BRAZOS G
WATER PLANNING GROUP

Brazos River Authority

2021 Brazos G Regional Water Plan

Volume II
Evaluation of Water Management Strategies

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1 Water Management Strategies

Title 31 TAC 357.7.34 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, interbasin transfers, new supply development, and others. Many of the strategies evaluated are updates from the evaluations performed for the 2016 Plan, with costs and supply typically being the most common items updated. Costs for these strategies as shown in specific Water User Group (WUG) and Wholesale Water Provider (WWP) plans have been updated to reflect September 2018 prices.

1.1 Identification of Potentially Feasible Strategies

TWDB rules require that the process for identifying potentially feasible Water Management Strategies (WMSs) be documented at a public meeting (31 TAC §357.12(b)). This section describes the documented process used by Brazos G to identify potentially feasible WMSs. On February 7, 2018, Brazos G formally considered the process for identifying, evaluating and selecting WMSs as described below.

Process for identifying, evaluating and selecting WMSs:

1. Include strategies identified in previous plans
    a. Include recommended and alternative strategies from 2016
    b. Include strategies evaluated, but not recommended in 2016
    c. Include strategies evaluated in previous Plans that were not moved forward
2. Identify draft needs and develop additional ideas to meet those needs
3. Maintain ongoing communication from local interests through the process

Then, an initial list of potentially feasible strategies is determined, and additional WMSs are included if local interests request them and the planning schedule and budget allow for the addition.

The Scope of Work Committee of Brazos G met on July 17, 2018, and August 17, 2018, to identify potentially feasible WMSs and determine which strategies to recommend evaluating for the 2021 Brazos G Plan.

Seawater desalination was not considered potentially feasible due to distance from the coast.

Brackish groundwater was not considered because it is considered part of the MAG, and would have only been considered if it was cheaper than going to a freshwater portion of an aquifer. The TWDB has recently identified Brackish Groundwater Production Zones, the supplies from which might be considered as separate from the MAG. In the next cycle of regional water planning, these Brackish Groundwater Production Zones might constitute additional sources of supply for water management strategies.

On August 12, 2020, the BGRWPG identified the threshold of significant water needs for consideration of aquifer storage and recovery projects to be 10,000 acft/yr or greater. Table 1-1 presents the 15 WUGs having needs exceeding this threshold, and an assessment of ASR potential for each WUG. Aquifer storage and recovery is recommended as a water management strategy for seven of those, either specifically as a strategy where the WUG is the sponsor, or as a strategy for a WWP that provides the WUG supply. In addition, ASR is recommended as a water management strategy for other WUGs with needs less than the 10,000 acft/yr threshold. ASR is not considered as a potential strategy for county-aggregated WUGs such as Irrigation or Steam-Electric unless a specific project sponsor requests it be recommended. None have made the request.

Table 1-1. Assessment of ASR Potential

Water User Group	2070 Need (acft/yr)	Assessment of ASR Potential
Abilene	(18,910)	ASR not identified as potentially feasible; hydrogeology appears unsuitable
Bryan	(19,650)	ASR recommended as a water management strategy
College Station	(13,360)	ASR recommended as a water management strategy
County-Other, Williamson	(37,814)	ASR recommended for WWP (BRA)
Georgetown	(65,467)	ASR recommended as a water management strategy and recommended for WWP (BRA)
Hutto	(10,703)	ASR recommended for WWP (BRA)
Leander	(19,041)	ASR recommended for WWP (LCRA, Region K)
Round Rock	(16,566)	ASR recommended for WWP (BRA) (LCRA, Region K)
Temple	(17,103)	ASR recommended for WWP (BRA)
Irrigation, Comanche	(15,292)	ASR not identified as potentially feasible
Irrigation, Haskell	(15,835)	ASR not identified as potentially feasible
Irrigation, Knox	(10,706)	ASR not identified as potentially feasible
Mining, Williamson	(10,745)	ASR not identified as potentially feasible
Steam-Electric Power, Milam	(32,254)	ASR not identified as potentially feasible
Steam-Electric Power, Somervell	(35,867)	ASR not identified as potentially feasible

Potentially feasible water management strategies evaluated during preparation of the 2021 Plan are listed in Table 1-2.

Table 1-2. Potentially Feasible Water Management Strategies Evaluated for the 2021 Brazos G Regional Water Plan

Chapter (Volume II)	*Water Management Strategy and Description*
2	**Water Conservation** (implement accelerated use of various water conservation techniques to achieve water savings above what is already included in the TWDB water demand projections)
3	**Wastewater Reuse** (use highly treated wastewater treatment plant effluent to meet non-potable and potable water needs)
4	**New Reservoirs** (new or updated evaluations of the following proposed new reservoirs) • Brazos River Main Stem Off-Channel Reservoirs • Brushy Creek Reservoir • Cedar Ridge Reservoir • Coryell County Off-Channel Reservoir • City of Groesbeck Off-Channel Reservoir • Hamilton County Reservoir • NCTMWA Lake Creek Reservoir • Red River Off-Channel Reservoir near Arthur City • South Bend Reservoir • New Throckmorton Reservoir • Turkey Peak Dam - Lake Palo Pinto Enlargement
5	**Groundwater** • City of Bryan Groundwater Strategies • City of College Station Groundwater Strategies • Williamson County Groundwater Strategies
6	**BRA System Operations**
7	**Conjunctive Use** (conjunctively use surface water supplies with available groundwater supplies) • Lake Granger Augmentation • Oak Creek Reservoir and Champion Well Field
8	**Aquifer Storage and Recovery** (Inject or percolate excess surface water into groundwater aquifers, storing for future use) • City of Bryan ASR • City of College Station ASR • Lake Georgetown ASR • Lake Granger ASR • Johnson County SUD and Acton MUD ASR • Trinity ASR in McLennan County
9	**Regional Water Supply Projects** • Bosque County Regional Project • Milam County Groundwater and Alcoa Supply for Williamson County • Brushy Creek RUA Water Supply Project • East Williamson County Water Supply Project • Lake Belton to Stillhouse Hollow Pipeline • Lake Whitney Water Supply Project (Cleburne) • Somervell County Water Supply Project • Trinity Basin Supplies to the Middle Brazos • West Central Brazos Water Distribution System • West Texas Water Partnership Supply to Abilene (Region F evaluation)
10	**Augmentation of Existing Reservoir Supplies** • Lake Aquilla Storage Reallocation • Lake Granger Storage Reallocation • Lake Whitney Reallocation • Lake Whitney Over-Drafting Supply with Off-Channel Reservoir • Millers Creek Reservoir Augmentation
11	**Control of Naturally Occurring Salinity**
12	**Brush Control** (increase deep percolation and discharge to streams by removing unwanted brush
13	**Miscellaneous Strategies** (various pipelines, treatment plants and groundwater wells to meet projected needs of water user groups and wholesale water providers)

1.2 Evaluation and Recommendation of Strategies

The following chapters contain technical evaluations of the potentially feasible water management strategies the Brazos G Regional Water Planning Group (RWPG) and the Texas Water Development Board (TWDB) wished to consider. 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 Brazos G Area.

Technical evaluations of water management strategies are presented at public meetings of the Brazos G RWPG. Most strategies are identified as potentially feasible to serve specific WUGs or WWPs, and are usually evaluated in coordination with potential sponsors. Other strategies are initially identified as potentially feasible to meet needs for multiple WUGs and/or WWPs. In the case where the preferred strategy for a WUG or WWP has not been communicated, the Brazos G RWPG recommends a strategy based on the WUG's existing sources of supply and the location and sources available to the strategy. These recommendations are presented and reviewed at three public subregional meetings prior to adoption of the Initially Prepared Plan to provide the opportunity for WUGs to request modification of the recommendations prior to adoption of the Initially Prepared Plan. The Brazos G RWPG desires for the Brazos G Regional Water Plan to reflect the initiatives of the water providers in the Brazos G Area.

1.3 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 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 minimal).

- 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 require 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 management strategies.
- Interbasin Transfers – The planning group may consider interbasin transfers as a supply option. The criteria require that the participating entities recognize and account for 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 – 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.

1.4 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.

1.5 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 1-3. All costs represent September 2018 prices.

Table 1-3. 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 and Surveying
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 Exhibit C, Second Amended General Guidelines for Fifth Cycle of Regional Water Plan Development (April 2018)[1], debt service for all projects was calculated assuming an annual interest rate of 3.5 percent and a 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 $0.08 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

[1] Available for download at: https://www.twdb.texas.gov/waterplanning/rwp/planningdocu/2021/doc/current_docs/contract_docs/2ndAmendedExhibitC.pdf?d=123001.1799999047

strategies are referred to as miscellaneous strategies and are summarized in Volume II, Section13.

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.

1.6 Quantitative Factors Used to Evaluate Environmental and Agricultural Impacts of Potentially Feasible 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.

Potential water management strategies were evaluated for potential impacts to the following environmental and agricultural resources.

- **Environmental water needs** – The water necessary to sustain a sound ecological environment. Surface water strategies could potentially utilize this water source. Reuse supplies could potentially use water that would have otherwise been discharged into a surface water body. Groundwater strategies are assumed to not have an impact on surface water needed for environmental needs.
- **Wildlife habitat** – The area disrupted from implementation of a strategy.
- **Threatened and 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 a proposed project area to determine if any threatened or endangered species or critical habitats for these species are present. The threated, endangered, candidate and species of greatest conservation need located in a county where a potential strategy is located were identified and used to quantitatively assess potential impacts.
- **Wetlands** – The area classified as wetlands that is disrupted from the implementation of a strategy. Pipelines, wells, pump stations, and water treatment plants are anticipated to be located outside of wetland areas. Therefore, only reservoir footprints and surface water intakes are considered to impact wetlands.
- **Cultural resources** – The physical evidence or place of past human activity that may be disrupted from the implementation of a strategy.
- **Bays and estuaries water needs** – The freshwater inflow necessary to sustain a sound ecological environment in the bays, estuaries, and arms of the Gulf of Mexico. Potential strategies included in the Brazos G Plan are located a

substantial distance from the coast and are not anticipated to impact water needs of bays and estuaries.

- **Agricultural resources** – The land required for agricultural production related to farming and ranching. Potential strategies located in rural locations are assumed to impact agricultural resources.

Each impacted resource was quantitatively assessed and scored using the following parameters. The amount of area impacted by the implementation of a strategy is estimated using the following assumptions.

- Reservoir footprint (actual acreage impacted)
- WTP (5 acres)
- Pipeline ROW width of 50 ft
- Groundwater wells (2 acres)
  - Intakes and pump stations (5 acres)
  - Well field connection pipelines and pipelines less than 24 in diameter are assumed to have negligible impacts and are not included in the total area impacted.

Scoring of the criteria ranges from a value of 1 (highest impacts) to 3 (lowest impacts). The quantitative criteria used to evaluate the impacts of potentially feasible strategies and projects is presented in Table 1-4. A matrix summarizing the impacts of the individual water management strategies can be found in Appendix P.

Table 1-4. Quantitative Criteria Applied to Evaluate Impacts to Environmental and Agricultural Resources of Water Management Strategies and Projects

Score	Impact	Environmental Water Needs	Wildlife Habitat Acres Impacted	Wetland Acres Impacted	Number of Species Present[1]	Bays and Estuaries (river miles from coast)[a]	Agricultural Resources (rural acres impacted)
1	High	None	>10,000	>1,000	>100	0 - 100	>10,000
2	Medium	Reuse, Surface Water	1,000 - 10,000	1 - 1,000	50 - 100	100 - 200	1,000 - 10,000
3	Low	Conservation, Groundwater	0 - 1000	0	0 - 50	>200	0 – 1000

1. Number of Threatened, Endangered, or Candidate Species located in County or Counties of strategy.

1.7 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. 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.

1.8 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, 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 to 2070 for entities with a water supply need (shortage) during the planning period. The Brazos G RWPG does not recommend water conservation as a strategy to meet steam-electric needs. The plan presents a list of recommended BMPs in Volume II, Section 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. 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 G.

1.9 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 certain types of TWDB funding and to obtain water right permits from the Texas Commission on Environmental Quality (TCEQ). 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 temporary or long term. 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 as miscellaneous strategies Section 13.

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; or
- 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. According to Texas Administrative Code statute, 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 7.

The TWDB guidance and Texas Administrative Code 357.34 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 2021 Regional Water Plans, the TWDB requires 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. Furthermore, water conservation strategies should identify capital or other costs for best management practices that result in an immediate, quantifiable increase in water savings or decrease in system water use or water losses, including active plumbing retrofit programs, replacement of portions of an existing leaking water transmission or distribution network, and/or meter replacement/SCADA installation (where applicable). This section 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)[1]. The Task Force summarized their recommendations in a Report to the 79th Legislature[2], which included Task Force recommendations of gpcd targets and goals that should be considered by retail public water suppliers when developing water conservation plans required by the state, as follows:

- 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, 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 TWDB has continued the work of the Task Force by providing additional resources for municipal water users to assist water utilities with water conservation, including:

- Water Conservation Best Management Practice Guides
    - Municipal Water Providers, May 2019
    - Wholesale Water Providers, October 2017
- Water Conservation Plan Guidance for Utilities, developed in January 2013
    - Water Conservation Plan Checklist
    - How to Develop a Water Conservation Plan
    - Identifying Water Conservation Targets and Goals

The TWDB provided tools for Regional Water Planning Groups to consider during development of municipal water conservation recommendations for the 2021 Regional Water Plans. These resources were considered during development of the 2021 Brazos G Regional Water Plan, with Brazos G-specific results summarized below in sub-bullets.

- Utility-Provided Best Management Practices Implemented as of the 2017 reporting year
    - 49 Brazos G municipal entities have water conservation BMPs identified in the TWDB document.
- Annual Water Conservation Report Data (Years 2015 and 2016)
    - 61 Brazos G municipal entities submitted annual reports on implementation of their water conservation plan (entities range in population from 135 to 139,072)
    - 57 reported that leaks were repaired (11,316 leaks repaired in Brazos G)
    - 45 reported that they tested meters (5,454 meters tested in Brazos G)
    - 21 reported specific conservation savings (gallons)
    - 29 reported specific reuse savings (gallons)

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[1] Texas Water Development Board, Water Conservation Implementation Task Force, Water Conservation Best Management Practices Guide, November 2004.

[2] Texas Water Development Board, Water Conservation Implementation Task Force Report to the 79th Legislature, November 2004. https://www.twdb.texas.gov/conservation/resources/doc/WCITF_Leg_Report.pdf

    - Total gallons conserved or reused in Brazos G = 6.06 Billion Gallons (18,600 acre-feet)
- Municipal Water Conservation Planning Tool
    - The Municipal Water Conservation Planning Tool was developed by the TWDB to assist individual water utilities with planning conservation programs. The tool allows the user to include a mix of BMPs, and produces the expected annual conservation savings and associated capital and annual costs. The tool comes with population and water demand projections (and other data such as number of connections) for many municipal water user groups. The tool includes user-based functionality to load baseline demand projections, select conservation measures (plan or single-year savings) based on implementation activity, manage scenarios (to evaluate various BMP combinations) and use this information to calculate water savings and costs.
    - 75 of the 246 Brazos G municipal water user groups (non-county other) are included in the Baseline Demand Projection, which includes population, connections, water demands, baseline per capita (gpcd), and water loss. The water demands reflect passive water conservation savings from plumbing efficiencies and appliance standards attributable to state and federal plumbing codes.

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 utility uses.

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.[3] 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 is suggested.

Table 2.1-2. 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

[3] "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 the Plumbing Act savings for all municipal water user groups with per capita use above 140 gpcd in the TWDB base gpcd[4], regardless of whether or not the entity has needs. For these entities, the goal is 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. For Williamson County entities, a water conservation goal of 120 gpcd is targeted with a goal of reducing per capita use by 1% annually until the target is met and then holding the 120 gpcd rate constant through the planning period.

Municipal water conservation can be achieved in a variety of ways, including using BMPs identified by the TWDB[5]:

1. System Water Audit and Water Loss,
2. Water Conservation Pricing,
3. Prohibition on Wasting Water,
4. Conservation Ordinance Planning and Development,
5. Showerhead, Aerator, and Toilet Flapper Retrofit,
6. Residential Toilet Replacement Programs with Ultra-Low-Flow toilets,
7. Residential Clothes Washer Incentive Program,
8. School Education,
9. Water Survey for Single-Family and Multi-Family Customers,
10. Landscape Irrigation Conservation and Incentives,
11. Water-Wise Landscape Design and Conversion Programs,
12. Athletic Field Conservation,
13. Golf Course Conservation,
14. Metering of all New Connections and Retrofitting of Existing Connections,
15. Wholesale Agency Assistance Programs,
16. Conservation Coordinator (updated 2019),
17. Water Reuse[6],
18. Public Information,
19. Rainwater Harvesting and Condensate Reuse[6],
20. New Construction Greywater,
21. Park Conservation,
22. Conservation Programs for Industrial, Commercial, and Institutional Accounts,
23. Residential Landscape Irrigation Evaluation,
24. Outdoor Watering Schedule (adopted 2019),
25. Custom Characterization (adopted 2019),
26. Public Outreach and Education (adopted 2019),
27. Partnerships with Nonprofit Organizations,
28. Custom Conservation Rebates (adopted 2019),
29. Plumbing Assistance for Economically Disadvantaged Customers (adopted 2019)

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

[5] https://www.twdb.texas.gov/conservation/BMPs/Mun/index.asp

[6] Reuse and Rainwater Harvesting are considered separate sources for purposes of regional water planning and are not classified as “conservation” in the regional water planning process.

The Brazos G RWPG does not recommend specific conservation BMPs for municipal entities, as each entity should choose those conservation strategies that best fit their individual situation.

The Brazos G RWPG considered TWDB-provided information for Brazos G Utility-Provided Best Management Practices Implemented as of the 2017 reporting year, described earlier. Based on this information, the top three most common water conservation BMPs for Brazos G municipal users includes:

- Metering of all new connections and retrofit of existing connections (40 out of 49 Brazos G respondents),
- Public information (38 out of 49 Brazos G respondents), and
- System water audit and water loss control (33 out of 49 Brazos G respondents).

2.1.3 Available Supply

Per capita water use from the 2017 State Water Plan was provided by the TWDB for 2021 Regional Water Planning purposes for each municipal WUG based on TWDB-approved population and water demand estimates for each decade from 2020 to 2070 (summarized in Volume I Chapter 2, Table 2.5). The historical per capita water use7 in 2011 was used as a basis for projected per capita water use in decades from 2020 to 2070 that might be expected with implementation of low flow plumbing fixtures. The available supply attributed to implementation of advanced strategy is a 1% annual reduction in demand over and above that assumed in the TWDB water demand projections attributable to low flow plumbing code implementation.

[7] Based on water user surveys provided voluntarily by water provider to the TWDB.

Table 2.1-3 shows a comparison of TWDB baseline per capita rates for the 2021 Brazos G Plan to per capita rates with advanced conservation for Brazos G entities with per capita rates greater than 140 gpcd, and greater than 120 gpcd for Williamson County. Table 2.1-4 lists the additional water savings attributable to the Brazos G RWPG conservation recommendations8. The projected savings attributed to advanced conservation in Brazos G is 24,971 ac-ft/yr in 2020 and increases to 111,339 ac-ft/yr by 2070, shown by WUG in Table 2.1-4. 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.

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

Table 2.1-3. Comparison of TWDB Baseline Per Capita Rates for the 2021 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					
WUG	COUNTY	2011	2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
ABILENE	JONES	172	162	158	155	153	153	153	162	147	140	140	140	140
ABILENE	TAYLOR	172	162	158	155	153	153	153	162	147	140	140	140	140
ALBANY	SHACKELFORD	258	248	244	241	240	239	239	248	224	203	183	166	150
AQUA WSC	LEE	156	147	143	141	140	140	140	147	140	140	140	140	140
ARMSTRONG WSC	BELL	168	158	154	151	149	149	149	158	143	140	140	140	140
ASPERMONT	STONEWALL	250	240	236	232	232	231	231	240	217	197	178	161	145
BARTLETT	BELL	181	171	166	163	161	161	161	171	154	140	140	140	140
BARTLETT	WILLIAMSON	181	171	166	163	162	161	161	171	154	139	126	120	120
BAYLOR SUD	THROCKMORTON	206	179	179	179	179	167	167	179	161	146	140	140	140
BAYLOR SUD	YOUNG	412	197	193	189	187	189	188	197	178	161	145	140	140
BAYLOR SUD	ARCHER	206	194	191	191	188	186	185	194	175	159	143	140	140
BAYLOR SUD	BAYLOR	206	197	192	189	189	188	188	197	178	161	146	140	140
BELL COUNTY WCID 3	BELL	155	146	142	139	138	138	138	146	140	140	140	140	140
BELL MILAM FALLS WSC	WILLIAMSON	142	133	130	128	126	126	125	133	120	120	120	120	120
BELTON	BELL	165	156	152	150	149	148	148	156	141	140	140	140	140
BETHESDA WSC	JOHNSON	197	187	183	181	179	179	179	187	169	153	140	140	140
BETHESDA WSC	TARRANT	197	187	183	181	179	179	179	187	169	153	140	140	140
BISTONE MUNICIPAL WATER SUPPLY DISTRICT	LIMESTONE	364	355	350	347	346	345	346	355	321	290	263	237	215
BRECKENRIDGE	STEPHENS	161	152	147	144	142	142	142	152	140	140	140	140	140
BREMOND	ROBERTSON	174	163	159	156	155	155	155	163	148	140	140	140	140
BRENHAM	WASHINGTON	219	210	206	203	202	202	202	210	190	172	155	140	140
BRUCEVILLE EDDY	FALLS	174	165	161	158	156	156	156	165	149	140	140	140	140
BRUCEVILLE EDDY	MCLENNAN	174	165	161	158	157	156	156	165	149	140	140	140	140
BRUSHY CREEK MUD	WILLIAMSON	146	136	133	132	131	131	130	136	123	120	120	120	120
BRYAN	BRAZOS	168	158	155	152	151	151	151	158	143	140	140	140	140
CALDWELL	BURLESON	197	187	184	181	180	180	180	187	169	153	140	140	140
CAMERON	MILAM	216	206	202	198	197	197	197	206	186	169	152	140	140
CEDAR PARK	WILLIAMSON	193	184	183	182	182	182	182	184	167	151	136	123	120
CEDAR PARK	TRAVIS	193	184	183	182	182	182	182	184	167	151	140	140	140
CEGO-DURANGO WSC	FALLS	159	149	145	142	141	141	141	149	140	140	140	140	140
CENTRAL TEXAS COLLEGE DISTRICT	BELL	160	153	151	138	138	138	138	153	140	140	140	140	140
CENTRAL TEXAS COLLEGE DISTRICT	CORYELL	160	151	147	145	143	143	143	151	140	140	140	140	140
CHISHOLM TRAIL SUD	BURNET	174	165	163	163	162	161	162	165	149	140	140	140	140
CISCO	EASTLAND	168	158	154	151	149	149	149	158	143	140	140	140	140
CLEBURNE	JOHNSON	172	163	159	156	155	155	155	163	147	140	140	140	140
CLIFTON	BOSQUE	173	163	158	155	154	154	154	163	147	140	140	140	140
COLLEGE STATION	BRAZOS	155	146	142	140	139	138	138	146	140	140	140	140	140
COOLIDGE	LIMESTONE	156	146	143	140	139	139	139	146	140	140	140	140	140
CORYELL CITY WATER SUPPLY DISTRICT	CORYELL	154	146	143	141	140	140	140	146	140	140	140	140	140
CORYELL CITY WATER SUPPLY DISTRICT	MCLENNAN	154	146	142	141	140	139	140	146	140	140	140	140	140
COUNTY-OTHER, BELL	BELL	162	150	145	144	144	144	143	150	140	140	140	140	140
COUNTY-OTHER, WILLIAMSON	WILLIAMSON	148	139	135	134	133	133	133	139	125	120	120	120	120
CRAWFORD	MCLENNAN	191	182	178	174	173	172	172	182	164	149	140	140	140
CROSS COUNTRY WSC	BOSQUE	158	150	146	143	143	142	142	150	140	140	140	140	140
CROSS COUNTRY WSC	MCLENNAN	158	149	146	144	142	142	142	149	140	140	140	140	140
CROSS PLAINS	CALLAHAN	162	152	147	144	143	143	143	152	140	140	140	140	140
DOUBLE DIAMOND UTILITIES	HILL	215	206	202	200	198	198	198	206	186	168	152	140	140
DOUBLE DIAMOND UTILITIES	JOHNSON	215	205	204	196	197	199	197	205	185	168	152	140	140
EAST CRAWFORD WSC	MCLENNAN	312	303	299	297	295	295	295	303	274	248	224	203	183
FERN BLUFF MUD	WILLIAMSON	190	183	181	180	179	179	179	183	165	150	135	122	120
FLAT WSC	CORYELL	201	191	189	186	185	184	185	191	173	156	141	140	140
FORT GATES WSC	CORYELL	187	177	174	172	171	170	170	177	160	145	140	140	140
FORT HOOD	BELL	215	204	200	197	197	197	197	204	185	167	151	140	140

Table 2.1-3 (Continued)

		GPCD Board Projections without Advanced Conservation							GPCD Goal with Advanced Conservation					
		Base GPCD	Projected GPCD						Projected GPCD					
WUG	COUNTY	2011	2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
FORT HOOD	CORYELL	215	204	200	197	197	197	196	204	185	167	151	140	140
FORT WORTH	JOHNSON	185	0	0	0	170	170	169	0	0	0	170	140	140
GATESVILLE	CORYELL	229	220	216	213	212	212	212	220	199	180	162	147	140
GEORGETOWN	BELL	205	196	194	193	192	192	192	196	177	160	145	140	140
GEORGETOWN	WILLIAMSON	205	196	194	193	192	192	192	196	178	161	145	131	120
GEORGETOWN	BURNET	205	198	194	193	193	193	192	198	179	162	146	140	140
GIDDINGS	LEE	188	178	174	171	170	170	170	178	161	145	140	140	140
GLEN ROSE	SOMERVELL	200	190	187	184	183	183	182	190	172	156	141	140	140
GORDON	ERATH	206	202	189	179	198	193	188	202	182	165	149	140	140
GORDON	PALO PINTO	206	197	193	191	189	189	189	197	178	161	145	140	140
GRAHAM	YOUNG	266	256	252	249	247	247	247	256	232	210	190	172	155
HAMILTON	HAMILTON	162	153	149	146	144	143	143	153	140	140	140	140	140
HAMLIN	JONES	178	168	163	160	160	159	159	168	152	140	140	140	140
HARKER HEIGHTS	BELL	182	174	170	169	168	167	167	174	157	142	140	140	140
HEARNE	ROBERTSON	161	151	147	143	143	142	142	151	140	140	140	140	140
HEWITT	MCLENNAN	165	156	152	149	148	148	148	156	141	140	140	140	140
HIGHLAND PARK WSC	BOSQUE	264	254	251	249	247	246	246	254	230	208	188	170	154
HIGHLAND PARK WSC	MCLENNAN	264	252	250	247	247	246	244	252	228	206	186	169	153
HILLSBORO	HILL	200	190	186	183	182	182	182	190	172	156	141	140	140
JAYTON	KENT	164	154	151	147	145	145	145	154	140	140	140	140	140
JONAH WATER SUD	WILLIAMSON	137	126	123	121	120	120	120	126	120	120	120	120	120
KEMPNER WSC	BELL	164	156	153	151	150	150	150	156	141	140	140	140	140
KEMPNER WSC	CORYELL	164	156	153	151	150	150	150	156	141	140	140	140	140
KEMPNER WSC	LAMPASAS	164	156	153	151	150	150	150	156	141	140	140	140	140
KEMPNER WSC	BURNET	164	155	153	151	150	150	149	155	140	140	140	140	140
KNOX CITY	KNOX	195	184	179	177	178	177	177	184	167	151	140	140	140
LAWN	TAYLOR	186	177	174	170	169	168	168	177	160	145	140	140	140
LEXINGTON	LEE	169	159	155	152	151	151	151	159	143	140	140	140	140
LITTLE ELM VALLEY WSC	BELL	171	161	158	156	154	154	154	161	146	140	140	140	140
LITTLE ELM VALLEY WSC	FALLS	171	160	159	155	153	157	155	160	145	140	140	140	140
LORENA	MCLENNAN	154	145	141	139	137	137	137	145	140	140	140	140	140
MANSFIELD	JOHNSON	252	245	242	241	240	240	240	245	221	200	181	164	148
MANVILLE WSC	WILLIAMSON	148	139	136	135	134	134	134	139	126	120	120	120	120
MARLIN	FALLS	254	244	239	236	235	235	235	244	220	199	180	163	147
MINERAL WELLS	PALO PINTO	155	146	142	139	137	137	137	146	140	140	140	140	140
MINERAL WELLS	PARKER	155	145	142	139	137	137	137	145	140	140	140	140	140
MOUNTAIN PEAK SUD	JOHNSON	290	280	277	275	274	274	273	280	253	229	207	187	169
MOUNTAIN PEAK SUD	ELLIS	290	280	277	275	274	274	273	280	253	229	207	187	170
MUNDAY	KNOX	180	170	165	162	162	162	162	170	154	140	140	140	140
MUSTANG VALLEY WSC	BOSQUE	206	197	193	191	189	189	189	197	178	161	146	140	140
MUSTANG VALLEY WSC	CORYELL	206	191	179	202	189	189	189	191	173	156	142	140	140
NAVASOTA	GRIMES	184	175	171	168	166	166	166	175	158	143	140	140	140
NORTH BOSQUE WSC	MCLENNAN	235	227	224	222	221	221	221	227	205	185	168	152	140
NORTH MILAM WSC	FALLS	167	158	158	141	134	134	170	158	142	140	140	140	140
NORTH MILAM WSC	MILAM	167	158	154	151	150	149	149	158	143	140	140	140	140
PFLUGERVILLE	WILLIAMSON	155	148	147	146	146	145	145	148	134	121	120	120	120
PFLUGERVILLE	TRAVIS	155	148	146	146	145	145	145	148	140	140	140	140	140
POSSUM KINGDOM WSC	PALO PINTO	392	383	379	376	375	374	374	383	346	313	283	256	231
POSSUM KINGDOM WSC	STEPHENS	392	379	376	372	378	378	374	379	343	310	281	254	230
PRAIRIE HILL WSC	LIMESTONE	157	148	143	141	139	139	139	148	140	140	140	140	140
PRAIRIE HILL WSC	MCLENNAN	157	148	144	140	140	139	138	148	140	140	140	140	140
RANGER	EASTLAND	171	161	157	153	153	152	152	161	146	140	140	140	140
RED RIVER AUTHORITY OF TEXAS	KNOX	229	217	216	214	209	209	208	217	196	178	161	145	140
ROBINSON	MCLENNAN	181	172	168	166	165	165	165	172	155	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					
WUG	COUNTY	2011	2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
ROBY	FISHER	175	166	162	160	157	157	157	166	150	140	140	140	140
ROCKDALE	MILAM	184	174	170	167	165	165	165	174	158	143	140	140	140
ROUND ROCK	WILLIAMSON	152	143	141	139	139	139	138	143	129	120	120	120	120
ROUND ROCK	TRAVIS	152	143	140	139	139	139	138	143	140	140	140	140	140
SALADO WSC	BELL	292	283	279	277	276	276	276	283	255	231	209	189	171
SNOOK	BURLESON	307	297	293	289	288	288	287	297	269	243	220	199	180
SOMERVILLE	BURLESON	170	159	155	152	152	152	151	159	144	140	140	140	140
SOUTHWEST MILAM WSC	WILLIAMSON	152	143	139	137	136	136	135	143	129	120	120	120	120
SPORTSMANS WORLD MUD	PALO PINTO	898	885	886	880	880	881	881	885	801	724	655	592	536
STAMFORD	HASKELL	237	236	210	210	210	230	223	236	214	193	175	158	143
STAMFORD	JONES	237	227	222	219	218	218	218	227	205	186	168	152	140
STRAWN	PALO PINTO	182	172	168	165	163	163	163	172	155	141	140	140	140
TAYLOR	WILLIAMSON	157	147	143	141	139	139	139	147	133	121	120	120	120
TDCJ LUTHER UNITS	GRIMES	183	175	172	171	170	170	170	175	158	143	140	140	140
TDCJ W PACK UNIT	GRIMES	218	210	208	206	205	205	205	210	190	172	155	141	140
TEMPLE	BELL	229	219	216	214	213	212	212	219	198	180	162	147	140
TEXAS A&M UNIVERSITY	BRAZOS	487	476	472	469	468	468	468	476	431	390	352	319	288
TEXAS STATE TECHNICAL COLLEGE	MCLENNAN	1378	1369	1365	1362	1361	1360	1360	1369	1238	1120	1013	916	828
THROCKMORTON	THROCKMORTON	205	195	191	187	187	187	187	195	177	160	144	140	140
TWIN CREEK WSC	ROBERTSON	167	158	154	152	151	150	150	158	143	140	140	140	140
VALLEY MILLS	BOSQUE	184	174	170	167	166	165	165	174	157	142	140	140	140
VALLEY MILLS	MCLENNAN	184	155	162	170	172	161	166	155	140	140	140	140	140
VENUS	JOHNSON	174	167	164	163	163	162	162	167	151	140	140	140	140
VENUS	ELLIS	174	165	166	160	162	164	163	165	150	140	140	140	140
WACO	MCLENNAN	220	211	207	204	202	202	202	211	191	172	156	141	140
WALSH RANCH MUD	WILLIAMSON	257	249	245	244	244	243	243	249	225	204	184	166	151
WELLBORN SUD	BRAZOS	170	160	157	155	154	154	154	160	145	140	140	140	140
WELLBORN SUD	ROBERTSON	170	160	157	155	154	154	154	160	145	140	140	140	140
WEST	MCLENNAN	160	151	147	144	142	141	141	151	140	140	140	140	140
WHITNEY	HILL	180	171	167	165	163	163	163	171	155	140	140	140	140
WILLIAMSON COUNTY MUD 10	WILLIAMSON	196	191	189	189	189	189	188	191	173	156	141	128	120
WILLIAMSON COUNTY MUD 11	WILLIAMSON	185	180	178	178	178	178	178	180	163	147	133	120	120
WILLIAMSON COUNTY MUD 9	WILLIAMSON	188	180	177	176	176	176	176	180	162	147	133	120	120
WINDSOR WATER	MCLENNAN	156	146	143	139	138	138	138	146	140	140	140	140	140
WOODWAY	MCLENNAN	352	342	337	334	333	333	333	342	309	280	253	229	207

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

County Name	Water User Group	Additional Water Saved-W/Advanced Conservation (acft)					
		2020	2030	2040	2050	2060	2070
ABILENE	JONES	0	70	95	86	86	88
ABILENE	TAYLOR	0	1,554	2,102	1,915	1,909	1,935
ALBANY	SHACKELFORD	0	50	98	146	191	233
AQUA WSC	LEE	0	11	4	0	0	0
ARMSTRONG WSC	BELL	0	35	37	33	35	36
ASPERMONT	STONEWALL	0	19	37	56	73	89
BARTLETT	BELL	0	13	29	31	34	37
BARTLETT	WILLIAMSON	0	15	32	52	65	70
BAYLOR SUD	THROCKMORTON	0	0	1	1	0	0
BAYLOR SUD	YOUNG	0	6	10	15	18	18
BAYLOR SUD	ARCHER	0	3	6	8	8	8
BAYLOR SUD	BAYLOR	0	14	29	44	49	50
BELL COUNTY WCID 3	BELL	0	22	0	0	0	0
BELL MILAM FALLS WSC	WILLIAMSON	0	4	4	4	4	5
BELTON	BELL	0	323	323	325	352	384
BETHESDA WSC	JOHNSON	0	327	735	1,190	1,331	1,487
BETHESDA WSC	TARRANT	0	186	408	639	690	742
BISTONE MUNICIPAL WSD	LIMESTONE	0	20	40	62	83	104
BRECKENRIDGE	STEPHENS	0	51	29	16	15	14
BREMOND	ROBERTSON	0	13	21	21	23	24
BRENHAM	WASHINGTON	0	367	755	1,170	1,592	1,648
BRUCEVILLE EDDY	FALLS	0	15	31	29	31	33
BRUCEVILLE EDDY	MCLENNAN	0	64	98	96	100	105
BRUSHY CREEK MUD	WILLIAMSON	0	233	263	243	238	237
BRYAN	BRAZOS	0	1,311	1,606	1,719	1,988	2,489
CALDWELL	BURLESON	0	83	167	239	242	246
CAMERON	MILAM	0	107	218	339	449	465
CEDAR PARK	WILLIAMSON	0	1,672	3,197	4,626	5,932	6,250
CEDAR PARK	TRAVIS	0	215	442	586	583	582
CEGO-DURANGO WSC	FALLS	0	6	3	2	1	1
CENTRAL TEXAS COLLEGE DISTRICT	BELL	0	1	0	0	0	0
CENTRAL TEXAS COLLEGE DISTRICT	CORYELL	0	6	4	3	3	3
CHISHOLM TRAIL SUD	BURNET	0	7	13	14	16	17
CISCO	EASTLAND	0	52	52	44	42	42
CLEBURNE	JOHNSON	0	561	942	1,018	1,171	1,302
CLIFTON	BOSQUE	0	53	76	71	71	71
COLLEGE STATION	BRAZOS	0	234	0	0	0	0
COOLIDGE	LIMESTONE	0	4	0	0	0	0
CORYELL CITY WATER SUPPLY DISTRICT	CORYELL	0	17	7	0	0	0

Table 2.1-4 (Continued)

County Name	Water User Group	Additional Water Saved-W/Conservation (acft)*					
		2020	2030	2040	2050	2060	2070
CORYELL CITY WATER SUPPLY DISTRICT	MCLENNAN	0	3	1	0	0	0
COUNTY-OTHER, BELL	BELL	0	17	14	14	30	43
COUNTY-OTHER, WILLIAMSON	WILLIAMSON	0	288	948	1,390	2,923	4,281
CRAWFORD	MCLENNAN	0	11	21	28	27	28
CROSS COUNTRY WSC	BOSQUE	0	6	3	3	2	2
CROSS COUNTRY WSC	MCLENNAN	0	18	11	7	6	6
CROSS PLAINS	CALLAHAN	0	10	6	4	5	4
DOUBLE DIAMOND UTILITIES	HILL	0	35	71	108	139	144
DOUBLE DIAMOND UTILITIES	JOHNSON	0	3	4	7	9	16
EAST CRAWFORD WSC	MCLENNAN	0	30	61	94	129	164
FERN BLUFF MUD	WILLIAMSON	0	101	197	285	367	382
FLAT WSC	CORYELL	0	9	20	32	36	40
FORT GATES WSC	CORYELL	0	33	73	93	101	110
FORT HOOD	BELL	0	293	582	885	1,094	1,094
FORT HOOD	CORYELL	0	239	472	718	887	886
FORT WORTH	JOHNSON	0	0	0	0	267	333
GATESVILLE	CORYELL	0	384	852	1,386	1,988	2,392
GEORGETOWN	BELL	0	65	146	240	296	325
GEORGETOWN	WILLIAMSON	0	2,884	7,106	12,854	20,175	28,862
GEORGETOWN	BURNET	0	8	18	31	39	41
GIDDINGS	LEE	0	95	199	237	238	240
GLEN ROSE	SOMERVELL	0	52	108	169	179	184
GORDON	ERATH	0	0	1	2	2	2
GORDON	PALO PINTO	0	12	24	36	42	43
GRAHAM	YOUNG	0	231	463	708	962	1,210
HAMILTON	HAMILTON	0	30	19	12	11	11
HAMLIN	JONES	0	30	55	57	57	58
HARKER HEIGHTS	BELL	0	559	1,274	1,498	1,656	1,819
HEARNE	ROBERTSON	0	43	22	19	17	17
HEWITT	MCLENNAN	0	247	236	227	240	258
HIGHLAND PARK WSC	BOSQUE	0	11	22	33	43	53
HIGHLAND PARK WSC	MCLENNAN	0	5	9	14	18	22
HILLSBORO	HILL	0	157	320	493	516	523
JAYTON	KENT	0	8	5	4	4	4
JONAH WATER SUD	WILLIAMSON	0	84	32	0	0	0
KEMPNER WSC	BELL	0	29	30	29	30	32
KEMPNER WSC	CORYELL	0	53	54	53	55	59
KEMPNER WSC	LAMPASAS	0	140	139	135	140	145
KEMPNER WSC	BURNET	0	12	11	11	12	12
KNOX CITY	KNOX	0	17	36	52	53	54

Table 2.1-4 (Continued)

County Name	Water User Group	Additional Water Saved-W/Conservation (acft)*					
		2020	2030	2040	2050	2060	2070
LAWN	TAYLOR	0	10	20	23	23	23
LEXINGTON	LEE	0	20	23	21	21	21
LITTLE ELM VALLEY WSC	BELL	0	24	36	37	40	44
LITTLE ELM VALLEY WSC	FALLS	0	1	2	2	2	2
LORENA	MCLENNAN	0	3	0	0	0	0
MANSFIELD	JOHNSON	0	87	223	407	641	922
MANVILLE WSC	WILLIAMSON	0	172	293	335	396	474
MARLIN	FALLS	0	151	296	432	583	730
MINERAL WELLS	PALO PINTO	0	30	0	0	0	0
MINERAL WELLS	PARKER	0	4	0	0	0	0
MOUNTAIN PEAK SUD	JOHNSON	0	113	264	451	677	936
MOUNTAIN PEAK SUD	ELLIS	0	314	766	1,444	2,293	3,360
MUNDAY	KNOX	0	17	35	36	35	36
MUSTANG VALLEY WSC	BOSQUE	0	38	79	120	137	138
MUSTANG VALLEY WSC	CORYELL	0	0	2	2	2	2
NAVASOTA	GRIMES	0	110	219	236	238	242
NORTH BOSQUE WSC	MCLENNAN	0	57	131	219	319	413
NORTH MILAM WSC	FALLS	0	0	0	0	0	1
NORTH MILAM WSC	MILAM	0	18	19	18	18	18
PFLUGERVILLE	WILLIAMSON	0	6	16	21	24	29
PFLUGERVILLE	TRAVIS	0	596	672	774	870	969
POSSUM KINGDOM WSC	PALO PINTO	0	77	155	233	311	383
POSSUM KINGDOM WSC	STEPHENS	0	3	6	9	12	14
PRAIRIE HILL WSC	LIMESTONE	0	3	1	0	0	0
PRAIRIE HILL WSC	MCLENNAN	0	3	0	0	0	0
RANGER	EASTLAND	0	33	40	38	37	37
RED RIVER AUTHORITY OF TEXAS	KNOX	0	3	5	7	9	10
ROBINSON	MCLENNAN	0	220	504	557	612	672
ROBY	FISHER	0	9	15	13	13	13
ROCKDALE	MILAM	0	89	180	198	202	209
ROUND ROCK	WILLIAMSON	0	1,934	4,192	5,026	4,972	4,951
ROUND ROCK	TRAVIS	0	1	0	0	0	0
SALADO WSC	BELL	0	178	379	597	831	1,074
SNOOK	BURLESON	0	25	50	78	104	129
SOMERVILLE	BURLESON	0	20	25	27	29	31
SOUTHWEST MILAM WSC	WILLIAMSON	0	25	54	61	73	85
SPORTSMANS WORLD MUD	PALO PINTO	0	13	24	36	48	59
STAMFORD	HASKELL	0	0	1	1	3	3
STAMFORD	JONES	0	68	136	212	285	342
STRAWN	PALO PINTO	0	11	23	22	23	24

Table 2.1-4 (Concluded)

County Name	Water User Group	Additional Water Saved-W/Conservation (acft)*					
		2020	2030	2040	2050	2060	2070
TAYLOR	WILLIAMSON	0	215	466	490	530	578
TDCJ LUTHER UNITS	GRIMES	0	25	54	61	64	66
TDCJ W PACK UNIT	GRIMES	0	36	75	116	159	166
TEMPLE	BELL	0	1,868	4,232	7,057	10,263	12,469
TEXAS A&M UNIVERSITY	BRAZOS	0	560	1,072	1,557	2,006	2,415
TEXAS STATE TECHNICAL COLLEGE	MCLENNAN	0	88	180	274	370	466
THROCKMORTON	THROCKMORTON	0	14	26	40	44	44
TWIN CREEK WSC	ROBERTSON	0	21	23	23	23	25
VALLEY MILLS	BOSQUE	0	21	43	46	46	47
VALLEY MILLS	MCLENNAN	0	1	1	2	1	2
VENUS	JOHNSON	0	59	115	126	139	156
VENUS	ELLIS	0	2	3	4	5	6
WACO	MCLENNAN	0	2,583	5,360	8,389	11,642	12,436
WALSH RANCH MUD	WILLIAMSON	0	16	32	48	61	74
WELLBORN SUD	BRAZOS	0	355	501	533	591	655
WELLBORN SUD	ROBERTSON	0	69	90	89	92	95
WEST	MCLENNAN	0	21	12	6	5	5
WHITNEY	HILL	0	38	76	74	75	77
WILLIAMSON COUNTY MUD 10	WILLIAMSON	0	65	126	182	233	261
WILLIAMSON COUNTY MUD 11	WILLIAMSON	0	73	142	206	264	266
WILLIAMSON COUNTY MUD 9	WILLIAMSON	0	45	90	131	169	170
WINDSOR WATER	MCLENNAN	0	2	0	0	0	0
WOODWAY	MCLENNAN	0	308	635	988	1,357	1,730
	Total Region G:	**0**	**24,971**	**47,829**	**68,967**	**92,264**	**111,339**

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

2.1.4 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 2.1-5.

Table 2.1-5. Environmental Issues: Municipal Water Conservation

Issue	Description
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

2.1.5 Engineering and Costing

The TWDB requires that costs and water supply estimates be developed for each recommended water management strategy. For the BMPs listed above in Section 2.1.2, water savings (yield) and costs to implement these strategies reported in TWDB guidance documents are summarized in Table 2.1-5. Costs and savings presented are general and often sparse, based on a range of variables affecting implementation and level of success.

Table 2.1-6. Costs and Savings of Municipal Water Conservation Techniques (BMPs)

Best Management Practices	Water Savings Estimates				Cost Estimates				Assumptions/Notes
	Min	Max	Avg	Savings Metric	Min	Max	Avg	Cost Metric	
Water Conservation Pricing/Seasonal or Inverted Block Rates	1	3	2	%	-	-	10	%	Average reduction in water use of 1 to 3% for every 10% increase in the average monthly water bill
Metering of All New Connections and Retrofit of Existing Connections	-	-	-	-	-	-	-	-	
System Water Audit and Water Loss Control	-	-	-	-	-	-	-	-	
Landscape Irrigation Conservation and Incentives	-	-	15	%	-	-	-	-	
Athletic Field Conservation	-	-	-	-	-	-	-	-	
Golf Course Conservation	15	100	58	%	-	-	-	-	Savings and costs highly variable based measures taken - from implementing a CCIS to switching from potable to non-potable
School Education	-	-	-	-	1	35	18	per student	
Public Information	-	-	-	-	1	3	2	per customer	
Water Reuse	-	100	-	%	-	-	-	-	
Prohibitions on Wasting Water	-	-	-	-	-	-	-	-	
Residential Toilet Replacement Programs	-	-	11	gpcd	70	100	85	per toilet	
Showerhead, Aerator, and Toilet Flapper Retrofit	6	13	9	gpd per device	10	50	30	per customer	5.5 gpd of permanent savings for showerheads and faucet aerators; 12.8 gpd for toilet flapper for 5 years (device life span)
Water Wise Landscape Design and Conversion Programs	-	-	-	-	0	1	1	per sq ft	Costs reflect customer rebates - does not include staff labor cost, which ranges between $50 to $100 per conversion
Custom Conservation Rebates	-	-	-	-	-	-	-	-	
Plumbing Assistance for Economically Disadvantaged Customers	300	262,080	131,190	gal/yr	-	-	-	-	
Rainwater Harvesting and Condensate Reuse	-	-	-	-	-	-	-	-	
Source TWDB: https://www.twdb.texas.gov/conservation/BMPs/Mun/index.asp									

Municipal water conservation costs for this strategy were based on the TWDB Municipal Water Conservation Planning Tool developed to assist individual water utilities with planning conservation programs. The tool allows the user to include a mix of BMPs, and produces the expected annual conservation savings and associated capital and annual costs. The tool comes with population and water demand projections (and other data such as number of connections) for municipal water user groups. The tool includes user-based functionality to load baseline demand projections, select conservation measures (plan or single-year savings) based on implementation activity, manage scenarios (to evaluate various BMP combinations) and use this information to calculate water savings and costs. The tool includes the following pre-defined BMPs:

- High Efficiency (HE) Toilet Rebate
- Bathroom Retrofit
- Showerhead and Aerator Kit
- Clothes Washer Rebate

- Home Water Reports
- Irrigation Audits- High Users
- High Efficiency Sprinkler Nozzle Rebate
- Smart Irrigation Controller Rebate
- WaterWise Landscape Rebate
- Rainwater Harvesting Rebate, and
- Rain Barrel

The costs to implement these BMPs ranges from $271 to $1,358 per acft saved, with the showerhead kit being the most economical ($271 per acft saved) and clothes washer rebates and rain barrels being the most expensive at $1,358 and $1,265 per acft, respectively. Since the TWDB tool only included 75 of the 246 Brazos G individual discrete municipal water user groups, three Brazos G water user groups were selected to represent a range of Small, Medium and Large utilities for costing purposes.

The City of Hico records in the TWDB tool were considered representative of “Small” Brazos G municipal water users; the City of Taylor was considered representative of “Medium” Brazos G municipal water users; and the City of Waco was considered representative of “Large.” Although the TWDB tool does not present costs for the most common water conservation BMPs from local water conservation plans in the Brazos G Area, the following BMPs from the TWDB tool were selected to estimate a unit cost for municipal water conservation: HE Toilet Rebate, Bathroom Retrofit, Showerhead and Aerator Kit, Home Water Reports, and WaterWise Landscape Rebate. The costs to implement these BMPs was $560 per acft water saved and did not vary much amongst small, medium, and large users.

The total program costs for municipal entities having per capita use greater than 140 gpcd (and greater than 120 gpcd for Williamson County) are presented in Table 2.1-7. Total conservation potential costs for Brazos G are estimated at $26,783,993 in 2040 and increasing to $62,350,091 by 2070. The CBRWPG has expressed a desire to offer BMPs to encourage conservation while maintaining flexibility for municipal users to adopt strategies that suit them the best.

These annual costs have been capitalized over a 20 year period at 3.5% interest rate by assuming that 70% of the annual costs for a municipal water conservation program are associated with repayment of debt issued to fund the initial capital expenditures. Capital costs are also shown in Table 2.1-7.

Table 2.1-7. Estimated Cost of Conservation to Achieve Water Savings Identified in Table 2.1-4

County Name	Water User Group	Costs of Water Savings (at $560 per acft saved)						Capital Costs ($)
		2020	2030	2040	2050	2060	2070	
ABILENE	JONES	0	$39,346	$53,106	$48,235	$48,326	$49,197	$528,000
ABILENE	TAYLOR	0	$870,006	$1,177,301	$1,072,304	$1,068,831	$1,083,692	$11,713,000
ALBANY	SHACKELFORD	0	$28,174	$54,976	$81,965	$107,034	$130,213	$1,295,000
AQUA WSC	LEE	0	$5,983	$2,244	$225	$0	$0	$60,000
ARMSTRONG WSC	BELL	0	$19,738	$20,989	$18,589	$19,339	$20,178	$209,000
ASPERMONT	STONEWALL	0	$10,820	$20,664	$31,593	$40,917	$49,856	$496,000
BARTLETT	BELL	0	$7,310	$16,179	$17,094	$18,920	$20,834	$207,000
BARTLETT	WILLIAMSON	0	$8,224	$18,155	$29,057	$36,589	$39,358	$392,000
BAYLOR SUD	THROCKMORTON	0	$161	$306	$363	$275	$275	$4,000
BAYLOR SUD	YOUNG	0	$3,191	$5,771	$8,641	$10,132	$9,956	$101,000
BAYLOR SUD	ARCHER	0	$1,547	$3,166	$4,361	$4,605	$4,517	$46,000
BAYLOR SUD	BAYLOR	0	$8,089	$15,983	$24,855	$27,704	$27,825	$277,000
BELL COUNTY WCID 3	BELL	0	$12,044	$0	$0	$0	$0	$120,000
BELL MILAM FALLS WSC	WILLIAMSON	0	$2,326	$2,150	$1,978	$2,508	$2,661	$26,000
BELTON	BELL	0	$180,728	$180,662	$182,018	$197,153	$215,317	$2,142,000
BETHESDA WSC	JOHNSON	0	$183,304	$411,557	$666,452	$745,285	$832,721	$8,284,000
BETHESDA WSC	TARRANT	0	$103,985	$228,622	$357,846	$386,227	$415,772	$4,136,000
BISTONE MUNICIPAL WSD	LIMESTONE	0	$11,116	$22,676	$34,952	$46,741	$58,043	$577,000
BRECKENRIDGE	STEPHENS	0	$28,388	$16,070	$9,154	$8,221	$8,113	$282,000
BREMOND	ROBERTSON	0	$7,514	$11,700	$12,021	$12,605	$13,365	$133,000
BRENHAM	WASHINGTON	0	$205,297	$422,922	$654,982	$891,575	$922,943	$9,182,000
BRUCEVILLE EDDY	FALLS	0	$8,330	$17,176	$16,377	$17,258	$18,226	$181,000
BRUCEVILLE EDDY	MCLENNAN	0	$35,951	$55,151	$54,005	$55,747	$58,576	$583,000
BRUSHY CREEK MUD	WILLIAMSON	0	$130,416	$147,459	$136,259	$133,459	$132,899	$1,467,000
BRYAN	BRAZOS	0	$733,963	$899,502	$962,914	$1,113,524	$1,393,972	$13,868,000
CALDWELL	BURLESON	0	$46,529	$93,416	$133,824	$135,682	$137,650	$1,369,000
CAMERON	MILAM	0	$60,061	$122,024	$190,045	$251,609	$260,663	$2,593,000
CEDAR PARK	WILLIAMSON	0	$936,185	$1,790,141	$2,590,558	$3,322,193	$3,500,159	$34,822,000
CEDAR PARK	TRAVIS	0	$120,642	$247,301	$328,415	$326,735	$326,175	$3,267,000
CEGO-DURANGO WSC	FALLS	0	$3,496	$1,410	$894	$795	$610	$35,000
CENTRAL TEXAS COLLEGE DISTRICT	BELL	0	$485	$0	$0	$0	$0	$5,000
CENTRAL TEXAS COLLEGE DISTRICT	CORYELL	0	$3,168	$2,048	$1,488	$1,488	$1,488	$32,000

Table 2.1-7 (Continued)

County Name	Water User Group	Costs of Water Savings (at $560 per acft saved)						Capital Costs ($)
		2020	2030	2040	2050	2060	2070	
CHISHOLM TRAIL SUD	BURNET	0	$4,011	$7,479	$8,019	$8,701	$9,438	$94,000
CISCO	EASTLAND	0	$29,356	$29,231	$24,576	$23,456	$23,456	$292,000
CLEBURNE	JOHNSON	0	$314,170	$527,611	$569,977	$655,741	$729,070	$7,253,000
CLIFTON	BOSQUE	0	$29,445	$42,731	$39,912	$39,749	$39,805	$425,000
COLLEGE STATION	BRAZOS	0	$131,155	$0	$0	$0	$0	$1,305,000
COOLIDGE	LIMESTONE	0	$2,455	$272	$0	$0	$0	$24,000
CORYELL CITY WATER SUPPLY DISTRICT	CORYELL	0	$9,423	$3,742	$156	$0	$0	$94,000
CORYELL CITY WATER SUPPLY DISTRICT	MCLENNAN	0	$1,405	$838	$182	$0	$0	$14,000
COUNTY-OTHER, BELL	BELL	0	$9,569	$7,643	$7,957	$16,658	$24,191	$241,000
COUNTY-OTHER, WILLIAMSON	WILLIAMSON	0	$161,462	$530,658	$778,376	$1,636,995	$2,397,334	$23,850,000
CRAWFORD	MCLENNAN	0	$6,128	$11,921	$15,665	$15,347	$15,589	$156,000
CROSS COUNTRY WSC	BOSQUE	0	$3,149	$1,755	$1,416	$1,306	$1,164	$31,000
CROSS COUNTRY WSC	MCLENNAN	0	$9,899	$6,057	$3,806	$3,148	$3,226	$98,000
CROSS PLAINS	CALLAHAN	0	$5,387	$3,291	$2,391	$2,666	$2,260	$54,000
DOUBLE DIAMOND UTILITIES	HILL	0	$19,708	$39,718	$60,506	$77,616	$80,616	$802,000
DOUBLE DIAMOND UTILITIES	JOHNSON	0	$1,478	$2,364	$3,871	$5,153	$8,933	$89,000
EAST CRAWFORD WSC	MCLENNAN	0	$16,656	$34,035	$52,745	$72,264	$92,035	$916,000
FERN BLUFF MUD	WILLIAMSON	0	$56,839	$110,401	$159,586	$205,481	$214,100	$2,130,000
FLAT WSC	CORYELL	0	$5,242	$11,055	$18,000	$20,155	$22,199	$221,000
FORT GATES WSC	CORYELL	0	$18,271	$40,971	$52,298	$56,675	$61,787	$615,000
FORT HOOD	BELL	0	$163,877	$325,749	$495,520	$612,547	$612,547	$6,094,000
FORT HOOD	CORYELL	0	$133,589	$264,203	$401,812	$496,901	$496,341	$4,944,000
FORT WORTH	JOHNSON	0	$0	$0	$0	$149,240	$186,204	$1,852,000
GATESVILLE	CORYELL	0	$215,242	$477,374	$776,034	$1,113,137	$1,339,592	$13,327,000
GEORGETOWN	BELL	0	$36,288	$81,875	$134,651	$165,991	$182,276	$1,813,000
GEORGETOWN	WILLIAMSON	0	$1,615,098	$3,979,465	$7,198,483	$11,298,264	$16,162,702	$160,798,000
GEORGETOWN	BURNET	0	$4,366	$10,341	$17,421	$21,581	$22,878	$228,000
GIDDINGS	LEE	0	$52,980	$111,538	$132,735	$133,385	$134,243	$1,336,000
GLEN ROSE	SOMERVELL	0	$28,898	$60,585	$94,655	$100,198	$103,132	$1,026,000
GORDON	ERATH	0	$146	$300	$1,113	$1,231	$1,143	$12,000
GORDON	PALO PINTO	0	$6,625	$13,389	$20,366	$23,571	$24,143	$240,000
GRAHAM	YOUNG	0	$129,298	$259,305	$396,735	$538,634	$677,710	$6,742,000
HAMILTON	HAMILTON	0	$16,895	$10,735	$6,815	$6,255	$6,255	$168,000
HAMLIN	JONES	0	$16,824	$31,024	$31,750	$31,730	$32,500	$323,000
HARKER HEIGHTS	BELL	0	$313,002	$713,241	$839,130	$927,292	$1,018,527	$10,133,000
HEARNE	ROBERTSON	0	$23,914	$12,577	$10,897	$9,777	$9,777	$238,000
HEWITT	MCLENNAN	0	$138,568	$131,977	$126,958	$134,402	$144,415	$1,437,000
HIGHLAND PARK WSC	BOSQUE	0	$6,030	$12,189	$18,329	$24,048	$29,811	$297,000
HIGHLAND PARK WSC	MCLENNAN	0	$2,522	$5,022	$7,734	$10,024	$12,200	$121,000
HILLSBORO	HILL	0	$87,718	$179,420	$276,289	$289,015	$292,621	$2,911,000
JAYTON	KENT	0	$4,507	$2,827	$2,267	$2,267	$2,267	$45,000

Table 2.1-7 (Continued)

County Name	Water User Group	Costs of Water Savings (at $560 per acft saved)						Capital Costs ($)
		2020	2030	2040	2050	2060	2070	
JONAH WATER SUD	WILLIAMSON	0	$46,891	$17,698	$103	$0	$0	$467,000
KEMPNER WSC	BELL	0	$16,077	$16,648	$16,126	$17,043	$17,893	$178,000
KEMPNER WSC	CORYELL	0	$29,844	$29,982	$29,859	$30,845	$33,203	$330,000
KEMPNER WSC	LAMPASAS	0	$78,583	$77,891	$75,747	$78,234	$81,357	$809,000
KEMPNER WSC	BURNET	0	$6,717	$6,193	$6,272	$6,702	$6,924	$69,000
KNOX CITY	KNOX	0	$9,452	$20,248	$29,369	$29,590	$30,073	$299,000
LAWN	TAYLOR	0	$5,619	$10,944	$13,018	$12,908	$13,062	$130,000
LEXINGTON	LEE	0	$11,025	$12,601	$11,591	$11,812	$11,790	$125,000
LITTLE ELM VALLEY WSC	BELL	0	$13,360	$20,033	$20,874	$22,626	$24,818	$247,000
LITTLE ELM VALLEY WSC	FALLS	0	$779	$947	$925	$1,376	$1,354	$14,000
LORENA	MCLENNAN	0	$1,777	$0	$0	$0	$0	$18,000
MANSFIELD	JOHNSON	0	$48,803	$124,900	$228,097	$359,186	$516,488	$5,138,000
MANVILLE WSC	WILLIAMSON	0	$96,465	$163,839	$187,595	$222,015	$265,185	$2,638,000
MARLIN	FALLS	0	$84,617	$165,517	$242,036	$326,406	$408,716	$4,066,000
MINERAL WELLS	PALO PINTO	0	$16,524	$0	$0	$0	$0	$164,000
MINERAL WELLS	PARKER	0	$2,312	$0	$0	$0	$0	$23,000
MOUNTAIN PEAK SUD	JOHNSON	0	$63,384	$147,940	$252,788	$379,196	$523,975	$5,213,000
MOUNTAIN PEAK SUD	ELLIS	0	$175,743	$428,846	$808,563	$1,284,026	$1,881,736	$18,721,000
MUNDAY	KNOX	0	$9,453	$19,535	$19,997	$19,866	$20,174	$201,000
MUSTANG VALLEY WSC	BOSQUE	0	$21,546	$44,397	$67,126	$76,692	$77,296	$769,000
MUSTANG VALLEY WSC	CORYELL	0	$104	$877	$991	$1,022	$1,022	$10,000
NAVASOTA	GRIMES	0	$61,652	$122,747	$132,201	$133,182	$135,447	$1,348,000
NORTH BOSQUE WSC	MCLENNAN	0	$31,966	$73,373	$122,562	$178,740	$231,191	$2,300,000
NORTH MILAM WSC	FALLS	0	$161	$11	$0	$0	$396	$4,000
NORTH MILAM WSC	MILAM	0	$10,300	$10,897	$9,822	$9,802	$10,133	$108,000
PFLUGERVILLE	WILLIAMSON	0	$3,638	$8,994	$11,549	$13,514	$16,148	$161,000
PFLUGERVILLE	TRAVIS	0	$333,636	$376,543	$433,313	$487,184	$542,393	$5,396,000
POSSUM KINGDOM WSC	PALO PINTO	0	$42,956	$86,850	$130,719	$174,065	$214,628	$2,135,000
POSSUM KINGDOM WSC	STEPHENS	0	$1,735	$3,248	$5,196	$6,627	$7,777	$77,000
PRAIRIE HILL WSC	LIMESTONE	0	$1,899	$484	$0	$0	$0	$19,000
PRAIRIE HILL WSC	MCLENNAN	0	$1,542	$148	$0	$0	$0	$15,000
RANGER	EASTLAND	0	$18,667	$22,531	$21,411	$20,851	$20,851	$224,000
RED RIVER AUTHORITY OF TEXAS	KNOX	0	$1,524	$2,873	$3,903	$5,136	$5,471	$54,000
ROBINSON	MCLENNAN	0	$123,429	$282,196	$311,757	$342,962	$376,263	$3,743,000
ROBY	FISHER	0	$4,960	$8,152	$7,032	$7,032	$7,032	$81,000
ROCKDALE	MILAM	0	$49,787	$100,957	$110,661	$113,303	$116,966	$1,164,000
ROUND ROCK	WILLIAMSON	0	$1,082,969	$2,347,691	$2,814,744	$2,784,504	$2,772,744	$28,003,000
ROUND ROCK	TRAVIS	0	$498	$0	$0	$0	$0	$5,000
SALADO WSC	BELL	0	$99,912	$212,065	$334,183	$465,532	$601,676	$5,986,000
SNOOK	BURLESON	0	$13,981	$27,916	$43,409	$58,377	$72,274	$719,000

Table 2.1-7 (Concluded)

County Name	Water User Group	Costs of Water Savings (at $560 per acft saved)						Capital Costs ($)
		2020	2030	2040	2050	2060	2070	
SOMERVILLE	BURLESON	0	$11,161	$14,110	$15,223	$16,194	$17,144	$171,000
SOUTHWEST MILAM WSC	WILLIAMSON	0	$14,082	$30,407	$34,396	$40,872	$47,447	$472,000
SPORTSMANS WORLD MUD	PALO PINTO	0	$7,052	$13,466	$20,356	$26,766	$32,921	$328,000
STAMFORD	HASKELL	0	$0	$358	$752	$1,569	$1,811	$18,000
STAMFORD	JONES	0	$37,927	$76,360	$118,609	$159,454	$191,702	$1,907,000
STRAWN	PALO PINTO	0	$6,320	$12,832	$12,407	$12,836	$13,319	$133,000
TAYLOR	WILLIAMSON	0	$120,291	$260,891	$274,387	$296,974	$323,771	$3,221,000
TDCJ LUTHER UNITS	GRIMES	0	$14,228	$30,196	$34,171	$35,611	$37,074	$369,000
TDCJ W PACK UNIT	GRIMES	0	$20,347	$41,986	$65,163	$88,817	$92,773	$923,000
TEMPLE	BELL	0	$1,045,905	$2,369,770	$3,951,925	$5,747,423	$6,982,884	$69,470,000
TEXAS A&M UNIVERSITY	BRAZOS	0	$313,383	$600,421	$871,819	$1,123,129	$1,352,435	$13,455,000
TEXAS STATE TECHNICAL COLLEGE	MCLENNAN	0	$49,556	$100,841	$153,629	$207,027	$261,221	$2,599,000
THROCKMORTON	THROCKMORTON	0	$7,666	$14,385	$22,487	$24,825	$24,825	$247,000
TWIN CREEK WSC	ROBERTSON	0	$11,642	$13,153	$13,003	$12,995	$13,811	$137,000
VALLEY MILLS	BOSQUE	0	$12,039	$24,266	$25,721	$25,766	$26,041	$259,000
VALLEY MILLS	MCLENNAN	0	$453	$792	$1,033	$803	$1,133	$11,000
VENUS	JOHNSON	0	$32,985	$64,175	$70,360	$78,105	$87,586	$871,000
VENUS	ELLIS	0	$1,074	$1,639	$2,310	$2,981	$3,596	$36,000
WACO	MCLENNAN	0	$1,446,640	$3,001,593	$4,697,693	$6,519,450	$6,964,137	$69,284,000
WALSH RANCH MUD	WILLIAMSON	0	$8,976	$18,052	$26,768	$34,090	$41,218	$410,000
WELLBORN SUD	BRAZOS	0	$198,990	$280,826	$298,660	$330,988	$366,986	$3,651,000
WELLBORN SUD	ROBERTSON	0	$38,596	$50,305	$49,697	$51,394	$53,454	$532,000
WEST	MCLENNAN	0	$11,651	$6,635	$3,212	$2,676	$2,788	$116,000
WHITNEY	HILL	0	$21,109	$42,318	$41,530	$41,905	$43,126	$429,000
WILLIAMSON COUNTY MUD 10	WILLIAMSON	0	$36,128	$70,774	$102,053	$130,288	$145,999	$1,452,000
WILLIAMSON COUNTY MUD 11	WILLIAMSON	0	$40,648	$79,533	$115,348	$147,872	$148,771	$1,480,000
WILLIAMSON COUNTY MUD 9	WILLIAMSON	0	$25,423	$50,281	$73,161	$94,866	$95,115	$946,000
WINDSOR WATER	MCLENNAN	0	$1,268	$0	$0	$0	$0	$13,000
WOODWAY	MCLENNAN	0	$172,428	$355,402	$553,058	$759,670	$968,857	$9,639,000
	Total Brazos G:	**0**	**$13,980,366**	**$26,778,221**	**$38,613,067**	**$51,657,779**	**$62,340,135**	**$624,971,000**

2.1.6 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 2.1-8, and the option meets each criterion.

Table 2.1-8. 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

2.1.7 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 2021 Brazos G Plan are to take into account anticipated water losses associated with 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. In the 2016 Brazos G Regional Water Plan, water loss reduction for municipal water user groups that prorated real losses greater than 15% of water system input volume through a pipeline replacement program was evaluated and costs were calculated. The total annual cost of pipeline replacement varied from $18,480 to $128 million, with annual unit costs ranging from $12,710 to $1.8 million per acft of water saved. Based on results from the 2016 Brazos G Plan, pipeline replacement was deemed too costly to implement and therefore is not considered in the 2021 Brazos G Plan.

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 Available Yield

All irrigators in the Brazos G Region are encouraged to conserve water.

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, twenty counties are projected to have irrigation needs (shortages) during the 2020 to 2070 planning period.

This conservation can be achieved in a variety of ways, including using BMPs identified by the TWDB[9], such as:

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 System;
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;

[9] TWDB website: https://www.twdb.texas.gov/conservation/BMPs/Ag/index.asp

17. Lining of District Irrigation Canals;
18. Replacement of District Irrigation canals and Lateral canals with Pipelines;
19. Tailwater Recovery and Use System; and
20. Nursery Production Systems.

For the BMPs listed above, water savings (yield) and costs to implement these strategies reported in TWDB guidance documents are summarized in Table 2.2-1. The TWDB describes how the BMPs reduce irrigation water use, however information regarding specific water savings and costs to install irrigation water saving systems is generally unavailable.

The Brazos G RWPG does not recommend specific conservation BMPs for irrigation entities, as each entity should choose those conservation strategies that best fit their individual situation.

Water savings and costs for three irrigation water conservation BMPs are presented: 1) furrow dikes; 2) low-pressure sprinklers (LESA); and 3) low-energy precision application systems (LEPA). These major irrigation water conservation techniques applicable in the Brazos G are described briefly below and used to estimate costs to implement irrigation water conservation programs to achieve target savings.

Furrow Dikes

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 holding precipitation that would have drained from the fields replaces required irrigation water on irrigated fields; and 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 gross quantity of water applied using sprinkler irrigation. Furrow dikes require special equipment and costs $5 to $30 per acre to install.

Table 2.2-1. Cost and Savings of Possible Irrigation Water Conservation Techniques (BMPs)

Best Management Practices	Water Savings Estimates				Cost Estimates				Assumptions/Notes
	Min	Max	Avg	Savings Metric	Min	Max	Avg	Cost Metric	
Irrigation Scheduling	0.3	0.5	0.4	acft/ac/yr	-	-	-	-	Verification of estimated savings attempted by Pacific NW Lab (1994), results inconclusive.
Volumetric Measurement of Irrigation Water Use	0.0	0.0	0.0	-	-	-	-	-	Helps inform conservation efforts, but does not directly lead to conservation savings. Cost varies.
Crop Residue Management and Conservation Tillage	0.3	1.0	0.6	acft/ac/yr	-	-	-	-	Cost varies, some conservation tillage programs are less expensive than conventional tillage.
On-farm Irrigation audit	-	-	-	-	-	-	-	-	No quantifiable savings or costs. Site and crop use specific.
Furrow Dikes	-	-	0.3	acft/ac/yr	5	30	18	per acre/yr	
Land Leveling	-	-	0.3	acft/ac/yr	150	500	325	per acre	Savings based on leveled rice fields near the Texas Gulf Coast. Costs reflect initial costs (touch-up costs are much less)
Contour Farming	-	-	-	-	5	10	8	per acre	
Conservation of Supplemental Irrigated Farmland to Dry-Land	-	-	-	-	-	-	-	-	
Brush Control/Management	0.3	0.6	0.5	acft/ac/yr	36	203	119	acre/10 yrs	Cost estimates are per a Texas A&M study; county average costs range from $150 to $200
Lining of On-Farm Irrigation ditches	-	-	-	-	3	4	3	per sq ft	Concrete lining saves about 80% (conservative estimate) of original seepage. Cost is for concrete lining.
Replacement of On-/farm Irrigation Ditches with Pipelines	-	-	-	-	-	-	-	-	
Low Pressure Center Pivot Sprinkler Irrigation Systems	0.3	0.7	0.5	acft/yr	300	500	400	per acre	Savings based on fraction. "Min" water savings estimate based on fair conditions.
Drip/Micro-Irrigation System	-	-	-	-	800	1,200	1,000	per acre	Costs reflect installation costs only (no O&M)
Gated and Flexible Pipe for Field Water Distribution Systems	-	-	-	-	20	25	23	per acft/yr	*Assuming that 0.25 acft/ac/yr of water is saved
Surge Flow Irrigation for Field Water Distribution Systems	0.1	0.4	0.3	acft/yr	20	25	23	per acft/yr	Savings based on a percentage. Cost estimates assume that 0.25 acft/ac/yr of water is saved by using a surge valve
Linear Move Sprinkler Irrigation Systems	0.3	0.7	0.5	acft/yr	300	700	500	per acre	Savings based on fraction. "Min" water savings estimate based on fair conditions.
Lining of District Irrigation Canals	-	-	-	-	3	4	3	per sq ft	Cost of concrete lining
Replacement of District Irrigation canals and Lateral canals with Pipelines	-	-	-	-	-	-	-	-	
Tailwater Recovery and Use System	0.5	1.5	1.0	acft/ac/yr	-	-	-	-	Cost Varies widely
Nursery Production Systems	-	-	-	-	-	-	-	-	

Source: TWDB Best Management Practices for Agricultural Water Users. https://www.twdb.texas.gov/conservation/BMPs/Ag/index.asp

Low Elevation Spray Application (LESA) and Low Energy Precision Application (LEPA)

Low Elevation Spray Application (LESA) with 75 to 90 percent application efficiency improve irrigation application efficiency in comparison to conventional furrow irrigation by reducing water requirements per acre by 15 percent. Low Energy Precision Application (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, which hold both precipitation and sprinkler applied water behind small mounds of earth within the furrows, LEPA systems can accomplish the irrigation objective with less water than is required for the furrow irrigation and pressurized sprinkler methods.

If LEPA is used with furrow dike systems an expected efficiency of 80 to 95 percent is expected. Use of LEPA and furrow dikes allows irrigation farmers to produce equivalent yields per acre at lower energy and labor costs of irrigation. 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 irrigation farmer who incurred the costs.

To determine the potential water savings (acft/acre) and cost per acft saved, a five year average of the irrigated acres and water use from 2013-2017 was calculated for each county based on information provided by the USDA National Agricultural Statistics Service. Based on information shown in Table 2.2-2 for low pressure center pivot sprinkler irrigation systems and linear move sprinkler irrigation systems, an average cost of $450 per acre to implement LESA/LEPA technologies was assumed. As a conservative estimate, the amount of water saved (acft/acre) assumed 80 percent application efficiency achieved by LESA or LEPA as compared to traditional non-BMP system with 60% efficiency. As shown in Table 2.2-2, this conversion to higher efficiency BMP is expected to save between 0.21 to 0.66 acft/acre at a cost of $680 to $2,118 per acft of water saved.

A 15 percent reduction in irrigation water demand by 2070 for irrigation counties with needs results in a water savings of up to 19,138 acft/yr in 2070 for the region as seen in Table 2.2-3.

Table 2.2-2. Costs and Savings by Implementing LESA/LEPA Water Conservation Techniques (BMPs)

Water User Group	Irrigated Acreage (5 yr avg 2013-2017), acres	Irrigation Water Use (5 yr avg 2013-2017), ac-ft	Cost per acre ($)	Water Saved (acft/acre)*	$ per acft
BELL COUNTY-IRRIGATION	2,008	2,732	$450	0.34	$1,323
BOSQUE COUNTY-IRRIGATION	1,406	2,610	$450	0.46	$970
BURLESON COUNTY-IRRIGATION	16,909	19,307	$450	0.29	$1,576
COMANCHE COUNTY-IRRIGATION	20,428	26,607	$450	0.33	$1,382
GRIMES COUNTY-IRRIGATION	358	468	$450	0.33	$1,376
HASKELL COUNTY-IRRIGATION	41,460	46,810	$450	0.28	$1,594
HILL COUNTY-IRRIGATION	548	1,450	$450	0.66	$680
JOHNSON COUNTY-IRRIGATION	398	577	$450	0.36	$1,241
JONES COUNTY-IRRIGATION	1,944	2,484	$450	0.32	$1,409
KNOX COUNTY-IRRIGATION	30,756	33,302	$450	0.27	$1,662
LAMPASAS COUNTY-IRRIGATION	348	488	$450	0.35	$1,285
MILAM COUNTY-IRRIGATION	4,850	5,660	$450	0.29	$1,542
NOLAN COUNTY-IRRIGATION	10,334	12,452	$450	0.30	$1,494
PALO PINTO COUNTY-IRRIGATION	958	1,649	$450	0.43	$1,045
ROBERTSON COUNTY-IRRIGATION	32,424	68,119	$450	0.53	$857
STEPHENS COUNTY-IRRIGATION	110	133	$450	0.30	$1,489
TAYLOR COUNTY-IRRIGATION	1,610	1,506	$450	0.23	$1,924
THROCKMORTON COUNTY-IRRIGATION	60	51	$450	0.21	$2,118
WILLIAMSON COUNTY-IRRIGATION	288	369	$450	0.32	$1,404
YOUNG COUNTY-IRRIGATION	343	641	$450	0.47	$963
Total Region G:	**167,540**	**227,416**			

TWDB BMPs for Ag Water Users. Low Pressure Center Pivot Sprinkler Irrigation Systems ($300-500 per acre) and Linear Move Sprinkler Irrigation Systems ($300-700 per acre). Avg is $400 and $500. Use $450 per acre.
*Assumes application of non-BMP system is 60% efficient. LESA/LEPA system gains 80% efficiency, as a conservative estimate.

Table 2.2-3. Projected Irrigation Water Savings (acft/yr) with Conservation

Water User Group	Projected Water Savings (acft/yr) with Voluntary Reduction in Demand of 3% by 2020; 5% by 2030; and 7% 2040-2070					
	2020	2030	2040	2050	2060	2070
BELL COUNTY-IRRIGATION	85	142	199	199	199	199
BOSQUE COUNTY-IRRIGATION	107	179	250	250	250	250
BURLESON COUNTY-IRRIGATION	804	1,340	1,876	1,876	1,876	1,876
COMANCHE COUNTY-IRRIGATION	964	1,606	2,248	2,248	2,248	2,248
GRIMES COUNTY-IRRIGATION	20	33	47	47	47	47
HASKELL COUNTY-IRRIGATION	1,747	2,912	3,922	3,933	4,010	4,010
HILL COUNTY-IRRIGATION	53	88	123	123	123	123
JOHNSON COUNTY-IRRIGATION	17	28	40	40	40	40
JONES COUNTY-IRRIGATION	85	141	198	198	198	198
KNOX COUNTY-IRRIGATION	1,319	2,199	2,791	2,665	2,829	2,829
LAMPASAS COUNTY-IRRIGATION	16	27	38	38	38	38
MILAM COUNTY-IRRIGATION	195	325	455	455	455	455
NOLAN COUNTY-IRRIGATION	347	578	809	809	809	809
PALO PINTO COUNTY-IRRIGATION	90	151	211	211	211	211
ROBERTSON COUNTY-IRRIGATION	2,375	3,959	5,579	5,612	5,612	5,612
STEPHENS COUNTY-IRRIGATION	5	8	11	11	11	11
TAYLOR COUNTY-IRRIGATION	49	82	114	114	114	114
THROCKMORTON COUNTY-IRRIGATION	5	8	11	11	11	11
WILLIAMSON COUNTY-IRRIGATION	10	17	23	23	23	23
YOUNG COUNTY-IRRIGATION	15	25	35	35	35	35
Total Region G:	**8,308**	**13,847**	**18,980**	**18,898**	**19,138**	**19,138**

2.2.3 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 result 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.

2.2.4 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 8,308 acft/yr beginning in 2020, 18,980 acft/yr in 2040 and 19,138 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

$450 per acre and water savings rate shown in Table 2.2-1 were used to calculate a cost per acft of water saved. This was then used to calculate a total estimated cost based on water saved in Table 2.2-3. The total cost of implementing these three BMPs for Brazos G entities is estimated to cost $25,224,527 in 2040 and $25,455,400 in 2070 as shown in Table 2.2-4.

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.

Table 2.2-4. Brazos G Irrigation Water Savings and Estimated Costs

Brazos G Water User Group	Projected Water Savings (acft/yr) with Voluntary Reduction in Demand of 3% by 2020; 5% by 2030; and 7% 2040-2070						$ per acft water saved	Costs of Water Savings ($)					
	2020	2030	2040	2050	2060	2070		2020	2030	2040	2050	2060	2070
BELL COUNTY-IRRIGATION	85	142	199	199	199	199	$1,323	$112,854	$188,090	$263,326	$263,326	$263,326	$263,326
BOSQUE COUNTY-IRRIGATION	107	179	250	250	250	250	$970	$104,070	$173,449	$242,829	$242,829	$242,829	$242,829
BURLESON COUNTY-IRRIGATION	804	1,340	1,876	1,876	1,876	1,876	$1,576	$1,267,630	$2,112,717	$2,957,804	$2,957,804	$2,957,804	$2,957,804
COMANCHE COUNTY-IRRIGATION	964	1,606	2,248	2,248	2,248	2,248	$1,382	$1,331,534	$2,219,223	$3,106,912	$3,106,912	$3,106,912	$3,106,912
GRIMES COUNTY-IRRIGATION	20	33	47	47	47	47	$1,376	$27,582	$45,970	$64,357	$64,357	$64,357	$64,357
HASKELL COUNTY-IRRIGATION	1,747	2,912	3,922	3,933	4,010	4,010	$1,594	$2,785,457	$4,642,428	$6,251,985	$6,270,511	$6,392,488	$6,392,488
HILL COUNTY-IRRIGATION	53	88	123	123	123	123	$680	$35,714	$59,524	$83,334	$83,334	$83,334	$83,334
JOHNSON COUNTY-IRRIGATION	17	28	40	40	40	40	$1,241	$21,075	$35,125	$49,175	$49,175	$49,175	$49,175
JONES COUNTY-IRRIGATION	85	141	198	198	198	198	$1,409	$119,575	$199,292	$279,009	$279,009	$279,009	$279,009
KNOX COUNTY-IRRIGATION	1,319	2,199	2,791	2,665	2,829	2,829	$1,662	$2,193,453	$3,655,754	$4,640,020	$4,431,025	$4,702,742	$4,702,742
LAMPASAS COUNTY-IRRIGATION	16	27	38	38	38	38	$1,285	$20,734	$34,557	$48,380	$48,380	$48,380	$48,380
MILAM COUNTY-IRRIGATION	195	325	455	455	455	455	$1,542	$300,861	$501,435	$702,009	$702,009	$702,009	$702,009
NOLAN COUNTY-IRRIGATION	347	578	809	809	809	809	$1,494	$518,232	$863,720	$1,209,208	$1,209,208	$1,209,208	$1,209,208
PALO PINTO COUNTY-IRRIGATION	90	151	211	211	211	211	$1,045	$94,437	$157,396	$220,354	$220,354	$220,354	$220,354
ROBERTSON COUNTY-IRRIGATION	2,375	3,959	5,579	5,612	5,612	5,612	$857	$2,035,254	$3,392,090	$4,780,352	$4,807,941	$4,808,000	$4,808,000
STEPHENS COUNTY-IRRIGATION	5	8	11	11	11	11	$1,489	$6,789	$11,314	$15,840	$15,840	$15,840	$15,840
TAYLOR COUNTY-IRRIGATION	49	82	114	114	114	114	$1,924	$94,375	$157,291	$220,207	$220,207	$220,207	$220,207
THROCKMORTON COUNTY-IRRIGATION	5	8	11	11	11	11	$2,118	$9,974	$16,624	$23,273	$23,273	$23,273	$23,273
WILLIAMSON COUNTY-IRRIGATION	10	17	23	23	23	23	$1,404	$14,027	$23,379	$32,730	$32,730	$32,730	$32,730
YOUNG COUNTY-IRRIGATION	15	25	35	35	35	35	$963	$14,323	$23,872	$33,421	$33,421	$33,421	$33,421
Total Region G:	**8,308**	**13,847**	**18,980**	**18,898**	**19,138**	**19,138**		**$11,107,950**	**$18,513,250**	**$25,224,527**	**$25,061,645**	**$25,455,400**	**$25,455,400**

2.2.5 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 2.2-5 and meets most criteria.

Table 2.2-5. 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.

Manufacturing is an important 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. There are ten (10) counties in the Brazos G Area with projected manufacturing needs: Bell, Burleson, Erath, Knox, Lampasas, Limestone, McLennan, Nolan, Stonewall, and Washington. In 2070, the estimated water needs are 1,891 acft/yr, which is 12% 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 be 232,894 acft/yr from 2030 through 2070. Grimes, Limestone, Milam, Robertson, and Somervell Counties comprise over 80 percent of the projected regional steam-electric water use in 2070. 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: Brazos, Grimes, Hill, Johnson, Limestone, Milam, and Somervell. In 2070, the estimated water needs are 74,477 acft/yr, which is 32% of the steam-electric water demand for the Brazos G Area.

In the Brazos G Area, the mining water demands increase from 59,340 acft/yr in 2040 to 60,838 acft/yr in 2070. In 2070, the Brazos G Area mining users are projected to receive over 90% of their water supplies from groundwater sources. Thirty-one (31) 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 28,236 acft, which is about 46% of the mining water demand for the Brazos G Area.

2.3.2 Available Yield

All mining entities in the Brazos G Region are encouraged to conserve water.

The Brazos G RWPG recommends that counties with projected needs (shortages) for industrial users (manufacturing 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 TWDB.

The Brazos G RWPG considered water conservation as a water management strategy for steam-electric users, but opted not to recommend water conservation due to variability in processes and water use practices.

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

1. Industrial Water Audit

[10] TWDB website: https://www.twdb.texas.gov/conservation/BMPs/Ind/index.asp

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 Facility Landscaping
14. Industrial Site-Specific Conservation

For the BMPs listed above, water savings (yield) and costs to implement these strategies reported in TWDB guidance documents are summarized in Table 2.3-1. The TWDB describes how the BMPs reduce water use, however information regarding specific water savings and costs to implement conservation programs is generally unavailable. Conservation savings and costs are facility and process specific. Since mining entities are presented on a county-wide basis and are not individually identified, identification and quantifying of savings of specific water management strategies are not reasonable expectations.

For the 10 manufacturing users with projected needs, the total water savings after 7 percent water demand reduction in 2070 is 708 acft/yr as shown in Table 2.3-2, which amounts to a 37% reduction in total regional manufacturing shortages.

For the thirty one (31) mining users with projected needs, the total water savings after 7 percent water demand reduction in 2070 is 3,317 acft/yr as also shown in Table 2.3-2, which amounts to a 20% reduction in total regional mining shortages.

Table 2.3-1. Cost and Savings of Possible Industrial Water Conservation Techniques (BMPs)

Best Management Practices	Water Savings Estimates				Cost Estimates				Assumptions/Notes
	Min	Max	Avg	Savings Metric	Min	Max	Avg	Cost Metric	
Industrial Water Audit	10.0	35.0	22.5	%	-	-	-	-	-
Industrial Water Waste Reduction	-	-	-	-	-	-	-	-	-
Industrial Sub-metering	-	-	-	-	-	-	-	-	-
Cooling Towers	-	-	-	-	-	-	-	-	Highly variable. Savings due to increased concentration ratio and implemented changes in operating procedures. TWDB guidance available for calculating water savings.
Cooling Systems (other than Cooling Towers)	-	90.0	-	%	-	-	-	-	Estimated that retrofitting of single-pass cooling equipment such as x-rays to recirculating water systems can cut water use by up to 90%.
Industrial Alternative Sources and Reuse and Recirculation of Process Water	-	-	-	-	-	-	-	-	-
Rinsing/Cleaning	-	-	-	-	-	-	-	-	-
Water Treatment	10.0	85.0	47.5	%	-	-	-	-	Water savings range widely based on specific updates - from process adjustments to reclaim systems.
Boiler and Steam Systems	-	-	-	-	-	-	-	-	Highly variable. Savings due to increased condensate return and increased concentration ratios. TWDB guidance available for calculating water savings.
Refrigeration (including Chilled Water)	-	-	-	-	-	-	-	-	-
Once-Through Cooling	-	-	-	-	-	-	-	-	-
Management and Employee Programs	-	-	-	-	-	-	-	-	-
Industrial Facility Landscaping	-	-	15.0	%	-	-	-	-	-
Industrial Site Specific Conservation	10.0	95.0	52.5	%	-	-	-	-	Savings vary widely - from water audits to changing from potable to recycled water.

Source: TWDB Best management Practices for Industrial Water Users, February 2013.
https://www.twdb.texas.gov/conservation/BMPs/Ind/index.asp

Table 2.3-2. Projected Water Savings for Manufacturing and Mining Water User Groups Considering up to a 7 Percent Demand Reduction by 2040

Water Savings (acft/yr) with Voluntary Reduction in Demand of 3% by 2020; 5% by 2030; and 7% from 2040-2070						
	2020 (3%)	*2030 (5%)*	*2040 (7%)*	*2050 (7%)*	*2060 (7%)*	*2070 (7%)*
Manufacturing						
BELL COUNTY-MANUFACTURING	19	34	48	48	48	48
BURLESON COUNTY-MANUFACTURING	4	6	8	8	8	8
ERATH COUNTY-MANUFACTURING	2	4	6	6	6	6
KNOX COUNTY-MANUFACTURING	0	0	0	0	0	0
LAMPASAS COUNTY-MANUFACTURING	6	11	15	15	15	15
LIMESTONE COUNTY-MANUFACTURING	10	19	26	26	26	26
MCLENNAN COUNTY-MANUFACTURING	144	373	522	522	522	522
NOLAN COUNTY-MANUFACTURING	13	26	37	37	37	37
STONEWALL COUNTY-MANUFACTURING	2	3	4	4	4	4
WASHINGTON COUNTY-MANUFACTURING	17	29	41	41	41	41
Total Brazos G water savings for Manufacturing WUGs with needs (acft/yr)	**217**	**506**	**708**	**708**	**708**	**708**
Mining						
BELL COUNTY-MINING	97	199	322	374	427	488
BOSQUE COUNTY-MINING	59	104	132	131	128	127
CALLAHAN COUNTY-MINING	7	11	15	14	13	13
COMANCHE COUNTY-MINING	13	26	25	19	13	9
CORYELL COUNTY-MINING	45	54	34	25	28	31
EASTLAND COUNTY-MINING	35	59	65	50	36	30
FALLS COUNTY-MINING	7	12	18	20	21	23
FISHER COUNTY-MINING	12	20	25	22	19	17

Table 2.3-2. Projected Water Savings for Manufacturing and Mining Water User Groups Considering up to a 7 Percent Demand Reduction by 2040

Water Savings (acft/yr) with Voluntary Reduction in Demand of 3% by 2020; 5% by 2030; and 7% from 2040-2070						
	2020 (3%)	*2030 (5%)*	*2040 (7%)*	*2050 (7%)*	*2060 (7%)*	*2070 (7%)*
GRIMES COUNTY-MINING	10	30	33	24	15	9
HAMILTON COUNTY-MINING	12	12	7	0	0	0
HASKELL COUNTY-MINING	3	5	6	5	5	4
HILL COUNTY-MINING	49	60	54	28	31	33
HOOD COUNTY-MINING	62	122	156	149	143	144
JOHNSON COUNTY-MINING	124	139	106	71	81	94
JONES COUNTY-MINING	7	12	15	14	13	12
KNOX COUNTY-MINING	0	1	1	1	1	1
LAMPASAS COUNTY-MINING	6	11	17	18	20	22
LEE COUNTY-MINING	95	159	0	0	0	0
LIMESTONE COUNTY-MINING	310	496	691	724	756	800
MCLENNAN COUNTY-MINING	76	150	214	246	268	295
NOLAN COUNTY-MINING	7	11	14	12	11	10
PALO PINTO COUNTY-MINING	20	42	44	34	24	16
SHACKELFORD COUNTY-MINING	17	37	39	31	23	17
SOMERVELL COUNTY-MINING	33	64	80	74	70	68
STEPHENS COUNTY-MINING	152	257	312	268	228	194
STONEWALL COUNTY-MINING	18	29	36	31	27	24
TAYLOR COUNTY-MINING	12	20	26	24	23	22
THROCKMORTON COUNTY-MINING	6	10	12	11	9	8
WASHINGTON COUNTY-MINING	17	43	49	38	26	18
WILLIAMSON COUNTY-MINING	155	313	516	599	685	783
YOUNG COUNTY-MINING	6	14	14	11	7	5
Total Brazos G water savings for Mining WUGs with needs (acft/yr)	**1,471**	**2,520**	**3,078**	**3,068**	**3,153**	**3,317**

2.3.3 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.

2.3.4 Engineering and Costing

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.

2.3.5 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 2.3-3 and the option meets each criterion.

Table 2.3-3. 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

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3 Wastewater Reuse

3.1 Overview

Wastewater reuse is defined as the types of projects that utilize treated wastewater effluent as a replacement for fresh water supply, reducing the overall demand for fresh water supply. Wastewater reuse typically involves a capital project connecting the wastewater 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. Virtually any water supply entity with a wastewater treatment plant could pursue a reuse alternative. 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 and/or energy development 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 (often referred to as “flange-to-flange”).
2. Indirect Reuse – Discharge treated wastewater to river, stream, or lake for subsequent diversion downstream (often referred to as “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 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;
6. City of Cedar Park; and
7. City of Georgetown.

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.

3.1.3 Direct and Indirect Potable Reuse

Reclaimed water can either be used for potable or non-potable purposes. Reuse applications typically refer to non-potable reuse where the reclaimed water does not get used for potable purposes from the drinking water system. With advanced water treatment methods available there are two options for potable use of reclaimed water. The two options are Indirect Potable Reuse and Direct Potable Reuse. Indirect potable Reuse is defined as “the use of reclaimed water for potable purposes by discharging to a water supply source, such as surface water or ground water.” The mixed reclaimed and natural waters then get additional treatment at a water treatment plant before entering the drinking water distribution system. Direct Potable reuse is defined as “the introduction of advanced treated reclaimed water either directly into the potable water system or into the raw water supply entering the water treatment plant.” Under these definitions, aquifer storage and recovery may be considered to be a type of indirect potable reuse.

Potable reclaimed water supplied to consumers is held to stricter standards than non-potable reclaimed water use and is required to meet federal and state drinking water standards.

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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 projected needs have the potential to develop wastewater reuse projects, and a general evaluation of wastewater reuse potential was conducted for these entities based on wastewater flows used to determine currently available surface water supplies.

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 identify 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.

Table 3.2-1. General Wastewater Reuse Potential in the Brazos G Area

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 Estimated Reuse (acft/yr)
Killeen	Bell	Bell County WCID#1	30,366	93%	N	45,120	18,602
Elm Creek WSC	Bell	City of Temple	196	24%	N	11,817	4,872
Bell County-Other	Bell	Bell County WCID#1	307	17%	N	45,120	18,602
Harker Heights	Bell	Bell County WCID#1	3,000	27%	N	45,120	18,602
Cedar Park	Bell	Cedar Park	5,427	52%	Y	9,221	3,986
Manufacturing	Bell	City of Temple	186	27%	N	11,817	4,872
Irrigation	Bell	Bell County WCID#1	719	25%	N	45,120	18,602
Mining	Bell	Bell County WCID#1	5,803	83%	N	45,120	18,602
Temple	Bell	BRA TBRSS	17,103	47%	N	19,209	7,920
Bryan	Brazos	City of Bryan	19,650	55%	Y	22,369	22,366
College Station	Brazos	City of College Station	13,360	44%	Y	24,703	24,696
College Station	Brazos	Texas A&M University	13,360	44%	Y	6,640	6,640
Gatesville	Coryell	City of Gatesville	4,688	66%	N	7,649	3,116
Cleburne	Johnson	City of Cleburne	7,324	54%	N	17,300	7,146
Steam-Electric	Johnson	City of Cleburne	571	30%	N	17,300	7,146
Mining	Jones	City of Abilene	90	53%	Y	11,113	11,110
Mining	Lee	BRA/LCRA BCRWSS West	0	0%	N	5,574	2,409
Mart	McLennan	WMARSS	244	55%	N	56,904	56,904
North Bosque WSC	McLennan	WMARSS	522	46%	N	56,904	56,904
Robinson	McLennan	WMARSS	2,255	50%	N	56,904	56,904
Manufacturing	McLennan	WMARSS	1,309	18%	N	56,904	56,904
Mining	McLennan	WMARSS	3,478	82%	N	56,904	56,904
Sweetwater	Nolan	City of Sweetwater	1,839	84%	Y	1,934	750
Steam-Electric	Robertson	City of Hearne	28,894	63%	N	1,411	562
Abilene	Taylor	City of Abilene	21,240	88%	Y	11,113	11,110
Merkel	Taylor	City of Abilene	41	10%	Y	11,113	11,110
Mining	Taylor	City of Abilene	181	57%	Y	11,113	11,110
Georgetown	Williamson	City of Georgetown	66,676	85%	Y	12,033	5,202
Granger	Williamson	City of Georgetown	56	20%	Y	12,033	5,202
Hutto	Williamson	BRA/LCRA BCRWSS West	10,703	90%	N	5,574	2,409

Table 3.2-1. General Wastewater Reuse Potential in the Brazos G Area

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 Estimated Reuse (acft/yr)
Leander	Williamson	City of Leander	22,322	78%	N	3,950	1,707
Mining	Williamson	City of Georgetown	10,743	96%	N	12,033	5,202
Round Rock	Williamson	BRA/LCRA BCRWSS East	16,642	44%	N	63,194	27,317
Williamson C-O	Williamson	City of Leander	37,798	86%	N	3,950	1,707
Irrigation	Williamson	BRA/LCRA BCRWSS East	172	52%	N	63,194	27,317
Florence	Williamson	BRA TBRSS	72	43%	N	19,209	7,920

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 quality wastewater effluent.

Table 3.2-2. Environmental Issues: General Wastewater Reuse

Issue	Description
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 greater than 57 percent of maximum capacity for systems supplying a large portion of the reuse water to industrial, non-municipal or other users that have a more uniform seasonal demand pattern.

Table 3.2-4. Required Distribution Facilities for Generalized Wastewater Reuse Scenarios

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

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 3.2-1 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	$5.75	$3.90	$2.87	$2.67
2	$9.89	$6.92	$4.67	$4.23
Debt Service (3.5 percent for 20 years)				

Figure 3.2-1. General Wastewater Reuse Annual Cost of Water ($ per acft available project yield

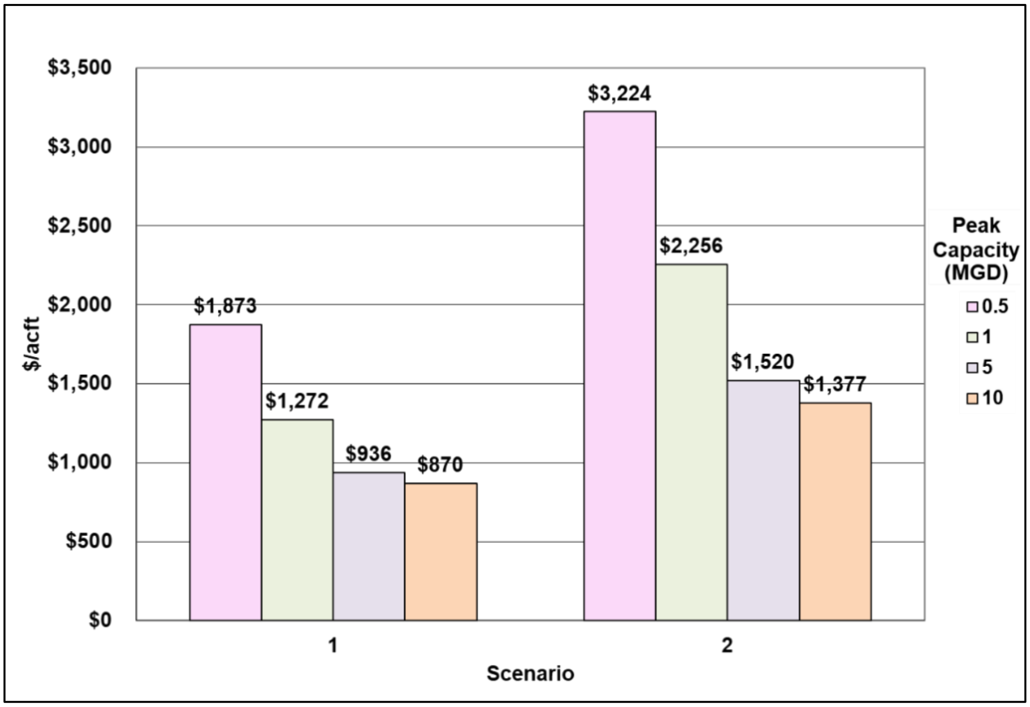

Table 3.2-7. General Wastewater Reuse Total Project Capital Cost ($ per gallon maximum capacity)

Scenario	Maximum Capacity (MGD)			
	0.5	1	5	10
1	$12.03	$7.89	$5.71	$2.86
2	$15.74	$10.55	$7.15	$3.57

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	$0.91	$0.73	$0.58	$0.53
2	$3.56	$2.68	$1.79	$1.62

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.

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	0.35	0.2	2	$9.89	$15.74	$5,510,000
Bell C-O	Bell	0.5	0.3	2	$9.89	$15.74	$7,871,000
Harker Heights	Bell	See Individual Option					
Cedar Park	Bell	See Individual Option					
Manufacturing	Bell	0.2	0.2	2	$9.89	$15.74	$3,148,000
Irrigation	Bell	1	1	2	$6.92	$10.55	$10,546,000
Mining	Bell	5	5	2	$4.67	$7.15	$35,745,000
Temple	Bell	10	5.7	2	$4.23	$3.57	$35,745,000
Bryan	Brazos	See Individual Option					
College Station	Brazos	See Individual Option					
Gatesville	Coryell	7.5	4.3	2	$4.23	$3.57	$26,808,000
Cleburne	Johnson	See Individual Option					
Steam-Electric	Johnson	5	5	2	$4.67	$7.15	$35,745,000
Mining	Jones	0.1	0.1	2	$9.89	$15.74	$1,574,000
Mining	Lee	0.5	0.5	2	$9.89	$15.74	$7,871,000
Mart	McLennan	See Individual Option					
North Bosque WSC	McLennan	0.8	0.5	1	$3.90	$7.89	$6,311,000
Robinson	McLennan	0.35	0.2	1	$5.75	$12.03	$4,211,000
Mining	McLennan	See Individual Option					
Manufacturing	McLennan	1	1	1	$3.90	$7.89	$7,889,000
Sweetwater	Nolan	2.8	1.6	1	$2.87	$5.71	$15,992,000
Steam-Electric	Robertson	0.2	0.2	2	$9.89	$15.74	$3,148,000
Abilene	Taylor	See WWP plan in Section 4C.38					
Merkel	Taylor	0.1	0.1	2	$9.89	$15.74	$1,574,000

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 ($)
Merkel	Taylor	0.1	0.1	2	$9.89	$15.74	$1,574,000
Mining	Taylor	0.2	0.2	2	$9.89	$15.74	$3,148,000
Georgetown	Williamson	10	5.7	2	$4.23	$3.57	$35,745,000
Granger	Williamson	0.15	0.1	2	$9.89	$15.74	$2,361,000
Hutto	Williamson	10	5.7	2	$4.23	$3.57	$35,745,000
Leander	Williamson	10	5.7	2	$4.23	$3.57	$35,745,000
Mining	Williamson	5	5.0	2	$4.67	$7.15	$35,745,000
Round Rock	Williamson	10	5.7	2	$4.23	$3.57	$35,745,000
Williamson C-O	Williamson	10	5.7	2	$4.23	$3.57	$35,745,000
Irrigation	Williamson	0.1	0.1	2	$9.89	$15.74	$1,574,000
Florence	Williamson	0.2	0.1	2	$9.89	$15.74	$3,148,000

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 3.2-10. 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 authorization. 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;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

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3.3 Bell County WCID No.1 Reuse Projects

3.3.1 Description of Option

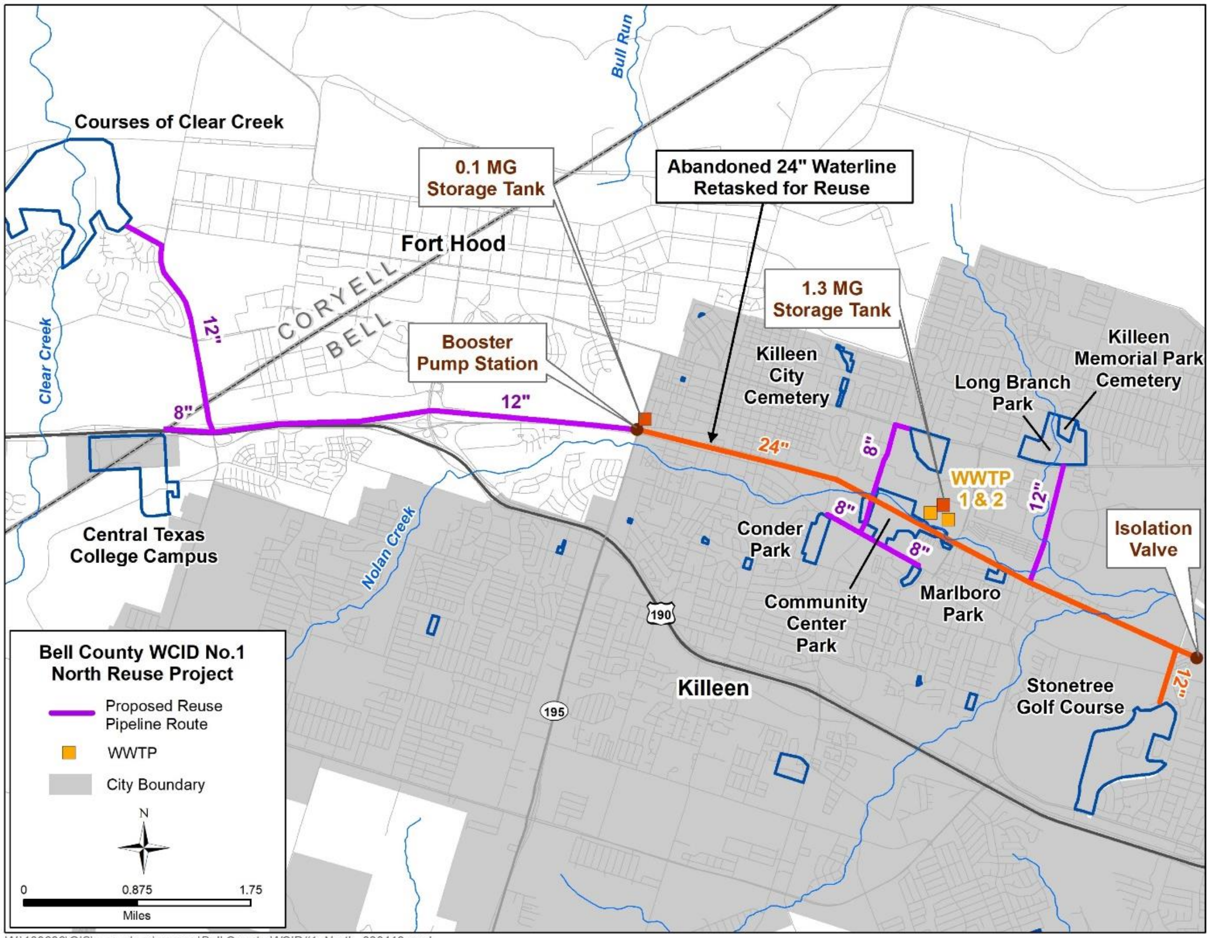
Bell County WCID No. 1 has evaluated several wastewater reuse options as part of its Master Plan update. The reuse portion of the Master Plan identifies both near-term potential customers as well as other future customers that would utilize the total available reuse supply generated through the District's 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. 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, golf courses including 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 3.3-1. 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 3.3-1. Although average annual demands total approximately 1,925 acft/yr (1.72 MGD annual average), the reuse system must be sized to meet the peak irrigation demand during the summer months, which is about 3.03 MGD.

Table 3.3-1. 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 3.3-1. Bell County WCID No. 1 North Reuse Project



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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 3.3-2. Average annual demand for the South project is approximately 748 acft/yr, and peak irrigation demand is about 1.18 MGD. Irrigation demands for the South project are shown in Table 3.3-2.

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 3.3-3 shows the future potential reuse demands.

3.3.2 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 3.3-2. Bell County WCID No. 1 South Reuse Project

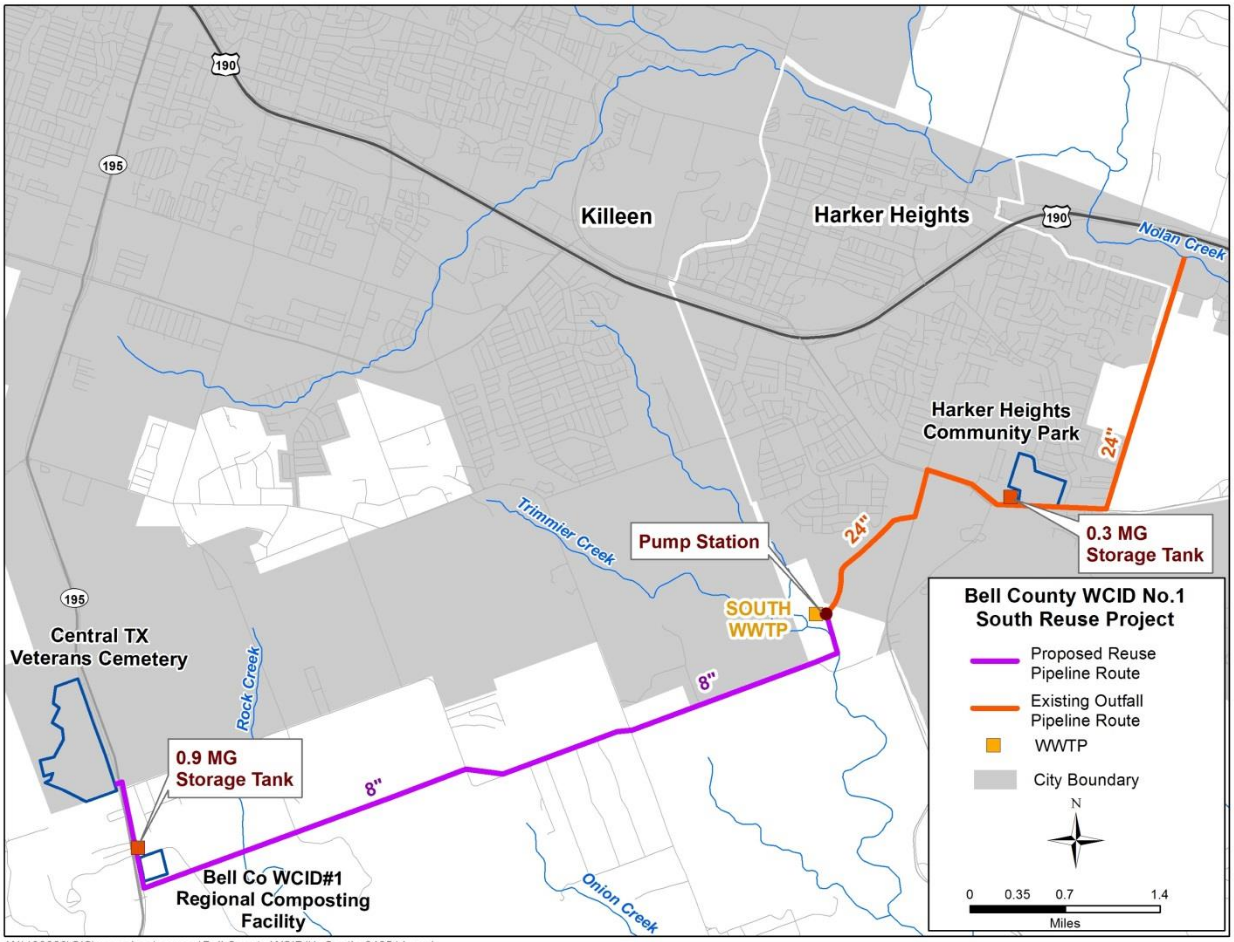

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Table 3.3-2. Water Reuse Demands for Bell County WCID No. 1 South Reuse Project

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 3.3-3 Other Potential Future Water Reuse Demands for Bell County WCID No. 1 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

3.3.3 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 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 3.3-4.

Table 3.3-4. Environmental Issues: Bell County WCID No. 1 North and South Reuse Projects

Issue	Description
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

3.3.4 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 3.3-5.

Table 3.3-5. Required Facilities – Bell County WCID No. 1 North Reuse Project

Facility	Description
Treatment Upgrade	Existing WWTP meets Type 2 reuse standards, basic treatment chorine disinfection included
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	1.3 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

Estimated costs for the North Reuse Project are summarized in Table 3.3-6. Total costs for the project are $15,186,000 with annual costs of $1,608,000. Annual costs include debt service estimated at 3.5% for 20 years, O&M for pipelines and pump stations and pumping energy. Annual unit costs are estimated to be $835/acft or $2.56/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 3.3-7.

Estimated costs for the South Reuse Project are summarized in Table 3.3-8. Total project costs for the project are $11,578,000 with annual costs of $1,020,000. Annual costs include debt service estimated at 3.5% for 20 years, O&M for pipeline and pump station and pumping energy. Annual unit costs are estimated at $274/acft or $4.18/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 3.3-6. Cost Estimate Summary: Bell County WCID No. 1 North Reuse Project

Item	*Estimated Costs for Facilities*
Transmission Pipeline (8 in dia., 2.2 miles and 12 in. dia, 6.1 miles)	**$5,133,000**
Transmission Pump Station(s) & Storage Tank(s)	**$4,255,000**
Storage Tanks (Other Than at Booster Pump Stations)	**$901,000**
Water Treatment Plant (9 MGD)	**$514,000**
TOTAL COST OF FACILITIES	**$10,803,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	**$3,525,000**
Environmental & Archaeology Studies and Mitigation	**$324,000**
Land Acquisition and Surveying (17 acres)	**$127,000**
Interest During Construction (3% for 1 years with a 0.5% ROI)	**$407,000**
TOTAL COST OF PROJECT	**$15,186,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	**$1,068,000**
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	**$69,000**
Intakes and Pump Stations (2.5% of Cost of Facilities)	**$84,000**
Water Treatment Plant	**$308,000**
Pumping Energy Costs (993,113 kW-hr @ 0.08 $/kW-hr)	**$79,000**
TOTAL ANNUAL COST	**$1,608,000**
Available Project Yield (acft/yr)	**1,925**
Annual Cost of Water ($ per acft), based on PF=1	**$835**
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	**$281**
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	**$2.56**
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	**$0.86**

Table 3.3-7. 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

Table 3.3-8. Cost Estimate Summary: Bell County WCID No. 1 South Reuse Project

Item	*Estimated Costs for Facilities*
CAPITAL COST	
Transmission Pipeline (8 in dia., 6.7 miles)	$1,885,000
Transmission Pump Station(s) & Storage Tank(s)	$3,754,000
Storage Tanks (Other Than at Booster Pump Stations)	$2,238,000
Two Water Treatment Plants (0.9 MGD and 0.3 MGD)	$119,000
TOTAL COST OF FACILITIES	**$7,996,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,704,000
Environmental & Archaeology Studies and Mitigation	$269,000
Land Acquisition and Surveying (39 acres)	$299,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$310,000
TOTAL COST OF PROJECT	**$11,578,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$815,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$59,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$49,000
Water Treatment Plant	$72,000
Pumping Energy Costs (311,116 kW-hr @ 0.08 $/kW-hr)	$25,000
TOTAL ANNUAL COST	**$1,020,000**
Available Project Yield (acft/yr)	748
Annual Cost of Water ($ per acft), based on PF=1.73	$1,364
Annual Cost of Water After Debt Service ($ per acft), based on PF=1.73	$274
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.73	$4.18
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.73	$0.84

As identified in Table 3.3-9, the combined yield of the North and South Reuse Projects are 2,673 acft/yr with annual unit costs of $983/acft or $3.01 per thousand gallons.

Table 3.3-9. Total Yield and Cost for North and South Reuse Projects

Project	Average Yield (acft/yr)	Unit Cost	
		($/acft)	($/kgal)
North Reuse Project	1,925	$835	$2.56
South Reuse Project	748	$1,364	$4.18
Total	2,673	$983	$3.01

3.3.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.3-10, 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;
- TPWD Sand, Shell, Gravel, and Marl permit for construction in state-owned streambeds; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

Table 3.3-10. 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

Impact Category	Comment(s)
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 City of Bryan Lake Bryan Reuse

3.4.1 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.

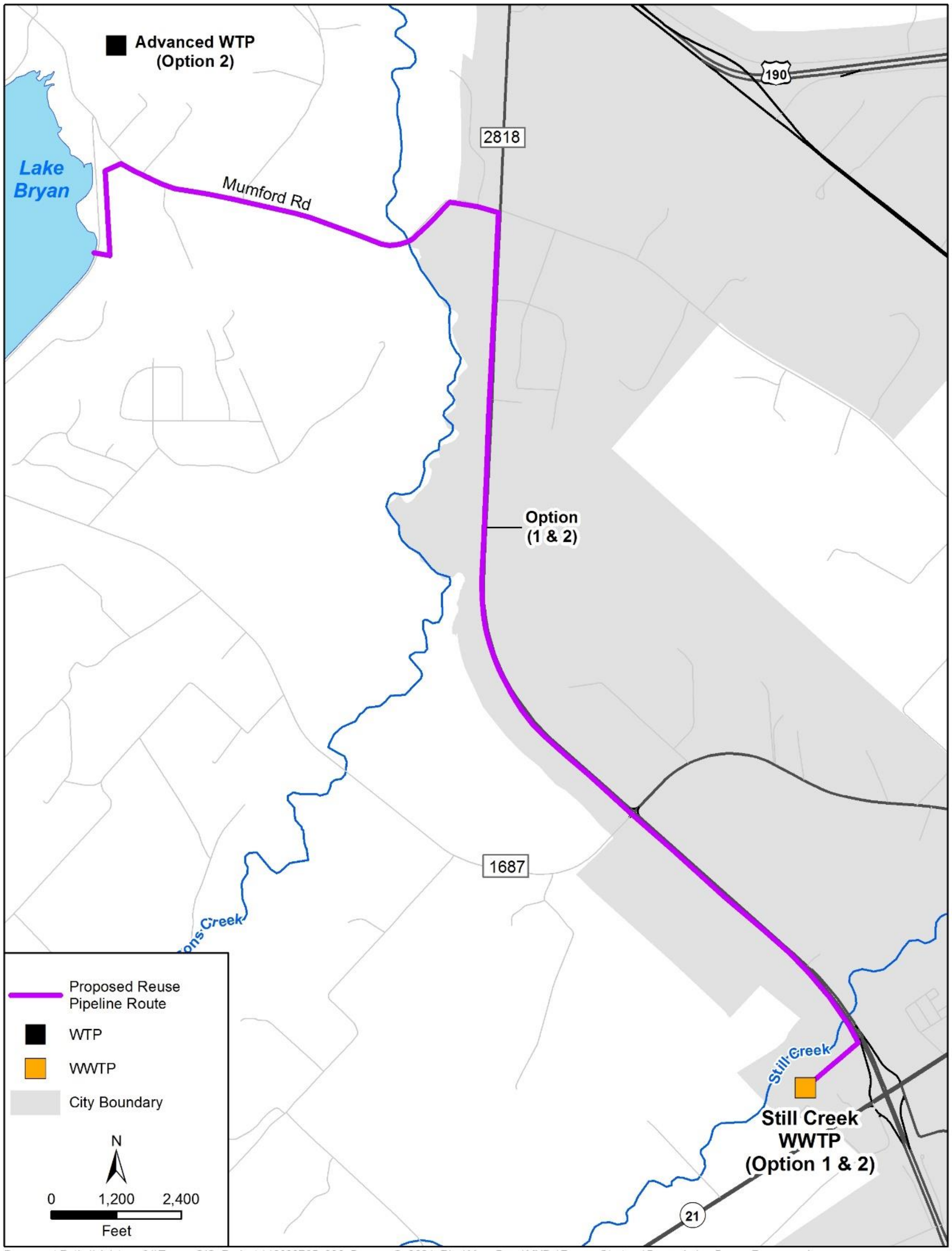
The City is considering two alternate reuse projects using treated supplies from Still Creek WWTP to either offset potable demand (Option 1) or as indirect potable reuse (Option 2). Option 1 consists of a reuse project to deliver Type 1 treated wastewater to Bryan Utilities Lake, a small lake associated with a power generation plant (Figure 3.4-1). 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.

3.4.2 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 5,621 acft/yr (5.02 MGD). The Burton Creek WWTP Year 2070 Estimated WWTP Effluent is 15,209 acft/yr (13.58 MGD).

Figure 3.4-1. Bryan Reuse Option 1 and Option 2



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3.4.3 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 3.4-1.

Table 3.4-1. Environmental Issues: Bryan Reuse

Issue	Description
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 required improvements to implement a wastewater reuse supply for Bryan's Option 1 are summarized in Table 3.4-2. Costs presented in Table 3.4-3 provide the total Option 1 costs for developing a wastewater reuse supply to Bryan Utilities Lake. The required improvements to implement an indirect potable reuse supply for Bryan's Option 2 are summarized in Table 3.4-4. Costs presented in Table 3.4-5 provide the total Option 2 costs for developing an indirect potable reuse supply. System integration costs are not included in the estimate.

Table 3.4-2. 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 (Booster); 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 3.4-3. Cost Estimate Summary: Option 1 Reuse for Bryan Utilities Lake Supply

Item	Estimated Costs for Facilities
Transmission Pipeline (12 in dia., 6 miles)	$2,610,000
Transmission Pump Station(s) & Storage Tank(s)	$1,249,000
Wastewater Treatment Plant Upgrades	$3,455,000
Total Cost Of Facilities	**$7,314,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,429,000
Environmental & Archaeology Studies and Mitigation	$214,000
Land Acquisition and Surveying (34 acres)	$838,000
Interest During Construction (4% for 1 years with a 1% ROI)	$297,000
Total Cost Of Project	**$11,092,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$780,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$26,000
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$31,000
Water Treatment Plant (2.5% of Cost of Facilities)	$635,000
Pumping Energy Costs (128,384 kW-hr @ 0.09 $/kW-hr)	$10,000
Total Annual Cost	**$1,482,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 4	605
Annual Cost of Water ($ per acft)	$2,450
Annual Cost of Water ($ per 1,000 gallons)	$7.52

Table 3.4-4. 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	2.2 MGD Advanced WTP (low pressure membranes, RO, advanced oxidation)
Pump Station	174 hp (Booster); 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 3.4-5. Cost Estimate Summary: Option 2 Indirect Potable Reuse for Bryan

Item	Estimated Costs for Facilities
Intake Pump Stations	$3,379,000
Transmission Pipeline (12 in dia., 6 miles)	$2,784,000
Transmission Pump Station(s) & Storage Tank(s)	$1,309,000
WWTP Improvements	$3,439,000
Advanced Water Treatment Plant (2.2 MGD)	$17,558,000
Total Cost Of Facilities	**$28,469,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$9,825,000
Environmental & Archaeology Studies and Mitigation	$255,000
Land Acquisition and Surveying (41 acres)	$1,455,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,101,000
Total Cost Of Project	**$41,105,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$2,892,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$28,000
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$117,000
Water Treatment Plant (2.5% of Cost of Facilities)	$543,000
Advanced Water Treatment Facility	$2,213,000
Pumping Energy Costs (1,418,459 kW-hr @ 0.09 $/kW-hr)	$106,000
Purchase of Water (acft/yr @ $/acft)	$0
Total Annual Cost	**$5,899,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	2,419
Annual Cost of Water ($ per acft)	$2,439
Annual Cost of Water ($ per 1,000 gallons)	$7.48

3.4.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.4-6, and the option meets each criterion. The City of Bryan might 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; and
- 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; and
- Integration of surface water source into a groundwater system which may affect water quality and disinfection compatibility.

Table 3.4-6. 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
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;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

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3.5 City of Bryan – Miramont Reuse

3.5.1 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. Figure 3.5-1 shows the potential route for reuse water to Miramont Country Club.

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

3.5.2 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 15,210 acft/yr (13.58 MGD).

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 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 3.5-1.

3.5.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply for the Miramont Country Club are summarized in Table 3.5-2. Project and annual costs are included in Table 3.5-3. The total project cost is estimated at $3,894,000 with an average annual cost of $315,000.

Figure 3.5-1 Bryan Miramont Reuse

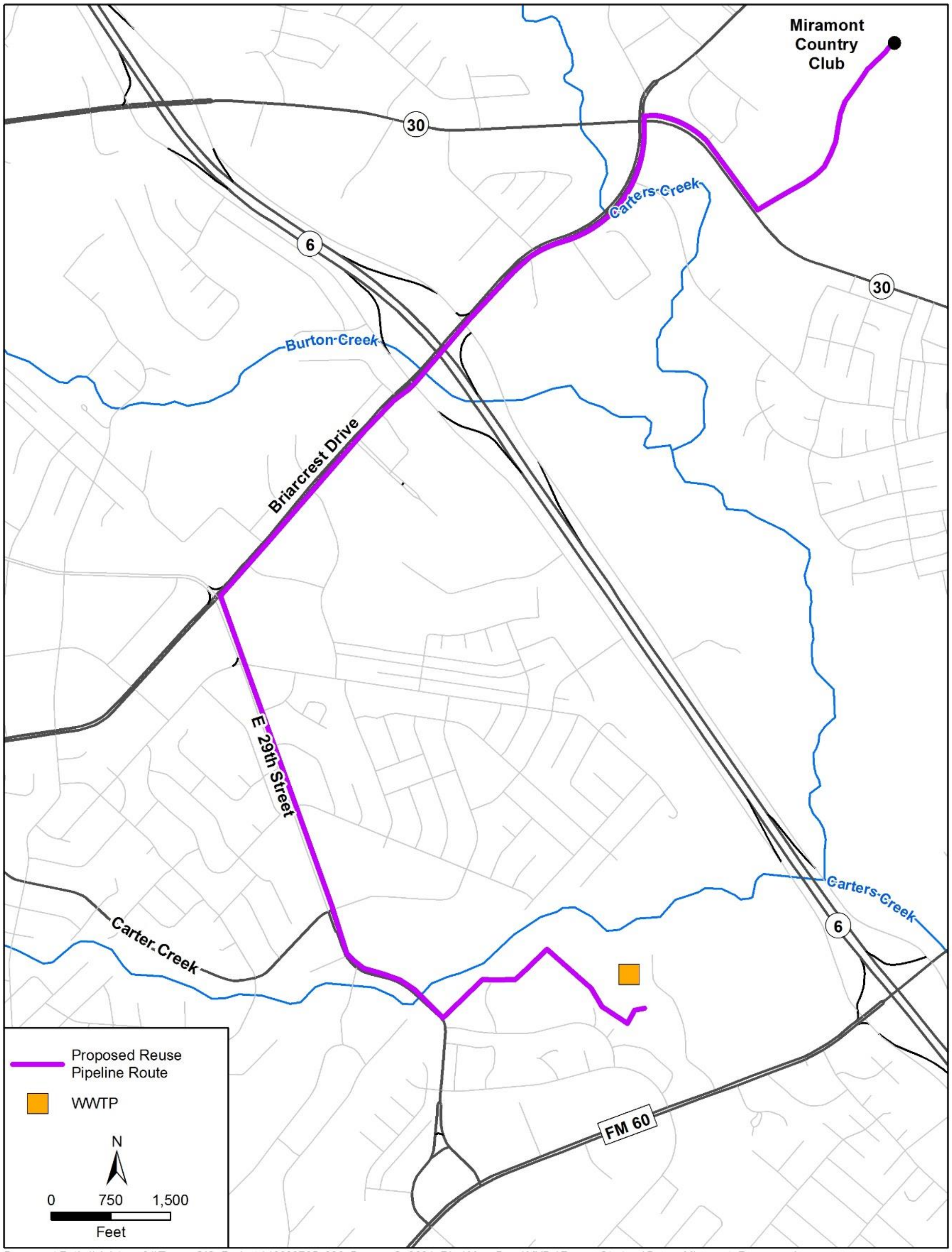

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Table 3.5-1. Environmental Issues: Bryan Miramont Reuse

Issue	Description
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 3.5-2. Required Facilities – Bryan Miramont Reuse

Facility	Description
Treatment Upgrade	Additional chlorine for distribution
Pump Station	50 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 3.5-3. Cost Estimate Summary: Bryan Miramont Reuse Project

Item	Estimated Costs for Facilities
Pump Station (1.6 MGD)	$585,000
Transmission Pipeline (12 in dia., 4 miles)	$2,097,000
Total Cost Of Facilities	**$2,682,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$834,000
Environmental & Archaeology Studies and Mitigation	$120,000
Land Acquisition and Surveying (22 acres)	$153,000
Interest During Construction (4% for 1 years with a 1% ROI)	$105,000
Total Cost Of Project	**$3,894,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$274,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$21,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$15,000
Pumping Energy Costs (67906 kW-hr @ 0.09 $/kW-hr)	$5,000
Total Annual Cost	**$315,000**
Available Project Yield (acft/yr)	**600**
Annual Cost of Water ($ per acft), based on a Peaking Factor of 3	**$525**
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 3	**$1.61**

3.5.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.5-4, 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;
- TPWD Sand, Shell, Gravel, and Marl permit for construction in state-owned streambeds; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

Table 3.5-4. 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

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3.6 Cedar Park Reuse

3.6.1 Description of Option

The City of Cedar Park WWTP has a permitted average effluent discharge of 2.5 MGD. Cedar Park is currently applying reuse as a water supply to Brushy Creek Sports Park through indirect reuse. Reuse supply available to the Sports Park is on average 32 acft/year (0.03 MGD). During peak demand the supply requirement to the Sports Park and other Public Works can be as great as 0.35 MGD. The City also has a contract with Avery Ranch golf course to provide up to 1 MGD of reuse water. The City operates a Water Reclamation Facility that treats water to Type 1 standards. The City can accommodate another 1 MGD of treated water for additional reuse applications. Two parks, Milburn Park and Fenway Park, have been identified as potential locations for additional reuse supply.

Locations of the Cedar Park WWTP plant, water reclamation facility, and proposed transmission pipelines, ground storage tanks, and pump stations are shown in Figure 3.6-1.

3.6.2 Available Supply

The planned capacity of the Cedar Park Reuse project is 1 MGD (1,120 acft/yr).

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 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 3.6-1.

Figure 3.6-1. Cedar Park Reuse

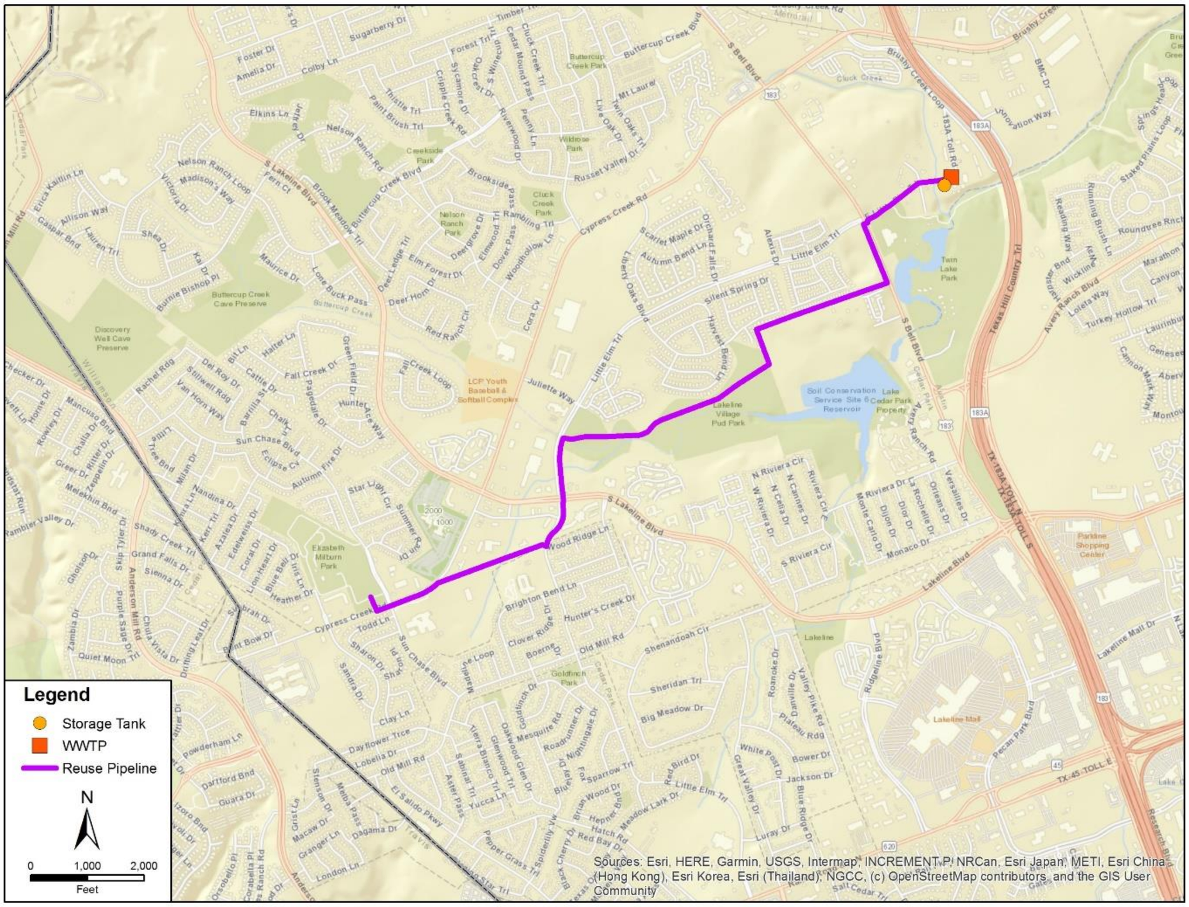

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Table 3.6-1. Environmental Issues: Cedar Park Reuse

Issue	Description
Implementation Measures	Development of additional water transmission pipelines, ground storage tanks 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
Edwards Aquifer	Possible increased water quality to stream flows and Edwards Aquifer recharge zone. Possible low impact on recharge rates due to decreased effluent flow from the contributing zone.
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

3.6.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply Cedar Park are summarized in Table 3.6-2. The project requires a 1 MGD pump station along with a 1 MG storage tank located at the Cedar Park WWTP. A 2.84 mile, 14-inch diameter pipe would deliver the reuse supply to Fenway Park and Milburn Park. Distribution lines not included in this cost estimate would deliver irrigation supply to both parks.

Table 3.6-2. Required Facilities – Cedar Park Reuse

Facility	Description
Pump Stations	300 HP at Cedar Park WWTP; 1 MGD capacity for peak deliver at uniform rate to Fenway and Milburn Parks
Storage Tanks	1 MG; balancing storage at Cedar Park WWTP
Pipelines	15,000 ft of 14-inch pipe; from Cedar Park WWTP to Fenway and Milburn Park
Available Project Yield	1.0 MGD (1,140 acft/yr)

The total costs for developing a wastewater reuse supply for Fenway Park and Milburn Park are shown in Table 3.6-3. The project will have an estimated total capital cost of $7,184,000 and an annual cost of $608,000. This cost translates to a $543 per acft or $1.67 per 1,000 gallons unit cost of the reuse water.

Table 3.6-3. Cost Estimate Summary: Cedar Park Reuse

Item	*Estimated Costs for Facilities*
Primary Pump Station (1 MGD)	$1,956,000
Transmission Pipeline (14 in dia., 2.84 miles)	$1,819,000
Storage Tanks (Other Than at Booster Pump Stations)	$1,297,000
Total Cost Of Facilities	**$5,072,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,684,000
Environmental & Archaeology Studies and Mitigation	$100,000
Land Acquisition and Surveying (31 acres)	$135,000
Interest During Construction (4% for 1 years with a 1% ROI)	$193,000
Total Cost Of Project	**$7,184,000**
Annual Cost	
Debt Service (3.5 percent, 20 years)	$505,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$31,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$49,000
Pumping Energy Costs (276,085 kW-hr @ 0.08 $/kW-hr)	$23,000
Total Annual Cost	**$608,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	1,120
Annual Cost of Water ($ per acft)	$543
Annual Cost of Water ($ per 1,000 gallons)	**$1.67**

Table 3.6-4. Comparison of Cedar Park 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;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

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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 received an authorization from TCEQ for 8,440 acre feet (7.5 MGD) to allow reuse of all authorized discharges.

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 power 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. 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 of a sports complex.

In addition to the existing reuse line, the city plans to develop a new West Loop Reclaimed Water Line and Pump Station to meet other identified reuse water needs. This project would include a 20-inch diameter reclaimed water pipeline on the west side of the city (Figure 3.7-1), which would carry water from the existing treatment facility to Lake Pat Cleburne functioning as a form of indirect potable reuse (IPR). The West Loop Reuse Pipeline will be sized to convey 6 MGD but will only carry 2 MGD at the time of completion because of high TDS levels in the wastewater treatment plant's influent. However, the City of Cleburne plans to construct a small, 1.25 MGD industrial wastewater treatment plant in the north of the city, which will supply direct reuse to its industrial customers. This new treatment facility will also reduce the TDS levels in the existing WWTP's influent allowing the city to capitalize on the West Loop's full 6 MGD capacity. Due to treatment losses, it is estimated that this 1.25 MGD treatment facility will provide 0.80 MGD to the city's industrial customers. A 16-inch diameter extension of the West Loop that would carry water north of Lake Pat Cleburne is also being considered by the city but has not been decided on. Coupled with a booster pump station and treatment plant expansion, this extension could convey an additional 2.5 MGD to potential reuse customers.

The West Loop will be sized to meet a peak daily capacity of 6.0 MGD. Demands for the reuse water are anticipated to increase from 3.2 MGD in 2020 to 4.9 MGD by 2045 as indicated in Table 3.7-1.

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

Reuse Customers	Year 2045
Municipal Water Supply	2,240
Brazos Electric Power Plant	1,232
James Hardie Manufacturing	919
Municipal Golf Course & Airport	582
Cleburne ISD	358
Sports Complex	112
Future Commercial Development	67
Total Demand (acft/yr)	5,511

3.7.3 Environmental Issues

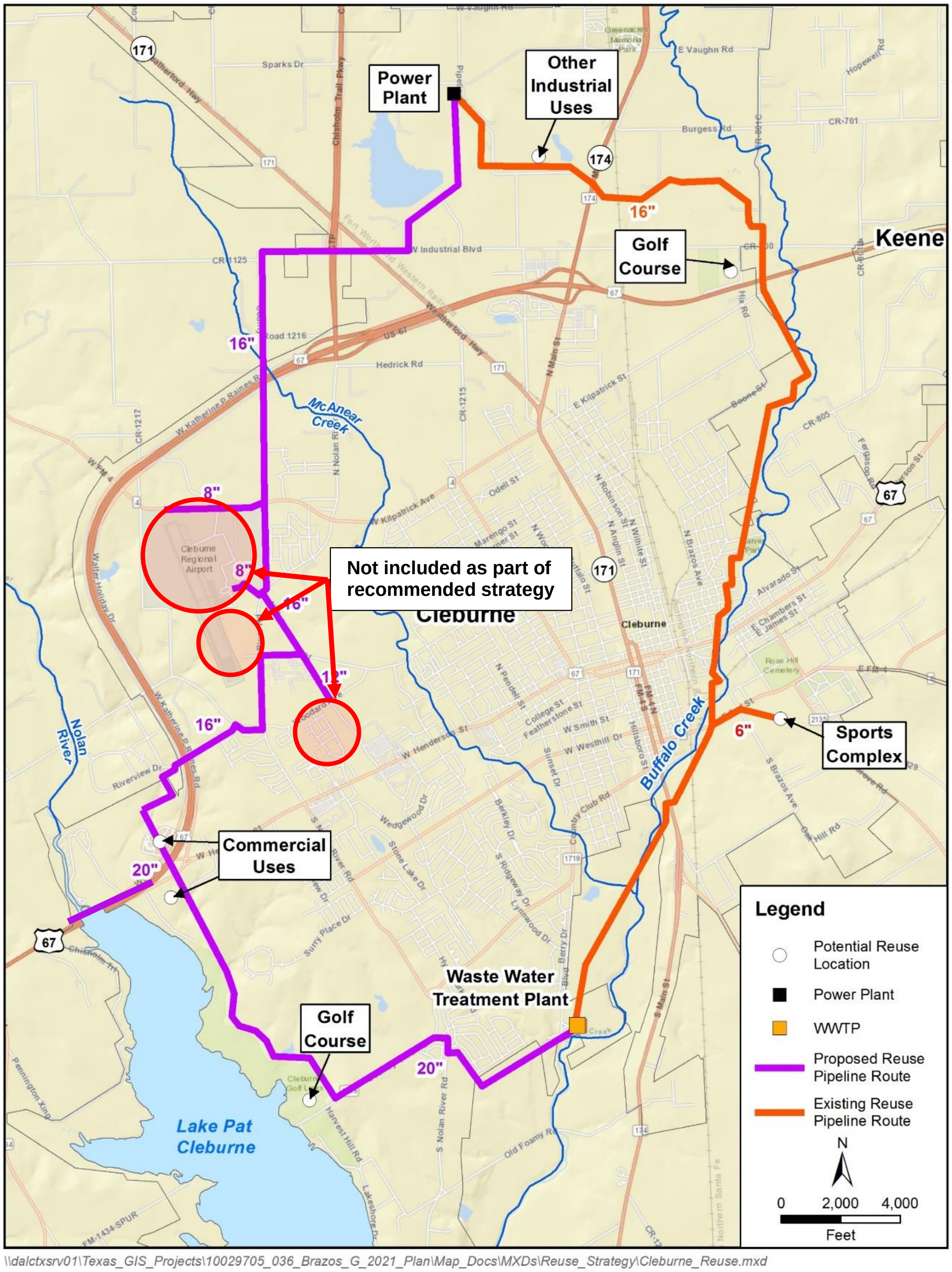
The City of Cleburne has filed for, and received, an authorization from TCEQ to reuse all effluent discharged pursuant to TPDES Permit No. 10006-001 and new outfall 003. The city is also in the process of amending its Chapter 210 Use of Reclaimed Water authorization to supply reuse water for irrigation 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



Note: Costs do not include the, two 8-inch lines and one 12-inch line shown above, but they are shown for completeness for City of Cleburne's information.

Table 3.7-2. Environmental Issues: Cleburne Reuse

Issue	Description
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 4.5 mile 20-inch diameter west loop to deliver reuse water to Lake Pat Cleburne;
- Expanded reuse water pump station
- Effluent outfall to Lake Pat Cleburne; and
- Construction of north industrial wastewater desalination plant.

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. The project will be phased into two projects. Phase One total capital costs are $10,202,000 with annual costs of $895,000 and unit costs $400/acft or $1.23/ thousand gallons. Phase Two total capital costs are $28,978,000 with annual costs of $2,955,000 and unit costs $550/acft or $1.69/ thousand gallons.

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.7-5, 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 Phase 1

Item	Estimated Costs for Facilities
Primary Pump Station (2 MGD)	$1,541,000
Transmission Pipeline (20 in dia., 4.5 miles)	$5,284,000
TOTAL COST OF FACILITIES	**$6,825,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,398,000
Environmental & Archaeology Studies and Mitigation	
Interest During Construction (3% for 1 years with a 0.5% ROI)	$274,000
TOTAL COST OF PROJECT	**$10,202,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$53,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$39,000
Pumping Energy Costs (0 kW-hr @ 0.08 $/kW-hr)	$85,000
TOTAL ANNUAL COST	**$895,000**
Available Project Yield (acft/yr)	2,240
Annual Cost of Water ($ per acft), based on PF=1	$400
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$79

Table 3.7-4. Cost Estimate Summary Cleburne Reuse Phase 2

Item	*Estimated Costs for Facilities*
Primary Pump Station (6 MGD)	$8,934,000
Transmission Pipeline (16 in dia., 8.3 miles)	$7,550,000
Transmission Pump Station(s) & Storage Tank(s)	$3,150,000
TOTAL COST OF FACILITIES	**$19,634,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$6,495,000
Environmental & Archaeology Studies and Mitigation	$417,000
Land Acquisition and Surveying (27 acres)	$1,409,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$769,000
TOTAL COST OF PROJECT	**$28,724,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$2,021,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$92,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$260,000
Water Treatment Plant	$200,000
Pumping Energy Costs (1485685 kW-hr @ 0.08 $/kW-hr)	$362,000
TOTAL ANNUAL COST	**$2,935,000**
Available Project Yield (acft/yr)	5,377
Annual Cost of Water ($ per acft), based on PF=1	$546
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$170
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.67
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.52

Table 3.7-5. 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

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3.8 City of College Station Non-Potable Reuse

3.8.1 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 located 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 3.8-1. As shown on the map, Veterans Park 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 3.8-1.

3.8.2 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 annual effluent flow from the Carters Creek WWTP for the year 2017 was 6,887 acft/yr (6.15 MGD).

College Station wastewater treatment plants include Carters Creek and Lick Creek WWTPs. The combined Year 2070 Estimated WWTP Effluent for these plants is 24,703 acft/yr (22.05 MGD).

Figure 3.8-1. College Station Non-Potable Reuse

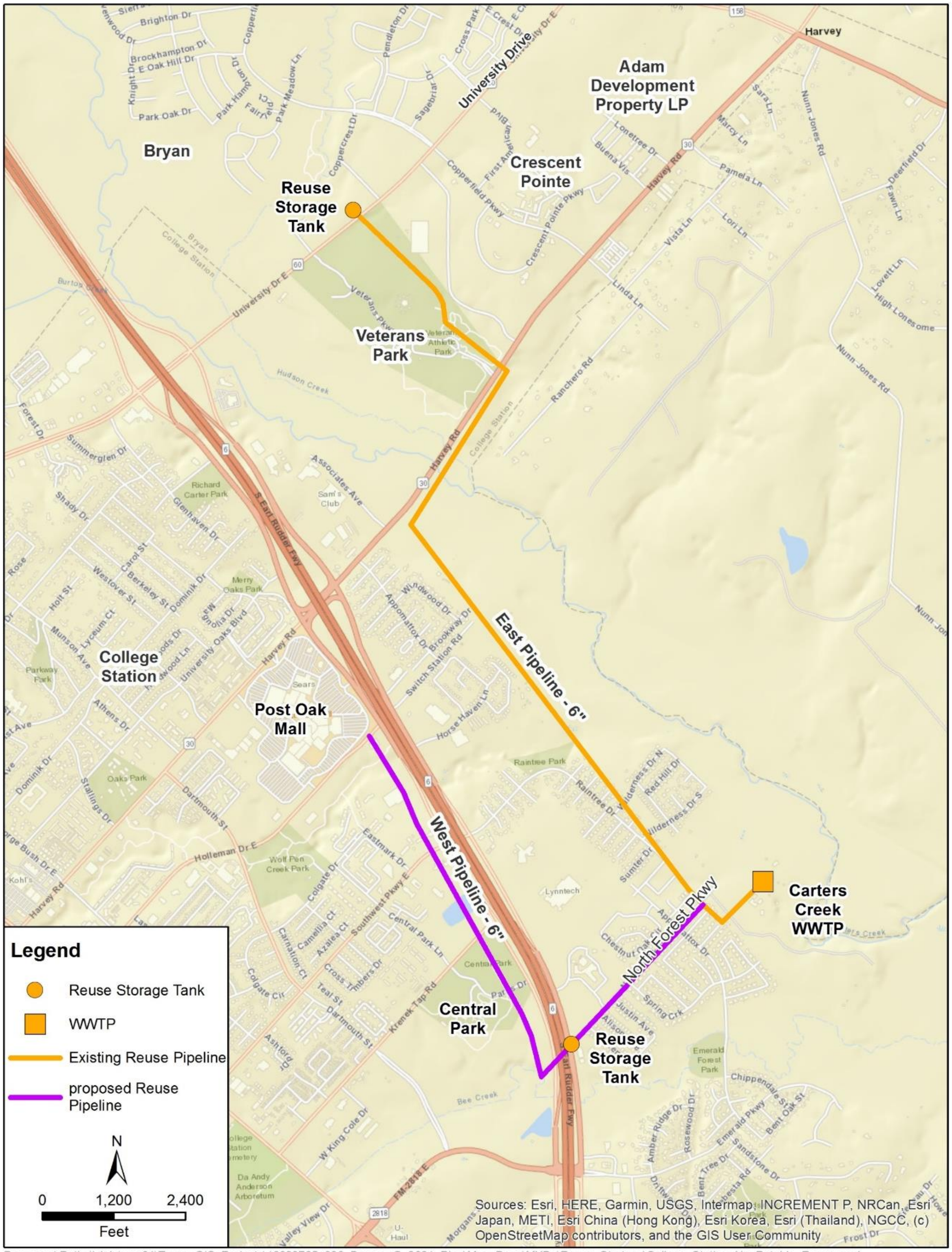

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Table 3.8-1. Water Reuse Demands for College Station Non-Potable Reuse Project

Reuse Customer	Current (acft/yr)	Proposed (acft/yr)
Veteran's Park	141	
Crescent Pointe	13	
Central Park		57
Post Oak Mall		33
Planned Industrial Park		13
Total	154	103

3.8.3 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 3.8-2.

Table 3.8-2. Environmental Issues: College Station Non-Potable Reuse

Issue	Description
Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, reuse storage tanks, 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

3.8.4 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 12-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 3.8-3. The total costs for expanding the reuse system are shown in Table 3.8-4. 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 3.8-3. 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 - 5 HP to deliver average demand of 0.09 MGD in 12 hours
Storage Tank	0.18; 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)

3.8.5 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, College Station will need to investigate concerns that would include at a minimum:

- Amount of treated effluent that is 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); and
- 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;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds; and

- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

Table 3.8-4. Cost Estimate Summary: College Station Non-Potable Reuse

Item	Estimated Costs for Facilities
Transmission Pipeline (6 in dia., 2 miles)	$800,000
Primary Pump Station(s) & Storage Tank(s)	$773,000
Storage Tanks (Other Than at Booster Pump Stations)	$937,000
Water Treatment Plant (0.1 MGD)	$23,000
Total Cost Of Facilities	**$2,533,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$846,000
Environmental & Archaeology Studies and Mitigation	$53,000
Surveying (17 acres)	$25,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$96,000
Total Cost Of Project	**$3,553,000**
Annual Cost	
Debt Service (3.5 percent, 20 years)	$250,000
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)	$19,000
Water Treatment Plant (2.5% of Cost of Facilities)	$14,000
Pumping Energy Costs (35784 kW-hr @ 0.09 $/kW-hr)	$1,000
Total Annual Cost	**$301,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 2.725	**103**
Annual Cost of Water ($ per acft)	**$2,922**
Annual Cost of Water ($ per 1,000 gallons)	**$8.97**

Table 3.8-5. 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

3.9 College Station Direct Potable Reuse

3.9.1 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 8.2 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:

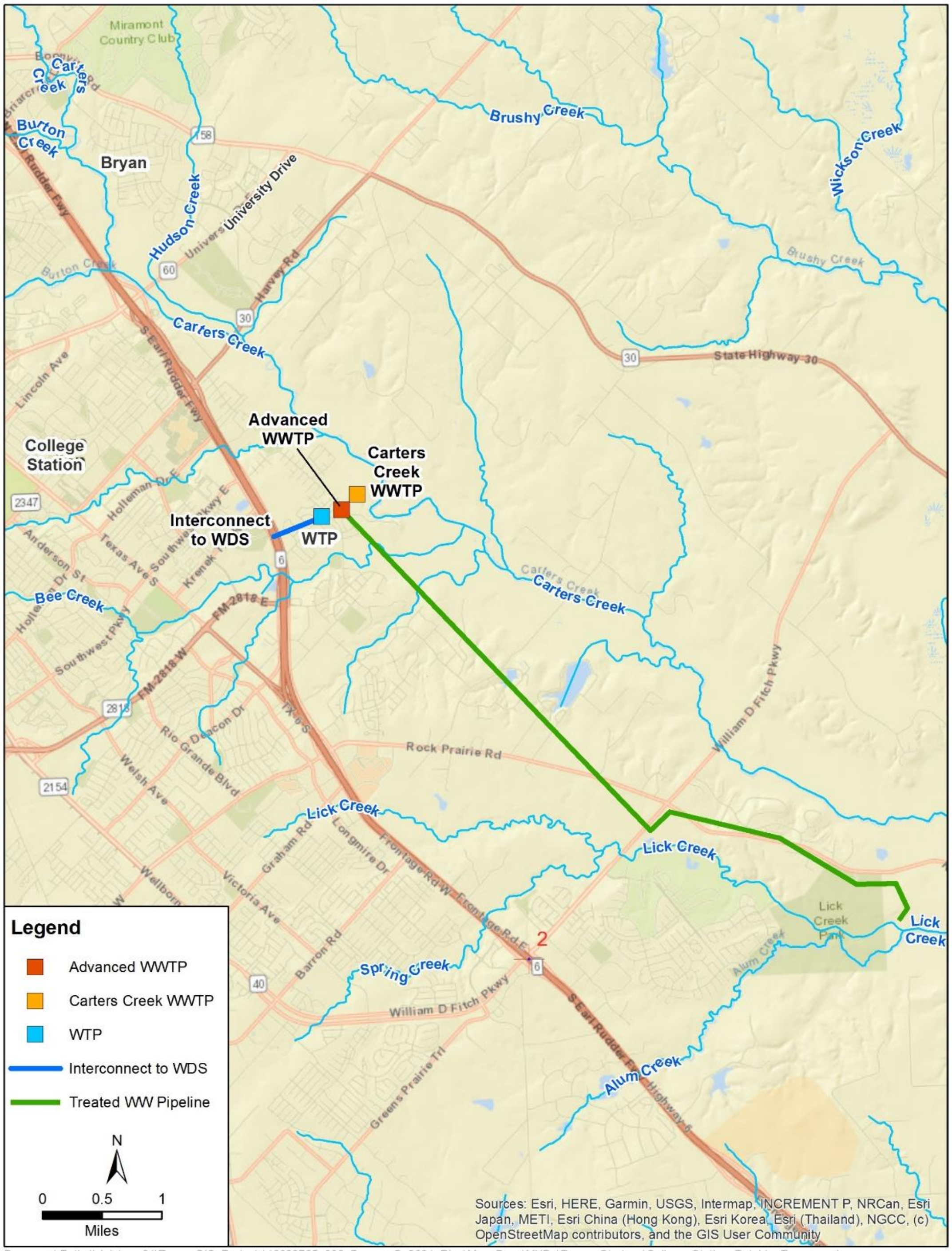
- Utilize existing wastewater effluent as the source of water for direct potable reuse. For 2013-2017, the average effluent discharges from Carters Creek WWTP and Lick Creek WWTP were 6.13 and 1.22 million gallons per day (MGD), respectively.
- A new Water Treatment Plant and Advance Wastewater Treatment Plant (AWWTP) would be located near the Carters Creek WWTP. Effluent from the much smaller Lick Creek WWTP would be transported to the AWWTP through a new pipeline.
- The AWWTP 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 3.9-1. 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 AWWTP, WTP and College Station's distribution system.

3.9.2 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 24,703 acft/yr (22.05 MGD).

Figure 3.9-1. Location of College Station's Direct Potable Reuse Project



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3.9.3 Environmental Issues

A summary of environmental issues is presented in Table 3.9-1.

Table 3.9-1. Environmental Issues: College Station Direct Potable Reuse

Issue	Description
Implementation Measures	Development of additional wastewater treatment and advanced water treatment plant facilities, transmission and distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low to moderate 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

3.9.4 Engineering and Costing

The major facilities required for these projects include:

- Pump station and transmission pipeline from Lick Creek WWTP;
- Advanced Wastewater Treatment Plant;
- Water Treatment Plant; and
- Transmission pipeline and interconnect between AWWTP and 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 3.9-2. The annual costs, including debt service, operation and maintenance, and power, is estimated to be $1,325 per acft for the College Station project.

3.9.5 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; and

- 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 3.9-3, and the option meets each criterion.

Table 3.9-2. Cost Estimate Summary: College Station DPR Project Option

Item	Estimated Costs for Facilities
Pump Stations (7.7 MGD)	$4,134,000
Transmission Pipelines (24 in dia., 0.5 miles and 10 in dia., 6.6 miles)	$3,207,000
Two Water Treatment Plant (7.4 MGD)	$18,671,000
Advanced Water Treatment Facility (7.4 MGD)	$33,929,000
Integration, Relocations, & Other	$250,000
TOTAL COST OF FACILITIES	**$60,191,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$20,907,000
Environmental & Archaeology Studies and Mitigation	$351,000
Land Acquisition and Surveying (43 acres)	$475,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$2,253,000
TOTAL COST OF PROJECT	**$84,177,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$5,923,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$35,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$103,000
Water Treatment Plant	$1,348,000
Pumping Energy Costs (3,396,219 kW-hr @ 0.08 $/kW-hr)	$272,000
Purchase of Water (acft/yr @ $/acft)	$0
TOTAL ANNUAL COST	**$10,909,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**8,232**
Annual Cost of Water ($ per acft)	**$1,325**
Annual Cost of Water ($ per 1,000 gallons)	**$1.86**

Table 3.9-3. 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 to moderate impact
2. Habitat	2. Low to moderate impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Possible impact
6. Wetlands	6. None or low impact
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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3.10 City of Georgetown Reuse

3.10.1 Description of Option

The City of Georgetown has an annual effluent discharge of 1.3 MGD from the Dove Springs Wastewater Treatment Plant (WWTP). Dove Springs WWTP has a permitted average effluent discharge at 2.5 MGD. Georgetown applies treated effluent as a source of reuse water with average reuse volume equal to 0.75 MGD in a year. Another 0.55 MGD of treated water could potentially be used for reuse purposes. Two potential options for reuse were considered. The preferred reuse option would be to connect a reclaimed water supply line from Dove Springs WWTP to the existing reclaimed irrigation lines. The proposed reuse pipeline from Dove springs WWTP would be 2.41 miles. Dove Springs WWTP is assumed to treat effluent to a Type 1 quality.

Locations of the Dove Springs WWTP plant, ground storage tank, pump stations and transmission pipeline are shown in Figure 3.10-1.

3.10.2 Available Supply

The planned capacity of the Georgetown Reuse project is 1.3 MGD (1,456 acft/yr).

3.10.3 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 low impact on recharge rates in Edwards Aquifer due to reduced effluent return flow rates;
- 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 3.10-1.

Figure 3.10-1 Georgetown Reuse

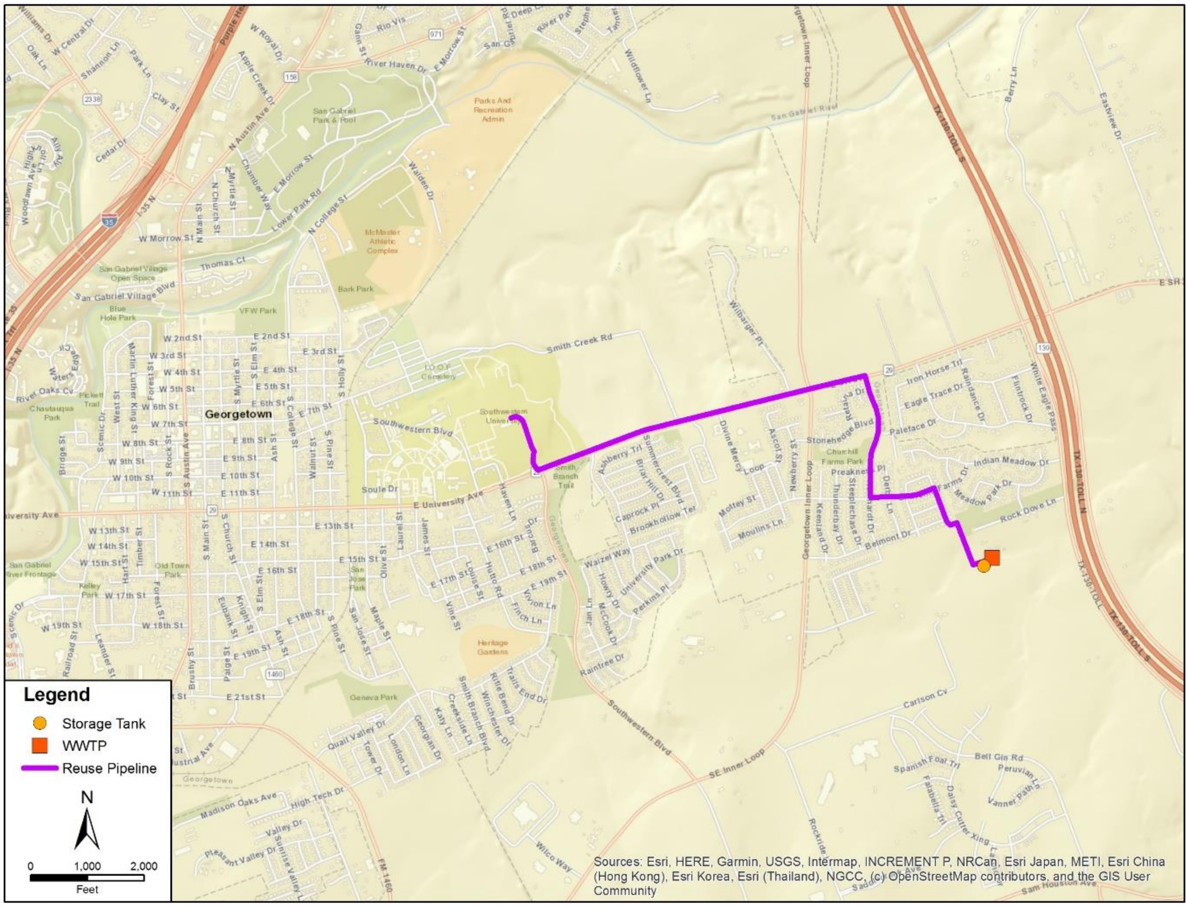

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Table 3.10-1. Environmental Issues: Georgetown Reuse

Issue	Description
Implementation Measures	Development of additional ground storage tank, transmission pipeline, 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
Edwards Aquifer	Possible increased water quality to stream flows and Edwards Aquifer recharge zone. Possible low impact on recharge rates due to decreased effluent flow
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

3.10.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply Georgetown are summarized in Table 3.10-2. The project requires a 5.2 MGD pump station along with a storage tank located at the Dove Springs WWTP. A 2.35 mile, 16-inch diameter pipe would deliver the reuse supply to the existing reuse system. This section does not include costs for potential distribution lines from the proposed reuse pipeline system.

Table 3.10-2. Required Facilities –Georgetown Reuse

Facility	Description
Pump Stations	160 HP at Dove Springs WWTP; 5.2 MGD capacity to deliver at peak capacity at uniform rate.
Storage Tanks	1.3 MG; balancing storage at Dove Springs WWTP.
Pipelines	12,800 ft of 16-inch pipe; from Dove Springs to East View High School
Available Project Yield	1.3 MGD (1,456 acft/yr)

The total costs for developing a wastewater reuse supply from Dove Springs WWTP are shown in Table 3.10-3. The project will have an estimated total capital cost $6,270,000 and an annual cost of $508,000. This cost translates to a $349 per acft or $1.07 per 1,000 gallons unit cost of the reuse water.

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;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

Table 3.10-3. Cost Estimate Summary: Georgetown Reuse

Item	*Estimated Costs for Facilities*
Primary Pump Station (1.3 MGD)	$1,202,000
Transmission Pipeline (18 in dia., 2.41 miles)	$1,812,000
Storage Tanks (Other Than at Booster Pump Stations)	$1,429,000
Total Cost Of Facilities	**$4,443,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,464,000
Environmental & Archaeology Studies and Mitigation	$111,000
Land Acquisition and Surveying (19 acres)	$84,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$168,000
Total Cost Of Project	**$6,270,000**
Annual Cost	
Debt Service (3.5 percent, 20 years)	$441,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$32,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$30,000
Pumping Energy Costs (55500 kW-hr @ 0.08 $/kW-hr)	$5,000
Total Annual Cost	**$508,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**1,456**
Annual Cost of Water ($ per acft)	**$349**
Annual Cost of Water ($ per 1,000 gallons)	**$1.07**

Table 3.10-4. Comparison of Georgetown 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

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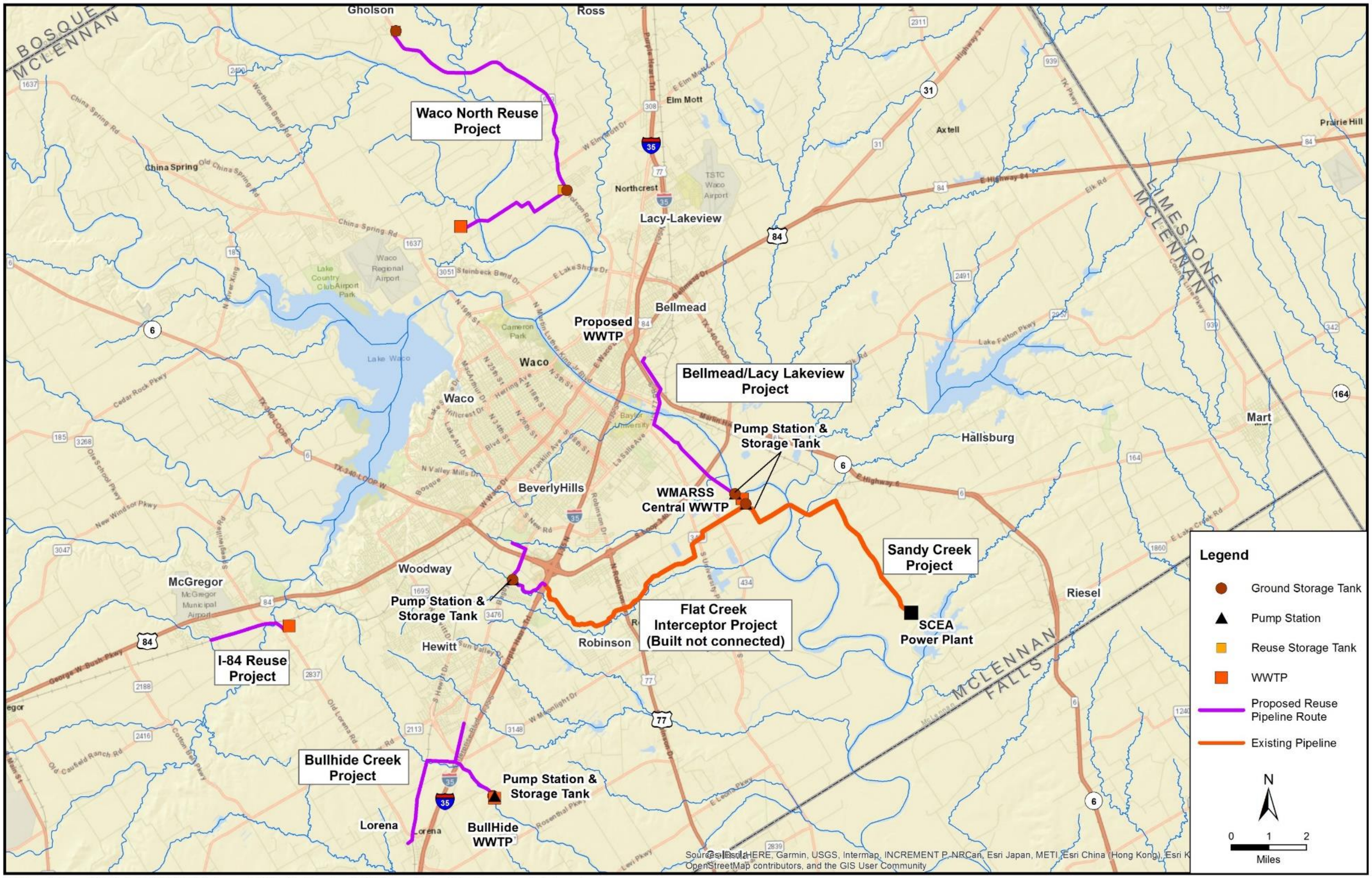
3.11 Waco WMARSS Reuse Projects

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 consider the development of four wastewater reuse systems to supply reuse water to customers. These reuse systems are referred to as the Waco North China Spring reuse, Flat Creek Interceptor Project and Bull Hide (3.5MGD) through the Bull Hide Creek, I-84 reuse and Bellmead/Lacy Lakeview reuse projects. 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 consist 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 3.11-1. Descriptions of each of the options are included in Sections 3.11.1 through 3.11.5.

Figure 3.11-1. Locations of Waco Area Reuse Projects



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3.11.1 WMARSS Bellmead/Lacy-Lakeview Reuse

Description of Option

WMARSS is considering 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 3.11-2.

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 3.11-1.

Figure 3.11-2. WMARSS Bellmead/Lacy-Lakeview Reuse

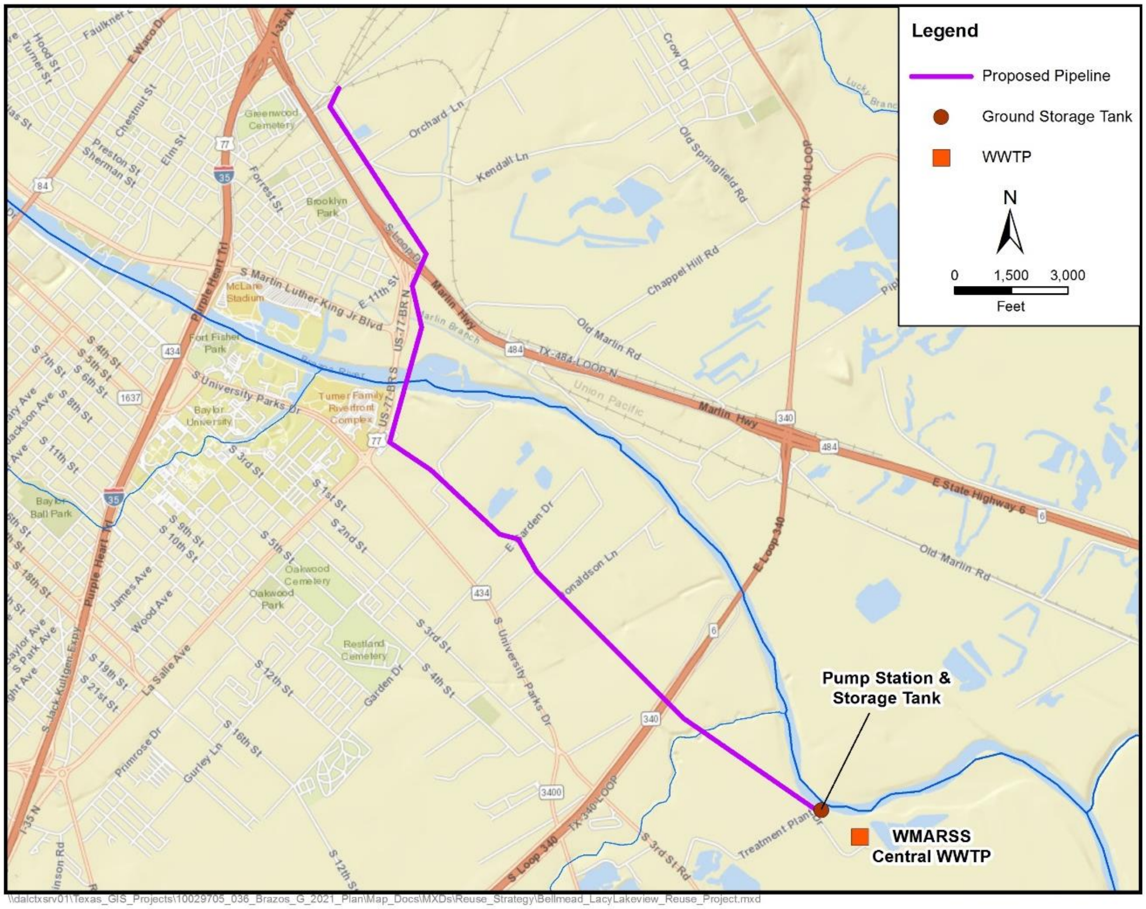

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Table 3.11-1. Environmental Issues: WMARSS Bellmead/Lacy-Lakeview Reuse

Issue	Description
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 3.11-2. 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 3.11-2. 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 3.11-3. The project will have an estimated total project cost of $8,038,000 and an annual cost of $949,000. This cost translates to a unit cost of $424 per acft or $1.30 per 1,000 gallons.

Table 3.11-3. Cost Estimate Summary: WMARSS Bellmead/Lacy Lakeview Reuse

Item	*Estimated Costs for Facilities*
Transmission Pipeline (12 in dia., 5 miles)	$2,619,000
Transmission Pump Station(s) & Storage Tank(s)	$1,089,000
Storage Tanks (Other Than at Booster Pump Stations)	$1,956,000
Total Cost Of Facilities	**$5,664,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,851,00
Environmental & Archaeology Studies and Mitigation	$144,000
Land Acquisition and Surveying (31 acres)	$107,000
Interest During Construction (4% for 1 years with a 1% ROI)	$272,000
Total Cost Of Project	**$8,038,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$673,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities) Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$46,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	27,000
Pumping Energy Costs (664,977 kW-hr @ 0.09 $/kW-hr) Pumping Energy Costs (714391 kW-hr @ 0.09 $/kW-hr)	$60,000
Purchase of Water (2,240 acft/yr @ 63.66 $/acft)Purchase of Water (2240 acft/yr @ 54.44 $/acft)	$143,000
Total Annual Cost	**$949,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**2,240**
Annual Cost of Water ($ per acft)	**$424**
Annual Cost of Water ($ per 1,000 gallons)	**$1.30**

Table 3.11-4. 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;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

3.11.2 WMARSS Bull Hide Creek Reuse

Description of Option

WMARSS is considering 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 3.11-3.

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 3.11-5.

Figure 3.11-3. WMARSS Bull Hide Creek Reuse

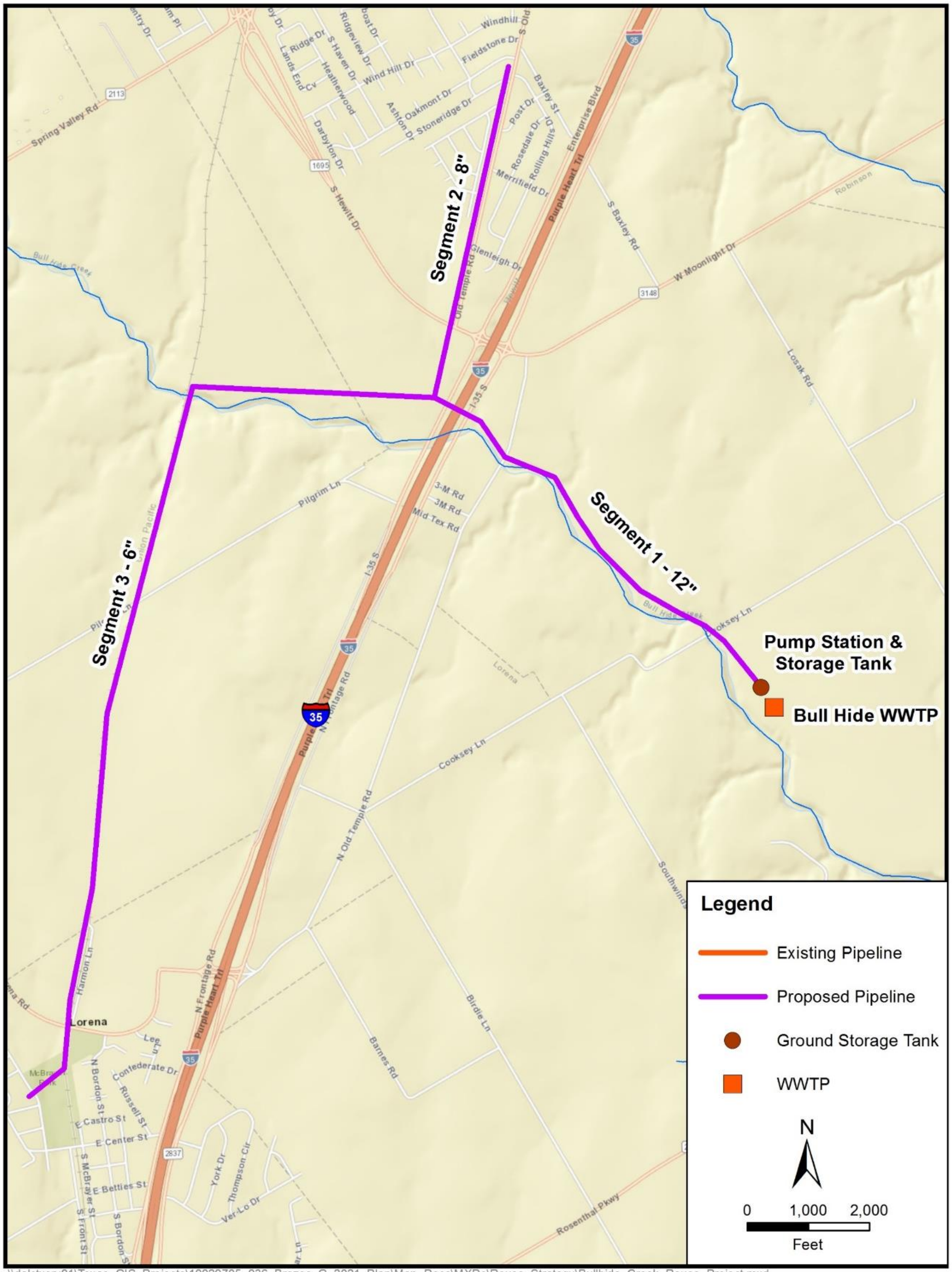

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Table 3.11-5. Environmental Issues: WMARSS Bull Hide Creek Reuse

Issue	Description
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 3.11-6. 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 3.11-6. 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 3.11-7 provide the total option costs for developing a wastewater reuse supply for Hewitt and Lorena. The project will have an estimated total project cost of $7,349,000 and an annual cost of $912,000. This cost translates to a unit cost of $543 per acft or $1.66 per 1,000 gallons.

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.11-8, 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 3.11-7. Cost Estimate Summary: WMARSS Bull Hide Creek Reuse

Item	Estimated Costs for Facilities
Transmission Pipeline (12 in dia., 5 miles)	$1,053,000
Transmission Pump Station(s) & Storage Tank(s)	$1,981,000
Storage Tanks (Other Than at Booster Pump Stations)	$928,000
Total Cost Of Facilities	**$5,089,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,702,000
Environmental & Archaeology Studies and Mitigation	$174,000
Land Acquisition and Surveying (39 acres)	$135,000
Interest During Construction (4% for 1 years with a 1% ROI)	$249,000
Total Cost Of Project	**$7,349,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$615,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$40,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$26,000
Water Treatment Plant (2.5% of Cost of Facilities)	$69,000
Pumping Energy Costs (652,313 kW-hr @ 0.09 $/kW-hr)	$55,000
Purchase of Water (1,681 acft/yr @ 54.44 $/acft)	$107,000
Total Annual Cost	**$912,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**1,681**
Annual Cost of Water ($ per acft)	**$543**
Annual Cost of Water ($ per 1,000 gallons)	**$1.66**

Table 3.11-8. 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;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

3.11.3 WMARSS Flat Creek Reuse

Description of Option

WMARSS is considering 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 3.11-4. Approximately 42,000 feet of 20-inch diameter pipeline has been constructed extending from the WMARSS Central WWTP to Interstate I-35.

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 Bull Hide 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 3.11-9.

Figure 3.11-4. WMARSS Flat Creek Reuse

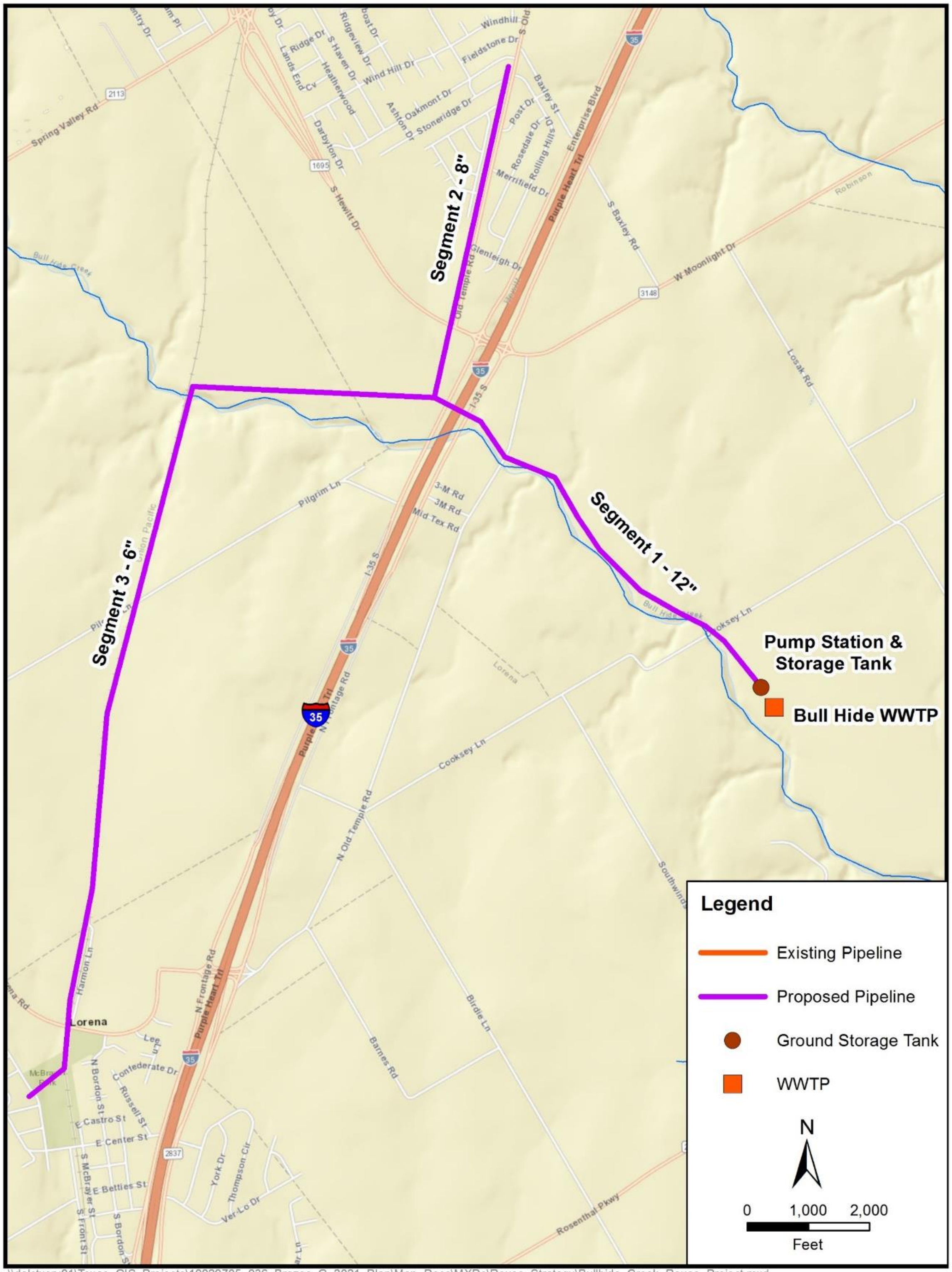

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Table 3.11-9. Environmental Issues: WMARSS Flat Creek Reuse

Issue	Description
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 3.11-10. 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 3.11-10. 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 3.11-11 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 project cost of $20,014,000 and an annual cost of $2,746,000. This cost translates to a unit cost of $350 per acft or $1.07 per 1,000 gallons, 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 **3.11-12**, 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.

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;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

Table 3.11-11. Cost Estimate Summary: WMARSS Flat Creek Reuse

Item	Estimated Costs for Facilities
Capital Costs	
Upgrade to WMARSS Intake & Pump Station (7 MGD)	$1,923,000
Two Ground Storage Tanks @ WMARSS (1.5 MG)	$3,033,000
Transmission Pipeline (20 in dia., 1 miles)	$974,000
Transmission Pipeline (12 in dia.,1.3 miles)	$586,500
Transmission Pump Station @ I-35 (2 MGD)	$1,426,000
Ground Storage Tank @ I-35 (1.0 MG)	$1,297,000
Total Cost Of Facilities	**$8,995,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$4,887,000
Environmental & Archaeology Studies and Mitigation	$120,000
Land Acquisition and Surveying (16 acres)	$143,000
Interest During Construction (4% for 1 years with a 1% ROI)	$677,000
Total Cost Of Project	**$20,014,000**
Annual Cost	
Debt Service (5.5 percent, 20 years)	$1,675,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$59,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$207,000
Pumping Energy Costs (3,384,493 kW-hr @ 0.09 $/kW-hr)	$305,000
Purchase of Water (7,847 acft/yr @ 63.66 $/acft)	$500,000
Total Annual Cost	**$2,746,000**
Available Project Yield (acft/yr)	**7,847**
Annual Cost of Water ($ per acft)	**$350**
Annual Cost of Water ($ per 1,000 gallons)	**$1.07**

Table 3.11-12. 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

3.11.4 Waco North – China Spring WWTP

Description of Option

The City of Waco is considering the development of a sattelite wastewater treatment plant for the area known as China Spring in the north portion of the city. The area is isolated hydraulically from the rest of the regional sewerage and it is more cost effective to develop a regional wastewater treatment plant than deliver the wastewater to the central WMARSS facility. This option consists of an integrated reuse project to deliver Type 1 reuse water from a new satellite wastewater treatment plant located north of Waco, which would divert wastewater from a collection main of the WMARSS. Treated reuse water from this satellite plant would be transported to Chalk Bluff WSC and the City of Gholson. The new satellite reuse treatment plant and transmission pipeline locations are shown in Figure 3.11-5.

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 1,264 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 3.11-13.

Available Supply

The wastewater treatment plant is currently under design with an average flow of 1,120 acft/yr (1.0 MGD) at 2050. The amount of reuse water available for Waco China Spring WWTP reuse will be limited by the wastewater flow in the collector main feeding the new satellite reuse treatment plant. The entire wastewater stream could be used for reuse.

Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points of WMARSS due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows;
- Possible low 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 3.11-14.

Figure 3.11-5. China Spring WWTP and Waco North Reuse

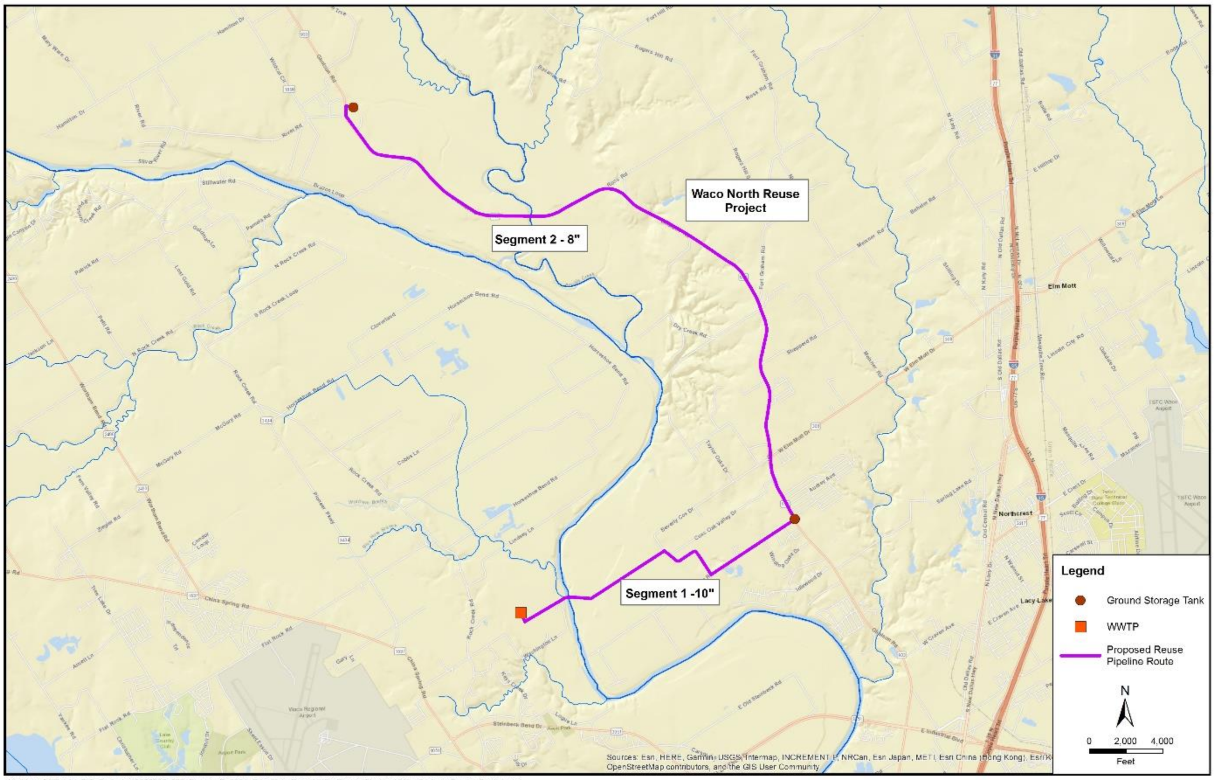


Table 3.11-13. Waco North Potential Reuse Water Demand

Entity	2070 Demand (acft/yr)	Reuse Water Demand (acft/yr)
Chalk Bluff WSC	243	73
Gholson WSC	450	135
McLennan County Mining	4,216	1,264
Total		**3,709**

Table 3.11-14. Environmental Issues: Waco North – China Spring WWTP Reuse

Issue	Description
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 low negative impact to fish and wildlife habitat with 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 and sited to avoid wetlands, waters of the U.S. and cultural resources, where possible.

Engineering and Costing

This option has a total project cost of $25,888,000 and an annual cost of $2,951,000. Many of the required improvements to implement a reuse supply for this option are shared between the multiple entities. These shared facilities include the China Spring satellite wastewater treatment plant, pump stations, and transmission pipelines. The shared facilities are sized to supply the combined demand for the entities served by each improvement.

The costs to develop the entire project are shown in Table 3.11-15. 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 China Spring - Waco North water supply option.

The required improvements to implement wastewater reuse supplies for Chalk Bluff WSC and Gholson are summarized in Table 3.11-16 through Table 3.11-18. Storage and irrigation pumping are included for Chalk Bluff WSC and Gholson.

Costs presented in Table 3.11-15 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.

Table 3.11-15. Cost Estimate Summary: WMARSS Waco North Reuse

Item	Estimated Costs for Facilities
Primary Pump Stations (1.1 MGD)	$1,001,000
Transmission Pipeline (10 in dia., 11 miles)	$4,772,000
Storage Tanks (Other Than at Booster Pump Stations)	$3,100,000
Water Treatment Plants (1.0 MGD)	$9,318,000
Total Cost Of Facilities	$18,191,000
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$6,128,000
Environmental & Archaeology Studies and Mitigation	$369,000
Land Acquisition and Surveying (65 acres)	$324,000
Interest During Construction (4% for 1 years with a 1% ROI)	$876,000
Total Cost Of Project	$25,888,000
Annual Cost	
Debt Service (5.5 percent, 20 years)	$2,166,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$79,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$25,000
Water Treatment Plant (2.5% of Cost of Facilities)	$642,000
Pumping Energy Costs (437,254 kW-hr @ 0.09 $/kW-hr)	$39,000
Total Annual Cost	$2,951,000
Available Project Yield (acft/yr), based on a Peaking Factor of 1	1,120
Annual Cost of Water ($ per acft)	$2,635
Annual Cost of Water ($ per 1,000 gallons)	$8.08

Table 3.11-16. Required Facilities –China Spring- Waco North

Facility	Description
WWTP	New 1.0 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 27 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	18,250 ft of 10-inch pipe; 40,702 ft of 8-inch pipe
Available Project Yield	Total yield is 1.0 MGD: 1.0 MGD (1,120 acft/yr) delivered, and 1.0 MGD available at plant.

Table 3.11-17. 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 3.11-18. Required Facilities – Gholson

Facility	Description
Treatment Upgrade	Purchase 0.12 MGD treated reuse water from Waco
Pump Station	79 hp; 0.48 MGD capacity to deliver peak daily capacity in 6 hours at 60 psi; shared use of segment 1 pump station
Storage Tank	0.12 MG; Store one days treated reuse water at tank in Gholson
Pipeline	Shared use of pipeline segments 1 and 2
Available Project Yield	0.12 MGD (135 acft/yr), yield is based on 30 percent of total year 2070 demand to be used for irrigation and/or industrial customers

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.11-19, 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;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

Table 3.11-19. Comparison of Waco North China Spring 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

3.11.5 WMARSS I-84 Indirect Potable Reuse

Description of Option

The City of Waco is pursuing the development of a satellite wastewater treatment plant known as I-84 Corridor WWTP to service rapid growth in the I-84 area west of Waco. Conveying water from the I-84 area to existing WMARSS wastewater plants would be costly and inefficient; and therefore, a satelite 1.5 MGD (1,680 acft/yr) WWTP is being planned for construction. The treated effluent from the proposed WWTP will outfall into the Harris Creek, a tributary to Lake Waco. Discharge from the plant will be treated to Level I standards for indirect potable reuse.

The treated effluent from the plant would mix with the natural streamflow of Harris Creek and travel 5.8 miles to Lake Waco. Travel time to Lake Waco and residence time in the lake will need to be determined. From the reservoir, the indirect reuse supply would be blended with water in the lake and supplement the WTP intake for the Mt. Carmel Drinking Water Treatment Plant. The new satellite reuse treatment plant, transmission pipeline, and outfall are shown in Figure 3.11-6.

Available Supply

The wastewater treatment plant is currently under design with an average flow of 1,680 acft/yr (1.5 MGD) at 2050. All flow will be considered indirect reuse supply. The amount of reuse water available for Waco I-84 WWTP indirect reuse will be limited by the wastewater flow in the collector main feeding the new satellite wastewater treatment plant. The entire wastewater stream could be considered for reuse.

Environmental Issues

Environmental impacts could include:

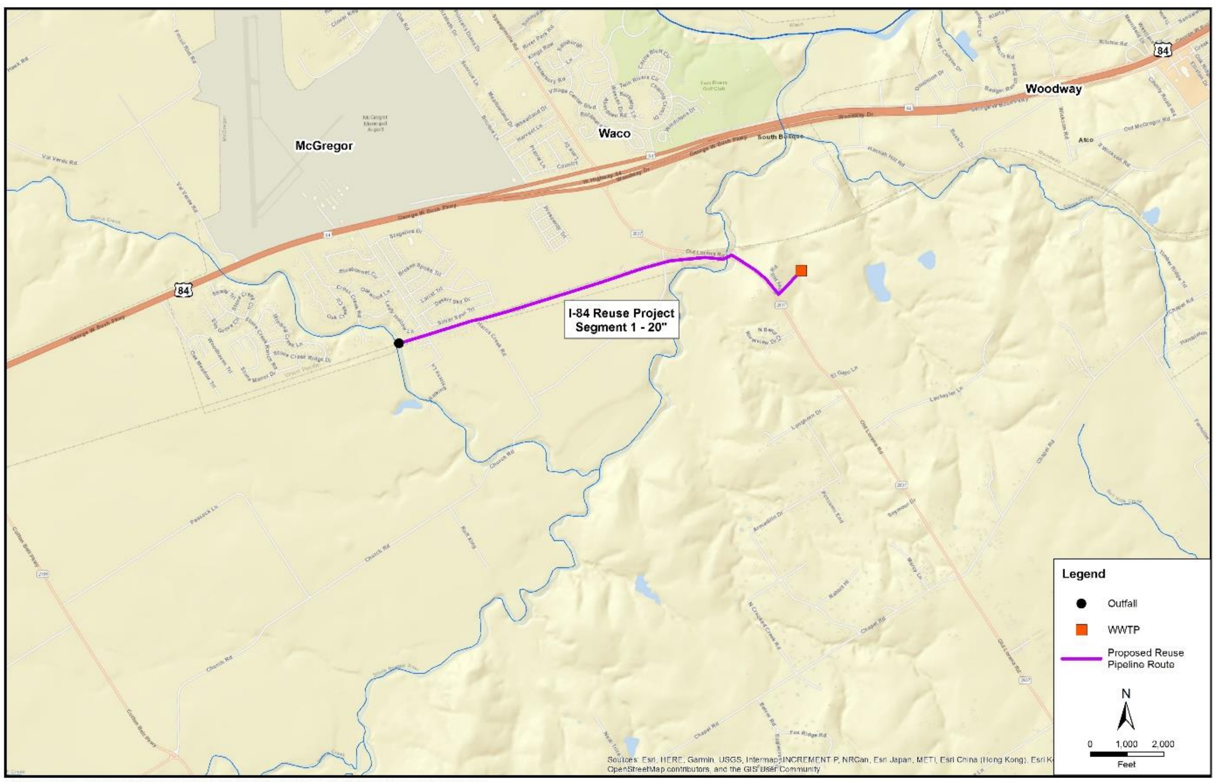
- Possible low impact on instream flows below discharge points on Harris Creek due to increased effluent return flow rates;
- Possible decreased water quality to stream flows;
- Possible low impact to fish and wildlife habitat with increased stream flows; and
- Possible negative impact to threatened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

A summary of environmental issues is presented in Table 3.11-20.

Table 3.11-20. Environmental Issues: WMARSS I-84 Reuse

Issue	Description
Implementation Measures	Development of additional wastewater treatment plant facilities, discharge pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to increased effluent return flows; possible decreased water quality to 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.
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 and sited to avoid wetlands, waters of the U.S. and cultural resources, where possible.

Figure 3.11-6. WMARSS I-84 Indirect Reuse



Engineering and Costing

This option has a total project cost of $28,249,000 and an annual cost of $6,234,000. A summary of costs is included in Table 3.11-21.

Table 3.11-21. Cost Estimate Summary: WMARSS Waco I-84 Indirect Potable Reuse

Item	Estimated Costs for Facilities
Primary Pump Stations (1.5 MGD)	$600,000
Transmission Pipeline (12 in dia., 2.3 miles)	$3,010,000
Wastewater Treatment Plants (1.5 MGD)	$13,928,000
Total Cost Of Facilities	$17,538,000
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$6,161,000
Environmental & Archaeology Studies and Mitigation	$1,237,000
Land Acquisition and Surveying (65 acres)	$1,344,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,473,000
Total Cost Of Project	$28,249,000
Annual Cost	
Debt Service (5.5 percent, 20 years)	$1,988,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$35,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$15,000
Water Treatment Plant (2.5% of Cost of Facilities)	$3,976,000
Pumping Energy Costs (436,285 kW-hr @ 0.09 $/kW-hr)	$229,000
Total Annual Cost	$6,234,000
Available Project Yield (acft/yr), based on a Peaking Factor of 1	1,680
Annual Cost of Water ($ per acft)	$3,711
Annual Cost of Water ($ per 1,000 gallons)	$11.39

Table 3.11-22. Required Facilities –Waco I-84

Facility	Description
WWTP	New 1.5 MGD satellite WWTP
Pump Station	31 hp; 1.5 MGD capacity to deliver at uniform rate to outfall on Harrison Creek
Pipeline	12,038 ft of 12-inch pipe
Available Project Yield	Total yield is 1.5 MGD: 1.5 MGD (1,680 acft/yr) delivered to outfall

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 3.11-23, and the option meets each criterion. Before pursuing wastewater reuse, the Waco I-84 entities will need to investigate concerns that would include at a minimum:

- Environmental impact of the effluent and increased flow in the rivers and streams.
- Water quality impacts on the surrounding area.

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;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

Table 3.11-23. Comparison of Waco I-84 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

4 New Reservoirs

4.1 Brazos River Main Stem Off-Channel Reservoirs

4.1.1 Description of Option

The Brazos River Main Stem Off-Channel Reservoirs (OCR) strategy could potentially provide supply to water user groups downstream of Waco. 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 pumped from the Brazos River. The locations of the 12 identified sites are shown in Figure 4.1-1. Each site was evaluated based on conservation storage capacity, storage efficiency (in order to minimize losses from evaporation), and potential conflicts.

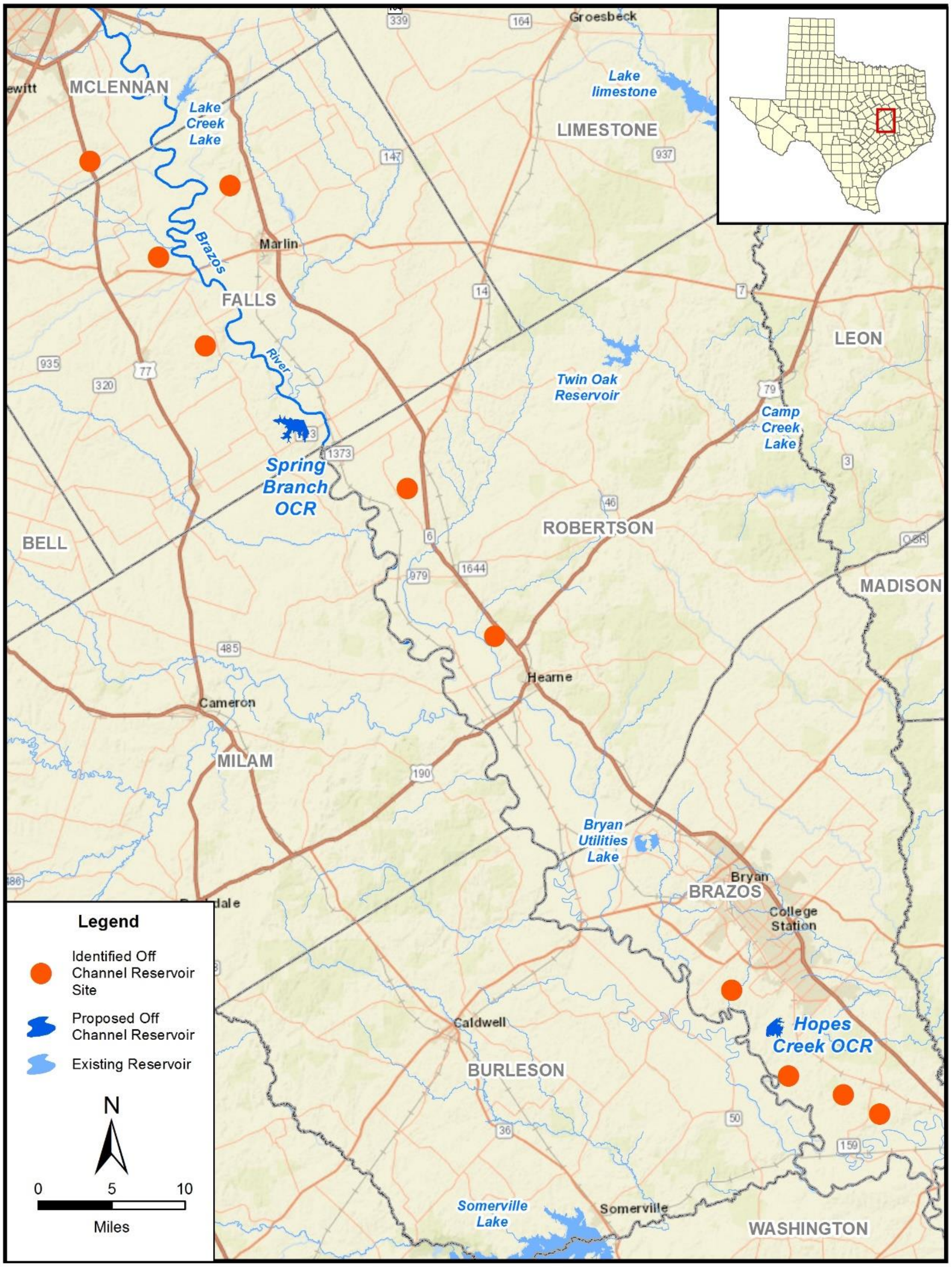
Of the 12 identified sites, the two most favorable sites were selected for yield and cost analyses. The two sites selected are the Spring Branch and Hopes Creek OCR sites. These two sites would divert and store water from the Brazos River and deliver supplies to potential customers in the area. The Spring Branch OCR is located about 12 miles south of Marlin near the Falls County border as shown in Figure 4.1-1. The OCR would provide a conservation storage capacity of 23,715 acft and inundate 1,268 surface acres. The Hopes Creek OCR is located near College Station in Brazos County as shown in Figure 4.1-1. The OCR would provide a conservation storage capacity of 18,618 acft and inundate 664 acres.

4.1.2 Available Yield

Water potentially available for diversion from the Brazos River and subsequent impoundment in the two OCR sites was estimated using the TCEQ Brazos WAM Run 3. The model assumes permitted storages and diversions for all surface water rights in the basin and 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 TCEQ environmental flow standards and without causing increased shortages to downstream rights.

Various maximum diversion capacities associated with potential pipeline sizes were evaluated. Results of the analysis indicate that pipeline sizes greater than 60-inch diameter do not provide a yield benefit to either OCR site; therefore, a 60-inch diameter pipeline is assumed to be the optimal size for delivering diversion from the Brazos River. The resulting calculated firm yield of the Spring Branch Creek OCR is 7,200 acft/yr and the firm yield of the Hopes Creek OCR is 6,300 acft/yr.

Figure 4.1-1. Locations of Identified Brazos River Main Stem OCR Sites



Document Path: \\dalctxsrv01\Texas_GIS_Projects\10029705_036_Brazos_G_2021_Plan\Map_Docs\MXDs\Reservoir_Strategy\Brazos_Main_Stem_OCR.mxd

Hopes Creek OCR

Figure 4.1-2 illustrates annual diversions from the Brazos River used to refill storage in Hopes Creek OCR under firm yield operations. On average, 6,825 acft/yr of water would be diverted.

The calculated firm yield of the Hopes Creek OCR is 6,300 acft/yr. Figure 4.1-3 and Figure 4.1-4 illustrates the simulated Hopes Creek OCR storage levels for the 1940 to 1997 historical period, subject to the firm yield of 6,300 acft/yr and assuming delivery of Brazos River diversions via a 60-inch pipeline. Simulated reservoir contents remain above 80 percent capacity about 77 percent of the time and above 50 percent capacity about 94 percent of the time.

Figure 4.1-5 illustrates the change in median streamflow in the Brazos River caused by the project. The Project would not result in any significant changes to median streamflows since diversion from the Brazos River would typically occur during wetter periods when unappropriated flow is available. Figure 4.1-6 illustrates the Brazos River streamflow frequency characteristics with the Hopes Creek OCR in place. This figure shows that diversions from the Brazos River for the project would not significantly reduce streamflow.

Figure 4.1-2 Hopes Creek Off-Channel Reservoir Diversions from Brazos River

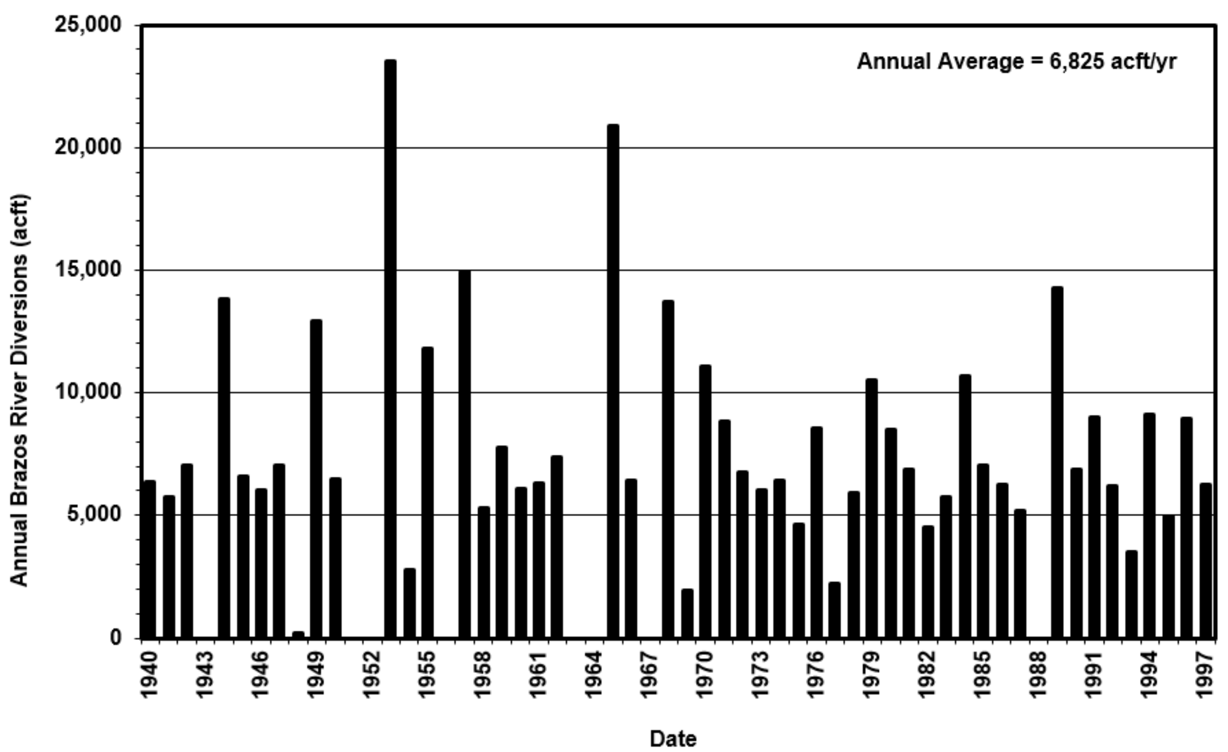


Figure 4.1-3. Hopes Creek Off-Channel Reservoir Storage Trace

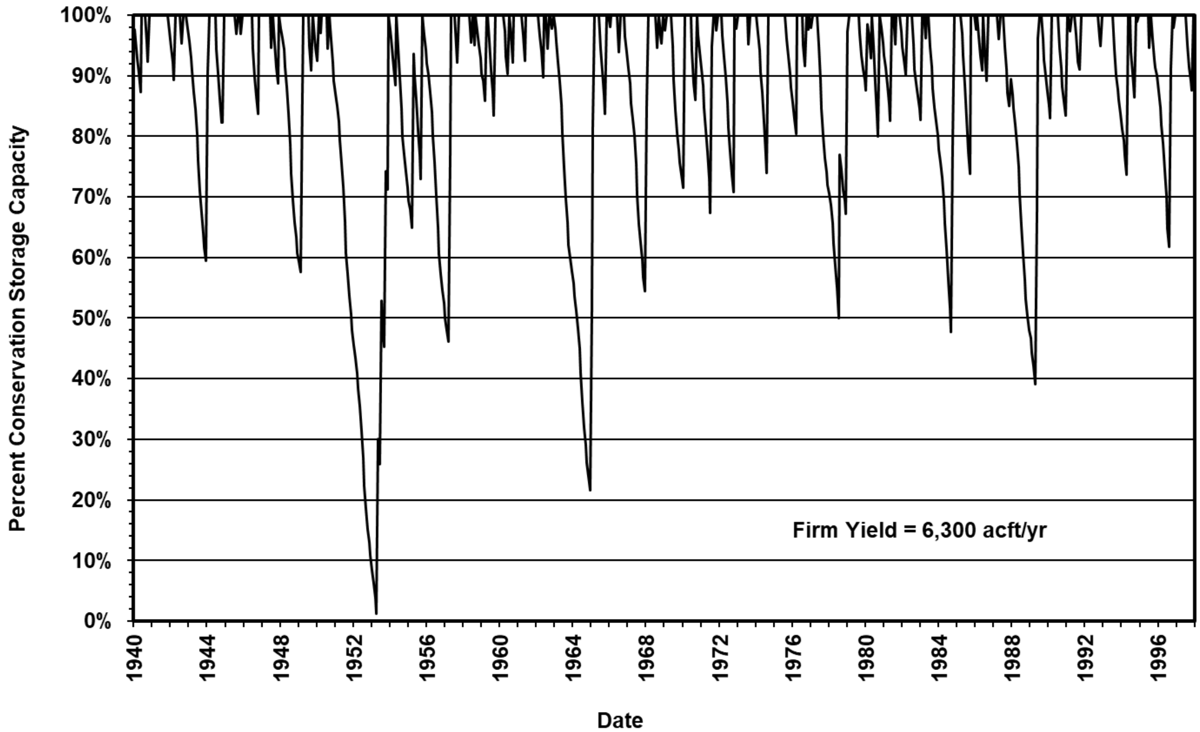


Figure 4.1-4. Hopes Creek Off-Channel Reservoir Storage Frequency

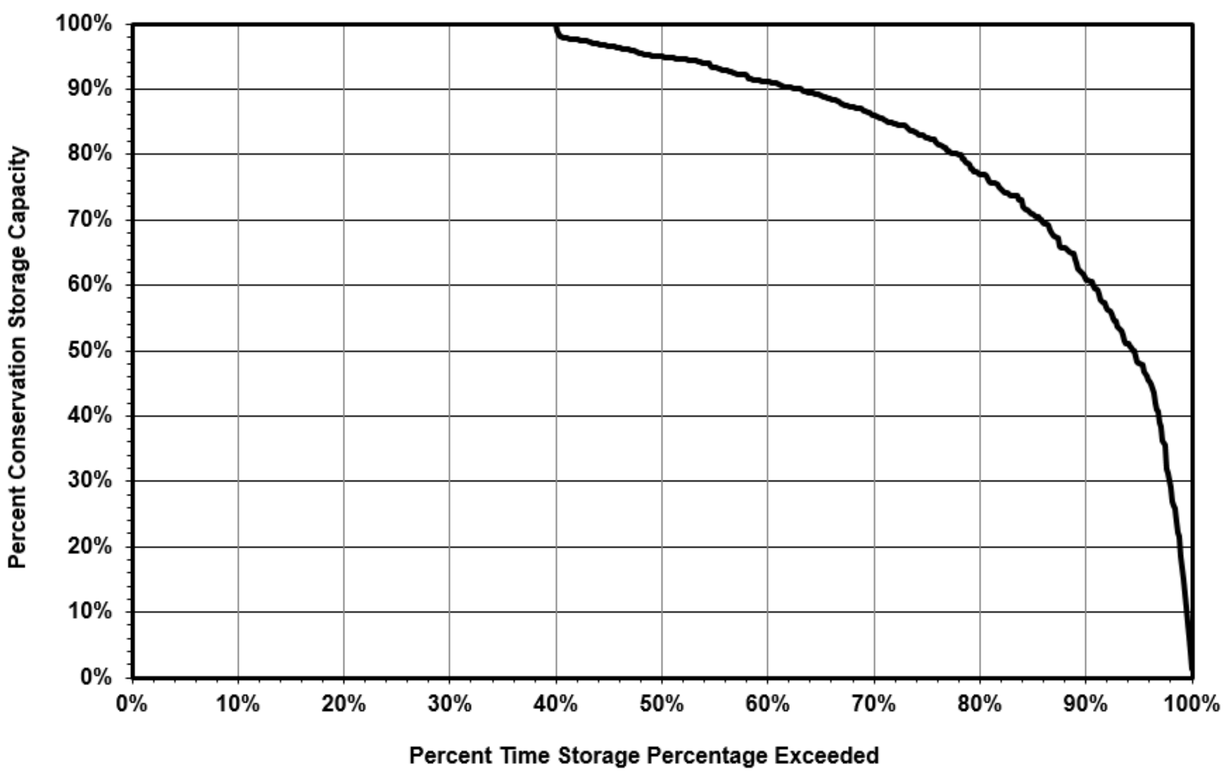


Figure 4.1-5. Monthly Median Streamflow Comparisons for the Brazos River with and without Diversions for Hopes Creek Off-Channel Reservoir

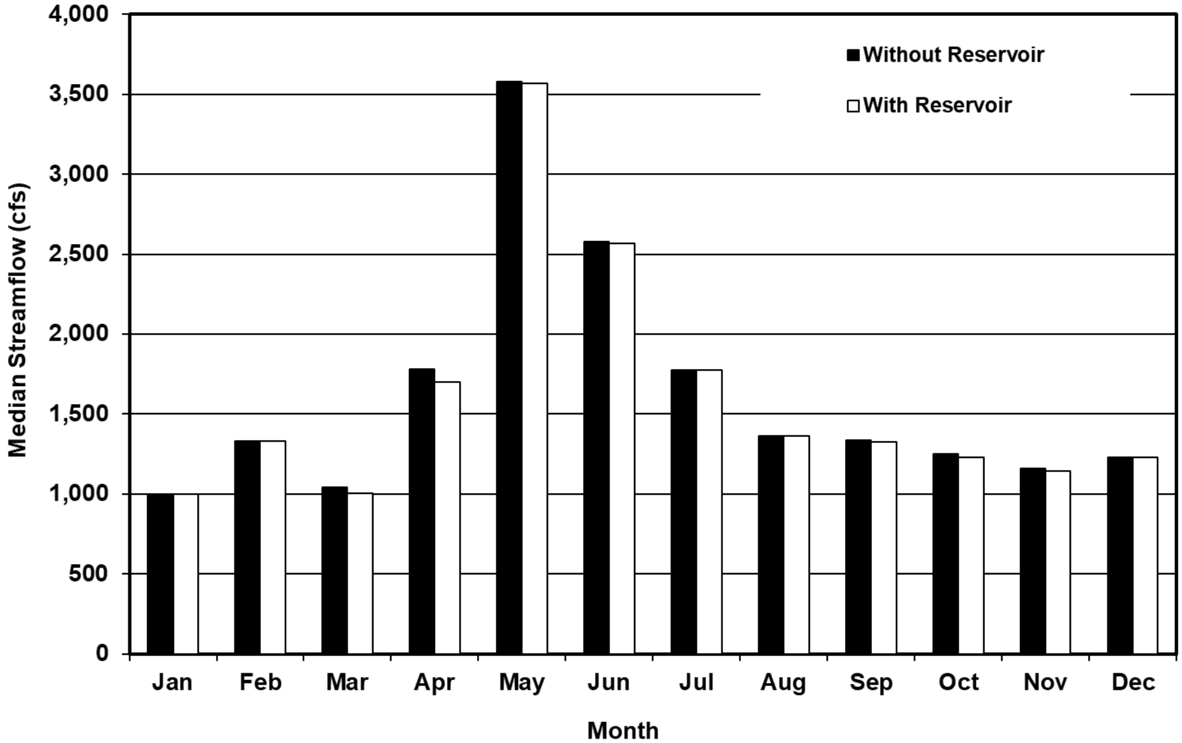
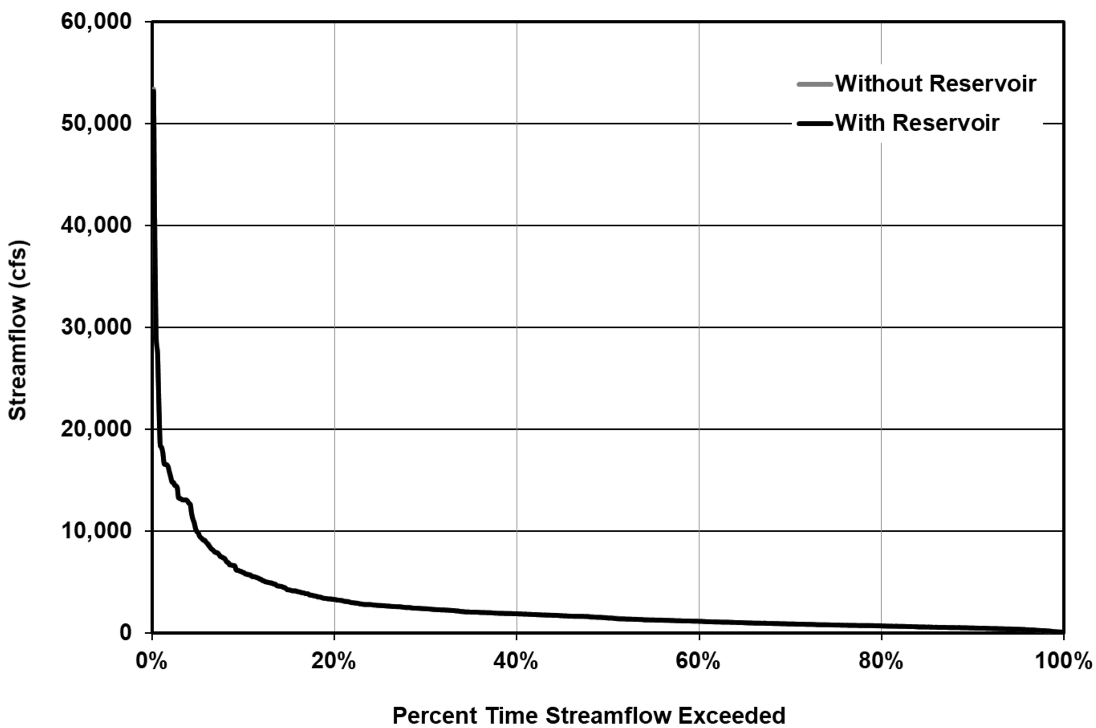


Figure 4.1-6. Streamflow Frequency Comparisons for the Brazos River with and without Diversions for Hopes Creek Off-Channel Reservoir



Spring Branch OCR

Figure 4.1-7 illustrates annual diversions from the Brazos River used to refill storage in Spring Branch OCR under firm yield operations. On average, 8,723 acft/yr of water would be diverted.

Figure 4.1-8 and Figure 4.1-9 illustrates the simulated Spring Branch OCR storage levels for the 1940 to 1997 historical period, subject to the firm yield of 7,200 acft/yr and assuming delivery of Brazos River diversions via a 60-inch pipeline. Simulated reservoir storage remains above 80 percent capacity about 72 percent of the time and above 50 percent capacity about 90 percent of the time.

Figure 4.1-10 illustrates the change in streamflows in the Brazos River caused by the project. Similar to Hopes Creek OCR diversion, diversions for the Spring Branch OCR would not result in significant decreases in streamflow in the Brazos River. Figure 4.1-11 illustrates the Brazos River streamflow frequency characteristics with the Spring Branch OCR in place.

Figure 4.1-7. Spring Branch Off-Channel Reservoir Diversions

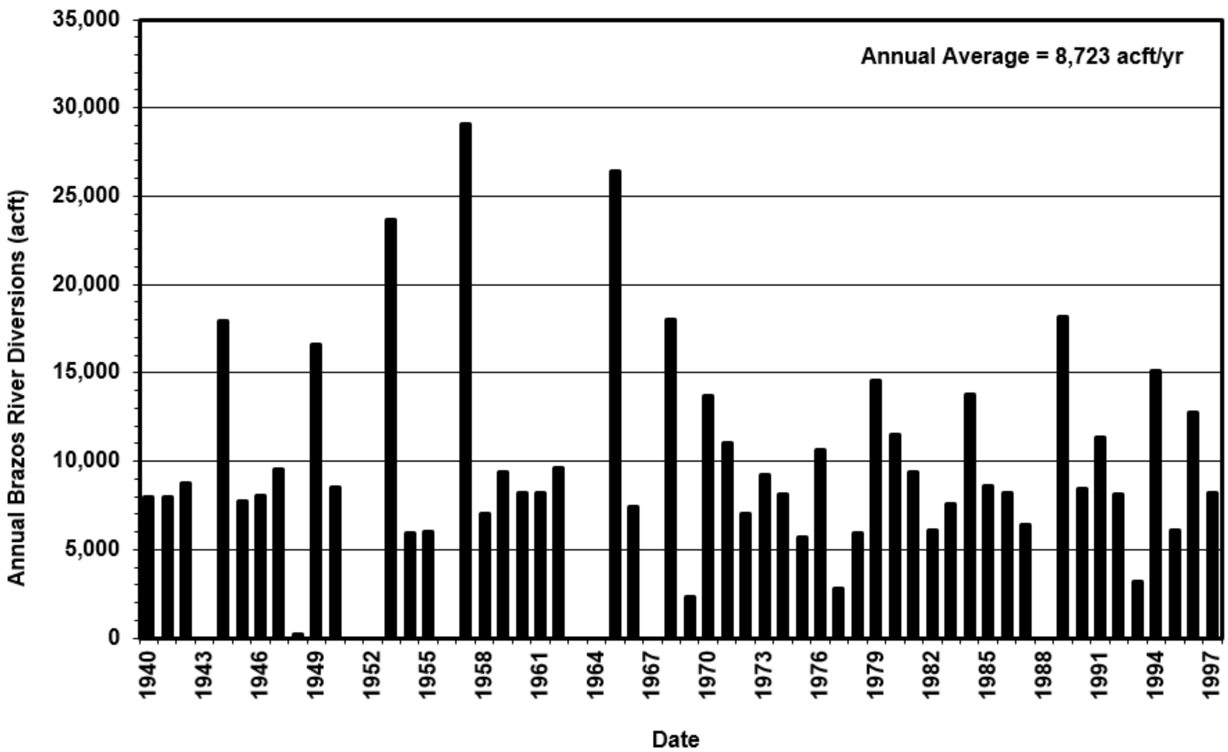


Figure 4.1-8 Spring Branch Off-Channel Reservoir Storage Trace

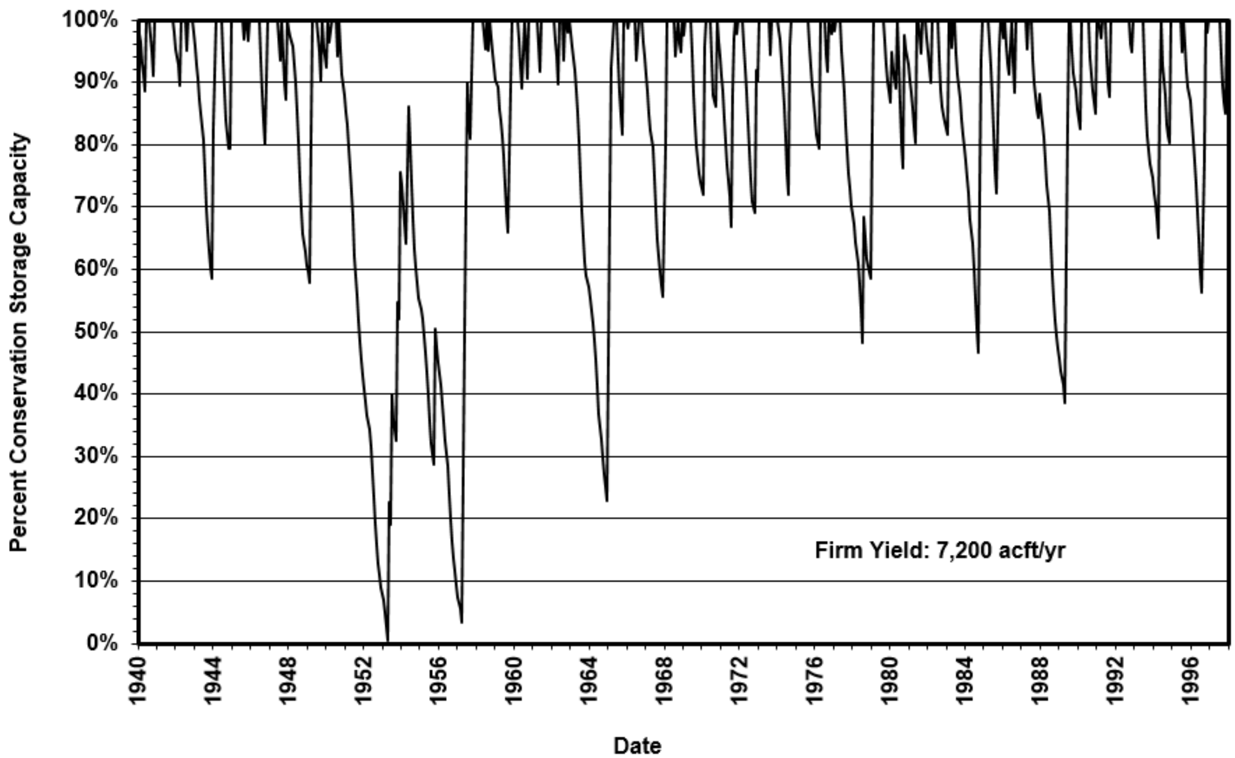


Figure 4.1-9 Spring Branch Off-Channel Reservoir Storage Frequency at Firm Yield

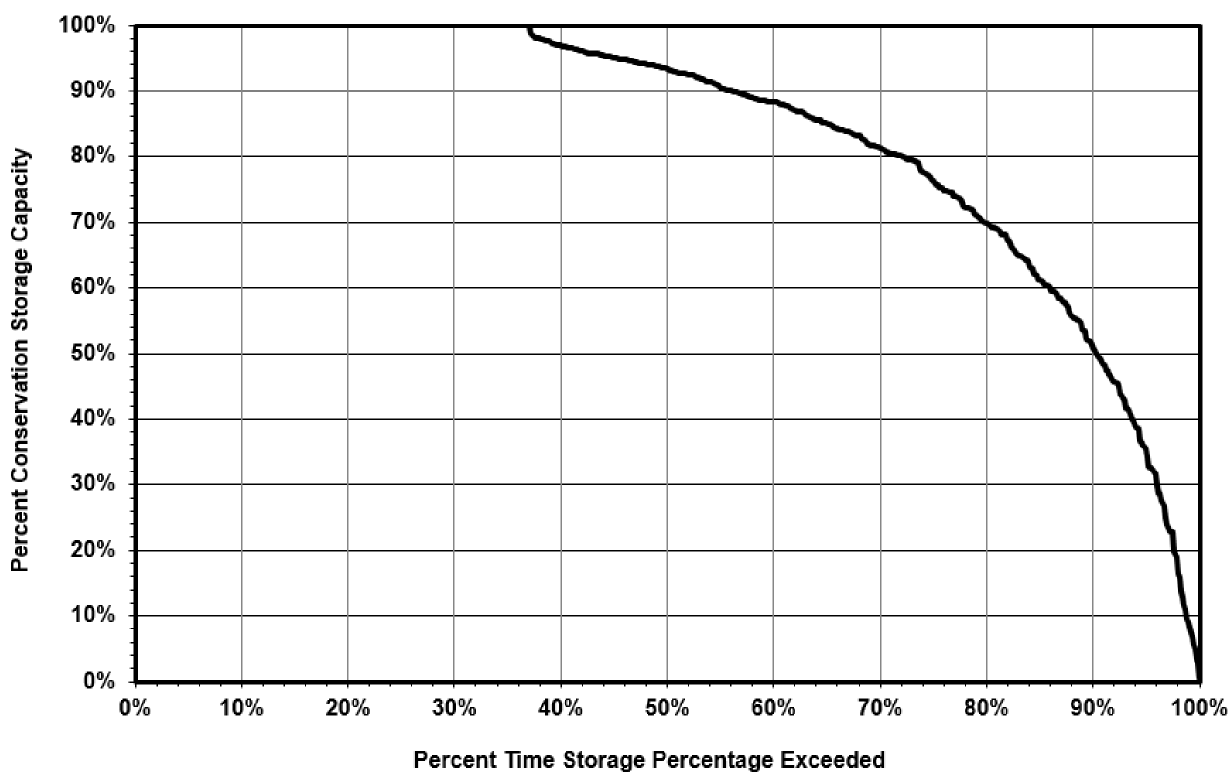


Figure 4.1-10 Monthly Median Streamflow Comparisons for the Brazos River with and without Diversions for Spring Branch Off-Channel Reservoir

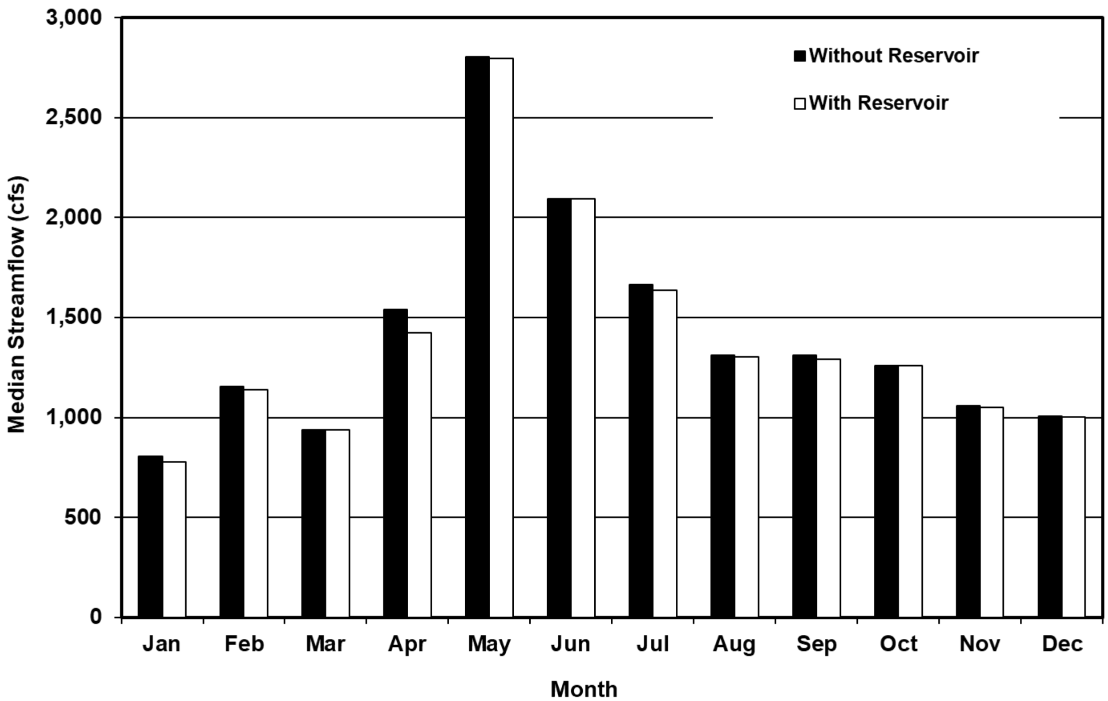
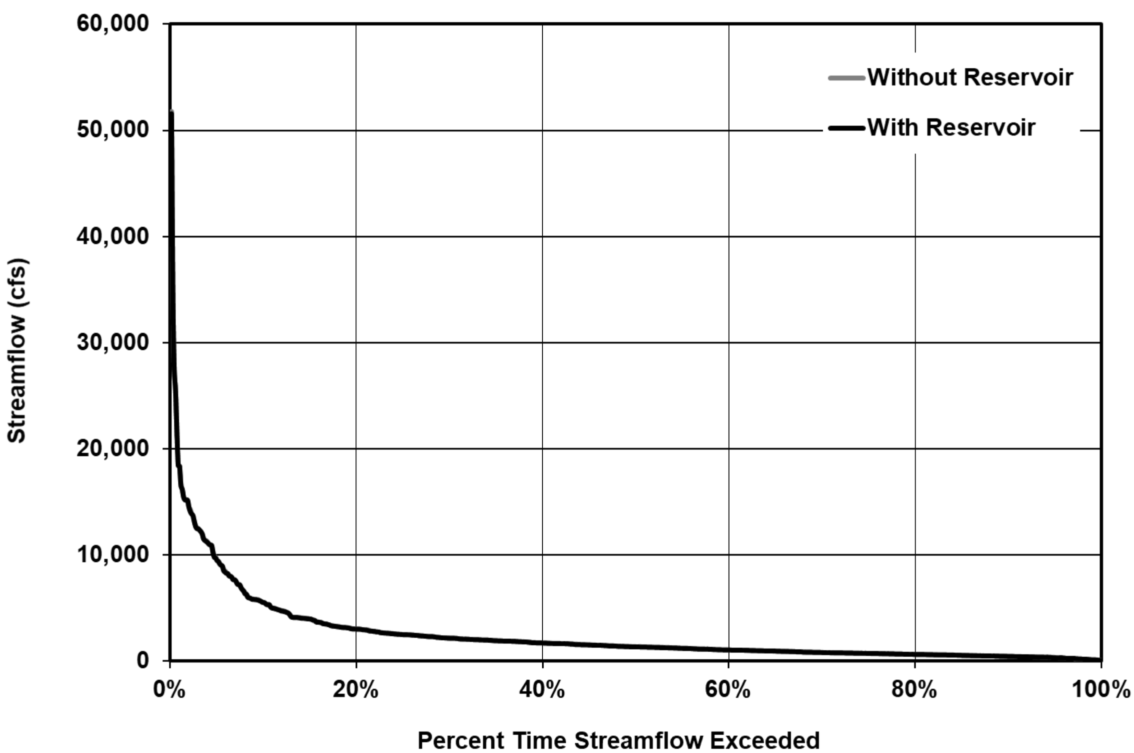


Figure 4.1-11 Streamflow Frequency Comparisons for the Brazos River with and without Diversions for Spring Branch Off-Channel Reservoir



4.1.3 Environmental Issues

Because of the greater yield and smaller project and unit cost (See Section 4.1.4), the Spring Brach OCR is considered the preferred OCR site. Therefore, environmental and implementation issues associated with the Hopes Creek OCR were not evaluated.

Existing Environment

The Spring Branch OCR site in Falls County is within the Texas Blackland Prairies Ecological Region, a fertile area of prairie and pastureland.[1] This region is located in northeast-central Texas west of the East Central Texas Plains and east of the Cross Timbers. The physiognomy of the region is made up of grassland and crops 300 to 800 feet above sea level. Much of the native vegetation has been displaced by agriculture and development.[2] The climate is characterized as subtropical humid, with warm summers. Average annual precipitation ranges between 28 and 40 inches.[3] The project area lies between the Carrizo and Trinity major aquifers, but is underlain by no major or minor aquifers.[4]

The proposed project is within an area identified as crops.[5] The crops vegetation type includes cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals.

Potential Impacts

Aquatic Environments including Bays & Estuaries

FEMA has not completed a study to determine flood hazard for Falls County and a flood map has not been published.[6]. Several wetlands (2 freshwater emergent wetlands, 1 forested/shrub wetland, 28 freshwater ponds, and 41 riverine wetlands) were identified on the National Wetland Inventory (NWI) maps adjacent to the potential reservoir. A Nationwide Permit or coordination with the U.S. Army Corps of Engineers would be required for impacts to waters of the U.S. Two surface waters were identified on the TCEQ Surface Water Quality Viewer[7], the Brazos River (Segment #1242) and the Little

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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), *Aquifers*, http://www.twdb.texas.gov/groundwater/aquifer/index.asp accessed February 3, 2020.

[5] 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.

[6] FEMA, 2020. FEMA Flood Map Service Center. Accessed online https://msc.fema.gov/portal/search?AddressQuery=fall%20county#searchresultsanchor February 4, 2020.

[7] TCEQ, 2020. Surface Water Quality Viewer. Accessed online https://tceq.maps.arcgis.com/apps/webappviewer/index.html?id=b0ab6bac411a49189106064b70bbe778 February 4, 2020.

Brazos River (Segment #1242E), within the proposed project area, or within 5 miles. These stream segments have no water quality impairments.

Threatened & Endangered Species

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Falls County can be found at https://tpwd.texas.gov/gis/rtest/.

According to the Information for Planning and Consultation (IPaC) website[8] maintained by the U.S. Fish & Wildlife Service (USFWS), the Whooping Crane and Texas fawnsfoot need to be considered for the proposed project. The Least Tern, Piping Plover, and Red Knot were also mentioned, but only need to be considered for wind energy projects.

Based on Texas Natural Diversity Data (TXNDD) obtained from the TPWD, there were four documented occurrences (sharpnose shiner, smalleye shiner, smooth pimpleback, and Texas fawnsfoot) in the within approximately one miles of the proposed OCR. Another documented occurrence of the smooth pimpleback was reported approximately 4.2 miles from the area of proposed improvements. No other documented occurrences of threatened, endangered or rare species or natural communities were reported within five miles of the project area. 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.

A biological survey of the project area, to determine whether populations of threatened or endangered species, or potential habitats used by listed species occur in the area to be affected, should be conducted if this strategy is selected. At that time, a determination on whether any impacts or effects to listed species may occur would made. 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

A review of the Texas Historical Commission's publically-available GIS database showed one cemetery (Powers Cemetery) is mapped within the proposed OCR site. Additionally, three other cemeteries (Ferguson Cemetery, Shilo Cemetery, and Powers Chapel Cemetery) are located within one mile of the footprint for the proposed OCR.

There are no National Register Properties, National Register Districts, State Historic Sites, or Historical Markers within one mile of the proposed OCR. Prior to construction of proposed OCR, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any cultural resources

[8] USFWS, 2020. Information for Planning and Consultation. Accessed online https://ecos.fws.gov/ipac/location/FLFV27QWYJH3VFVFFBGPVMSLEM/resources February, 2020.

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.

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.

Field surveys conducted at the appropriate phase of development should be employed to minimize the impacts of project construction and operations on sensitive resources.

4.1.4 Engineering and Costing

Cost estimates for the two selected main stem OCR sites were prepared using the TWDB uniform costing model are presented in Table 4.1-1. Project costs include construction of the dam, reservoir, Brazos River intake and pump station, and raw water pipeline from the Brazos River to the reservoir site. Comparison of the cost estimates indicate the Spring Branch OCR would provide a greater firm yield at a lower total project cost, annual cost, and unit cost of water.

Table 4.1-1. Cost Estimate Summary for Main Stem Off-Channel Reservoirs with Diversions from the Brazos River

Item	Estimated Costs for Spring Brach OCR Facilities	Estimated Costs for Hopes Creek OCR Facilities
Off-Channel Storage/Ring Dike	$31,177,000	$27,651,000
Brazos River Intake Pump Station	$36,856,000	$38,237,000
Transmission Pipeline (60 in dia., 0.5 miles and 60 in dia., 2.1 miles)	$1,059,000	$6,931,000
TOTAL COST OF FACILITIES	**$69,092,000**	**$72,819,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$24,129,000	$25,140,000
Environmental & Archaeology Studies and Mitigation	$4,320,000	$4,260,000
Land Acquisition and Surveying	$4,384,000	$4,332,000
Interest During Construction (3% for 4 years with a 0.5% ROI)	$5,607,000	$5,862,000
TOTAL COST OF PROJECT	**$107,532,000**	**$112,413,000**
ANNUAL COST		
Debt Service (3.5 percent, 20 years)	$3,800,000	$4,516,000
Reservoir Debt Service (3.5 percent, 40 years)	$2,506,000	$2,258,000
Operation and Maintenance		
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$11,000	$69,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$921,000	$956,000
Dam and Reservoir (1.5% of Cost of Facilities)	$468,000	$415,000
Pumping Energy Costs (0.08 $/kW-hr)	$148,000	$153,000
TOTAL ANNUAL COST	**$7,854,000**	**$8,367,000**
Available Project Yield (acft/yr)	**7,200**	**6,300**
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	**$1,091**	**$1,328**
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	**$3.35**	**$4.08**

4.1.5 Implementation Issues

The Spring Branch and Hopes Creek OCR water supply options are similar and have been compared to the plan development criteria, as shown in Table 4.1-2. The two OCR options meets each criterion.

Table 4.1-2. Evaluations of Hopes Creek and Spring Branch Off-Channel Reservoir Options 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 one of the off-channel reservoir projects 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;
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction; 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.

4.2 Brushy Creek Reservoir

4.2.1 Description of Option

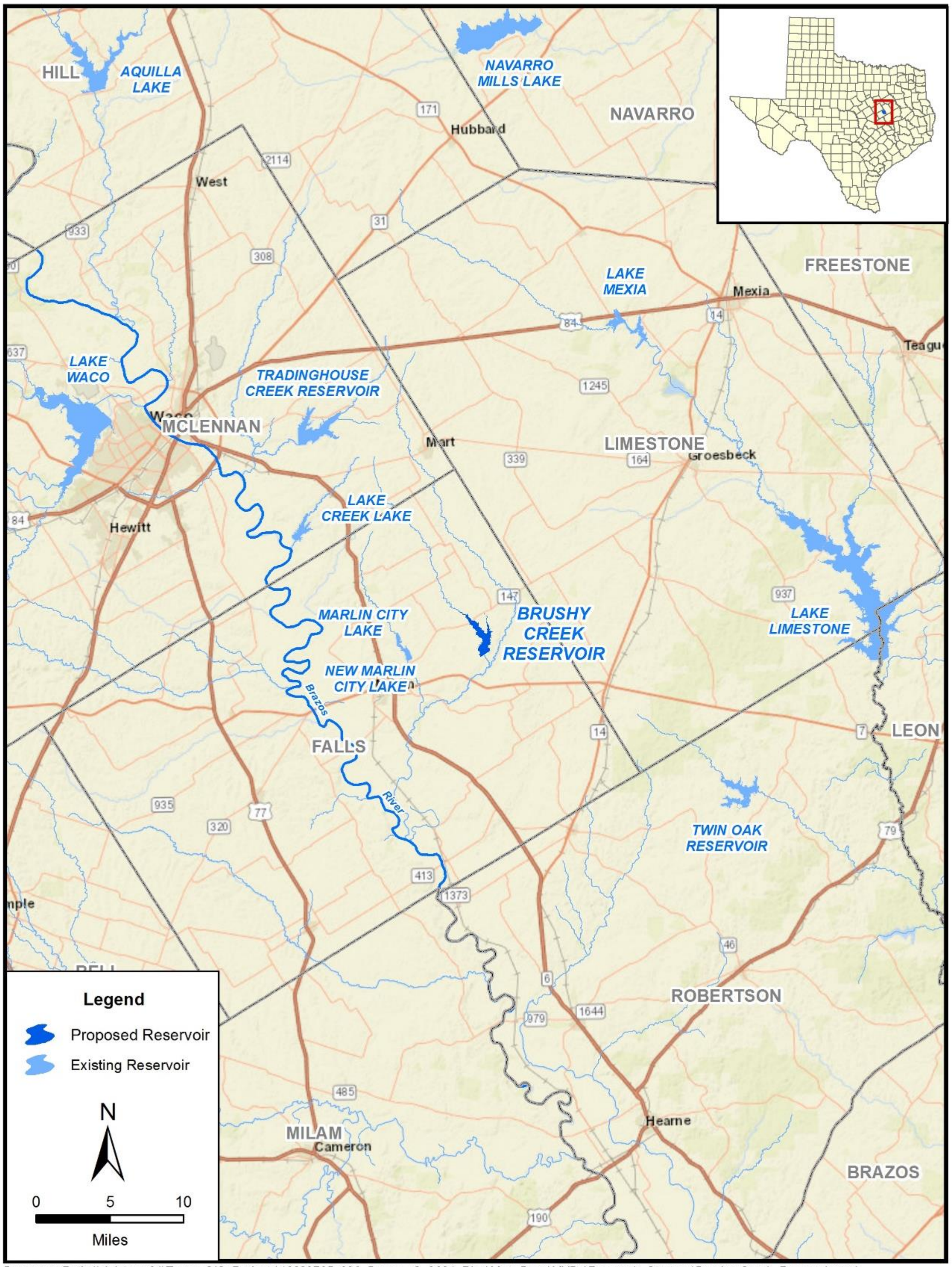
The proposed Brushy Creek Reservoir will serve water supply, recreation and flood control purposes in the Big Creek watershed. The reservoir site is located in Falls County on Brushy Creek, which is a tributary to Big Creek. The proposed reservoir is located approximately 26 miles southeast of the City of Waco and 8 miles east of the City of Marlin (Figure 4.2-1). This project was included as a water management strategy in the 2001, 2006, 2011, and 2016 Brazos G Regional Water Plans. Other Brushy Creek Reservoir studies include the 1984 Final Watershed Plan and Environmental Impact Statement for the Big Creek Watershed for Falls, Limestone, and McLennan Counties1 and the 2008 Reservoir Site Protection Study2.

Certificate of Adjudication 12-4355, as amended, authorizes 6,560 acre-feet of storage at a conservation level of 380.5 feet above mean sea level (ft-msl) in Brushy Creek Reservoir. The conservation pool of the reservoir will inundate an area of approximately 697 acres and the land required to create the reservoir has already been acquired by the City of Marlin.

The certificate also authorizes New Marlin City Lake 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 City Lake 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 4.2-1 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 4.2-1. Brushy Creek Reservoir Location



Document Path: \\dalctxsrv01\Texas_GIS_Projects\10029705_036_Brazos_G_2021_Plan\Map_Docs\MXDs\Reservoir_Strategy\Brushy_Creek_Reservoir.mxd

Table 4.2-1. Summary of Authorizations for Certificate of Adjudication 12-4355

Source	Storage (acft)	Impoundment Priority Date	Diversion (acft/year)	Use	Diversion 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

4.2.2 Available Yield

Water potentially available for impoundment in the proposed Brushy Creek Reservoir is 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 computes streamflow available for impoundment in Brushy Creek Reservoir without causing increased shortages to existing downstream rights and subject to the reservoir and diversion having to pass inflows to meet environmental flow standards. Additionally, impoundment of streamflows in Brushy Creek Reservoir is subject to a minimum required instream flow release of 0.1 cfs as specified in Special Condition G of Certificate of Adjudication 12-4355.

The firm yield of the reservoir is calculated to be 2,000 acre-feet per year assuming the authorized storage capacity of Brushy Creek Reservoir. This yield is in addition to the yield of the City's existing reservoir storage, i.e., New Marlin Reservoir. The elevation-area-capacity relationship assumed in the water availability analysis is shown in Table 4.2-2.

Figure 4.2-2 shows the simulated storage in Brushy Creek Reservoir assuming an annual diversion amount equal to the firm yield of 2,000 acft/yr. The storage frequency curve is presented in Figure 4.2-3.

Table 4.2-2. 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*

* Authorized conservation pool elevation and storage.

4.2.3 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.

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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.

Figure 4.2-2. Simulated Storage in Brushy Creek Reservoir

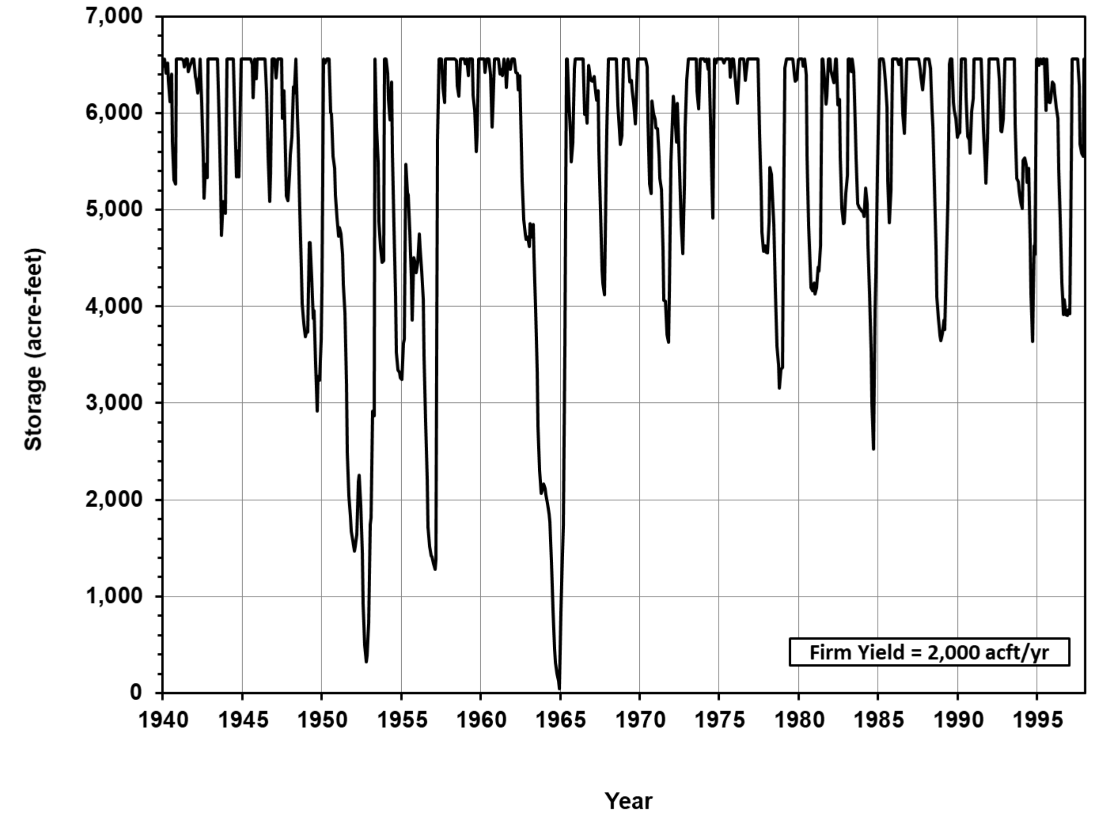
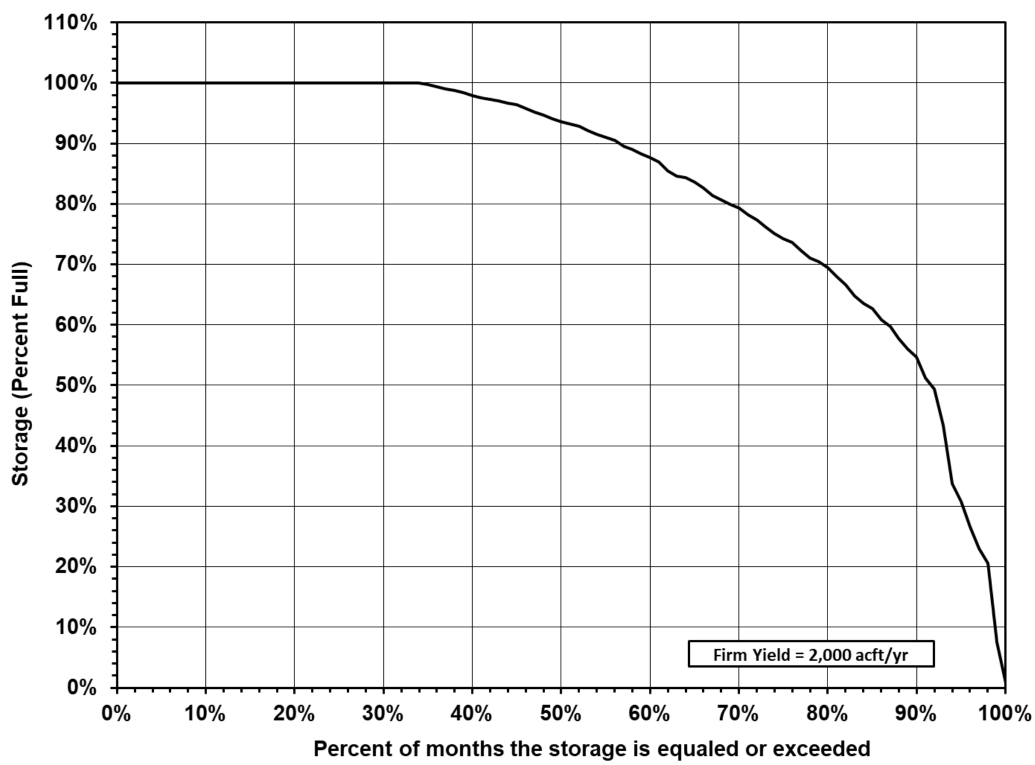


Figure 4.2-3. Storage Frequency Curve for Brushy Creek Reservoir



Potential Impacts

Aquatic Environments including Bays and Estuaries

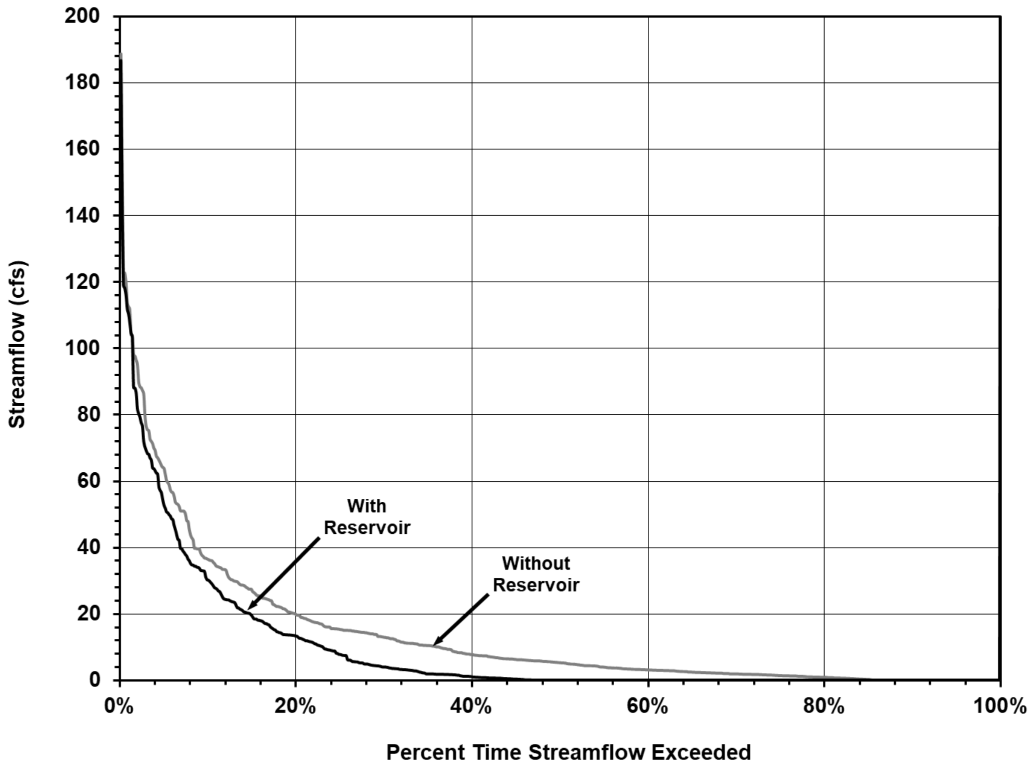
Construction of the Brushy Creek Reservoir project could reduce the quantity and variability of median monthly streamflows in Brushy Creek downstream of the reservoir (Table 4.2-3). Assuming annual diversions equal to the permitted amounts, these reductions could range from 1.9 cfs (95 percent) in October to 8.8 cfs (64 percent) in May. Figure 4.2-4 shows that without the reservoir, streamflow would likely cease 14% 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 over 50% 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.

Table 4.2-3. Median Monthly Streamflow for Brushy Creek Reservoir

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	6.9	1.6	5.4	77.6
February	6.6	0.2	6.4	97.1
March	6.7	1.4	5.3	78.6
April	6.3	1.6	4.8	75.2
May	13.7	4.9	8.8	64.0
June	11.3	3.0	8.2	73.2
July	3.7	0.1	3.6	97.3
August	3.4	0.1	3.3	97.1
September	2.3	0.1	2.2	95.8
October	2.0	0.1	1.9	95.1
November	3.1	0.1	3.0	96.8
December	5.8	0.2	5.6	95.8

Figure 4.2-4. Brushy Creek Reservoir Streamflow Frequency Comparison



Threatened & Endangered Species

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD frequently updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Falls County can be found at https://tpwd.texas.gov/gis/rtest/.

Two bird species that could potentially occur in the vicinity of the Brushy Creek 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 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.

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[5] USFWS. Critical Habitat Portal. Accessed online at http://ecos.fws.gov/crithab/ May 13, 2019.

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 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.

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[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.

[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.

4.2.4 Engineering and Costing

The Brushy Creek Reservoir strategy includes the construction of a rolled earth dam and a 12-inch diameter, 12-mile pipeline to deliver raw water supplies to the City of Marlin. Table 4.2-4 shows the estimated costs for the strategy, including the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and engineering services. The City of Marlin has previously acquired the land for the reservoir; therefore, only land acquisition for the pipeline right-of-way is included in the costs.

The estimated cost of the project is $33.2 million. The annual costs of the project, including debt service and operation and maintenance, are estimated to be $2.5 million. The resulting unit cost of 2,000 acft/yr of raw water from the strategy is $1,247 per acft ($3.82 per 1,000 gallons).

Table 4.2-4. Cost Estimate Summary for Brushy Creek Reservoir

Item	Estimated Costs for Facilities
Dam and Reservoir (Conservation Pool 6,560 acft, 697 acres)	$5,924,000
Intake Pump Stations (1.9 MGD)	$5,802,000
Transmission Pipeline (12 in dia., 12 miles)	$5,468,000
Integration, Relocations, and Other	$4,146,000
TOTAL COST OF FACILITIES	**$21,340,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$7,196,000
Environmental & Archaeology Studies and Mitigation	$2,656,000
Land Acquisition and Surveying (72 acres)	$304,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$1,733,000
TOTAL COST OF PROJECT	**$33,229,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$1,567,000
Reservoir Debt Service (3.5 percent, 40 years)	$513,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$96,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$145,000
Dam and Reservoir (1.5% of Cost of Facilities)	$89,000

Table 4.2-4. Cost Estimate Summary for Brushy Creek Reservoir

Item	Estimated Costs for Facilities
Pumping Energy Costs (1,039,970 kW-hr @ 0.08 $/kW-hr)	$83,000
TOTAL ANNUAL COST	**$2,493,000**
Available Project Yield (acft/yr)	2,000
Unit Cost of Water ($ per acft)	$1,247
Unit Cost of Water ($ per 1,000 gallons)	$3.82

4.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.2-5 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;
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction; 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 4.2-5. 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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4.3 Cedar Ridge Reservoir

4.3.1 Description of Option

Cedar Ridge Reservoir (CRR) is recommended in the 2001, 2006, 2011, and 2016 Brazos G Regional Plans. The proposed reservoir is located 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 4.3-1. Initially located further downstream and known as the Breckenridge Reservoir, this project was originally studied in 1971 by the Texas Water Development Board. The proposed reservoir will contain approximately 227,127 acft of conservation storage and inundate 6,635 acres at the conservation storage level of 1,489 ft-msl. The contributing drainage area of the proposed reservoir is approximately 2,748 sq. miles. Additionally, Abilene and BRA have signed an interlocal agreement for the subordination of Possum Kingdom Reservoir water rights to the proposed CRR.

The water supply from CRR will be used to meet municipal shortages in the area, and Abilene plans to operate CRR as a supply in conjunction with its existing water supply system. Abilene is actively pursuing the necessary permits to implement this project and the information contained in this section is based on the water right permit application filed at the Texas Commission on Environmental Quality (TCEQ) and the Clean Water Act, Section 404 permit application filed with the U.S. Army Corps of Engineers, Ft. Worth District (USACE).

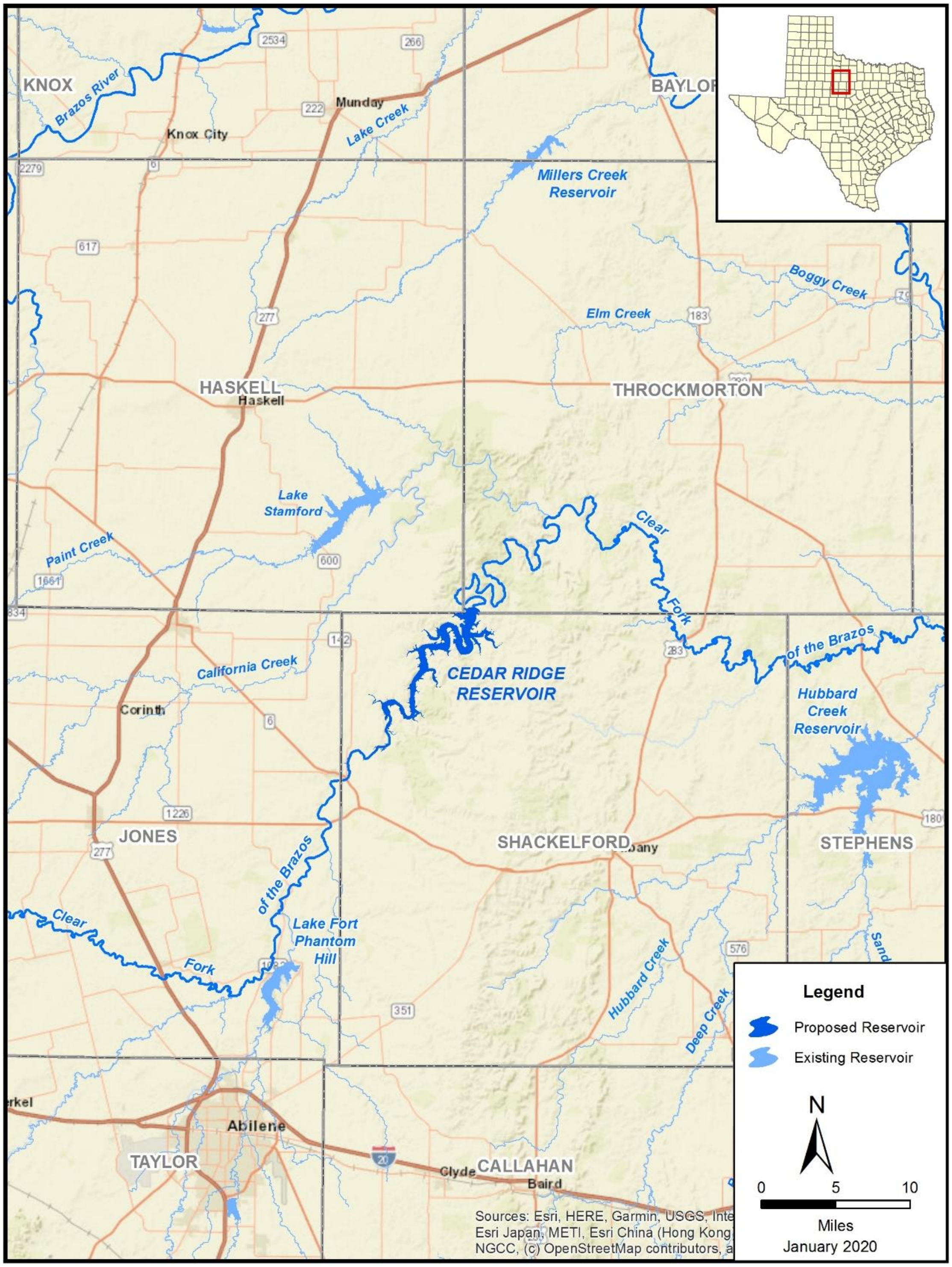
4.3.2 Available Yield

Abilene has applied for a water right permit with the TCEQ to impound 227,127 acft and divert up to 34,400 acft/yr of water from the reservoir for multi-purpose uses including: municipal, domestic, industrial, agriculture, livestock, steam-electric, mining, and recreation. The calculated firm yield of the reservoir using the TCEQ Brazos WAM is 36,300 acft/yr, assuming permitted storages and authorized diversions for all other water right holders in the Brazos basin for the 1940 to 1997 hydrologic period and subordination of Possum Kingdom Reservoir (C5155 owned by the BRA) water rights.

Severe drought conditions have occurred in the upper Brazos Basin resulting in a new drought of record for the Clear Fork watershed since 1997, which is outside of the period of record for the TCEQ Brazos WAM. A water availability analysis performed by HDR Engineering, Inc. as part of the Section 404 permitting process indicates the 2020 firm yield of CRR has been reduced to 22,500 acft/yr as a result of the severe drought conditions occurring from 1997 to 2016. For purposes of this evaluation, the more conservative 22,500 acft/yr firm yield is assumed for the project.

Additionally, the water availability analyses performed as part of the Section 404 permitting process considers future droughts more severe than the current drought of record to project future reliable supplies from the project. Those analyses project the firm yield of CRR to reduce to 10,100 acft/yr by 2070. For the purposes of this evaluation and for consistency with Abilene’s previous water supply planning evaluations, it is assumed that the firm yield of CRR will be linearly reduced from 22,500 acft/yr in 2020 to 10,100 acft/yr in 2070.

Figure 4.3-1. Cedar Ridge Reservoir



Document Path: C:\Users\ngonsalv\Documents\ArcGIS\Packages\Cedar_Ridge_Reservoir_37E6F8BE-90AC-4C74-9774-63D0F047689D\v106\Cedar_Ridge_Reservoir.mxd

Figure 4.3-2 illustrates the simulated Cedar Ridge Reservoir storage levels operated at a firm yield demand of 22,500 acft/yr for the 1940 to 2016 historical period. The storage trace shows that the recent drought beginning in the late 1990s is significantly more severe than the drought of the 1950s.

Figure 4.3-3 illustrates the storage frequency of the simulated Cedar Ridge Reservoir subject to the firm yield demand of 22,500 acft/yr. Simulated reservoir contents remain above half full almost 80 percent of the time under the firm yield demand.

Figure 4.3-4 presents the changes in Clear Fork monthly median streamflows caused by impoundments in the reservoir considering pass-through flows for downstream senior water rights and environmental needs per TCEQ environmental flow requirements. Figure 4.3-5 compares the existing Clear Fork streamflow frequency characteristics for the full period (1940 – 2016) of the analysis without the project to simulated streamflow characteristics with the project.

Figure 4.3-2. Cedar Ridge Reservoir Firm Yield Storage Trace

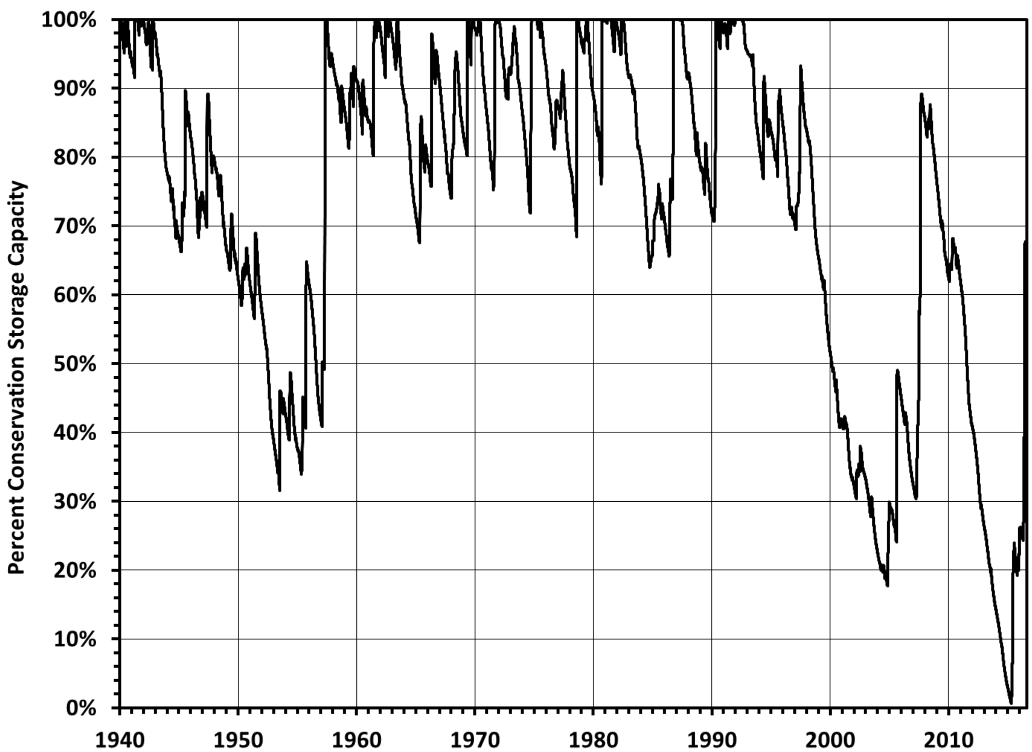


Figure 4.3-3. Cedar Ridge Reservoir Firm Yield Storage Frequency

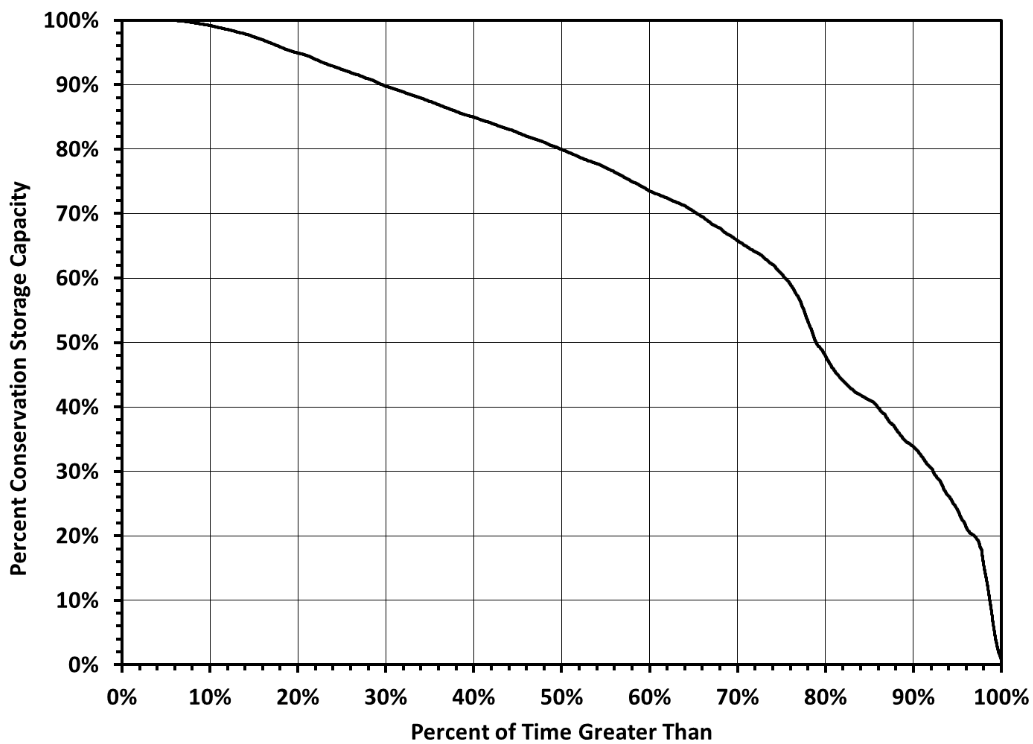


Figure 4.3-4. Cedar Ridge Reservoir Median Streamflow Comparison

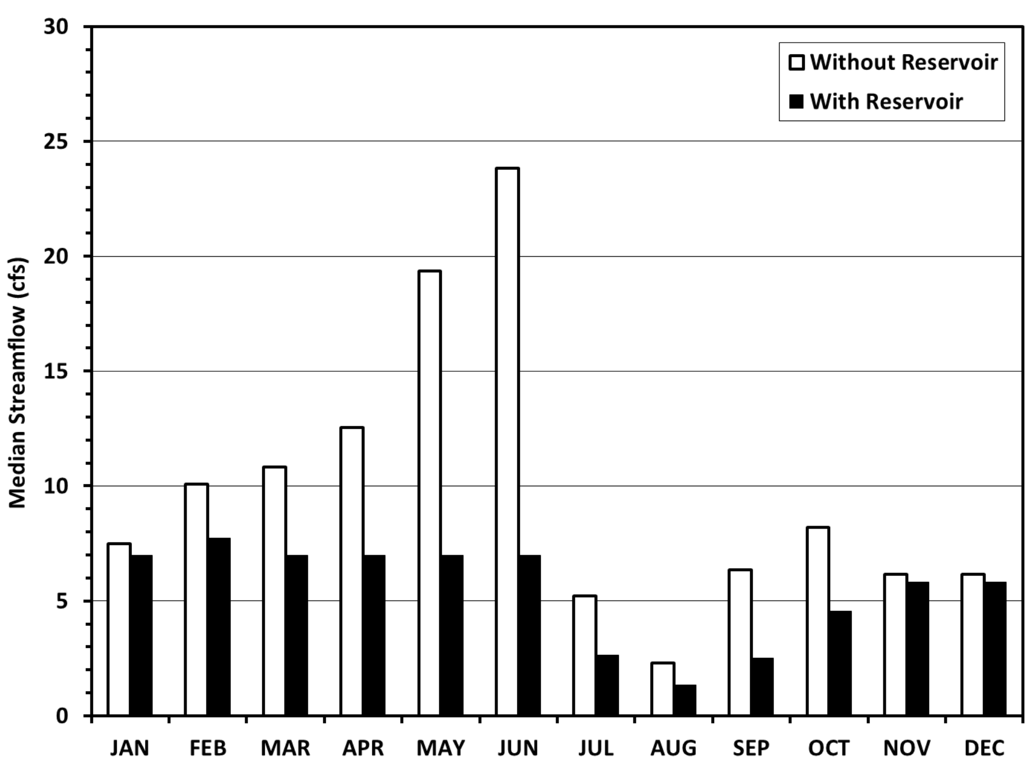
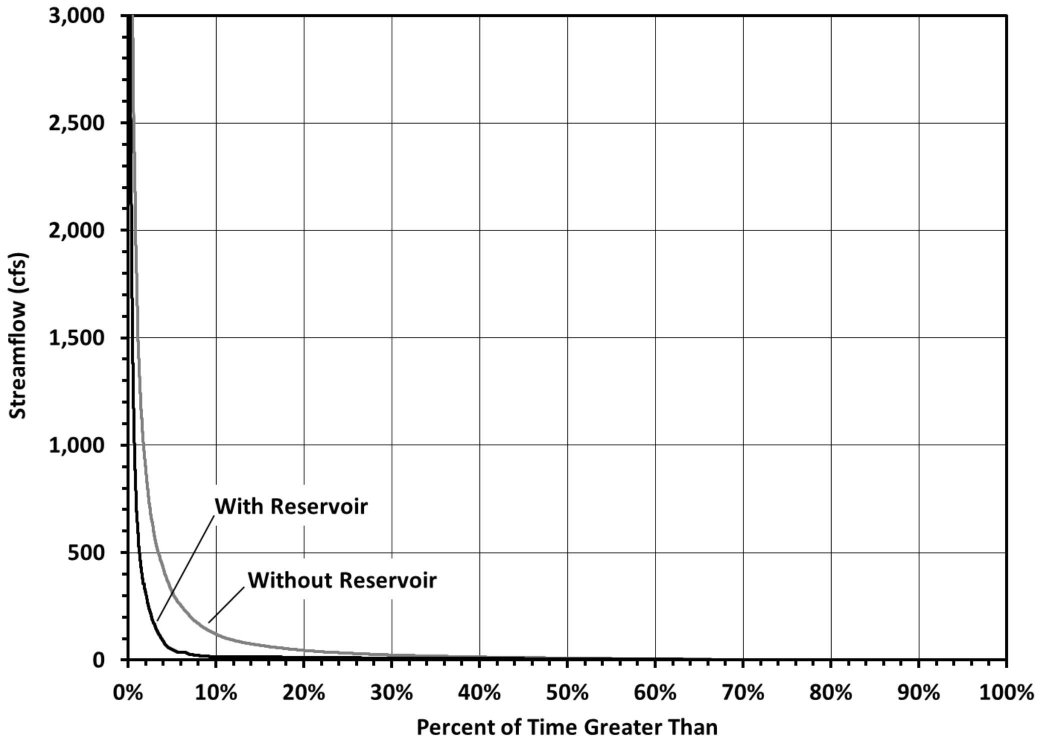


Figure 4.3-5. Cedar Ridge Reservoir Streamflow Frequency Comparison



4.3.3 Environmental Issues

The following section focuses on providing a general summary of environmental issues consistent with other water management strategies evaluated as part of the 2021 Brazos G Plan.

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 at one of the City's existing water treatment plants, and a transmission pipeline of approximately 29 miles. Water diverted from this reservoir will be used to meet water supply needs 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.[1]

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 64°F.[2] 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[3] and the vegetational area known as the Rolling Plains.[4] 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 Cedar Ridge Reservoir.[5] 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.).[6]

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*).[7]

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

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

3 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.

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.

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

6 Ibid.

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

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 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.

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.[8] 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 specific biologic need.

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

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 after reservoir filling.

Threatened & Endangered Species

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Haskell, Jones, Shackelford, and Throckmorton counties can be found at https://tpwd.texas.gov/gis/rtest/.

A search of the Texas Natural Diversity Database (TNDD)[9] 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, 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.

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.[10] 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

9 Texas Parks and Wildlife Department (TPWD). 2019. Element occurrence records for Haskell, Jones, Shackelford, and Throckmorton Counties. Texas Natural Diversity Database, Texas Parks and Wildlife Department.

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

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 moderate-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.[11] 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 about the preferred habitat of this species; however, it is known to be intolerant of impoundment.[12] Texas fawnsfoot specimens potentially occurring downstream of the new reservoir are not anticipated to be significantly impacted by 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, mesquite grasslands, shrublands, desert scrub, and desert grasslands.[13] 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 would likely be minimal given the estimated slow filling rate of the new reservoir and abundant suitable habitat immediately surrounding the project area.

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.[14] Investigation of the project area indicates 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 the Cedar Ridge Reservoir include the inundation and loss of existing habitat along the Clear Fork. However,

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

12 Ibid.

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

14 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.

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.

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 per 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 multi-component 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 per 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 and hay fields and 58 acres of cropland. These two agricultural land uses account for less than two percent of the reservoir footprint.

4.3.4 Engineering and Costing

The proposed CRR includes the construction of an earthen dam, principal spillway, emergency spillway, and appurtenant structures. eHT and HDR completed a study[15] in 2009 of the proposed Cedar Ridge Reservoir. Estimated costs for the reservoir included in the study are indexed to September 2018 dollars. Transmission facilities are sized to deliver the firm yield supply of 22,500 acft/yr with an estimated five percent downtime. Estimated capital costs for transmission facilities, relocations, and integration were provided by Abilene.

The capital cost of the project is estimated to be $159.1 million and includes the construction of the dam, land acquisition, and resolution of conflicts. Also included in the capital costs are facilities to deliver supplies to the City through a 42-inch, 29-mile pipeline. The total cost of the project is estimated to be $283.6 million and includes environmental permitting and mitigation, and technical services. A summary of the estimated costs for the project is provided in Table 4.3-1. The annual project costs are estimated to be $19.2 million, which includes annual debt service, operation and maintenance, and an annual payment to BRA for lost yield in Possum Kingdom Reservoir. The resulting unit cost to deliver the firm yield supply 22,500 acft/yr is $2.62 per 1,000 gallons or $853 per acft. Treatment costs are included in another water management strategy recommended for Abilene.

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

Table 4.3-1. Cost Estimate for Cedar Ridge Reservoir

Item	Estimated Costs for Facilities
Dam and Reservoir	$81,831,000
Intake Pump Stations (21.1 MGD)	$12,105,000
Transmission Pipeline (42 in dia., 29 miles)	$50,122,000
Integration, Relocations, & Other	$15,012,000
TOTAL COST OF FACILITIES	**$159,070,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$53,168,000
Environmental & Archaeological Studies and Mitigation	$30,980,000
Land Acquisition and Surveying (9,985 acres)	$18,809,000
Interest During Construction (3% for 3 years with a 0.5% ROI)	$21,619,000
TOTAL COST OF PROJECT	**$283,646,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$7,835,000
Reservoir Debt Service (3.5 percent, 40 years)	$8,068,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$651,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$303,000
Dam and Reservoir (1.5% of Cost of Facilities)	$1,227,000
Pumping Energy Costs ($0.08 kwh)	$1,019,000
Purchase of Water (1,100 acft/yr @ 76.50 $/acft)	$84,000
TOTAL ANNUAL COST	**$19,187,000**
Available Project Yield (acft/yr)	**22,500**
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1.53	**$853**
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1.53	**$2.62**

4.3.5 Implementation Issues

The CRR water supply option has been compared to the plan development criteria, as shown in Table 4.3-2, 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 dredged 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;
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction; 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 mitigation plans could include market transactions or other local landowner agreements;
- Additional acquisition of rights-of-way and easements may be required; and
- Relocations or removal of residences, utilities, roads, or other structures.

Table 4.3-2. 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 the site
4. Bays and Estuaries	4. Low impact due to distance from the 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 the 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

4.4 Coryell County Off-Channel Reservoir

4.4.1 Description of Option

The Coryell County Off-Channel Reservoir (OCR) is located on a tributary adjacent to Cowhouse Creek about four miles southeast of the Coryell-Hamilton County Line, as shown in Figure 4.4-1. Supplies from the OCR would be used to meet needs in Coryell County and potentially Bell, Lampasas, Williamson, or Hamilton Counties.

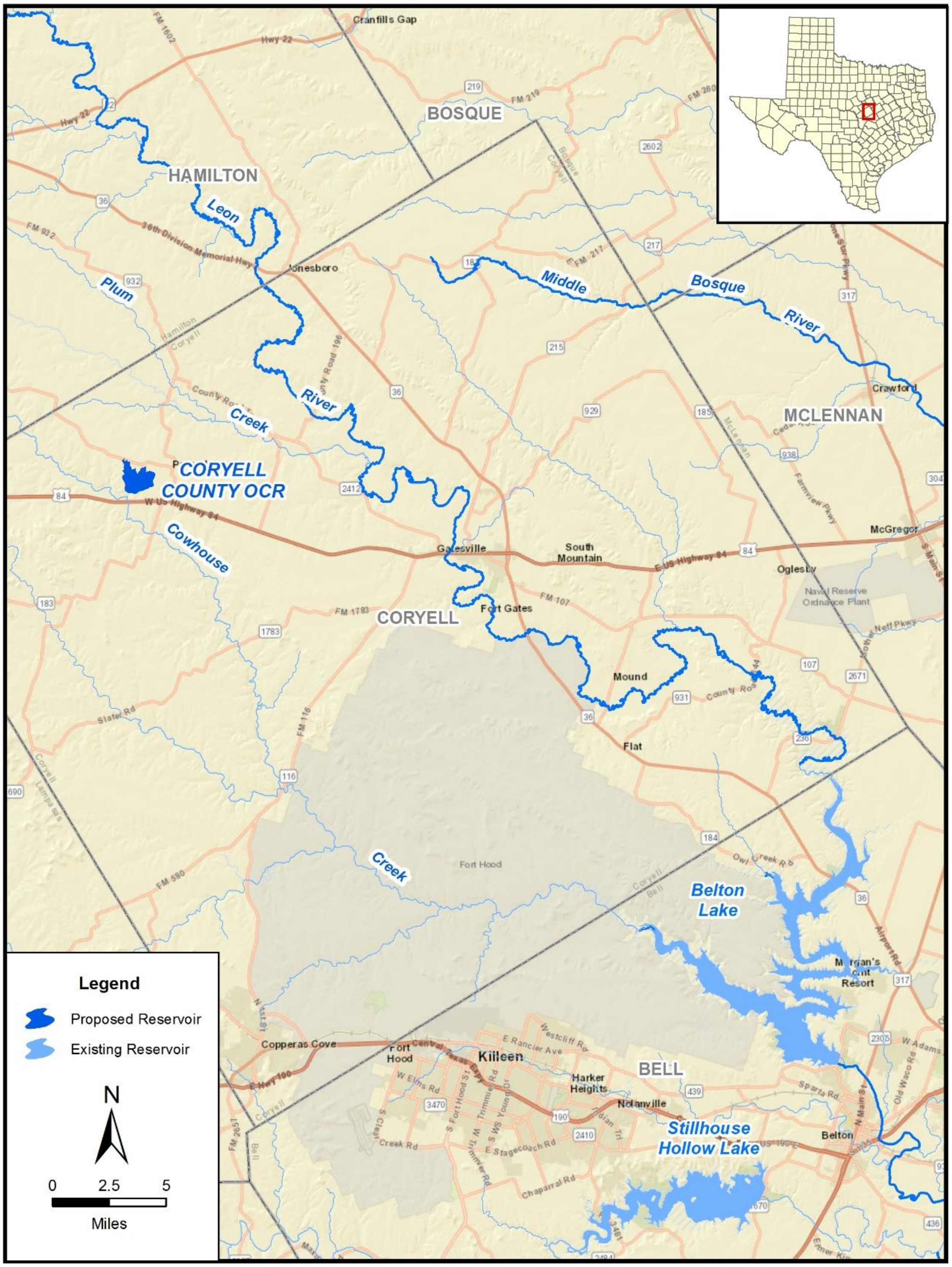
The OCR would impound streamflow pumped from Cowhouse Creek from a diversion site directly downstream of the proposed OCR dam location. The OCR would consist of a 4,767 ft earthfill embankment dam on the Cowhouse Creek tributary stream with a crest elevation at 1,080 ft-msl. The OCR includes a 5 ft vertical freeboard and 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 through the dam and not impounded.

For the project to be economically feasible, an agreement with the Brazos River Authority (BRA) would be required to subordinate Lake Belton water rights to diversions from Cowhouse Creek for impoundment in the OCR. Without subordination, the unappropriated flows in Cowhouse Creek are not sufficient to maintain adequate water levels in the OCR. Currently, BRA indicates that no subordination agreement is likely to be possible.

4.4.2 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 computes streamflow available for diversion from Cowhouse Creek into the Coryell OCR without causing increased shortages to existing downstream rights and subject to the subordination agreement with Lake Belton. Estimates of water availability were derived subject to all diversions and impoundments having to pass streamflows to meet TCEQ environmental flow standards.

Figure 4.4-1. Coryell County Off-Channel Reservoir



Document Path: \\dalctxsrv01\Texas_GIS_Projects\10029705_036_Brazos_G_2021_Plan\Map_Docs\MXDs\Reservoir_Strategy\Coryell_County_OCR.mxd

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 2018 at Cowhouse Creek near Pidcoke, TX. The estimated streamflow indicates that on average, only 5.2 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 acre-feet per month of flow from Cowhouse Creek. Figure 4.4-2 illustrates the annual diversion amount under firm yield conditions from Cowhouse Creek used to refill storage. On average, 3,744 acft/yr of water would be diverted.

The calculated firm yield of the Coryell County OCR is 3,135 acft/yr. Figure 4.4-3 and Figure 4.4-4 illustrates the simulated Coryell County OCR storage levels for the 1940 to 1997 historical period, subject to the firm yield demand 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 32 percent of the time and above 50 percent capacity about 66 percent of the time. Results of the WAM simulation indicate the yield impact to Lake Belton is 2,536 acft/yr when subordinated to the Cowhouse Creek diversions for the OCR.

Figure 4.4-5 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 4.4-6 illustrates the Cowhouse Creek streamflow frequency characteristics with and without the Coryell County OCR in place.

Figure 4.4-2. Coryell County Off-Channel Reservoir Firm Yield Diversions from Cowhouse Creek

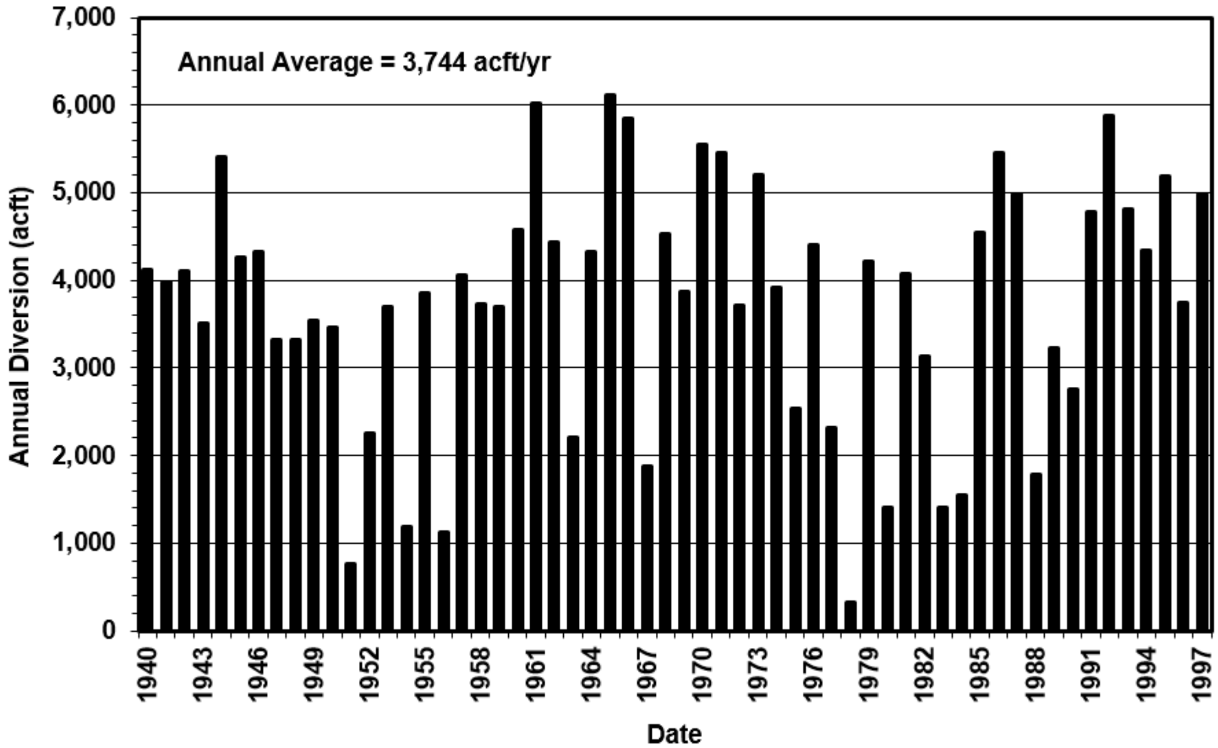


Figure 4.4-3. Coryell County Off-Channel Reservoir Storage Trace

Figure 4.4-4. Coryell County Off-Channel Reservoir Storage Frequency at Firm Yield

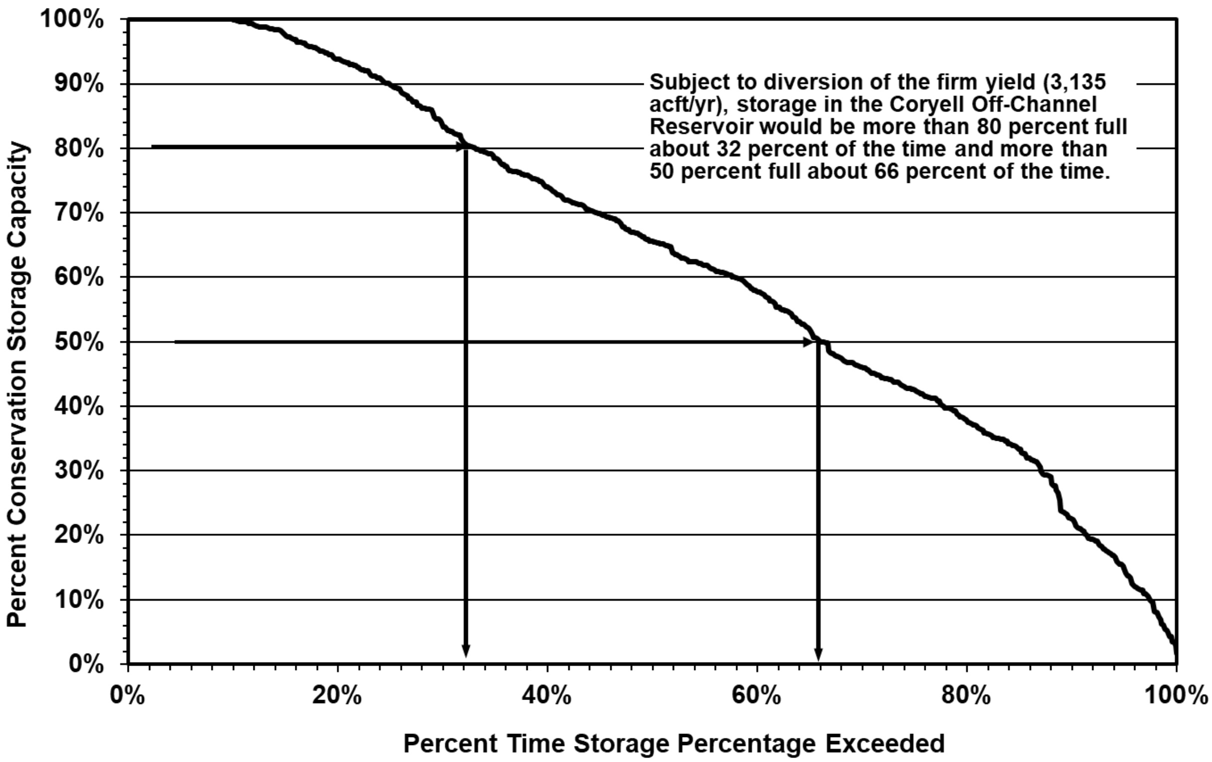


Figure 4.4-5. Cowhouse Creek Diversion Median Streamflow Comparison

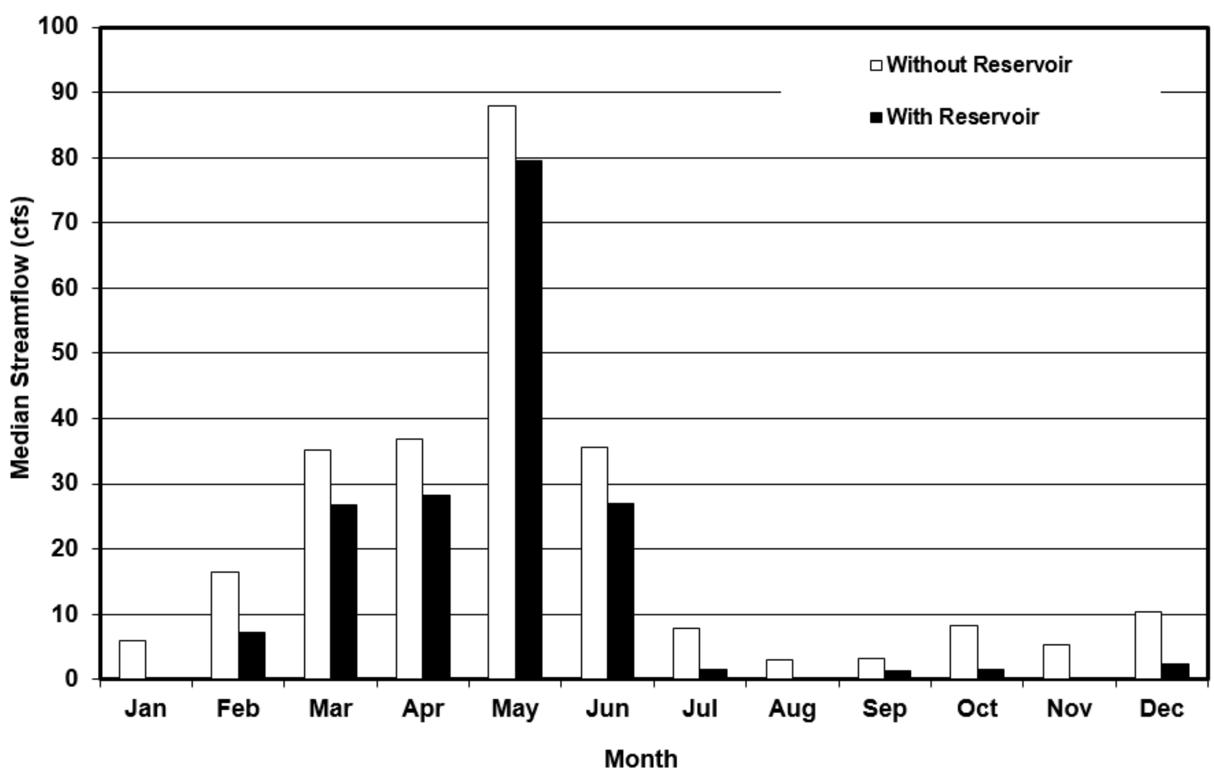
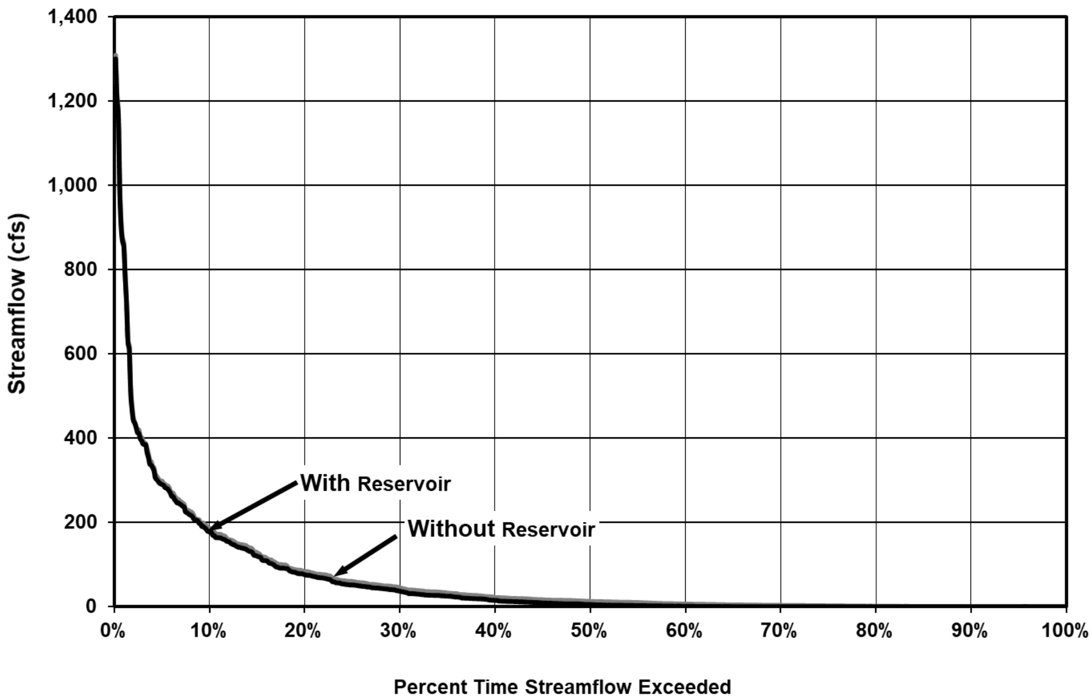


Figure 4.4-6. Cowhouse Creek Diversion Streamflow Frequency Comparison



4.4.3 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 (*Bouteloua 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 4.4-1. Median monthly flows are expected to be reduced in all months of the year. Changes in flow variability at the diversion point is 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

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Coryell County can be found at https://tpwd.texas.gov/gis/rtest/.

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 4.4-1. Median Monthly Streamflow: Cowhouse Creek Diversion Site

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	6.04	0.37	5.67	94%
February	16.48	7.27	9.21	56%
March	35.08	26.77	8.31	24%
April	36.74	28.17	8.57	23%
May	87.88	79.58	8.29	9%
June	35.54	26.90	8.63	24%
July	7.75	1.50	6.25	81%
August	3.07	0.26	2.81	91%
September	3.29	1.32	1.98	60%
October	8.34	1.62	6.71	81%
November	5.26	0.04	5.22	99%
December	10.31	2.28	8.03	78%

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.

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.

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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.

4.4.4 Engineering and Costing

The 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 32 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 451 acres of land for the reservoir and pipeline right-of-way.

A summary of the total project cost in September 2018 dollars is presented in Table 4.4-2. The total project cost of the Coryell County OCR project is estimated to be $82.6 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 OCR to future customers is not included. The annual project costs are estimated to be $6,322,000. 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 $2,017 per ac-ft or $6.19 per 1,000 gallons.

Table 4.4-2. Cost Estimate Summary for Coryell County Off-Channel Reservoir

Item	Estimated Costs for Facilities
Dam and Off-Channel Reservoir (Conservation Pool 15,380 acft, 445 acres)	$25,140,000
Channel Dam and Intake Pump Stations (32 MGD)	$30,378,000
Transmission Pipeline (36 in dia., 674 feet)	$195,000
TOTAL COST OF FACILITIES	**$55,713,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$19,490,000
Environmental & Archaeology Studies and Mitigation	$1,526,000
Land Acquisition and Surveying (451 acres)	$1,549,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$4,306,000
TOTAL COST OF PROJECT	**$82,584,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$3,066,000
Reservoir Debt Service (3.5 percent, 40 years)	$1,827,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$2,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$691,000
Dam and Reservoir (1.5% of Cost of Facilities)	$418,000
Pumping Energy Costs	$124,000
Purchase of Water (2,536 acft/yr @ 76.5 $/acft)	$194,000
TOTAL ANNUAL COST	**$6,322,000**
Available Project Yield (acft/yr)	3,135
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	$2,017
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	$6.19

4.4.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.4-3, and the option meets each criterion.

Table 4.4-3. 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;
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction; 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.

4.5 City of Groesbeck Off-Channel Reservoir

4.5.1 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 4.5-1 and Figure 4.5-2. 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 sufficient to meet the City's full water demand and the City was forced to use stored water from Springfield Lake. Springfield Lake is owned by the TPWD for recreation purposes; however, Groesbeck's 500 acft storage right extends to 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 for subsequent diversion downstream at the water treatment plant intake.

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 completed to determine the reliable supply to Groesbeck from its Navasota River diversion rights 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. Results of the yield analysis indicate that the firm yield of the City's water right, supplemented with storage from Springfield Lake, is 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

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[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 4.5-1. Location of Groesbeck Off-Channel Reservoir

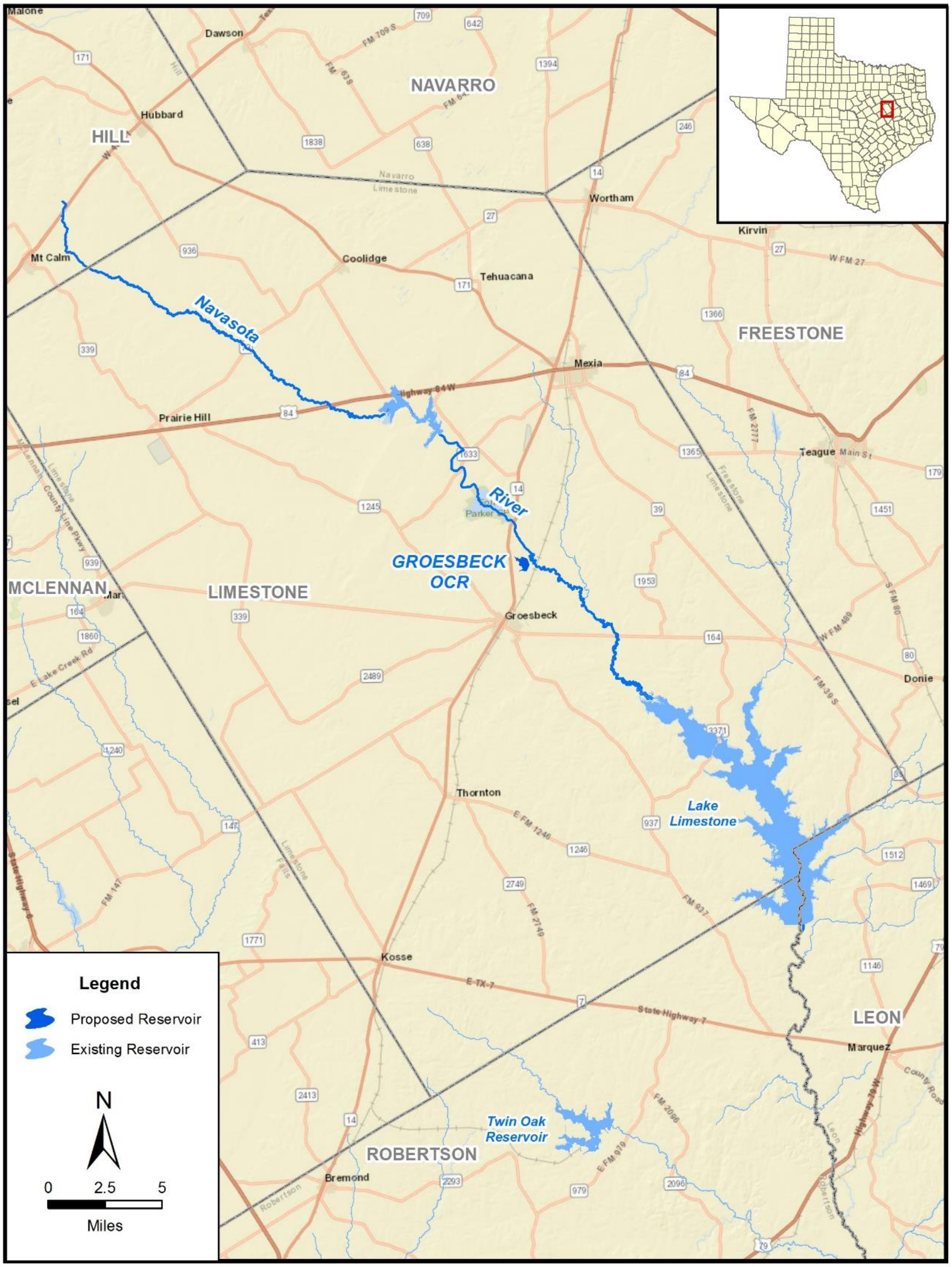

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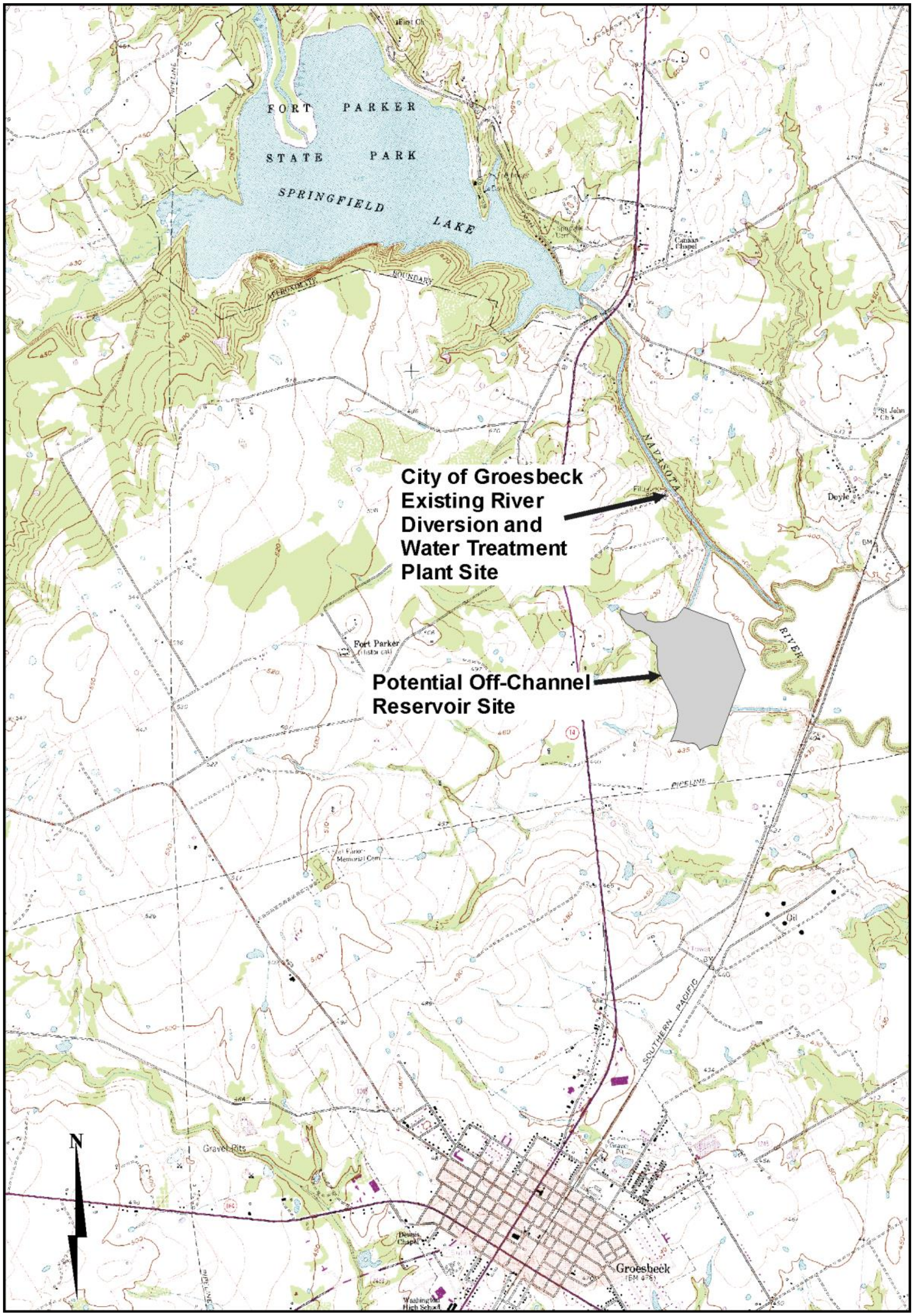
Figure 4.5-2. Groesbeck Off-Channel Reservoir



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.

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 4.5-2. 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 and impound flows diverted from the Navasota River. All flows from the small watershed above the reservoir would be passed through the reservoir.

The City's senior water right with a diversion of 2,500 acft/yr and a priority of June 1921 would be utilized to divert water from the Navasota River to the off-channel reservoir. The City would then divert water from the reservoir for municipal use, allowing 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, a subordination agreement with BRA is not required. 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 existing authorization would require the purchase of Lake Limestone supplies from BRA, or a subordination agreement with the BRA. Currently, BRA indicates that no subordination agreement is likely to be possible.

4.5.2 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 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 Groesbeck Off-Channel Reservoir without causing increased shortages to existing downstream rights. The off-channel reservoir was modeled such that it does not impound streamflow originating from its own contributing 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 2018 for the Navasota River above Groesbeck (USGS Gage 08110325) indicates that 25 percent of the time or on average 7.6 days per month, the required streamflow of 16.2 cfs is exceeded. 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 4.5-3 illustrates the annual diversions 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 4.5-4 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 4.5-5 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 4.5-6 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 decreases in median streamflow from the implementation of the off-channel reservoir. Figure 4.5-7 also illustrates the Navasota River streamflow frequency characteristics with the Groesbeck Off-Channel Reservoir in place.

Figure 4.5-3. Groesbeck OCR Firm Yield Diversions from Navasota River

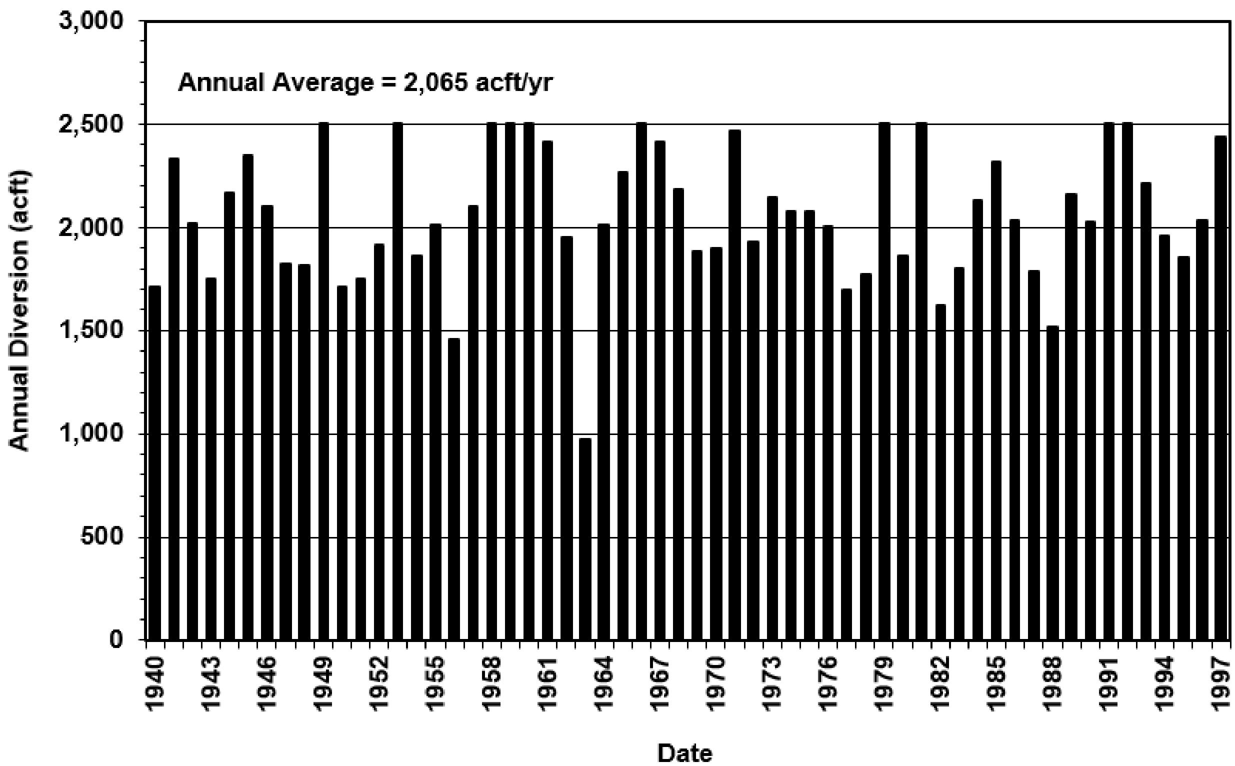


Figure 4.5-4. Groesbeck OCR Firm Yield Storage Trace

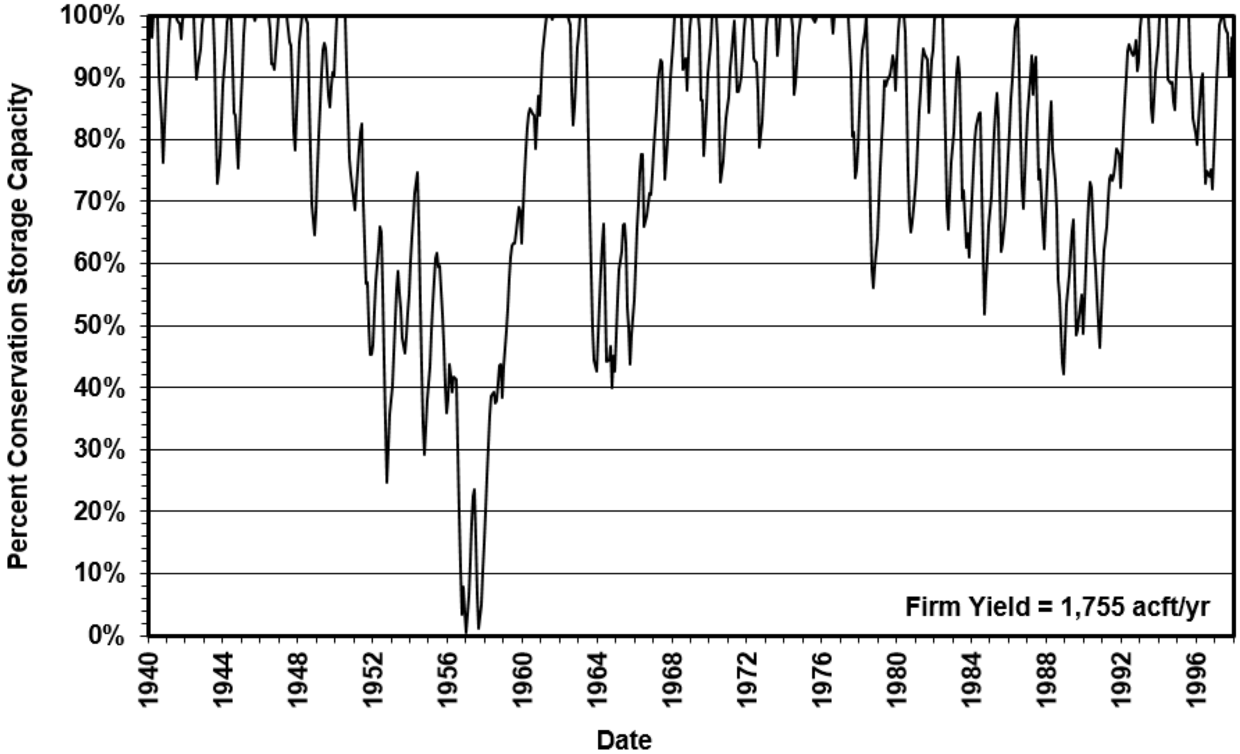


Figure 4.5-5. Storage Frequency at Firm Yield

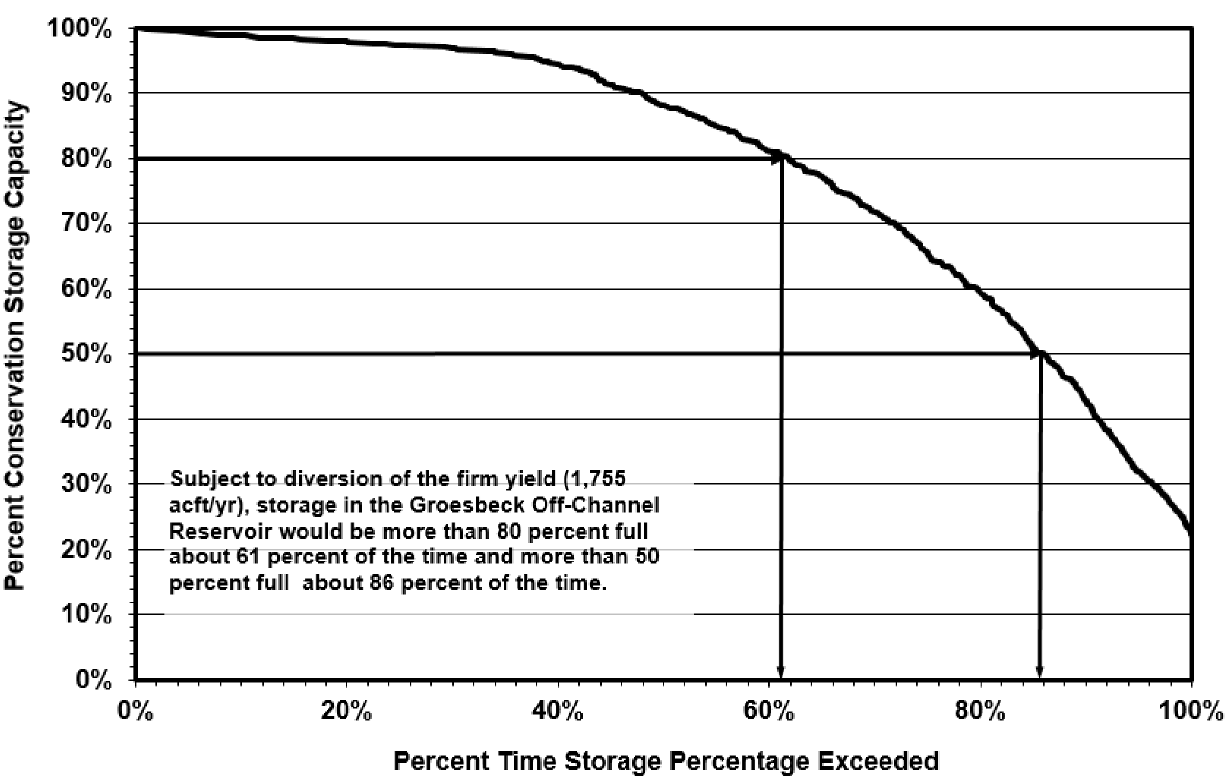


Figure 4.5-6. Navasota River Diversion - Median Streamflow Comparison

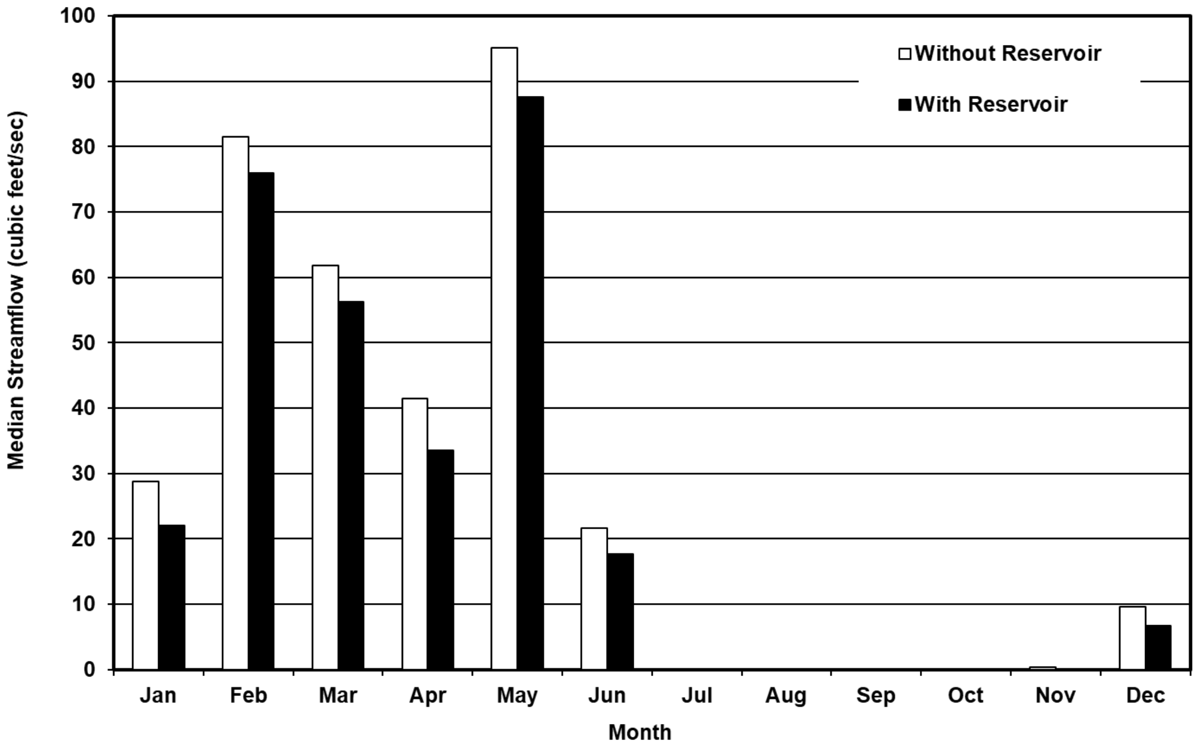
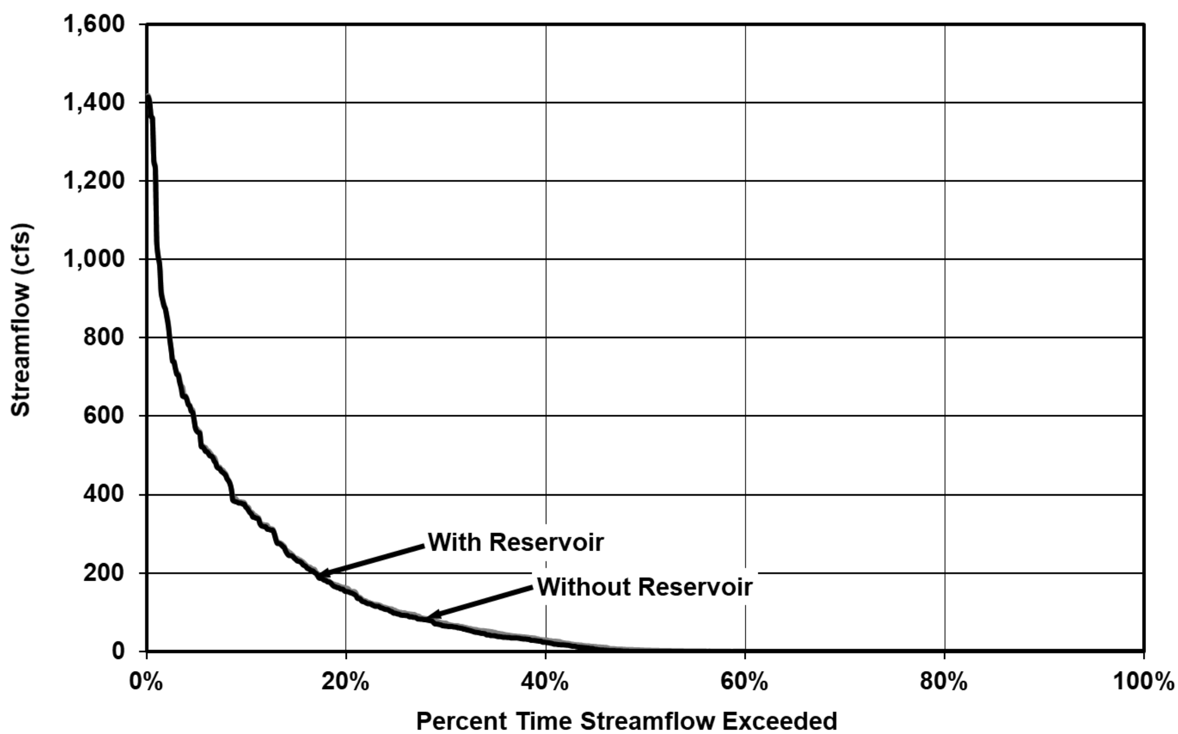


Figure 4.5-7. Navasota River Diversion- Streamflow Frequency Comparison



4.5.3 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 4.5-1. 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 0.015 cfs without the project and zero cfs with the project.

Table 4.5-1. Median Monthly Streamflow: Navasota River Diversion Site

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	28.82	21.98	6.84	24%
February	81.53	75.97	5.56	7%
March	61.77	56.22	5.55	9%
April	41.51	33.57	7.94	19%
May	95.16	87.54	7.62	8%
June	21.61	17.69	3.92	18%
July	0.04	0.00	0.04	100%
August	0.02	0.00	0.02	100%
September	0.03	0.00	0.03	100%
October	0.11	0.00	0.11	100%

Table 4.5-1. Median Monthly Streamflow: Navasota River Diversion Site

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
November	0.30	0.00	0.30	100%
December	9.63	6.64	2.98	31%

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

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD frequently updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Limestone County can be found at https://tpwd.texas.gov/gis/rtest/.

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.

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

[6] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, 04/18/2019.

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

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 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).

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[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.

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.

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.

4.5.4 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 10.2 MGD;
- 3,500 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 4.5-2. The proposed Groesbeck Off-Channel Reservoir project would cost approximately $23.6 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 $1,853,000. This includes annual debt service, operation and maintenance, and pumping energy costs.

Table 4.5-2. 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)	$4,821,000
Intake Pump Stations (10.2 MGD & 3 MGD)	$10,103,000
Transmission Pipeline (24 in dia., 1 miles; 12 in dia., 0.7 miles)	$840,000
TOTAL COST OF FACILITIES	**$15,764,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$5,475,000
Environmental & Archaeology Studies and Mitigation	$561,000
Land Acquisition and Surveying (164 acres)	$568,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$1,231,000
TOTAL COST OF PROJECT	**$23,599,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$1,103,000
Reservoir Debt Service (3.5 percent, 40 years)	$371,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$8,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$253,000
Dam and Reservoir (1.5% of Cost of Facilities)	$72,000
Pumping Energy Costs (0.08 $/kW-hr)	$46,000
TOTAL ANNUAL COST	**$1,853,000**
Available Project Yield (acft/yr)	1,755
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	$1,056
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	$3.24

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.

Table 4.5-3. 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;
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.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; and

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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4.6 Hamilton County Off-Channel Reservoir

4.6.1 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 4.6-1. The proposed OCR will be located on the South Fork of Neils Creek and will contain approximately 49,849 acft of storage and inundate 1,374 acres at the conservation pool elevation of 1,080 ft-msl. The OCR would impound available streamflow diverted from the Leon River. For the project to be economically feasible, an agreement with the Brazos River Authority is required to subordinate water rights associated with Lake Belton to the Leon River diversions. Without the subordination agreement, the unappropriated flows available for diversion would not be sufficient to maintain adequate water levels in the proposed reservoir. Currently, BRA indicates that no subordination agreement is likely to be possible.

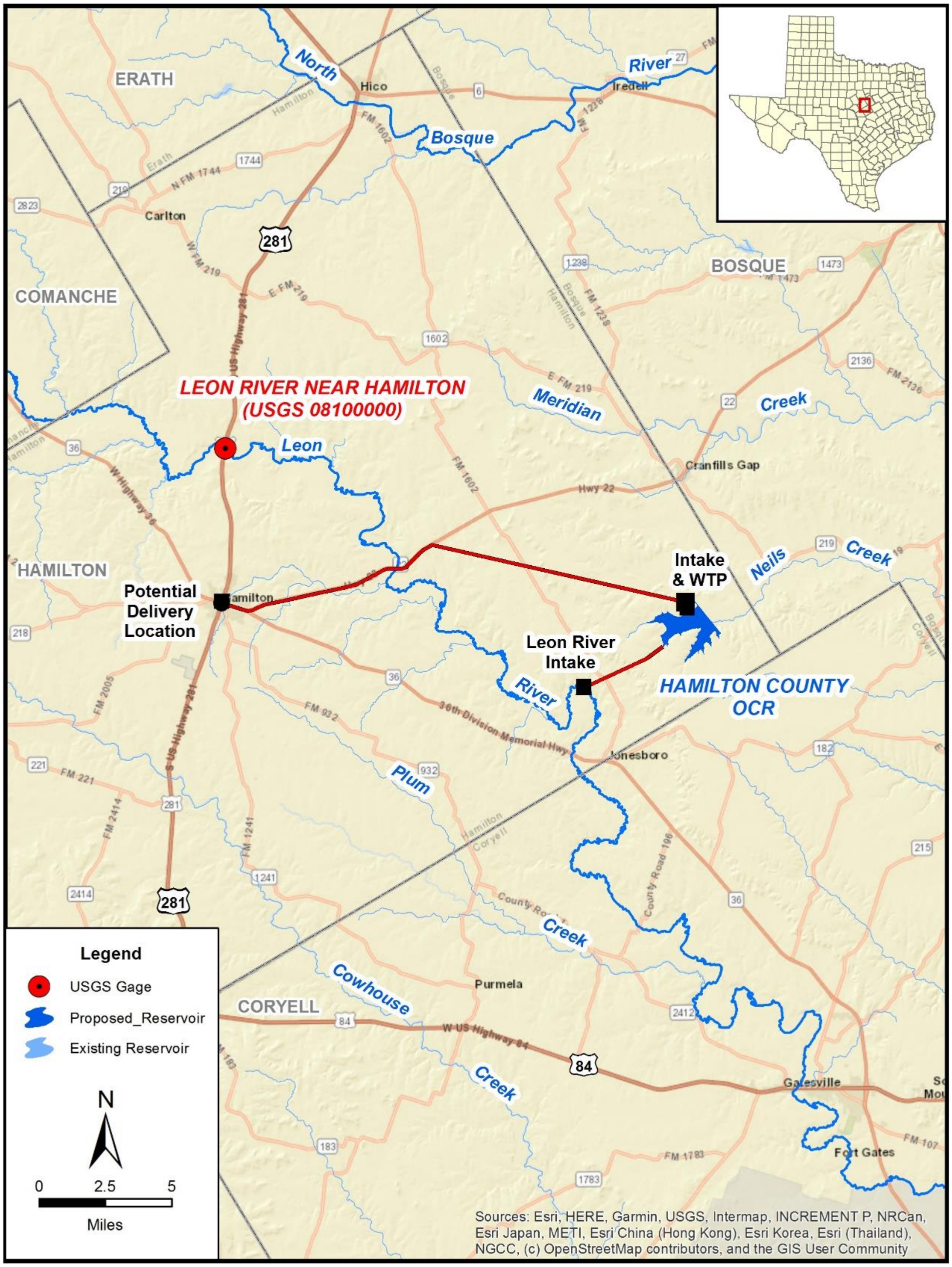
Raw water supplies from the project would be treated at a new water treatment facility located next to the OCR. The treated supplies would then be delivered to customers within Hamilton County to meet County-Other needs. Specific customers have not yet been identified; therefore, the treated water is assumed to be delivered to the City of Hamilton, located near the center of the county.

4.6.2 Available Yield

Water potentially available for impoundment in the proposed Hamilton County OCR is 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 OCR was modeled such that no streamflow contributing from its own drainage area is impounded. 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 a subordination agreement regarding Lake Belton and TCEQ environmental flow standards.

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 4.6-1. 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 4.6-2 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 4.6-1. Hamilton County Off-Channel Reservoir



Document Path: \\dalctxsrv01\Texas_GIS_Projects\10029705_036_Brazos_G_2021_Plan\Map_Docs\MXDs\Reservoir_Strategy\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 1,750 acft/yr. Figure 4.6-3 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 4.6-4 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 4.6-5 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 12,372 acft/yr.

Figure 4.6-6 and Figure 4.6-7 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 streamflow from implementing the project would occur in May with a reduction of 15 cfs or 6 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 and in some months the median streamflow increases with the project. This is a result of Lake Proctor making additional releases upstream as part of the BRA system operations to compensate for the impact to Lake Belton from the subordination agreement.

Figure 4.6-2. Daily Streamflow at Leon River Diversion Site

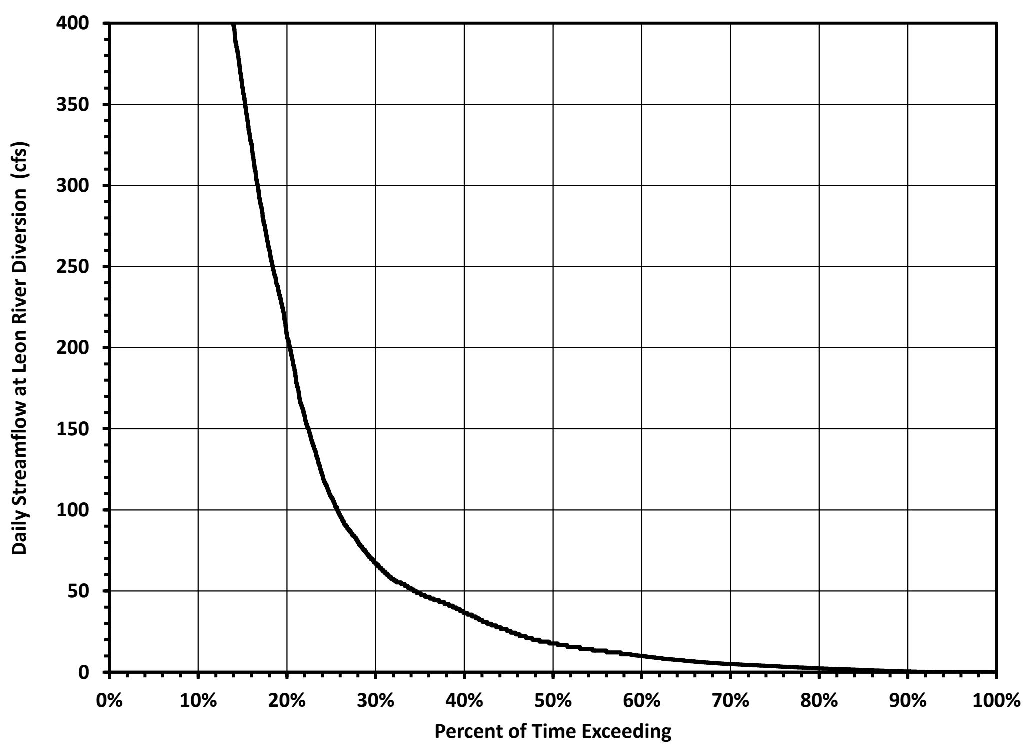


Figure 4.6-3. Hamilton County Reservoir Storage Trace

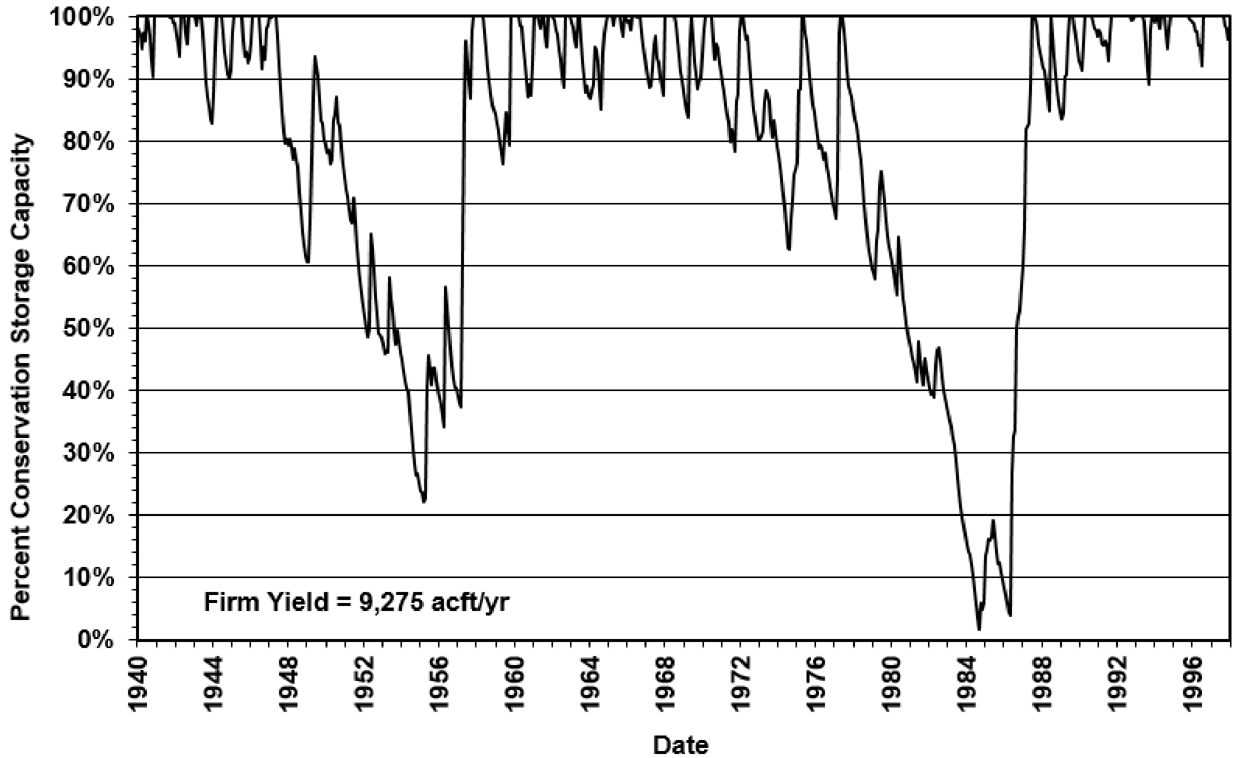


Figure 4.6-4. Hamilton County Reservoir Storage Frequency

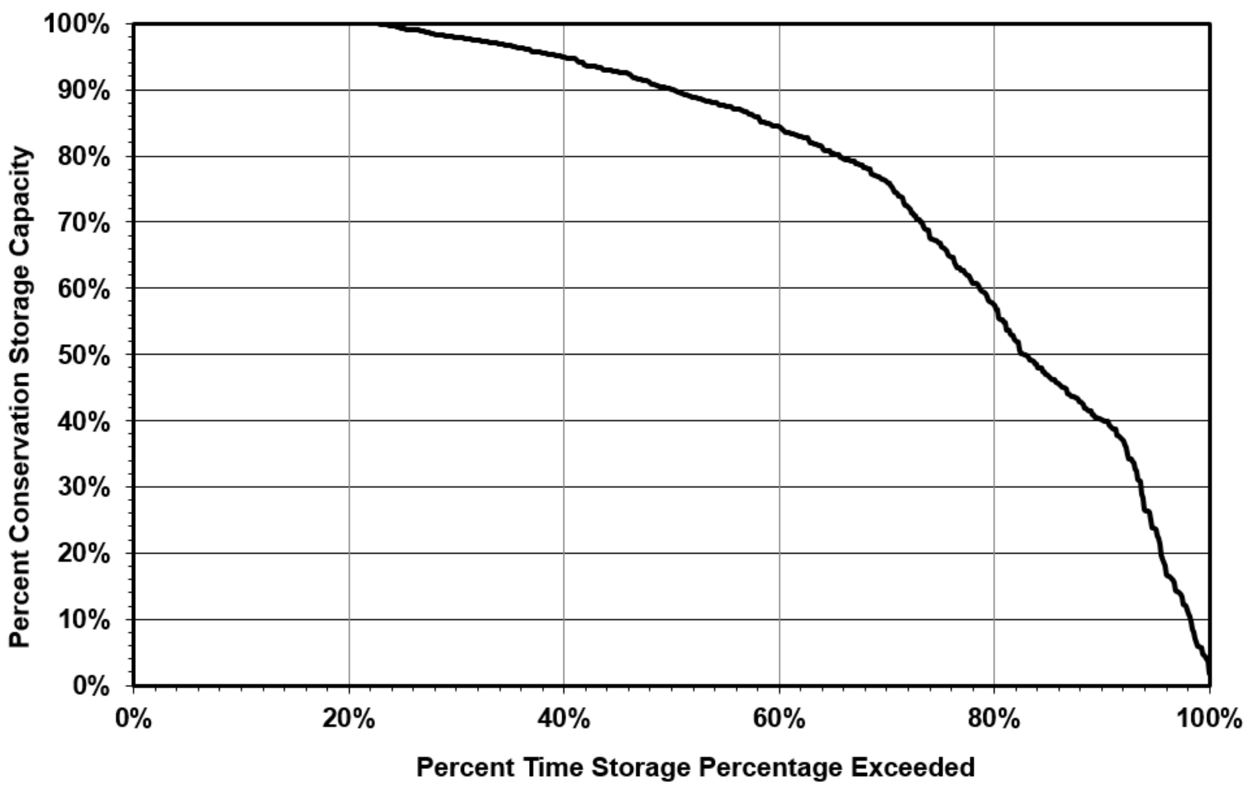


Figure 4.6-5. Annual Diversions from Leon River

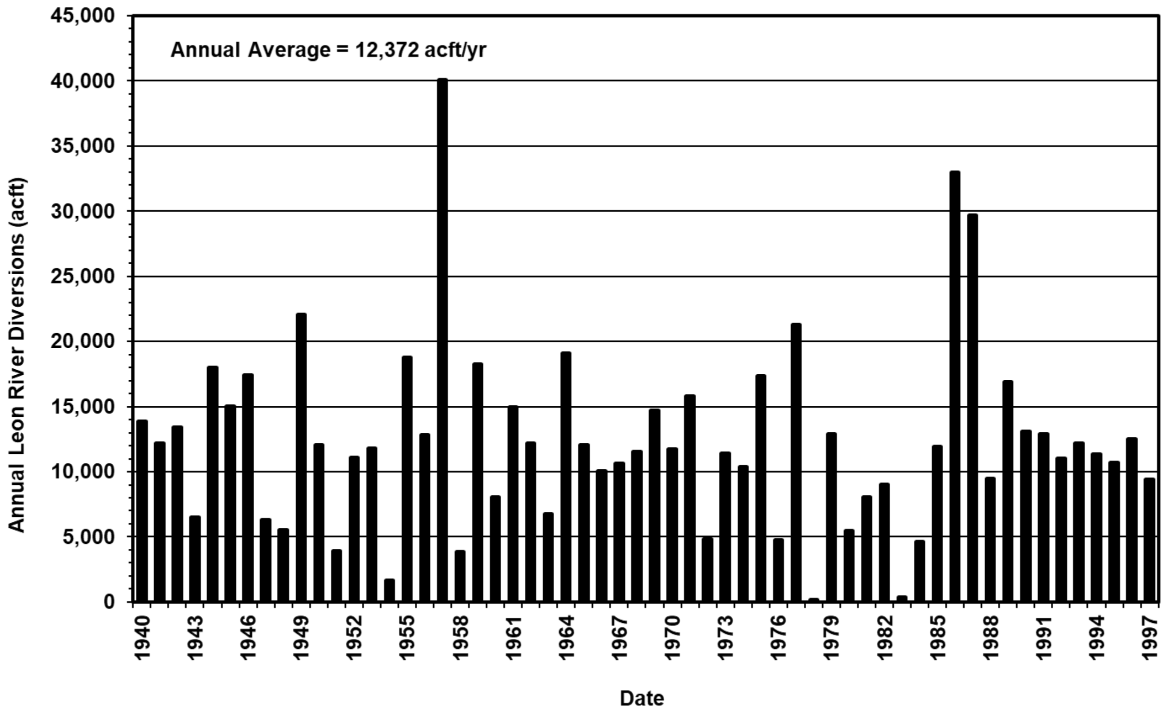


Figure 4.6-6. Leon River Simulated Monthly Median Streamflow with and without Diversion

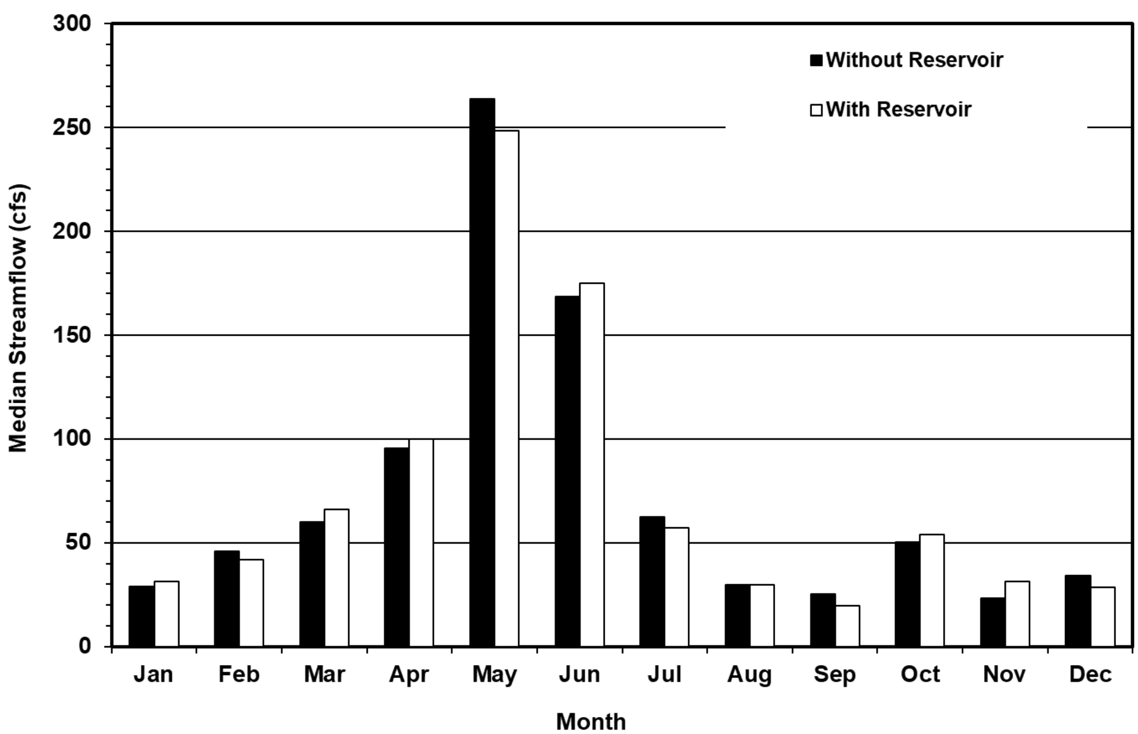
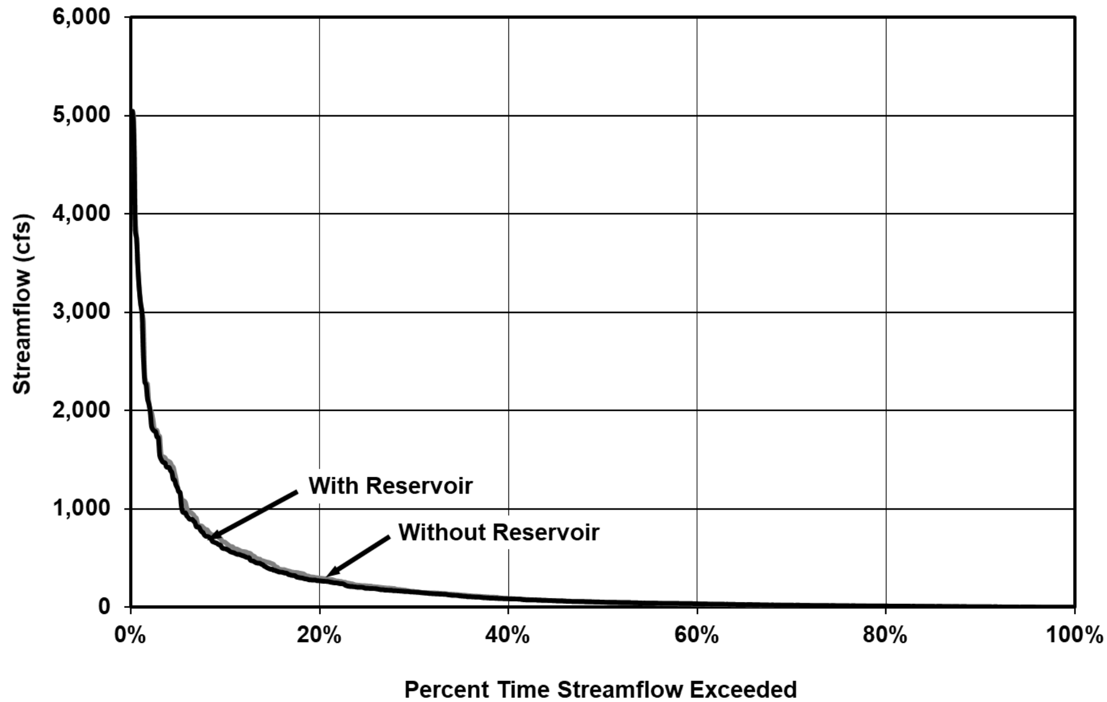


Figure 4.6-7. Leon River Simulated Streamflow Frequency with and without Diversion



4.6.3 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

[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

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Hamilton County can be found at https://tpwd.texas.gov/gis/rtest/.

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 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.

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

[7] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, 06/06/2019.

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 24-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 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

[8] Texas Parks and Wildlife. Ecological Mapping Sytem GIS layer. Accessed at http://www.tpwd.state.tx.us/gis/data/ 06/06/2019.

[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.

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.

Agricultural Impacts

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

4.6.4 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; and
- 18-mile, 24-in treated water pipeline to County-Other distribution lines.

A summary of the total project cost in September 2018 dollars is presented in Table 4.6-1. The proposed Hamilton Creek OCR project would cost approximately $248.3 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 $29.4 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 $3,170 per acft or $9.73 per 1,000 gallons.

Table 4.6-1. 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)	$17,279,000
Leon River Channel Dam & Intake Pump Station (129 MGD)	$52,628,000
Leon River Diversion Pipeline (72 in dia., 3 miles)	$9,961,000
OCR Intake Pump Station (8.7 MGD)	$19,523,000
OCR Transmission Pipeline (24 in dia., 18 miles)	$26,445,000
Water Treatment Plant (8.7 MGD)	$37,256,000
TOTAL COST OF FACILITIES	**$163,092,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$55,262,000
Environmental & Archaeology Studies and Mitigation	$5,262,000
Land Acquisition and Surveying (1,664 acres)	$5,767,000
Interest During Construction (3% for 3 years with a 0.5% ROI)	$18,925,000
TOTAL COST OF PROJECT	**$248,308,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$10,342,000
Reservoir Debt Service (3.5 percent, 40 years)	$1,885,000
Operation and Maintenance	
Pipelines, Wells, and Storage Tanks (1% of Cost of Facilities)	$364,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$1,804,000
Dam and Reservoir (1.5% of Cost of Facilities)	$259,000
Water Treatment Plant (2.5% of Cost of Facilities)	$2,635,000
Pumping Energy Costs (0.08 $/kW-hr)	$7,429,000
Purchase of Water (3,590 acft/yr @ 76.5 $/acft)	$275,000
TOTAL ANNUAL COST	**$29,406,000**
Available Project Yield (acft/yr)	9,275
Annual cost of Water ($ per acft)	$3,170
Annual cost of Water ($ per 1,000 gallons)	$9.73

4.6.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.6-2 and the option meets each criterion.

Table 4.6-2. 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

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;
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction; 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.

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4.7 NCTMWA Lake Creek Reservoir (formerly Millers Creek Off-Channel Reservoir)

4.7.1 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 Figure 4.7-1. The proposed Lake Creek diversion site for the Millers Creek Augmentation WMS is shown in Figure 4.7-1 for comparison purposes.

The proposed NCTMWA Lake Creek Reservoir, also known as the Millers Creek Off-Channel Reservoir, will contain approximately 58,560 acft of conservation storage and inundate 2,866 acres at the conservation pool elevation 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 the BRA regarding Possum Kingdom Reservoir would allow for these inflows to be impounded by the NCTMWA Lake Creek Reservoir, thus significantly increasing the yield of the project. Currently, BRA indicates that no subordination agreement is likely to be possible.

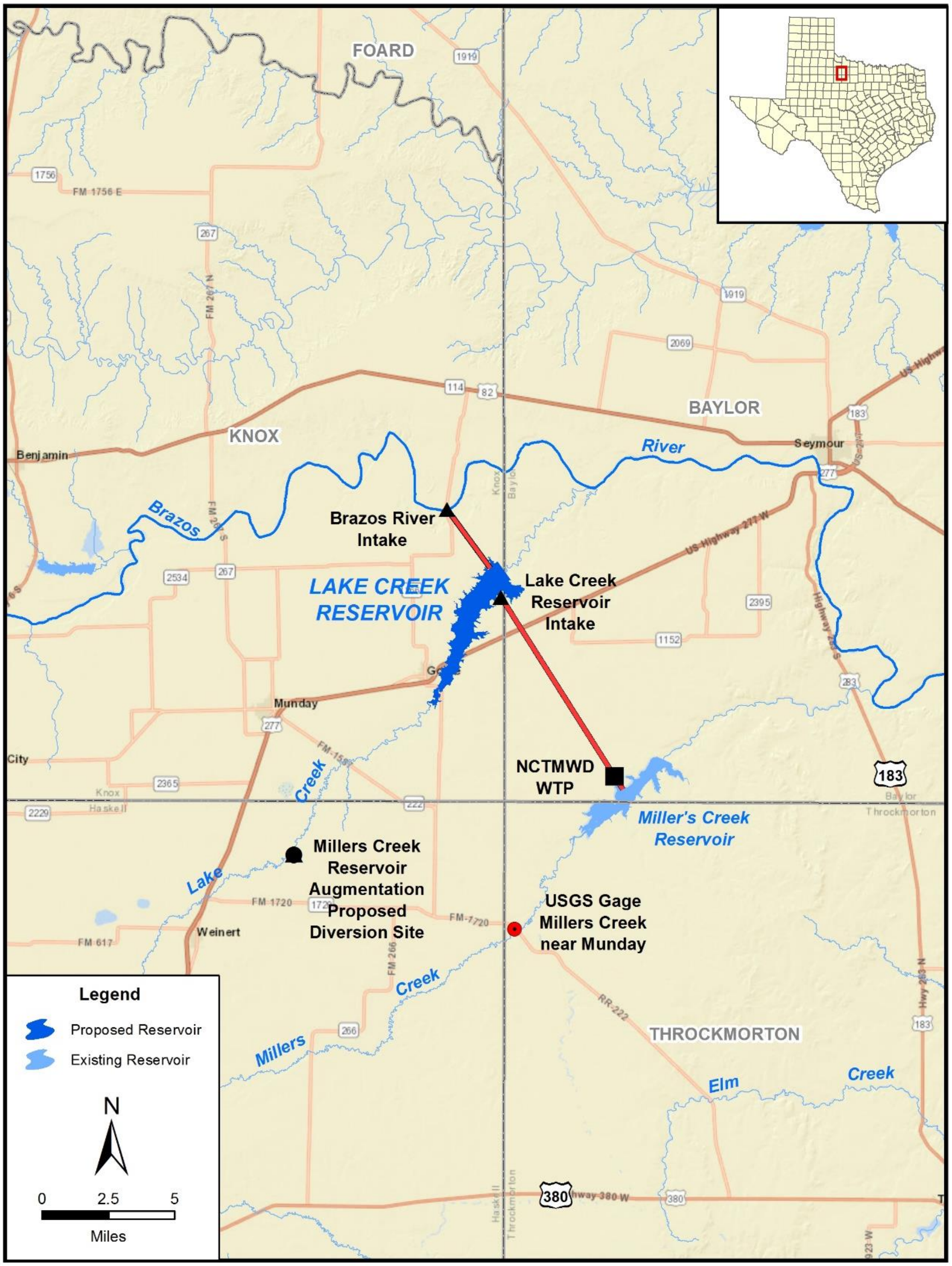
Diversions from the Brazos River would be transported through a 3-mile, 120-in pipeline to the reservoir for impoundment. Due to water quality concerns in the main stem of the Brazos River, diversions would only occur during flood flow periods. However, a significant portion of the available streamflow during high flow periods is now appropriated by BRA under the System Operations permit. As a result, a contract with BRA for non-firm system water during these high flow periods is necessary for adequate supplies to be diverted from the Brazos River for impoundment in NCTMWA Lake Creek Reservoir.

Stored water in the reservoir would be transported to the NCTMWA WTP or Millers Creek Reservoir via an 8-mile, 30-in pipeline. NCTMWA would have the operational flexibility to treat the supplies or discharge the raw water into Millers Creek Reservoir if storage is available. A 12.1 MGD expansion of the WTP would also be required to treat the additional raw water supplied by the project.

4.7.2 Available Yield

Water potentially available for impoundment in the proposed NCTMWA 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

Figure 4.7-1. NCTMWA Lake Creek Reservoir



Document Path: \\dalctxsrv01\Texas_GIS_Projects\10029705_036_Brazos_G_2021_Plan\Map_Docs\MXDs\Reservoir_Strategy\Lake_Creek_Reservoir.mxd

TCEQ environmental flow standards. 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 NCTMWA Lake Creek Reservoir project is 12,900 acft/yr. Figure 4.7-2 provides the individual contributions to the total firm yield from junior reservoir impoundments, the Possum Kingdom subordination and the Brazos River diversions. The project would not provide any firm supplies without the subordination agreement or Brazos River diversions. The Brazos River diversions provide the greatest contribution to the firm yield (8,100 acft/yr) and are required to make the project economically feasible. The subordination agreement would result in a 1,270 acft/yr yield impact to Possum Kingdom Reservoir.

Figure 4.7-3 provides the annual volumes of reservoir impoundments and Brazos River diversion for the model simulation period.

Figure 4.7-2. NCTMWA Lake Creek Reservoir Firm Yield Components

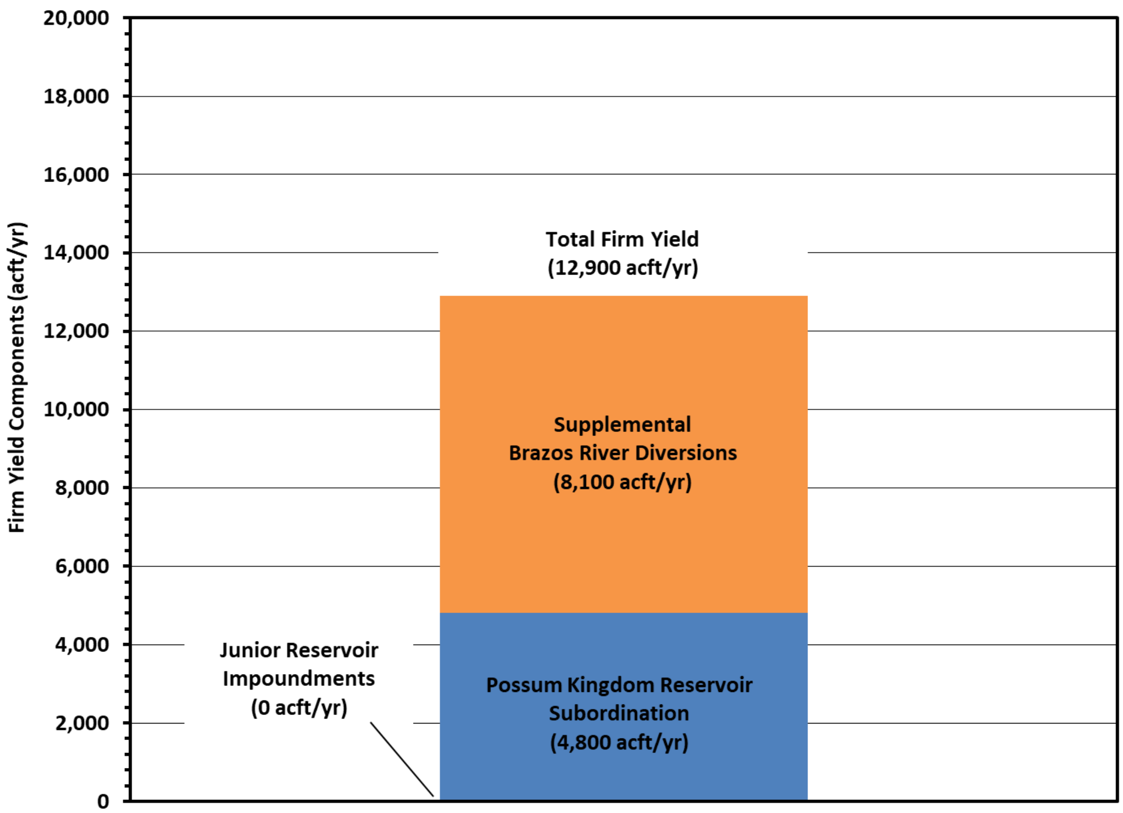


Figure 4.7-3. Annual NCTMWA Lake Creek Impoundments and Brazos River Diversions

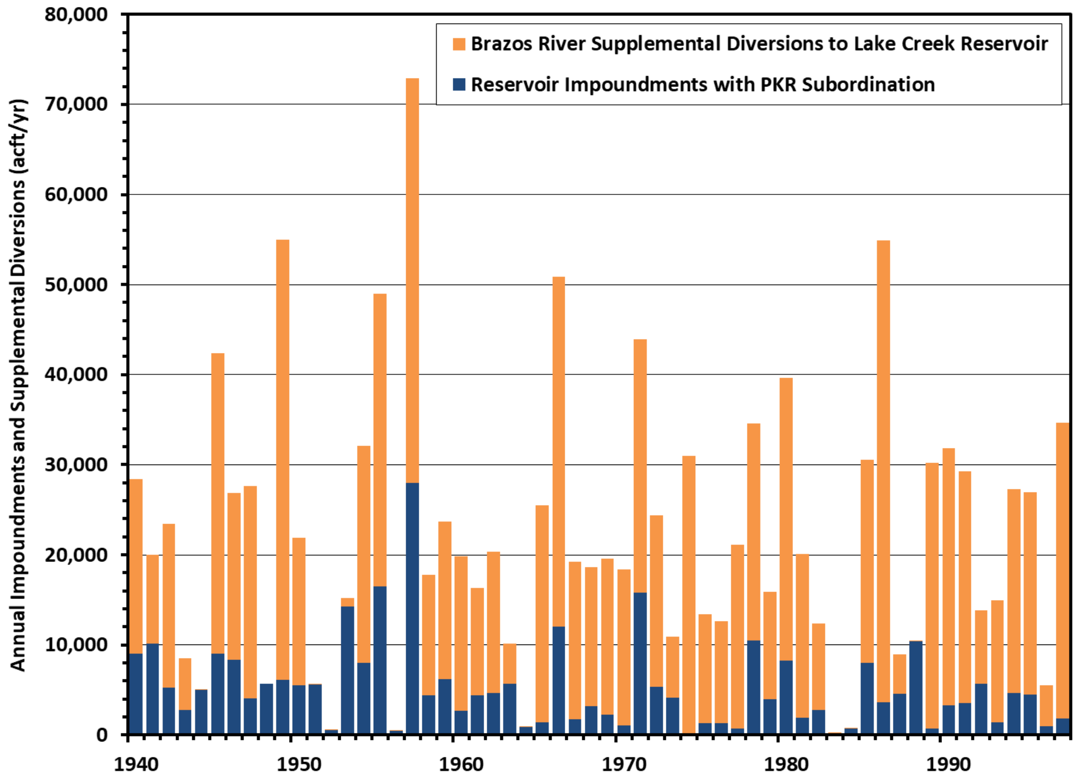


Figure 4.7-4 illustrates the storage trace of NCTMWA Lake Creek Reservoir for the 57-year model simulation period under the firm yield demand of 12,900 acft/yr. Figure 4.7-5 provides a frequency of the storage in NCTMWA Lake Creek Reservoir under the firm yield demand. The storage frequency reveals that the reservoir remains full about 10 percent of the time and over half full approximately 82 percent of the time.

Figure 4.7-6 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 4.7-7 compares the existing Lake Creek streamflow frequency characteristics without the project to simulated streamflow characteristics with NCTMWA 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 4.7-8 and Figure 4.7-9 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 months of May and June when flood flows typically occur the most.

Figure 4.7-4. NCTMWA Lake Creek Reservoir Firm Yield Storage Trace

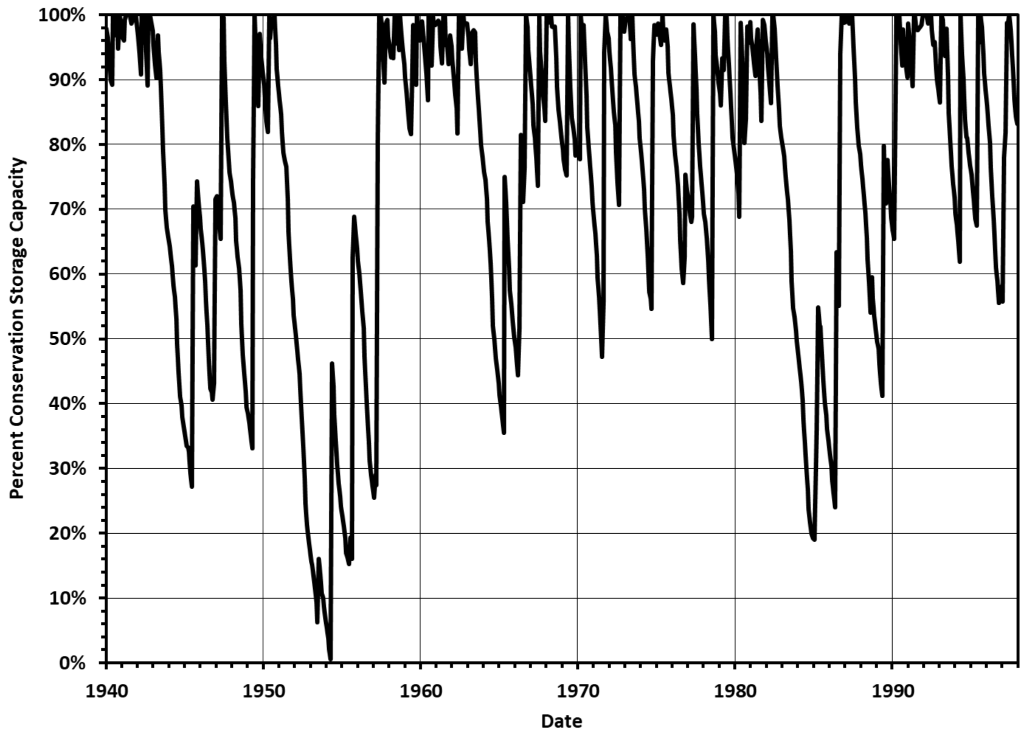


Figure 4.7-5. NCTMWA Lake Creek Reservoir Firm Yield Storage Frequency

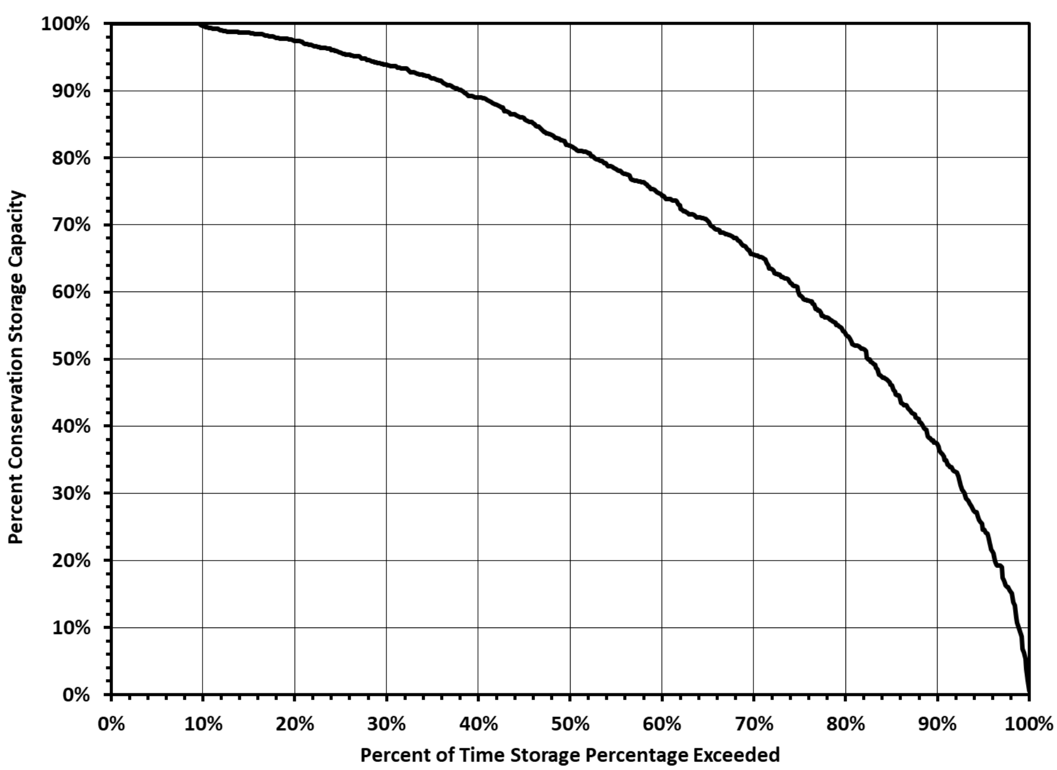


Figure 4.7-6. Lake Creek Median Streamflow Comparison

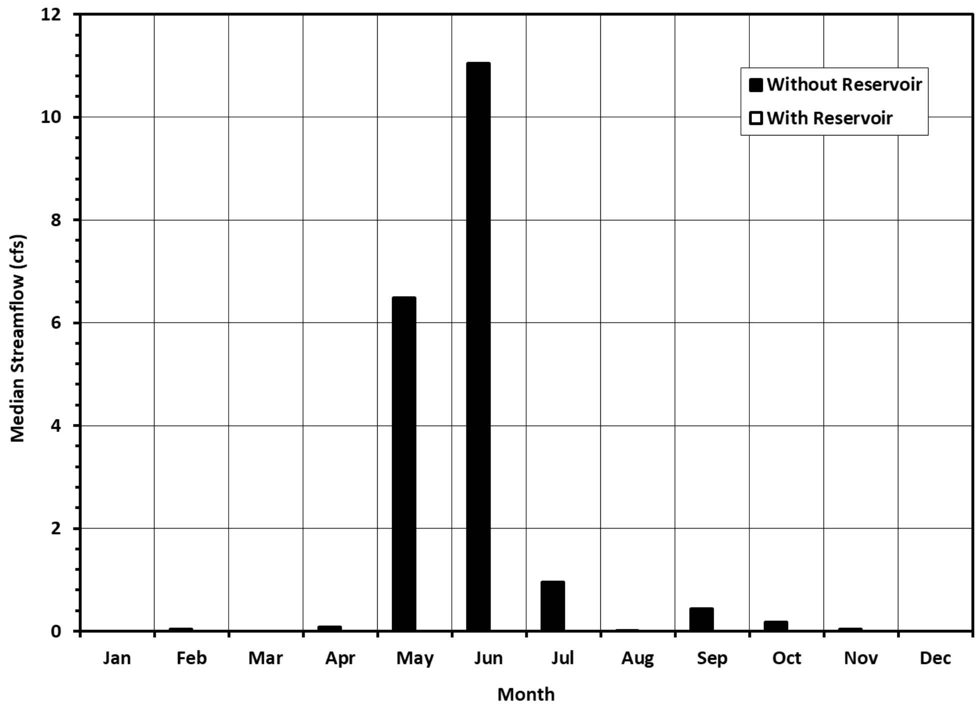


Figure 4.7-7. Lake Creek Streamflow Frequency Comparison

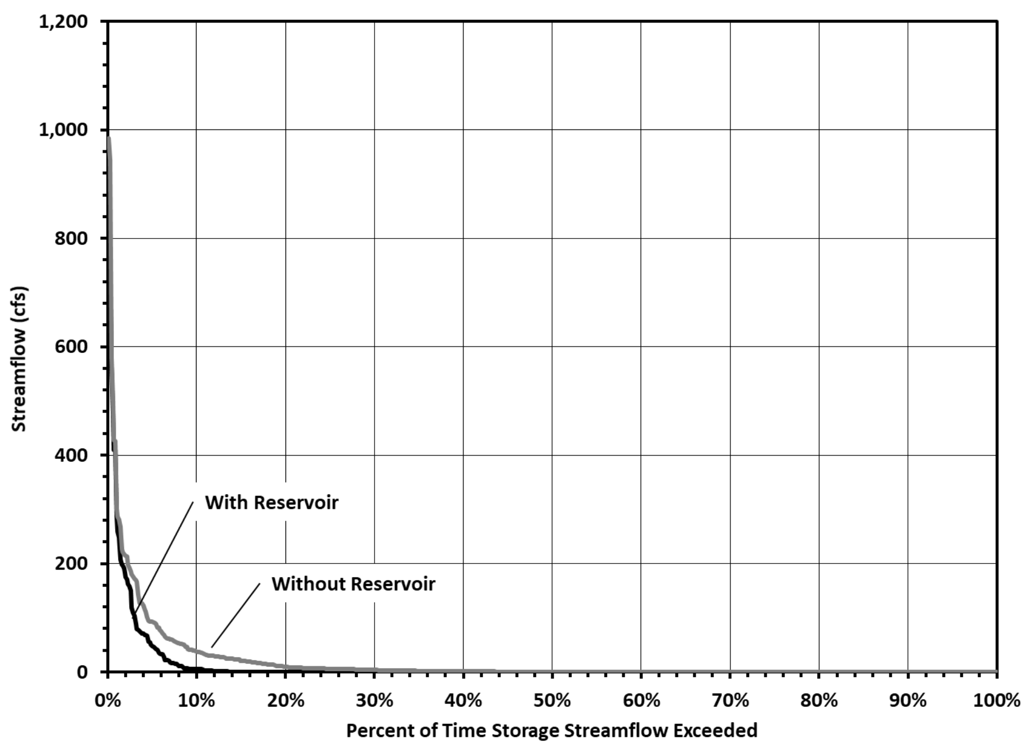


Figure 4.7-8. Brazos River Diversion Median Streamflow Comparison

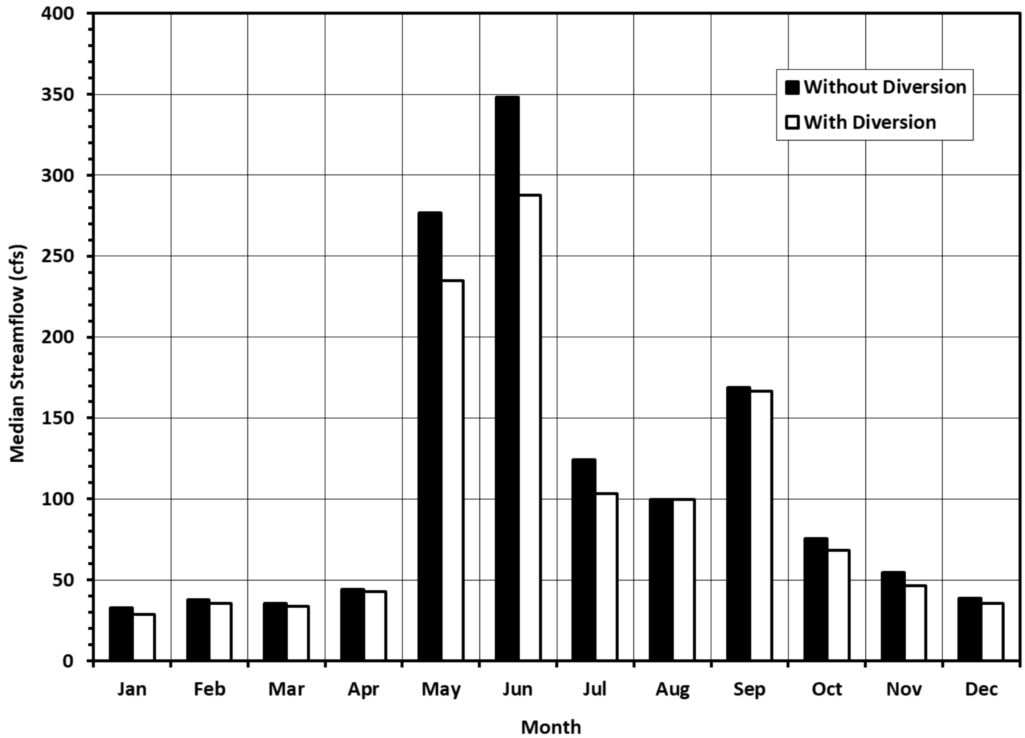
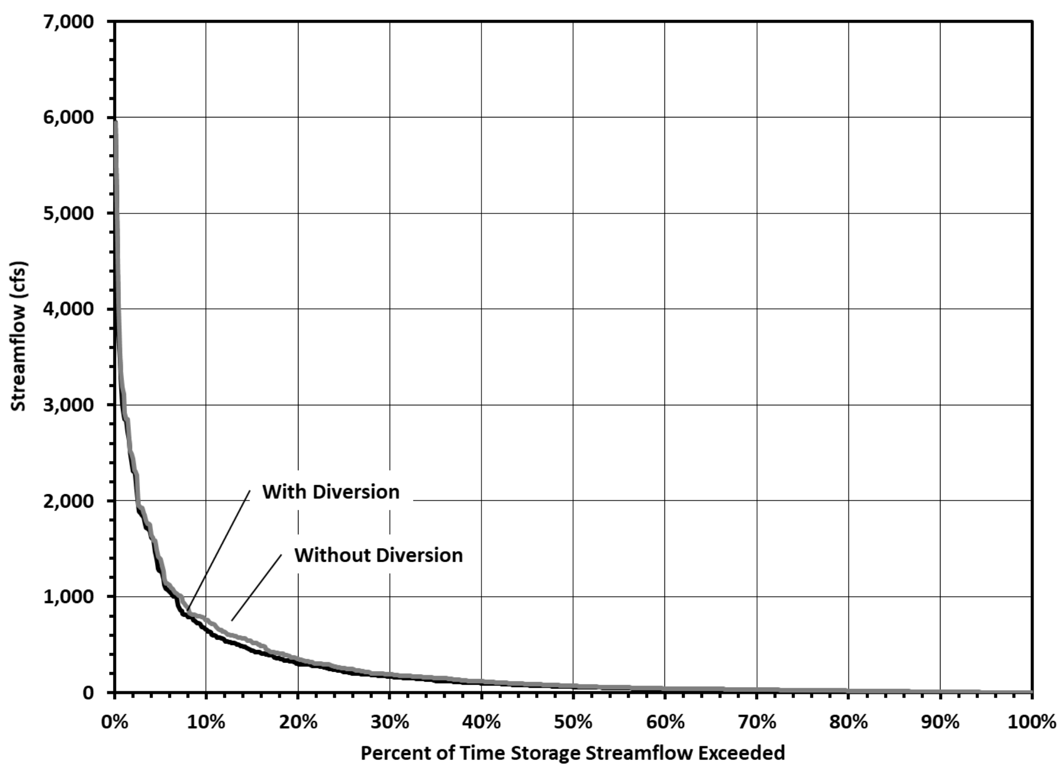


Figure 4.7-9. Brazos River Diversion Streamflow Frequency Comparison



4.7.3 Environmental Issues

The proposed NCTMWA 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 NCTMWA Lake Creek Reservoir to provide supplemental diversions to the reservoir, and 3) an intake and pipeline from NCTMWA 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*).

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Baylor and Knox counties can be found at https://tpwd.texas.gov/gis/rtest/.

Two fish species, the sharpnose shiner (*Notropis oxyrhynchus*) and smalleye shiner (*Notropis buccula*) are 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 NCTMWA 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.

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 NCTMWA 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.

4.7.4 Engineering and Costing

In addition to the new reservoir, the potential NCTMWA 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 the NCTMWA Lake Creek Reservoir;
- On-channel dam including spillway, intake tower, and 2,866 acres of land for the reservoir;
- 12.1 MGD intake and pump station at NCTMWA Lake Creek Reservoir;
- 8-mile, 30-in pipeline to NTMWD WTP and Millers Creek Reservoir; and
- 12.1 MGD expansion of the NTMWD WTP.

A summary of the total project cost in September 2018 dollars is presented in Table 4.7-1. The estimated total project cost for the proposed NCTMWA Lake Creek Reservoir project is $259.0 million. This cost includes land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $21.4 million. This includes annual debt service, operation and maintenance, pumping energy costs, and purchase of firm and non-firm water from BRA. The off-channel reservoir project will be able to provide treated water at a unit cost of $1,657 per acft or $5.08 per 1,000 gallons.

Table 4.7-1. Cost Estimate for NCTMWA Lake Creek Reservoir

Item	Estimated Costs for Facilities
Dam and Reservoir	$54,091,000
Brazos River Intake Pump Station & Channel Dam (258 MGD)	$52,038,000
Brazos River Transmission Pipeline (120 in dia., 3 miles)	$19,686,000
Reservoir Intake Pump Station (12.1 MGD)	$8,050,000
Transmission Pipeline (30 in dia., 8 miles)	$9,190,000
Water Treatment Plant Expansion (12.1 MGD)	$27,167,000
TOTAL COST OF FACILITIES	**$170,222,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$58,134,000
Environmental & Archaeological Studies and Mitigation	$5,449,000
Land Acquisition and Surveying (3,012 acres)	$5,456,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$19,740,000
TOTAL COST OF PROJECT	**$259,001,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$11,866,000
Reservoir Debt Service (3.5 percent, 40 years)	$4,231,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$289,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$1,497,000
Dam and Reservoir (1.5% of Cost of Facilities)	$814,000
Water Treatment Plant	$1,902,000
Pumping Energy Costs ($0.08 kwh)	$434,000
Purchase of Firm Water (1,270 acft/yr @ $76.50 /acft)	$97,000
Purchase of Non-Firm Water (3,235 acft/yr @ $76.50/acft)	$247,000
Total Annual Cost	**$21,377,000**
Available Project Yield (acft/yr)	**12,900**
Annual Cost of Water ($ per acft)	**$1,657**
Annual Cost of Water ($ per 1,000 gallons)	**$5.08**

4.7.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.7-2, and the option meets each criterion.

Table 4.7-2. Comparison of NCTMWA 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;
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.
- 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; and

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.

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4.8 Red River Off-Channel Reservoir

4.8.1 Description of Option

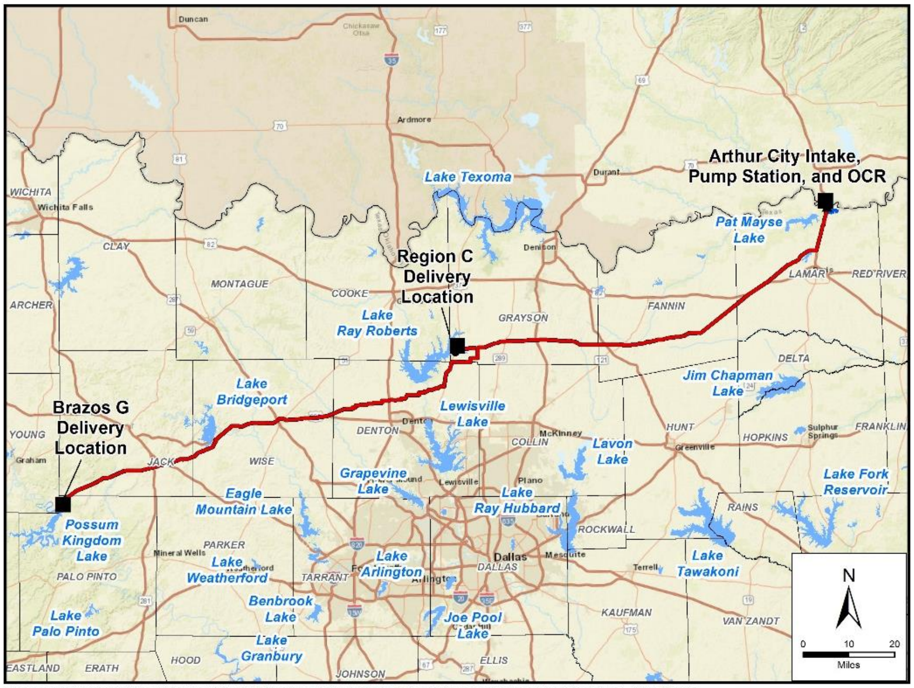
The Red River Off-Channel Reservoir (OCR) strategy was originally evaluated in the 2014 Dallas Long Range Water Supply Plan (LRWSP) as an alternative strategy. The project has the potential to generate a significant amount of supply for water users in the Region C and Brazos G planning areas. The LRWSP estimates the project can produce 310,000 acft/yr of firm supply on an annual basis with 114,000 acft/yr of this supply assumed to be dedicated to the City of Dallas in Region C. The remaining 196,000 acft/yr is assumed to be available for delivery to Possum Kingdom Reservoir for use in Brazos G.

The project includes a 750 cfs intake and pump station to divert and transmit water from the Red River near Arthur City through approximately 2 miles of 132-in pipeline to three OCRs in series. The first OCR consists of a 2,500 acft basin for initial sediment settling and subsequent removal. The next OCR would consist of a 5,300 acft basin for water quality improvement and additional sediment removal. Finally, a third OCR would consist of a 32,000 acft storage basin to allow for extended pumping during those times when flow in the Red River is extremely low or water quality is impaired.

A 535 cfs intake and pump station would then deliver supplies from the final OCR to the Region C drop-off location in Lake Ray Roberts through a 144-inch, 100-mile transmission pipeline. Delivery of the remaining supplies to Possum Kingdom Reservoir would require a 120-inch, 107-mile transmission pipeline. The delivery system is designed with a 1.25 peaking factor to allow for over pumping to compensate for delivery shortages during periods when diversions from the OCR are not available. Facilities required for this strategy are shown in Figure 4.8-1 and Figure 4.8-2 provides further detail of the OCR layout and flow of water through the three OCRs.

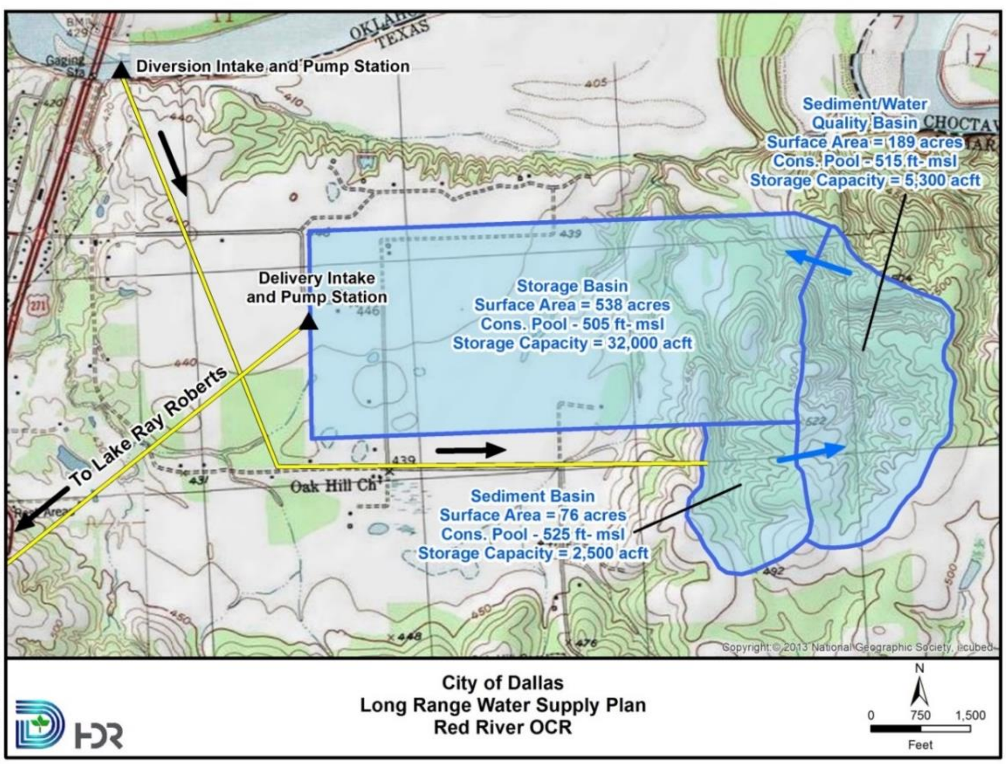
Several key issues would need to be overcome to make the project feasible. These issues include bank stability for the intake structure along the Red River, water quality and sediment control, invasive species, and regulatory and permitting issues considering the Red River Compact.

Figure 4.8-1. Red River Off-Channel Reservoir Pipeline Route



Document Path: \\dalctxsrv01\Texas_GIS_Projects\10029705_036_Brazos_G_2021_Plan\Map_Docs\MXDs\Reservoir_Strategy\Red_River_OCR_nr_Arthur_City.mxd

Figure 4.8-2. Red River Off-Channel Reservoir Project



4.8.2 Available Yield

Water potentially available for diversion and impoundment in the proposed Red River OCR was estimated using the TCEQ Red River WAM Run 3. The TCEQ Red River WAM includes only the Texas portion of streamflows potentially available for diversion from the Red River, utilizes a January 1948 through December 1998 hydrologic period of record, assumes no return flows and permitted storages and diversions for all Texas water rights in the basin. The model computed streamflow available for diversion from the Red River at Arthur City into the OCR without causing increased shortages to existing downstream rights, and subject to the instream flow targets of the Red River Basin Interstate Compact.

TCEQ environmental flow standards have not been adopted in the Red River Basin and because the TCEQ Red River WAM includes only the Texas portion of streamflows potentially available for diversion from the Red River, Consensus Criteria for Environmental Flow Needs (CCEFN) instream flow requirements could not be accurately modeled to consider environmental flow needs. Review of historical streamflows recorded at the Red River at Arthur City gage (USGS 07335500) show daily historical streamflows are greater than the 750 cfs maximum diversion rate of the proposed intake more than 95 percent of the time during the WAM period of record, indicating the project will have limited impact on daily flows in the Red River at the proposed diversion site. Likewise, historical streamflow recorded at the Red River at Index gage (USGS 07337000) show daily historical streamflows are greater than the 750 cfs maximum diversion rate more than 99 percent of the time, indicating diversions would unlikely be limited to comply with the Red River Compact.

Results of the availability analysis indicate the project can produce an annual firm yield of 310,000 acft/yr.Figure 4.8-3 and Figure 4.8-4 provide time series and frequency plots of storage of the 32,000 acft OCR. For the yield analysis, the storage capacities of the two smaller OCR sedimentation basins were not considered. The storage frequency indicates that the 32,000 acft OCR would remain full almost 90 percent of the time. During the WAM simulation, the OCR storage is emptied in several months. However, since the delivery pump station capacity is sized with a 1.25 peaking factor, shortages during these months were overcome with the additional delivery capacity in the following months to keep the annual reliability at 100 percent.

Figure 4.8-5 presents the changes in the Red River at Arthur City monthly median streamflows caused by impoundments in the reservoir considering flows passed through for downstream senior water rights and environmental needs in accordance with TCEQ environmental flow requirements. Figure 4.8-6 compares the existing Red River at Arthur City streamflow frequency characteristics for the full period of the analysis with and without the project.

Figure 4.8-3. Red River Off-Channel Reservoir Firm Yield Storage Trace

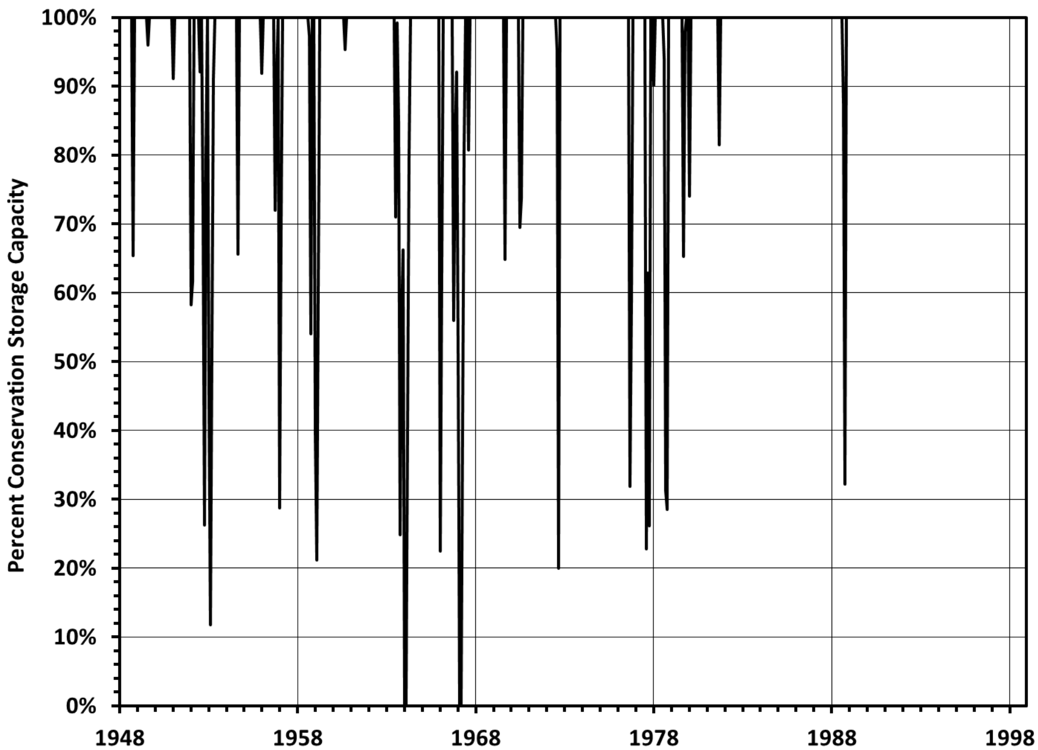


Figure 4.8-4. Red River Off-Channel Reservoir Firm Yield Storage Frequency

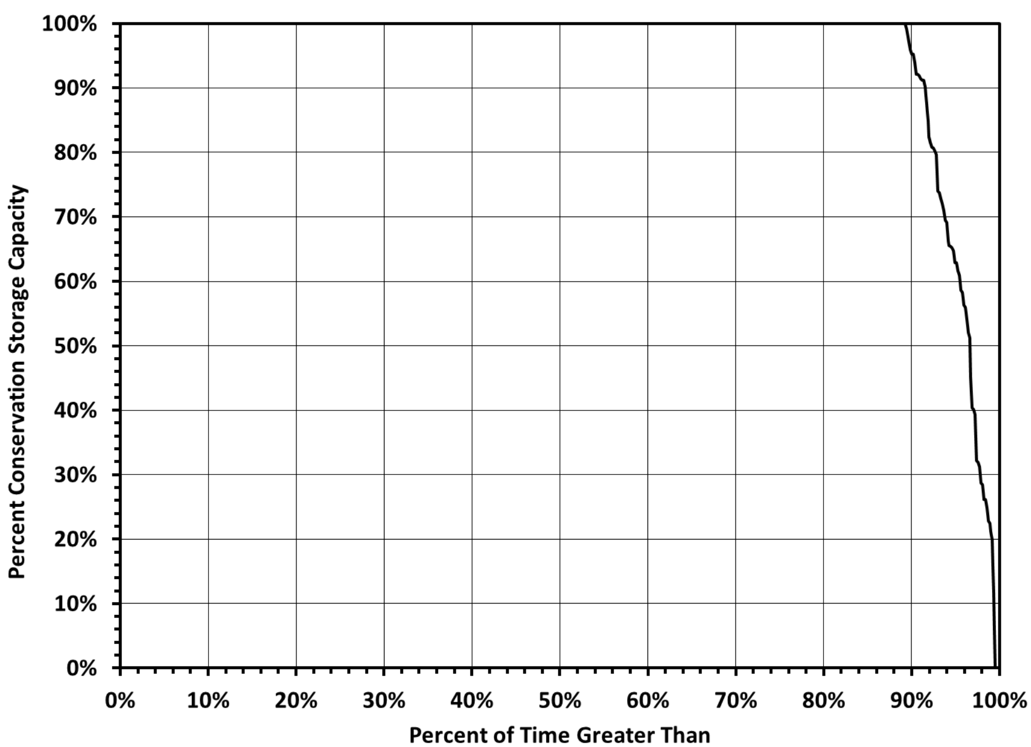


Figure 4.8-5. Red River at Arthur City Median Streamflow Comparison

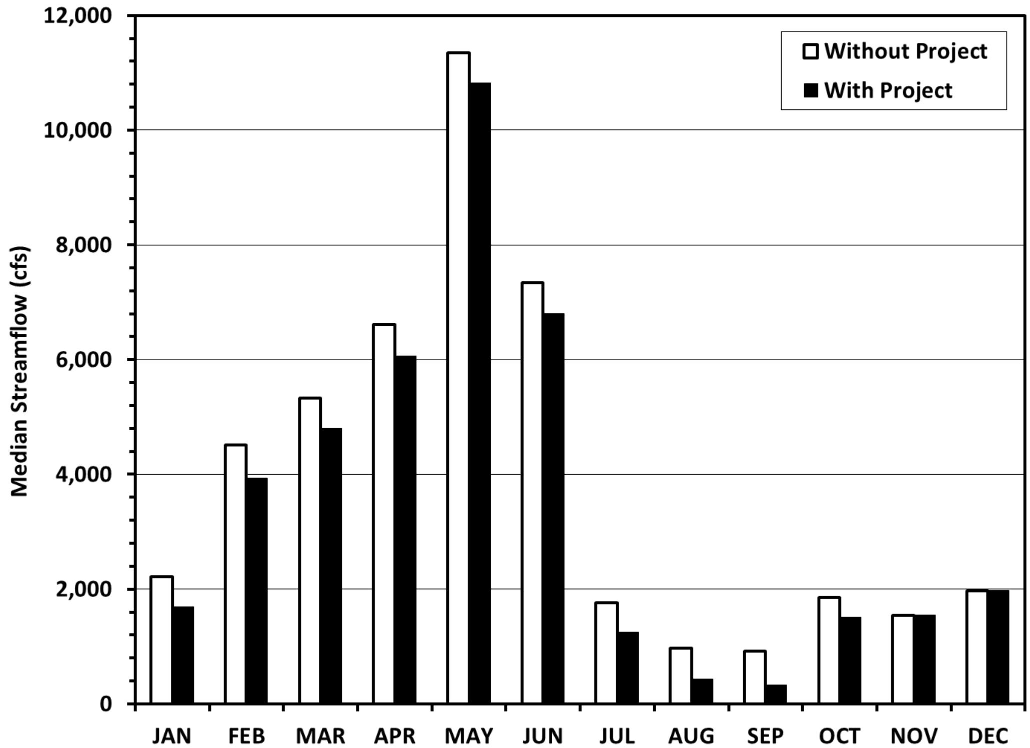
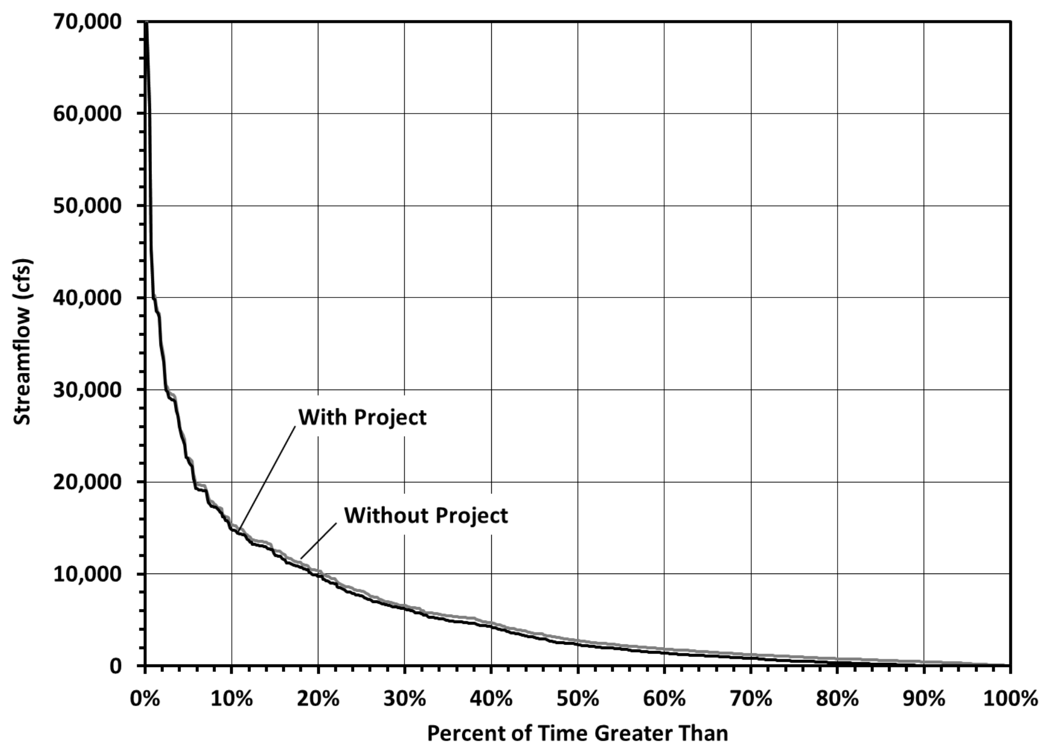


Figure 4.8-6. Red River at Arthur City Streamflow Frequency Comparison



Diversion from the Red River would also need to comply with all provisions included in the Red River Compact[1]. The diversion at Arthur City would be located in Reach II, Subbasin 5 of the Red River Compact. Under Section 5.05 of the Compact, the main stem of the Red River within Reach II (i.e. subbasin 5) is defined as "that portion of the Red River, together with its tributaries, from Denison Dam down to the Arkansas-Louisiana State boundary, excluding all tributaries included in the other four subbasins of Reach II."

Water availability analyses performed as part of the LRWSP estimate the amount of available flow in accordance with the Compact is about 2 million acft/yr less than the average annual available flow calculated in the TCEQ Red River WAM. The discrepancy in available flow is a result of the TCEQ Red River WAM including only a portion of the Red River Compact stipulations and not including inflows into the main stem of the Red River from Oklahoma tributaries or Oklahoma water rights and reservoirs. In addition, the TCEQ WAM and gaged flows used to estimate water availability in the LRWSP do not have similar periods of record. The gaged flows at the Arkansas-Louisiana boundary were only available after the WAM period of record and contain several drought periods including the drought of 2011 – 2015.

As a result of the analyses performed as part of the LRWSP, it is assumed that provision in the Compact will not significantly reduce the yield of project.

4.8.3 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 2021 Brazos G Plan.

Existing Environment

The proposed project occurs within the Post Oak Savannah, Blackland Prairie, and Crosstimbers physiographic regions of Texas and is within the Texan biotic province[2]. The project components are within areas defined as crops, Bluestem Grassland, Live Oak – Ashe Juniper Parks, Post Oak Parks/Woods, and Post Oak Woods/Forest vegetation types[3]. Crops include cultivated cover or row crops providing food or fiber and also may include grassland associated with crop rotations. Ecological Mapping Systems of Texas (EMST) data, more detailed vegetation data recently produced by the Texas Parks and Wildlife Department (TPWD)[4], show the area containing barren land and disturbed/tame grasslands.

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[1] http://www.statutes.legis.state.tx.us/Docs/WA/htm/WA.46.htm

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

[3] McMahan, C.A., R.G. Frye, and K.L. Brown, 1984. The Vegetation Types of Texas. Accessed online https://tpwd.texas.gov/publications/pwdpubs/pwd_bn_w7000_0120/ March 22, 2019.

[4] TPWD, Ecological Mapping Systems of Texas, High Plains. Accessible to download online https://tpwd.texas.gov/gis/programs/landscape-ecology/by-ecoregion-vector

Potential Impacts

Aquatic Environments including Bays & Estuaries

The proposed pipeline spans seven counties and crosses areas of 100-year floodplain (Zones A and AE) associated with several rivers and streams. The National Wetland Inventory (NWI) maps were reviewed and the proposed pipeline has the potential to cross numerous creeks, streams, and wetland areas. Impacts to waters of the U.S. should be minimized to the extent practical during project design. Impacts to waters of the U.S. would need to be permitted through the U.S. Army Corps of Engineers. Several surface waters were identified on the TCEQ Surface Water Quality Viewer within the proposed project area, or within 5 miles. According to the draft 2020 Texas Integrated Report – Texas 303(d) List[1], the following surface water segments located within five miles of the proposed project pipelines were fully supporting of their uses and were not impaired: Little Elm Creek (0823A), Sister Grove Creek (0821B), North Sulpher River (0305), Rowdy Creek (0305A), Auds Creek (0305B), Six Mile Creek (0202P), Pine Creek (0202D), Red River below Lake Texoma (0202), Elm Fork Trinity River below Ray Roberts Lake (0839), Denton Creek (0826A), and Big Sandy Creek (0810A). The following stream segments were listed as impaired for bacteria in water (recreational use) [2]: East Fork Trinity River (0821D), Choctaw Creek (0202F), Clear Creek (0823C), Martin Branch (0810C), West Fork Trinity River below Bridgeport Reservoir (0810), Beans Creek (0811B), Upper South Sulpher River (0306) (this segment was also impaired for pH), Bois D'Arc Creek (0202A), Honey Grove Creek (0202L), Smith Creek (0202G), and Hicks Creek (0202N).

Threatened & Endangered Species

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Palo Pinto, Jack, Wise, Denton, Grayson, Fannin, and Lamar counties can be found at https://tpwd.texas.gov/gis/rtest/.

According to the Information for Planning and Consultation (IPaC) website[5] maintained by the U.S. Fish & Wildlife Service (USFWS), the golden-cheeked warbler, least tern, whooping crane, sharpnose shiner, smalleye shiner, Texas fawnsfoot, American burying beetle, and *Geocarpon minimum* need to be considered for the proposed project. The

[1] TCEQ, 2020. Draft 2020 Texas Integrated Report – Texas 303(d) List (Category 5). Accessed online https://www.tceq.texas.gov/assets/public/waterquality/swqm/assess/20txir/2020_303d.pdf February 5, 2020.

[2] TCEQ, 2020. Draft 2020 Texas Integrated Report – Texas 303(d) List (Category 5). Accessed online https://www.tceq.texas.gov/assets/public/waterquality/swqm/assess/20txir/2020_303d.pdf February 5, 2020.

[5] USFWS, 2020. Information for Planning and Consultation. Accessed online https://ecos.fws.gov/ipac/location/2CDHNRFRWZBEFN2BCFV527IIXM/resources February 5, 2020.

piping plover and red knot were also mentioned, but only need to be considered for wind energy projects. There are no critical habitats in the project area.

Texas Natural Diversity Data (TXNDD) from the TPWD was revealed 87 documented occurrences (including several reported occurrences of the golden-cheeked warbler, Brazos watersnake, colonial wading bird colony, chub shiner, silver chub, blackspot shiner, orangebelly darter, eastern spotted skunk, timber rattlesnake, southern crawfish frog, bald eagle, American burying beetle, Ouachita rock pocketbook, Hall's prairie clover, vertisol blackland prairie, mollisol blackland prairie, Gammagrass – Switchgrass tallgrass prairie, little bluestem – indiangrass series, *Silveanus* Dropseed series, sShortleaf pine-oak series, Texas oak series and *Schizachyrium scoparium – Bouteloua curtipendula – Nassella leucotricha* herbaceous vegetation) of threatened, endangered, or rare species or natural communities within five miles of the limited review area. No other documented occurrences of threatened, endangered or rare species or natural communities were reported within five miles of the project area.

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 (P196-515), and the Archeological and Historic Preservation Act (PL93-291). The City, as the owner or controller of the project, would be required to comply with the Antiquities Code. Based on the review of publically-available Geographic Information System (GIS) datasets from the Texas Historical Commission, many cemeteries were in proximity to the proposed pipeline routes (within a one-mile buffer). In Jack County, the cemeteries include: Joplin Fairview, Fairview, Barton Chapel, Wood, and Halsell Ranch cemeteries. In Wise County, the cemeteries included: Oaklawn, Eternal Oaks, Hyde, Sweetwater, and Allison Family cemeteries. In Denton County the cemeteries included: unknown (Plainview, McGill, Blue Mound, unknown (Gribble Springs), unknown (Green Valley), Wilson-Black Jack, Belew, Skinner, Pilot Point Community, St. Thomas, Pilot Point Memorial, and Craven cemeteries. In Fannin County cemeteries within one-mile of the proposed pipeline routes included: Providence Cemetery, Oak Hill #1, Pig Branch, Carlisle-Wolfe, Smyrna, Cedar Hill, Oakwood, Onstott-Stewart, White Rock, McCraws, and Allen cemeteries. In Lamar County the cemeteries within one mile of the proposed pipeline routes included: Pleasant Hill, unknown (Hopewell), Jackson and Restlawn cemeteries. In Grayson County, cemeteries within one mile of the proposed pipeline routes included Bethel Baptist and White Mound cemeteries.

The Thomas and Katherine Trout House (Fannin County), Pilot Point Downtown Historic District (Denton), Texas Tourist Camp (Wise County), Wassover Mansion (Wise County), and Wise County Courthouse were listed on the National Register of Historic Places and were within one-mile of the proposed pipeline routes. No historical markers or State Historic Sites were located within a one-mile buffer of the proposed project area. A review of archeological resources in the proposed project area should be conducted during project planning and be in compliance with the Texas Antiquities Code, if required.

4.8.4 Engineering and Costing

The Red River OCR Project requires a 750 cfs river intake and pumping facility to be constructed on the Red River and a 2 mile, 132-in transmission pipeline to deliver the supplies to three OCRs. A 535 cfs OCR intake facility and a 144-in, 100-mile transmission pipeline would need to be constructed to deliver supplies to Lake Ray Roberts. The cost estimate assumes a Brazos G sponsor would split costs of these facilities with Dallas based on annual supply amounts.

Delivery of the remaining supplies to Possum Kingdom Reservoir would require a 120-inch, 107-mile transmission pipeline. The delivery system is designed with a 1.25 peaking factor to allow for over pumping to compensate for delivery shortages during periods when diversions from the OCR are not available.

A summary of project and annual costs for the Red River OCR strategy with delivery to Possum Kingdom Reservoir is presented in Table 4.8-1. Annual costs include estimates for periodic dredging of the sedimentation basins and chemical addition for zebra mussel control. The costs presented in Table 4.8-1 do not include delivery or treatment of the supplies from Possum Kingdom Reservoir to water users in Brazos G.

Table 4.8-1. Cost Estimate Summary for Red River Off-Channel Reservoir

Item	Estimated Cost for Facilities
CAPITAL COST	
Off-Channel Storage Reservoir (32,000 acft, 800 acres; BRA Portion)	$104,523,000
Red River Intake and Pump Station (485 MGD; BRA Portion)	$49,750,000
Transmission Pipeline from Red River to Off-Channel Reservoir (132-in dia., 2 mile; Brazos G Portion)	$22,106,000
Off-Channel Reservoir Intake and Pump Stations to Lake Ray Roberts (346 MGD; BRA Portion)	$93,074,000
Transmission Pipeline from Off-Channel Reservoir to Lake Ray Roberts (144-in, 100-mile; BRA Portion)	$667,996,000
Pump Stations to Possum Kingdom Reservoir (219 MGD)	$146,607,000
Transmission Pipeline from Lake Ray Roberts to Possum Kingdom Reservoir (120-in dia., 107-mile)	$865,043,000
TOTAL COST OF FACILITIES	**$1,949,099,000**
OTHER PROJECT COSTS	
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$604,427,000
Environmental & Archaeology Studies and Mitigation	$10,372,000
Land Acquisition and Surveying (3,286 acres)	$14,359,000
Interest During Construction (4% for 2 years with a 1% ROI)	$212,707,000
TOTAL COST OF PROJECT	**$2,790,964,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$185,935,000
Reservoir Debt Service (5.5 percent, 40 years)	$6,948,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$15,551,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$7,236,000
Dam and Reservoir (1.5% of Cost of Facilities)	$1,419,000
Zebra Mussel Treatment	$5,952,000
Pumping Energy Costs (0.08 $/kW-hr)	$48,241,000
Sediment Dredging	$1,419,000
TOTAL ANNUAL COST	**$272,701,000**
Available Project Yield (acft/yr)	**196,000**
Annual Cost of Water ($ per acft), based on PF=1.25	**$1,391**
Annual Cost of Water After Debt Service ($ per acft), based on PF=1.25	**$407**
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.25	**$4.27**
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.25	**$1.25**

4.8.5 Implementation Issues

Several key issues would need to be overcome to make the project feasible. These issues include bank stability for the intake structure along the Red River, water quality and sediment control, invasive species, and regulatory and permitting issues considering the Red River Compact.

This water supply option has been compared to the plan development criteria, as shown in Table 4.8-2, and the option meets each criterion.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permit;
- Texas Commission on Environmental Quality Interbasin Transfer permit;
- 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;
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved; and
- Compliance with the Red River Compact.

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;
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction; 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 4.8-2. Comparison of Red River Off-Channel 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. High
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impact
2. Habitat	2. Moderate 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	Yes
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

4.9 South Bend Reservoir

4.9.1 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 4.9-1. 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 supplies from the reservoir would provide the greatest benefit as part of the BRA System.

4.9.2 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 the BRA system. The stand-alone firm yield of South Bend Reservoir is calculated to be only 14,800 acft/yr as a result of the BRA System Operations permit appropriating most of the remaining available streamflow upstream of Possum Kingdom Reservoir. If South Bend Reservoir is operated as part of the BRA System, preliminary analyses indicate that the reservoir could increase the system yield by up to 65,000 acft/yr. Because the stand-alone operations would result in a yield that is insufficient to make the project feasible, results presented in the remainder of this section are for the BRA System yield scenario of South Bend Reservoir.

When the reservoir is operated as part of the BRA System, streamflows are impounded during wet periods when unappropriated streamflow are available and held in reserve until being released during drought periods when downstream contract holders begin to experience supply shortages. Figure 4.9-2 shows the annual releases from South Bend Reservoir. Figure 4.9-3 illustrates simulated South Bend Reservoir storage levels for the 1940 to 1997 historical period and Figure 4.9-4 shows the storage frequency. The figures show that the reservoir releases all available storage during the 1950s drought to help meet downstream needs of the BRA system.

Figure 4.9-1. South Bend Reservoir Location

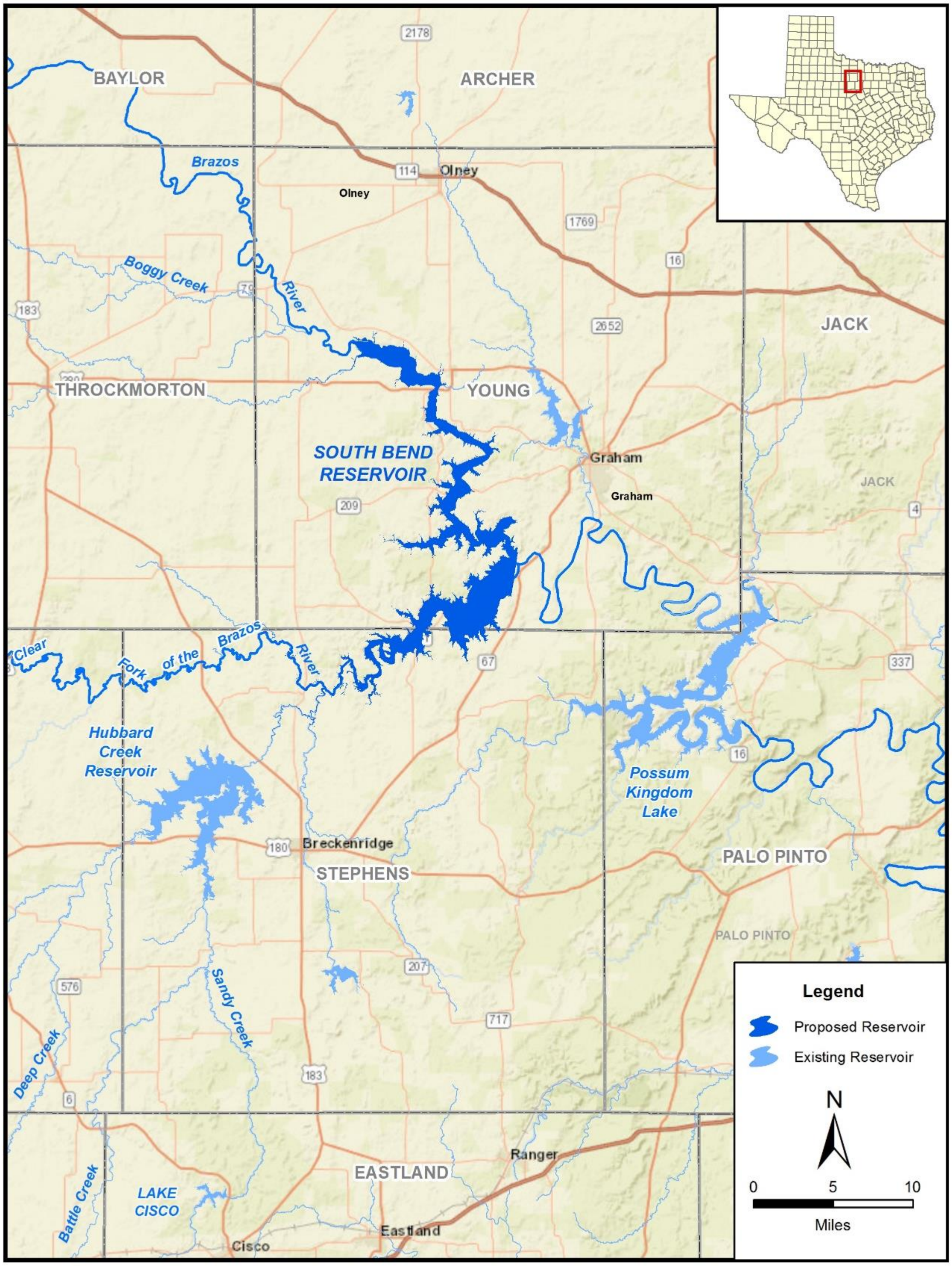

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Figure 4.9-2. South Bend Reservoir Releases as Part of BRA System Operations

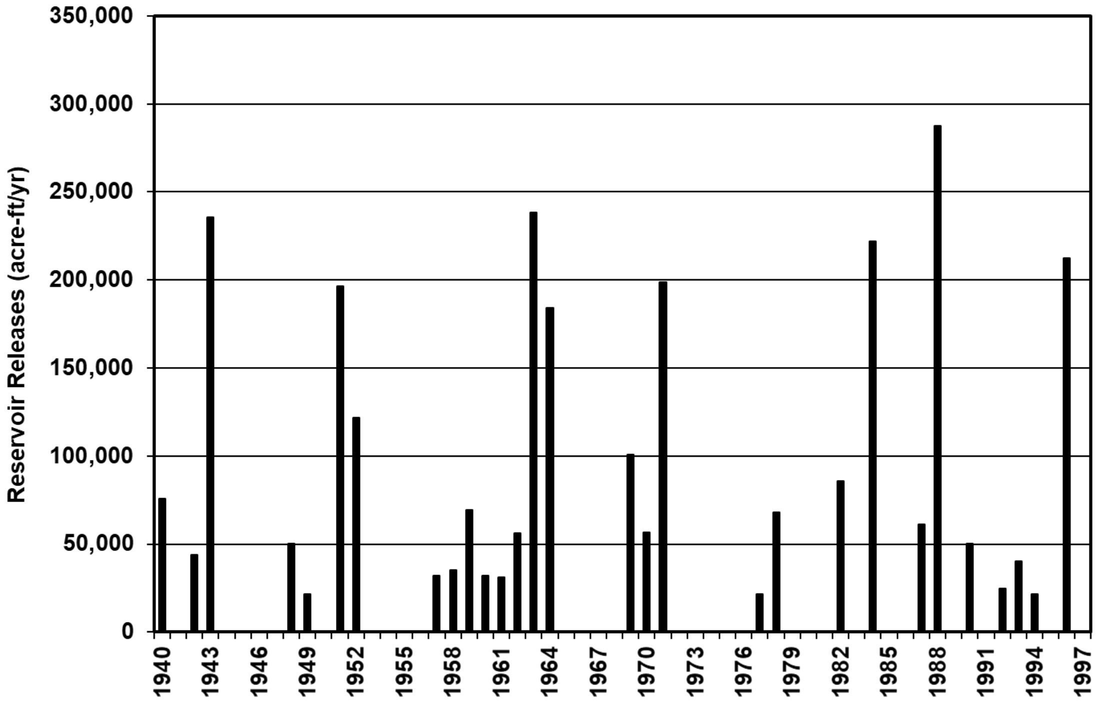


Figure 4.9-3. South Bend Reservoir System Operations Storage Trace

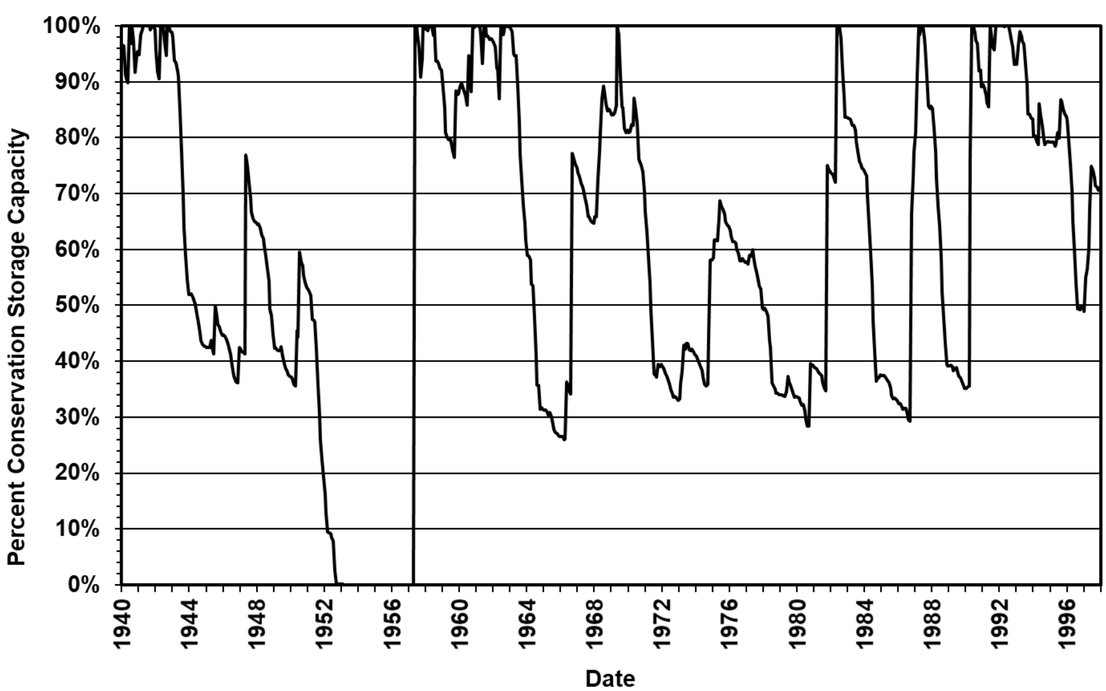


Figure 4.9-4. South Bend Reservoir Storage Frequency at Firm Yield

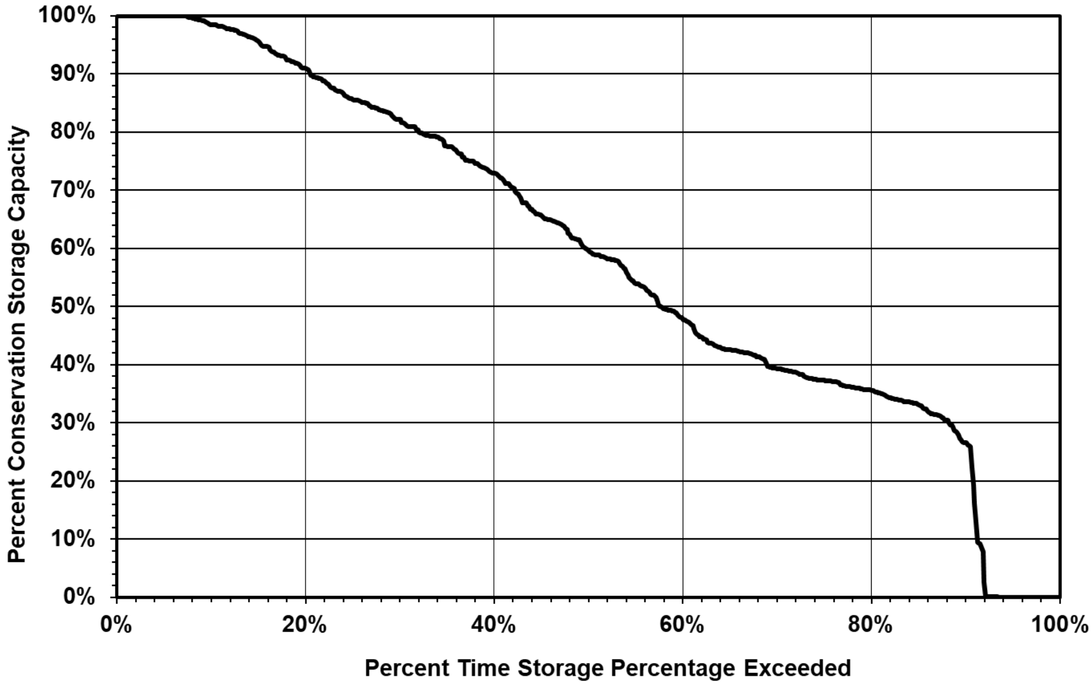


Figure 4.9-5 illustrates the changes in Brazos River median streamflows at the South Bend Reservoir Dam resulting from the project and Figure 4.9-6 compares the streamflow frequency with and without the project. The greatest reduction in flow would occur in the spring and summer months of May and June. The largest decline occurs in June, where the median streamflow is reduced by 33 cfs. During the months outside of April-Jun, the reservoir is typically not able to impound flows in excess of those required for downstream senior water rights and environmental needs and releases of stored water from the reservoir increase flows in many months. Comparison of the frequency of streamflow demonstrates how the reservoir reduces streamflow through impoundments during higher flow periods (flows typically greater than 7,500 cfs) and increases streamflow through reservoir releases during drought periods.

Figure 4.9-5. Monthly Median Streamflow at Proposed South Bend Reservoir Dam

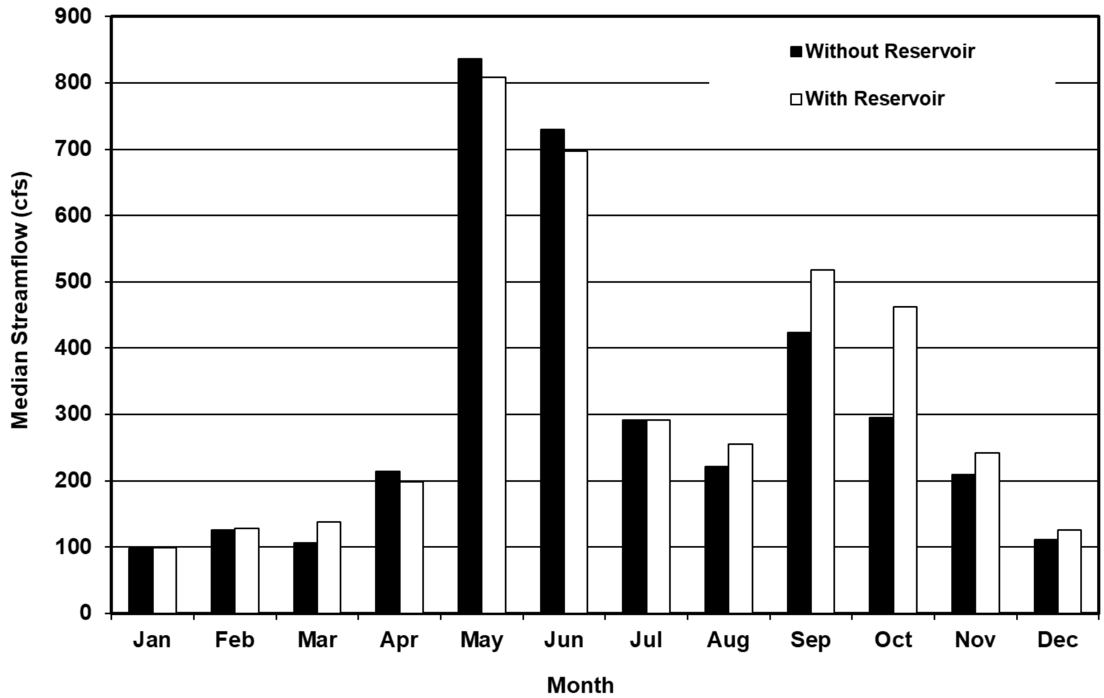
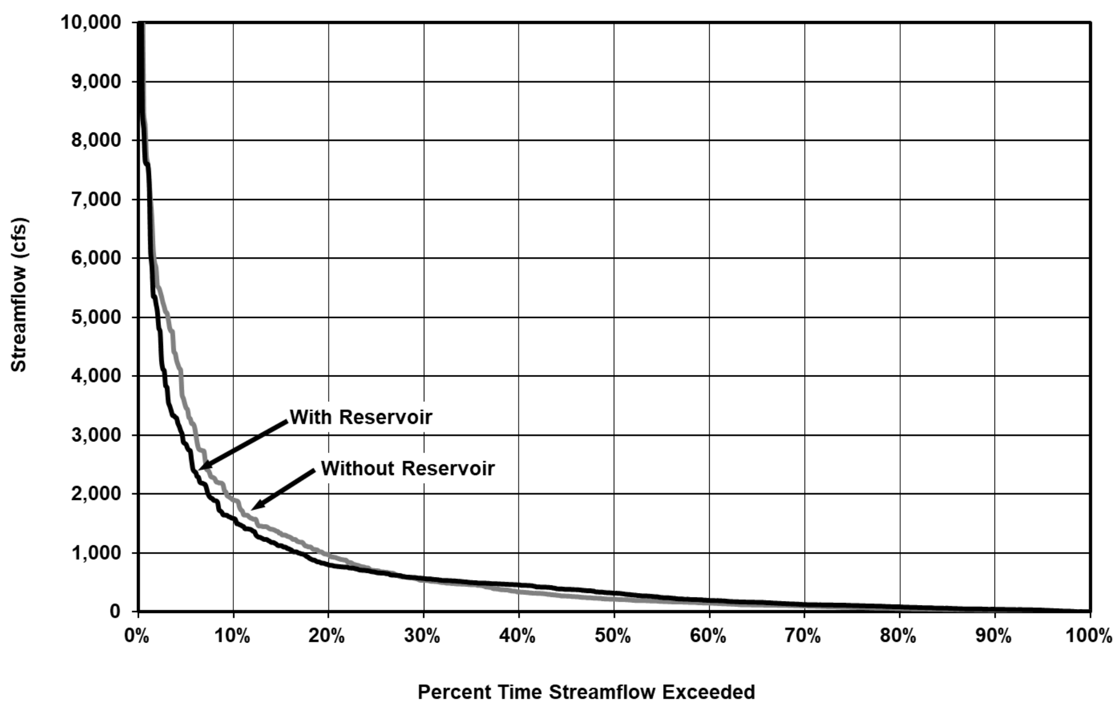


Figure 4.9-6. Streamflow Frequency at Proposed South Bend Reservoir Dam



4.9.3 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 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

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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), *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.

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 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*).

[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.

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 July to 33 cfs (5 percent) in June, as shown in Table 4.9-1. The highest reductions would occur in April and June. 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 115 cfs without the proposed reservoir in place and 129 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 4.9-1. Median Monthly Streamflow at South Bend Reservoir Dam

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	97.19	98.79	-1.61	-2%
February	125.33	127.62	-2.29	-2%
March	106.04	138.13	-32.09	-30%
April	213.73	198.22	15.51	7%
May	836.47	808.24	28.23	3%
June	729.90	696.75	33.15	5%
July	291.99	291.99	0.00	0%
August	221.41	255.19	-33.78	-15%
September	423.08	517.40	-94.32	-22%
October	294.78	461.57	-166.79	-57%
November	209.50	241.37	-31.87	-15%
December	111.60	125.80	-14.21	-13%

Threatened & Endangered Species

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Stephens and Young counties can be found at https://tpwd.texas.gov/gis/rtest/.

A search of the Texas Natural Diversity Database [9] 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.

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.

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[9] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, *Element of Occurrence Records*, 06/06/2019.

[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.

Construction of the reservoir would inundate habitat identified as critical to the Smalleye Shiner and Sharpeye Shiner, and further fragment the upper Brazos River stream channel upstream of Possum Kingdom Reservoir.

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), 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.

4.9.4 Engineering and Costing

The cost estimate summary for the South Bend Reservoir strategy is presented in Table 4.9-2. The total project costs are estimated to be $623,882,000. The cost for the estimated increase in system yield of 65,000 acft/yr, translates to an annual unit cost of raw water at the reservoir of $1.65 per 1,000 gallons, or $538 per acft. The annual project costs are estimated to be $35.0 million; this includes annual debt service, and operation and maintenance costs.

Table 4.9-2. Cost Estimate Summary for South Bend Reservoir

Item	Estimated Costs for Facilities
Dam and Reservoir (Conservation Pool 771,604 acft, 29,877 acres)	$204,833,000
Integration, Relocations, & Other	$60,701,000
TOTAL COST OF FACILITIES	**$265,534,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$92,937,000
Environmental & Archaeology Studies and Mitigation	$107,438,000
Land Acquisition and Surveying (59,754 acres)	$110,425,000
Interest During Construction (3% for 3 years with a 0.5% ROI)	$47,548,000
TOTAL COST OF PROJECT	**$623,882,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$6,242,000
Reservoir Debt Service (3.5 percent, 40 years)	$25,061,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$607,000
Dam and Reservoir (1.5% of Cost of Facilities)	$3,072,000
TOTAL ANNUAL COST	**$34,982,000**
Available Project Yield (acft/yr)	65,000
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	$538
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	$1.65

4.9.5 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 4.9-3, and the option meets each criterion.

Table 4.9-3. 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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4.10 New Throckmorton Reservoir

4.10.1 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 4.10-1. 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.

4.10.2 Available Yield

Water potentially available for impoundment in the proposed New Throckmorton Reservoir was estimated using the TCEQ Brazos WAM Run 3. The model includes a January 1940 through December 1997 hydrologic period of record and computes streamflow available from North Elm Creek without causing increased shortages to existing downstream rights. The safe yield of the project was computed subject to the reservoir and North Elm Creek diversion having to pass inflows to meet TCEQ environmental flow standards.

This strategy would require a subordination agreement with BRA for Possum Kingdom Reservoir. The calculated safe yield of New Throckmorton Reservoir is 3,500 acft/yr, assuming subordination of Possum Kingdom Reservoir. The estimated impact to the Possum Kingdom firm yield from the subordination is 2,390 acft/yr. Currently, BRA indicates that no subordination agreement is likely to be possible.

Figure 4.10-2 illustrates the simulated New Throckmorton Reservoir storage levels for the 1940 to 1997 historical period, subject to the safe yield of 3,500 acft/yr. Figure 4.10-3 shows that simulated reservoir contents remain above 80 percent capacity about 64 percent of the time and above 50 percent capacity above 96 percent of the time. Figure 4.10-4 illustrates the changes in North Elm Fork streamflows caused by impounding unappropriated water. Median streamflow would be reduced to zero in all months from implementation of the project. The largest changes would be declines in median streamflow of 24 cfs during May and 21.8 cfs during June. Figure 4.10-5 also illustrates the North Elm Creek streamflow frequency characteristics with New Throckmorton Reservoir in place.

Figure 4.10-1. New Throckmorton Reservoir

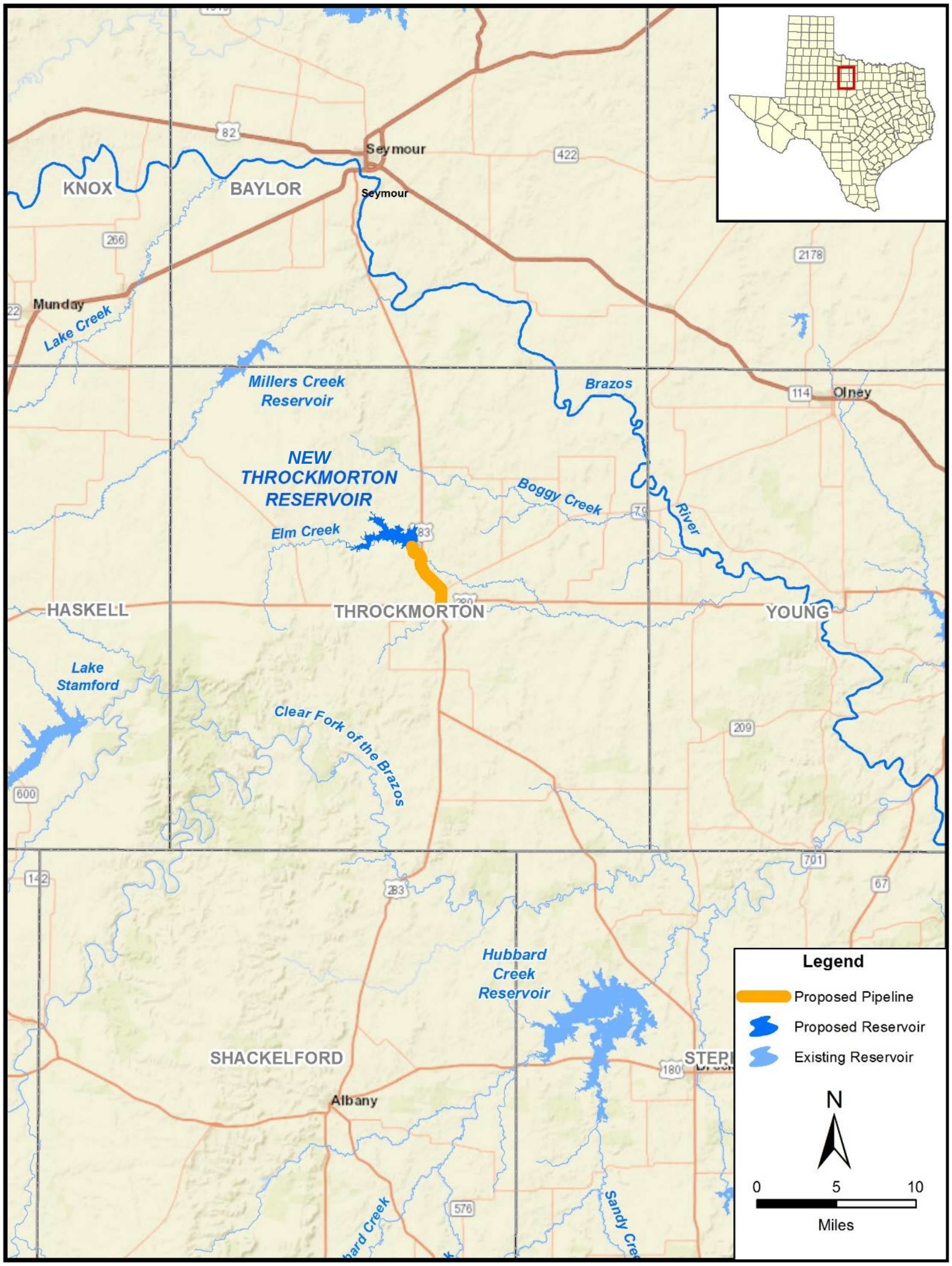

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Figure 4.10-2. New Throckmorton Reservoir Firm Yield Storage Trace

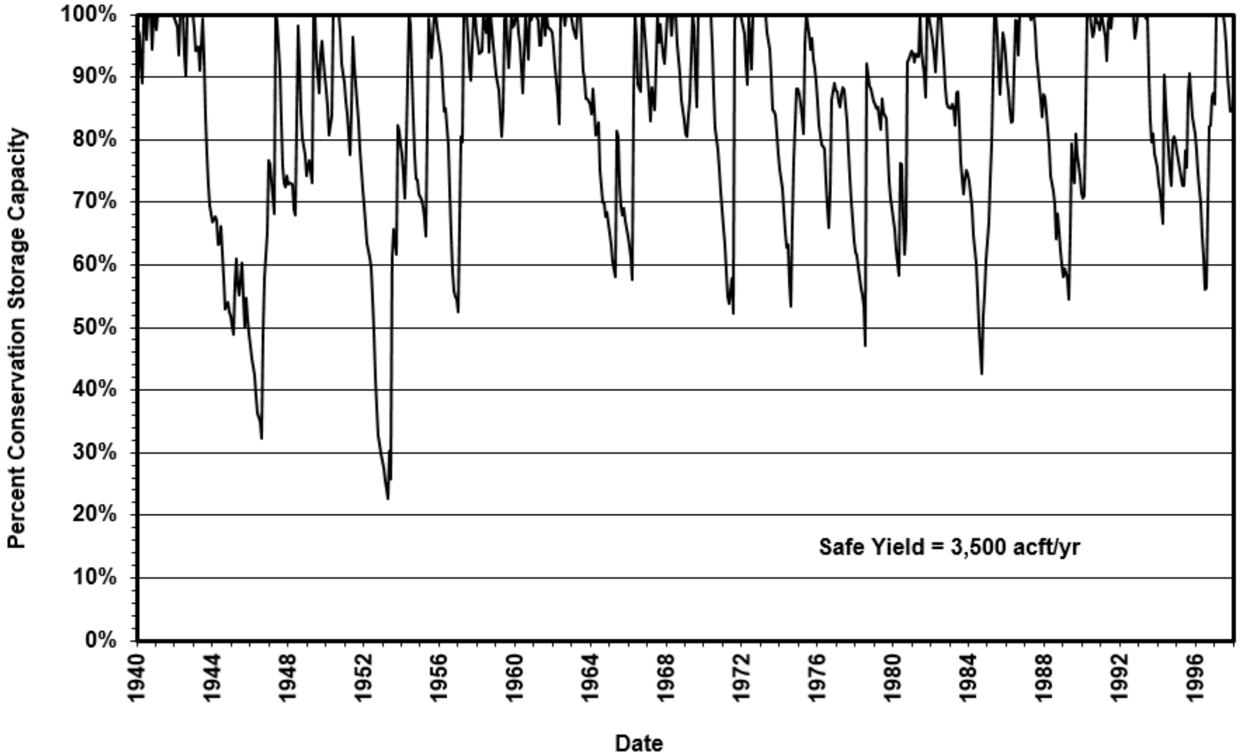


Figure 4.10-3. New Throckmorton Reservoir Storage Frequency at Safe Yield

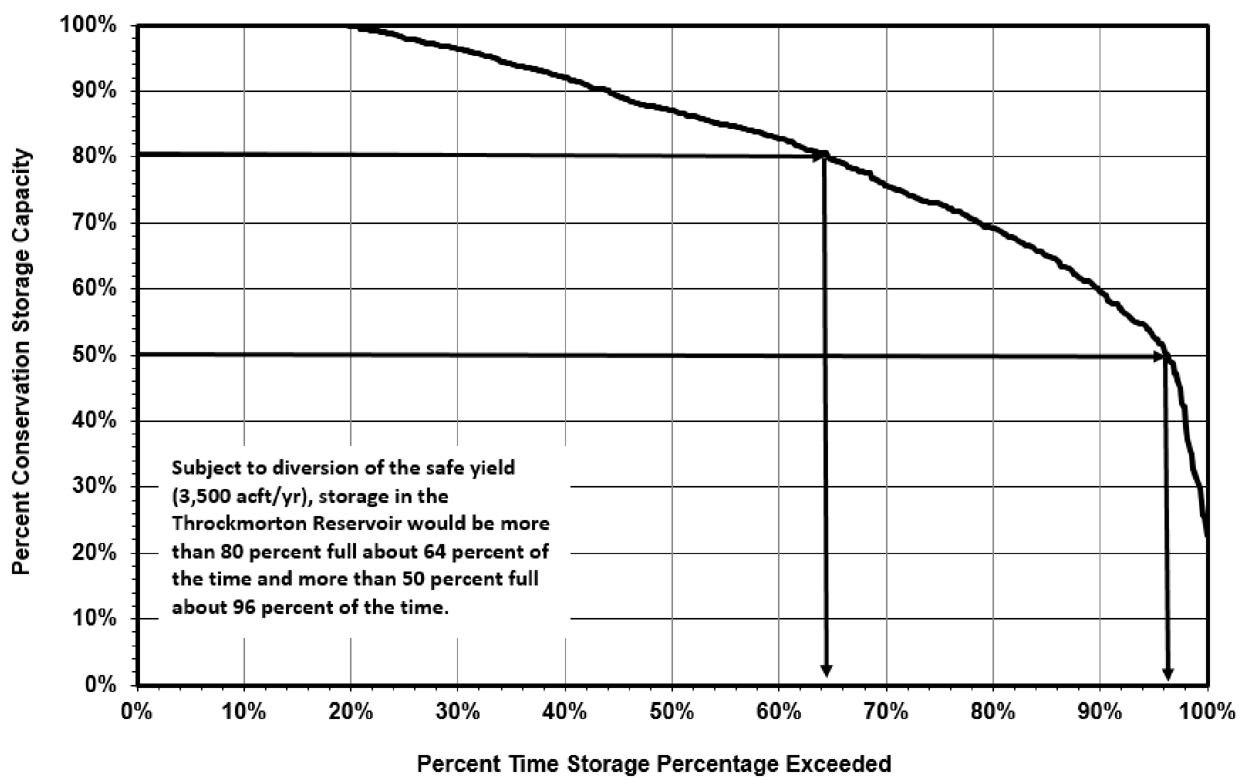


Figure 4.10-4. North Elm Fork Diversion - Median Streamflow Comparison

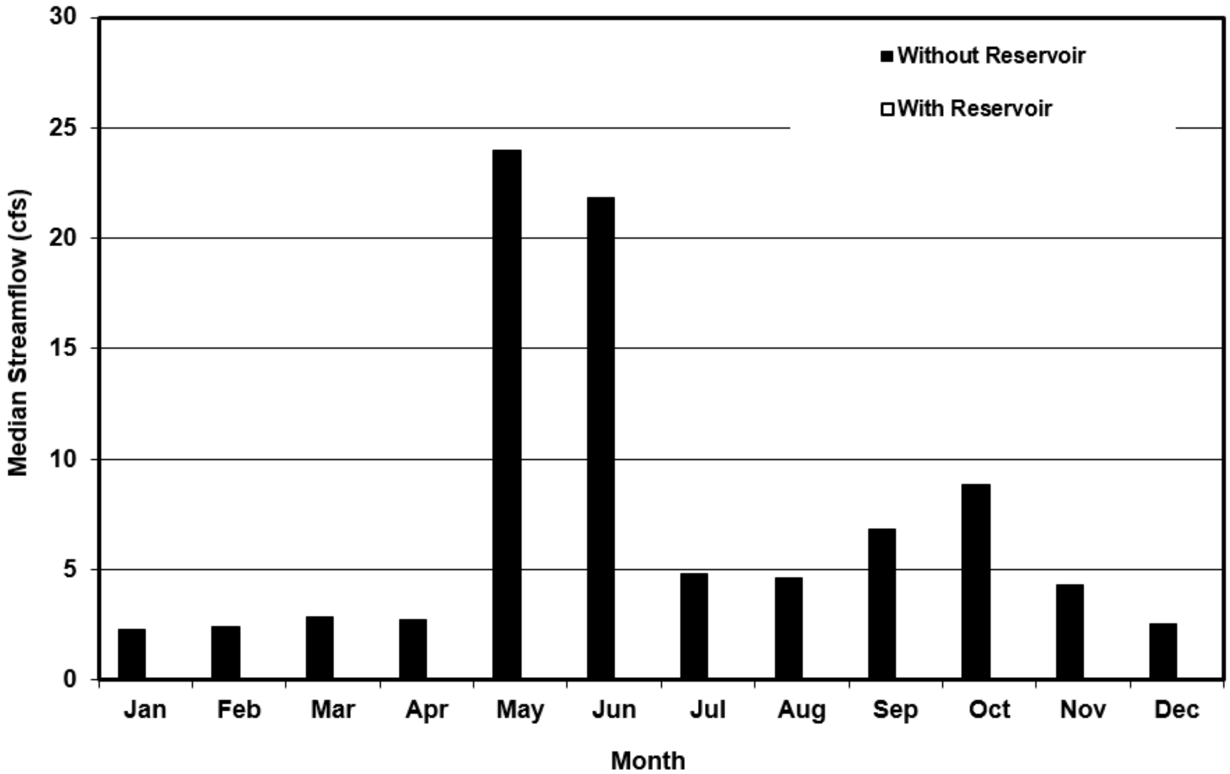
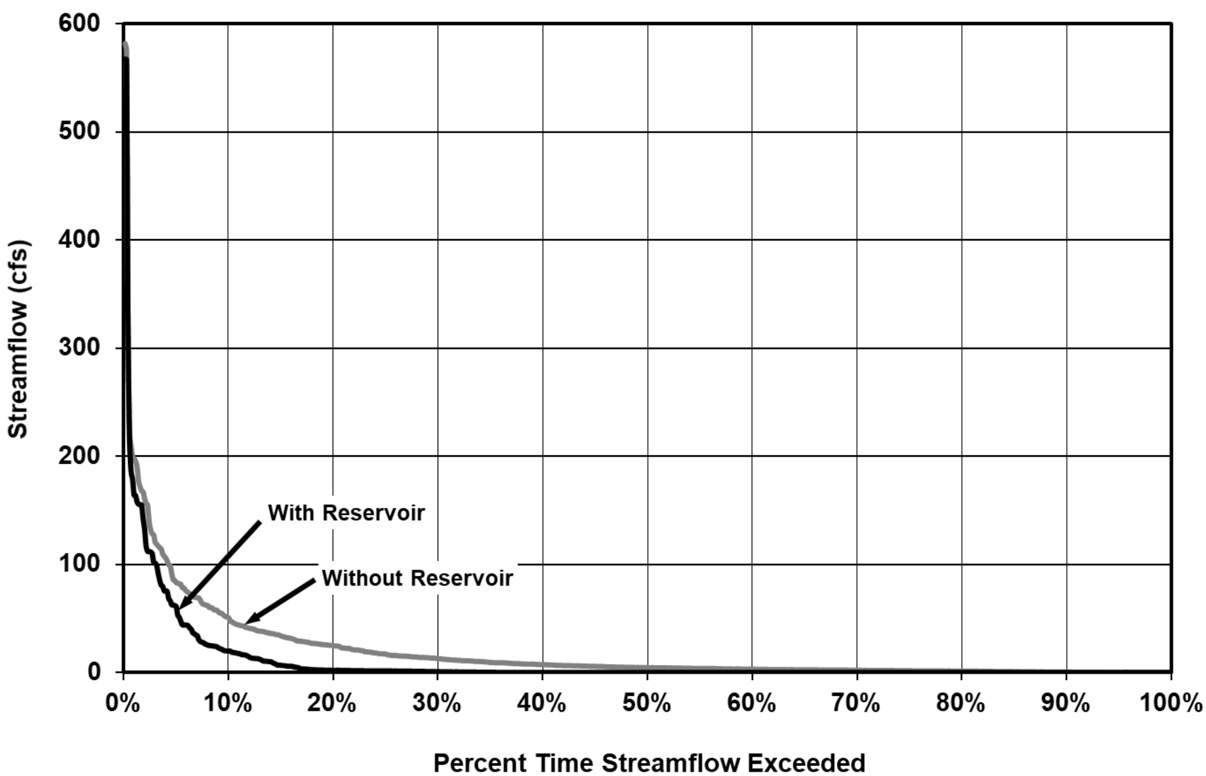


Figure 4.10-5. North Elm Fork Diversion- Streamflow Frequency Comparison



4.10.3 Environmental Issues

Existing Environment

The New 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 4.10-1. 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 0.72 cfs only 15 percent of the time (85 percent exceedance value) and would be less than 0.72 cfs 70 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

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[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 New Throckmorton Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

Table 4.10-1. Median Monthly Streamflow: North Elm Creek Diversion Site

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	2.26	0.00	2.26	100%
February	2.44	0.00	2.44	100%
March	2.88	0.00	2.88	100%
April	2.74	0.00	2.74	100%
May	23.95	0.00	23.95	100%
June	21.84	0.00	21.84	100%
July	4.82	0.00	4.82	100%
August	4.65	0.00	4.65	100%
September	6.82	0.00	6.82	100%
October	8.87	0.00	8.87	100%
November	4.31	0.00	4.31	100%
December	2.52	0.00	2.52	100%

Threatened & Endangered Species

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Throckmorton County can be found at https://tpwd.texas.gov/gis/rtest/.

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 New 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.

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.

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

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[9] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, *Element of Occurrence Records*, November 24, 2014.

[10] Texas Parks & Wildlife Department (TPWD), "Ecological Mapping Systems of Texas," https://drive.google.com/folderview?id=0B32g5sG2VKbgbl9oOGlneUdMZjA&usp=sharing accessed November 21, 2014.

[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.

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 New 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.

4.10.4 Engineering and Costing

Construction of the New Throckmorton Reservoir project will cost approximately $68.1 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 $5.91 million; this includes annual debt service and operation and maintenance. The cost for the available project safe yield of 3,500 acft/yr translates to an annual unit cost of raw water of $5.18 per 1,000 gallons, or $1,687/acft. A summary of the cost estimate is provided in Table 4.10-2. 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 New Throckmorton Reservoir. Note that any subordination agreement would need to be negotiated with BRA.

Table 4.10-2. Cost Estimate Summary for New Throckmorton Reservoir

Item	Estimated Costs for Facilities
Dam and Reservoir (Conservation Pool 15,900 acft; 1,161 acres)	$17,506,000
Intake Pump Station (3.3 MGD)	$5,603,000
Transmission Pipeline (12in. dia., 5 miles)	$2,957,000
Water Treatment Plant (3.3 MGD)	$15,440,000
TOTAL COST OF FACILITIES	**$41,506,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$14,379,000
Environmental & Archaeology Studies and Mitigation	$4,306,000
Land Acquisition and Surveying (2,357 acres)	$4,361,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$3,551,000
TOTAL COST OF PROJECT	**$68,103,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$2,409,000
Reservoir Debt Service (3.5 percent, 40 years)	$1,586,000
Operation and Maintenance	
Dam and Reservoir (1.5% of Cost of Facilities)	$263,000
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$30,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$140,000
Water Treatment Plant	$1,220,000
Pumping Energy Costs (0.08 $/kW-hr)	$75,000
Purchase of Water (2,390 acft/yr @ 76.50 $/acft)	$183,000
TOTAL ANNUAL COST	**$5,906,000**
Available Project Yield (acft/yr)	3,500
Annual Cost of Water ($ per acft), based on a Peaking Factor of 1	$1,687
Annual Cost of Water ($ per 1,000 gallons), based on a Peaking Factor of 1	$5.18

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.

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;
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction; 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 4.10-3. Evaluations of New 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

4.11 Turkey Peak Dam – Lake Palo Pinto Enlargement

4.11.1 Description of Option

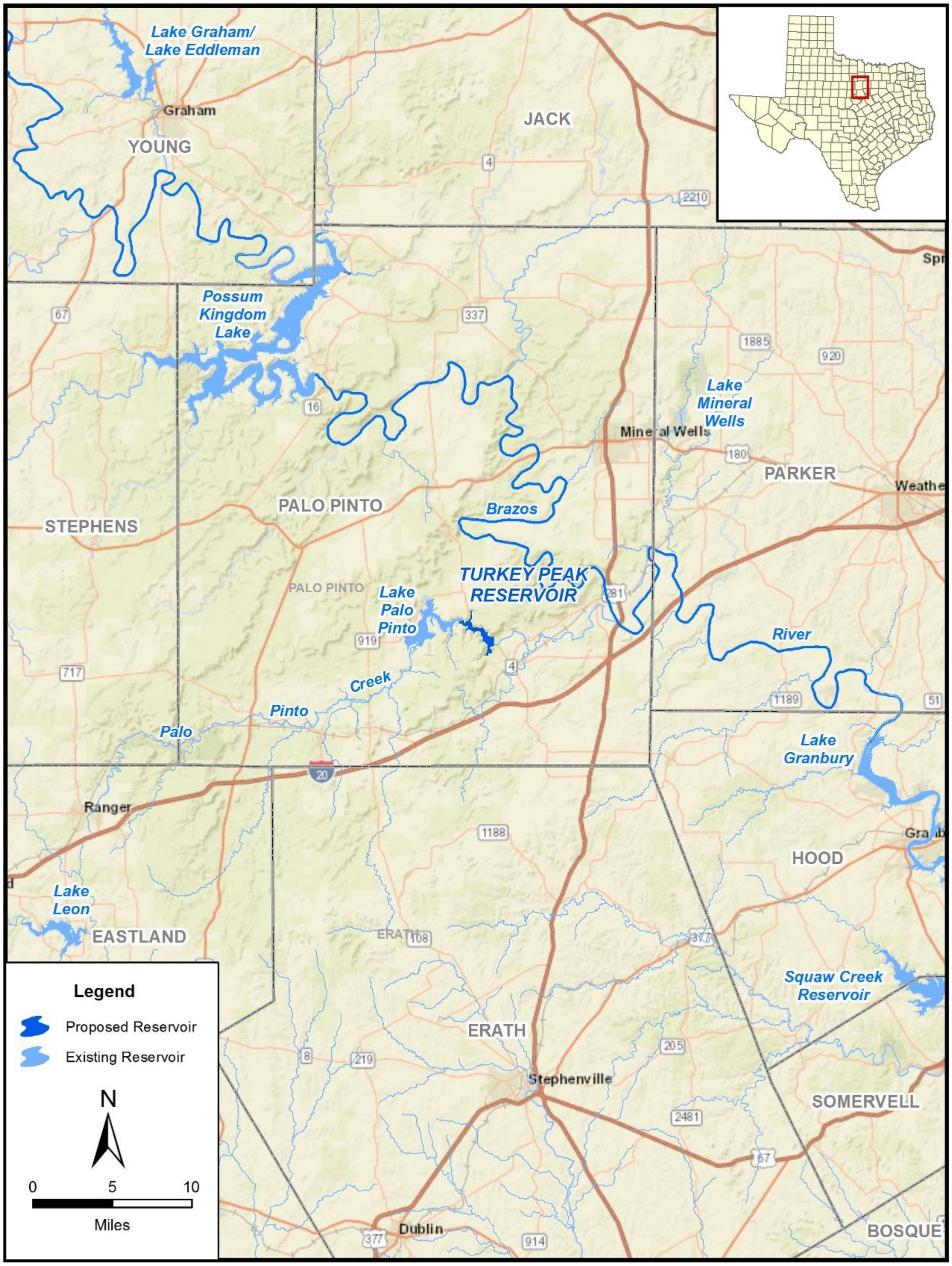
The Lake Palo Pinto (LPP) dam was initially constructed in 1963 and 1964 with a conservation pool level of 863.0 feet above mean sea level (ft-msl) and deliberate impoundment began in April 1964. In 1966 the conservation storage level was raised four feet to 867.0 ft-msl. The Palo Pinto County Municipal Water District No. 1 (District) operates LPP by making releases through the reservoir outlet works for subsequent diversion downstream. Additionally, the District's water right allows for the diversion of intervening streamflow entering Palo Pinto Creek downstream of LPP. As a result, the District is able to conserve storage in LPP by ceasing releases from LPP during wet periods and meeting demands by diverting the intervening streamflow.

In the early 1980s, the District became concerned about the capacity of LPP and in 1985, a volumetric survey of the reservoir was performed. This survey determined the reservoir's conservation capacity to be 27,650 acft, 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, the LPP conservation pool currently inundates 2,176 acres at its conservation level and has an average depth of only 12.5 feet. The construction of the Turkey Peak Dam is currently being pursued by the District to expand LPP and recover the storage authorized under Certificate of Adjudication 12-4031.

The proposed Turkey Peak Dam is located on Palo Pinto Creek immediately downstream of LPP, as shown in Figure 4.11-1. The proposed dam 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 the expanded portion of LPP is 22,577 acft and covers 648 acres, resulting in an average reservoir depth of 35 ft.

The normal pool elevation of the expanded LPP will be 867.0 ft-msl, the same as the existing LPP. A portion of the existing dam and spillway at LPP will be removed and the two reservoir pools will be connected above an elevation of 863.0 ft-msl. Below this elevation a pipe will connect both pools and the two pools can be operated either as a single reservoir or as separate reservoirs. The expanded LPP will contain approximately 49,792 acft of conservation storage and inundate 2,824 acres at its conservation storage level of 867 ft-msl.

Figure 4.11-1. Location of Turkey Peak Dam – Lake Palo Pinto Enlargement



Document Path: \\dalctxsrv01\Texas_GIS_Projects\10029705_036_Brazos_G_2021_Plan\Map_Docs\MXDs\Reservoir_Strategy\Turkey_Peak_Reservoir.mxd

The Turkey Peak Dam will increase storage by 83 percent (as compared to the existing LPP), while only inundating an additional 20 percent of the surface area of the existing LPP. Because the expanded portion of the reservoir is significantly deeper than the existing LPP, the surface area of the combined reservoirs is 695 acres less (20 percent) when compared to raising the conservation level of LPP 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 has been granted an amendment to their surface water permit for LPP (Certificate of Adjudication 12-4031A) for the expansion of the reservoir and has obtained the required Section 404 permit of the Clean Water Act for construction of the Turkey Peak Dam. The District is currently in the final design phase of the project and is beginning to acquire property. The District anticipates construction to begin in 2025.

4.11.2 Available Yield

Water potentially available for impoundment in the expanded LPP 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. Estimates of water availability were derived subject to the reservoir having to pass inflows to meet TCEQ environmental flow standards.

Because this project is being pursued to recover lost storage in LPP and to increase the reliability of the supply as currently authorized by the District's water right, the additional storage provided by Turkey Peak Dam was modeled at the LPP priority date of July 3, 1962, which is consistent with Certificate of Adjudication 12-4031A. When the expanded LPP is simulated with the TCEQ Brazos WAM Run 3 and diversions of released water from the reservoir taken at the downstream diversion point, the full authorized diversion amount of 18,500 acft/yr is firm.

However, during the recent 2015 drought, storage levels in LPP were reduced to critical levels, signifying a new drought of record for the Palo Pinto Creek watershed. As a result, the District adopted a 12-month safe yield for planning purposes. The recent drought is not included in the TCEQ Brazos WAM hydrologic period of record. Analyses performed by HDR considering the recent drought indicates the safe yield of the existing LPP is 4,700 acft/yr. With the expanded LPP, the safe yield is increased by 6,000 acft/yr to 10,700 acft/yr.

Figure 4.11-2 shows the simulated expanded LPP storage levels for the 1940 to 1997 period included in the TCEQ Brazos WAM, subject to the safe yield demand of 10,700 acft/yr. Figure 4.11-3 illustrates the storage frequency of the combined reservoir under the same safe yield demand. Simulated contents remain full over 20 percent of the time and above 90 percent full more than half of the time. Figure 4.11-4 shows the annual releases from storage for subsequent diversion downstream. For years in which releases are less than the safe yield amount of 10,700 acft, intervening streamflow downstream of the Turkey Peak Dam is utilized to meet portions of the safe yield demand.

Figure 4.11-2. Expanded Lake Palo Pinto Storage Trace

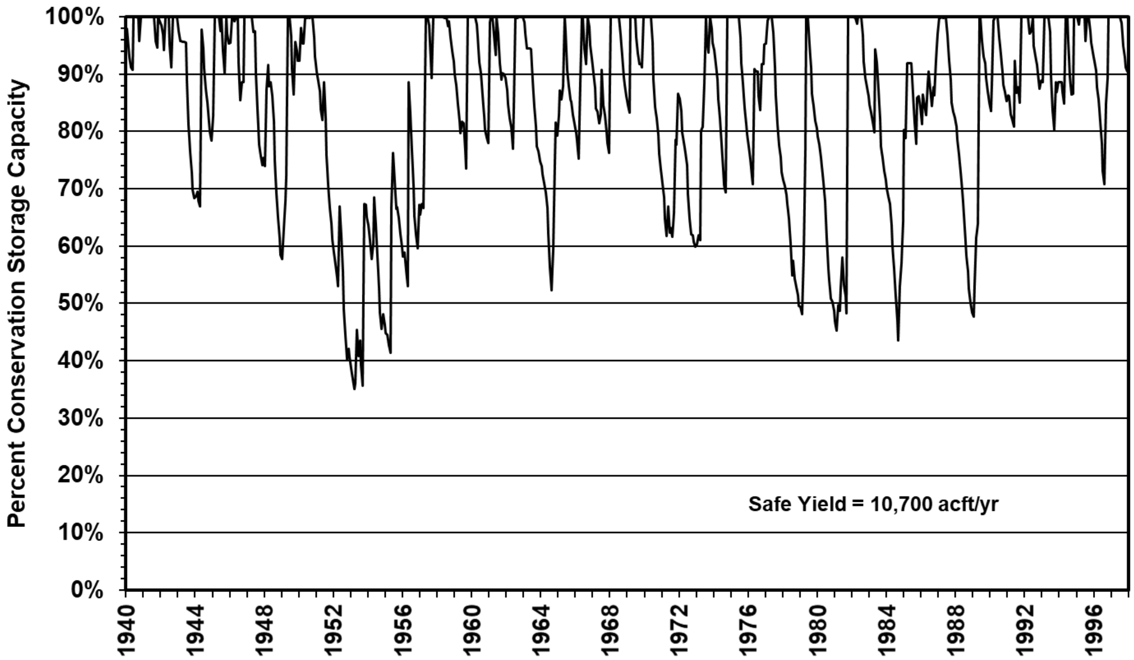


Figure 4.11-3. Expanded Lake Palo Pinto Reservoir Storage Frequency

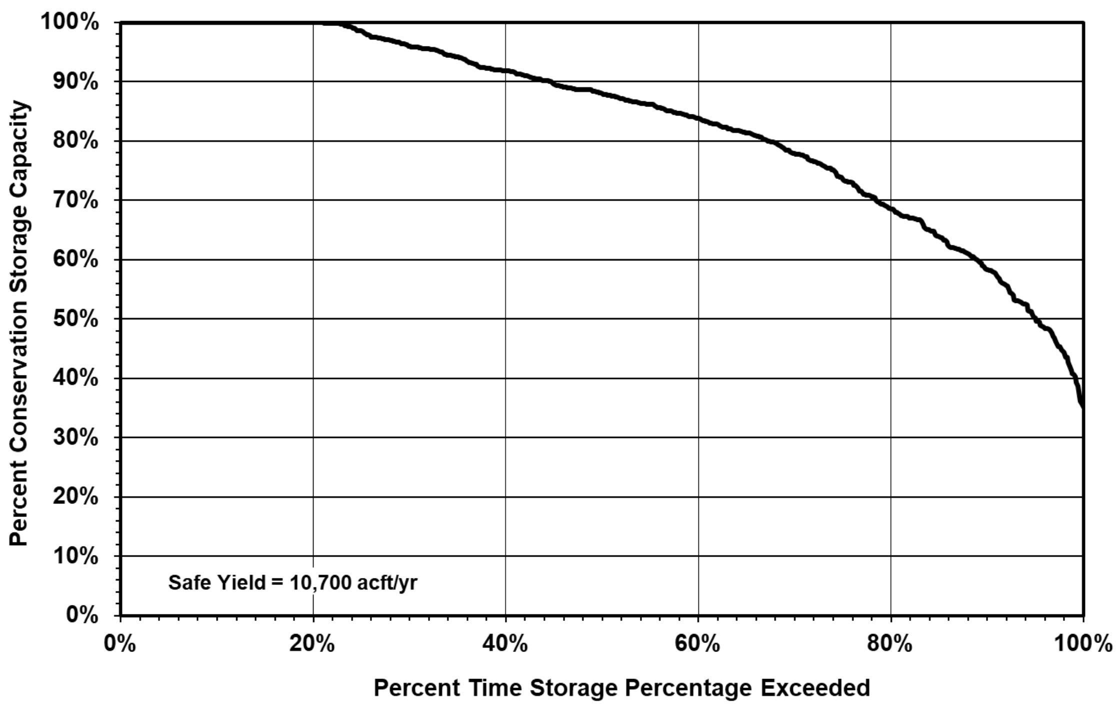


Figure 4.11-4. Releases from Expanded LPP for Water Supply

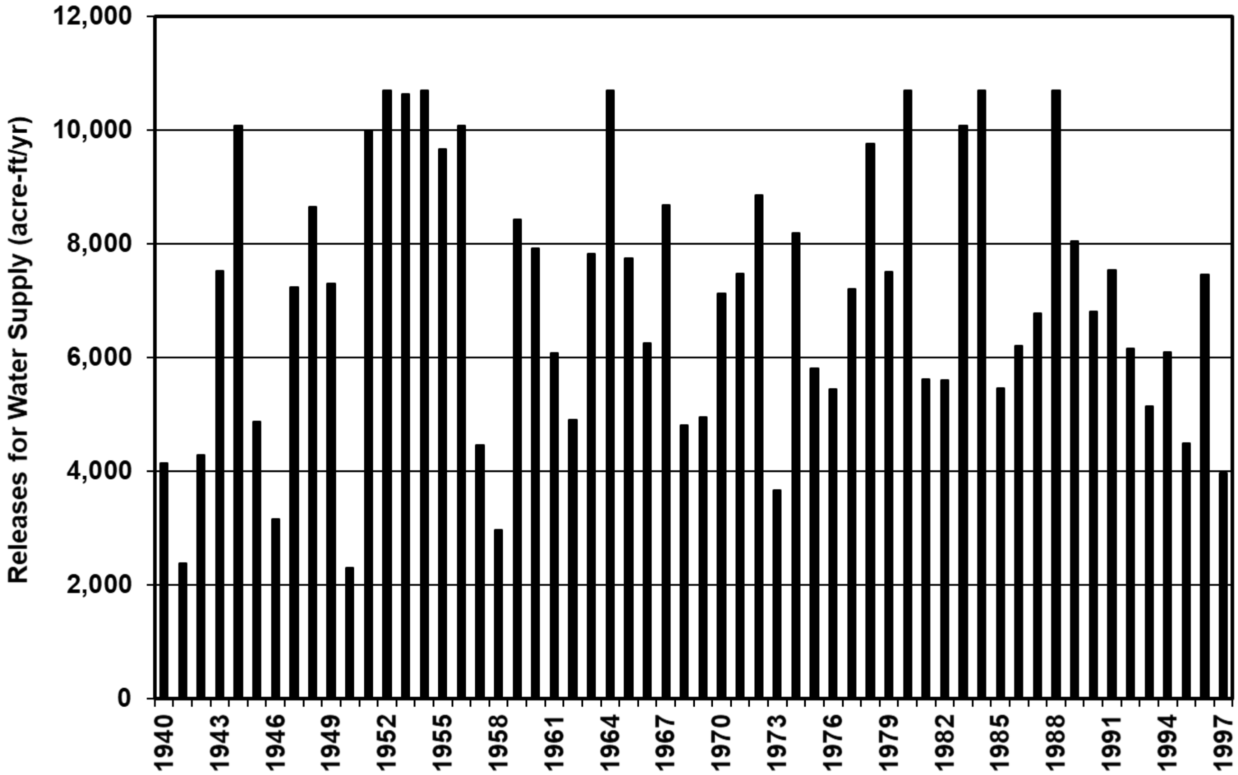


Figure 4.11-5 illustrates the changes in Palo Pinto Creek streamflows as a result of the Turkey Peak dam construction. The median streamflows are reduced in May and June as a result of the expanded reservoir impounding a greater amount of available streamflow. Median streamflows are increased in all other months of the project due to the expanded reservoir being able to release additional water for subsequent diversion downstream. Figure 4.11-6 compares the streamflow frequency at the Proposed Turkey Peak Dam with and without the project. The figure shows that streamflow will not be significantly impacted from implementation of the project.

Figure 4.11-5. Monthly Median Streamflow near Proposed Turkey Peak Reservoir Dam

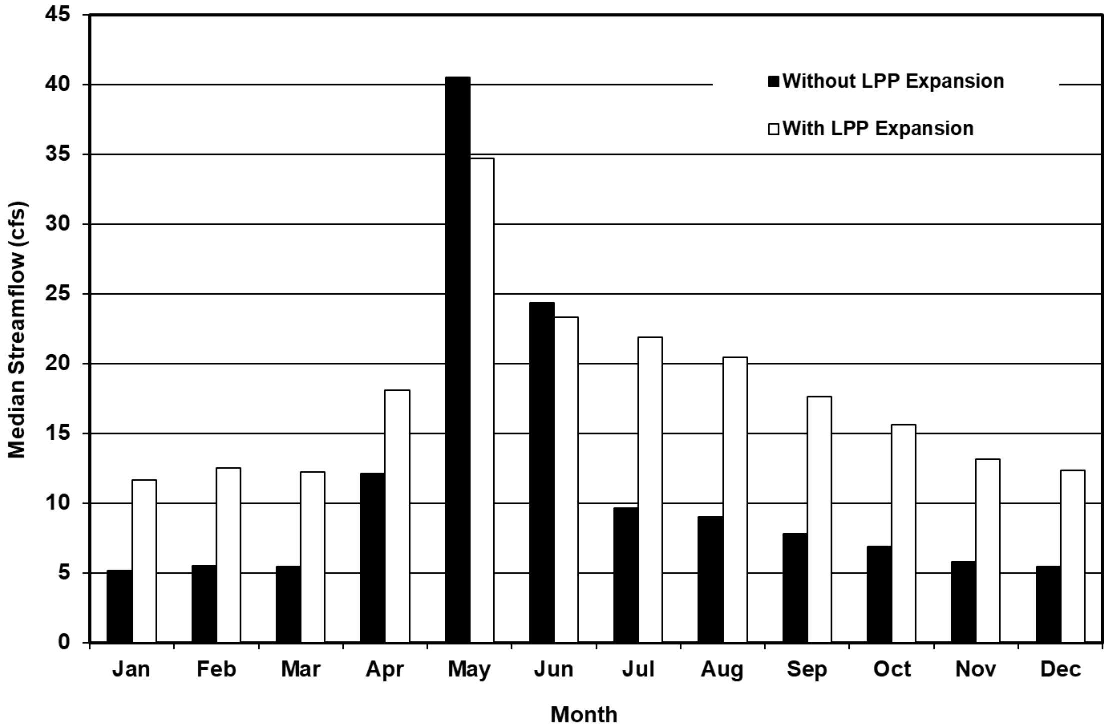
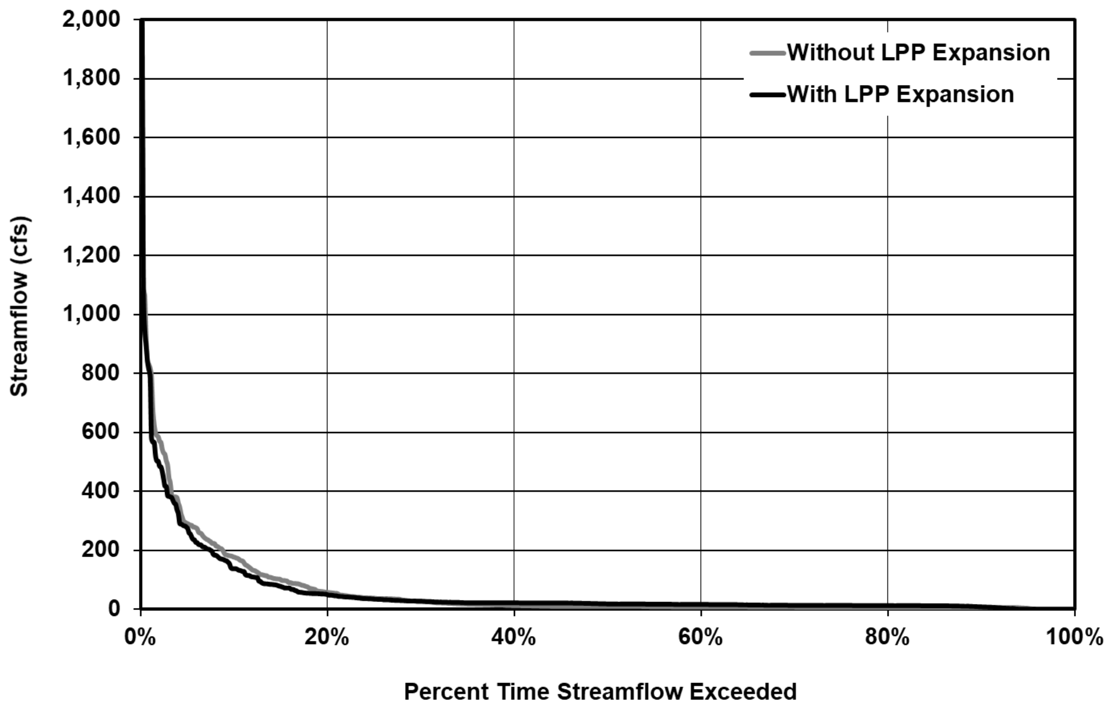


Figure 4.11-6. Streamflow Frequency Comparison at Turkey Peak Dam



4.11.3 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 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

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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 (color poster with map, descriptive text, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:2,3000,000).

[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.

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 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 permit issued by TCEQ for the Turkey Peak project requires pass through of inflows originating in the intervening drainage area between the dams of 1 cfs for subsistence flow and between 1 and 4 cfs for base flows in Palo Pinto Creek. Additionally, the USACE 404 permit requires the District to maintain a minimum 1 cfs flow downstream of the Turkey Peak dam by passing inflows or releasing stored water when the reservoir is greater than 50% full. 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

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD frequently updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Palo Pinto County can be found at https://tpwd.texas.gov/gis/rtest/. 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.

Three bird species federally listed as threatened or endangered may occur in the project vicinity. These include the golden-cheeked warbler (*Dendroica chrysoparia*), interior least tern (*Sterna antillarum athalassos*), and whooping crane (Grus americana). Two of these bird species are seasonal migrants that could pass through the project area. 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 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 bald eagle (*Haliaeetus leucocephalus*). 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 the bald eagle 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*), three state threatened species, and the plains spotted skunk (*Spilogale putorius interrupta*), Texas garter snake (*Thamnophis sirtalis annectens*), and granite spiderwort (*Tradescantia pedicellata*), three 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

[8] Ladd, Clifton and Amanda Aurora. Endangered Species Survey Summary for the Golden-Cheeked Warbler. Loomis Austin, 2006.

[9] Ibid.

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 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 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. The Guadalupe bass (*Micropterus treculii*) is endemic to the perennial streams of the Edwards Plateau region and is considered introduced in the Nueces River system. It is possible, but unlikely, that this species will be found within project area.

Information received from the TPWD Texas Natural Diversity Database[10] revealed no documented occurrences of endangered or threatened species within or near the 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*).

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[10] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, Received 10/04/2014.

[11] Blair, W. Frank. 1950. "The Biotic Provinces of Texas," Texas Journal of Science 2 (1):93-117, modified by TPWD GIS lab.

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 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

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[12] TPWD. 2014. Texas Ecological Systems GIS mapping layers.

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 includes hay fields and a pecan orchard. As a result, some impacts are expected for agricultural land use.

4.11.4 Engineering and Costing

An opinion of probable construction costs (OPCC) is currently being developed as part of the final design of the project. However, the final OPCC was not available at the time of completion of this Initially Prepared Plan. If the OPCC becomes available during the IPP review period, costs shown here will be updated to reflect the OPCC.

As a result, cost estimates for the Turkey Peak/Palo Pinto Reservoir were indexed to current September 2018 dollars from those originally prepared by HDR, Inc. in 2013 as part of a preliminary design study. The estimated capital cost of $56.4 million includes costs 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 $102.5 million (Table 4.11-1). 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. Since the project is currently being implemented, the District has already financed a portion of the permitting, planning and design activities as well as legal assistance associated with permit acquisitions. The 12-month safe yield increase of 6,000 acft/yr from the project would provide raw water to the District at a unit cost of $972 per acft or $2.98 per 1,000 gallons.

Table 4.11-1. Cost Estimate for Turkey Peak Project

Item	Estimated Costs for Facilities
Capital Cost	
Dam and Reservoir	$46,347,000
Integration, Relocation, & Other	$10,083,000
Total Cost of Facilities	**$56,430,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$19,751,000
Environmental & Archaeological Studies and Mitigation	$10,252,000
Land Acquisition and Surveying (9,978 acres)	$10,751,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$5,346,000
Total Cost Of Project	**$102,530,000**
Debt Service (3.5 percent, 20 years)	$1,010,000
Reservoir Debt Service (3.5 percent, 40 years)	$4,129,000
Operation and Maintenance	
Dam and Reservoir	$695,000
Pumping Energy Costs ($0.09 kwh)	$0
Total Annual Cost	**$5,834,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**6,000**
Annual Cost of Water ($ per acft)	**$972**
Annual Cost of Water ($ per 1,000 gallons)	**$2.98**

4.11.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4.11-2, and the option meets each criterion.

The District is actively implementing this project with plans to begin construction in 2020. A summary of the planned implementation steps for the project follows.

- Complete final design of the project.
- Complete land acquisition for the project.
- Secure additional state funding to implement the project.
- Begin construction of the project.

Remaining Regulatory Requirements:

- None

Table 4.11-2. 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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5 Groundwater Supplies and Projects

5.1 City of Bryan Groundwater Strategies

5.1.1 Description of Option

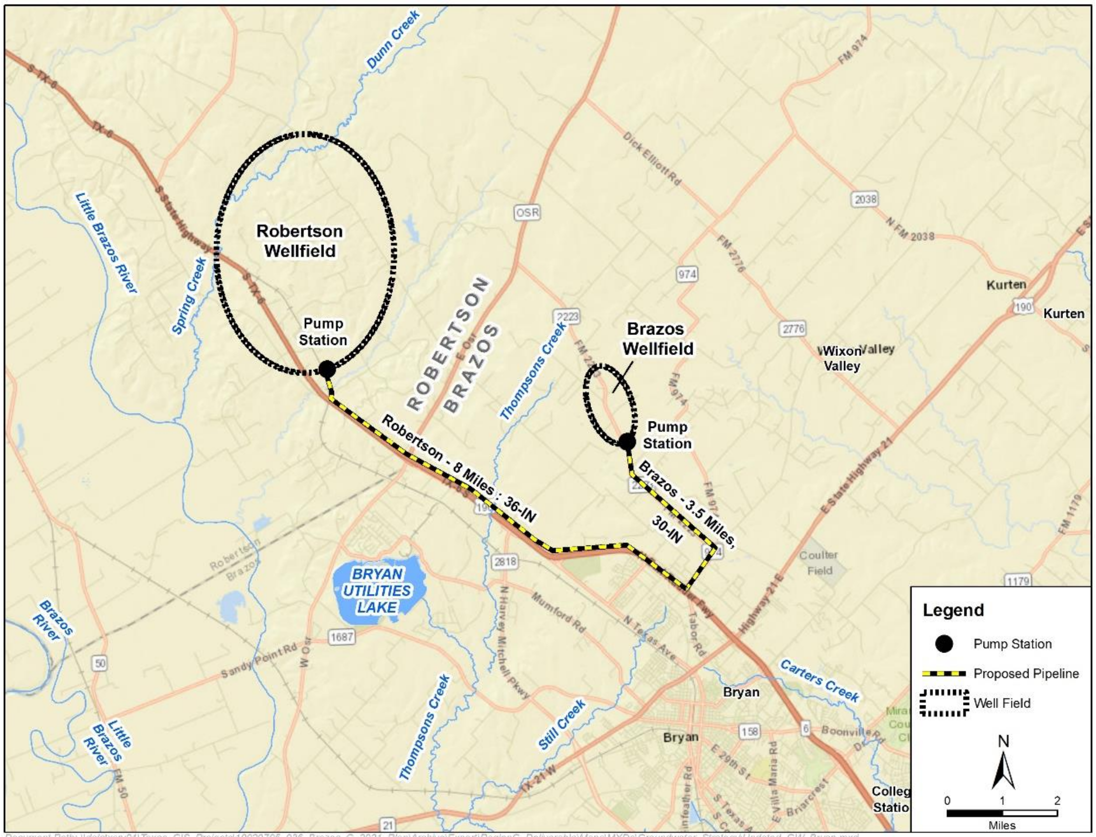
The City of Bryan (Bryan) currently supplies all of its customers with water from the Sparta and Simsboro (Carrizo-Wilcox) Aquifers in Brazos County. In 2070, Bryan has been allocated 19,398 acft/yr from the Carrizo-Wilcox Aquifer through this regional planning process. Bryan is projected to grow significantly over the planning period and the needs can no longer be met solely by groundwater within Brazos County. Estimated water needs for Bryan ranges from a surplus of about 215 acft/yr in 2020 to a shortage of about 17,161 acft/yr in in 2070. A review of the MAG for the Carrizo-Wilcox in Brazos County after existing supplies are accounted for shows availability from 7,501 acft.yr in 2020 increasing to about 19,893 acft/yr in 2070, accounting for the MAG Peak Factors adopted by Brazos G and approved by the Brazos Valley Groundwater Conservation District. A review of the MAG for the Carrizo-Wilcox in Robertson County after existing supplies are accounted for shows groundwater availability to increase from about 10,483 acft/yr in 2020 to about 12,175 acft/yr in 2070, with little availability in the Sparta Aquifer.

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 Formation wells northwest of the existing Bryan well field in Brazos County. The Robertson and Brazos well field expansions are expected to meet Bryan’s needs through 2070. Figure 5.1-1 illustrates the proposed regional groundwater system for Bryan.

5.1.2 Available Yield

The new production wells in Brazos and Robertson Counties produce water from the Simsboro Formation of the Carrizo-Wilcox Aquifer. 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 99,940 in 2020 and 114,024 acft/yr in 2070, respectively, accounting for the MAG Peak Factor in Brazos County. Three wells will be drilled with one as a standby well.

Figure 5.1-1. Locations of Planned Bryan Well Fields and Facilities



5.1.3 Environmental Issues

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 six 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*).

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

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[1] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.

[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.

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 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.

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Brazos and Robertson counties can be found at https://tpwd.texas.gov/gis/rtest/.

No USFWS designated critical habitat areas occur near the project area.

5.1.4 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 3 Simsboro wells in Robertson and Brazos counties, 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 3 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 17,474 acft/yr for the City of 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 5.1-1.

The Robertson County Simsboro wells were assumed to be 2,500 feet deep and have a peaking capacity of 4,000 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 of $523 per acft (Table 5.1-1) during debt service.

The Brazos County Simsboro wells were assumed to be 2,800 feet deep and have a peaking capacity of 4,000 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 $471 per acft (Table 5.1-2) during debt service.

5.1.5 Implementation Issues

Implementation of the City of Bryan Groundwater Strategies with well fields in Brazos and Robertson Counties could involve limited conflicts with other planned water supply projects. The development of groundwater in the Carrizo-Wilcox Aquifer in the Brazos G Area 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 regional 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 5.1-3, and the option meets each criterion.

Table 5.1-1. Cost Estimate Summary for Robertson County Well Field for Bryan

Item	Estimated Costs for Facilities
Primary Pump Station (17.8 MGD)	$5,365,000
Transmission Pipeline (36 in dia.,8.2 miles)	$15,128,000
Well Fields (Wells, Pumps, and Piping)	$15,184,000
Water Treatment Plant (17.8 MGD)	$1,009,000
TOTAL COST OF FACILITIES	**$36,686,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$12,084,000
Environmental & Archaeology Studies and Mitigation	$338,000
Land Acquisition and Surveying (132 acres)	$800,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$1,373,000
TOTAL COST OF PROJECT	**$51,281,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$3,608,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$303,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$134,000
Water Treatment Plant	$605,000
Pumping Energy Costs (7085455 kW-hr @ 0.08 $/kW-hr)	$567,000
TOTAL ANNUAL COST	**$5,217,000**
Available Project Yield (acft/yr)	9,973
Annual Cost of Water ($ per acft), based on PF=2	$523
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$161
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$1.61
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.50

Table 5.1-2. Cost Estimate Summary for Brazos County Well Field for Bryan

Item	Estimated Costs for Facilities
Primary Pump Station (13.4 MGD)	$2,285,000
Transmission Pipeline (30 in dia., 3.5 miles)	$5,328,000
Well Fields (Wells, Pumps, and Piping)	$16,405,000
Water Treatment Plant (13.4 MGD)	$760,000
TOTAL COST OF FACILITIES	**$24,778,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$8,406,000
Environmental & Archaeology Studies and Mitigation	$208,000
Land Acquisition and Surveying (74 acres)	$396,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$930,000
TOTAL COST OF PROJECT	**$34,718,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$2,443,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$217,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$57,000
Water Treatment Plant	$456,000
Pumping Energy Costs (4532762 kW-hr @ 0.08 $/kW-hr)	$363,000
TOTAL ANNUAL COST	**$3,536,000**
Available Project Yield (acft/yr)	7,501
Annual Cost of Water ($ per acft), based on PF=2	$471
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$146
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$1.45
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.45

Table 5.1-3. Comparison of Bryan Regional Groundwater Option to Plan Development Criteria

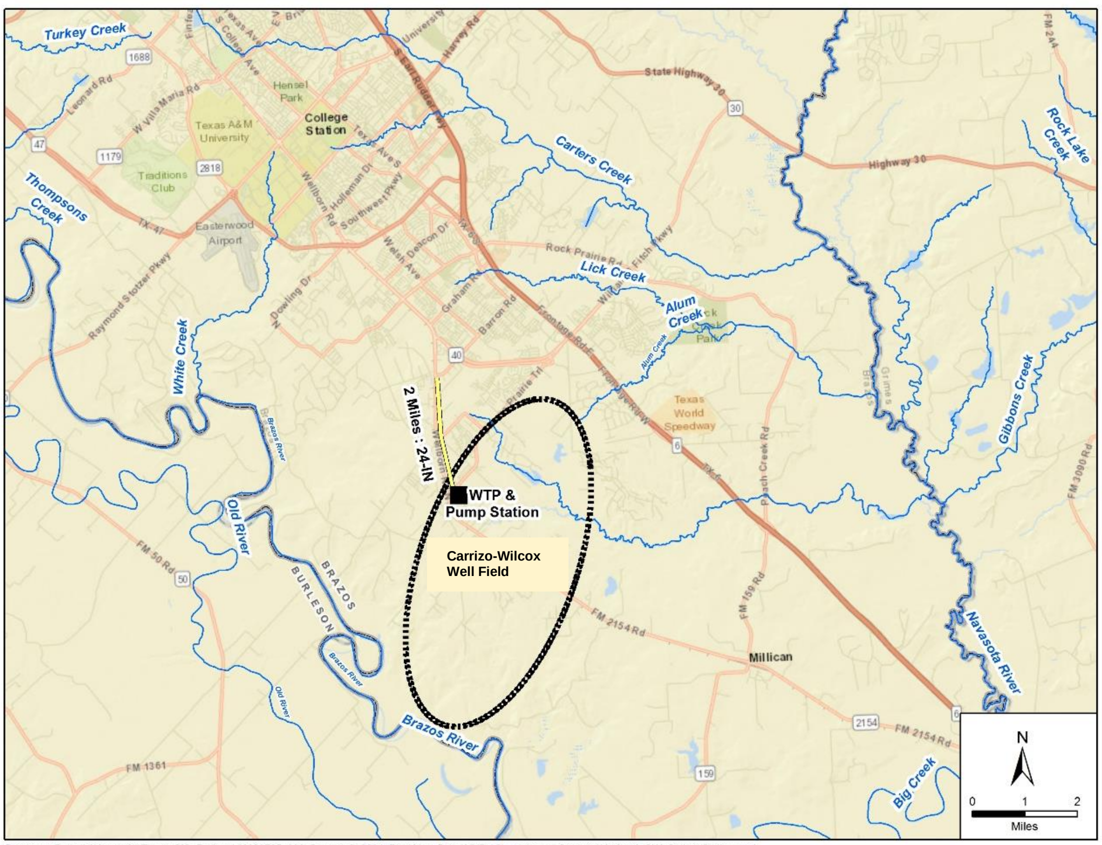
Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Meets Demands
2. Reliability	2. High
3. Cost	3. Low to Moderate
B. Environmental factors	
1. Environmental Water Needs	1. None
2. Habitat	2. None
3. Cultural Resources	3. None
4. Bays and Estuaries	4. None
5. Threatened and Endangered Species	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

5.2 College Station Groundwater Strategies

5.2.1 Description of Option

The City of College Station (College Station) currently supplies all its customers with groundwater from the Sparta, Carrizo and Simsboro Aquifers in Brazos County. In 2070, College Station has been allocated 16,264 acft of Carrizo-Wilcox Aquifer and 606 to 745 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 wells. Estimated water needs for College Station range from about 3,492 acft/yr in 2030 to 13,360 acft/yr in 2070. A review of the MAG for the Carrizo-Wilcox shows remaining availability ranging from 7,501 to 19,893 acft/yr from 2020 to 2070, but some of this availability will be utilized by other WUGs. The MAG peak factor increased the total availability of water in the Carrizo-Wilcox. The proposed project for College Station contains an ultimate build out of four 2,746 gpm Carrizo-Wilcox wells south of College Station. Figure 5.2-1 illustrates the proposed groundwater strategy for College Station.

Figure 5.2-1. Location of College Station Well Field and Facilities



Document Path: \\dalctxsrv01\Texas_GIS_Projects\10029705_036_Brazos_G_2021_Plan\Map_Docs\MXDs\Groundwater_Strategy\Updated_GW_CollegeStation.mxd

5.2.2 Available Yield

The Carrizo-Wilcox in Brazos County has modeled available groundwater supply which could be used by College Station. According to hydrogeologic information in the area, the Carrizo-Wilcox wells are capable of producing 2,746 gpm and are about 2,700 ft deep. The TWDB has determined that the Modeled Available Groundwater (MAG) for the Carrizo-Wilcox Aquifer in Brazos County is 57,167 acft/yr in 2070, but with the MAG peak factor the availability increases to 65,742 acft/yr. After allowance for existing groundwater supplies, the MAG constrained availability ranges between 6,962 acft/yr in 2020 to 19,354 acft/yr in 2070. To meet the 2070 needs for College Station, 9,796 acft/yr of this supply would be developed.

5.2.3 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 Carrizo-Wilcox Aquifer, a well collection pipeline, pump stations, a water treatment plant and a transmission pipeline. The well field will include a total of 4 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 ecoregion, which lies between the Blackland Prairie to the west and the Pineywoods to the east.[1] 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[2] 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. TPWD has recently produced more detailed vegetation maps called the Ecological Mapping Systems of Texas (EMST). The EMST shows the project area including Blackland Prairie disturbance or tame grassland and floodplain hardwood forest.

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

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[1] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.

[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.

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 activities. National Wetland Inventory (NWI) maps show a number of wetlands occurring along the transmission pipeline and within the well field area. These include numerous freshwater ponds, riverine wetlands, freshwater forested/shrub wetlands and a freshwater lake. Two surface waters (The Brazos River [TCEQ Segment 1242] and Carters Creek [TCEQ Segment 1209C]) were identified on the TCEQ Surface Water Quality Viewer[3] within the proposed project area, or within 5 miles. Carters Creek is shown as impaired on the Surface Water Quality Viewer, however, Segment 1209C was not listed in either the 2018 or draft 2020 303(d) List. 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. Coverage under a Nationwide Permit or coordination with the U.S. Army Corps of Engineers would be required for construction within waters of the U.S.

Concerns associated with the development of the well field include changes in water levels in the Carrizo-Wilcox 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 Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Brazos County can be found at https://tpwd.texas.gov/gis/rtest/.

According to the Information for Planning and Consultation (IPaC) website[4] maintained by the U.S. Fish & Wildlife Service (USFWS), the Whooping Crane, Texas fawnsfoot, and Navasota ladies-tresses need to be considered for the proposed project. The Least Tern, Piping Plover, and Red Knot were also mentioned, but only need to be considered for wind energy projects. The Whooping Crane could be a migrant through the project area, but no adverse impacts to the Whooping Crane would be expected. The Texas fawnsfoot is found in rivers and larger streams and Navasota Ladies-tresses is found on

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[3] TCEQ, Surface Water Quality Viewer. Accessible online https://tceq.maps.arcgis.com/apps/webappviewer/index.html?id=b0ab6bac411a49189106064b70bbe778 accessed January 13, 2020.

[4] USFWS, 2020. Information for Planning and Consultation. Accessed online https://ecos.fws.gov/ipac/location/2CDHNRFRWZBEFN2BCFV527IIXM/resources January 13, 2020.

sandy loams in openings in post oak woodlands. No USFWS designated critical habitat areas occur near the project area. If this strategy is selected then surveys for potential habitat for these species should be initiated and coordination with USFWS for impacts to listed species.

According to the Texas Natural Diversity Data (TXNDD) obtained from the TPWD, there were 56 documented occurrences state listed threatened, endangered, and SGCN species within 5 miles of the project area these included occurrences of the following endangered species: Houston Toad, sharpnose shiner, and Navasota ladies-tresses; candidate species: smooth pimpleback and Texas fawnsfoot; state listed species: timber rattlesnake; SGCN: Strecker's chorus frog, southern crawfish frog, chub shiner, silverband shiner, eastern spotted skunk, plains spotted skunk, branched gay-feather, bristle nailwort, Florida pinkroot, Texas meadow-rue, small-headed pipewort, and Texas sunnybell.

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 identified two cemeteries, Wellborn Cemetery (approximately 300 feet east of the proposed pipeline) and Minter Springs Cemetery located approximately 0.6 mile west of the proposed well field area. No National Register Properties, National Register Districts, State Historic Sites, historical markers, or other cemeteries are located within a one-mile buffer of the proposed transmission pipeline route or well field area. 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 review of the project area should be undertaken to more accurately determine 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. municipality), they will be required to comply with the Texas Antiquities Code prior to 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, 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.

5.2.4 Engineering and Costing

The envisioned Carrizo-Wilcox groundwater project for the College Station will be developed in phases as necessary to meet growing needs. At ultimate build out, in 2050, there will be 4 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 and cooling before distribution. When completed, the new well field will have a maximum capacity of 9,796 acft/yr for College Station. The major facilities required for this strategy are:

- Carrizo-Wilcox wells
- Well field collection pipeline(s)
- Transmission pipeline/pump stations
- Storage tanks for cooling
- Water Treatment Plant for disinfection and cooling.

The approximate locations of these facilities are displayed in Figure 5.2-1.

The Carrizo-Wilcox wells are estimated to be 2,700 ft deep and have an estimated capacity of 2,746 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 Carrizo-Wilcox well field to College Station will have a unit cost that ranges from to $513 per acft/yr in 2020 to $198 per acft/yr after debt service.

5.2.5 Implementation Issues

Implementation of the Local Groundwater Plan for College Station with a Carrizo-Wilcox option could involve limited 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:

- Acquisition of water rights from landowners,
- 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 5.2-2, and the option meets each criterion.

Table 5.2-1. Cost Estimate Summary for Carrizo-Wilcox Well Field for College Station

Item	Estimated Costs for Facilities
Primary Pump Station (17.5 MGD)	$4,023,000
Transmission Pipeline (36 in dia., 2.2 miles)	$5,194,000
Well Fields (Wells, Pumps, and Piping)	$16,517,000
Storage Tanks (Other Than at Booster Pump Stations)	$4,445,000
Water Treatment Plant (17.5 MGD)	$992,000
TOTAL COST OF FACILITIES	**$31,171,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$10,650,000
Enviromental & Archaeology Studies and Mitigation	$271,000
Land Acquisition and Surveying (71 acres)	$646,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$1,176,000
TOTAL COST OF PROJECT	**$43,914,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$3,090,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$262,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$101,000
Water Treatment Plant	$595,000
Pumping Energy Costs (12252430 kW-hr @ 0.08 $/kW-hr)	$980,000
TOTAL ANNUAL COST	**$5,028,000**
Available Project Yield (acft/yr)	**9,796**
Annual Cost of Water ($ per acft), based on PF=2	**$513**
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	**$198**
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	**$1.57**
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	**$0.61**

Table 5.2-2. 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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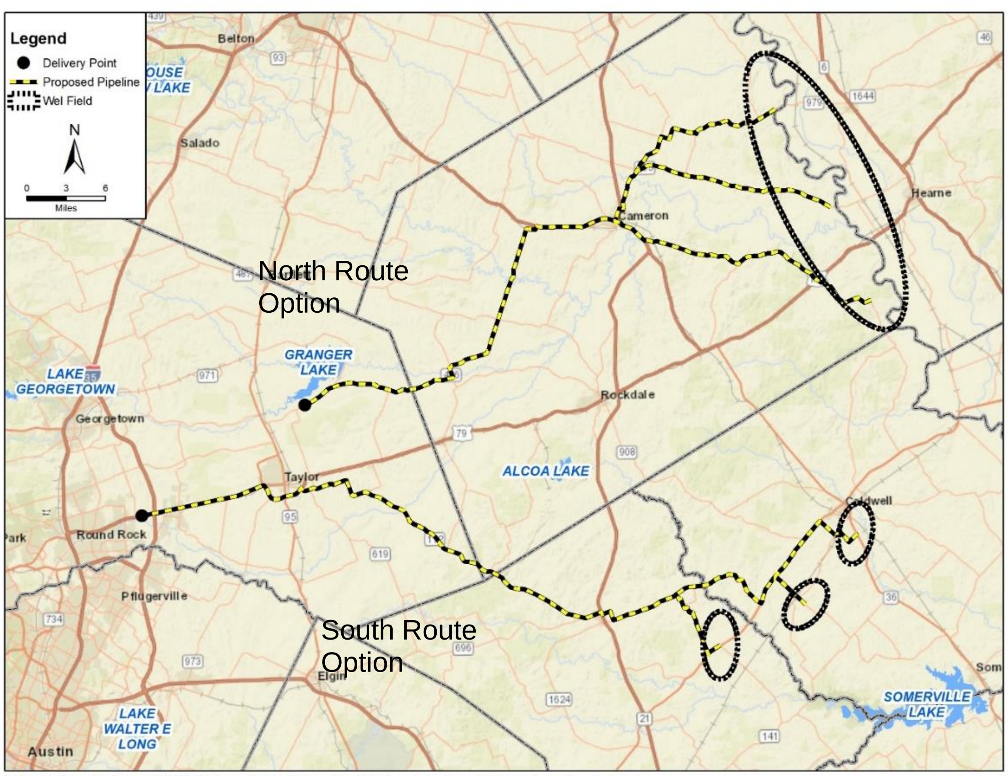
5.3 Williamson County Groundwater Strategies

5.3.1 Description of Option

Williamson County currently meets approximately 13 percent of municipal demands with groundwater and 87 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 162,000 acft/yr of unmet needs and limited groundwater supplies. To meet some of the future needs in Williamson County, three well fields are proposed in Milam, Burleson and Lee Counties. At build-out, the Burleson County well field project includes nine Sparta Aquifer wells and 23 250 gpm Yegua Jackson wells. The Lee County well field at buildout includes nine 1,000 gpm Carrizo-Wilcox Aquifer wells, and two 500 gpm Sparta Aquifer wells to supplement the supply. . The Milam County Well field will have wells ranging from 400-1,000 gpm for over 80 wells in the Brazos River Alluvium Aquifer. Conversations with local groundwater conservation districts indicated that availability from the Brazos River Alluvium Aquifer likely is overstated. Raw water pipelines from the multiple well fields will drop off at two locations: one south and one north. The south drop off location is near the I-30 corridor which is assumed there will be infrastructure eventually to take the supply and deliver it to the areas with needs. The north drop off is near the BRA East Williamson County Water Treatment Plant near Lake Granger. After treatment, pump stations and pipelines will deliver the water through a regional system to meet needs. Figure 5.3-1 illustrates the proposed Regional Groundwater System for Williamson County.

Figure 5.3-1. Location of Regional Williamson County Well Fields and Facilities



5.3.2 Available Yield

There is groundwater available within the MAG in Burleson, Lee, and Milam Counties. Burleson County has availability in the Sparta Aquifer ranging from 750 acft/yr to 5,239 acft/yr in 2070 and from the Yegua Jackson Aquifer from 7,500 to 9,300 acft/yr. Lee County has availability in the Carrizo-Wilcox Aquifer ranging from 6,476 acft/yr to 4,279 acft/yr from 2020 to 2070 and Sparta Aquifer from 1,211 acft/yr from 2020 to 1,222 acft/yr from 2070. Milam County has availability in the Brazos River Alluvium Aquifer from 43,157 acft/yr to 41,951 acft/yr, although this volume may be overstated. According to hydrogeologic maps of the area, the Carrizo-Wilcox Aquifer wells are capable of producing 1,500 gpm and are 1,500 ft deep.

5.3.3 Environmental Issues

The Regional Groundwater for Williamson County Project involves the development of three new well fields, one each in Milam, and Burleson counties, and two in Lee County, associated well collection pipelines and pumps, two new drop-off stations (one north and one south), and a shared distribution pipeline system. The Burleson County well field will include 20 Sparta wells, the Lee County well field will include three Carrizo wells and five Sparta wells. The Milam County well field will include over 80 wells in the Brazos River Alluvium Aquifer. 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.[1] 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 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

[1] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.

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. 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, 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 creeks crossed by the raw water pipelines 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 three 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 three project well field areas include several tributaries of Yegua Creek in Lee County, Davidson Creek in Burleson County, and Little River, Pond Creek, and the Brazos River in Milam County.

The Draft 2018 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 several segments within 5 miles of project components, including portions of Brushy Creek, Willis Creek, Little Creek, Big Elm Creek, Mud Creek, Pin Oak Creek, Spring Creek, Davison Creek, and Middle Yegua Creek for elevated bacteria levels. Davidson Creek was also listed for depressed dissolved oxygen. These listed segments were 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 or 5c, which means additional information needs to be collected or evaluated for one or more parameters prior to selecting a management strategy.

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Burleson, Lee, Milam and Williamson counties can be found at https://tpwd.texas.gov/gis/rtest/.

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 four federally-listed species, the sharpnose shiner (*Notropis oxyrhynchus*), smooth pimpleback (*Quadrula houstonensis*), Texas fawnsfoot (*Trunchilla macrodon*), and Navasota ladies' tresses (*Spiranthes parksii*). The sharpnose shiner is listed as endangered and was documented within the proposed Milam County well field in the Brazos River. The smooth pimpleback and Texas fawnsfoot were listed as a federal candidate species and state threatened; these species were documented within the proposed Milam County well field and along the Little, Brazos, and San Gabriel Rivers in Milam and Williamson counties. Navasota ladies' tresses are federal and state listed endangered; this species was documented near the Milam County well field south of the southernmost pipeline in Milam County. The timber (canebrake) rattlesnake (*Crotalus horridus*) and false spike mussel (*Fusconaia mitchelli*) are state listed as threatened species. The timber (canebrake) rattlesnake was documented in Lee County within two miles of the proposed pipeline and the false spike mussel was documented within two miles of the proposed project pipelines in the San Gabriel and Little rivers in Milam and Williamson counties. . Several other species of concern were identified within two miles of the proposed well fields and pipelines. Species of concern are considered to be rare, but are not protected by USFWS or TPWD.

Suitable habitat for federal or state listed species may exist within the project area, however, significant impacst to these species would not be 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 two National Register Properties (the Thomas & Mary Kraitchar House in Burleson County and Dr. Nathan & Lula Cass House in Milam County), one National Register Historic District (the Hutto Commercial Historic District in Williamson County), and 13 cemeteries located within 500 feet of the proposed pipeline route or well field areas. 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.

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.

5.3.4 Engineering and Costing

The envisioned Milam, 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 nineSparta Aquifer wells and 23, 250 gpm Yegua Jackson wells. The Lee County well field at buildout includes nine 1,000 gpm Carrizo-Wilcox Aquifer wells, and two 500 gpm Sparta Aquifer wells to supplement the supply. The Milam County Well field will have wells ranging from 400-1,000 gpm for over 80 wells in the Brazos River Alluvium Aquifer. 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, the well fields are started at the beginning of the planning period to meet 2020 needs. The shared water treatment plant will provide disinfection and cooling before the water enters the shared distribution system. When completed, the Milam County well field will have a maximum capacity of 41,300 acft/yr and the Burleson and Lee county well field will have a maximum capacity of 10,622 acft/yr. These capacities utilize nearly all of the remaining groundwater availability under the MAG accounting for projected local demands. The combined capacity in 2070 for the strategy is 51,922 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 5.3-1. For the Burleson County component of this Regional Groundwater Strategy, approximately 80 percent of the supply will be coming from the Brazos Alluvium Aquifer wells and 20 percent from the Carrizo-Wilcox and Sparta Aquifers. Power costs were estimated by calculating the horsepower needed to operate the wells and pump the water from the well fields 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 and Lee county well field excluding the shared pipeline and associated pump stations will have a unit cost that ranges from $739 per acft/yr to $1,670 per acft/yr (Table 5.3-1).

For the Milam County component 100 percent of the supply will be coming from the Brazos River Alluvium Aquifer. 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 Milam County well field excluding the shared pipeline and associated pump stations will have a unit cost that ranges from $536 per acft/yr to $1,507 per acft/yr (Table 5.3-2).

5.3.5 Implementation Issues

Implementation of the Regional Groundwater Strategy for Williamson County utilizing Carrizo-Wilcox Aquifer supplies in Burleson and Lee Counties involve potential conflicts with other planned water supply projects. MAG estimates for the Brazos River Alluvium Aquifer likely are overstated and may not be considered a reliable supply.

The development of groundwater 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 5.3-3, and the option meets each criterion.

Table 5.3-1. Cost Estimate Summary for Burleson and Lee County Well Fields (South Option)

Item	*Estimated Costs for Facilities*
Primary Pump Station (21.8 MGD)	$32,347,000
Transmission Pipeline (36 in dia., 878,918 ft and 48 in.)	$226,777,000
Well Fields (Wells, Pumps, and Piping)	$35,573,000
Water Treatment Plant (9.5 MGD)	$539,000
TOTAL COST OF FACILITIES	$295,236,000
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$91,994,000
Environmental & Archaeology Studies and Mitigation	$4,699,000
Land Acquisition and Surveying (2104 acres)	$11,979,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$11,108,000
TOTAL COST OF PROJECT	$415,016,000
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$29,201,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$2,624,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$809,000
Water Treatment Plant	$324,000
Pumping Energy Costs (100,520,163 kW-hr @ 0.08 $/kW-hr)	$8,042,000
TOTAL ANNUAL COST	$41,000,000
Available Project Yield (acft/yr)	23,250
Annual Cost of Water ($ per acft), based on PF=1	$1,763
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$507
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$5.41
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$1.56
Available Project Yield (acft/yr)	23,250
Annual Cost of Water ($ per acft), based on PF=1	$1,763
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$507

Table 5.3-2. Cost Estimate Summary for Milam County Well Field (North Option)

Item	*Estimated Costs for Facilities*
Primary Pump Station (38.8 MGD)	$36,466,000
Transmission Pipeline (48 in dia., 159 miles)	$377,499,000
Well Fields (Wells, Pumps, and Piping)	$4,304,000
TOTAL COST OF FACILITIES	**$418,269,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$127,519,000
Environmental & Archaeology Studies and Mitigation	$4,221,000
Land Acquisition and Surveying (1022 acres)	$4,583,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$15,252,000
TOTAL COST OF PROJECT	**$569,844,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$40,095,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$3,818,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$912,000
Pumping Energy Costs (217,730,069 kW-hr @ 0.08 $/kW-hr)	$17,418,000
Purchase of Water (acft/yr @ $/acft)	$0
TOTAL ANNUAL COST	**$62,243,000**
Available Project Yield (acft/yr)	41,300
Annual Cost of Water ($ per acft), based on PF=1	$1,507
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$536
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$4.62
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$1.65

Table 5.3-3. 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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6 System Operations

6.1 BRA System Operations

6.1.1 Description of Option

In 2016 the Brazos River Authority (BRA) obtained Water Use Permit No. 5851 (System Operations Permit) from the Texas Commission on Environmental Quality (TCEQ) for the diversion, impoundment, and use of (1) previously unappropriated state water in the Brazos River Basin, and (2) BRA owned return flows discharged into state watercourses not already authorized for use by other entities. The water right currently authorizes a maximum combined diversion of up to 334,345 acft/yr. Diversions are authorized in 40 individual stream segments basin-wide, with each stream segment assigned a specific maximum annual diversion amount. If the Comanche Peak Nuclear Power Plant is expanded and Allens Creek Reservoir is constructed, the authorized maximum combined diversion amount would increase to 421,177 acft/yr and the individual stream segment maximum diversion amounts would increase in accordance with the permit terms and special conditions.

6.1.2 Available Yield

The BRA System Operations appropriation creates a considerable amount of supply to the Brazos River Basin for use in the Brazos G Area and in adjacent regions where the BRA supplies water, most notably Region H (Houston area).

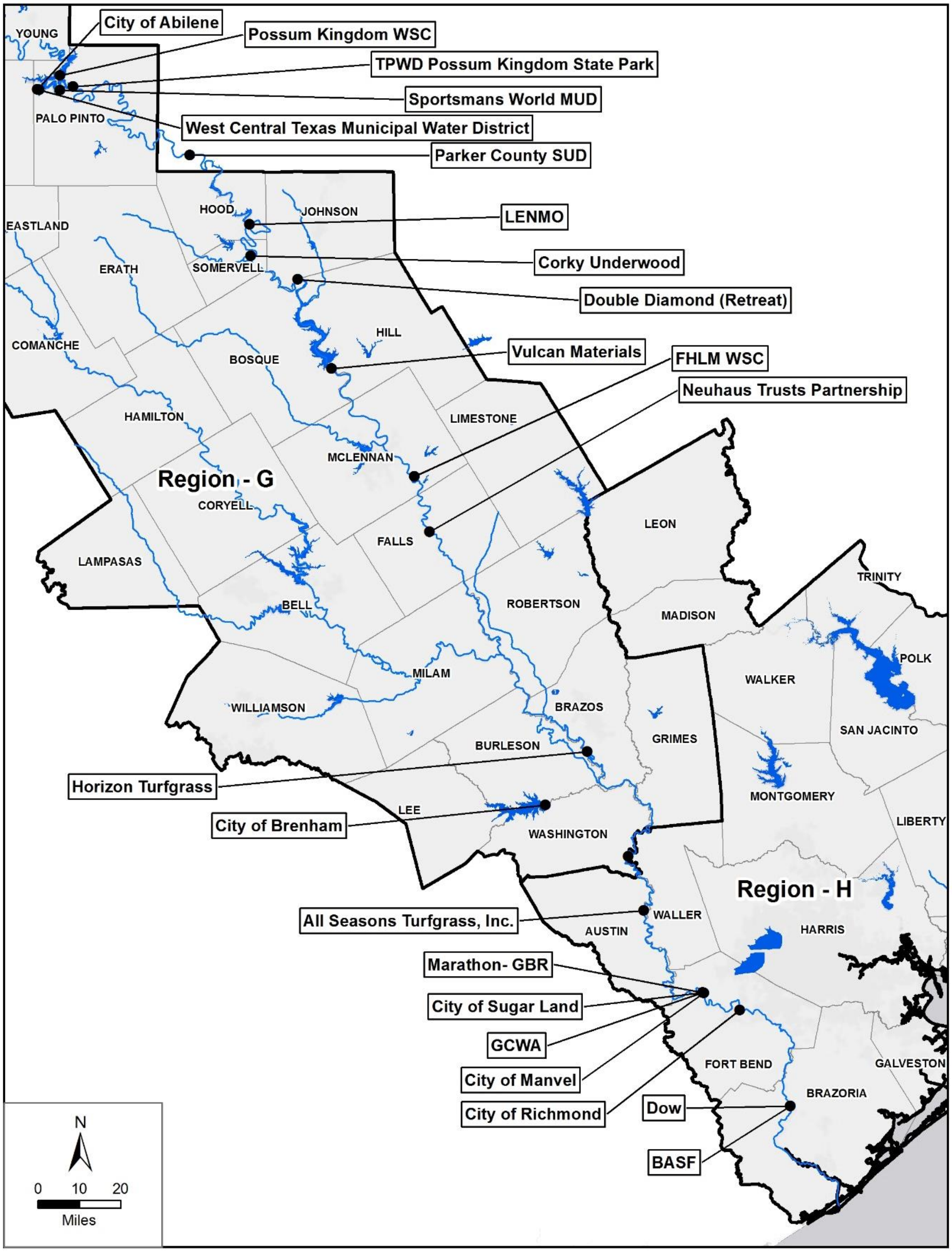
The System Operations appropriation has a priority date senior to environmental flow standards associated with Senate Bill 3 (SB3). However, permit conditions still require authorized diversions to be subject to these environmental flow requirements. As a result of the relatively junior priority of the permit and environmental flow requirements, diversions are considered non-firm and must be backed up with stored water in BRA reservoirs. Because the BRA currently holds multiple contracts to supply water to cities, districts, irrigators and industry throughout the Brazos River Basin, not every BRA reservoir can contribute storage or releases to every contractual diversion location. Because of these constraints, the BRA has determined that 106,031 acft/yr of additional diversions under the System Operations permit can be made firm through reservoir operations.

Table 6.1-1 lists the entities the BRA plans to provide additional firm water supplies to under the system operations strategy and Figure 6-1 provides the location of diversions for each of the entities. Eleven of these entities are in the Brazos G Area and are planned to receive 15,211 acft/yr of firm supply for municipal, irrigation, and mining use. Of these eleven entities, seven have existing contracts with the BRA. The Neuhaus Trust Partnership, Corky Underwood, FHLM WSC, and TPWD Possum Kingdom State Park are new contractual entities.

Table 6.1-1. Supplies from BRA System Operations (acft/yr)

Customer	Diversion County	Region	Use Type	Volume (acft/yr)
Double Diamond (Retreat)	Johnson	G	IRR	619
West Central Texas MWD	Palo Pinto	G	IRR	774
LENMO	Hood	G	IRR	774
TPWD Possum Kingdom State Park	Palo Pinto	G	MUN	15
Sportsman's World MUD	Palo Pinto	G	MUN	290
City of Abilene	Palo Pinto	G	MUN	7,737
Parker County SUD	Parker	G	MUN	774
Possum Kingdom WSC	Palo Pinto	G	MUN	1,934
Corky Underwood	Somervell	G	MIN	54
Neuhaus Trust Partnership	Falls	G	IRR	309
FHLM WSC	McLennan	G	MUN	1,934
Horizon Turfgrass	Brazos	G	IRR	348
City of Brenham	Washington	G	MUN	774
Vulcan Materials	Bosque/Hill	G	MIN	387
Brazos G Total				**16,723**
All Seasons Turfgrass, Inc.	Austin/Waller	H	IRR	90
City of Sugar Land	Fort Bend	H	MUN	10,279
City of Richmond	Fort Bend	H	MUN	2,773
City of Manvel	Fort Bend	H	MUN	3,731
Dow	Brazoria	H	IND	15,473
BASF	Brazoria	H	IND	3,868
Marathon-GBR	Fort Bend	H	IND	5,700
GCWA	Fort Bend	H	MUN, IND, IRR	36,362
Region H Total				**78,276**
TPWD Water Trust	–	Basin wide	–	6,035
GM Reserve	–-	Basin wide	–	4,997
Total System Operations Supply				**106,031**

Figure 6-1. Diversion Location of Entities Receiving BRA System Operations Supplies



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6.1.3 Environmental Issues

Because the BRA reservoirs already exist, the BRA System Operations strategy will only require environmental permits for the infrastructure needed to divert and deliver supplies to the place of use. A summary of environmental issues for the BRA System Operations is presented in Table 6.1-2.

Table 6.1-2. Environmental Issues: BRA System Operations

Issue	Description
Implementation Measures	Each entity receiving the supply requires 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.
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.

6.1.4 Engineering and Costing

Table 6.1-3 provides a summary of costs for the entities planned to receive system operations supplies. Costs included in the BRA System Operations strategy are for the purchase of water from BRA and required infrastructure to divert, treat and deliver water to location of use.

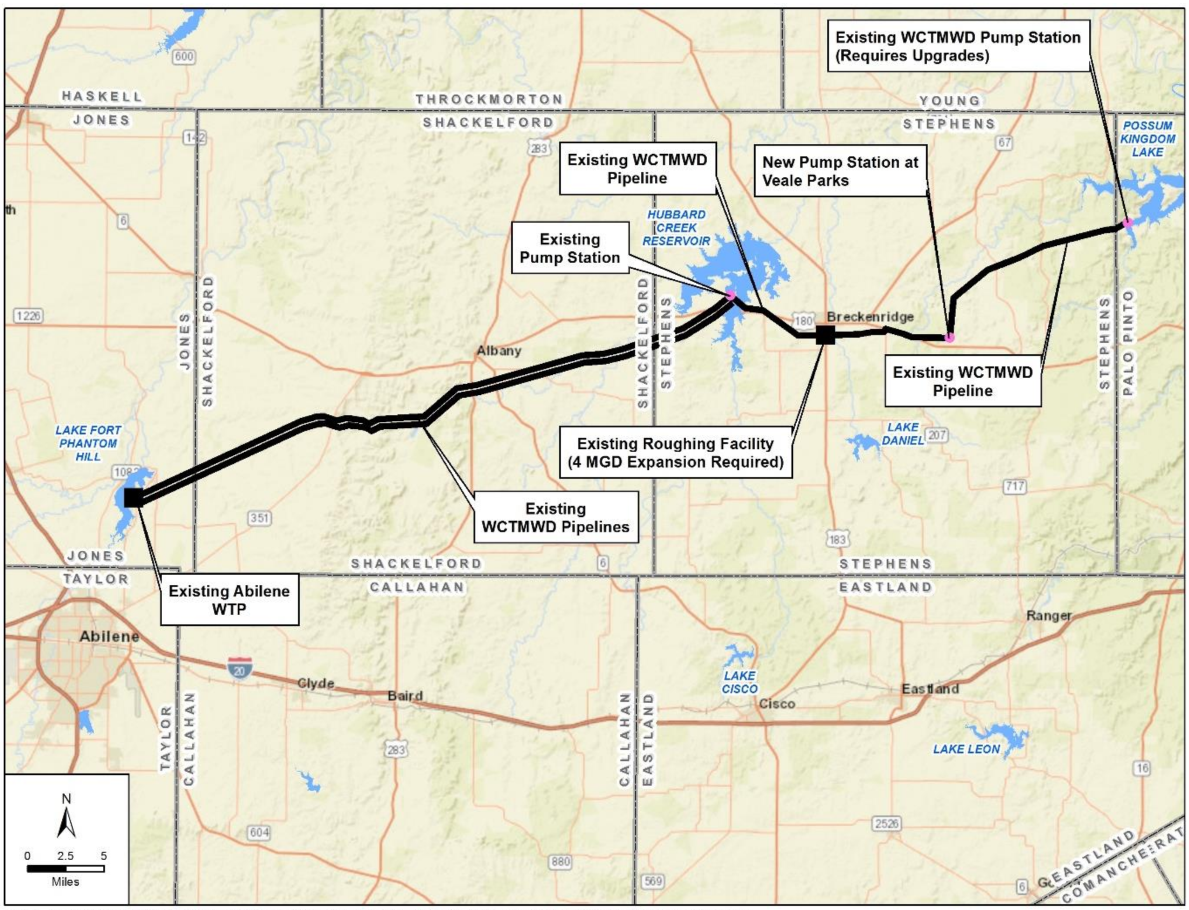
All of the entities planned to receive System Operations supplies with the exception of the FHLM WSC are able to utilize existing infrastructure or do not require large scale infrastructure investments due to the relatively small supply amounts for irrigation and mining purposes (Possum Kingdom State Park, Cork Underwood, and Neuhaus Trusts Partnership). As a result, no project costs are assumed for these entities and the annual cost of water is equal to the cost of purchasing water from BRA.

The 2016 Plan included a recommended strategy for Abilene to purchase BRA water from Possum Kingdom Reservoir. In response to the recent drought, Abilene implemented the strategy and contracted with BRA for the purchase of 11,681 acft/yr of water from Possum Kingdom Reservoir. The West Central Texas Municipal Water District (WCTMWD) purchased the intake and transmission pipeline known as the West Central Brazos Water Distribution System (formerly known as the Kerr-McGee Pipeline) from the BRA and Abilene funded improvements to the intake and the transmission system as a part of a water transportation agreement with WCTMWD. Abilene completed additional improvements to connect the transmission system to a new roughing facility located in Breckenridge and constructed a transmission pipeline from this facility to the dual Hubbard

Creek Reservoir (HCR) transmission pipelines which deliver HCR water to Abilene. Figure 6-2 shows the location of the existing pipelines and roughing facility.

As currently configured, Abilene has the capability of taking the current 11,681 acft/yr of contracted water and providing roughing treatment to reduce TDS to levels comparable with HCR supplies. The Possum Kingdom supplies can then be delivered into Abilene's conventional water treatment plants. Accommodating the additional 7,737 acft/yr of System Operations supplies will require improvements to the pump station at Possum Kingdom Reservoir, the addition of a pump station at Veal Parks (Figure 6-2), and a 4 MGD expansion of the roughing facility to treat and blend a portion of the supplies to reduce TDS to levels comparable with HCR supplies. Estimated costs for the improvements required for roughing treatment and delivery of the System Operations supply are based on contractor pricing provided during the initial improvement phase to deliver the current 11,681 acft/yr of contracted water. These estimated costs are provided in Table 6.1-3.

Figure 6-2. Location Map of Possum Kingdom Reservoir to Abilene Delivery System



The FHLM WSC will require a new treatment plant, off-channel storage, and transmission pipelines to deliver treated supplies to the various entities that are participating members of FHLM WSC. Several of these entities have experienced arsenic concentration violations in their existing groundwater supplies and plan to use BRA System Operations supplies to blend with groundwater supplies to reduce arsenic concentrations. Cost estimates for the required infrastructure were obtained from 2015 FHLM Regional Water Facility Planning Study and indexed to September 2018 dollars.

Table 6.1-3. Cost Summary for BRA System Operations Supply

Entity	Supply (acft/yr)	Capital Cost	Total Project Cost	Annual Cost	Unit Cost	
					$/acft	$/kgal
City of Abilene[1,2,3]	6,890	$6,483,000	$8,993,000	$2,391,000	$347	$1.06
Corky Underwood	54	–	–	$4,131	$76.50	$0.23
Double Diamond (Retreat)	619	–	–	$47,354	$76.50	$0.23
FHLM WSC[4]	1,934	$68,481,000	$95,792,000	$8,696,000	$4,496	$13.80
LENMO	774	–	–	$59,211	$76.50	$0.23
Neuhaus Trust Partnership	309	–	–	$23,639	$76.50	$0.23
Parker County SUD	774	–	–	$59,211	$76.50	$0.23
Possum Kingdom WSC	1,934	–	–	$147,951	$76.50	$0.23
Sportsman's World MUD	290	–	–	$22,185	$76.50	$0.23
TPWD Possum Kingdom State Park	12	–	–	$918	$76.50	$0.23
West Central Texas MWD	774	–	–	$59,211	$76.50	$0.23

[1]Abilene anticipates 11% of the BRA System Operations supply of 7,737 acft/yr will be lost to brine reject during the treatment process, resulting in a usable supply of 6,890 acft/yr in 2020. This supply is expected to be further reduced to 5,230 acft/yr beginning in 2050.
[2] Consistent with the City of Abilene's Purpose and Need memorandum, BRA supplies to Abilene are assumed to be reduced by 24% in 2050 to 5,230 acft/yr to account for reductions in supply due to future more severe droughts.
[3]Estimated costs based on contractor pricing provided during the initial improvement phase to deliver the current 11,681 acft/yr of contracted water to Abilene.
[4]Costs obtained from 2015 FHLM Regional Water Facility Planning Study.

6.1.5 Implementation Issues

Because the BRA has already obtained the necessary water right permits and will not need to construct any new facilities, there are no implementation issues for BRA. However, it may be necessary for one or more of the contract entities receiving System Operations supplies to obtain these permits for the construction of facilities to divert and transmit water.

- 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;
- TPWD Sand, Gravel, and Marl Permit for construction in state owned streambeds;
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.
- NPDES Storm Water Pollution Prevention Plan;
- GLO easement for use of the state-owned streambed; and
- Section 404 certification from the TCEQ related to the Clean Water Act.

Permitting, at a minimum, will require these studies:

- Habitat mitigation plan;
- Environmental studies of potential impact on endangered species; and
- 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 6.1-4, and the option meets each criterion.

Table 6.1-4. 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. Low
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, irrigation, and mining shortages
F. Requirements for Interbasin Transfers	None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

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7 Conjunctive Use

7.1 Lake Granger Augmentation

7.1.1 Description of Option

Rapid population growth and development in Williamson County require additional water supplies throughout the planning period. 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 could add up to 48,949 acft/yr (2,684 from Phase I plus up to 46,265 acft/yr from Phase II[1] in 2070) by augmenting the long-term firm yield of Lake Granger with groundwater pumped from the Trinity Aquifer (Phase I) and the Carrizo-Wilcox Aquifer or another aquifer (Phase II). 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 or another aquifer in areas east of Williamson County, such as Milam, Lee and/or Burleson Counties and be blended with treated Lake Granger water. 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 I and II are depicted in Figure 7.1-1 and Figure 7.1-2, 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].

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 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. A Lake Granger ASR project is evaluated in Chapter 8 of Volume II.

7.1.2 Available Yield

Phase I – Conjunctive Use with the Trinity Aquifer

Phase I (Figure 7.1-1) would consist of one or more wells constructed in the Trinity Aquifer in eastern Williamson County, which would be blended with treated water from Lake Granger. Water from the Trinity Aquifer in the Lake Granger area is relatively high in

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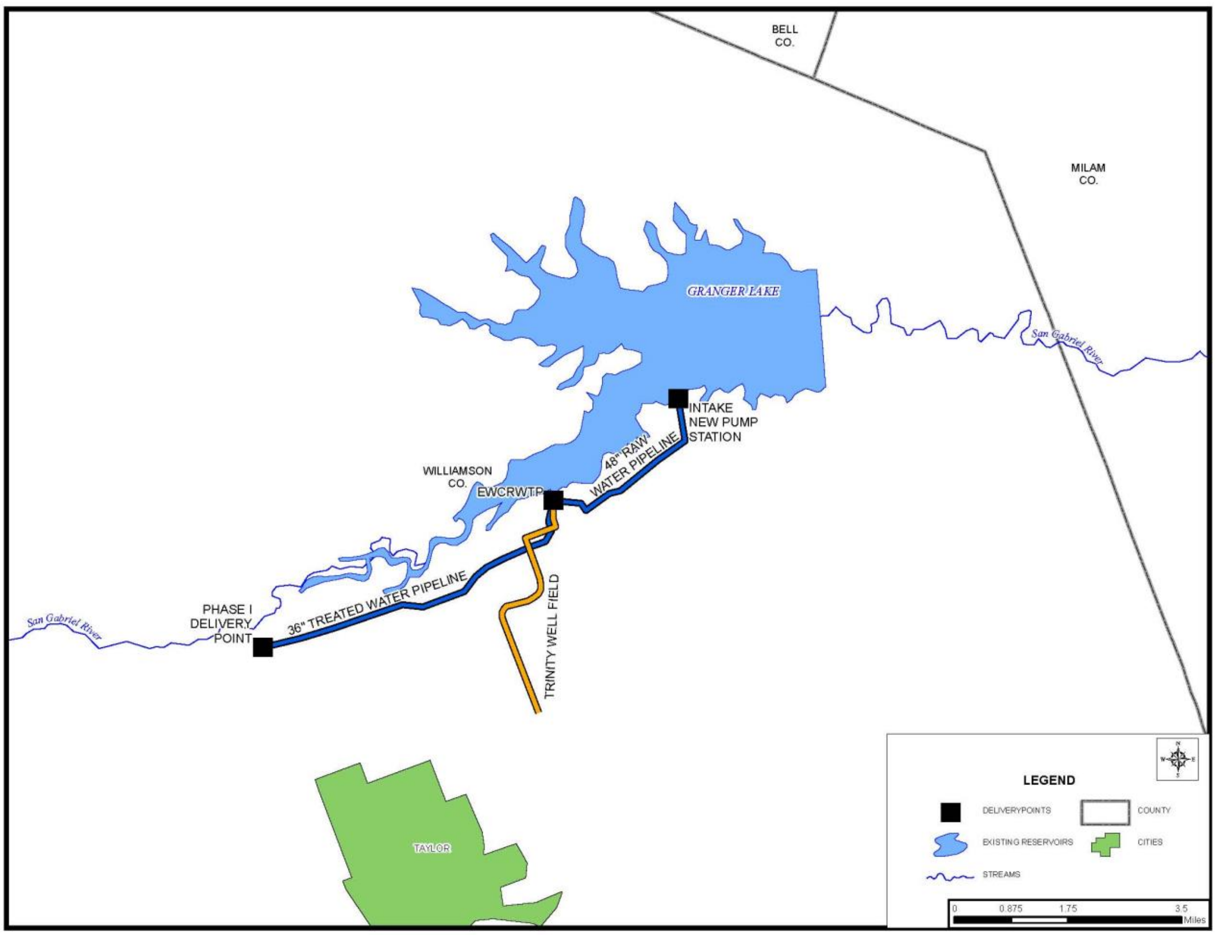
[1] Parsons Brinkerhoff Quade and Douglas, Inc. and Espey Consultants: Williamson County Water Supply Plan Groundwater Procurement, Implementation and Costs, prepared for the Brazos River Authority, July 2005.

[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.

dissolved solids and a ratio of 3 parts Lake Granger water to 1 part Trinity Aquifer water should meet drinking water standards; however, water from the Trinity Aquifer in Williamson County is fully allocated in Brazos G to meet existing demands and no Managed Available Groundwater (MAG) remains for use by this project. For purposes of preparing costs of the required infrastructure for this analysis, it is assumed that 2,700 acft/yr of supply from the Trinity Aquifer could be made available to Phase I of this project, although the recommended strategy will not include this supply and will not include the Phase 1 infrastructure. Note that the BRA has already constructed a Trinity well as a first step in developing this supply. Assuming sufficient MAG were made available, Phase 1 would supply 2,700 acft/yr in all planning decades.

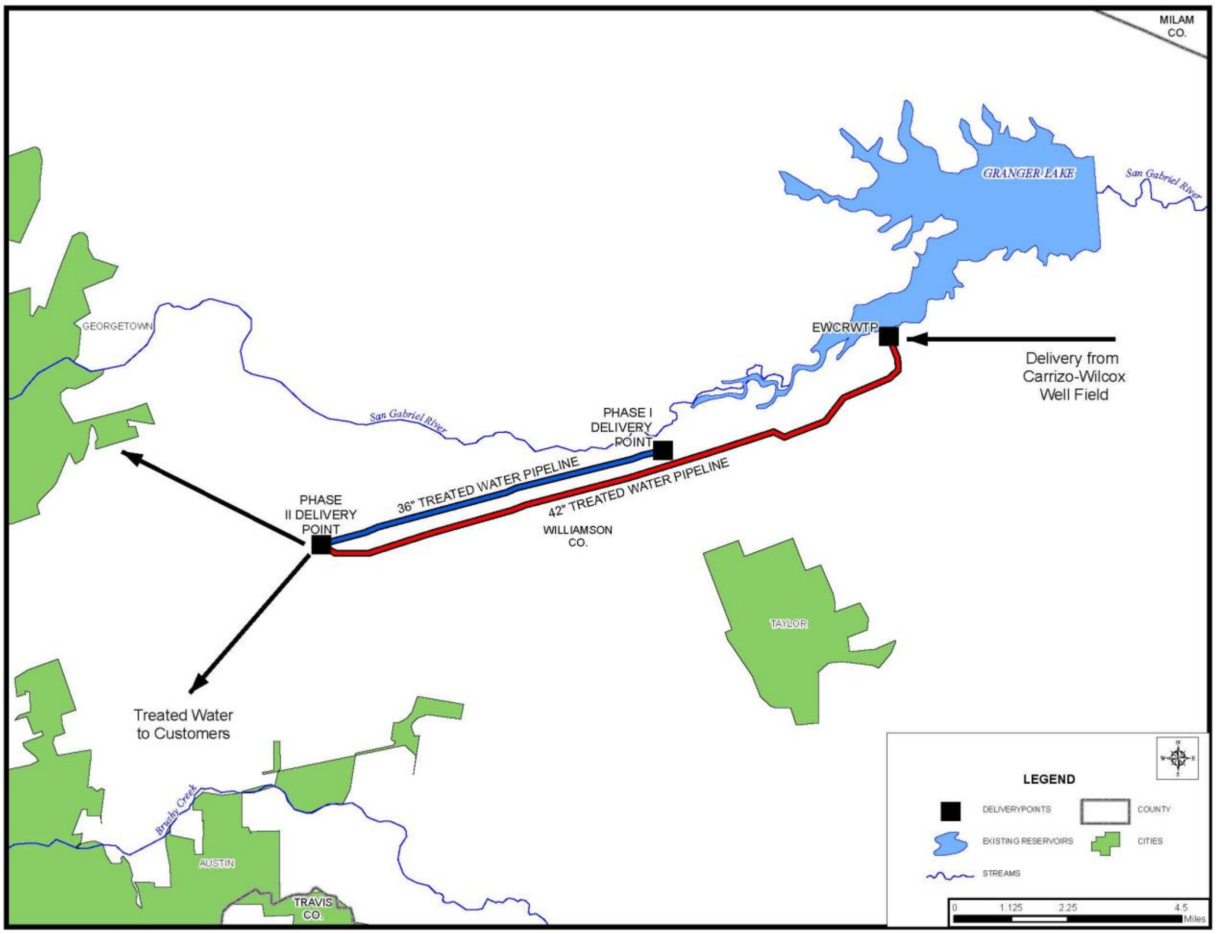
Figure 7.1-1. Phase I – Conjunctive Use with the Trinity Aquifer



Phase II – Conjunctive use with the Carrizo-Wilcox Aquifer

The second phase of the project (Figure 7.1-2) calls for overdrafting Lake Granger during times of high flow, utilizing non-firm surface water authorized by the BRA System Operations Permit. Surface water supplies will be supplemented by water from the Carrizo-Wilcox Aquifer or another aquifer when water from Lake Granger is not available. For purposes of this evaluation, it is assumed that groundwater from Milam County would be utilized.

Figure 7.1-2. Phase II – Conjunctive Use with the Carrizo-Wilcox Aquifer



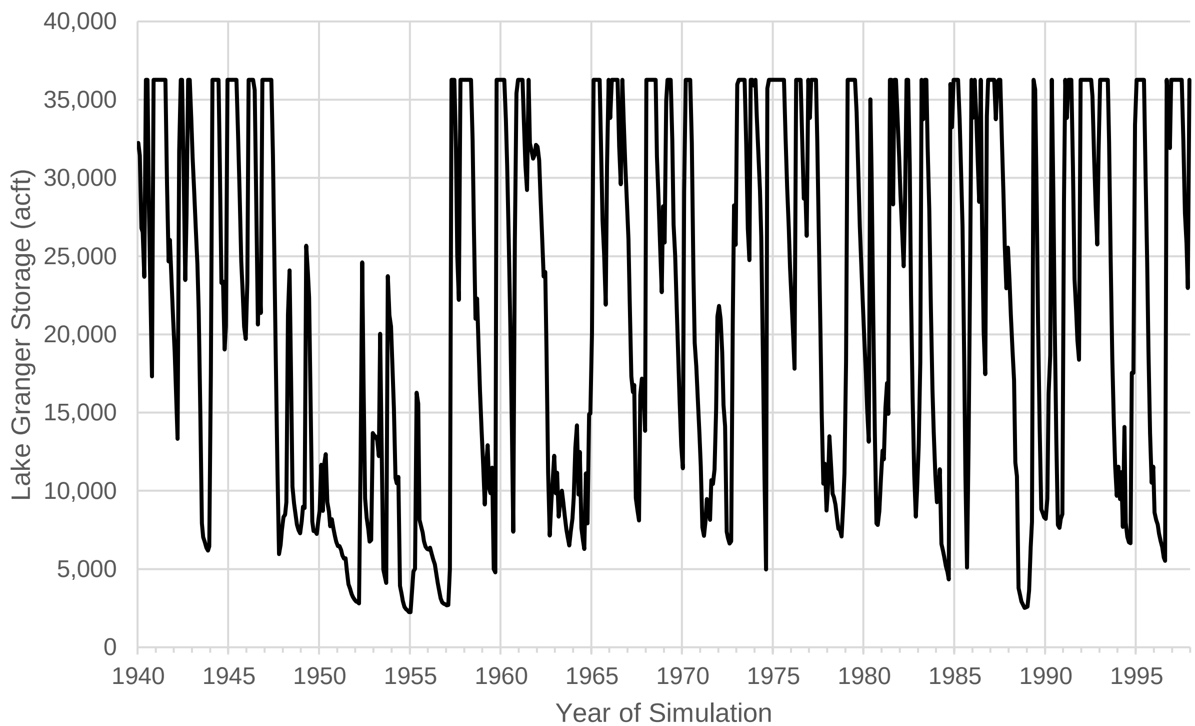
The conjunctive use project would develop a total supply of up to 48,965 acft/yr (2,700 acft/yr from Phase I in 2070 plus up to 46,265 acft/year from Phase II). The 46,265 acft/year supply in Phase II was reported in the 2005 study[4]. A portion of the water from Phase II is used to firm up the 19,840 acft/yr of permitted diversions out of Lake Granger, of which only 11,016 acft/yr are firm in 2070 without the conjunctive use project. EWCRWTP customers and other water utilities who receive supply from Lake Granger are likely candidates for this additional water supply.

[4] 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.

The TCEQ Brazos WAM (Run 3) was utilized to simulate operations of Lake Granger supplemented with the groundwater pumping. To evaluate this strategy, the WAM was modified to remove Lake Granger from BRA System operations and to simulate projected sediment conditions for Lake Granger in 2070 (all other reservoirs were left at their permitted storages). In the simulation, it was assumed that all of the demand (less the Trinity Aquifer water from Phase I) was taken from Lake Granger until the reservoir was drawn down to 30% of capacity. When the reservoir is 30% full or less, the demand is met by pumping from groundwater. Figure 7.1-3 shows the storage trace for Lake Granger modeled with these assumptions.

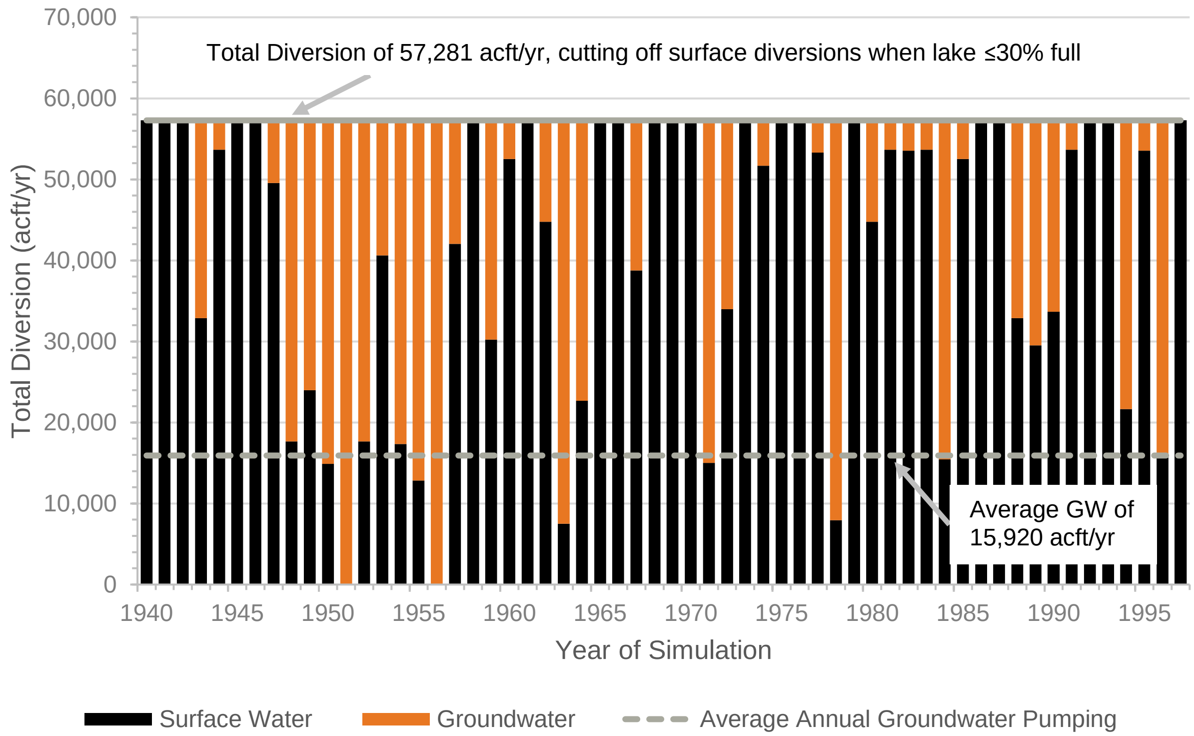
Adding the 8,824 acft/yr used to firm up the permitted (senior) diversions to a new (junior) diversion of 37,441 acft/yr gives a total new project yield of up to 46,265 acft/yr. According to the WAM simulation, this new yield can be achieved with an average annual groundwater pumping of 15,920 acft/yr (Figure 7.1-4). Maximum groundwater pumping in any single year would be equal to the total combined supply of 57,281 acft/yr, as shown in Figure 7.1-4.

Figure 7.1-3. Lake Granger Storage – 2070 Conditions



Note: Storage trace assumes a total diversion of 57,281 acft/yr, of which 19,840 acft/yr is already permitted, and surface water diversions are cutoff if Lake Granger storage drops below 30% of capacity.

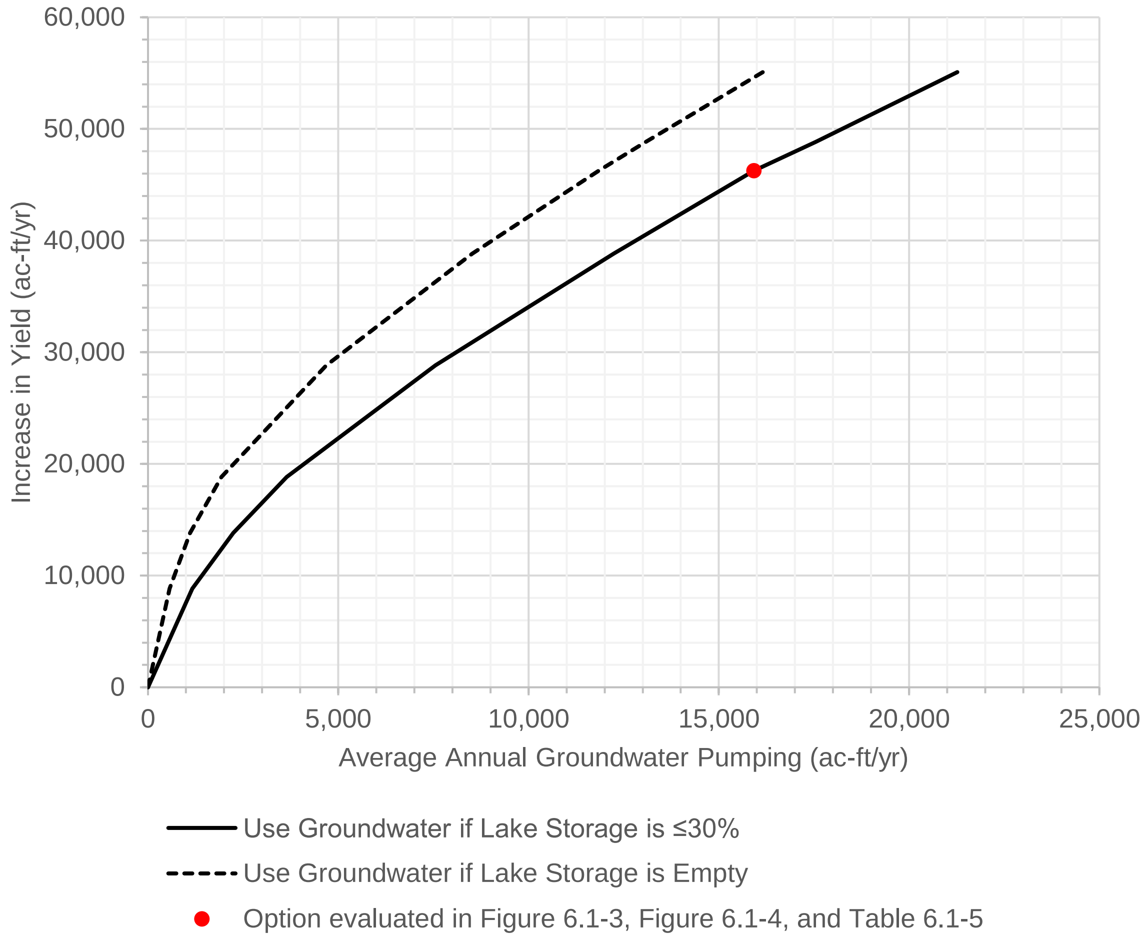
Figure 7.1-4. Distribution of Water Sources for Lake Granger Augmentation – 2070 Conditions



Note: Distribution assumes a total diversion of 57,281 acft/yr, of which 19,840 acft/yr is already permitted but only 11,016 acft/yr is firm in 2070. Surface water diversions are cutoff if Lake Granger storage drops below 30% of capacity.

Average annual pumping from groundwater would be less if the storage in Lake Granger were allowed to drop below 30% before switching to groundwater. Furthermore, the total annual diversion amount could be reduced depending on available groundwater supplies (Figure 7.1-5). Figure 7.1-5 shows how supply from Phase II would vary depending on how the project is operated and how much groundwater is made available. For example, if the reservoir were allowed to go empty the project would generate approximately 9,000 acft/yr of additional yield.

Figure 7.1-5. Relationship between Average Annual Groundwater Pumping and Increase in Yield for Two Operating Policies for Lake Granger Augmentation – 2070 Conditions



The above scenario, as stated, would result in a single maximum groundwater withdrawal of 57,281 acft/yr, which greatly exceeds the MAG remaining after accounting for existing uses. Regional water planning rules do not allow the MAG to be exceeded, even though the average annual groundwater withdrawn from the aquifer would be within the remaining MAG available for this project. Brazos G attempted to develop a MAG Peak Factor for the Carrizo-Wilcox Aquifer in Milam County, but the issue was not supported by the Post Oak Savannah Groundwater Conservation District or Groundwater Management Area 12. Per TWDB requirements, a revised analysis was performed for this conjunctive use project limiting single-year groundwater withdrawals so that the MAG would not be exceeded in any single year. Modeled in this way, the Lake Granger Augmentation project would provide 5,000 acft/yr of new surface water availability in conjunction with 14,168 acft/yr (maximum single year) of groundwater from the Carrizo-Wilcox Aquifer in Milam County. These values for the supply from the project have been entered into the regional water planning database.

7.1.3 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 7.1-1.

Table 7.1-1. Environmental Issues: Groundwater/Surface Water Conjunctive Use (Lake Granger Augmentation)

Issue	Description
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

7.1.4 Engineering and Costing

Facilities for this option are shown in Figure 7.1-1 and Figure 7.1-2, and Table 7.1-2 and Table 7.1-3. 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. Other facilities include a well field collection system, cooling towers, expansions to the EWCRWTP, and a 3.7-mile 36-inch treated water pipeline from EWCRWTP to an existing customer delivery point.

Conceptual designs and construction 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 2018 prices.

The total capital costs for Phase I is $68.6 million as shown in Table 7.1-2. Additional costs for professional services, land acquisition, well mitigation, and interest during construction add $28.1 million for a total project cost of $96.7 million. Annual debt service on this principal amount, calculated on the basis of 3.5 percent interest for 20-year amortization is $6.8 million. Operation and maintenance costs for pumping, transmission, and treatment to deliver a total annual supply of 13,716 acft (11,016 acft/yr from Lake Granger in 2070 plus 2,700 acft/ry 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 $4.5 million added to the annual debt service gives a total annual cost for the full project of $11.2 million. For Phase I, the unit cost of water is $819per acft/yr or $2.51 per 1,000 gallons during debt service, assuming the 2,700 acft/yr supply could be made available.

Phase II could provide up to 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 approximately 44 miles away from the EWCRWTP, located in Milam County. All or part of the required well field may be located in Milam, Burleson, Lee or other counties to the east of Williamson County, and groundwater supplies could originate from either of the Williamson County Groundwater Supply Options (North or South), from the Alcoa Property Supplies (Carrizo-Wilcox Aquifer in Milam County), or a combination of these sources. Groundwater would 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 would 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 Georgetown, Round Rock or County-Other users would need to build treated water pipelines to the delivery point. Costs for Phase II are included here for the infrastructure size needed to develop the entire supply anticipated by the project sponsor. Unit costs and annual costs for water are shown assuming the smaller supply eligible under regional water planning rules.

The Phase II total capital cost is $496.7 million as shown in Table 7.1-3. Additional costs for professional services, land acquisition, well mitigation, and interest during construction add $348.9 million for a total project cost of $845.6 million. Annual debt service on this principal amount is $51.1 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 $24.4 million added to the annual debt service gives a total annual cost for the full project of $75.5 million. For Phase II, the unit cost of water is $1,631 per acft/yr or $5.01 per 1,000 gallons under the full supply. Under the reduced supply eligible under regional water planning rules, the unit cost of water is $3,937 per acft/yr or $12.08 per 1,000 gallons. Compensation to BRA may be required if this strategy were developed by an entity other than BRA to compensate for any subordination or use of the System Operations Permit.

Table 7.1-2. Cost Estimate Summary for Phase I of Lake Granger Augmentation (note that Phase 1 is not included in the 2021 Brazos G Plan as a recommended strategy. Costs are shown here to illustrate the project should MAG values change in the future.)

Item	Estimated Costs for Facilities
Trinity Aquifer Well Field (4 wells)	$27,579,000
EWCRWTP Expansions (12.5 MGD)	$33,526,000
Treated water pipeline (36 in. dia., 3.7 miles)	$5,208,000
Transmission Pump Station(s)	$2,250,000
TOTAL COST OF FACILITIES	**$68,563,000**
Engineering, Legal Costs and Contingencies	$23,737,000
Environmental & Archaeology Studies and Mitigation	$302,000
Land Acquisition and Surveying (36 acres)	$252,000
Interest During Construction (1.5 years)	$3,831,000
TOTAL COST OF PROJECT	**$96,685,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$6,803,000
Operation and Maintenance	$2,327,000
Pumping Energy Costs)	$1,059,000
Purchase of Water (13,716 acft/yr @ $76.50/acft)	$1,049,000
TOTAL ANNUAL COST	**$11,238,000**
Available Project Yield (acft/yr)	**13,716**
Annual Cost of Water ($ per acft)	**$819**
Annual Cost of Water ($ per 1,000 gallons)	**$2.51**

Table 7.1-3. Cost Estimate Summary for Phase II of Lake Granger Augmentation

Item	Estimated Costs for Facilities
Well Field (30 wells)	$39,455,000
Pipeline from Well Field to EWCRWTP (36 & 48 in. dia. each 44 miles)	$132,111,000
Blending Facility	$11,648,000
EWCRWTP Expansions (83 MGD)	$108,352,000
Treated water pipeline from delivery to customers (various dia., 68 miles)	$77,342,000
Transmission Pump Stations & Storage Tanks	$125,275,000
Storage Tanks (Other Than at Booster Pump Stations)	$2,488,000
TOTAL COST OF FACILITIES	**$496,671,000**
Engineering, Legal Costs and Contingencies	$163,362,000
Environmental & Archaeology Studies and Mitigation	$4,435,000
Land and/or Groundwater Rights Acquisition	$120,000,000
Land Acquisition and Surveying	$5,799,000
Interest During Construction (3 years)	$55,297,000
TOTAL COST OF PROJECT	**$845,564,000**
ANNUAL COST	
Debt Service for Infrastructure (3.5 percent, 20 years)	$51,051,000
Operation and Maintenance	$14,449,000
Pumping Energy Costs	$5,089,000
Annual Cost to Purchase Water (46,265 acft/yr at assumed $76.50 per acft)	$3,655,000
Annual Groundwater Permitting Cost (15,920 acft/yr at assumed $76.50 per acft)	$1,218,000
TOTAL ANNUAL COST	**$75,462,000**
Available Project Yield (acft/yr)	**19,168**
Annual Cost of Water ($ per acft)	**$3,937**
Annual Cost of Water ($ per 1,000 gallons)	**$12.08**

7.1.5 Implementation Issues

Early significant activity toward implementation of this strategy has been accomplished by the Brazos River Authority via its ownership of Lake Granger water supply, obtaining the System Operation Permit, ownership of the existing water treatment plant on Lake Granger, construction of a test well into the Trinity Aquifer, 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.

For this project to be eligible for certain types of state funding under the full supply it can develop, the MAG will need to be increased for the Trinity Aquifer in Williamson County (for Phase 1), and a MAG Peak factor likely will need to be adopted for the Carrizo-Wilcox Aquifer in Milam, Burleson and/or Lee Counties (for Phase 2) to allow the full supply to be developed within regional water planning rules.

This water supply option has been compared to the plan development criteria, as shown in Table 7.1-4.

Potential Regulatory Requirements:

Requirements for permits to use surface water and groundwater, as well as for pipeline construction, will require permits as follows:

- Local groundwater district pumping permits as needed;
- Prior to implementation, the BRA Water Management Plan that is a part of the System Operation Permit will need to be updated to address non-firm appropriations;
- 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; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

Table 7.1-4. 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	• Option is considered to meet municipal and ‘County-Other’ shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

7.2 Oak Creek Reservoir

7.2.1 Description of Option

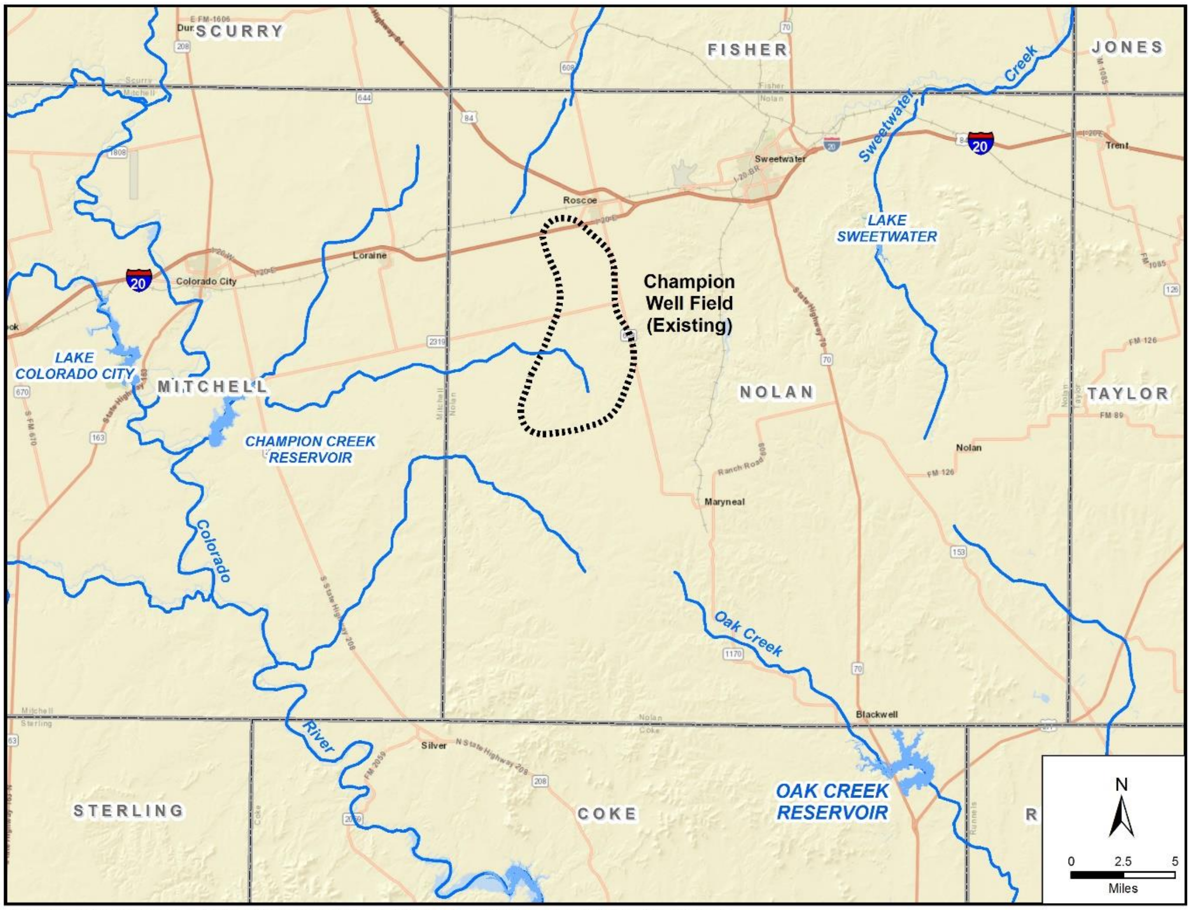
The City of Sweetwater (Sweetwater) utilizes water supplies from the Oak Creek Reservoir in Coke County and the Champion Well Field in Nolan County. The wells are in the Dockum Aquifer. Prior to the drought beginning in 1998, the primary water supply was Oak Creek Reservoir and supplemental supplies 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 35 new wells in the Champion Well Field on an emergency basis. During the latter 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, which would exceed the MAG for the Dockum Aquifer in Nolan County when considered with other existing uses, such as irrigation.

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) prior to the 2016 Brazos G Plan. 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 maximum annual use of groundwater from the Dockum must remain within the MAG and cannot 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 7.2-1.

Figure 7.2-1. Existing Champion Well field and Oak Creek Reservoir Locations



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7.2.2 Available Yield

The Champion Well field has a production capacity of 4,142 acft/yr after the 2014 expansion. However, for regional water planning purposes, the supply availability to Sweetwater is limited to 2,329 acft/yr, consisting of supplies from both the Brazos Basin and Colorado Basin portions of the Dockum Aquifer in Nolan County. An analysis of Sweetwater's demands and water supply contracts shows the maximum demand during the planning period is greater than the City's supply availability. Sweetwater also utilizes water supplies from the Oak Creek Reservoir; however, the reservoir is not a reliable drought supply and has no firm yield without subordination agreements with downstream senior water right holders.

A preliminary analysis was conducted to determine the potential yield increase from operating the City's well field and Oak Creek Reservoir in conjunction to meet demands, with the requisite subordination agreements in place. The analysis balances the use of groundwater and surface water to maximize supplies from the two sources without exceeding the long-term groundwater supply of 2,329 acft/yr. With the proposed subordination agreement assumed in place, conjunctive operation of Oak Creek Reservoir and the Champion Well Field can create an additional yield increase of 1,500 acft/yr without overdrafting the MAG volumes for the Dockum Aquifer in Nolan County.

In the analysis, Oak Creek Reservoir is operated as the primary supply source and is overdrafted during wet periods and underutilized during drought periods. The Champion Well Field is operated as a backup supply source to supplement supplies from the reservoir during drought periods. The storage level in Oak Creek Reservoir was used to determine the commencement of groundwater supplies to supplement surface water supplies. Groundwater supplies commence when reservoir storage levels drop below 40 percent of the storage capacity provides the maximum firm yield of 3,829 acft/yr.

Figure 7.2-2 shows the temporal distribution of annual diversions and annual pumpage to meet the conjunctive use firm yield of 3,829 acft/yr and assumes groundwater supplies commence when storage levels drop below 40% of capacity in the reservoir. The long-term average groundwater use for this strategy is 1,188 acft/yr.

Figure 7.2-2. Simulated Annual Distribution of Water Sources for Conjunctive Use Operations

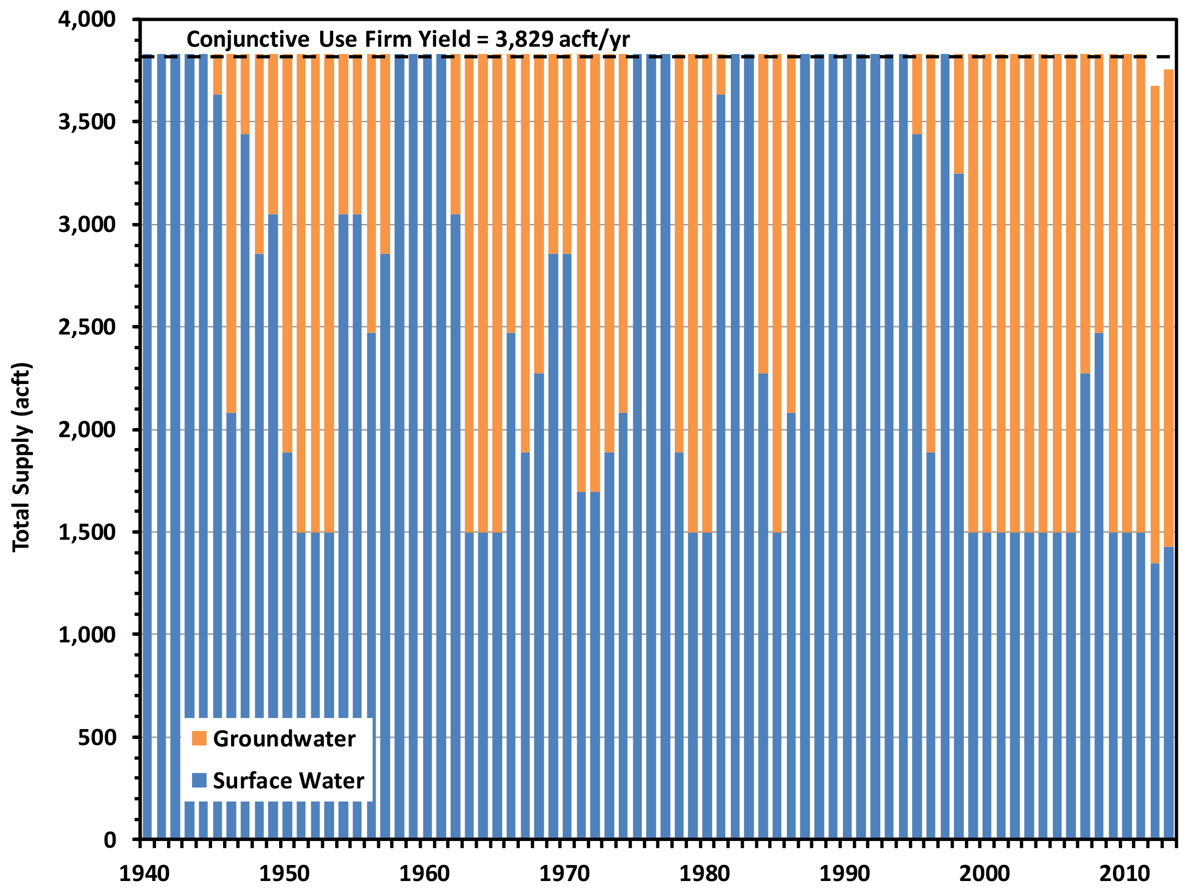


Figure 7.2-2 shows the temporal distribution of annual diversions and annual pumpage to meet the conjunctive use firm yield of 3,829 acft/yr and assumes groundwater supplies commence when storage levels drop below 40% of capacity in the reservoir. The long-term average groundwater use for this strategy is 1,188 acft/yr.

Figure 7.2-2Figure 7.2-3 shows the resulting storage trace for Oak Creek Reservoir under the conjunctive use firm yield demand of 3,829 acft/yr and Figure 7.2-4 provides the resulting storage frequency. The figures show that storage in the reservoir remains less than half full in the simulation for about 75 percent of the time due to the overdrafting of surface water supplies to maximize the conjunctive use yield. The storage trace figure also shows that storage levels were reduced to near zero during the drought conditions occurring the last two decades of the simulation.

Figure 7.2-3. Oak Creek Reservoir Simulated Storage under Conjunctive Use Operations

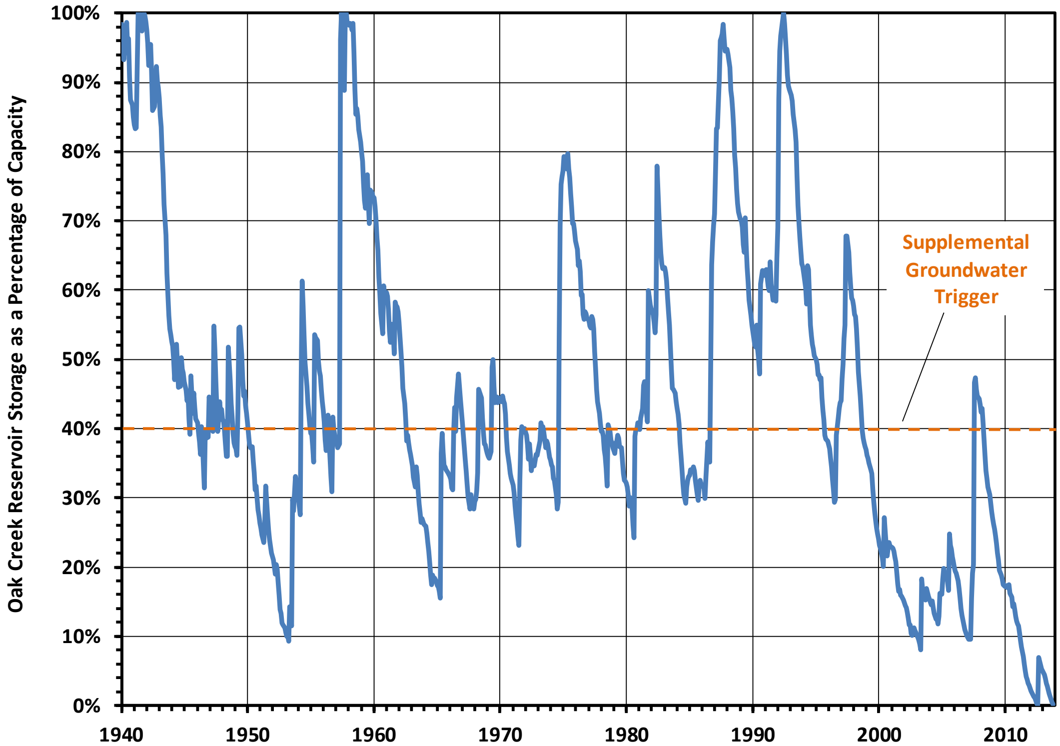
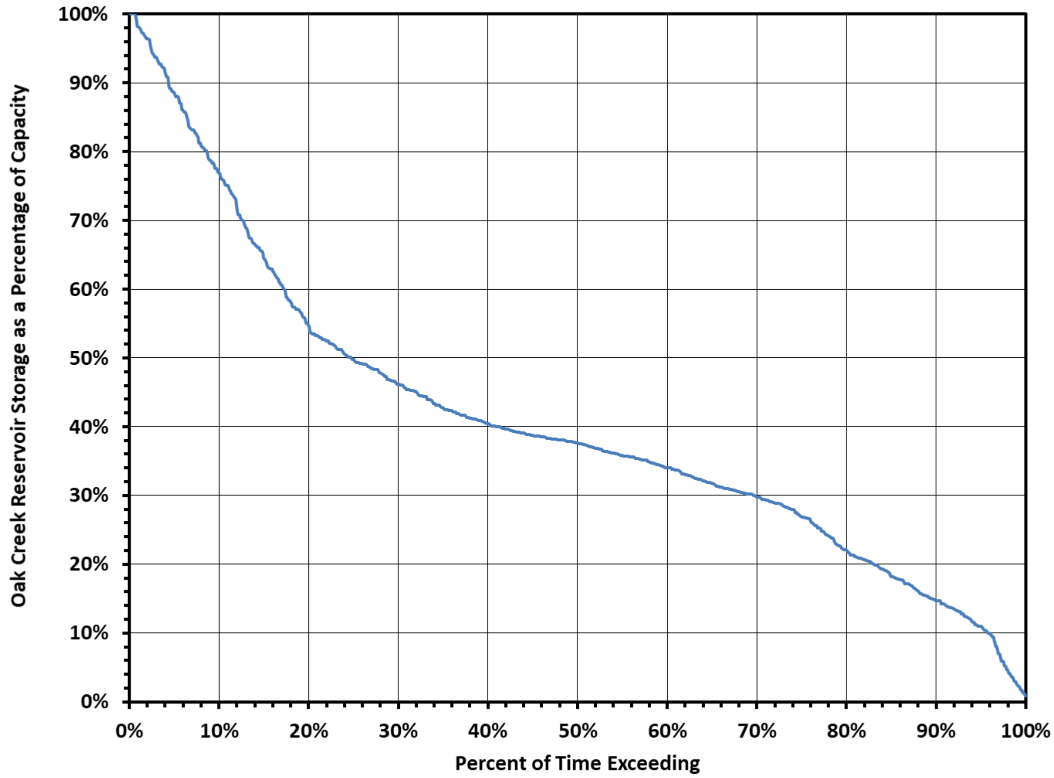


Figure 7.2-4. Oak Creek Reservoir Simulated Storage Frequency under Conjunctive Use Operations



7.2.3 Environmental Issues

There are no new environmental impacts associated with this strategy. No wells, pipelines or other infrastructure is required for this strategy.

7.2.4 Engineering and Costing

No wells, pipelines or other infrastructure is required for this strategy. As a result, there are no costs associated with this strategy.

7.2.5 Implementation Issues

Development of this water management strategy requires the subordination of the senior water rights that are downstream of Oak Creek Reservoir. This issue is discussed in the 2021 Region F Regional Water Plan.

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8 Aquifer Storage and Recovery (ASR)

8.1 City of Bryan ASR

8.1.1 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 8.1-1 by decade. This analysis shows Bryan will need an additional 19,650 acft/yr by 2070. A groundwater strategy that is described in Section 5.1 will provide 17,474 acft/yr from the Carrizo Aquifer in Brazos and Robertson Counties. 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 production 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 or when peak day use exceeds the current system capacity. 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 make available 14,626 acft/yr of the City's supplies that are not currently accessible. The modeling of the strategy is discussed further in Section 8.1.2.

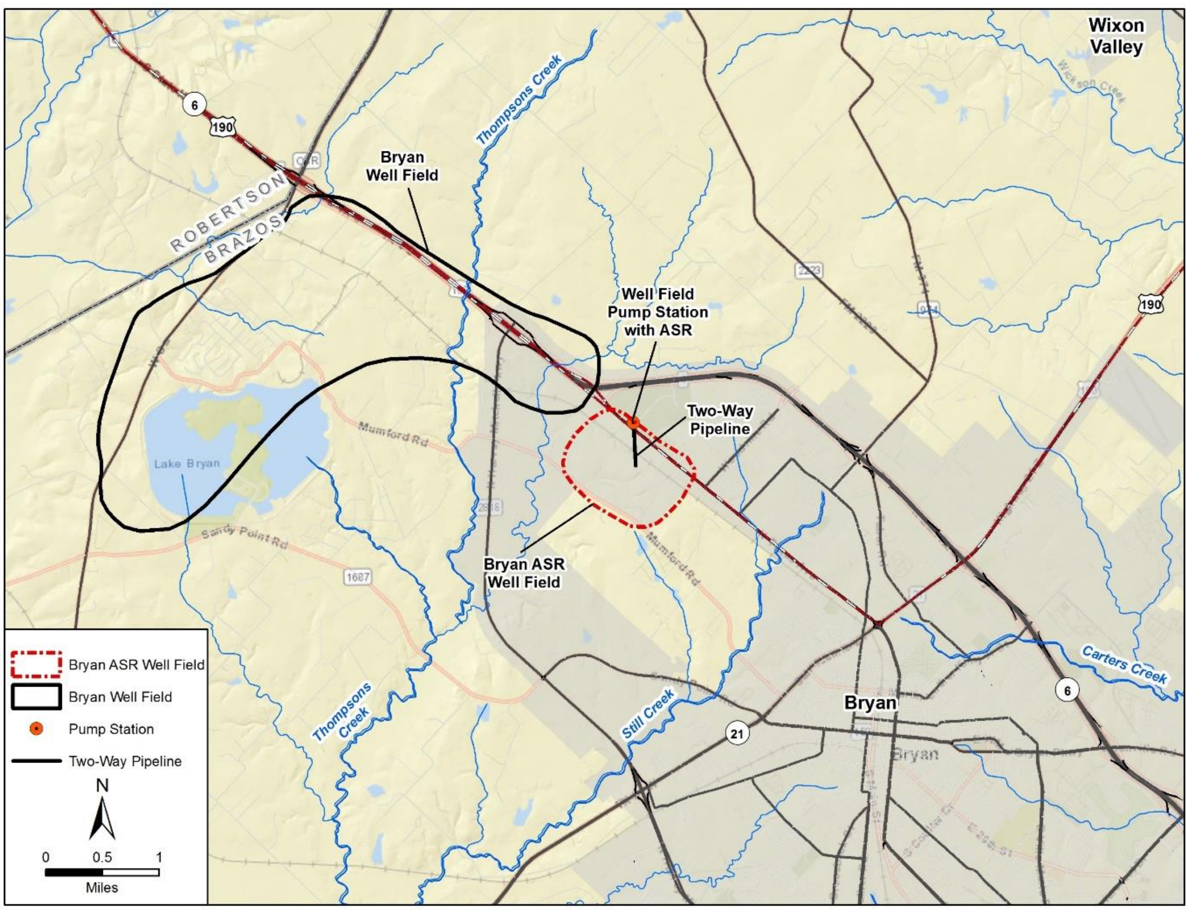
In addition to the wells required for this strategy, two-way pipelines between the ASR well field and the Well Field Pump Station, an ASR pump station at Well Field Pump Station, and an interconnect into the storage tanks are needed. A map showing the locations of the well fields is shown in Figure 8.1-1. 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.

Table 8.1-1. Bryan's Water Supply and Demand (acft/yr)

Year	Total Supply	Total Demand[1]	Balance
2020	19,730	19,515	215
2030	19,855	21,751	-1,896
2040	19,872	24,450	-4,578
2050	19,872	27,906	-8,034
2060	19,872	32,195	-12,323
2070	19,872	39,522	-19,650

1 - Includes sales to other entities.

Figure 8.1-1. Bryan's Existing Well Field and Proposed ASR Well Field



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8.1.2 Modeling and Available Supply

A probabilistic model was developed by consultants to the City of Bryan 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 8.1-2 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 Brazos 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 8.1-1.

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 8.1-3. The inflection points at 2030, 2040, and 2050 indicate when increases in the MAG allowed for additional pumping.

Figure 8.1-2. Fit of Demand Model

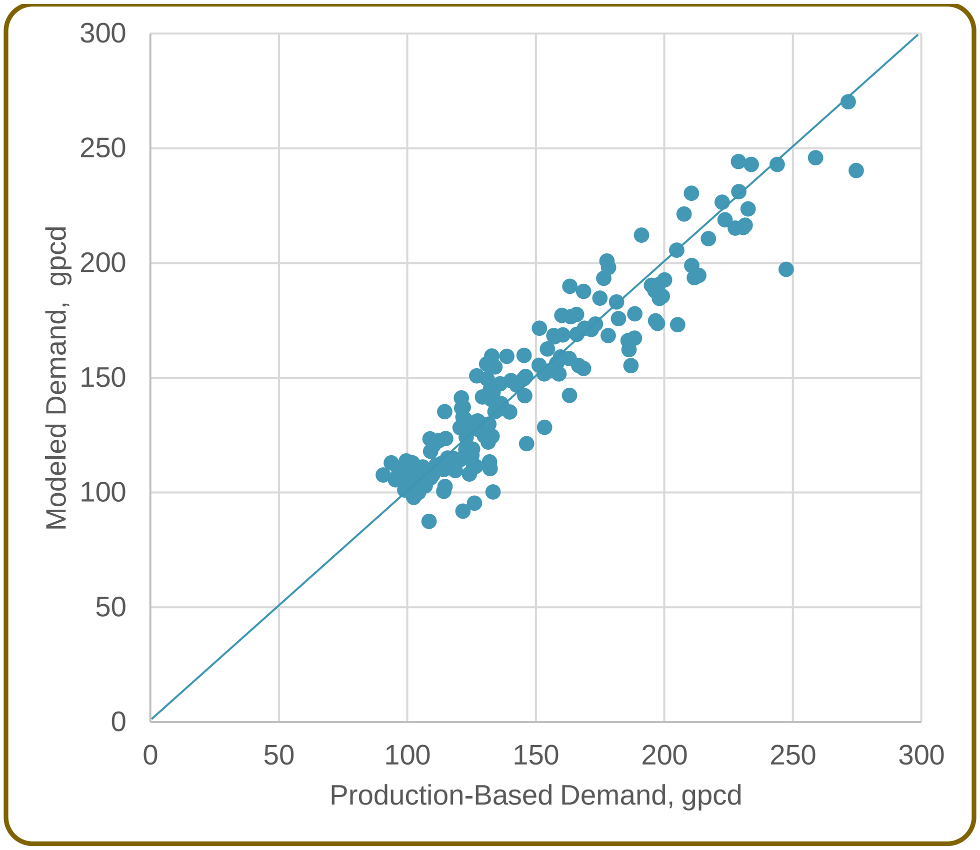
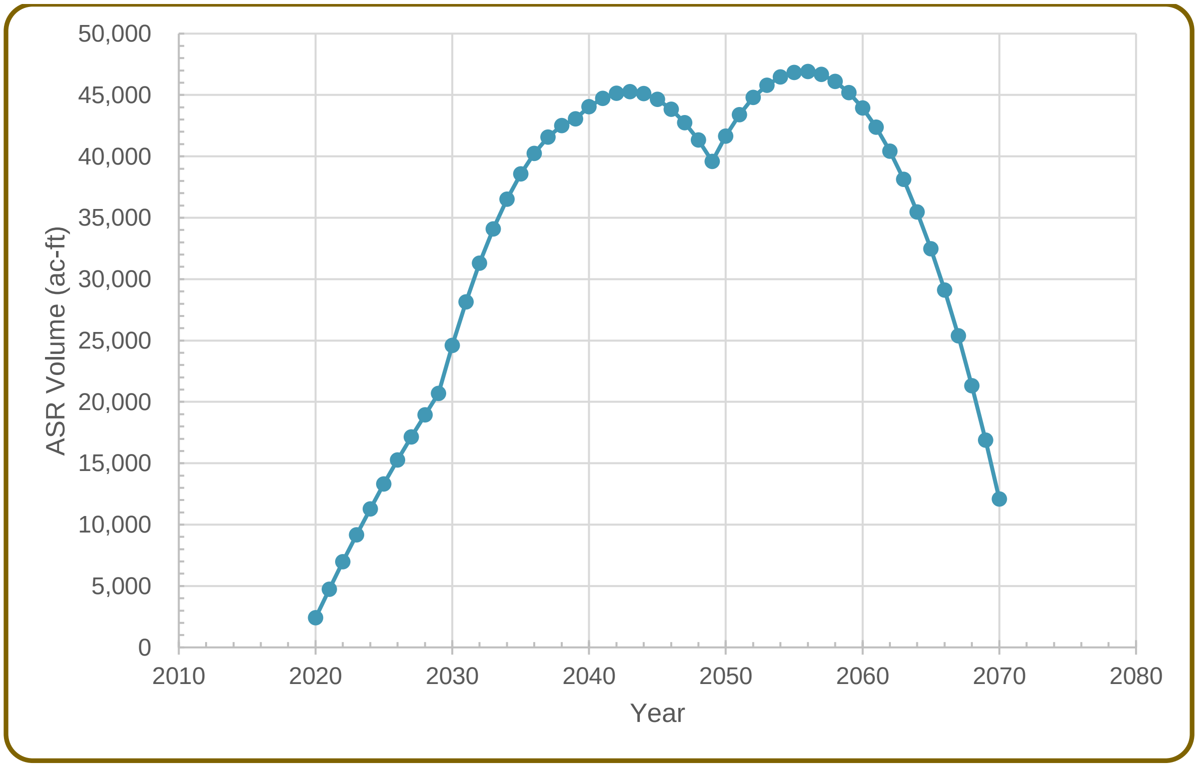


Figure 8.1-3. Time series Plot of ASR Recoverable Volume

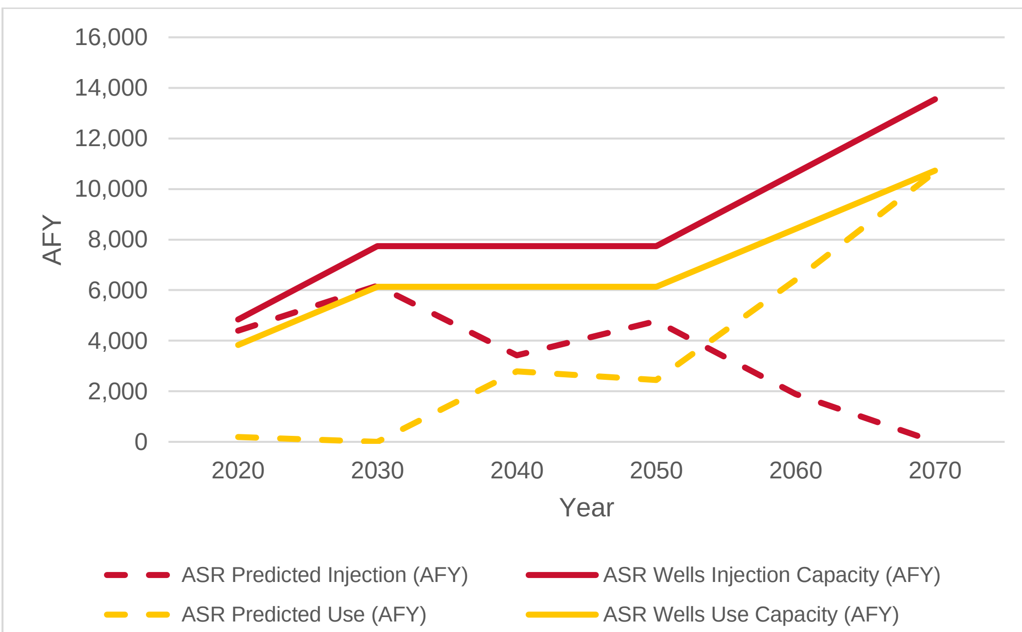


8.1.3 Infrastructure Timing

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 production well is assumed to have a rated capacity of 3,000 gpm. Production estimates assume 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 8.1-4 shows 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 prior to 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 8.1-4. ASR Injection, Capacity and Use Curves over Time



8.1.4 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.

8.1.5 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.

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. 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.

current list of rare, threatened and endangered species for Brazos County can be found at https://tpwd.texas.gov/gis/rtest/.

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 most of the disturbed areas will return to their previous habitat types excluding 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 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., municipality), they will be required to coordinate with the Texas Historical Commission prior to project construction.

8.1.6 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 8.1-2.

Table 8.1-2. 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 annual yield of the ASR and recovery wells is around 14,626 acft.

The major facilities required for these projects include:

- Pump station,
- Pipeline,
- ASR and Recovery wells,
- Collector pipelines, 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 8.1-3. The annual costs, including debt service, operation and maintenance, and power, is estimated to be $445 per acft.

8.1.7 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 8.1-4, and the option meets each criterion.

Table 8.1-3. Cost Estimate Summary: City of Bryan ASR

Item	Estimated Costs for Facilities
Primary Pump Station (15 MGD)	$2,643,000
Transmission Pipeline (30 in dia., 2.5 miles)	$1,520,000
Well Fields (Wells, Pumps, and Piping)	$44,824,000
Water Treatment Plant (13.1 MGD)	$743,000
TOTAL COST OF FACILITIES	**$51,222,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$17,851,000
Environmental & Archaeology Studies and Mitigation	$626,000
Land Acquisition and Surveying (39 acres)	$767,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$1,938,000
TOTAL COST OF PROJECT	**$72,404,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$5,094,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$478,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$66,000
Water Treatment Plant	$446,000
Pumping Energy Costs (5,391,403 kW-hr @ 0.08 $/kW-hr)	$431,000
TOTAL ANNUAL COST	**$6,515,000**
Available Project Yield (acft/yr)	14,626
Annual Cost of Water ($ per acft)	$445
Annual Cost of Water ($ per 1,000 gals)	$1.37

Table 8.1-4. Comparison of City of Bryan ASR 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

8.2 City of College Station ASR

8.2.1 Description

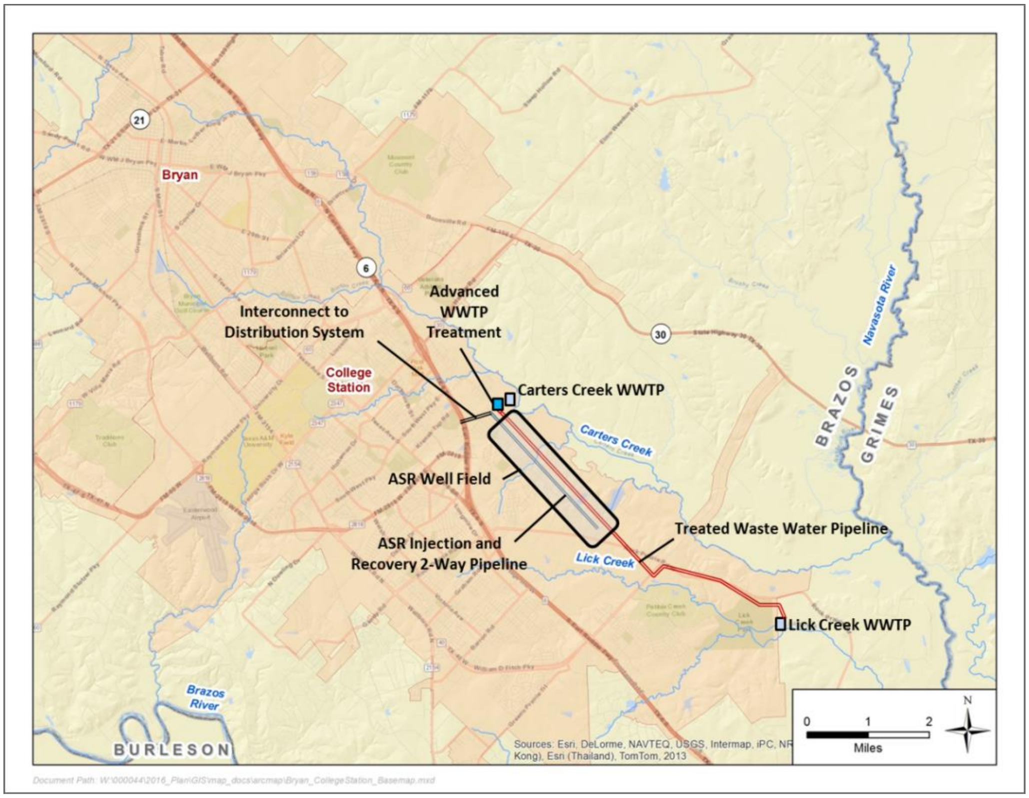
The concept for the City of College Station (College Station) ASR project is to:

- Utilize existing wastewater effluent as the source of water for ASR. For 2013-20017 the average effluent discharges from Carters Creek WWTP and Lick Creek WWTP were 6.07 and 1.17 million gallons per day (MGD), respectively.
- A new Advance Water Treatment Plant (AWTP) would be located near the Carters Creek WWTP. Effluent from the smaller Lick Creek WWTP would be transported to the AWTP through a new pipeline.
- The AWTP would treat the wastewater effluent with: (1) Low Pressure Membrane, (2) Reverse Osmosis, and (3) Oxidation before the water would be recharged.
- 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 2,225 ft deep, respectively. An estimated 20 wells would be required at 10 sites.
- The recharge cycle of ASR would occur from October to March. Recovery would occur from April to September to supplement summer peaking demands.
- Recovered water would be disinfected before being delivered to the existing potable water distribution system.

A schematic showing the location of the project is shown in Figure 8.2-1. 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 WWTP and Carters Creek WWTP, advanced water treatment plant, interconnects between AWTP and the ASR well field and the AWTP and College Station's distribution system, a two-way pipeline between the AWTP and the ASR well field, and a chlorine disinfection facility.

For purposes of this ASR project, an assumed supply of 6.5 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 6.5 MGD during April to September.

Figure 8.2-1. Location of College Station's ASR Project



8.2.2 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 8.2-2. 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 extend 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.

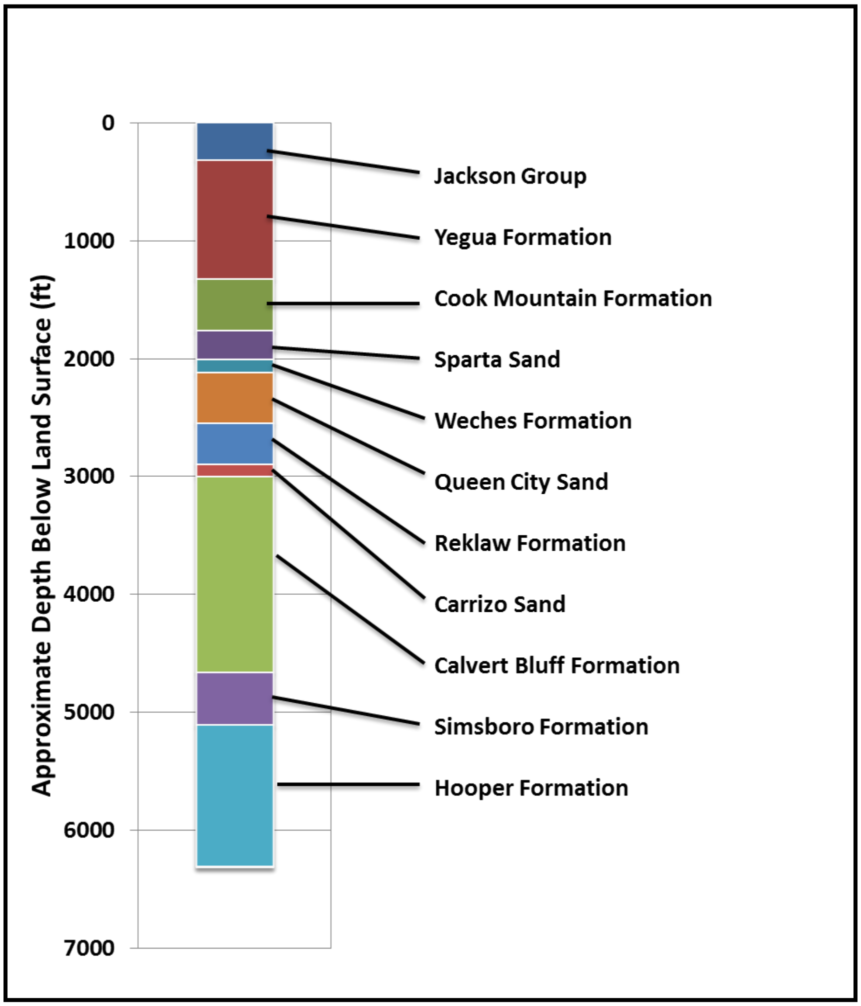
Electric geophysical logs[1] for a geologic cross-section suggest that the Sparta and Queen have rather extensive sands with fresh to brackish water. Electric geophysical logs[2] for another geologic cross-section provide picks for the Simsboro Formation. These logs suggest that the water quality in 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

[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.

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.

Figure 8.2-2. Geologic Profile in Target Area for ASR Well



8.2.3 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.

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Brazos County can be found at https://tpwd.texas.gov/gis/rtest/.

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

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.

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.

8.2.4 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 7 MGD injection rate, 10 Sparta and 10 Queen City wells would be required. The wells would be spaced about 1,000 ft apart.

The major facilities required for these projects include:

- Pump Station at Lick Creek WWTP,
- 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,
- Interconnect to existing distribution system, and
- Chlorine disinfection water treatment plant.

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 8.2-1. The annual costs, including debt service, operation and maintenance, and power, is estimated to be $3,277 per acft.

Table 8.2-1. Cost Estimate Summary: College Station ASR Project Option

Item	Estimated Costs for Facilities
Pump Stations	$2,114,000
Transmission Pipelines (20 in. dia., 0.5 miles and 10 in. dia., 6.6 miles)	$2,803,000
ASR Well Field (Wells, Pumps, and Piping)	$24,778,000
Chlorine Disinfection Water Treatment Plant (6.5 MGD)	$386,000
Advanced Water Treatment Plant (7 MGD)	$33,146,000
Integration, Relocations, & Other	$250,000
TOTAL COST OF FACILITIES	**$63,477,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$22,077,000
Environmental & Archaeology Studies and Mitigation	$562,000
Land Acquisition and Surveying (47 acres)	$655,000
Interest During Construction (4% for 1 years with a 1% ROI)	$2,387,000
TOTAL COST OF PROJECT	**$89,158,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$6,273,000
Operation and Maintenance	
Pipelines, Wells, and Storage Tanks (1% of Cost of Facilities)	$278,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$53,000
Chlorine Disinfection Water Treatment Plant	$232,000
Advanced Water Treatment Plant	$3,138,000
Pumping Energy Costs (24,836,738 kW-hr @ 0.08 $/kW-hr)	$1,956,000
TOTAL ANNUAL COST	**$11,930,000**
Available Project Yield (acft/yr)	**3,640**
Annual Cost of Water ($ per acft)	**$3,277**
Annual Cost of Water ($ per 1,000 gallons)	**$10.06**

8.2.5 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 8.2-2, and the option meets each criterion.

Table 8.2-2. 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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8.3 Lake Georgetown ASR

8.3.1 Description of Option

The concept for the Lake Georgetown ASR project is to:

- Utilize existing BRA contractual water supply in Lake Georgetown of 45,707 acft/yr.
- Utilize spare treatment capacity at the Lake Water Treatment Plant (WTP), which has a total production capacity of 35.5 million gallons per day (mgd).
    - Utilize Lake Georgetown flood storage, when available, to assist in meeting growing demand.
- Install new Trinity Aquifer ASR wells and associated infrastructure.
- Operate recharge cycle during wet months when there is excess supply, decreased demand, and spare treatment capacity at the Lake WTP. Recovery could be at any time, but typically would be during the summer when demand is relatively high or during periods of drought. The recovered water would be minimally treated before being discharged back into distribution pipelines along with other supplies from the Lake WTP.

New facilities required for this option are ASR wells (dual-purpose wells that are designed for injection and recovery), well field distribution and collection pipelines, additional WTP capacity, and chlorination facilities. The general location of the proposed ASR and production well field, pipeline, and Lake Water Treatment Plant (LWTP) are shown in Figure 8.3-1.

The City of Georgetown is experiencing rapid increases in water demand, due primarily to unprecedented levels of residential and commercial growth. Projected supplies and demands are illustrated in Table 8.3-2. The City of Georgetown's BRA contract supply of 45,707 acft/yr becomes insufficient to meet demand of 48,810 acft/yr in 2040. An ASR system can provide a means to utilize BRA contract water while supply still exceeds demand, and bank that water until need arises. Additionally, as shown in Figure 8.3-2, utilizing water in the Lake Georgetown flood pool has the potential to significantly increase water supply. ASR can utilize this excess water, when available, to assist in meeting growing demand and provide a more robust water supply system.

Figure 8.3-1. Possible Location of Lake Georgetown ASR Project

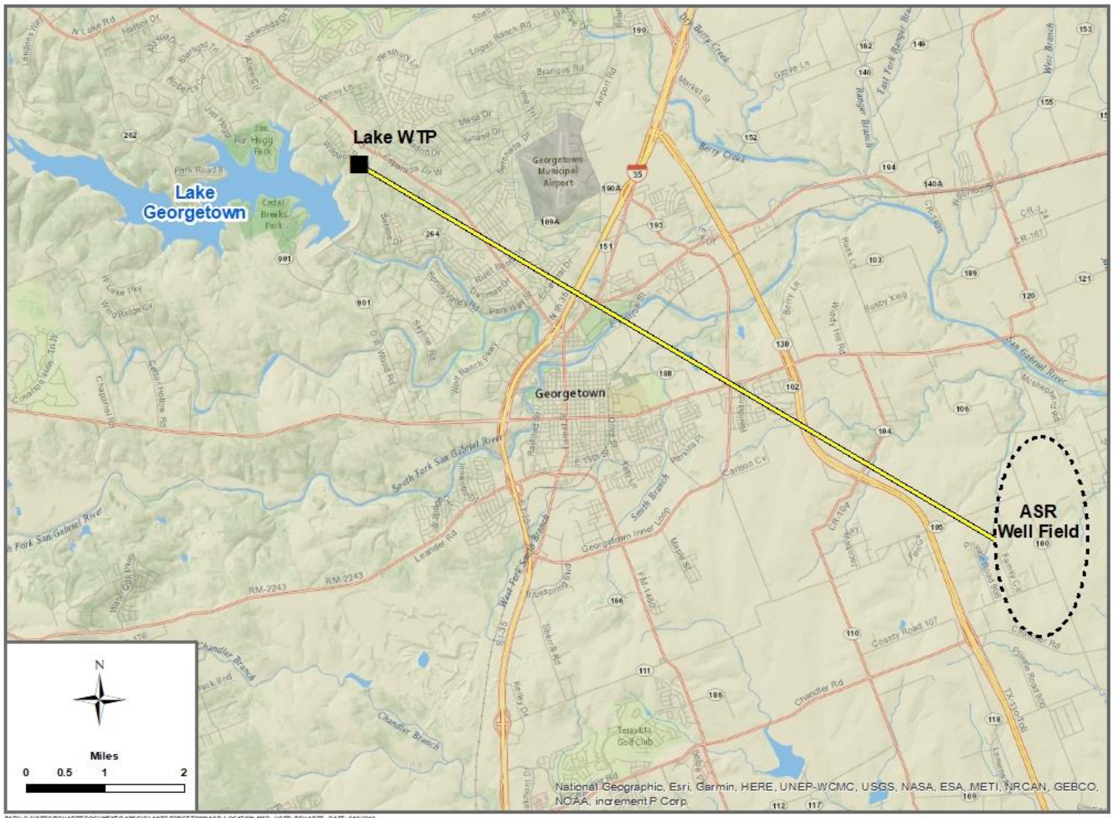
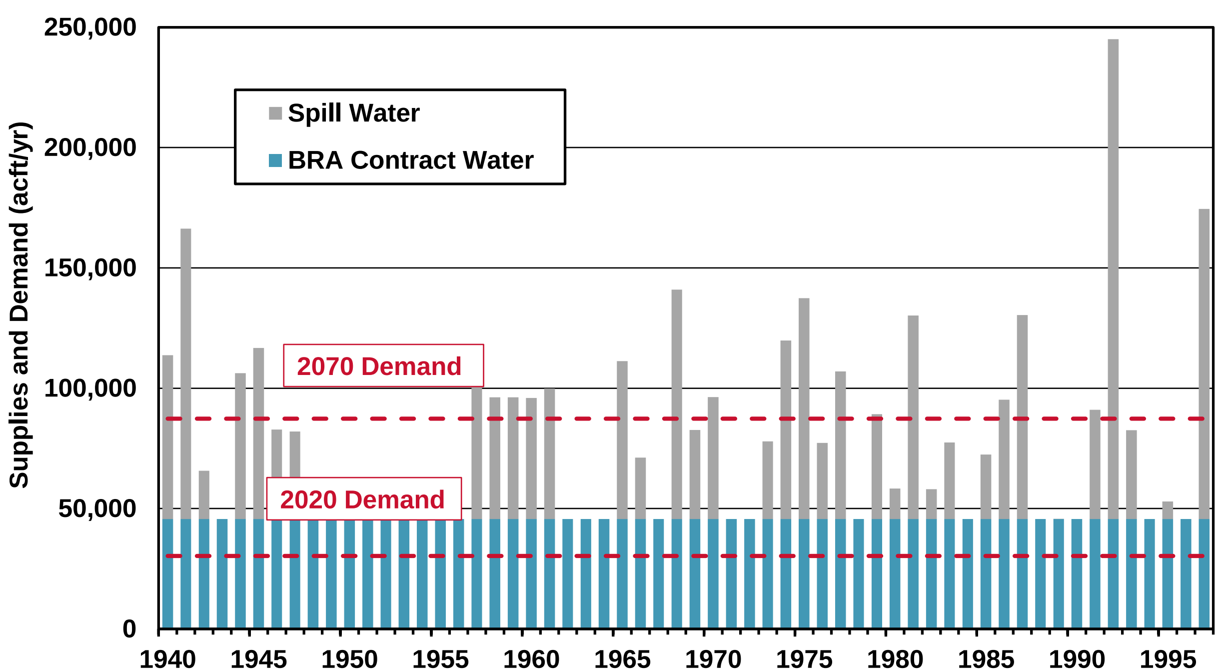


Figure 8.3-2. Lake Georgetown Water Supplies and Projected Demand



8.3.2 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 average magnitude and timing of Lake Georgetown overflow. This average modeled overflow along with BRA contractual water supply and projected municipal water demands serve as the basis for estimating ASR availability at Lake Georgetown, as shown in Table 8.3-1. Under the assumptions and constraints detailed in Table 8.3-2, an average of approximately 10,200 acft/yr are available for recharge from 2020 through 2079.

The source of water available for ASR, BRA contractual supply or Lake Georgetown flood water, varies through time, as shown in Figure 8.3-3.

Throughout 2020, all ASR water is obtained from spare BRA contract water. As demand and LWTP capacity increase in 2030, a mix of BRA and Lake Georgetown flood water is recharged for ASR. From 2040 through 2070, annual water demand exceeds BRA contract supply and ASR water is sourced entirely from Lake Georgetown flood water.

Figure 8.3-4 and Figure 8.3-5 illustrate the magnitude and timing of simulated monthly recharge from 2020 through 2070.

In the 2020 and 2030 decades, the ASR recharge cycle operates annually during wet months when there is excess supply, decreased demand, and spare treatment capacity at the Lake WTP. However, as projected demand outpaces BRA contractual supply and the ASR recharge cycle becomes wholly reliant on water temporarily stored in the Lake Georgetown flood pool, the timing of recharge becomes less predictable and generally less frequent. In order to maintain a similar annual average recharge volume to previous decades, the ASR system must expand its capacity by 2040 to account for the more sporadic recharge cycle.

Assuming an 85% recovery rate, the Lake Georgetown ASR project has the potential to increase the area’s supply by about 8,600 acft/yr.

Table 8.3-1. Lake Georgetown ASR Availability

Decade	Average Annual BRA Contract Water Recharged	Average Annual Flood Water Recharged	Average Annual Water Recharged	Maximum Monthly Recharge	Maximum Annual Recharge
	acft/yr	acft/yr	acft/yr	acft/mo	acft/mo
2020	9,700	0	9,700	1,400	9,700
2030	6,400	4,500	10,900	2,500	20,500
2040	0	10,100	10,100	4,100	27,800
2050	0	10,100	10,100	4,100	27,400
2060	0	10,100	10,100	4,100	27,800
2070	0	10,100	10,100	4,100	28,100

Table 8.3-2. Lake Georgetown ASR Availability Assumptions and Constraints

Decade	Treatment Plant Capacity		Annual BRA Contract	Annual Demand	Recharge Rate	Number of Recharge Wells
	mgd	acft/yr	acft/yr	acft/yr	gpm	
2020	35.5	39,765	45,707	30,325	1,200	15
2030	70	78,410	45,707	39,266	1,200	15
2040	100	112,014	45,707	48,810	1,200	25
2050	110	123,216	45,707	60,087	1,200	25
2060	130	145,619	45,707	72,781	1,200	25
2070	156	174,742	45,707	87,365	1,200	25

Figure 8.3-3. Source of Lake Georgetown ASR Recharge Water by Decade

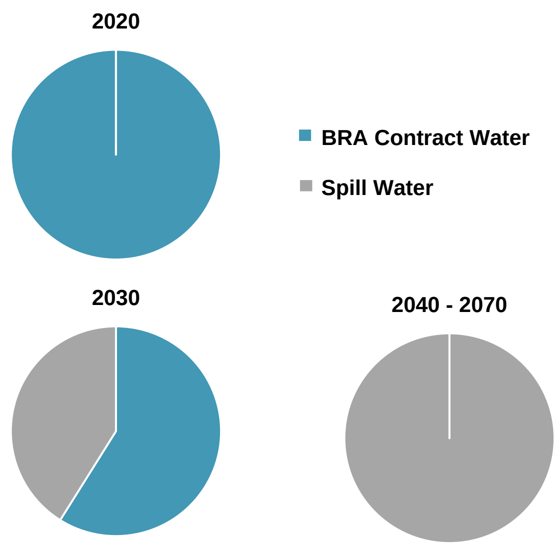


Figure 8.3-4. Simulated Timeline of Recharge by Planning Decade

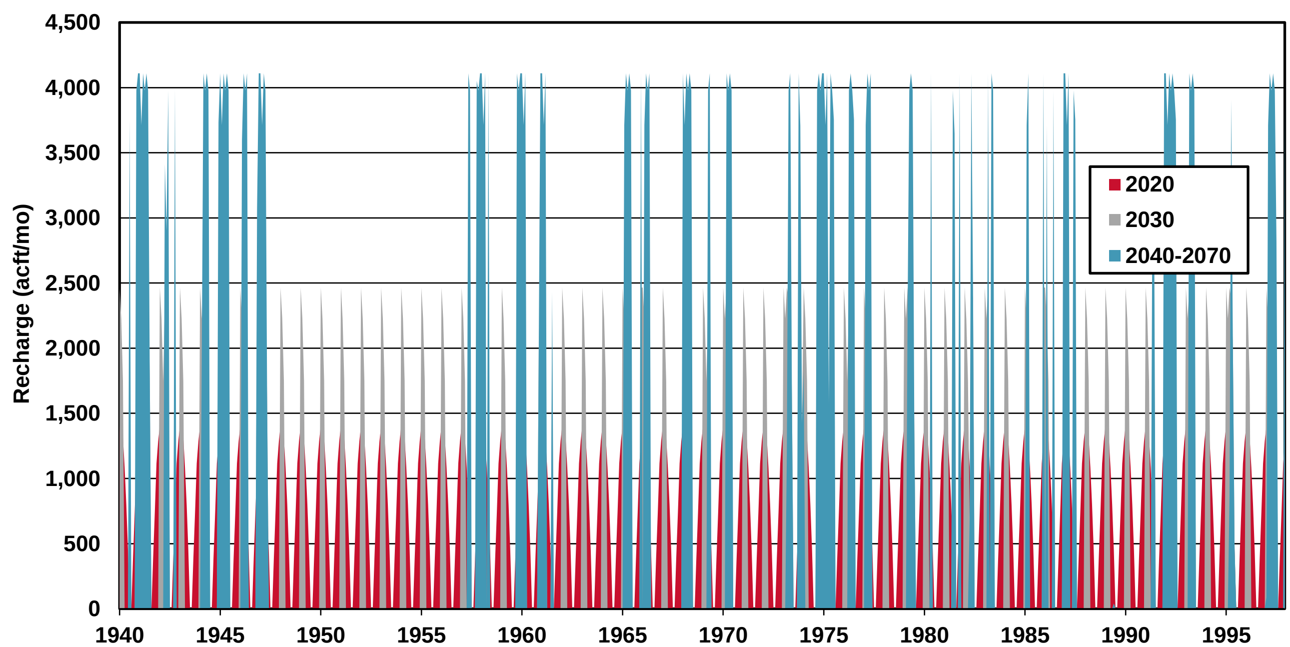
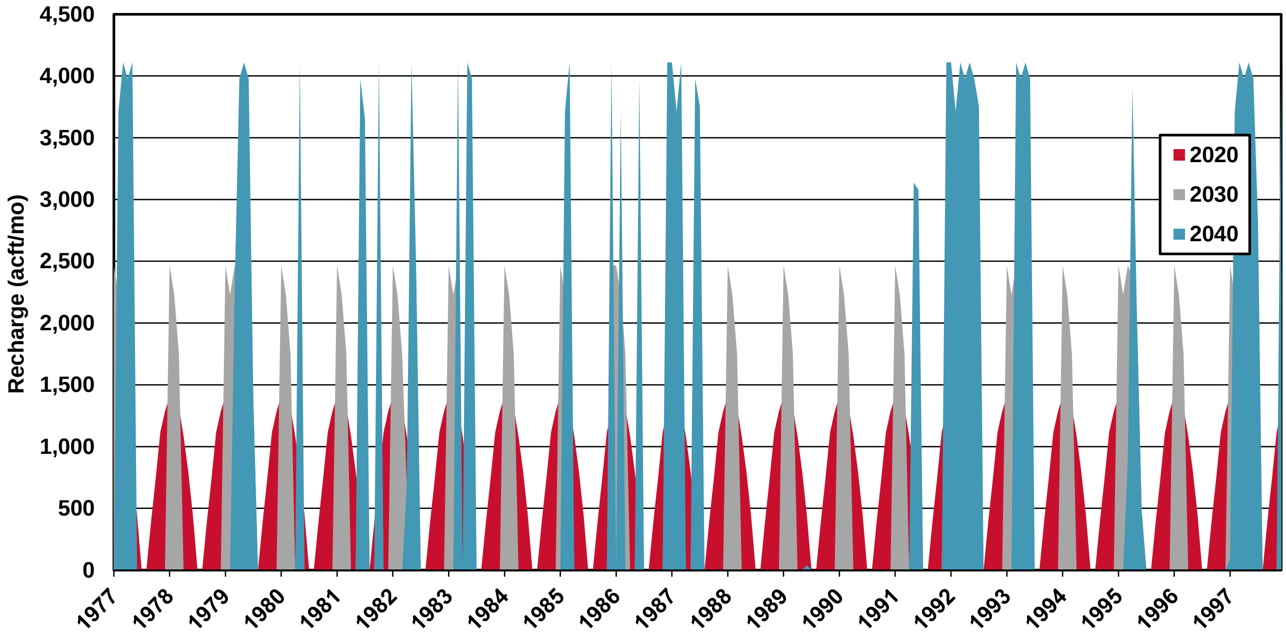


Figure 8.3-5. Zoomed-In Simulated Timeline of Recharge by Planning Decade



8.3.3 Environmental Issues

Environmental issues for the proposed Lake Georgetown ASR Project in Williamson County are described below. This project includes the development of a well field, production wells, well field distribution and collection pipelines, and an interconnect to a water treatment plant east of Lake Georgetown. 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 Georgetown ASR project well field would occur in close proximity to Lake Georgetown, a number of tributaries to the San Gabriel River, and the San Gabriel River, a Traditional Navigable Water. 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 Cross Timbers and Prairies and Blackland Prairies Ecoregions[1] and lies within the Texan Biotic Province.[2] Vegetation types within the Lake

[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.

Georgetown ASR well field area as described by the Texas Parks and Wildlife Department (TPWD)[3] includes disturbed or tame grasslands, floodplain deciduous shrubland, floodplain hardwood forest, floodplain herbaceous vegetation, riparian deciduous shrubland, evergreen shrubland, riparian hardwood evergreen forest, riparian hardwood forest, riparian herbaceous vegetation, evergreen motte and woodland, hardwood motte and woodland, savanna grassland, deciduous woodland, juniper shrubland, mesquite shrubland, crops, urban high intensity cover, and urban low intensity cover. 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.

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Williamson County can be found at https://tpwd.texas.gov/gis/rtest/.

Information received from the TPWD Texas Natural Diversity Database (TXNDD) shows documented occurrences of Bone Cave harvestman (SGCN), cave myotis bats (SGCN), Georgetown salamander (LE), Golden-cheeked warbler (LE/E), gravelbar brickellbush (SGCN), Guadalupe bass (SGCN), Jollyville Plateau salamander (LT), Kretschmarr Cave mold beetle (LE), Plateau loosestrife (SGCN),Redell harvestman (LT), Salado Springs salamander (LT), Texas shiner (SGCN),and western hog-nosed skunk (SGCN) within three miles of the project area.

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 most of the disturbed areas will return to their previous habitat condition, excluding areas where maintenance activities are required.

Element occurrence records for the Coffin Cave mold beetle and western hog-nosed skunk intersect the proposed project area. 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).

[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.

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.

8.3.4 Engineering and Costing

This ASR strategy recommends a total of 25 storage and recovery (ASR) wells, with 15 installed in 2020 and an additional 10 installed in 2040. Available records indicate that Trinity Aquifer wells in eastern Williamson County average 3,300 feet deep. A typical injection and recovery rate is estimated to be 1,200 gpm and 1,500 gpm. The well field design would space the wells about 3,000 ft apart. The recharge water will be pumped from Lake Georgetown, to the LWTP, and then to the well field (Figure 8.3-1) through a 42”, 12 mile long, two-way transmission pipeline. The existing pump station at the treatment plant would deliver the treated water to the ASR well field. A chlorination facility would be built at or near the well field for minimal treatment of extracted water and connected to existing transmission pipelines for direct delivery to users.

The major facilities required for these projects include:

- ASR wells,
- Well field collector and transmission pipelines,
- Chlorination facility, 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 8.3-3.

Table 8.3-3. Cost Estimate Summary: Lake Georgetown ASR Option

Item	Estimated Costs for Facilities
Transmission Pipeline (42 in dia., 12 miles)	$20,079,000
Well Fields (Wells, Pumps, and Piping)	$64,393,000
Two Water Treatment Plants (74.4 MGD and 7.7 MGD)	$136,225,000
TOTAL COST OF FACILITIES	**$220,697,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$76,240,000
Environmental & Archaeology Studies and Mitigation	$890,000
Land Acquisition and Surveying (59 acres)	$251,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$8,198,000
TOTAL COST OF PROJECT	**$306,276,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$21,550,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$845,000
Water Treatment Plant	$9,771,000
Pumping Energy Costs (20,416,759 kW-hr @ 0.08 $/kW-hr)	$1,633,000
TOTAL ANNUAL COST	**$33,799,000**
Available Project Yield (acft/yr)	8,645
Annual Cost of Water ($ per acft), based on PF=1	$3,910
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$1,417
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$12.00
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$4.35

8.3.5 Implementation

Implementation of the Lake Georgetown ASR water management strategy for BRA includes the following issues:

- Regulations (30 Texas Administrative Code Section 331.19(a) “Injection Into or Through the Edwards Aquifer”) currently do not allow injection of water through wells that transect the environmentally sensitive Edwards Aquifer in Williamson County and special legislative consideration is likely necessary to allow this project to proceed;
- 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 ASR wells as needed as the frequency of recharge events decreases and the magnitude increases;
- Ability to increase WTP capacity as needed to reflect changes in recharge events;
- 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 8.3-4, and the option meets each criterion.

Table 8.3-4. Comparison of Lake Georgetown 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 - 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 shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None

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8.4 Lake Granger ASR

8.4.1 Description of Option

The concept for the Lake Granger and ASR conjunctive use project is to:

- Supply local Lake Granger demands of 13,015 acft/yr, referred to herein as the "base rights."
- Overdraft Lake Granger to supply an additional 11,900 acft/yr, and recharge up to 11,520 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 with ASR and production wells when reservoir level drops to a volume equivalent to one-year supply of the lakeside demands.

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 8.4-1.

Operation of Lake Granger and the ASR project will be controlled by the available storage in the reservoir. When reservoir storage is at 70% (35,531 acft) or greater, water from the reservoir (stored water and inflows) will be used to meet the 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. As storage drops below a volume equivalent to one year of the base rights (13,015 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 8.4-2.

Figure 8.4-1. Lake Granger ASR Project Location

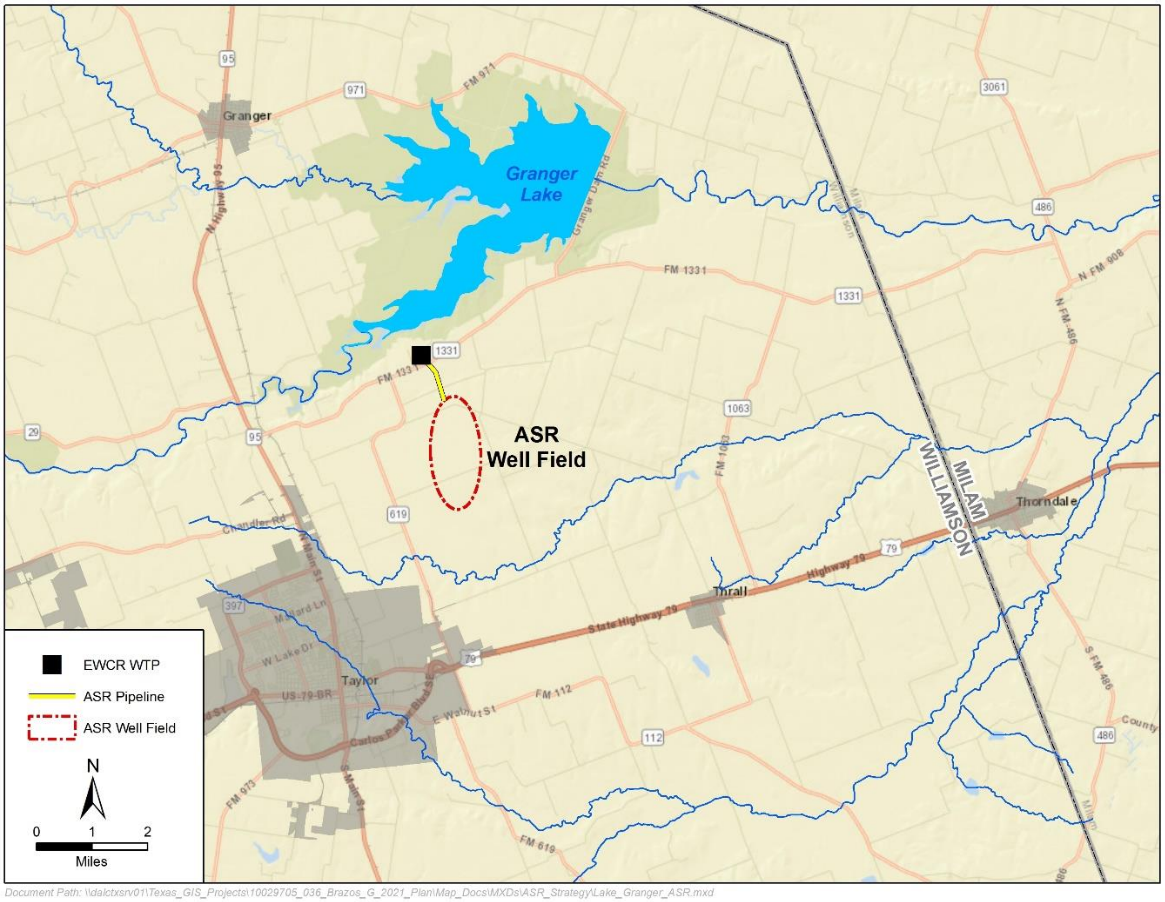
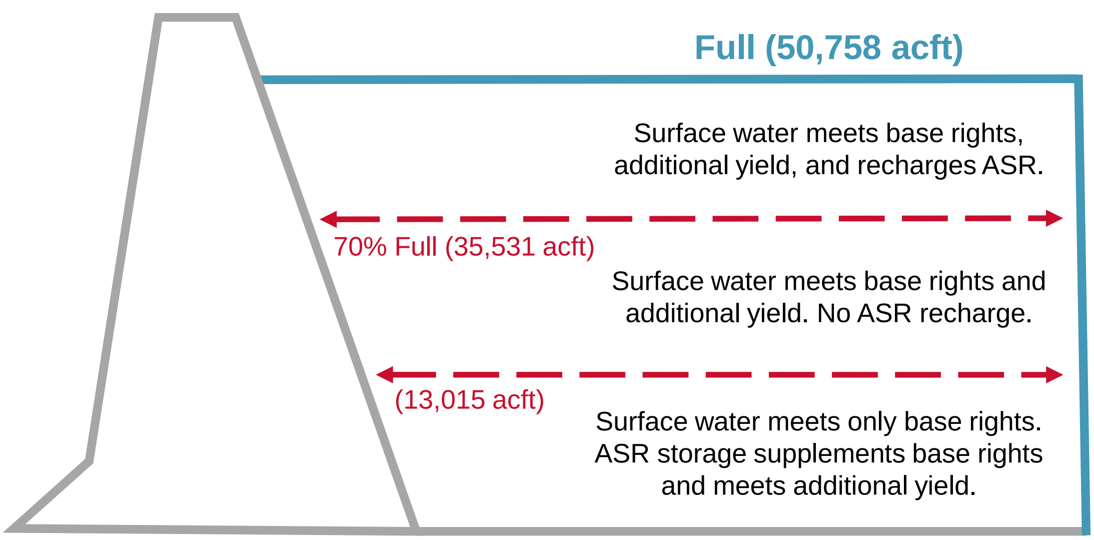


Figure 8.4-2. Operational Schematic of Lake Granger and ASR Project



8.4.2 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 1,200 gpm (160 acft/mo) during injection and 1,500 gpm (200 acft/mo) during recovery. 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 of Lake Granger with the proposed ASR well field. The ASR well field was assumed to require 6,200 acft of dead storage and was capped for analysis purposes at 80,000 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 11,900 acft/yr, increasing the total BRA water supply from Lake Granger to about 25,000 acft/yr. Figure 8.4-3 shows the annual source of diversions (Lake Granger or ASR storage) over the modeled time period. Figure 8.4-4 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 8.4-5). 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 about 60% of the time. A storage trace of Lake Granger alone, shown in Figure 8.4-6, 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 additional, interuptible surface water supplied from Lake Granger for this strategy would be authorized by the BRA’s System Operations Permit.

Figure 8.4-3. Utilization of Lake Granger and ASR Facility to Meet Lake Granger Demands and Provide Additional ASR Yield (13,015 acft/yr base plus 11,900 acft/yr additional)

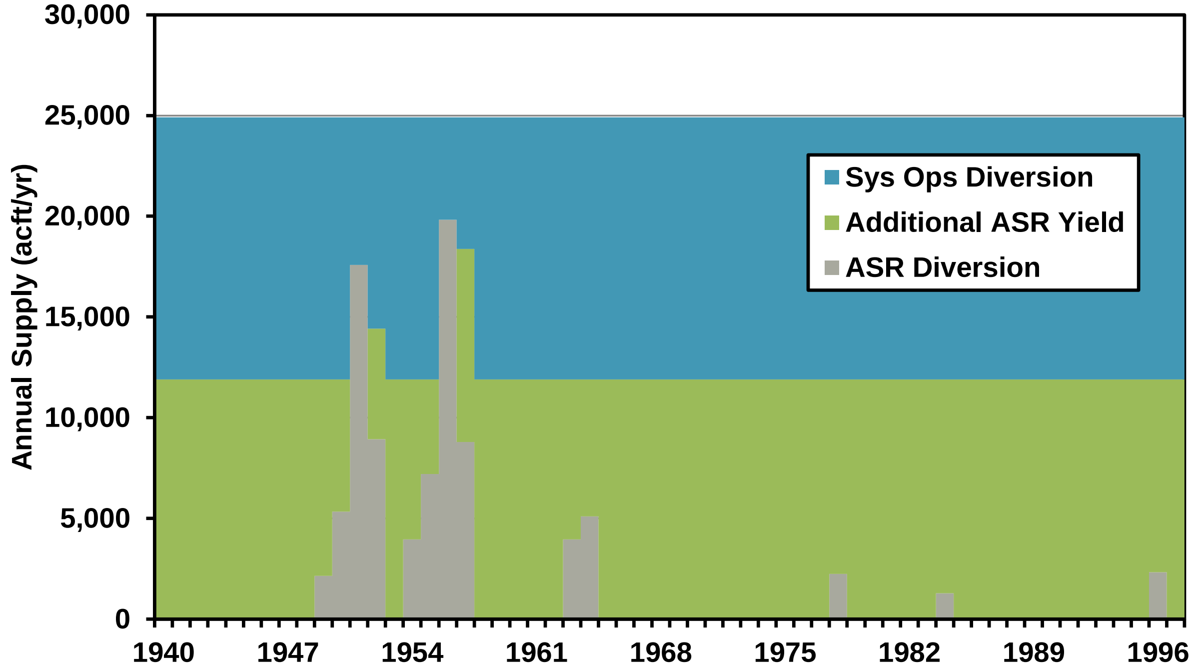


Figure 8.4-4. Combined System Storage for Lake Granger and ASR

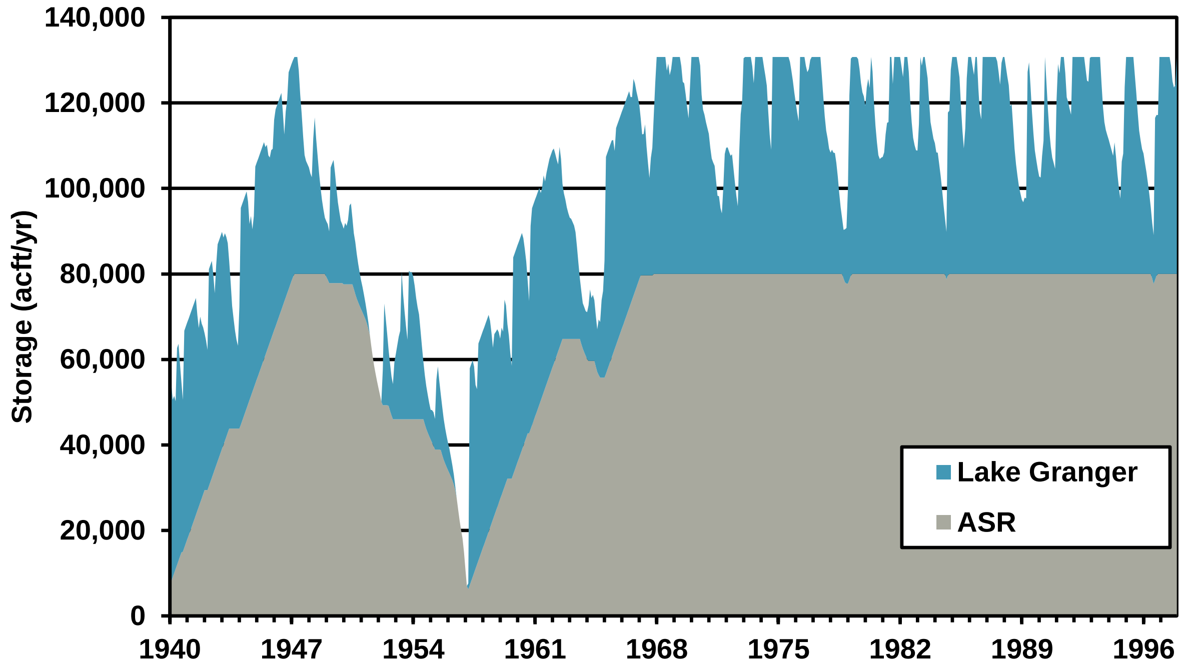


Figure 8.4-5. Lake Granger Storage Frequency

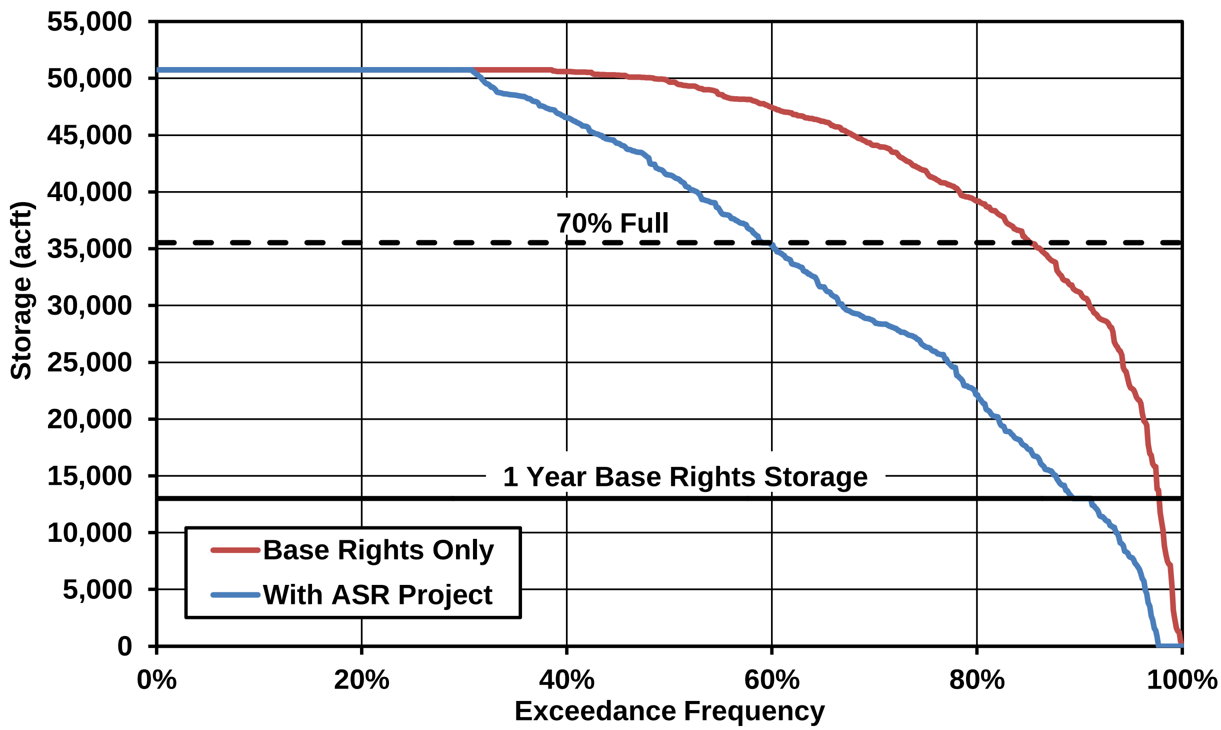
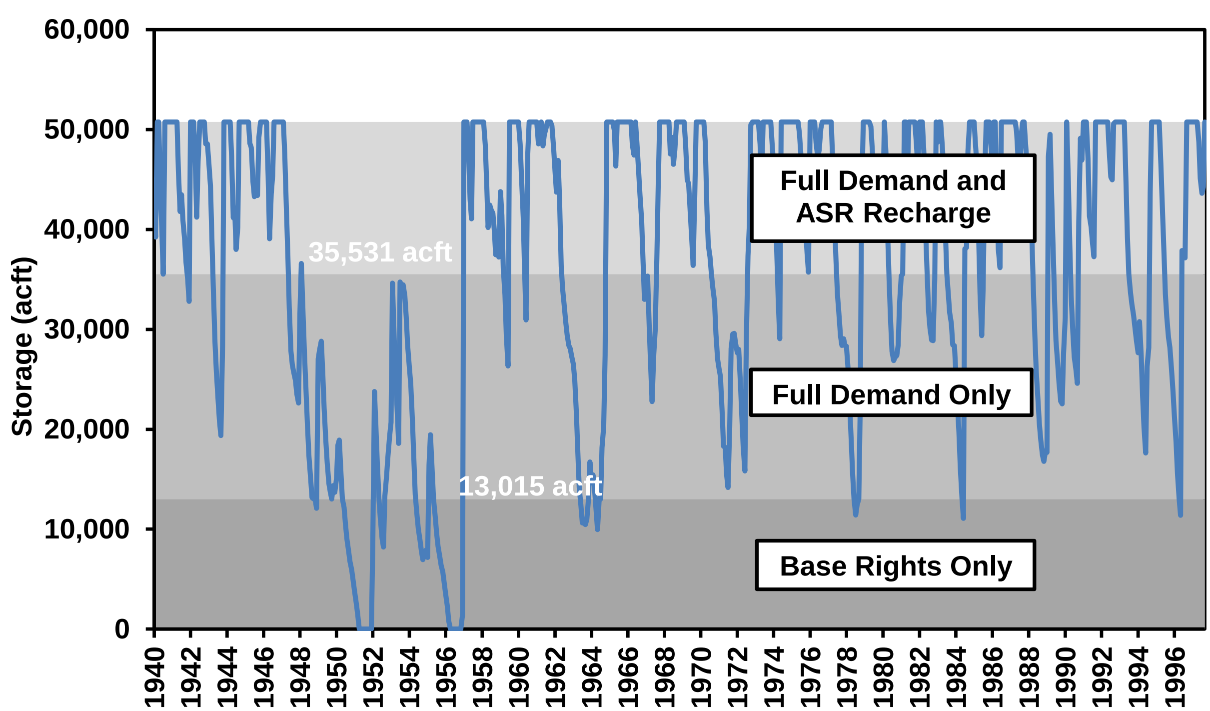


Figure 8.4-6. Lake Granger Storage Trace Operated Conjunctively with ASR Project



8.4.3 Environmental Issues

Environmental issues for the proposed Lake Granger ASR Project in Williamson County are described below. This project includes the development of an 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 near 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 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.

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Williamson County can be found at https://tpwd.texas.gov/gis/rtest/.

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.

Since 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.

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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.

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.

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, 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.

8.4.4 Engineering and Costing

Available records indicate that Trinity Aquifer wells in eastern Williamson County average 3,300 feet deep. For an 11,900 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, six (6) ASR wells are able to meet the peak injection rates, and 22 wells are required for recovery and production. Sixteen of the wells would be nearby production (recovery-only) wells, and six 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 30", 1.4 miles 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 8.4-1.

The cost estimate below assumes that only the six 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 eight recover-only wells would be constructed in each of the two later phases. The second phase includes only these additional wells, while the final phase considers the eight recover-only wells plus associated well field pipelines. 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 $271 per acft during the third phase.

Table 8.4-1 Cost Estimate Summary: Lake Granger ASR Option

Item	*Estimated Phase 1 Costs*	*Estimated Phase 2 Costs**	*Estimated Phase 3 Costs***
CAPITAL COST			
Transmission Pipeline (30 in dia., 1.4 miles)	$3,006,000	$0	$0
Well Fields (Wells, Pumps, and Piping)	$14,506,000	$15,360,000	$17,375,000
Water Treatment Plant (16.2 MGD)	$33,522,000	$0	$0
TOTAL COST OF FACILITIES	**$51,034,000**	**$15,360,000**	**$17,375,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$17,712,000	$5,376,000	$6,081,000
Environmental & Archaeology Studies and Mitigation	$268,000	$0	$16,000
Land Acquisition and Surveying (20.1 acres)	$69,000	$0	$22,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$1,900,000	$571,000	$647,000
TOTAL COST OF PROJECT	**$70,983,000**	**$21,307,000**	**$24,141,000**
ANNUAL COST			
Debt Service (3.5 percent, 20 years)	$4,994,000	$6,493,000	$8,192,000
Operation and Maintenance			
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$175,000	$329,000	$503,000
Water Treatment Plant	$2,347,000	$2,347,000	$2,347,000
Pumping Energy Costs (4573425 kW-hr @ 0.08 $/kW-hr)	$366,000	$952,000	$2,138,000
Purchase of Water (acft/yr @ $/acft)	$248,000	$579,000	$910,000
TOTAL ANNUAL COST	$8,130,000	$10,700,000	$14,090,000
Available Project Yield (acft/yr), based on a Peaking Factor of 1	3,200	7,600	11,900
Annual Cost of Water After Debt Service ($ per acft)	$966	$223	$271
Annual Cost of Water After Debt Service ($ per 1,000 gallons)	$2.97	$0.68	$0.83
** Phase 2 assumed to be built within 10 years from Phase 1* ***Phase 3 assumed to be built within 15 years of Phase 1*			

8.4.5 Implementation

Implementation of the Lake Granger ASR 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.

This water supply option has been compared to the plan development criteria, as shown in Table 8.4-2, and the option meets each criterion.

Table 8.4-2 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

8.5 Johnson County SUD and Acton MUD ASR

8.5.1 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 supply contracts from 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 BRPUA.
- 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 an indirect 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 would be 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.

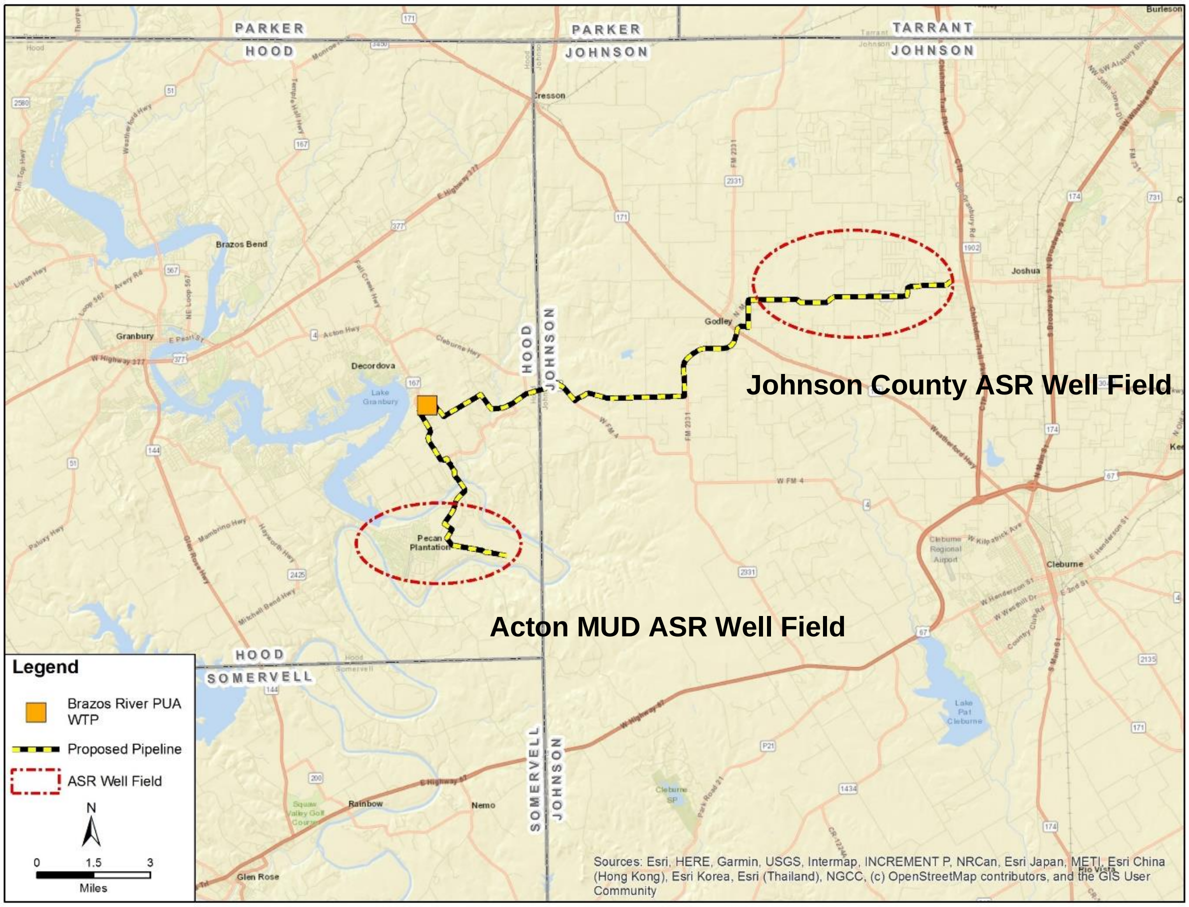
A schematic showing the location of the project facilities is shown in Figure 8.5-1. New facilities required for this option are ASR wells, well field distribution and collection pipelines and interconnects between the pipeline and ASR well fields.

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 8.5-2. As indicted in Figure 8.5-2, JCSUD’s water supplies exceed 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 8.5-3. 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.

Both JCSUD and AMUD ASR could yield 6,162 ac-ft/yr based on water treatment plant capacity availability and contract water available.

Figure 8.5-1. Location of Johnson County and Acton MUD ASR Projects



\\dalctxsrv01\Texas_GIS_Projects\10029705_036_Brazos_G_2021_Plan\Map_Docs\MXDs\ASR_Strategy\Trinity_Aquifer_ASR_Johnson_County.mxd

Figure 8.5-2. Water Supplies and Demand for JCSUD

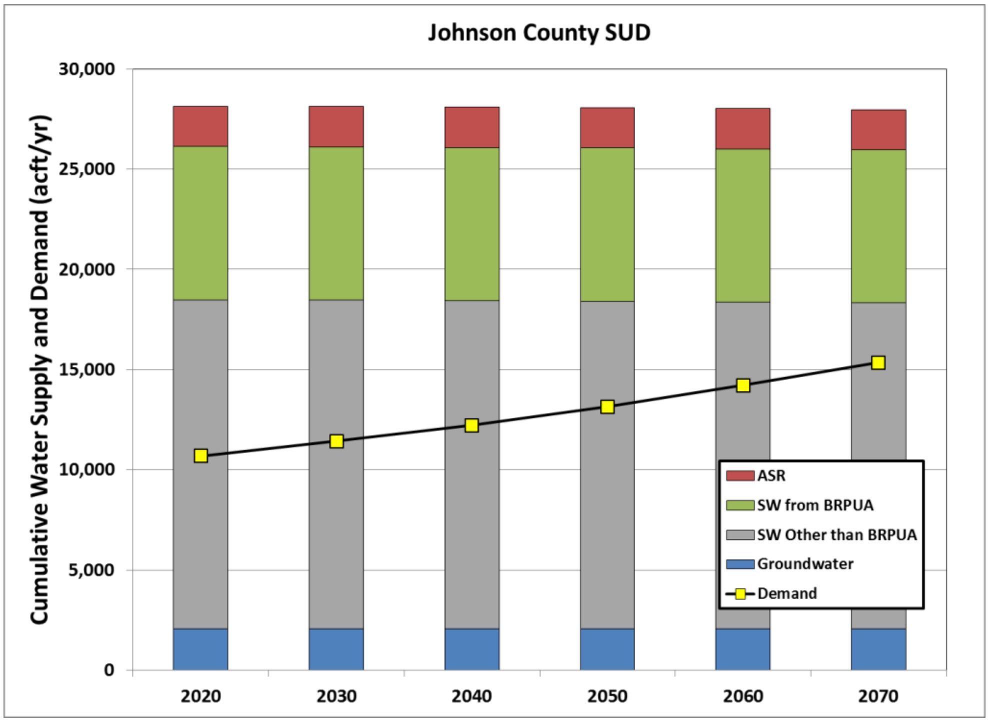
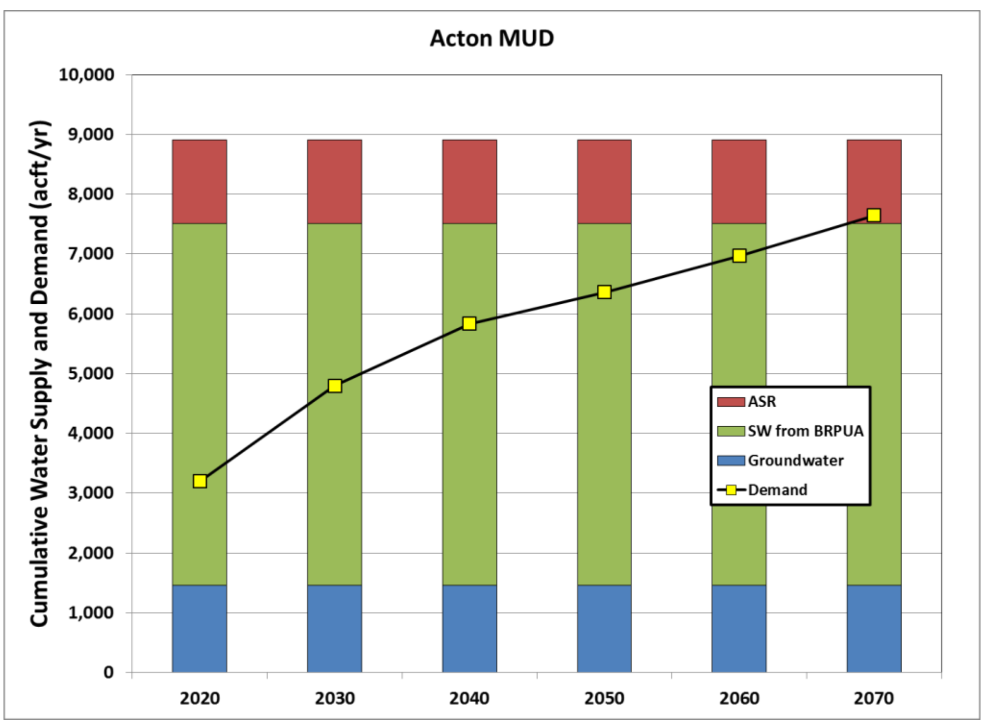


Figure 8.5-3. Water Supplies and Demand for AMUD

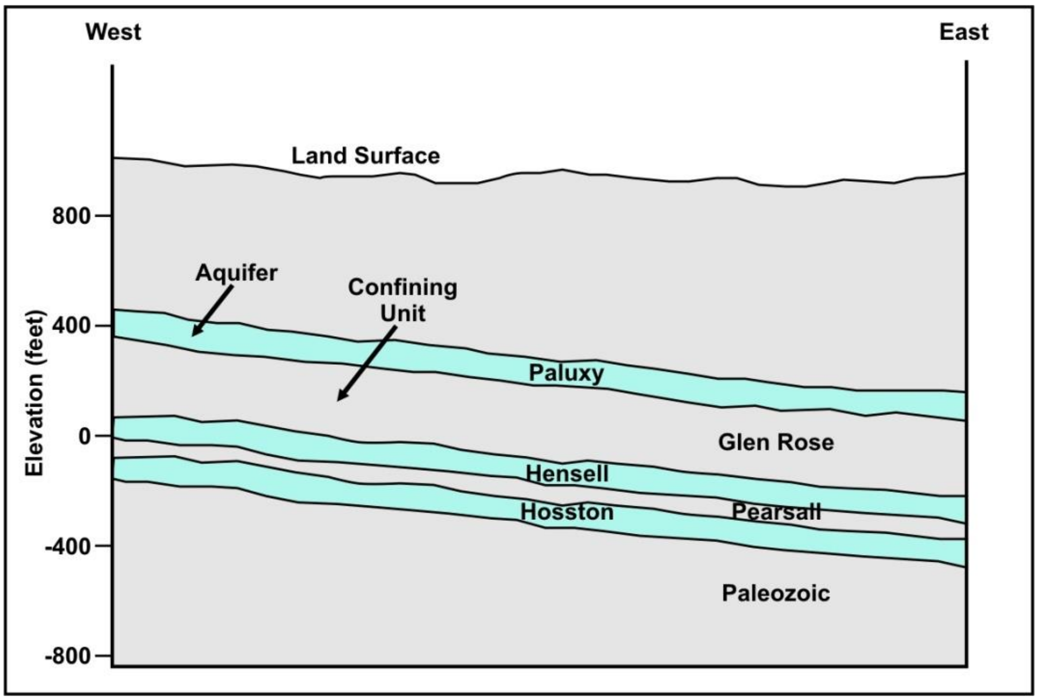


8.5.2 Available Yield

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 8.5-4). 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 insignificant because the intent 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 8.5-4. Hydrogeological Profile in ASR Well Field



8.5.3 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 Counties 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, exceptional aquatic life, and high aesthetic value. 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.

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Hood and Johnson counties can be found at https://tpwd.texas.gov/gis/rtest/.

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 most of the disturbed

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.

areas will return to their previous 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.

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 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.

8.5.4 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 250 gpm. For a 3,574 acft/yr system in Johnson County, 27 ASR wells are required. For a 2,526acft/yr system for AMUD, 13 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 8.5-1 and Table 8.5-2 for the Johnson County and Acton MUD projects, respectively. The annual costs, including debt service, operation and maintenance, and power, are estimated to be $633 per acft for the Johnson County project and $662 per acft for the AMUD project.

Table 8.5-1 Johnson County SUD ASR Cost Summary

Item	Estimated Costs for Facilities
Well Fields (Wells, Pumps, and Piping)	$11,253,000
Integration, Relocations, & Other	$700,000
TOTAL COST OF FACILITIES	**$13,231,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$4,631,000
Environmental & Archaeology Studies and Mitigation	$482,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$530,000
TOTAL COST OF PROJECT	**$19,789,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$1,392,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$120,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$32,000
Pumping Energy Costs (9,003,951 kW-hr @ 0.08 $/kW-hr)	$720,000
TOTAL ANNUAL COST	**$2,264,000**
Available Project Yield (acft/yr)	3,574
Annual Cost of Water ($ per acft), based on PF=1	$633
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$244
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.94
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.75

Table 8.5-2 Acton MUD ASR Cost Summary

Item	Estimated Costs for Facilities
Well Fields (Wells, Pumps, and Piping)	$10,454,000
Integration, Relocations, & Other	$950,000
TOTAL COST OF FACILITIES	**$11,404,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$3,991,000
Environmental & Archaeology Studies and Mitigation	$507,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$463,000
TOTAL COST OF PROJECT	**$17,296,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$1,217,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$114,000
Pumping Energy Costs (4,253,579 kW-hr @ 0.08 $/kW-hr)	$340,000
TOTAL ANNUAL COST	**$1,671,000**
Available Project Yield (acft/yr)	2,526
Annual Cost of Water ($ per acft), based on PF=1	$662
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$180
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$2.03
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.55

8.5.5 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 8.5-3, and the option meets each criterion.

Table 8.5-3. 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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8.6 Trinity ASR in McLennan County

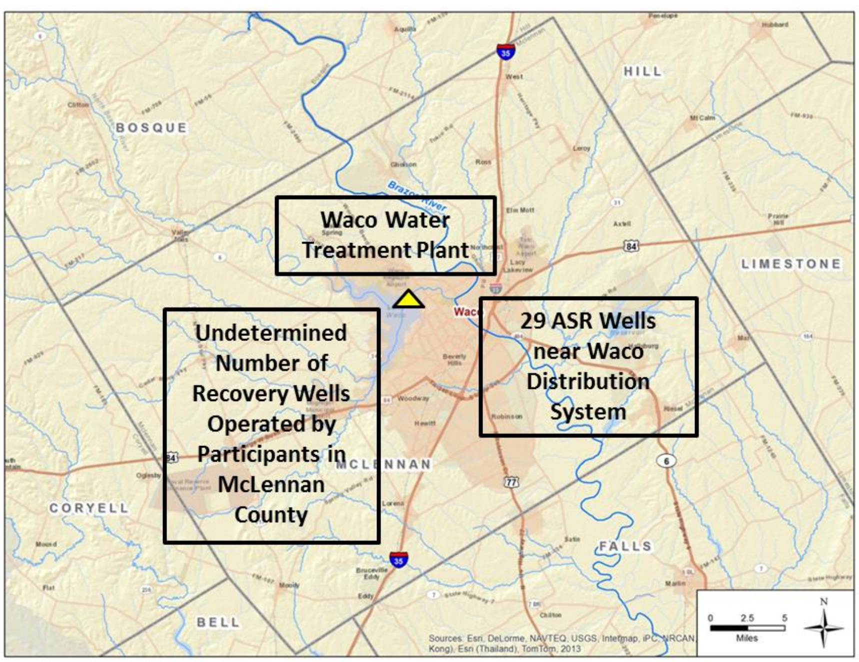
8.6.1 Description of Option

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).
- 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 water indirectly transferred 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 ASR injection cycle from October to May which coincides when there is excess treatment capacity. 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 8.6-1. 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.

Figure 8.6-1. Location of Waco and McLennan County ASR Project



8.6.2 Available Yield

The projected water supplies for Waco if unconstrained by water treatment capacity, and demands are illustrated in Figure 8.6-2. 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 eight months of October to May when Waco's demands are relatively low (see Figure 8.6-3). 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.

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.

8.6.3 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.

Figure 8.6-2 Treated vs Untreated Supplies for City of Waco

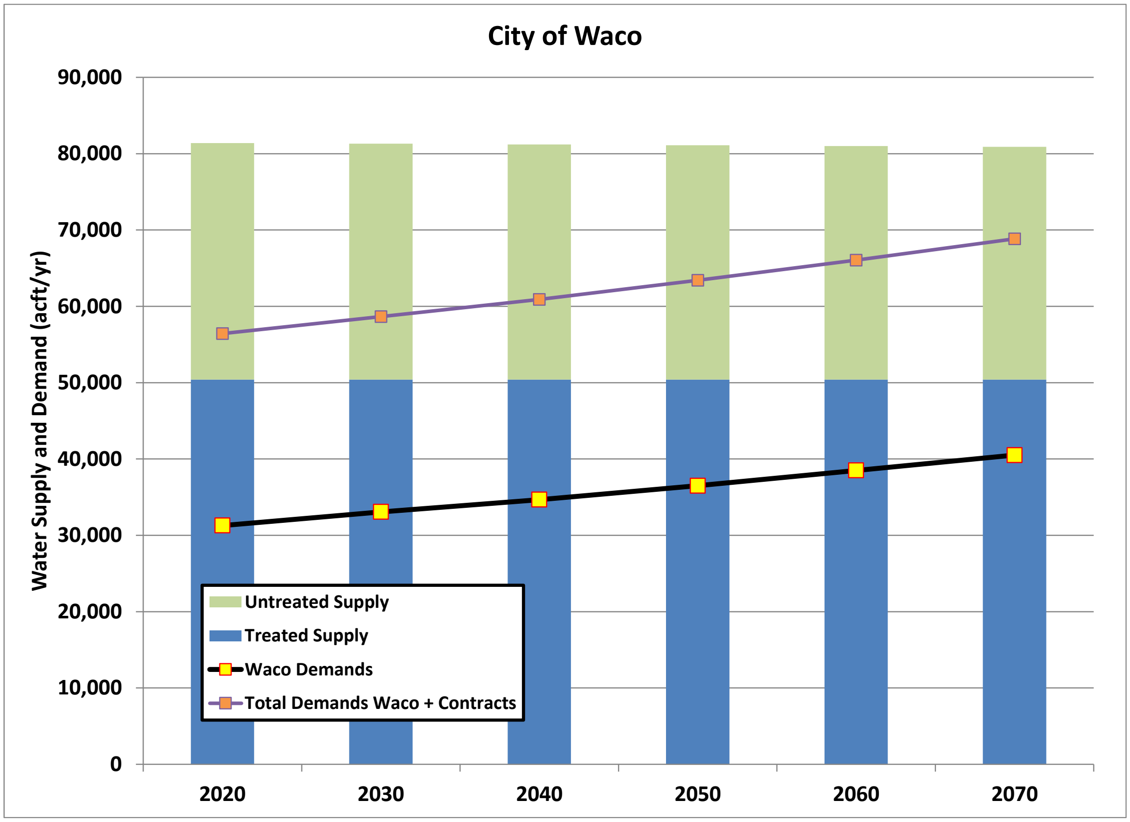
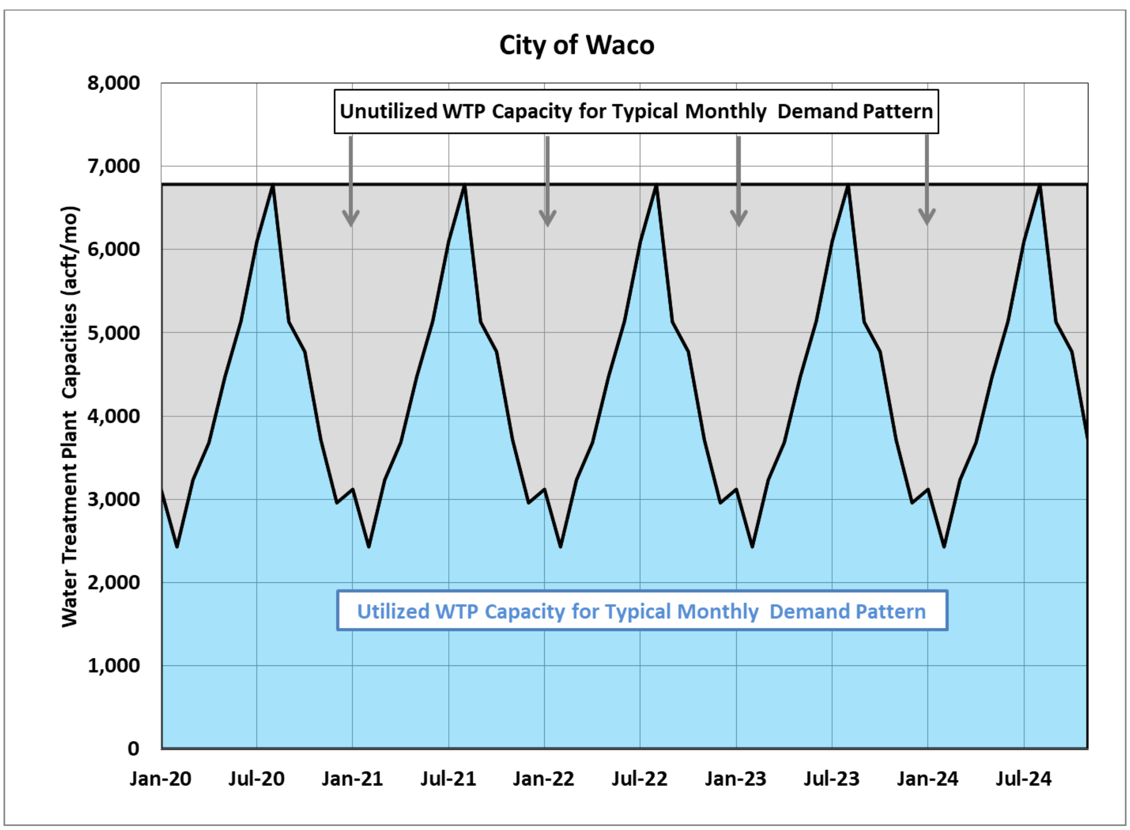


Figure 8.6-3. Water Treatment Capacity and Utilization of Waco's WTP



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.

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for McLennan County can be found at https://tpwd.texas.gov/gis/rtest/.

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.

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

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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.

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.

8.6.4 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 (injection wells), and
- SCADA and interconnections at each well site.

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 8.6-1. The annual costs, including debt service, operation and maintenance, and power, are estimated to be $645 per acft. The costs do not include any compensation to the City of Waco for use of their surface water right. Costs include the energy cost associated with pumping water through the pipeline and the power connection costs for each well.

8.6.5 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 8.6-2, and the option meets each criterion.

Table 8.6-1. Cost Estimate Summary: McLennan County ASR Project Option

Item	Estimated Costs for Facilities
Well Fields (Wells, Pumps, and Piping)	$36,220,000
Integration, Relocations, & Other	$8,554,000
TOTAL COST OF FACILITIES	**$44,774,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$15,671,000
Environmental & Archaeology Studies and Mitigation	$78,000
Land Acquisition and Surveying (76 acres)	$404,000
Interest During Construction (3% for 3 years with a 0.5% ROI)	$5,027,000
TOTAL COST OF PROJECT	**$65,954,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$4,641,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$448,000
Pumping Energy Costs (864,877 kW-hr @ 0.08 $/kW-hr)	$69,000
TOTAL ANNUAL COST	**$5,158,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**8,000**
Annual Cost of Water ($ per acft)	**$645**
Annual Cost of Water ($ per 1,000 gallons)	**$1.98**

Table 8.6-2. 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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9 Regional Water Supply Projects

9.1 Bosque County Regional Project

9.1.1 Description of Option

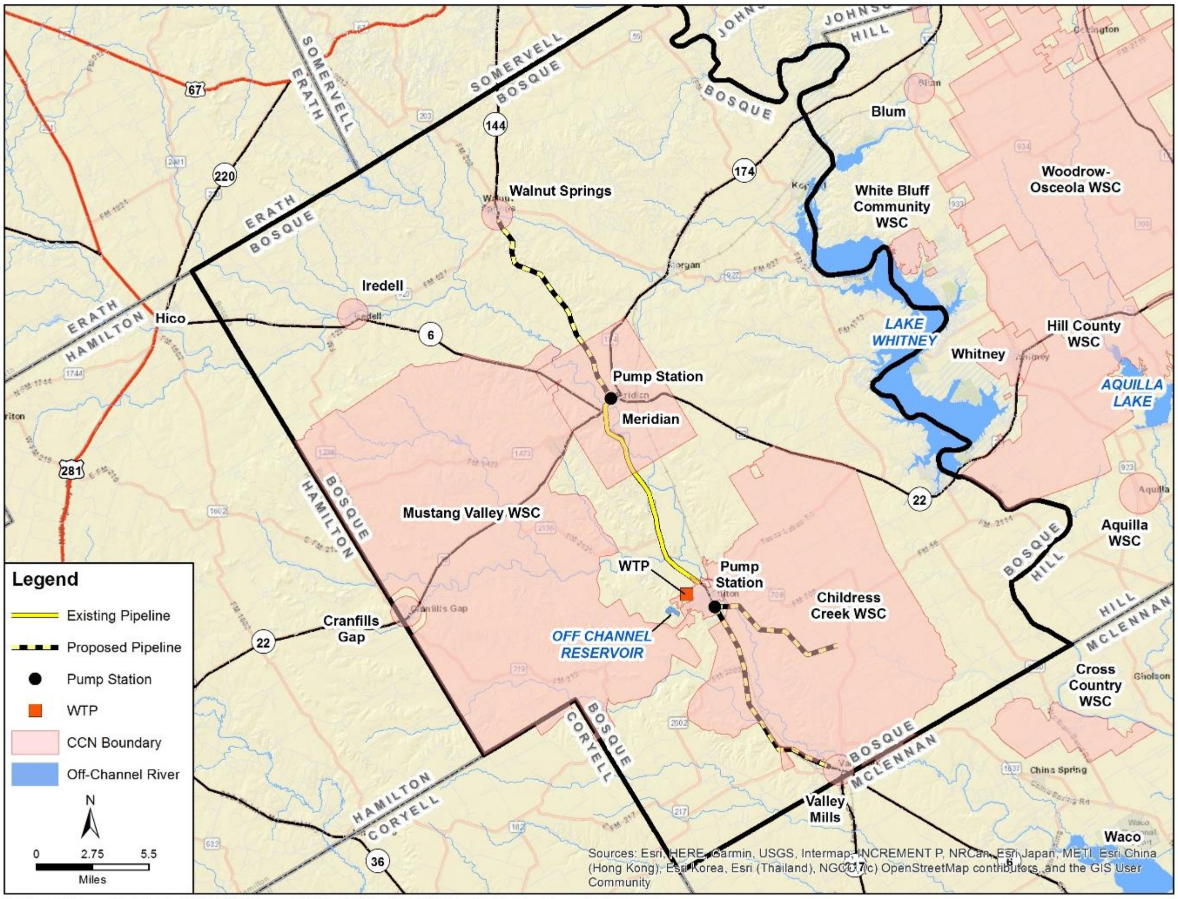
The Bosque County Regional Project has been a recommended water management strategy in both the 2011 and 2016 the regional water plans to address municipal water needs in Bosque County. Groundwater reliability remains a significant concern for the WUGs due to the large groundwater declines anticipated 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, Childress Creek Water Supply Corp. (WSC), and Bosque County Other. 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 9.1-1 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 9.1-1. Interconnection of Bosque County Systems



\\dalctxsrv01\Texas_GIS_Projects\10029705_036_Brazos_G_2021_Plan\Map_Docs\MXDs\Regional_Strategy\Bosque_Regional.mxd

9.1.2 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/yr for municipal use. The second water right dated December 13, 1996 allows the City to divert and impound 2,000 acft/yr 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 the North Bosque River watershed to be senior to rights in Lake Waco.

A previous yield analysis[2] for the Clifton OCR on the North Bosque River subject to instream flow conditions is included in Table 9.1-1.

[2] HDR, February 1997. City of Clifton Water Supply Plan. Preliminary Engineering Report

Table 9.1-1. 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 Bosque County Other; 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.

9.1.3 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, Childress Creek, and Bosque County Other. 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 Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Bosque County can be found at https://tpwd.texas.gov/gis/rtest/.

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," https://tpwd.texas.gov/landwater/water/conservation/water_resources/water_quantity/sigsegs/regiong.phtml. Accessed July 18, 2019.

[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/ July 18, 2019.

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.

No designated critical habitat for the endangered 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.

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.[7]

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.

9.1.4 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

[7] USFWS Ecological Services. Sharpnose and smalleye shiners. Accessed online at http://www.fws.gov/southwest/es/arlingtontexas/shiner.htm, on May 29, 2014.

would be needed to connect the City of Clifton to Childress WSC, Valley Mills, Meridian and Bosque County Other:

- 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.

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 Bosque County Other 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 9.1-2. 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 $3.5 million and by entity: Childress, $708,000;

Valley Mills, $683,000; Meridian, $597,000; Bosque County Other, $447,000; and Clifton, $1,019,000.

9.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 9.1-3, 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; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

Table 9.1-2. Cost Estimate Summary: Bosque County Regional Project

Item	Estimated Costs for Facilities	Childress Creek WSC	Valley Mills	Meridian	Bosque County Other	Clifton
Off-Channel Reservoir Expansion	$9,451,000	$1,793,000	$1,608,000	$1,979,000	$565,000	$3,507,000
Primary Pump Stations	$2,588,000	$491,000	$440,000	$542,000	$155,000	$960,000
Transmission Pipeline (6 in dia., 28 miles)	$5,325,000	$1,330,000	$1,967,000	$0	$2,028,000	$0
Transmission Pump Station(s) & Storage Tank(s)	$1,600,000	$576,000	$141,000	$196,000	$687,000	$0
Water Treatment Plant (2 MGD)	$8,190,000	$1,554,000	$1,393,000	$1,715,000	$490,000	$3,039,000
TOTAL COST OF FACILITIES	**$27,154,000**	**$5,744,000**	**$5,549,000**	**$4,432,000**	**$3,925,000**	**$7,506,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$9,238,000	$1,944,000	$1,844,000	$1,551,000	$1,272,000	$2,627,000
Environmental & Archaeology Studies and Mitigation	$980,000		$200,000	$160,000	$142,000	$271,000
Land Acquisition and Surveying (188 acres)	$574,000	$121,000	$117,000	$94,000	$83,000	$159,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,044,000	$221,000	$213,000	$170,000	$151,000	$289,000
TOTAL COST OF PROJECT	**$38,990,000**	**$8,030,000**	**$7,923,000**	**$6,407,000**	**$5,573,000**	**$10,852,000**
Debt Service (5.5 percent, 20 years)	$1,821,000	$375,000	$370,000	$299,000	$260,000	$507,000
Reservoir Debt Service (5.5 percent, 40 years)	$614,000	$126,000	$125,000	$101,000	$88,000	$171,000
Operation and Maintenance						
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$134,000	$34,000	$36,000	$10,000	$40,000	$14,000
Dam and Reservoir (1.5% of Cost of Facilities)	$142,000	$27,000	$24,000	$30,000	$8,000	$53,000
Water Treatment Plant (2.5% of Cost of Facilities)	$739,000	$140,000	$126,000	$155,000	$44,000	$274,000
Pumping Energy Costs (213654 kW-hr @ 0.09 $/kW-hr)	$17,000	$6,000	$2,000	$2,000	$7,000	$0
TOTAL ANNUAL COST	**$3,467,000**	**$708,000**	**$683,000**	**$597,000**	**$447,000**	**$1,019,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1.5	**1,070**	**203**	**182**	**224**	**64**	**397**
Annual Cost of Water ($ per acft)	**$3,240**	**$3,488**	**$3,753**	**$2,665**	**$6,984**	**$2,567**
Annual Cost of Water ($ per 1,000 gallons)	**$9.94**	**$10.70**	**$11.52**	**$8.18**	**$21.43**	**$7.88**

Table 9.1-3. 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

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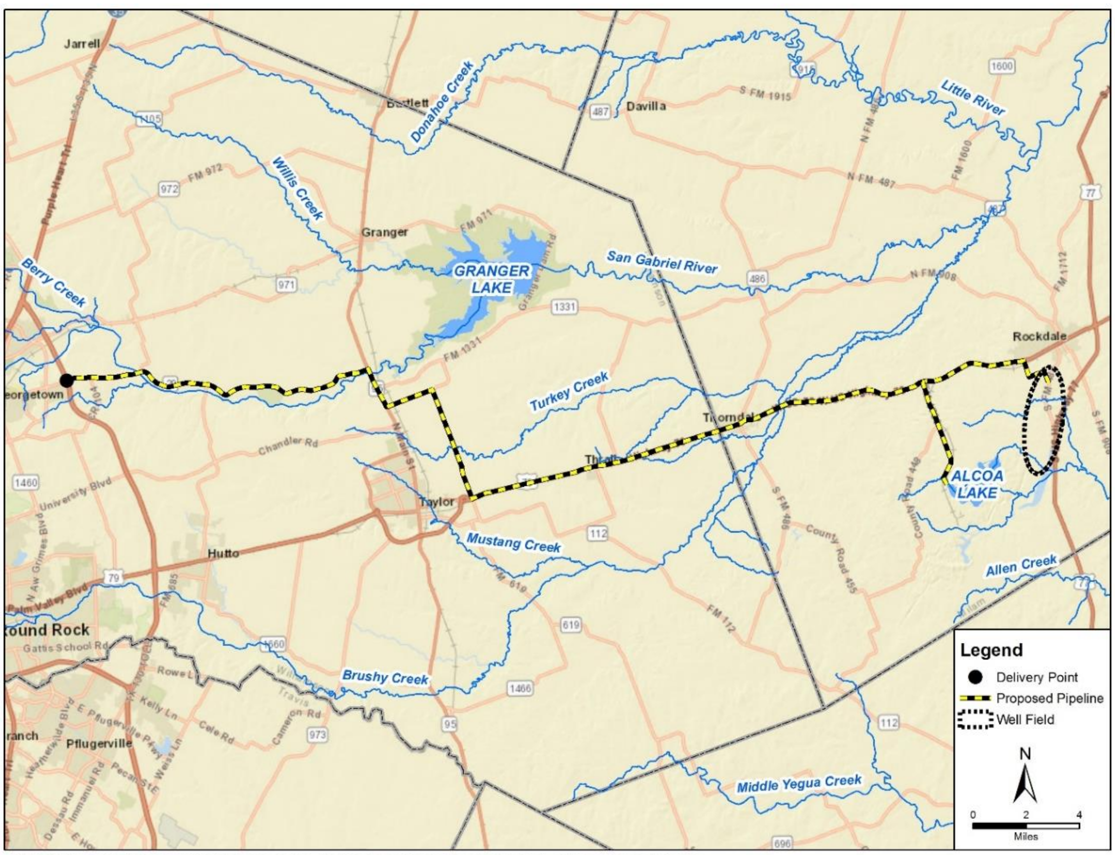
9.2 Milam County Groundwater and Alcoa Supply for Williamson County

9.2.1 Description of Option

In the Milam County area Alcoa has ceased operations and is offering to sell the property and the water rights for Lake Alcoa, Little River diversions rights, and groundwater supply associated with the property near Alcoa's former Rockdale plant. Water at the site has recently been used by Luminant for steam-electric power generation, but the power facilities have been shut down as well. This indicates that water supply dedicated to steam-electric cooling is no longer required for that purpose, which would free up those supplies for other uses. These supplies include the firm yield of Lake Alcoa and associated diversions from the Little River, and Carrizo-Wilcox Aquifer supplies available under the modeled available groundwater (MAG) in Milam County.

This strategy assesses converting the Alcoa surface water supplies and groundwater supplies in Milam County from industrial to municipal water use and delivering the supply to supply municipal water needs in Williamson County. Figure 9.2-1 shows the existing and proposed infrastructure and delivery to a point just west of the State Highway 130 corridor east of Georgetown.

Figure 9.2-1. Proposed Infrastructure of the Milam County Groundwater and Alcoa Water Supply Project



9.2.2 Available Supply

Alcoa has surface water rights that can supply up to 18,600 acre-feet per year from Lake Alcoa, including a separate water right and an additional contract with the BRA to divert flows from the Little River. The associated groundwater supplies are permitted for up to 33,600 acft/yr, but for regional water planning purposes will supply only between 14,006 to 17,529 acft/yr due to MAG limitations. These supplies are assumed to be available for municipal use in Williamson County, provided that certain existing permit limitations can be amended.

9.2.3 Environmental Issues

There would be limited environmental impacts due to construction of the proposed pipeline from the existing Alcoa well field or Lake Alcoa to the distribution point. Environmental impacts could include:

- Possible impacts to riparian corridors and waters of the U.S., depending on location of the proposed pipeline
- Possible minor impacts to cultural resources
- Other possible minor impacts to vegetation and wildlife habitat due to 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 9.2-1. The proposed pipeline can be sited to avoid impacts to any critical wildlife habitat.

Table 9.2-1. Environmental Issues: Milam County Groundwater and Alcoa Supply for Williamson County

Issue	Description
Implementation Measures	A pipeline from the existing Alcoa well field and Lake Alcoa to the distribution point in Williamson County
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.

9.2.4 Engineering and Costing

Figure 9.2-1 shows the facilities included in the water management strategy to meet needs in Williamson County. Brazos G considered three options for supplying Williamson County municipal needs:

- 14,000 acft/yr Milam County groundwater supply,
- 18,600 acft/yr Alcoa surface water supply, and
- 32,600 acft/yr combined groundwater and surface water.

Infrastructure for the groundwater supply would include: primary pump station, pipeline route from the well fields to the delivery point, water treatment plant costs for chlorine disinfection, cost to upgrade the wells, and other associated project costs. Infrastructure for the surface water strategy includes: intake, WTP, primary pump station, pipeline route from Lake Alcoa to the delivery point, and other associated project costs. Infrastructure for the combined supplies would include: intake, pump stations, pipeline route from the well fields to the delivery point, pipeline route from Lake Alcoa to the delivery point, water treatment plant costs, cost to upgrade the wells, and other associated project costs. Due to the magnitude of municipal needs in Williamson County, the Brazos G RWPG has recommended the combined supply option. Costs are presented in Table 9.2-3. For a combined supply of 32,600 acft/yr, the total project would be $359,500,000 with an annual cost of $44,328,000.

9.2.5 Implementation Issues

As a large regional water supply project, this evaluation assumes that the Brazos River Authority would be the lead agency, although another regional water provider or private enterprise could also develop the project on behalf of Williamson County entities. Supplies from this project could be used by BRA as the groundwater portion of the Lake Granger Augmentation strategy recommended for the BRA.

Issues that may impede implementation are the required amendments to the surface water rights and groundwater permits. Surface water rights would need to be amended to change the type and place of use. Existing agreements between Luminant and Alcoa likely would need to be modified. The BRA contract would also need to be modified to change the type and place of use. The groundwater permits would need to be amended from on-site industrial use to municipal use off-site. It is likely that when the groundwater permits are modified, they would not retain their historical use status, which offers some level of protection against future reductions in permitted volume. Use of the groundwater in Williamson County would require that the new permit holders obtain export permits authorizing use of the water outside of the Post Oak Savannah Groundwater Conservation District (Milam and Burleson Counties). Table 9.2-4 compares this water management strategy to the plan development criteria.

Table 9.2-2. Cost Estimate Summary for Surface Water Only Option for Delivery to Williamson County

Item	Estimated Costs for Facilities
Intake Pump Stations (17.5 MGD)	$31,910,000
Transmission Pipeline (36 in dia., 42 miles)	$69,313,000
Transmission Pump Station(s) & Storage Tank(s)	$8,802,000
Water Treatment Plant (16.6 MGD)	$64,207,000
TOTAL COST OF FACILITIES	**$174,232,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$57,516,000
Environmental & Archaeology Studies and Mitigation	$1,119,000
Land Acquisition and Surveying (525 acres)	$2,353,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$6,469,000
TOTAL COST OF PROJECT	**$241,689,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$17,005,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$709,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$977,000
Water Treatment Plant	$4,494,000
Pumping Energy Costs (16,563,378 kW-hr @ 0.08 $/kW-hr)	$1,325,000
Purchase of Water (18,600 acft/yr @ 76.5 $/acft)	$1,423,000
TOTAL ANNUAL COST	**$25,933,000**
Available Project Yield (acft/yr)	18,600
Annual Cost of Water ($ per acft), based on PF=1	$1,394
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$480
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$4.28
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$1.47

Table 9.2-3. Cost Estimate Summary for Combined Surface Water and Groundwater Option for Delivery to Williamson County

Item	Estimated Costs for Facilities
Intake Pump Stations (30.6 MGD)	$38,345,000
Transmission Pipeline (42 in dia., 42 miles)	$82,639,000
Transmission Pump Station(s) & Storage Tank(s)	$16,086,000
Well Fields (Wells, Pumps, and Piping)	$13,913,000
Water Treatment Plant (29.2 MGD)	$105,758,000
TOTAL COST OF FACILITIES	**$258,477,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$86,335,000
Environmental & Archaeology Studies and Mitigation	$2,027,000
Land Acquisition and Surveying (678 acres)	$3,039,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$9,622,000
TOTAL COST OF PROJECT	**$359,500,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$25,295,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$1,005,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$1,306,000
Water Treatment Plant	$7,403,000
Pumping Energy Costs (85,309,616 kW-hr @ 0.08 $/kW-hr)	$6,825,000
Purchase of Water (32,600 acft/yr @ 76.5 $/acft)[1]	$2,494,000
TOTAL ANNUAL COST	**$44,328,000**
Available Project Yield (acft/yr)	32,600
Annual Cost of Water ($ per acft), based on PF=1	$1,360
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$584
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$4.17
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$1.79

1 - Costs to purchase supply assumed at the BRA System Rate.

Table 9.2-4. Comparison of Milam County Groundwater and Alcoa Supply for Williamson County Project to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Meets some of the needs for Williamson County municipal WUGs
2. Reliability	2. High reliability
3. Cost	3. Relatively high, but reasonable for a regional 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

Potential Regulatory Requirements:

Implementation of this water management strategy will require the following permits for pipeline construction:

- Amendment of water right permit authorizing Lake Alcoa.
- Amendment of water right permit authorizing diversions from the Little River.
- Amendment of groundwater permits issued by the Post Oak Savannah Groundwater Conservation District.
- Amendment of contract with the Brazos River Authority.

- 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.
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.
- If the project is completed by a political subdivision of the state of Texas, then the project would be required to comply with the Texas Antiquities Code and a cultural resources survey may be required.
- Appropriate permits will have to be obtained for TxDOT highway crossings.

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9.3 Brushy Creek Regional Utility Authority System

9.3.1 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 23,000 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 of 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 144.7 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 26.9 MGD of raw water to Cedar Park's existing water treatment plant and 12 MGD to Leander's water treatment plant.

The BCRUA will utilize an existing 17 MGD, expandable to 32.5 MGD, interim floating intake structure located near the Cedar Park WTP, until a deep water 144.7 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 9.3-1. The allocation of capacity for the proposed regional system is detailed in Table 9.3-1.

9.3.2 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 22,128 acft/yr (20,928 acft/yr to Round Rock and 1,200 acft/yr to Liberty Hill). 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 be sufficient to meet a large portion of Williamson County's projected 2070 shortages. However, for Williamson

[1] House Bill 1437, 76th Session, Texas Legislature.

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 9.3-2 presents the projected allocation of water under the original 25,000 acft/yr, and an additional allocation of water of 47,000 acft/yr. Cedar Park and Leander would obtain additional supply above the original HB 1437 amount.

Figure 9.3-1. Brushy Creek Regional Utility Authority System

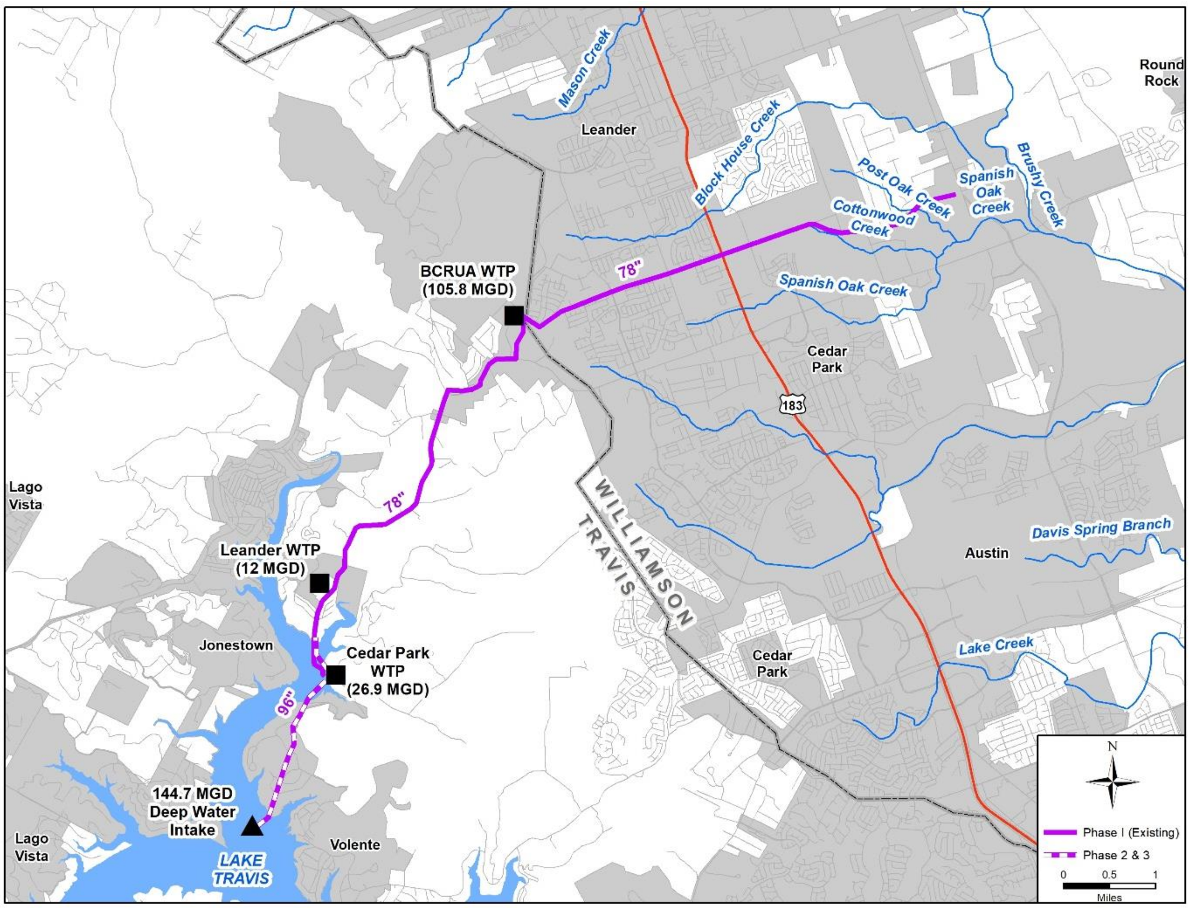

Table 9.3-1. Brushy Creek Regional Utility Authority System Participation with Peaking Capacity

	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)	*41.9*	*40.8*	*62*	*144.7*
Deep Water Intake Allocation (%)	*28.96%*	*28.20%*	*42.85%*	*100%*

Table 9.3-2. 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	23,000	23,000
Chisholm Trail SUD[1]	2,540	0	0	0
Liberty Hill	600	1,200	0	1,200
Round Rock	11,444	20,928	0	20,928
Leander	0	0	24,000	24,000
Georgetown	6,944	0	0	0
Unallocated	3,472	2,872	0	0
Total	25,000	25,000	47,000	69,128

[1] Chisholm Trail SUD and Georgetown have merged.

9.3.3 Environmental Issues

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.

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Travis County can be found at https://tpwd.texas.gov/gis/rtest/.

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 rare Black-capped vireo and endangered 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.

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 negatively impact 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.

9.3.4 Engineering and Costing

The project is planned in three phases. The first phase is under construction and assumed complete for purposes of the 2021 Brazos G Plan, and the second phase is currently in design.

The first phase of the project provides 32.5 MGD of treated water. Total projected costs for Phase I is $152,480,000. The major facilities constructed as Phase I of this project are:

- Construction of 17 MGD floating raw water pump station and subsequent pump station expansion;
- Raw water transmission pipeline from Lake Travis to Regional Water Treatment Plant;
- Construction of a new 17 MGD water treatment plant and subsequent expansions to 32.5 MGD treatment capacity; and
- Treated water transmission pipelines to Cedar Park, Leander and Round Rock.

The second phase will be constructed to provide a treated water capacity of 67 MGD. Total projected cost for Phase II is $257,635,000. The major facilities planned for Phase II of the project are:

- Construction of a new deep water intake near Volente and raw water pump station;
- Raw water transmission tunnels from the deep water intake; and
- Two Expansions of the regional water treatment plant; the first expansion will increase treatment plant capacity to 42 MGD; the second expansion following completion of the deep water intake will expand treatment capacity to 67 MGD.

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 $70,362,500. Major facilities include:

- Increase deep water intake capacity to 144.7 MGD; and
- Expansion at the regional water treatment plant by 38.8 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 9.3-3 summarizes the costs for Phase II and Phase III based on September 2018 prices.

9.3.5 Implementation Issues

This water supply option has been compared to the plan development criteria, 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.
   - D. Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.
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 9.3-3. Summary of Costs for BCRUA Water Supply Project (Phases II- III)

Item	Estimated Costs for Facilities	Cedar Park	Round Rock	Leander[3]
Phase 2 - Deep Water Intake and Pump Station (144.7 MGD)	$145,000,000	$41,986,869	$40,884,589	$62,128,542
Phase 2 - WTP Expansion (42 MGD)	$12,000,000	$1,701,323	$4,627,599	$5,671,078
Phase 2 - WTP Expansion (67 MGD)	$50,000,000	$7,088,847	$19,281,664	$23,629,490
Phase 3 - WTP Expansion (105.8 MGD) and Deep Water Intake Pump Station Expansion (144.7 MGD)	$55,000,000	$9,127,821	$20,276,795	$25,595,385
Total Cost of Facilities	**$262,000,000**	**$59,905,000**	**$85,071,000**	**$117,024,000**
Engineering, Legal Costs and Contingencies	$41,000,000	$9,655,334	$13,115,529	$18,229,137
Land Acquisition and Surveying	$0	$0	$0	$0
Interest During Construction (3 years)[1]	$24,997,500	$3,544,069	$9,639,868	$11,813,563
Total Project Cost	**$327,997,500**	**$73,104,263**	**$107,826,043**	**$147,067,194**
Annual Costs				
Debt Service (3.5 percent, 20 years)[1]	$18,127,476	$4,483,642	$5,648,211	$7,995,623
Operation and Maintenance				
Intake, Pipeline, Pump Station	$3,850,000	$1,114,824	$1,085,556	$1,649,620
Water Treatment Plant	$9,729,433	$1,379,409	$3,751,993	$4,598,031
Pumping Energy Costs (@$0.08/kW-hr)	$15,600,000	$4,517,208	$4,398,618	$6,684,174
Purchase of Water ($157.5/acft)	$3,937,500	$0	$3,843,000	$95,000
Purchase of Water ($126/acft)	$5,292,000	$2,268,000	$0	$3,024,000
Total Annual Cost	**$56,536,409**	**$13,763,083**	**$18,727,378**	**$24,046,448**
Available Project Yield (acft/yr)[2]	**69,128**	**23,000**	**20,928**	**25,200**
Annual Cost of Water ($ per acft)	**$817.85**	**$598.39**	**$894.85**	**$954.22**
Annual Cost of Water ($ per 1,000 gallons)	**$2.51**	**$1.84**	**$2.75**	**$2.93**

Costs developed from BCRUA Regional Water Supply Project Environmental Assessment. March 2014, Phase 1 bid data, Phase 2 Preliminary Engineering Opinion of Probable Construction Cost, and additional cost information provided by BCRUA's design consultant for Phase 2.

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 1,200 acft/yr for Liberty Hill.

Table 9.3-4. Comparison of Brushy Creek Regional Utility Authority System 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 to medium 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 to medium 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	• None
E. Equitable Comparison of Strategies	• Done
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

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9.4 East Williamson County Water Supply Project

9.4.1 Description of Option

Lone Star Regional Water Authority (RWA) has connected a water supply transmission system to deliver supplies from Lake Granger to meet growing demands in Williamson County. 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, City of Jarrell, and Williamson County.

The East Williamson County Water Supply Project is a transmission system to convey treated water from the Brazos River Authority East Williamson County Regional Water System water 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 customers as indicated in Figure 9.4-1, 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.

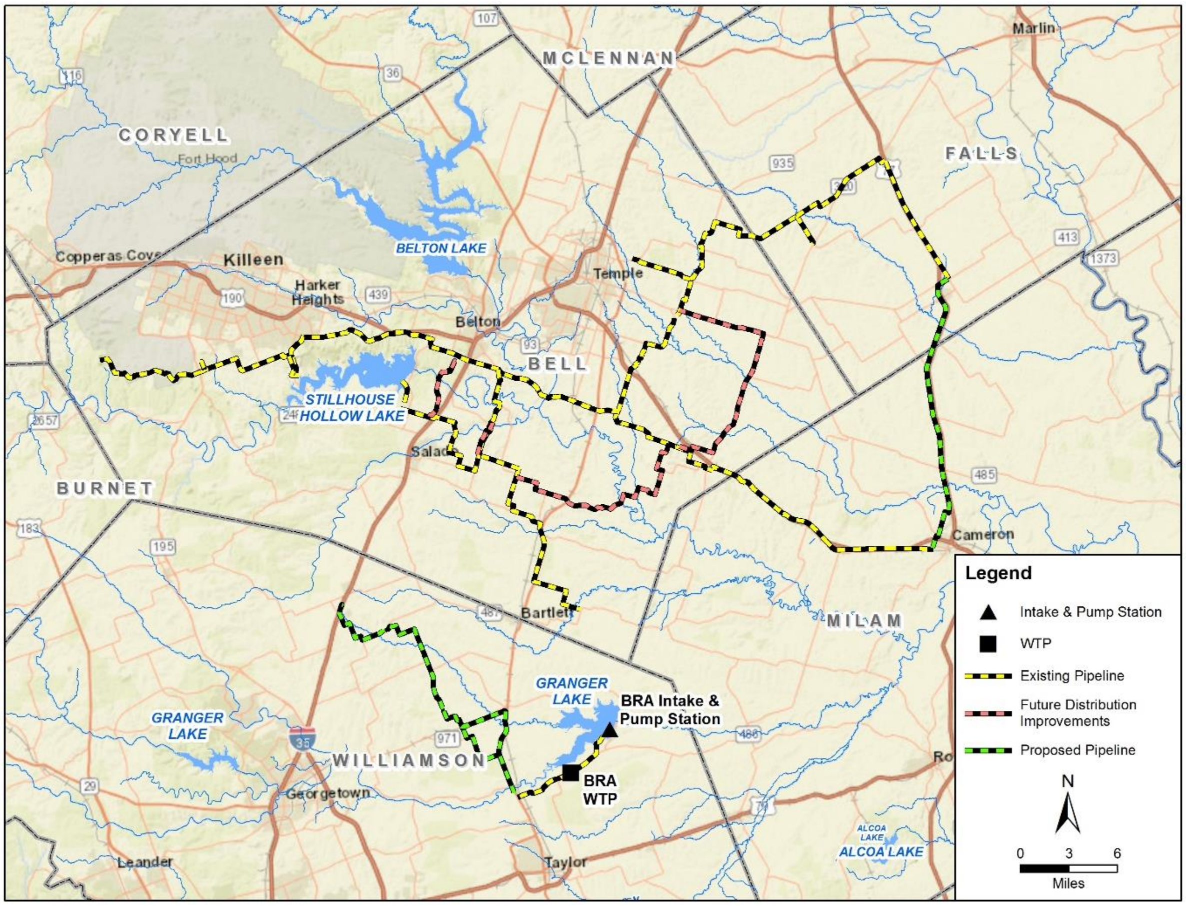
The transmission infrastructure will be designed with a 1.2 peaking factor. Lone Star RWA has contracted with BRA for 11,760 acft/yr (10.5 mgd) of Lake Granger supplies.

9.4.2 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. This project could be supplied by other potential new supplies developed and delivered to near Lake Granger including the Lake Granger Augmentation strategy, Lake Granger ASR, Williamson County Groundwater Strategies (South Option), and Milam County Groundwater and Alcoa Supply.

Figure 9.4-1. East Williamson County Water Supply Project



9.4.3 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 9.4-1. No adverse impacts to federally-listed threatened or endangered species are anticipated.

Table 9.4-1. Environmental Issues: East Williamson County Water Supply Project

Issue	Description
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.

9.4.4 Engineering and Costing

Cost estimates were prepared using the TWDB Unified Costing Model. Cost tables were updated to September 2018 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 9.4-2.

The transmission system is sized with a 1.2 peaking factor. Operating and maintenance and energy costs are projected based on the average annual operation of 11,762 acft per year. Entities would need to contract for treated supplies at the BRA WTP, and those purchase costs are not included here. The total project cost for treatment and delivery of 11,762 acft of potable water to the project participants is $30,264,420. The associated debt service and annual operating cost are projected at $2,765,000, yielding a finished water cost of $235 per acft, or $0.72 per thousand gallons.

9.4.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 9.4-3, 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.

- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.
- Appropriate permits have been and will be obtained for TxDOT highway crossings.

Table 9.4-2 Cost Summary of East Williamson County Water Supply Project

Item	Estimated Costs for Facilities
CAPITAL COST	
Contract No. 1 - 24" Water Line "A"	$6,504,539
Contract No. 2 - 30" San Gabriel River Bore	$870,355
Contract No. 3 - 24" Water Line "A" (Part of) and Water Line "B"	$6,338,515
Contract No. 4 - 10.5 MGD Pump Station No. 1	$2,263,511
Contract No. 5 - 10.5 MGD Pump Station No. 2	$2,440,243
Contract No. 6A - 0.5 MGD Ground Storage Tank No. 1	$749,800
Contract No. 6B - 0.5 MGD Ground Storage Tank No. 2	$648,000
Copntract No. 7 - 0.5 MGD Elevated Tank	$1,229,935
Contract No. 8 - 12" Water Line "C"	$1,376,331
Contract No. 8 - 12" Water Line "D"	$439,614
Contract No. 8 - 12" Water Line "E"	$391,209
TOTAL COST OF FACILITIES	**$23,252,052**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$4,771,023
Environmental & Archaeology Studies and Mitigation	$98,000
Land Acquisition and Surveying	$1,119,345
Interest During Construction (4% for 1 years with a 1% ROI)	$1,024,000
TOTAL COST OF PROJECT	**$30,264,420**
ANNUAL COST	
Debt Service (5.5 percent, 20 years)	$2,533,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$185,000
Intakes and Pump Stations (1% of Cost of Facilities)	$47,000
TOTAL ANNUAL COST	**$2,765,000**
Available Project Yield (acft/yr)	11,762
Annual Cost of Water ($ per acft)	$235
Annual Cost of Water After Debt Service ($ per acft)	$20
Annual Cost of Water ($ per 1,000 gallons)	$0.72
Annual Cost of Water After Debt Service ($ per 1,000 gallons)	$0.06

Table 9.4-3. 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	• None
E. Equitable Comparison of Strategies	• Done
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

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9.5 Lake Belton to Lake Stillhouse Hollow Pipeline

9.5.1 Description of Option

A pipeline is proposed to connect Lake Belton to Lake Stillhouse Hollow (Figure 9.5-1) 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 (BRA) 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, as well as water to BRA customers downstream. 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 9.5-1 summarizes storage and diversion authorizations for the reservoirs. Included in the table are the reach diversion limits, which are the maximum volume that can be diverted in a year using the System Operation Permit (Permit No. 5851, priority date October 15, 2004).

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. 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. In the future, supplementing the supply at Lake Stillhouse Hollow with water transferred from Lake Belton limits drawdowns in Lake Stillhouse Hollow and prevents shortages.

The locations of facilities and a pipeline route for this project have not been established and 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 9.5-1. Connection between Lakes Belton and Stillhouse Hollow

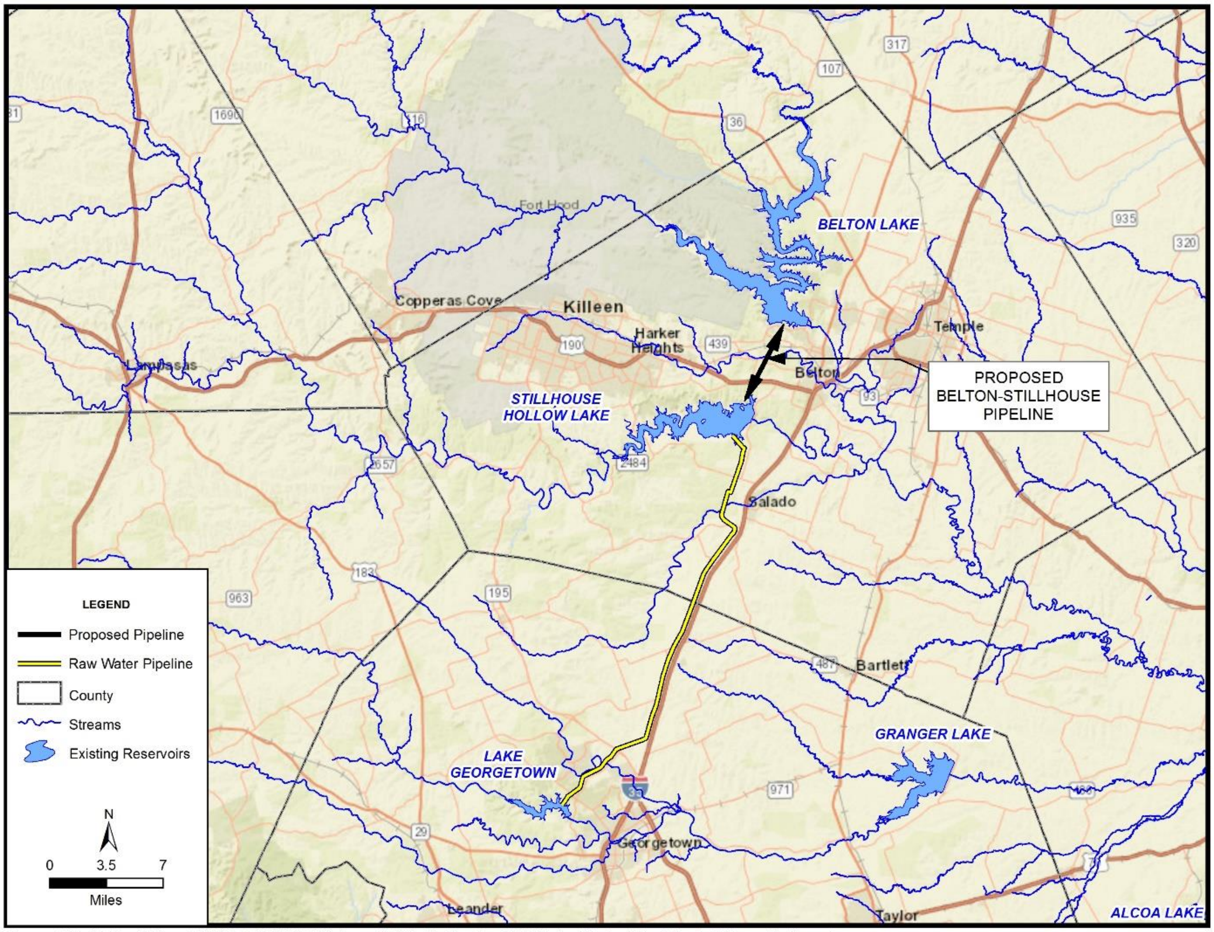

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Table 9.5-1. Diversion and Storage Data for Lakes Belton, Stillhouse Hollow and Georgetown

Reservoir Name	Water Right	Authorized Storage (acft)	Authorized Priority Diversion (acft/yr)	Priority Date	SysOps Reach Diversion Limit (acft/yr)
Belton	CA 12-5160	457,600	100,257	12/16/1963	22,523
Stillhouse Hollow	CA 12-5161	235,700	67,768	12/16/1963	12,808
Georgetown	CA 12-5162	37,100	13,610	2/12/1968	10,059

CA – Certificate of Adjudication
Note: The priority date of the System Operations Permit is 3/1/2012

9.5.2 Available Yield

The project is expected to deliver around 30,000 acft/yr from Lake Belton to Lake Stillhouse Hollow based on an estimate of the need in the area served by Lakes Stillhouse Hollow and Georgetown. 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 right for Lake Belton and Lake Stillhouse Hollow. For purposes of planning guidelines, this strategy is considered to make available 5,000 acft/yr of existing supplies.

Under this strategy, the demands at Lake Georgetown can be met by water pumped from Lake Stillhouse Hollow through the Williamson County Regional Raw Water Line that connects Lake Stillhouse to Lake Georgetown and from Lake Belton through the Lake Belton to Lake Stillhouse Hollow pipeline. The proposed Belton to Stillhouse Hollow pipeline would allow the BRA to use supplies from Lake Belton to meet demands at the other two reservoirs.

9.5.3 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.

The pipeline would have a minimal impact on the frequency of time that these reservoirs are full and spilling because pumping would not occur until Lake Stillhouse Hollow has been drawn down significantly. The project would have minimal impact on instream flows or bays and estuaries because the frequency and volume of spills would be about the same with and without the pipeline.

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.

9.5.4 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 9.5-2 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 $48.1 million. Total project costs, including engineering, contingencies, permitting, mitigation and interest during construction are an additional $19.9 million for a total project cost of $68.0 million. Annual costs, including debt service, power cost and operation and maintenance are approximately $6.5 million per year. The resulting unit costs are $1,309 per acre-foot or $4.02 per thousand gallons, based on the project increasing supplies to Georgetown by 5,000 acft/yr.

9.5.5 Implementation Issues

This water supply options have been compared to the plan development criteria, as shown in Table 9.5-3, and the option meets each criterion. Implementation steps for the project are presented below.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality (TCEQ) Water Right and Storage permits
- 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)
- TCEQ 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 USACE for discharge into Lake Stillhouse Hollow

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

- Possible analysis of 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
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.
- 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 9.5-2. Estimated Costs for the Lake Belton to Lake Stillhouse Hollow Pipeline

Item	Estimated Costs
CAPITAL COSTS	
Intake & Pump Station (33 MGD)	$35,876,000
Pipeline (48 in. dia., 6.8 mi and Discharge Structure)	$12,182,000
TOTAL COST OF FACILITIES	**$48,058,000**
Engineering, Legal Costs and Contingencies	$16,219,000
Environmental & Archeological Studies and Mitigation	$933,000
Land Acquisition	$963,000
Interest During Construction (12 months)	$1,820,000
TOTAL COST OF PROJECT	**$67,993,000**
ANNUAL COSTS	
Debt Service (3.5 percent, 20 years)	$4,784,000
Electricity	$742,000
Operation & Maintenance	$1,019,000
TOTAL ANNUAL COST	**$6,545,000**
Available Project Yield (acft/yr)	**5,000**
Annual Cost of Water ($ per acft)	**$1,309**
Annual Cost of Water ($ per 1,000 gallons)	**$4.02**

Table 9.5-3. 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

9.6 Lake Whitney Water Supply Project (Cleburne)

9.6.1 Description of Option

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.

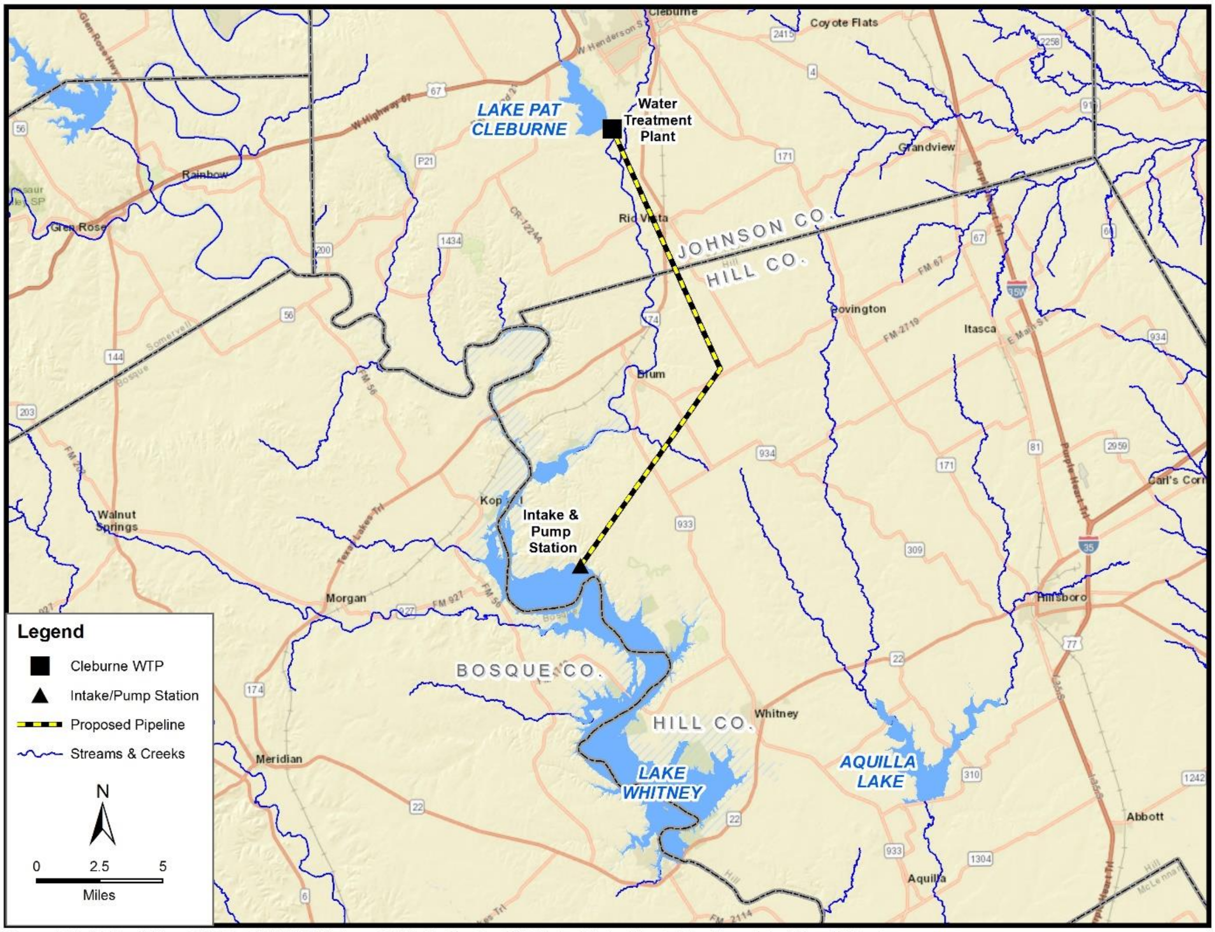
The project would require a deep water intake, diversion pump station to take water out of Lake Whitney, an advanced water treatment facility for the Lake Whitney water, blending tanks, a booster pump station, and a pipeline to Cleburne, and all associated appurtenances for a fully functional and operational water supply delivery and treatment system. This project would supply the City of Cleburne and possibly 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.

The proposed project includes advanced treatment to remove dissolved solids from a portion of the water from Lake Wey. Approximately 70 to 85 percent of the water will need to be treated to remove sufficient salt loads to maintain acceptable water quality. For costing purposes, it was assumed that the brine reject will be discharged back into Lake Whitney.

Previous versions of the Brazos G Plan have included alternatives to this strategy that included bringing water from Lake Whitney to supplement supplies from Lake Aquilla. These options used additional water from the BRA system to meet the needs of other Lake Aquilla users. At this time the City of Cleburne is not considering the joint strategy, so it is not considered in the current plan.

Figure 9.6-1. Lake Whitney Water Supply Project



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9.6.2 Available Yield

Although the City of Cleburne holds contracts for 9,700 acft/yr, water diverted from Lake Whitney requires desalination or blending for municipal use. For this strategy, approximately 24 percent of the water will be lost in the desalination process, resulting in an available supply of about 7,400 acft/yr. The water from the project would come from Lake Whitney and other water supply sources in the BRA system.

9.6.3 Environmental Issues

A 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 Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Bosque, Hill and Johnson counties can be found at https://tpwd.texas.gov/gis/rtest/. 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.

No designated critical habitat for the rare black-capped vireo or endangered 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 could include changes in salinity of the water within Lake Whitney or impacts from the construction and maintenance of the associated pipelines, pump stations or water treatment facilities. If 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.

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.

9.6.4 Engineering and Costing

The strategy was evaluated to determine required infrastructure and costs to develop water supplies from Lake Whitney. The strategy includes pretreatment of Lake Whitney water before it is delivered to Cleburne. The project could be implemented in two phases. The first phase delvers an average of 3.8 MGD and includes a lake pump station, desalination plant, booster pump station and main transmission line. The second phase includes expansion of existing pump stations and treatment facilities for an additional supply of 2.8 MGD.

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 water from Lake Aquilla or Lake Pat Cleburne before full treatment at the city's water treatment plant. Future options may include full treatment at the take point. The total capital cost for Phase I of the Lake Whitney to Cleburne project is $89.4 million with total annual costs of $10.8 million. The second phase of the project is $32.9 million with total annual cost increase of $6.4 million. A summary of the costs for this option is provided in Table 9.6-1.

Table 9.6-1. Cost Estimate for Phase I and II Lake Whitney Diversion to Cleburne

Item	Estimated Phase I Costs	Estimated Phase II Costs	Estimated Total Costs for Facilities
CAPITAL COST			
Desal to City (24 in dia., 19.2 miles)	$15,599,000	$0	$15,599,000
Primary Pump Stations (9.9 MGD)	$3,154,000	$2,191,000	$5,345,000
Transmission Pump Station(s) & Storage Tank(s)	$3,921,000	$2,334,000	$6,255,000
Intake to desal (30 in dia., 0.4 miles)	$519,000	$0	$519,000
Intake Pump Stations (13 MGD)	$13,211,000	$1,948,000	$15,159,000
Brine discharge (14 in dia., 0.4 miles)	$235,000	$0	$235,000
Primary Pump Stations (3.1 MGD)	$588,000	$390,000	$978,000
Transmission Pump Station(s) & Storage Tank(s)	$1,803,000	$901,000	$2,704,000
Storage Tanks (Other Than at Booster Pump Stations)	$1,544,000	$772,000	$2,316,000
Water Treatment Plant (11 MGD)	$20,108,000	$14,561,000	$34,669,000
TOTAL COST OF FACILITIES	**$60,682,000**	**$23,097,000**	**$83,779,000**

Table 9.6-1. Cost Estimate for Phase I and II Lake Whitney Diversion to Cleburne

Item	Estimated Phase I Costs	Estimated Phase II Costs	Estimated Total Costs for Facilities
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$20,421,000	$8,085,000	$28,506,000
Environmental & Archaeology Studies and Mitigation	$837,000	$0	$837,000
Land Acquisition and Surveying (173 acres)	$2,770,000	$0	$2,770,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$4,659,000	$1,716,000	$6,375,000
TOTAL COST OF PROJECT	**$89,369,000**	**$32,898,000**	**$122,267,000**
ANNUAL COST			
Debt Service (3.5 percent, 20 years)	$6,288,000	$2,315,000	$8,603,000
Operation and Maintenance			
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$217,000	$27,000	$244,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$472,000	$146,000	$618,000
Water Treatment Plant	$3,088,000	$3,381,000	$6,469,000
Pumping Energy Costs (6,730,780 kW-hr @ 0.08 $/kW-hr)	$288,000	$250,000	$538,000
Purchase of Water (9,700 acft/yr @ 70.5 $/acft)	$397,000	$287,000	$684,000
TOTAL ANNUAL COST	**$10,750,000**	**$6,406,000**	**$17,156,000**
Available Project Yield (acft/yr)	4,300	3,100	7,400
Annual Cost of Water ($ per acft)	$2,500	$2,066	$2,318
Annual Cost of Water After Debt Service ($ per acft)	$1,038	$1,320	$1,156
Annual Cost of Water ($ per 1,000 gallons)	$7.67	$6.34	$7.11
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.5	$3.18	$4.05	$3.55

9.6.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 9.6-2, and the option meets each criterion.

A summary of the implementation steps for the project is presented below.

- Pilot study to evaluate RO treatment of Lake Whitney water.
- Analysis of potential impact of 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;
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

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 9.6-2. 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. High
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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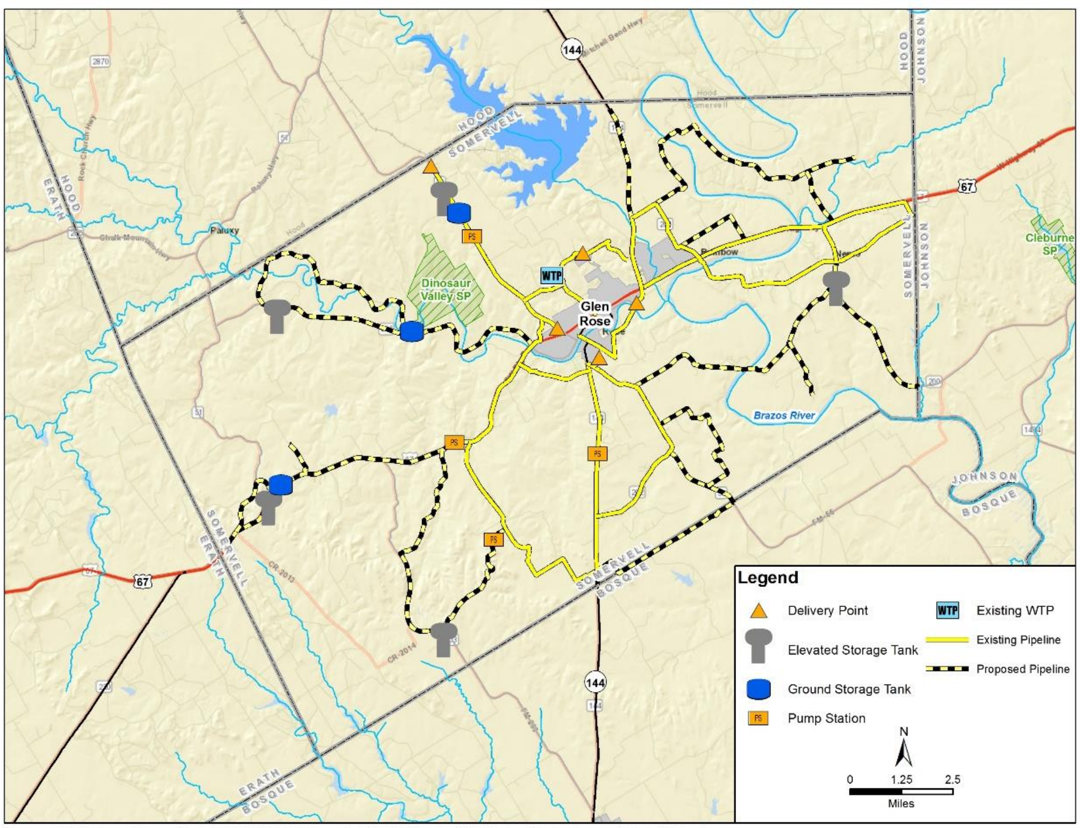
9.7 Somervell County Water Supply Project

9.7.1 Description of Option

The Somervell County Water District (SCWD) completed the first part of their surface water supply system in October 2016. 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 2030. When complete, the project will provide 2,000 acre-feet per year of surface water supplies to water users in Somervell County. Figure 9.7-1 shows SCWD's the existing and proposed infrastructure and major delivery points.

Figure 9.7-1. Proposed Phases of the Somervell County Water Supply Project



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9.7.2 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 provide 1,400 acre-feet per year. The planned water treatment plant expansion in 2030 will allow the SCWD to use the full yield of the project[2].

9.7.3 Environmental Issues

There would be limited environmental impacts due to the water treatment plant expansion, provided all terms and conditions of the permits are met. Environmental impacts could include:

- Possible minor impacts to riparian corridors, depending on location of distribution pipelines
- Other possible minor impacts from distribution 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 9.7-1. The water treatment plant expansion would occur at the existing plant, which does not provide suitable habitat for the black-capped vireo (in recovery) or the golden-cheeked warbler. The piping plover, red knot and the whooping crane could be present in the project area during migration, but in the past have not been observed in the proposed construction areas. No adverse impacts to federally-listed threatened or endangered species are anticipated[2].

Table 9.7-1. Environmental Issues: Somervell County Water Supply Project

Issue	Description
Implementation Measures	A 1.25 MGD water treatment plant expansion and distribution 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.
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.

9.7.4 Engineering and Costing

Figure 9.7-1 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 100 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 and 2016 Brazos G Plans. 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 9.7-2 summarizes the capital costs for the phases that have yet to be constructed (i.e., Phases 7A and 9 through 17), which total $26,916,000 in September 2018 dollars. Contingencies, professional services, land costs, and interest during construction will add $9,334,000, for a total project cost of $36,250,000. With 3.5 percent interest and 20-year bonds, the annual debt service is $2,551,000. Operation and maintenance costs for pumping, transmission and treatment add $927,000 per year, for a total annual cost of $3,546,000 for delivery of 600 acre-feet. All costs are for retail, as opposed to wholesale, facilities. The cost of treated water delivered is $5,910 per acre-foot, or $18.13 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 2,000 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 about $12.89 per thousand gallons.

Table 9.7-2. Cost Estimate Summary for Somervell County Water Supply Project Phases 7A & 9-17

Item	Estimated Cost for Facilities
Primary Pump Station	$105,000
Transmission Pipeline	$20,271,000
Transmission Pump Station(s) & Storage Tank(s)	$628,000
Storage Tanks (Other Than at Booster Pump Stations)	$4,865,000
Water Treatment Plant (1.3 MGD)	$1,047,000
TOTAL COST OF FACILITIES	**$26,916,000**
Engineering, Legal Costs and Contingencies	$6,081,000
Land Costs	$2,282,000
Interest During Construction (1 year)	$971,000
TOTAL COST OF PROJECT	**$36,250,000**
ANNUAL COST	
Debt Service (3.5 percent for 20 years)	$2,551,000
Operation and Maintenance	$927,000
Energy Costs (852,700 kWh @ $0.08/kWh)	$68,000
TOTAL ANNUAL COST	**$3,546,000**
Available Project Yield (acft/yr)	**600**
Annual Cost of Water ($ per acft)	**$5,910**
Annual Cost of Water ($ per 1,000 gallons)	**$18.13**

Notes:

1. All costs are for retail facilities

2. Total project yield is 2,000 acft/yr; 1,400 acft/yr provided by other phases

9.7.5 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 9.7-3 compares this water management strategy to the plan development criteria.

Table 9.7-3. 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.
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.
- Appropriate permits have been and will be obtained for TxDOT highway crossings.

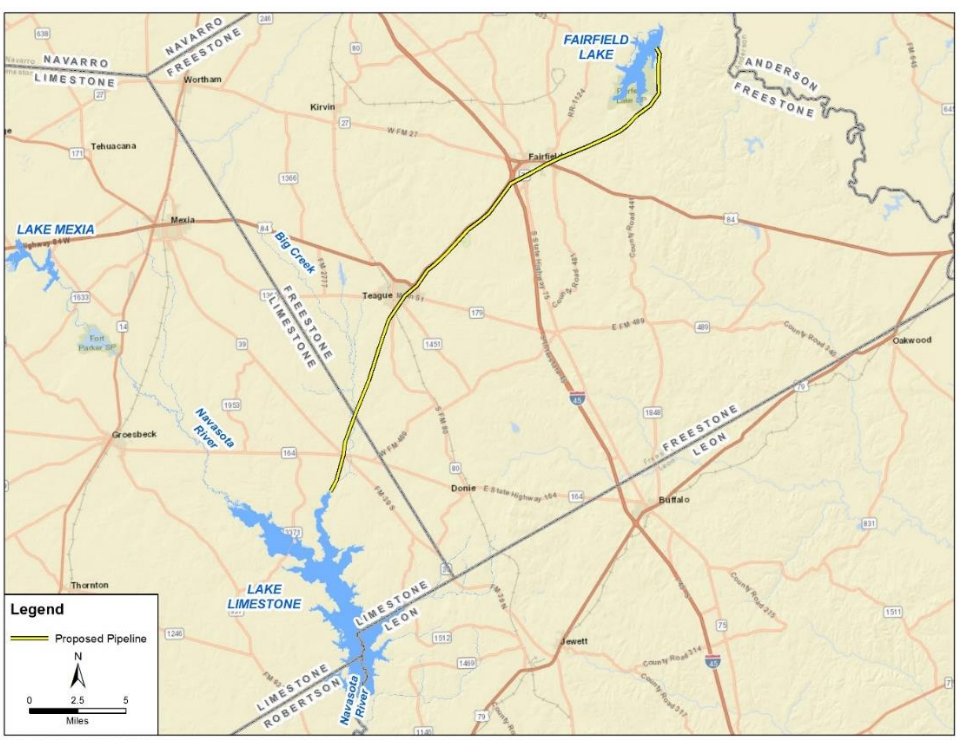
9.8 Trinity Basin Supplies to Middle Brazos

9.8.1 Description of Option

Luminant Power owns Certificates of Adjudication (CA) 08-5040 and CA 08-2388 (collectively referred to as the Luminant water rights) authorizing the use of state water in the Trinity River Basin for industrial purposes associated with steam-electric generation at the Big Brown Power Plant located on Lake Fairfield. CA 08-5040 authorizes the impoundment of streamflow in Lake Fairfield containing 50,600 acft of storage and the consumptive use of up to 14,150 acft/yr of water from the reservoir for industrial (thermal-electric power generation) purposes. Additionally, Lake Livingston is subordinated to authorizations included CA 08-5040. CA 08-2388, as amended, authorizes diversion of up to 3,188 acft/yr of streamflow from the Trinity River near Lake Fairfield. Diversions from the Trinity River are discharged into Lake Fairfield and used for steam-electric generation.

In 2018, Luminant decommissioned the power plant and is no longer utilizing the water rights for steam-electric generation. This strategy assumes Luminant would sell water authorized for use under the water rights to the Brazos River Authority (BRA) for use in the Brazos River Basin. The strategy would require a 30-mile, 24-inch raw water pipeline from Lake Fairfield to Lake Limestone for subsequent delivery to BRA customers. This strategy also requires a new intake and pump station at Lake Fairfield because the existing intake at the power plant has a minimum intake elevation 5 ft below the top of the conservation pool and could not be used during critical drought situations when lake levels will most likely be below this elevation unless upgraded or modified. The location of the new intake and pump station and raw water pipeline route is shown in Figure 9.8-1.

Figure 9.8-1. Trinity Supplies to Middle Brazos River Basin Strategy



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9.8.2 Available Yield

The reliability of the Luminant water rights was calculated using the Texas Commission on Environmental Quality (TCEQ) Trinity River Basin Water Availability Model (WAM) Run 3. The WAM assumes surface water rights modeled at full consumptive amounts per certificates of adjudication and permits, and no treated effluent discharges (return flows).

Lake Fairfield was simulated assuming sediment conditions as reported in 1999 TWDB Volumetric Survey. The TWDB report estimates a conservation pool capacity of 44,169 acft (authorized conservation pool capacity is 50,600 acft). The entire conservation pool of Lake Fairfield is assumed to be available for diversion (no dead pool). Note that the existing intake structure at the Big Brown Power Plant has a minimum intake elevation 5 ft below the conservation pool elevation. It is assumed a new intake structure would be constructed to fully utilize the conservation pool. Supplemental diversions from the Trinity River were simulated at the maximum authorized diversion rate (44.56 cfs) until the authorized annual diversion amount was reached (3,188 acft) in each year of the simulation.

The calculated firm yield of Lake Fairfield with the supplemental diversion from the Trinity River is 8,100 acft/yr. Figure 9.8-2 and Figure 9.8-3 illustrate the simulated Lake Fairfield storage levels and storage frequency for the 1940 to 1996 historical period, subject to the firm yield demand of 5,700 acft/yr, and Figure 9.8-4 shows the annual supplemental diversion from the Trinity River to Lake Fairfield. Simulated reservoir contents remain above 80 percent capacity almost 80 percent of the time and above 50 percent capacity more than 90 percent of the time.

Figure 9.8-2. Lake Fairfield Firm Yield Reservoir Storage Trace

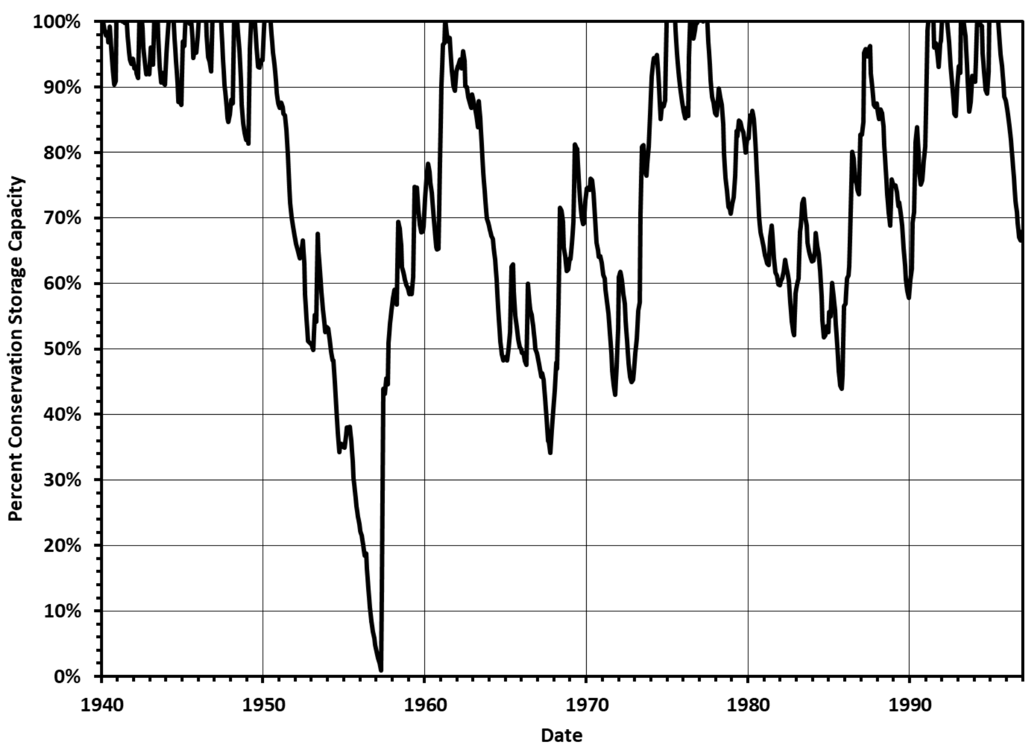


Figure 9.8-3. Lake Fairfield Firm Yield Storage Frequency

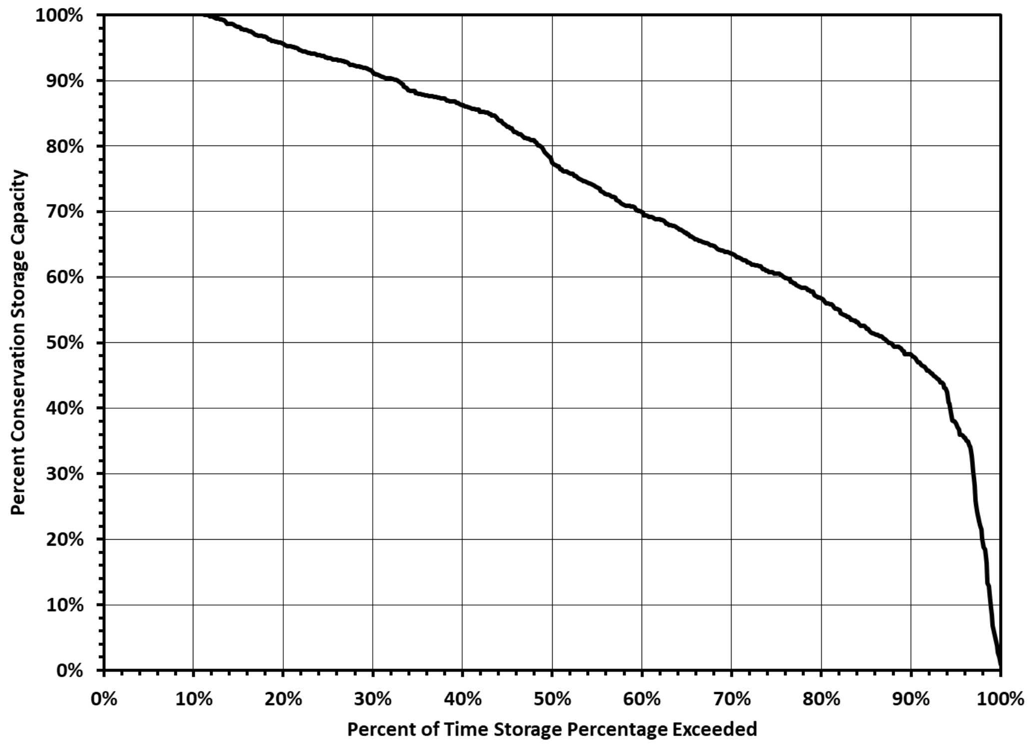
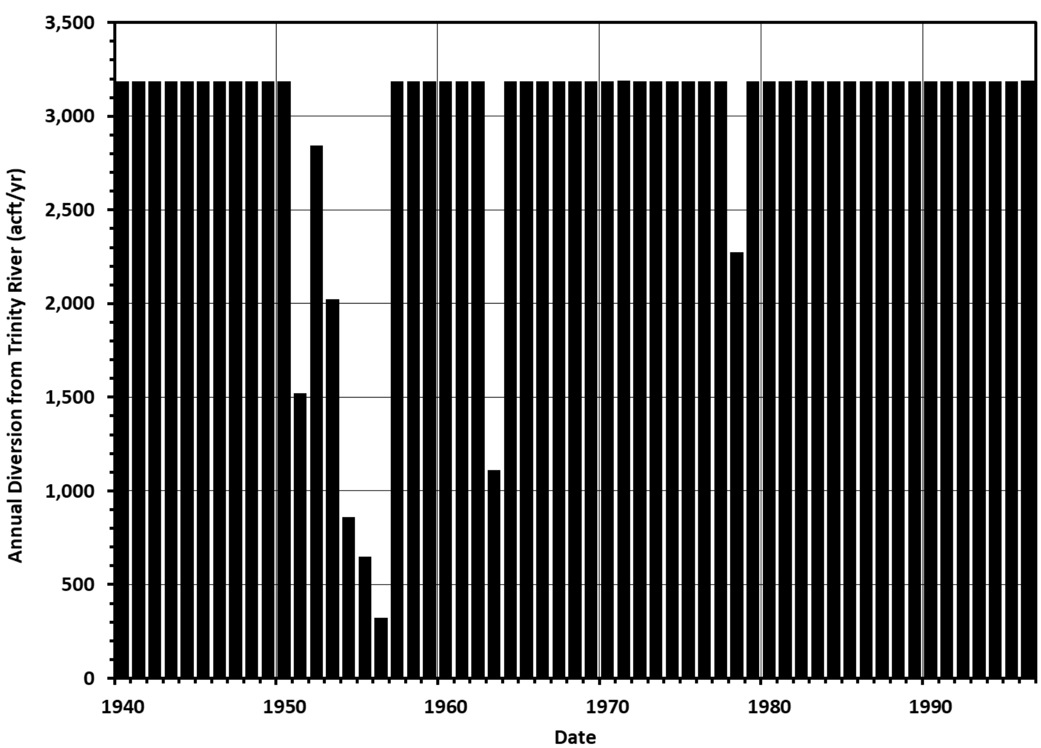


Figure 9.8-4. Supplemental Diversions to Lake Fairfield from Trinity River



9.8.3 Environmental Issues

Existing Environment

The proposed project occurs within the Post Oak Savannah physiographic region of Texas and is within the Texan biotic province[1]. The project components are within an area defined as Post Oak Woods, Forest and Grassland Mosaic vegetation type[2]. This vegetation type commonly includes blackjack oak, eastern redcedar, mesquite, black hickory, yaupon, and live oak. The Ecological Mapping Systems of Texas (EMST) data, more detailed vegetation data recently produced by the Texas Parks and Wildlife Department (TPWD)[3], show the area containing primarily Post Oak Motte and Woodland and Savanna Grassland with scattered urban areas and various other vegetation types.

Potential Impacts

Aquatic Environments including Bays and Estuaries

Hundreds of wetlands including riverine, freshwater ponds, freshwater forested/shrub wetland, freshwater emergent wetlands, and lakes were identified on the National Wetland Inventory (NWI) maps adjacent to the potential pipeline. A Nationwide Permit or coordination with the U.S. Army Corps of Engineers may be required for impacts to waters of the U.S. Seven surface waters (Trinity River [Segment #0804], Tehuacana Creek [Segment #0804F], Big Brown Creek [Segment #0804I], Mims Creek [Segment #0804C], Upper Keechi Creek [Segment #0804H], Lake Limestone [Segment #1252], and Lake Fairfield [Segment #0804J]) were identified on the TCEQ Surface Water Quality Viewer[4] within the proposed project area, or within 5 miles. The Trinity River (Segment #0804) was listed as impaired for dioxins and PCBs in edible tissue. Upper Keechi Creek (Segment #0804H) was listed as impaired for depressed dissolved oxygen, and Lake Limestone (Segment #1252) was classified as impaired due to pH. The remaining surface water segments were fully functioning and not impaired.

FEMA's National Flood Hazard Layer (NFHL) does not have digital data available for most of Freestone County, however, the portion of the project in Limestone County is within flood zone X and is outside the 100-year floodplain.[5]

Threatened & Endangered Species

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state

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

[2] McMahan, C.A., R.G. Frye, and K.L. Brown, 1984. The Vegetation Types of Texas. Accessed online https://tpwd.texas.gov/publications/pwdpubs/pwd_bn_w7000_0120/ March 22, 2019.

[3] TPWD, Ecological Mapping Systems of Texas, High Plains. Accessible to download online https://tpwd.texas.gov/gis/programs/landscape-ecology/by-ecoregion-vector

[4] TCEQ, Surface Water Quality Viewer. Accessible online https://tceq.maps.arcgis.com/apps/webappviewer/index.html?id=b0ab6bac411a49189106064b70bbe778 accessed January 13, 2020.

[5] FEMA, 2020. FEMA Flood Map Service Center. Accessed online https://www.fema.gov/national-flood-hazard-layer-nfhl February 4, 2020.

listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Freestone and Limestone counties can be found at https://tpwd.texas.gov/gis/rtest/.

According to the Information for Planning and Consultation (IPaC) website[6] maintained by the U.S. Fish & Wildlife Service (USFWS), the Whooping Crane, Least Tern, Texas fawnsfoot, large-fruited sand-verbena, and Navasota ladies' tresses need to be considered for the proposed project. The Piping Plover and Red Knot were also mentioned, but only need to be considered for wind energy projects. There are no critical habitats within the project area.

Based on Texas Natural Diversity Data (TXNDD) obtained from the TPWD, there were seven documented occurrences reported within a 5-mile buffer of the area of proposed improvements (one blackspot shiner, two bald eagle, two small-headed pipewort, one goldenwave tickseed, and one rookery). No other documented occurrences of threatened, endangered or rare species or natural communities were reported within five miles of the project area.

A biological survey of the project area should be conducted to determine whether populations of threatened or endangered species, or potential habitats used by listed species occur in the area to be affected, if this strategy is selected. A determination on whether any impacts or effects to listed species may occur would then be made. 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

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 (P196-515), and the Archeological and Historic Preservation Act (PL93-291). If the owner or controller of the project is a political subdivision of the state of Texas, then they would be required to comply with the Texas Antiquities Code. Based on the review of available GIS datasets, six cemeteries (Limestone Cemetery, Greenwood Cemetery, Driver Cemetery, Fairfield Cemetery, Chancellor Union Cemetery, and Day Cemetery) and 24 historical markers (Personville, Boll Weevil Railway, William Rufus Boyd, Jr., First Baptist Church of Teague, First Presbyterian Church of Teague, Dr. Emmet Headlee, Llewellyn Notley, Teague, Driver Cemetery, Rev. George Washington Baines, Capitain L.D. Bradley, Butler Church Bell, Carter Log House, Fairfield Female College, Fridolin Fischer, Freestone County, Freestone Jail, General John Gregg, David Hall Love, Manahan House, William L. Moody, Potter-Watson Lob Cabin, James Bonner Rogers, and Val Verde Battery), and one NRHP site (Trinity and Brazos Valley Railroad Depot and Office Building) were identified in the datasets within a one-mile buffer of the proposed project area. No State Historic Sites were located within a one-mile buffer of the proposed project area. A review of archeological resources in the proposed project area should be conducted during project planning, and in compliance with the Texas Antiquities Code.

[6] USFWS, 2020. Information for Planning and Consultation. Accessed online https://ecos.fws.gov/ipac/location/2CDHNRFRWZBEFN2BCFV527IIXM/resources January 13, 2020.

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.

9.8.4 Engineering and Costing

This strategy would require additional facilities to divert and deliver water from Lake Fairfield to Lake Limestone. The facilities required for implementation of the project include:

- Raw water intake and pump station at Lake Fairfield with a capacity of 5.4 MGD; and
- 30 miles of raw water pipeline (24-inch diameter) from the pump station at Lake Fairfield to Lake Limestone.

A summary of the total project cost in September 2018 dollars is presented in Table 9.8-1. The total project cost of the strategy is estimated to be $54.2 million for surface water supply facilities. This includes land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $5.1 million. These costs include annual debt service, operation and maintenance, pumping energy costs, and purchase of water from Luminant. The strategy would be able to provide 5,700 acft/yr of raw water to BRA or other entities in the Middle Brazos Basin at a unit cost of $888 per acft or $2.72 per 1,000 gallons.

9.8.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 9.8-2, and the option meets each criterion.

Implementation of the strategy will require permits from various state and federal agencies, land acquisition, and design and construction of the facilities. The strategy will require amending the Luminant water rights to authorize the interbasin transfer of water. A summary of the implementation steps for the project is presented below.

Table 9.8-1. Cost Estimate Summary for Coryell County Off-Channel Reservoir

Item	Estimated Costs for Facilities
Intake Pump Stations (5.4 MGD)	$11,540,000
Transmission Pipeline (24 in dia., 30 miles)	$27,487,000
TOTAL COST OF FACILITIES	**$39,027,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$12,285,000
Environmental & Archaeology Studies and Mitigation	$779,000
Land Acquisition and Surveying (190 acres)	$706,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$1,452,000
TOTAL COST OF PROJECT	**$54,249,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$3,817,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$275,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$289,000
Pumping Energy Cost	$245,000
Purchase of Water (5,700 acft/yr @ 76.5 $/acft)	$436,000
TOTAL ANNUAL COST	**$5,062,000**
Available Project Yield (acft/yr)	5,700
Annual Cost of Water ($ per acft)	$888
Annual Cost of Water ($ per 1,000 gallons)	$2.72

Table 9.8-2. Evaluation of Trinity Supplies to Middle Brazos

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

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right amendments;
- 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;
- Assessment of impacts on Federal- and State-listed endangered and threatened species;
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction; 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 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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9.9 West Texas Water Partnership

9.9.1 Description of Option

In December 2010, the cities of Abilene, Midland and San Angelo met to discuss cooperative strategies in response to a developing drought. As the drought intensified a cooperative response could not be timely implemented, and the cities constructed and brought on-line individual strategies to provide adequate water supplies for their customers. Recognizing the benefits of working together to address future water supplies, the three cities continued to meet and evaluate long-term water supplies for the West Texas region. Through an Interlocal Agreement, the cities formed the West Texas Water Partnership (Partnership or WTWP) to pursue water management strategies that could be jointly developed by the Partnership.

The WTWP recently contracted for groundwater from the Edwards-Trinity Plateau Aquifer in Pecos County. The total contracted supply is 28,400 acre-feet per year (acft/yr), allocated as follows: Abilene – 8,400 acft/yr; Midland – 15,000 acft/yr; and San Angelo – 5,000 acft/yr.

To provide 28,400 acft/yr, twelve (12) groundwater supply wells are anticipated to be constructed. Produced groundwater will be transported through a network of well field collector pipes to a single standpipe. Water will then be transported generally north via gravity in a 42-inch transmission pipeline to an intermediate pump station near Monahans, Texas. From this intermediate pump station, water will be transported in a 42-inch transmission pipeline to the T-Bar Ranch, owned by the City of Midland.

Advanced treatment will be required for a portion of the groundwater flow to meet regulatory standards. Preliminary evaluations indicate about 60% of the flow will undergo treatment using ultrafiltration followed by reverse osmosis. Final treatment requirements will be determined during preliminary design. To maximize use of this groundwater source, a recovery stage is proposed for both the ultrafiltration and reverse osmosis processes. Waste from the treatment process is expected to be approximately 5 percent, which is comparable to conventional treatment. Waste will be disposed using evaporation ponds. The treatment plant will be located on Midland's T-Bar Ranch.

From the treatment plant, the Edwards-Trinity Plateau groundwater will be transported to Midland and San Angelo using the City of Midland's T-Bar transmission system and a direct 27-inch pipeline from Midland to San Angelo. No groundwater will be delivered directly to Abilene. Abilene will receive its share of the WTWP through an exchange of contracted supplies in Lake Ivie from Midland and San Angelo. This water will be transported to Abilene through existing infrastructure.

An alternative version is also described in the Region F Plan whereby all of the groundwater would be transported solely to Midland, and both Abilene and San Angelo would receive their shares of the project supply through an exchange of contracted supplies in O.H. Ivie.

9.9.2 Available Yield

The total quantity of supply from this strategy is 28,400 acre-feet. Elevated levels of total dissolved solids, notably chloride, will require a portion of the supply to undergo advanced treatment. The reliability for this source is high.

To minimize the size and cost of the transmission pipeline between Midland and San Angelo, the Partnership anticipates developing a cooperative use strategy for its collective supplies in O.H. Ivie Reservoir (Ivie). Each of the three of the WTWP cities contract with the Colorado River Municipal Water District (CRMWD) for 16.54% of the safe yield from Ivie. Under the anticipated cooperative use strategy, Abilene would utilize Midland's Ivie allocation in exchange for a portion of Abilene's Edwards-Trinity Plateau groundwater allocation. Abilene would also use a portion of San Angelo's Ivie allocation in exchange for a portion of Abilene's Edwards Plateau groundwater to reach their total of 8,400 acre-feet per year supply from the WTWP. This approach reduces the quantity of groundwater to be transported beyond Midland and the associated infrastructure requirements. Abilene's share of the Edwards-Trinity groundwater is then used by Midland and San Angelo to offset the Ivie supplies sent to Abilene. The supplies allocated to each member of the WTWP is shown in Table 9.9-1.

Table 9.9-1. Supply to Each User from the West Texas Water Partnership (acft/yr)

	Supply 2020	Supply 2030	Supply 2040	Supply 2050	Supply 2060	Supply 2070
Midland Ivie Water to Abilene		5,209	5,070	4,930	4,791	4,651
San Angelo Ivie Water to Abilene		3,191	3,330	3,470	3,609	3,749
Total WTWP Supply to Abilene		***8,400***	***8,400***	***8,400***	***8,400***	***8,400***
San Angelo Original Groundwater Share		5,000	5,000	5,000	5,000	5,000
Groundwater to San Angelo to Replace Ivie Water Sent to Abilene		3,191	3,330	3,470	3,609	3,749
Total Groundwater to San Angelo		***8,191***	***8,330***	***8,470***	***8,609***	***8,749***
Midland Original Groundwater Share		15,000	15,000	15,000	15,000	15,000
Groundwater to Midland to Replace Ivie Water Sent to Abilene		5,209	5,070	4,930	4,791	4,651
Total Groundwater to Midland		***20,209***	***20,070***	***19,930***	***19,791***	***19,651***
Total Groundwater Supply		***28,400***	***28,400***	***28,400***	***28,400***	***28,400***

9.9.3 Environmental Issues

The environmental issues associated with this strategy are expected to be low. It is assumed that the new pipelines would be routed around sensitive environmental areas to limit potential impacts. The conceptual design for this project includes evaporation ponds for the disposal of treatment waste stream. A properly designed and maintained facility should have minimal environmental impact.

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.

9.9.4 Engineering and Costing

More detailed information regarding the groundwater, transmission and treatment facilities can be found in the 2021 Region F Regional Water Plan, as all associated facilities will be located in Region F.

The capital cost to fully implement this strategy is $549,093,000. Costs for development and construction of the project are shown in Table 9.9-2. These costs would be allocated based on each participant’s share of the supply.

9.9.5 Implementation Issues

Construction of the pipeline may have temporary impacts on agricultural or rural users whose land is temporarily disrupted but no permanent impacts are anticipated. The treatment facility and evaporation ponds are anticipated to be built on the Midland T-Bar Ranch which is property already owned by the City so it will not cause further impacts to agricultural land.

The current conceptual design for this project uses evaporation ponds to dispose of the brine waste stream. If this were to change and the brine was released to a stream, impacts to the receiving water body would need to be evaluated.

This strategy is compared to plan development criteria in Table 9.9-3.

Table 9.9-2. Cost Estimate Summary for the West Texas Water Partnership (from Region F Plan)

Construction Costs	Quantity	Unit	Unit Price	Cost
Well Field				
Water Wells	12	EA	$650,000	$7,800,000
Well Field Piping	1	LS	$3,750,000	$3,750,000
Access Roadways	1	LS	$2,500,000	$2,500,000
Electrical Distribution	1	LS	$3,500,000	$3,500,000
Storage Tank	1	LS	$2,000,000	$2,000,000
Contractor Mob/Demob (3%)				$590,000
Engineering and Contingencies (35%)				$7,050,000
Subtotal Well Field				**$27,190,000**
Pipeline				
Transmission Pipeline - 42"	419,000	LF	$300	$125,700,000
Transmission Pipeline - 27"	610,000	LF	$235	$143,350,000
Right-of-Way Easements	61,600	ROD	$200	$12,320,000
Contractor Mob/Demob (3%)				$8,070,000
Engineering and Contingencies (30%)				$86,830,000
Subtotal Pipeline				**$376,270,000**
Pump Station & Ground Storage				
Pump Station	2	LS	$3,500,000	$7,000,000
Electrical/SCADA	2	LS	$800,000	$1,600,000
Storage Tank	3	LS	$1,300,000	$3,900,000
Contractor Mob/Demob (3%)				$380,000
Engineering and Contingencies (35%)				$4,510,000
Subtotal Pump Station/Ground Storage				**$17,390,000**
Treatment				
Ultrafiltration (Primary/Recovery)	1	LS	$14,800,000	$14,800,000

Table 9.9-2. Cost Estimate Summary for the West Texas Water Partnership (from Region F Plan)

Construction Costs	Quantity	Unit	Unit Price	Cost
Reverse Osmosis (Primary/Recovery)	1	LS	$16,830,000	$16,830,000
Chemical Systems	1	LS	$1,940,000	$1,940,000
Evaporation Pond	1	LS	$9,400,000	$9,400,000
Buildings/Yard Piping	1	LS	$12,930,000	$12,930,000
Electrical/SCADA	1	LS	$10,500,000	$10,500,000
Storage Tanks (Pretreatment/Clearwells)	1	LS	$8,170,000	$8,170,000
Contractor Mob/Demob (3%)				$2,240,000
Engineering and Contingencies (35%)				$26,880,000
Subtotal Treatment				**$103,690,000**
CONSTRUCTION TOTAL				**$524,540,000**
Permitting and Mitigation				$2,800,000
Interest During Construction (3%)				$21,753,000
TOTAL COST				**$549,093,000**
ANNUAL COSTS				
Debt Service (3.5%)				$38,635,000
Operation and Maintenance				$6,320,000
Electricity ($0.08/kwh)				$4,960,000
Total Annual Costs				$49,915,000
UNIT COSTS (Until Amortized)				
Per Acre-Foot of treated water				$1,783
Per 1,000 Gallons				$5.47
UNIT COSTS (After Amortization)				
Per Acre-Foot				$403
Per 1,000 Gallons				$1.24

Table 9.9-3. Comparison of West Texas Water Partnership 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	Moderate
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

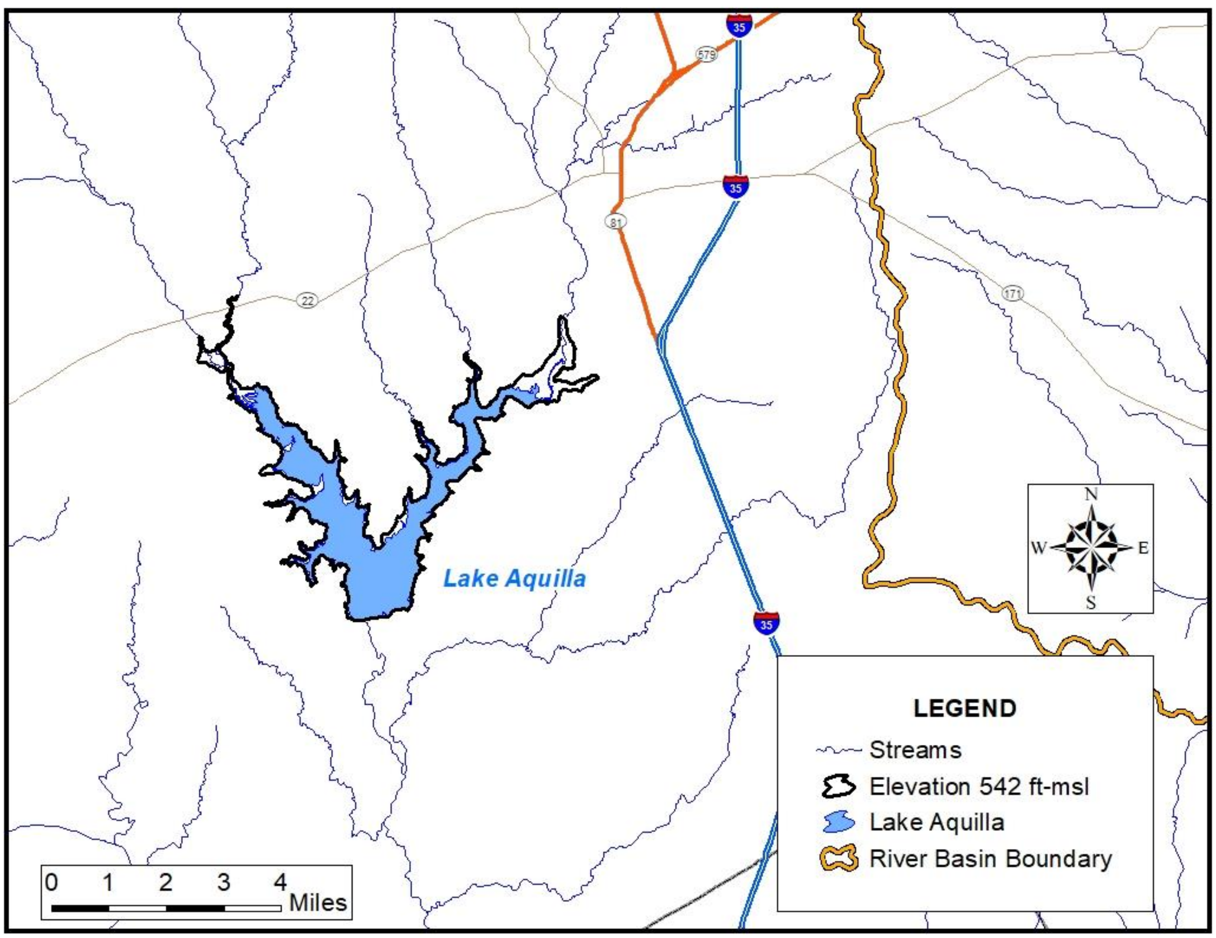
10 Augmentation of Existing Reservoir Supplies

10.1 Lake Aquilla Storage Reallocation

10.1.1 Description of Option

Figure 10.1-1 is a map of Lake Aquilla showing the water surface area at the current conservation pool elevation of 537.5 feet above mean sea level (ft-msl), as well as at an alternative pool elevation at 542 ft-msl. According to a July 2014 volumetric survey, Aquilla Lake has 43,279 acre-feet of storage and a surface area of 3,084 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 10.1-1).

Figure 10.1-1. Map of Lake Aquilla with Elevation Contour of Reallocation



[1] Texas Water Development Board, Volumetric Survey of Aquilla Lake July 2014 Survey, June 2015.

Table 10.1-1. Lake Aquilla Characteristics[2]

Ownership	
Reservoir Owner	U.S. Army Corps of Engineers
Water Supply Contract	
Owner	Brazos River Authority
Storage amount	100% of conservation storage
Texas Water Right	
Number	Certificate of Adjudication 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]	93,600 acft
Conservation Pool[4]	
Top elevation	537.5 ft
Surface area	3,084 ac
Storage	43,279 acft
Sediment Pool[4]	
Top elevation	503 ft
Storage	36 acft

10.1.2 Available Yield

In its 2017 draft report on the reallocation of Lake Aquilla, the U.S. Army Corps of Engineers (USACE) said “the recommended plan is to increase the top of conservation by 4.5 feet” to 542 ft-msl[5]. As part of the 2021 Brazos G Regional Water Plan, the Texas Commission on Environmental Quality (TCEQ) Brazos Water Availability Model (WAM) Run 3 was used to calculate yields for Lake Aquilla under the following two scenarios:

- Existing – Current conservation storage elevation of 537.5 ft-msl
- Raise conservation elevation to 542.0 feet, an increase of 4.5 ft-msl

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[2] Certificate of Adjudication 12-5158

[3] Storage within flood pool based on original volumetric survey, October 1983

[4] Texas Water Development Board, Volumetric Survey of Aquilla Lake July 2014 Survey, June 2015.

[5] Middle Brazos Systems Assessment, Phase II: Aquilla Water Supply Reallocation Report and Environmental Assessment. Prepared by the U.S. Army Corps of Engineers, Southwest Division, Fort Worth District. February 28, 2018.

Yields were computed subject to downstream senior rights and having to pass inflows to meet environmental flow standards associated with Senate Bill 3 (SB3).

Figure 10.1-1 shows the elevation contours for the proposed conservation storage elevation if flood storage in Lake Aquilla were to be reallocated to conservation storage. Table 10.1-2 is a summary of the yield studies conducted for the 2021 Brazos G Plan.

Table 10.1-2. Comparison of Firm Yield of Lake Aquilla with Flood Storage Reallocation using Brazos 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	537.5	43,174	12,604	0	37,374	11,408	0
4.5 ft increase	542.0	58,879	15,262	2,658	53,079	13,891	2,483

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. Raising the conservation pool 4.5 feet to 542 ft-msl is within this discretionary authority, and therefore would not require congressional approval[6].

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 11,408 acre-feet per year. If the conservation pool elevation was increased to 542.0 feet, the yield of Lake Aquilla would be 13,891 acre-feet per year, resulting in 2,483 acre-feet per year of additional yield in 2070. This is a nearly 22% increase over the existing scenario yield. Figure 10.1-2 and Figure 10.1-3 show the storage trace in the year 2070 for Lake Aquilla under existing conditions and with a 4.5-foot pool raise, respectively.

This strategy could potentially provide additional supply under the recently approved BRA System Operation permit, however this evaluation models Lake Aquilla as a stand-alone reservoir that does not participate in System Operations because most of the supply from Lake Aquilla is committed locally and very little is available for system operation. 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.

[6] Middle Brazos Systems Assessment, Phase II: Aquilla Water Supply Reallocation Report and Environmental Assessment. Prepared by the U.S. Army Corps of Engineers, Southwest Division, Fort Worth District. February 28, 2018.

Figure 10.1-2. 2070 Lake Aquilla Storage Trace, Current Conservation Elevation (537.5 ft-msl)

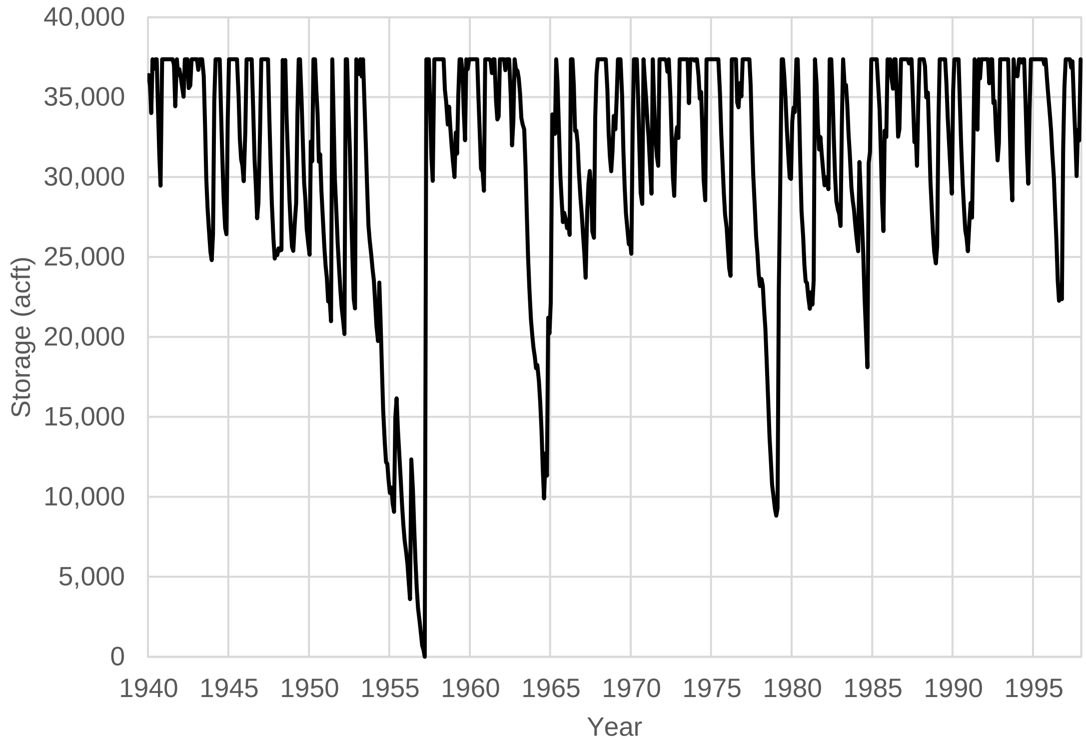
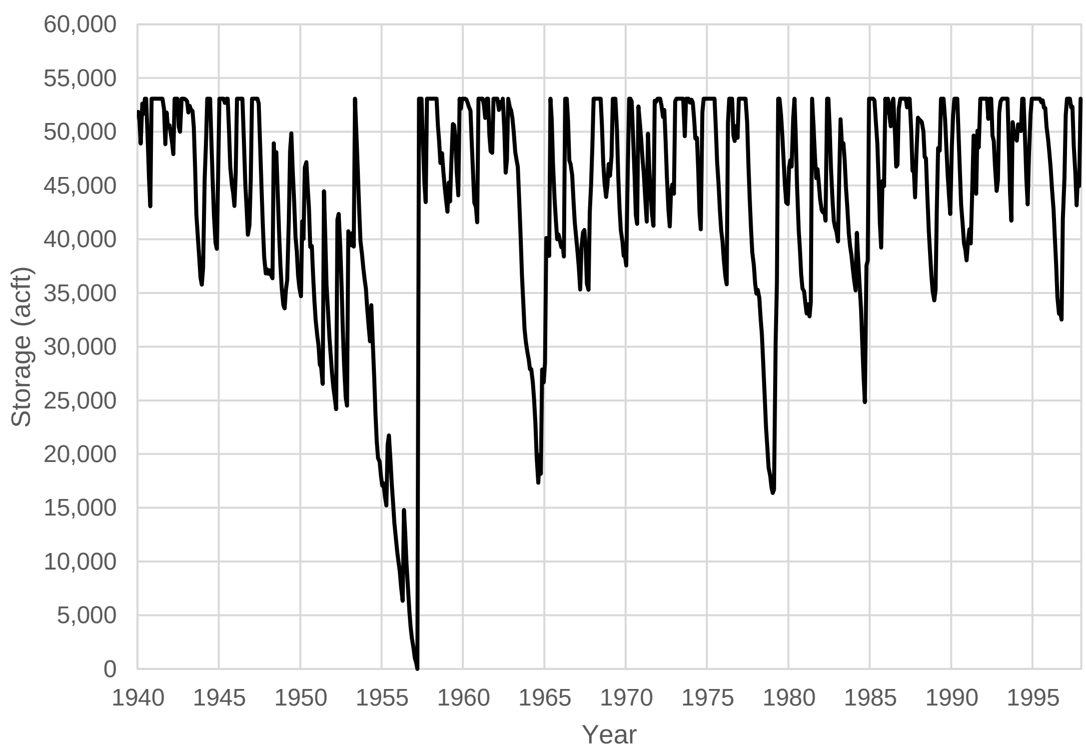


Figure 10.1-3. 2070 Lake Aquilla Storage Trace for Conservation Elevation at 542 ft-msl



10.1.3 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. Wetlands and bottomland hardwoods located in the upper reaches of the lake will be impacted by raising the conservation elevation.

The water surface area at conservation under current conditions is 3,084 acres according to TWDB's most recent volumetric survey. If the conservation pool elevation were increased to 542 ft-msl, the maximum surface area would be 3,905 acres[7], and the reservoir would inundate an additional 821 acres when full. 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.

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD frequently updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Hill County can be found at https://tpwd.texas.gov/gis/rtest/.

The USACE did not encounter any habitats that appeared suitable for the rare black-capped vireo or endangered 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 USACE did not find evidence of either the smalleye shiner or sharpnose shiner within the study area.

10.1.4 Engineering and Costing

Increasing the conservation pool elevation of Lake Aquilla to 542 ft-msl is the plan recommended by USACE because it maximizes yield at the lowest marginal cost. 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 $24.4 million. Detailed costs are shown in Table 10.1-3.

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.

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[7] Texas Water Development Board, Volumetric Survey of Aquilla Lake March 2008 Survey Recalculated July 2014, June 2015.

Table 10.1-3. Cost Estimate Summary for Lake Aquilla Pool Reallocation

Item	Estimated Costs for Facilities
Improvements to Dam	$3,149,000
Relocations	$1,650,000
TOTAL COST OF FACILITIES	**$4,799,000**
Engineering, Legal Costs and Contingencies	$1,680,000
Environmental & Archaeology Studies and Mitigation	$919,000
Land Acquisition	$0
Storage Reallocation from USACE to BRA	$14,234,000
Slope Stability, Seepage and Geotechnical Studies	$0
Water Rights Permit from TCEQ	$1,250,000
Administrative Cost for USACE Storage Reallocation Process	$1,200,000
Interest During Construction (12 months)	$271,000
TOTAL COST OF PROJECT	**$24,353,000**
ANNUAL COSTS	
Debt Service (3.5 percent, 20 years)	$1,714,000
Operation and Maintenance	$444,000
TOTAL ANNUAL COST	**$2,158,000**
Available Project Yield (acft/yr)	**2,483**
Annual Cost of Water ($ per acft)	**$869**
Annual Cost of Water ($ per 1,000 gallons)	**$2.67**

10.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 10.1-4, 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. An assessment in June 2016 found that the risks associated with Aquilla Dam are considered to be low, and that a pool increase would not change that conclusion; although the dam should continue to be monitored if a pool raise is implemented. The habitat lost to inundation will have to be mitigated. Mitigation property has not yet been identified. 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
- 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
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

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 10.1-4. 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 to moderate 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 to moderate 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

10.2 Lake Granger Storage Reallocation

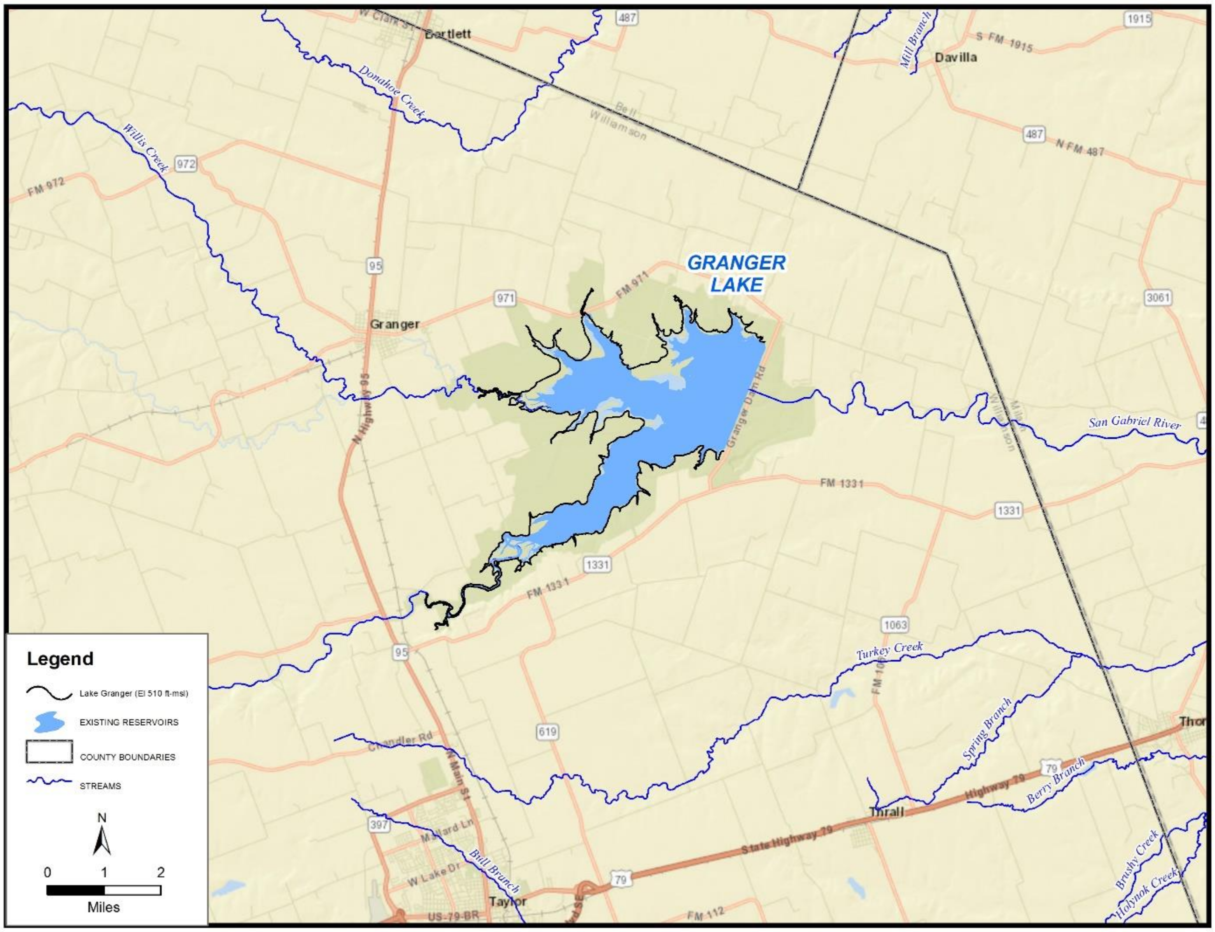
10.2.1 Description of Option

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 10.2-1). 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 10.2-1). The total useable 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 10.2-1).

Lake Granger was intended to be one of three lakes on the San Gabriel River. However, the proposed South Fork Lake, upstream of Lake Granger, 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 10.2-1. Map of Lake Granger showing Contour at 510 ft



Document Path: \\dalctxsrv01\Texas_GIS_Projects\10029705_036_Brazos_G_2021_Plan\Map_Docs\MXDs\Existing_Reservoir_Augmentation_Strategy\Lake_Granger_Storage_Reallocation.mxd

10.2.2 Available Supply

The Brazos Water Availability Model (WAM) Run 3 with Senate Bill 3 environmental flows and the Brazos River Authority's System Operation permit was used to calculate yields for Lake Granger. The firm yield of Lake Granger was evaluated for 2020 and 2070 conditions under the following two scenarios:

- Existing – Current conservation storage elevation of 504.0 ft-msl
- Raise conservation elevation to 510.0 ft-msl, an increase of 6 feet

The USACE has the authority to reallocate at its own discretion up to 50,000 acft 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 6-foot pool raise proposed by this strategy is within the discretionary authority of the USACE.

Table 10.2-1. Lake Granger Characteristics

Ownership	
Reservoir Owner	U.S. Army Corps of Engineers
Water Supply Contract	
Owner	Brazos River Authority
Storage amount	100% of conservation between 440 and 504 ft-msl
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.

Figure 10.2-1 shows the surface area of the reservoir after reallocation. Table 10.2-2 is a summary of the firm yield analyses. The current storage in Lake Granger is expected to decrease from 47,917 to 36,271 acft 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 11,016 acft/yr. If the conservation pool were raised to elevation 510.0 feet, the yield of Lake Granger would be 12,551 acft/yr, resulting in 1,535 acft of additional yield in 2070, or a 14% increase over the existing scenario yield.

This strategy could potentially provide additional supply under the recently approved BRA System Operation permit. However, because of local commitments, the extent to which the reservoir could participate in system operation is uncertain, so this analysis evaluates only the increase in the stand-alone yield of the reservoir. 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 10.2-2. 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	14,585	0	36,271	11,016	0
6 ft increase	510.00	77,976	15,790	1,205	66,276	12,551	1,535

10.2.3 Environmental Issues

Raising the conservation pool elevation of the reservoir from 504 ft-msl to 510 ft-msl would inundate an additional 1,586 acres approximately. Most of the 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.

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Williamson County can be found at https://tpwd.texas.gov/gis/rtest/.

According to the USACE's Phase I Information Paper[1], suitable habitat for threatened and endangered species is unlikely to be found at Lake Granger. 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.

[1] Draft Information Paper for Brazos River Basin Systems Assessment Interim Feasibility Study, Phase 1. Updated July 2008. Prepared by U.S. Army Corps of Engineers, Fort Worth District.

10.2.4 Engineering and Costing

Table 10.2-3 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 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 land acquisition 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. The updated investment cost for the reallocated water supply storage in Lake Granger was estimated to be about $22,133,000 in 2018 dollars. The estimate for annual operation and maintenance (O&M) cost was based on a 3-year average (2013-2015) O&M bill for the BRA. Given the increase in storage, the increase in their O&M bill was estimated to be about $678,000 per year. The total project costs for the reallocation of storage to an elevation of 510 ft-msl is $33.2 million. Given a yield of 1,535 acft/yr and a cost of $3,017,000 per year, the annual cost of water is $1,965 per acre-foot ($6.03 per 1,000 gallons).

Table 10.2-3. Cost Estimate Summary for Reallocation of Storage in Lake Granger

Item	Estimated Costs
CAPITAL COSTS	
Improvements to Dam	$3,859,000
Relocations	$414,000
TOTAL COST OF FACILITIES	**$4,273,000**
Engineering, Legal Costs and Contingencies	$1,496,000
Environmental & Archaeology Studies and Mitigation	$854,000
Storage Reallocation from USACE to BRA	$22,133,000
Water Rights Permit from TCEQ	$1,500,000
Administrative Cost for USACE Storage Reallocation Process	$2,684,000
Interest During Construction (12 months)	$298,000
TOTAL COST OF PROJECT	**$33,238,000**
ANNUAL COSTS	
Debt Service (3.5 percent, 20 years)	$2,339,000
Operation and Maintenance	$678,000
TOTAL ANNUAL COST	**$3,017,000**
Available Project Yield (acft/yr)	**1,535**
Annual Cost of Water ($ per acft)	**$1,965**
Annual Cost of Water ($ per 1,000 gallons)	**$6.03**

10.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 10.2-4, and the option meets each criterion.

Table 10.2-4. 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

10.2.6 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. 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, if necessary
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 the Texas Commission on Environmental Quality (TCEQ)

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10.3 Lake Whitney Reallocation

10.3.1 Description of Options

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 10.3-1. Lake Whitney was completed in 1951 by the U.S. Army Corps of Engineers for the primary purposes of flood control, water supply, and production of hydroelectric power. According to a 1959 volumetric survey, the total storage in Lake Whitney was 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 as of 2005[1]. 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 2005 survey (Table 10.3-1). In 1972, the top of the power pool was raised from 520 ft-msl to 533ft-msl, and the top of power head reserve (i.e. the bottom of the power pool) was raised from 510 ft-msl to 520 ft-msl, making 248,000 acft of storage available to hydropower[2]. In 1982, approximately 20 percent of the hydropower storage (50,000 acft) was reallocated to water conservation storage (water supply). 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 10.3-1). By 2005, the amount stored between elevations 520 ft-msl and 533 ft-msl, which includes both the hydropower pool and BRA's storage, was 233,492 acft.

Hydroelectric power generation from Lake Whitney is administered through the Southwestern Power Administration (SWPA), a federal agency. The Whitney Dam powerhouse uses two generators that originally had a capacity of 30 megawatts (MW) but were upgraded in 2014 and now have a capacity of 43 MW. According to the 2005 TWDB volumetric survey, the average annual power production was 73.1 million kilowatt-hours.

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[3]. 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.

In addition to Lake Whitney reallocation, a project was evaluated to deliver supply from the reallocated storage at Lake Whitney downstream towards Milam County to deliver water

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[1] Volumetric Survey of Lake Whitney. June 2005 Survey. Prepared by The Texas Water Development Board, September 2006.

[2] Whitney Reservoir Section 216 Initial Appraisal Report. Prepared by the U.S. Army Corps of Engineers. December 2014.

[3] Texas Water Resources Institute, "Reservoir/River System Reliability Considering Water Rights and Water Quality," (TR-165) Texas A&M University, March 1994.

to Williamson County. This water would be diverted through an intake on the Brazos River, treated and delivered to various water users with needs in Williamson County. Figure 10.3-2 displays the suggested route and strategy.

Figure 10.3-1. Map of Lake Whitney

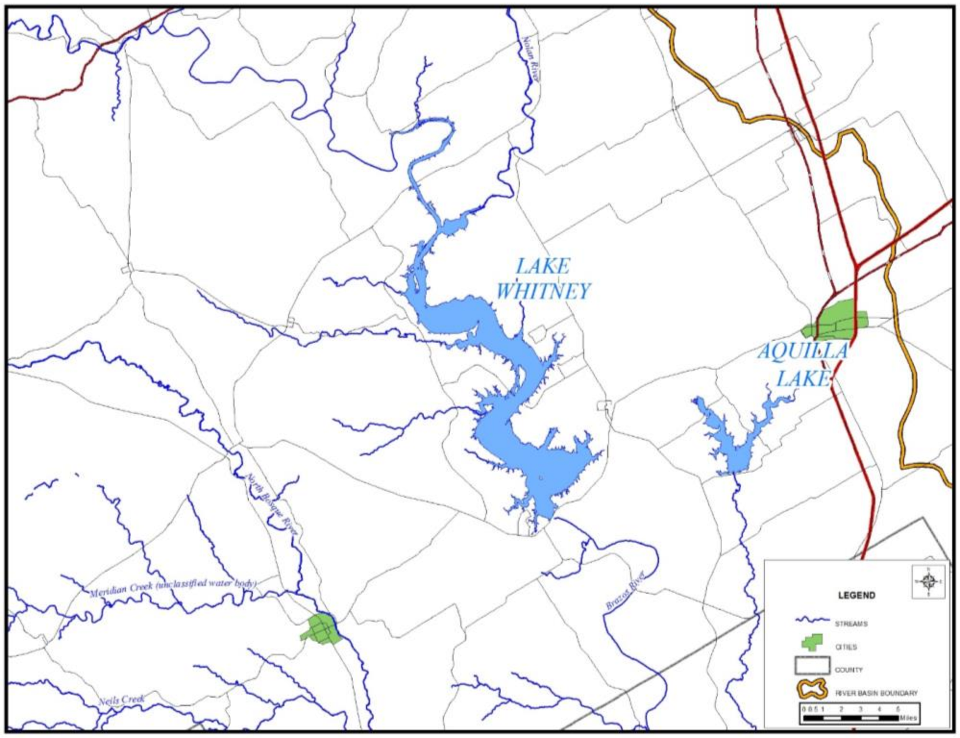

Figure 10.3-2. Map of Lake Whitney Option to Meet Needs in Williamson County

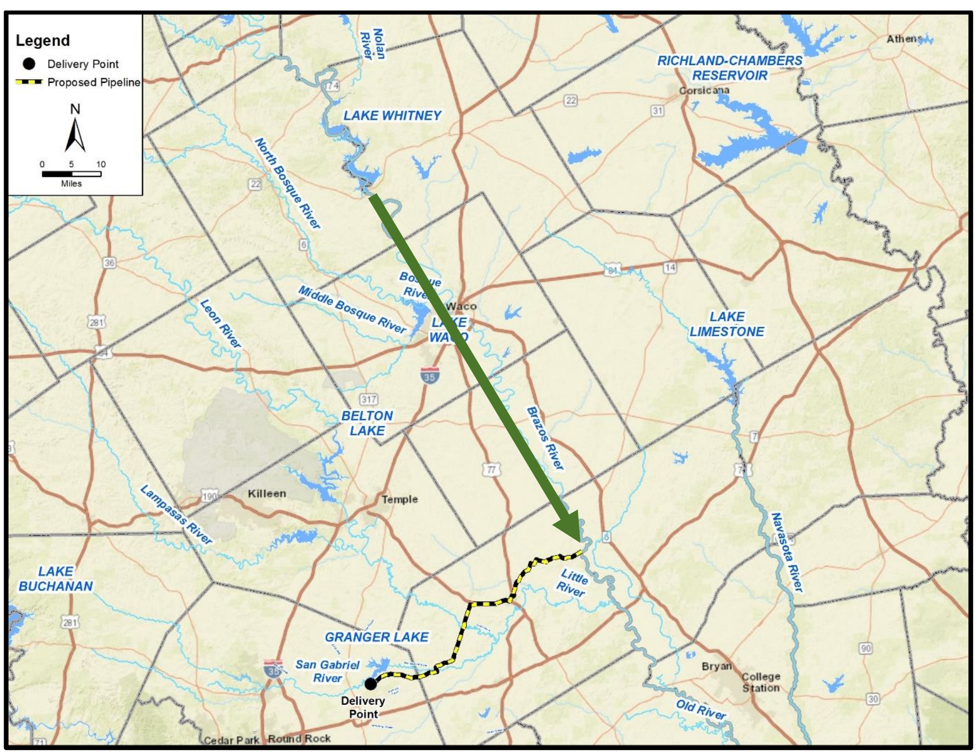

Table 10.3-1. Lake Whitney Characteristics

Ownership	
Reservoir Owner	U.S. Army Corps of Engineers
Water Supply Contract	
Owner	Brazos River Authority
Storage amount	22.017% of conservation storage
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 Pool[1]	
Top elevation	571 ft
Storage	1,372,400 acft
Conservation Pool[2]	
Top elevation	533 ft
Surface area	23,220 ac
Storage	554,203 acft
Inactive Storage[3]	
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.

10.3.2 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 and the BRA's System Operation permit. 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. Since most of the supply from this strategy would be used as part of the BRA system, this analysis determines the increase in BRA system yield made available from the additional storage. The increase in system yield was measured as the increase in firm diversions at a downstream point in the basin (i.e. Rosharon Gage) as a result of the reallocation project. The increase in system yield for reallocation of the hydropower storage in Lake Whitney was found to be 38,480 acft/yr for 2070 conditions assuming use of the total storage between elevations 520 feet and 533 feet (Table 10.3-1). If ten feet of previously inactive storage were reallocated to water supply, the increase in yield would be 77,600 acft/yr for 2070 conditions assuming use of the total storage between elevations 510 feet and 533 feet (Table 10.3-2). 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 available supply could also be less unless the new supplies are operated as part of the BRA system.

The available supply could be used to meet needs in Williamson County. About 10,561 acft/yr is being considered currently for that purpose.

Table 10.3-2. Storage Capacities and the Increase in System 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	
		Conservation Storage (acft)	System Yield Increase (acft/yr)	Conservation Storage (acft)	System Yield Increase (acft/yr)
520.00	533.00	50,000	0	50,000	0
520.00	533.00	231,084	59,300	226,999	38,480
510.00	533.00	351,448	82,270	341,301	77,600

10.3.3 Environmental Issues

Reallocation of hydroelectric and inactive storage in Lake Whitney could reduce hydroelectric generation and downstream streamflows and may impact reservoir pool levels. The effect on downstream flows would be greater if the diversions from Lake Whitney were taken lakeside. However, as modeled in this evaluation, it is more likely that the lake will continue to be used to meet system demands downstream, so reservoir releases would mitigate some impacts to hydroelectric generation and downstream flows.

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 to the extent those impacts are not mitigated by reservoir releases. The evaluation summarized in Table 10.3-3 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. 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 possibly have 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 10.3-3. 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 Whitney[1]	Possible Moderate Impacts on Brazos River below Lake Whitney[1]	Possible Low Impacts	Possible Moderate Impacts on Brazos River Segment below Lake Whitney[2]	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 potentially reduced downstream flows caused by 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.

Environmental impacts of the delivery pipeline are equivalent to those of the pipeline from the Williamson County Groundwater Supply – North Option, because the same pipeline route is followed.

10.3.4 Engineering and Costing

Development of the increase in system 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 10.3-4 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, or 2) the amount of money needed to compensate for lost hydropower revenue. The updated total investment cost for Lake Whitney was estimated to be $244,974,000. The increase in cost for water supply storage was estimated to be $24,258,000. 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 releases from the reservoir to increase the system yield, the impact to hydroelectric power generation could be around 12 percent of the annual power generation amount. The mitigation cost for the reduction in hydroelectric power generation was based on a replacement cost of $0.08 per kWh, which results in an annual cost of $701,760. This amount was converted from an annual value to a present value of $22,052,000 by assuming a 50-year planning horizon and an inflation rate of 2%. This corresponds to the second number referred to above. Because $24.3 million is larger than $22.1 million, the cost for the increase in storage, rather than hydropower compensation, was taken as the cost for reallocated storage. The total annual cost for this reallocation strategy is estimated to be $2,679,000. Based on the increase in firm yield of 38,480 acft/yr in 2070, this results in a unit cost of raw water of $70 per acft ($0.21 per 1,000 gallons).

Table 10.3-5 summarizes the costs associated with delivering a portion of the Lake Whitney Reallocation supply to Williamson County. This includes an intake, pipeline and a water treatment plant. Those facility costs would be borne by Williamson County-Other entities.

Compensation to BRA may be required if this strategy were developed by an entity other than BRA to compensate for any subordination of the System Operations strategy. The available supply could be less if the new supplies were not operated as part of the BRA system.

Table 10.3-4. Cost Estimate Summary for Reallocation of Hydropower Storage in Lake Whitney

Item	Estimated Costs
CAPTIAL COSTS	
Improvements to Dam	$4,444,000
TOTAL COST OF FACILITIES	$4,444,000
Engineering, Legal Costs and Contingencies	$1,555,000
Environmental & Archaeological Studies and Mitigation	$888,000
Storage Reallocation from USACE to BRA	$24,258,000
Water Rights Permit from TCEQ	$1,500,000
Administrative Cost for USACE Storage Reallocation Process	$3,711,000
Interest During Construction (12 months)	$333,000
TOTAL COST OF PROJECT	$36,689,000
ANNUAL COSTS	
Debt Service (3.5 percent for 20 years)	$2,581,000
Operation and Maintenance	$98,000
TOTAL ANNUAL COST	$2,679,000
Available Project Yield (acft/yr)	38,480
Annual Cost of Water ($ per acft)	$70
Annual Cost of Water ($ per 1,000 gallons)	$0.21

Table 10.3-5. Cost Estimate Summary for Delivery of Lake Whitney Reallocation Supplies to Williamson County

Item	Estimated Costs
CAPTIAL COSTS	
Intake Pump Stations (27.8 MGD)	$44,805,000
Transmission Pipeline (42 in dia.)	$105,369,000
Water Treatment Plant (27.8 MGD)	$72,873,000
TOTAL COST OF FACILITIES	**$223,047,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$72,798,000
Environmental & Archaeology Studies and Mitigation	$1,354,000
Land Acquisition and Surveying (327 acres)	$1,275,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$8,209,000
TOTAL COST OF PROJECT	**$306,683,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$21,579,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$1,054,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$1,120,000
Water Treatment Plant	$13,609,000
Pumping Energy Costs (7,903,331 kW-hr @ 0.08 $/kW-hr)	$2,702,000
Purchase of Water (26,000 acft/yr @ 76.5 $/acft)	$1,989,000
TOTAL ANNUAL COST	**$42,053,000**
Available Project Yield (acft/yr)	26,000
Annual Cost of Water ($ per acft), based on PF=1.2	$1,617
Annual Cost of Water After Debt Service ($ per acft), based on PF=1.2	$787
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.2	$4.96
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.2	$2.42

10.3.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 10.3-6, and the option meets each criterion.

Table 10.3-6. 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	Reduction in intentional hydropower releases, but few other 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

10.3.6 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 potentially an 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 (if implemented by others)

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10.4 Lake Whitney Over-Drafting Supply with Off-Channel Reservoir

10.4.1 Description of Option

Lake Whitney, located on the Brazos River, is owned and operated by the USACE and has a conservation pool storage of 554,203 acft at an elevation of 533 ft-msl. The Brazos River Authority (BRA) owns a contract for use of 50,000 acft of storage between elevations 533 ft-msl and 520 ft-msl of the lake. The remaining storage in Lake Whitney is designated for federal hydropower and the power generated is managed and sold by Southwest Power Administration.

Lake Whitney has been historically underutilized and storage levels in the lake have not fallen below 47% of the conservation pool storage capacity since the reservoir began impounding streamflow in 1952. Figure 10.4-1 shows the historical storage of Lake Whitney as percentage of conservation pool capacity and Figure-10.4-2 provides the historical frequency as a percentage of conservation pool capacity. The historical data shows the Lake Whitney conservation pool has been full over 28% of the time with storage levels entering the flood pool of the lake during these periods.

Because Lake Whitney frequently contains water in the flood pool, the opportunity exists to divert water from the flood pool during wet periods for storage in an off-channel reservoir (OCR) located near the lake. Figure 10.4-3 provides the location of the proposed OCR, Lake Whitney diversion intake and pump station, and pipeline route included in this strategy.

10.4.2 Available Yield

Water potentially available for diversion from the Lake Whitney flood pool and impoundment in the OCR was estimated using the TCEQ Brazos WAM Run 3 (Brazos WAM). The Brazos WAM assumes no return flows 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 computes streamflow available for diversion from the Lake Whitney flood pool without causing increased shortages to existing downstream rights and subject to TCEQ environmental flow standards. The off-channel reservoir was modeled such that it does not impound streamflow originating from its own contributing drainage area.

A 102-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 (284 cfs), a possible 17,134 acft of water could be diverted per month if the transmission system operated every day at full capacity. Figure 10.4-4 illustrates the annual diversion amount under firm yield conditions from the Lake Whitney flood pool used to refill storage. On average, 6,880 acft/yr of water would be diverted.

Figure 10.4-1. Historical Lake Whitney Storage as a Percentage of Conservation Pool Capacity

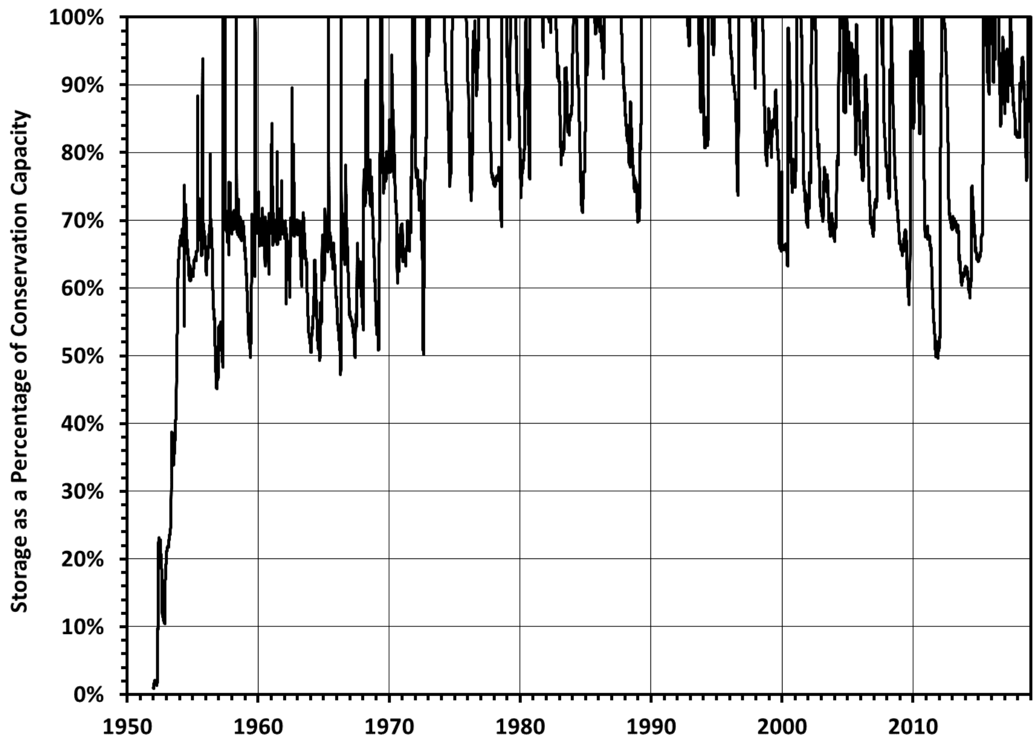


Figure-10.4-2. Historical Lake Whitney Storage Frequency as a Percentage of Conservation Pool Capacity

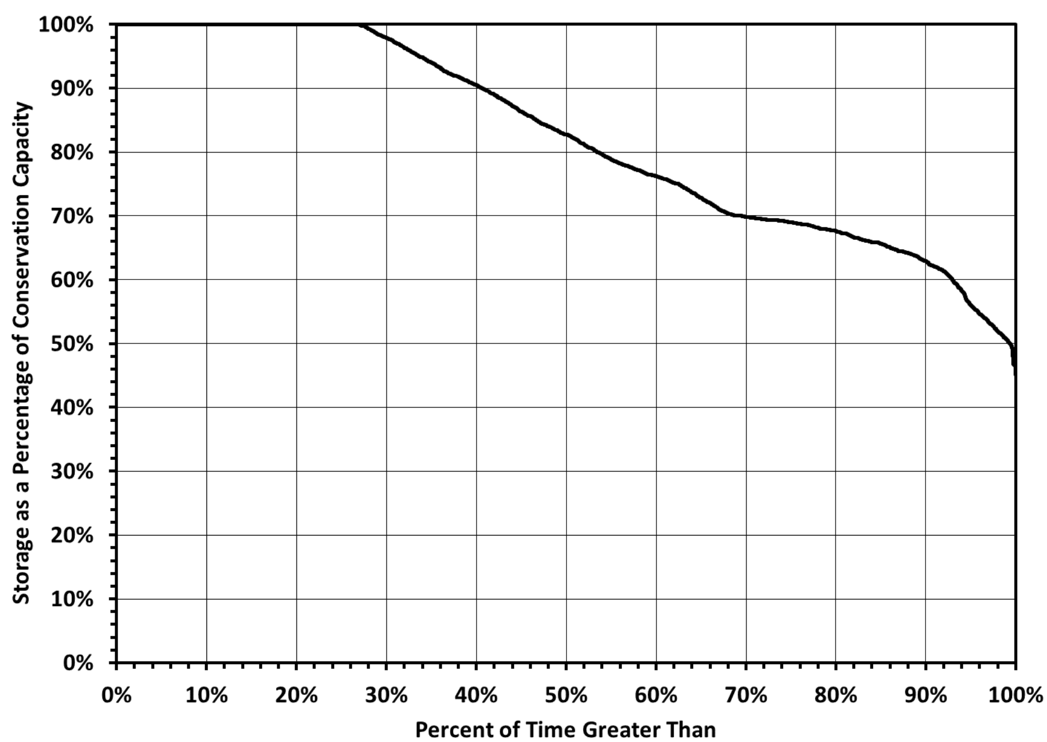
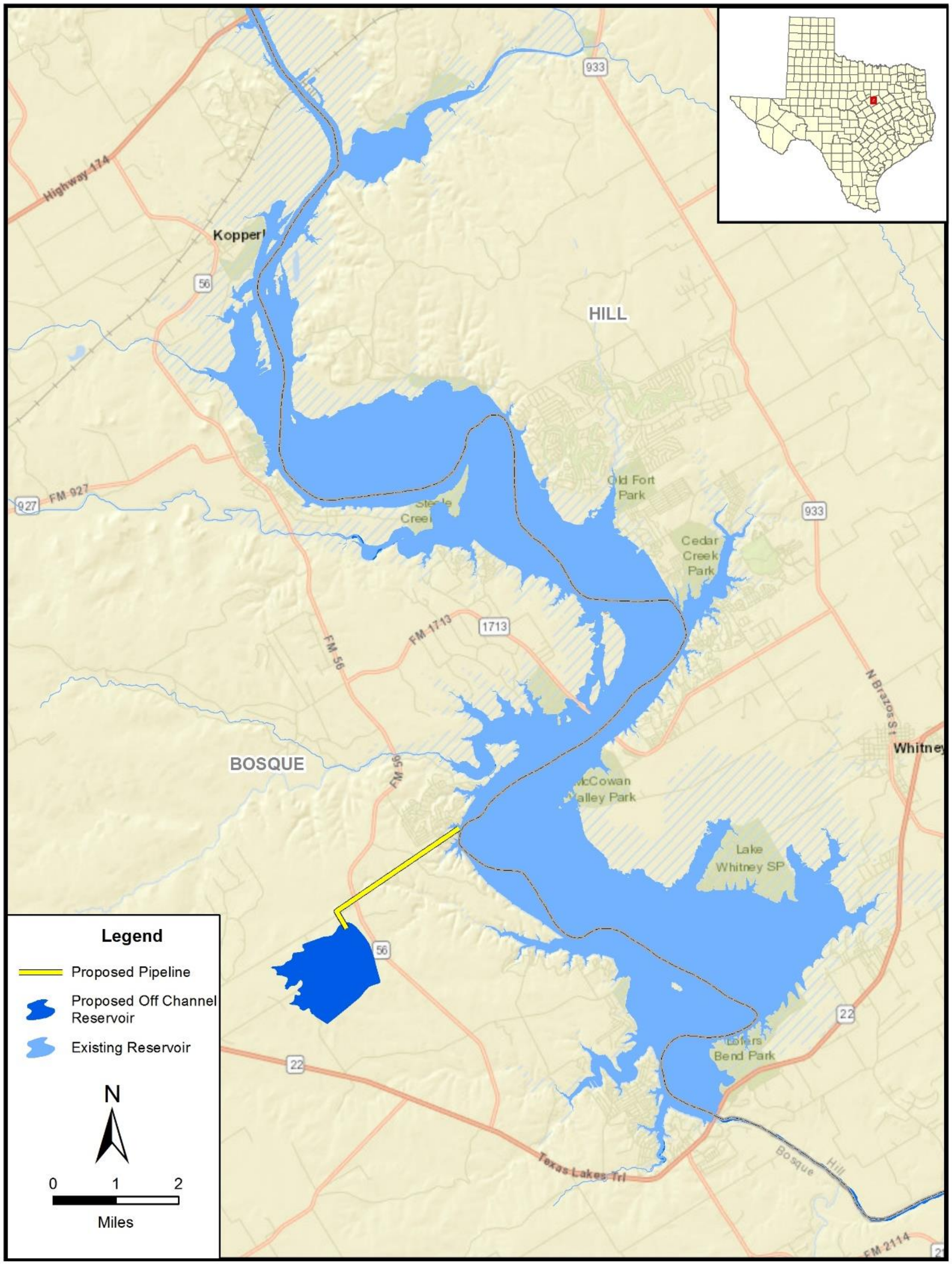
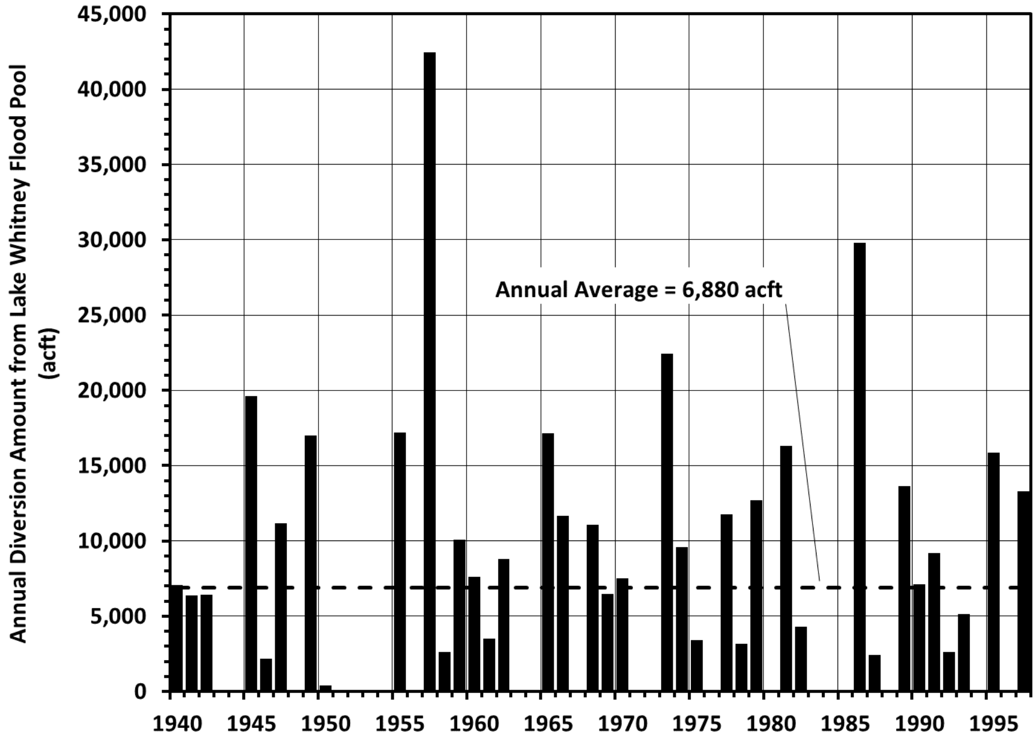


Figure 10.4-3. Location of Proposed OCR from Lake Whitney



Document Path: \\dalctxsrv01\Texas_GIS_Projects\10029705_036_Brazos_G_2021_Plan\Map_Docs\MXDs\Existing_Reservoir_Augmentation_Strategy\Lake_Whitney_OCR.mxd

Figure 10.4-4. Annual Diversion amount under Firm Yield conditions from Lake Whitney



The calculated firm yield of the Lake Whitney Off-Channel Reservoir is 5,200 acft/yr. Figure 10.4-5 illustrates the simulated Off-Channel Reservoir storage levels for the 1940 to 1997 historical period, subject to the firm yield demand. Figure 10.4-6 shows the storage frequency associated with firm yield. Simulated reservoir contents remain above 80 percent capacity about 65 percent of the time and above 50 percent capacity about 90 percent of the time.

Figure 10.4-5. Simulated Lake Whitney off-Channel Reservoir Storage Levels Subject to Firm Yield Demands

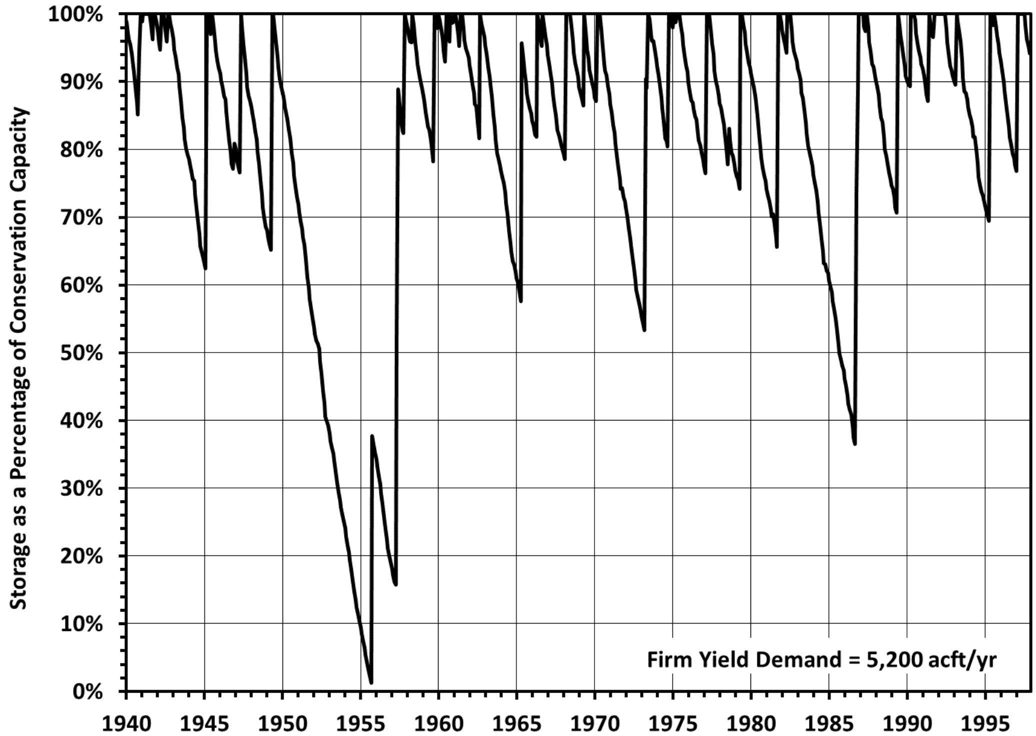


Figure 10.4-6. Storage Frequency associated with Firm Yield

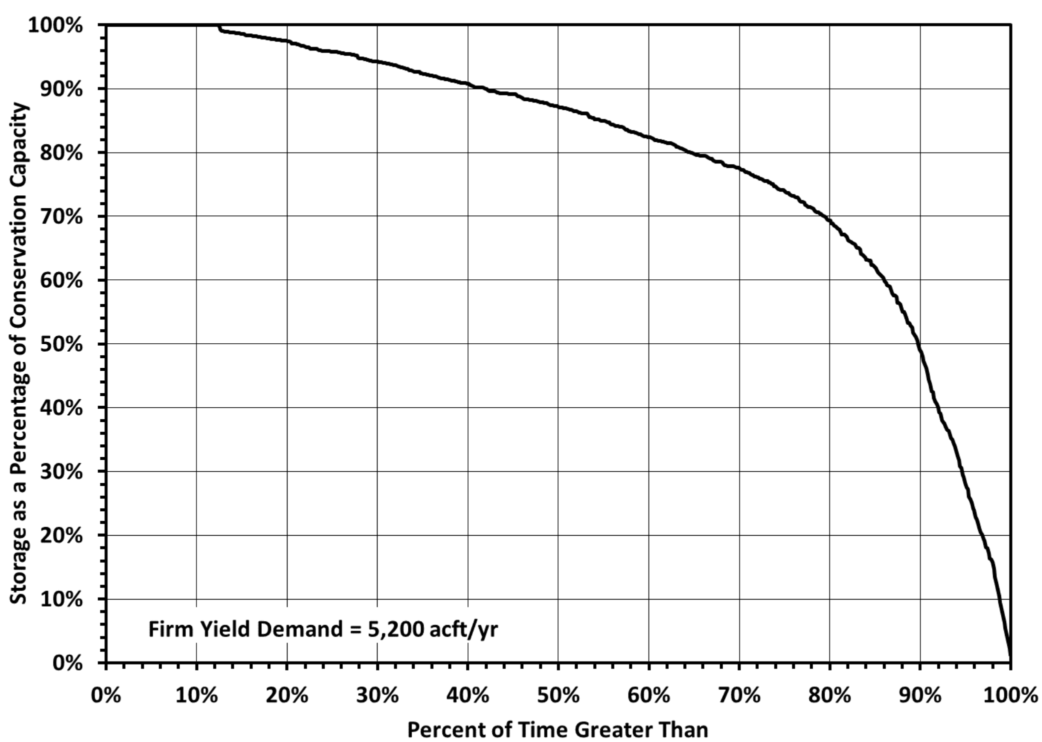


Figure 10.4-7 and Table 10.4-1 present a comparison of median monthly streamflows below Lake Whitney caused by the diversions from the flood pool. Because flood pool diversions would only occur during high flow periods, there is no significant change in median streamflow from implementation of the off-channel reservoir project. Streamflow frequencies below Lake Whitney are shown in Figure 10.4-8.

Figure 10.4-7. Comparison of Median Monthly Streamflow below Lake Whitney

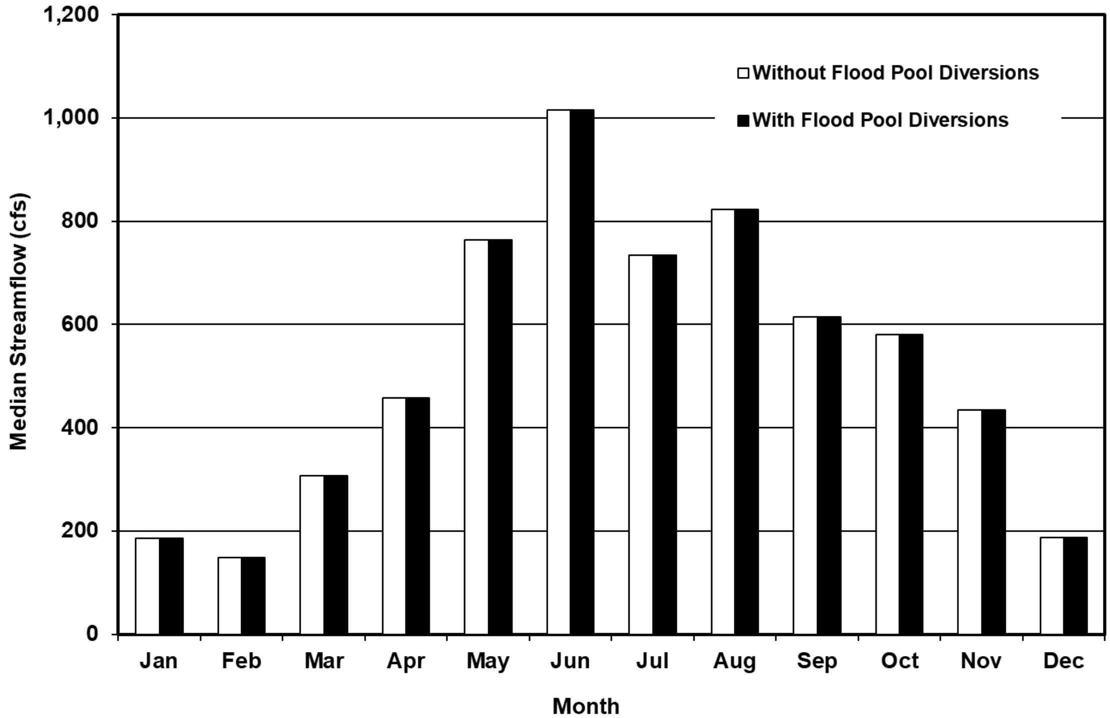
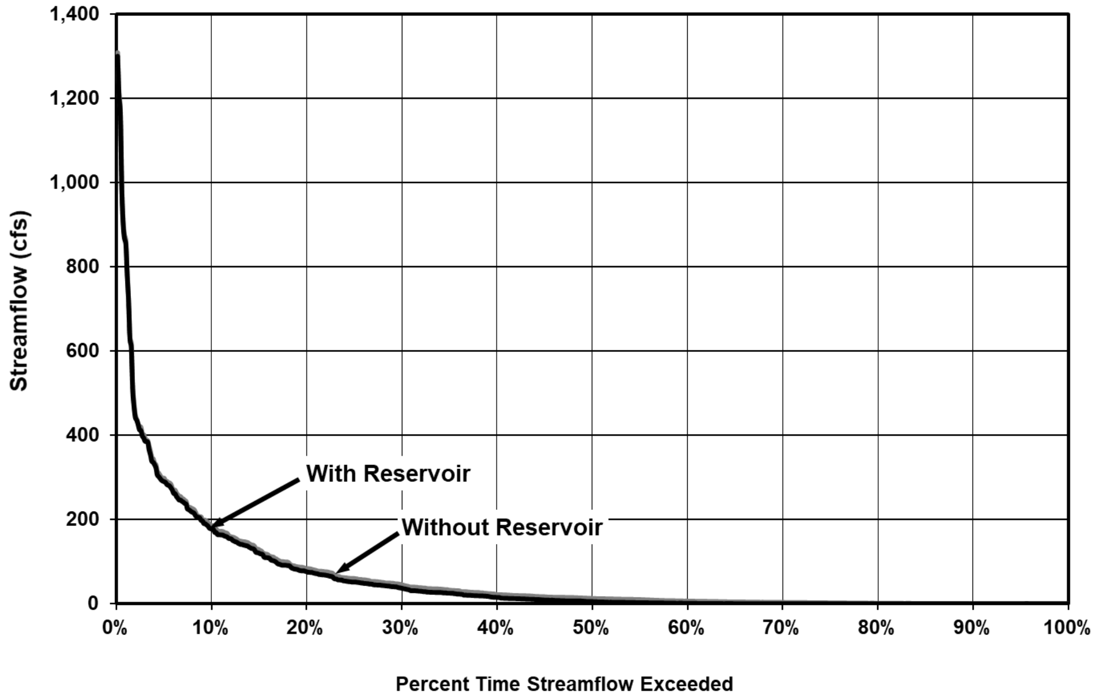


Table 10.4-1. Median Monthly Streamflow below Lake Whitney

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	185	185	0	0%
February	149	149	0	0%
March	307	307	0	0%
April	458	458	0	0%
May	764	764	0	0%
June	1,016	1,016	0	0%
July	734	734	0	0%
August	823	823	0	0%
September	615	615	0	0%
October	581	580	1	0.2%
November	435	435	0	0%
December	188	188	0	0%

Figure 10.4-8. Frequency Comparison of Streamflow below Lake Whitney



10.4.3 Environmental Issues

The Lake Whitney OCR Strategy involves the diverting water from Lake Whitney during wet periods and storing it in an OCR. In addition to the OCR, project components would include an intake in Lake Whitney, a pump station and pipeline from Lake Whitney to the OCR. This report section discusses the potential impacts to environmental and cultural resources known to exist within the proposed project area.

The project area is in the Cross Timbers and Prairies ecoregion of north-central Texas.[1] 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[2] within the project area include Bluestem Grassland and Oak-Mesquite-Juniper Parks/Woods. Bluestem Grasslands are most common over the Gulf Prairies and Marshes. Commonly associated plants include, but are not limited to, bushy bluestem, slender bluestem, buffalograss with woody species including mesquite and live oak. The Oak-Mesquite-Juniper Parks/Woods vegetation type commonly occurs as associations or as a mixture of individual (woody species stands on uplands in the Cross Timbers and Prairies.

[1] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.

[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.

Construction of the diversion intake, transmission pipeline, and primarily the OCR, would involve the disturbance of existing habitat. If possible, this pipeline should be sited along existing rights-of-way, or in other previously disturbed areas, to minimize the overall vegetative impact. Land use would be expected to change from Bluestem Grassland to open water with the implementation of this strategy.

The intake pipeline would originate at Lake Whitney and cross King Creek, a tributary to Lake Whitney, and a few of its unnamed tributaries to the proposed OCR. According to the National Wetland Inventory (NWI) maps, the OCR area would be located along the upper reaches of some unnamed tributaries to King Creek, which include freshwater ponds, freshwater emergent wetlands, and freshwater forested/shrub wetlands. 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.

The Texas Surface Water Quality Viewer[3] identifies stream segments and impaired bodies of water in Texas. Whitney Lake reservoir (Segment 1203) is not listed as impaired for any water quality standards. There are no stream segments within five miles of the proposed project improvements which are listed as impaired on the Texas 303(d) List. Potential impacts to existing water quality are not anticipated from this project.

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Bosque County can be found at https://tpwd.texas.gov/gis/rtest/.

According to the USFWS Information for Planning and Consultation, no USFWS designated critical habitat areas occur near the project area.

[3] TCEQ, 2020. Surface Water Quality Viewer. Accessed online https://tceq.maps.arcgis.com/apps/webappviewer/index.html?id=b0ab6bac411a49189106064b70bbe778 January 31, 2020.

The Texas Natural Diversity Data (TxNDD) was reviewed for the project area. No threatened or endangered species have been documented within the proposed project area, however, the golden-cheeked warbler (state and federally-listed endangered), black-capped vireo (state species of greatest conservation need [SGCN]), and the Guadalupe bass (SGCN) were documented within five miles of the proposed project components. A habitat survey should be conducted prior to construction to determine the potential for the presence of threatened, endangered or rare species habitat within the proposed project area. Coordination with TPWD or USFWS would be required if there would be impacts to threatened or endangered species, or their habitat.

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 pipeline route or OCR area, and no archeological surveys have occurred adjacent to or 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 comply with the Antiquities Code of Texas and an archeological survey and coordination with the Texas Historical Commission will likely be required 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, 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.

10.4.4 Engineering and Costing

The potential off-channel reservoir project would require additional facilities to divert water from the flood pool of Lake Whitney to the off-channel reservoir site. The facilities required for implementation of the project included:

- Raw water intake and pump station at the Lake Whitney diversion site with a capacity of 184 MGD;
- 3 miles of raw water pipeline (102-inch diameter) from the pump station to the off-channel reservoir;
- Off-channel dam including spillway, intake tower, and 994 acres of land for the reservoir.

A summary of the total project cost is presented in Table 10.4-2. The proposed project would cost approximately $171.7 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 $12,879,000. This includes annual debt service, operation and maintenance, and pumping energy costs. The resulting unit cost of 5,200 acft/yr of raw water from the strategy is $2,477 per acft ($7.60 per 1,000 gallons).

Table 10.4-2. Cost Estimate Summary for Lake Whitney Overdrafting Supply with an Off-Channel Reservoir

Item	Estimated Costs for Facilities
Off-Channel Storage (Conservation Pool 45,400 ac-ft, 994 acres)	$45,439,000
Intake Pump Stations (184 MGD)	$55,820,000
Transmission Pipeline (102 in dia., 3 miles)	$14,732,000
TOTAL COST OF FACILITIES	**$115,991,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond	$39,860,000
Environmental & Archaeology Studies and Mitigation	$3,444,000
Land Acquisition and Surveying (1,015 acres)	$3,489,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$8,954,000
TOTAL COST OF PROJECT	**$171,738,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$7,027,000
Reservoir Debt Service (3.5 percent, 40 years)	$3,365,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$147,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$1,395,000
Dam and Reservoir (1.5% of Cost of Facilities)	$682,000
Pumping Energy Costs (3,285,249 kW-hr @ 0.08 $/kW-hr)	$263,000
TOTAL ANNUAL COST	**$12,879,000**
Available Project Yield (acft/yr)	5,200
Annual Cost of Water ($ per acft)	$2,477
Annual Cost of Water ($ per 1,000 gallons)	$7.60

10.4.5 Implementation Issues

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. Evaluations of Lake Whitney Overdraft with Off-Channel Storage 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	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 project 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;
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction; 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.

10.5 Millers Creek Reservoir Augmentation

10.5.1 Description of Strategy

Augmentation of Millers Creek Reservoir was studied for the 2006, 2011, and 2016 Brazos G Regional Water Plans. The previous plans 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, and
- 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 10.5-1 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 10.5-1 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 10.5-1. 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 10.5-1 lists the drainage areas for the TCEQ WAM incremental drainage area and the Lake Creek diversion site.

Figure 10.5-1. WAM Incremental Drainage Areas used to calculate Naturalized Flows at Millers Creek Reservoir and Lake Creek Diversion Site

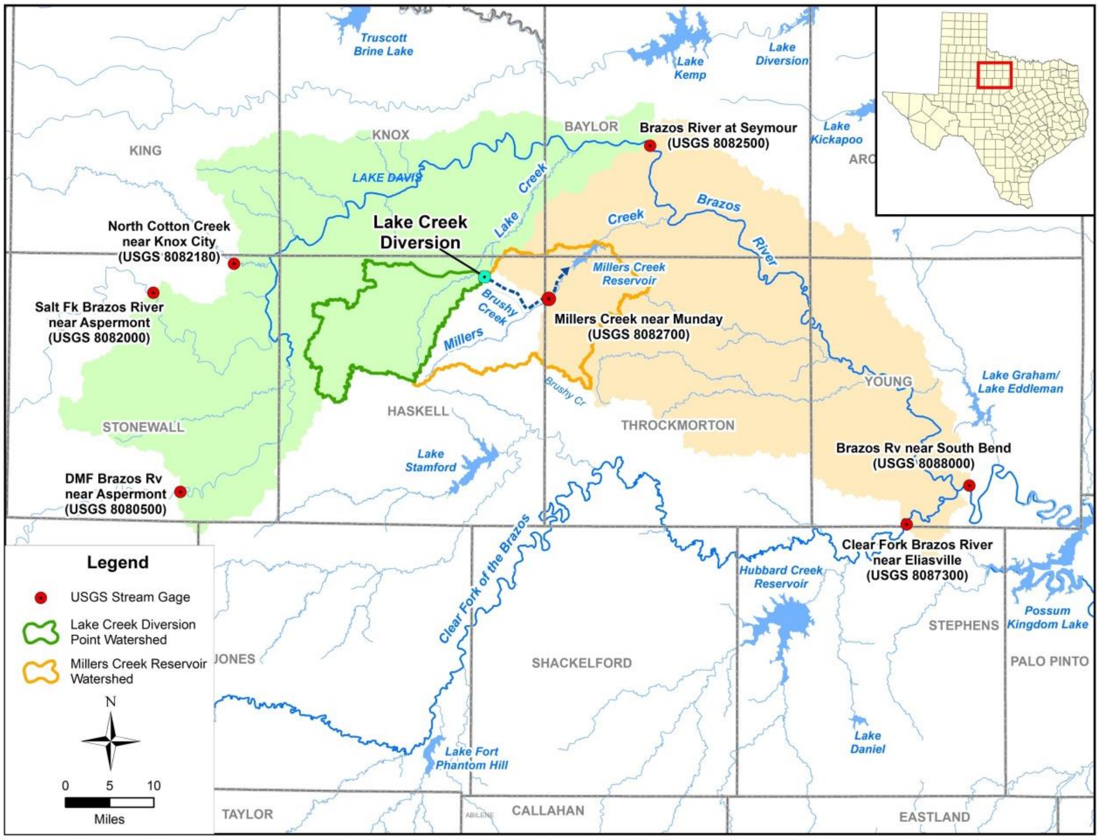


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Table 10.5-1. Drainage Areas used to Translate Naturalized Flows to Millers Creek Reservoir and Lake Creek Diversion Site

Watershed	Drainage Area (sq-mi)
Millers Creek Reservoir	
Millers Creek nr Munday Gage	104
Millers Creek Reservoir	239
TCEQ WAM Incremental (tan shade)	1,319
Lake Creek Diversion Site	
Millers Creek nr Munday Gage	104
Lake Creek Diversion Site	167
TCEQ WAM Incremental (green shade)	1,352

The TCEQ WAM methodology overestimates 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 10.5. This assumption results in significant decreases in firm yield for the augmentation options when compared to the previous plans.

The yield of each reservoir augmentation option is assumed to be the difference in firm yield of the reservoir with and without the augmentation option implemented 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 senior permitted storages and diversions and environmental flow standards adopted by TCEQ. Firm yield with the augmentation options implemented was computed assuming subordination of Possum Kingdom Reservoir. Currently, BRA indicates that no subordination agreement is likely to be possible. The firm yield of Millers Creek Reservoir under these assumptions without an augmentation option implemented and without Possum Kingdom Reservoir subordination is calculated to be 1,700 acft/yr. This is a substantially larger firm yield than determined in the current supply analysis, because the current supply analysis utilizes a longer period of record which includes a drought worse than that experienced from 1940-1997. Supplies calculated with the various augmentation options will be compared to this number only to determine a yield increase resulting from the augmentation option.

10.5.2 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 10.5-2.

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 10.5-3. 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 10.5-2. Canal Option: Lake Creek Diversion to Millers Creek Reservoir

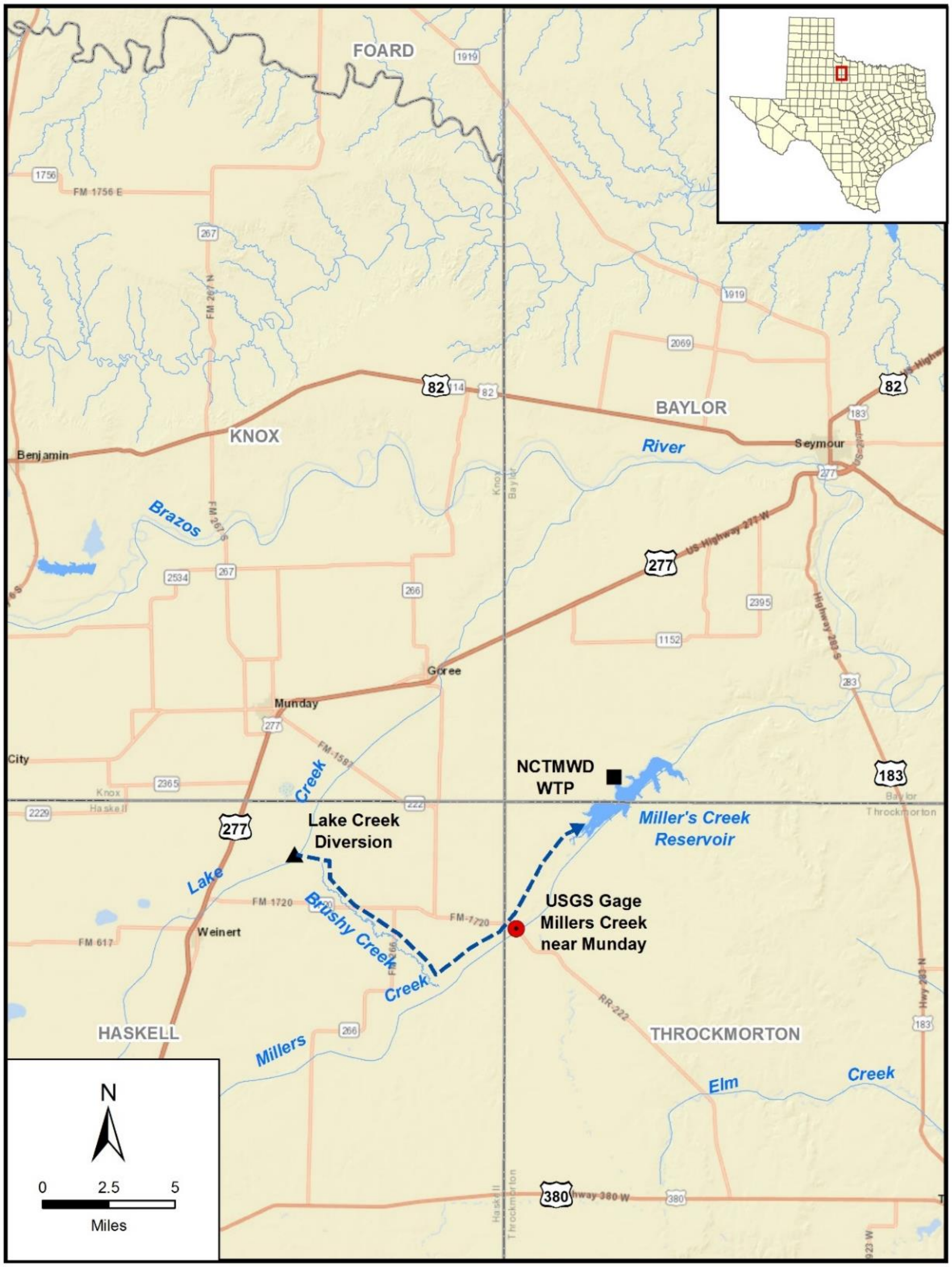
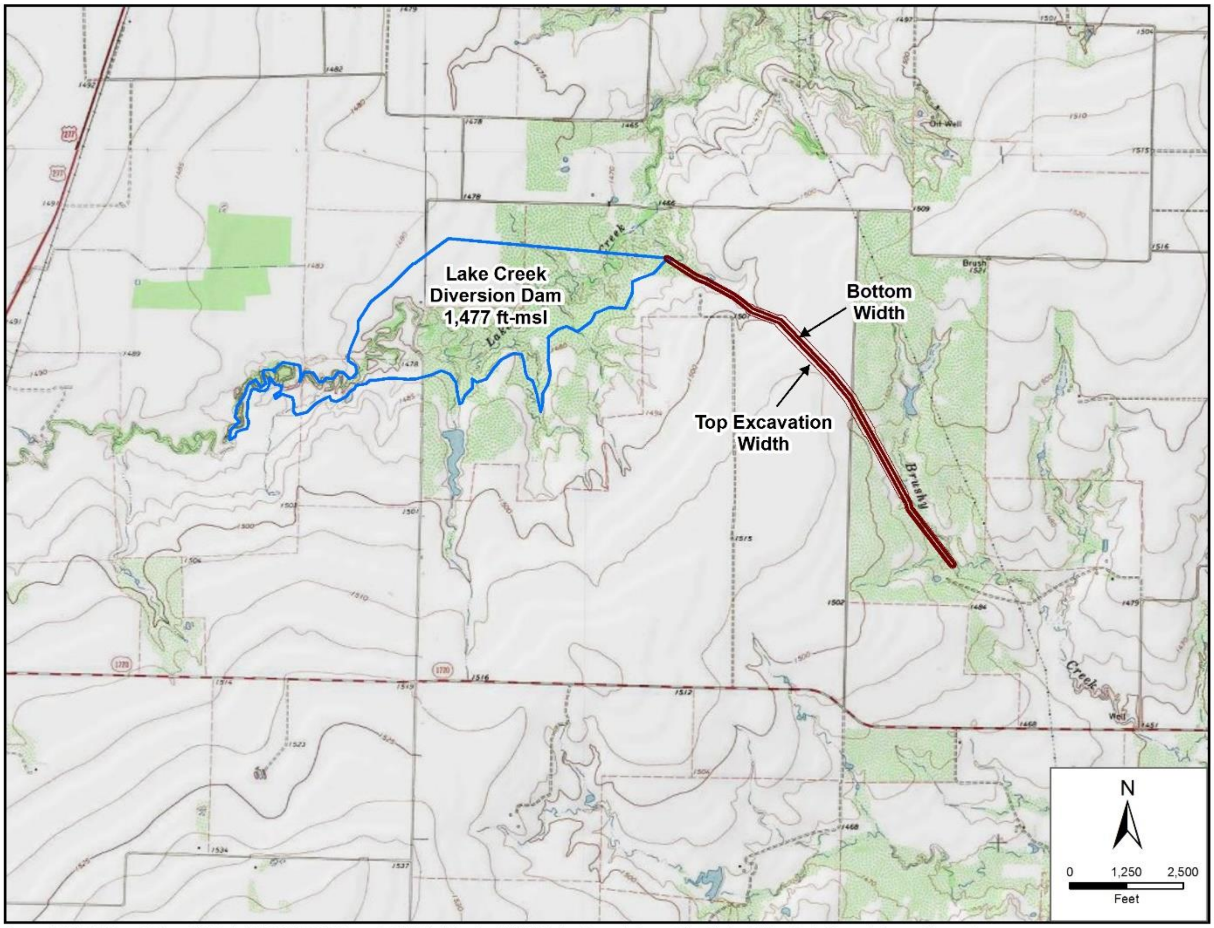


Figure 10.5-3. Lake Creek Diversion Dam and Canal to Brushy Creek



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Available Yield

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 by 2,075 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 1,187 acft/yr for costing purposes. A subordination agreement would have to be negotiated and acquired for this strategy to be implemented as presented in this section.

Figure 10.5-4 illustrates the simulated Millers Creek Reservoir storage levels for the 1940 to 1997 historical period, subject to the firm yield of 3,775 acft/yr. The storage trace shows that the critical drought of record occurs in 1978. Figure 10.5-5 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 10.5-6 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 10.5-7 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 10.5-4. Millers Creek Reservoir Firm Yield Storage Trace with Canal Diversion

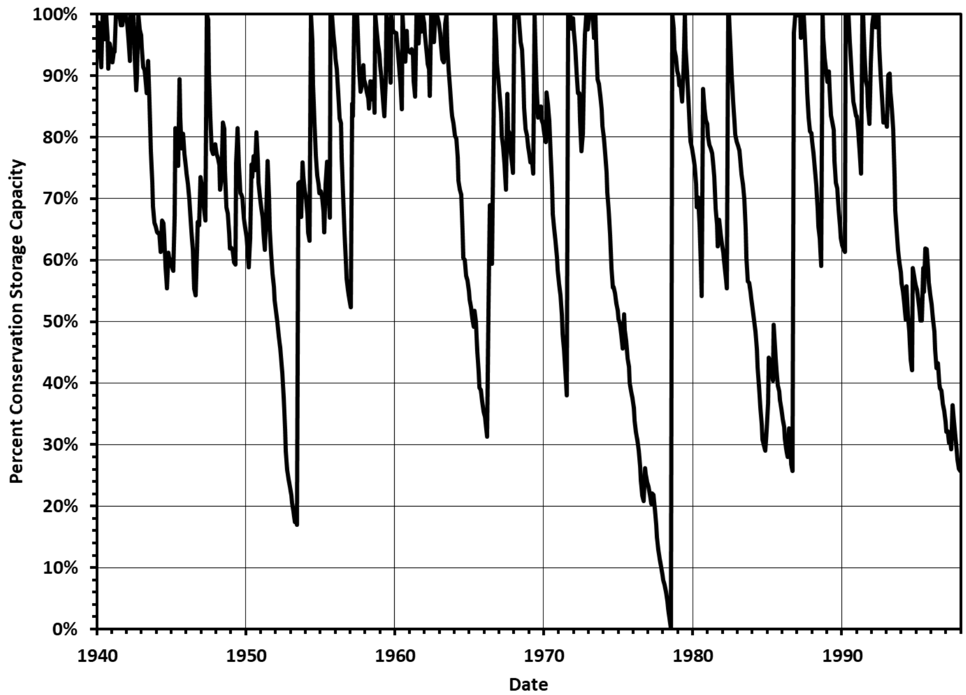


Figure 10.5-5. Millers Creek Reservoir Firm Yield Storage Frequency with Canal Diversion

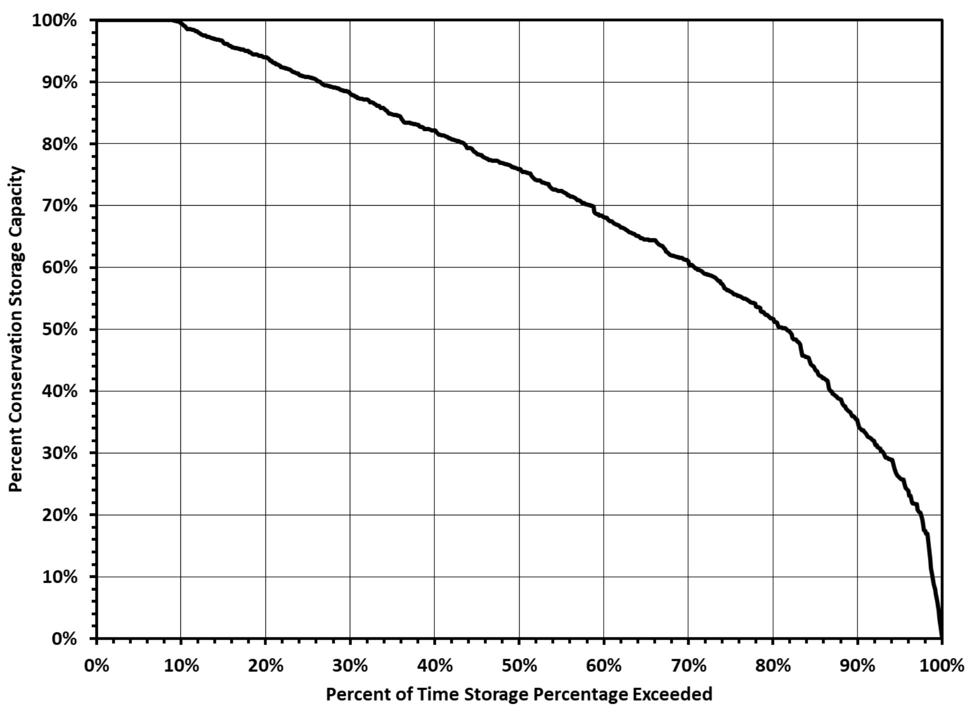


Figure 10.5-6. Comparison of Median Monthly Streamflow below Lake Creek Diversion Point With and Without Canal Diversion

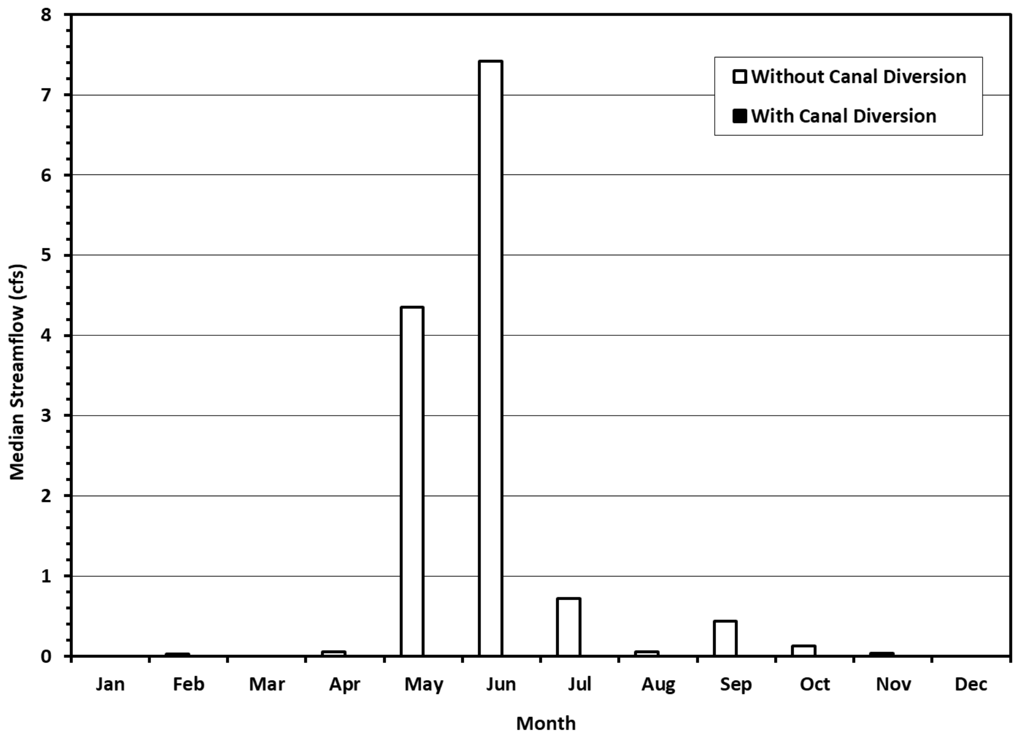
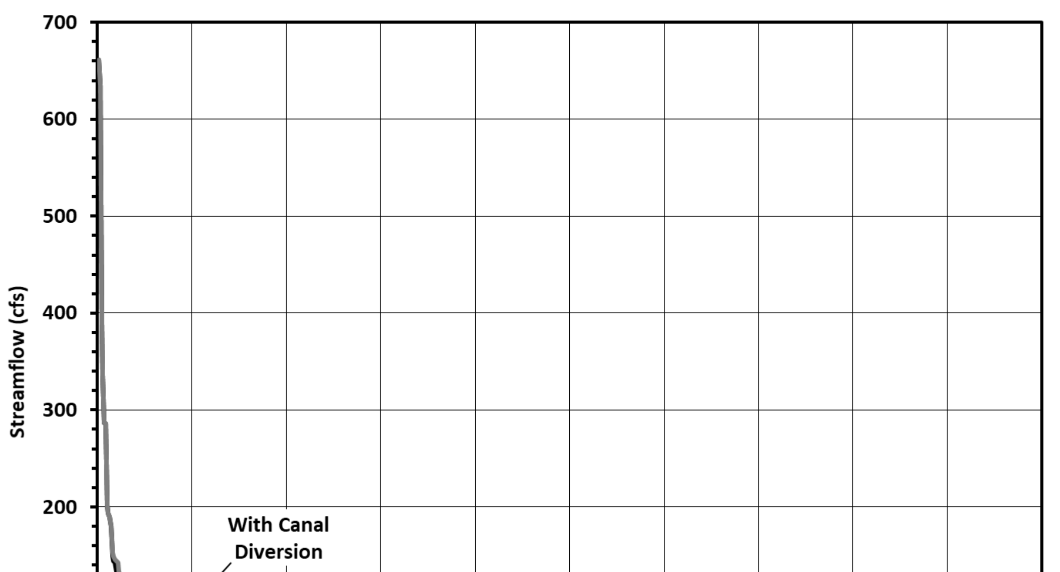


Figure 10.5-7. Comparison of Streamflow Frequency below Lake Creek Diversion Point With and Without Canal Diversion



Environmental Issues

The environmental issues associated with the four options for augmenting Millers Creek reservoir are discussed together in Section 10.5.6.

Engineering and Costing

The total estimated project cost for the channel dam and grass lined canal is $29.2 million. The annual project costs are estimated to be $1.74 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 10.5-2. The cost for the estimated additional firm yield increase of 2,075 acft/yr translates to an annual unit cost for raw water of $2.58 per 1,000 gallons, or $840/acft.

Table 10.5-2. Cost Estimate for Augmentation of Millers Creek Reservoir (Canal Option)

Item	Estimated Costs for Facilities
Capital Cost	
Lake Creek Channel Dam, Reservoir, and Canal	$19,158,000
Total Cost Of Facilities	**$19,158,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$6,705,000
Environmental & Archaeological Studies and Mitigation	$883,000
Land Acquisition and Surveying (491 acres)	$907,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$1,521,000
Total Cost Of Project	**$29,174,000**
Annual Cost	
Reservoir Debt Service (3.5 percent, 40 years)	$1,366,000
Operation and Maintenance	
Dam and Reservoir	$287,000
Purchase of Water (1,187 acft/yr @ 65.65 $/acft)	$91,000
Total Annual Cost	**$1,744,000**
Available Project Yield (acft/yr)	**2,075**
Annual Cost of Water ($ per acft)	**$840**
Annual Cost of Water ($ per 1,000 gallons)	**$2.58**

Implementation Issues

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 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; 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.

10.5.3 Pipeline Option

Description of Option

Another option for augmenting Millers Creek Reservoir previously studied[1] and included in the 2006, 2011, and 2016 Brazos G Plans 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 10.5-2. The capacity of the 24-inch pipe is assumed to be approximately 10 cfs or 7,200 acft/yr.

Available Yield

The firm yield of Millers Creek Reservoir with the pipeline diversion was computed to be 3,700 acft/yr, which is an increase of 2,000 acft/yr over firm yield of 1,700 acft/yr for the reservoir with no augmentation and no Possum Kingdom Reservoir subordination. 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 1,144 acft/yr for costing purposes. A subordination agreement would have to be negotiated and acquired for this strategy to be implemented as presented in this section. Currently, BRA indicates that no subordination agreement is likely to be possible.

Figure 10.5-8 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 10.5-9 also illustrates the Lake Creek streamflow frequency characteristics with and without the project in place.

[1] Freese & Nichols, Inc, "West Central Brazos River Basin Regional Water Treatment and Distribution Facility Plan," August 2004.

Figure 10.5-8. Comparison of Median Monthly Streamflow below Lake Creek Diversion Point With and Without Pipeline Diversion

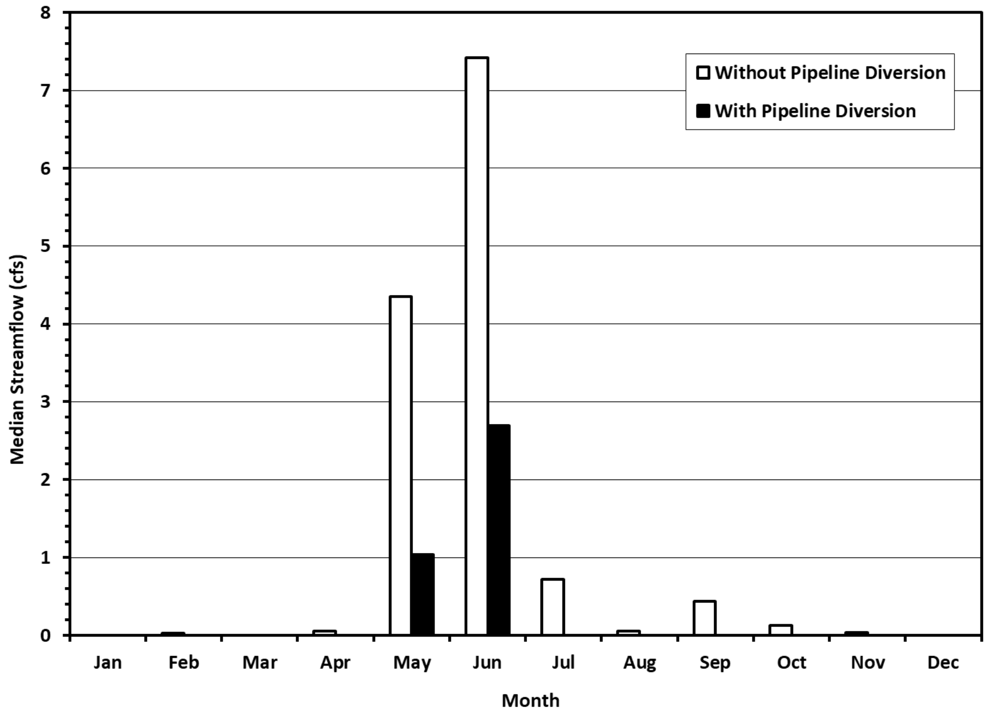
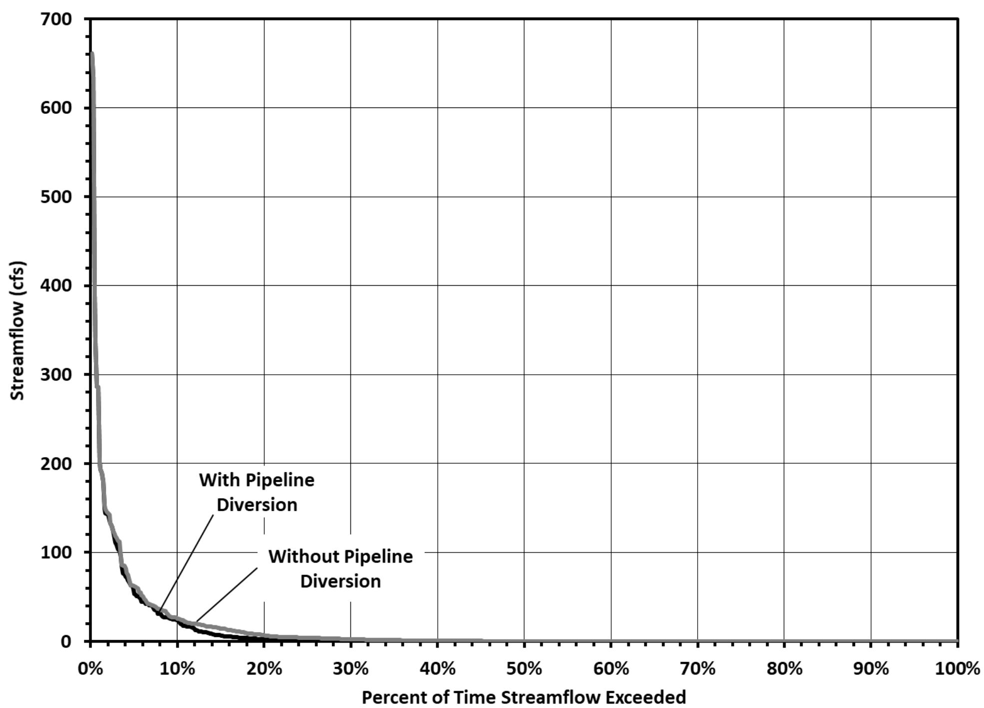


Figure 10.5-9. Comparison of Streamflow Frequency below Lake Creek Diversion Point With and Without Pipeline Diversion



Environmental Issues

The environmental issues associated with the four options for augmenting Millers Creek reservoir are discussed together in Section 10.5.6.

Engineering and Costing

The total estimated project cost is $22.6 million for the diversion weir, intake canal, pipeline, and pump station. The annual project costs are estimated to be $1.85 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. A summary of the project costs is presented in Table 10.5-4. The cost for the estimated increase in Millers Creek Reservoir firm yield of 2,000 acft/yr translates to an annual unit cost for raw water of $2.84 per 1,000 gallons, or $925 per acft.

Table 10.5-4. Cost Estimate for Augmentation of Millers Creek Reservoir (Pipeline Option)

Item	Estimated Costs for Facilities
Capital Cost	
Lake Creek Channel Dam and Intake Canal)	$5,125,000
Intake Pump Stations (6.5 MGD)	$8,476,000
Transmission Pipeline (24 in dia., 2 miles)	$2,277,000
Total Cost Of Facilities	**$15,878,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$5,487,000
Environmental & Archaeological Studies and Mitigation	$53,000
Land Acquisition and Surveying (491 acres)	$23,000
Interest During Construction (4% for 2 years with a 1% ROI)	$1,180,000
Total Cost Of Project	**$22,621,000**
Annual Cost	
Debt Service (3.5 percent, 20 years)	$1,078,000
Reservoir Debt Service (3.5 percent, 40 years)	$342,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$23,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$212,000
Dam and Reservoir (1.5% of Cost of Facilities)	$77,000
Pumping Energy Costs (0.08 $/kW-hr)	$30,000
Purchase of Water (1,144 acft/yr @ 76.50 $/acft)	$88,000
Total Annual Cost	**$1,850,000**
Available Project Yield (acft/yr)	**2,000**
Annual Cost of Water ($ per acft)	**$925**
Annual Cost of Water ($ per 1,000 gallons)	**$2.84**

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 10.5-5 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.

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 10.5-5. 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

10.5.4 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. Figure 10.5-10 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.

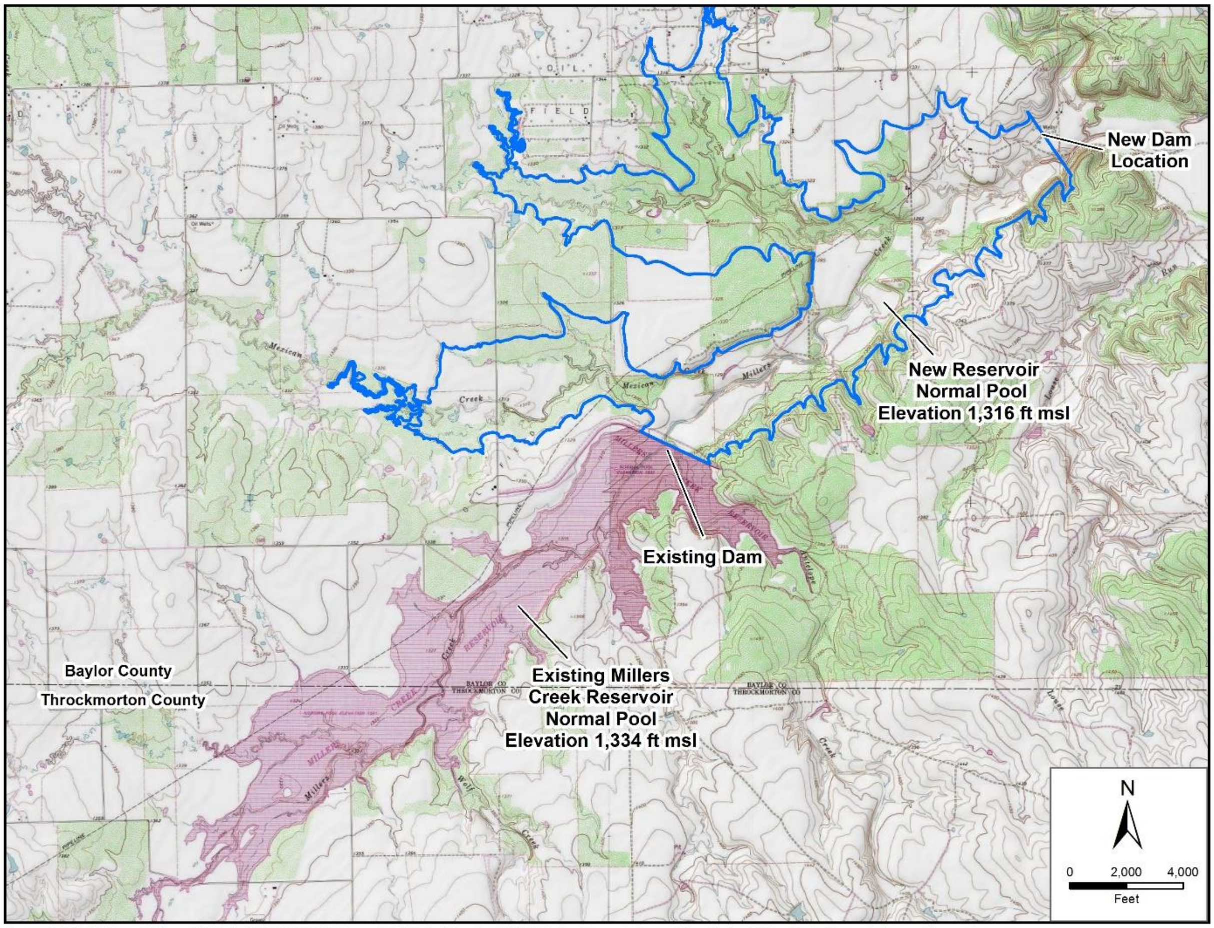
Preliminary design parameters for the dam were identified in the Freese, Nichols and Endress study. The study recommends an earthen embankment dam with 3:1 downstream side slopes, and upstream side slopes of 3:1 below the normal pool elevation and 2:1 above the normal pool elevation. The study recommends 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 calculated firm yield of the new reservoir is 750 acft/yr, with the subordination and priority assumptions noted above. Along with a computed 1,600 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 2,350 acft/yr. Based on a delivery factor of 0.572, the yield impact on Possum Kingdom Reservoir was estimated to be 1,344 acft/yr for costing purposes. Figure 10.5-11 shows the simulated storage levels of the new reservoir for the 1940 to 1997 historical period, subject to the firm yield of 750 acft/yr. The new reservoir experiences long drawdown periods because it is reliant on spills from the existing reservoir for storage recovery. Figure 10.5-12 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.

Figure 10.5-10. 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 10.5-13 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 10.5-11. New Reservoir Storage Trace

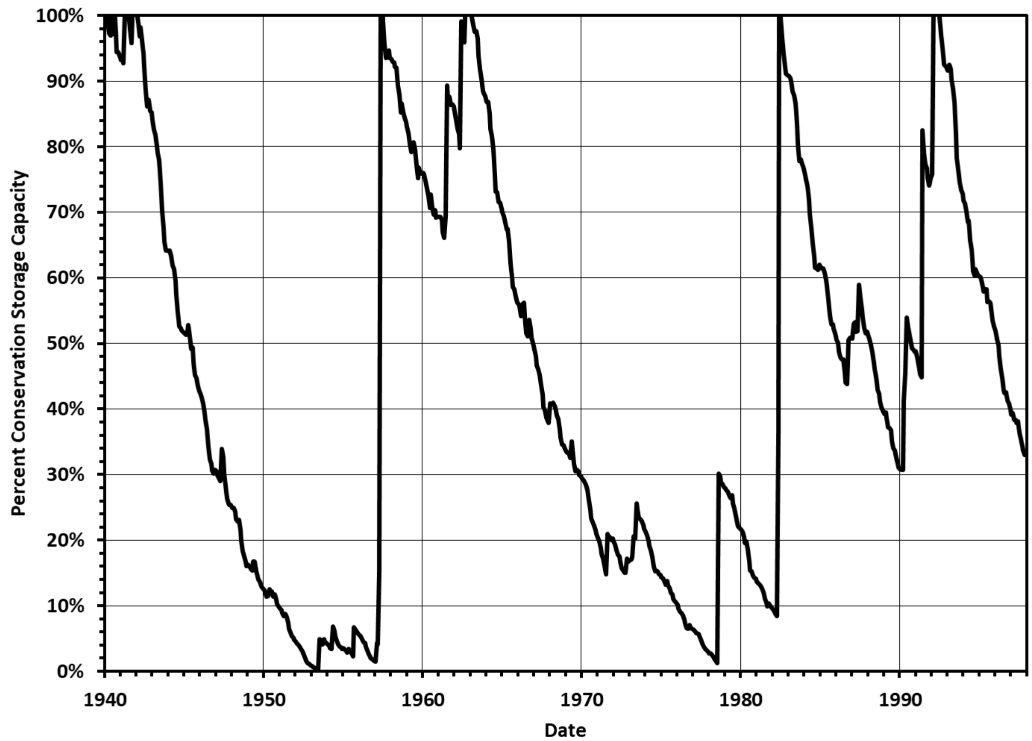


Figure 10.5-12. New Reservoir Storage Frequency

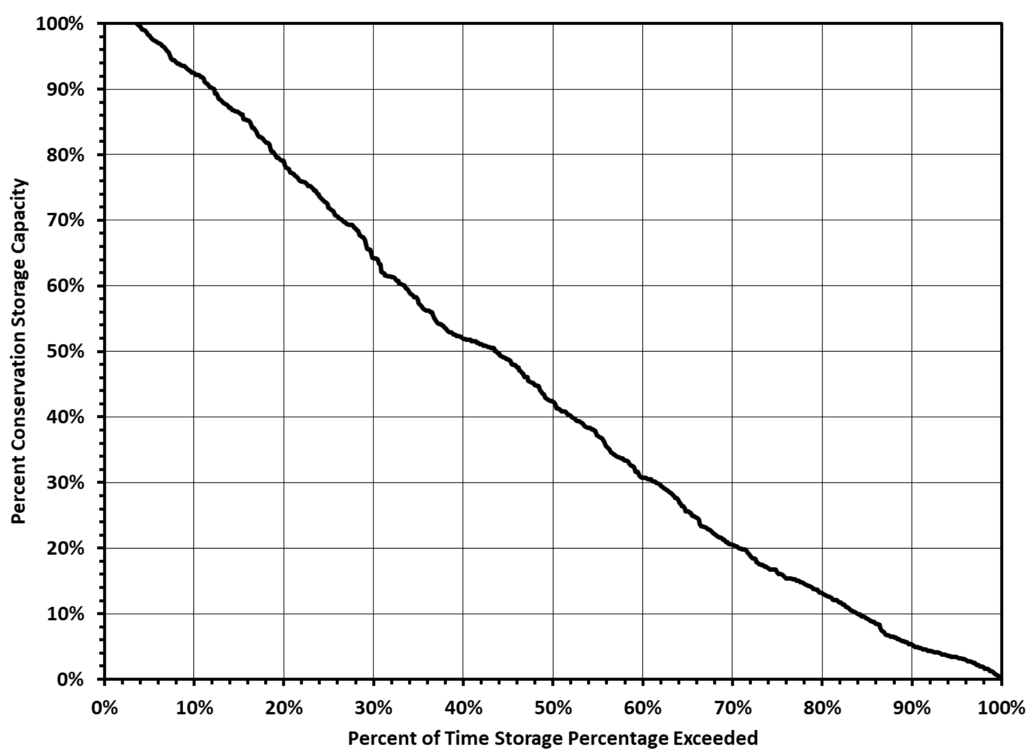
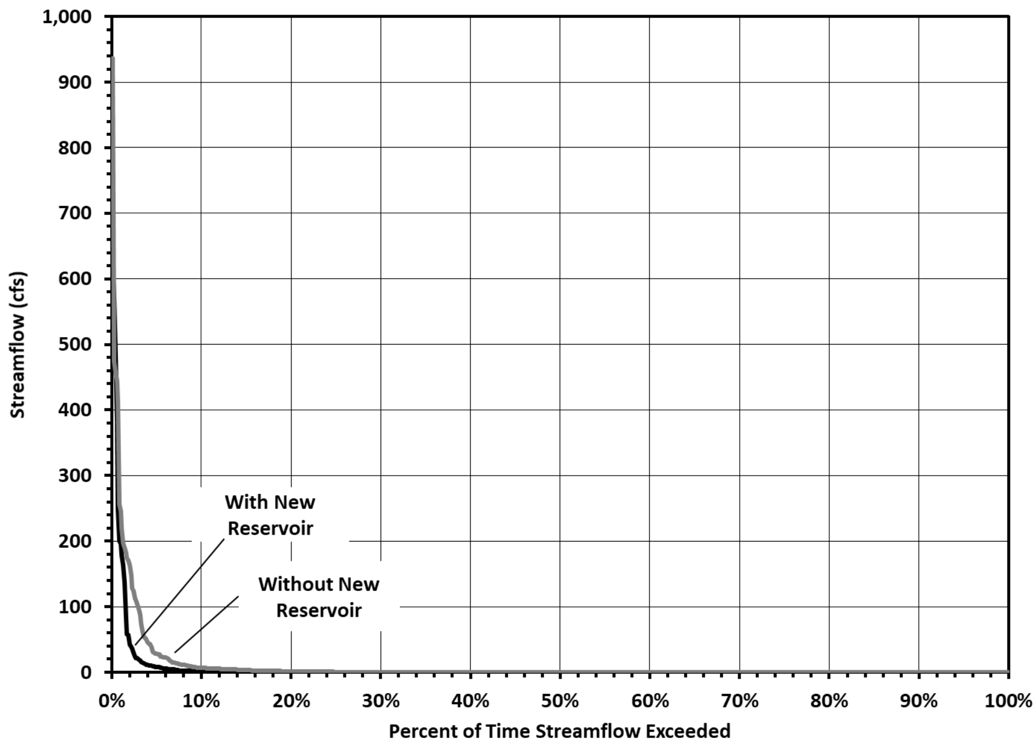


Figure 10.5-13. Comparison of Millers Creek Streamflow Frequency With and Without New Reservoir



Environmental Issues

The environmental issues associated with the four options for augmenting Millers Creek reservoir are discussed together in Section 10.5.6.

Engineering and Costing

Table 10.5-6 summarizes estimated costs for the new dam and reservoir. The total estimated project cost for the new dam and reservoir is $81.3 million. The annual project costs are estimated to be $4.63 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 2,300 acft/yr translates to an annual unit cost for raw water of $6.05 per 1,000 gallons, or $1,971 per acft.

Table 10.5-6. Cost Estimate for Augmentation of Millers Creek Reservoir (New Reservoir Option)

Item	Estimated Costs for Facilities
Capital Cost	
New Dam and Reservoir	$46,256,000
Integration, Relocations, & Other	$601,000
Total Cost Of Facilities	**$46,857,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$16,400,000
Environmental & Archaeological Studies and Mitigation	$6,823,000
Land Acquisition and Surveying (3,795 acres)	$7,013,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$4,241,000
Total Cost Of Project	**$81,334,000**
Debt Service (3.5 percent, 20 years)	$60,000
Reservoir Debt Service (3.5 percent, 40 years)	$3,769,000
Operation and Maintenance	
Dam and Reservoir	$700,000
Purchase of Water (1,344 acft/yr @ 76.50 $/acft)	$103,000
Total Annual Cost	**$4,632,000**
Available Project Yield (acft/yr)	**2,350**
Annual Cost of Water ($ per acft)	**$1,971**
Annual Cost of Water ($ per 1,000 gallons)	**$6.05**

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 10.5-7, 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 10.5-7. 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

10.5.5 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 10.5.2 with the new dam and reservoir described in Section 10.5.4. 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 computed firm yield of Millers Creek Reservoir with the canal diversions is 3,700 acft/yr as noted in Section 10.5.2. Under this demand on Millers Creek Reservoir, the new reservoir firm yield was computed to be 1,025 acft/yr. Therefore, the combined firm yield of the existing reservoir and new reservoir with the canal diversion and subordination assumptions is 4,725 acft/yr, which is an increase of 3,025 acft/yr from the baseline firm yield of 1,700 acft for Millers Creek Reservoir without augmentation and without Possum Kingdom subordination.

When the canal option and new reservoir option are modeled separately, the firm yield sum is 4,425 acft/yr (2,350 acft/yr from the new reservoir and 2,075 acft/yr from the canal diversions). When the two options are combined, the system operations increases the combined firm yield by 300 acft/yr to 4,725 acft/yr. Based on a delivery factor of 0.572, the yield impact on Possum Kingdom Reservoir was estimated to be 1,730 acft/yr for costing purposes. Figure 10.5-14 shows the simulated storage levels of the new reservoir for the 1940 to 1997 historical period, subject to the firm yield demand of 4,725 acft/yr. Figure 10.5-15 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 10.5-14. New Reservoir Storage Trace at Firm Yield with Canal Diversion

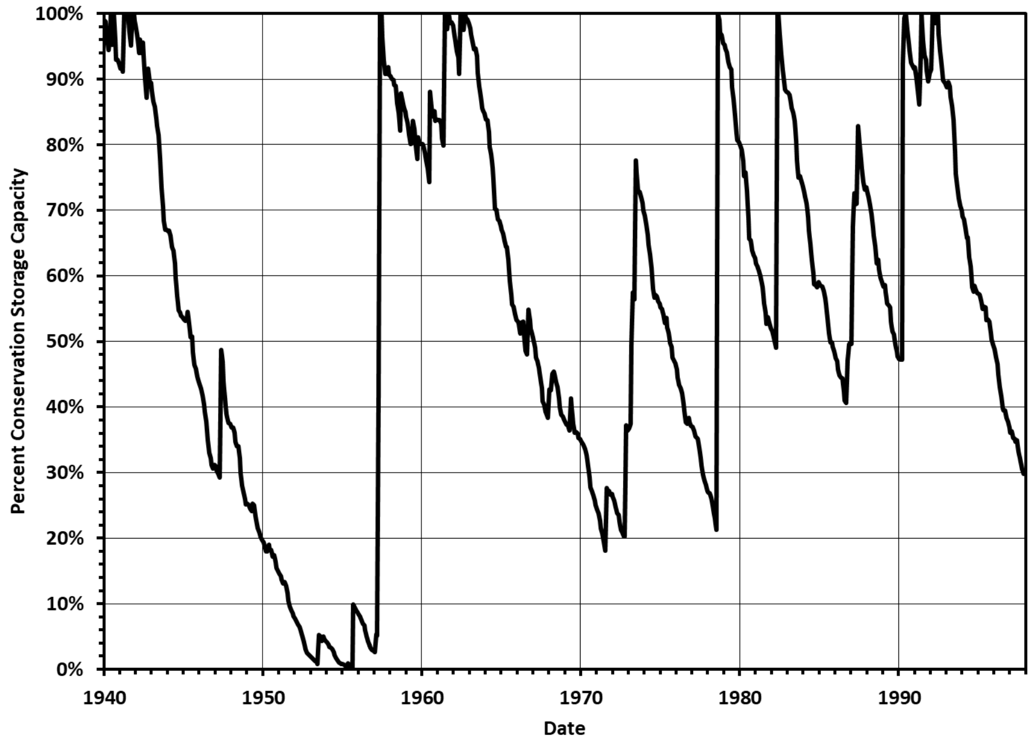
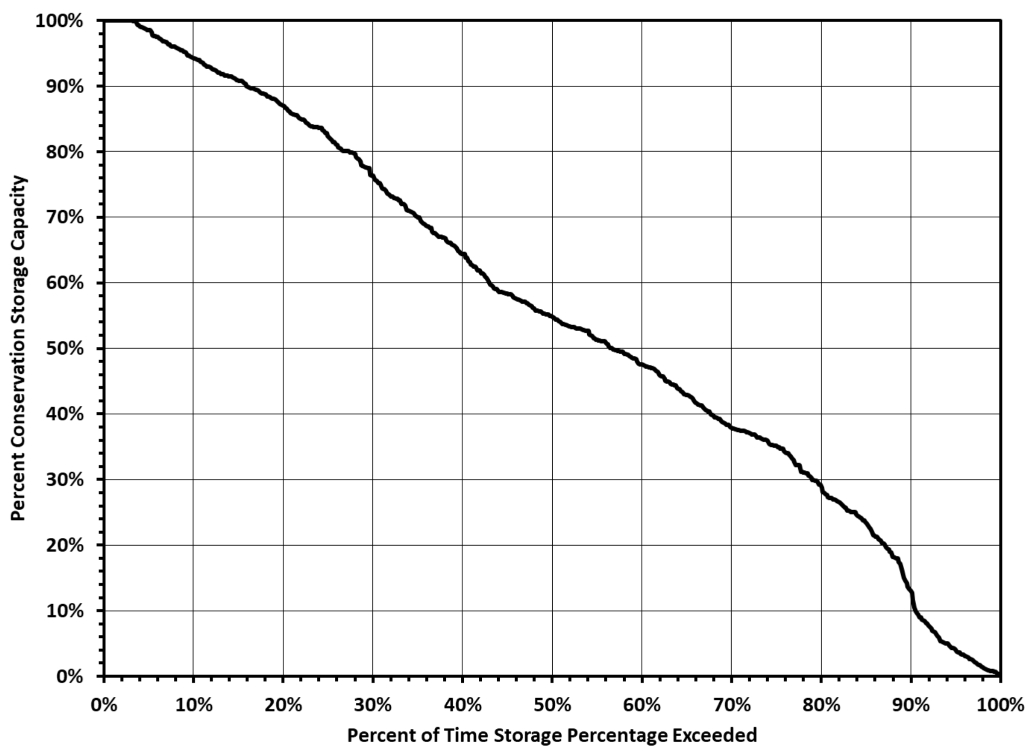


Figure 10.5-15. New Reservoir Storage Frequency at Firm Yield with Canal Diversion



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 10.5.2 and shown in Figure 10.5-6. 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 10.5-16 and Figure 10.5-17 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 10.5.2 and shown in Figure 10.5-7. 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 10.5-16. Comparison of Streamflow Frequency below Lake Creek Diversion Point with and without New Reservoir and Canal Diversion

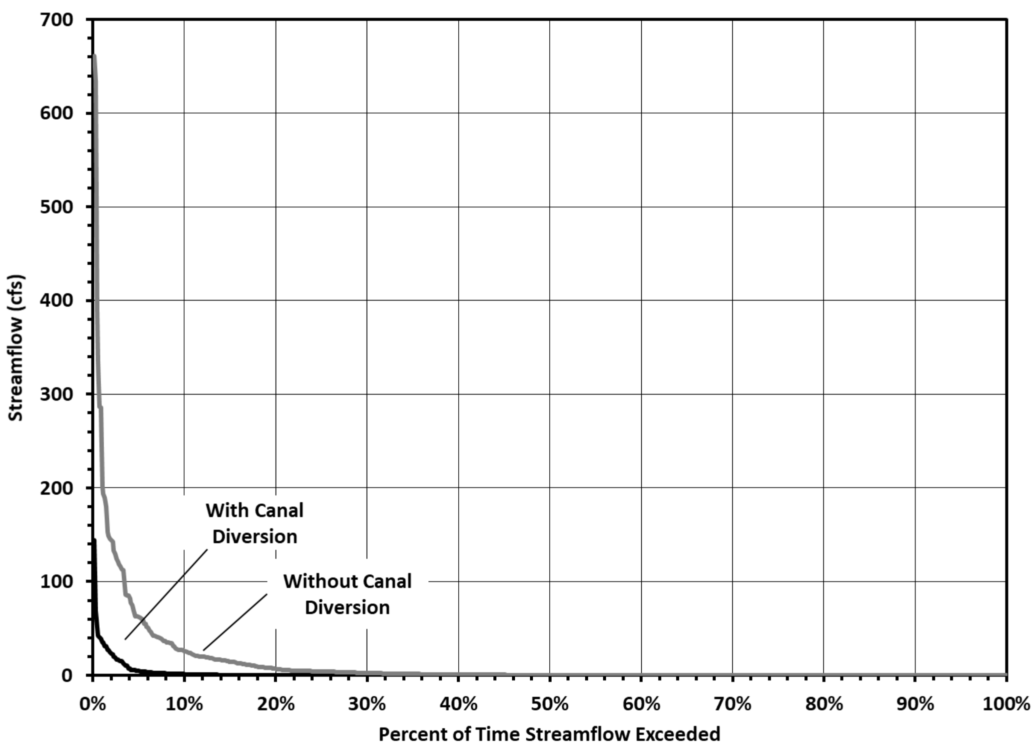
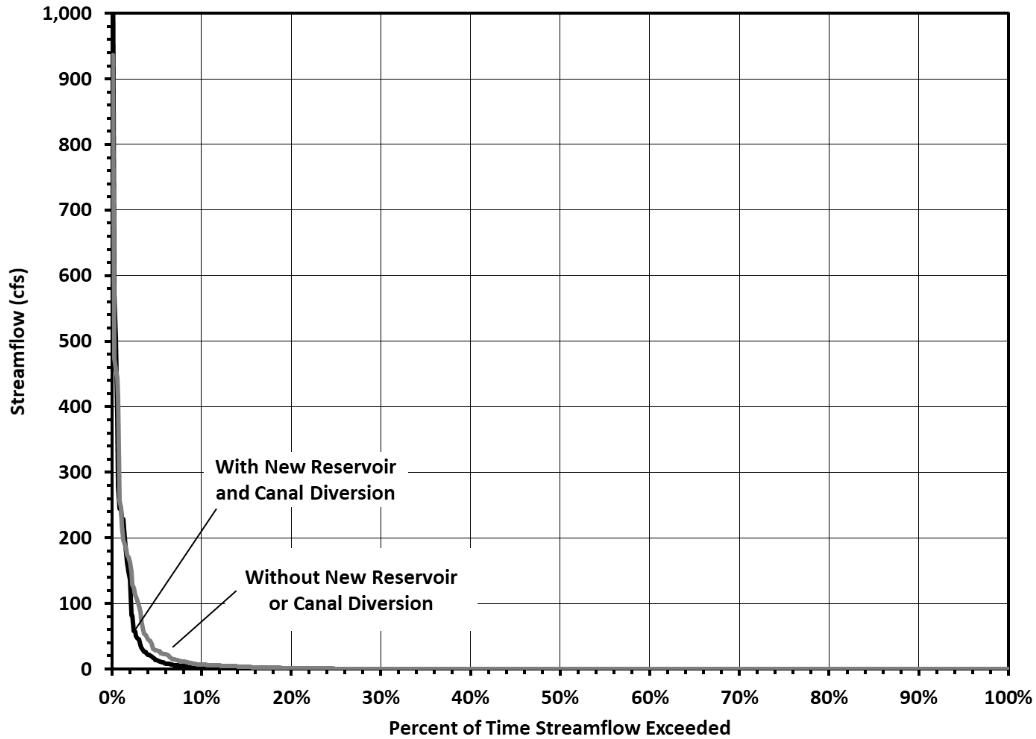


Figure 10.5-17. Comparison of Millers Creek Streamflow Frequency With and Without New Reservoir and Canal Diversion



Environmental Issues

The environmental issues associated with the four options for augmenting Millers Creek reservoir are discussed together in Section 10.5.6.

Engineering and Costing

Table 10.5-8 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 $113.4 million. The annual project costs are estimated to be $6.45 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 3,025 acft/yr translates to an annual unit cost for raw water of $6.54 per 1,000 gallons, or $2,132 per acft.

Table 10.5-8. 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	$19,158,000
Lake Creek Channel Dam, Reservoir, and Canal	$46,256,000
Integration, Relocations, & Other	$601,000
Total Cost Of Facilities	**$66,015,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$23,105,000
Environmental & Archaeological Studies and Mitigation	$7,706,000
Land Acquisition and Surveying (4,286 acres)	$7,921,000
Interest During Construction (4% for 3 years with a 1% ROI)	$8,642,000
Total Cost Of Project	**$113,389,000**
Annual Costs	
Debt Service (3.5 percent, 20 years)	$62,000
Reservoir Debt Service (3.5 percent, 40 years)	$5,269,000
Operation and Maintenance	
Dam and Reservoir	$987,000
Purchase of Water (1,730 acft/yr @ 76.50 $/acft)	$132,000
Total Annual Cost	**$6,450,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**3,025**
Annual Cost of Water ($ per acft)	**$2,132**
Annual Cost of Water ($ per 1,000 gallons)	**$6.54**

10.5.6 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

[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.

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 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 physiography of the region includes recharge sand, undissected red beds, loose surficial sand, flood prone areas, and severely eroded land.[7] Three major vegetation types occur within the general vicinity of the project area: Mesquite - Lotebush Shrub, Mesquite-Saltcedar Brush/Woods, and Crops.[8] Variations in these primary types occur with changes in the composition of woody and herbaceous species and localized conditions.

Potential Impacts

Aquatic Environments including Bays & Estuaries

Several freshwater emergent wetlands, forested/shrub wetlands, ponds, riverine and lake wetlands were identified on the National Wetland Inventory (NWI) maps adjacent to the potential pipeline. A Nationwide Permit or coordination with the U.S. Army Corps of Engineers would be required for impacts to waters of the U.S. One surface water (Millers Creek Reservoir – TCEQ Segment 1208A) was identified on the TCEQ Surface Water Quality Viewer[9] within the proposed project area, or within 5 miles. This surface water was fully functioning and was not impaired.

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

[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] 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.

[8] 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.

[9] TCEQ, Surface Water Quality Viewer. Accessible online https://tceq.maps.arcgis.com/apps/webappviewer/index.html?id=b0ab6bac411a49189106064b70bbe778 accessed January 13, 2020.

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

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for the project area counties can be found at https://tpwd.texas.gov/gis/rtest/.

According to the Information for Planning and Consultation (IPaC) website[10] maintained by the U.S. Fish & Wildlife Service (USFWS), the Whooping Crane needs to be considered for the proposed project. The Least Tern, Piping Plover, and Red Knot were also mentioned, but only need to be considered for wind energy projects. The Whooping Crane could be a migrant through the project area, but no adverse impacts to the Whooping Crane would be expected. Reduced effluent return rates could potentially affect the sharpnose or smalleye shiner if area tributaries flow into occupied habitat. 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.

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.

Based on Texas Natural Diversity Data (TXNDD) obtained from the TPWD, two documented occurrences of colonial wading bird colonies (unranked) and one documented occurrence of the Rolling Plains goldenrod, a rare species, occurred within a 5-mile radius of the proposed project. No other documented occurrences of threatened, endangered or rare species or natural communities were reported within five miles of the project area.

A biological survey of the project area should be conducted to determine whether populations of threatened or endangered species, or potential habitats used by listed species occur in the area to be affected, if this strategy is selected. A determination on whether any impacts or effects to listed species may occur would then be made.

[10] USFWS, 2020. Information for Planning and Consultation. Accessed online https://ecos.fws.gov/ipac/location/2CDHNRFRWZBEFN2BCFV527IIXM/resources January 13, 2020.

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.

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 approximately 360 acres of wildlife habitat. The diversion area is located within an area that is currently used for cropland.

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 4 stream miles of riparian habitat. Vegetation types found within this site include portions of Mesquite-Lotebush Shrub, Mesquite-Saltcedar Brush/Woods and Crop areas.

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. 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.

10.5.7 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 10.5-9, 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 10.5-9. 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

11 Control of Naturally Occurring Salinity

11.1 Characterization of Salinity in the Brazos River

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 of the Brazos River. However, as the Brazos River flows to the Gulf of Mexico, inflows from tributaries decrease the concentration of dissolved minerals and salts, which in turn improves the quality of water.

11.1.1 Sources

The primary sources of natural salt concentrations 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 11-1).

A substantial portion 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 producing area is a semi-arid region, where sedimentary rocks containing gypsum and other salts outcrop in 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 basement material. 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 salt flats. Wherever there is a joint or 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 surround the salt flats and streams. The Brazos River receives a tremendous salt load when local rainfall is sufficient to dissolve the deposited salt.

[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.

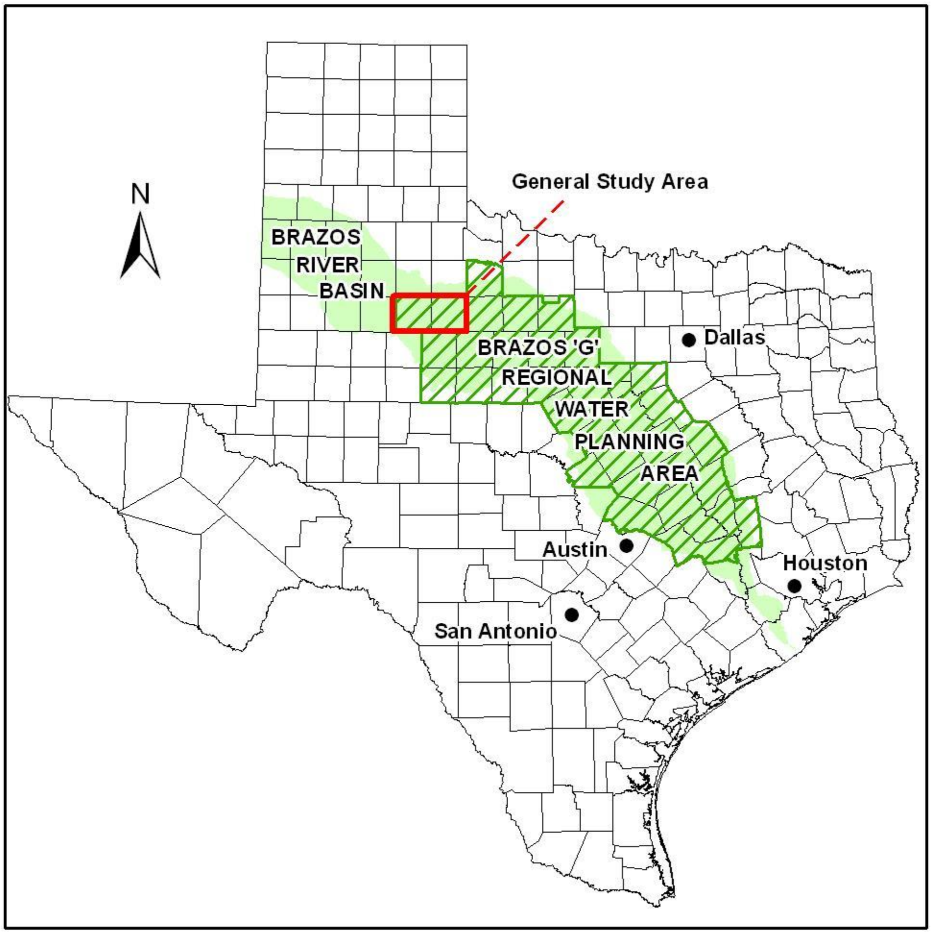
[4] Mason-Johnson & Associates, "Dove Creek Salt Study, Stonewall County, Texas," 1955.

[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 11-1. Salinity Control Study Area



11.1.2 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 11-2. 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 11-2 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 11-3, 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 majority of salinity in the watershed originates above the Seymour gage. A decrease in concentration with distance down the main stem of the Brazos River is evident, as tributaries having lower salinity concentrations join the main stem. Based on the data in Table 11-3, 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 11-4 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 11-1. 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 11-1. 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 11-2. Selected USGS Water Quality Monitoring Stations

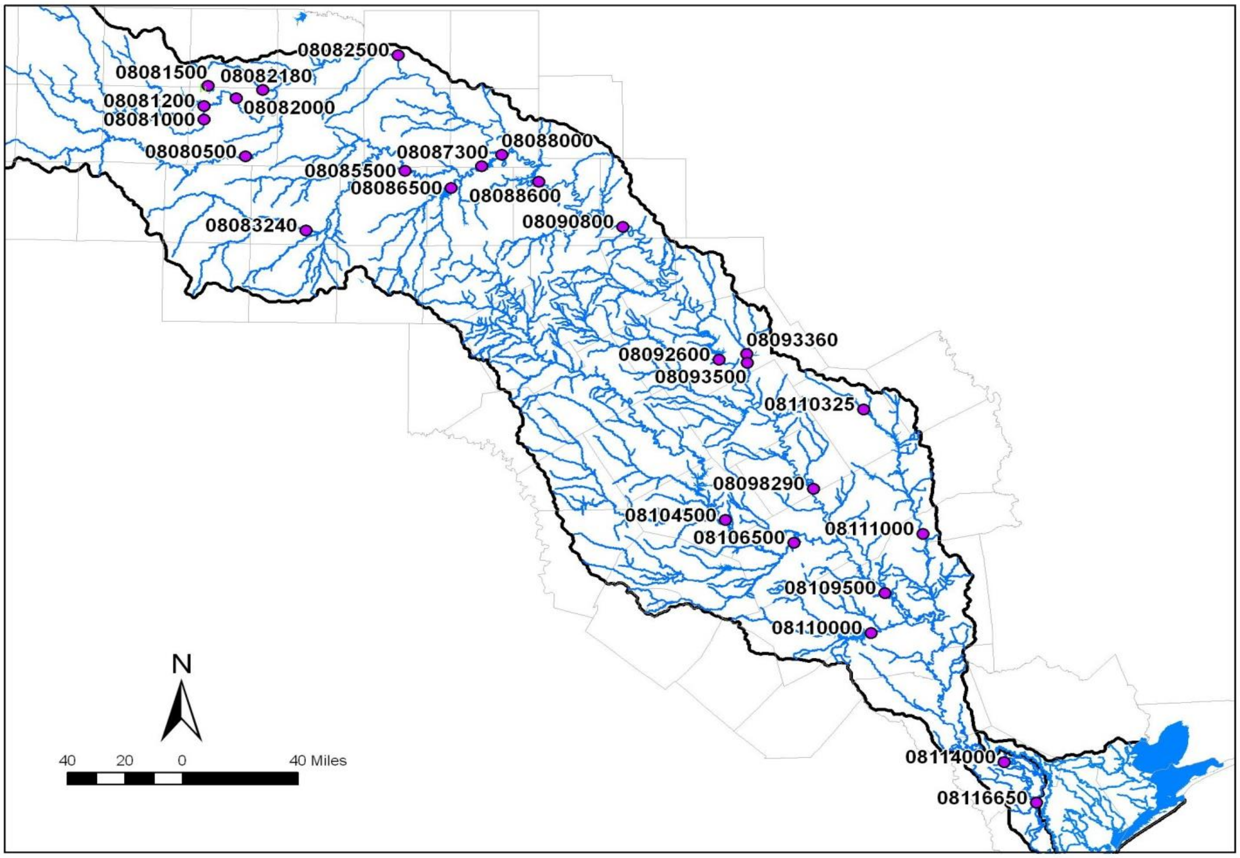


Table 11-2. Mean Discharges, Loads, and Concentrations for Period of Record

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
08082500	Seymour	Main Stem	27	292	2,638	1,018	447	3,356	1,295	569

Table 11-2. 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
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
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 11-3. 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
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 11-4. 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 Concentration (mg/L)[1]	Maximum Monthly Mean Concen-tration (mg/L)[1]	Date of Maximum Monthly Mean Concentration (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 11-5 lists the range of the arithmetic averages of the monthly mean concentrations at the Seymour, Whitney, and Richmond gages. Of the three gages, 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.

11.1.3 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 11-3 through Figure 11-7.

Table 11-5. 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.

Figure 11-3. TDS Concentration-Duration Curve at Seymour

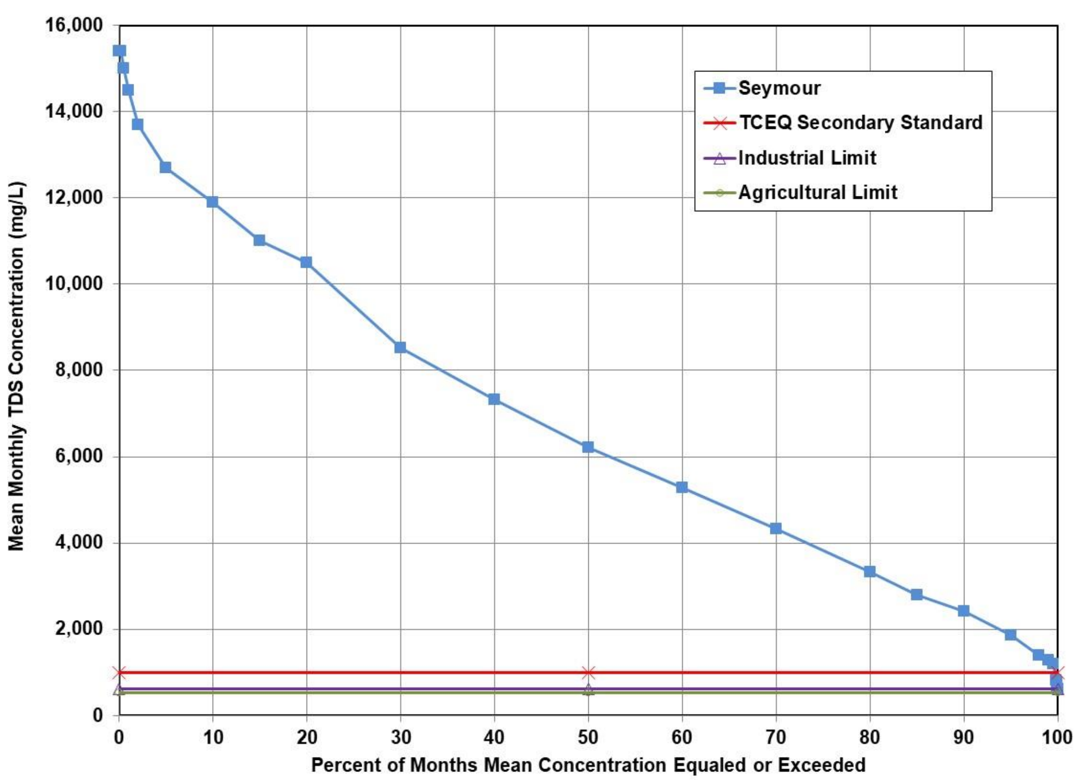


Figure 11-4. TDS Concentration-Duration Curve at Possum Kingdom

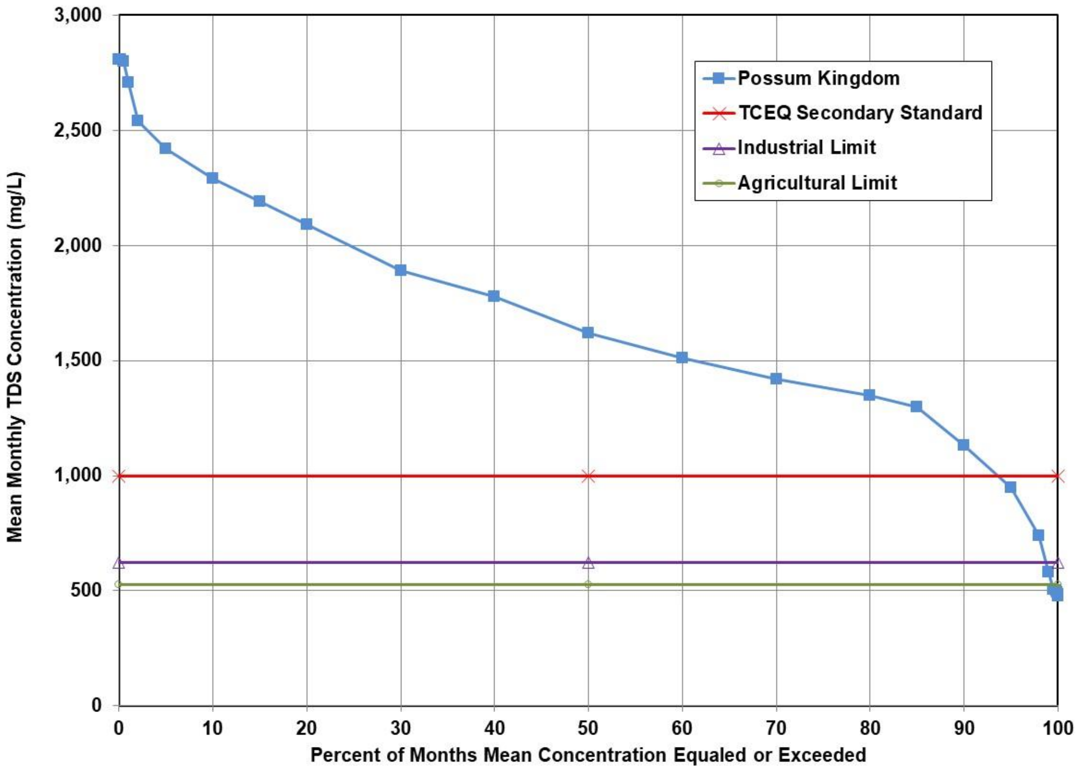


Figure 11-5. TDS Concentration-Duration Curve at Whitney

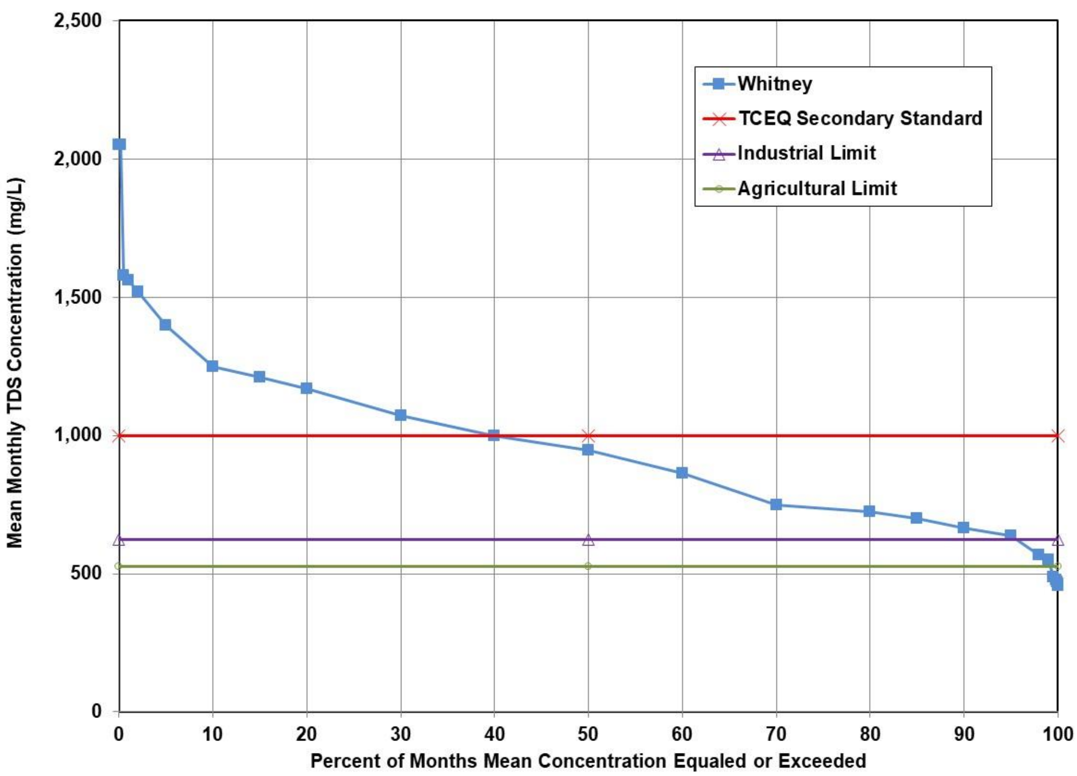


Figure 11-6. TDS Concentration-Duration Curve at College Station

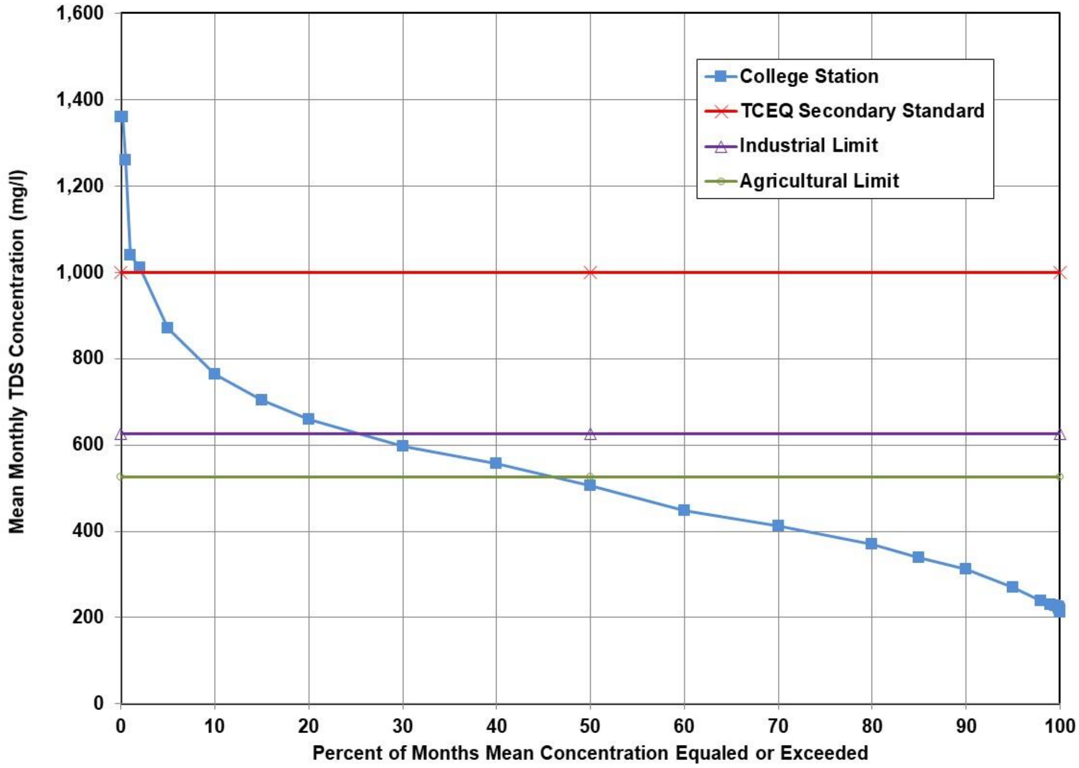
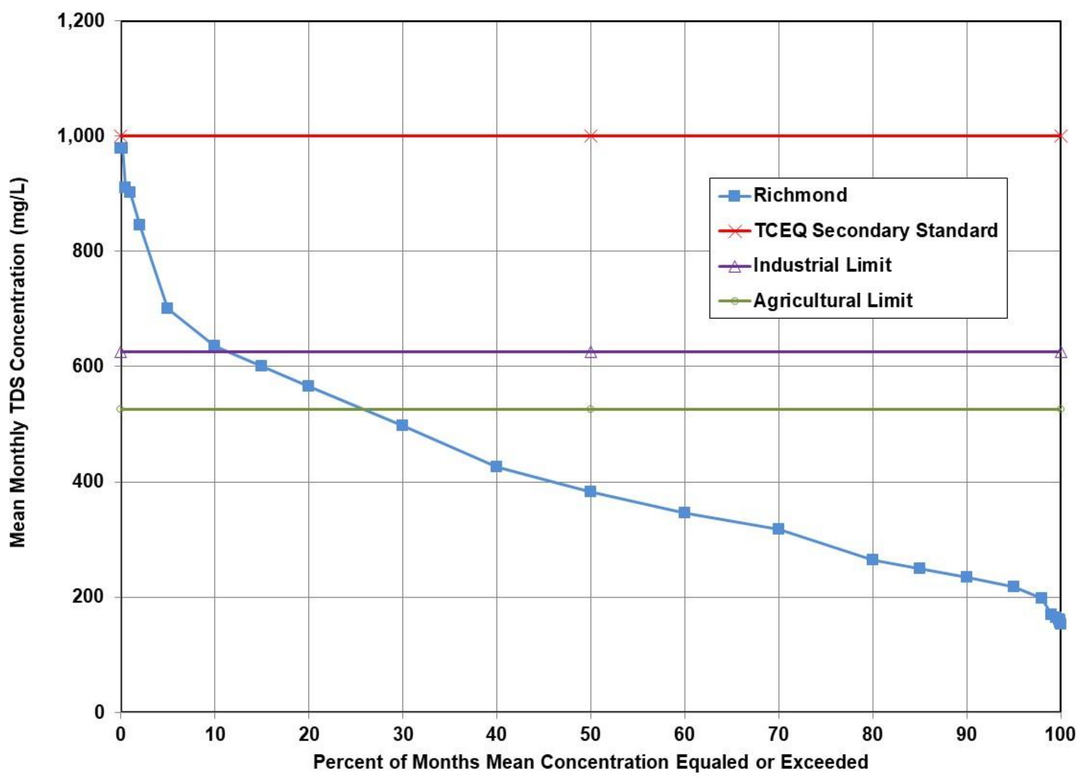


Figure 11-7. TDS Concentration-Duration Curve at Richmond



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 11-2 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 11-6 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 11-7 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 provided by Hem.[11] Assuming a desirable TDS concentration of less than 525 mg/L for irrigation use, Figure 11-3 through Figure 11-7 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.

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 11-3 through Figure 11-7 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.

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[10] Fipps, G. “Irrigation Water Quality Standards and Salinity Management Strategies,” Texas A&M Agricultural Research and Extension Center, April 2003.

[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.

Table 11-6. 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 11-7. Irrigation Water Quality Guidelines

Degree of Restriction on Use	TDS Concentration (mg/L)
None	< 450
Slight to Moderate	450 – 2,000
Severe	> 2,000

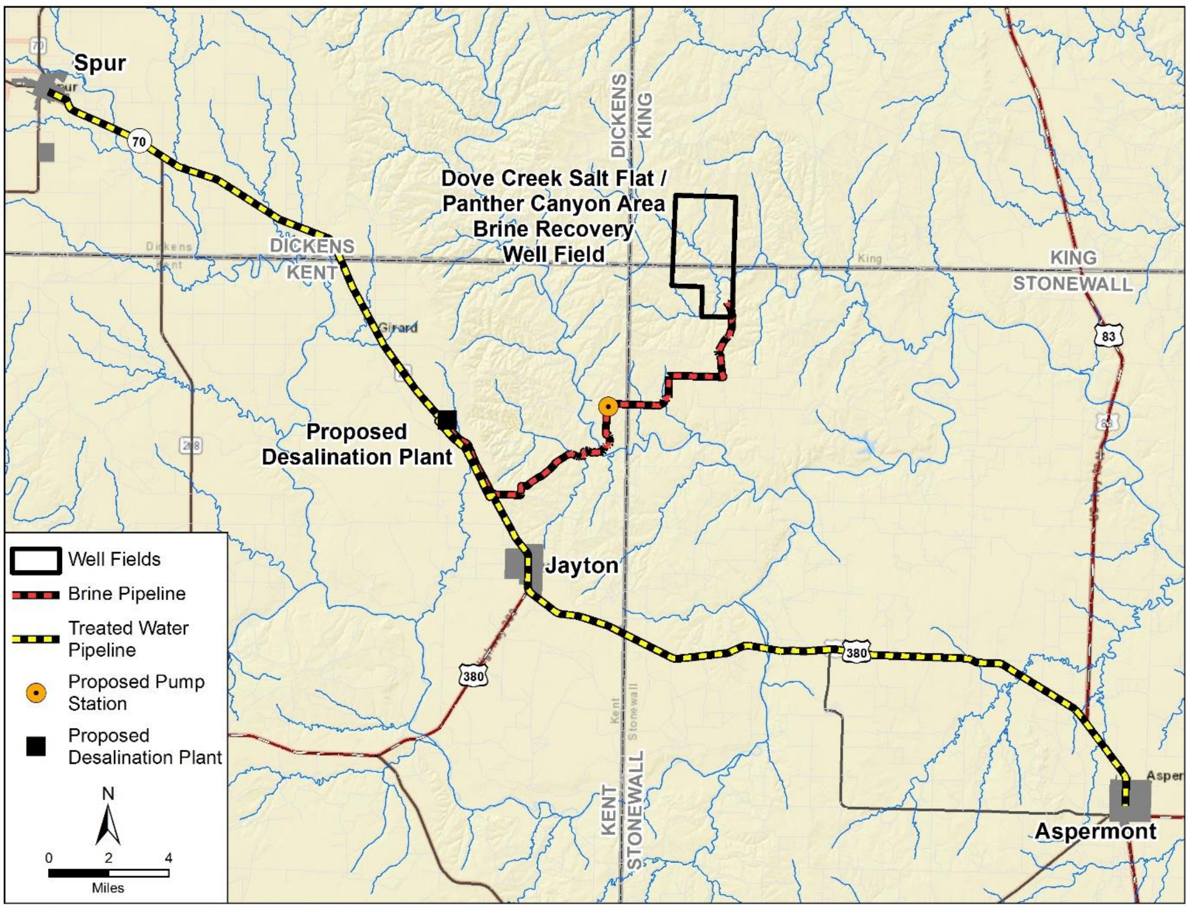
Source: Ayers, R.S., and D.W. Westcot, "Water Quality for Agriculture," Food and Agricultural Organization of the United Nations, Irrigation and Drainage Paper No. 29, rev. 1, 1985, as cited in U.S. Department of Agriculture Natural Resources Conservation Service. Part 623 National Engineering Handbook, Chapter 2, "Irrigation Water Requirements," 1993.

11.2 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, conveys the recovered brine to a utilization and management complex (BUMC) where it would be converted into marketable sodium chloride (NaCl) salt products and potable water. 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 11-8. Project components are located in Kent, Stonewall, Dickens, and King Counties and include ten brine recovery wells, a brine conveyance pipeline, the BUMC, and three water supply pipelines. The proposed brine recovery well field is located in the Dove Creek Salt Flat/ Panther Canyon Area, adjacent to salt springs contributing flows to Salt Croton Creek. Dual ten inch diameter transmission lines will convey the brine from the Panther Canyon well field to a battery of ground storage tanks located immediately upstream of the proposed BUMC. One intermediate pump station is included in the transmission system. The proposed BUMC is located in Kent County approximately 5.5 miles northwest of Jayton and 55 miles north of Snyder and consists of a Dynamic Vapor Recompression (DyVaR) Plant, an evaporative desalination plant developed by Salttech, and remineralization facilities. The DyVaR system will produce desalinated water and dry salts with little to no waste. Product water will be remineralized, converted to potable water, and delivered to users in Kent, Stonewall, and Garza Counties via the proposed water supply lines. The salt byproduct will also be sold and revenues are expected to cover annual operation and maintenance costs and help offset the price of treated water. Costing for the rehabilitation of BNSF rail spur and transportation system improvements are included in this evaluation. The rail spur will facilitate long distance shipping of salt products.

Figure 11-8. Project Layout Map



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11.3 Evaluation of the Potential Effectiveness of the Salinity Control Project

11.3.1 Modeling Approach

Evaluating the potential effectiveness of the salinity control project involved modeling TDS concentrations in the Brazos River Basin under 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)[13] provided salinity input data used in the modeling.

Brazos WAM WRAP-SALT Input File Without Salinity Control

Wurbs and Lee (2009)[14] 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[15] software. WRAP-SALT is the salinity modeling component of the Water Rights Analysis Package (WRAP).[16] 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 11-8 provides a summary of the Wurbs and Lee (2009) TDS budget. Water volumes, TDS loads, and TDS concentrations of inflows and losses to the Brazos River system are summarized by mean values over the 1964 through 1986 water year period. Inflow values are summarized at five control points representing five USGS gaging stations, and 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 minus losses (Table 11-8) is the mean TDS load of flow at the Richmond gage as entered in the WRAP-SALT input file. The actual mean load at the Richmond gage (Table 11-10) 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 the change in reservoir storage, and approximately 1,900 is accounted for by water supply diversions from Lake

[13] 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.

[14] Ibid.

[15] Wurbs, R.A, "Salinity Simulation with WRAP," Texas Water Resources Institute Technical Report No. 317, July 2009.

[16] Wurbs, R.A, "Water Rights Analysis Package (WRAP) Modeling System Reference Manual," Texas Water Resources Institute Technical Report No. 255, August 2008.

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. 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 point is encountered with a different incremental inflow concentration. Thus, incremental inflow concentrations are applied to all incremental inflows entering the model below the upstream boundaries.

Table 11-8. 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**
Losses Leaving the Reservoir System						

Table 11-8. 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)
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 11-9 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 11-9. 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 11-8 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 initial storage 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 with Salinity Control

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.[17,18] 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 11-10 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 11-10 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 effects 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 11-10. 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 11-9 shows the location of the previously proposed brine recovery well fields in relation to major brine springs and USGS stream gages. Prior work has indicated that the brine recovery well system proposed in the 2016 Plan would reduce the TDS loads in the Brazos River above Possum Kingdom Lake by 41%.[19] 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 11-10 and Figure 11-9). The TDS load of Salt Creek is approximately 10% of the load of the Salt Fork of the Brazos River near Peacock[20], or approximately 68

[17] U.S. Army Corps of Engineers Fort Worth District, "Natural Salt Pollution Control Study, Brazos River Basin, Texas," Volumes 1-4, 1973.

[18] 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.

[19] 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.

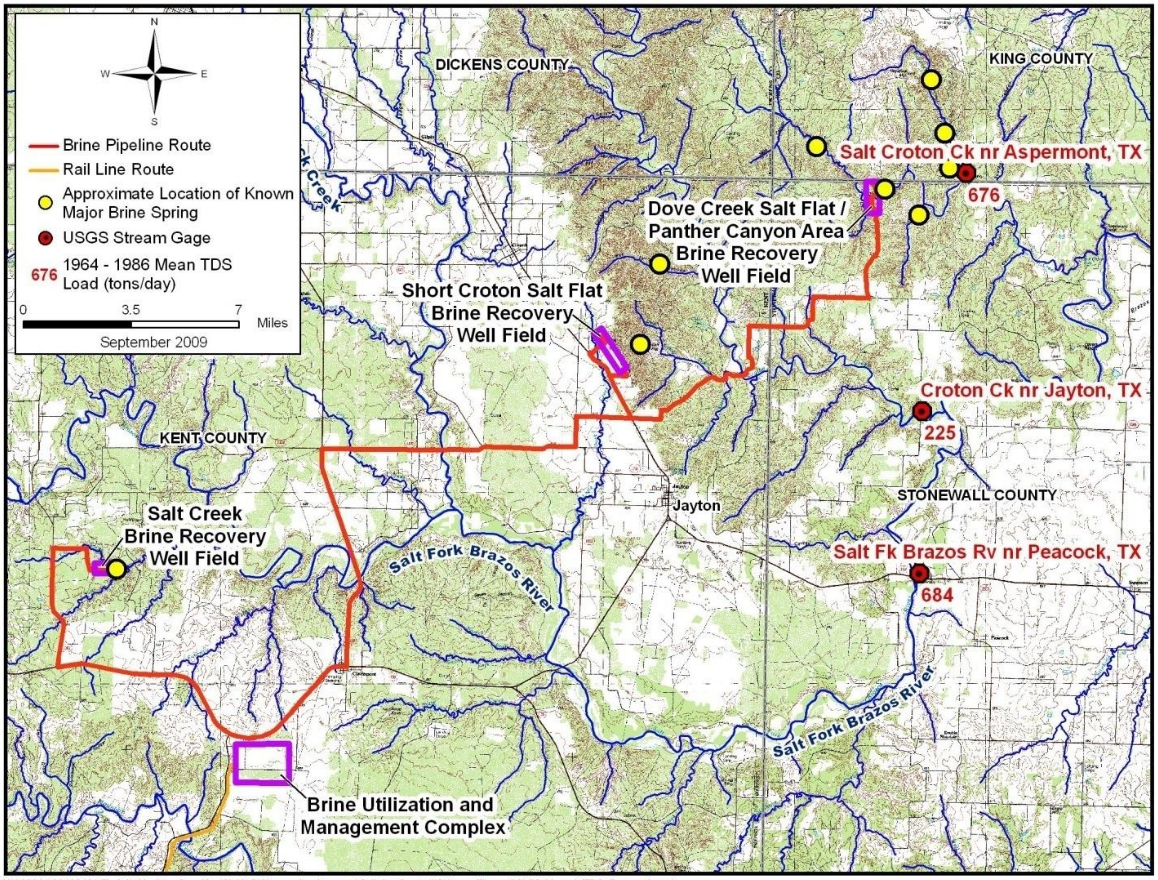
[20] Rodgers, R.W., "Natural Chloride Salt Pollution Control in the Upper Brazos River Basin," prepared for the Salt Fork Water Quality District, Stonewall, Kent, and Garza Counties, Texas, 2008.

tons per day based on the 1964 through 1986 mean load at the gage near Peacock (Table 11-10 and Figure 11-9). 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 11-10. 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.						

Figure 11-9. Previously Proposed Project Layout and TDS Loads



W:\000044\00100490-Task4b-Update_Specific_WMS\GIS\map_docs\arcmap\Salinity_Control\Writeup_Figures\Wellfield_and_TDS_Removal.mxd

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.[21] 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 only salinity sources to the receiving creeks and that any salt stored in the system would

[21] 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.

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.[22] 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.

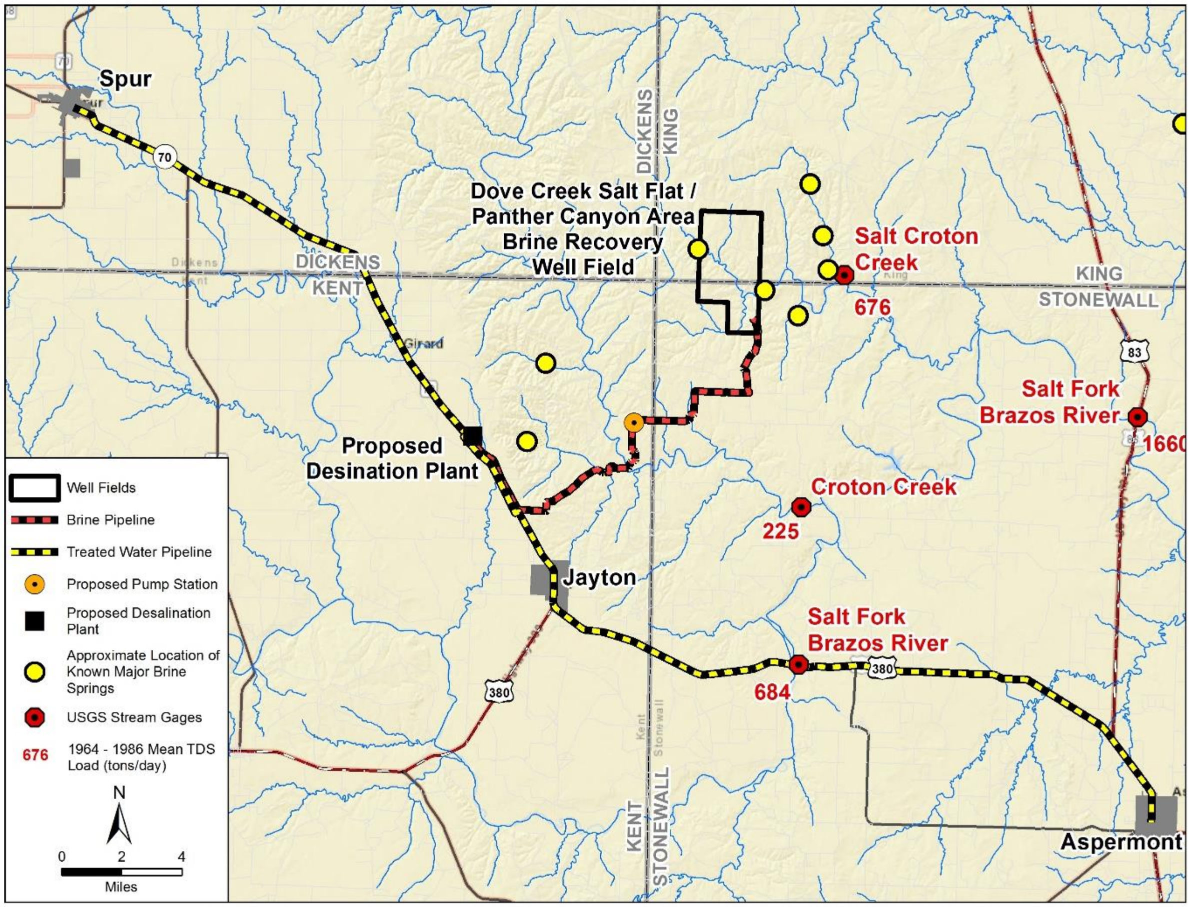
The first assumption noted by Wurbs and Lee (2009) appears to be reasonable, as the sum of the mean 1964 through 1986 TDS loads at the Double Mountain Fork of the Brazos River near Aspermont (USGS gage 08080500), the Salt Fork of the Brazos River near Aspermont (USGS Gage 08082000), and North Croton 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 11-3 and Table 11-10), 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.

11.3.2 Model Output Modifications

Adjustments have been made to the proposed SFWQ salinity control project since the 2016 Planning Cycle. Most notably, the 2016 Plan describes three brine collection well fields (Figure 11-9) while the current project considers only one (Figure 11-8 and Figure 11-10Figure 11-1). As shown in Figure 11-9 and Figure 11-10, the currently proposed Dove Creek Salt Flat/Panther Canyon well field and upstream area host the bulk of major known brine springs. Therefore, based on flow and load data (Table 11-10) it is assumed that the project will reduce TDS in the Brazos River near Seymour by 26%, a 14% reduction from the originally simulated scenario. To account for this change, model results representing implementation of the 2016 proposed project were multiplied by a factor of 1.14. Multiplying the model output by 14% is reasonable for planning purposes and because WRAP-SALT is a mass balance model.

[22] 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.

Figure 11-10. Well Field and TDS Loads



11.3.3 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 11-11 and Figure 11-11 through Figure 11-16 summarize the results of the WRAP-SALT analysis at key locations in the Brazos River Basin. The tables and figures provide TDS concentrations 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. Presented values are based on the monthly concentration output for the 696 months of the 1940 through 1997 Brazos WAM simulation period.

Table 11-11 provides mean TDS concentrations at each location, computed as the arithmetic average of the concentrations for the 696 simulation periods, both with and without the salinity control project. The last row in Table 11-11 lists the percent reductions in 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 diminish with distance downstream. Wurbs and Lee (2009) explain that this is due to the effects of load losses in the channel and reservoirs.[23] There is a 32% reduction in mean TDS concentration at Seymour, while reductions of 19% to 13% are computed at the three reservoirs. With the removal of two of the three well fields proposed in the 2016 Plan, benefits of the salinity control project are not realized further downstream no reduction in TDS concentrations at Bryan or Richmond.

Table 11-12 lists exceedance frequencies without and with the salinity control project for applicable water quality limits. The data are based on the model-predicted concentration-duration curves presented on Figure 11-11 through Figure 11-16. The water quality limits are also plotted in Figure 11-11 through Figure 11-16 for comparison to the concentration-duration curves. The effects of the project are demonstrated by the reduction in percentage of months a water quality limit is exceeded. For example, the percentage of months where the TCEQ secondary TDS standard is equaled or exceeded in Lake Whitney is reduced by approximately 18% (36.2% - 18.5% = 17.7%). Of the locations shown in Table 11-12, Lake Whitney is the location with the greatest reduction in time exceeding the TCEQ standard. The greatest reduction in time exceeding the industrial limits is also seen in Lake Whitney, at about 6%, while the greatest reduction in time exceeding agricultural limits is 2% at Lake Granbury.

Table 11-11. Mean Model-Predicted TDS Concentration-Duration Curves With and Without Project

	Seymour (mg/L)	*Possum Kingdom Lake (mg/L)*	*Lake Granbury (mg/L)*	*Lake Whitney (mg/L)*	*Bryan (mg/L)*	*Richmond (mg/L)*
TDS Without Project (mg/L)	**6,398**	**1,751**	**1,374**	**936**	**551**	**449**
TDS With Project (mg/L)	**4,376**	**1,415**	**1,140**	**815**	**551**	**449**
Percent Reduction in Mean	**32**	**19**	**17**	**13**	**0**	**0**

[23] 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.

Figure 11-11. Model-Predicted TDS Concentration-Duration Curve at Seymour

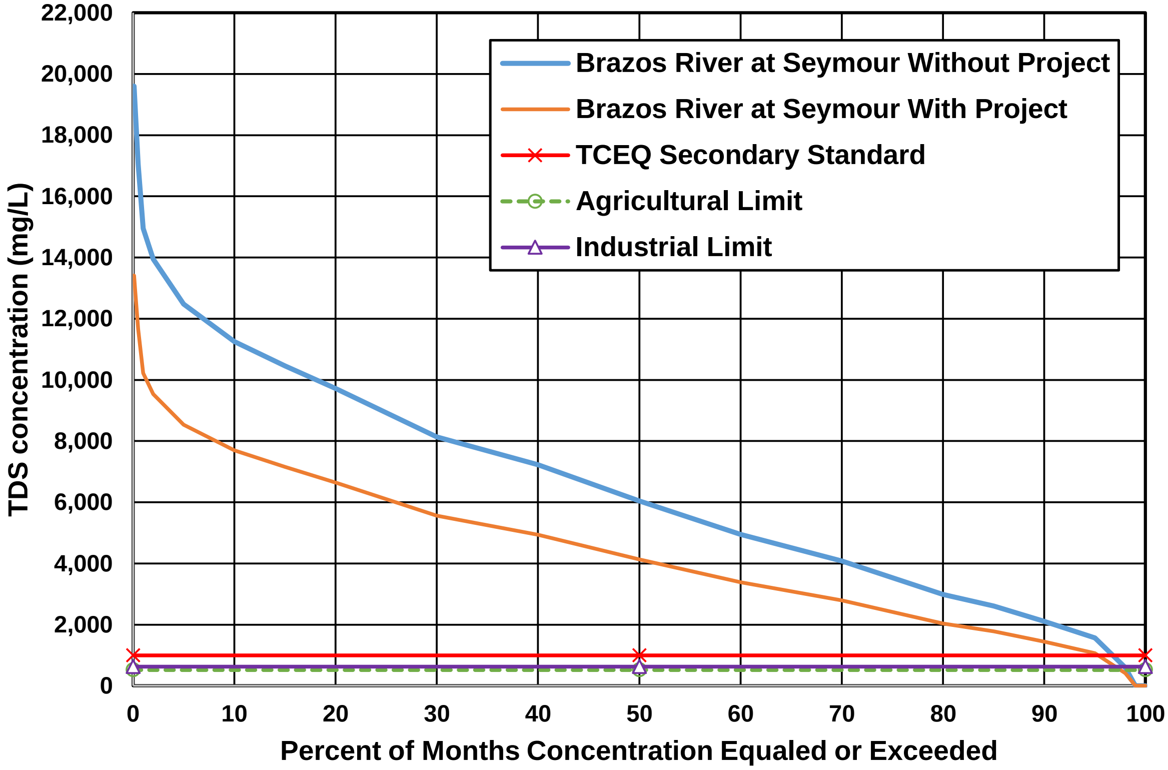


Figure 11-12. Model-Predicted TDS Concentration-Duration Curve at Possum Kingdom Lake

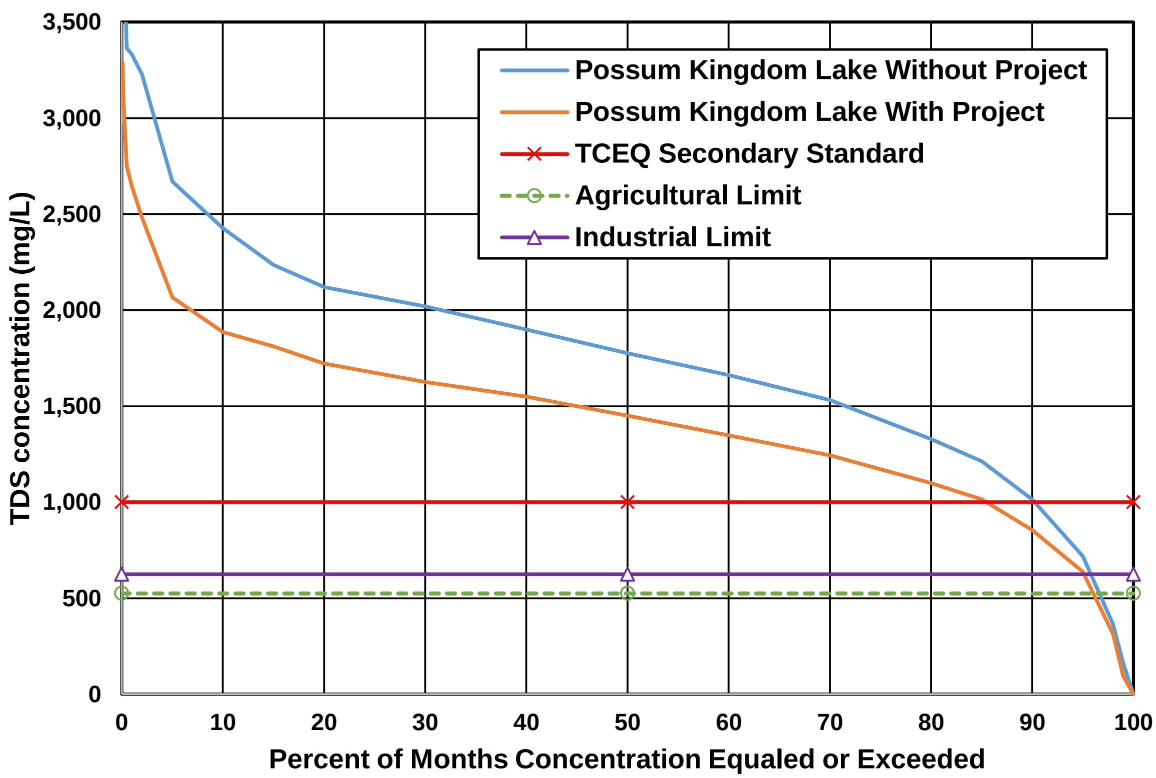


Figure 11-13. Model-Predicted TDS Concentration-Duration Curve at Lake Granbury

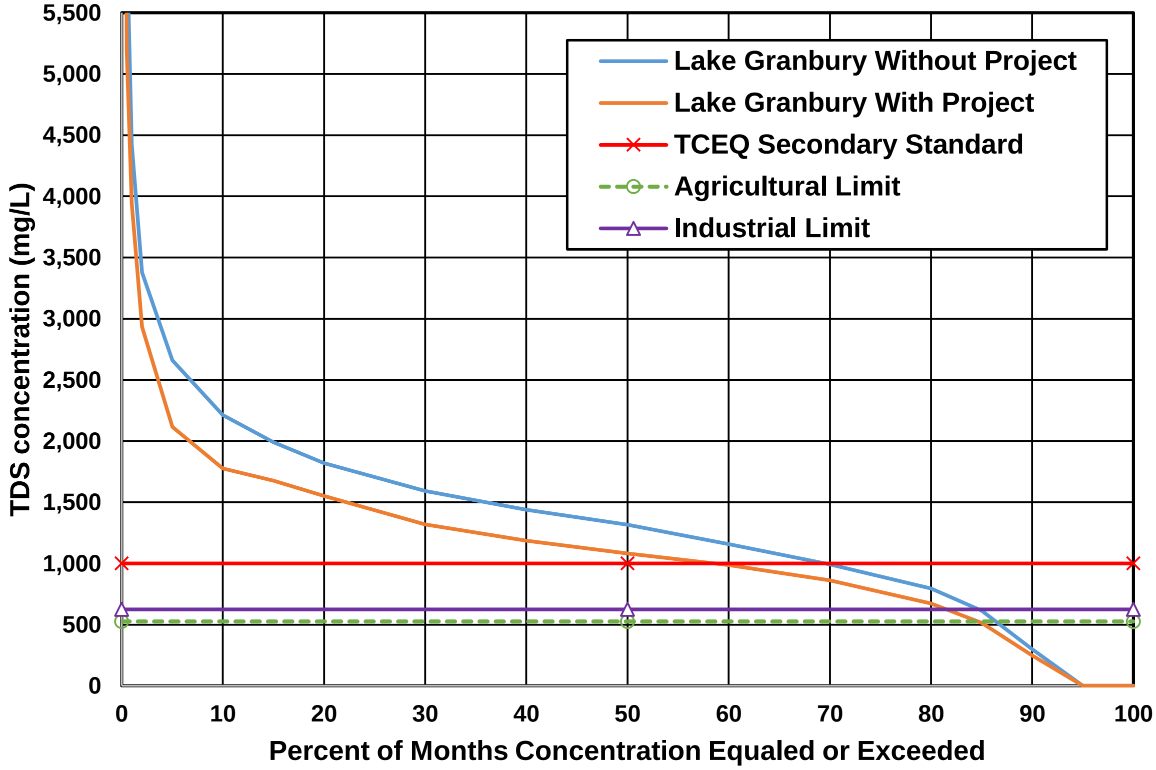


Figure 11-14. Model-Predicted TDS Concentration-Duration Curve at Lake Whitney

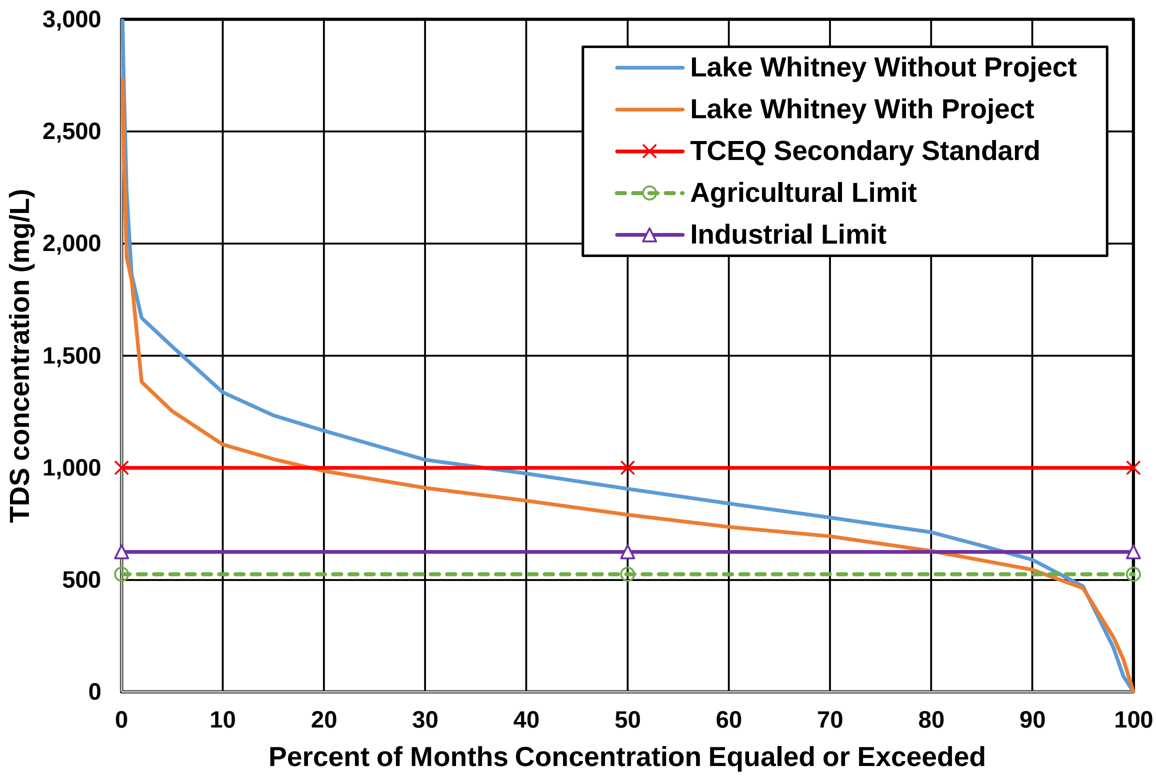


Figure 11-15. Model-Predicted TDS Concentration-Duration Curve at Lake Bryan

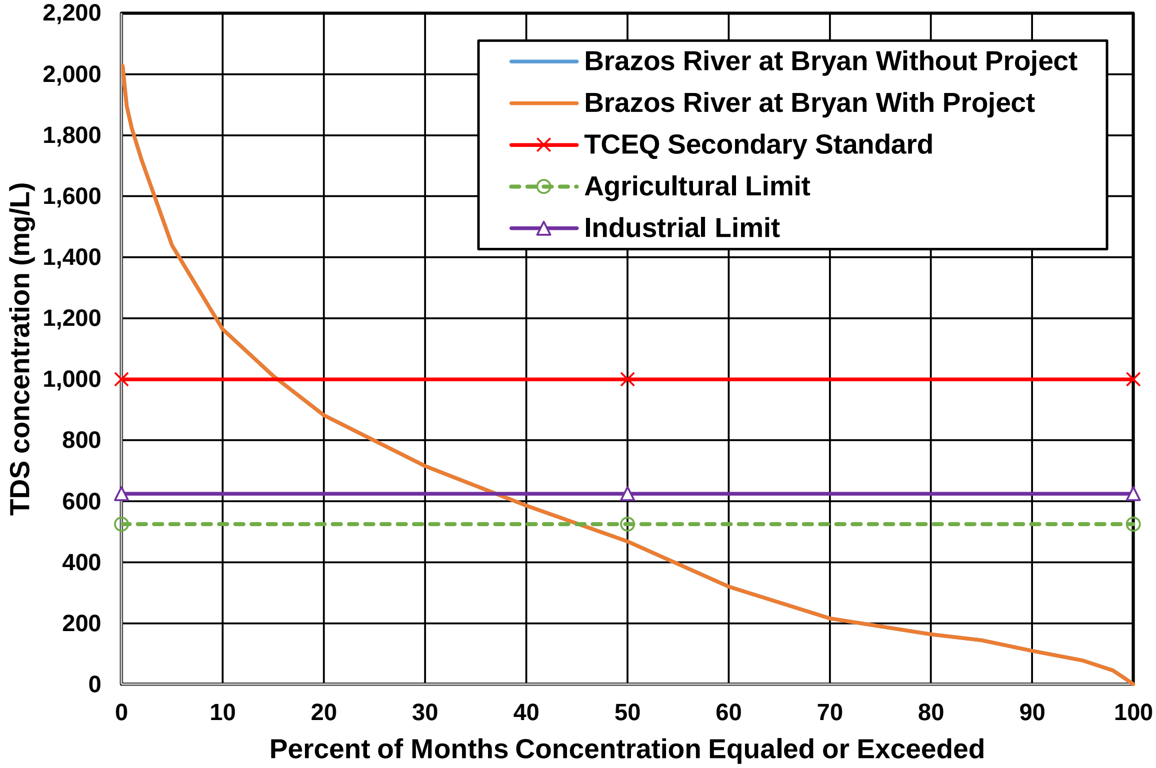


Figure 11-16. Model-Predicted TDS Concentration-Duration Curve at Richmond

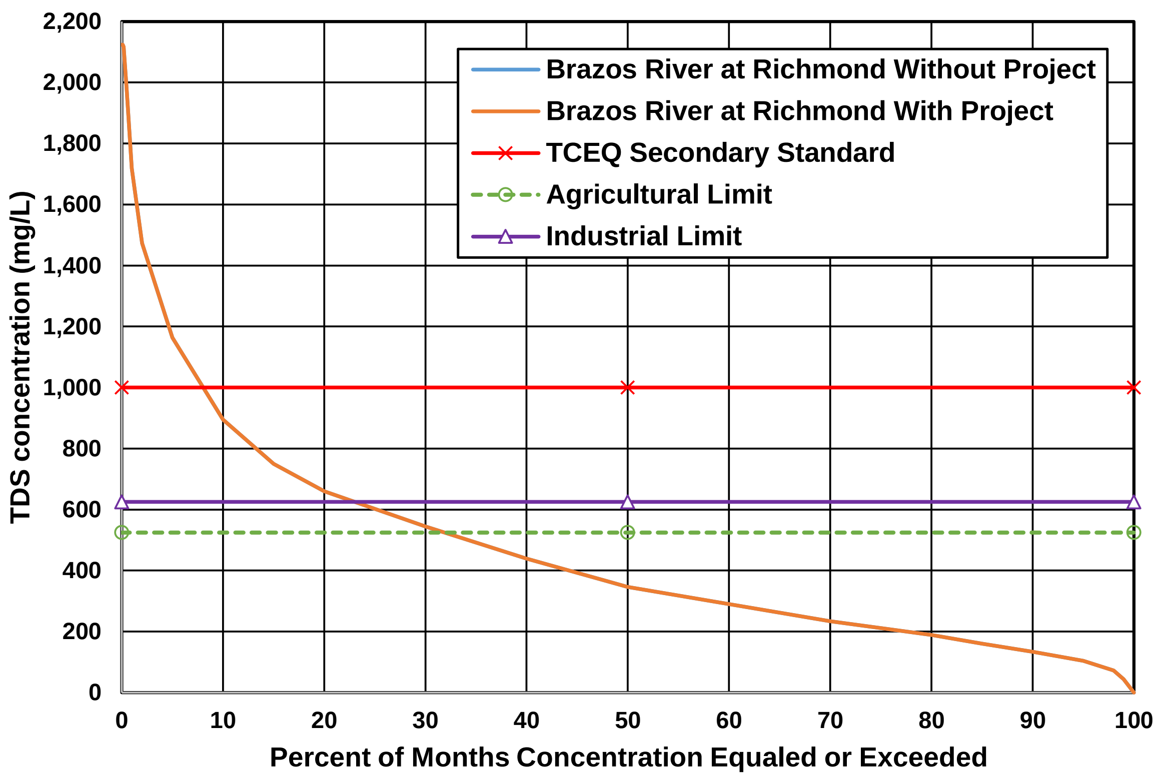


Table 11-12. Model-Predicted Exceedance Frequencies for Applicable Water Quality Limits Without and With Project

Application	*TDS Concen-tration 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	96.4	86.2	58.4	18.5	15.6	7.0
Agricultural	525	97.7	96.6	84.9	91.8	45.4	31.3
Industrial	625	97.6	95.2	81.5	80.8	37.1	21.6
Difference (Without Project – With Project)							
TCEQ Secondary Standard	1.2	4.3	11.5	17.7	0	0	1.2
Agricultural	0.4	0.6	1.8	1.3	0	0	0.4
Industrial	0.3	1.3	3.1	6.4	0	0	0.3

The TDS concentration frequency results for the without project scenario can be compared to the concentration frequency curves developed by Wurbs et. al.[24] 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

[24] 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.

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.

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.

11.4 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 are the construction of ten brine recovery wells, a brine conveyance pipeline, the BUMC, and three water supply pipelines.

11.4.1 Environmental Setting

The study area is located in the Southwestern Tablelands Ecological Region as designated by the Texas Parks and Wildlife Department (TPWD).[25] 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, on the west by the High Plains Ecological Region, and on the east by the Central Great Plains Ecological Region.

The study area is located in the Rolling Plains Vegetational area.[26] 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

[25] Texas Parks and Wildlife Department, 2005.

[26] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, "Vegetational areas of Texas," TX Agri. Ext. Serv. L-492.

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*), 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.[27] Pockets of Havard shin oak-mesquite brush are also found within the area. The majority of the treated water pipeline would be through areas of crops, with smaller areas of mesquite-lotebush shrub and brush and Havard shin oak-mesquite brush. 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.

11.4.2 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

[27] Texas Parks and Wildlife Department, "The Vegetation Types of Texas," Austin, Texas, 1984.

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.

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Dickens, Kent, King and Stonewall counties can be found at https://tpwd.texas.gov/gis/rtest/.

One listed species, the Whooping Crane, is considered endangered by both the FWS and TPWD. 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 Piping Plover and Red Knot are both state and federally-listed threatened species. The Piping Plover is a medium-distance migrant, with breeding populations along the Atlantic Coast, Great Lakes region, and central U.S. Populations who breed inland from the Atlantic coast migrate to the Gulf of Mexico or Atlantic coast for the winter. This species may be present in the project area during migratory periods. Similarly, the Red Knot is also a migratory species that may be present in the project area on its way to and from wintering grounds along the Gulf Coast.[28]

Historically, the smalleye shiner and the sharpnose shiner, both federally-listed endangered species, 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 more favorable quality 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 not adversely affect any federally listed threatened or endangered species, its

[28] The Cornell Lab, 2019. All About Birds. Accessed online https://www.allaboutbirds.org/news/#/_ga=2.255157576.1366775756.1574099801-1022759099.1553272842 November 18, 2019.

habitat, or designated habitat, nor would it adversely affect any state endangered species, except for possible impacts to aquatic species for which a higher salinity environment is favorable, i.e. the smalleye and sharpnose shiners, and potentially the state-threatened red river pupfish and the club shiner[29]. Although suitable habitat for several state threatened species, including the Palo Duro mouse, Texas kangaroo rat, and Texas horned lizard may exist within the project area, no impact to these species is anticipated due to the small area utilized by the wells, 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.

11.4.3 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.[30] 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.

11.4.4 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 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.

[29] Texas Parks and Wildlife Department, letter commenting on the Initially Prepared 2021 Brazos G Regional Water Plan, August 25, 2020 (see Chapter 10).

[30] Salt Institute. Solar Salt Production. 2004

In general, the brine pipeline would traverse flat to gently rolling terrain and occasional surface areas designated as 100-year floodplains. Wetlands 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.

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.

11.5 Engineering and Costing

Table 11-13 summarizes the estimated costs for the salinity control system. The majority of project costs, including operation and maintenance costs, engineering costs, land acquisition costs, and some capital costs were provided by the SFWQ Corporation's consultants, while other costs were estimated for preparation of the regional water plan using the unified cost model (UCM). Costs calculated through the UCM are the brine transmission pump station and storage tank; treated water transmission pipelines, pump stations, and storage tanks; debt service; and interest during construction. Treated water transmission pipeline costs are based on mileage provided by the SFWQ Corporation. A two-year construction period was assumed for computing interest during construction.

The operation and maintenance costs in Table 11-13 are offset by salt revenue. 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 $57,606,000. The estimated combined total project cost for the brine collection and transmission system and the BUMC is $106,537,000, and the estimated combined annual cost is $6,194,000 – offset by salt revenue and water sales. Estimated total capital costs for the treated water delivery systems range from $1,021,000 for Jayton to $6,789,000 for White River Municipal Water District, and total annual costs range from $542,000 to $1,128,000. Note that this project is not currently recommended in the 2021 Region O Plan, but is identified as an "other" potential source of supply that can be made available to Region O.

11.6 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 such high TDS concentrations. 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 Figure 11-11 through Figure 11-16 and summarized in Table 11-11. The table 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 11-14 through Table 11-19. 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. Varying TDS concentrations impact both the plant capital and the operating and maintenance costs. Water treatment plant capital costs are based on the 90th percentile TDS concentrations while concentrate disposal 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.

Table 11-13. Cost Estimate Summary for the Salinity Control Project

Item	Brine Utilization and Management System	White River Municipal Water District	Jayton	Aspermont
Brine Transmission Pipeline (12 in dia., 17 miles)	$14,467,000	-	-	-
Brine Transmission Pump Station(s) & Storage Tank(s)	$1,874,000	-	-	-
Treated Water Transmission Pipeline	-	$5,836,000	$579,000	$4,057,000
Treated Water Transmission Pump Station(s) & Storage Tank(s)	-	$953,000	$442,000	$1,384,000
Well Fields (Wells, Pumps, and Piping)	$839,000	-	-	-
Storage Tanks (Other Than at Booster Pump Stations)	$600,000	-	-	-
Two Water Treatment Plants (1 MGD and 1 MGD)	$34,326,000	-	-	-
Integration, Relocations, & Other	$5,500,000	-	-	-
TOTAL COST OF FACILITIES	**$57,606,000**	**$6,789,000**	**$1,021,000**	**$5,441,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$36,216,000	$2,084,000	$328,000	$1,702,000
Environmental & Archaeology Studies and Mitigation	$1,619,000	$150,000	$600,000	$625,000
Land Acquisition and Surveying (80 acres)	$5,541,000	-	$55,000	$55,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$5,555,000	$497,000	$111,000	$431,000
TOTAL COST OF PROJECT	**$106,537,000**	**$9,520,000**	**$2,115,000**	**$8,254,000**
Debt Service (3.5 percent, 20 years)	$7,496,000	$670,000	$149,000	$581,000
Operation & Maintenance	$7,826,000	$82,000	$17,000	$75,000
Purchase of Water (949 acft/yr @ 1,189.36 $/acft)	($1,128,000)	$214,000	$140,000	$296,000
Salt Revenue	($8,000,000)	-	-	-
TOTAL ANNUAL COST	**$6,194,000**	**$966,000**	**$306,000**	**$952,000**
Available Project Yield (acft/yr)	949	180	118	249
Annual Cost of Water ($ per acft), based on PF=1	$6,527	$5,367	$2,593	$3,823
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$20.03	$16.47	$7.96	$11.73

The project will benefit water quality but will also have an impact on the available supply to entities required to desalinate 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. Therefore, decreasing TDS in the Brazos River reduces the volume of water required for desalination and increases the overall supply by improving desalination recovery rates.

Based on the cost estimates shown in Table 11-14 through Table 11-19, 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 $13,314,000, or $1,189 per acft on a unit cost basis. With the salinity control project, the estimated annual cost of desalination at Seymour is $11,497,000, or $1,026 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 $162 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 $65, $77, and $87 per acft, respectively. With the reduction in the number of well fields from the 2016 Plan, benefits from the salinity control project are no longer realized downstream of the Lakes at Bryan and Richmond.

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 11-20 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 11-20 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 $236,262,000. With the project, the total annual cost of desalination treatment is estimated to be $231,674,000. Therefore, implementation of the project results in reduced annual desalination costs of $4,588,000. Total annual cost exceeds downstream desalination cost savings by $1,606,000.

Table 11-14. 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	7,701	
50th Percentile TDS	6,044	4,134	
% of Water Desalinated	100%	94%	
CAPITAL COST			
RO Desalination Plant (10 MGD)[1]	$35,773,000	$32,746,000	$3,027,000
Concentrate Disposal	$13,077,000	$9,691,000	$3,386,000
TOTAL COST OF FACILITIES	**$48,850,000**	**$42,437,000**	**$6,413,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$17,098,000	$14,853,000	$2,245,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,814,000	$1,576,000	$238,000
TOTAL COST OF PROJECT	**$67,762,000**	**$58,866,000**	**$8,896,000**
ANNUAL COST			
Debt Service (5.5 percent, 20 years)	$4,768,000	$4,142,000	$626,000
Operation and Maintenance			
Desalination Water Treatment Plant	$7,998,000	$6,894,000	$1,104,000
Concentrate Disposal	$548,000	$461,000	$87,000
TOTAL ANNUAL COST	**$13,314,000**	**$11,497,000**	**$1,817,000**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$1,189**	**$1,026**	**$162**
Annual Cost of Water ($ per 1,000 gallons)	**$3.65**	**$3.15**	**$0.50**

[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 11-15. 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	1,886	
50th Percentile TDS	1,776	1,450	
% of Water Desalinated	81%	76%	
CAPITAL COST			
RO Desalination Plant[1]	$26,908,000	$25,194,000	$1,714,000
Concentrate Disposal	$7,510,000	$6,238,000	$1,272,000
TOTAL COST OF FACILITIES	**$34,418,000**	**$31,432,000**	**$2,986,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$12,047,000	$11,001,000	$1,046,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,278,000	$1,167,000	$111,000
TOTAL COST OF PROJECT	**$47,743,000**	**$43,600,000**	**$4,143,000**
ANNUAL COST			
Debt Service (5.5 percent, 20 years)	$3,359,000	$3,068,000	$291,000
Operation and Maintenance			
Desalination Water Treatment Plant	$5,137,000	$4,760,000	$377,000
Concentrate Disposal	$358,000	$297,000	$61,000
TOTAL ANNUAL COST	**$8,854,000**	**$8,125,000**	**$729,000**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$790**	**$725**	**$65**
Annual Cost of Water ($ per 1,000 gallons)	**$2.43**	**$2.23**	**$0.20**

[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 11-16. 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	1,777	
50th Percentile TDS	1,316	1,081	
% of Water Desalinated	79%	74%	
CAPITAL COST			
RO Desalination Plant[1]	$26,221,000	$24,342,000	$1,879,000
Concentrate Disposal	$6,436,000	$4,951,000	$1,485,000
TOTAL COST OF FACILITIES	**$32,657,000**	**$29,293,000**	**$3,364,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$11,430,000	$10,252,000	$1,178,000
Interest During Construction (4% for 1 years with a 1% ROI)	$1,213,000	$1,088,000	$125,000
TOTAL COST OF PROJECT	**$45,300,000**	**$40,633,000**	**$4,667,000**
ANNUAL COST			
Debt Service (5.5 percent, 20 years)	$3,187,000	$2,859,000	$328,000
Operation and Maintenance			
Desalination Water Treatment Plant	$4,985,000	$4,526,000	$459,000
Concentrate Disposal	$306,000	$236,000	$70,000
TOTAL ANNUAL COST	**$8,478,000**	**$7,621,000**	**$857,000**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$757**	**$680**	**$77**
Annual Cost of Water ($ per 1,000 gallons)	**$2.32**	**$2.09**	**$0.23**

[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 11-17. 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	1,105	
50th Percentile TDS	906	790	
% of Water Desalinated	65%	57%	
CAPITAL COST			
RO Desalination Plant[1]	$21,568,000	$19,072,000	$2,496,000
Concentrate Disposal	$4,654,000	$2,971,000	$1,683,000
TOTAL COST OF FACILITIES	**$26,222,000**	**$22,043,000**	**$4,179,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$9,178,000	$7,715,000	$1,463,000
Interest During Construction (4% for 1 years with a 1% ROI)	$974,000	$819,000	$155,000
TOTAL COST OF PROJECT	**$36,374,000**	**$30,577,000**	**$5,797,000**
ANNUAL COST			
Debt Service (5.5 percent, 20 years)	$2,559,000	$2,151,000	$408,000
Operation and Maintenance			
Desalination Water Treatment Plant	$4,031,000	$3,548,000	$483,000
Concentrate Disposal	$222,000	$141,000	$81,000
TOTAL ANNUAL COST	**$6,812,000**	**$5,840,000**	**$972,000**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$608**	**$521**	**$87**
Annual Cost of Water ($ per 1,000 gallons)	**$1.87**	**$1.60**	**$0.27**

[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 11-18. 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	1,164	
50th Percentile TDS	468	468	
% of Water Desalinated	60%	60%	
CAPITAL COST			
RO Desalination Plant[1]	$20,082,000	$20,082,000	$0
Concentrate Disposal	$1,980,000	$1,980,000	$0
TOTAL COST OF FACILITIES	**$22,062,000**	**$22,062,000**	**$0**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$7,722,000	$7,722,000	$0
Interest During Construction (4% for 1 years with a 1% ROI)	$820,000	$820,000	$0
TOTAL COST OF PROJECT	**$30,604,000**	**$30,604,000**	**$0**
ANNUAL COST			
Debt Service (5.5 percent, 20 years)	$2,153,000	$2,153,000	$0
Operation and Maintenance			
Desalination Water Treatment Plant	$3,740,000	$3,740,000	$0
Concentrate Disposal	$94,000	$94,000	$0
TOTAL ANNUAL COST	**$5,987,000**	**$5,987,000**	**$0**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$534**	**$534**	**$0**
Annual Cost of Water ($ per 1,000 gallons)	**$1.64**	**$1.64**	**$0.00**

[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 11-19. 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	895	
50th Percentile TDS	346	346	
% of Water Desalinated	47%	47%	
CAPITAL COST			
RO Desalination Plant[1]	$16,052,000	$16,052,000	$0
Concentrate Disposal	$1,980,000	$1,980,000	$0
TOTAL COST OF FACILITIES	**$18,032,000**	**$18,032,000**	**$0**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$6,311,000	$6,311,000	$0
Interest During Construction (4% for 1 years with a 1% ROI)	$670,000	$670,000	$0
TOTAL COST OF PROJECT	**$25,013,000**	**$25,013,000**	**$0**
ANNUAL COST			
Debt Service (5.5 percent, 20 years)	$1,760,000	$1,760,000	$0
Operation and Maintenance			
Desalination Water Treatment Plant	$2,973,000	$2,973,000	$0
Concentrate Disposal	$94,000	$94,000	$0
TOTAL ANNUAL COST	**$4,827,000**	**$4,827,000**	**$0**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$431**	**$431**	**$0**
Annual Cost of Water ($ per 1,000 gallons)	**$1.32**	**$1.32**	**$0.00**

[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 11-20. 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
		Without Salinity Control Project	With Salinity Control Project	Without Salinity Control Project	With Salinity Control Project	
Seymour to Above Possum Kingdom Lake	0	$1,189	$1,026	$0	$0	$0
Possum Kingdom Lake to Above Lake Granbury	3,298	$790	$725	$2,607,000	$2,392,000	$215,000
Lake Granbury to Above Lake Whitney	35,644	$757	$680	$26,976,000	$24,250,000	$2,726,000
Lake Whitney to Above Bryan	18,975	$608	$521	$11,539,000	$9,892,000	$1,647,000
Bryan to Above Richmond	19,935	$534	$534	$10,654,000	$10,654,000	$0
Richmond to Gulf of Mexico	428,136	$431	$431	$184,486,000	$184,486,000	$0
Total	**505,988**			**$236,262,000**	**$231,674,000**	**$4,588,000**

[1] Includes Brazos River Authority Contract amounts and TCEQ Water Rights for municipal use, as of March 2015.

Comparing the desalination cost savings to the total annual cost of the project, the annual costs of the project exceed the benefits by $1,606,000. However, additional benefits not quantified here would accrue for industrial 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 11-20 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.

11.7 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 11-21 and the option meets each criterion.

Table 11-21. 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. High for water produced to be sold
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	• Generates relatively small fresh 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;
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction; 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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12 Brush Control

Brush control is a potential water management strategy that could 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 WSEP program is described in the January 2017 *State Water Supply Enhancement Plan*[1].

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 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 needs with the highest projected water yield from brush control.

For a watershed to be considered eligible for allocation of WSEP cost-share funds, a feasibility study must demonstrate runoff increases in project post-treatment conditions. At this time, two feasibility studies have been completed in the Brazos G Region, resulting in on-going projects:

- Lake Fort Phantom Hill watershed – in FY 2018 the TSSWCB provided $250,000 in matching funds Subbasin 15.
- Lake Palo Pinto watershed – in FY 2018 the TSSWCB provided $200,000 in matching funds for Subbasin 2210808[2].

Proposed feasibility studies in Brazos G include the Carrizo-Wilcox Aquifer Recharge Zone in Burleson, Lee, Milam and Williamson Counties, Hubbard Creek Reservoir (saltcedar specific), Lake Graham, Lake Whitney including Steele Creek, Stillhouse Hollow Reservoir, Upper Brazos River above Possum Kingdom Reservoir (saltcedar specific), and the White River Reservoir (saltcedar specific).

Eligible species under the WSEP program that are of concern in the Brazos G area include:

- mesquite (*Prosopis spp*.)
- juniper (*Juniperus spp*.)
- saltcedar (*Tamarix spp*.)

Other species of interest that could be eligible include:

- huisache (Acacia smallii)
- Carrizo cane (Arundo donax)

[1] State Water Supply Enhancement Plan, TSSWCB, January 2017.

[2] Annual Report, January 1, 2019, Texas State Soil and Water Conservation Board.

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 very small, 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 identified brush control as a recommended water management strategy in the 2016 Brazos G Regional Water Plan but acknowledged that the firm supply benefit was zero during drought of record conditions.

12.1 General Description of Brush Control

Since the European settlement of Texas, overgrazing, fire suppression and droughts have led to the increase and dominance of noxious brush species such as juniper and mesquite over the native grasses and trees. This noxious brush utilizes much of the available water resources with little return to the watershed.[3] Brush control is a land management practice that converts land that is covered with brush (such as juniper, mesquite, and salt cedar) back 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. There is also the potential for increased runoff during rainfall events.[4]

The actual supply benefit resulting from a brush control project is site specific. 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. Thus, the supply benefit to be obtained from this particular water management strategy will be considered to be zero for supply purposes. However, the potential positive impacts of rangeland management during other times makes this a recommended policy by the Brazos G Water Planning Group.

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.[5] All ecoregions in Texas have a potential evapotranspiration rate of over 15 inches per year, and the average annual rainfall in almost all of the Brazos G Region is greater than 18 inches per year, so the entire region meets the climatic requirements for brush control.

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. The rate of brush

[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.

[5] Hibbert, A.R. 1983. Water Yield Improvement by Vegetation Management on Western Range lands. Water Resources Bulletin. 19:375-381.

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.

12.2 Brush Control in the Fort Phantom Hill Watershed

Lake Fort Phantom Hill is one of the primary sources of water for the City of Abilene. The reservoir is located on Elm Creek, a tributary of the Clear Fork of the Brazos River, in Jones County. The WSEP is currently sponsoring brush control activities in Subbasin 15 in the watershed[2]. This watershed is upstream of Lake Abilene, and most of the water supply benefit will be to that source.

12.2.1 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. According to the latest volumetric survey, this reservoir has a capacity of 74,300 acre-feet[6]. To supply additional water to the City, diversion facilities were constructed in 1954 to divert flows into Fort Phantom Hill Reservoir from the Clear Fork of the Brazos River and Deadman's Creek.

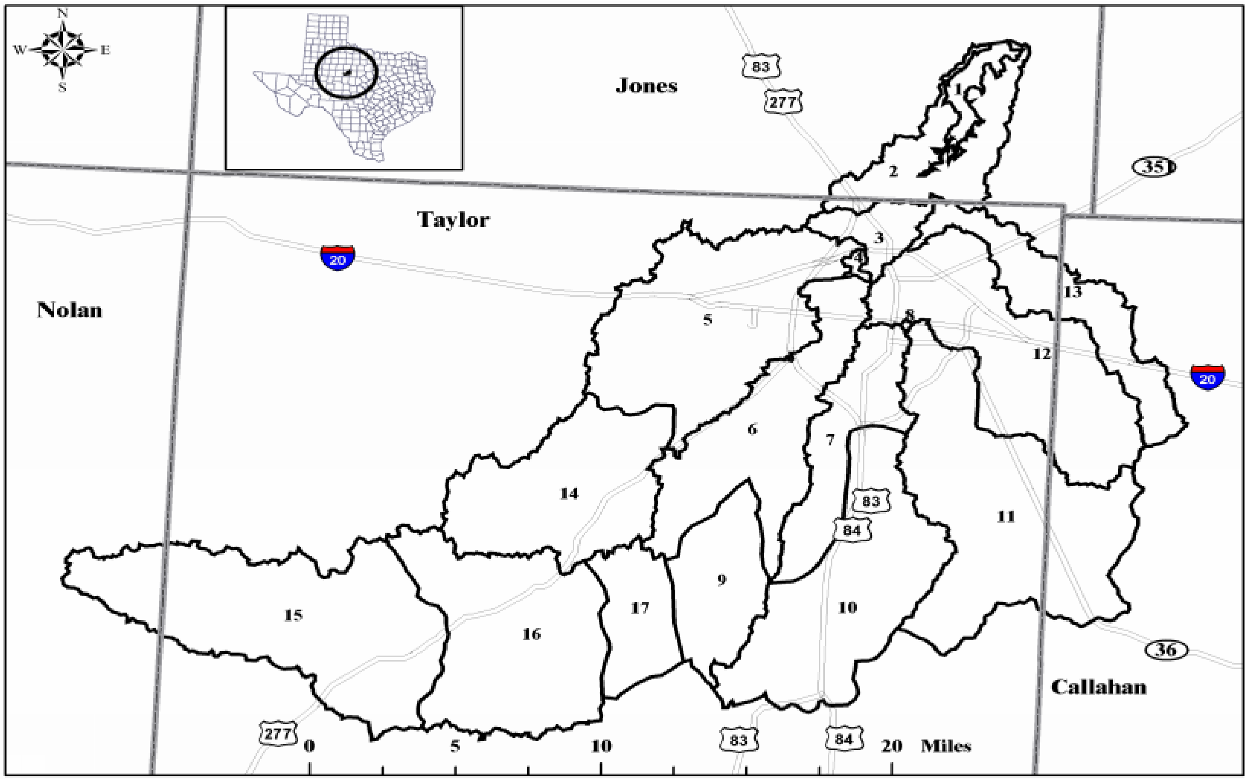
Figure 12-1 is a map of the Lake Fort Phantom hill watershed with various subbasins delineated.

Climate

The climate of the watershed is classified as subtropical sub-humid. The watershed is characterized by hot summers and dry winters. The average annual rainfall is approximately 24 inches, but the amount of rainfall varies considerably from year to year. 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.

[6] Volumetric Survey of Fort Phantom Hill Reservoir, prepared for the City of Abilene, Texas Water Development Board, March 2003.

Figure 12-1. Sub basin Map of the Fort Phantom Hill Watershed



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 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

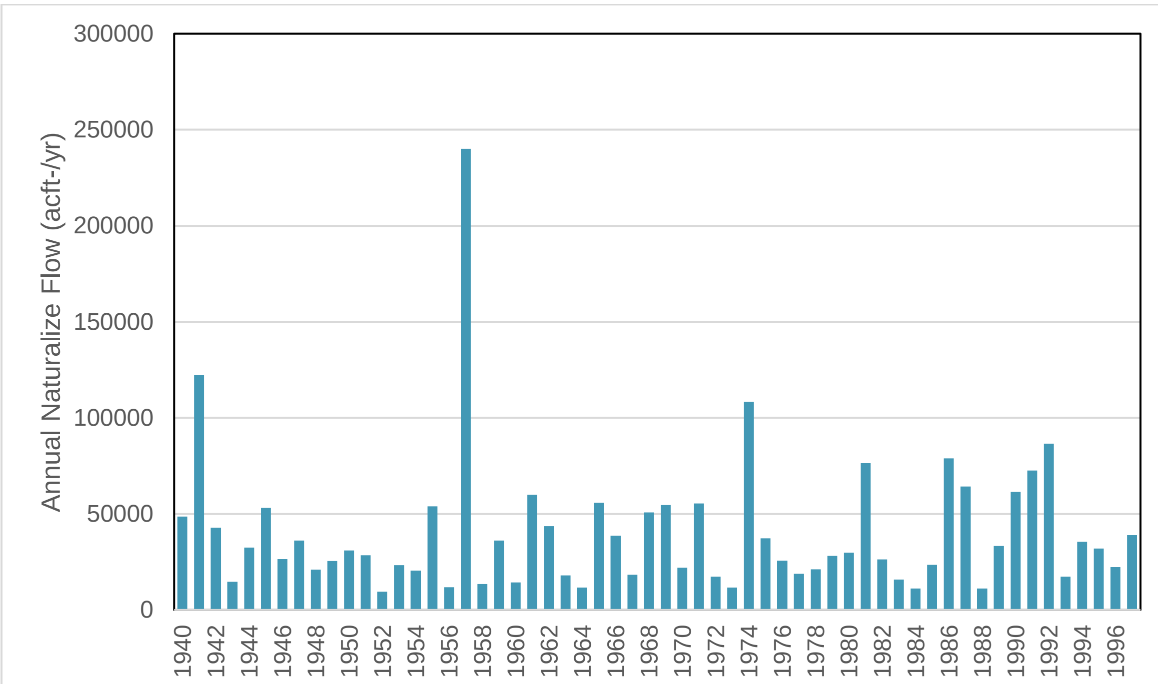
The land use in the watershed is dominated by agribusiness including feedlots, rangeland, and row-crop agriculture. Rangeland is used mainly for cattle, goats, and sheep. Crop production is largely dominated by wheat, cotton, sorghum, and hay. Urban land use includes the City of Abilene and the towns 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. Nearly all of the initial flow in the tributaries to Fort Phantom Hill Reservoir is derived from precipitation. Discharge from the watershed occurs as spills and releases from Lake Fort Phantom Hill 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.

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. Figure 12-2 shows the annual naturalized flow at Lake Fort Phantom Hill, which demonstrate these cycles of high and low flows. Annual flows vary from a minimum of 9,502 acft/yr in 1952 to a maximum of 240,006 acft/yr in 1957.

Figure 12-2: Annual Naturalized Flow at Lake Fort Phantom Hill



12.2.2 Potential Brush Control Project

Currently the TSSWCB is funding brush control activities in subbasin 15 of the Lake Fort Phantom Hill watershed. For this plan, a strategy evaluation was performed for a program that expands these activities to 9 more subbasins. 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. Table 12-1 shows the subbasin data from the feasibility study and the assumed acreage of treated brush. Watersheds are organized by the potential for water production, with the watersheds with the highest potential listed first.

Table 12-1. Subbasins Targeted for Potential Brush Control Project

Subbasin[1]	Total Area (acres)	Total Brush Area (acres)	Treated Brush[2] (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
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
[2]75 percent of the Total Brush Area
NI – Not included in potential brush control project.

12.3 Environmental Issues

12.3.1 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, well-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 comprised of noncalcareous to calcareous clay loams.[9] Major aquifers that 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 fire suppression and intensive livestock grazing. Five major vegetation types now occur in the study area,[12] including: Mesquite-Lotebush Shrub, Mesquite-Juniper Brush, Mesquite Juniper Live Oak Brush, Crops and Urban. Major land uses in the area include cattle ranches and farms, oil fields, hunting leases, and minerals.[13]

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[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.

[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.

12.3.2 Potential Impacts

Threatened & Endangered Species

The Texas Parks and Wildlife Department (TPWD) maintains a list of Rare, Threatened, and Endangered Species of Texas by County. This list includes the federal and state listing status and a habitat description for each species which may be a resident or migrant through the county. TPWD regularly updates the listing status, range data, and habitat descriptions on their published county lists, based on the most recently available data. The current list of rare, threatened and endangered species for Jones, Taylor, Nolan and Callahan counties can be found at https://tpwd.texas.gov/gis/rtest/.

The endangered bird species include the whooping crane (*Grus americana*) and the least tern (*Sterna antillarum*). These birds are seasonal migrants that could pass through the project area. The whooping crane could potentially use area 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. According to the U.S. Fish and Wildlife Service's Information for Planning and Consultation website, the least tern should only be considered in these counties for wind energy projects[14]. Potential impacts on this species by brush control should be confirmed before initiating the project.

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 portions of the Upper Brazos River Basin as critical habitat for these two fish. Critical habitat for the sharpnose shiner does not include the study area[16]. However, the study area does include critical habitat for the smalleye shiner[17]. Potential impacts on the smalleye shiner will need to be evaluated before initiating the proposed brush control project.

There are five additional species which are listed as threatened by the state of Texas within the project counties. These include the piping plover (*Charadrius melodus*), Texas fatmucket (*Lampsilis bracteate*), Texas fawnsfoot (*Truncilla macrodon*), Brazos water snake (*Nerodia harteri*), Texas horned lizard (*Phrynosoma cornutum*), and the Timber (canebrake) rattlesnake (*Crotalus horridus*). The piping plover is a migrant within the project area and are not anticipated to be adversely affected by the project. The Texas fatmucket and the Texas fawnsfoot are freshwater mussel species found in rivers and larger streams and are 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 three species. The Texas

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[14] USFWS IPaC Information for Planning and Consulting, https://ecos.fws.gov/ipac/.

[15] USFWS. 2014. *Sharpnose Shiner and Smalleye Shiner Protected under the Endangered Species Act*. News Release, August 4, 2014.

[16] U.S. Fish and Wildlife Service, ECOS Environmental Conservation Online System, Sharpnose Shiner (Notropis oxyrhynchus), available on-line at https://ecos.fws.gov/ecp0/profile/speciesProfile?sId=6492

[17] U.S. Fish and Wildlife Service, ECOS Environmental Conservation Online System, Smalleye Shiner (Notropis buccula), available on-line at https://ecos.fws.gov/ecp0/profile/speciesProfile?sId=1774

horned lizard is normally found in varied and sparsely vegetated uplands. Suitable habitat for the Texas horned lizard may exist within the study area and possible impacts to this species should be assessed during project planning. Timber rattlesnakes are usually found in moist lowland forest and hilly woodlands or thickets near water sources[18]. These habitats are limited in the study area, but those that do exist could be affected by the brush control project.

The information presented in this strategy evaluation is based on general data for the project area. Prior to implementing the brush control project, on-site evaluations by qualified biologists will be needed to confirm the occurrence of sensitive species or habitats within the affected area.

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 regulated 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 generally have sufficient flexibility to avoid most impacts or to mitigate unavoidable 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 activities 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

[18] Texas Parks and Wildlife Department, Timber Rattlesnake (Crotalushorridus), available on-line at https://tpwd.texas.gov/huntwild/wild/species/timberrattlesnake/

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 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 wildfires 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.

12.4 Engineering and Costing

Costs associated with brush control in each subbasin were assessed using the cost estimates developed for the feasibility study, as shown in Table 12-2. 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 3.5 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 12-2. Cost Estimate Summary for Brush Control Project

Item	Estimated Costs for Facilities
Chemical and Mechanical Brush Treatment (48,792 acres)	$6,524,000
TOTAL COST OF FACILITIES	**$6,524,000**
Interest During Construction (3% for 10 years with a 0.5% ROI)	$1,794,000
TOTAL COST OF PROJECT	**$7,308,000**
Debt Service (3.5 percent, 10 years)	$1,000,168
TOTAL ANNUAL COST	**$1,000,168**
Available Project Yield (acft/yr)[1]	0
[1] The yield of brush control during a drought is likely to be zero.	

12.5 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 landowner 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, which is likely to be the case in some of the target watersheds, are less likely to have the contiguous landowner 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.

Since some of the subbasins may include urban and suburban areas, impacts to residents must be considered as well, particularly when considering chemical controls or prescribed burning. The watershed also serves as a drinking water supply, so water quality impacts must be considered as well.

The success of such a program for providing increased water supplies is dependent on climatic conditions 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 landowner participation in a brush control program can depends on the landowner's expected economic benefits from the program. The primary benefits of brush control might not lie with increased surface water runoff but with 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 12-3.

Table 12-3. 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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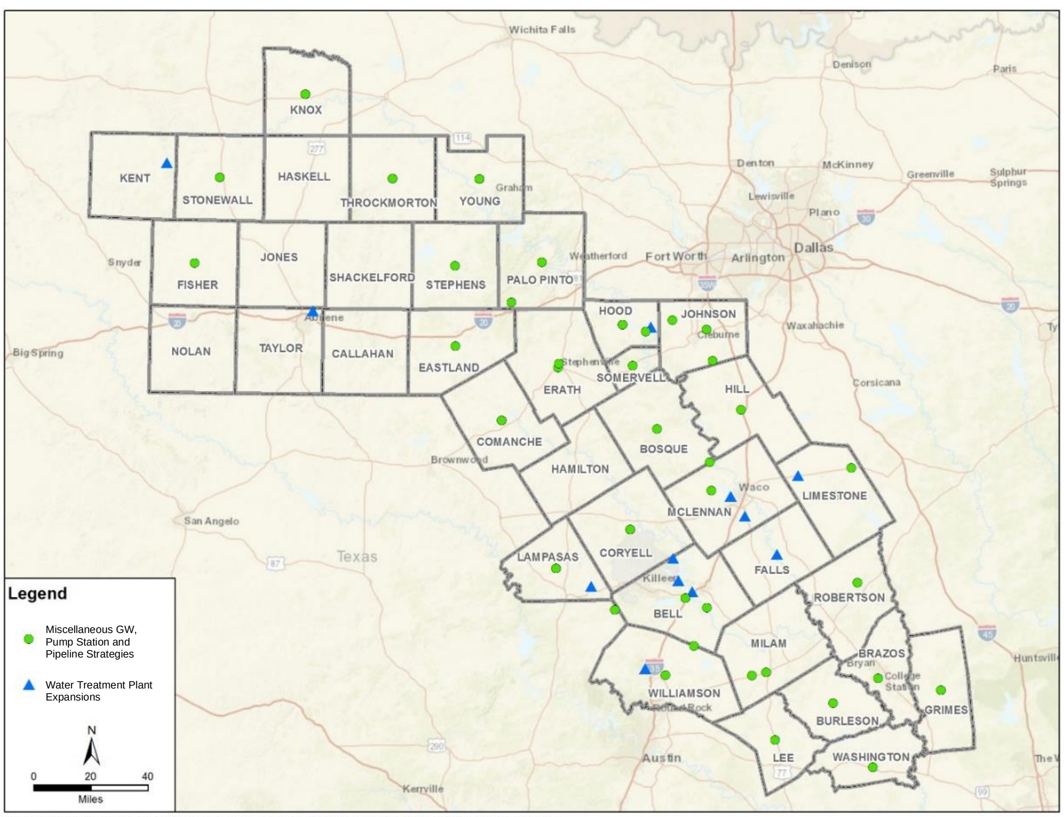
13 Miscellaneous Strategies

13.1 Strategy Overview

Miscellaneous Strategies represent 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 13.3 through Section 13.5. Figure 13-1 shows the locations of the miscellaneous strategies recommended in the 2021 Brazos G Plan. Locations for county-aggregated WUGs are shown at the center of each county.

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 2018 dollars. Debt service is calculated at 3.5% 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. Not all strategies presented in this section are recommended in the 2021 Brazos G Plan.

Figure 13-1. Miscellaneous Strategies and Water Treatment Plant Expansions



\\dalctxsrv01\Texas_GIS_Projects\10029705_036_Brazos_G_2021_Plan\Map_Docs\MXDs\Misc_Strategy\Misc_Strategies.mxd

13.2 Evaluation of Miscellaneous Water Management Strategies

The miscellaneous strategies for each WUG were evaluated based on plan development criteria. Groundwater, surface water and reuse water supplies are adequate to implement these miscellaneous strategies. Environmental impacts will need to be mitigated to protect habitat, cultural resources, threatened and endangered species and wetlands. Generally, it is assumed that pipelines can be routed, well fields and water treatment plants can be located to avoid environmentally and culturally 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; and
  - 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; and
- Aquatic Resource Relocation Plan (ARRP) and a relocation permit may be required from TPWD if a dewatering event is required during construction.

Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

13.3 Miscellaneous Pipelines, Pump Stations, and Groundwater Strategies by County

13.3.1 Bell County

WUG: Bell County Irrigation

Strategy: Edwards Aquifer Development

Source: Edwards Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $657,000

Total Project Cost: $922,000

Total Annual Cost: $88,000

Available Project Yield: 585 acft/yr (2070)

Annual Cost of Water: $150 per acft/yr or $0.46 per 1,000 gal

This project will include two 365 gpm wells drilled to 500 ft with 200 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Bell County Irrigation - Edwards BFZ Aquifer Development	
Item	***Estimated Costs for Facilities (for 1 well)***
Well Fields (Wells, Pumps, and Piping)	$657,000
TOTAL COST OF FACILITIES	**$657,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$230,000
Environmental & Archaeology Studies and Mitigation	$5,000
Land Acquisition and Surveying (1 acres)	$5,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$25,000
TOTAL COST OF PROJECT	**$922,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$65,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$7,000
Pumping Energy Costs (196,537 kW-hr @ 0.08 $/kW-hr)	$16,000

TOTAL ANNUAL COST	**$88,000**
Available Project Yield (acft/yr)	585
Annual Cost of Water ($ per acft), based on PF=1	$150
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$39
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$0.46
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.12

WUG: Bell County Mining

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $6,186,000

Total Project Cost: $8,771,000

Total Annual Cost: $2,101,000

Available Project Yield: 4,700 acft/yr

Annual Cost of Water: $447 per acft/yr or $1.37 per 1,000 gal

This project will include 17, 210 gpm wells drilled to around 800 ft with 1,000 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Bell County Mining - Trinity for Bell County Mining	
Item	***Estimated Costs for Facilities (for 1 well)***
Well Fields (Wells, Pumps, and Piping)	$6,186,000
TOTAL COST OF FACILITIES	**$6,186,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,165,000
Environmental & Archaeology Studies and Mitigation	$85,000
Land Acquisition and Surveying (9 acres)	$100,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$235,000
TOTAL COST OF PROJECT	**$8,771,000**

ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$617,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$62,000
Pumping Energy Costs (17,777,753 kW-hr @ 0.08 $/kW-hr)	$1,422,000
TOTAL ANNUAL COST	**$2,101,000**
Available Project Yield (acft/yr)	4,700
Annual Cost of Water ($ per acft), based on PF=1	$447
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$316
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.37
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.97

WUG: Bell County Mining

Strategy: Edwards Aquifer Development

Source: Edwards Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $1,003,000

Total Project Cost: $1,423,000

Total Annual Cost: $199,000

Available Project Yield: 615 acft/yr

Annual Cost of Water: $324 per acft/yr or $0.99 per 1,000 gal

This project will include three 365 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Bell County Mining - Edwards BFZ Aquifer Development	
Item	***Estimated Costs for Facilities (for 1 well)***
Well Fields (Wells, Pumps, and Piping)	$1,003,000
TOTAL COST OF FACILITIES	**$1,003,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$351,000

Environmental & Archaeology Studies and Mitigation	$15,000
Land Acquisition and Surveying (2 acres)	$15,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$39,000
TOTAL COST OF PROJECT	**$1,423,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$100,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$10,000
Pumping Energy Costs (1,102,640 kW-hr @ 0.08 $/kW-hr)	$89,000
TOTAL ANNUAL COST	**$199,000**
Available Project Yield (acft/yr)	615
Annual Cost of Water ($ per acft), based on PF=1	$324
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$161
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$0.99
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.49

WUG: Bell County WCID 2

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $680,000

Total Project Cost: $979,000

Total Annual Cost: $92,000

Available Project Yield: 63 acft/yr

Annual Cost of Water: $1,460 per acft/yr or $4.48 per 1,000 gal (Maximum of Phased Costs)

This project will include two 80 gpm wells drilled to 800 ft as well as 200 ft of collection pipeline per well and disinfection treatment.

Cost Estimate Summary September 2018 Prices	
Bell County WCID 2 - Trinity Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$656,000
Water Treatment Plant (0.1 MGD)	$24,000
TOTAL COST OF FACILITIES	**$680,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$238,000
Environmental & Archaeology Studies and Mitigation	$16,000
Land Acquisition and Surveying (2 acres)	$18,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$27,000
TOTAL COST OF PROJECT	**$979,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$69,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$7,000
Water Treatment Plant	$14,000
Pumping Energy Costs (21,933 kW-hr @ 0.08 $/kW-hr)	$2,000
TOTAL ANNUAL COST	**$92,000**
Available Project Yield (acft/yr)	63
Annual Cost of Water ($ per acft), based on PF=2	$1,460
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$365
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$4.48
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$1.12

13.3.2 Bosque County

WUG: Bosque County Irrigation

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $1,746,000

Total Project Cost: $2,473,000

Total Annual Cost: $245,000

Available Project Yield: 1,259 acft/yr (2070)

Annual Cost of Water: $195 per acft/yr or $0.60 per 1,000 gal

This project will include four 280 gpm wells drilled to 930 ft with 1,000 ft of transmission pipeline per well.

Cost Estimate Summary, September 2018 Prices	
Bosque County Irrigation - Trinity for Bosque County Irrigation	
Item	***Estimated Costs for Facilities (for 1 well)***
Well Fields (Wells, Pumps, and Piping)	$1,746,000
TOTAL COST OF FACILITIES	**$1,746,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$611,000
Environmental & Archaeology Studies and Mitigation	$24,000
Land Acquisition and Surveying (2 acres)	$25,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$67,000
TOTAL COST OF PROJECT	**$2,473,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$174,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$17,000
Pumping Energy Costs (682,713 kW-hr @ 0.08 $/kW-hr)	$55,000
TOTAL ANNUAL COST	**$246,000**
Available Project Yield (acft/yr)	1,259
Annual Cost of Water ($ per acft), based on PF=3.75	$195
Annual Cost of Water After Debt Service ($ per acft), based on PF=3.75	$57
Annual Cost of Water ($ per 1,000 gallons), based on PF=3.75	$0.60
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=3.75	$0.18

WUG: Highland Park WSC

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $1,245,000

Total Project Cost: $1,829,000

Total Annual Cost: $159,000

Available Project Yield: 82 acft/yr

Annual Cost of Water: $1,939 per acft/yr or $5.95 per 1,000 gal

This project will include two 110 gpm wells drilled to 1,280 ft as well as 1,000 ft of transmission pipeline per well and disinfection treatment.

Cost Estimate Summary September 2018 Prices	
Highland Park WSC - Trinity for Highland Park WSC	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$1,222,000
Water Treatment Plant (0.1 MGD)	$23,000
TOTAL COST OF FACILITIES	**$1,245,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$436,000
Environmental & Archaeology Studies and Mitigation	$34,000
Land Acquisition and Surveying (8 acres)	$65,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$49,000
TOTAL COST OF PROJECT	**$1,829,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$129,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$12,000
Water Treatment Plant	$14,000
Pumping Energy Costs (45,180 kW-hr @ 0.08 $/kW-hr)	$4,000
TOTAL ANNUAL COST	**$159,000**
Available Project Yield (acft/yr)	82

Annual Cost of Water ($ per acft), based on PF=2	$1,939
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$366
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$5.95
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$1.12

13.3.3 Brazos County

WUG: Texas A&M University

Strategy: Sparta Aquifer Development

Source: Spara Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $3,507,000

Total Project Cost: $4,931,000

Total Annual Cost: $490,000 (Maximum of Phased Costs)

Available Project Yield: 638 acft/yr

Annual Cost of Water: $768 per acft/yr or $2.36 per 1,000 gal (Maximum of Phased Costs)

This project will include two 500 gpm wells drilled to 2,500 ft as well as 1,000 ft of transmission pipeline per well and disinfection treatment.

Cost Estimate Summary September 2018 Prices	
Texas A&M University - Sparta Aquifer Development	
Item	***Estimated Costs for Facilities (for 1 well)***
Well Fields (Wells, Pumps, and Piping)	$3,411,000
Water Treatment Plant (1.1 MGD)	$96,000
TOTAL COST OF FACILITIES	**$3,507,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,228,000
Environmental & Archaeology Studies and Mitigation	$14,000
Land Acquisition and Surveying (2 acres)	$50,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$132,000
TOTAL COST OF PROJECT	**$4,931,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$347,000

Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$34,000
Water Treatment Plant	$58,000
Pumping Energy Costs (637,085 kW-hr @ 0.08 $/kW-hr)	$51,000
TOTAL ANNUAL COST	**$490,000**
Available Project Yield (acft/yr)	638
Annual Cost of Water ($ per acft), based on PF=2	$768
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$224
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$2.36
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.69

13.3.4 Burleson County

WUG: Burleson County Manufacturing

Strategy: Sparta Aquifer Development

Source: Sparta Aquifer

Facilities: Well Field, collection pipes, treatment

Total Capital Cost: $166,000

Total Project Cost: $233,000

Total Annual Cost: $18,000 (Maximum of Phased Costs)

Available Project Yield: 25 acft/yr

Annual Cost of Water: $18,000 per acft/yr or $2.33 per 1,000 gal (Maximum of Phased Costs)

This project will include one 200 gpm well drilled to 1,500 ft as well as 400 ft of transmission pipeline.

Cost Estimate Summary September 2018 Prices	
Burleson County Manufacturing - Sparta for Burleson County Manufacturing	
Item	***Estimated Costs for Facilities (for 1 well)***
Well Fields (Wells, Pumps, and Piping)	$166,000
TOTAL COST OF FACILITIES	**$166,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$58,000

Environmental & Archaeology Studies and Mitigation	$2,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$7,000
TOTAL COST OF PROJECT	**$233,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$16,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$2,000
Pumping Energy Costs (6,610 kW-hr @ 0.08 $/kW-hr)	$1,000
TOTAL ANNUAL COST	**$19,000**
Available Project Yield (acft/yr)	25
Annual Cost of Water ($ per acft), based on PF=1	$760
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$120
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$2.33
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.37

13.3.5 Comanche County

WUG: Comanche County Other

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer (Erath County)

Facilities: Well Field, collection pipes, transmission pipeline, and treatment

Total Capital Cost: $3,451,000

Total Project Cost: $5,359,000

Total Annual Cost: $492,000

Available Project Yield: 488 acft/yr

Annual Cost of Water: $1,008 per acft/yr or $3.09 per 1,000 gal

This project will include four 300 gpm wells drilled to 500 ft as well as 1,000 ft of collection pipeline and disinfection treatment per well and approximately 5 miles of transmission pipeline.

Cost Estimate Summary September 2018 Prices	
Comanche County-Other - Trinity Aquifer Development (Erath County)	
Item	***Estimated Costs for Facilities***
Transmission Pipeline (6 in dia., 5 miles)	$207,000
Well Fields (Wells, Pumps, and Piping)	$3,165,000
Water Treatment Plant (0.9 MGD)	$79,000
TOTAL COST OF FACILITIES	**$3,451,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,198,000
Environmental & Archaeology Studies and Mitigation	$239,000
Land Acquisition and Surveying (31 acres)	$328,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$143,000
TOTAL COST OF PROJECT	**$5,359,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$377,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$34,000
Water Treatment Plant	$48,000
Pumping Energy Costs (407,984 kW-hr @ 0.08 $/kW-hr)	$33,000
TOTAL ANNUAL COST	**$492,000**
Available Project Yield (acft/yr)	488
Annual Cost of Water ($ per acft), based on PF=2	$1,008
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$236
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$3.09
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.72

WUG: Comanche County Mining

Strategy: Trinity Aquifer Development (Erath County)

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, and transmission pipeline

Total Capital Cost:	$1,229,000
Total Project Cost:	$2,223,000
Total Annual Cost:	$184,000
Available Project Yield:	288 acft/yr
Annual Cost of Water:	$639 per acft/yr or $1.96 per 1,000 gal

This project will include three 150 gpm wells drilled to 500 ft as well as 1,000 ft of collection pipeline per well and approximately 5 miles of transmission pipeline.

Cost Estimate Summary September 2018 Prices	
Comanche County-Mining - Trinity Aquifer Development (Erath County)	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$1,229,000
TOTAL COST OF FACILITIES	**$1,229,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$430,000
Environmental & Archaeology Studies and Mitigation	$207,000
Land Acquisition and Surveying (26 acres)	$298,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$59,000
TOTAL COST OF PROJECT	**$2,223,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$156,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$12,000
Pumping Energy Costs (203,891 kW-hr @ 0.08 $/kW-hr)	$16,000
TOTAL ANNUAL COST	**$184,000**
Available Project Yield (acft/yr)	288
Annual Cost of Water ($ per acft), based on PF=1	$639
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$97
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.96
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.30

13.3.6 Coryell County

WUG: Coryell County Other

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, treatment.

Total Capital Cost: $3,227,327

Total Project Cost: $4,710,000

Total Annual Cost: $407,000 (Maximum of Phased Costs)

Available Project Yield: 1,107 acft/yr

Annual Cost of Water: $784 per acft/yr or $2.41 per 1,000 gal (Maximum of Phased Costs)

This project will include five 200 gpm wells drilled to 1,000 ft as well as 200 ft of collection pipiniing and disinfection treatment per well.

Cost Estimate Summary September 2018 Prices	
Coryell County Other - Trinity Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$609,000
Water Treatment Plant (0.3 MGD)	$37,000
TOTAL COST OF FACILITIES	**$646,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$226,000
Environmental & Archaeology Studies and Mitigation	$10,000
Land Acquisition and Surveying (2 acres)	$11,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$49,000
TOTAL COST OF PROJECT	**$942,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$66,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$6,000
Water Treatment Plant	$22,000
Pumping Energy Costs (453,153 kW-hr @ 0.08 $/kW-hr)	$36,000

TOTAL ANNUAL COST	**$130,000**
Available Project Yield (acft/yr)	1,107
Annual Cost of Water ($ per acft), based on PF=2	$117
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$58
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$0.36
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.18

WUG: Coryell County Mining

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $2,138,000

Total Project Cost: $3,145,000

Total Annual Cost: $282,000

Available Project Yield: 1,270 acft/yr

Annual Cost of Water: $ 222 per acft/yr or $0.68 per 1,000 gal

This project will include ten 100 gpm wells drilled to 1,000 ft as well as 200 ft of collection pipeline per well.

Cost Estimate Summary September 2018 Prices	
Coryell County Mining - Trinity Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$2,138,000
TOTAL COST OF FACILITIES	**$2,138,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$748,000
Environmental & Archaeology Studies and Mitigation	$37,000
Land Acquisition and Surveying (7 acres)	$58,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$164,000
TOTAL COST OF PROJECT	**$3,145,000**
ANNUAL COST	

Debt Service (3.5 percent, 20 years)	$221,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$21,000
Pumping Energy Costs (494,854 kW-hr @ 0.08 $/kW-hr)	$40,000
TOTAL ANNUAL COST	**$282,000**
Available Project Yield (acft/yr)	1,270
Annual Cost of Water ($ per acft), based on PF=1	$222
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$48
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$0.68
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.15

13.3.7 Eastland County

WUG: Eastland County Mining

Strategy: Trinity Aquifer Development (Erath County)

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, transmission pipeline

Total Capital Cost: $2,268,000

Total Project Cost: $3,669,000

Total Annual Cost: $329,000

Available Project Yield: 886 acft/yr

Annual Cost of Water: $371 per acft/yr or $1.14 per 1,000 gal

This project will include five 150 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Eastland County Mining - Trinity Aquifer Development (Erath Co)	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$1,992,000
TOTAL COST OF FACILITIES	**$2,268,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$780,000
Environmental & Archaeology Studies and Mitigation	$213,000

Land Acquisition and Surveying (28 acres)	$310,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$98,000
TOTAL COST OF PROJECT	**$3,669,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$258,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$23,000
Pumping Energy Costs (603,032 kW-hr @ 0.08 $/kW-hr)	$48,000
TOTAL ANNUAL COST	**$329,000**
Available Project Yield (acft/yr)	886
Annual Cost of Water ($ per acft), based on PF=1	$371
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$80
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.14
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.25

13.3.8 Erath County

WUG: Stephenville

Strategy: Trinity Aquifer Well Field Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, roads, pads & electrical distribution

Total Capital Cost: $4,559,000

Total Project Cost: $7,344,000

Total Annual Cost: $655,000

Available Project Yield: 484 acft/yr

Annual Cost of Water: $1,353 per acft/yr or $4.15 per 1,000 gal

This project will include constructing five new Trinity Aquifer wells, collection and transmission pipelines, disinfection treatment, well access roads, and electrical power distribution. Project annual cost estimated based on capital and construction cost provided by the City of Stephenville.

Cost Estimate Summary September 2018 Prices	
City of Stephenville - Trinity Aquifer Development	
Item	***Estimated Costs for Facilities***
Transmission Pipeline (10 in dia., 4 miles)	$18,000
Well Fields (Wells, Pumps, and Piping)	$2,760,000
Water Treatment Plant (1.7 MGD)	$128,000
Integration, Relocations, & Other	$1,653,000
TOTAL COST OF FACILITIES	**$4,559,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,276,000
Environmental & Archaeology Studies and Mitigation	$128,000
Land Acquisition and Surveying (21 acres)	$184,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$197,000
TOTAL COST OF PROJECT	**$7,344,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$517,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$44,000
Water Treatment Plant	$77,000
Pumping Energy Costs (213,162 kW-hr @ 0.08 $/kW-hr)	$17,000
TOTAL ANNUAL COST	**$655,000**
Available Project Yield (acft/yr)	484
Annual Cost of Water ($ per acft), based on PF=2	$1,353
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$285
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$4.15
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.87

WUG: Erath County Other

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, and treatment

Total Capital Cost: $917,000

Total Project Cost: $1,350,000

Total Annual Cost: $152,000 (Maximum of Phased Costs)

Available Project Yield: 347 acft/yr

Annual Cost of Water: $438 per acft/yr or $1.34 per 1,000 gal

This project will include two 300 gpm wells drilled to 500 ft as well as 200 ft of collection pipe and disinfection treatment.

Cost Estimate Summary September 2018 Prices	
Erath County-Other - Trinity Aquifer Development	
Item	***Estimated Costs for Facilities***
Transmission Pipeline (8 in dia., 1 miles)	$55,000
Well Fields (Wells, Pumps, and Piping)	$801,000
Water Treatment Plant (0.6 MGD)	$61,000
TOTAL COST OF FACILITIES	**$917,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$318,000
Environmental & Archaeology Studies and Mitigation	$34,000
Land Acquisition and Surveying (5 acres)	$45,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$36,000
TOTAL COST OF PROJECT	**$1,350,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$95,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$9,000
Water Treatment Plant	$37,000
Pumping Energy Costs (139,153 kW-hr @ 0.08 $/kW-hr)	$11,000

TOTAL ANNUAL COST	**$152,000**
Available Project Yield (acft/yr)	347
Annual Cost of Water ($ per acft), based on PF=2	$438
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$164
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$1.34
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.50

13.3.9 Fisher County

WUG: Fisher County Mining

Strategy: Blaine Aquifer Development

Source: Blaine Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $305,000

Total Project Cost: $511,000

Total Annual Cost: $55,311 (Maximum of Phased Costs)

Available Project Yield: 179 acft/yr

Annual Cost of Water: $309 per acft/yr (Maximum of Phased Costs)

This project will include two 76 gpm wells drilled to 55 ft,10,560 ft of transmission pipeline, and a water treatment with chlorine disinfection of 0.1 MGD.

Cost Estimate Summary September 2018 Prices	
Mining Fisher - Mining Blaine Fisher	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$281,000
Water Treatment Plant (0.1 MGD)	$24,000
TOTAL COST OF FACILITIES	**$305,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$107,000
Environmental & Archaeology Studies and Mitigation	$67,000
Land Acquisition and Surveying (11 acres)	$18,000

Interest During Construction (3% for 1 years with a 0.5% ROI)	$14,000
TOTAL COST OF PROJECT	**$511,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$36,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$3,000
Water Treatment Plant	$14,000
Pumping Energy Costs (29,880 kW-hr @ 0.08 $/kW-hr)	$2,000
TOTAL ANNUAL COST	**$55,000**
Available Project Yield (acft/yr)	179
Annual Cost of Water ($ per acft), based on PF=1	$307
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$106
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$0.94
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.33

13.3.10 Grimes County

WUG: Grimes County Mining

Strategy: Gulf Coast Aquifer Development

Source: Gulf Coast Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $513,000

Total Project Cost: $744,000

Total Annual Cost: $64,000 (Maximum of Phased Costs)

Available Project Yield: 382 acft/yr

Annual Cost of Water: $480 per acft/yr or $1.47 per 1,000 gal (Maximum of Phased Costs)

This project will include two 250 gpm wells drilled to 500 ft as well as 200 ft of collection pipe per well.

Cost Estimate Summary September 2018 Prices	
Grimes County-Mining - Gulf Coast Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$513,000
TOTAL COST OF FACILITIES	**$513,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$180,000
Environmental & Archaeology Studies and Mitigation	$12,000
Land Acquisition and Surveying (1 acres)	$19,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$20,000
TOTAL COST OF PROJECT	**$744,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$52,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$5,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$0
Dam and Reservoir (1.5% of Cost of Facilities)	$0
Water Treatment Plant	$0
Advanced Water Treatment Facility	$0
Pumping Energy Costs (84,694 kW-hr @ 0.08 $/kW-hr)	$7,000
Purchase of Water (acft/yr @ $/acft)	$0
TOTAL ANNUAL COST	**$64,000**
Available Project Yield (acft/yr)	382
Annual Cost of Water ($ per acft), based on PF=1	$168
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$31
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$0.51
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.10

WUG: Grimes County Irrigation

Strategy: Gulf Coast Development

Source: Gulf Coast Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $441,000

Total Project Cost: $623,000

Total Annual Cost: $50,000

Available Project Yield: 131 acft/yr

Annual Cost of Water: $382 per acft/yr or $1.17 per 1,000 gal (Maximum of Phased Costs)

This project will include two 200 gpm wells drilled to 500 ft as well as 200 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Grimes County-Irrigation - Gulf Coast Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$441,000
TOTAL COST OF FACILITIES	**$441,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$154,000
Environmental & Archaeology Studies and Mitigation	$2,000
Land Acquisition and Surveying (1 acres)	$9,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$17,000
TOTAL COST OF PROJECT	**$623,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$44,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$4,000
Pumping Energy Costs (28,855 kW-hr @ 0.08 $/kW-hr)	$2,000
TOTAL ANNUAL COST	**$50,000**

Available Project Yield (acft/yr)	131
Annual Cost of Water ($ per acft), based on PF=3.75	$382
Annual Cost of Water After Debt Service ($ per acft), based on PF=3.75	$46
Annual Cost of Water ($ per 1,000 gallons), based on PF=3.75	$1.17
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=3.75	$0.14

13.3.11 Hamilton County

WUG: Hamilton County Mining

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $375,000

Total Project Cost: $548,000

Total Annual Cost: $46,000

Available Project Yield: 125 acft/yr

Annual Cost of Water: $368 per acft/yr or $1.13 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.

Cost Estimate Summary September 2018 Prices	
Hamilton County-Mining - Gulf Coast Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$375,000
TOTAL COST OF FACILITIES	**$375,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$131,000
Environmental & Archaeology Studies and Mitigation	$12,000
Land Acquisition and Surveying (1 acres)	$15,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$15,000
TOTAL COST OF PROJECT	**$548,000**

ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$39,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$4,000
Pumping Energy Costs (35,580 kW-hr @ 0.08 $/kW-hr)	$3,000
TOTAL ANNUAL COST	**$46,000**
Available Project Yield (acft/yr)	125
Annual Cost of Water ($ per acft), based on PF=1	$368
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$56
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.13
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.17

13.3.12 Hill County

WUG: Hill County Irrigation

Strategy: Woodbine Aquifer Development

Source: Woodbine Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $617,000

Total Project Cost: $870,000

Total Annual Cost: $74,000

Available Project Yield: 158 acft/yr

Annual Cost of Water: $468 per acft/yr or $1.44 per 1,000 gal

This project will include two 200 gpm wells drilled to 895 ft as well as 200 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Hill County Irrigation - Woodbine Aquifer Development	
Item	***Estimated Costs for Facilities (for 1 well)***
Well Fields (Wells, Pumps, and Piping)	$617,000
TOTAL COST OF FACILITIES	**$617,000**

Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$216,000
Environmental & Archaeology Studies and Mitigation	$3,000
Land Acquisition and Surveying (1 acres)	$10,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$24,000
TOTAL COST OF PROJECT	**$870,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$61,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$6,000
Pumping Energy Costs (79,082 kW-hr @ 0.08 $/kW-hr)	$7,000
TOTAL ANNUAL COST	**$74,000**
Available Project Yield (acft/yr)	158
Annual Cost of Water ($ per acft), based on PF=3.75	$468
Annual Cost of Water After Debt Service ($ per acft), based on PF=3.75	$82
Annual Cost of Water ($ per 1,000 gallons), based on PF=3.75	$1.44
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=3.75	$0.25

13.3.13 Hood County

WUG: Acton MUD

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, treatment

Total Capital Cost: $679,000

Total Project Cost: $965,000

Total Annual Cost: $89,000

Available Project Yield: 51 acft/yr

Annual Cost of Water: $1,745 per acft/yr or $5.35 per 1,000 gal

This project will include two 150 gpm wells drilled to 500 ft as well as 600 ft of transmission pipeline and disinfection treatment.

Cost Estimate Summary September 2018 Prices	
Acton MUD - Trinity for Acton MUD	
Item	***Estimated Costs for Facilities (for 1 well)***
Well Fields (Wells, Pumps, and Piping)	$658,000
Water Treatment Plant (0.1 MGD)	$21,000
TOTAL COST OF FACILITIES	**$679,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$237,000
Environmental & Archaeology Studies and Mitigation	$13,000
Land Acquisition and Surveying (1 acres)	$10,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$26,000
TOTAL COST OF PROJECT	**$965,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$68,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$7,000
Water Treatment Plant	$12,000
Pumping Energy Costs (23,554 kW-hr @ 0.08 $/kW-hr)	$2,000
TOTAL ANNUAL COST	**$89,000**
Available Project Yield (acft/yr)	51
Annual Cost of Water ($ per acft), based on PF=2	$1,745
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$412
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$5.35
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$1.26

WUG: Hood County-Other

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, and treatment

Total Capital Cost: $3,818,000

Total Project Cost: $6,210,000

Total Annual Cost: $803,000

Available Project Yield: 1,845 acft/yr

Annual Cost of Water: $435 per acft/yr or $1.34 per 1,000 gal

This project will include ten 150 gpm wells drilled to 500 ft as well as 1,000 ft of transmission pipeline per well and disinfection treatment.

Cost Estimate Summary September 2018 Prices	
Hood County-Other - Trinity for Hood County-Other	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$3,607,000
Water Treatment Plant (3.3 MGD)	$211,000
TOTAL COST OF FACILITIES	**$3,818,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,909,000
Environmental & Archaeology Studies and Mitigation	$119,000
Land Acquisition and Surveying (14 acres)	$197,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$167,000
TOTAL COST OF PROJECT	**$6,210,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$437,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$36,000
Water Treatment Plant	$126,000
Pumping Energy Costs (2,554,934 kW-hr @ 0.08 $/kW-hr)	$204,000
TOTAL ANNUAL COST	**$803,000**
Available Project Yield (acft/yr)	1,845
Annual Cost of Water ($ per acft), based on PF=2	$435
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$198

Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$1.34
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.61

WUG: Hood County Mining

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, treatment

Total Capital Cost: $718,000

Total Project Cost: $1,027,000

Total Annual Cost: $102,000

Available Project Yield: 913 acft/yr

Annual Cost of Water: $112 per acft/yr or $0.34 per 1,000 gal

This project will include four 150 gpm wells drilled to 400 ft as well as 200 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Hood County Mining - Trinity for Hood County Mining	
Item	***Estimated Costs for Facilities (for 1 well)***
Well Fields (Wells, Pumps, and Piping)	$718,000
TOTAL COST OF FACILITIES	**$718,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$251,000
Environmental & Archaeology Studies and Mitigation	$10,000
Land Acquisition and Surveying (2 acres)	$20,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$28,000
TOTAL COST OF PROJECT	**$1,027,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$72,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$7,000

Pumping Energy Costs (286,974 kW-hr @ 0.08 $/kW-hr)	$23,000
TOTAL ANNUAL COST	**$102,000**
Available Project Yield (acft/yr)	913
Annual Cost of Water ($ per acft), based on PF=1	$112
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$33
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$0.34
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.10

13.3.14 Johnson County

WUG: City of Godley

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, transmission

Total Capital Cost: $686,000

Total Project Cost: $1,101,000

Total Annual Cost: $15,015 (Maximum of Phased Costs)

Available Project Yield: 65 acft/yr (After Full Implementation)

Annual Cost of Water: $1,423per acft/yr

This project will include one 140 gpm well drilled to 1,170 ft as well as 5,280 ft of transmission pipeline per well, and chlorine disinfection water treatment.

Cost Estimate Summary September 2018 Prices	
City of Godley – Godley Trinity Johnson	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$672,000
Water Treatment Plant (0.1 MGD)	$14,000
TOTAL COST OF FACILITIES	**$686,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$240,000
Environmental & Archaeology Studies and Mitigation	$82,000
Land Acquisition and Surveying (5 acres)	$63,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$30,000

TOTAL COST OF PROJECT	**$1,101,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$77,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$7,000
Water Treatment Plant	$8,000
TOTAL ANNUAL COST	**$92,000**
Available Project Yield (acft/yr)	65
Annual Cost of Water ($ per acft), based on PF=1	$1,415
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$231
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$4.34
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.71

WUG: Johnson County SUD

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, transmission

Total Capital Cost: $6,237,497

Total Project Cost: $9,305,940

Total Annual Cost: $735,155 (Maximum of Phased Costs)

Available Project Yield: 1,491 acft/yr (After Full Implementation)

Annual Cost of Water: $437 per acft/yr

This project will include eight 140 gpm wells drilled to 1,170 ft as well as 5,280 ft of transmission pipeline per well and disinfection treatment.

Cost Estimate Summary ***September 2018 Prices***	
Johnson County SUD – Johnson Co SUD Trinity Johnson	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$6,207,000
Water Treatment Plant (0.2 MGD)	$31,000
TOTAL COST OF FACILITIES	**$6,238,000**

Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,183,000
Environmental & Archaeology Studies and Mitigation	$407,000
Land Acquisition and Surveying (43 acres)	$228,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$250,000
TOTAL COST OF PROJECT	**$9,306,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$655,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$62,000
Water Treatment Plant	$18,000
TOTAL ANNUAL COST	**$735,000**
Available Project Yield (acft/yr)	1,491
Annual Cost of Water ($ per acft), based on PF=1	$437
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$48
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.34
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.15

WUG: Parker WSC

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, transmission

Total Capital Cost: $698,000

Total Project Cost: $1,045,000

Total Annual Cost: $95,845 (Maximum of Phased Costs)

Available Project Yield: 145 acft/yr (After Full Implementation)

Annual Cost of Water: $661 per acft/yr

This project will include one 140 gpm well drilled to 1,170 ft as well as 5,280 ft of transmission pipeline per well and disinfection treatment.

Cost Estimate Summary September 2018 Prices	
Parker WSC – Parker WSC Trinity Johnson	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$672,000
Water Treatment Plant (0.1 MGD)	$26,000
TOTAL COST OF FACILITIES	**$698,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$244,000
Environmental & Archaeology Studies and Mitigation	$49,000
Land Acquisition and Surveying (5 acres)	$26,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$28,000
TOTAL COST OF PROJECT	**$1,045,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$74,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$7,000
Water Treatment Plant	$16,000
TOTAL ANNUAL COST	**$97,000**
Available Project Yield (acft/yr)	145
Annual Cost of Water ($ per acft), based on PF=1	$669
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$159
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$2.05
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.49

13.3.15 Knox County

WUG: Knox County Irrigation

Strategy: Blaine Aquifer Development

Source: Blaine Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $452,000

Total Project Cost: $631,000

Total Annual Cost: $55,000

Available Project Yield: 405 acft/yr

Annual Cost of Water: $136 per acft/yr or $0.42 per 1,000 gal (Maximum of Phased Costs)

This project will include two 300 gpm wells drilled to 250 ft as well as 200 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Knox County-Irrigation - Blaine Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$452,000
TOTAL COST OF FACILITIES	**$452,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$158,000
Environmental & Archaeology Studies and Mitigation	$2,000
Land Acquisition and Surveying (1 acres)	$2,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$17,000
TOTAL COST OF PROJECT	**$631,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$44,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$5,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$0
Pumping Energy Costs (77,116 kW-hr @ 0.08 $/kW-hr)	$6,000
TOTAL ANNUAL COST	**$55,000**
Available Project Yield (acft/yr)	405
Annual Cost of Water ($ per acft), based on PF=3.75	$136
Annual Cost of Water After Debt Service ($ per acft), based on PF=3.75	$27
Annual Cost of Water ($ per 1,000 gallons), based on PF=3.75	$0.42
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=3.75	$0.08

WUG: Knox County Manufacturing

Strategy: Blaine Aquifer Development

Source: Blaine Aquifer

Facilities: Well Field, collection pipes, treatment

Total Capital Cost: $221,000

Total Project Cost: $331,000

Total Annual Cost: $28,000

Available Project Yield: 25 acft/yr

Annual Cost of Water: $1,120 per acft/yr or $3.44 per 1,000 gal (Maximum of Phased Costs)

This project will include two 25 gpm wells drilled to 250 ft as well as 200 ft of transmission pipeline and disinfection treatment per well.

Cost Estimate Summary September 2018 Prices	
Knox County-Manufacturing - Blaine Aquifer Development	
Item	**_Estimated Costs for Facilities_**
Well Fields (Wells, Pumps, and Piping)	$216,000
Water Treatment Plant (0.02 MGD)	$5,000
TOTAL COST OF FACILITIES	**$221,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$77,000
Environmental & Archaeology Studies and Mitigation	$12,000
Land Acquisition and Surveying (1 acres)	$12,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$9,000
TOTAL COST OF PROJECT	**$331,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$23,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$2,000
Water Treatment Plant	$3,000
TOTAL ANNUAL COST	**$28,000**
Available Project Yield (acft/yr)	25

Annual Cost of Water ($ per acft), based on PF=1	$1,120
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$200
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$3.44
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.61

WUG: Knox County Mining

Strategy: Blaine Aquifer Development

Source: Blaine Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $110,000

Total Project Cost: $178,000

Total Annual Cost: $14,000

Available Project Yield: 25 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 two 20 gpm wells drilled to 250 ft as well as 200 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Knox County-Mining - Blaine Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$110,000
TOTAL COST OF FACILITIES	**$110,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$39,000
Environmental & Archaeology Studies and Mitigation	$12,000
Land Acquisition and Surveying (1 acres)	$12,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$5,000
TOTAL COST OF PROJECT	**$178,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$13,000
Operation and Maintenance	

Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$1,000
TOTAL ANNUAL COST	**$14,000**
Available Project Yield (acft/yr)	25
Annual Cost of Water ($ per acft), based on PF=1	$560
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$40
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.72
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.12

13.3.16 Lampasas County

WUG: Lampasas County Irrigation

Strategy: Marble Falls Aquifer Development

Source: Marble Falls Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $1,425,000

Total Project Cost: $2,054,000

Total Annual Cost: $175,974 (Maximum of Phased Costs)

Available Project Yield: 211 acft/yr

Annual Cost of Water: $834 per acft/yr (Maximum of Phased Costs)

This project will include one 1,000 gpm well drilled to 1,000 ft as well as 5,280 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Irrigation – Irrigation Marble Falls Lampasas	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$1,396,000
Water Treatment Plant (0.2 MGD)	$29,000
TOTAL COST OF FACILITIES	**$1,425,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$499,000
Environmental & Archaeology Studies and Mitigation	$49,000
Land Acquisition and Surveying (5 acres)	$26,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$55,000

TOTAL COST OF PROJECT	**$2,054,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$145,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$14,000
Water Treatment Plant	$17,000
TOTAL ANNUAL COST	**$176,000**
Available Project Yield (acft/yr)	211
Annual Cost of Water ($ per acft), based on PF=1	$834
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$147
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$2.56
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.45

WUG: Lampasas County Mining

Strategy: Ellenburger-San Saba Aquifer Development

Source: Ellenburger-San Saba Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $1,423,000

Total Project Cost: $2,051,000

Total Annual Cost: $204,252 (Maximum of Phased Costs)

Available Project Yield: 187 acft/yr

Annual Cost of Water: $936 per acft/yr (Maximum of Phased Costs)

This project will include one 1,000 gpm wells drilled to 1,000 ft as well as 5,280 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Mining – Mining Ellenburger-San Saba Lampasas	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$1,396,000
Water Treatment Plant (0.2 MGD)	$27,000
TOTAL COST OF FACILITIES	**$1,423,000**

Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$498,000
Environmental & Archaeology Studies and Mitigation	$49,000
Land Acquisition and Surveying (5 acres)	$26,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$55,000
TOTAL COST OF PROJECT	**$2,051,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$144,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$14,000
Water Treatment Plant	$16,000
TOTAL ANNUAL COST	**$174,000**
Available Project Yield (acft/yr)	187
Annual Cost of Water ($ per acft), based on PF=1	$930
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$160
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$2.86
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.49

13.3.17 Lee County

WUG: Lee County Mining

Strategy: Carrizo-Wilcox Aquifer Development

Source: Carrizo-Wilcox Aquifer

Facilities: Well Field, collection pipes, transmission

Total Capital Cost: $2,162,000

Total Project Cost: $3,077,000

Total Annual Cost: $254,340 (Maximum of Phased Costs)

Available Project Yield: 180 acft/yr

Annual Cost of Water: $1,413 per acft/yr

This project will include one 1,800 gpm well drilled to 1,225 ft as well as 5,280 ft of transmission pipeline per well and disinfection treatment.

Cost Estimate Summary ***September 2018 Prices***	
Mining Lee County – Mining Lee	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$2,135,000
Water Treatment Plant (0.2 MGD)	$27,000
TOTAL COST OF FACILITIES	**$2,162,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$757,000
Environmental & Archaeology Studies and Mitigation	$49,000
Land Acquisition and Surveying (5 acres)	$26,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$83,000
TOTAL COST OF PROJECT	**$3,077,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$217,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$21,000
Water Treatment Plant	$16,000
TOTAL ANNUAL COST	**$254,000**
Available Project Yield (acft/yr)	180
Annual Cost of Water ($ per acft), based on PF=1	$1,411
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$206
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$4.33
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.63

13.3.18 Limestone County

WUG: Bistone Municipal Water Supply District

Strategy: Carrizo-Wilcox Aquifer Development

Source: Carrizo-Wilcox Aquifer (Brazos Basin)

Facilities: Well Field, treatment, collection pipes

Total Capital Cost: $1,257,000

Total Project Cost: $1,772,000

Total Annual Cost: $165,000

Available Project Yield: 460 acft/yr

Annual Cost of Water: $358.70 per acft/yr or $1.10 per 1,000 gal (Maximum of Phased Costs)

This project will include two 300 gpm wells drilled to 800 ft as well as 200 ft of transmission pipeline and disinfection treatment per well.

Cost Estimate Summary September 2018 Prices	
Bistone Municipal WSD - Carrizo-Wilcox Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$1,217,000
Water Treatment Plant (0.3 MGD)	$40,000
TOTAL COST OF FACILITIES	**$1,257,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$440,000
Environmental & Archaeology Studies and Mitigation	$12,000
Land Acquisition and Surveying (2 acres)	$15,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$48,000
TOTAL COST OF PROJECT	**$1,772,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$125,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$12,000
Water Treatment Plant	$24,000
Pumping Energy Costs (51791 kW-hr @ 0.08 $/kW-hr)	$4,000
TOTAL ANNUAL COST	**$165,000**
Available Project Yield (acft/yr)	460
Annual Cost of Water ($ per acft), based on PF=2	$359
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$87
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$1.10
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.27

WUG: Limestone County-Manufacturing

Strategy: Carrizo-Wilcox Aquifer Development

Source: Carrizo-Wilcox Aquifer

Facilities: Well Field, treatment, collection pipes, treatment

Total Capital Cost: $1,253,000

Total Project Cost: $1,767,000

Total Annual Cost: $165,000

Available Project Yield: 314 acft/yr

Annual Cost of Water: $525 per acft/yr or $1.61 per 1,000 gal

This project will include two 300 gpm wells drilled to 800 ft as well as 200 ft of transmission pipeline and disinfection treatment per well.

Cost Estimate Summary September 2018 Prices	
Limestone County -Manufacturing - Carrizo-Wilcox Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$1,217,000
Water Treatment Plant (0.3 MGD)	$36,000
TOTAL COST OF FACILITIES	**$1,253,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$439,000
Environmental & Archaeology Studies and Mitigation	$12,000
Land Acquisition and Surveying (2 acres)	$15,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$48,000
TOTAL COST OF PROJECT	**$1,767,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$124,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$12,000
Water Treatment Plant	$22,000
Pumping Energy Costs (89,354 kW-hr @ 0.08 $/kW-hr)	$7,000
TOTAL ANNUAL COST	**$165,000**

Available Project Yield (acft/yr)	315
Annual Cost of Water ($ per acft), based on PF=1	$525
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$131
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.61
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.40

WUG: Limestone County Steam-Electric

Strategy: Carrizo-Wilcox Aquifer Development

Source: Carrizo-Wilcox Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $1,212,000

Total Project Cost: $1,709,000

Total Annual Cost: $141,000

Available Project Yield: 388 acft/yr

Annual Cost of Water: $363 per acft/yr or $1.12 per 1,000 gal (Maximum of Phased Costs)

This project will include two 300 gpm wells drilled to 800 ft as well as 200 ft of collection pipeline per well.

Cost Estimate Summary September 2018 Prices	
Limestone County -Steam Electric - Carrizo-Wilcox Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$1,212,000
TOTAL COST OF FACILITIES	**$1,212,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$424,000
Environmental & Archaeology Studies and Mitigation	$12,000
Land Acquisition and Surveying (1 acres)	$15,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$46,000
TOTAL COST OF PROJECT	**$1,709,000**

ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$120,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$12,000
Pumping Energy Costs (111,104 kW-hr @ 0.08 $/kW-hr)	$9,000
TOTAL ANNUAL COST	**$141,000**
Available Project Yield (acft/yr)	388
Annual Cost of Water ($ per acft), based on PF=1	$363
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$54
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.12
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.17

13.3.19 McLennan County

WUG: North Bosque WSC

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $1,069,347

Total Project Cost: $1,558,911

Total Annual Cost: $148,322 (Maximum of Phased Costs)

Available Project Yield: 109 acft/yr (by 2070)

Annual Cost of Water: $1,358 per acft/yr or $4.17 per 1,000 gal (Maximum of Phased Costs)

This project will use supply from the McLennan County ASR project. This project will include one 300 gpm well drilled to 1,250 ft as well as 5,280 ft of transmission pipeline per well and disinfection treatment.

Cost Estimate Summary September 2018 Prices	
North Bosque WSC – North Bosque WSC Trinity McLennan	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$1,022,000
Water Treatment Plant (0.4 MGD)	$47,000

TOTAL COST OF FACILITIES	**$1,069,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$374,000
Environmental & Archaeology Studies and Mitigation	$48,000
Land Acquisition and Surveying (6 acres)	$25,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$42,000
TOTAL COST OF PROJECT	**$1,558,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$110,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$10,000
Water Treatment Plant	$28,000
TOTAL ANNUAL COST	**$148,000**
Available Project Yield (acft/yr)	109
Annual Cost of Water ($ per acft), based on PF=1	$1,358
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$349
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$4.17
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$1.07

13.3.20 Palo Pinto County

WUG: City of Strawn

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, disinfection, and pipeline from Strawn to Erath County

Total Capital Cost: $1,436,000

Total Project Cost: $2,447,000

Total Annual Cost: $255,000

Available Project Yield: 182 acft/yr

Annual Cost of Water: $1,401 per acft/yr or $4.30 per 1,000 gal

This project will include one 180 gpm well drilled to 420 ft as well as 5,280 ft of transmission pipeline per well and disinfection and 8.2 miles of pipeline to transfer water from Erath County to City of Strawn.

Cost Estimate Summary September 2018 Prices	
City of Strawn – Strawn Trinity Erath	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$465,000
Water Treatment Plant (0.3 MGD)	$39,000
TOTAL COST OF FACILITIES	**$1,436,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$503,000
Environmental & Archaeology Studies and Mitigation	$252,000
Land Acquisition and Surveying (50 acres)	$190,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$66,000
TOTAL COST OF PROJECT	**$2,447,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$172,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$5,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$23,000
Water Treatment Plant	$24,000
Pumping Energy Costs (385,582 kW-hr @ 0.08 $/kW-hr)	$31,000
TOTAL ANNUAL COST	**$255,000**
Available Project Yield (acft/yr)	182
Annual Cost of Water ($ per acft), based on PF=2	$1,401
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$456
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$4.30
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$1.40

WUG: Palo Pinto Mining

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, disinfection and pipeline from Palo Pinto Mining to Erath County

Total Capital Cost: $3,192,000

Total Project Cost: $4,885,000

Total Annual Cost: $590,000

Available Project Yield: 844 acft/yr

Annual Cost of Water: $699 per acft/yr or $2.14 per 1,000 gal

This project will include four 180 gpm wells drilled to 420 ft as well as 21,120 ft of transmission pipeline per well and disinfection and 3.51 miles of pipeline to transfer water from Erath County to City of Strawn.

Cost Estimate Summary September 2018 Prices	
Mining Palo Pinto - Mining Palo Pinto Trinity Erath	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$2,160,000
Water Treatment Plant (0.8 MGD)	$74,000
TOTAL COST OF FACILITIES	**$3,192,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,117,000
Environmental & Archaeology Studies and Mitigation	$276,000
Land Acquisition and Surveying (44 acres)	$169,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$131,000
TOTAL COST OF PROJECT	**$4,885,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$344,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$22,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$24,000
Water Treatment Plant	$44,000
Pumping Energy Costs (1,950,700 kW-hr @ 0.08 $/kW-hr)	$156,000
TOTAL ANNUAL COST	**$590,000**
Available Project Yield (acft/yr)	844
Annual Cost of Water ($ per acft), based on PF=1	$699
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$291

Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$2.14
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.89

WUG: Palo Pinto Irrigation

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, disinfection and pipeline from Palo Pinto Irrigation to Erath County

Total Capital Cost: $34,728,000

Total Project Cost: $49,832,000

Total Annual Cost: $4,986,000

Available Project Yield: 2,236 acft/yr

Annual Cost of Water: $2,230 per acft/yr or $6.84 per 1,000 gal

This project will include ten 180 gpm wells drilled to 420 ft as well as 52,800 ft of transmission pipeline per well and disinfection and 19.9 miles of pipeline to transfer water from Erath County to City of Strawn.

Cost Estimate Summary September 2018 Prices	
Irrigation Palo Pinto - Irrigation Palo Pinto Trinity Erath	
Cost based on ENR CCI 11170.28 for September 2018 and	
a PPI of 202.4 for September 2018	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$6,306,000
Water Treatment Plant (7.5 MGD)	$434,000
TOTAL COST OF FACILITIES	**$34,728,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$12,155,000
Environmental & Archaeology Studies and Mitigation	$969,000
Land Acquisition and Surveying (159 acres)	$646,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$1,334,000
TOTAL COST OF PROJECT	**$49,832,000**
ANNUAL COST	

Debt Service (3.5 percent, 20 years)	$3,506,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$122,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$551,000
Water Treatment Plant	$260,000
Pumping Energy Costs (6,834,630 kW-hr @ 0.08 $/kW-hr)	$547,000
TOTAL ANNUAL COST	**$4,986,000**
Available Project Yield (acft/yr)	2,236
Annual Cost of Water ($ per acft), based on PF=3.753	$2,230
Annual Cost of Water After Debt Service ($ per acft), based on PF=3.753	$662
Annual Cost of Water ($ per 1,000 gallons), based on PF=3.753	$6.84
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=3.753	$2.03

13.3.21 Milam County

WUG: City of Cameron

Strategy: Little River Intake

Source: Little River water right

Facilities: Intake, pump station, pipeline

Total Capital Cost: $8,578,000

Total Project Cost: $13,006,000

Total Annual Cost: $1,137,000

Available Project Yield: 2,792 acft/yr

Annual Cost of Water: $407 per acft/yr

This project will include one 5 mgd intake and pump station and 2 miles of 18-inch diameter pipe.

Cost Estimate Summary September 2018 Prices	
City of Cameron - Little River Intake	
Item	***Estimated Costs for Facilities***
Intake and Primary Pump Station (5 MGD)	$7,213,000
Transmission Pipeline (18 in dia., 2 miles)	$1,365,000
TOTAL COST OF FACILITIES	**$8,578,000**

Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$4,016,000
Environmental & Archaeology Studies and Mitigation	$53,000
Land Acquisition and Surveying (5 acres)	$10,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$349,000
TOTAL COST OF PROJECT	**$13,006,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$915,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$14,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$180,000
Pumping Energy Costs (346,599 kW-hr @ 0.08 $/kW-hr)	$28,000
TOTAL ANNUAL COST	**$1,137,000**
Available Project Yield (acft/yr)	2,792
Annual Cost of Water ($ per acft), based on PF=2	$407
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$80
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$1.25
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.24

WUG: City of Rockdale

Strategy: Lee County: Carrizo-Wilcox Aquifer Development

Source: Lee County: Carrizo-Wilcox Aquifer

Facilities: Well Field, collection pipes, treatment

Total Capital Cost: $3,182,000

Total Project Cost: $5,086,000

Total Annual Cost: $447,000

Available Project Yield: 433 acft/yr (maximum need for Rockdale)

Annual Cost of Water: $1,034 per acft/yr

This project will include one 1,800 gpm well drilled to 1,225 ft as well as 5,280 ft of transmission pipeline per well and disinfection treatment.

Cost Estimate Summary September 2018 Prices	
Mining Lee County – Mining Carrizo Wilcox Lee	
Item	***Estimated Costs for Facilities***
Primary Pump Station (0.7 MGD)	$979,000
Well Fields (Wells, Pumps, and Piping)	$2,135,000
Water Treatment Plant (0.7 MGD)	$68,000
TOTAL COST OF FACILITIES	**$3,182,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,113,000
Environmental & Archaeology Studies and Mitigation	$345,000
Land Acquisition and Surveying (64 acres)	$309,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$137,000
TOTAL COST OF PROJECT	**$5,086,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$358,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$21,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$24,000
Water Treatment Plant	$41,000
Pumping Energy Costs (40,834 kW-hr @ 0.08 $/kW-hr)	$3,000
TOTAL ANNUAL COST	**$447,000**
Available Project Yield (acft/yr)	433
Annual Cost of Water ($ per acft), based on PF=2	$1,032
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$206
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$3.17
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.63

WUG: Southwest Milam WSC

Strategy: Lee County: Carrizo-Wilcox Aquifer Development

Source: Lee County: Carrizo Aquifer

Facilities: Well Field, collection pipes, treatment

Total Capital Cost: $3,177,000

Total Project Cost: $5,080,000

Total Annual Cost: $455,000

Available Project Yield: 534 acft/yr

Annual Cost of Water: $853 per acft/yr

This project will include one 1,800 gpm well drilled to 1,225 ft as well as 5,280 ft of transmission pipeline per well and disinfection treatment.

Cost Estimate Summary September 2018 Prices	
Mining Lee County – Southwest Milam WSC Carrizo Wilcox Lee	
Item	***Estimated Costs for Facilities***
Primary Pump Station (1 MGD)	$957,000
Well Fields (Wells, Pumps, and Piping)	$2,135,000
Water Treatment Plant (1 MGD)	$85,000
TOTAL COST OF FACILITIES	**$3,177,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,112,000
Environmental & Archaeology Studies and Mitigation	$345,000
Land Acquisition and Surveying (64 acres)	$310,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$136,000
TOTAL COST OF PROJECT	**$5,080,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$357,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$21,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$24,000
Water Treatment Plant	$51,000
Pumping Energy Costs (24,003 kW-hr @ 0.08 $/kW-hr)	$2,000
TOTAL ANNUAL COST	**$455,000**
Available Project Yield (acft/yr)	534
Annual Cost of Water ($ per acft), based on PF=2	$852

Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$184
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$2.61
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.56

13.3.22 Robertson County

WUG: Robertson County WSC

Strategy: Carrizo Aquifer Development

Source: Carrizo Aquifer

Facilities: Well Field, collection pipes, treatment

Total Capital Cost: $2,351,000

Total Project Cost: $3,440,000

Total Annual Cost: $447,000

Available Project Yield: 550 acft/yr

Annual Cost of Water: $813 per acft/yr or $2.49 per 1,000 gal

This project will include four 150 gpm wells drilled to 1,080 ft as well as 1,000 ft of transmission pipeline per well and disinfection treatment.

Cost Estimate Summary September 2018 Prices	
Robertson County WSC - Carrizo-Wilcox for Robertson County WSC	
Item	***Estimated Costs for Facilities (for 1 well)***
Well Fields (Wells, Pumps, and Piping)	$2,263,000
Water Treatment Plant (1 MGD)	$88,000
TOTAL COST OF FACILITIES	**$2,351,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$823,000
Environmental & Archaeology Studies and Mitigation	$68,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$93,000
TOTAL COST OF PROJECT	**$3,440,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$242,000
Operation and Maintenance	

Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$23,000
Water Treatment Plant	$53,000
Pumping Energy Costs (1,612,774 kW-hr @ 0.08 $/kW-hr)	$129,000
TOTAL ANNUAL COST	**$447,000**
Available Project Yield (acft/yr)	550
Annual Cost of Water ($ per acft), based on PF=2	$813
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$373
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$2.49
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$1.14

13.3.23 Somervell County

WUG: Somervell County Mining

Strategy: Trinity Aquifer Development

Source: Trinity Aquifer

Facilities: Well Field and collection pipes

Total Capital Cost: $617,000

Total Project Cost: $876,000

Total Annual Cost: $85,000

Available Project Yield: 426 acft/yr

Annual Cost of Water: $200 per acft/yr or $0.61 per 1,000 gal (Maximum of Phased Costs)

This project will include three 150 gpm wells drilled to 400 ft as well as 1,000 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Somervell County Mining - Trinity for Somervell County Mining	
Cost based on ENR CCI 11170.28 for September 2018 and	
a PPI of 202.4 for September 2018	
Item	***Estimated Costs for Facilities (for 1 well)***
Well Fields (Wells, Pumps, and Piping)	$617,000
TOTAL COST OF FACILITIES	**$617,000**

Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$216,000
Environmental & Archaeology Studies and Mitigation	$19,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$24,000
TOTAL COST OF PROJECT	**$876,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$62,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$6,000
Pumping Energy Costs (214,907 kW-hr @ 0.08 $/kW-hr)	$17,000
TOTAL ANNUAL COST	**$85,000**
Available Project Yield (acft/yr)	426
Annual Cost of Water ($ per acft), based on PF=1	$200
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$54
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$0.61
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.17

13.3.24 Stephens County

WUG: Stephens County Irrigation

Strategy: Other Aquifer Development

Source: Other Aquifer

Facilities: Well Field and collection pipes

Total Capital Cost: $101,000

Total Project Cost: $143,000

Total Annual Cost: $12,000

Available Project Yield: 30 acft/yr

Annual Cost of Water: $400 per acft/yr or $1.23 per 1,000 gal (Maximum of Phased Costs)

This project will include two 25 gpm wells drilled to 200 ft as well as 600 ft of transmission pipeline.

Cost Estimate Summary September 2018 Prices	
Stephens County Irrigation - Other Aquifer Development	
Item	***Estimated Costs for Facilities (for 1 well)***
Well Fields (Wells, Pumps, and Piping)	$101,000
TOTAL COST OF FACILITIES	**$101,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$35,000
Environmental & Archaeology Studies and Mitigation	$3,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$4,000
TOTAL COST OF PROJECT	**$143,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$10,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$1,000
Pumping Energy Costs (8,790 kW-hr @ 0.08 $/kW-hr)	$1,000
TOTAL ANNUAL COST	**$12,000**
Available Project Yield (acft/yr)	30
Annual Cost of Water ($ per acft), based on PF=1	$400
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$67
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.23
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.20

13.3.25 Stonewall County

WUG: Stonewall County Manufacturing

Strategy: Blaine Aquifer Development

Source: Blaine Aquifer

Facilities: Well Field and collection pipes

Total Capital Cost: $136,000

Total Project Cost: $192,000

Total Annual Cost: $15,000

Available Project Yield: 56 acft/yr

Annual Cost of Water: $268 per acft/yr or $0.82 per 1,000 gal (Maximum of Phased Costs)

This project will include one 50 gpm well drilled to 250 ft as well as 400 ft of transmission pipeline.

Cost Estimate Summary ***September 2018 Prices***	
Stonewall County Manufacturing - Blaine for Stonewall County Manufacturing	
Item	***Estimated Costs for Facilities (for 1 well)***
Well Fields (Wells, Pumps, and Piping)	$136,000
TOTAL COST OF FACILITIES	**$136,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$48,000
Environmental & Archaeology Studies and Mitigation	$2,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$6,000
TOTAL COST OF PROJECT	**$192,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$13,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$1,000
Pumping Energy Costs (14,813 kW-hr @ 0.08 $/kW-hr)	$1,000
TOTAL ANNUAL COST	**$15,000**
Available Project Yield (acft/yr)	56
Annual Cost of Water ($ per acft), based on PF=1	$268
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$36
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$0.82
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.11

WUG: Stonewall County Mining

Strategy: Blaine Aquifer Development

Source: Blaine Aquifer

Facilities: Well Field and collection pipes

Total Capital Cost: $482,000

Total Project Cost: $687,000

Total Annual Cost: $81,000

Available Project Yield: 372 acft/yr

Annual Cost of Water: $218 per acft/yr or $0.67 per 1,000 gal (Maximum of Phased Costs)

This project will include six 50 gpm wells drilled to 250 ft as well as 500 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Stonewall County Mining - Blaine for Stonewall County Mining	
Item	***Estimated Costs for Facilities (for 1 well)***
Well Fields (Wells, Pumps, and Piping)	$482,000
TOTAL COST OF FACILITIES	**$482,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$169,000
Environmental & Archaeology Studies and Mitigation	$17,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$19,000
TOTAL COST OF PROJECT	**$687,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$48,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$5,000
Pumping Energy Costs (349,924 kW-hr @ 0.08 $/kW-hr)	$28,000
TOTAL ANNUAL COST	**$81,000**
Available Project Yield (acft/yr)	372
Annual Cost of Water ($ per acft), based on PF=1	$218
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$89
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$0.67
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.27

13.3.26 Throckmorton County

WUG: Throckmorton County Mining

Strategy: Cross Timbers Aquifer Development

Source: Cross Timbers Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $211,000

Total Project Cost: $344,000

Total Annual Cost: $27,000

Available Project Yield: 84 acft/yr

Annual Cost of Water: $321 per acft/yr or $0.99 per 1,000 gal

This project will include four 25 gpm wells drilled to 200 ft as well as 200 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Throckmorton County-Mining - Cross Timbers Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$211,000
TOTAL COST OF FACILITIES	**$211,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$74,000
Environmental & Archaeology Studies and Mitigation	$24,000
Land Acquisition and Surveying (3 acres)	$25,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$10,000
TOTAL COST OF PROJECT	**$344,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$24,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$2,000
Pumping Energy Costs (10,425 kW-hr @ 0.08 $/kW-hr)	$1,000
TOTAL ANNUAL COST	**$27,000**
Available Project Yield (acft/yr)	84
Annual Cost of Water ($ per acft), based on PF=1	$321

Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$36
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$0.99
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.11

WUG: Throckmorton County Irrigation

Strategy: Cross Timbers Aquifer Development

Source: Cross Timbers

Facilities: Well Field, collection pipes

Total Capital Cost: $287,000

Total Project Cost: $405,000

Total Annual Cost: $33,000

Available Project Yield: 152 acft/yr

Annual Cost of Water: $217 per acft/yr or $0.67 per 1,000 gal

This project will include three 94 gpm wells drilled to 200 ft as well as 200 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Throckmorton County-Irrigation - Cross Timbers Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$287,000
TOTAL COST OF FACILITIES	**$287,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$100,000
Environmental & Archaeology Studies and Mitigation	$3,000
Land Acquisition and Surveying (2 acres)	$4,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$11,000
TOTAL COST OF PROJECT	**$405,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$28,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$3,000
Pumping Energy Costs (18,902 kW-hr @ 0.08 $/kW-hr)	$2,000
TOTAL ANNUAL COST	**$33,000**

Available Project Yield (acft/yr)	152
Annual Cost of Water ($ per acft), based on PF=3.75	$217
Annual Cost of Water After Debt Service ($ per acft), based on PF=3.75	$33
Annual Cost of Water ($ per 1,000 gallons), based on PF=3.75	$0.67
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=3.75	$0.10

13.3.27 Washington County

WUG: Brenham

Strategy: Gulf Coast Aquifer Development

Source: Gulf Coast Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $1,911,000

Total Project Cost: $2,958,000

Total Annual Cost: $331,000

Available Project Yield: 628 acft/yr

Annual Cost of Water: $527 per acft/yr or $1.62 per 1,000 gal

This project will include three 154 gpm wells drilled to 820 ft as well as 5,280 ft of transmission pipeline per well and disinfection treatment.

Cost Estimate Summary September 2018 Prices	
Brenham - Brenham Gulf Coast Washington	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$1,852,000
Water Treatment Plant (0.6 MGD)	$59,000
TOTAL COST OF FACILITIES	**$1,911,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$669,000
Environmental & Archaeology Studies and Mitigation	$181,000
Land Acquisition and Surveying (16 acres)	$117,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$80,000
TOTAL COST OF PROJECT	**$2,958,000**

ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$208,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$19,000
Water Treatment Plant	$35,000
Pumping Energy Costs (865,482 kW-hr @ 0.08 $/kW-hr)	$69,000
TOTAL ANNUAL COST	**$331,000**
Available Project Yield (acft/yr)	628
Annual Cost of Water ($ per acft), based on PF=1	$527
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$196
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.62
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.60

WUG: Corix Utilities Texas Inc

Strategy: Gulf Coast Aquifer Development

Source: Gulf Coast Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $1,913,000

Total Project Cost: $2,892,000

Total Annual Cost: $255,000 (Maximum of Annual Costs)

Available Project Yield: 281 acft/yr

Annual Cost of Water: $512 per acft/yr or $1.57 per 1,000 gal (Maximum of Phased Costs)

This project will include three 140 gpm wells drilled to 960 ft as well as 5,280 ft of transmission pipeline per well and disinfection treatment.

Cost Estimate Summary September 2018 Prices	
Corix Utilities Texas Inc – Corix Utilities Texas Inc Gulf Coast Washington	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$1,863,000
Water Treatment Plant (0.5 MGD)	$50,000
TOTAL COST OF FACILITIES	**$1,913,000**

Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$670,000
Environmental & Archaeology Studies and Mitigation	$149,000
Land Acquisition and Surveying (16 acres)	$82,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$78,000
TOTAL COST OF PROJECT	**$2,892,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$203,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$19,000
Water Treatment Plant	$30,000
Pumping Energy Costs (37,373 kW-hr @ 0.08 $/kW-hr)	$3,000
TOTAL ANNUAL COST	**$255,000**
Available Project Yield (acft/yr)	498
Annual Cost of Water ($ per acft), based on PF=1	$512
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$104
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.57
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.32

WUG: Washington County Mining

Strategy: Gulf Coast Aquifer Development

Source: Gulf Coast Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $2,129,000

Total Project Cost: $3,348,000

Total Annual Cost: $379,000

Available Project Yield: 745 acft/yr

Annual Cost of Water: $509 per acft/yr or $1.56 per 1,000 gal

This project will include three 154 gpm wells drilled to 820 ft as well as 21,120 ft of transmission pipeline per well and disinfection.

Cost Estimate Summary September 2018 Prices	
Mining Washington County - Mining Gulf Coast Washington	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$2,062,000
Water Treatment Plant (0.7 MGD)	$67,000
TOTAL COST OF FACILITIES	**$2,129,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$745,000
Environmental & Archaeology Studies and Mitigation	$235,000
Land Acquisition and Surveying (21 acres)	$149,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$90,000
TOTAL COST OF PROJECT	**$3,348,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$236,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$21,000
Water Treatment Plant	$40,000
Pumping Energy Costs (1,026,726 kW-hr @ 0.08 $/kW-hr)	$82,000
TOTAL ANNUAL COST	**$379,000**
Available Project Yield (acft/yr)	745
Annual Cost of Water ($ per acft), based on PF=1	$509
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$192
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.56
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.59

13.3.28 Williamson County

WUG: City of Bartlett

Strategy: Trinity Aquifer Development (Bell County)

Source: Trinity Aquifer

Facilities: Well Field, collection pipes, transmission and treatment

Total Capital Cost: $1,317,000

Total Project Cost: $1,872,000

Total Annual Cost: $184,000

Available Project Yield: 275 acft/yr (After Full Implementation)

Annual Cost of Water: $669 per acft/yr or $2.05 per 1,000 gal (Maximum of Phased Costs)

This project will include two 300 gpm wells drilled to 800 ft as well as 1,000 ft of transmission pipeline per well and disinfection treatment.

Cost Estimate Summary September 2018 Prices	
City of Bartlett - Trinity Aquifer Development (Bell County)	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$1,265,000
Water Treatment Plant (0.5 MGD)	$52,000
TOTAL COST OF FACILITIES	**$1,317,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$461,000
Environmental & Archaeology Studies and Mitigation	$21,000
Land Acquisition and Surveying (3 acres)	$22,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$51,000
TOTAL COST OF PROJECT	**$1,872,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$132,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$13,000
Water Treatment Plant	$31,000
Advanced Water Treatment Facility	$0
Pumping Energy Costs (98,939 kW-hr @ 0.08 $/kW-hr)	$8,000
TOTAL ANNUAL COST	**$184,000**
Available Project Yield (acft/yr)	275
Annual Cost of Water ($ per acft), based on PF=2	$669
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$189

Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$2.05
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.58

WUG: Williamson County Irrigation

Strategy: Edwards Aquifer Development

Source: Edwards Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $458,000

Total Project Cost: $675,000

Total Annual Cost: $57,000 (Maximum of Phased Costs)

Available Project Yield: 172 acft/yr

Annual Cost of Water: $331 per acft/yr or $1.02 per 1,000 gal (Maximum of Phased Costs)

This project will include three 188 gpm wells drilled to 300 ft as well as 200 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Williamson County-Irrigation - Edwards Aquifer (BFZ) Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$458,000
TOTAL COST OF FACILITIES	**$458,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$160,000
Environmental & Archaeology Studies and Mitigation	$18,000
Land Acquisition and Surveying (2 acres)	$21,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$18,000
TOTAL COST OF PROJECT	**$675,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$48,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$5,000
Pumping Energy Costs (49,017 kW-hr @ 0.08 $/kW-hr)	$4,000

TOTAL ANNUAL COST	**$57,000**
Available Project Yield (acft/yr)	172
Annual Cost of Water ($ per acft), based on PF=3.75	$331
Annual Cost of Water After Debt Service ($ per acft), based on PF=3.75	$52
Annual Cost of Water ($ per 1,000 gallons), based on PF=3.75	$1.02
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=3.75	$0.16

13.3.29 Young County

WUG: Young County Mining

Strategy: Cross Timbers Aquifer Development

Source: Cross Timbers Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $316,000

Total Project Cost: $514,000

Total Annual Cost: $41,000

Available Project Yield: 181 acft/yr

Annual Cost of Water: $227 per acft/yr or $0.70 per 1,000 gal

This project will include six 25 gpm wells drilled to 200 ft as well as 200 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Young County-Mining - Cross Timbers Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$316,000
TOTAL COST OF FACILITIES	**$316,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$111,000
Environmental & Archaeology Studies and Mitigation	$36,000
Land Acquisition and Surveying (4 acres)	$37,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$14,000
TOTAL COST OF PROJECT	**$514,000**

ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$36,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$3,000
Pumping Energy Costs (22,463 kW-hr @ 0.08 $/kW-hr)	$2,000
TOTAL ANNUAL COST	**$41,000**
Available Project Yield (acft/yr)	181
Annual Cost of Water ($ per acft), based on PF=1	$227
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$28
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$0.70
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.08

WUG: Young County Irrigation

Strategy: Cross Timbers Aquifer Development

Source: Cross Timbers Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $382,000

Total Project Cost: $540,000

Total Annual Cost: $46,000

Available Project Yield: 450 acft/yr

Annual Cost of Water: $102 per acft/yr or $0.31 per 1,000 gal

This project will include four 94 gpm wells drilled to 200 ft as well as 200 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Young County-Irrigation - Cross Timbers Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$382,000
TOTAL COST OF FACILITIES	**$382,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$134,000
Environmental & Archaeology Studies and Mitigation	$4,000

Land Acquisition and Surveying (3 acres)	$5,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$15,000
TOTAL COST OF PROJECT	**$540,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$38,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$4,000
Pumping Energy Costs (55,962 kW-hr @ 0.08 $/kW-hr)	$4,000
Purchase of Water (acft/yr @ $/acft)	$0
TOTAL ANNUAL COST	**$46,000**
Available Project Yield (acft/yr)	450
Annual Cost of Water ($ per acft), based on PF=3.75	$102
Annual Cost of Water After Debt Service ($ per acft), based on PF=3.75	$18
Annual Cost of Water ($ per 1,000 gallons), based on PF=3.75	$0.31
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=3.75	$0.05

WUG: Young County Livestock

Strategy: Cross Timbers Aquifer Development

Source: Cross Timbers Aquifer

Facilities: Well Field, collection pipes

Total Capital Cost: $105,000

Total Project Cost: $151,000

Total Annual Cost: $12,000

Available Project Yield: 11 acft/yr

Annual Cost of Water: $1,091 per acft/yr or $3.35 per 1,000 gal

This project will include two 25 gpm wells drilled to 200 ft as well as 200 ft of transmission pipeline per well.

Cost Estimate Summary September 2018 Prices	
Young County-Livestock - Cross Timbers Aquifer Development	
Item	***Estimated Costs for Facilities***
Well Fields (Wells, Pumps, and Piping)	$105,000
TOTAL COST OF FACILITIES	**$105,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$37,000
Environmental & Archaeology Studies and Mitigation	$2,000
Land Acquisition and Surveying (1 acres)	$2,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$5,000
TOTAL COST OF PROJECT	**$151,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$11,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$1,000
TOTAL ANNUAL COST	**$12,000**
Available Project Yield (acft/yr)	11
Annual Cost of Water ($ per acft), based on PF=1	$1,091
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$91
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$3.35
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.28

13.4 Miscellaneous Purchases, Interconnects & Reallocations

13.4.1 Bell County

WUG: 439 WSC

Strategy: Purchase Raw Water Supply from Fort Hood

Source: Fort Hood (Lake Belton)

Facilities: None; purchasing raw in place in Lake Belton

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $62,600

Available Project Yield: 626 acft/yr

Annual Cost of Water: $100 per acft/yr or $0.31 per 1,000 gal

This project will include contracting with Fort Hood to purchase portions of Fort Hood's projected surplus of raw water supply in Lake Belton. Water purchased under this strategy will be diverted, treated, and delivered to 439 WSC by Bell County WCID No. 1 using existing infrastructure. Cost of raw water is assumed and is estimated based on an approximately 33 percent markup to typical raw water wholesale cost from the Brazos River Authority.

WUG: 439 WSC

Strategy: Purchase Diversion, Treatment, and Delivery Capacity from Bell County WCID No. 1

Source: 439 WSC (Lake Belton)

Facilities: None; existing infrastructure assumed sufficient.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $1,161,000

Available Project Yield: 1,161 acft/yr

Annual Cost of Water: $1,000 per acft/yr or $3.07 per 1,000 gal

This strategy includes contracting with the Bell County WCID No. 1 to increase allocated capacity to divert, treat, and deliver raw water from Lake Belton to 439 WSC by Bell County WCID No.1. Cost of water estimated based on unit cost of water associated with expansion of Bell County WCID No. 1 treatment facilities.

WUG: Elm Creek WSC

Strategy: Reallocation of Supply from Moffat WSC

Source: Moffat WSC

Facilities: None; existing infrastructure assumed sufficient.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $1,161,000

Available Project Yield: 154 acft/yr

Annual Cost of Water: $978 per acft/yr or $3.00 per 1,000 gal

This strategy involves reallocation/purchasing a portion of Moffat WSC's surplus supply from Bluebonnet WSC. Reimbursement/purchase cost of water assumed equal to Moffat WSC current contract with Bluebonnet WSC.

WUG: Harker Heights

Strategy: Purchase Raw Water Supply from Fort Hood

Source: Fort Hood (Lake Belton)

Facilities: None; purchasing raw in place in Lake Belton

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $48,700

Available Project Yield: 487 acft/yr

Annual Cost of Water: $100 per acft/yr or $0.31 per 1,000 gal

This project will include contracting with Fort Hood to purchase portions of Fort Hood's projected surplus of raw water supply in Lake Belton. Water purchased under this strategy will be diverted, treated, and delivered to Harker Heights by Bell County WCID No. 1 using existing infrastructure. Cost of raw water is assumed and is estimated based on an approximately 33 percent markup to typical raw water wholesale cost from the Brazos River Authority.

WUG: Harker Heights

Strategy: Purchase Diversion, Treatment, and Delivery Capacity from Bell County WCID No. 1

Source: Harker Heights (Lake Belton)

Facilities: None; existing infrastructure assumed sufficient.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $1,232,000

Available Project Yield: 1,232 acft/yr

Annual Cost of Water: $1,000 per acft/yr or $3.07 per 1,000 gal

This strategy includes contracting with the Bell County WCID No. 1 to increase allocated capacity to divert, treat, and deliver raw water from Lake Belton to Harker Heights by Bell County WCID No.1. Cost of water estimated based on unit cost of water associated with expansion of Bell County WCID No. 1 treatment facilities.

WUG: Bell County-Other

Strategy: Purchase Additional Water Supply 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: $387,024

Available Project Yield: 264 acft/yr

Annual Cost of Water: $1,466 per acft/yr or $4.50 per 1,000 gal

This strategy includes increasing contracted supply from Central Texas WSC. Unit cost based on retail costs for Kempner WSC.

WUG: Bell County-Manufacturing

Strategy: Purchase Reuse Supplies from Bell County WCID No. 1 (North)

Source: Bell County WCID No. 1

Facilities: None; existing infrastructure assumed sufficient.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $139,612

Available Project Yield: 152 acft/yr

Annual Cost of Water: $919 per acft/yr or $2.82 per 1,000 gal

This strategy includes purchasing existing reuse supplies; unit cost of reuse water based on Bell County WCID No. 1's cost to develop reuse supply.

13.4.2 Callahan County

WUG: City of Baird

Strategy: Additional Purchase from Abilene

Source: City of Abilene

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $277,816 (Maximum of Phased Costs)

Available Project Yield: 164 acft/yr

Annual Cost of Water: $1,694 per acft/yr

This project will include a contract increase of up to 164 acft/yr additional utilizing existing infrastructure from Abilene to the City of Baird.

WUG: Callahan County – Mining

Strategy: Additional Purchase from EULA WSC and City of Cross Plains

Source: EULA WSC and City of Cross Plains

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $674,934 (Maximum of Phased Costs)

Available Project Yield: 141 acft/yr

Annual Cost of Water: $6,617 per acft/yr

This project will include a contract increase of up to 141 acft/yr additional utilizing existing infrastructure from EULA WSC and City of Cross Plains to the Callahan County – Mining.

13.4.3 Coryell County

WUG: Multi-County WSC

Strategy: Purchase Additional Treated Water Supply 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:	maximum of $43,560
Available Project Yield:	174 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 174 additional acft/yr utilizing existing infrastructure from the City of Hamilton to Multi-County WSC.

WUG: Flat WSC

Strategy: Purchase Additional Treated Water Supply from the City of Gatesville

Source: City of Gatesville

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	maximum of $28,798
Available Project Yield:	22 acft/yr
Annual Cost of Water:	$1,309 per acft/yr or $4.02 per 1,000 gal (City of Gatesville Wholesale Cost)

This project will include a contract increase of up to 22 additional acft/yr utilizing existing infrastructure from the City of Gatesville to Flat WSC.

WUG: City of Copperas Cove

Strategy: Purchase Raw Water Supply from Fort Hood

Source: Fort Hood (Lake Belton)

Facilities: None; purchasing raw in place in Lake Belton

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	maximum of $128,500
Available Project Yield:	1,285 acft/yr

Annual Cost of Water: $100 per acft/yr or $0.31 per 1,000 gal

This project will include contracting with Fort Hood to purchase portions of Fort Hood's projected surplus of raw water supply in Lake Belton. Water purchased under this strategy will be diverted, treated, and delivered to Copperas Cove by Bell County WCID No. 1 using existing infrastructure. Cost of raw water is assumed and is estimated based on an approximately 33 percent markup to typical raw water wholesale cost from the Brazos River Authority.

WUG: City of Copperas Cove

Strategy: Purchase Diversion, Treatment, and Delivery Capacity from Bell County WCID No. 1

Source: City of Copperas Cove (Lake Belton)

Facilities: None; existing infrastructure assumed sufficient.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: maximum of $1,285,000

Available Project Yield: 1,285 acft/yr

Annual Cost of Water: $1,000 per acft/yr or $3.07 per 1,000 gal

This strategy includes contracting with the Bell County WCID No. 1 to increase allocated capacity to divert, treat, and deliver raw water from Lake Belton to City of Copperas Cove by Bell County WCID No.1. Cost of water estimated based on unit cost of water associated with expansion of Bell County WCID No. 1 treatment facilities.

WUG: Fort Gates WSC

Strategy: Purchase Diversion, Treatment, and Delivery Capacity from City of Gatesville

Source: Fort Gates WSC

Facilities: None; existing infrastructure assumed sufficient.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: maximum of $234,400

Available Project Yield: 200 acft/yr

Annual Cost of Water: $1,172 per acft/yr or $3.60 per 1,000 gal

This strategy includes increasing existing contract with the City of Gatesville to divert, treat, and deliver additional raw water supply for Fort Gates WSC. Annual cost of water estimated based on unit cost of water associated with expansion of City of Gatesville treatment facilities.

WUG: Fort Gates WSC

Strategy: Purchase Treated Water Supply from City of Gatesville

Source: City of Gatesville

Facilities: None; existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: maximum of $248,710

Available Project Yield: 190 acft/yr

Annual Cost of Water: $1,309 per acft/yr or $4.02 per 1,000 gal (City of Gatesville Wholesale Cost)

This strategy includes contracting with the City of Gatesville for treated water supply beyond what contracted Fort Gates WSC's raw water supply will yield.

WUG: City of Gatesville

Strategy: Purchase Additional Raw Water Supply from the Brazos River Authority

Source: Coryell County OCR

Facilities: None; existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: maximum of $126,990

Available Project Yield: 1,660 acft/yr

Annual Cost of Water: $76.50/acft

This strategy includes increasing existing raw water purchase contracts with the Brazos River Authority; water supplied under this increase will be sourced from the new Coryell County OCR.

13.4.4 Erath County

WUG: Erath County-Manufacturing

Strategy: Purchase Additional Supply from the City of Stephenville

Source: City of Stephenville

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $4,920 (Maximum of Phased Costs)

Available Project Yield: 2 acft/yr

Annual Cost of Water: $ 2,460.00 per acft/yr or $7.55 per 1,000 gal

This project will include a contract increase of up to 2 additional acft/yr utilizing existing infrastructure from the City of Stephenville to Erath County-Manufacturing. Annual cost of water is estimated based on City of Stephenville's retail service rate structure.

13.4.5 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: $86,829

Available Project Yield: 76 acft/yr

Annual Cost of Water: $ 1,142.49 per acft/yr or $3.51 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.

13.4.6 Hill County

WUG: Chatt WSC

Strategy: Purchase Additional Supply from Files Valley WSC

Source: Files Valley WSC via Aquilla Water Supply

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $7,820

Available Project Yield: 12 acft/yr

Annual Cost of Water: $652 per acft/yr or $2.00 per 1,000 gal (White Bluff base rates)

This project will include a voluntary sale of 12 acft/yr from Files Valley WSC utilizing existing infrastructure from Aquilla Water Supply to Chatt WSC.

WUG: Post Oak SUD

Strategy: Purchase Additional Supply from Corsicana

Source: Corsicana

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $281,274

Available Project Yield: 208 acft/yr

Annual Cost of Water: $1,352 per acft/yr

This project will include additional sale of 208 acft/yr utilizing existing infrastructure from Corsicana to Post Oak SUD.

WUG: Hill County-Other

Strategy: Purchase Additional Supply from Brandon-Irene WSC

Source: Brandon-Irene WSC

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	$114,048
Available Project Yield:	70 acft/yr
Annual Cost of Water:	$1,629 per acft/yr or $5.00 per 1,000 gal (based on Brandon-Irene tier 1 rates)

This project will include additional sale of up to 70 acft/yr utilizing existing infrastructure from Brandon-Irene WSC to Hood County-Other.

13.4.7 Jones County

WUG: Jones County Other

Strategy: Purchase Additional Supplies from City of Abilene

Source: City of Abilene

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	$283,987
Available Project Yield:	121 acft/yr
Annual Cost of Water:	$2,347 per acft/yr

WUG: Jones County Mining

Strategy: Purchase Additional Supplies from City of Abilene

Source: City of Abilene

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	$359,091
Available Project Yield:	153 acft/yr
Annual Cost of Water:	$2,347 per acft/yr

WUG: Jones County Irrigation

Strategy: Purchase Additional Supplies from City of Abilene

Source: City of Abilene

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	$248,782
Available Project Yield:	106 acft/yr
Annual Cost of Water:	$2,347 per acft/yr

13.4.8 Johnson County

WUG: Bethesda WSC

Strategy: Additional Purchase from the City of Fort Worth

Source: The City of Fort Worth

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	$22,833
Available Project Yield:	43 acft/yr
Annual Cost of Water:	$531 per acft/yr

This project will include a contract increase of up to 43 additional acft/yr utilizing existing infrastructure from the City of Fort Worth to Bethesda WSC.

WUG: City of Burleson

Strategy: Additional Purchase from the City of Fort Worth

Source: The City of Fort Worth

Facilities: Transmission pipeline and primary pump station

Total Capital Cost:	$13,593,000
Total Project Cost:	$19,163,000
Total Annual Cost:	$2,306,000
Available Project Yield:	4,075 acft/yr
Annual Cost of Water:	$566 per acft/yr

This project will include a contract increase of up to 4,075 additional acft/yr updating infrastructure from the City of Fort Worth to City of Burleson.

Cost Estimate Summary September 2018 Prices	
Johnson County Mining - Johnson County Burleson to Fort Worth Pipeline	
Item	***Estimated Costs for Facilities***
Primary Pump Station (4.6 MGD)	$76,000
Transmission Pipeline (18 in dia., 16 miles)	$13,441,000
Transmission Pump Station(s) & Storage Tank(s)	$76,000
TOTAL COST OF FACILITIES	**$13,593,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$4,086,000
Environmental & Archaeology Studies and Mitigation	$430,000
Land Acquisition and Surveying (83 acres)	$541,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$513,000
TOTAL COST OF PROJECT	**$19,163,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$1,348,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$134,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$4,000
Pumping Energy Costs (1,993,822 kW-hr @ 0.08 $/kW-hr)	$160,000
Purchase of Water (4,075 acft/yr @ 162 $/acft)	$660,000
TOTAL ANNUAL COST	**$2,306,000**
Available Project Yield (acft/yr)	4,075
Annual Cost of Water ($ per acft), based on PF=2	$566
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$235
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$1.74
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.72

WUG: City of Crowley

Strategy: Additional Purchase from the City of Fort Worth

Source: The City of Fort Worth

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $11,151

Available Project Yield: 21 acft/yr

Annual Cost of Water: $531 per acft/yr

This project will include a contract increase of up to 21 additional acft/yr utilizing existing infrastructure from the City of Fort Worth to City of Crowley.

WUG: City of Forth Worth

Strategy: Additional Purchase from the Tarrant Regional Water District

Source: The Tarrant Regional Water District

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $822,498

Available Project Yield: 841 acft/yr

Annual Cost of Water: $978 per acft/yr

This project will include a contract increase of up to 841 additional acft/yr utilizing existing infrastructure from the Tarrant Regional Water District to City of Fort Worth.

WUG: City of Mansfield

Strategy: Additional Purchase from the Tarrant Regional Water District

Source: The Tarrant Regional Water District

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $443,034

Available Project Yield: 453 acft/yr

Annual Cost of Water: $978 per acft/yr

This project will include a contract increase of up to 453 additional acft/yr utilizing existing infrastructure from the Tarrant Regional Water District to City of Mansfield.

WUG: Mountain Peak SUD

Strategy: Additional Purchase from Midlothian

Source: Midlothian

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $53,790

Available Project Yield: 55 acft/yr

Annual Cost of Water: $978 per acft/yr

This project will include a contract increase of up to 55 additional acft/yr utilizing existing infrastructure from Midlothian to Mountain Peak SUD.

WUG: City of Venus

Strategy: Additional Purchase from Midlothian

Source: Midlothian

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $642,546

Available Project Yield: 657 acft/yr

Annual Cost of Water: $978 per acft/yr

This project will include a contract increase of up to 657 additional acft/yr utilizing existing infrastructure from Midlothian to City of Venus.

WUG: Johnson County – Steam-Electric

Strategy: Additional Purchase from reuse water from City of Cleburne

Source: City of Cleburne

Facilities: Pump station, transmission pipeline, storage tanks, and water treatment plant

Total Capital Cost: $4,677,000

Total Project Cost: $6,649,000

Total Annual Cost: $674,000

Available Project Yield: 571 acft/yr

Annual Cost of Water: $1,180 per acft/yr

This project will include a contract increase of up to 571 additional acft/yr utilizing new infrastructure from Cleburne to Johnson County – Steam Electric.

Cost Estimate Summary ***September 2018 Prices***	
Johnson County Steam-Electric - Johnson County Steam-Electric Pipeline	
Item	***Estimated Costs for Facilities***
Primary Pump Station (1 MGD)	$878,000
Transmission Pipeline (18 in dia., 5 miles)	$3,799,000
TOTAL COST OF FACILITIES	**$4,677,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,447,000
Environmental & Archaeology Studies and Mitigation	$155,000
Land Acquisition and Surveying (29 acres)	$192,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$178,000
TOTAL COST OF PROJECT	**$6,649,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$468,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$38,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$22,000
Pumping Energy Costs (53,697 kW-hr @ 0.08 $/kW-hr)	$4,000
Purchase of Water (2,555 acft/yr @ 55.55 $/acft)	$142,000
TOTAL ANNUAL COST	**$674,000**
Available Project Yield (acft/yr)	571
Annual Cost of Water ($ per acft), based on PF=2	$1,180
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$361
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$3.62
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$1.11

WUG: Johnson County – Mining

Strategy: Additional Purchase from reuse water from City of Cleburne

Source: City of Cleburne

Facilities: Pump station, transmission pipeline, storage tanks, and water treatment plant

Total Capital Cost: $5,055,000

Total Project Cost: $7,173,000

Total Annual Cost: $742,000

Available Project Yield: 2,555 acft/yr

Annual Cost of Water: $290 per acft/yr

This project will include a contract increase of up to 2,555 additional acft/yr utilizing new infrastructure from Cleburne to Johnson County – Mining.

Cost Estimate Summary September 2018 Prices	
Johnson County Mining - Johnson County Mining Pipeline	
Cost based on ENR CCI 11170.28 for September 2018 and	
a PPI of 202.4 for September 2018	
Item	***Estimated Costs for Facilities***
Primary Pump Station (4.6 MGD)	$1,256,000
Transmission Pipeline (18 in dia., 5 miles)	$3,799,000
TOTAL COST OF FACILITIES	**$5,055,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,579,000
Environmental & Archaeology Studies and Mitigation	$155,000
Land Acquisition and Surveying (29 acres)	$192,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$192,000
TOTAL COST OF PROJECT	**$7,173,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$505,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$38,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$31,000
Pumping Energy Costs (328,761 kW-hr @ 0.08 $/kW-hr)	$26,000

Purchase of Water (2,555 acft/yr @ 55.55 $/acft)	$142,000
TOTAL ANNUAL COST	**$742,000**
Available Project Yield (acft/yr)	2,555
Annual Cost of Water ($ per acft), based on PF=2	$290
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$93
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$0.89
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.28

13.4.9 Limestone County

WUG: City of Mexia

Strategy: Purchase Additional Supply from Bistone Municipal Water Supply District

Source: Bistone Municipal Water Supply District

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $130,680

Available Project Yield: 363 acft/yr

Annual Cost of Water: $360 per acft/yr or $1.10 per 1,000 gal

This project will include a contract increase of up to 363 acft/yr of additional groundwater supply utilizing existing infrastructure from the Bistone Municipal Water Supply District to the City of Mexia, with some sales to the City of Wortham in Region C. Cost of water estimated based on Bistone Municipal Water Supply District's cost of developing additional supplies.

13.4.10 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: $300,000

Available Project Yield: 600 acft/yr

Annual Cost of Water: $585 per acft/yr (City of Lampasas Wholesale Costs)

This project will include a treated water contract increase of up to 600 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.

WUG: Lampasas County Manufacturing

Strategy: Increase treated water contract from City of Lampasas

Source: City of Lampasas

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $8,000

Available Project Yield: 16 acft/yr

Annual Cost of Water: $500 per acft/yr (City of Lampasas Wholesale Costs)

This project will include a treated water contract increase of up to 16 additional acft/yr utilizing existing infrastructure from Lampasas Manufacturing to the City of Lampasas.

13.4.11 McLennan County

WUG: Axtell WSC

Strategy: Purchase water from City of Waco

Source: City of Waco

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $340,392

Available Project Yield: 104 acft/yr

Annual Cost of Water: $3,273 per acft/yr

This project will include a treated water contract increase for additional 104 acft/yr utilizing existing infrastructure from City of Waco to the City of Bellmead.

WUG: East Crawford WSC

Strategy: Purchase water from City of Waco

Source: City of Waco

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $369,849

Available Project Yield: 113 acft/yr

Annual Cost of Water: $3,273 per acft/yr

This project will include a treated water contract increase for additional 113 acft/yr utilizing existing infrastructure from City of Waco to the East Crawford WSC.

WUG: EOL WSC

Strategy: Purchase water from City of Waco

Source: City of Waco

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $451,674

Available Project Yield: 138 acft/yr

Annual Cost of Water: $3,273 per acft/yr

This project will include a treated water contract increase for additional 138 acft/yr utilizing existing infrastructure from City of Waco to the EOL WSC.

WUG: City of Hewitt

Strategy: Purchase water from City of Waco

Source: City of Waco

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $1,668,444

Available Project Yield: 771 acft/yr

Annual Cost of Water: $2,164 per acft/yr

This project will include additional 771 acft/yr utilizing existing infrastructure from City of Waco to the City of Hewitt.

WUG: Leroy Tours Gerald WSC

Strategy: Purchase water from Brazos River Authority

Source: BRA System Operations Supplies

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $386,656

Available Project Yield: 86 acft/yr

Annual Cost of Water: $4,496 per acft/yr

This project will include additional 86 acft/yr utilizing infrastructure developed by FHLM WSC.

WUG: Leroy Tours Gerald WSC

Strategy: Alternative Purchase water from City of Waco

Source: City of Waco

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	$281,478
Available Project Yield:	86 acft/yr
Annual Cost of Water:	$3,273 per acft/yr

This project will include additional 86 acft/yr utilizing existing infrastructure from City of Waco to the Leroy Tours Gerald WSC.

WUG: City of Mart

Strategy: Purchase water from City of Waco

Source: City of Waco

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	$528,016
Available Project Yield:	244 acft/yr
Annual Cost of Water:	$2,164 per acft/yr

This project will include additional 244 acft/yr utilizing existing infrastructure from City of Waco to the City of Mart.

WUG: McLennan County Manufacturing

Strategy: Purchase water from City of Waco-WMARSS Flat Creek

Source: City of Waco-WMARSS Flat Creek

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	$875,000
Available Project Yield:	2,500 acft/yr
Annual Cost of Water:	$350 per acft/yr

This project will include additional 2,500 acft/yr utilizing existing infrastructure from City of Waco to the McLennan County Manufacturing.

WUG: McLennan County Mining

Strategy: Purchase water from City of Waco-WMARSS Flat Creek

Source: City of Waco-WMARSS Flat Creek

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $1,120,000

Available Project Yield: 3,200 acft/yr

Annual Cost of Water: $350 per acft/yr

This project will include additional 3,200 acft/yr utilizing existing infrastructure from City of Waco to the McLennan County Mining.

13.4.12 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: $27,013,000

Total Project Cost: $38,106,000

Total Annual Cost: $3,525,000

Available Project Yield: 1,839 acft/yr

Annual Cost of Water: $1,914 per acft/yr or $5.87 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 $116.94/acft. Project costs to be shared between the two entities.

Cost Estimate Summary September 2018 Prices	
City of Sweetwater – Sweetwater Nolan	
Item	***Estimated Costs for Facilities***
Primary Pump Station (1.7 MGD)	$5,047,000
Transmission Pipeline (12 in dia., 40 miles)	$14,669,000
Transmission Pump Station(s) & Storage Tank(s)	$6,147,000
Storage Tanks (Other Than at Booster Pump Stations)	$1,150,000
TOTAL COST OF FACILITIES	**$27,013,000**

Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$8,721,000
Environmental & Archaeology Studies and Mitigation	$1,011,000
Land Acquisition and Surveying (201 acres)	$341,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$1,020,000
TOTAL COST OF PROJECT	**$38,106,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$2,681,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$186,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$210,000
Pumping Energy Costs (3,303,353 kW-hr @ 0.08 $/kW-hr)	$264,000
Purchase of Water (1,839 acft/yr @ 100 $/acft)	$184,000
TOTAL ANNUAL COST	**$3,525,000**
Available Project Yield (acft/yr)	1,839
Annual Cost of Water ($ per acft), based on PF=1	$1,914
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$456
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$5.87
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$1.40

WUG: Bitter Creek WSC

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: $236,099

Available Project Yield: 1,874 acft/yr

Annual Cost of Water: $1,031per acft/yr

This project will include a contract increase of up to 1,874 additional acft/yr utilizing existing infrastructure from the City of Sweetwater to Bitter Creek WSC.

WUG: City of Roscoe

Strategy: Additional Purchase from the City of Sweetwater

Source: City of Sweetwater

Facilities: None, existing infrastructure assumed sufficient

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	$110,317
Available Project Yield:	107 acft/yr
Annual Cost of Water:	$1,031per acft/yr

This project will include a contract increase of up to 107 additional acft/yr utilizing existing infrastructure from the City of Sweetwater to City of Roscoe.

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:	$5,155
Available Project Yield:	5 acft/yr
Annual Cost of Water:	$1,031 per acft/yr

This project will include a contract increase of up to 5 additional acft/yr utilizing existing infrastructure from the City of Sweetwater to Nolan County Manufacturing.

WUG: Nolan County Mining

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:	$223,861
Available Project Yield:	218 acft/yr
Annual Cost of Water:	$1,031per acft/yr

This project will include a contract increase of up to 218 additional acft/yr utilizing existing infrastructure from the City of Sweetwater to Nolan County Mining.

13.4.13 Palo Pinto County

WUG: City of Gordon

Strategy: Purchase water from City of Strawn

Source: City of Strawn

Facilities: Wholesale rate included only. Not enough information to cost delivery.

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	$318,549
Available Project Yield:	147 acft/yr
Annual Cost of Water:	$2,167 per acft/yr or $6.65 per 1,000

This project will include a contract for the purchase of water up to 147 acft/yr. Infrastructure such as pipelines, pump stations, and storage tanks will be needed once the location(s) of use are determined.

WUG: Possum Kingdom WSC

Strategy: Voluntary Redistribution from Palo Pinto Manufacturing

Source: Palo Pinto Manufacturing

Facilities: Wholesale rate included only. Not enough information to cost delivery.

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	$9,027
Available Project Yield:	118 acft/yr
Annual Cost of Water:	$76.50 per acft/yr

This project will include a contract for the purchase of water up to 118 acft/yr. Infrastructure such as pipelines, pump stations, and storage tanks will be needed once the location(s) of use are determined.

WUG: Santo SUD

Strategy: Purchase Additional Supply from the City of Mineral Wells

Source: City of Mineral Wells

Facilities: Wholesale rate included only. Not enough information to cost delivery.

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	$29,232
Available Project Yield:	14 acft/yr
Annual Cost of Water:	$2,088 per acft/yr

This project will include a contract for the purchase of water up to 14 acft/yr. Infrastructure such as pipelines, pump stations, and storage tanks will be needed once the location(s) of use are determined.

WUG: Sportsmans World MUD

Strategy: Voluntary Redistribution from Palo Pinto Manufacturing

Source: Palo Pinto Manufacturing

Facilities: Wholesale rate included only. Not enough information to cost delivery.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $2,525

Available Project Yield: 33 acft/yr

Annual Cost of Water: $76.50 per acft/yr

This project will include a contract for the purchase of water up to 33 acft/yr. Infrastructure such as pipelines, pump stations, and storage tanks will be needed once the location(s) of use are determined.

WUG: Palo Pinto County Other

Strategy: Purchase Additional Supply from the City of Mineral Wells

Source: City of Mineral Wells

Facilities: Wholesale rate included only. Not enough information to cost delivery.

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $398,808

Available Project Yield: 191 acft/yr

Annual Cost of Water: $2,088 per acft/yr

This project will include a contract for the purchase of water up to 191 acft/yr. Infrastructure such as pipelines, pump stations, and storage tanks will be needed once the location(s) of use are determined.

13.4.14 Stephens County

WUG: Fort Griffin SUD

Strategy: Purchase of Water from the City of Albany

Source: City of Albany

Facilities: None

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $3,878

Available Project Yield: 2 acft/yr

Annual Cost of Water: $1,939 per acft/yr or $5.95 per 1,000 gallons

This project will include a contract for the purchase of water up to 2 acft/yr. Assumes existing infrastructure is sufficient. Purchase cost of water based on Fort Griffin SUD's lowest tier rate of $5.95 per 1,000 gal.

13.4.15 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: $69,454

Available Project Yield: 41 acft/yr

Annual Cost of Water: $1,694 acft/yr

This project will include a contract increase of up to additional 41 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: $992,684

Available Project Yield: 586 acft/yr

Annual Cost of Water: $1,694 acft/yr

This project will include a contract increase of up to additional 586 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: $289,674

Available Project Yield: 171 acft/yr

Annual Cost of Water: $1,694 acft/yr

This project will include a contract increase of up to additional 171 acft/yr utilizing existing infrastructure from the City of Abilene to Steamboat Mountain WSC.

WUG: 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: $22,022

Available Project Yield: 13 acft/yr

Annual Cost of Water: $1,694 acft/yr

This project will include a contract increase of up to additional 13 acft/yr utilizing existing infrastructure from the City of Abilene to The City of Tye.

WUG: View Caps 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: $25,410

Available Project Yield: 15 acft/yr

Annual Cost of Water: $1,694 acft/yr

This project will include a contract increase of up to additional 15 acft/yr utilizing existing infrastructure from the City of Abilene to View Caps WSC.

WUG: Taylor County-Other

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: $228,690

Available Project Yield: 135 acft/yr

Annual Cost of Water: $1,694 acft/yr

This project will include a contract increase of up to additional 135 acft/yr utilizing existing infrastructure from the City of Abilene to Taylor County-Other.

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: $28,665

Available Project Yield: 245 acft/yr

Annual Cost of Water: $1,694 acft/yr

This project will include a contract for the purchase of water up to 245 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: $142,389

Available Project Yield: 1,217 acft/yr

Annual Cost of Water: $1,694 acft/yr

This project will include a contract for the purchase of water up to 1,217 acft/yr. Infrastructure such as pipelines, pump stations, and storage tanks will be needed once the location(s) of use are determined.

13.4.16 Williamson County

WUG: City of Bartlett

Strategy: Purchase Supply from Jarrell-Schwertner WSC

Source: Jarrell-Schwertner WSC

Facilities: assumed delivery through existing infrastructure

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: $672,375

Available Project Yield: 275 acft/yr

Annual Cost of Water: $2,445 per acft/yr or $7.50 per 1,000 gal

WUG: Brushy Creek MUD

Strategy: Purchase Supply from City of Round Rock

Source: City of Round Rock

Facilities: assumed delivery through existing infrastructure

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	$228,000
Available Project Yield:	250 acft/yr
Annual Cost of Water:	$912 per acft/yr or $2.80 per 1,000 gal

WUG: City of Florence

Strategy: Purchase Supply from City of Georgetown

Source: City of Georgetown

Facilities: assumed delivery through existing infrastructure

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	maximum of $56,304
Available Project Yield:	72 acft/yr
Annual Cost of Water:	maximum of $782 per acft/yr or $2.40 per 1,000 gal

WUG: City of Leander

Strategy: Contract Amendment with LCRA or Redistribution of Supplies through the BCRUA Project

Source: LCRA

Facilities: assumed delivery through existing infrastructure

Total Capital Cost:	N/A
Total Project Cost:	N/A
Total Annual Cost:	maximum of $1,261,200
Available Project Yield:	1,441 acft/yr
Annual Cost of Water:	$844 per acft/yr or $2.59 per 1,000 gal

WUG: Williamson County-Other

Strategy: Purchase Supply from Round Rock

Source: City of Round Rock

Facilities: assumed delivery through existing infrastructure

Total Capital Cost:	N/A
Total Project Cost:	N/A

Total Annual Cost: maximum of $2,443,248

Available Project Yield: 2,679 acft/yr

Annual Cost of Water: $912 per acft/yr or $2.80 per 1,000 gal

WUG: Williamson County-Other

Strategy: Purchase Supply from SAWS Vista Ridge Project (Region L)

Source: SAWS Vista Ridge

Facilities: assumed delivery through existing infrastructure

Total Capital Cost: N/A

Total Project Cost: N/A

Total Annual Cost: maximum of $13,771,200

Available Project Yield: 5,700 acft/yr

Annual Cost of Water: $2,416 per acft/yr or $7.40 per 1,000 gal

13.4.17 Young County

WUG: Fort Belknap WSC

Strategy: Purchase Additional Water 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: $83,600

Available Project Yield: 95 acft/yr

Annual Cost of Water: $880 per acft/yr or $2.70 per 1,000 gal (City of Graham Wholesale Costs)

WUG: City of Graham

Strategy: Treated Water Purchase and Conveyance

Source: City of Throckmorton

Facilities: Pump station, transmission pipeline, storage tanks

Total Capital Cost: $109,663,000

Total Project Cost: $153,846,000

Total Annual Cost: $12,299,000

Available Project Yield: 1,500 acft/yr

Annual Cost of Water: $8,199 per acft/yr (Maximum of Phased Costs)

This project will include approximately thirty-six miles of 14 inch transmission pipeline and associated pump station to convey treated surface water from the City of Throckmorton (New Throckmorton Reservoir) to the City of Graham. Project cost includes cost of purchasing water from the City of Throckmorton.

Cost Estimate Summary September 2018 Prices	
Graham - Graham to Throckmorton	
Item	***Estimated Costs for Facilities***
Primary Pump Station (3 MGD)	$1,395,000
Transmission Pipeline (14 in dia., 36 miles)	$89,654,000
Transmission Pump Station(s) & Storage Tank(s)	$18,614,000
TOTAL COST OF FACILITIES	**$109,663,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$33,899,000
Environmental & Archaeology Studies and Mitigation	$3,295,000
Land Acquisition and Surveying (640 acres)	$2,871,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$4,118,000
TOTAL COST OF PROJECT	**$153,846,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$10,825,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$975,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$305,000
Pumping Energy Costs (1,384,350 kW-hr @ 0.08 $/kW-hr)	$111,000
Purchase of Water (1,500 acft/yr @ 55 $/acft)	$83,000
TOTAL ANNUAL COST	**$12,299,000**
Available Project Yield (acft/yr)	1,500
Annual Cost of Water ($ per acft), based on PF=2	$8,199
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$983
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$25.16
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$3.02

13.5 Miscellaneous WTP Upgrades and Facilities Expansions

There are a total of 13 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 13.5-1 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 13.5-1. 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	$44,426,812	$61,664,832	$7,448,681	$573	$1.76
Acton MUD and Johnson County SUD	Increase WTP Capacity (SWATS) by 10.8 MGD	6,031	$25,062,000	$34,765,000	$4,200,000	$696	$2.14
Bell County WCID No. 1	Water Treatment Plant Expansion (Lake Belton)	3,360	$20,300,000	$28,964,000	$2,731,000 (max of phased cost)	$1,116 (max of phase cost)	$3.43 (max of phased cost)
Bell County WCID No. 1	New Water Treatment Plant (Lake Stillhouse Hollow)	9,521	$65,527,000	$93,404,000	$11,159,000	$1,172	$3.60
City of Belton	Water Treatment Plant Expansion	1,167	$8,355,000	$11,925,000	$1,588,000	$1,361	$4.18
City of Gatesville	Water Treatment Plant Expansion	1,355	$6,721,000	$9,329,000	$1,308,000	$965	$2.96
City of Temple	Water Treatment Plant Expansion	4,704	$25,002,000	$35,666,000	$3,247,000 (max of phased cost)	$957 (max of phase cost)	$2.94 (max of phased cost)
Falls County-Other (Moore WSC)	Upgrade Treatment for Arsenic	53	$165,000	$255,000	$84,000	$1,585	$4.86
Georgetown	Expand WTP by 21 MGD	17,000	$31,873,000	$46,095,000	$5,566,000	$327	$1.00
Granbury North Water Treatment Plant	New Water Treatment Plant	2,800	$34,057,000	$45,500,000	$7,155,000	$2,555	$4.33
Jayton	New WTP (0.4 MGD)	249	$2,533,000	$3,555,000	$710,000	$2,851	$8.75
Kempner WSC	New WTP (1.8 MGD)	2,015	$7,799,000	$10,821,000	$1,477,000	$879	$2.70

WUG/WWP	Strategy	Project Yield (acft/yr)	Capital Cost	Total Project Cost	Annual Cost	Unit Cost	
						$/acft	$/kgal
McLennan County-Other (FHLM WSC)	Upgrade Treatment for Arsenic	917	$2,871,000	$4,425,000	$835,000	$911	$2.79
Prairie Hill WSC	Upgrade Treatment for Arsenic	268	$913,000	$1,408,000	$268,000	$1,000	$3.07
Robinson	Expand WTP by 4 MGD	4,481	$12,109,000	$16,813,000	$2,155,000	$481	$1.48

13.5.1 WTP Cost Summaries

13.5.1.1 Abilene

Cost Estimate Summary September 2018 Prices	
Abilene WTP Expansion	
Item	***Estimated Costs for Facilities***
Water Treatment Plant (23.2 MGD)	$44,427,000
TOTAL COST OF FACILITIES	**$44,427,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$15,549,000
Environmental & Archaeology Studies and Mitigation	$18,000
Land Acquisition and Surveying (12 acres)	$20,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$1,651,000
TOTAL COST OF PROJECT	**$61,665,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$4,339,000
Operation and Maintenance	
Water Treatment Plant	$3,110,000
TOTAL ANNUAL COST	**$7,449,000**
Available Project Yield (acft/yr)	26,005

Annual Cost of Water ($ per acft), based on PF=1	$286
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$120
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$0.88
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.37

13.5.1.2 Acton MUD, Granbury, and Johnson County SUD

Cost Estimate Summary September 2018 Prices	
Acton MUD and Johnson County SUD SWATS WTP Expansion	
Item	***Estimated Costs for Facilities***
Water Treatment Plant (10.8 MGD)	$25,062,000
TOTAL COST OF FACILITIES	**$25,062,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$8,772,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$931,000
TOTAL COST OF PROJECT	**$34,765,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$2,446,000
Operation and Maintenance	
Water Treatment Plant	$1,754,000
TOTAL ANNUAL COST	**$4,200,000**
Available Project Yield (acft/yr)	6,031
Annual Cost of Water ($ per acft), based on PF=2	$696
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$291
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$2.14
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$0.89

13.5.1.3 Bell County WCID No. 1 (Lake Belton)

Bell County WCID No. 1 WTP Expansion
Cost Estimate Summary (September 2018 Prices)

Item	2020	2030	2040	2050	2060	2070
CAPITAL COST						
Water Treatment Plant (3 MGD)	--	$10,150,000	0	0	0	$10,150,000
TOTAL COST OF FACILITIES	--	**$10,150,000**	**0**	**0**	**0**	**$10,150,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	--	$3,552,000	0	0	0	$3,552,000
Environmental & Archaeology Studies and Mitigation	--	$10,000	0	0	0	$10,000
Land Acquisition and Surveying (2 acres)	--	$15,000	0	0	0	$15,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	--	$755,000	0	0	0	$755,000
TOTAL COST OF PROJECT	**--**	**$14,482,000**	**0**	**0**	**0**	**$14,482,000**
ANNUAL COST						
Debt Service (3.5 percent, 20 years)	--	$1,019,000	$1,019,000	0	0	$1,019,000
Operation and Maintenance						
Water Treatment Plant	--	$856,000	$856,000	$856,000	$856,000	$1,712,000
TOTAL ANNUAL COST	**--**	**$1,875,000**	**$1,875,000**	**$856,000**	**$856,000**	**$2,731,000**
Available Project Yield (acft/yr)	--	1,680	1,680	1,680	1,680	3,360
Annual Cost of Water ($ per acft), based on PF=1	--	$1,116.07	$1,116.07	$509.52	$509.52	$812.80
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	--	$3.43	$3.43	$1.56	$1.56	$2.49

13.5.1.4 Bell County WCID No. 1 (Lake Stillhouse Hollow)

Cost Estimate Summary September 2018 Prices	
Bell County WCID No 1 Lake Still Hollow WTP	
Item	***Estimated Costs for Facilities***
Water Treatment Plant (17 MGD)	$65,527,000
TOTAL COST OF FACILITIES	**$65,527,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$22,935,000
Environmental & Archaeology Studies and Mitigation	$31,000
Land Acquisition and Surveying (9 acres)	$41,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$4,870,000
TOTAL COST OF PROJECT	**$93,404,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$6,572,000
Operation and Maintenance	
Water Treatment Plant	$4,587,000
TOTAL ANNUAL COST	**$11,159,000**
Available Project Yield (acft/yr)	9,521
Annual Cost of Water ($ per acft), based on PF=2	$1,172
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$482
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$3.60
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$1.48

13.5.1.5 City of Belton

Cost Estimate Summary September 2018 Prices	
City of Belton WTP Expansion	
Item	***Estimated Costs for Facilities***
Water Treatment Plant (2.1 MGD)	$8,355,000
TOTAL COST OF FACILITIES	**$8,355,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,924,000
Environmental & Archaeology Studies and Mitigation	$10,000
Land Acquisition and Surveying (1 acres)	$14,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$622,000
TOTAL COST OF PROJECT	**$11,925,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$839,000
Operation and Maintenance	
Water Treatment Plant	$749,000
TOTAL ANNUAL COST	**$1,588,000**
Available Project Yield (acft/yr)	1,167
Annual Cost of Water ($ per acft), based on PF=2	$1,361
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$642
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$4.18
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$1.97

13.5.1.6 City of Gatesville

Cost Estimate Summary September 2018 Prices	
Gatesville WTP Expansion	
Item	***Estimated Costs for Facilities***
Water Treatment Plant (1.3 MGD)	$6,721,000
TOTAL COST OF FACILITIES	**$6,721,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,352,000
Environmental & Archaeology Studies and Mitigation	$3,000
Land Acquisition and Surveying (1 acres)	$3,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$250,000
TOTAL COST OF PROJECT	**$9,329,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$656,000
Operation and Maintenance	
Water Treatment Plant	$652,000
TOTAL ANNUAL COST	**$1,308,000**
Available Project Yield (acft/yr)	1,355
Annual Cost of Water ($ per acft), based on PF=1	$965
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$481
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$2.96
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$1.48

13.5.1.7 City of Temple

Cost Estimate Summary September 2018 Prices	
City of Temple WTP Expansion	
Item	***Estimated Costs for Facilities***
Water Treatment Plant (4.2 MGD)	$12,501,000
TOTAL COST OF FACILITIES	**$12,501,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$4,375,000
Environmental & Archaeology Studies and Mitigation	$10,000
Land Acquisition and Surveying (2 acres)	$17,000
Interest During Construction (3% for 2 years with a 0.5% ROI)	$930,000
TOTAL COST OF PROJECT	**$17,833,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$1,255,000
Operation and Maintenance	
Water Treatment Plant	$996,000
TOTAL ANNUAL COST	**$2,251,000**
Available Project Yield (acft/yr)	4,704
Annual Cost of Water ($ per acft), based on PF=1	$479
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$212
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.47
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.65

13.5.1.8 Falls County-Other (Moore WSC)

Cost Estimate Summary *September 2018 Prices*	
Falls County-Other - Upgrade for Arsenic Treatment	
Item	***Estimated Costs for Facilities***
Water Treatment Plant (0.1 MGD)	$165,000
TOTAL COST OF FACILITIES	**$165,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$83,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$7,000
TOTAL COST OF PROJECT	**$255,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$18,000
Operation and Maintenance	
Water Treatment Plant	$66,000
TOTAL ANNUAL COST	**$84,000**
Available Project Yield (acft/yr)	53
Annual Cost of Water ($ per acft), based on PF=1	$1,585
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$1,245
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$4.86
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$3.82

13.5.1.9 Georgetown

Cost Estimate Summary September 2018 Prices	
Georgetown WTP Expansion	
Item	***Estimated Costs for Facilities***
Water Treatment Plant (16 MGD)	$33,180,000
TOTAL COST OF FACILITIES	**$33,180,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$11,613,000
Environmental & Archaeology Studies and Mitigation	$32,000
Land Acquisition and Surveying (8 acres)	$36,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$1,234,000
TOTAL COST OF PROJECT	**$46,095,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$3,243,000
Operation and Maintenance	
Water Treatment Plant	$2,323,000
TOTAL ANNUAL COST	**$5,566,000**
Available Project Yield (acft/yr)	17,000
Annual Cost of Water ($ per acft), based on PF=1	$327
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$137
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.00
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.42

13.5.1.10 Granbury North Water Treatment Plant

Cost Estimate Summary September 2018 Prices	
City of Granbury North Water Treatment Plant	
Item	***Estimated Costs for Facilities***
Primary Pump Station and Intake (5 MGD)	$4,370,000
Transmission Pipeline (18 in dia., 0.25 miles)	$191,000
Advanced Water Treamtent Facility (5 MGD)	$29,496,000
TOTAL COST OF FACILITIES	**$34,057,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$10,217,000
Environmental & Archaeology Studies and Mitigation	$6,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$1,218,000
TOTAL COST OF PROJECT	**$45,500,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$3,201,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$2,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$109,000
Advanced Water Treatment Facility	$3,818,000
Pumping Energy Costs (311751 kW-hr @ 0.08 $/kW-hr)	$25,000
TOTAL ANNUAL COST	**$7,155,000**
Available Project Yield (acft/yr)	2,800
Annual Cost of Water ($ per acft), based on PF=2	$2,555
Annual Cost of Water After Debt Service ($ per acft), based on PF=2	$1,412
Annual Cost of Water ($ per 1,000 gallons), based on PF=2	$7.84
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=2	$4.33

13.5.1.11 Jayton

Cost Estimate Summary September 2018 Prices	
City of Jayton WTP	
Item	***Estimated Costs for Facilities***
Water Treatment Plant (0.4 MGD)	$2,533,000
TOTAL COST OF FACILITIES	**$2,533,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$886,000
Environmental & Archaeology Studies and Mitigation	$15,000
Land Acquisition and Surveying (0 acres)	$25,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$96,000
TOTAL COST OF PROJECT	**$3,555,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$250,000
Operation and Maintenance	
Water Treatment Plant	$460,000
TOTAL ANNUAL COST	**$710,000**
Available Project Yield (acft/yr)	249
Annual Cost of Water ($ per acft), based on PF=1	$2,851
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$1,847
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$8.75
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$5.67

13.5.1.12 Kempner WSC

Cost Estimate Summary September 2018 Prices	
Kempner WSC WTP Expansion	
Item	***Estimated Costs for Facilities***
Water Treatment Plant (1.8 MGD)	$7,799,000
TOTAL COST OF FACILITIES	**$7,799,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$2,729,000
Environmental & Archaeology Studies and Mitigation	$1,000
Land Acquisition and Surveying (1 acres)	$2,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$290,000
TOTAL COST OF PROJECT	**$10,821,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$761,000
Operation and Maintenance	
Water Treatment Plant	$716,000
TOTAL ANNUAL COST	**$1,477,000**
Available Project Yield (acft/yr)	1,681
Annual Cost of Water ($ per acft), based on PF=1	$879
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$426
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$2.70
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$1.31

13.5.1.13 McLennan County-Other (FHLM WSC)

Cost Estimate Summary September 2018 Prices	
McLennan County-Other - Individual Treatment Plants for Arsenic	
Item	***Estimated Costs for Facilities***
Water Treatment Plant (0.8 MGD)	$2,871,000
TOTAL COST OF FACILITIES	**$2,871,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$1,435,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$119,000
TOTAL COST OF PROJECT	**$4,425,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$311,000
Operation and Maintenance	
Water Treatment Plant	$524,000
TOTAL ANNUAL COST	**$835,000**
Available Project Yield (acft/yr)	917
Annual Cost of Water ($ per acft), based on PF=1	$911
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$571
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$2.79
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$1.75

13.5.1.14 Prairie Hill WSC

Cost Estimate Summary September 2018 Prices	
Prairie Hill WSC - Upgrade for Arsenic Treatment	
Item	***Estimated Costs for Facilities***
Water Treatment Plant (0.2 MGD)	$913,000
TOTAL COST OF FACILITIES	**$913,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$457,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$38,000
TOTAL COST OF PROJECT	**$1,408,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$99,000
Operation and Maintenance	
Water Treatment Plant	$169,000
TOTAL ANNUAL COST	**$268,000**
Available Project Yield (acft/yr)	268
Annual Cost of Water ($ per acft), based on PF=1	$1,000
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$631
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$3.07
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$1.93

13.5.1.15 Robinson

Cost Estimate Summary September 2018 Prices	
Robinson WTP Expansion	
Item	***Estimated Costs for Facilities***
Water Treatment Plant (4 MGD)	$12,109,000
TOTAL COST OF FACILITIES	**$12,109,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$4,238,000
Environmental & Archaeology Studies and Mitigation	$8,000
Land Acquisition and Surveying (2 acres)	$8,000
Interest During Construction (3% for 1 years with a 0.5% ROI)	$450,000
TOTAL COST OF PROJECT	**$16,813,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$1,183,000
Operation and Maintenance	
Water Treatment Plant	$972,000
TOTAL ANNUAL COST	**$2,155,000**
Available Project Yield (acft/yr)	4,481
Annual Cost of Water ($ per acft), based on PF=1	$481
Annual Cost of Water After Debt Service ($ per acft), based on PF=1	$217
Annual Cost of Water ($ per 1,000 gallons), based on PF=1	$1.48
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1	$0.67