747,000
Transmission Pipelines	$2,317,000
ASR Well Field (Wells, Pumps, and Piping)	$16,710,000
Water Treatment Plant	$23,100,000
Integration, Relocations, & Other	$250,000
TOTAL COST OF FACILITIES	**$45,124,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$15,678,000
Environmental & Archaeology Studies and Mitigation	$486,000
Land Acquisition and Surveying (47 acres)	$402,000
Interest During Construction (4% for 1 years with a 1% ROI)	$2,160,000
TOTAL COST OF PROJECT	**$63,850,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$5,343,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$261,000
Water Treatment Plant (2.5% of Cost of Facilities)	$2,586,000
Pumping Energy Costs (4463825 kW-hr @ 0.09 $/kW-hr)	$402,000
Purchase of Water (acft/yr @ $/acft)	$0
TOTAL ANNUAL COST	**$8,592,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 2	**2,800**
Annual Cost of Water ($ per acft)	**$3,069**
Annual Cost of Water ($ per 1,000 gallons)	**$9.42**

10.2.5 Implementation

Implementation of the ASR water management strategy for College Station includes the following issues:

- Acquiring permits from the Brazos Valley Groundwater Conservation District;
- Acquiring permits from TCEQ for Advanced Water Treatment Plant and ASR facilities construction and operations;

- Chemical and geochemical compatibility of native aquifer water and materials and imported water are chemically compatible;
- Lack of experience to develop confidence in the ability to inject and recover water from an aquifer, which includes the uncertainty about the compatibility of the injected water with native groundwater and aquifer materials;
- Initial and operational cost; and
- Development of a management plan to efficiently use the ASR wells with a balance of injection and recovery cycles.

This water supply option has been compared to the plan development criteria, as shown in Table 10.2-3, and the option meets each criterion.

Table 10.2-3. Comparison of College Station ASR Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Does not fully meet shortages
2. Reliability	2. High reliability
3. Cost	3. High
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. None
3. Cultural Resources	3. None
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. None
C. Impact on Other State Water Resources	None
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered in an attempt to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

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10.3 Johnson County SUD and Acton MUD ASR

10.3.1 Description of Option

The concept for the Johnson County and Acton MUD ASR project is:

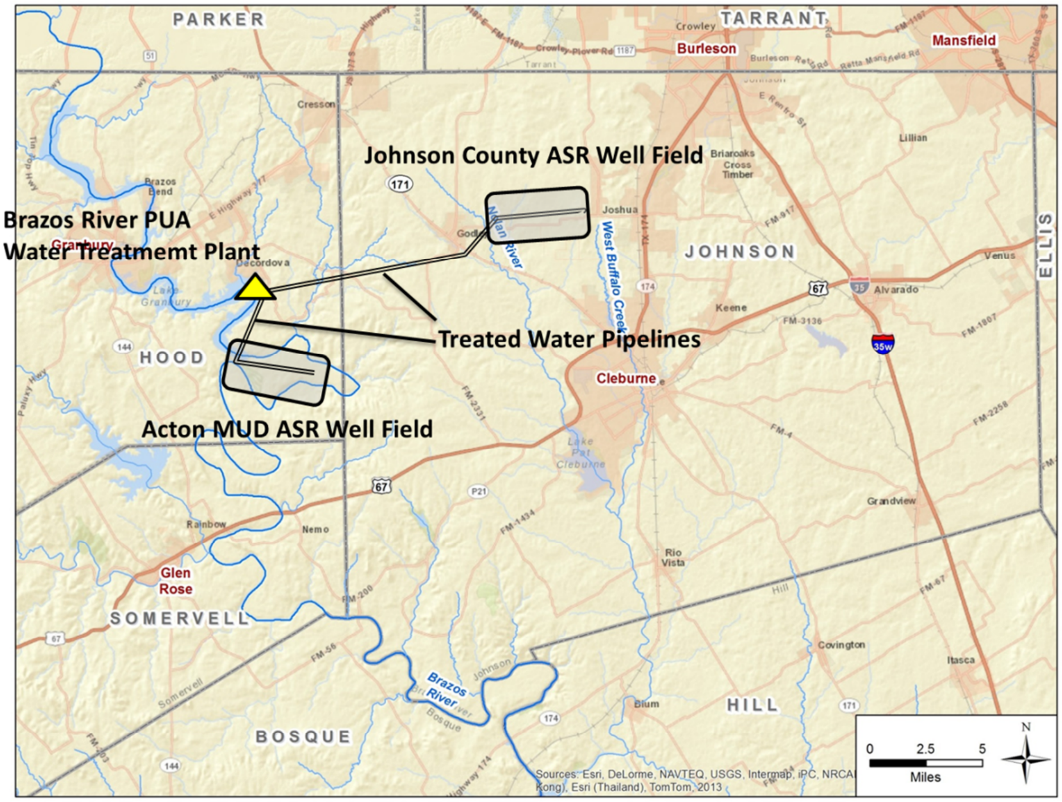
- Utilize existing surface water rights in Lake Granbury that are owned by the BRA and purchased by Johnson County SUD (JCSUD) and Acton MUD (AMUD). JCSUD and AMUD surface water rights in Lake Granbury are 9,210 and 7,000 acft/yr, respectively.
- Utilize Brazos Regional Public Utility Agency (BRPUA) water treatment facility, which has a total rated production capacity of 13 million gallons a day (MGD). JCSUD and AMUD are the owners of BPRUA.
- For Johnson County participants, new Trinity Aquifer ASR wells would be located in central Johnson County and near the existing treated water pipeline between Lake Granbury and existing customers. Recovery of the water would be by participant's water wells. This procedure is considered to be an indirectly transfer water from JCSUD to participants. Unlike traditional ASR projects where the injected water would be recovered by the same well, the indirect transfer would involve an accounting process within Johnson County where water stored in the Trinity Aquifer by JCSUD and credited to a participant's allocation. The participants would pay JCSUD for the raw water, water treatment, water transmission, recharge wells, and associated facilities and operations.
- For AMUD, new Trinity Aquifer ASR wells would be located near their existing treated water pipeline between Granbury and their distribution system.
- The recharge cycle of ASR would occur from October to May and would coincide when there is excess capacity in the BRPUA WTP. For Johnson County participants, recovery could be at any time, but typically would be during the summer when demand is relatively high. For AMUD, recovery would be during June-September. The recovered water would be discharged back into the treated water pipeline for eventual distribution to participants along with other supplies from the BRPUA WTP.

A schematic showing the location of the project facilities is shown in Figure 10.3-1. New facilities required for this option are ASR wells, well field distribution and collection pipelines and interconnects between the pipeline and ASR well fields.

JCSUD's water supplies include groundwater, purchased surface water in Lake Granbury and other purchased surface water. These projected supplies and demands are illustrated in Figure 10.3-2. Also, shown in this figure is a 2,000 acft/yr supply from the ASR project that is derived from an estimate of excess capacity in the BRPUA WTP during low water demand months (Figure 10.3-3). As indicted in Figure 10.3-2, JCSUD's water supplies are well in excess of their demands through 2070.

AMUD's water supplies include groundwater and purchased surface water in Lake Granbury. These projected supplies and demands are illustrated in Figure 10.3-4. Also, shown in this figure is a 1,400 acft/yr supply from the ASR project. This supply is derived from an estimate of excess capacity in the BRPUA WTP during low water demand months (Figure 10.3-4). As indicted in Figure 10.3-4, AMUD's water supplies in 2070 need water from the ASR project or some other project.

Figure 10.3-1. Location of Johnson County and Acton MUD ASR Projects.



Document Path: W:\000044\2016_Plan\GIS\map_docs\arcmap\Johnson_Hood_Somervell_Basemap.mxd

Figure 10.3-2. Water Supplies and Demand for JCSUD

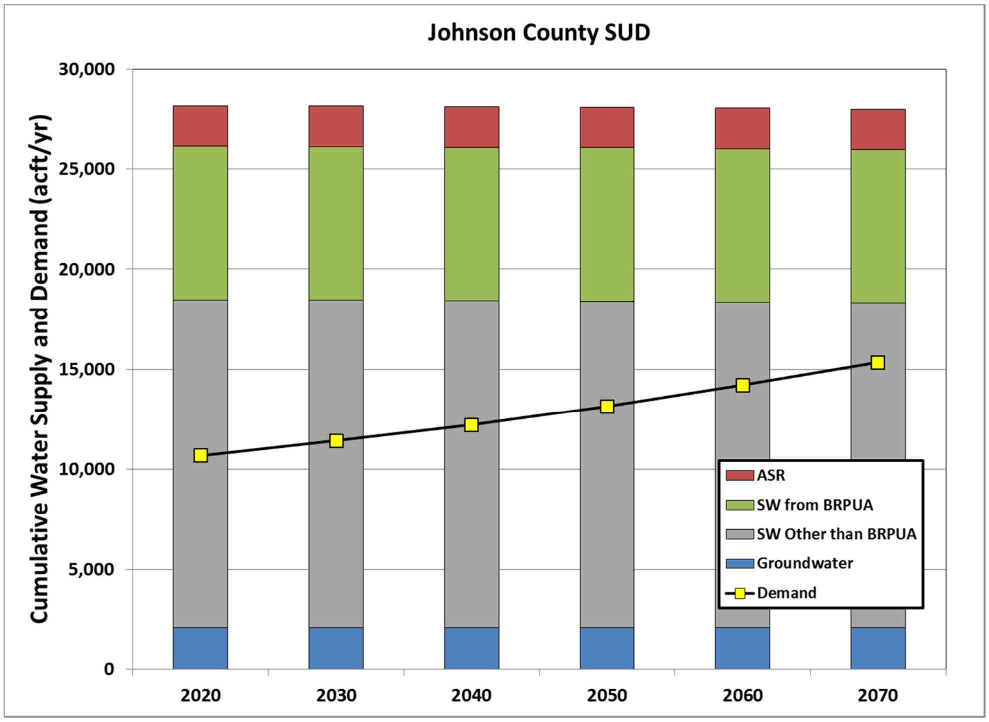


Figure 10.3-3. Water Treatment Capacity and Utilization of JCSUD's share of BRPUA WTP

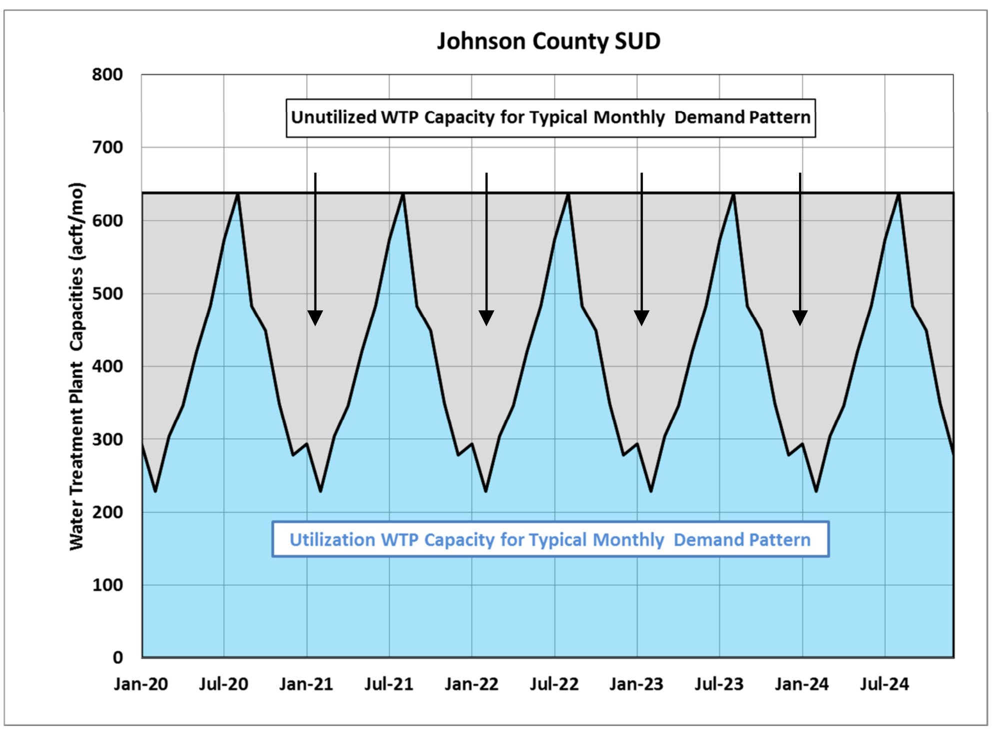


Figure 10.3-4. Water Supplies and Demand for AMUD

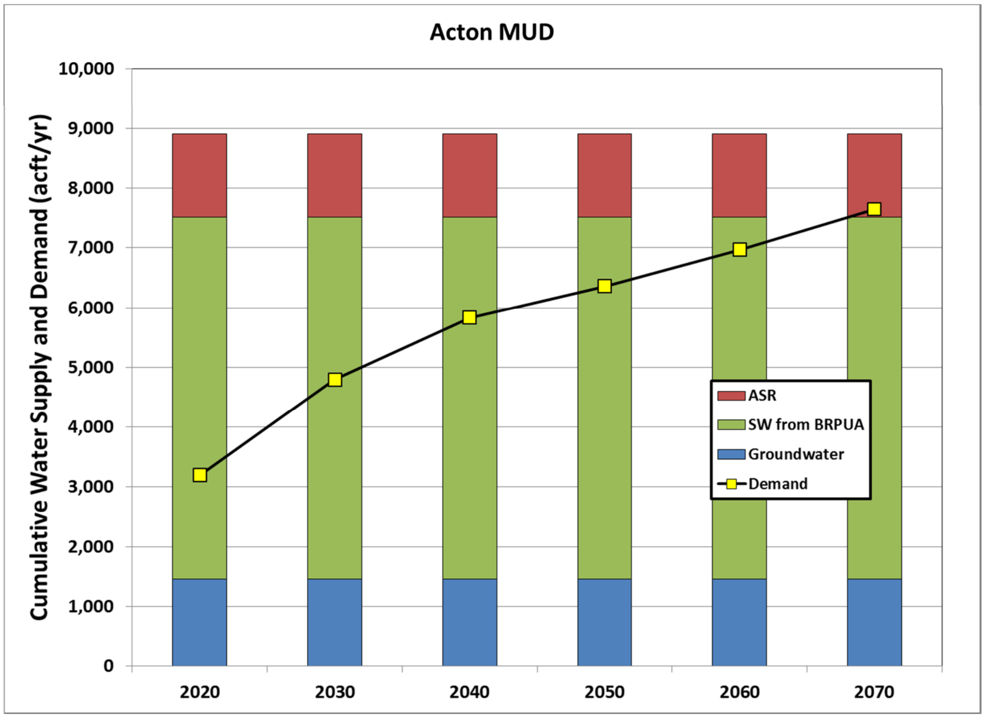
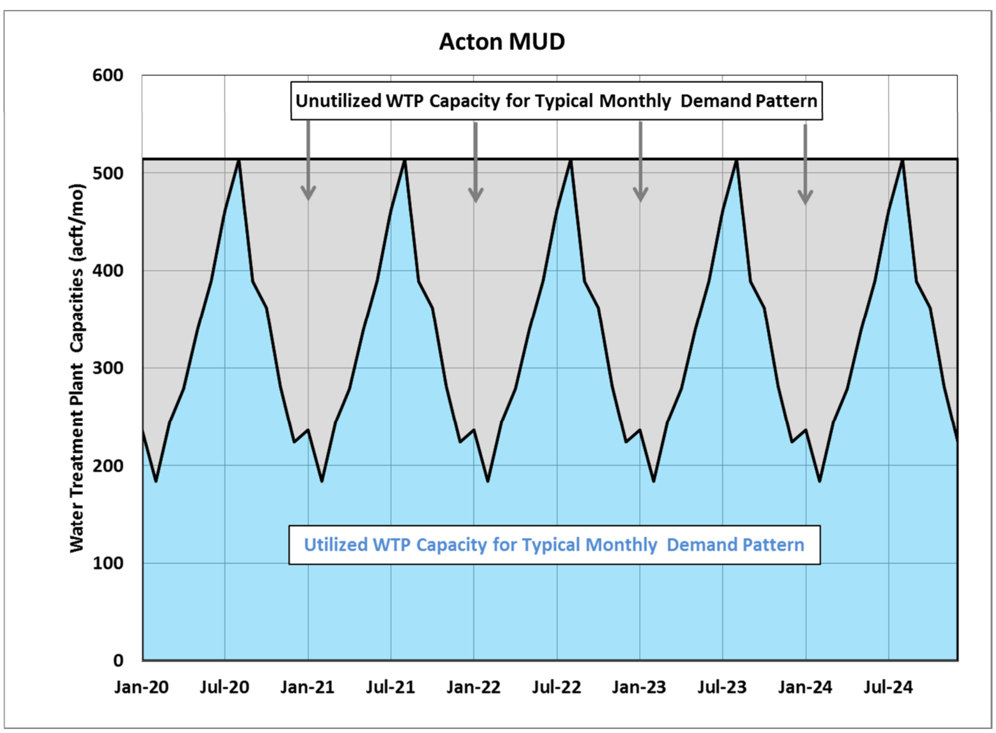


Figure 10.3-5. Water Treatment Capacity and Utilization of AMUD's share of BRPUA

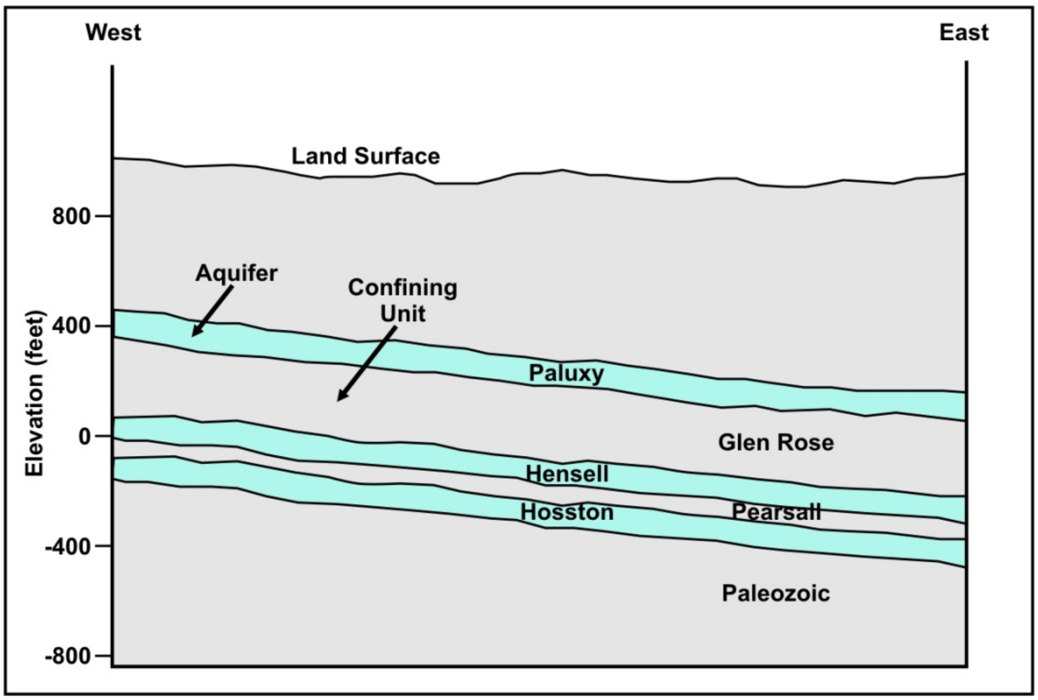


10.3.2 Available Yield

In Johnson and Hood Counties, the Trinity Aquifer system is composed of three sandy aquifer units that are confined and separated by nearly impermeable clay units. These aquifer units include, from youngest to oldest: the Paluxy, Hensell, and Hosston (Figure 10.3-6). In the proposed ASR well field, the water-bearing units are confined with artesian pressures generally rising several hundred feet above the top of the aquifer(s). The geometry and hydraulic properties of the hydrogeologic units of the Trinity Aquifer units vary throughout Johnson and Hood Counties. In general, the most hydraulically transmissive (i.e., sand-rich) portions of the units vary from 50 to 100 feet in thickness. High-capacity production wells typically yield from 150 to 250 gallons per minute (gpm).

The long-term impact on the Trinity Aquifer is considered to be insignificant because the strategy for this project is to balance the recharge and recovery of water. In the short-term, the impact will be a noticeable, but temporary, rise in groundwater levels during the recharge cycle and a similar decline during the recovery cycle.

Figure 10.3-6. Hydrogeologic Profile in ASR Well Field



10.3.3 Environmental Issues

Environmental issues for the proposed Johnson County and Acton MUD project are described below. This project includes the development of two ASR well fields, one along the border of Hood and Johnson County south of Granbury and the second west of Joshua in Johnson County. Additional well field distribution and collection pipelines and interconnects to existing transmission pipelines would also be required for the project. Implementation of this project would require field surveys by qualified professionals to document vegetation/habitat types, waters of the U.S. including wetlands, and cultural resources that may be impacted. Where impacts to protected species habitat or significant cultural resources cannot be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. The project sponsor would also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to wetland areas and compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

The pipelines and wells needed for the Acton MUD ASR well field would occur in close proximity to the Brazos River. The Texas Parks & Wildlife Department (TPWD) has identified a number of stream segments throughout the state as ecologically significant on the basis of biological function, hydrologic function, riparian conservation, exceptional aquatic life uses, and/or threatened or endangered species. The portion of the Brazos River near the proposed ASR well field is listed by the TPWD as ecologically significant. This segment of the Brazos River is considered to have outstanding wildlife values, high water quality and exceptional aquatic life. Coordination with the U.S. Army Corps of Engineers would be required for construction within any waters of the U.S. Any impacts from this proposed project which would result in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

The project occurs within the Central Oklahoma/Texas Plains Ecoregion[1] and lies within the Texan Biotic Province.[2] Vegetation types within the Johnson County ASR well field as described by the Texas Parks and Wildlife Department (TPWD)[3] includes areas of crops, and Post Oak Woods, Forest and Grassland Mosaic. The Acton MUD ASR well field occurs primarily within the Oak-Mesquite-Juniper Parks/Woods vegetation type but also contains a small area of Bluestem grassland vegetation type in the southeastern section of the area. Both well field areas contain large areas that have been developed or disturbed and include homes, business, and farms. Avoidance of the remaining areas of riparian and woods habitat within the well field areas would help minimize potential impacts to existing area species.

Table 10.3-1 lists state listed endangered or threatened species, and federally listed endangered or threatened species along with species of concern that may occur in Hood or Johnson Counties. This information comes from the county lists of rare species published by the Texas Parks and Wildlife Department (TPWD) online. Inclusion in this table does not mean that a species will occur within the project area, but only acknowledges the potential for its occurrence in the project area counties.

Because the project will result in an equal exchange of water to the aquifer, no significant impacts to existing stream flows or aquatic species are anticipated. Potential impacts to listed species within the project area are anticipated to include disturbance of existing habitat resulting from the construction of well fields and their associated pipelines. However these disturbances will be minimized by the small areas generally needed for well field and pipeline construction. After construction is completed the majority of the disturbed areas will return to their previous condition excluding areas where maintenance activities are required.

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1 Griffith Glenn, Sandy Bryce, James Omernik, and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality.

2 Blair, W. Frank. 1950. The Biotic Provinces of Texas. Texas Journal of Science 2(1):93-117.

3 McMahan, Craig A., Roy G. Frye and Kirby L. Brown. 1984. The Vegetation Types of Texas. Wildlife Division, Texas Parks and Wildlife Department, Austin, Texas.

A survey of the project area would be required prior to well field and pipeline construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291).

Table 10.3-1. Endangered, Threatened, and Species of Concern for Hood and Johnson Counties

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County(s)
			USFWS	TPWD	
BIRDS					
American peregrine falcon	Falco peregrinus anatum	Resident and local breeder in West Texas. Migrant across the state.	DL	T	Possible Migrant
Arctic peregrine falcon	Falco peregrinus tundrius	Migrant throughout the state.	DL	--	Possible Migrant
Baird’s sparrow	Ammodramus bairdii	Prefers shortgrass prairie with scattered low bushes and matted vegetation. Migratory in western half of the state.	--	--	Possible Migrant
Bald eagle	Haliaeetus leucocephalus	Found primarily near rivers and large lakes, migrant.	DL	T	Possible Migrant
Black-capped vireo	Vireo atricapillus	Oak-juniper woodlands,	LE	E	Resident
Golden-cheeked warbler	Setophaga chrysoparia	Juniper-oak woodlands.	LE	E	Resident
Henslow's sparrow	Ammodramus henslowii	Wintering individuals found in weedy or cut-over areas.	--	--	Possible Migrant
Interior least tern	Sterna antillarum athalassos	Nests along sand and gravel bars in braided streams	LE	E	Resident
Mountain plover	Charadrius montanus	Non-breeding, shortgrass plains and fields	--	--	Nesting/ Migrant
Sprague’s pipit	Anthus spragueii	Migrant in Texas in winter. Strongly tied to native upland prairie.	C	--	Migrant

Table 10.3-1. Endangered, Threatened, and Species of Concern for Hood and Johnson Counties

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County(s)
			USFWS	TPWD	
Western Burrowing owl	Athene cunicularia hypugaea	Open grasslands, especially prairie, plains and savanna	--	--	Resident
White-faced ibis	Plegadis chihi	Prefers freshwater marshes, sloughs, and irrigated rice fields.	--	T	Resident
Whooping crane	Grus americana	Potential migrant	LE	E	Potential Migrant
FISH					
Sharpnose shiner	Notropis oxyrhynchus	Endemic to Brazos River Drainage. Found in large rivers with a bottom of sand, gravel, and clay-mud.	LE	--	Resident
Smalleye shiner	Notropis buccula	Endemic to upper Brazos River system and its tributaries.	LE	--	Resident
MAMMALS					
Black bear	Ursus americanus	Found in bottomland hardwoods and large tracts of inaccessible forested areas.	T/SA;NL	T	Historic Resident
Gray wolf	Canis lupus	Extirpated, formerly known throughout the western two-thirds of the state.	LE	E	Historic Resident
Plains spotted skunk	Spilogale putorius interrupta	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	Canis rufus	Extirpated.	LE	E	Historic Resident
MOLLUSKS					
Texas fawnsfoot	Truncilla macrodon	Possibly occurs in rivers and larger streams and is intolerant of impoundment. Brazos and Colorado River basins.	C	T	Resident
PLANTS					
Comanche peak prairie-clover	Dalea reverchonii	Texas endemic found in shallow, calcareous clay to sandy clay soils over limestone in grasslands or openings in post oak woodlands often on barren sites.	--	--	Resident

Table 10.3-1. Endangered, Threatened, and Species of Concern for Hood and Johnson Counties

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County(s)
			USFWS	TPWD	
Glen rose yucca	Yucca necopina	Texas endemic found on grasslands on sandy soils and limestone outcrops.	--	--	Resident
REPTILES					
Brazos water snake	Nerodia harteri	Found in upper Brazos River drainage in shallow water with a rocky bottom.	--	T	Resident
Texas garter snake	Thamnophis sirtalis annectens	Wet or moist microhabitats	--	--	Resident
Texas horned lizard	Phrynosoma cornutum	Varied, sparsely vegetated uplands.	--	T	Resident
Timber rattlesnake	Crotalus horridus	Floodplains, upland pine, deciduous woodlands, riparian zones.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL, PDL=Federally Delisted/Proposed for Delisting
T/SA=Listed as Threatened by Similarity of Appearance
E, T=State Listed Endangered/Threatened
Blank= Species of concern, but no regulatory listing status
Source: TPWD, 2014. Annotated County List of Rare Species – Hood County, Revised 9/04/2014, and Johnson County Revised 9/04/2014.

Based on the review of publically available Geographic Information System (GIS) records obtained from the Texas Historical Commission, there are no State Historic Sites, National Register Properties, or National Register Districts within the well field areas. However one Historical Marker and one cemetery are located within the Johnson County ASR well field area and one cemetery occurs within the Acton MUD ASR well field area. Avoidance of these cultural resource areas should be possible by careful selection of the areas for well sites and their associated pipelines. A review of archaeological resources in the proposed project area should be conducted during the project planning phase. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction.

10.3.4 Engineering and Costing

The actual number of wells and land required for the well field is dependent upon local depth to water, and the thickness and character of sands present at each well field site. This site-specific information would need to be acquired through a research or a test drilling and field testing program prior to implementation of an ASR system in the region.

Available records indicate that wells in central Johnson County average between 1,100 and 1,200 feet deep. Near AMUD wells typically are 500-600 ft deep. Based on existing wells in central Johnson County, the maximum recharge and recovery rate is 300 gpm.

Near AMUD, the maximum recharge and recovery rate is 200 gpm. For a 2,000 acft/yr system in Johnson County, 13 ASR wells are required. For a 1,400 acft/yr system for AMUD, 15 ASR wells are required. The ASR wells would be used for recharge from October through May and for recovery from June through September. The well field design has the wells spaced about 1,000 feet apart and in the vicinity of the treated water transmission pipeline. The relatively close well spacing is based on seasonal ASR operations.

The major facilities required for these projects include:

- ASR wells,
- Collector Pipelines,
- Pump Stations
- Terminal Storage, and
- Interconnect.

Estimates were prepared for capital and project costs, annual debt service, operation and maintenance, power, land, and environmental mitigation. These costs are summarized in Table 10.3-2 and Table 10.3-3 for the Johnson County and Acton MUD projects, respectively. The annual costs, including debt service, operation and maintenance, and power, are estimated to be $1,743 per acft for the Johnson County project and $1,151 per acft for the AMUD project. For purposes of these cost estimates, Johnson County participants are assessed an assumed $500/acft/yr for the purchase of the raw water and the utilization of the BRPUA facilities. If this ASR project goes forward, the charges would need to be negotiated. Similar charges are not assessed for AMUD because they are part owners of the BRPUA facilities.

Table 10.3-2. Cost Estimate Summary: Johnson County SUD ASR Project Option

Item	Estimated Costs for Facilities
Well Fields (Wells, Pumps, and Piping)	$8,154,000
Integration, Relocations, & Other	$650,000
TOTAL COST OF FACILITIES	**$8,804,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$3,081,000
Environmental & Archaeology Studies and Mitigation	$357,000
Interest During Construction (4% for 1 years with a 1% ROI)	$429,000
TOTAL COST OF PROJECT	**$12,671,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$1,060,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$82,000
Water Treatment Plant (2.5% of Cost of Facilities)	$1,123,000
Pumping Energy Costs (2455766 kW-hr @ 0.09 $/kW-hr)	$221,000
Purchase of Water (2000 acft/yr@ $500/acft)	$1,000,000
TOTAL ANNUAL COST	**$3,486,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**2,000**
Annual Cost of Water ($ per acft)	**$1,743**
Annual Cost of Water ($ per 1,000 gallons)	**$5.35**

Table 10.3-3. Cost Estimate Summary: Acton MUD ASR Project Option

Item	Estimated Costs for Facilities
Intake Pump Stations (0 MGD)	$0
Well Fields (Wells, Pumps, and Piping)	$6,143,000
Integration, Relocations, & Other	$400,000
TOTAL COST OF FACILITIES	**$6,543,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,290,000
Environmental & Archaeology Studies and Mitigation	$148,000
Interest During Construction (4% for 1 years with a 1% ROI)	$318,000
TOTAL COST OF PROJECT	**$9,382,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$785,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$61,000
Water Treatment Plant (2.5% of Cost of Facilities)	$735,000
Pumping Energy Costs (341421 kW-hr @ 0.09 $/kW-hr)	$31,000
Purchase of Water (acft/yr @ $/acft)	$0
TOTAL ANNUAL COST	**$1,612,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**1,400**
Annual Cost of Water ($ per acft)	**$1,151**
Annual Cost of Water ($ per 1,000 gallons)	**$3.53**

10.3.5 Implementation

Implementation of the ASR water management strategy for Johnson County and Acton MUD includes the following issues:

- Permits from TCEQ for ASR construction and operations and for storage of surface water in the Trinity Aquifer can be obtained;
- Chemical and geochemical compatibility of native aquifer water and materials and imported water are chemically compatible;
- Lack of experience to develop confidence in the ability to inject and recover water from an aquifer, which includes the uncertainty about the compatibility of the injected water with native groundwater and aquifer materials;
- Controlling the loss of the injected water to others;

- Initial cost;
- Experience in operating the facilities; and
- Development of a management plan to efficiently use the ASR wells with a balance of recharge and recovery cycles.

This water supply option has been compared to the plan development criteria, as shown in Table 10.3-4, and the option meets each criterion.

Table 10.3-4. Comparison of Johnson County SUD and Acton MUD ASR Options to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Meets shortages
2. Reliability	2. High
3. Cost	3. Moderate to High
B. Environmental factors	
1. Environmental Water Needs	1. None
2. Habitat	2. None
3. Cultural Resources	3. None
4. Bays and Estuaries	4. None
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. None
C. Impact on Other State Water Resources	None
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered in an attempt to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

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10.4 Lake Granger ASR

10.4.1 Description of Option

The concept for the Lake Granger and ASR conjunctive use project is to:

- Utilize existing surface water rights (base rights) in Lake Granger that are owned by the Brazos River Authority (BRA). Operate these rights under a Year 2020 firm yield demand of 17,018 acft/yr, referred to herein as the “base rights.”
- Overdraft Lake Granger to supply an additional 9,050 acft/yr supply, and recharge up to 9,677 acft/yr, when available.
- Install new Trinity Aquifer ASR and production wells and associated infrastructure.
- Operate the recharge cycle of ASR system when the reservoir is at greater than 70% capacity. Recover stored water in ASR with ASR and production wells when reservoir level drops to a volume equivalent to one-year supply of the base rights firm yield.

New facilities required for this option are ASR wells (dual-purpose wells that are designed for injection and recovery), production wells to provide additional recovery capacity, well field distribution and collection pipelines and interconnect to the water treatment plant. The general location of the proposed ASR and production well field, pipeline and East Williamson County Regional Water Treatment Plant (EWCRWTP) are shown in Figure 10.4-1.

Operation of Lake Granger and the ASR project will be controlled by the available storage in the reservoir. When reservoir storage is at 70% or greater (33,530 acft), water from the reservoir (stored water and inflows) will be used to meet the existing firm yield (base rights) and the additional yield created by the project (overdraft of Lake Granger), and supply water to the ASR system for recharge. When storage drops below 70%, diversion to the ASR project ceases, and reservoir storage and inflows are used to meet the base rights and additional yield. When storage drops below a volume equivalent to one year of the firm yield of the base rights (17,018 acft), reservoir storage and inflows are constrained to meet only the existing demand from base rights and water stored in the ASR project is used to meet the additional yield. If necessary, the ASR storage is also used to supplement the base rights. A schematic showing the operation of the project is shown in Figure 10.4-2.

Figure 10.4-1. Project Location

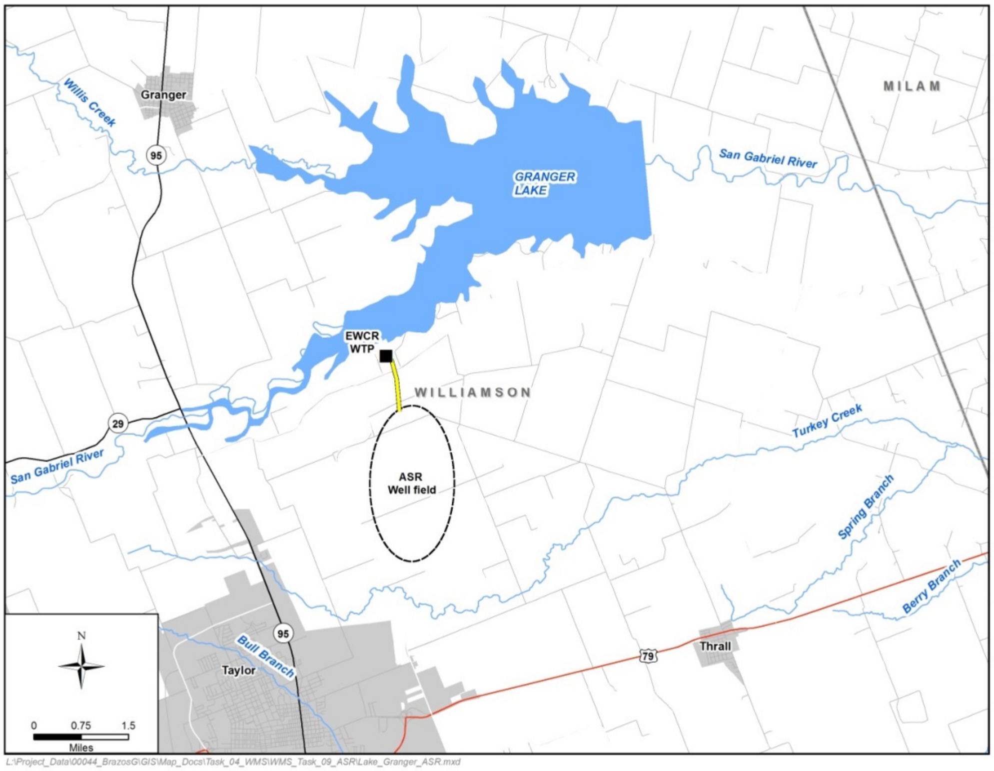
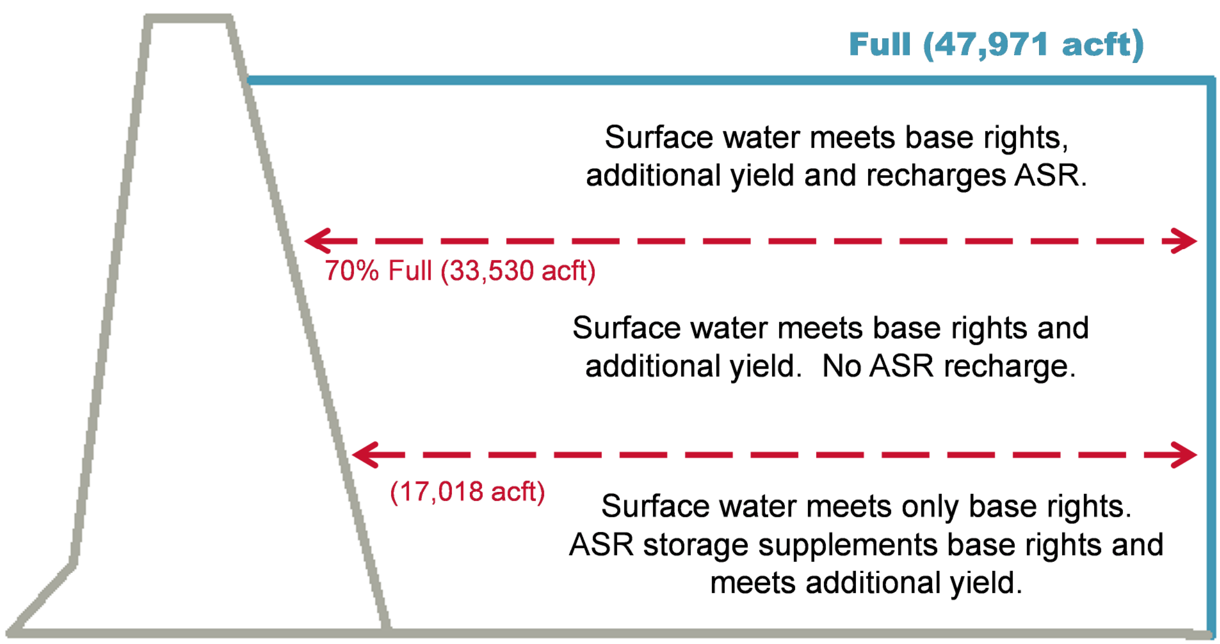


Figure 10.4-2. Operational Schematic of Lake Granger and ASR Project



10.4.2 Available Yield

In Williamson County, the Lower Trinity Aquifer system is a productive ground water formation. In general, the most hydraulically transmissive (i.e., sand-rich) portions occur around 3,300 ft deep, and wells are expected to have yields from 800-2,000 gpm. For purposes of this analysis, the ASR wells were assumed to have a capacity of 1,500 gpm (200 acft/mo) during recovery and 1,200 gpm (160 acft/mo) during injection. The nearby production wells are assumed to have a capacity of 1,500 gpm (200 acft/mo). The long-term impact on the Trinity Aquifer is considered to be minimal on a county-wide basis because the strategy for this project is to balance the recharge and recovery of water. However, there is expected to be local variations in groundwater levels due to varying times of recharge and recovery and the location of ASR and nearby production wells.

The TCEQ Brazos Water Availability Model (WAM) Run 3 with Senate Bill 3 (SB3) environmental flow standards was used to determine the potential additional yield that could be reliably supplied by conjunctive operation with the proposed ASR well field. The ASR well field was assumed to require 5,000 acft of dead storage and was capped for analysis purposes at 65,000 acft of stored ASR water (including dead storage). The model was run with year 2020 sediment conditions for Lake Granger. The additional reliable yield available through the proposed conjunctive operation with the ASR well field was determined to be 9,050 acft/yr, increasing the total BRA water supply from Lake Granger to 26,000 acft/yr. Figure 10.4-3 shows the annual source of diversions (Lake Granger or ASR storage) over the modeled time period. Figure 10.4-4 shows the combined storage trace for both Lake Granger and the ASR facility.

A storage frequency plot of Lake Granger with and without the ASR system illustrates the effect that conjunctive use has on the reservoir (Figure 10.4-5). As would be expected, Lake Granger would be full less often under the increased demands of the additional firm supply and diversions to the ASR facility. Under conjunctive operation of the reservoir and ASR system, the reservoir supplies the existing and additional firm yield roughly 90% of the time, and is able to contribute to ASR storage more than 60% of the time. A storage trace of Lake Granger alone, shown in Figure 10.4-6, illustrates a chronological record of the simulated lake levels and a visual representation of how long the lake would be under various operating conditions for this conjunctive use project.

This strategy could potential be provided supply under the BRA System Operation permit (See Section 7.12), currently pending at the Texas Commission on Environmental Quality. If an entity other than the BRA were to sponsor and pursue this strategy, then an agreement with the BRA would be required to address concerns related to the potential subordination of the System Operation strategy.

Figure 10.4-3. Utilization of Lake Granger and ASR Facility to Meet Firm Yield and Additional Demands (17,017 acft/yr firm plus 9,050 acft/yr additional)

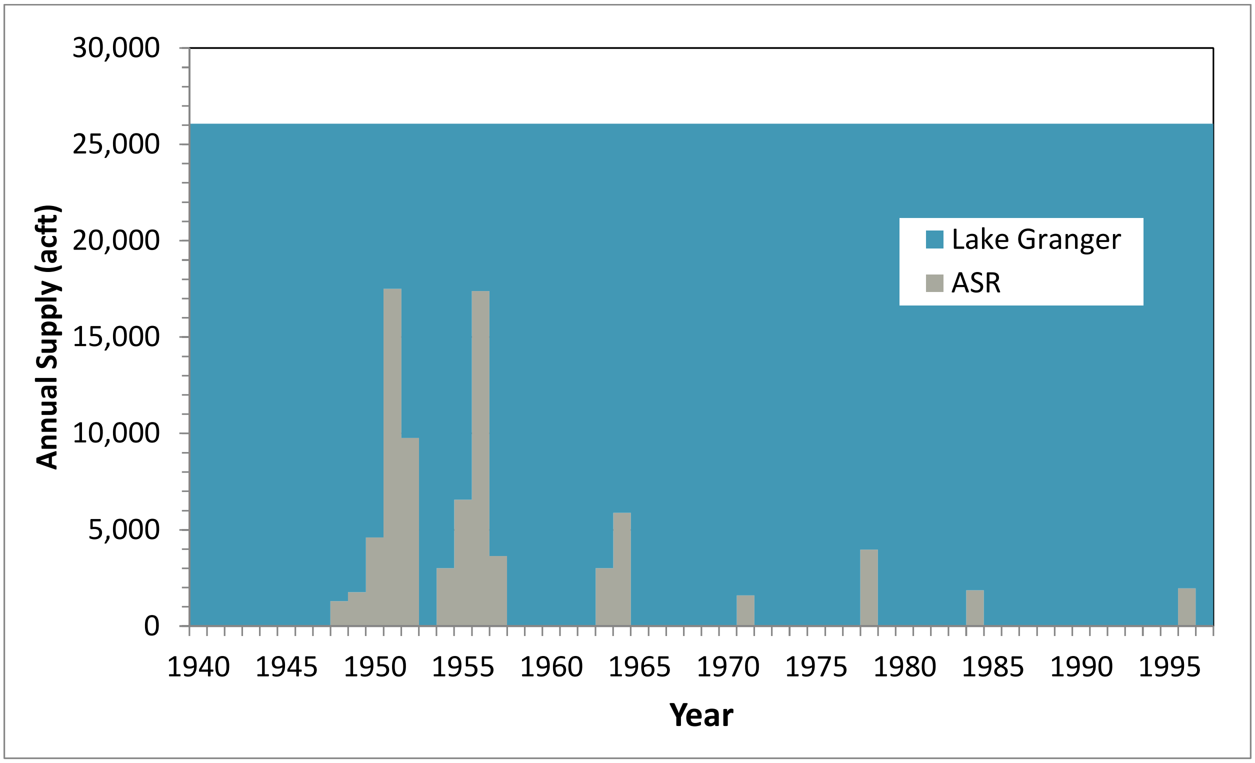


Figure 10.4-4. Combined System Storage for Lake Granger and ASR

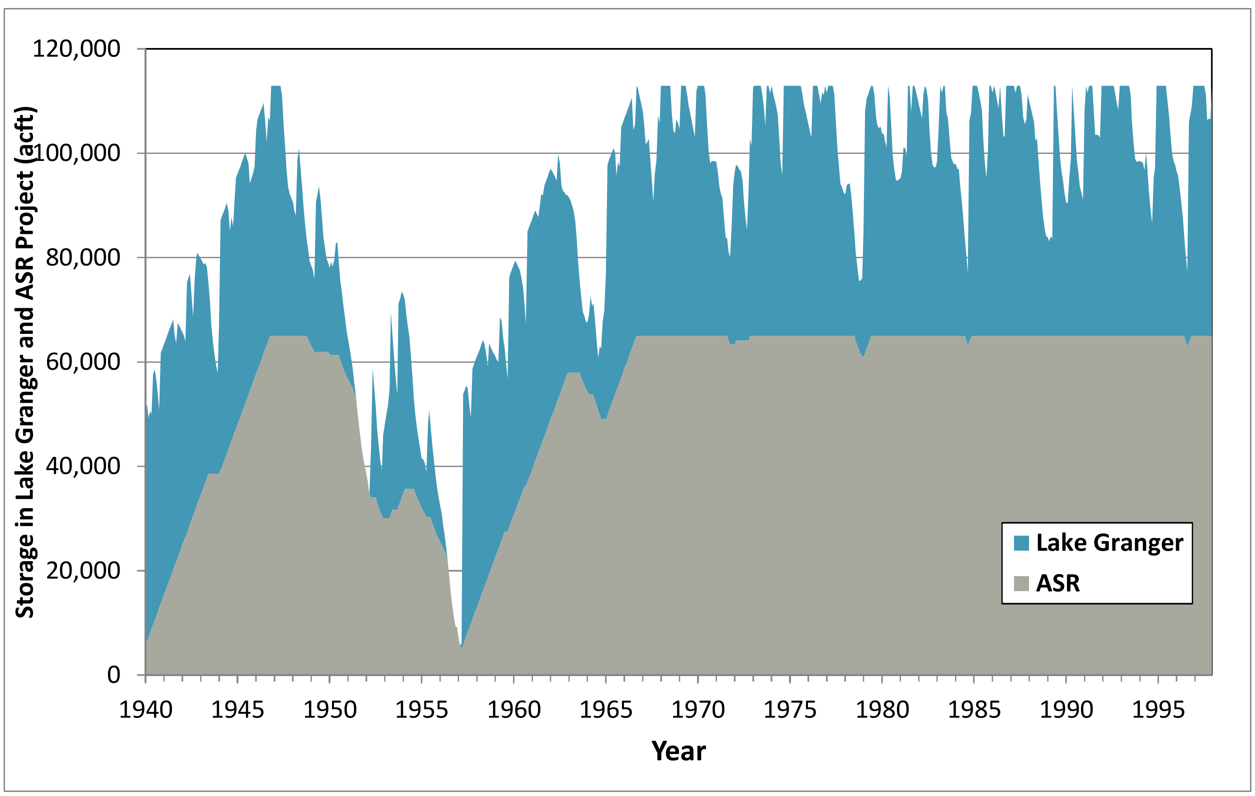


Figure 10.4-5. Lake Granger Storage Frequency

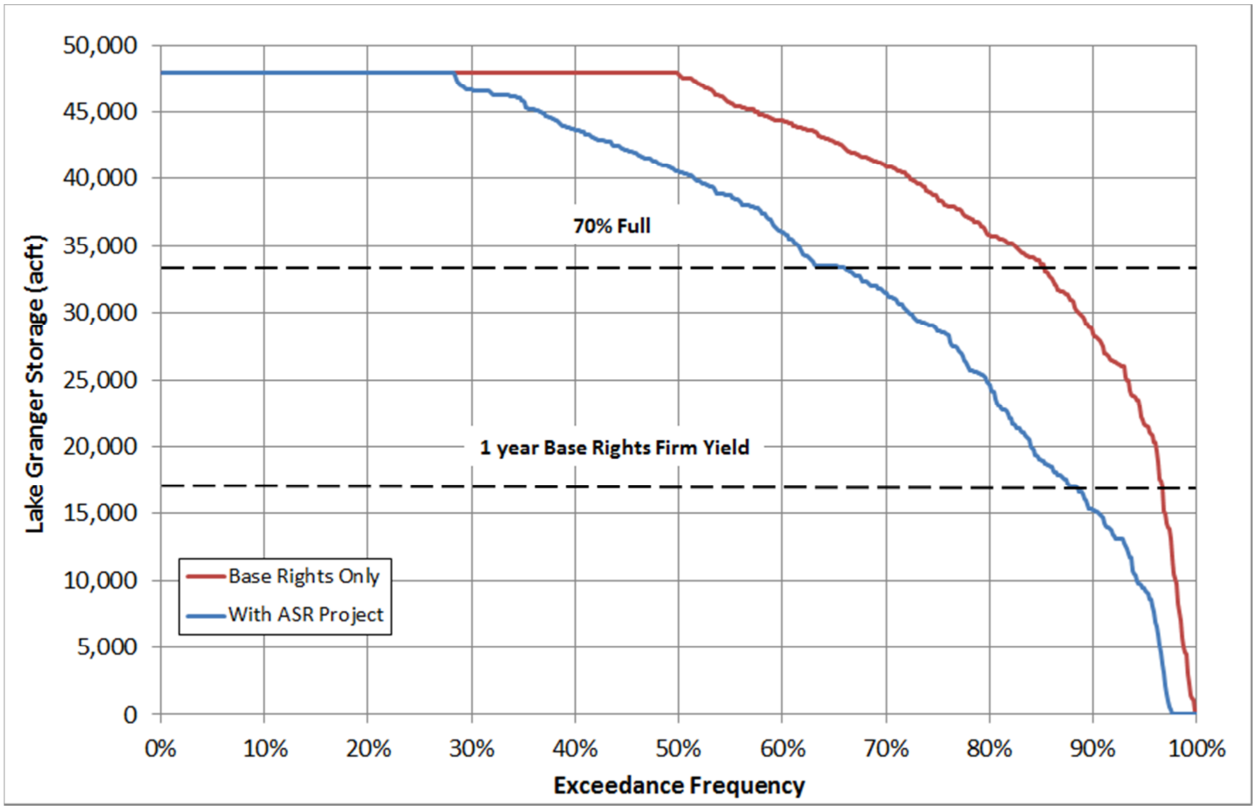
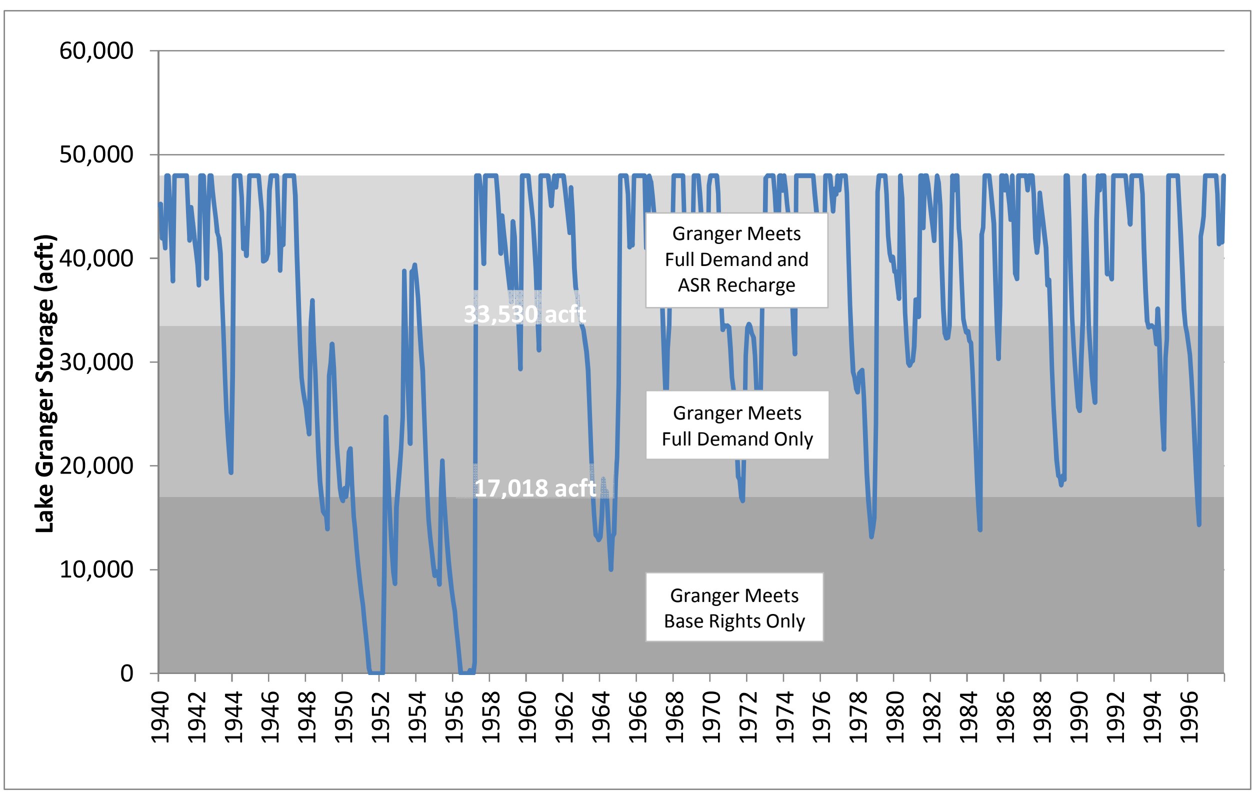


Figure 10.4-6. Lake Granger Storage Trace for a Conjunctive Use Project



10.4.3 Environmental Issues

Environmental issues for the proposed Lake Granger ASR Project in Williamson County are described below. This project includes the development of a Trinity Aquifer ASR well field, production wells, well field distribution and collection pipelines, and an interconnect to an existing water treatment plant. Implementation of this project would require field surveys by qualified professionals to document vegetation/habitat types, waters of the U.S. including wetlands, and cultural resources that may be impacted. Where impacts to protected species habitat or significant cultural resources cannot be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. The project sponsor would also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to wetland areas and compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

The pipelines and wells needed for the Lake Granger ASR project well field would occur in close proximity to Lake Granger, Pecan Creek and a tributary of Turkey Creek. Coordination with the U.S. Army Corps of Engineers would be required for construction within any waters of the U.S. Any impacts from this proposed project which would result in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

The project occurs within the Texas Blackland Prairies Ecoregion[1] and lies within the Texan Biotic Province.[2] Vegetation types within the Waco and McLennan County ASR well field area as described by the Texas Parks and Wildlife Department (TPWD)[3] as crops. Avoidance of riparian areas near creeks and other relatively undisturbed natural habitats within the well field areas would help minimize potential impacts to existing area species.

Table 10.4-1 lists the state listed endangered or threatened species, and federally listed endangered or threatened species along with species of concern that may occur in Williamson County. This information comes from the county lists of rare species published online by the Texas Parks and Wildlife Department (TPWD). Inclusion in this table does not mean that a species will occur within the project area, but only acknowledges the potential for its occurrence in the project area county. Information received from the TPWD Texas Natural Diversity Database (TXNDD) shows documented occurrences of two species of concern, the mountain plover and Texas garter snake within three miles of the project area.

Because the project will result in an equal exchange of water to the aquifer, no significant impacts to existing stream flows or aquatic species are anticipated. Potential impacts to listed species within the project area are anticipated to include disturbance of existing habitat resulting from the construction of well fields and their associated pipelines. However these disturbances would be minimized by the small areas generally required

[1] Griffith Glenn, Sandy Bryce, James Omernik, and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality.

[2] Blair, W. Frank. 1950. The Biotic Provinces of Texas. Texas Journal of Science 2(1):93-117.

[3] McMahan, Craig A., Roy G. Frye and Kirby L. Brown. 1984. The Vegetation Types of Texas. Wildlife Division, Texas Parks and Wildlife Department, Austin, Texas.

for well field and pipeline construction. After construction is completed the majority of the disturbed areas will return to their previous habitat condition, excluding areas where maintenance activities are required.

A survey of the project area would be required prior to well field and pipeline construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Table 10.4-1. Endangered, Threatened, and Species of Concern for Williamson County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
AMPHIBIANS					
Georgetown salamander	*Eurycea naufragia*	Endemic species known from springs and waters around Georgetown.	LT	--	Resident
Jollyville Plateau salamander	*Eurycea tonkawae*	Known from springs and waters of some caves north of the Colorado River.	LT	--	Resident
Salado Springs salamander	*Eurycea chisholmensis*	Endemic species found in surface springs and subterranean waters of the Salado Springs system.	LT	--	Resident
ARACHNIDS					
Bandit Cave spider	*Cicurina bandida*	Very small, subterrestrial, subterranean obligate	--	--	Resident
Bone Cave harvestman	*Texella reyesi*	Small, blind, cave-adapted harvestman endemic to a few caves in Travis and Williamson counties.	LE	--	Resident
BIRDS					
American peregrine falcon	*Falco peregrinus anatum*	Resident and local breeder in West Texas. Migrant across the state.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	Found primarily near rivers and large lakes, migrant.	DL	T	Possible Migrant
Black-capped Vireo	*Vireo atricapilla*	Requires oak-juniper woodlands with a distinctive patchy, two-layered aspect.	LE	E	Migrant

Table 10.4-1. Endangered, Threatened, and Species of Concern for Williamson County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
Golden-cheeked warbler	*Setophaga chrysoparia*	Juniper-oak woodlands.	LE	E	Resident
Mountain plover	*Charadrius montanus*	Breeding species nests on high plains or shortgrass prairie.	--	--	Migrant
Piping plover	*Charadrius melodus*	Small shore bird, wintering in Texas.	LT	L	Possible Migrant
Sprague's pipit	*Anthus spragueii*	Migrant in Texas in winter. Strongly tied to native upland prairie.	C	--	Migrant
Western Burrowing owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna	--	--	Resident
Whooping crane	*Grus americana*	Potential migrant	LE	E	Potential Migrant
CRUSTACEANS					
An amphipod	*Stygobromus russelli*	Found in subterranean waters, usually in caves and limestone aquifers.	--	--	Resident
Bifurcated cave amphipod	*Stygobromus bifurcates*	Found in cave pools.	--	--	Resident
Ezell's cave amphipod	*Stygobromus flagellates*	Known only from artesian wells.	--	--	Resident
FISHES					
Guadalupe bass	*Micropterus treculii*	Endemic to perennial streams of the Edward's Plateau region.	--	--	Resident
Sharpnose shiner	*Notropis oxyrhynchus*	Endemic to Brazos River Drainage. Found in large rivers with a bottom of sand, gravel, and clay-mud.	LE	--	Resident
Smalleye shiner	*Notropis buccula*	Endemic to upper Brazos River system and its tributaries.	LE	--	Resident
INSECTS					
A mayfly	*Procloeon distinctum*	Mayflies are distinguished by a aquatic larval stage with adults generally found in shoreline vegetation	--	--	Resident

Table 10.4-1. Endangered, Threatened, and Species of Concern for Williamson County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
A mayfly	*Pseudocentroptiloides morihari*	Mayflies are distinguished by a aquatic larval stage with adults generally found in shoreline vegetation	--	--	Resident
Coffin Cave mold beetle	*Batrisodes texanus*	Small cave-adapted beetle found in small Edwards Limestone caves in Travis and Williamson counties.	LE	--	Resident
Leonora's dancer damselfly	*Argia leonorae*	Found in south central and western Texas in small streams and seepages.	--	--	Resident
Tooth Cave ground beetle	*Rhadine Persephone*	Small cave-adapted beetle found in small Edwards Limestone caves in Travis and Williamson counties.	LE	--	Resident
MAMMALS					
Cave myotis bat	*Myotis velifer*	Colonial and cave-dwelling species that also roost in rock crevices, old buildings and under bridges.	--	--	Resident
Plains spotted skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	Extirpated.	LE	E	Historic Resident
MOLLUSKS					
Creeper (squawfoot)	*Strophitus undulates*	Found in small to large streams.	--	--	Resident
False spike mussel	*Quadrula mitchelli*	Possibly extirpated in Texas, probably found in medium to large rivers.	--	T	Historic Resident
Smooth pimpleback	*Quadrula houstonensis*	Found in small to moderate streams and rivers and moderate size reservoirs.	C	T	Resident
Texas fawnsfoot	*Truncilla macrodon*	Possibly occurs in rivers and larger streams and is intolerant of impoundment. Brazos and Colorado River basins.	C	T	Resident
REPTILES					

Table 10.4-1. Endangered, Threatened, and Species of Concern for Williamson County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
Spot-tailed earless lizard	*Holbrookia lacerate*	Found in central and southern Texas and adjacent Mexico in moderately open prairie-brushland.	--	--	Resident
Texas garter snake	*Thamnophis sirtalis annectens*	Wet or moist microhabitats	--	--	Resident
Texas horned lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands.	--	T	Resident
Timber rattlesnake	*Crotalus horridus*	Floodplains, upland pine, deciduous woodlands, riparian zones.	--	T	Resident
PLANTS					
Elmendorf's onion	*Allium elmendorfii*	Texas endemic found in grassland openings in oak woodlands.	--	--	Resident

LE/LT=Federally Listed Endangered/Threatened
DL, PDL=Federally Delisted/Proposed for Delisting
T/SA=Listed as Threatened by Similarity of Appearance
E, T=State Listed Endangered/Threatened
Blank= Species of concern, but no regulatory listing status
Source: TPWD, 2015. Annotated County List of Rare Species – Williamson County revised 9/4/2014.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291).

Based on the review of publically available Geographic Information System (GIS) records obtained from the Texas Historical Commission, there are no State Historic Sites, National Register Properties, National Register Districts, cemeteries or Historical Markers within the potential well field or pipeline area. Avoidance of any cultural resource areas discovered during project surveys should be possible by careful selection of the areas for well sites and their associated pipelines. A review of archaeological resources in the proposed project area should be conducted during the project planning phase. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction

10.4.4 Engineering and Costing

Available records indicate that Trinity Aquifer wells in eastern Williamson County average 3,300 feet deep. For a 9,050 acft/yr ASR system in Williamson County that accommodates existing water rights and operational constrains on Lake Granger, there is a considerable imbalance between peak injection water supply and peak recovery demands. In consideration of this imbalance, five (5) ASR wells are able to meet the peak injection rates, and fifteen wells are required for recovery and production. Ten of the wells would be nearby production (recovery-only) wells, and five would be dual-purpose ASR wells. The number of wells is based on an assumption that an ASR well's recharge rate is 1,200 gpm, and ASR and production wells have a recovery capacity of 1,500 gpm. The water will be pumped from the well field to the EWDRWTP through a 24", 1.4 mile long, two-way transmission pipeline. The existing pump station at the treatment plant would deliver the treated water to the ASR well field and through transmission pipelines to east Williamson County.

The major facilities required for these projects include:

- ASR and production wells
- Well field collector and transmission pipelines, and
- Water treatment plant interconnect and upgrades

Estimates were prepared for capital and project costs, annual debt service, operation and maintenance, power, land, and environmental mitigation. These costs are summarized in Table 10.4-2.

The cost estimate below assumes that only the ASR wells and associated pipelines and connections would be required in an initial phase. Subsequent phases are assumed to occur after a cumulative 10 years and 15 years, where five recover-only wells would be constructed in each of the two later phases.   The timing for the construction of the recovery wells could vary considerably from these assumptions because the wells would not be constructed until needed to produce peak demands of previously stored ASR water during a prolonged drought period. The annual costs, including debt service, operation and maintenance, and power, are estimated to be $1,291 per acft during the third phase.

Compensation to BRA may be required if this strategy were developed by another entity other than BRA to compensate for any subordination of the System Operations strategy.

Table 10.4-2. Cost Estimate Summary: Lake Granger ASR Option

Item	Estimated Phase 1 Costs	Estimated Phase 2 Costs*	Estimated Phase 3 Costs**
CAPITAL COSTS			
Transmission Pipeline (24 in dia., 1.4 miles)	$1,113,000	$0	$0
Well Fields (Wells, Pumps, and Piping)	$14,997,000	$14,544,000	$14,544,000
Water Treatment Plant (16.2 MGD)	$26,007,000	$0	$0
TOTAL COST OF FACILITIES	**$42,117,000**	**$14,544,000**	**$14,544,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$14,685,000	$5,090,000	$5,090,000
Environmental & Archaeology Studies and Mitigation	$141,000	$43,000	$43,000
Land Acquisition and Surveying (22 acres)	$119,000	$13,000	$13,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,998,000	$690,000	$690,000
TOTAL COST OF PROJECT	**$59,060,000**	**$20,380,000**	**$20,380,000**
ANNUAL COST			
Debt Service (5.5 percent, 20 years)	$4,942,000	$6,647,000	$8,352,000
Operation and Maintenance			
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$161,000	$306,000	$451,000
Water Treatment Plant (2.5% of Cost of Facilities)	$2,601,000	$2,601,000	$2,601,000
Pumping Energy Costs (@ 0.09 $/kW-hr)	$170,000	$226,000	$282,000
Purchase of Water	$0	$0	$0
TOTAL ANNUAL COST	**$7,874,000**	**$9,780,000**	**$11,686,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	9,050	9,050	9,050
Annual Cost of Water ($ per acft)	$870	$1,081	$1,291
Annual Cost of Water ($ per 1,000 gallons)	$2.67	$3.32	$3.96

** Phase 2 assumed to be built within 10 years from Phase 1*
***Phase 3 assumed to be built within 15 years of Phase 1*

10.4.5 Implementation

Implementation of the Lake Granger ASR water management strategy for BRA includes the following issues:

- Agreements between BRA and participants;
- Acquiring permits from TCEQ for ASR construction and operations and for storage of surface water in the Trinity Aquifer;
- Chemical and geochemical compatibility of native aquifer water and materials and imported water are chemically compatible;
- Lack of experience to develop confidence in the ability to inject water from a lake, which includes the uncertainty about the compatibility of the injected water with native groundwater and aquifer materials and failure of the ASR well;
- Controlling the loss of the injected water to others;
- Initial cost;
- Ability to add recovery wells as needed as reservoir reaches critical levels;
- Experience in operating the facilities; and

- Development of a management plan to efficiently use the ASR wells.
- Coordination with BRA on any potential subordination agreements for the System Operations strategy.

This water supply option has been compared to the plan development criteria, as shown in Table 10.4-3, and the option meets each criterion.

Table 10.4-3. Comparison of Lake Granger ASR Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. High
2. Reliability	2. High
3. Cost	3. Moderate
B. Environmental factors	
1. Environmental Water Needs	1. None
2. Habitat	2. None
3. Cultural Resources	3. None
4. Bays and Estuaries	4. None
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. None
C. Impact on Other State Water Resources	None
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered in an attempt to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

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10.5 Waco and McLennan County ASR

10.5.1 Description of Option

The concept for the Waco and McLennan County ASR project is to:

- Utilize existing surface water rights in Lake Waco that are owned by the City of Waco (Waco). These water rights total 85,477 acft/yr.
- More fully utilize Waco's water treatment plant (WTP) capacity of 50,400 acft/yr.
- Install new Trinity Aquifer ASR wells that would be located in the vicinity of Waco's distribution system where there is sufficient capacity to deliver additional treated water to the ASR wells. Recovery of the water would be by participant's existing or new water wells at locations other than the ASR wells. This would be an indirectly transferred water from Waco to participants. Unlike traditional ASR projects where the recharged water would be recovered by the same well, the indirect transfer would involve an accounting process within McLennan County where water stored by Waco would be credited to a participant. The participants would pay Waco for the water right, water treatment, water transmission, recharge wells, and associated facilities and operations.
- Operate the recharge cycle of ASR would be from October to May which coincides when there is excess capacity in the Waco's WTP. Recovery could be at any time, but typically would be during the summer when demands are relatively high.

A schematic showing the location of the project is shown in Figure 10.5-1. New facilities required for this option are the ASR wells, well field distribution and collection pipelines and interconnects between the pipeline and ASR well fields.

The projected water supplies for Waco, unconstrained by water treatment capacity, and demands are illustrated in Figure 10.5-2. For purposes of this proposed ASR project, an assumed supply of 1,000 acft/mo would be made available to the ASR project during the months of October to May when Waco's demands are relatively low (see Figure 10.5-3). This 8,000 acft/yr supply is derived from an estimate of excess capacity in the Waco WTP during low water demand months and would not require an expansion of the WTP.

Figure 10.5-1. Location of Waco and McLennan County ASR Project.

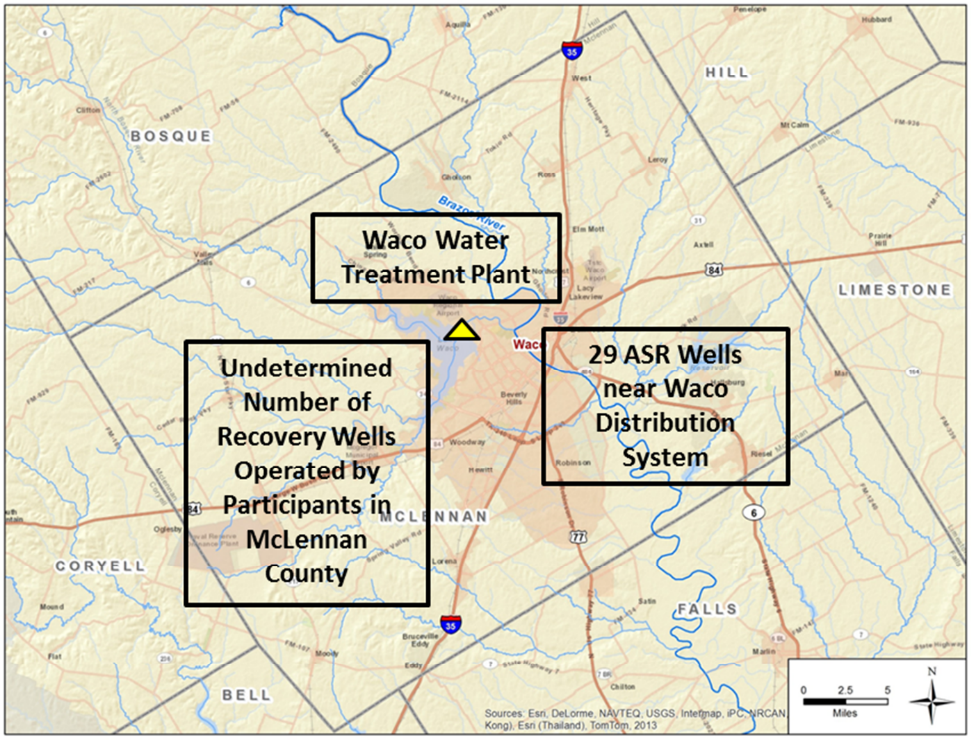


Figure 10.5-2. Water Supplies and Demand for City of Waco

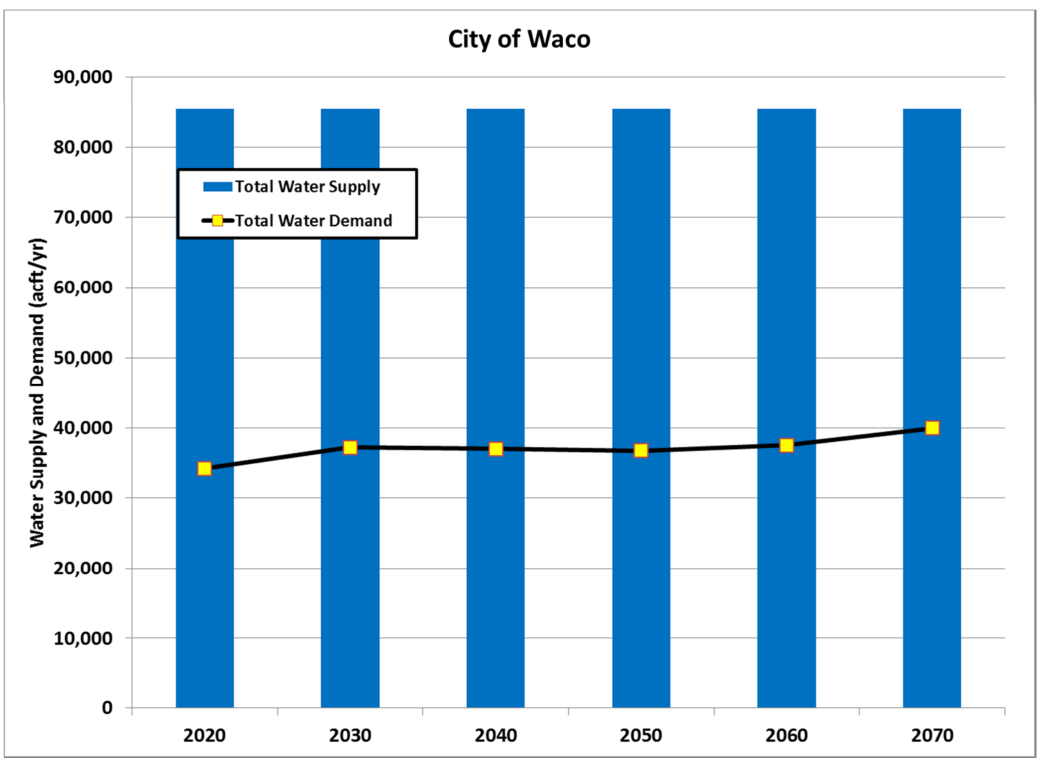
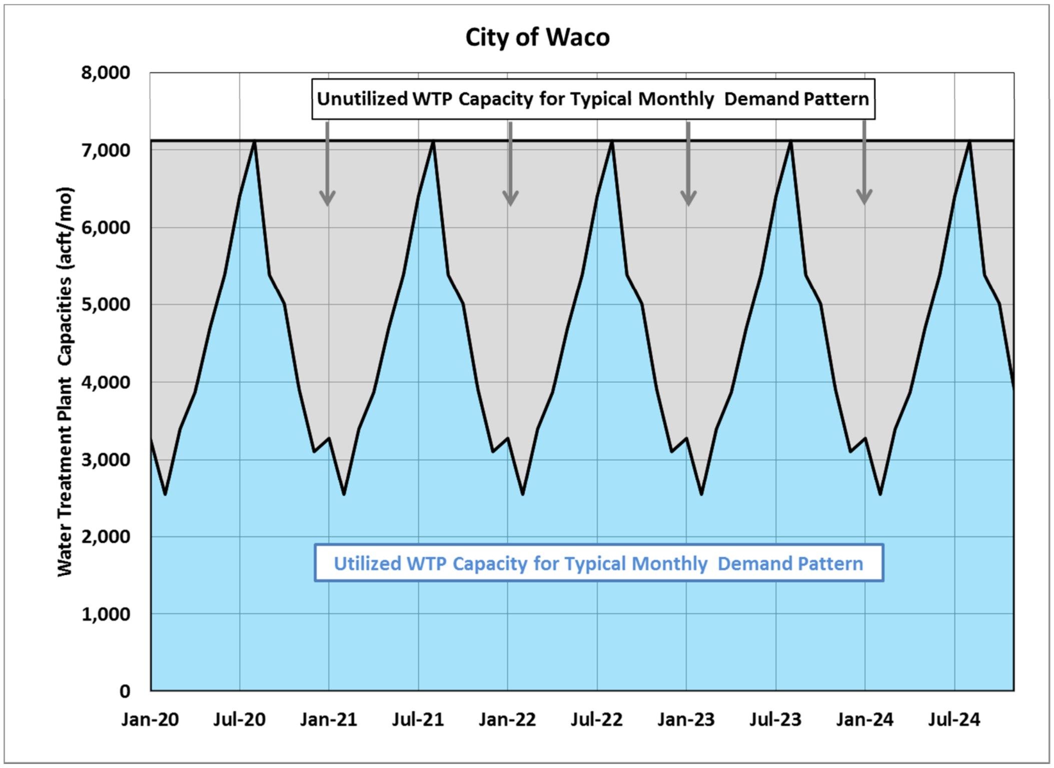


Figure 10.5-3. Water Treatment Capacity and Utilization of Waco's WTP



10.5.2 Available Yield

In McLennan County, the Trinity Aquifer system is composed of three sandy aquifer units that are confined and separated by nearly impermeable clay units. These aquifer units include, from youngest to oldest: the Paluxy, Hensell, and Hosston. The target unit is the Hosston. In general, the most hydraulically transmissive (i.e., sand-rich) portions of the unit vary from 100-200 feet in thickness and high-capacity production wells typically have yields from 350-450 gpm.

The long-term impact on the Trinity Aquifer is considered to be insignificant on a county-wide basis because the strategy for this project is to balance the recharge and recovery of water. However, there is expected to be local variations in groundwater level changes due to varying locations of recharge and recovery.

10.5.3 Environmental Issues

Environmental issues for the proposed Waco and McLennan County ASR Project are described below. This project includes the development of an ASR well field and additional well field distribution and collection pipelines and interconnects to existing transmission pipelines. Additional wells would need to be developed by individuals intending to utilize the stored water if existing wells are not available. Implementation of this project would require field surveys by qualified professionals to document vegetation/habitat types, waters of the U.S. including wetlands, and cultural resources that may be impacted. Where impacts to protected species habitat or significant cultural resources cannot be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. The project sponsor would also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to wetland areas and compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

The pipelines and wells needed for the Waco and McLennan County ASR project well field would occur in close proximity to the Brazos River. Coordination with the U.S. Army Corps of Engineers would be required for construction within any waters of the U.S. Any impacts from this proposed project which would result in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

The project occurs within portions of the Central Oklahoma/Texas Plains, Texas Blackland Prairies and Edwards Plateau Ecoregions[1] and lies within the Texan Biotic Province.[2] Vegetation types within the Waco and McLennan County ASR well field area as described by the Texas Parks and Wildlife Department (TPWD)[3] includes crops, and urban areas. The majority of these areas have been developed or disturbed and now include homes, business, and farms. Avoidance of riparian areas near the Brazos River and other relatively undisturbed natural habitats within the well field areas would help minimize potential impacts to existing area species.

Table 10.5-1 lists the state listed endangered or threatened species, and federally listed endangered or threatened species along with species of concern that may occur in McLennan County. This information comes from the county lists of rare species published online by the Texas Parks and Wildlife Department (TPWD). Inclusion in this table does not mean that a species will occur within the project area, but only acknowledges the potential for its occurrence in the project area county.

Because the project will result in an equal exchange of water to the aquifer, no significant impacts to existing stream flows or aquatic species are anticipated. Potential impacts to listed species within the project area are anticipated to include disturbance of existing habitat resulting from the construction of well fields and their associated pipelines. However these disturbances would be minimized by the small areas generally required for well field and pipeline construction. After construction is completed the majority of the disturbed areas will return to their previous habitat condition excluding areas where maintenance activities are required.

A survey of the project area would be required prior to well field and pipeline construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

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[1] Griffith Glenn, Sandy Bryce, James Omernik, and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality.

[2] Blair, W. Frank. 1950. The Biotic Provinces of Texas. Texas Journal of Science 2(1):93-117.

[3] McMahan, Craig A., Roy G. Frye and Kirby L. Brown. 1984. The Vegetation Types of Texas. Wildlife Division, Texas Parks and Wildlife Department, Austin, Texas.

Table 10.5-1. Endangered, Threatened, and Species of Concern for McLennan County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
BIRDS					
American peregrine falcon	Falco peregrinus anatum	Resident and local breeder in West Texas. Migrant across the state.	DL	T	Possible Migrant
Arctic peregrine falcon	Falco peregrinus tundrius	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	Haliaeetus leucocephalus	Found primarily near rivers and large lakes, migrant.	DL	T	Possible Migrant
Golden-cheeked warbler	Setophaga chrysoparia	Juniper-oak woodlands.	LE	E	Resident
Henslow's sparrow	Ammodramus henslowii	Wintering individuals found in weedy or cut-over areas.	--	--	Possible Migrant
Interior least tern	Sterna antillarum athalassos	Nests along sand and gravel bars in braided streams	LE	E	Resident
Sprague's pipit	Anthus spragueii	Migrant in Texas in winter. Strongly tied to native upland prairie.	C	--	Migrant
Western Burrowing owl	Athene cunicularia hypugaea	Open grasslands, especially prairie, plains and savanna	--	--	Resident
White-faced ibis	Plegadis chihi	Prefers freshwater marshes, sloughs, and irrigated rice fields.	--	T	Resident
Whooping crane	Grus americana	Potential migrant	LE	E	Potential Migrant
FISH					
Guadalupe bass	Micropterus treculii	Endemic to perennial streams of the Edward's Plateau region.	--	--	Resident
Sharpnose shiner	Notropis oxyrhynchus	Endemic to Brazos River Drainage. Found in large rivers with a bottom of sand, gravel, and clay-mud.	LE	--	Resident
Smalleye shiner	Notropis buccula	Endemic to upper Brazos River system and its tributaries.	LE	--	Resident
MAMMALS					

Table 10.5-1. Endangered, Threatened, and Species of Concern for McLennan County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
Cave myotis bat	Myotis velifer	Colonial and cave-dwelling species that also roost in rock crevices, old buildings and under bridges.	--	--	Resident
Plains spotted skunk	Spilogale putorius interrupta	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	Canis rufus	Extirpated.	LE	E	Historic Resident
MOLLUSKS					
False spike mussel	Quadrula mitchelli	Possibly extirpated in Texas, probably found in medium to large rivers.	--	T	Historic Resident
Smooth pimpleback	Quadrula houstonensis	Found in small to moderate streams and rivers and moderate size reservoirs.	--	--	Resident
Texas fawnsfoot	Truncilla macrodon	Possibly occurs in rivers and larger streams and is intolerant of impoundment. Brazos and Colorado River basins.	C	T	Resident
REPTILES					
Texas garter snake	Thamnophis sirtalis annectens	Wet or moist microhabitats	--	--	Resident
Texas horned lizard	Phrynosoma cornutum	Varied, sparsely vegetated uplands.	--	T	Resident
Timber rattlesnake	Crotalus horridus	Floodplains, upland pine, deciduous woodlands, riparian zones.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL, PDL=Federally Delisted/Proposed for Delisting
T/SA=Listed as Threatened by Similarity of Appearance
E, T=State Listed Endangered/Threatened
Blank= Species of concern, but no regulatory listing status
Source: TPWD, 2014. Annotated County List of Rare Species – McLennan County revised 9/4/2014.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291).

Based on the review of publically available Geographic Information System (GIS) records obtained from the Texas Historical Commission, there are no State Historic Sites, three National Register Properties, three National Register Districts, 24 cemeteries and 47 Historical Markers within the potential well field area. The National Register Properties and Districts occur within the northwest corner of the well field area within the City of Waco. Avoidance of these cultural resource areas should be possible by careful selection of the areas for well sites and their associated pipelines. A review of archaeological resources in the proposed project area should be conducted during the project planning phase. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction

10.5.4 Engineering and Costing

Available records indicate that wells in central McLennan County average between 1,800 and 2,200 feet deep. A typical recharge rate is estimated to be 300 gpm and a recovery rate of 400 gpm. For an 8,000 acft/yr ASR system in McLennan County, 29 ASR wells are required.

The major facilities required for these projects include:

- ASR wells, and
- Interconnect.

Estimates were prepared for capital and project costs, annual debt service, operation and maintenance, power, land, and environmental mitigation. These costs are summarized in Table 10.5-2. The annual costs, including debt service, operation and maintenance, and power, are estimated to be $752 per acft. The costs do not include any compensation to the City of Waco for use of their surface water right.

Table 10.5-2. Cost Estimate Summary: McLennan County ASR Project Option

Item	Estimated Costs for Facilities
Well Fields (Wells, Pumps, and Piping)	$33,253,000
Integration, Relocations, & Other	$2,900,000
TOTAL COST OF FACILITIES	**$36,153,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$12,654,000
Environmental & Archaeology Studies and Mitigation	$0
Interest During Construction (4% for 1 years with a 1% ROI)	$1,709,000
TOTAL COST OF PROJECT	**$50,516,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$4,227,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$362,000
Water Treatment Plant (2.5% of Cost of Facilities)	$1,318,000
Pumping Energy Costs	$110,000
Purchase of Water	$0
TOTAL ANNUAL COST	**$6,017,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**8,000**
Annual Cost of Water ($ per acft)	**$752**
Annual Cost of Water ($ per 1,000 gallons)	**$2.31**

10.5.5 Implementation

Implementation of the ASR water management strategy for Waco and McLennan County includes the following issues:

- Agreements between Waco and participants;
- Acquiring permits from the McLennan County Groundwater Conservation District;
- Acquiring permits from TCEQ for ASR construction and operations and for storage of surface water in the Trinity Aquifer;
- Chemical and geochemical compatibility of native aquifer water and materials and imported water are chemically compatible;

- Lack of experience to develop confidence in the ability to inject water from an aquifer, which includes the uncertainty about the compatibility of the injected water with native groundwater and aquifer materials and failure of the ASR well;
- Controlling the loss of the injected water to others;
- Initial cost;
- Experience in operating the facilities; and
- Development of a management plan to efficiently use the ASR wells.

This water supply option has been compared to the plan development criteria, as shown in Table 10.5-3, and the option meets each criterion.

Table 10.5-3. Comparison of Bryan ASR Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. High
2. Reliability	2. High
3. Cost	3. Moderate
B. Environmental factors	
1. Environmental Water Needs	1. None
2. Habitat	2. None
3. Cultural Resources	3. None
4. Bays and Estuaries	4. None
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. None
C. Impact on Other State Water Resources	None
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered in an attempt to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

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11 Brackish Groundwater

Many aquifers in Texas contain a large volume of brackish groundwater for which desalination may be feasible to help meet increasing demand for potable water. TWDB classifies and Brazos G categories water salinity as follows:

Table 11-1. Saline Water Classifications

TWDB Classification	Brazos G Categories	Total Dissolved Solids (mg/L)
Fresh	Fresh	Less than 1,000
Slightly Saline	Brackish	1,000-3,000
Moderately Saline	Saline	3,000-10,000
Very Saline	Very Saline	10,000-35,000

As shown above and for purposes of this Brazos G planning report, slightly saline water is called brackish and moderately saline is called saline. If used for public water supplies, other than fresh groundwater must be treated (desalinated) or blended with other waters to reduce the concentrations of total dissolved solids and other water quality parameters to drinking water standards. Water containing total dissolved solids (TDS) concentrations of up to 3,000 milligrams per liter can be used for irrigation in most cases and likely for most poultry and livestock watering.

According to the TWDB, since 2013, there are 46 municipal brackish water desalination facilities in Texas. Twelve of these facilities use brackish surface water as a source of raw water, which accounts for a design capacity of 50 million gallons per day (56,000 acre-feet per year). Thirty-four facilities use brackish groundwater as a raw water source, which accounts for a design capacity of approximately 73 million gallons per day (81,760 acre-feet per year). Among brackish groundwater desalination facilities, El Paso Water Utilities' Kay Bailey Hutchison Desalination facility has the highest design capacity in the state (27.5 million gallons per day or 30,800 acre-feet per year). In Brazos G, there are six water utilities using desalination. Only the City of Evant is using groundwater for a water source. Reverse osmosis is the predominant desalination technology used in Texas with 44 of 46 desalination facilities.

To encourage and facilitate the development of brackish groundwater in the state, the TWDB proposed the Brackish Groundwater Desalination Initiative in 2004. The goal of the initiative was to develop models of brackish groundwater desalination that illustrated the use of innovative, cost-effective technologies and offered practical solutions to key challenges to implementing desalination projects.

Under current planning and regulations, brackish groundwater desalination projects in Texas are greatly hampered by: (1) brackish groundwater pumping counts against the Modeled Available Groundwater (MAG), just like freshwater pumping does; (2) brackish groundwater is almost always in the deepest part of the aquifer and well yields are lower that comparable wells in the freshwater zone; and (3) concentrate disposal from desalination water treatment continues to be a major challenge.

An assessment of the opportunity for development of groundwater supplies is presented by aquifer, progressing from west to east.

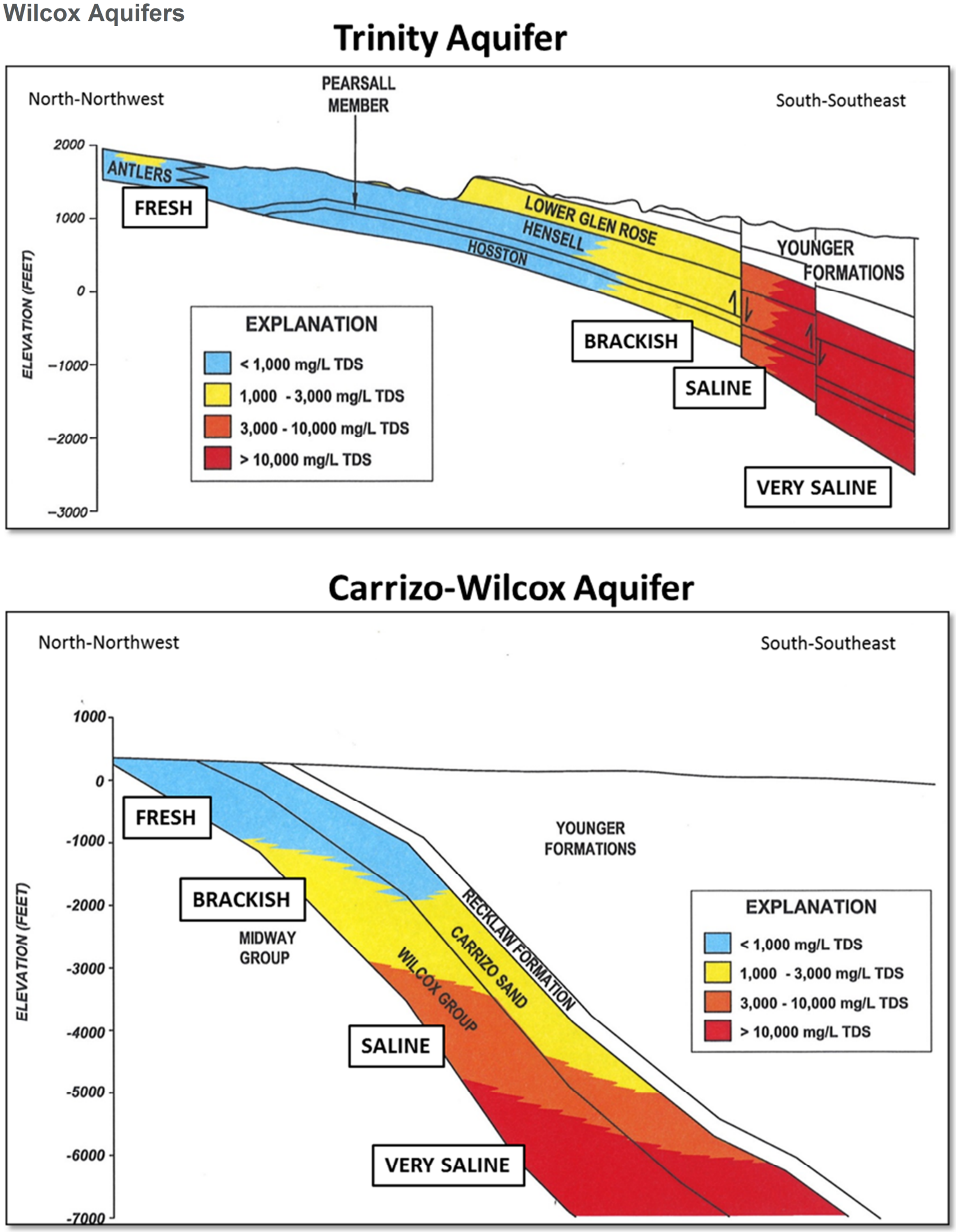
11.1 Hydrogeology

Major, minor and local aquifers in Brazos G occur in many stratigraphic units of eight geologic systems. Table 11-2 correlates the aquifers with the geologic system and shows the aquifer classification. A major aquifer produces large amounts of water over large areas. A minor aquifer either produces a minor amount of water over a large area or a large amount of water over a small area. Local aquifers produce a minor amount of water over small areas. In Brazos G, local aquifers occur mostly in the Permian and Pennsylvanian system. In most locations only one aquifer occurs. However, in the southeastern part of the planning area, as many as five aquifers occur at a given location. For most all of the major and minor aquifers, the updip part of the aquifer contains freshwater and transitions to brackish, to saline and to very saline water in the downdip direction. This is illustrated in Figure 11-1 for the Trinity and Carrizo-Wilcox Aquifers. The Ogallala, Seymour and Brazos River Alluvium Aquifers are relatively thin and do not exhibit the pattern.

Table 11-2. List of Aquifers and Classification

Geologic System	Name of Aquifer	Aquifer Classification
QUATERNARY	Seymour	Major
	Brazos River Alluvium	Minor
TERTIARY	Ogallala	Major
	Yegua-Jackson	Minor
	Sparta	Minor
	Queen City	Minor
	Carrizo	Major
	Simsboro	Major
CRETACEOUS	Woodbine	Minor
	Edwards	Major
	Trinity	Major
TRIASSIC	Dockum	Minor
PERMIAN	Blaine	Minor
	Clear Fork	Local
	Wichita/Albany	Local
PENNSYLVANIAN	Cisco	Local
	Canyon	Local
	Strawn	Local
	Marble Falls	Minor
ORDOVICAN	San Saba	Minor
	Ellenburger	Minor
CAMBRIAN	Hickory	Minor

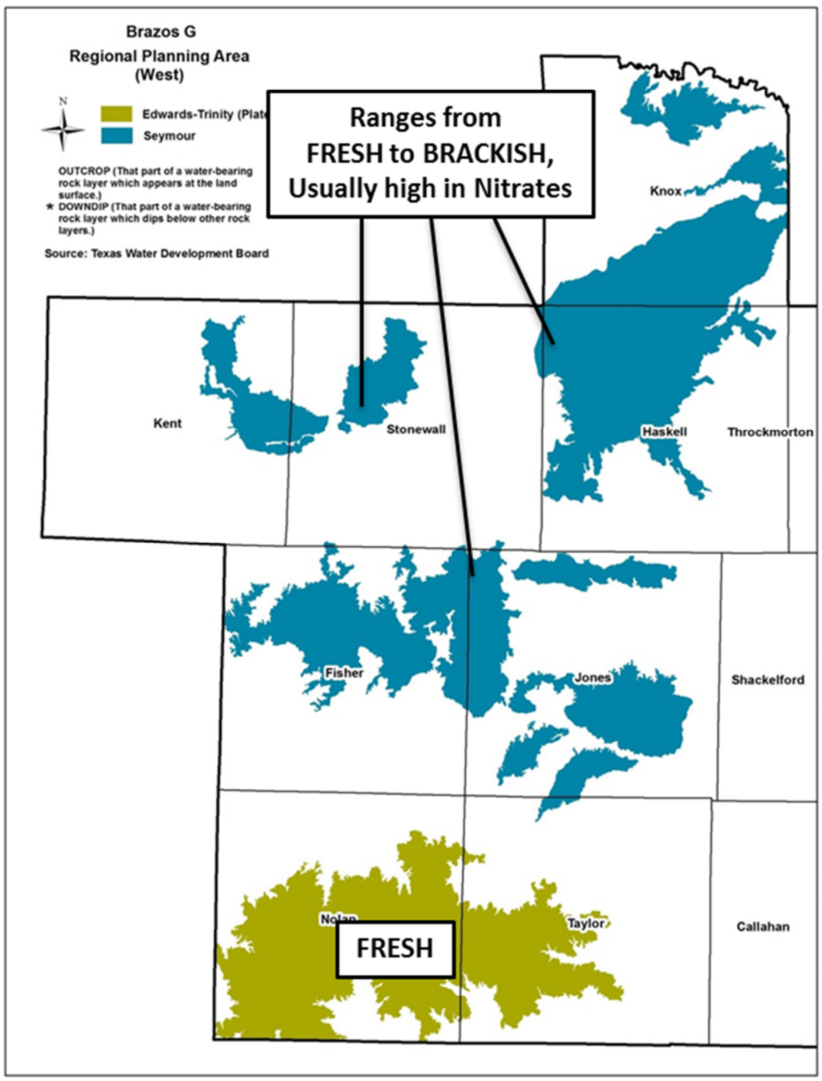
Figure 11-1. Schematic showing Transition of Groundwater Salinity in Trinity and Carrizo-Wilcox Aquifers



11.2 Seymour Aquifer

Figure 11-2 illustrates the location where the Seymour and Edwards-Trinity (Plateau) occur. The water in the Seymour Aquifer commonly is fresh; however, there are areas where the water is brackish. Also, much of the groundwater is affected by relatively high nitrates. Typically, there is some potential to develop brackish groundwater desalination projects where the aquifer’s saturated thickness is relatively thick and potential well yields are moderate or higher.

Figure 11-2. Location of Seymour and Edwards-Trinity (Plateau) Aquifers



11.3 Edwards-Trinity (Plateau) Aquifer

The location of the Edwards-Trinity (Plateau) in Nolan and Taylor Counties is shown in Figure 11-2. In this area, it contains only freshwater. Thus, there is no need or opportunity for groundwater desalination projects.

11.4 Blaine Aquifer

The location of the Blaine Aquifer is shown in Figure 11-3. Groundwater mostly occurs in beds of anhydrite and gypsum, which contribute to the water being of low quality. Well yields are highly variable and greatly depend on the number and size of solution channels intersected by the well. Overall, the TDS is usually greater than 2,500 mg/L. In areas where well yields are suitable for municipal wells, there is a potential to develop brackish groundwater desalination projects.

11.5 Dockum Aquifer

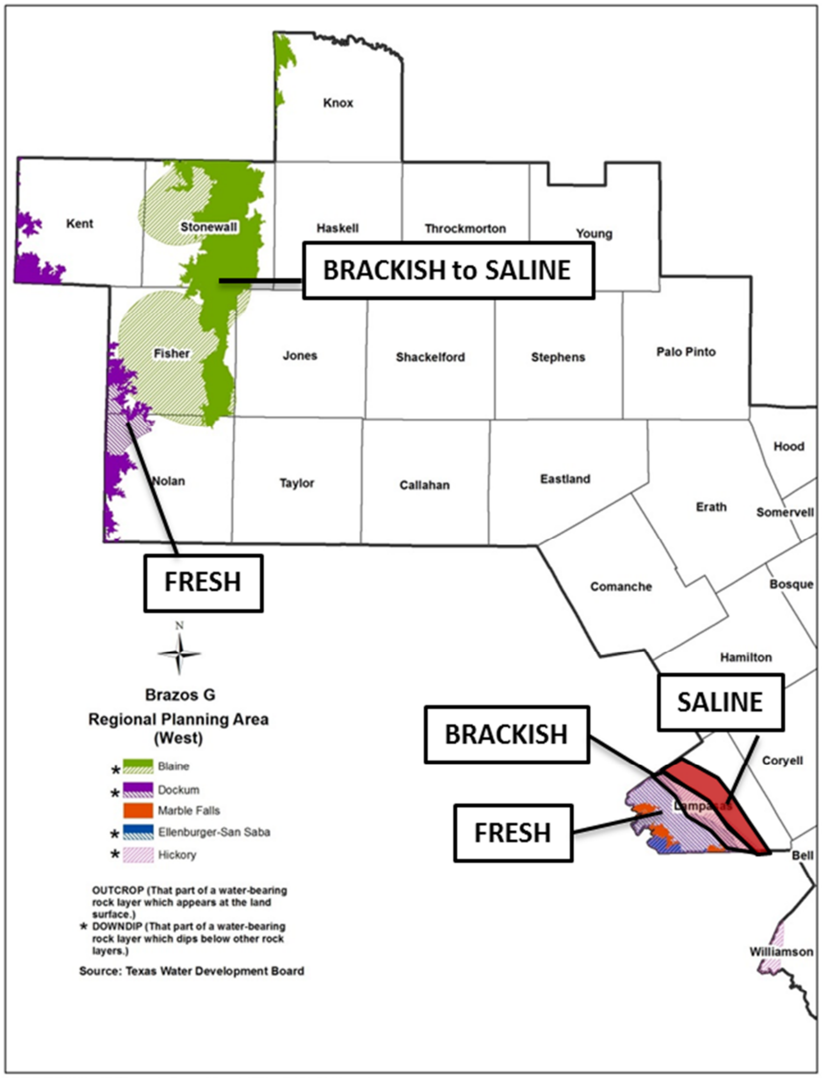
The location of the Dockum Aquifer is shown in Figure 11-3. As indicated, only fringes of the aquifer extend into Brazos G. In this part of the Dockum, the groundwater is fresh.

11.6 Marble Falls, Ellenburger-San Saba, and Hickory Aquifers

These aquifers are shown in Figure 11-3. In Brazos G (Lampasas County), all of these aquifers have a steep geologic dip toward the east. The Marble Falls Aquifer is of very limited extent. TDS concentrations show the water is usually fresh, but brackish groundwater occurs in the downdip area. The Ellenburger-San Saba Aquifer usually produces freshwater. However, brackish water can be expected in the very deep part of the aquifer where wells are over 3,000 ft deep. Elevated concentrations of radium and radon occur in some areas. The Hickory Aquifer is known for producing water with naturally occurring radioactivity, including: gross alpha radiation, radium, and radon.

The potential feasibility to develop a brackish groundwater desalination project in Lampasas County from these three aquifers is considered to be very limited because brackish groundwater supply projects would require very deep wells, the area of opportunity is very small, and potential for elevated concentrations of radium and radon.

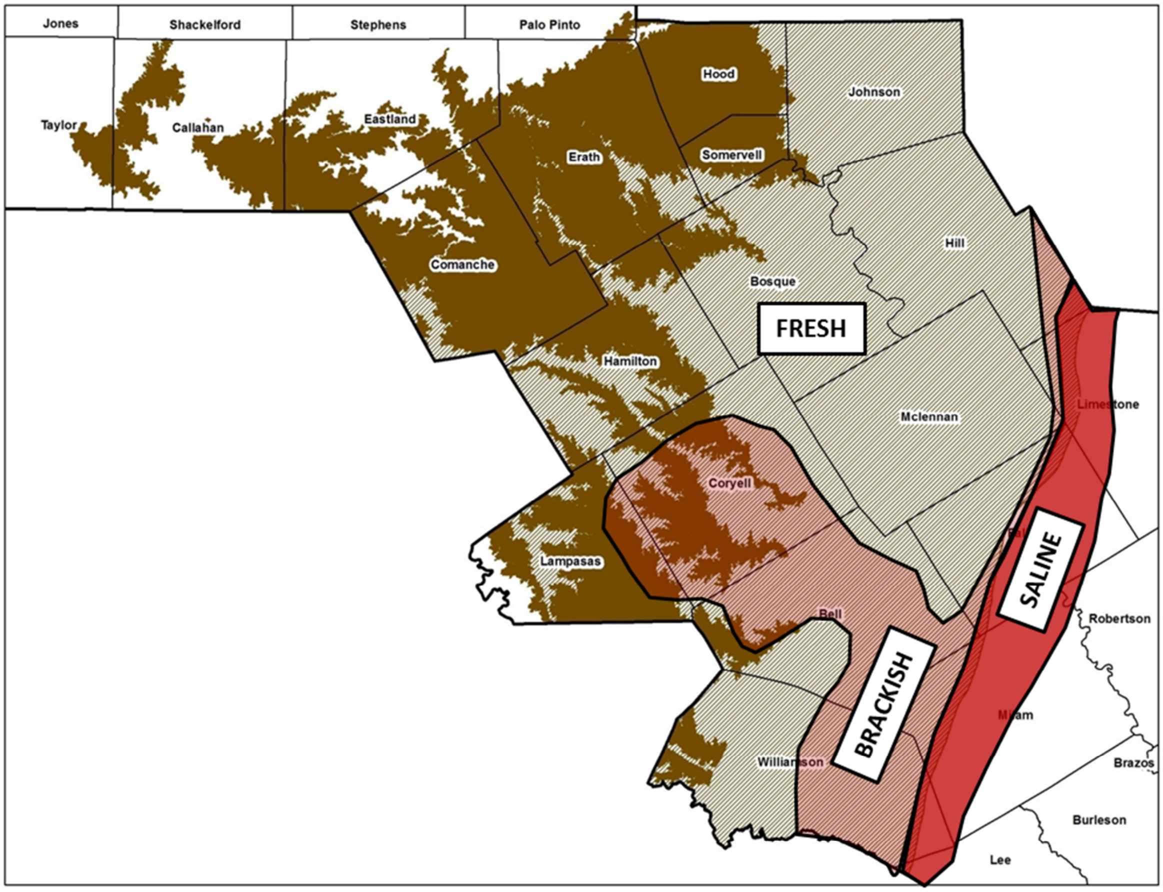
Figure 11-3. Location of Blain, Dockum, Marble Falls, Ellenburger-San Saba, and Hickory Aquifers



11.7 Trinity Aquifer

The location of the Trinity Aquifer is shown in Figure 11-4. The Trinity Aquifer is the most extensive in Brazos G. It is geologically complex with several water-bearing formations, including: Antlers, Glen Rose, Paluxy, Twin Mountains, Travis Peak, Hensell, and Hosston. These water-bearing formations consist of limestones, sands, gravels, and conglomerates. As indicated in Figure 11-1, the salinity of the Trinity trends from fresh in the west to saline in the east. However, parts of Lampasas, Coryell, and Bell Counties have relatively poor quality water because of relatively low transmissivity of the aquifer. This area along with eastern Williamson County is considered to have potential for brackish groundwater desalination projects. In the Lampasas, Coryell, and Bell County area, high capacity wells typically yield only about 100 gallons per minute (gpm). In eastern Williamson County, wells are rather deep and may yield may be up to 400 gpm. In the other brackish and saline zone areas, the feasibility of a brackish groundwater desalination project is low because of: (1) well depths, (2) localized target area, and (3) relatively hot water.

Figure 11-4. Location of Trinity Aquifer

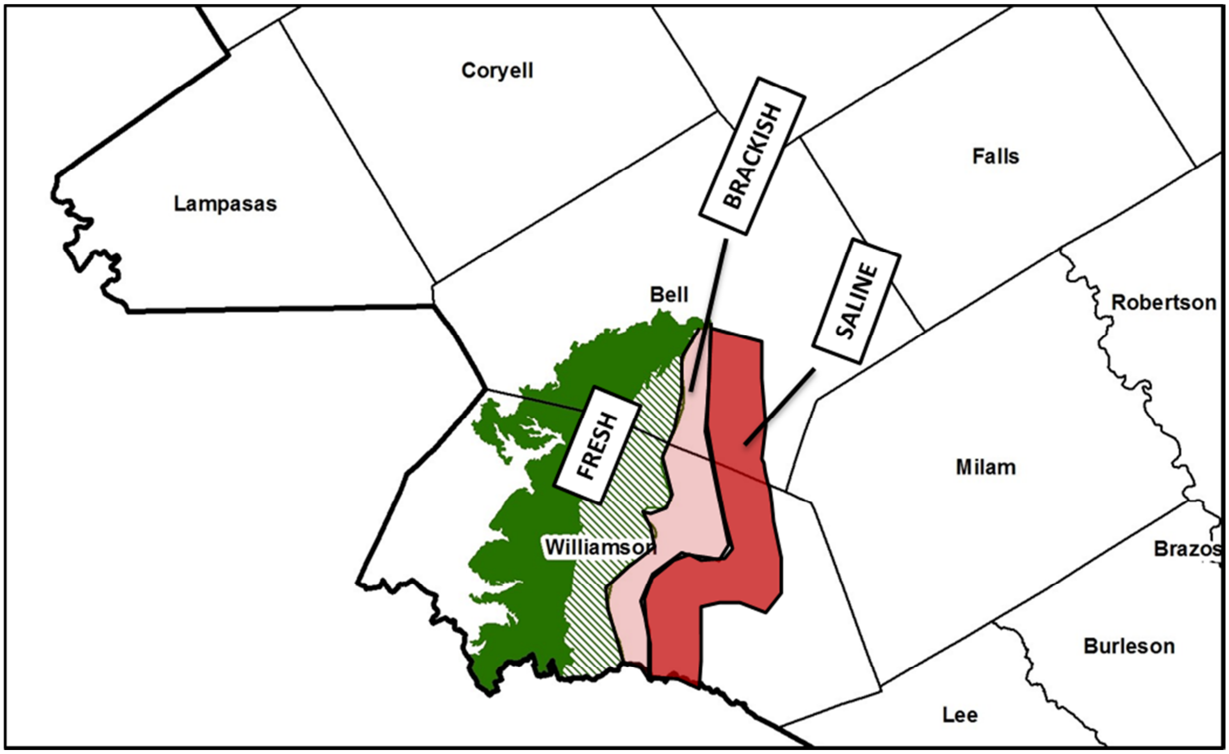


11.8 Edwards (Balcones Fault Zone) Aquifer

The location of the northern segment of the Edwards (Balcones Fault Zone (BFZ)) Aquifer is shown in Figure 11-5. The Edwards BFZ Aquifer in Brazos G is the northern extent of the aquifer that extends from west of Uvalde to San Antonio, to Austin, to Salado. This aquifer has become increasing important in Brazos G because of great increases in populations and associated water demands. The aquifer outcrops to the west and generally becomes confined east of I-35. In Brazos G, major springs include Salado, Berry, and San Gabriel Springs. Groundwater conditions are very much influenced by recent rainfall. Following major rainfall event that greatly recharge the aquifer, well yields can be substantial if the well penetrates karst features. However, extended drought conditions usually greatly reduce these well yields. The most responsive area to major rainfall events is in the outcrop area, along the Balcones Fault Zone and near streams. The least responsive area is the deep confined zone east of I-35.

As shown in Figure 11-5, about a third to a half of the aquifer contains brackish and saline water and may be suitable for groundwater desalination projects.

Figure 11-5. Location of Edwards (Balcones Fault Zone) Aquifer

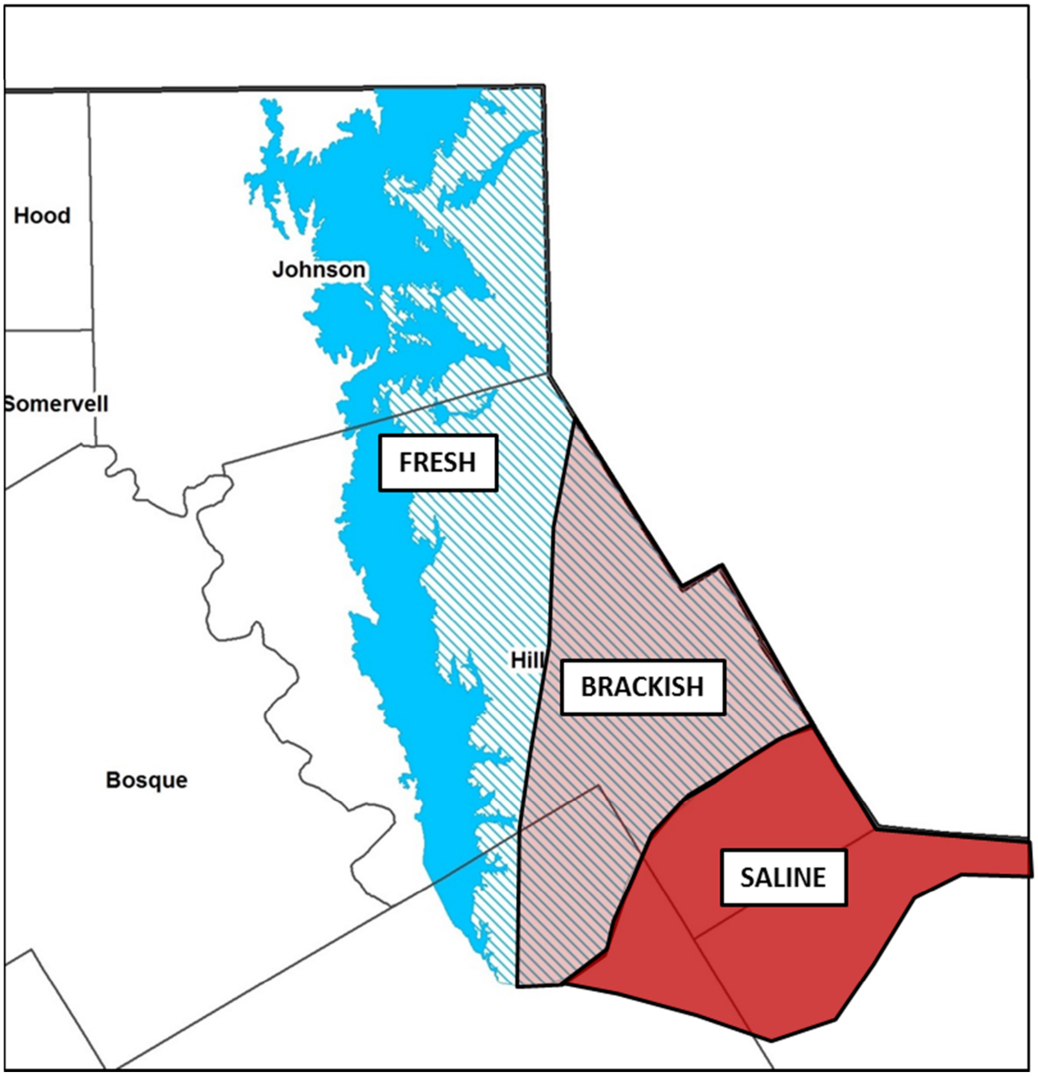


11.9 Woodbine Aquifer

The location of the Woodbine Aquifer is Brazos G is shown in Figure 11-6. This is a minor aquifer and dips to the east. The water quality deteriorates in the downdip direction and at depths greater than 1,000 ft. In some areas, the water quality condition is affected by naturally occurring high sulfate and iron concentrations. Well yields in some areas are several hundred gallons per minute, but most wells yield much less.

As shown in Figure 11-6, a substantial part of the Woodbine in eastern Hill County and parts of McLennan and Limestone County appear to be suitable for brackish groundwater desalination projects.

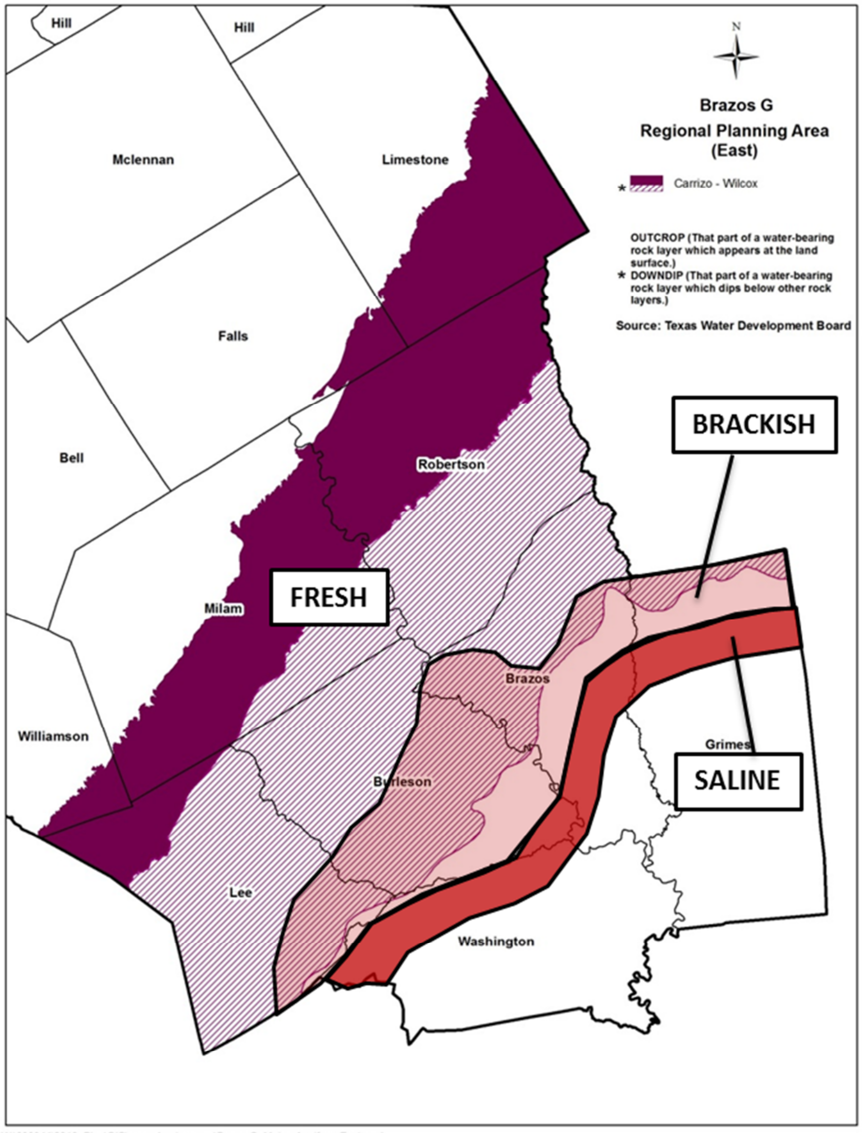
Figure 11-6. Location of Woodbine Aquifer



11.10 Carrizo-Wilcox Aquifer

The location of the Carrizo-Wilcox Aquifer is Brazos G is shown in Figure 11-7. This is a major aquifer and extends across Texas from the Rio Grande to the Texas-Louisiana border. In Brazos G, the Carrizo-Wilcox Aquifer has two major water-bearing zones; the Carrizo Sands and the Simsboro Member of the Wilcox Group. The Simsboro is extensively developed in the Bryan-College Station area. As shown in Figure 11-1, the aquifer dips toward the south-southeast and has stratified layers that trend from freshwater in the shallower areas to saline water in the deep areas. As shown in Figure 11-7, the opportunities for brackish groundwater desalination projects are mostly in the southeastern part of Brazos and Burleson Counties. In this area, these aquifers are very deep and produce hot water. Also, the development of brackish groundwater well fields in this area is expected to cause additional drawdown in existing wells for Bryan, College Station, and Texas A&M. With these considerations, the potential for brackish groundwater desalination projects is considered to be low.

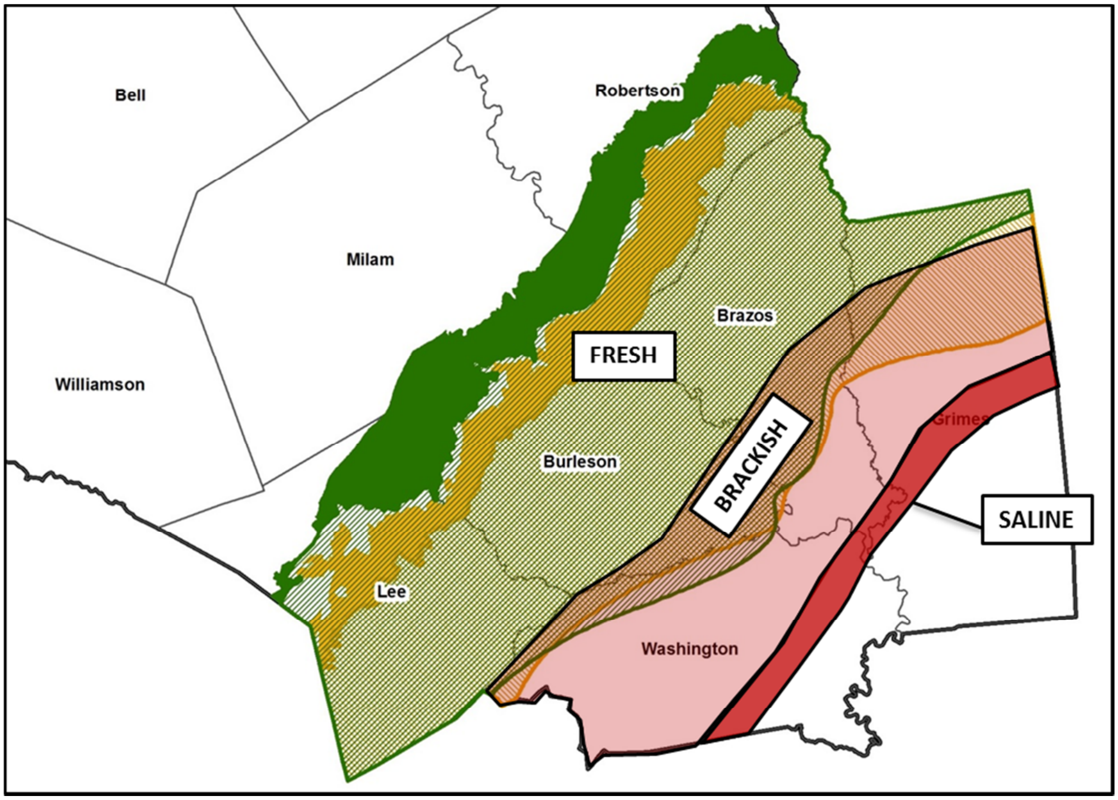
Figure 11-7. Location of Carrizo-Wilcox Aquifer



11.11 Sparta and Queen City Aquifers

The location of the Sparta and Queen City Aquifers is Brazos G is shown in Figure 11-8. These are two minor aquifers and extends across Texas from the Rio Grande to the Texas-Louisiana border, like the Carrizo-Wilcox. These aquifers overlay the Carrizo-Wilcox Aquifer and are separated by confining beds. The aquifers outcrop to the northwest and dip to the southeast. Neither of these aquifers is nearly as productive as the Carrizo or Simsboro. As shown in Figure 11-8, the opportunities for brackish groundwater desalination projects are mostly in the very eastern part of Brazos and Burleson Counties and western part of Grimes and Washington Counties. In this area, these aquifers are relatively deep and produce moderate well yields. With these considerations, the potential for brackish groundwater desalination projects is considered to be relatively low.

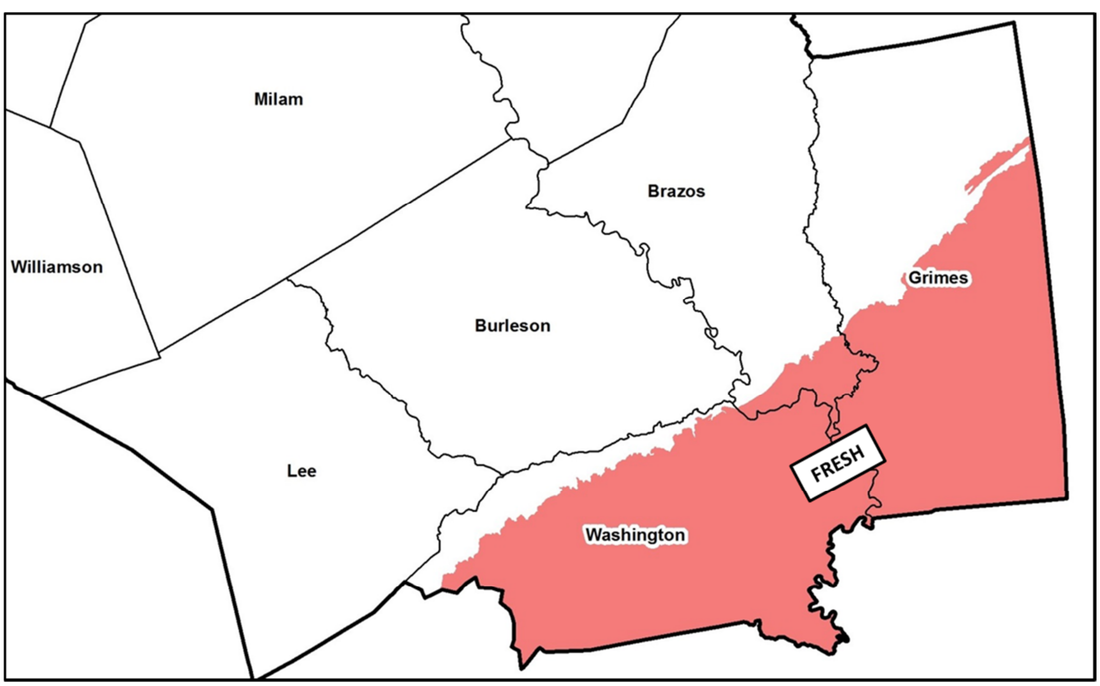
Figure 11-8. Location of Sparta and Queen City Aquifers



11.12 Gulf Coast Aquifer

The location of the Gulf Coast Aquifer in Brazos G is shown in Figure 11-9. In this area, it contains only freshwater. Thus, there is no need for groundwater desalination projects.

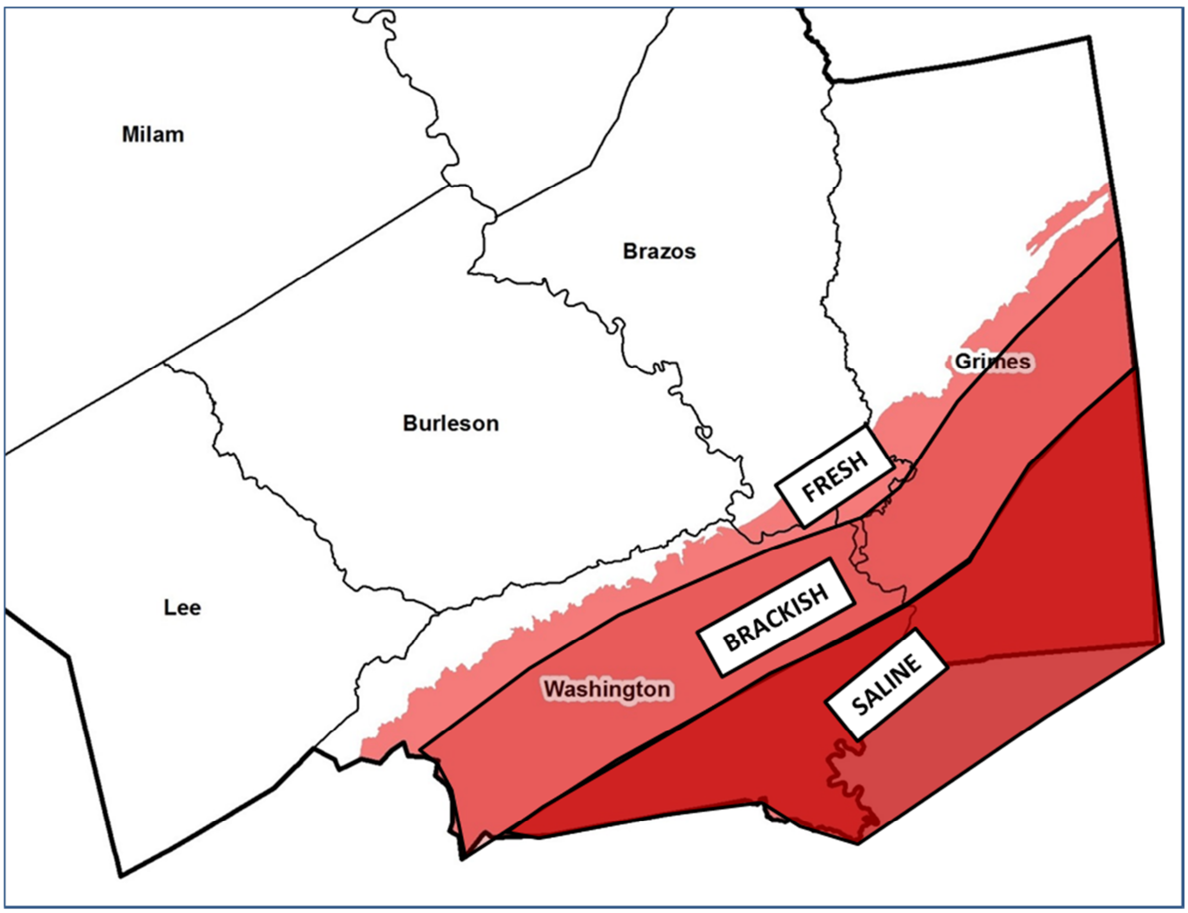
Figure 11-9. Location of Gulf Coast Aquifer



11.13 Yegua-Jackson Aquifer

The location of the Yegua-Jackson Aquifer in Brazos G is shown in Figure 11-10. This is a minor aquifer and extends across Texas from the Rio Grande to the Texas-Louisiana border. These aquifers underlay the Gulf Coast Aquifer and are separated by confining beds. The aquifer outcrops to the northwest and dips to the southeast. As shown in Figure 11-10, the extent of the freshwater part is rather limited, while the brackish and saline zones are much more extensive. Thus, there appears to be opportunities for brackish groundwater desalination projects in most of Grimes and Washington Counties. In this area, the aquifer has experienced very little development and test drilling because of the availability of groundwater in shallower formations. This causes great uncertainty as to the potential well yields and water quality conditions.

Figure 11-10. Location of Yegua-Jackson Aquifer

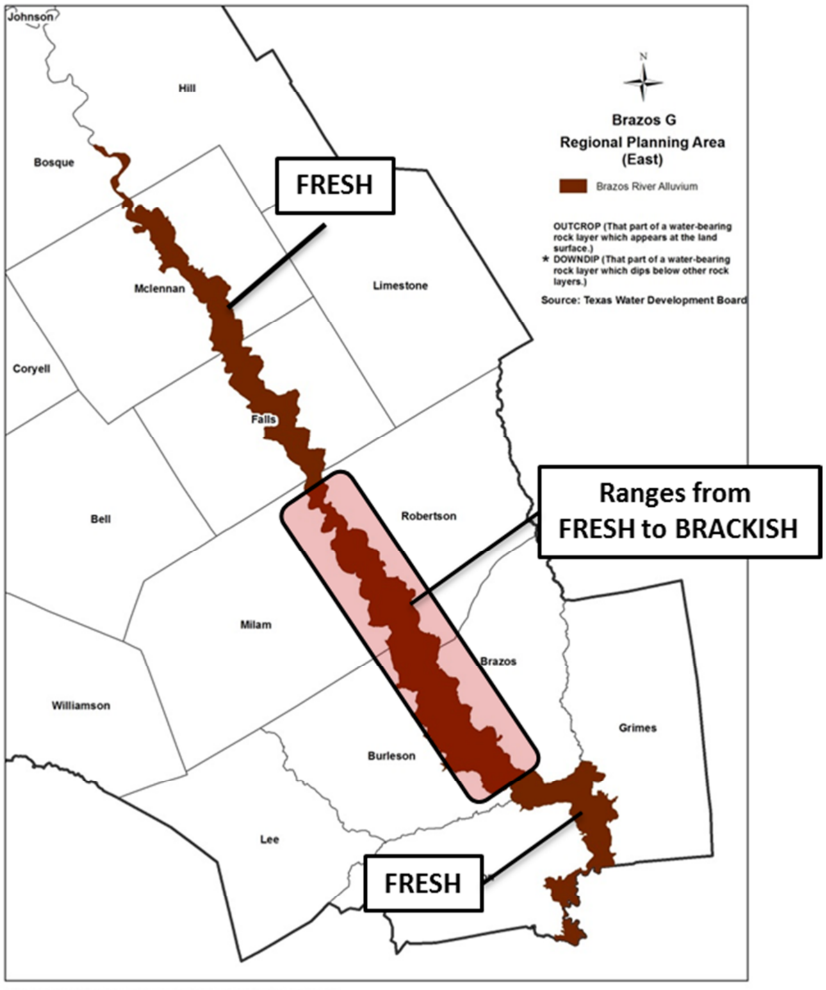


11.14 Brazos River Alluvium Aquifer

The location of the Brazos River Alluvium Aquifer in Brazos G is shown in Figure 11-11. This is a minor aquifer and, its extent is limited to the vicinity of the Brazos River south of Bosque County. The aquifer is in hydraulic connection with the Brazos River and usually discharges into the river. The aquifer is relatively thin, but many wells produce 250-500 gpm. Irrigation is extensive in areas where relatively high capacity wells can be constructed. Groundwater from this aquifer is usually fresh except in the reach between

Falls County and Washington County where the groundwater ranges from fresh to brackish. In the heavy farmed area, groundwater is likely to contain elevated concentrations of nitrates and pesticides. The potential for brackish groundwater desalination projects is considered to be low because of the thin aquifer, proximity to the Brazos River and being susceptible to drought conditions.

Figure 11-11. Location of Brazos River Alluvium Aquifer



11.15 Discussion

Major consideration of brackish groundwater desalination projects for municipal, industrial and agricultural supplies follow:

- Pumping brackish groundwater counts against groundwater availability (MAG) just like pumping fresh groundwater does. In regional planning this is a great disincentive if there are opportunities for freshwater from the same aquifer.
- Brackish wells in major and minor aquifers are almost always in the deep part of the aquifer and have lower well yields than comparable wells in the freshwater zone.

- Concentrate disposal from desalination water treatment continues to be a major challenge.
- In Brazos G, brackish and saline groundwater occurs in local aquifers in the west-central- part of the planning area but well yields are very low and salinity concentrations very high.

12 Miscellaneous Strategies

12.1 Strategy Overview

Miscellaneous Strategies represent 117 remaining strategies such as transmission projects, well field development, interconnections between water user groups, and water treatment plant expansions which are not included in any of the other water management strategies. Strategies were developed to overcome the water shortages identified between 2020 and 2070 after other specific water management strategies including conservation were applied for all WUGs. The WUGs with Miscellaneous Strategies are organized by county and are detailed in Section 12.3 through Section 12.5

Strategies are summarized below by the name of the miscellaneous strategy, the source of water for the strategy, a list of the facilities necessary, costs, project yield and a short description of the strategy. Costs are consistent with the TWDB and Brazos G assumptions as described in Volume II, Chapter 1 and are priced in September 2013 dollars. Debt service is calculated at 5.5% for 20 years. Some strategies include estimates of wholesale water costs as verified through discussion with water providers or as base costs from other strategies.

12.2 Implementation Issues

The miscellaneous strategies for each WUG were evaluated and determined based on plan development criteria. Groundwater, surface water and reuse water supplies are projected to be adequate to implement these miscellaneous strategies. Environmental impacts will need to be mitigated to protect instream flow requirements, habitat, cultural resources, threatened and endangered species and wetlands. Generally, it is assumed that pipelines can be routed to avoid environmentally sensitive areas. Strategies were considered to meet municipal and industrial shortages in the planning area and will not have an apparent negative impact on other state water resources, or on agriculture and natural resources. The strategies do not require interbasin transfers.

Some of the miscellaneous strategies are feasible only if other recommended strategies are implemented. Other considerations for implementation of the miscellaneous strategies are summarized below:

- In general, any development of additional groundwater in the Brazos G Area must address several issues including:
- Competition with others for groundwater in the area.
- Purchase of groundwater rights.
- Impact on water levels in the aquifer which could trigger reduction in production permits from the regulating Groundwater Conservation District.
- Restricted availability under the MAG

The regulatory permits that are expected to be requirements specific to wells and pipelines include:

- Regulations and permits by the groundwater conservation districts.
- U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the pipelines impacting wetlands or navigable waters of the United States.
- General Land Office easement for use of state-owned land.
- Texas Parks and Wildlife Department Sand, Gravel, and Marl permit for construction in state-owned streambeds.
- Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

12.3 Miscellaneous Pipelines, Pump Stations, and Groundwater Options by County

12.3.1 Bell County

WUG: Bell County Irrigation

Strategy: Brackish Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $1,815,000

Total Project Cost: $2,541,000

Total Annual Cost: $231,894 (Maximum of Phased Costs)

Available Project Yield: 140 acft/yr (2070)

Annual Cost of Water: $ 1,656 per acft/yr or $ 5.08 per 1,000 gal (Maximum of Phased Costs)

This project will include 5 brackish 150 gpm wells drilled to 800ft with 200 ft of 4 inch diameter transmission pipeline per well.

WUG: Bell County Irrigation

Strategy: Edwards Aquifer Development

Source: Edwards Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $9,562,000

Total Project Cost: $13,384,000

Total Annual Cost: $1,222,446

Available Project Yield: 1,091 acft/yr (After Full Implementation)

Annual Cost of Water: $1,120 per acft/yr or $3.44 per 1,000 gal

This project will include 29 200 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well.

WUG: Bell County Mining

Strategy: Brackish Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost:	$3,993,000
Total Project Cost:	$5,588,000
Total Annual Cost:	$514,267
Available Project Yield:	582 acft/yr (After Full Implementation)
Annual Cost of Water:	$ 884 per acft/yr or $ 2.71per 1,000 gal (Maximum of Phased Costs)

This project will include 11 brackish 150 gpm wells drilled to 800ft with 200 ft of 4 inch diameter transmission pipeline per well.

WUG: Bell County Mining

Strategy: Edwards Aquifer Development

Source: Edwards Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost:	$9,892,000
Total Project Cost:	$13,846,000
Total Annual Cost:	$1,281,486
Available Project Yield:	2,176 acft/yr (After Full Implementation)
Annual Cost of Water:	$589 per acft/yr or $1.81 per 1,000 gal

This project will include 30 200 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well .

WUG: Bell County Other

Strategy: Brackish Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, transmission and treatment

Total Capital Cost:	$15,824,000
Total Project Cost:	$22,147,000
Total Annual Cost:	$3,177,000 (Maximum of Phased Costs)
Available Project Yield:	806 acft/yr (After Full Implementation)
Annual Cost of Water:	$ 4,858 per acft/yr or $ 14.91 per 1,000 gal (Maximum of Phased Costs)

This project will include 10 brackish 100 gpm wells drilled to 800ft, 2,000 ft of 4 inch diameter transmission pipeline, brackish desalination, and disposal of concentrate at a landfill.

WUG: Bell County Other

Strategy: Edwards Aquifer Development

Source: Edwards Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $2,672,000

Total Project Cost: $3,736,000

Total Annual Cost: $380,823

Available Project Yield: 2,081 acft/yr (After Full Implementation)

Annual Cost of Water: $ 183 per acft/yr or $0.56 per 1,000 gal (Maximum of Phased Costs)

This project will include two 200 gpm wells drilled to 500 ft as well as 1,000 ft of transmission pipeline and, disinfection treatment.

12.3.2 Bosque County

WUG: Bosque County Irrigation

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $7,898,000

Total Project Cost: $11,048,000

Total Annual Cost: $1,006,457 (Maximum of Phased Costs)

Available Project Yield: 475 acft/yr (2070)

Annual Cost of Water: $ 2,119 per acft/yr or $ 6.50 per 1,000 gal (Maximum of Phased Costs)

This project will include 15 200gpm wells drilled to 1,100ft with 200 ft of 4 inch diameter transmission pipeline per well.

WUG: Childress Creek

Strategy: Trinity Well Rehab

Source: Trinity Aquifer

Facilities: Rehab Costs

Total Capital Cost: $10,000

Total Project Cost: $15,000

Total Annual Cost: $1,000

Available Project Yield: 161 acft/yr

Annual Cost of Water: $ 6 per acft/yr or $0.2 per 1,000 gal

This project will involve the rehab of one 100 gpm well.

12.3.3 Brazos County

WUG: Wellbourne SUD

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $11,423,000

Total Project Cost: $16,016,000

Total Annual Cost: $2,548,000 (Maximum of Phased Costs)

Available Project Yield: 3,226 acft/yr (After Full Implementation)

Annual Cost of Water: $ 790 per acft/yr or $2.42 per 1,000 gal (Maximum of Phased Costs)

This project will include four 1,000 gpm wells drilled to 2,000 ft as well as 800 ft of transmission pipeline and, disinfection treatment.

WUG: Brazos County Manufacturing

Strategy: Gulf Coast Aquifer Development

Source: Gulf Coast Aquifer

Facilities: Well Field, collection pipes, treatment

Total Capital Cost: $6,319,000

Total Project Cost: $8,932,000

Total Annual Cost: $961,727 (Maximum of Phased Costs)

Available Project Yield: 530 acft/yr (After Full Implementation)

Annual Cost of Water: $ 1,815 per acft/yr or $5.57 per 1,000 gal (Maximum of Phased Costs)

This project will include fifteen100 gpm wells drilled to 1,100 ft as well as 200 ft of transmission pipeline per well and disinfection treatment.

12.3.4 Burleson County

WUG: Burleson County Manufacturing

Strategy: Sparta Aquifer Development

Source: Sparta Aquifer

Facilities: Well Field, collection pipes, treatment

Total Capital Cost: $656,000

Total Project Cost: $932,000

Total Annual Cost: $107,534 (Maximum of Phased Costs)

Available Project Yield: 85 acft/yr (After 2030)

Annual Cost of Water: $ 1,265 per acft/yr or $3.88 per 1,000 gal (Maximum of Phased Costs)

This project will include two 150 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well and disinfection treatment.

WUG: Burleson County Mining

Strategy: Sparta Aquifer Development

Source: Sparta Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $3,904,000

Total Project Cost: $5,466,000

Total Annual Cost: $501,602 (Maximum of Phased Costs)

Available Project Yield: 740 acft/yr (After 2030)

Annual Cost of Water: $ 678 per acft/yr or $2.08 per 1,000 gal (Maximum of Phased Costs)

This project will include fourteen 150 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well.

12.3.5 Callahan County

WUG: Callahan County Mining

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes,

Total Capital Cost: $1,208,000

Total Project Cost: $1,695,000

Total Annual Cost: $155,732 (Maximum of Phased Costs)

Available Project Yield: 740 acft/yr

Annual Cost of Water: $ 692 per acft/yr or $2.12 per 1,000 gal (Maximum of Phased Costs)

This project will include seven 100 gpm wells drilled to 300 ft as well as 200 ft of transmission pipeline per well .

12.3.6 Comanche County

WUG: Comanche County Other

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $1,446,000

Total Project Cost: $2,033,000

Total Annual Cost: $149,000 (Maximum of Phased Costs)

Available Project Yield: 242 acft/yr (After Full Implementation)

Annual Cost of Water: $ 924 per acft/yr or $2.83 per 1,000 gal (Maximum of Phased Costs)

This project will include three 100 gpm wells drilled to 600 ft as well as 600 ft of transmission pipeline and, disinfection treatment.

WUG: Comanche County Mining

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $3,195,000

Total Project Cost: $4,475,000

Total Annual Cost: $411,796 (Maximum of Phased Costs)

Available Project Yield: 473 acft/yr

Annual Cost of Water: $ 871 per acft/yr or $2.67 per 1,000 gal (Maximum of Phased Costs)

This project will include thirteen 100 gpm wells drilled to 600 ft as well as 200 ft of transmission pipeline per well .

WUG: Comanche County Irrigation

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $7,865,000

Total Project Cost: $11,015,000

Total Annual Cost: $1,004,806 (Maximum of Phased Costs)

Available Project Yield: 603 acft/yr

Annual Cost of Water: $ 1,666 per acft/yr or $5.11 per 1,000 gal (Maximum of Phased Costs)

This project will include thirty-two 100 gpm wells drilled to 600 ft as well as 200 ft of transmission pipeline per well .

12.3.7 Coryell County

WUG: Coryell County Other

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, transmission and treatment

Total Capital Cost: $3,147,000

Total Project Cost: $4,428,000

Total Annual Cost: $488,806 (Maximum of Phased Costs)

Available Project Yield: 565 acft/yr (After Full Implementation)

Annual Cost of Water: $ 931 per acft/yr or $ 2.86 per 1,000 gal (Maximum of Phased Costs)

This project will include seven brackish 100 gpm wells drilled to 200 ft, as well as 200 ft of transmission pipeline per well and disinfection.

WUG: Coryell County Mining

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $14,447,000

Total Project Cost: $20,220,000

Total Annual Cost: $1,853,751 (Maximum of Phased Costs)

Available Project Yield: 1,500 acft/yr

Annual Cost of Water: $ 1,236 per acft/yr or $3.79 per 1,000 gal (Maximum of Phased Costs)

This project will include thirteen 100 gpm wells drilled to 200 ft as well as 200 ft of transmission pipeline per well .

12.3.8 Eastland County

WUG: Eastland County Irrigation

Strategy: Trinity Aquifer Development (Erath County)

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $17,291,000

Total Project Cost: $24,210,000

Total Annual Cost: $2,213,162 Maximum of Phased Costs)

Available Project Yield: 2,033 acft/yr

Annual Cost of Water: $ 1,089 per acft/yr or $3.34 per 1,000 gal (Maximum of Phased Costs)

This project will include 62: 150 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well .

WUG: Eastland County Mining

Strategy: Trinity Aquifer Development (Erath County)

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $5,857,000

Total Project Cost: $8,202,000

Total Annual Cost: $758,354 (Maximum of Phased Costs)

Available Project Yield: 1,150 acft/yr

Annual Cost of Water: $ 560 per acft/yr or $1.72 per 1,000 gal (Maximum of Phased Costs)

This project will include 21: 150 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well .

12.3.9 Erath County

WUG: Erath County Other

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $1,488,000

Total Project Cost: $2,195,000

Total Annual Cost: $247,000 (Maximum of Phased Costs)

Available Project Yield: 363 acft/yr (After Full Implementation)

Annual Cost of Water: $ 681 per acft/yr or $2.09 per 1,000 gal (Maximum of Phased Costs)

This project will include three 150 gpm wells drilled to 500 ft as well as 600 ft of transmission pipeline and, disinfection treatment.

12.3.10 Falls County

WUG: Tri-County SUD

Strategy: Carrizo Aquifer Development

Source: Carrizo Aquifer

Facilities: Well Field, transmission and treatment

Total Capital Cost: $ 1,030,000

Total Project Cost: $1,445,000

Total Annual Cost: $268,000

Available Project Yield: 202 acft/yr

Annual Cost of Water: $ 1,329 per acft/yr or $ 4.08 per 1,000

This project will include one 250 gpm wells drilled to 550ft, 200ft of 4 inch diameter transmission pipeline, and Chlorine disinfection.

WUG: West Brazos WSC

Strategy: Carrizo Aquifer Development

Source: Carrizo Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $1,965,000

Total Project Cost: $2,752,000

Total Annual Cost: $292,010 (Maximum of Phased Costs)

Available Project Yield: 216 acft/yr (After Full Implementation)

Annual Cost of Water: $ 1,446 per acft/yr or $4.44 per 1,000 gal (Maximum of Phased Costs)

This project will include two 250 gpm wells drilled to 2,000 ft as well as 400 ft of transmission pipeline and, disinfection treatment.

12.3.11 Fisher County

WUG: Fisher County Mining

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer (Brackish)

Facilities: Well Field, collection pipes

Total Capital Cost: $2,159,000

Total Project Cost: $3,035,000

Total Annual Cost: $278,431 (Maximum of Phased Costs)

Available Project Yield: 400 acft/yr

Annual Cost of Water: $ 696 per acft/yr or $2.14 per 1,000 gal (Maximum of Phased Costs)

This project will include twenty-one 50 gpm wells drilled to 200 ft as well as 200 ft of transmission pipeline per well .

WUG: Fisher County Manufacturing

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer (Brackish)

Facilities: Well Field, collection pipes, treatment, disposal

Total Capital Cost: $7,207,000

Total Project Cost: $10,081,000

Total Annual Cost: $1,517,030 (Maximum of Phased Costs)

Available Project Yield: 400 acft/yr

Annual Cost of Water: $ 14,040 per acft/yr or $43.08 per 1,000 gal (Maximum of Phased Costs)

This project will include eight 50 gpm wells drilled to 200 ft as well as 200 ft of transmission pipeline per well and treatment/disposal.

12.3.12 Grimes County

WUG: Grimes County Mining

Strategy: Brackish Carrizo Aquifer Development

Source: Carrizo Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $4,152,000

Total Project Cost: $5,805,000

Total Annual Cost: $881,856 (Maximum of Phased Costs)

Available Project Yield: 550 acft/yr (by 2030)

Annual Cost of Water: $ 1,764 per acft/yr or $5.41 per 1,000 gal (Maximum of Phased Costs)

This project will include five 300 gpm wells drilled to 3000 ft as well as 200 ft of transmission pipeline per well .

WUG: Grimes County Steam-Electric

Strategy: Gulf Coast Development

Source: Gulf Coast Aquifer

Facilities: Well Field, collection pipes, treatment

Total Capital Cost: $15,869,000

Total Project Cost: $22,459,000

Total Annual Cost: $2,639,903 (Maximum of Phased Costs)

Available Project Yield: 6,236 acft/yr

Annual Cost of Water: $ 423 per acft/yr or $1.30 per 1,000 gal (Maximum of Phased Costs)

This project will include thirty-six 250 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well and disinfection .

WUG: Grimes County Steam-Electric

Strategy: Brackish Carrizo Aquifer Development

Source: Carrizo Aquifer

Facilities: Well Field, collection pipes, treatment

Total Capital Cost: $5,831,000

Total Project Cost: $8,182,000

Total Annual Cost: $1,081,979 (Maximum of Phased Costs)

Available Project Yield: 343 acft/yr

Annual Cost of Water: $ 2,971 per acft/yr or $9.12 per 1,000 gal (Maximum of Phased Costs)

This project will include four 300 gpm wells drilled to 3000 ft as well as 200 ft of transmission pipeline per well .

12.3.13 Hamilton County

WUG: Hamilton County Mining

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $1,952,000

Total Project Cost: $2,734,000

Total Annual Cost: $251,735 (Maximum of Phased Costs)

Available Project Yield: 370 acft/yr (by 2030)

Annual Cost of Water: $ 680 per acft/yr or $2.09 per 1,000 gal (Maximum of Phased Costs)

This project will include seven 150 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well .

WUG: Hamilton County Irrigation

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $837,000

Total Project Cost: $1,173,000

Total Annual Cost: $106,733 (Maximum of Phased Costs)

Available Project Yield: $60 acft/yr (by 2030)

Annual Cost of Water: $1,779 per acft/yr or $5.46 per 1,000 gal (Maximum of Phased Costs)

This project will include three 150 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well .

12.3.14 Hill County

WUG: Hill County Mining

Strategy: Woodbine Aquifer Development

Source: Woodbine Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $3,343,000

Total Project Cost: $4,684,000

Total Annual Cost: $429,460 (Maximum of Phased Costs)

Available Project Yield: 550 acft/yr

Annual Cost of Water: $ 767 per acft/yr or $2.35 per 1,000 gal (Maximum of Phased Costs)

This project will include fifteen 100 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well .

12.3.15 Hood County

WUG: City of Cresson

Strategy: Groundwater Development – Trinity Aquifer

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $540,000

Total Project Cost: $771,000

Total Annual Cost: $93,379 (Maximum of Phased Costs)

Available Project Yield: 60 acft/yr

Annual Cost of Water: $1,556 per acft/yr or $4.78 per 1,000 gal

This project will include two 150 gpm wells drilled to 600ft, 1,400ft of 4 inch diameter transmission pipeline, and Chlorine disinfection.

WUG: City of Tolar

Strategy: Trinity Aquifer Well Rehab

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $20,000

Total Project Cost: $30,000

Total Annual Cost: $1,100 (Maximum of Phased Costs)

Available Project Yield: 24 acft/yr (After Full Implementation)

Annual Cost of Water: $91 per acft/yr or $0.28 per 1,000 gal (Maximum of Phased Costs)

This project will include the rehab of two 100 gpm well.

WUG: Hood County Other

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, transmission and treatment

Total Capital Cost: $4,372,000

Total Project Cost: $6,164,000

Total Annual Cost: $680,000

Available Project Yield: 605 acft/yr

Annual Cost of Water: $ 703 per acft/yr or $ 2.16 per 1,000

This project will include eight 150 gpm wells drilled to 600ft, 1,400ft of 4 inch diameter transmission pipeline, and Chlorine disinfection.

WUG: Hood County Mining

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost:	$4,423,000
Total Project Cost:	$6,197,000
Total Annual Cost:	$569,308 (Maximum of Phased Costs)
Available Project Yield:	1,120 acft/yr
Annual Cost of Water:	$ 508 per acft/yr or $1.56 per 1,000 gal (Maximum of Phased Costs)

This project will include twenty 150 gpm wells drilled to 300 ft as well as 200 ft of transmission pipeline per well .

12.3.16 Johnson County

WUG: City of Godley

Strategy: Woodbine Aquifer Development

Source: Woodbine Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost:	$263,000
Total Project Cost:	$375,000
Total Annual Cost:	$44,206 (Maximum of Phased Costs)
Available Project Yield:	216 acft/yr (After Full Implementation)
Annual Cost of Water:	$ 1,474 per acft/yr or $4.52 per 1,000 gal (Maximum of Phased Costs)

This project will include one 100 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well, and disinfection treatment.

WUG: Parker WSC

Strategy: Woodbine Aquifer Development

Source: Woodbine Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost:	$791,000
Total Project Cost:	$1,128,000
Total Annual Cost:	$132,617 (Maximum of Phased Costs)
Available Project Yield:	180 acft/yr (After Full Implementation)
Annual Cost of Water:	$ 737 per acft/yr or $2.26 per 1,000 gal (Maximum of Phased Costs)

This project will include three 100 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well, and disinfection treatment

WUG: City of Rio Vista

Strategy: Woodbine Aquifer Development

Source: Woodbine Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $528,000

Total Project Cost: $753,000

Total Annual Cost: $88,411 (Maximum of Phased Costs)

Available Project Yield: 75 acft/yr (After Full Implementation)

Annual Cost of Water: $ 1,179 per acft/yr or $3.62 per 1,000 gal (Maximum of Phased Costs)

This project will include two 100 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well, and disinfection treatment.

WUG: City of Venus

Strategy: Woodbine Aquifer Development

Source: Woodbine Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $1,055,000

Total Project Cost: $1,503,000

Total Annual Cost: $207,234 (Maximum of Phased Costs)

Available Project Yield: 450 acft/yr (After Full Implementation)

Annual Cost of Water: $ 589 per acft/yr or $1.81 per 1,000 gal (Maximum of Phased Costs)

This project will include six 100 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well, and disinfection treatment.

WUG: Johnson County Mining

Strategy: Woodbine Aquifer Development

Source: Woodbine Aquifer

Facilities: Well Field, collection pipes, transmission

Total Capital Cost: $3,343,000

Total Project Cost: $4,684,000

Total Annual Cost: $437,051 (Maximum of Phased Costs)

Available Project Yield: 1,140 acft/yr (After Full Implementation)

Annual Cost of Water: $ 383 per acft/yr or $1.18 per 1,000 gal

This project will include six 100 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well.

12.3.17 Knox County

WUG: Knox County Irrigation

Strategy: Blaine Aquifer Development

Source: Blaine Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $1,737,000

Total Project Cost: $2,436,000

Total Annual Cost: $222,054 (Maximum of Phased Costs)

Available Project Yield: 461 acft/yr

Annual Cost of Water: $482 per acft/yr or $1.48 per 1,000 gal (Maximum of Phased Costs)

This project will include elleven 100 gpm wells drilled to 250 ft as well as 200 ft of transmission pipeline per well .

WUG: Knox County Irrigation

Strategy: Seymour Aquifer Development

Source: Seymour Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $7,005,000

Total Project Cost: $9,817,000

Total Annual Cost: $896,747 (Maximum of Phased Costs)

Available Project Yield: 1,571 acft/yr

Annual Cost of Water: $571 per acft/yr or $1.75 per 1,000 gal (Maximum of Phased Costs)

This project will include thirty-six 200 gpm wells drilled to 250 ft as well as 200 ft of transmission pipeline per well.

WUG: Knox County Mining

Strategy: Blaine Aquifer Development

Source: Blaine Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $158,000

Total Project Cost: $223,000

Total Annual Cost: $20,815 (Maximum of Phased Costs)

Available Project Yield: 15 acft/yr

Annual Cost of Water: $1,388 per acft/yr or $4.26 per 1,000 gal (Maximum of Phased Costs)

This project will include one 100 gpm wells drilled to 250 ft as well as 200 ft of transmission pipeline per well .

12.3.18 Lampasas County

WUG: Lampasas County Irrigation

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $2,175,000

Total Project Cost: $3,049,000

Total Annual Cost: $278,636 (Maximum of Phased Costs)

Available Project Yield: 210 acft/yr

Annual Cost of Water: $1,327 per acft/yr or $4.07 per 1,000 gal (Maximum of Phased Costs)

This project will include eleven 100 gpm wells drilled to 400 ft as well as 200 ft of transmission pipeline per well.

WUG: Lampasas County Mining

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $1,582,000

Total Project Cost: $2,219,000

Total Annual Cost: $204,252 (Maximum of Phased Costs)

Available Project Yield: 275 acft/yr

Annual Cost of Water: $743 per acft/yr or $2.28 per 1,000 gal (Maximum of Phased Costs)

This project will include eight 100 gpm wells drilled to 400 ft as well as 200 ft of transmission pipeline per well.

12.3.19 Lee County

WUG: Heart of Texas

Strategy: Carrizo Aquifer Development

Source: Carrizo Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $81,194,000

Total Project Cost: $127,086,000

Total Annual Cost: $9,054,000 (Maximum of Phased Costs)

Available Project Yield: 11,994 acft/yr (After Full Implementation)

Annual Cost of Water: $ 1,619 per acft/yr or $4.97 per 1,000 gal (Maximum of Phased Costs)

This project will include five 1000 gpm wells drilled to 2000 ft as well as 25 miles of transmission pipeline, two pump stations, and disinfection treatment.

12.3.20 Limestone County

WUG: Bistone Municipal WSD

Strategy: Carrizo Aquifer Development

Source: Carrizo Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $16,148,000

Total Project Cost: $22,689,000

Total Annual Cost: $2,541,878 (Maximum of Phased Costs)

Available Project Yield: 3,112 acft/yr (After Full Implementation)

Annual Cost of Water: $ 817 per acft/yr or $2.51 per 1,000 gal (Maximum of Phased Costs)

This project will include two 100 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well, and disinfection treatment.

WUG: Limestone County Mining

Strategy: Carrizo Aquifer Development

Source: Carrizo Aquifer (Brazos Basin)

Facilities: Well Field, collection pipes

Total Capital Cost: $22,552,000

Total Project Cost: $31,546,000

Total Annual Cost: $2,898,125 (Maximum of Phased Costs)

Available Project Yield: 4,806 acft/yr

Annual Cost of Water: $603 per acft/yr or $1.85 per 1,000 gal (Maximum of Phased Costs)

This project will include forty-three 300 gpm wells drilled to 800 ft as well as 200 ft of transmission pipeline per well .

WUG: Limestone County Mining

Strategy: Carrizo Aquifer Development

Source: Carrizo Aquifer (Trinity Basin)

Facilities: Well Field, collection pipes

Total Capital Cost: $4,196,000

Total Project Cost: $5,871,000

Total Annual Cost: $538,837 (Maximum of Phased Costs)

Available Project Yield: 888 acft/yr

Annual Cost of Water: $607 per acft/yr or $1.86 per 1,000 gal (Maximum of Phased Costs)

This project will include eight 300 gpm wells drilled to 800 ft as well as 200 ft of transmission pipeline per well.

12.3.21 McLennan County

WUG: McLennan County Irrigation

Strategy: Brazos River Alluvium Development

Source: Brazos River Alluvium

Facilities: Well Field, collection pipes

Total Capital Cost: $11,953,000

Total Project Cost: $16,763,000

Total Annual Cost: $1,531,732 (Maximum of Phased Costs)

Available Project Yield: 2,200 acft/yr

Annual Cost of Water: $696 per acft/yr or $2.14 per 1,000 gal (Maximum of Phased Costs)

This project will include seventy-seven 150 gpm wells drilled to 100ft as well as 200 ft of transmission pipeline per well.

WUG: McLennan County Irrigation

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $8,201,000

Total Project Cost: $11,477,000

Total Annual Cost: $1,047,405 (Maximum of Phased Costs)

Available Project Yield: 1,000 acft/yr

Annual Cost of Water: $1,047 per acft/yr or $3.21 per 1,000 gal (Maximum of Phased Costs)

This project will include twenty-one 250 gpm wells drilled to 550ft as well as 200 ft of transmission pipeline per well.

WUG: McLennan County Mining

Strategy: Brazos River Alluvium Development

Source: Brazos River Alluvium

Facilities: Well Field, collection pipes

Total Capital Cost: $5,123,000

Total Project Cost: $7,185,000

Total Annual Cost: $708,732 (Maximum of Phased Costs)

Available Project Yield: 2,900 acft/yr (by 2070)

Annual Cost of Water: $364 per acft/yr or $1.12 per 1,000 gal (Maximum of Phased Costs)

This project will include seventy-seven 150 gpm wells drilled to 100ft as well as 200 ft of transmission pipeline per well.

12.3.22 Nolan County

WUG: Nolan County Mining

Strategy: Edwards-Trinity Development

Source: Edwards-Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $1,745,000

Total Project Cost: $2,448,000

Total Annual Cost: $223,861 (Maximum of Phased Costs)

Available Project Yield: 220 acft/yr (by 2070)

Annual Cost of Water: $1,018 per acft/yr or $3.12 per 1,000 gal (Maximum of Phased Costs)

This project will include twelve 50 gpm wells drilled to 400ft as well as 200 ft of transmission pipeline per well.

12.3.23 Robertson County

WUG: Robertson County Other

Strategy: Carrizo Aquifer Development

Source: Carrizo Aquifer

Facilities: Well Field, transmission and treatment

Total Capital Cost: $588,000

Total Project Cost: $825,000

Total Annual Cost: $87,000

Available Project Yield: 81 acft/yr

Annual Cost of Water: $ 1,079 per acft/yr or $ 3.31 per 1,000

This project will include one 100 gpm wells drilled to 1000 ft, 200 ft of 4 inch diameter transmission pipeline, and Chlorine disinfection.

WUG: Robertson County Irrigation

Strategy: Carrizo Aquifer Development

Source: Carrizo Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $91,556,000

Total Project Cost: $128,018,000

Total Annual Cost: $11,713,251 (Maximum of Phased Costs)

Available Project Yield: 16,143 acft/yr

Annual Cost of Water: $726 per acft/yr or $2.23 per 1,000 gal (Maximum of Phased Costs)

This project will include 113: 750 gpm wells drilled to 1,000 ft as well as 200 ft of transmission pipeline per well.

12.3.24 Shackelford County

WUG: Shackelford County Mining

Strategy: Other Aquifer Development

Source: Other Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $5,750,000

Total Project Cost: $8,095,000

Total Annual Cost: $741,015 (Maximum of Phased Costs)

Available Project Yield: 710 acft/yr

Annual Cost of Water: $1,044 per acft/yr or $3.20 per 1,000 gal (Maximum of Phased Costs)

This project will include seventy-six 25 gpm wells drilled to 200 ft as well as 200 ft of transmission pipeline per well.

12.3.25 Somervell County

WUG: Somervell County Mining

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $2,500,000

Total Project Cost: $3,502,000

Total Annual Cost: $320,542 (Maximum of Phased Costs)

Available Project Yield: 550 acft/yr

Annual Cost of Water: $583 per acft/yr or $1.79 per 1,000 gal (Maximum of Phased Costs)

This project will include ten 150 gpm wells drilled to 400 ft as well as 200 ft of transmission pipeline per well.

WUG: Somervell County Steam-Electric

Strategy: BRA System Operations

Source: Brazos River

Facilities: Intakes, pump stations, and transmission lines for makeup and blowdown lines

Total Capital Cost: $89,493,000

Total Project Cost: $128,162,000

Total Annual Cost: $22,866,000 (Maximum of Phased Costs)

Available Project Yield: 103,717 acft/yr

Annual Cost of Water: $285 per acft/yr or $0.87 per 1,000 gal (Maximum of Phased Costs)

The project will include two 12-mile, 42-inch makeup lines for the Comanche Peak Cooling Tower from Lake Granbury and two 12-mile, 36-in blowdown lines. The 103,717 acft/yr of yield includes existing Luminant contract supplies from BRA of 27,447 acft/yr and 76,270 acft/yr of new supplies from Sys-Ops.

12.3.26 Stephens County

WUG: Stephens County Irrigation

Strategy: Other Aquifer Development

Source: Other Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $454,000

Total Project Cost: $640,000

Total Annual Cost: $58,592 (Maximum of Phased Costs)

Available Project Yield: 26 acft/yr

Annual Cost of Water: $2,254 per acft/yr or $6.91 per 1,000 gal (Maximum of Phased Costs)

This project will include six 25 gpm wells drilled to 200 ft as well as 200 ft of transmission pipeline per well.

12.3.27 Stonewall County

WUG: Stonewall County Mining

Strategy: Blaine Aquifer Development

Source: Blaine Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $2,444,000

Total Project Cost: $3,434,000

Total Annual Cost: $316,023 (Maximum of Phased Costs)

Available Project Yield: 400 acft/yr

Annual Cost of Water: $790 per acft/yr or $2.42 per 1,000 gal (Maximum of Phased Costs)

This project will include twenty-two 50 gpm wells drilled to 250 ft as well as 200 ft of transmission pipeline per well.

12.3.28 Throckmorton County

WUG: Throckmorton County Mining

Strategy: Other Aquifer Development

Source: Other Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $1,664,000

Total Project Cost: $2,344,000

Total Annual Cost: $214,373 (Maximum of Phased Costs)

Available Project Yield: 200 acft/yr

Annual Cost of Water: $1,072 per acft/yr or $3.29 per 1,000 gal (Maximum of Phased Costs)

This project will include twenty-two 25 gpm wells drilled to 200 ft as well as 200 ft of transmission pipeline per well.

12.3.29 Washington County

WUG: Washington County Manufacturing

Strategy: Gulf Coast Aquifer Development

Source: Gulf Coast Aquifer

Facilities: Well Field, collection pipes, disinfection

Total Capital Cost: $2,374,000

Total Project Cost: $3,380,000

Total Annual Cost: $393,990 (Maximum of Phased Costs)

Available Project Yield: 326 acft/yr

Annual Cost of Water: $ 1,209 per acft/yr or $3.71 per 1,000 gal (Maximum of Phased Costs)

This project will include nine 100 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well and disinfection.

WUG: Washington County Mining

Strategy: Gulf Coast Aquifer Development

Source: Gulf Coast Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $4,457,000

Total Project Cost: $6,245,000

Total Annual Cost: $571,931 (Maximum of Annual Costs)

Available Project Yield: 823 acft/yr

Annual Cost of Water: $ 695 per acft/yr or $2.13 per 1,000 gal (Maximum of Phased Costs)

This project will include twenty 100 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well

12.3.30 Williamson County

WUG: Bartlett

Strategy: Brackish Trinity Aquifer Development

Source: Bell County- Trinity Aquifer

Facilities: Well Field, transmission and treatment

Total Capital Cost: $7,454,000

Total Project Cost: $10,428,000

Total Annual Cost: $1,388,000 (Maximum of Phased Costs)

Available Project Yield: 645 acft/yr (After Full Implementation)

Annual Cost of Water: $ 2,827 per acft/yr or $ 8.68 per 1,000 gal (Maximum of Phased Costs)

This project will include two brackish 400 gpm wells drilled to 2,500 ft, 400ft of 4 inch diameter transmission pipeline, brackish desalination, and disposal of concentrate at a landfill.

WUG: Brushy Creek MUD

Strategy: Edwards BFZ Aquifer Development

Source: Edwards BFZ Aquifer

Facilities: Well Field, transmission and treatment

Total Capital Cost: $124,000

Total Project Cost: $182,000

Total Annual Cost: $23,028

Available Project Yield: 12 acft/yr (After Full Implementation)

Annual Cost of Water: $ 1,919 per acft/yr or $ 5.89 per 1,000

This project will include one 50 gpm wells drilled to 200ft, 200ft of 4 inch diameter transmission pipeline, and treatment.

WUG: Florence

Strategy: Edwards BFZ Aquifer Development

Source: Edwards BFZ Aquifer

Facilities: Well Field, transmission and treatment

Total Capital Cost: $150,000

Total Project Cost: $218,000

Total Annual Cost: $26,226

Available Project Yield: 24 acft/yr (After Full Implementation)

Annual Cost of Water: $ 1,093 per acft/yr or $ 3.35 per 1,000

This project will include one 50 gpm wells drilled to 300ft, 200ft of 4 inch diameter transmission pipeline, and treatment.

WUG: Florence

Strategy: Brackish Trinity Aquifer Development (Bell)

Source: Bell County- Trinity Aquifer

Facilities: Well Field, transmission and treatment

Total Capital Cost:	$2,608,000
Total Project Cost:	$3,778,000
Total Annual Cost:	$701,000
Available Project Yield:	121 acft/yr (After Full Implementation)
Annual Cost of Water:	$ 5,795 per acft/yr or $ 17.78 per 1,000

This project will include one brackish 400 gpm wells drilled to 2,500ft, 200ft of 4 inch diameter transmission pipeline per well, brackish desalination, and disposal of concentrate at a landfill.

WUG: Williamson County Irrigation

Strategy: Edwards Aquifer Development

Source: Edwards Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost:	$868,000
Total Project Cost:	$1,220,000
Total Annual Cost:	$110,802 (Maximum of Phased Costs)
Available Project Yield:	66 acft/yr
Annual Cost of Water:	$1,679 per acft/yr or $5.15 per 1,000 gal (Maximum of Phased Costs)

This project will include seven 50 gpm wells drilled to 300ft as well as 200 ft of transmission pipeline per well.

12.3.31 Young County

WUG: Young County Mining

Strategy: Other Aquifer Development

Source: Other Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost:	$2,194,000
Total Project Cost:	$3,089,000
Total Annual Cost:	$282,900
Available Project Yield:	270 acft/yr

Annual Cost of Water: $1,048 per acft/yr or $3.22 per 1,000 gal (Maximum of Phased Costs)

This project will include twenty-nine 25 gpm wells drilled to 200 ft as well as 200 ft of transmission pipeline per well.

WUG: Young County Irrigation

Strategy: Other Aquifer Development

Source: Other Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $832,000

Total Project Cost: $1,172,000

Total Annual Cost: $107,418 (Maximum of Phased Costs)

Available Project Yield: 50 acft/yr

Annual Cost of Water: $2,148 per acft/yr or $6.59 per 1,000 gal (Maximum of Phased Costs)

This project will include eleven 25 gpm wells drilled to 200 ft as well as 200 ft of transmission pipeline per well.

12.4 Miscellaneous Purchases, Interconnects & Reallocations

12.4.1 Bell County

WUG: City of Harker Heights

Strategy: Additional Purchase from BRA

Source: BRA

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $109,701 (Maximum of Phased Costs)

Available Project Yield: 1,671 acft/yr

Annual Cost of Water: $ 65.65 per acft/yr or $ 0.20 per 1,000 gal (BRA Wholesale Costs)

This project will include a contract increase of up to 1,671 additional acft/yr utilizing existing infrastructure from BRA to the City of Harker Heights.

WUG: City of Harker Heights

Strategy: Purchase water from City of Killeen

Source: City of Killeen

Facilities: Pump Station, storage tank, transmission pipeline

Total Capital Cost: $1,670,000

Total Project Cost: $2,580,000

Total Annual Cost: $541,000 (Maximum of Phased Costs)

Available Project Yield: 302 acft/yr

Annual Cost of Water: $ 1,791 per acft/yr or $ 5.50 per 1,000 gal

This project will include an interconnection between the City of Killeen and the City of Harker Heights including six miles of 6 inch diameter transmission pipeline, a pump station and storage tank. Water will be purchased from the City of Killeen at an estimated wholesale rate of $977/acft. Project costs to be shared between the two entities.

WUG: City of Nolanville

Strategy: Voluntary Redistribution of Supplies from Bell WCID #1

Source: Bell WCID #1

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $202,110 (Maximum of Phased Costs)

Available Project Yield: 1,088 acft/yr

Annual Cost of Water: $ 185.76 per acft/yr or $ 0.58 per 1,000 gal (Bell County WCID #1 Wholesale Costs)

This project will include a contract increase of up to 1,088 additional acft/yr utilizing existing infrastructure from Bell County WCID #1 to the City of Nolanville.

WUG: Little River Academy

Strategy: Voluntary Redistribution of Supplies from the City of Temple

Source: Temple

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $175,860 (Maximum of Phased Costs)

Available Project Yield: 180 acft/yr

Annual Cost of Water: $ 977 per acft/yr or $ 3.03 per 1,000 gal (Assumed Temple Wholesale Costs)

This project will include a contract increase of up to 180 additional acft/yr utilizing existing infrastructure from the City of Temple to Little River Academy

WUG: Bell County-Other

Strategy: Voluntary Redistribution from Central Texas WSC

Source: Central Texas WSC

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $125,000

Available Project Yield: 500 acft/yr

Annual Cost of Water: $ 250 per acft/yr or $ 0.78 per 1,000 gal (Assumed Redistribution Cost)

This project will include a contract increase of up to 500 additional acft/yr utilizing existing infrastructure from Central Texas WSC to Bell County-Other.

WUG: Bell County-Other

Strategy: Purchase Additional Supply from Bell County WCID #1

Source: Bell County WCID #1

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $185,036

Available Project Yield: 995 acft/yr

Annual Cost of Water: $ 185.76 per acft/yr or $ 0.58 per 1,000 gal (Bell County WCID #1 Wholesale Costs)

This project will include a contract increase of up to 919 additional acft/yr in 2070 utilizing existing infrastructure from Bell County WCID #1 to Bell County-Other. For these supplies to be made available would require a reallocation of contract with Killeen.

12.4.2 Brazos County

WUG: City of College Station

Strategy: Purchase water from BRA

Source: BRA

Facilities: Pump Station, storage tank, transmission pipeline, WTP Upgrades

Total Capital Cost: $26,354,000

Total Project Cost: $37,109,000

Total Annual Cost: $6,388,000

Available Project Yield: 6,000 acft/yr

Annual Cost of Water: $ 1,065 per acft/yr or $ 3.27 per 1,000 gal

This project will include an interconnection between BRA and the City of College Station including four miles of 18 inch diameter transmission pipeline, a pump station storage tank, and WTP upgrades. Water will be purchased from the City of Killeen at an estimated wholesale rate of $56.65/acft. Project costs to be shared between the two entities.

WUG: Brazos County Irrigation

Strategy: Additional Purchase from BRA

Source: BRA

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $669,630

Available Project Yield: 10,200 acft/yr

Annual Cost of Water: $ 185.76 per acft/yr or $ 0.58 per 1,000 gal (BRA Wholesale Costs)

This project will include a contract increase of up to 10,200 additional acft/yr utilizing existing infrastructure from BRA to Brazos County Irrigation.

WUG: Brazos County Manufacturing

Strategy: Purchase of water from Texas A&M

Source: Texas A&M

Facilities: Wholesale rate included only. Not enough information to cost delivery.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $1,367,800

Available Project Yield: 1,400 acft/yr

Annual Cost of Water: $ 977 per acft/yr or $ 3.03 per 1,000 gal

This project will include a contract for the purchase of water up to 1,400 acft/yr. Infrastructure such as pipelines, pump stations, and storage tanks will be needed once the location(s) of use are determined.

12.4.3 Burleson County

WUG: Burleson County Manufacturing

Strategy: Purchase of water from the City of Caldwell

Source: The City of Caldwell

Facilities: Wholesale rate included only. Not enough information to cost delivery.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $42,500

Available Project Yield: 85 acft/yr

Annual Cost of Water: $ 500 per acft/yr or $ 1.55 per 1,000

This project will include a contract for the purchase of water up to 85 acft/yr. Infrastructure such as pipelines, pump stations, and storage tanks will be needed once the location(s) of use are determined.

12.4.4 Coryell County

WUG: Coryell County-Other

Strategy: Additional Purchase from the City of Gatesville

Source: The City of Gatesville

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $687,225

Available Project Yield: 525 acft/yr

Annual Cost of Water: $ 1,309 per acft/yr or $ 4.06 per 1,000 gal (City of Gatesville Wholesale Costs)

This project will include a contract increase of up to 525 additional acft/yr utilizing existing infrastructure from the City of Gatesville to Coryell County-Other.

WUG: Multi-County WSC

Strategy: Additional Purchase from the City of Hamilton

Source: The City of Hamilton

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $25,000

Available Project Yield: 100 acft/yr

Annual Cost of Water: $ 250 per acft/yr or $ 0.78 per 1,000 gal (City of Hamilton Wholesale Costs)

This project will include a contract increase of up to 100 additional acft/yr utilizing existing infrastructure from the City of Hamilton to Multi-County WSC.

12.4.5 Falls County

WUG: Falls County Manufacturing

Strategy: Additional Purchase from the City of Marlin

Source: The City of Marlin

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $1,522

Available Project Yield: 1 acft/yr

Annual Cost of Water: $ 1,522 per acft/yr or $ 4.72 per 1,000 gal (City of Marlin Wholesale Costs)

This project will include a contract increase of up to 1 additional acft/yr utilizing existing infrastructure from the City of Marlin to manufacturing entities.

12.4.6 Fisher County

WUG: City of Rotan

Strategy: Additional Purchase from the City of Snyder

Source: The City of Snyder

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $74,252

Available Project Yield: 76 acft/yr

Annual Cost of Water: $ 977 per acft/yr or $ 3.03 per 1,000 gal (City of Snyder Wholesale Costs)

This project will include a contract increase of up to 76 additional acft/yr utilizing existing infrastructure from the City of Snyder to the City of Rotan.

12.4.7 Grimes County

WUG: Grimes County Steam-Electric

Strategy: Purchase of reuse supply from cities of College Station and Bryan

Source: Treated effluent from College Station and Bryan

Facilities: None

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: maximum of $3,336,100

Available Project Yield: varies by decade up to 11,056 acft/yr in 2070

Annual Cost of Water: $ 304 per acft/yr or $ 0.93 per 1,000 gal

This strategy provides available treated effluent to Grimes County Steam-Electric to meet future projected shortages. Supply will be made available at the WWTP. Infrastructure may be necessary to deliver these supplies.

12.4.8 Hood County

WUG: Hood County-Other

Strategy: Additional Purchase from Acton MUD

Source: Acton MUD

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $946,000

Available Project Yield: 968 acft/yr

Annual Cost of Water: $ 977 per acft/yr or $ 3.03 per 1,000 gal (Acton MUD Wholesale Costs)

This project will include a contract increase of up to 968 additional acft/yr utilizing existing infrastructure from Acton MUD to entities in Hood County-Other.

12.4.9 Lampasas County

WUG: City of Lampasas

Strategy: Increase Treated Water Contract with Kempner WSC

Source: Kempner WSC

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $252,500

Available Project Yield: 505 acft/yr

Annual Cost of Water: $ 500 per acft/yr or $ 1.55 per 1,000 gal (City of Lampasas Wholesale Costs)

This project will include a treated water contract increase of up to 505 additional acft/yr utilizing existing infrastructure from Kempner WSC to the City of Lampasas. The City already has a BRA contract for the raw water supply.

12.4.10 McLennan County

WUG: City of Bruceville-Eddy

Strategy: Additional Purchase from Bluebonnet WSC

Source: Bluebonnet WSC

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $35,500

Available Project Yield: 71 acft/yr

Annual Cost of Water: $ 500 per acft/yr or $ 1.55 per 1,000 gal (Bluebonnet WSC Wholesale Costs)

This project will include a contract increase of up to 71 additional acft/yr utilizing existing infrastructure from Bluebonnet WSC to the City of Bruceville-Eddy.

WUG: Cross County WSC

Strategy: Purchase water from City of Waco

Source: City of Waco

Facilities: Pump Station, storage tank, transmission pipeline

Total Capital Cost: $1,672,000

Total Project Cost: $2,579,000

Total Annual Cost: $491,000

Available Project Yield: 150 acft/yr

Annual Cost of Water: $ 3,273 per acft/yr or $ 10.04 per 1,000 gal

This project will include an interconnection between the City of Waco and Cross County WSC including six miles of 6 inch diameter transmission pipeline, a pump station and storage tank. Water will be purchased from the City of Waco at an estimated wholesale rate of $979/acft.

WUG: Mart

Strategy: Purchase water from City of Waco

Source: City of Waco

Facilities: Pump Station, storage tank, transmission pipeline

Total Capital Cost: $3,601,000

Total Project Cost: $5,617,000

Total Annual Cost: $788,000

Available Project Yield: 250 acft/yr

Annual Cost of Water: $ 3,152 per acft/yr or $ 9.67 per 1,000 gal

This project will include an interconnection between the City of Waco and City of Mart including fifteen miles of 6 inch diameter transmission pipeline, a pump station, booster station and storage tank. Water will be purchased from the City of Waco at an estimated wholesale rate of $979/acft.

WUG: North Bosque WSC

Strategy: Purchase water from City of Waco

Source: City of Waco

Facilities: Pump Station, storage tank, transmission pipeline

Total Capital Cost: $1,462,000

Total Project Cost: $2,203,000

Total Annual Cost: $465,000

Available Project Yield: 200 acft/yr

Annual Cost of Water: $ 2,325 per acft/yr or $ 7.13 per 1,000 gal

This project will include an interconnection between the City of Waco and North Bosque WSC including four miles of 6 inch diameter transmission pipeline, a pump station and storage tank. Water will be purchased from the City of Waco at an estimated wholesale rate of $979/acft.

WUG: City of Riesel

Strategy: Additional Purchase from RMS WSC

Source: RMS WSC (Trinity Groundwater)

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $19,540

Available Project Yield: 20 acft/yr

Annual Cost of Water: $ 977 per acft/yr or $ 3.03 per 1,000 gal (RMS-WSC Wholesale Costs)

This project will include a contract increase of up to 20 additional acft/yr utilizing existing infrastructure from RMS WSC to the City of Riesel.

WUG: City of Woodway

Strategy: Additional Purchase from Bluebonnet WSC

Source: Bluebonnet WSC

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $51,500

Available Project Yield: 103 acft/yr

Annual Cost of Water: $ 500 per acft/yr or $ 1.55 per 1,000 gal (Bluebonnet WSC Wholesale Costs)

This project will include a contract increase of up to 103 additional acft/yr utilizing existing infrastructure from Bluebonnet WSC to the City of Woodway.

12.4.11 Nolan County

WUG: City of Sweetwater

Strategy: Purchase water from City of Abilene

Source: City of Abilene

Facilities: Pump Station, storage tank, transmission pipeline

Total Capital Cost: $8,311,000

Total Project Cost: $13,036,000

Total Annual Cost: $1,448,000

Available Project Yield: 1,777 acft/yr

Annual Cost of Water: $ 815 per acft/yr or $ 2.50 per 1,000 gal

This project will include an interconnection between the City of Abilene and the City of Sweetwater including 40 miles of 6 inch diameter transmission pipeline, a pump station and storage tank. Water will be purchased from the City of Abilene at an estimated wholesale rate of $100/acft. Project costs to be shared between the two entities.

WUG: Nolan County-Other

Strategy: Additional Purchase from the City of Sweetwater

Source: Oak Creek Reservoir

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $173,208

Available Project Yield: firm up existing contract of 168 acft/yr

Annual Cost of Water: $ 1,031 per acft/yr or $ 3.20 per 1,000 gal (City of Sweetwater Wholesale Costs)

Sweetwater's Oak Creek Reservoir conjunctive use project with subordination will firm up the existing contract with City of Blackwell (Nolan County-Other entity). Delivery of supplies uses utilizing existing infrastructure from the City of Sweetwater.

WUG: Nolan County-Manufacturing

Strategy: Additional Purchase from the City of Sweetwater

Source: The City of Sweetwater

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $1,657,848

Available Project Yield: 1,608 acft/yr

Annual Cost of Water: $ 1,031 per acft/yr or $ 3.20 per 1,000 gal (City of Sweetwater Wholesale Costs)

This project will include a contract increase of up to 1,608 additional acft/yr utilizing existing infrastructure from the City of Sweetwater to Nolan County-Manufacturing.

WUG: Nolan County Steam-Electric

Strategy: Purchase of water from Abilene

Source: The City of Abilene

Facilities: Wholesale rate included only. Not enough information to cost delivery.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $1,000,000

Available Project Yield: 10,000 acft/yr

Annual Cost of Water: $ 100 per acft/yr or $ 0.31 per 1,000 gal

This project will include a contract for the purchase of water up to 10,000 acft/yr. Infrastructure such as pipelines, pump stations, and storage tanks will be needed once the location(s) of use are determined.

12.4.12 Palo Pinto County

WUG: Palo Pinto County Irrigation

Strategy: Purchase of water from PPMWD #1

Source: PPMWD #1

Facilities: Wholesale rate included only. Not enough information to cost delivery.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $1,194,626

Available Project Yield: 2,492 acft/yr

Annual Cost of Water: $ 479 per acft/yr or $ 1.48 per 1,000

This project will include a contract for the purchase of water up to 2,492 acft/yr. Infrastructure such as pipelines, pump stations, and storage tanks will be needed once the location(s) of use are determined.

12.4.13 Robertson County

WUG: Robertson County Steam-Electric

Strategy: Purchase of water from Walnut Creek Mine

Source: Walnut Creek Mine

Facilities: Wholesale rate included only. Not enough information to cost delivery.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $4,500,000

Available Project Yield: 9,000 acft/yr

Annual Cost of Water: $ 500 per acft/yr or $ 1.55 per 1,000

This project will include a contract for the purchase of water up to 9,000 acft/yr. Infrastructure such as pipelines, pump stations, and storage tanks will be needed once the location(s) of use are determined.

12.4.14 Taylor County

WUG: City of Merkel

Strategy: Additional Purchase from the City of Abilene

Source: The City of Abilene

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $900

Available Project Yield: 9 acft/yr

Annual Cost of Water: $ 100 per acft/yr or $ 0.31 per 1,000 gal (City of Abilene Wholesale Costs)

This project will include a contract increase of up to 9 additional acft/yr utilizing existing infrastructure from the City of Abilene to the City of Merkel.

WUG: Potosi WSC

Strategy: Additional Purchase from the City of Abilene

Source: The City of Abilene

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $54,200

Available Project Yield: 542 acft/yr

Annual Cost of Water: $ 100 per acft/yr or $ 0.31 per 1,000 gal (City of Abilene Wholesale Costs)

This project will include a contract increase of up to 542 additional acft/yr utilizing existing infrastructure from the City of Abilene to Potosi WSC.

WUG: Steamboat Mountain WSC

Strategy: Additional Purchase from the City of Abilene

Source: The City of Abilene

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $21,000

Available Project Yield: 210 acft/yr

Annual Cost of Water: $ 100 per acft/yr or $ 0.31 per 1,000 gal (City of Abilene Wholesale Costs)

This project will include a contract increase of up to 210 additional acft/yr utilizing existing infrastructure from the City of Abilene to Steamboat Mountain WSC.

WUG: The City of Tye

Strategy: Additional Purchase from the City of Abilene

Source: The City of Abilene

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $1,500

Available Project Yield: 15 acft/yr

Annual Cost of Water: $ 100 per acft/yr or $ 0.31 per 1,000 gal (City of Abilene Wholesale Costs)

This project will include a contract increase of up to 15 additional acft/yr utilizing existing infrastructure from the City of Abilene to The City of Tye.

WUG: Taylor County Mining

Strategy: Purchase of water from Abilene

Source: The City of Abilene

Facilities: Wholesale rate included only. Not enough information to cost delivery.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $37,900

Available Project Yield: 379 acft/yr

Annual Cost of Water: $ 100 per acft/yr or $ 0.31 per 1,000 gal

This project will include a contract for the purchase of water up to 379 acft/yr. Infrastructure such as pipelines, pump stations, and storage tanks will be needed once the location(s) of use are determined.

WUG: Taylor County Irrigation

Strategy: Purchase of water from Abilene

Source: The City of Abilene

Facilities: Wholesale rate included only. Not enough information to cost delivery.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $101,000

Available Project Yield: 1,010 acft/yr

Annual Cost of Water: $ 100 per acft/yr or $ 0.31 per 1,000 gal

This project will include a contract for the purchase of water up to 1,010 acft/yr. Infrastructure such as pipelines, pump stations, and storage tanks will be needed once the location(s) of use are determined.

12.4.15 Williamson County

WUG: Chisholm Trail SUD

Strategy: Reallocation from Georgetown

Source: Brazos River Authority

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $391,000

Available Project Yield: 400 acft/yr

Annual Cost of Water: $ 977 per acft/yr or $ 3.03 per 1,000 gal (Georgetown Wholesale Costs)

This project will include a contract increase of up to 400 additional acft/yr utilizing existing infrastructure from Georgetown to Chisholm Trail SUD.

WUG: The City of Hutto

Strategy: Additional Purchase from Heart of Texas

Source: Heart of Texas

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $3,886,506

Available Project Yield: 3,978 acft/yr

Annual Cost of Water: $ 977 per acft/yr or $ 3.03 per 1,000 gal (Heart of Texas Wholesale Costs)

This project will include a contract increase of up to 3,978 additional acft/yr utilizing existing infrastructure from Heart of Texas to the City of Hutto.

WUG: Williamson County-Other

Strategy: Purchase from SAWS Vista Ridge Project

Source: Carrizo-Wilcox Aquifer, Burleson County

Facilities: assumed delivery through existing infrastructure

Total Capital Cost: None – SAWS will bear the cost

Total Project Cost: None – SAWS will bear the cost

Total Annual Cost: $12,408,900

Available Project Yield: 5,700 acft/yr

Annual Cost of Water: $2,177 per acft/yr or $6.68 per 1,000 gal

This project will be a contract to purchase 5,700 acft/yr from Vista Ridge Project sponsored by San Antonio Water Systems. Costs are based on costs in the Region L Plan.

12.4.16 Young County

WUG: Fort Belknapp WSC

Strategy: Additional Purchase from the City of Graham

Source: City of Graham

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $74,800

Available Project Yield: 85 acft/yr

Annual Cost of Water: $ 880 per acft/yr or $ 2.70 per 1,000 gal (City of Graham Wholesale Costs)

This project will include a contract increase of up to 85 additional acft/yr utilizing existing infrastructure from the City of Graham to Fort Belknapp WSC.

12.5 Miscellaneous WTP Upgrades and Facilities Expansions

There are a total of eleven water user groups and or wholesale water providers that will require a water treatment plant expansion, treated water reallocation or a new water treatment plant to meet potable water demand during the planning period. New or expanded treatment plants are sized for peaking capacity. However the yield of these projects is assumed to be 50% of the expansion or plant size to be consistent with the methodology for the surface water constraints. Table 12.5-1 summarizes water treatment plant strategies. This table includes only the water treatment plant strategies that are not included in any of the other Volume II water management strategy evaluations.

Table 12.5-1. Miscellaneous Strategies: Water Treatment Plant Strategies for WUGs/WWPs

WUG/WWP	Strategy	Project Yield (acft/yr)	Capital Cost	Total Project Cost	Annual Cost	Unit Cost	
						$/acft	$/kgal
Abilene	Expand WTP by 23.2	12,992	$34,537,000	$48,257,000	$7,492,000	$577	$1.77
Acton MUD	Reallocate SWATS Capacity	200	N/A	N/A	$110,400	$552	$1.69
Chisholm Trail SUD	Expand WTP by 13.4 MGD	7,500	$22,675,000	$31,675,000	$4,918,000	$656	$2.01
Georgetown	Expand WTP by 21 MGD	11,626	$31,873,000	$44,534,000	$6,917,000	$595	$1.82
Jayton	New WTP (0.4 MGD)	224	$2,531,000	$3,537,000	$549,000	$2,451	$7.52
Robinson	Expand WTP by 4 MGD	2,240	$9,413,000	$13,153,000	$2,042,000	$912	$2.80
Wellborn SUD	Expand WTP by 4 MGD	2,240	$9,413,000	$13,153,000	$2,042,000	$912	$2.80
McLennan County-Other	Upgrade Treatment for Arsenic	917	$2,455,000	$3,811,000	$936,000	$1,021	$3.13
Falls County-Other	Upgrade Treatment for Arsenic	53	$141,000	$220,000	$115,000	$2,177	$6.68
Hill County-Other	Upgrade Treatment for Arsenic	250	$671,000	$1,042,000	$364,000	$1,453	$4.46
Limestone County-Other	Upgrade Treatment for Arsenic	268	$718,000	$1,115,000	$379,000	$1,414	$4.34

13 Brush Control

Brush control is a potential water management strategy that could possibly create additional water supply in the Brazos G Area. The Texas Brush Control Program, created in 1985 and operated by the Texas State Soil and Water Conservation Board (TSSWCB), served to study and implement brush control programs until September 2011. HB1808 established a new program in 2012, the Water Supply Enhancement Program (WSEP), with the purpose and intent of increasing available surface and ground water supplies through the selective control of brush species detrimental to water conservation.

The TSSWCB collaborates with soil water conservation districts and other local, regional, state, and federal agencies to identify watersheds across the state where it is feasible to implement brush control in order to enhance water supplies. The TSSWCB uses a competitive grant process to rank feasible projects and allocate WSEP grant funds, giving priority to projects that balance the most critical water conservation need of municipal water user groups with the highest projected water yield from brush control.

An analysis of climate, evapotranspiration, and runoff in the western United States indicated that sites with tree and shrub communities need to have an evapotranspiration rate of 15 inches per year and need to receive over 18 inches of precipitation per year to yield significantly more water if converted to grassland.[1] While all ecoregions in Texas have a potential evapotranspiration rate of over 15 inches per year, the average annual rainfall in the western portion of the Brazos Basin is approximately 24 inches.

For a watershed to be considered eligible for allocation of WSEP cost-share funds, a feasibility study must demonstrate increases in project post-treatment conditions. Figure 13-1 provides the locations of completed feasibility study watersheds in Texas.

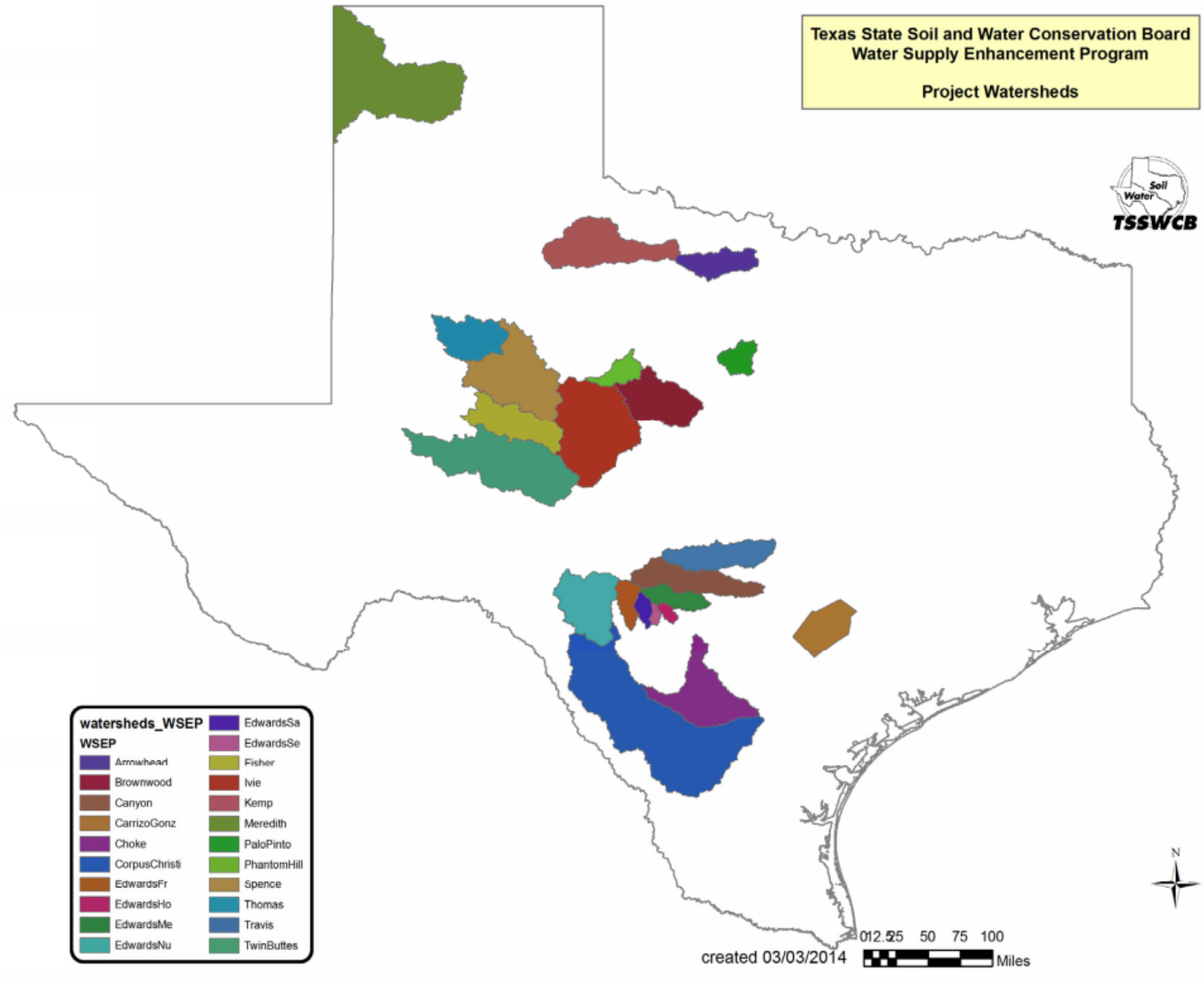
Brush control for water supply enhancement is addressed differently by the 16 Regional Water Planning Groups (RWPG). It typically is described as, alternatively, brush control, brush management, land stewardship, or range management. Brush control is a possible recommended or alternative Water Management Strategy which may have a quantified yield or a zero yield; the 2012 State Water Plan identifies only 2 regions (Regions F and J) where it is a recommended strategy with a corresponding entry in the TWDB water planning database.

In prioritizing projects for funding, brush control for water supply enhancement must be viewed favorably by the RWPG where the proposed project is located. "Viewed favorably" is distinguished as a recommended or alternative Water Management Strategy or as a Policy Recommendation. Otherwise, the application is considered not to qualify for funding.[2]

[1] Hibbert, A.R. 1983. Water Yield Improvement by Vegetation Management on Western Range lands. Water Resources Bulletin. 19:375-381.

[2] State Water Supply Enhancement Plan, TSSWCB, July 2014.

Figure 13-1. Watersheds of Completed Feasibility Studies



Studies have shown that brush management can yield additional runoff from a treated watershed. However, most experts agree that this benefit is limited during an extended drought cycle when rainfall is below normal. Because the firm supply of brush control during a drought is likely to be zero, brush control generally is not included as a recommended water management strategy since it would not be able to demonstrate an actual water supply benefit on a firm yield basis. For this reason, the Brazos G Regional Water Planning Group chose to not identify brush control as a recommended water management strategy in the 2011 Brazos G Regional Water Plan, but did include text in the plan supporting brush control as having a general benefit.

Since the European settlement of Texas, improper livestock grazing practices, fire suppression and droughts have led to the increase and dominance of noxious brush species over the native grasses and trees. The improper livestock grazing of the watershed's rangeland in the late 19th century and early 20th century reduced the ability of grasses to suppress seedling tree establishment and led to the establishment of invasive woody species, such as juniper and mesquite. This noxious brush utilizes much of the available water resources with little return to the watershed and reduced production capabilities of the region.[3]

Brush control is a land management practice that converts land that is covered with brush (such as juniper, mesquite, and salt cedar) to grasslands. This practice can potentially increase water availability through reduced extraction of soil water for transpiration and increased recharge to shallow groundwater and emergent springs. To a lesser extent, there is the potential for increased runoff during rainfall events.[4]

The actual supply benefit resulting from a brush control project is site specific and cannot be identified as a specific value for purposes of this evaluation. Under most circumstances, the additional runoff or recharge attained from a brush control project is not sustained during a prolonged drought because recharge to shallow aquifers feeding emergent springs is greatly diminished or nonexistent during a drought. The supply benefit to be obtained from this particular water management strategy will be considered to be zero.

Virtually all of the renewable and sustainable water resources available for the Brazos G Area originate as precipitation within the boundaries of the region. The inflow from the upstream tributaries of the Brazos River is limited in amount and quality. The significant majority of this precipitation falls on agricultural lands, which includes crop land, improved pastures, improved range, native range, and other rural lands, such as rocky outcrops, heavy brush and trees, and other land that is not used for production. This water then infiltrates into the soil, runs off the land to nearby streams, or evaporates from localized ponding.

Modification of the landscape has a significant impact on the partitioning of rainfall into runoff and infiltration, and ultimately the usability of this water. From a water yield standpoint, the ideal range (non-cropland) landscape has a good grass cover at all times of the year, whether the grass is alive or dormant. The grass retards surface runoff and allows more time for infiltration of the rainfall into the soil. The grass prevents sealing of the soil surface and the roots improve the soil structure, which also increases infiltration (water flow into the soil) and percolation (water flow within the soil). The active root zone of most grasses is easily within the top 3 feet of the soil, so the infiltrated soil water that is in excess to the storage capacity of the soil will percolate to the groundwater table. In aquifer outcrop areas, this percolation recharges the aquifer. If there is no aquifer, the shallow groundwater will emerge as springs and soil water movement into creek, stream, and river channels. This is the source of the highly desirable base flow of rivers that continuously recharge the reservoirs and provide wildlife habitat, livestock water, fish habitat, and recreational uses. Flash flood runoff does not contribute significantly to this base flow. The grass cover provides grazing for stock, which provides the economic incentive for the landowner to maintain the ranges in good condition.

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[3] Fort Phantom Hill Watershed: Brush Control Assessment and Feasibility Study, Prepared for TSSWCB, Brazos River Authority, 2003.

[4] Brush Control and Range Management: 2011 Brazos G Regional Water Plan.

The worst case from a water yield standpoint is a landscape that is covered with brush, such as juniper and mesquite. The grass cover is reduced under the brush (especially juniper) and, therefore, not fully effective in reducing runoff. The major impact of the brush, however, is the continuing extraction of soil water for transpiration long after the rainfall event has ended. Whereas most grasses have an effective rooting zone of 3 feet or less, mesquite can pull moisture from 10 to 20 feet deep and perhaps even deeper. Juniper is much shallower rooted, but will still extract moisture from below the grass root zone. Although each fair-sized shrub or small tree (10-foot diameter canopy) would only use 10 to 15 gallons of water a day, it would use the water every day and all of the water use for an area adds to a significant amount of groundwater consumed. Grass, with its much shallower root zone, is limited to the amount of soil water available for extraction.

Groundwater initially receives most of the additional water that is produced from brush removal, although surface water flows may be enhanced directly and indirectly following initial groundwater recharge. The rate of brush regrowth and brush control maintenance is important to maintaining stable, long-term water yield. Control methods that kill and remove the entire brush plant are more desirable than simply killing the brush. Water yield projections usually exceed actual results, and optimum results are achieved only under optimum conditions.

There are three primary methods to remove upland brush: mechanical removal, chemical removal, and prescribed burning. Bio-control through Asian leaf beetles is limited to salt cedar removal, which generally occurs in riparian zones and lakes, and may be an option for some areas in the upper portion of the Brazos River Basin.

Target species are those noxious brush species that consume water to a degree that is detrimental to water conservation (i.e., phreatophytes).

Eligible Species:

- mesquite (*Prosopis spp*.)
- juniper (*Juniperus spp*.)
- saltcedar (*Tamarix spp*.)

Other species of interest conditionally eligible:

- huisache (Acacia smallii)
- Carrizo cane (Arundo donax)

13.1 Brush Control in the Fort Phantom Hill Watershed

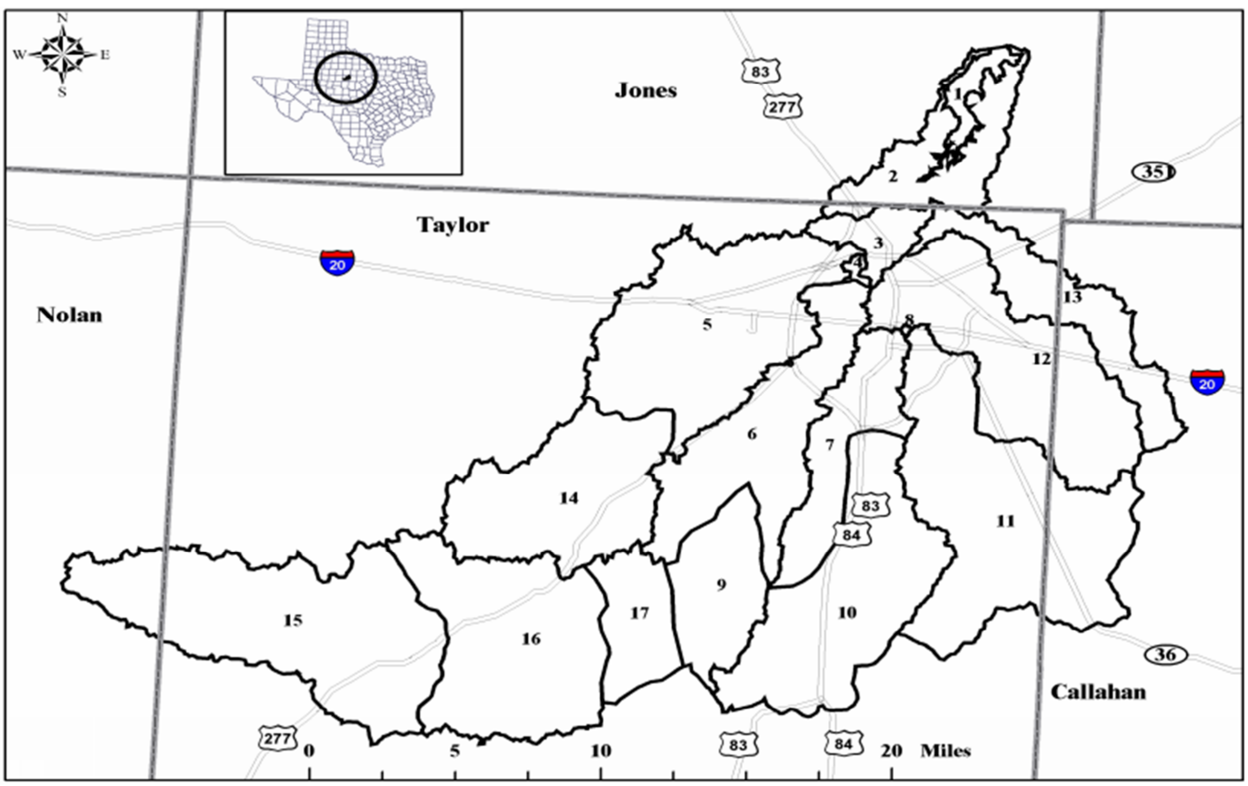
13.1.1 Watershed Characteristics

In response to declining water supply the City of Abilene began a period of reservoir and diversion construction in the Clear Fork watershed beginning in 1918 and ending in 1954. The first reservoir to be constructed was Lake Abilene, a 11,868 acre-feet capacity reservoir begun in 1918. Next came Lake Kirby, constructed in 1927, the lake impounds 8,500 acre-feet of water. The final reservoir constructed in the watershed is Fort Phantom Hill. Construction on the dam began in 1937. This reservoir has a capacity of 73,690 acre-feet. To supply additional water to the City, a diversion facility was constructed to divert flows into Fort Phantom Hill Reservoir from the Clear Fork of the Brazos River in 1954 and Deadman's Creek in 1954. Figure 13-2 presents a map with various subbasins delineated.

The western portion of the Brazos River Basin ranges from desert-like conditions to semi-arid climate with minimal rainfall. Fort Phantom Hill Reservoir, operated by the City of Abilene, is one of the major water supply reservoirs in the western part of the region. The watershed is located entirely within the Brazos River drainage system. Fort Phantom Hill Reservoir discharges to the Clear Fork of the Brazos River through Elm Creek. The Clear Fork of the Brazos River then discharges into the Brazos River in Young County southwest of the City of Graham.

The primary water quality issue for the reservoir is the increasing potential for water contamination from nonpoint source pollution. Row crop agriculture and urban expansion from the City of Abilene increase the potential for increased levels of anthropogenic compounds to enter the reservoir. Due to the watershed's high dependency on precipitation for surface water supply and declining groundwater well quantities, protecting the watershed from nonpoint source pollution is imperative.

Figure 13-2. Sub basin Map of the Fort Phantom Hill Watershed



Climate

There have been no significant changes in the historical climate patterns within the watershed, including precipitation frequency, duration, and intensity. The climate of the watershed is classified as subtropical sub-humid. The marine climate is caused by the predominant onshore flow of tropical maritime air from the Gulf of Mexico. The onshore flow is modified by a decrease in moisture and by intermittent seasonal intrusions of continental air.

The climate of the watershed is characterized by hot summers and dry winters. The amount of rainfall in the watershed varies considerably from year to year, but the average annual rainfall is approximately 24 inches. In exceptionally wet years, much of the rain comes within short periods and causes excessive runoff. The annual rainfall distribution in the watershed has two peaks. Spring is typically the wettest season, with a peak occurring in May. These spring rains are caused by convective thunderstorms, which produce high intensity, short-duration storm events. The second peak which is generated by the tropical cyclone season is usually in September. The Fort Phantom Hill Reservoir watershed is in the region that the TSSWCB has defined as generally suitable for brush control projects, based on rainfall and brush infestation.

Large evaporative rates occur in the summer months due to high temperatures, high light intensities, low humidity, and high wind speeds. The wide range between maximum and minimum temperatures in the watershed is characteristic of the Rolling Plains. Temperature changes are rapid, especially in winter and early spring when cold, dry polar air replaces the warm, moist tropical air. Periods of very cold weather are short and even in January; fair, mild weather is frequent. High daytime temperatures prevail for a long period in the summer but rapid cooling occurs after nightfall.[3]

Land Use

The land use in the watershed is dominated by agribusiness including: feedlots, rangeland, and row-crop agriculture. Rangeland is used mainly for livestock: cattle, goats, and sheep. Crop production is largely dominated by wheat, cotton, sorghum, and hay. Urban land use is limited to the City of Abilene and the towns of Potosi, Buffalo Gap, and Tye. Dyess Air Force Base lies west of the City of Abilene in the watershed and the oil industry is prominent in the watershed with exploration, drilling, refining, and oil field service industries.[3]

Hydrology

Precipitation enters the watersheds hydrologic system as runoff or infiltrates surface soil or bedrock and recharges the underlying aquifers. Additionally, some water may enter the system from groundwater flow from outside the watershed boundary; however, water may also be removed from the system in the same manner. Nearly all of the initial flow in the tributaries to Fort Phantom Hill Reservoir is derived from precipitation. With no significant change in precipitation patterns occurring since the European settlers began recording data, losses in baseflow and reservoir capacity are principally due to evaporation and water supply diversions. Discharge from the watershed occurs as streamflow into the Clear Fork of the Brazos River, as artificial surface water and groundwater withdrawals, as groundwater crossing the downgradient boundary of the watershed, and as returns to the atmosphere through evapotranspiration. Additionally, as alluvial water levels decline, water may flow from the streams and reservoirs into the alluvial deposits. Diversions of water from other watersheds into Fort Phantom Hill Reservoir help supplement storage in the reservoir relatively static.

The hydrologic characteristics of the Fort Phantom Hill Reservoir watershed are closely linked to precipitation patterns in the river basin, especially the cycles of floods and droughts. Major flood and drought events are those recurrence intervals longer than 25 years and 10 years respectively. Stream flow measurements began in the river basin in 1950, and show that there has been a drought in almost every decade since then. Average monthly inflows into the reservoir range from approximately 51,450 acft in June to about 45,500 acft in February and March. The watershed has varying topography with steep channels in the southern and western portions of the watershed and flat slopping channels in the northeast, which results in rapid runoff and flash floods during intense rain events. The average annual runoff into Fort Phantom Hill Reservoir from 1950 through 1973 was 28,800 acft.

Good quality data on stream flow in the watershed have not been collected for an extended period of time. USGS gauging stations have been operated at many locations in the watershed but gauging at any one location has been limited to less than twenty consecutive years. While most historical accounts of stream flow are qualitative, a pattern of alternating normal to severe drought conditions is apparent. However, several predictable trends exist between water levels and climatic parameters such as temperature and precipitation in the Fort Phantom Hill Reservoir watershed from 1950 to 2001, including: significant relationships between reservoir capacity and precipitation, stream flow and precipitation and evaporation and temperature.

Early explorers of the watershed mentioned springs but no quantitative historical information on spring flow exists. Use of ground water from wells and springs is reported as early as the 1880s in Taylor County. No major springs are known to be discharging in the watershed. While data on springs in Jones and Taylor Counties is limited, reports on springs from nearby Haskell County document that the drought of 1948 through 1957 resulted in the exhaustion of most of the springs in the county.[5] The earliest known irrigation with alluvium groundwater was the mid-1940s along Elm Creek.[6] In the watershed, irrigation pumping has increased steadily since the mid-1940s.

Water level fluctuations in the alluvial aquifer follow a general pattern of declining levels through summer, a stasis point through winter, and a period of recharge and increasing levels in the spring. The water level in the alluvium of the watershed is experiencing a gradual decline with time. This is most likely a result of the increased pumping volume in the area.

The highly intermittent nature of stream flow in the watershed, the watershed’s strong correlation between reservoir capacity and precipitation, and the watershed’s dependence on diversions of water from other watersheds suggest that there is little groundwater discharge into the watershed. With declining alluvial aquifer levels and intermittent springs it is unlikely that a significant amount of surface water in the Fort Phantom Hill Reservoir watershed is derived from groundwater.

The general direction of movement of groundwater in the watershed is northerly towards Fort Phantom Hill Reservoir. The slope of the water table in the alluvium in the watershed is directly correlated to the slope of the land. However, localized pumping can

[5] Brune, Gunnar. 1980. Springs of Texas. Texas A&M University Press, College Station, Texas.
[6] Taylor, Howard D. 1978. Occurrence, Quantity, and Quality of Ground Water in Taylor County, Texas. Texas Department of Water Resources, Austin, Texas.

cause the water in the immediate area of the pumping to move towards these points of artificial discharge instead of towards Fort Phantom Hill Reservoir. The main sources of recharge to the aquifer is precipitation falling directly on the outcrop and surface runoff; however, in areas of irrigation the water used can also serve as a source of recharge if it infiltrates the alluvium. Because natural discharge through springs is not known in the watershed, groundwater discharge from the alluvium is a result of pumping.

Annual groundwater discharge in the Fort Phantom Hill Reservoir watershed can vary considerably depending on the amount, frequency, and distribution of precipitation. Groundwater levels, storage, and natural discharge increase during periods of high recharge. Conversely, during periods of low recharge, groundwater levels decline, storage is reduced, and natural discharge ceases. When groundwater levels and the land surface are at equal elevations, groundwater in the watershed can discharge at seeps and springs.[3]

13.1.2 Potential Brush Control Project

Even though landowner support is assessed as high by the TSSWCB, the levels of participation assumed in the TSSWCB feasibility study (100 percent) will probably not be realized. Actual participation and removal percentages most likely will be less. For this project it was assumed that landowner participation would be approximately 50 percent of the total watershed. Subbasins with the highest projected amount of water generated from brush removal per acre were targeted for inclusion in the project. It was also assumed that 75 percent of the brush within the targeted subbasins would be removed. The subbasin data were obtained from the feasibility study and are shown in Table 13.1-1.

Table 13.1-1. Subbasins Targeted for Potential Brush Control Project

Subbasin[1]	Total Area (acres)	Total Brush Area (acres)	Treated Brush (acres)
1	2,540	537	403
8	68	28	21
15	36,789	24,241	18,181
2	12,087	3,735	2,801
3	4,451	1,114	836
10	27,797	12,690	9,518
5	30,985	9,356	7,017
9	11,914	5,931	4,448
4	453	149	112
6	21,928	7,275	5,456

Table 13.1-1. Subbasins Targeted for Potential Brush Control Project

Subbasin[1]	Total Area (acres)	Total Brush Area (acres)	Treated Brush (acres)
16	28,340	19,218	NI
14	23,069	12,073	NI
17	8,803	6,102	NI
7	12,483	4,431	NI
12	28,282	11,245	NI
11	38,084	14,597	NI
13	13,045	5,672	NI
Total - Watershed	301,118	138,394	n/a
Total - Project	149,012	65,056	48,792

[1]Listed in order of projected water production
NI – Not included in potential brush control project.

13.2 Environmental Issues

13.2.1 Existing Environment

The Lake Fort Phantom Hill Watershed Brush Control Study Area includes portions of Jones, Taylor, Callahan and Nolan Counties. The central and western portions of the study area are within the Edwards Plateau Vegetational Area, while the northern and eastern portions of the study area are within the Rolling Plains Vegetational Area.[7] The physiography of the study area includes recharge sands, massive limestone, caliche with some soil cover, severely eroded lands, and undissected red beds.[8] Topography varies from rough, rolling hills to nearly level terrain. This diverse area contains several soil associations including the Tarrant-Tobosa association which consists of well-drained upland soils that are very shallow to steep calcareous and cobbly clays. The Tillman-Vernon association consists of deep, nearly level to sloping, we ll-drained upland soils that include non-calcareous to calcareous clay loams and clays. The Sagerton-Rowena-Rotan association includes deep, nearly level to gently sloping, well-drained soils that are

[7] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin. *Vegetational Areas of Texas*. Texas A&M University, Agricultural and Experiment Station Leaflet 492, 1960.

[8] Kier, R.S., L.E. Garner, and L.F. Brown, Jr. *Land Resources of Texas – A map of Texas Lands Classified According to Natural Suitability and Use Considerations*. University of Texas, Bureau of Economic Geology, Land Resources Laboratory Series, 1977.

comprised of noncalcareous to calcareous clay loams.[9] Major aquifers that may are minimally represented in the study area include the Edwards-Trinity Aquifer in the western portion and the Trinity Aquifer in the eastern portion.[10] Area climate is characterized as subtropical, sub humid, with hot summers and dry winters and average annual precipitation ranges between 23 and 25 inches.[11]

Vegetation and resulting wildlife habitats within the study area have been greatly affected by human activities over the last 200 years. The prairie grasslands once covering a large portion of the area have gradually changed to shrub and brush land communities as a result of the suppression of wild fires and intensive livestock grazing. Five major vegetation types now occur in the study area,[12] these include: Mesquite-Lotebush Shrub, Mesquite-Juniper Brush, Mesquite Juniper Live Oak Brush, Crops and Urban. Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Major land uses in the area include cattle ranches and farms, oil fields, hunting leases, and minerals.[13]

13.2.2 Potential Impacts

Threatened & Endangered Species

Table 13.2-1 lists the state and federally threatened, endangered, or otherwise rare species that could occur in Jones, Taylor, Callahan, and Nolan Counties. This table includes the listing status of these taxa, as well as descriptions of suitable habitat for each species. Inclusion in this table does not mean that a species will occur within the project area but acknowledges the potential for its occurrence within one of the four counties in which the project area exists. On-site evaluations by qualified biologists would be required to confirm or refute the occurrence of sensitive species or habitats. A total of 14 species could potentially occur within the vicinity of the project that are state or federally listed as threatened or endangered according to county lists of rare species provided by the U.S. Fish and Wildlife Service (USFWS) and the Texas Parks and Wildlife Department (TPWD). These listed species include three reptiles, five birds, three mammals, one freshwater mussel, and two fish.

Two bird species, two fish species, and three mammal species which are federally-listed as endangered could occur (or historically occurred) in the study area. The bird species include the black-capped vireo (*Vireo atricapilla*), and whooping crane (*Grus americana*). These birds are seasonal migrants that could pass through the project area. The black-capped vireo prefers oak-juniper woodlands with a shrub and tree layer with open grassy

[9] Soil Conservation Service. *Soil Survey of Taylor County, Texas*. U.S. Department of Agriculture Soil Conservation Service, 1976.

[10] Texas Water Development Board. *Major Aquifers of Texas, 1990*. A map.

[11] Larkin, T.J., and G.W. Bomar. *Climatic Atlas of Texas*. Texas Department of Water Resources LP-192, 1983.

[12] McMahan, C.A., R.G. Frye, and K.L. Brown. *The Vegetation Types of Texas including Cropland*. Texas Parks and Wildlife Department Bulletin 7000-120, 1984.

[13] Telfair, R.C. II. *Ecological Regions of Texas: Description, Land Use, and Wildlife*. In Ray C. Telfair, Editor, *Texas Wildlife Resources and Land Uses*. University of Texas Press. Austin, Texas, 1999.

spaces and the whooping crane could potentially utilize areas which contain water sources for food acquisition and rest during their migratory trips to and from the Gulf Coast. The whooping crane would not likely be directly affected by brush control practices; however the impacts of brush control could directly affect the black-capped vireo. This bird species nests in brush communities about 6 feet in height with about 30 to 60 percent canopy coverage.[14]

The sharpnose shiner (*Notropis oxyrhynchus*) and smalleye shiner (*Notropis buccula*) are listed as endangered by the USFWS.[15] These two minnows are native to the arid prairie streams of Texas and are considered to be in danger of extinction. The USFWS has designated approximately 623 miles of the Upper Brazos River Basin and the upland areas extending beyond the river channel by 98 feet on each side as critical habitat for these two fish. These areas of the Upper Brazos River Basin occur within the counties of Baylor, Crosby, Fisher, Garza, Haskell, Kent, King, Knox, Stonewall, Throckmorton and Young. Because preferred habitat for these species does not occur within the study area, they are not anticipated to be affected by the proposed project activities.

Mammal species which are federally listed as endangered include the gray wolf (*Canis lupus*), red wolf (*Canis rufus*), and black-footed ferret (*Mustela nigripes*). Both the gray wolf and red wolf are considered to be extirpated within the project counties. Although the black-footed ferret (*Mustela nigripes*) historically occurred in the area, there have been no confirmed reports of this species in Texas since 1963.[16] The black-footed ferret historically occurred in prairie dog towns, but is thought to be extirpated throughout its historical range in Texas. Therefore these listed mammal species would not be adversely affected by the brush control activities.

There are six additional species which are listed as threatened by the state of Texas within the project counties. These include the American peregrine falcon (*Falco peregrinus anatum*), bald eagle (*Haliaeetus leucocephalus*), piping plover (*Charadrius melodus*), Texas fawnsfoot (*Truncilla macrodon*), Brazos water snake (*Nerodia harteri*), and Texas horned lizard (*Phrynosoma cornutum*). The three state threatened bird species are migrants within the project area and are not anticipated to be adversely affected by the project. The Texas fawnsfoot is a freshwater mussel species found in rivers and larger streams and is intolerant of impoundment. The Brazos water snake is known to inhabit rocky areas along waterways within the Brazos River Basin. Changes in aquatic habitat within the study area could potentially affect these species.

The Texas horned lizard is normally found in varied and sparsely vegetated uplands. Suitable habitat for the state threatened Texas horned lizard may exist within the study area and possible impacts to this species should be assessed during project planning. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats within the study area. The presence or absence of potential

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[14] Campbell, Linda. *Endangered and Threatened Animals of Texas*. Texas Parks and Wildlife Department, Endangered Resources Branch, Austin, Texas, 1995.

[15] USFWS. 2014. *Sharpnose Shiner and Smalleye Shiner Protected under the Endangered Species Act*. News Release, August 4, 2014.

[16] Campbell, Linda. 1995. Endangered and Threatened Animals of Texas. Texas Parks and Wildlife Department, Endangered Resources Branch. Austin, Texas.

habitat does not confirm the presence or absence of a listed species. No species specific surveys were conducted in the study area for this report.

Table 13.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Jones, Taylor, Callahan, and Nolan Counties

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
BIRDS					
American peregrine falcon	*Falco peregrinus anatum*	Migrant and local breeder in West Texas.	DL	T	Possible Migrant
Arctic peregrine falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL	--	Possible Migrant
Baird's sparrow	*Ammodramus bairdii*	Found in shortgrass prairie with scattered low bushes and matted vegetation migratory in western part of state.	--	--	Possible Migrant
Bald eagle	*Haliaeetus leucocephalus*	Primarily found near waterbodies.	DL	T	Nesting/ Migrant
Black-capped vireo	*Vireo atricapilla*	Prefers oak-juniper woodlands with distinctive patchy, two-layered aspect; shrub and tree layer with open, grassy spaces.	LE	E	Possible Migrant
Ferruginous hawk	*Buteo regalis*	Open country primarily prairies, plains, and badlands nesting near water.	--	--	Possible Migrant
Mountain plover	*Charadrius montanus*	Non-breeding, shortgrass plains and fields	--	--	Nesting/ Migrant
Piping plover	*Charadrius melodus*	A small pale shorebird of open sandy beaches and alkali flats, the Piping Plover is found along the Atlantic and Gulf coasts.	LT	T	Possible Migrant
Snowy plover	*Charadrius alexandriunus*	Potential migrant winters along coast	--	--	Possible Migrant
Sprague's pipit	*Anthus spragueii*	Migrant in Texas in winter mid Sept. to early April. Strongly tied to native upland prairie.	C	--	Possible Migrant

Table 13.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Jones, Taylor, Callahan, and Nolan Counties

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Western burrowing owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna	--	--	Resident
Western snowy plover	*Charadrius alexandrines nivosus*	Potential migrant, winters along coast.	--	--	Possible Migrant
Whooping crane	*Grus americana*	Potential migrant	LE	E	Potential Migrant
FISHES					
Sharpnose shiner	*Notropis oxyrhynchus*	Endemic to Brazos River drainage. Found in large rivers.	LE	--	Resident
Smalleye shiner	*Notropis buccula*	Endemic to upper Brazos River system and its tributaries. Found in medium to large prairie streams with sandy substrate.	LE	--	Resident
MAMMALS					
Black-footed ferret	*Mustela nigripes*	Extirpated, inhabited prairie dog towns.	LE	--	Historic Resident
Black-tailed prairie dog	*Cynomys ludovicianus*	Found on dry, flat, short grasslands.	--	--	Resident
Cave myotis bat	*Myotis velifer*	Roosts colonially in caves, rock crevices	--	--	Resident
Gray wolf	*Canis lupus*	Extirpated formerly known in western two-thirds of the state.	LE	E	Historic Resident
Plains spotted skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	*Canis rufus*	Extirpated.	LE	E	Historic Resident
MOLLUSKS					

Table 13.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Jones, Taylor, Callahan, and Nolan Counties

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
Texas fawnsfoot	*Truncilla macrodon*	Found in rivers and larger streams, intolerant of impoundment.	C	T	Resident
PLANTS					
Dwarf broomspurge	*Chamaesyce jejuna*	Found on grama-grass prairie on caliche uplands and slopes.	--	--	Resident
Llano butterweed	*Packera texensis*	Endemic to Llano Uplift of the Edwards Plateau on granite sands.	--	--	Resident
Warnock's coral-root	*Hexalectric warnockii*	Found in leaf litter and humus in oak-juniper woodlands on shaded slopes and creekbeds in canyons.	--	--	Resident
REPTILES					
Brazos water snake	*Nerodia harteri*	Found in upper Brazos River drainage in shallow water with rocky bottoms.	--	T	Resident
Spot-tailed earless lizard	*Holbrookia lacerata*	Found in central and southern Texas and adjacent Mexico in moderately open prairie-brushland.	--	--	Resident
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands.	--	T	Resident

Table 13.2-1. Endangered, Threatened, Candidate and Species of Concern Listed for Jones, Taylor, Callahan, and Nolan Counties

Common Name	Scientific Name	Summary of Habitat Preference	USFWS Listing	TPWD Listing	Potential Occurrence in County
LE/LT=Federally Listed Endangered/Threatened DL=Federally Delisted C=Candidate for Federal Listing PT=Proposed Threatened E, T=State Listed Endangered/Threatened Blank = Considered rare, but no regulatory listing status TPWD, 2015. Annotated County List of Rare Species –Nolan County 5/25/2011, Jones County 1/27/2015, Callahan County 8/7/2012, and Taylor County 5/25/2011. USFWS, 2015. Endangered Species List for Haskell, Jones, Shackelford and Baylor Counties, Texas. At http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action, April 2, 2015.					

Wildlife Habitat

The project area is located within the Kansan biotic province. The Kansan Province is divided into three districts that include (from west to east) the short-grass plains, mixed-grass plains, and the mesquite plains. The project area is situated within the mesquite plains district. Within this district the typical vegetation community generally consists of clusters of mesquite and other shrubs interspersed with open areas of grasses. Common wildlife species found in the Kansan Biotic Province include the Great Plains toad (Anaxyrus cognatus), turkey vulture (Cathartes aura), scaled quail (Callipepla squamata), big brown bat (Eptesicus fuscus) and eastern collared lizard (Crotaphytus collaris) among others. Wildlife species inhabiting the project area utilize it to varying extents depending on their specific biologic needs.

Cultural Resources

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available GIS datasets provided by the Texas Historical Commission (THC), there are no State Historic Sites within the study area; however 52 National Register Properties, 9 National Register Districts, 17 cemeteries and 38 historical markers are located within the study area. The owner or controller of the project would be required to coordinate with the Texas Historical Commission regarding potential impacts to cultural resources.

Specific project activities such as brush control generally have sufficient design flexibility to avoid most impacts or significantly mitigate potential impacts to geographically limited environmental and cultural resource sites. Field surveys conducted at the appropriate phase of development should be employed to minimize the impacts of project construction and operations on sensitive resources.

Threats to Natural Resources

Impacts of brush control can positively or negatively affect the existing terrestrial and aquatic environments depending on the type of control method used and the location, and extent of application. If brush removal is planned and implemented as part of a comprehensive range management strategy, then positive environmental benefits can result. Properly planned and applied brush control using mechanical, chemical, or prescribed fire can enhance soil conditions, increase water tables, provide greater streamflow thus improving water quantity and quality, provide higher energy and nutrient inputs, increase vegetation diversity, and enhance the quality of wildlife habitat with resulting higher abundance and diversity of wildlife species. However, removal of established of brush on uplands or removal of riparian woody vegetation along stream courses without consideration of a comprehensive long term management strategy can be detrimental to wildlife and associated habitats. Other adverse impacts could occur depending on the type of control method employed.

Mechanical treatment using mechanized equipment to root plow, brush mow, bulldoze or scrape the ground surface could result in moderate to high levels of soil disturbance that could result in erosion and sedimentation into adjacent streams and water bodies. There would also be a change in vegetation communities toward earlier succession species. Soil disturbance would favor both re-establishment of both grasses and forbs (herbaceous) in addition to re-invasion of woody brush and shrub species, prompting the need for re-treatment in future years. Soil disturbance would also have the potential of disturbing cultural or archeological artifacts, if present, within 12 inches of the ground surface. The probability of cultural and archeological artifacts being present is higher for sites along water courses, and old homesteads and settlements.

The use of herbicides for brush control must to follow the current recommended practices for their application. Some of these chemicals are to be used only on upland areas and are not approved for use in or near water. If improperly applied, aerial or ground spraying could have possible biological impacts to wildlife through direct contact and/or potential pollution of surface water. There could also be effects to non-target plant species from broadcast applications.

The use of prescribed fire provides many ecological benefits. Historically, prairie wild fires were a major factor is suppressing invasion of woody vegetation among the prairie grassland communities. Other benefits include increased soil fertility through release of organic nutrients, stimulated growth of new plant material, and greater diversity of herbaceous plants tolerant to fire. Prescribed fire could adversely affect other vegetation such as damaging or killing established trees not intended for treatment, can be difficult to control if applied during the wrong season or during improper weather conditions, and could affect air quality regulated under federal and state laws.

13.3 Engineering and Costing

Costs associated with brush control in each subbasin were assessed using the cost estimates developed for the feasibility study. The total cost for each subbasin includes costs typically attributed to the landowner, as well as State participation costs. To assess the cost for the brush control project, the total cost was amortized over a 10-year period at an annual interest rate of 5.5 percent. Ten years were selected because the removal cost includes 10 years of maintenance activities and that is equivalent to the life of the project.

Table 13.3-1. Cost Estimate Summary for Brush Control Project

Item	Estimated Costs for Facilities
Chemical and Mechanical Brush Treatment (48,792 acres)	$5,579,000
TOTAL COST OF FACILITIES	**$5,579,000**
Interest During Construction (4% for 10 years with a 1% ROI)	$1,953,000
TOTAL COST OF PROJECT	**$7,532,000**
Debt Service (5.5 percent, 10 years)	$999,295
TOTAL ANNUAL COST	**$999,295**
Available Project Yield (acft/yr)[1]	0
[1] The yield of brush control during a drought is likely to be zero.	

13.4 Implementation Issues

The extent of implementation of brush control will depend on the amount of funding available for state cost-sharing with landowners. State funding would be contingent upon following provisions of the Water Supply Enhancement Program. Other funding may be available through federal and local agencies, which may have additional provisions. The extent of brush control that may be desired by landowners will depend on how they plan to manage their land for wildlife and how the brush control will affect the value of the land for wildlife recreation purposes. In recent years, the value of ranch lands which have sufficient brush cover to support wildlife populations, particularly white-tailed deer, wild turkey, bobwhite and scaled quail, has increased at a faster rate than the value of those lands which are void of brush or woody vegetation. Consequently, many landowners can be expected to support brush control to the extent that it does not exclude wildlife populations.

Other implementation issues for land owner participation include the perceived economic benefit of brush control. If the land is currently not actively managed for ranching or wildlife recreation the owner may chose not to participate. Decreased profitability of sheep, goat and cattle grazing systems will influence the economics of brush control by ranchers, and consequently their willingness to participate. Also, the size of the land tracts can affect the total amount of brush removed and the effectiveness of a program. Watersheds that contain many small tracts are less likely to have the contiguous land owner participation that is needed to realize the water supply benefits associated with brush control. No land acquisition or relocations would be required for this water management strategy.

Brush control can positively affect the environment depending on the type of control method used, location, and extent of application. However, if brush removal is not planned properly or implemented as part of a comprehensive range management strategy, negative environmental impacts can result.

Grazing management is very important following any type of upland brush control to allow the desirable forages to exert competition with the brush plants and to maintain good herbaceous groundcover, which hinders establishment of woody plant seedlings. Continued maintenance of brush is necessary to ensure the benefits of this potential strategy.

On specific tracts where brush control would incorporate state or federal funding, regulatory compliance with the Texas Antiquities Code and National Historic Preservation Act may be required that may involve cultural resource surveys and incorporation of preservation measures. The Texas Commission on Environmental Quality has established regulations governing prescribed burning. There may also be local and county regulations associated with burning practices.

The success of such a program for providing increased water supplies is dependent on increased surface water runoff and significant landowner participation. It should be noted that public benefit in the form of additional water depends on proper implementation and maintenance of the appropriate brush control practices. It is also important to understand that rancher participation in a brush control program primarily depends on the rancher's expected economic consequences resulting from participation. The primary benefits of brush control might not lie with increased surface water runoff, but increased deep soil percolation and improved land management. Significant landowner participation will require adequate external funding on a continuous basis because the benefits of brush control are lost if the maintenance activities are not continued. Securing these funds will depend upon the success of on-going pilot studies and brush programs. Support of the on-going brush programs with continued data collection is necessary to demonstrate the realized water benefits of brush control.

This water supply option has been compared to the plan development criteria, as shown in Table 13.4-1, and the option meets each criterion.

Table 13.4-1. Evaluations of Brush Control Option to Enhance Water Supplies

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Uncertain
2. Reliability	2. Low reliability during drought conditions
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Negligible impact
2. Habitat	2. High positive or negative impact
3. Cultural Resources	3. Negligible to low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. High positive or negative impact
6. Wetlands	6. Negligible impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts	• None

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