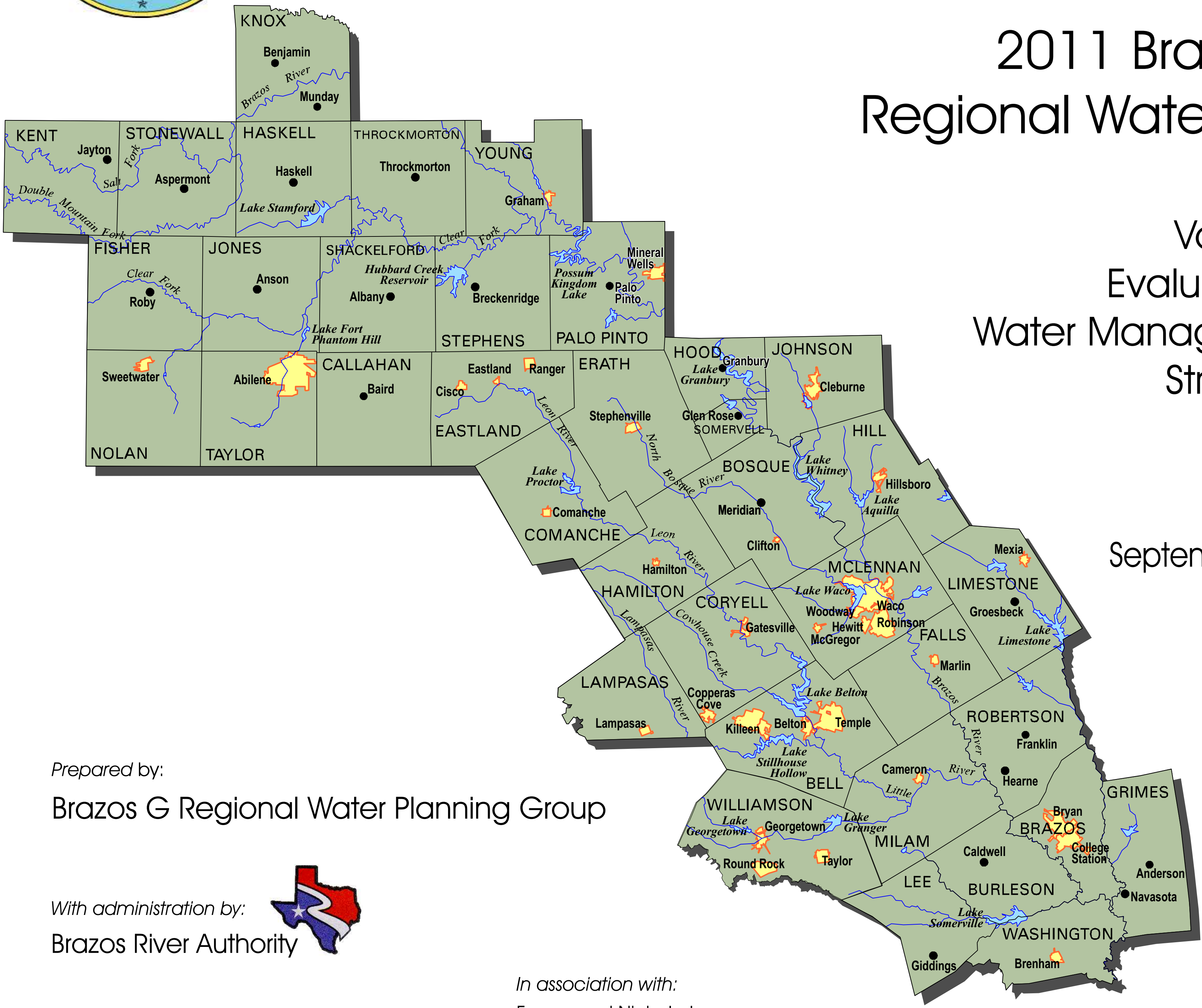
Brazos G Regional Water Planning Area

2011 Brazos G Regional Water Plan

Volume II Evaluation of Water Management Strategies

September 2010



Prepared by:

Brazos G Regional Water Planning Group

With administration by:

Brazos River Authority

With technical assistance by:

HDR Engineering, Inc.

In association with:

Freese and Nichols, Inc.

R.W. Harden and Associates, Inc.

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Fletcher Communications

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Section 4B
Identification, Evaluation, and Selection of Water Management Strategies

4B.1 Water Management Strategies

Title 31 TAC 357.7(a)(7) requires that the regional water planning group evaluate all water management strategies determined to be potentially feasible. The guidelines list multiple types of strategies and numerous subtypes, including water conservation; drought management measures; reuse of wastewater; expanded use of existing facilities, including systems optimizations, conjunctive use, reallocation of storage to new uses, etc.; interbasin transfers; new supply development; and others. At the beginning of the 2006 planning cycle, the Brazos G RWPG identified approximately 25 water management strategies to be potentially feasible. For the 2011 Plan update, 20 categories of strategies were investigated with some categories containing 11 individual strategies. Many of these were evaluated for the previous 2006 Plan. Several strategies were re-evaluated due to changed conditions such as new hydrologic information or requests for further information. Packages describing amendments to the 2006 Plan are included in Section 4B.21, as originally adopted by the Brazos G RWPG. Costs for these strategies as shown in specific WUG and WWP plans have been updated to September 2008 prices.

Potential water supply strategy categories evaluated during preparation of the 2011 Plan are listed in Table 4B.1-1. Within some of the 15 types of water management strategies listed in Table 4B.1-1 there are a number of sub-options. For instance, in the section on New Reservoirs (Section 4B.12), eleven potential reservoir sites are evaluated.

The remainder of this section describes methods and procedures utilized to evaluate water management strategies considered for inclusion in the 2011 Plan.

4B.1.1 Evaluation of Strategies

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

Table 4B.1-1.
Water Management Strategies Evaluated
for the 2011 Brazos G Regional Water Plan

Section No. (Located in Volume II)	***Title***
4B.2	Water Conservation
4B.3	Wastewater Reuse
4B.4	System Operation of Brazos River Authority Reservoirs
4B.5	Groundwater/Surface Water Conjunctive Use (Lake Granger Augmentation)
4B.6	Desalination
4B.7	Millers Creek Reservoir Augmentation
4B.8	Aquifer Storage and Recovery
4B.9	Brush Control and Range Management
4B.10	Weather Modification
4B.11	Interregional Water Management
4B.12	New Reservoirs
4B.13	Off-Channel Reservoirs
4B.14	Interconnection of Regional and Community Systems
4B.15	Carrizo-Wilcox Aquifer Development
4B.16	Voluntary Redistribution
4B.17	Miscellaneous Strategies
4B.18	Storage Reallocation in Federal Reservoirs
4B.19	Chloride Control
4B.20	BRA Reservoir Connections
4B.21	Amendments to the 2006 Plan Brought Forward to the 2011 Plan

4B.1.2 Plan Development Criteria

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

- Water Supply – Water supply must be evaluated with respect to quantity, reliability, and cost. The criteria for quantity are that the plan must be sufficient to meet all projected needs in the planning period. The criteria for reliability is that it meet municipal and industrial needs 100 percent of the time, and 75 percent of agricultural needs 75 percent of the time. The criteria for cost are that the projected cost be reasonable to meet the projected needs.
- Environmental Issues – Environmental considerations must be examined with respect to environmental water needs, wildlife habitat, cultural resources, and bays and estuaries. The criteria for environmental water flows and wildlife habitat are that stream conditions must meet permit requirements for diversions that currently have permits. For projects that require permit acquisition the project will provide adequate environmental instream flows for aquatic habitat. Projects should be sited to avoid known cultural resources, if possible. Flows to bays and estuaries should meet expected permit conditions. (It should be noted that the Brazos River does not have a well-defined estuary or bay system, so bay and estuary inflow requirements are expected to be low).
- Impacts on Other State Water Resources – The criteria recommend a follow-up study by the Brazos G RWPG if any significant impacts are anticipated on other state water resources.
- Threats to Agriculture and Natural Resources – The criteria requires that the planning group identify any potential impact, compare the impact to the proposed benefit of the plan, and make recommendations. With the exception of large projects that will affect large acreages, such as reservoir projects, the water management strategies evaluated will have no significant impact to the State's Agricultural resources.
- Equitable Comparison of Feasible Strategies – This is achieved by the equal application of criteria across different water development plans.
- Interbasin Transfers – The planning group may consider interbasin transfers as a supply option. The criteria require that the participating entities recognize and follow Texas Water Code requirements for expected permitting requirements.
- Impacts from Voluntary Redistribution – The criteria require that any potential third party social or economic impacts from voluntary redistribution of water rights be identified and described.
- Other Criteria – Texas Water Development Board (TWDB) allows the Brazos G RWPG to adopt other criteria. The Brazos G RWPG has not adopted any further criteria.

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

4B.1.3 Engineering

A procedure was developed to maintain equal and consistent consideration of various design and cost variables across differing water management strategy options. These are planning level estimates only, and do not reflect detailed site-specific design work, nor any extensive optimization and selection of design variables. These procedures standardized the consideration of the following design and costing issues as closely as possible, given the varying scope and magnitude of differing projects. For each option, major cost components were determined at the outset. Estimates of volume of water and rate of delivery needed were developed from the supply-demand comparisons presented in Section 4A, 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 4B.2 through 4B.21.

4B.1.4 Cost Estimates

The cost estimates of this study are expressed in three major categories: (1) construction costs or capital (structural) costs, (2) other (non-structural) project costs, and (3) annual costs. 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 4B.1-2. All costs represent second September 2008 prices.

To estimate capital costs, tables of unit costs for each major component in the capital costs were developed through an internal review of bid documents and project cost audits of projects that HDR and Freese & Nichols (subconsultant) have implemented in the past. The cost tables report all-inclusive costs to construct, including the construction, infrastructure and control equipment, and all other materials, labor, and installation costs. Unit costs were developed for pump stations, intake structures, pipelines, wells, reservoir structures, channel dams and any other structural component called for in a water supply option.

Table 4B.1-2.
Major Project Cost Categories

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

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

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

Debt service is the estimated annual payment that can be expected for repayment of borrowed funds based on the total project cost, an assumed finance rate, and the finance period in years. As specified by the TWDB in Section 4.1.2 of *Exhibit C, General Guidelines for*

Regional Water Plan Development (2007 – 2011), debt service for all projects was calculated assuming an annual interest rate of 6 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 $0.09 per kilo-Watt-hour (kWh). The amount of energy consumed is based upon the pumping horsepower required.

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

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

Numerous recommended water management strategies are included in plans for individual water user groups that are not analyzed to the exact level of detail as the separate water management strategies described in most of Volume II. These generally involve small interconnections between two neighboring systems or purchases of additional supplies from a wholesale water provider or adjacent water user group. These strategies are referred to as miscellaneous strategies and are summarized in section 4B.17.

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.

4B.1.5 Methods Used to Investigate Environmental Effects of Proposed Regional Water Management Strategies

The Regional Water Planning Guidelines (31 TAC 357.7) require that each regional water management strategy includes an evaluation of environmental factors, specifically effects on environmental water needs, wildlife habitat, cultural resources, agricultural resources, upstream development on bays, estuaries, and arms of the Gulf of Mexico. These factors were evaluated for each of the proposed water management strategies according to the level of description and engineering design information provided. Details regarding the methodology to investigate environmental water needs, instream flow needs, impact on bays and estuaries, and fish and wildlife habitat are generally included in the analysis of each strategy.

4B.1.6 Agricultural Water Management Strategies

New firm water supplies often cannot be developed for irrigated agriculture, because the cost of development usually far exceeds the value of the water in irrigated production. The assumption is made that the available groundwater resources are already fully exploited. Cloud seeding and brush control for water yield are the only potential new supplies of water for irrigated agriculture, but a firm yield cannot be assigned to these practices. 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 4B.2.2.

4B.1.7 Water Conservation and Drought Preparation

Water conservation recommendations are included in the plans for individual water user groups. Water conservation as a water management strategy for individual municipal water user groups was evaluated as per the description in Volume II, Section 4B.2.1. 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 4B.2.2. For conservation for other types of use (manufacturing, steam electric, mining, livestock) the Brazos G RWPG has recommended a target goal of seven percent reduction in overall water demands for entities with projected shortages, and has presented a list of recommended BMPs in Volume II, Section 4B.2.3. 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 <u>not</u> 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 I.

4B.1.8 Funding and Permitting by State Agencies of Projects Not in the Regional Water Plan

Senate Bill 1 requires water supply projects to be consistent with approved regional water plans to be eligible for TWDB funding and to obtain TCEQ permits. Texas Water Code[1] 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[2] 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

[1] Texas Water Code, Section 11.134
[2] Texas Water Code, Section 16.053(j)

project will be addressed in a manner that is consistent with the appropriate regional water plan. The TWDB may waive this provision if conditions warrant.

The Brazos G RWPG has considered the variety of actions and permit applications that may come before the TCEQ and the TWDB and does not want to unduly constrain projects or applications for small amounts of water that may not be included specifically in the adopted regional water plan. "Small amounts of water" is defined as involving no more than 1,000 acft/yr, regardless of whether the action is for a temporary or long term action. The Brazos G RWPG provides direction to TCEQ and TWDB regarding appropriations, permit amendments, and projects involving small amounts of water that will not have a significant impact on the region's water supply as follows: such projects are consistent with the regional water plan, even though not specifically recommended in the plan. However, many of the projects associated with these "small amounts of water" have been included where possible in the miscellaneous strategies Section 4B.17.

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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4B.2 Water Conservation

4B.2.1 Municipal Water Conservation

4B.2.1.1 Description of Option

Water conservation is defined as those methods and practices that either reduce the demand for water supply or increase the efficiency of the supply, or use facilities so that available supply is conserved and made available for future use. Water conservation is typically a non-capital intensive alternative that any water supply entity can and should pursue. All water supply entities and some major water right holders are required by Senate Bill 1 regulations to submit a Drought Contingency and Water Conservation Plan to the TCEQ for approval. These plans must detail the water supply entities' plans to reduce water demand at times when the demand threatens the total capacity of the water supply delivery system or overall supplies are low.

In 2001, the Texas Legislature amended the Texas Water Code, Texas Administrative Code 357.7(a)7(A), to require Regional Water Planning Groups to consider water conservation and drought management measures for each water user group with a need (projected water shortage). The Water Conservation Implementation Task Force was created by Senate Bill 1094 to identify and describe Water Conservation Best Management Practices (BMPs) and provide a BMP Guide for use by Regional Water Planning groups in the development of the 2006 Regional Water Plans. Two documents, GDS Associates Report[1] and Water Conservation Implementation Task Force Report,[2] provide guidance for municipal water conservation.

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 person per day (gpcd) – that a typical person uses.

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

[2] Water Conservation Implementation Task Force, Report to the 79th Legislature, Texas Water Development Board, Special Report, Austin, Texas, November 2004.

The Water Conservation Implementation Task Force recommends that a standardized methodology be used for determining per capita per day (gpcd) municipal water use so as to allow consistent evaluations of effectiveness of water conservation measures among Texas cities that are located in the different climates and parts of Texas. The Task force further recommends 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, based upon a 5-year moving average, until such time as the entity achieves a total gpcd of 140 gpcd or less, or
- Municipal water use (gpcd) goals approved by regional water planning groups.

The current Texas Water Development Board (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 savings projected by the TWDB include a 100 percent replacement of existing plumbing fixtures to water efficient fixtures by Year 2045 (assumed 2 percent per year replacement). The projections also 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.

Conservation is recommended for every municipal WUG with a projected need (shortage) and a per capita water use rate greater than 140 gallons per capita per day (gpcd) in 2060. The Brazos G Regional Water Planning Group (BGRWPG) recommends conservation for municipal WUGs with per capita rates greater than 140 gpcd based on the Water Conservation

Task Force's statewide gpcd target. This conservation can be achieved in a variety of ways, including using these BMPs identified by the Water Conservation Implementation Task Force:

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

The BGRWPG does not recommend specific conservation BMPs for each municipal entity, as each entity should choose those conservation strategies that best fit their individual situation. The TWDB requires that costs and water supply estimates be developed for each recommended water management strategy. However, the Task Force Report does not present methods for computing water savings and costs for each of the above BMPs, reducing the list of specific BMPs that can be used to compute costs and savings. Estimated water savings for municipal water conservation are presented in Table 4B.2-1 for specific BMPs. The BMPs presented in Table 4B.2-1 were used to provide a basis for estimating costs and expected water savings. A city may choose other BMPs not included in Table 4B.2-1 to reduce their per capita water use.

Table 4B.2-1.
Selected Municipal Water Conservation BMPs

Conservation BMP	Savings	Source
Advanced Conservation • Toilet retrofit • Showerheads and Aerators • Irrigation Audit – High User	7 gpcd*	GDS Associates, savings are for existing connections only
Landscape Irrigation	11 gpcd	Based upon 15% reduction referenced in Task Force report
Public Education Programs	3 gpcd	TCEQ
Total	**21 gpcd**	

* Note: This is an average for the WUGs analyzed, and represents 50 percent replacement of existing fixtures. In contrast, the TWDB maximum savings for a specific WUG in Region G (Brazos County-other) is about 13 gpcd, representing 100 percent replacement of existing fixtures for a WUG projected to have declining population and, consequently, minimal new construction.

If all of the programs listed in Table 4B.2-1 were implemented by a utility, an estimated total per capita water use reduction of 21 gpcd can be expected. This total reduction of 21 gpcd includes those reductions already incorporated into the TWDB demand projections. In order to meet both short and long-term needs, it is assumed that the 21 gpcd reductions will occur by Year 2020 for all municipal WUGs with needs, regardless of the timing of the needs. A portion of the 21 gpcd reduction is therefore an acceleration of the savings expected due to full implementation of the 1991 Plumbing Act. The savings shown in Table 4B.2-1 are average expected savings across the Brazos G Area. Actual expected savings are computed separately for each WUG.

4B.2.1.2 Available Supply

The available supply to any entity from this strategy would be the reduction in demand over and above that assumed in the TWDB water demand projections. All entities, in order to be in line with projections, will need to verify that their conservation planning measures are consistent with TCEQ standards and the TWDB projections. Beyond that, some communities with projected needs may be able to reduce or eliminate those needs with stronger conservation planning.

Table 4B.2-2 lists 39 municipal WUGs with per capita use rates greater than 140 gpcd, and projected shortages. The table also lists the potential additional water savings attributable to the BGRWPG conservation recommendations[3]. Please see the individual water supply plans presented in Section 4C to identify those WUGs for which conservation is a recommended water management strategy to meet needs.

Table 4B.2-2. Municipal Water User Groups for which Conservation is a Recommended WMS

ID	County Name	Water User Group	Water Savings-with Conservation (acft)*					
			2010	2020	2030	2040	2050	2060
1	TAYLOR	ABILENE	977	2,189	1,785	1,346	1,173	1,136
2	SHACKELFORD	ALBANY	16	34	26	20	14	12
3	CALLAHAN	BAIRD	11	26	20	15	11	11
4	WILLIAMSON	BARTLETT	12	30	25	19	18	18
5	LIMESTONE	BISTONE MWSD	4	9	7	5	4	4
6	WILLIAMSON	BRUSHY CREEK MUD	92	124	133	133	133	133
7	WILLIAMSON	CEDAR PARK	461	1,557	1,593	1,935	1,935	1,936
8	WILLIAMSON	CHISHOLM TRAIL SUD	213	665	925	1,207	1,513	1,842
9	JOHNSON	CLEBURNE	240	580	519	482	488	532
10	BRAZOS	COLLEGE STATION	545	1,378	1,320	1,177	1,149	1,184
11	HILL	FILES VALLEY WSC	15	35	29	21	20	21
12	WILLIAMSON	FLORENCE	9	24	22	21	23	27
13	CORYELL	GATESVILLE	131	326	323	324	313	333
14	WILLIAMSON	GEORGETOWN	274	1,049	1,185	1,371	1,680	2,012
15	SOMERVELL	GLEN ROSE	22	47	41	32	28	29
16	HOOD	GRANBURY	55	158	148	156	165	193
17	MCLENNAN	HALLSBURG	4	10	8	6	6	6
18	HASKELL	HASKELL	23	47	36	26	19	18
19	WILLIAMSON	JARRELL-SCHWERTNER WSC	22	83	94	97	117	139
20	Kent	CITY OF JAYTON	3	8	6	3	3	2
21	JOHNSON	JOHNSON COUNTY SUD	491	1,485	2,085	3,008	4,241	5,171
22	CORYELL	KEMPNER WSC	81	241	265	272	268	283
23	KNOX	KNOX CITY	9	21	17	13	11	11
24	WILLIAMSON	LEANDER	129	393	430	489	603	727
25	WILLIAMSON	LIBERTY HILL	17	62	87	107	134	163
26	HOOD	LIPAN	5	16	19	23	31	44
27	FALLS	MARLIN	46	112	141	169	242	340
28	PALO PINTO	MINERAL WELLS	101	255	231	181	170	178
29	KNOX	MUNDAY	10	24	19	14	10	10
30	MCLENNAN	NORTH BOSQUE WSC	10	33	36	38	37	42
31	WILLIAMSON	ROUND ROCK	704	2,248	2,546	2,949	3,620	4,338
32	PALO PINTO	STRAWN	7	14	11	9	9	9
33	NOLAN	SWEETWATER	94	195	156	113	95	91
34	THROCKMORTON	THROCKMORTON	6	14	10	7	5	5
35	HOOD	TOLAR	6	15	16	14	13	15
36	BOSQUE	VALLEY MILLS	10	24	20	14	14	14
37	WILLIAMSON	WEIR	7	12	14	16	20	24
38	HILL	WHITE BLUFF COMMUNITY WSC	11	29	31	33	40	45
39	BRAZOS	BRYAN	--	--	--	--	122	248

* Note: This conservation is in addition to savings attributed to the 1991 Water Efficient Plumbing Fixtures Act. Conservation beyond Year 2020 is based on Year 2020 gpcd being held constant through Year 2060, except for cases where TWDB gpcd increases over time, in which case projected gpcd is reduced by 21 gpcd in each decade after 2020.

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

4B.2.1.3 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 environmental issues that might arise for this alternative are presented in Table 4B.2-3.

Table 4B.2-3.
Environmental Issues: Municipal Water Conservation

Water Management Option	*Municipal Water Conservation*
Implementation Measures	Voluntary reduction, reduced diversions, 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 result in possibly 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; possible low to moderate positive impact to aquatic and riparian habitats with substantial reductions as more stream flow would be available to these habitats; possible moderate positive benefits from implementation of site-specific xeriscape landscaping
Cultural Resources	No substantial impact anticipated
Threatened and Endangered Species	No substantial impact identified, assuming relatively low reduction in diversions and return flows; possible 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

4B.2.1.4 Engineering and Costing

Since water conservation plans are required for each community by Senate Bill 1, regular costs for implementing and enforcing a general conservation program were not estimated. Only the efforts needed to enforce a more stringent conservation plan over and above that assumed in the projections were studied. These might include those BMPs included in Table 4B.2-1 or other conservation measures as deemed appropriate by each individual entity. Based upon the costs obtained for the selected BMPs from the GDS Associates report updated to September 2008 dollars (Table 4B.2-4), the average cost per acft of water saved would be between $425 and $525. An average cost of $475 per acre-foot is assumed for purposes of assigning a cost to the water conservation strategy. This is the cost associated with water savings above those already included in the TWDB water demand projections.

Table 4B.2-4.
Savings and Costs Associated with Municipal Water Conservation

Conservation BMP	Savings	Estimated Cost ($/acft of water saved)
Advanced Conservation • Toilet retrofit • Showerheads and Aerators • Irrigation Audit – High User	7 gpcd*	$425 to $504
Landscape Irrigation	11 gpcd	$525
Public Education Programs	3 gpcd	N/A
Total	**21 gpcd**	**$425 to $525**

* Note: This is an average for the WUGs analyzed, and represents 50 percent replacement of existing fixtures. In contrast, the TWDB maximum savings for a specific WUG in Region G (Brazos County-other) is about 13 gpcd, representing 100 percent replacement of existing fixtures for a WUG projected to have declining population and, consequently, minimal new construction.

4B.2.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.2-5, and the option meets each criterion.

4B.2.2 Irrigation Water Conservation

4B.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.

Table 4B.2-5.
Comparison of Municipal Water Conservation Option to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply 1. Quantity 2. Reliability 3. Cost	 1. Variable, dependent on current per capita rate 2. Variable, dependent on public acceptance 3. Reasonable
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries 5. Threatened and Endangered Species 6. Wetlands	 1. None or low impact 2. No apparent negative impact 3. None 4. None or low impact 5. None or low impact 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

In the 37 counties of the Brazos G Area, irrigation varies from county to county along with the crops irrigated. In 2000, crops grown on irrigated acres in the Brazos G Area included alfalfa, corn, cotton, sorghum, hay-pasture, forage crops, peanuts, pecans, wheat and other grains, and vegetables. According to TWDB estimates, the entire Brazos G Area had 217,916 irrigated acres in 2000 with approximately 75 percent of the acreage planted to cotton, hay-pasture, peanuts, and wheat and other grains. Table 4B.2-6 summarizes the variety of crops grown in the Brazos G Area and number of irrigated acres for each crop in each county in 2000.

In 1994, irrigators in the Brazos G Area used 202,460 acft of water, of which nearly 80 percent was from groundwater sources. In 2000, the TWDB estimated that the irrigators used 233,686 acft (an increase of 15 percent over 1994). This increase is due to an increase in irrigated acreage of 1.8 percent and increased application rates, which changed from 0.95 acft/acre in 1994 to 1.07 acft/acre in 2000.

The TWDB irrigation water demand projections for the Brazos G Area predict significant decreases in irrigation usage in the future, declining to 222,691 acft/yr by 2030 and 208,386 acft/yr by 2060 (Volume I, Table 2-7). This decline in water use is attributable to expected reductions in irrigated land and partly to increased efficiencies.

In the Brazos G Area, six counties are projected to have irrigation needs (shortages) during the 2000 to 2060 planning period, as shown in Table 4B.2-7: Eastland, Haskell, Knox, Nolan, Shackelford, and Throckmorton. The predominant crops in these counties are cotton and wheat/other grains, constituting 45 percent and 25 percent of the irrigated acres, respectively (Table 4B.2-6).

Irrigation shortages range from less than 100 acft/yr in Shackelford County to greater than 28,000 acft in Haskell County (2010). Generally, the shortages decrease over time except for Eastland County, where minimal increases in shortages (less than 100 acft/yr) are anticipated from 2010 to 2060. Four of the six counties (Eastland, Haskell, Knox, and Nolan) use both surface water and groundwater supplies to meet irrigation water demands. Shackelford County and Throckmorton County irrigators receive surface water supplies.

TWDB rules for regional water planning require regional water planning groups to consider water conservation and drought management measures for each water user group with a need (projected water shortage). In addition, the rules direct water conservation "Best Management Practices," as identified by the Water Conservation Implementation Task Force (Task Force), be considered in the development of the water conservation water management strategy. The irrigation demand in Throckmorton County is new, and no conservation savings are expected because it is anticipated that modern, efficient methods of water application will be employed.

Table 4B.2-6.
Irrigated Acres by Crop (2000) in the Brazos G Area

County	alfalfa	corn	cotton	forage crops	grain sorghum	hay-pasture	other orchard	peanuts and other oil crops	pecans	soybeans	vegetables	wheat and other grains	all other crops	Total
Bell	0	520	80	0	0	1,141	61	0	0	0	35	110	0	1,947
Bosque	0	220	0	241	0	657	0	754	50	0	0	175	60	2,157
Brazos	0	2,147	5,437	0	381	0	25	0	0	263	0	0	0	8,253
Burleson	0	2,743	11,348	0	686	0	0	0	0	3,137	0	0	1,000	18,914
Callahan	0	0	0	0	0	1,135	0	125	0	0	0	0	0	1,260
Comanche	125	0	0	4,050	0	5,078	0	6,097	9,482	0	1,450	1,772	0	28,054
Coryell	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eastland	166	0	0	1,860	538	6,424	0	3,655	53	0	293	1,232	0	14,221
Erath	0	0	0	3,646	0	3,002	0	1,829	0	0	32	0	56	8,565
Falls	0	2,229	0	0	0	15	0	0	27	0	60	0	0	2,331
Fisher	136	0	2,081	125	0	575	0	0	0	0	0	160	0	3,077
Grimes	0	0	504	0	0	60	10	0	40	0	102	0	0	716
Hamilton	0	100	0	0	0	358	0	0	0	0	0	40	22	520
Haskell	146	4	18,699	560	291	1,909	0	7,599	11	0	367	10,117	0	39,703
Hill	0	0	0	0	0	0	0	0	0	0	0	0	26	26
Hood	0	0	0	0	0	190	0	0	1,560	0	0	0	840	2,590
Johnson	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jones	100	0	3,085	0	1,500	2,200	0	1,200	0	0	0	1,500	0	9,585
Kent	19	0	0	0	92	195	0	0	45	0	0	304	21	676
Knox	0	0	17,704	144	680	683	0	1,295	67	0	722	17,156	34	38,485
Lampasas	0	58	0	0	0	60	0	40	1	0	0	0	2	161
Lee	0	46	0	0	0	1,252	20	121	141	31	0	0	0	1,611
Limestone	0	0	0	0	0	0	0	0	0	0	0	0	0	0
McLennan	0	915	1,850	0	0	130	0	180	212	0	50	0	635	3,972
Milam	0	1,074	136	3,868	0	748	0	0	5	60	0	0	40	5,931
Nolan	0	0	2,345	0	0	250	0	0	38	0	20	203	35	2,891
Palo Pinto	0	0	0	0	0	735	0	0	0	0	0	0	252	987
Robertson	0	4,879	11,994	0	0	749	0	0	254	0	0	0	12	17,888
Shackelford	17	0	0	110	15	17	0	0	0	0	0	158	0	317
Somervell	0	0	0	0	0	160	0	0	0	0	0	0	210	370
Stephens	0	0	0	0	0	260	0	0	0	0	0	463	0	723
Stonewall	40	0	77	0	0	73	0	94	0	62	0	64	0	410
Taylor	0	0	150	0	200	330	0	0	0	0	0	190	0	870
Throckmorton	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Washington	0	0	0	0	0	85	40	0	265	0	0	0	173	563
Williamson	0	0	0	0	0	10	0	0	20	0	0	0	50	80
Young	0	0	0	0	0	60	0	0	2	0	0	0	0	62
Total	**749**	**14,935**	**75,490**	**14,604**	**4,383**	**28,541**	**156**	**22,989**	**12,273**	**3,553**	**3,131**	**33,644**	**3,468**	**217,916**
Percent	**0.3**	**6.9**	**34.6**	**6.7**	**2.0**	**13.1**	**0.1**	**10.5**	**5.6**	**1.6**	**1.4**	**15.4**	**1.6**	**100**

Table 4B.2-7. Projected Irrigation Water Demands, Supplies, and Needs (Shortages) in Counties Having Projected Irrigation Shortages

	Projections (acft/yr)						
County	***2000***	***2010***	***2020***	***2030***	***2040***	***2050***	***2060***
Eastland							
Irrigation Demand	16,274	16,302	16,327	16,352	16,370	16,377	16,385
Irrigation Existing Supply							
Groundwater	4,563	4,563	4,563	4,563	4,563	4,563	4,563
Surface water	2,404	2,404	2,404	2,404	2,404	2,404	2,404
Total Irrigation Supply	6,967	6,967	6,967	6,967	6,967	6,967	6,967
Shortage	(9,307)	(9,335)	(9,360)	(9,385)	(9,403)	(9,410)	(9,418)
Haskell							
Irrigation Demand	50,820	49,309	47,844	46,422	45,040	43,702	42,405
Irrigation Existing Supply							
Groundwater	19,360	19,360	19,360	19,360	19,360	19,360	19,360
Surface water	847	844	841	839	836	833	830
Total Irrigation Supply	20,207	20,204	20,201	20,199	20,196	20,193	20,190
Shortage	(30,613)	(29,105)	(27,643)	(26,223)	(24,844)	(23,509)	(22,215)
Knox							
Irrigation Demand	43,124	42,065	41,033	40,025	39,041	38,082	37,147
Irrigation Existing Supply							
Groundwater	23,807	23,807	23,807	23,807	23,807	23,807	23,807
Surface water	2,951	2,951	2,951	2,951	2,951	2,951	2,951
Total Irrigation Supply	26,758	26,758	26,758	26,758	26,758	26,758	26,758
Shortage	(16,366)	(15,307)	(14,275)	(13,267)	(12,283)	(11,324)	(10,389)
Nolan							
Irrigation Demand	5,276	5,138	5,003	4,871	4,741	4,618	4,497
Irrigation Existing Supply							
Groundwater	3,286	3,286	3,286	3,286	3,286	3,286	3,286
Surface water	120	120	120	120	120	120	120
Total Irrigation Supply	3,406	3,406	3,406	3,406	3,406	3,406	3,406
Shortage	(1,870)	(1,732)	(1,597)	(1,465)	(1,335)	(1,212)	(1,091)
Shackelford							
Irrigation Demand	195	189	183	178	173	168	163
Irrigation Existing Supply							
Groundwater	0	0	0	0	0	0	0
Surface water	85	85	85	85	85	85	85
Total Irrigation Supply	85	85	85	85	85	85	85
Shortage	(110)	(104)	(98)	(93)	(88)	(83)	(78)
Throckmorton							
Irrigation Demand	0	4,000	4,000	4,000	4,000	4,000	4,000
Irrigation Existing Supply							
Groundwater	0	0	0	0	0	0	0
Surface water	12	12	12	12	12	12	12
Total Irrigation Supply	12	12	12	12	12	12	12
Shortage	12	(3,988)	(3,988)	(3,988)	(3,988)	(3,988)	(3,988)

4B.2.2.2 Available Yield

In February 2005, the Brazos G RWPG recommended that counties with projected irrigation needs (shortages) reduce their irrigation water demands by 3 percent by 2010, 5 percent by 2020, and 7 percent from 2030 to 2060 by using Best Management Practices (BMPs) identified by the Task Force. A reduction in irrigation water demand subsequently reduces shortages for each decade, if water supplies remain constant. In 2060, with conservation reductions, the shortage reductions would range between 12 percent for Eastland County to 25 percent for Knox County (Table 4B.2-8). The maximum water savings expected amongst the six counties is for Haskell County, with a recommended savings of 3,250 acft/yr in 2030.

Table 4B.2-8.
Projected Water Demands and Needs (Shortages) for
Irrigation Users after Recommended Irrigation Water Conservation

Counties	*2010*	*2020*	*2030*	*2040*	*2050*	*2060*
Eastland						
New Demand (acft/yr)	15,813	15,511	15,207	15,224	15,231	15,238
Expected Savings (acft/yr)	*489*	*816*	*1,145*	*1,146*	*1,146*	*1,147*
New shortage (acft/yr)	(8,846)	(8,544)	(8,240)	(8,257)	(8,264)	(8,271)
Shortage Reduction (acft/yr)	5%	9%	12%	12%	12%	12%
Haskell						
New Demand (acft/yr)	47,830	45,452	43,172	41,887	40,643	39,437
Expected Savings (acft/yr)	*1,479*	*2,392*	*3,250*	*3,153*	*3,059*	*2,968*
New shortage (acft/yr)	(27,626)	(25,251)	(22,973)	(21,691)	(20,450)	(19,247)
Shortage Reduction (acft/yr)	5%	9%	12%	13%	13%	13%
Knox						
New Demand (acft/yr)	40,803	38,981	37,223	36,308	35,416	34,547
Expected Savings (acft/yr)	*1,262*	*2,052*	*2,802*	*2,733*	*2,666*	*2,600*
New shortage (acft/yr)	(14,045)	(12,223)	10,465)	(9,550)	(8,658)	(7,789)
Shortage Reduction (acft/yr)	8%	14%	21%	22%	24%	25%
Nolan						
New Demand (acft/yr)	4,984	4,753	4,530	4,409	4,295	4,182
Expected Savings (acft/yr)	*154*	*250*	*341*	*332*	*323*	*315*
New shortage (acft/yr)	(1,578)	(1,347)	(1,124)	(1,003)	(889)	(776)
Shortage Reduction (acft/yr)	9%	16%	23%	25%	27%	29%
Shackelford						
New Demand (acft/yr)	183	174	166	161	156	152
Expected Savings (acft/yr)	*6*	*9*	*12*	*12*	*12*	*11*
New shortage (acft/yr)	(98)	(89)	(82)	(77)	(72)	(69)
Shortage Reduction (acft/yr)	6%	9%	13%	13%	14%	14%

Thockmorton County had no irrigation water use in 2000 according to the TWDB. The irrigation demand projections for Throckmorton County are reflective of this with a demand of 0 acft/yr in 2000 and 4,000 acft/yr from 2010 through 2060. It is assumed that since this appears to be new irrigation in the county, the irrigators will utilize the most efficient means to irrigate their crops; therefore, no additional irrigation conservation is recommended for Throckmorton County.

The Task Force report[4] lists the following irrigation BMPs that may be used to achieve the recommended water savings:

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

The Task Force report describes the above BMP methods and how they reduce irrigation water use; however, information regarding specific water savings and costs to install irrigation water saving systems is generally unavailable. The Task Force report does include water savings and costs for three irrigation water conservation BMPs: (1) furrow dikes; (2) low-pressure

[4] Water Conservation Implementation Task Force, Report to the 79th Legislature, Texas Water Development Board, Special Report, Austin, Texas, November 2004.

sprinklers (LESA); and (3) low-energy precision application systems (LEPA). These major irrigation water conservation techniques applicable in the Brazos G Area are described briefly below.

Furrow dikes are small mounds of soil mechanically installed a few feet apart in the furrow. These mounds of soil create small reservoirs that capture precipitation and hold it until it soaks into the soil instead of running down the furrow and out the end of the field. This practice can conserve (capture) as much as 100 percent of rainfall runoff, and furrow dikes are used to prevent irrigation runoff under sprinkler systems. This maintains high irrigation uniformity and increases irrigation application efficiencies. Capturing and holding precipitation that would have drained from the fields replaces required irrigation water. Furrow dikes have been demonstrated to be useful management tools on both irrigated and non-irrigated cropland. Use of furrow dikes can have water savings up to 12 percent of the gross quantity of water applied using sprinkler irrigation. If all six counties with projected irrigation shortages (excluding Throckmorton County) in the Brazos G Area install furrow dikes, the expected water savings could be up to 11,462 acft/yr, assuming 100 percent participation of irrigated lands with sprinkler systems. Furrow dikes require special tillage equipment and cost $7 to $39 per acre to install.

Low-pressure sprinklers (LESA), with 90 percent application efficiency, improve irrigation application efficiency in comparison to conventional furrow irrigation by reducing water requirements per acre by between 10 and 25 percent. Low-pressure sprinklers spray water into the atmosphere above the crops as the sprinkler systems are moved across the fields. In the six Brazos G counties with projected water needs (excluding Throckmorton County), conversion to LESA systems would save about 0.14 to 0.25 acft/acre converted and result in a total savings of 16,567 acft/yr.

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

A comparison of irrigation rates for furrow dikes, LESA, and LEPA systems to irrigation rates before irrigation water conservation are shown in Table 4B.2-9.

4B.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 shown that there are no significant environmental issues associated with this water management strategy. This method improves water use efficiency without making changes to wildlife habitat. This method of application, when coupled with furrow dikes, reduces runoff of both applied irrigation water and rainfall. The results are reduced transport of sediment and any fertilizers or other chemicals that have been applied to the crops. Thus, the proposed conservation practices do not have potential adverse effects, and may have potentially beneficial environmental effects.

4B.2.2.4 Engineering and Costing

The Brazos G RWPG recommended irrigation water conservation (7 percent reduction in demands) as a water management strategy for irrigation needs, resulting in a maximum water savings of 7,552 acft/yr. Furrow dikes could save up to 11,461 acft/yr at an average unit cost of $308 per acft (Table 4B.2-10). Installing LESA or LEPA systems would incur a greater capital cost, and therefore higher annual costs, however both achieve a substantially higher water savings potential and therefore have more economical unit cost ($/acft) when compared to furrow dikes. The maximum water conservation potential can be realized by using the LEPA system, as shown in Table 4B.2-10. The capital cost to install LEPA irrigation is approximately $524 per acre.[5] It is estimated that it would take a total investment of $40.2 million to equip the estimated 76,707 irrigated acres currently served by sprinkler systems within five of the six counties (Throckmorton excluded) with projected irrigation shortages. This investment, at an annual cost of $3.5 million (20 years at 6 percent), would save an estimated 20,722 acft/yr at an average unit cost of $169 per acft of water saved.

[5] Ibid.

Table 4B.2-9.
Region G Irrigated Acreages and Effects of Water Conservation on Irrigation Water Use and Application Rates

County	Acreage Irrigated with Sprinklers (2000)	Without Conservation		With Conservation								
				Furrow Dikes[1]			LESA[2]			LEPA[3]		
		Irrigation Water Use (acft)	Irrigation Rate (acft per acre)	Irrigation Water Use (acft)	Irrigation Rate (acft per acre)	Estimated water savings (acft)	Irrigation Water Use (acft)	Irrigation Rate (acft per acre)	Estimated water savings (acft)	Irrigation Water Use (acft)	Irrigation Rate (acft per acre)	Estimated water savings (acft)
Eastland	14,221	16,274	1.14	14,321	1.01	1,953	12,658	0.89	3,616	11,991	0.84	4,283
Haskell	31,107	44,584	1.43	39,234	1.26	5,350	37,153	1.19	7,431	35,198	1.13	9,386
Knox	28,647	29,846	1.04	26,264	0.92	3,581	24,871	0.87	4,974	23,562	0.82	6,283
Nolan	2,575	4,709	1.83	4,144	1.61	565	4,185	1.63	523	3,965	1.54	743
Shackelford	157	102	0.65	90	0.57	12	79	0.50	23	75	0.48	27

[1] 12 percent savings of water applied using sprinkler irrigation.
[2] Assumes application efficiency of 90 percent.
[3] Assumes application efficiency of 95 percent.

Table 4B.2-10.
Potential Water Savings and Costs (Total Project, Annual Average, and Unit Costs) to Implement Irrigation Water Conservation Best Management Practices

County	Maximum Desired Water Savings (acft)	Furrow Dikes			LESA (90% efficiency)				LEPA (95% efficiency)			
		Max. Amt. Saved (acft)	Annual Cost[1] (average)	Avg. Cost per acft	Max. Amt. Saved (acft)	Total Project Cost (average)	Annual Cost[1] (average)	Avg. Cost per acft	Max. Amt. Saved (acft)	Total Project Cost (average)	Annual Cost[1] (average)	Avg. Cost per acft
Eastland	1,147	**1,953**	$327,083	$335	**3,616**	$7,451,804	$649,682	$180	**4,283**	$7,451,804	$649,682	$152
Haskell	3,250	**5,350**	$715,461	$267	**7,431**	$16,300,068	$1,421,114	$191	**9,386**	$16,300,068	$1,421,114	$151
Knox	2,802	**3,581**	$658,881	$368	**4,974**	$15,011,028	$1,308,730	$263	**6,283**	$15,011,028	$1,308,730	$208
Nolan	341	**565**	$59,225	$210	**523**	$1,349,300	$117,638	$225	**743**	$1,349,300	$117,638	$0
Shackelford	12	**12**	$3,611	$591	**23**	$82,268	$7,172	$317	**27**	$82,268	$7,172	$268
Total	**7,552**	**11,461**	**$1,764,261**	**$308**	**16,567**	**$40,194,468**	**$3,504,336**	**$212**	**20,722**	**$40,194,468**	**$3,504,336**	**$169**

[1] Annual costs calculated assuming debt service for 20 years at 6 percent interest.

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

It may not be economically feasible for agricultural producers to pay for additional water supplies to meet projected irrigation water needs (shortages), even if such supplies were available. For example, in 2004, the estimated income for irrigated cotton remaining after other production expenses had been paid was about $68 per acre, and the income for wheat with high input management was about $65 per acre. At an application rate of about 1 acft/acre, the cost of water from other sources far exceeds these values. For example, costs for water management strategies (new reservoirs) considered to meet projected municipal needs ranged between $210 per acft and $1,176 per acft for raw water supply at the reservoirs. The costs greatly exceed the income that would be realized from land irrigated with these water supplies.

4B.2.2.5 Implementation Issues

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 4B.2-11 and the options meets most criteria.

Table 4B.2-11.
Comparison of Irrigation Water Conservation Option to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Firm Yield: Variable according to BMP selected. Ranges from 11,461 acft/yr to 20,722 acft/yr
2. Reliability	2. High reliability
3. Cost	3. High for internal use: Ranges from $169 to $308 per acft water saved (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 Strategies Deemed Feasible	• Standard analyses and methods used
F. Requirements for Interbasin Transfers	• None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.2.3 Water Conservation for Industrial Uses

4B.2.3.1 Description of Strategy

Water uses for industrial purposes (manufacturing, steam-electric power generation, and mining) are primarily associated with manufacturing products, cleaning and waste removal, waste heat removal, dust control, landscaping, and mine dewatering. In the Brazos G Area, industrial water demands amounted to 193,123 acft/yr in 2000 (24% total water demand) and are projected to increase to 373,069 acft/yr in 2060 (30% of total water demand) as shown in Table 4B.2-12.

Table 4B.2-12.
Projected Water Demands, Supplies, and Needs (Shortages) for Industrial Uses in the Brazos G Area

	Projections (acft/yr)						
	2000	*2010*	*2020*	*2030*	*2040*	*2050*	*2060*
Manufacturing							
Demand	16,939	19,787	23,201	25,077	26,962	30,191	31,942
Existing Supply							
Groundwater	13,843	16,710	16,710	16,710	16,710	16,710	16,710
Surface water	35,185	35,876	36,364	36,816	37,273	37,676	38,239
Total Supply	49,041	52,493	52,981	53,433	53,983	54,386	54,949
Manufacturing Balance	32,102	32,706	29,780	28,356	27,021	24,195	23,007
Steam-Electric							
Demand	103,330	168,193	221,696	254,803	271,271	300,859	319,884
Existing Supply							
Groundwater	9,585	9,119	9,119	9,119	9,119	9,119	9,119
Surface water	235,701	257,070	258,396	257,804	257,232	256,650	256,069
Total Supply	245,286	266,189	267,515	266,923	266,351	265,769	265,188
Steam-Electric Balance	141,956	97,996	45,819	12,120	(4,920)	(35,090)	(54,696)
Mining							
Demand	72,854	36,664	37,591	38,037	27,251	20,744	21,243
Existing Supply							
Groundwater	49,285	28,657	28,725	28,753	17,628	10,717	10,755
Surface water	4,269	4,272	4,275	4,278	4,282	4,285	4,288
Total Supply	53,554	32,929	33,000	33,031	21,910	15,002	15,043
Mining Balance	(19,300)	(3,735)	(4,591)	(5,006)	(5,341)	(5,742)	(6,200)
Total Industrial							
Demand	193,123	224,644	282,488	317,917	325,484	351,794	373,069
Existing Supply							
Groundwater	72,726	54,393	54,461	54,489	43,457	36,546	36,584
Surface water	275,154	297,218	299,035	298,898	298,786	298,611	298,596
Total Supply	347,880	351,611	353,496	353,387	342,243	335,157	335,180
Total Industrial Balance	154,757	126,967	71,008	35,470	16,759	(16,637)	(37,889)

Manufacturing is a significant part of the Brazos G Area's economy, and industries use water as a component of the final product, for cooling, and cleaning/wash-down of parts and/or products. Regional industries that are major water users include food and kindred products, apparel, fabricated metal, machinery, and stone and concrete production. Manufacturing water demand is projected at 19,787 acft/yr in 2010 and expected to increase to 31,942 acft/yr by 2060. There are five counties in the Brazos G Area with projected manufacturing needs: Johnson, Lampasas, Limestone, Nolan, and Williamson. In 2060, the estimated water needs are 10,924 acft/yr, which is 34% of the manufacturing water demand for the Brazos G Area.

In the Brazos G Area, the trends for steam-electric water demands are projected to increase each decade with a maximum demand of 319,884 acft/yr by 2060. Grimes, Limestone, McLennan, Nolan, Robertson, and Somervell Counties comprise over 80 percent of the projected regional steam-electric water use in 2060. The increase in water demand is due to projected increases in population and manufacturing growth and estimated increases in fresh water use based on projected power generation capacities. The Brazos G Area steam-electric users receive 96% of their water supplies from surface water sources. There are ten counties in the Brazos G Area with projected steam-electric needs: Bell, Bosque, Grimes, Johnson, Limestone, McLennan, Milam, Nolan, Robertson, and Somervell. In 2060, the estimated water needs are 132,871 acft/yr, which is 42% of the steam-electric water demand for the Brazos G Area.

Gross state product data released from the U.S. Department of Commerce shows mining economic outputs of $37.6 billion for 1999 and $29.9 billion for 2000.[6] The TWDB water demand projections for mining users is generally based on projected economic output, assuming that past and current water use trends remain constant over time. In the Brazos G Area, the trends for mining water demands are projected to decrease during the planning period from 36,664 acft/yr in 2010 to 21,243 acft/yr by 2060, largely due to projected closure of the Sandow Mine in Milam County. In 2000, the Brazos G Area mining users received 92% of their water supplies from groundwater sources. Groundwater use is expected to decline to 71% of the regional mining water supply by 2060. There are three counties in the Brazos G Area with projected mining needs: Nolan, Stephens, and Williamson. In 2060, the estimated water needs are 12,156 acft, which is 57% of the steam-electric water demand for the Brazos G Area.

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

TWDB Rules for regional water planning require Regional Water Planning Groups to consider water conservation and drought management measures for each water user group with a need (projected water shortage). In addition, the Rules direct that water conservation BMPs, as identified by the Water Conservation Implementation Task Force (Task Force), be considered in the development of the water conservation water management strategy.

4B.2.3.2 Available Yield

In February 2005, the Brazos G RWPG recommended that counties with projected needs (shortages) for industrial users (manufacturing, steam electric, or mining) reduce those water demands by 3 percent by 2010, 5 percent by 2020, and 7 percent from 2030 to 2060 by using Best Management Practices identified by the Water Conservation Implementation Task Force.

For the five manufacturing users with projected needs, the total water savings after 7 percent water demand reduction in 2060 is 594 acft/yr (a 10% reduction in total regional manufacturing shortages) as shown in Table 4B.2-13.

For the ten steam-electric users with projected needs, the total water savings after 7 percent water demand reduction in 2060 is 20,977 acft/yr (a 25% reduction in total regional steam-electric shortages) as shown in Table 4B.2-14. Bell, Nolan and Somervell Counties have significant increases in steam-electric demands during the planning period. It is assumed that with these new demands generating facilities will utilize the most water efficient means appropriate to produce power; therefore, no additional steam-electric conservation is recommended for Bell, Nolan and Somervell counties.

For the three mining users with projected needs, the total water savings after 7 percent water demand reduction in 2060 is 973 acft/yr (a 16% reduction in total regional mining shortages) as shown in Table 4B.2-15.

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

1. Industrial Water Audit,
2. Industrial Water Waste Reduction,
3. Industrial Submetering,
4. Cooling Towers,
5. Cooling Systems (other than Cooling Towers),

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

6. Industrial Alternative Sources and Reuse and Recirculation of Process Water,
7. Rinsing/Cleaning,
8. Water Treatment,
9. Boiler and Steam Systems,
10. Refrigeration (including Chilled Water),
11. Once-Through Cooling,
12. Management and Employee Programs,
13. Industrial Landscape, and
14. Industrial Site Specific Conservation.

Table 4B.2-13.
Projected Water Demands and Needs (Shortages) for Manufacturing Users Considering up to a 7 Percent Demand Reduction by 2030

	Projections (acft/yr)					
	2010	***2020***	***2030***	***2040***	***2050***	***2060***
Johnson						
New Demand	2,057	2,391	2,700	3,064	3,391	3,714
Expected Savings	64	126	203	231	255	280
New Shortage	(1,295)	(1,629)	(1,938)	(2,322)	(2,629)	(2,952)
Shortage Reduction	5%	7%	9%	9%	9%	9%
Lampasas						
New Demand	125	135	142	153	162	174
Expected Savings	4	7	11	11	12	13
New Shortage	(107)	(117)	(124)	(135)	(144)	(156)
Shortage Reduction	4%	6%	8%	8%	8%	8%
Limestone						
New Demand	47	50	54	59	62	67
Expected Savings	1	3	4	4	5	5
New Shortage	(17)	(25)	(35)	(45)	(54)	(64)
Shortage Reduction	6%	11%	10%	8%	8%	7%
Nolan						
New Demand	756	869	965	1,078	1,177	1,276
Expected Savings	23	46	73	81	89	96
New Shortage	—	—	—	—	—	—
Shortage Reduction	—	—	—	—	—	100%
Williamson						
New Demand	1,539	1,761	1,971	2,221	2,446	2,656
Expected Savings	48	93	149	167	184	200
New Shortage	(1,203)	(1,425)	(1,635)	(1,885)	(2,110)	(2,320)
Shortage Reduction	4%	6%	8%	8%	8%	8%
Total Savings	**140**	**275**	**440**	**494**	**540**	**594**

Table 4B.2-14.
Projected Water Demands and Needs (Shortages) for
Steam-Electric Users Considering up to a 7% Percent Demand Reduction by 2030

	Projections (acft/yr)					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Bell[1]						
New Demand	0	3,490	3,995	4,699	5,558	6,605
Expected Savings	—	184	301	354	419	497
New Shortage	—	(3,490)	(3,995)	(4,699)	(5,558)	(6,605)
Shortage Reduction	—	5%	7%	7%	7%	7%
Bosque						
New Demand	4,193	5,879	6,729	7,914	9,360	11,124
Expected Savings	130	309	506	596	705	837
New Shortage	—	—	(229)	(1,414)	(2,860)	(4,624)
Shortage Reduction	—	—	69%	30%	20%	15%
Grimes						
New Demand	11,640	30,172	30,839	32,234	34,094	36,884
Expected Savings	360	1,588	2,321	2,426	2,566	2,776
New Shortage	—	(13,711)	(14,378)	(15,773)	(17,633)	(20,423)
Shortage Reduction	—	10%	14%	13%	13%	12%
Johnson						
New Demand	3,395	6,650	6,510	6,510	6,510	6,510
Expected Savings	105	350	490	490	490	490
New Shortage	(2051)	(5,306)	(5,166)	(5,166)	(5,166)	(5,166)
Shortage Reduction	5%	6%	9%	9%	9%	9%
Limestone						
New Demand	21,662	21,468	24,571	28,903	34,185	40,623
Expected Savings	670	1,130	1,849	2,176	2,573	3,058
New Shortage	—	—	—	(2,519)	(7,940)	(14,518)
Shortage Reduction	—	—	—	46%	24%	17%
Milam						
New Demand	12,125	11,875	11,625	11,625	14,880	14,880
Expected Savings	375	625	875	875	1,120	1,120
New Shortage	—	—	—	—	(880)	(880)
Shortage Reduction	—	—	—	—	56%	56%

Table 4B.2-14. (Concluded)

	Projections (acft/yr)					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Nolan[1]						
New Demand	783	10,745	18,600	18,600	18,600	18,600
Expected Savings	24	566	1,400	1,400	1,400	1,400
New Shortage	(783)	(10,745)	(18,600)	(18,600)	(18,600)	(18,600)
Shortage Reduction	3%	5%	7%	7%	7%	7%
Robertson						
New Demand	15,315	16,988	28,935	33,823	44,750	46,797
Expected Savings	474	894	2,178	2,546	3,368	3,522
New Shortage	—	—	—	—	(10,908)	(12,963)
Shortage Reduction	—	—	—	100%	24%	21%
Somervell[1]						
New Demand	82,272	80,576	78,880	78,880	78,880	78,880
Expected Savings	2,545	4,241	5,937	5,937	5,937	5,937
New Shortage	(33,035)	(31,301)	(29,568)	(29,530)	(29,493)	(29,455)
Shortage Reduction	7%	12%	17%	17%	17%	17%
Total Savings	**4,683**	**9,887**	**15,857**	**16,800**	**18,578**	**19,637**

[1] – Conservation is not recommended since these represent new demands utilizing efficient technology.

Table 4B.2-15.
Projected Water Demands and Needs (Shortages) for
Mining Users Considering up to a 7% Percent Demand Reduction by 2030

	Projections (acft/yr)					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Nolan						
New Demand	270	264	259	259	259	259
Expected Savings	8	14	19	19	19	19
New Shortage	(100)	(94)	(89)	(89)	(89)	(89)
Shortage Reduction	7%	13%	18%	18%	18%	18%
Stephens						
New Demand	8,454	8,862	8,897	9,112	9,322	9,623
Expected Savings	261	466	670	686	702	724
New Shortage	(7,360)	(7,768)	(7,803)	(8,018)	(8,228)	(8,529)
Shortage Reduction	3%	6%	8%	8%	8%	8%
Williamson						
New Demand	2,283	2,484	2,599	2,764	2,929	3,050
Expected Savings	71	131	196	208	220	230
New Shortage	(1,798)	(1,999)	(2,114)	(2,279)	(2,444)	(2,565)
Shortage Reduction	4%	6%	8%	8%	8%	8%
Total Savings	**340**	**611**	**885**	**913**	**941**	**973**

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

4B.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 changes to wildlife habitat. Thus, the proposed conservation practices do not have anticipated potential adverse effects, and may have potentially beneficial environmental effects.

4B.2.3.4 Engineering and Costing

The Brazos G RWPG recommends implementing water conservation for industrial users (manufacturing, steam-electric, and mining) with projected needs amounting to a 3 percent water demand reduction by 2010, 5 percent by 2020, and 7 percent from 2030 to 2060. The six counties in the Brazos G Area with projected manufacturing shortages can save up to 1,016 acft/yr in 2060. The ten counties in the Brazos G Area with projected steam-electric shortages can save up to 20,977 acft in 2060. The three counties in the Brazos G Area with projected mining shortages can save up to 973 acft in 2060. 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.

4B.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 4B.2-16 and the option meets each criterion.

Table 4B.2-16.
Comparison of Industrial Water Conservation Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1 Quantity	1. Manufacturing Firm Yield: up to 1,430 acft/yr Steam-Electric Firm Yield: up to 13,281 acft/yr Mining Firm Yield: up to 1,074 acft/yr
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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4B.3 Wastewater Reuse

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

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

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

4B.3.1 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 4B.3-1. 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 4B.3-1.
TCEQ Quality Standards for Reuse Water

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

1 geometric mean
2 single grab sample

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

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

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

1. City of College Station;
2. City of Round Rock;
3. City of Bryan;
4. City of Cleburne;
5. WMARSS - Waco East – LS Power Station, Hallsburg, Mart, and Riesel;
6. WMARSS - Bellmead/Lacy-Lakeview;
7. WMARSS - Bull Hide Creek;
8. WMARSS - Flat Creek; and
9. WMARSS - Waco North – Chalk Bluff WSC and Gholson.
10. Bell County WCID No.1 – Killeen and Harker Heights

4B.3.1.1 General Evaluation of Direct Reuse Potential for Multiple Water User Groups

4B.3.1.1.1 Description of Option

Many water user groups with need have the potential to develop wastewater reuse projects, and a general evaluation of wastewater reuse potential was conducted for these entities. Figure 4B.3-1 shows the municipal county balances and the "Year 2060 Confirmed Discharge" for wastewater treatment plants with 1 MGD or greater treatment capacity. The "Year 2060 Confirmed Discharge" is the projected wastewater discharge into the receiving stream as reported by the entity responsible for the wastewater treatment plant. Some entities reported that they intended to utilize all 2060 wastewater effluent for reuse and therefore the confirmed discharge reported is zero. Figure 4B.3-2 shows the municipal balance of individual water user groups.

4B.3.1.1.2 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

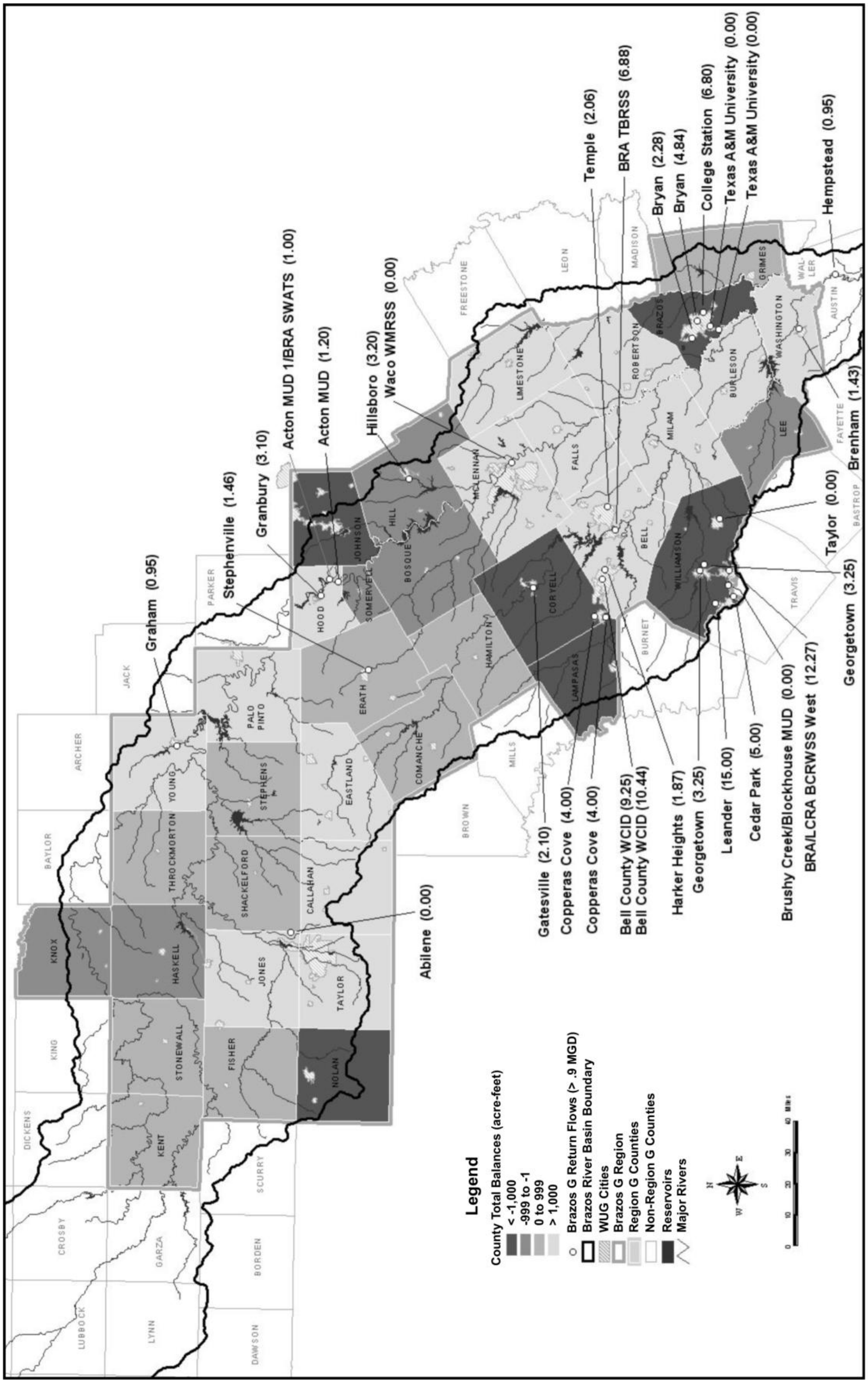

Figure 4B.3-1. Year 2060 Confirmed Discharges and County Balances

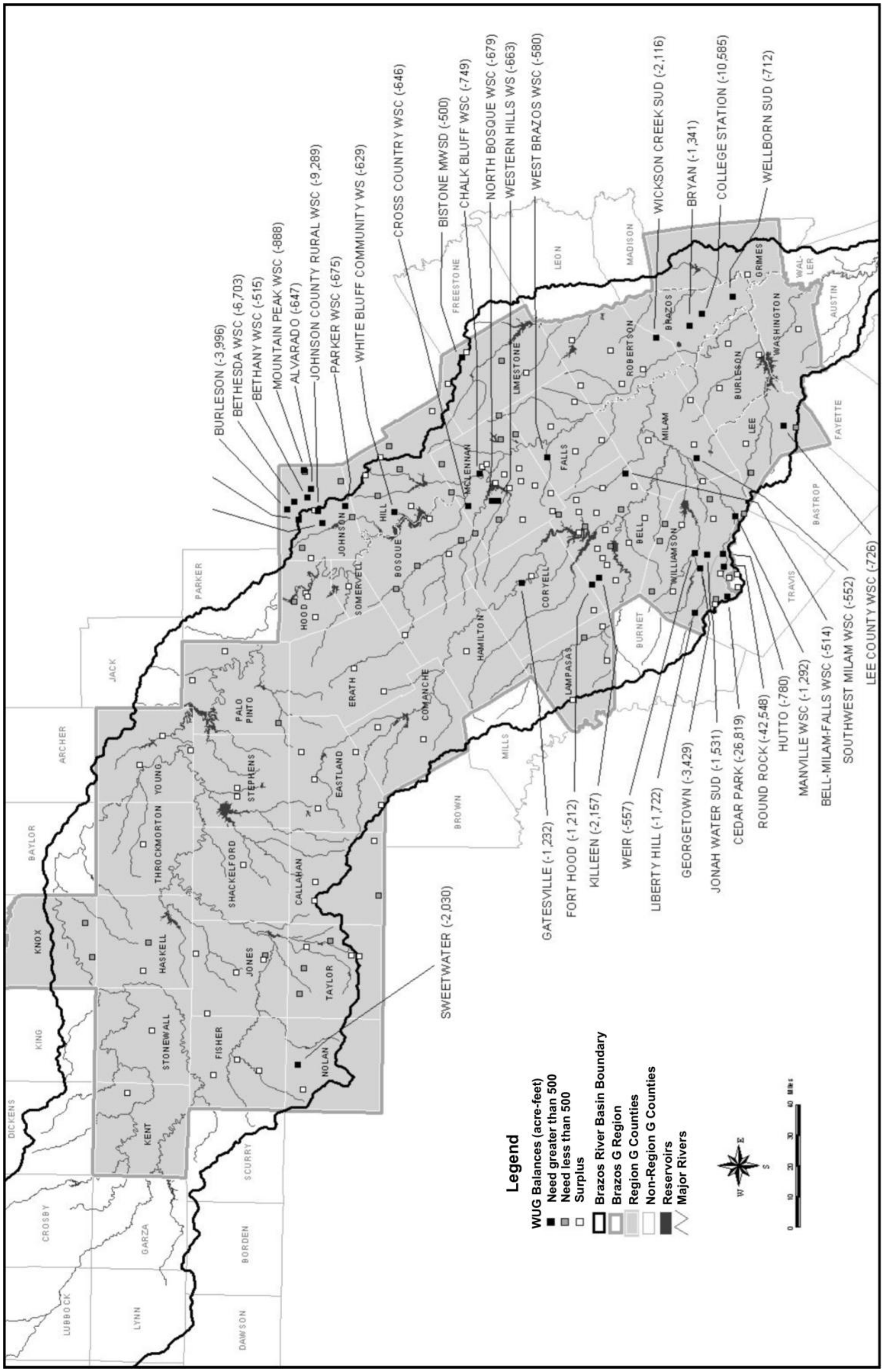

Figure 4B.3-2. Year 2060 Water User Group Balances plants or open land that benefits from irrigation, such as golf courses, are located relatively close to the plant, then reuse can provide a substantial benefit to water supplies.

In order to isolate those communities that may potentially benefit from a reuse program, information regarding each of the communities with both a projected need for additional water supply and a wastewater treatment plant (WWTP) proximate to need was gathered. Table 4B.3-2 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 2060 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.

4B.3.1.1.3 Environmental Issues

A summary of environmental issues is presented in Table 4B.3-3.

4B.3.1.1.4 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 4B.3-4. To provide more flexibility in the types of wastewater reuse applications possible, the scenarios assume the use of a type 1 wastewater effluent.

Table 4B.3-2. General Wastewater Reuse Potential

WUG	*County*	*Proximate WW Treatment Facility Over 1 MGD*	*2060 Projected Need (acft/yr)*	*2060 Projected Need Percent of Demand*	*Current Reuse*	*2060 Maximum Available WWTP Effluent (acft/yr)*	*2060 Confirmed Reuse by owner (acft/yr)*
Killeen	Bell	Bell County WCID#1-3	4,468	13%	N	19,001	7,298
Little River Academy	Bell	BRA TBRSS	27	9%	N	14,092	6,382
Morgan's Point Resort	Bell	BRA TBRSS	332	53%	N	14,092	6,382
Steam Electric	Bell	City of Temple	7,102	100%	N	2,304	0
Temple	Bell	BRA TBRSS	14,319	47%	Y	14,092	6,382
Bryan	Brazos	City of Bryan-1 & 2	313	2%	Y	8,354	8,354
College Station	Brazos	City of College Station + Texas A&M University - 1 & 2	5,631	18%	Y	8,354	8,354
Wickson Creek SUD	Brazos	City of Bryan-1	2,300	62%	N	8,354	8,354
Gatesville	Coryell	City of Gatesville-2	1,450	24%	Y	4,029	1,675
Kempner WSC	Coryell	City of Copperas Cove-2	181	5%	N	1,786	0
Oak Trail Shores Sub.	Hood	City of Granbury	333	69%	N	2,136	0
Cleburne	Johnson	City of Cleburne	1,954	20%	Y	2,616	2,616
Godley	Johnson	City of Godley	353	82%	N	331	331
Joshua	Johnson	JCSUD	0	0%	N	0	0
Johnson County SUD	Johnson	Acton MUD 1	17,513	71%	Y	1,836	715
Hawley WSC	Jones	City of Abilene	5	1%	N	14,460	14,460
Aqua WSC	Lee	BRA/LCRA BCRWSS West	264	34%	N	13,742	0
Bellmead	McLennan	WMRSS	0	0%	Y	31,781	31,781
Chalk Bluff WSC	McLennan	WMRSS	0	0%	N	31,781	31,781
Hallsburg	McLennan	WMRSS	45	25%	N	31,781	31,781
Lacy Lakeview	McLennan	WMRSS	0	0%	Y	31,781	31,781
Mart	McLennan	WMRSS	272	66%	N	31,781	31,781
Riesel	McLennan	WMRSS	31	23%	N	31,781	31,781
Sweetwater	Nolan	City of Sweetwater	1,117	40%	Y	0	0
Glen Rose	Somervell	Acton MUD 1	77	9%	Y	1,836	715
Abilene	Taylor	City of Abilene	17,812	81%	Y	14,460	14,460
Blockhouse MUD	Williamson	Block House MUD	2,058	61%	N	2,879	2,879
Brushy Creek MUD	Williamson	Brushy Creek MUD	478	12%	N	2,448	2,448
Cedar Park	Williamson	City of Cedar Park	9,586	44%	N	23,584	17,979
Chisolm Trail SUD	Williamson	City of Georgetown-1	3,909	29%	N	6,342	2,699
Georgetown	Williamson	City of Georgetown-1	16,082	48%	Y	6,342	2,699
Hutto	Williamson	BRA/LCRA BCRWSS West	3,295	59%	N	13,742	0
Jonah Water SUD	Williamson	City of Georgetown-2	2,345	48%	N	6,790	3,248
Leander	Williamson	City of Leander	7,039	52%	Y	3,347	0
Liberty Hill	Williamson	City of Leander	1,797	96%	N	3,347	0
Manufacturing	Williamson	City of Georgetown-2	2,520	88%	N	6,790	3,248
Mining	Williamson	City of Georgetown-2	2,795	85%	N	6,790	3,248
Round Rock	Williamson	BRA/LCRA BCRWSS East	59,492	79%	N	0	0
Thrall	Williamson	City of Taylor	293	96%	N	3,367	3,367
Weir	Williamson	City of Georgetown-1	568	98%	N	6,342	2,699
Williamson C-O	Williamson	City of Leander	3,355	72%	N	3,347	0

Table 4B.3-3.
Environmental Issues: General Wastewater Reuse

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

Table 4B.3-4.
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 Tables 4B.3-5. 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 4B.3-6 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 4B.3-6, the annual available project yield is 57 percent of the reuse system capacity. Available project yield may be higher than 57 percent of maximum capacity for systems supplying a large portion of the reuse water to industrial or other users that have a more uniform reuse water demand.

Table 4B.3-5.
Wastewater Reuse Scenarios 1, and 2 Required Distribution Facilities

Facility	Maximum Capacity (MGD)				Description
	0.5	1	5	10	
Pump Station, HP	127	248	1,209	2,332	Capacity to deliver maximum daily demand in 6 hours
Storage Tank, MG	0.5	1	5	10	Store one days treated reuse water at WWTP
Pipeline, Size in Inches (Length in Miles)	12 (2)	16 (2)	33 (3) 18 (2) 12 (1)	48 (4) 18 (3) 12 (2)	Capacity to deliver maximum daily demand in 6 hours
Available Project Yield, acft/yr (MGD)	319 (0.28)	638 (0.57)	3,193 (2.85)	6,385 (5.7)	Yield is 57 percent of maximum treatment capacity based on seasonal use shown in Table 4B.3-7

Table 4B.3-6.
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 4B.3-7 shows annual cost of reuse water per 1,000 gallons for a range of project scenarios and capacities. Figure 4B.3-3 expresses those costs graphically as an annual cost per acft. These costs are for general planning purposes and will vary significantly depending on the specific circumstances of an individual water user group. Tables 4B.3-8 and 4B.3-9 show the total project capital costs and total operations and maintenance costs for reuse water supplies, respectively.

Table 4B.3-7.
General Wastewater Reuse Annual Cost of Water
($ per 1,000 gal available project yield)
September 2008 Prices

Scenario	***Capacity (MGD)***			
	0.5	***1***	***5***	***10***
1	$4.00	$2.94	$1.91	$1.69
2	$7.61	$5.57	$3.47	$3.04
Debt Service (6 percent for 20 years)				

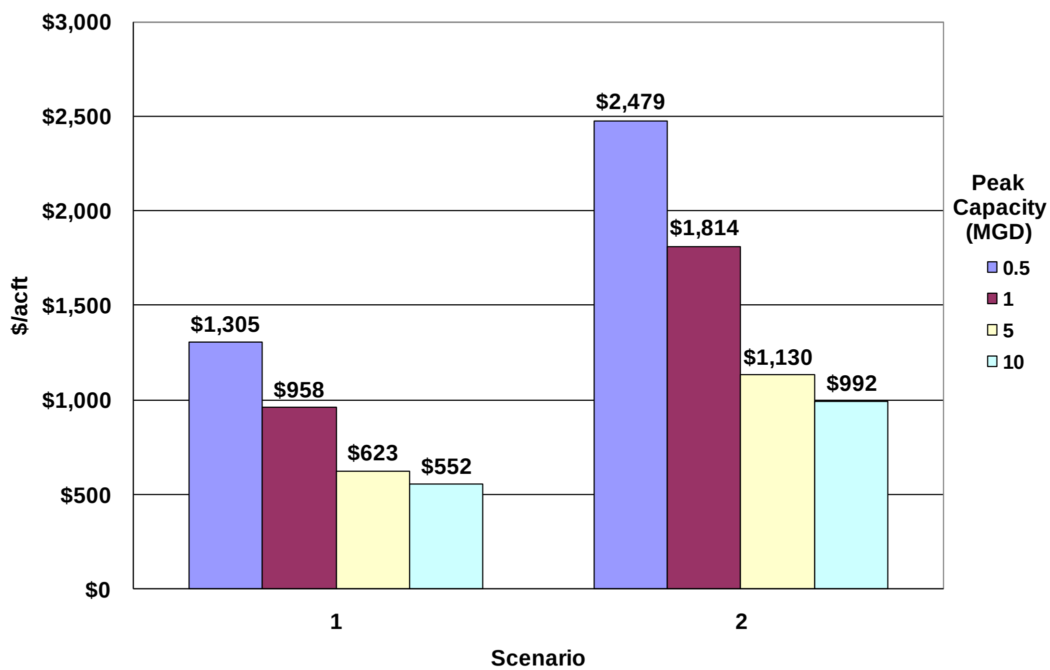

Figure 4B.3-3. General Wastewater Reuse Annual Cost of Water
($ per acft available project yield)
September 2008 Prices

Table 4B.3-8.
General Wastewater Reuse Total Project Capital Cost
($ per gallon maximum capacity)
September 2008 Prices

	Maximum Capacity (MGD)			
Scenario	***0.5***	***1***	***5***	***10***
1	$7.91	$5.67	$3.73	$1.87
2	$11.10	$7.96	$4.97	$2.48

Table 4B.3-9.
General Wastewater Reuse Total Operations and Maintenance Cost
($ per 1,000 gallons)
September 2008 Prices

	Maximum Capacity (MGD)			
Scenario	***0.5***	***1***	***5***	***10***
1	$0.69	$0.56	$0.35	$0.30
2	$2.95	$2.23	$1.39	$1.23

The general wastewater reuse costs are utilized to develop the cost estimates for individual water user groups shown in Table 4B.3-10. The reuse project maximum capacity (MGD) for each water user group was developed based on the "2060 Projected Need" and "2060 Potential Reuse," as shown in Table 4B.3-3. A reuse scenario, as shown in Table 4B.3-4, 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 as water supply options are not included in Table 4B.3-10; the individual options should be referenced for information on reuse options for these water user groups.

4B.3.1.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-11, 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.

Table 4B.3-10. Cost Estimate Summaries Reuse as a Water Management Strategy for Multiple Water User Groups September 2008 Prices

Water User Group	County	Reuse Maximum Capacity (MGD)	Available Project Yield (MGD)	Scenario	Unit Cost ($/1000 gal)	Project Cost ($/gal)	Project Cost ($)
Killeen	Bell	See Individual Option					
Little River Academy	Bell	0.20	0.11	2	$7.61	$11.10	$2,220,562
Morgan's Point Resort	Bell	0.20	0.11	2	$7.61	$11.10	$2,220,562
Steam Electric	Bell	7.50	7.50	2	$3.04	$2.48	$17,404,000
Bryan	Brazos	See Individual Option					
College Station	Brazos	See Individual Option					
Wickson Creek SUD	Brazos	0.20	0.11	2	$7.61	$11.10	$2,220,562
Gatesville	Coryell	1.00	0.57	2	$5.57	$7.96	$7,955,169
Kempner WSC	Coryell	1.00	0.57	2	$5.57	$7.96	$7,955,169
Oak Trail Shores Sub.	Hood	0.20	0.11	2	$7.61	$11.10	$2,220,562
Cleburne	Johnson	See Individual Option					
Godley	Johnson	0.10	0.06	2	$7.61	$11.10	$1,110,281
Joshua	Johnson	0.10	0.06	2	$7.61	$11.10	$1,110,281
Johnson County SUD	Johnson	1.00	0.57	2	$5.57	$7.96	$7,955,169
Hawley WSC	Jones	0.10	0.06	2	$7.61	$11.10	$1,110,281
Aqua WSC	Lee	0.10	0.06	2	$7.61	$11.10	$1,110,281
Chalk Bluff WSC	McLennan	See Individual Option					
Hallsburg	Mclennan	See Individual Option					
Mart	Mclennan	See Individual Option					
Riesel	Mclennan	See Individual Option					
Bellmead	McLennan	See Individual Option					
Lacy-Lakeview	McLennan	See Individual Option					
Sweetwater	Nolan	0.50	0.29	1	$4.00	$7.91	$3,956,426
Glen Rose	Somervell	0.50	0.29	2	$7.61	$11.10	$5,551,405
Abilene	Taylor	See WWP plan in Section 4C.38.13					
Blockhouse MUD	Williamson	0.50	0.29	2	$7.61	$11.10	$5,551,405
Brushy Creek MUD	Williamson	0.50	0.29	2	$7.61	$11.10	$5,551,405
Cedar Park	Williamson	5.00	2.85	2	$3.47	$4.97	$24,836,447
Chisolm Trail SUD	Williamson	1.00	0.57	2	$5.57	$7.96	$7,955,169
Hutto	Williamson	0.50	0.29	2	$7.61	$11.10	$5,551,405
Georgetown	Williamson	5.00	2.85	2	$3.47	$4.97	$24,836,447
Jonah Water SUD	Williamson	1.00	0.57	2	$5.57	$7.96	$7,955,169
Leander	Williamson	1.00	0.57	2	$5.57	$7.96	$7,955,169
Liberty Hill	Williamson	0.50	0.29	2	$7.61	$11.10	$5,551,405
Round Rock	Williamson	See Individual Option					
Thrall	Williamson	0.10	0.06	2	$7.61	$11.10	$1,110,281
Weir	Williamson	0.10	0.06	2	$7.61	$11.10	$1,110,281
Williamson C-O	Williamson	0.20	0.11	2	$7.61	$11.10	$2,220,562
Manufacturing	Williamson	2.00	2.00	2	$3.47	$4.97	$9,934,579
Mining	Williamson	2.50	2.50	2	$3.47	$4.97	$12,418,224

- 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.

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

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

Table 4B.3-11.
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

4B.3.1.2 City of College Station Reuse

4B.3.1.2.1 Description of Option

The City of College Station currently does not utilize wastewater reuse as a water supply. The City has obtained TCEQ Reclaimed Water Type 1 permits to utilize treated wastewater from the Lick Creek and Carters Creek WWTPs in the future if desired. The City evaluated several wastewater reuse options in a 2009 report titled "College Station Water Master Plan and Wastewater System Investigations". The assumptions from the study are utilized in developing this wastewater reuse option for the City.

In this study, potential customers for irrigation use of wastewater include the Veteran's Park, Central Park, Adam Development Properties, Crescent Pointe Development, and Post Oak Mall. The location of the customers and project is shown in Figure 4B.3-4. As shown on the map, Veterans Park, Adam Development, and Crescent Pointe are north of Carters Creek WWTP; and, the Post Oak Mall, Central Park and a planned Industrial Park are to the west of Carters Creek WWTP. This setting requires separate east and west distribution systems. A summary of irrigation demand for listed customers is included in Table 4B.3-12.

Although average annual demand totals approximately 312 acft/yr, the reuse system must be sized to meet the peak irrigation demand during the summer months, which is about 0.76 MGD or 853 acft/yr.

4B.3.1.2.2 Available Supply

The water supply that would be potentially available for College Station would be that portion of their wastewater effluent stream that has suitable uses within an economical distance from the treatment plant. The average daily effluent flow from the Carters Creek WWTP for the summer months of the year 2000 was 3,540 gpm (5.10 MGD). The reported minimum hourly flow from the Carters Creek WWTP for the summer of the year 2000 was approximately 1,540 gpm (2.22 MGD).

Wastewater treatment plants located within the College Station water user group include two College Station operated WWTPs (Carters Creek and Lick Creek) and two Texas A&M University operated WWTPs. The combined Year 2060 Estimated WWTP Effluent for these four WWTP plants is 15,312 acft/yr (13.67 MGD). Based on feedback from the WWTP operators the combined Year 2060 Confirmed WWTP Effluent for these four WWTP is 0 acft/yr since the City is planning on reusing all of the treated wastewater.

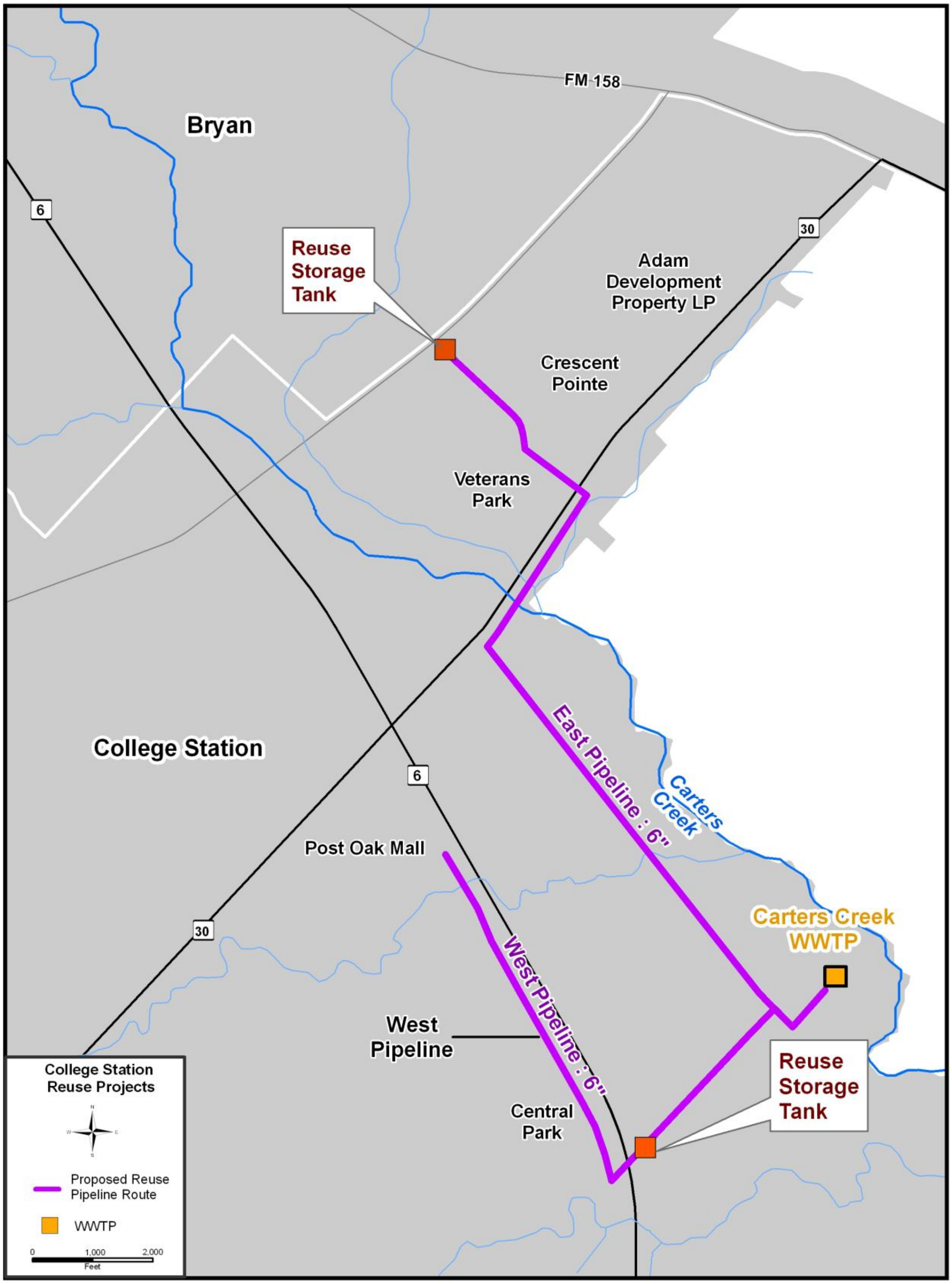

Figure 4B.3-4. College Station Reuse

Table 4B.3-12.
Water Reuse Demands for
College Station Reuse Project

Reuse Customer	***Demand (acft/yr)***
Veteran's Park	141
Central Park	57
Crescent Pointe	13
Adam Development	56
Post Oak Mall	33
Planned Industrial Park	13
Total	312

4B.3.1.2.3 *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 4B.3-13.

Table 4B.3-13.
Environmental Issues: College Station Reuse

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

4B.3.1.2.4 Engineering and Costing

The irrigation option will include a pump station at the wastewater treatment plant, a pipeline to customers east of Texas Hwy 6, a pipeline for customers west of Texas Hwy 6, and ground storage at the end of each pipeline to balance the daily supply and hourly demand. The distribution facilities are sized to deliver the total daily demand in a 6-hour period. Pumping facilities are sized to deliver the water to a ground storage tank near the irrigation demand. Distribution pumps and pipelines would draw water from the storage tank as needed. The required improvements to implement a wastewater reuse supply for College Station are summarized in Table 4B.3-14.

Table 4B.3-14.
Required Facilities – College Station Reuse for Veterans Park Irrigation

Facility	Description
Treatment Upgrade	0.28 MGD, Scenario 1; existing WWTP meets type 1 reuse standards, requiring only the addition of chlorine for distribution
Pump Station(s)	Two pump stations - 44 hp and 9 HP to deliver average demand of 0.28 MGD in 6 hours
Storage Tank	0.4 MG and 0.17; Store one days treated reuse water at the end of each pipeline
Pipeline	26,761 ft of 6-inch pipe
Available Project Yield	0.28 MGD (312 acft/yr).

Costs presented in Table 4B.3-15 provide the total option costs for developing a wastewater reuse supply for irrigation of Veterans Park. 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).

4B.3.1.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-16, and the option meets each criterion. Before pursuing wastewater reuse, College Station will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit requirements.

Table 4B.3-15.
Cost Estimate Summary
Reuse as a Water Management Strategy for College Station
(September 2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station	$767,000
Transmission Pipeline (6 in dia., 5 miles)	$1,933,000
Transmission Pump Station(s)	$566,000
Water Treatment Plant (0.28 MGD)	$25,000
Total Capital Cost	**$3,291,000**
Engineering, Legal Costs and Contingencies	$1,055,000
Environmental & Archaeology Studies and Mitigation	$127,000
Land Surveying (29 acres)	$20,000
Interest During Construction (0.5 years)	$90,000
Total Project Cost	**$4,583,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$400,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$44,000
Water Treatment Plant	$9,000
Pumping Energy Costs (122745 kW-hr @ 0.09 $/kW-hr)	$11,000
Total Annual Cost	**$464,000**
Available Project Yield (acft/yr)	312
Annual Cost of Water ($ per acft)	$1,485
Annual Cost of Water ($ per 1,000 gallons)	$4.56

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Table 4B.3-16.
Comparison of College Station 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

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

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

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

4B.3.1.3 City of Round Rock Reuse

4B.3.1.3.1 Description of Option

The City of Round Rock currently irrigates the Forest Creek Golf Course with treated wastewater effluent (0.5 MGD) from the Brushy Creek Regional WWTP (BCRWWTP) that is currently owned by the Lower Colorado River Authority (LCRA) and is operated by the Brazos River Authority (BRA). However the sale of the plant to the City of Round Rock, Austin, and Cedar Park is expected to be finalized in late 2009. The reuse water supplied to Forest Creek Golf Course meets Type 2 effluent requirements. The City has evaluated additional wastewater reuse options utilizing Type 1 effluent[1] and has planned for future reuse. A 24 inch reuse line that runs west from the WWTP along US 79 beyond the entrances to the Dell Diamond was constructed as part of a sewer interceptor project in anticipation of future reuse of water at Old Settlers Park, the Dell Diamond and elsewhere in the City of Round Rock. The line is shown on Figure 4B.3-5, and has not yet been activated. Figure 4B.3-5 shows the location of the pipeline from the BCRWWTP to the Forest Creek Golf Course.

The assumptions from previous evaluations are utilized in developing a wastewater reuse option for the City. Phase 1 of this option consists of a reuse project to deliver Type 1 treated wastewater for irrigation of Old Settler's Park. Subsequent Phases 2 through 5 involve extension of the reclaimed water distribution system to points north and west of Old Settler's Park to serve the Texas State and Texas A&M campuses as well as other development in the areas. The potential reusers listed in Table 4B.3-17 have a projected average day demand of approximately 3.9 MGD, or 4,320 acft/yr. However the system will have capacity to serve approximately 8.9 MGD, or 10,000 acft/yr. Figure 4B.3-5 identifies the extension of the reuse system.

At present, there are no industrial, power generation, or agricultural users located such that reuse water could be provided to them at a cost that would be economically feasible. In the future, as the reuse water distribution system expands or potential users develop in the proximity of the BCRWWTP, it may be feasible to expand the customer diversification and to serve some such customers.

[1] HDR Engineering, Inc., "Master Plan for the Development of the Brushy Creek Regional Reclaimed Water System," Prepared for the Lower Colorado River Authority, March 2001.

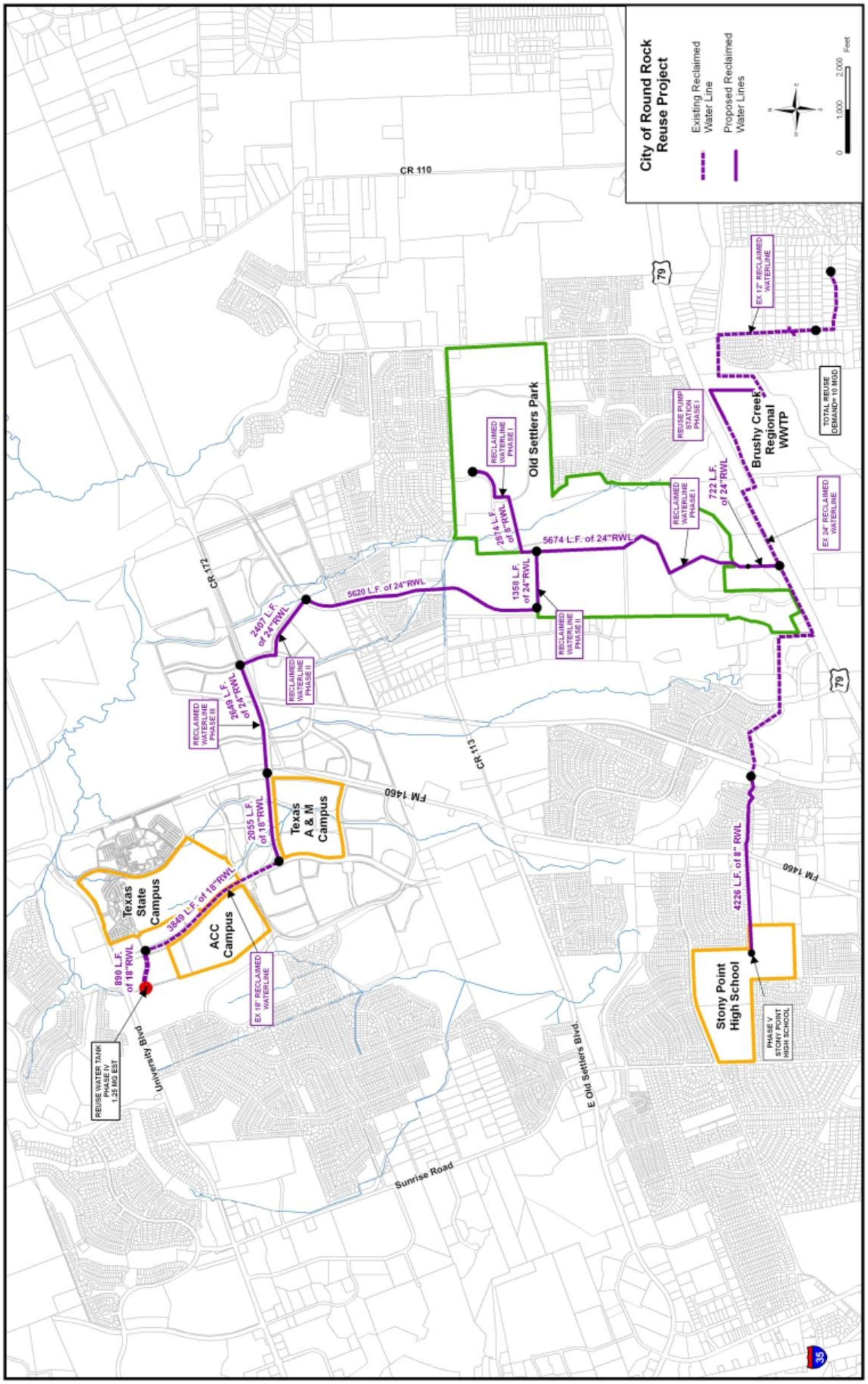

Figure 4B.3-5. City of Round Rock Proposed Water Reuse Master Plan Phases I, II, III, IV, and V

Table 4B.3-17.
Potential Water Reusers

Water Reuser	Use	Phase	Projected Demand (MGD)[1] Average	Peak Day
Forest Creek Golf Course	Irrigation	Currently active	0.5	1.5 [2]
CORR Old Settler's Park	Irrigation	I	2.3	2.3
Dell Diamond (Minor League Ball Park)	Irrigation	I	0.01	0.03
Miscellaneous, Residential & Other	Irrigation	II	0.15	0.3
Texas A&M Campus	Irrigation	III	0.2	0.4
Texas State Campus	Irrigation	IV	0.2	0.4
Austin Community College Campus	Irrigation	IV	0.2	0.4
Stony Point High School	Irrigation	V	0.3	0.3

Projected peak instantaneous flow is three times peak day flow and determines conveyance capacity required.
Storage available at golf course.

4B.3.1.3.2 Available Supply

The water supply reductions that would be potentially available for Round Rock would be that portion of their wastewater effluent stream that has suitable uses within an economical distance from the treatment plant. The Brushy Creek Regional WWTP Year 2060 Estimated WWTP Effluent is in the range of 35,000 acft/yr (31 MGD) prior to diversion of effluent to reclaimed water use. This volume is based on Round Rock's 2060 projected demand of 68,000 acft/yr and a 50 percent return flow.

Type 1 reuse water will be supplied from the BCRWWTP. This WWTP currently produces an effluent that meets TCEQ Type 2 reclaimed water standards and will require treatment upgrades to meet Type 1 standards. The existing capacity of the plant is a nominal 21.5 MGD. Current average flow to the plant is about 15 MGD (16,800 acft/yr), and the ultimate nominal planned capacity is 40 MGD. The plant is a conventional activated sludge plant that provides advanced secondary treatment. Ultimately, it is anticipated that stream standards will require that all effluent from the plant be filtered and that phosphorous removal also be included in the treatment process. Adding filters is proposed as part of this project to treat the portion of flow that will be routed to reuse. All plant flow is available for reuse. Proposed reuse will be significantly less than current flows.

4B.3.1.3.3 Environmental Issues

The Bureau of Reclamation has completed a draft Environmental Assessment (EA) for the Round Rock reuse project. Two alternatives, the Build Alternative and the No Build Alternative, were documented in the EA. The following resource areas were analyzed: wildlife, threatened and endangered species, water resources, air quality, noise, vegetation, visual resources, land use/ transportation/ access, historic and cultural resources, geology and soils, environmental justice, hazardous materials and climate change. Table 4B.3-18 presents the resource categories and impacts associated with the Build alternatives.

Table 4B.3-18.
Summary of Environmental Impacts[2]

Resource Area	Build Alternative
Wildlife	Local wildlife may be temporarily displaced by construction noise and disturbance; no permanent impacts.
Threatened and Endangered Species	Threatened or endangered species are unlikely to occur in the project area based on geography, preferred habitat, or migratory status. No impacts anticipated.
Water Resources	No impacts to groundwater resources. Waters of the U.S. would be crossed; the proposed project would qualify for Nationwide permit 12. The project would require compliance with TCEQ general permit TXR150000 for stormwater discharges from construction sites.
Air Quality	Temporary increase in fugitive dust emissions during construction. No permanent impacts anticipated.
Noise	Noise level increases within the project area anticipated during construction. No permanent change to area's noise levels.
Vegetation	No permanent impacts to maintained areas. Narrow removal of riparian corridor vegetation anticipated.
Visual Resources	Temporary visual impacts due to construction. Installation of approximately 125 foot water tank similar in appearance to other water tanks in the area.
Land Use / Transportation / Access	Temporary road closures and changes in land use expected during construction. No permanent impacts anticipated.
Historic and Cultural Resources	No impacts to historic or cultural resources are anticipated.
Geology and Soils	Soils have been previously disturbed. No impact to area geology or soils.
Environmental Justice	No environmental justice populations reside in the project area. No environmental justice impacts.
Hazardous Materials	No impacts to hazardous materials sites are anticipated.
Climate Change	Project would likely have minimal impact on climate change when compared with the overall area. Impacts to the proposed project from climate change are unknown.

[2] Table adapted from HDR, Engineering, Inc. "Engineering Feasibility Report City of Round Rock Reuse Water System," Prepared for City of Round Rock, September 2009

Impacts identified in the EA would primarily be associated with the temporary construction phase of the project. Temporary increases in fugitive dust and noise and temporary land use and access changes would be anticipated during construction. Heavy equipment would affect the visual resources within the project area during construction; visual resources would also be affected by the installation of an approximately 125-foot high water tank during Phase IV of the proposed project. Potential impacts to other resource areas would not be anticipated or would be minimal.

4B.3.1.3.4 Engineering and Costing

The proposed project will be constructed in five phases. The five phases have been shown on Figure 4B.3-5, and are listed and described in Table 4B.3-19.

Table 4B.3-19.
Project Components by Phases

Phase	Description
1	Filters to treat to water to TCEQ Type 1 reuse standards. Pumping facilities for reuse water. Disinfection facilities for reuse side stream. Piping to convey reuse water into Old Settler's Park.
2	Piping to extend reuse distribution system approximately 1.5 miles north of Old Settler's Park to CR 172.
3	Piping to extend reuse distribution system approximately 0.9 miles west to the Higher Education Center (HEC) campus area.
IV	Construction of an elevated tank near Chandler Road for pressure maintenance and to provide storage for use during peak demand periods.
V	Construction of approximately 0.8 miles of pipeline to extend the reuse distribution system to Stony Point High School.

Costs presented in Table 4B.3-20 provide the total option costs for developing a wastewater reuse supply in five phases for Round Rock reuse as identified in the HDR Engineering Feasibility Report from September 2009. These costs have been indexed to be consistent with the TWDB costing methodology using September 2008 as identified in Table 4B.3-21. Total project cost for the five construction phases is $18,102,000, annual costs for this project are approximately $2,139,000.

Table 4B.3-20.
Summary — Estimated Project Cost Information[1]

Phase	Description	Imp. Cost	Annual Cost					
			Debt Service		O & M		Total	
			Inc for Phase	Accumul.	Inc. for Phase	Accumul.	Inc. for Phase	Accumul.
1	Filters, Pumping Station, piping to Old Settler's Park	$5,257,600	$386,863	$386,863	$277,737	$277,737	$664,600	$664,600
2	Filter & pumping expansion at plant, lines north to CR 172, and system booster pump station	$5,748,800	$423,007	$809,870	$106,973	$384,670	$529,940	$1,194,540
3	Piping extension to HEC	$1,408,600	$103,647	$913,517	$57,365	$442,035	$161,012	$1,355,552
4	1.5 million gallon elevated tank at north end of proposed system	$5,075,500	$373,464	$1,286,982	$80,130	$522,165	$453,595	$1,809,147
5	Piping at Stony Point High School	$672,900	$49,513	$1,336,495	$38,932	$561,097	$88,445	$1,897,591

[1]Costs are based on HDR Engineering, Inc., "Engineering Feasibility Report, City of Round Rock Reuse Water System, " prepared for City of Round Rock, September 2009.

Notes:

Debt service based on 4 percent interest rate for 20 years.

Power cost based on $0.10 per KWH.

"Inc for Phase" column indicates increase in cost for the item in the respective phase. Costs are present worth.

Annual O&M costs include reserve fund contribution for equipment replacement and major maintenance items.

Table 4B.3-21.
Cost Estimate Summary
Reuse as a Water Management Strategy for Round Rock
September 2008 Prices

Item	*Estimated Costs for Facilities*
Project Costs By Phases	
Phase I	$5,240,000
Phase II	$5,729,000
Phase III	$1,404,000
Phase IV	$5,058,000
Phase V	$671,000
Total Project Cost	**$18,102,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$1,578,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$393,000
Pumping Energy Costs	$168,000
Total Annual Cost	**$2,139,000**
Available Project Yield (acft/yr)	4,320
Annual Cost of Water ($ per acft)	$495
Annual Cost of Water ($ per 1,000 gallons)	$1.52

4B.3.1.3.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-22, and the option meets each criterion. Before pursuing wastewater reuse, Round Rock 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.

Supply of reuse wastewater requires a TCEQ permit. An amendment of the TCEQ discharge permit for the WWTP will be required for the upgrades to the plant for this project.

Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

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

Table 4B.3-22.
Comparison of Round Rock 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. 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; 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

4B.3.1.4 City of Bryan Reuse

4B.3.1.4.1 Description of Option

The City of Bryan currently irrigates the Traditions Golf Course with Type 2 treated wastewater effluent from Turkey Creek WWTP, a small package treatment plant located near the golf course with a capacity of 0.35 MGD. The City has two other WWTPs, Burton Creek and Still Creek, that produce effluent requiring additional treatment to meet Type 1 or 2 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.

This option 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 4B.3-6). 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.

4B.3.1.4.2 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 2060. The Still Creek WWTP Year 2060 Estimated WWTP Effluent is 4,178 acft/yr (3.73 MGD). The Burton Creek WWTP Year 2060 Estimated WWTP Effluent is 8,345 acft/yr (7.45 MGD).

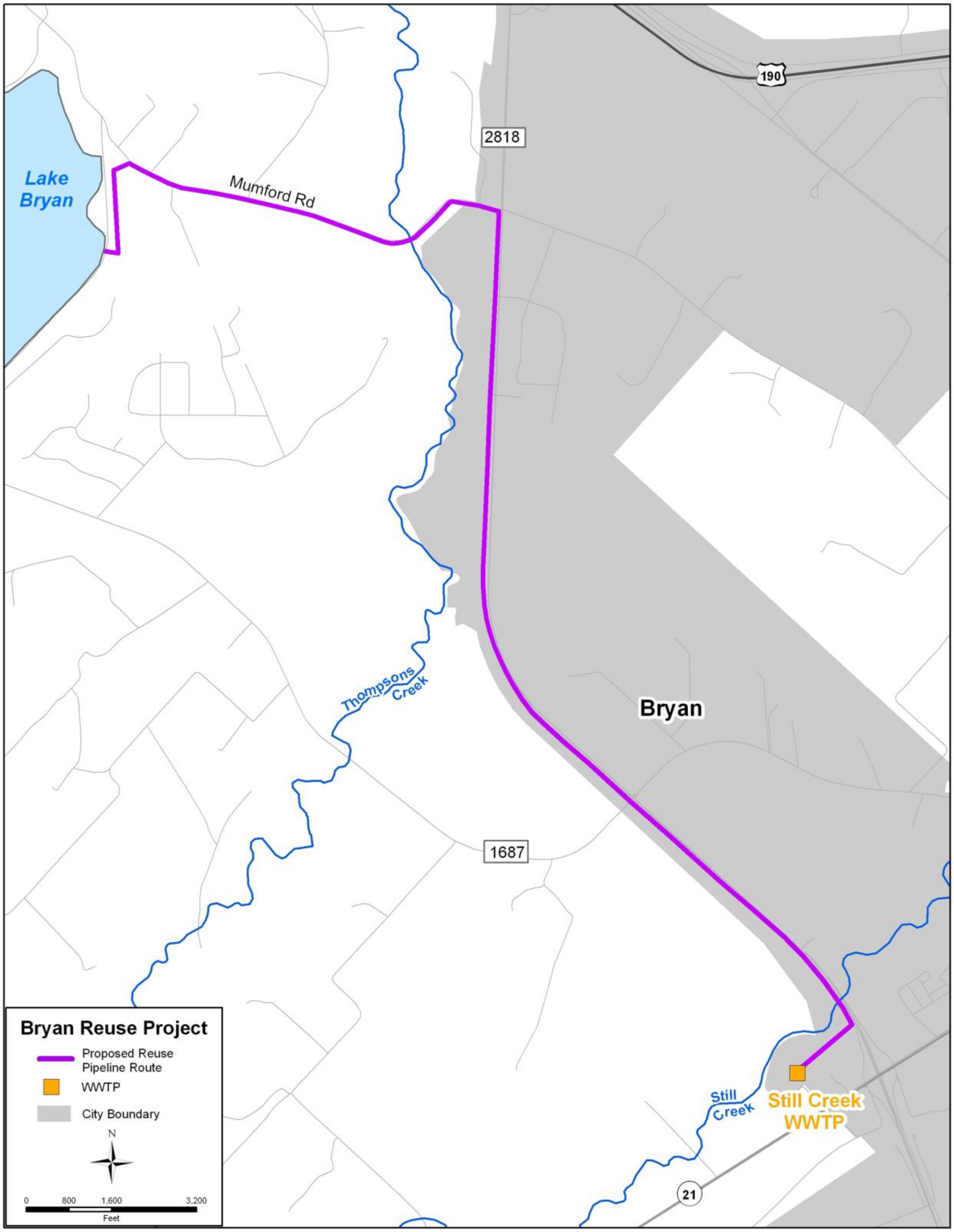

Figure 4B.3-6. Bryan Reuse

4B.3.1.4.3 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 4B.3-23.

Table 4B.3-23.
Environmental Issues: Bryan Reuse

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

4B.3.1.4.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply for Bryan are summarized in Table 4B.3-24.

Table 4B.3-24.
Required Facilities – Bryan Reuse for Bryan Utilities Lake

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	237 hp; 2.16 MGD capacity to deliver peak capacity at uniform rate
Storage Tank	None
Pipeline	29,000 ft of 12-inch pipe
Available Project Yield	0.54 MGD (605 acft/yr), yield is 3 months per year of peak demand supplied to lake

Costs presented in Table 4B.3-25 provide the total option costs for developing a wastewater reuse supply to Bryan Utilities Lake.

Table 4B.3-25.
Cost Estimate Summary
Reuse as a Water Management Strategy for Bryan
Costs for Bryan Utilities Lake Supply
September 2008 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Pump Station (237 MGD)	$2,102,000
Transmission Pipeline (12 in dia., 6 miles)	$1,994,000
Waste Water Treatment Plant Upgrades (2.16 MGD)	$2,607,000
Total Capital Cost	**$6,703,000**
Engineering, Legal Costs and Contingencies	$2,246,000
Environmental & Archaeology Studies and Mitigation	$174,000
Land Acquisition and Surveying (25 acres)	$232,000
Interest During Construction (4 years)	$1,497,000
Total Project Cost	**$10,852,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$946,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$72,000
Water Treatment Plant	$152,000
Pumping Energy Costs (1472536 kW-hr @ 0.09 $/kW-hr)	$33,000
Total Annual Cost	**$1,203,000**
Available Project Yield (acft/yr)	605
Annual Cost of Water ($ per acft)	$1,988
Annual Cost of Water ($ per 1,000 gallons)	$6.10

4B.3.1.4.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-26, and the option meets each criterion. Before pursuing wastewater reuse, 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.

Table 4B.3-26. Comparison of Bryan 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

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

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

4B.3.1.5 City of Cleburne Reuse

4B.3.1.5.1 Description of Option

The City of Cleburne obtains its water supply from Lake Pat Cleburne, Lake Aquilla, and groundwater from the Trinity Aquifer. The city owns and operates Lake Pat Cleburne, which 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. Based on the existing water supply available to the city, no shortages are projected through the year 2040. However, the City of Cleburne is projected to have a long-term deficit of 1,954 acft/yr in the year 2060.

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 2060, and has recently filed a water rights application for 8,440 acre feet (7.5 MGD) with TCEQ to allow reuse of all authorized discharges, which would provide for the city's needs well beyond the current planning horizon.

4B.3.1.5.2 Available Supply

The City currently supplies 1.2 MGD (1,344 acft/yr) of reuse water directly to a Brazos Electric Power Cooperative Plant located north of the city for use as cooling water. The City of Cleburne owns and operates the existing reuse water treatment facility located on the City's wastewater treatment plant site. The facility is rated for 7.5 MGD capacity and utilizes inclined plate clarification technology to produce a Type 1 effluent for use in unrestricted areas. A 16-inch diameter reuse water transmission line exists along the east side of the city to convey reuse water from the wastewater facility to the power plant.

The City intends to expand the existing reuse water treatment facilities and expand the existing east line to accommodate planned increases in reuse. A 40 acre wetland will also be constructed for additional polishing treatment. Expansion of the existing east line will supply an average of 250,000 gallons per day to a new sports complex for irrigation of the turf fields. The project would deliver reuse water via a new 6-inch diameter branch line, approximately 3,170 feet in length, which would intersect the existing 16-inch diameter reuse water pipeline. Other potential future uses for the east loop reuse line identified by the City of Cleburne include irrigation of a new golf course planned northeast of the city. The reuse projects considered for estimating costs associated with the east loop reuse line include average annual demands of 351 acft/yr, delivered for seasonal uses.

In addition to the expansion of the existing reuse line, the City is planning to develop a new West Loop Reclaimed Water Line and Pump Station to meet other identified non-potable water needs. This project would include a 16-inch diameter reclaimed water pipeline on the west side of the City (Figure 4B.3-7), which would join the existing east reclaimed water line serving the Brazos Electric Power Plant (Steam Electric) to form a looped system. This new west loop line would supply reclaimed water for oil and gas development (Mining), irrigation use by Cleburne Municipal Golf Course and commercial facilities, and industrial use (Manufacturing) by the existing James Hardie manufacturing plant and others. This project would supply the City of Cleburne and Johnson County mining, manufacturing, steam electric and irrigation water through Cleburne. The West Loop will be sized to meet a peak daily capacity of 4.5 MGD. Demands for the reuse water are anticipated to increase from 3.3 MGD in 2010 to 5 MGD by 2050 as indicated in Table 4B.3-27.

4B.3.1.5.3 Environmental Issues

The City of Cleburne is currently in the process of filing a water rights application with TCEQ to reuse all effluent discharged pursuant to TPDES Permit No. 10006-001, currently authorized as 8,440 acre feet (7.5 MGD). 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 fracing. Additional future reuse will require further amendment of the city's reuse authorization.

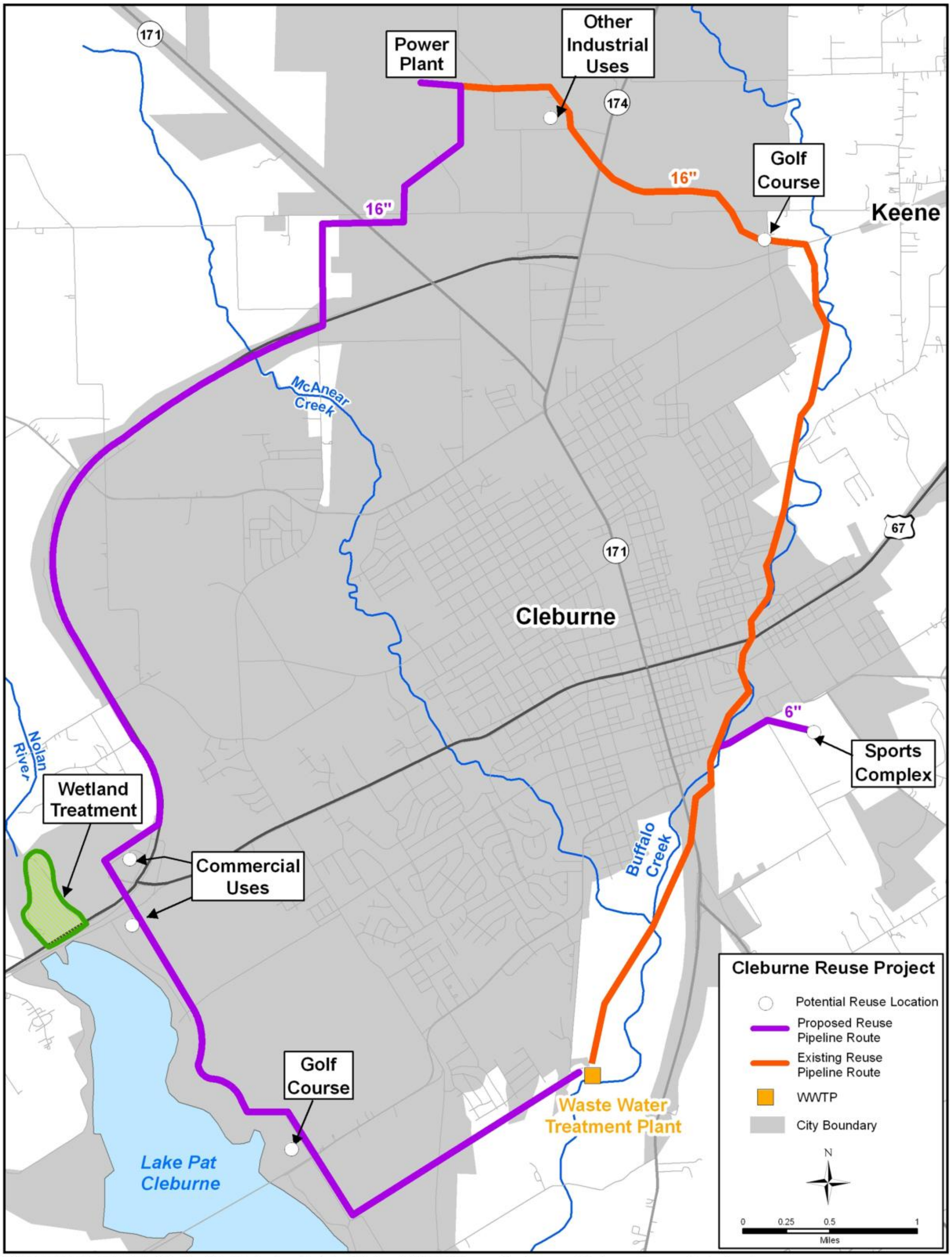

Figure 4B.3-7. Cleburne Reuse

Table 4B.3-27.
Projected Reuse Demands for Cleburne Reuse Project

Reuse Customers	***Year 2010***	***Year 2050***
Brazos Electric Power Plant	1,344	1,344
James Hardie Manufacturing	1,030	3,192
Mining	840	560
Golf course, commercial irrigation	487	487
Sports Complex	17	17
Total Demand (acft/yr)	3,718	5,600

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 4B.3-28.

Table 4B.3-28.
Environmental Issues: Cleburne Reuse

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

4B.3.1.5.4 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:

- Extension of reuse water lines from existing 16-inch mainline to the sports complex and new golf course;
- Construction of 10.7 mile 16-inch diameter west loop to deliver reuse water to additional and existing customers; and
- Expanded reuse water pump station.
- Construction of 40 acre wetland for polishing treatment

In keeping with the city's goal to maximize its use of reuse water, the additional expansion of the reuse water facilities may cost more than other alternatives that could be used to meet additional portions of the projected water shortage of 1,954 acft/yr in year 2060. 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 4B.3-29. Total capital costs for the project are $8,291,000 with annual costs of $1,344,000. This translates to $662/ acft or $2.03/ thousand gallons.

4B.3.1.5.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-30, 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.

4B.3.1.6 Waco WMARSS Reuse Projects

The Waco Metropolitan Area Regional Sewerage System (WMARSS) is currently pursuing the development of four wastewater reuse systems to supply reuse water to customers. These reuse systems are referred to as the Bellmead/Lacy Lakeview Project, Sandy Creek (LS Power) Project, Flat Creek Interceptor Project and Bullhide Creek Project. The WMARSS system will supply 16,000 acft/yr (14.3 MGD) of the treated effluent from the WMARSS system to the Sandy Creek Project (LS Power). An additional 3,920 acft/yr (3.5 MGD) would be supplied through the Bullhide Creek and Bellmead/Lacy Lakeview reuse projects. Assuming simultaneous implementation of the other reuse projects, potential available supply from the Flat Creek Reuse Project would be 5,319 acft/yr in 2010, 6,918 acft/yr in 2020, and the full 7,847 acft/yr (7 MGD) capacity sometime prior to 2030. The Year 2000 estimated effluent from WMARSS is 24,575 acft/yr (21.92 MGD). The Year 2060 estimated effluent from WMARSS is 31,779 acft/yr (28.4 MGD). These options consists of integrated reuse projects to deliver Type 1 reuse water from the existing WMARSS Central Wastewater Treatment Plant located southeast of Waco along the Brazos River and from a proposed Bull Hide WWTP.

Table 4B.3-29.
Cost Estimate Summary
Reuse as a Water Management Strategy for Cleburne
Incremental Costs to Meet Year 2060 Projected Shortage
September 2008 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
West Loop Pump Station (1.5 MGD)	$510,000
East Loop Pump Station Expansion	$137,000
Expansion of East Loop Pipeline (6 in dia., 0.6 mile)	$350,000
New West Loop Transmission Pipeline (16 in dia., 11 miles)	$5,767,000
Wetlands Treatment (40 acres)	**$987,000**
Meter(s)	**$110,000**
Storage Tank(s)	**$430,000**
Total Capital Cost	**$8,234,000**
Engineering, Legal Costs and Contingencies	$2,557,000
Environmental & Archaeology Studies and Mitigation	$311,000
Land Acquisition and Surveying (45 acres)	$798,000
Interest During Construction (2 years)	$479,000
Total Project Cost	**$12,436,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$1,084,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$83,000
Wetlands	$16,000
Pumping Energy Costs (1,790,333 kW-hr @ 0.09 $/kW-hr)	$161,000
Total Annual Cost	**$1,344,000**
Available Project Yield (acft/yr)	2,031
Annual Cost of Water ($ per acft)	$662
Annual Cost of Water ($ per 1,000 gallons)	$2.03

Table 4B.3-30.
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

The Waco North Reuse Project, included in the 2006 Regional Water Plan, would provide potential reuse water to Gholson and Chalk Bluff WSC from a satellite plant. This strategy has been updated as a alternative strategy. Locations of each of the Waco reuse projects including treatment plants, proposed transmission pipelines, ground storage tanks, and pump stations are shown in Figure 4B.3-8 A description of each of the options are included in Sections 4B.3.1.6.1 through 4B.3.1.6.5

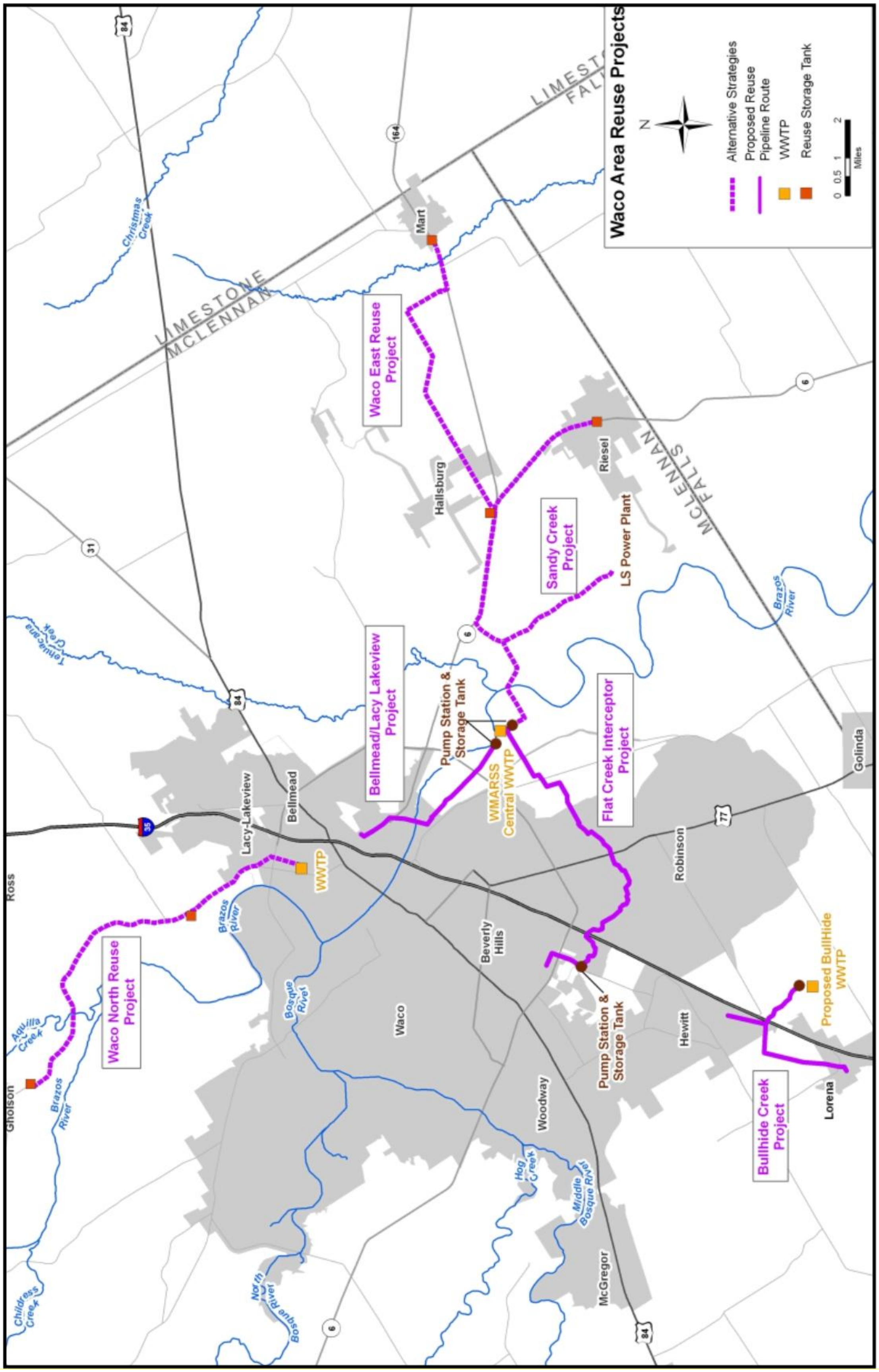

Figure 4B.3-8. Waco Area Reuse Project

4B.3.1.6.1 Waco East – Sandy Creek Project (LS Power Station) and Cities of Hallsburg, Mart, and Riesel Reuse

4B.3.1.6.1.1 Description of Option

The City of Waco is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the City of Waco and potentially to other entities within the vicinity of Waco. Several water user groups in the vicinity of Waco showing a water supply need by the year 2060 may potentially be provided reuse water as part of this larger Waco reuse system. This option consists of an integrated reuse project to deliver Type 1 reuse water from the Waco Metropolitan Area Regional Sewerage System (WMARSS) wastewater treatment plant to a new power station (LS Power Station) planned southeast of Waco and potentially to the Cities of Hallsburg, Mart, and Riesel. The new power station is to be located near Lake Creek Reservoir as shown in Figure 4B.3-9. The City of Waco has negotiated a contract to supply the LS Power Station with 16,000 acft/yr of water to be used for cooling tower and other non-potable purposes. This option assumes that the full 16,000 acft/yr of water supplied by Waco to LS Power Station will be Type 1 reuse water from WMARSS. The portion of the project for LS Power is assumed as current supply and is not included in the cost estimate for this option.

The potential reuse water demand for the Cities of Hallsburg, Mart, and Riesel is estimated at 30 percent of each city's 2060 water demand for purposes of this option. This Type 1 reuse water may be utilized for landscape irrigation at existing or future parks, schools, ball fields, and other green spaces. Reuse water may also potentially supply existing or future industrial customers within these cities. For this option the transmission system to supply reuse water for these three cities also includes capacity to supply 900 acft/yr of reuse water for use by County-Other 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 4B.3-31.

4B.3.1.6.1.2 Available Supply

The Year 2060 Estimated WWTP Effluent for WMARSS is 31,779 acft/yr (28.37 MGD). Based on feedback from the City of Waco the combined Year 2060 Confirmed WWTP Effluent for this WWTP is 0 acft/yr (0 MGD). Therefore, the 2060 Potential Reuse is the difference between the Estimated and Confirmed WWTP Effluent which is 31,779 acft/yr (28.37 MGD).

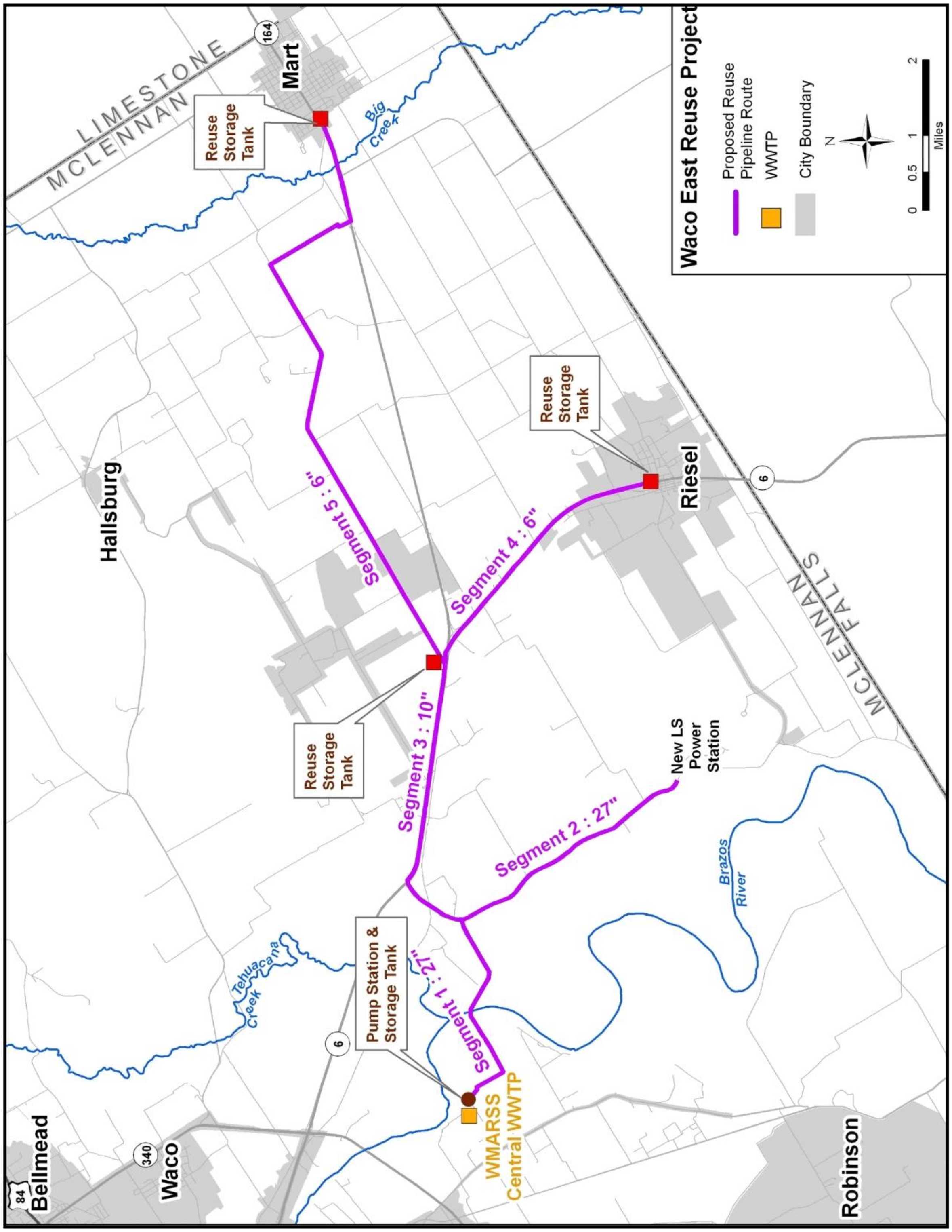

Figure 4B.3-9. Waco East Reuse Project

Table 4B.3-31.
Waco East Reuse Water Demand

Entity	2060 Demand (acft/yr)	Reuse Water Demand (acft/yr)	2060 Need (acft/yr)
Hallsburg	182	55	45
Mart	415	124	272
Riesel	137	41	31
County-Other	7,881	900	0
Total		**1,120**	

4B.3.1.6.1.3 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 4B.3-32.

Table 4B.3-32.
Environmental Issues: Waco East Reuse

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

4B.3.1.6.1.4. Engineering and Costing

Many of the required improvements to implement a reuse supply for this option are shared between the multiple entities. These shared facilities include the upgraded treatment at the WMARSS treatment plant, pump stations, and transmission pipelines. The shared facilities are sized to supply the combined demand for the entities served by each improvement. To determine each entities share of the total improvement cost, the shared improvements are estimated separately and costs per acft of total supply are developed for each shared improvement. The total cost estimates for each entity include the cost of these shared improvements as annual costs based on the quantity supplied by the improvement to each entity. Due to the economy of scale, significant cost savings are realized by utilizing shared larger improvements for the treatment and delivery of reuse water to all entities supplied by the Waco East water supply option. The total project cost is estimated at $11,992,000 with an average annual cost of $1,219,000.

Figure 4B.3-9 details the required facilities for this project. The already constructed segment 1 is the initial pipeline segment that transmits reuse water from the WMARSS treatment plant to other pipelines supplying the LS Power Station, Hallsburg, Mart, Riesel, and County-Other. The Segment 1 improvements are assumed to be sized for the total demand for all these entities (17,120 acft/yr). Segment 2 is a 27-inch diameter pipeline from the end of Segment 1 to LS Power. Segments 1 and 2 are assumed to have been constructed prior to 2010. Segment 3, 4, and 5 are sized to convey 1,120 acft/yr to the additional potential users of the reuse system. The required facilities for Segment 3 - 5 are shown in Table 4B.3-33 through Table 4B.3-35.

Table 4B.3-33.
Required Facilities – Waco East Segment 3

Facility	*Description*
Pump Station	101 hp; 1.0 MGD capacity to deliver at uniform rate to storage tanks located at Hallsburg, Mart, or Riesel with 25 psi residual pressure
Storage Tank	1.0 MG; balancing storage at intersection of segment 1 and 3
Pipeline	20,583 ft of 10-inch pipe; from intersection of segments 1 and 3 to Hallsburg tank
Available Project Yield	1.0 MGD (1120 acft/yr); total yield for combined Hallsburg, Mart, and Riesel plus 900 acft/yr for County-Other

Table 4B.3-34.
Required Facilities – Waco East Segment 4

Facility	Description
Pump Station	No Pump Station; Segment 3 pump station pressure utilized
Storage Tank	No Storage Tank
Pipeline	19,832 ft of 6-inch pipe; from Hallsburg tank to Riesel tank
Available Project Yield	0.3 MGD (341 acft/yr); 41 acft/yr Riesel plus 300 acft/yr County-Other

Table 4B.3-35.
Required Facilities – Waco East Segment 5

Facility	Description
Pump Station	No Pump Station; Segment 3 pump station pressure utilized
Storage Tank	No Storage Tank
Pipeline	45,505 ft of 6-inch pipe; from Hallsburg tank to Mart tank
Available Project Yield	0.38 MGD (425 acft/yr); 125 acft/yr Riesel plus 300 acft/yr County-Other

The required improvements to implement wastewater reuse supplies for Hallsburg, Mart, and Riesel are summarized in Tables 4B.3-37 through 4B.3-39. Storage and irrigation pumping are included for Hallsburg, Mart, and Riesel.

Costs shown in Table 4B.3-36 are based on the share of the reuse water and the infrastructure requirements to deliver the water to each entity. The treatment upgrades at WMARSS to supply a Type 1 reuse effluent are additional tertiary treatment and chlorine addition to provide a residual for distribution. Treatment Plant upgrades and O&M are passed to the additional reuse users through the treated reuse water costs of $54.44/acft.

Table 4B.3-36.
Cost Estimate Summary
Waco East Reuse
(September 2008 Prices)

Item	*Estimated Costs for Facilities*	*Hallsburg (Segment 3)*	*Riesel (Segments 3,4)*	*Mart (Segments 3,5)*	*County Other (Segments 3-5)*
Capital Costs					
Transmission Pipeline (25 miles)	$5,728,000	$148,000	$404,000	$779,000	$4,397,000
Transmission Pump Station(s) (1 MGD)	$1,871,000	$92,000	$68,000	$207,000	$1,504,000
Total Capital Cost	**$7,599,000**	**$240,000**	**$472,000**	**$986,000**	**$5,901,000**
Engineering, Legal Costs and Contingencies	$2,315,000	$73,000	$144,000	$300,000	$1,798,000
Environmental & Archaeology Studies and Mitigation	$682,000	$20,000	$56,000	$95,000	$578,000
Land Acquisition and Surveying (99 acres)	$934,000	$27,000	$77,000	$130,000	$792,000
Interest During Construction (1 year)	$462,000	$14,000	$30,000	$61,000	$363,000
Total Project Cost	**$11,992,000**	**$374,000**	**$779,000**	**$1,572,000**	**$9,432,000**
Annual Costs					
Debt Service (6 percent, 20 years)	$1,045,000	$33,000	$68,000	$137,000	$822,000
Operation and Maintenance					
Intake, Pipeline, Pump Station	$92,000	$3,000	$6,000	$12,000	$71,000
Water Treatment Plant	$0				
Pumping Energy Costs (236,988 kW-hr @ 0.09 $/kW-hr)	$21,000	$1,000	$1,000	$2,000	$17,000
Treated Water Cost ($54.44/acft)	$60,973	$2,994	$2,232	$6,751	$48,996
Total Annual Cost	**$1,218,973**	**$39,994**	**$77,232**	**$157,751**	**$958,996**
Available Project Yield (acft/yr)	1,120	55	41	124	900
Annual Cost of Water ($ per acft)	$1,088	$727	$1,884	$1,272	$1,066
Annual Cost of Water ($ per 1,000 gallons)	$3.34	$2.23	$5.78	$3.90	$3.27

Table 4B.3-37.
Required Facilities – Hallsburg

Facility	***Description***
Treatment Upgrade	Purchase 0.05 MGD treated reuse water from Waco
Pump Station	8 hp; 0.2 MGD capacity to deliver peak daily capacity in 6 hours at 60 psi; shared use of segment 1 and 3 pump stations
Storage Tank	0.05 MG; Store one days treated reuse water at tank in Hallsburg
Pipeline	Shared use of pipeline segment 3
Available Project Yield	0.05 MGD (55 acft/yr), yield is based on 30 percent of total year 2060 demand to be used for irrigation and/or industrial customers

Table 4B.3-38.
Required Facilities – Mart

Facility	***Description***
Treatment Upgrade	Purchase 0.11 MGD treated reuse water from Waco
Pump Station	17 hp; 0.44 MGD capacity to deliver peak daily capacity in 6 hours at 60 psi; shared use of segment 1 and 3 pump stations
Storage Tank	0.11 MG; Store one days treated reuse water at tank in Mart
Pipeline	Shared use of pipeline segments 3 and 5
Available Project Yield	0.11 MGD (125 acft/yr), yield is based on 30 percent of total year 2060 demand to be used for irrigation and/or industrial customers

Table 4B.3-39.
Required Facilities – Riesel

Facility	***Description***
Treatment Upgrade	Purchase 0.04 MGD treated reuse water from Waco
Pump Station	6 hp; 0.16 MGD capacity to deliver peak daily capacity in 6 hours at 60 psi; shared use of segment 1 and 3 pump stations
Storage Tank	0.04 MG; Store one days treated reuse water at tank in Riesel
Pipeline	Shared use of pipeline segments 3, and 5
Available Project Yield	0.04 MGD (41 acft/yr), yield is based on 30 percent of total year 2060 demand to be used for irrigation and/or industrial customers

4B.3.1.6.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-40, and the option meets each criterion. Before pursuing wastewater reuse, the Waco East entities will need to investigate concerns that would include at a minimum:

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

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

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

Table 4B.3-40.
Comparison of Waco East Reuse Option to Plan Development Criteria

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

4B.3.1.6.2 WMARSS Bellmead/Lacy-Lakeview Reuse

4B.3.1.6.2.1 Description of Option

The Waco Metropolitan Area Regional Sewerage System (WMARSS) is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the Cities of Bellmead and Lacy-Lakeview. This option consists of an integrated reuse project to deliver Type 1 reuse water from the existing WMARSS Central Wastewater Treatment Plant (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 4B.3-10.

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.

4B.3.1.6.2.2 Available Supply

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

4B.3.1.6.2.3 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 4B.3-41.

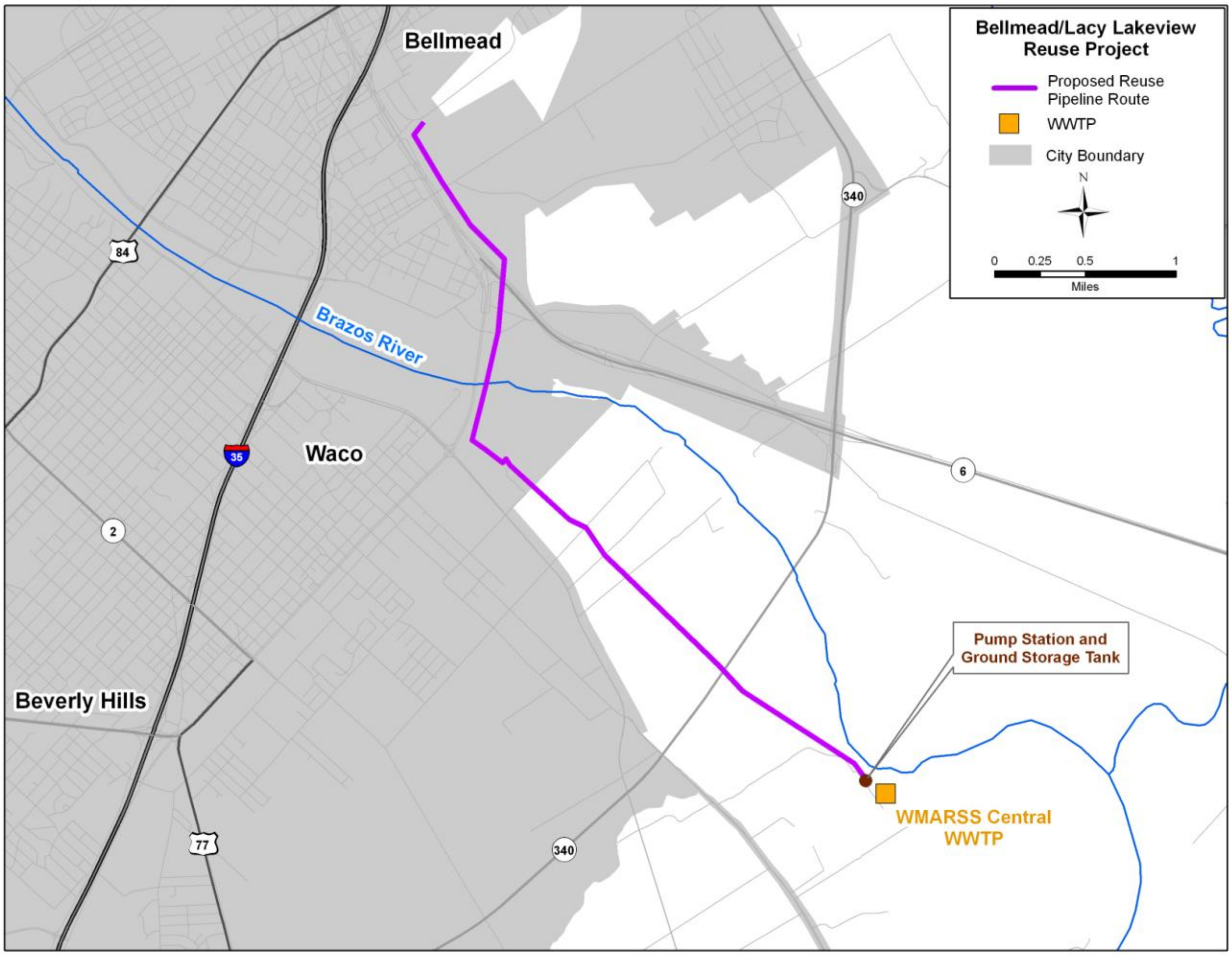

Figure 4B.3-10. WMARSS Bellmead/Lacy-Lakeview Reuse

Table 4B.3-41. Environmental Issues: WMARSS Bellmead/Lacy-Lakeview Reuse

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

4B.3.1.6.2.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply for Bellmead and Lacy-Lakeview are summarized in Table 4B.3-42. 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 4B.3-42.
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 20-inch pipe; from WMARSS Central WWTP to I-35 Pump Station
Available Project Yield	2.0 MGD (2,242 acft/yr); total yield for all Bellmead/Lacy-Lakeview projects supplied

Costs presented in Table 4B.3-43 provide the total option costs for developing a wastewater reuse supply for Bellmead and Lacy-Lakeview. The project will have an estimated total capital cost of $4,429,000 and an annual cost of $784,000. This cost translates to a $350 per acft or $1.07 per 1,000 gallons unit cost of the reuse water.

The cost to each City for the use of the reclaimed water from the Bellmead/Lacy-Lakeview Project is shown in Table 4B.3-44. The costs are divided between the cities based on the quantity of water supplied to each.

4B.3.1.6.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-45, 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 transmission facilities to the ultimate points of end use.

Table 4B.3-43.
Cost Estimate Summary
WMARSS Bellmead/Lacy Lakeview Reuse
September 2008 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (2 MGD)	$1,194,000
Transmission Pipeline (12 in dia., 5 miles)	$2,190,000
Ground Storage Tank (1.5 MG)	$1,045,000
Total Capital Cost	**$4,429,000**
Engineering, Legal Costs and Contingencies	$1,441,000
Environmental & Archaeology Studies and Mitigation	$149,000
Land Acquisition and Surveying (22 acres)	$200,000
Interest During Construction (2 years)	$249,000
Total Project Cost	**$6,468,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$564,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$62,000
Pumping Energy Costs (770073 kW-hr @ 0.09 $/kW-hr)	$69,000
Purchase of Water (2242 acft/yr @ 39.75 $/acft)	$89,000
Total Annual Cost	**$784,000**
Available Project Yield (acft/yr)	2,242
Annual Cost of Water ($ per acft)	$350
Annual Cost of Water ($ per 1,000 gallons)	$1.07

Table 4B.3-44.
Cost to each City
WMARSS Bellmead and Lacy-Lakeview Reuse

City	**Reuse Water Demand (acft/yr)**	**Unit Cost ($/acft)**	**Annual Cost ($/yr)**
City of Bellmead	1,121	$350	$392,000
City of Lacy Lakeview	1,121	$350	$392,000
Total	**2,242**		**$538,000**

Table 4B.3-45.
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. Highly reliable
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Reduces instream flows—possible low impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	Could offset the need for voluntary redistribution of other supplies

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

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

4B.3.1.6.3 WMARSS Bull Hide Creek Reuse

4B.3.1.6.3.1 Description of Option

The Waco Metropolitan Area Regional Sewerage System (WMARSS) is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the Cities of Hewitt and Lorena. This option consists of an integrated reuse project to deliver Type 1 reuse water from the proposed WMARSS Bull Hide Creek Wastewater Treatment Plant 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 4B.3-11.

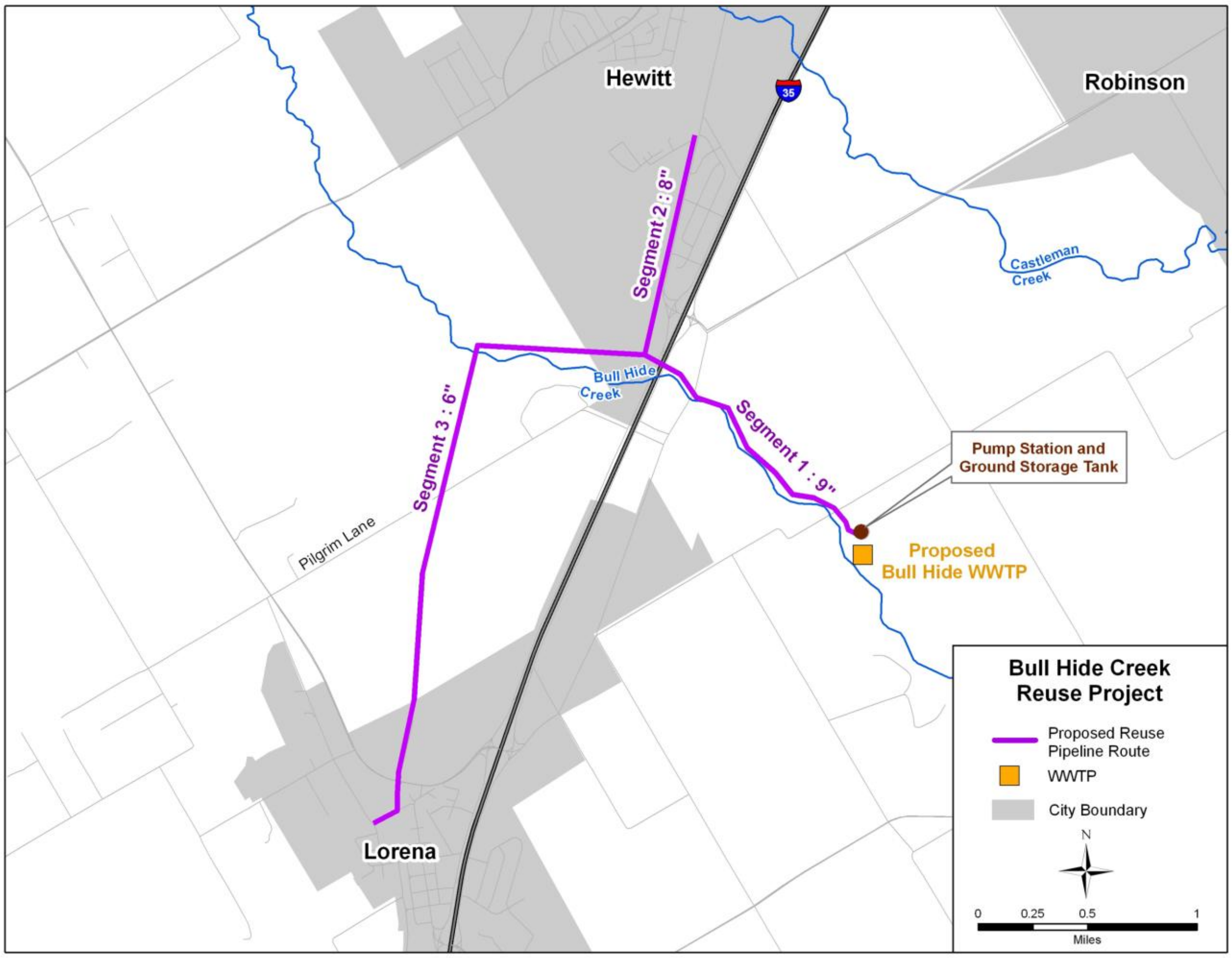

Figure 4B.3-11. WMARSS Bull Hide Creek Reuse

The potential reuse water demand for the City of Hewitt and Lorena is based upon hydraulic constraints of the transmission system. The transmission system will be capable of delivering 1.5 MGD (1,681 acft/yr) of treated reuse water from the proposed 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.

4B.3.1.6.3.2 Available Supply

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

4B.3.1.6.3.3 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 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 4B.3-46.

Table 4B.3-46.
Environmental Issues: WMARSS Bull Hide Creek Reuse

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

4B.3.1.6.3.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply for Hewitt and Lorena are summarized in Table 4B.3-47. The project requires a 1.5 MGD pump station along with a 1.5 MG storage tank located at the proposed WMARSS Bull Hide Creek WWTP site. The transmission pipeline system is separated into three separate components. The first segment is a 9-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 4B.3-47.
Required Facilities – WMARSS Bull Hide Creek Reuse

Facility	Description
WWTP	1.5 MGD proposed WMARSS Bull Hide Creek WWTP
Pump Stations	129 HP at proposed 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 Central WWTP
Pipelines	Segment 1; 1.3 miles of 9-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 4B.3-48 provide the total option costs for developing a wastewater reuse supply for Hewitt and Lorena. The project will have an estimated total capital cost of $14,856,000 and an annual cost of $2,056,000. This cost translates to a $1,233 per acft or $3.75 per 1,000 gallons unit cost of the reuse water.

The cost to each City for the use of the reclaimed water from the Bull Hide Creek WWTP is shown in Table 4B.3-49. The costs are divided between the cities based on the quantity of water supplied to each.

4B.3.1.6.3.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-50, 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 4B.3-48.
Cost Estimate Summary
WMARSS Bull Hide Creek Reuse
September 2008 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Pump Station (2 MGD)	$1,070,000
Waste Water Treatment Plant Upgrades (1.5 MGD)	$11,280,000
Ground Storage Tank (1.5 MG)	$1,045,000
Segment 1 Transmission Pipeline (12 in dia., 1.3 miles)	$545,000
Segment 2 Transmission Pipeline (8 in dia.,1.0 miles)	$237,000
Segment 3 Transmission Pipeline (6 in dia.,3.0 miles)	$679,000
Total Capital Cost	**$14,856,000**
Engineering, Legal Costs and Contingencies	$5,127,000
Environmental & Archaeology Studies and Mitigation	$171,000
Land Acquisition and Surveying (25 acres)	$227,000
Interest During Construction (2 years)	$816,000
Total Project Cost	**$21,197,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$1,848,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$52,000
Water Treatment Plant	$31,000
Pumping Energy Costs (643666 kW-hr @ 0.09 $/kW-hr)	$58,000
Purchase of Water (1681 acft/yr @ 39.75 $/acft)	$67,000
Total Annual Cost	**$2,056,000**
Available Project Yield (acft/yr)	1,681
Annual Cost of Water ($ per acft)	$1,223
Annual Cost of Water ($ per 1,000 gallons)	$3.75

Table 4B.3-49.
Cost to each City
WMARSS Bull Hide Creek Reuse

City	*Reuse Water Demand (acft/yr)*	*Unit Cost ($/acft)*	*Annual Cost ($/yr)*
City of Hewitt	1,233	$1,223	$1,508,000
City of Lorena	448	$1,223	$548,000
Total	**1,681**		**$2,056,000**

Table 4B.3-50.
Comparison of WMARSS Bull Hide Creek Reuse Option to Plan Development Criteria

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

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

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

4B.3.1.6.4 WMARSS Flat Creek Reuse

4B.3.1.6.4.1 Description of Option

The Waco Metropolitan Area Regional Sewerage System (WMARSS) is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the City of Waco. This option consists of an integrated reuse project to deliver Type 1 reuse water from the existing WMARSS Central Wastewater Treatment Plant 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 4B.3-12.

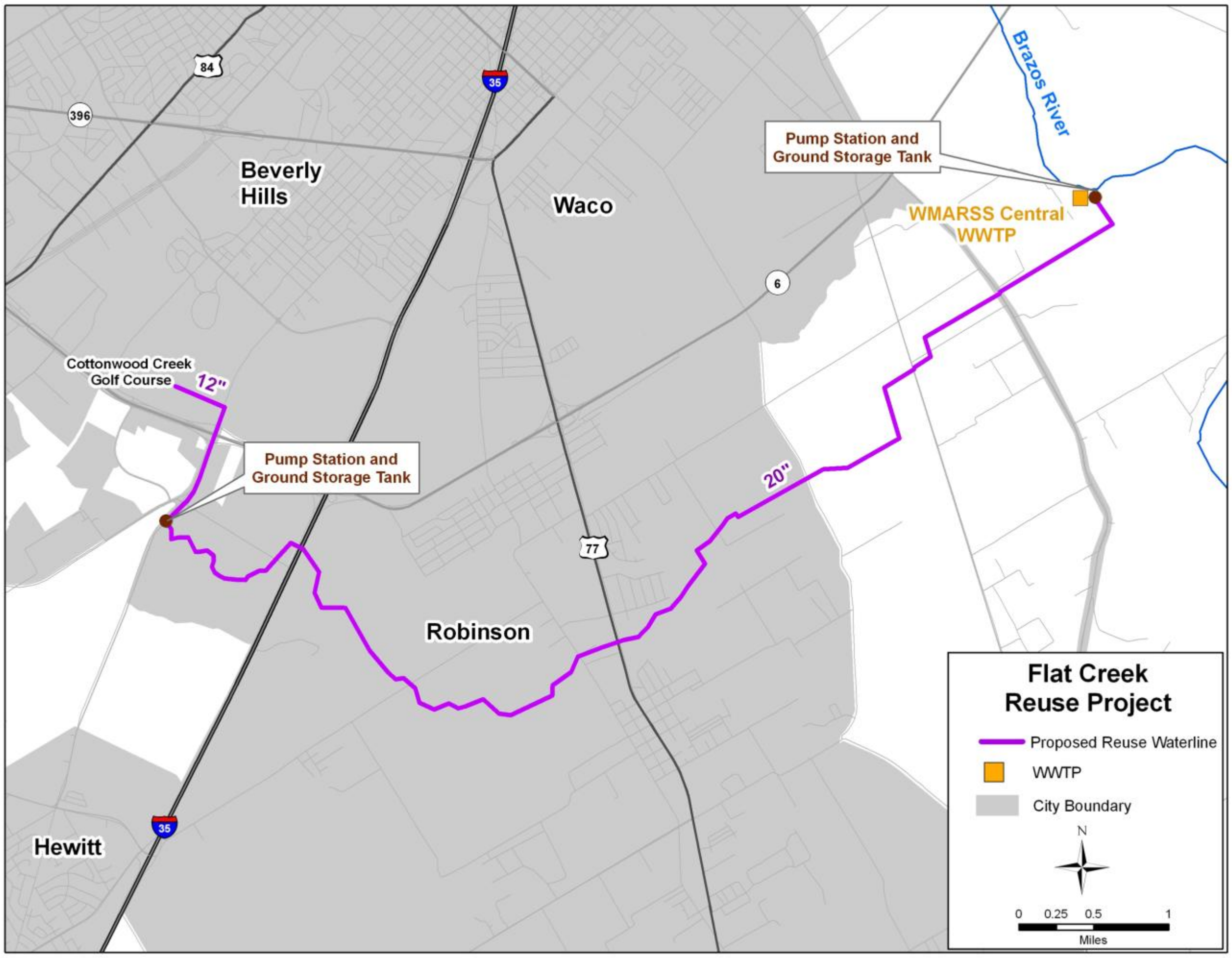

Figure 4B.3-12. WMARSS Flat Creek Reuse

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. The transmission system will be capable of delivering 7 MGD (7,847 acft/yr) of treated reuse water from the WMARSS Central WWTP.

4B.3.1.6.4.2 Available Supply

The WMARSS system will supply 16,000 acft/yr (14.3 MGD) of the treated effluent from the WMARSS system to the Sandy Creek Project (LS Power) (Section 4B.3.1.6.1). An additional 3,920 acft/yr (3.5 MGD) would be supplied through the Bullhide Creek and Bellmead/Lacy Lakeview reuse projects. The Year 2000 estimated effluent from WMARSS is 24,575 acft/yr (21.92 MGD). The Year 2060 estimated effluent from WMARSS is 31,779 acft/yr (28.4 MGD). Assuming simultaneous implementation of the other reuse projects, potential available supply from the Flat Creek Reuse Project would be 5,319 acft/yr in 2010, 6,918 acft/yr in 2020, and the full 7,847 acft/yr (7 MGD) capacity sometime prior to 2030.

4B.3.1.6.4.3 Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible 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 4B.3-51.

Table 4B.3-51.
Environmental Issues: WMARSS Flat Creek Reuse

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

4B.3.1.6.4.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply for Waco are summarized in Table 4B.3-52. The project requires a 7 MGD pump station along with two 1.5 MG storage tanks located at the WMARSS Central WWTP. A 51,000 ft, 20-inch diameter pipe connects the pump station 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 4B.3-52.
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	51,000 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 4B.3-53 provide the total option costs for developing a wastewater reuse supply for Waco and Cottonwood Creek Golf Course. The project will have an estimated total capital cost of $8,250,000 and an annual cost of $1,747,000. This cost translates to a $223 per acft or $0.68 per 1,000 gallons unit cost of the reuse water, upon utilization of the full 7 MGD (7,847 acft/yr).

4B.3.1.6.4.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-54, and the option meets each criterion. Before pursuing wastewater reuse, the WMARSS entities will need to investigate concerns that would include at a minimum:

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

Table 4B.3-53.
Cost Estimate Summary
WMARSS Flat Creek Reuse
September 2008 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Upgrade to WMARSS Intake & Pump Station (7 MGD)	$1,474,000
Two Ground Storage Tanks @ WMARSS (1.5 MG)	$1,792,000
Transmission Pipeline (20 in dia., 9.7 miles)	$2,731,000
Transmission Pipeline (12 in dia.,1.3 miles)	$435,000
Transmission Pump Station @ I-35 (2 MGD)	$1,059,000
Ground Storage Tank @ I-35 (1.0 MG)	$759,000
	-
Total Capital Cost	**$8,250,000**
Engineering, Legal Costs and Contingencies	$2,729,000
Environmental & Archaeology Studies and Mitigation	$74,000
Land Acquisition and Surveying (11 acres)	$91,000
Interest During Construction (2 years)	$446,000
Total Project Cost	**$11,590,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$1,010,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$120,000
Water Treatment Plant	$0
Pumping Energy Costs (3384493 kW-hr @ 0.09 $/kW-hr)	$305,000
Purchase of Water (7847 acft/yr @ 39.75 $/acft)	$312,000
Total Annual Cost	**$1,747,000**
Available Project Yield (acft/yr)	7,847
Annual Cost of Water ($ per acft)	$223
Annual Cost of Water ($ per 1,000 gallons)	$0.68

Table 4B.3-54.
Comparison of Flat Creek Reuse Option to Plan Development Criteria

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

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

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

4B.3.1.6.5 Waco North – Chalk Bluff WSC and Gholson Reuse

4B.3.1.6.5.1 Description of Option

The City of Waco is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the City of Waco and potentially to other entities within the vicinity of Waco. Several water user groups in the vicinity of Waco showing a water supply need by the year 2060 may potentially be provided reuse water as part of this larger Waco reuse system. This option consists of an integrated reuse project to deliver Type 1 reuse water from a new satellite wastewater reuse treatment plant located north of Waco and diverting wastewater from a collection main of the Waco Metropolitan Area Regional Sewerage System (WMARSS). Treated reuse water from this satellite plant is transported to Chalk Bluff WSC and the City of Gholson. The new satellite reuse treatment plant and transmission pipeline locations are shown in Figure 4B.3-13.

The potential reuse water demand for Chalk Bluff WSC and the City of Gholson is estimated at 30 percent of their 2060 water demand for purposes of this option. This Type 1 reuse water may be utilized for landscape irrigation at existing or future parks, schools, ball fields, and other green spaces. Reuse water may also potentially supply existing or future industrial customers. For this option the transmission system to supply reuse water for these entities also includes capacity to supply 811 acft/yr of reuse water for use by County-Other 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 4B.3-55. All estimated reuse demands are less than the total needs (shortages) projected for each WUG in 2060.

4B.3.1.6.5.2 Available Supply

The Year 2060 Estimated WWTP Effluent for WMARSS is 31,779 acft/yr (28.37 MGD). Based on feedback from the City of Waco the combined Year 2060 Confirmed WWTP Effluent Discharge for this WWTP is 0 acft/yr (0 MGD). Therefore, the 2060 Potential Reuse is the difference between the Estimated and Confirmed WWTP Effluent which is 31,779 acft/yr (28.37 MGD). The amount of reuse water available for Waco North reuse will be limited by the wastewater flow in the collector main feeding the new satellite reuse treatment plant.

4B.3.1.6.5.3 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 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 4B.3-56.

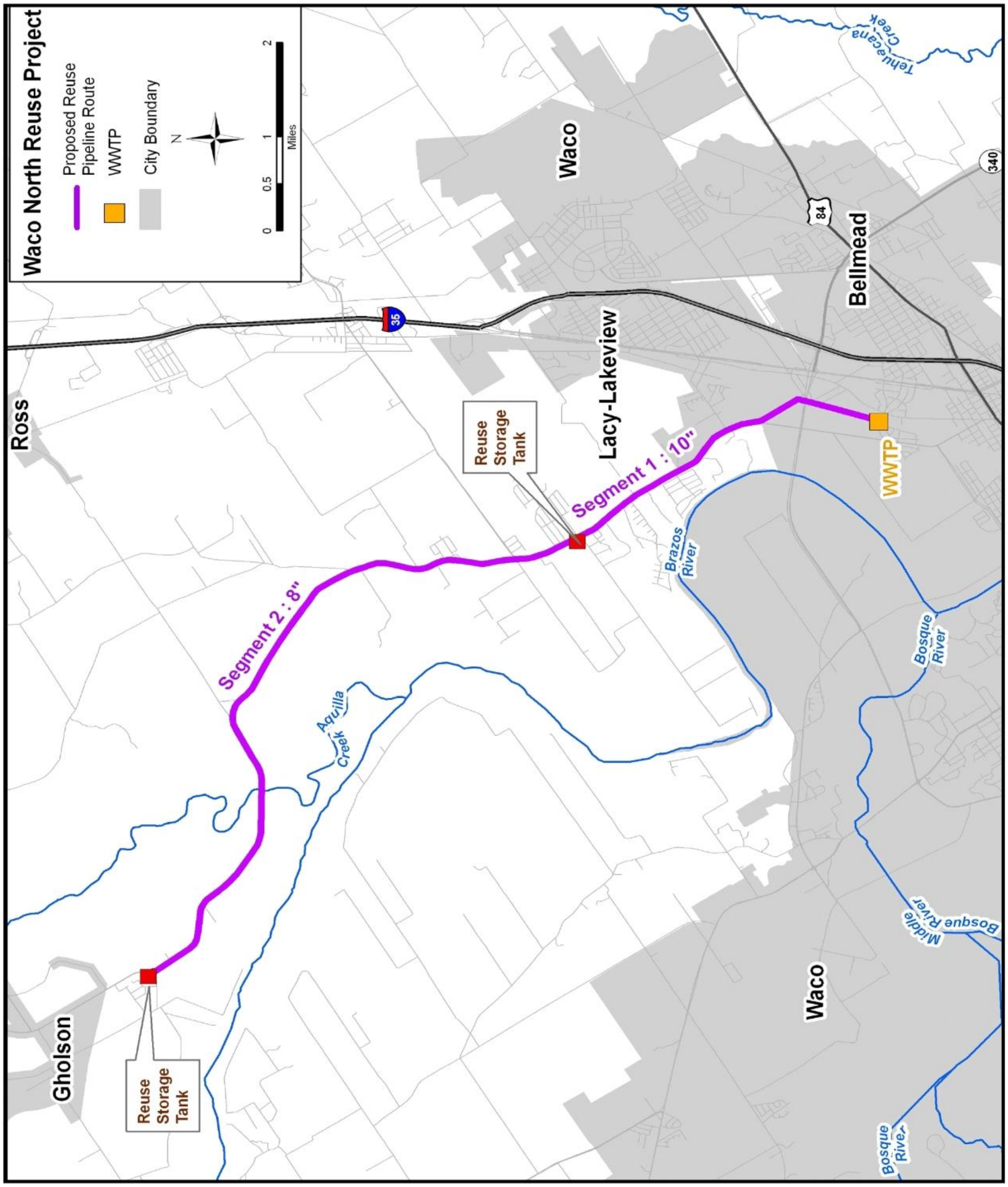

Figure 4B.3-13. Waco North Reuse

Table 4B.3-55. Waco North Reuse Water Demand

Entity	***2060 Demand (acft/yr)***	***Reuse Water Demand (acft/yr)***	***2060 Need (acft/yr)***
Chalk Bluff WSC	798	240	190
Gholson	231	69	0
County-Other	7,881	811	0
Total		**1,120**	

Table 4B.3-56. Environmental Issues: Waco North Reuse

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

4B.3.1.6.5.4 *Engineering and Costing*

This option has a total capital cost of $14,482,000 and an annual cost of $3,035,000. Many of the required improvements to implement a reuse supply for this option are shared between the multiple entities. These shared facilities include the satellite reuse treatment plant in north Waco, pump stations, and transmission pipelines. The shared facilities are sized to supply the combined demand for the entities served by each improvement. Table 4B.3-59 identifies the Project costs as determined by the share of each infrastructure component for each entity. Due to the economy of scale, significant cost savings are realized by utilizing shared larger improvements for the treatment and delivery of reuse water to all entities supplied by the Waco North water supply option.

Table 4B.3-57.
Required Facilities – Waco North Segment 1

Facility	*Description*
Pump Station	73 hp; 1.0 MGD capacity to deliver at uniform rate to storage tanks at Chalk Bluff WSC and Gholson with 25 psi residual pressure
Storage Tank	1 MG; balancing storage at new satellite reuse plant
Pipeline	18,434 ft of 10-inch pipe; from satellite reuse plant to Chalk Bluff WSC and start of segment 2
Available Project Yield	1.0 MGD (1,120 acft/yr); total yield for all Waco North projects supplied

Segment 1 shown in Figure 4B.3-13. is the initial pipeline segment that transmits reuse water from the satellite reuse treatment plant to Chalk Bluff WSC, County-Other, and the Segment 2 pipeline supplying Gholson and County-Other. The Segment 1 improvements are sized for the total demand for all these entities (1,120 acft/yr). The required facilities for Segment 1 are shown in Table 4B.3-57. The costs are divided between the supplied entities based on the quantity of water supplied to each. Gholson and County-Other share the transmission costs associated with Segment 2. The required facilities for Segment 2 improvements to implement a wastewater reuse supply for all Waco North entities are shown in Table 4B.3-58.

Table 4B.3-58.
Required Facilities – Waco North Segment 2

Facility	*Description*
Pump Station	No pump station, pressure from segment 1 pump station utilized
Storage Tank	No storage tank
Pipeline	39,722 ft of 8-inch pipe; from end of segment 1 to Gholson tank
Available Project Yield	0.5 MGD (560 acft/yr); 69 acft/yr yield for Gholson and 491 acft/yr yield for County-Other

The treatment upgrades to supply a Type 1 reuse effluent are a new satellite reuse treatment plant with a treatment capacity of 3 MGD. The satellite treatment plant is oversized by 2 MGD for this option to allow for additional reuse water demand in the vicinity of the new plant [1 MGD (1,120 acft/yr) demand for Waco North; 2 MGD (2,240 acft/yr) demand for others in the vicinity of reuse plant]. Costs per entity for the treatment plant upgrades are estimated at $691/acft. This cost was included as a treated water cost for Chalk Bluff WSC, Gholson and County-Other (Table 4B.3-59).

Table 4B.3-59.
Cost Estimate Summary -Waco North
September 2008 Prices

Item	*Estimated Costs for Facilities*	*New WWTP*	*Chalk Bluff (Segment 1)*	*Gholson (Segments 1, 2)*	*County Other (Segments 1,2)*
Capital Costs					
Transmission Pipeline (11 miles)	$4,046,000		$630,000	$434,000	$2,982,000
Transmission Pump Station(s)	$428,000		$92,000	$27,000	$309,000
New Waste Water Treatment Plant (3 MGD)	$10,008,000	$10,008,000			
Total Capital Cost	**$14,482,000**	**$10,008,000**	**$722,000**	**$461,000**	**$3,291,000**
Engineering, Legal Costs and Contingencies	$4,537,000	$3,503,000	$226,000	$144,000	$1,031,000
Environmental & Archaeology Studies and Mitigation	$358,000	$27,000	$38,000	$201,000	$92,000
Land Acquisition and Surveying (52 acres)	$475,000	$30,000	$51,000	$270,000	$124,000
Interest During Construction (2 years)	$1,589,000	$543,000	$169,000	$108,000	$769,000
Total Project Cost	**$21,441,000**	**$14,111,000**	**$1,206,000**	**$1,184,000**	**$5,307,000**
Annual Costs					
Debt Service (6 percent, 20 years)	$1,869,000	$1,230,000	$105,000	$103,000	$463,000
Operation and Maintenance					
Intake, Pipeline, Pump Station	$51,000		$9,000	$5,000	$38,000
Water Treatment Plant	$1,092,000	$1,092,000			
Pumping Energy Costs (256324 kW-hr @ 0.09 $/kW-hr)	$23,000		$7,000	$2,000	$14,000
Treated Water Cost ($691/acft)	-	-	$166,000	$48,000	$560,000
Total Annual Cost	**$3,035,000**	**$2,322,000**	**$287,000**	**$158,000**	**$1,075,000**
Available Project Yield (acft/yr)	3,360	3,360	240	69	811
Annual Cost of Water ($ per acft)	$903	$691	$1,196	$2,290	$1,326
Annual Cost of Water ($ per 1,000 gallons)	$2.77	$2.12	$3.67	$7.03	$4.07

The required improvements to implement wastewater reuse supplies for Chalk Bluff WSC and Gholson are summarized in Tables 4B.3-60 and 4B.3-61. Storage and irrigation pumping are included for Chalk Bluff WSC and Gholson.

Table 4B.3-60.
Required Facilities – Chalk Bluff WSC

Facility	*Description*
Treatment Upgrade	Purchase 0.22 MGD treated reuse water from Waco
Pump Station	52 hp; 0.88 MGD capacity to deliver peak daily capacity in 6 hours at 60 psi; shared use of segment 1pump station
Storage Tank	0.22 MG; Store one days treated reuse water at tank near Chalk Bluff WSC demand
Pipeline	Shared use of pipeline segment 1
Available Project Yield	0.22 MGD (240 acft/yr), yield is based on 30 percent of total year 2060 demand to be used for irrigation and/or industrial customers

Table 4B.3-61.
Required Facilities – Gholson

Facility	*Description*
Treatment Upgrade	Purchase 0.06 MGD treated reuse water from Waco
Pump Station	14 hp; 0.24 MGD capacity to deliver peak daily capacity in 6 hours at 60 psi; shared use of segment 1 pump station
Storage Tank	0.06 MG; Store one days treated reuse water at tank in Gholson
Pipeline	Shared use of pipeline segments 1 and 2
Available Project Yield	0.06 MGD (69 acft/yr), yield is based on 30 percent of total year 2060 demand to be used for irrigation and/or industrial customers

Costs presented in Tables 4B.3-59 provide the total option costs for developing a wastewater reuse supply for Chalk Bluff WSC, Gholson and County-Other. The demand from County-Other is divided between pipeline Segments 1 and 2. Inclusion of the County-Other 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 County-Other 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.

4B.3.1.6.5.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-62, 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.

Table 4B.3-62.
Comparison of Waco North Reuse Option to Plan Development Criteria

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

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

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

4B.3.1.7 Bell County WCID No.1 – Reuse

4B.3.1.7.1 Description of Option

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

The near-term potential customers will be served through two projects identified as the North Reuse Project and the South Reuse Project. The North Reuse Project consists of supplying treated wastewater from WWTPs 1 and 2 to potential customers for irrigation use at several municipal parks, two cemeteries in Killeen, the Courses of Clear Creek near Fort Hood, the Killeen Golf Course, and the Texas A&M Killeen campus. 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 4B.3-14. Although average annual demands total approximately 1,925 acft/yr, the reuse system must be sized to meet the peak irrigation demand during the summer months, which is about 3.03 MGD (3,394 acft/yr). Irrigation demands for the North project are shown in Table 4B.3-63.

Table 4B.3-63.
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
Killeen Golf Course	0.44	0.78
Community Center Ball Park	0.25	0.44
Long Branch Park	0.21	0.38
Texas A&M Killeen	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

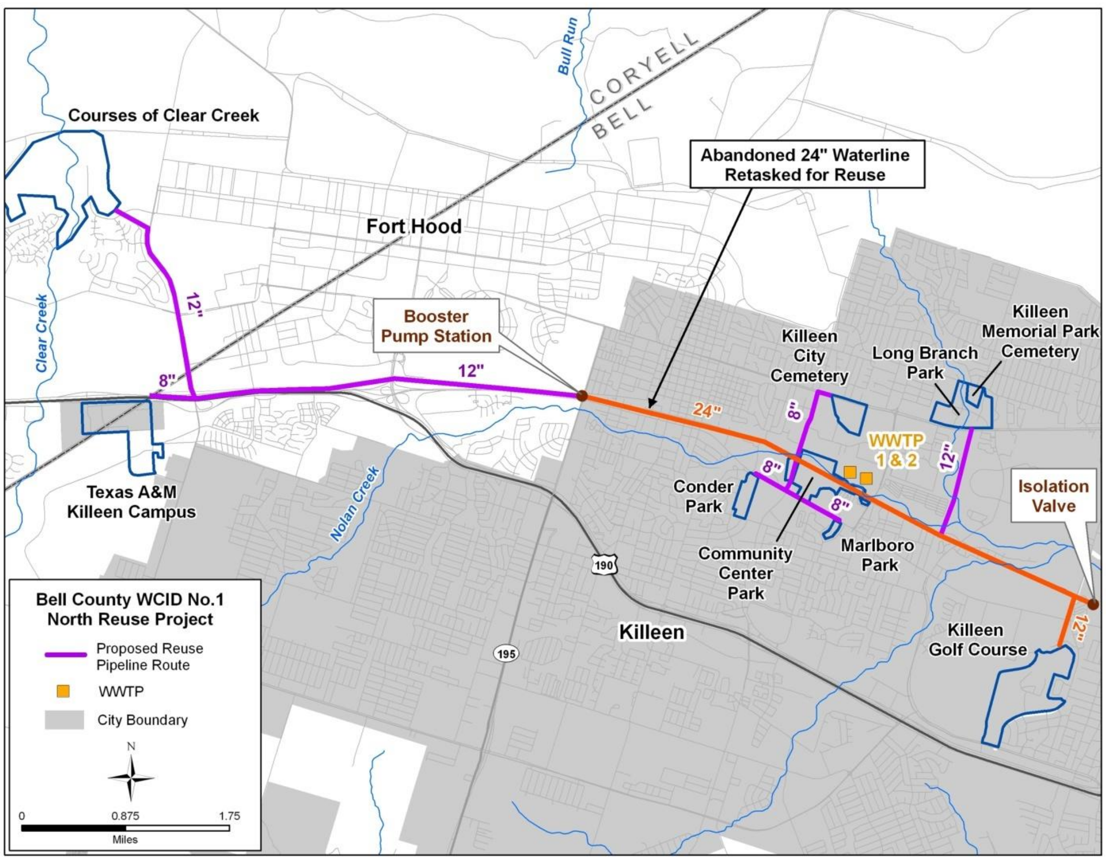

Figure 4B.3-14. Bell County WCID No. 1 North Reuse Project

The South project includes potential irrigation customers to be supplied from the South WWTP. A portion of the existing effluent discharge line will be used to deliver a portion of the reuse supply. The locations of the WWTP, potential customers and proposed South Reuse Project facilities are shown in Figure 4B.3-15. Average annual demand for the South project is approximately 748 acft/yr, and peak irrigation demand is about 1.18 MGD or 1,318 acft/yr. Irrigation demands for the South project are shown in Table 4B.3-64.

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 4B.3-65 shows the future potential reuse demands.

4B.3.1.7.2 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.

Table 4B.3-64. Water Reuse Demands for Bell County WCID South Reuse Project

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

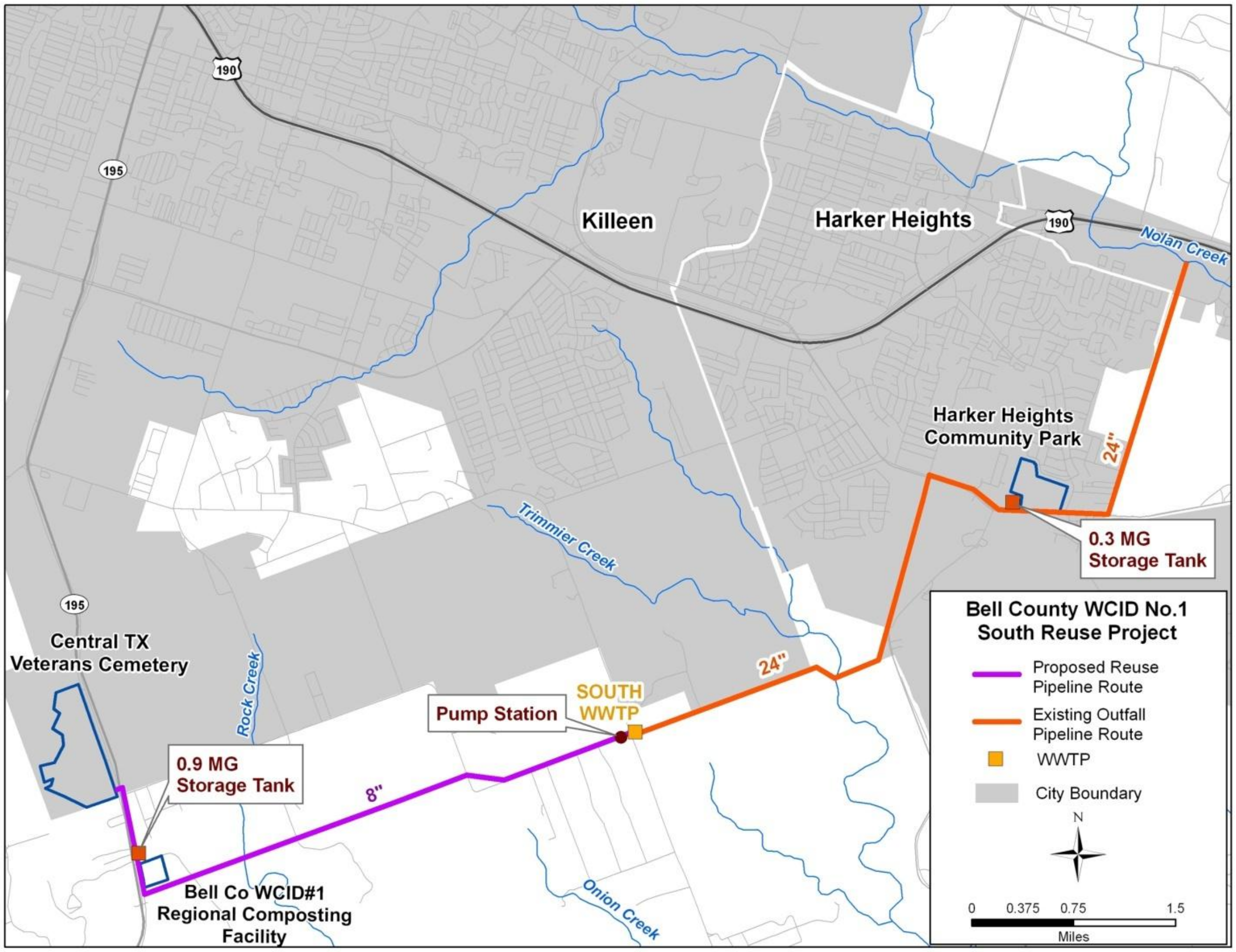

Figure 4B.3-15. Bell County WCID No. 1 South Reuse Project

The Year 2060 Estimated WWTP Effluent for WWTP 1 and 2 is 20,957 acft/yr (18.7 MGD) and 5,645 acft/yr (5 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 all of the year 2060 estimated WWTP effluent for the District.

Table 4B.3-65.
Other Potential Future Water Reuse Demands for Bell County WCID Reuse System

Reuse Customer	***Average Demand (MGD)***	***Peak Demand (MGD)***
Fort Hood		
Vehicle Wash	5.00	5.00
Dust Control	1.20	1.20
Irrigation	6.25	11.06
Site Cooling	0.50	0.50
Future Development (Stilhouse 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

4B.3.1.7.3 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 4B.3-66.

Table 4B.3-66.
Environmental Issues: Bell County WCID No. 1 North and South Reuse Projects

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

4B.3.1.7.4. 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 4B.3-67.

Table 4B.3-67.
Required Facilities – Bell County WCID No. 1 North Reuse Project

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

Estimated costs for the North Reuse Project are summarized in Table 4B.3-68. Total costs for the project are $13,104,000 with annual costs of $1,450,000. Annual costs include debt service estimated at 6% for 20 years, O&M for pipelines and pump stations and pumping energy. Annual unit costs are estimated to be $753/acft or $2.31/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 4B.3-69.

Estimated costs for the South Reuse Project are summarized in Table 4B.3-70. Total project costs for the project are $5,219,000 with annual costs of $570,000. Annual costs include debt service estimated at 6% for 20 years, O&M for pipeline and pump station and pumping energy. Annual unit costs are estimated at $762/acft or $2.34/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 4B.3-68.
Cost Estimate Summary
Bell County WCID No. 1 North Reuse Project

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pump Station	$2,282,000
Transmission Pipeline (8 -12 in dia., 8 miles)	$4,467,000
Transmission Pump Station	$1,436,000
Storage Tank	$713,000
Chlorine Disinfection	$170,000
Total Capital Cost	**$9,068,000**
Engineering, Legal Costs and Contingencies	$2,950,000
Environmental & Archaeology Studies and Mitigation	$248,000
Land Acquisition and Surveying (36 acres)	$334,000
Interest During Construction (1 years)	$504,000
Total Project Cost	**$13,104,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$1,142,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$143,000
Water Treatment Plant	$76,000
Pumping Energy Costs (993,113 kW-hr @ 0.09 $/kW-hr)	$89,000
Total Annual Cost	**$1,450,000**
Available Project Yield (acft/yr)	1,925
Annual Cost of Water ($ per acft)	$753
Annual Cost of Water ($ per 1,000 gallons)	$2.31

Table 4B.3-69.
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 pump station - 86 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	23,793 ft of 8-inch pipe
Available Project Yield	0.67 MGD (748 acft/yr).

As identified in Table 4B.3-71, the combined yield of the North and South Reuse Projects are 2,673 acft/yr with annual unit costs of $756/acft or $2.32 per thousand gallons.

4B.3.1.7.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-72, and the option meets each criterion. Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

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

Table 4B.3-70.
Cost Estimate Summary
Bell County WCID No. 1 South Reuse Project

Item	Estimated Costs for Facilities
Capital Costs	
Transmission Pipeline (8 in dia., 4.5 miles)	$2,644,000
Transmission Pump Station (0.9 MGD)	$1,012,000
Chlorine Disinfection	$83,000
Total Capital Cost	**$3,739,000**
Engineering, Legal Costs and Contingencies	$980,000
Environmental & Archaeology Studies and Mitigation	$127,000
Land Acquisition and Surveying (22 acres)	$172,000
Interest During Construction (1 years)	$201,000
Total Project Cost	**$5,219,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$455,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$51,000
Water Treatment Plant	$35,000
Pumping Energy Costs (319980 kW-hr @ 0.09 $/kW-hr)	$29,000
Total Annual Cost	**$570,000**
Available Project Yield (acft/yr)	748
Annual Cost of Water ($ per acft)	$762
Annual Cost of Water ($ per 1,000 gallons)	$2.34

Table 4B.3-71.
Total Yield and Cost for North and South Reuse Projects

Project	Average Yield (acft/yr)	Unit Cost	
		($/acft)	($/kgal)
North Reuse Project	1,925	$753	$2.31
South Reuse Project	748	$762	$2.34
Total	2,673	$756	$2.32

Table 4B.3-72.
Comparison of Bell County WCID No.1 North and South Reuse Projects to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Potentially important source reducing demand for potable supplies
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Reduces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. Potential impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal 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

4B.3.2 Indirect Reuse

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

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

> § 11.021. STATE WATER. (a) The water of the ordinary flow, underflow, and tides of every flowing river, natural stream, and lake, and of every bay or arm of the Gulf of

Mexico, and the storm water, floodwater, and rainwater of every river, natural stream, canyon, ravine, depression, and watershed in the state is the property of the state.

(b) Water imported from any source outside the boundaries of the state for use in the state and which is transported through the beds and banks of any navigable stream within the state or by utilizing any facilities owned or operated by the state is the property of the state.

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

§ 11.042. DELIVERING WATER DOWN BANKS AND BEDS. (a) Under rules prescribed by the commission, a person, association of persons, corporation, water control and improvement district, water improvement district, or irrigation district supplying stored or conserved water under contract as provided in this chapter may use the bank and bed of any flowing natural stream in the state to convey the water from the place of storage to the place of use or to the diversion point of the appropriator.

(b) A person who wishes to discharge and then subsequently divert and reuse the person's existing return flows derived from privately owned groundwater must obtain prior authorization from the commission for the diversion and the reuse of these return flows. The authorization may allow for the diversion and reuse by the discharger of existing return flows, less carriage losses, and shall be subject to special conditions if necessary to protect an existing water right that was granted based on the use or availability of these return flows. Special conditions may also be provided to help maintain in stream uses and freshwater inflows to bays and estuaries. A person wishing to divert and reuse future increases of return flows derived from privately owned groundwater must obtain authorization to reuse increases in return flows before the increase.

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

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

Table 4B.3-73 shows the Brazos G entities with indirect reuse applications currently filed with TCEQ.

Table 4B.3-73.
Current and Pending Indirect Reuse Applications Filed at the TCEQ in Region G as of September 30, 2009

Owner	Water Right	Stream	County	Amount [acft/yr]	Use Type
City of Cleburne	4106 - Certificate of Adjudication	Nolan River	Johnson	5,760	Municipal, Industrial
City of Cleburne	4106 - Certificate of Adjudication	Nolan River	Johnson	240	Multiple Uses
City of Abilene	4266 - Permit	Deadman Creek	Jones, Shackelford	4,330	Irrigation
City of Abilene	4161 - Certification of Adjudication (Amendment Pending)	Clear Fork of the Brazos River	Multiple along the Clear Fork	24,640	Multiple Uses
Brazos River Authority	5730 - Permit	Colorado River	Williamson	25,000	Multiple Uses
Somervell County Water District	5744 - Permit	Paluxy River, Wheeler Branch	Somervell	5,000	Multiple Uses
City of Navasota	5748 - Permit	Cedar Creek	Grimes	430	Irrigation
Buhari Inc.	5771 - Permit	Buttonwillow Creek	Taylor	2	Irrigation
Burl G. Harris	5771 - Permit	Buttonwillow Creek	Taylor	18	Irrigation
City of Albany	5802 - Permit	Unnamed Tributary of North Fork Creek	Shackelford	50	Irrigation, Recreation
City of Waco	5840 - Permit	Brazos River	McLennan		Multiple Uses
City of Bryan	5912 - Pending Permit	Brazos River	Brazos	14,282	Multiple Uses
City of College Station	5913 - Pending Permit	Brazos River	Brazos	12,881	Multiple Uses
Brazos River Authority	5851 – Pending System Operation Permit	Varies	Multiple	Varies	Multiple Uses

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4B.4 System Operation of Brazos River Authority Reservoirs

The Brazos River Authority (BRA) has submitted to the Texas Commission on Environmental Quality (TCEQ) water rights permit application 12-5851 requesting additional appropriation of water that could be made available through system operations of the BRA's existing water rights and reservoirs. The application requested an appropriation of up to 421,449 acft/yr of firm supply. The BRA also requests authorization to use up to 90,000 acft/yr of its firm supply to produce, along with other unappropriated flows, an interruptible supply of up to 670,000 acft/yr for appropriation. By conventional definition, at least 75 percent of an interruptible supply is available at least 75 percent of the time. An initial draft permit was released by the TCEQ on December 1, 2008. A draft permit has been issued and proceedings have initiated before the State Office of Administrative Hearings.

The Brazos G RWPG evaluated the BRA System Operations (Sys-Ops) as a potential water management strategy for the 2011 Brazos G Regional Water Plan (2011 Plan).

The evaluation was completed through two tasks:

1. Incorporate the BRA System Operations into the Brazos G WAM and determine the maximum amount that could be made available under the constraints of existing contractual obligations and future reservoir sedimentation conditions.
2. Determine the additional water supply that would be made available by the BRA System Operations to Water User Groups (WUGs) with needs that could potentially utilize the additional supply.

4B.4.1 Availability of Water from the BRA System Operations

The water requested in the BRA water rights permit application was the maximum amount of water that could be developed by the BRA System if all of the water were utilized (diverted) near the Gulf of Mexico. Diverting all water supply from the BRA System (both existing and new appropriations) near the Gulf maximizes the supply available by (a) allowing all BRA reservoirs to contribute and make releases, and (b) maximizes the area contributing flows (uncontrolled runoff and wastewater return flows[1,2]) that originate downstream of the BRA reservoirs. Under this hypothetical operation (diverting all supply near the Gulf), uncontrolled flow originating downstream of the BRA reservoirs is diverted during wet times,

[1] This water management strategy shall not impair or prejudice the rights of an owner of groundwater based discharges to seek or obtain authorization to reuse such discharges either directly or indirectly pursuant to Texas Water Code Section §11.042 (b) consistent with state law.

[2] The permit application interrupts BRA's appropriation for reuse by the discharger if such reuse is within the discharger's water service area.

and firmed up by releases from storage in the upstream BRA reservoirs during dry times. In this fashion, a total "system" yield can be developed that is substantially greater than the sum of the individual reservoir yields.

The BRA currently holds multiple contracts to supply water to cities, districts, irrigators and industry throughout the Brazos River Basin. Many of these contracts are supplied proximate to the BRA's reservoirs, or through lakeside diversions. This reduces the efficiency of the BRA System because (a) not every BRA reservoir can contribute releases to every contractual diversion location, and (b) diversion of the contracts from the basin upstream of the Gulf reduces the opportunity to utilize flows contributed by the basin downstream of the reservoir system. Because of this constraint, the total amount of water that the BRA could realize through system operations of its reservoirs is less than the amount stated in the permit application.

The Brazos G WAM was utilized to determine the availability of water from the BRA System. The Brazos G WAM, as developed by the Brazos G RWPG, includes 619,616 acft of the 698,440 acft of existing BRA contracts simulated at their actual points of diversion in the basin. Priority calls agreements that the BRA has accounts for 2,781 acft of this difference, and another 24,800 acft of the difference is because it is ties to supply from the Colorado River Basin. Some of the BRA contracts, especially those in the Little River System (Proctor, Belton, Stillhouse, Georgetown), are shorted, or in other words, they are not 100% reliable when simulated under the Brazos G WAM assumptions. Some of these contracts' diversion amounts were reduced in the modeling effort so that their reliability was reported as 100%. This was done so that when the Sys-Ops component was added to the model the user just had to make sure reliabilities stayed at 100% and not some other percentage. These shortages are the result of the BRA contracting policy of meeting current demands from existing sources, realizing that new sources of water must be developed in the future to meet all contractual commitments. The thought was always that these are not shortages on these contract holders, but rather shortages on BRA as the Wholesale Water Provider (WWP). Due to a TWDB database rule, shortages can not be shown in this manner. Because of the iterative process required when modifying the Sys-Ops, instead of going back and prorating each contract and rerunning the model, select contracts were reduced and the proration was applied after the modeling step. Spreadsheet work was done that took the difference in the total contract amounts and the amount modeled, and then applied these differences using a proration to all the contracts, except in a few exceptions that BRA indicated, shown below.

- City of Temple 18,500 acft storage contract should be kept at 18,500 acft.
- City of Taylor contract – this is a needs met contract and BRA allocates 13,000 acft to meet Taylor and Jonah's needs. BRA suggested showing a supply to Taylor of 5,344 acft (meets their 2060 demand);
- Jonah SUD – needs met contract, suggest showing an additional surface water supply of 1,960 acft (meets their 2060 needs).
- Because Lake Proctor is a stand-alone supply used to meet local needs – its supply and contracts should be excluded from the allocation of supplies and contracts in the rest of the Little River System.

The BRA System operations concept was incorporated into the Brazos G WAM by specifying which contracts could receive releases from multiple reservoirs, and then allowing those reservoirs to make releases during model simulations. The remaining water available from the BRA System (after supplying current contractual commitments) was then evaluated at the Gulf of Mexico. The BRA application includes estimates of potential system diversions at three locations: Brazos River near Glen Rose, Brazos River near Highbank, and the Brazos River at Richmond. The analysis performed for the Brazos G RWPG evaluating the effects of the BRA System Operations includes only the Brazos River at the Richmond system diversion location.

During the model simulations, the BRA contracts are met first from the BRA System, followed by the remaining amount that could be met at the Richmond diversion. This would be the maximum amount that could be realized by the BRA under the agency's current contractual commitments. If the BRA's contractual commitments change in the future, the availability of water from the BRA System would also change accordingly. All simulations assume Year 2060 reservoir sedimentation conditions. The Allens Creek reservoir project was included in the BRA Sys-Ops analysis, as it is permitted, but not constructed, and is included as part of the pending application on file at the TCEQ.

Results of the water availability analysis are shown in Table 4B.4-1. The sum of the BRA's existing contractual obligations included in this analysis total 619,616 acft/year, which includes reducing some downstream contractual demands by 8% to account for delivery losses from the upstream reservoirs. Table 4B.4-2 summarizes the existing BRA contractual commitments that are located outside of the Brazos G Area in Region H.

Table 4B.4-1.
Water Availability from BRA System Operations

BRA Stand Alone Firm Yield (acft/yr)	*BRA Contractual Diversions[1] (acft/yr)*	*Upstream Luminant Contract (acft/yr)*	*Diversions at Richmond (acft/yr)*	*Total BRA System Diversions[2] (acft/yr)*	*Yield Benefit from System Operations[2] (acft/yr)*
631,086	619,616	76,270	137,000	832,886	201,800

[1] This value includes only the portions of contracts simulated in the model analysis.

[2] The Allen's Creek Reservoir Project is included in these runs as it is permitted and included as part of the BRA Sys-Ops application pending with the TCEQ even though it is not currently constructed. Supplies shown include Allen's Creek Reservoir operated as part of the BRA System.

Table 4B.4-2.
BRA Contracts in Region H

Owner	*BRA Contracted Diversions (acft/yr)*	*Diversion[1] Simulated (acft/yr)*
All Seasons Turf Grass, Inc.	50	50
Dow Pipeline Company	16,000	14,720
Gulf Coast Water Authority	37,668	34,654
Horizon Turf Grass, Inc.	350	350
NRG Texas, LLC	83,000	76,360
Pecan Grove MUD	3,100	2,852
City of Richmond	3,000	2,760
City of Rosenberg	4,500	4,140
South Texas Water Co.	5,625	5,175
Vulcan Const. Materials L.P.	400	368
Totals	**153,693**	**141,429**

[1] Some of these contracts were reduced for delivery losses from the main stem BRA reservoirs. BRA contracts are generally structured so that the purchaser assumes the delivery losses from the reservoir to the diversion point.

The actual BRA contractual commitments total 670,589 acft/yr, exclusive of subordination agreements, which were simulated in the model instead of being included as contracts. The BRA has indicated plans to contract a portion of the Sys-Ops supply to Luminant Power to provide an additional 76,270 acft/yr for steam electric generation purposes out of Lake

Granbury with additional releases from Possum Kingdom. This supply was evaluated and the Brazos G 2006 Regional Water Plan was amended accordingly. After meeting existing upstream contractual commitments and the anticipated Luminant commitment, an additional 137,000 acft/yr of firm supply could be developed at Richmond by system operations of the BRA reservoirs. This total includes both currently permitted yield that is not utilized by existing contracts, and unpermitted yield that could be developed by the system operations.

The availability of interruptible supply was not evaluated for this update of the Brazos G 2011 Plan. The Richmond diversion scenario was utilized as the standard "base run" with which the remaining portion of the analysis was completed.

4B.4.2 Utilization of the BRA System Operations as a Water Management Strategy for Specific WUGs in the Brazos G Area

Water available from BRA System Operations represents a new supply of water that could be utilized to meet future needs in the Brazos G Area without construction of new reservoirs. WUGs with projected needs were identified in counties adjacent to the main stem of the Brazos River. Demands equal to those needs were included as new contractual diversions in the system operations version of the Brazos G WAM. The model was then used to determine if sufficient water was available from system operations to meet the projected needs of each of the WUGs, as well as the facility and operational costs for diversion, transmission, and treatment.

4B.4.2.1 Selected WUG with Needs

In consultation with the BRA, seventeen potential WUGs were identified proximate to the main stem of the Brazos River with projected needs. These WUG needs were simulated as being diverted from seven different locations along the main stem of the Brazos River. Figure 4B.4-1 shows the seven diversion locations, and Table 4B.4-2 lists the seventeen WUGs selected for which water available from BRA System Operations might be a feasible water management strategy. WUGs with needs based on infrastructure constraints were not included as selected WUGs.

4B.4.2.2 Water Availability to WUGs with Needs

The individual WUG diversions were incorporated into the model in upstream to downstream order, and assigned priority junior to BRA's existing water supply contracts. As

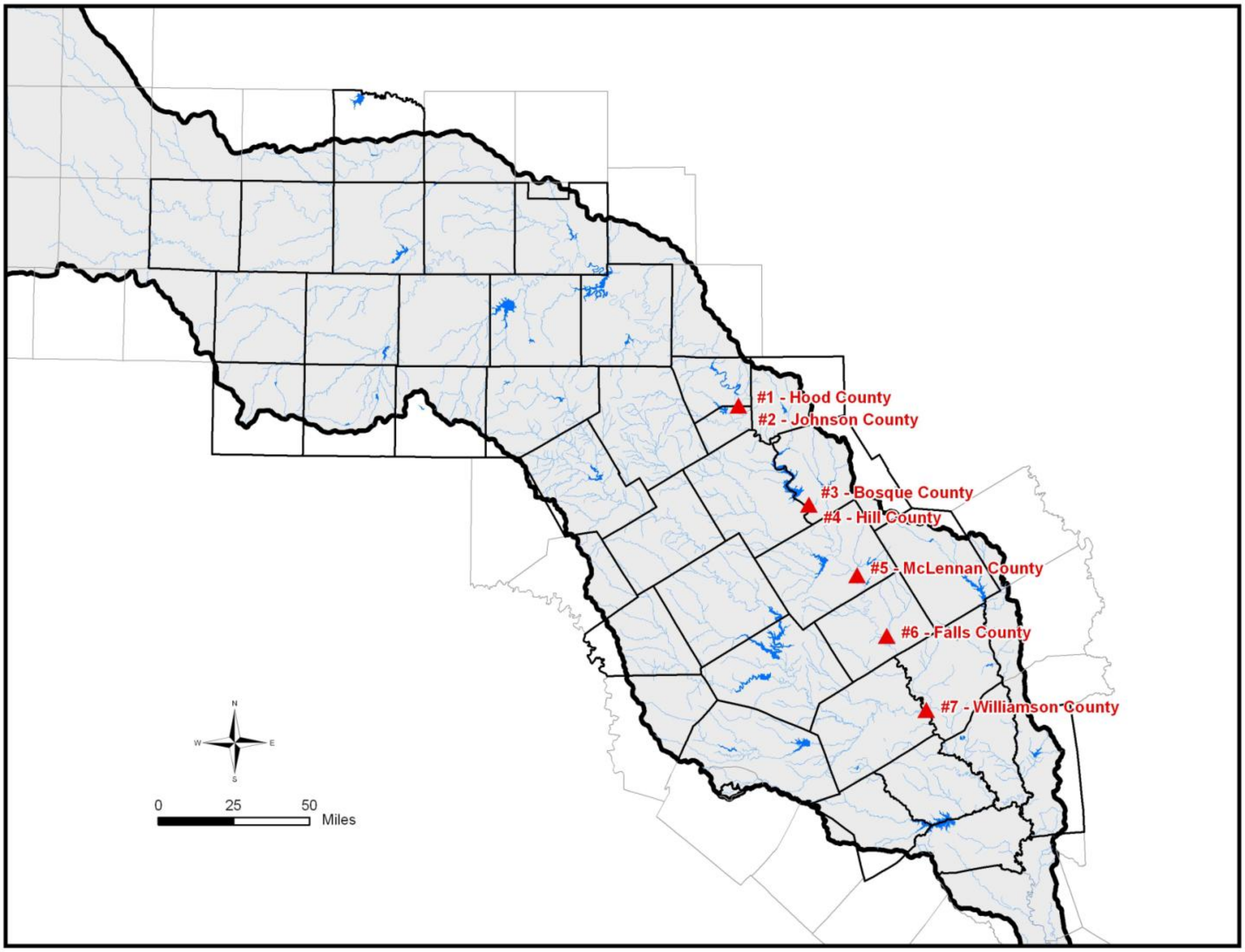


Figure 4B.4-1. WUG Diversion Locations

additional WUG diversions are added in the downstream direction, additional BRA reservoirs are capable of making releases to meet the demands, and the remaining supply available at the Richmond location is reduced in response to the additional upstream demand.

All 17 WUG needs are able to be met exclusively by the BRA system without negatively impacting any existing BRA water supply obligations. However, in order to be able to meet the additional 13,927 acft of identified WUG demands, the remaining supply at Richmond was reduced by 12,000 acft to 125,000 acft/yr. This quantity includes operation of Allen's Creek Reservoir as part of the BRA System.

Table 4B.4-2.
Potential WUGs for Availability and Cost Analysis

Diversion Location #	County	Combined WUG Need (acft/yr)	Included WUGs
1	Hood County	1,815	Cresson DeCordova Lipan Oak Trail Shores Subdivision Tolar
2	Johnson County	5,446	Cleburne Cresson Keene Parker WSC Johnson County Manufacturing
3	Bosque County	5,461	Bosque Steam Electric
4	Hill County	673	White Bluff Community WSC Woodrow-Osceoal WSC
5	McLennan County	112	Robinson
6	Falls County	241	West Brazos WSC
7	Williamson County	179	Bartlett BMF WSC
Total WUG Needs		13,927	

4B.4.2.3 Costs for Meeting WUG Needs with BRA System Supply

The following sections describe the estimated facilities and operational costs associated with diverting, transmitting, and treating the BRA system water to meet the identified WUG needs. Raw water costs were set equal to the FY 2008 BRA system rate of $54.50 per acft for most strategies to be consistent with the TWDB assumption of using September 2008 prices. Facilities and operation costs for the 6 WUG supply scenarios were estimated using the cost estimating procedure used for other water management strategies evaluated for the 2011 Plan.

Of the 17 WUG strategies evaluated, six are recommended to meet future needs. Table 4B.4-3 presents a summary comparison of the costs for the six individual WUGs for which BRA System Operation Supply is a recommended strategy. Unit costs vary considerably due to economies of scale and treatment considerations for the type of use contemplated. Desalination was considered necessary for all municipal and manufacturing uses, but not mining or steam electric uses. Large individual unit costs could be decreased by serving additional WUGs beyond those enumerated herein. The costs for the Somervell County Steam Electric need are presented in the plan section for Somervell County (Section 4C.30), updated to September 2008 prices from the 2006 plan amendment documents included in Volume II, Section 4B.21.

Table 4B.4-3.
WUGs for which BRA System Operation Supply is a Recommended Strategy

WUG	WUG Location	Demand (acft/yr)	Capital Cost	Annual Cost	Unit Cost ($/acft)	Unit Cost ($/1,000 gal)
Bosque Steam-Electric	Bosque County	5,222	$17,125,000	$3,307,000	$633	$1.94
White Bluff Community WS	Hill County	600	$6,533,000	$1,288,000	$2,147	$6.59
Woodrow-Osceola WSC	Hill County	150	$4,744,000	$819,000	$5,460	$16.75
Cleburne	Johnson County	1,530	$9,337,000	$1,526,000	$997	$3.06
Keene	Johnson County	157	$1,847,000	$481,000	$3,064	$9.40
Somervell County Steam-Electric	Somervell County	103,717[1]	$47,866,000	$12,927,000	$125	$0.38

[1] 103,717 includes 27,447 of existing Luminant contract supplies from BRA and the Sys-Ops portion is 76,270 acft.

4B.4.3 Summary of Hydrologic Findings Concerning the Proposed BRA System Operations

The proposed BRA System Operations appropriation would add a considerable amount of firm supply to the Brazos River Basin that could be used in the Brazos G Area, but also in adjacent regions where the BRA supplies water, most notably Region H (Houston area). New proposed water management strategies may be impacted negatively by the BRA System Operations, but only to the extent that priority limits availability to the new options.

Supply from the BRA System Operations can be utilized to meet WUG demands throughout the Brazos Basin. Several WUGs with needs were identified, and unit cost estimates for using BRA System Operations supply to meet these needs ranged from $286 to $2,909 per acft.

The BRA System Operations would negatively affect the yields of several proposed water management strategies that are considered for the 2011 Brazos G Regional Water Plan. The proposed BRA System Operations appropriation would be granted with a priority date senior to any of these proposed reservoir projects, and would have a priority call on inflows. However, any of these proposed reservoirs could be operated in conjunction with the BRA

System, and the resulting increase in supply to the Brazos River Basin would be greater than that obtained from the projects operated on a stand-alone basis with a priority senior to the proposed BRA appropriation.

The benefits of including an existing water supply project (Lake Waco) into the BRA System are limited by constraints designed to protect water supply for local needs. These types of constraints would likely be included in agreements with any local entity willing to include a local water supply reservoir in BRA System Operations.

4B.4.4 Environmental and Implementation Issues

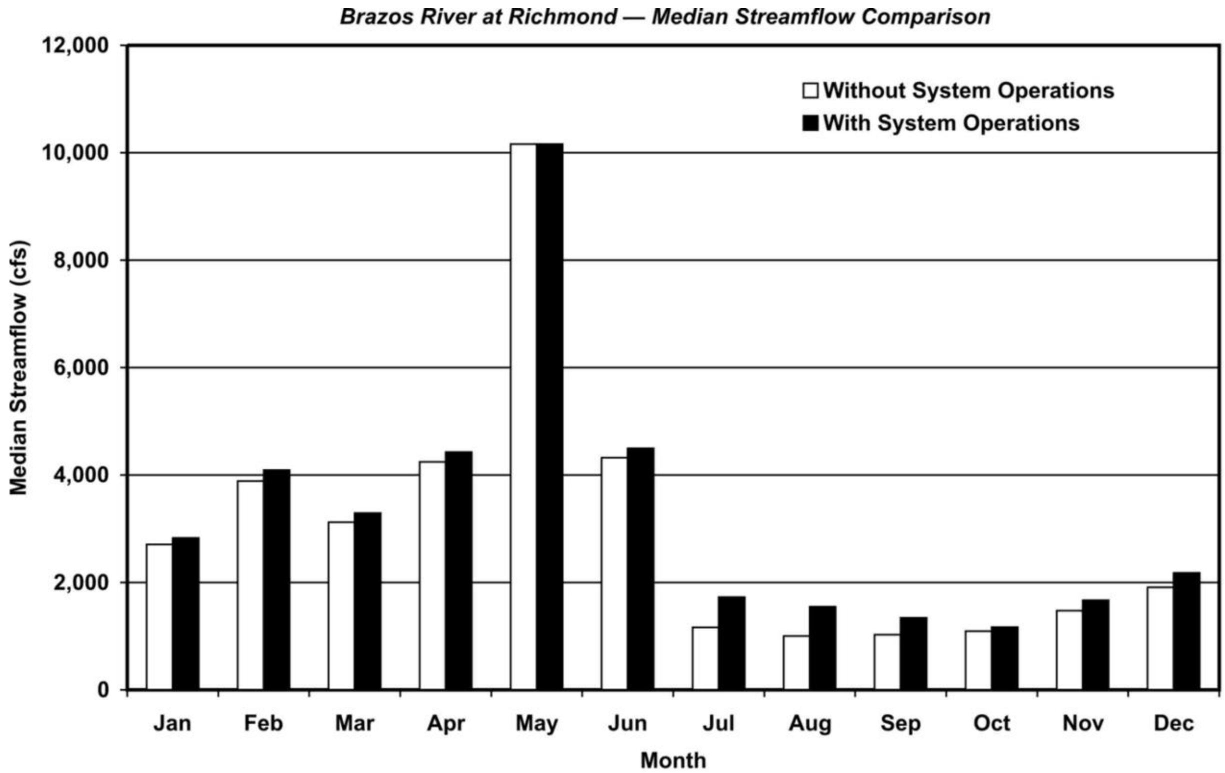
Unlike the typical implementation of a large surface water reservoir, the proposed BRA System Operations appropriation requires no environmental permits because the reservoirs already exist. However, instream flow restrictions likely to be placed on the new appropriation could limit supplies that could be developed by the project. Figure 4B.4-4 illustrates streamflows in the Brazos River at the Richmond gage, both with and without the proposed BRA System appropriation. Figure 4B.4-5 illustrates the expected Brazos River flows downstream into the Gulf of Mexico. The figures indicate that with the proposed BRA appropriation, as modeled with the majority of the proposed appropriation diverted from the lower basin, streamflows would generally be greater up to the point of diversion. However, flows into the Gulf of Mexico would generally decrease.

A summary of environmental issues for the BRA System Operations is presented in Table 4B.4-4. This water supply option has been compared to the plan development criteria, as shown in Table 4B.4-5, and the option meets each criterion.

A summary of the implementation steps for the project is presented below.

1. It will be necessary to obtain these permits:
   a. TCEQ Water Right permit[3];
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for reservoirs and pipelines impacting wetlands or navigable waters of the U.S;

[3] Consideration of water rights permits, including the need for water for specific purposes, and conditions of the permits, is the responsibility of TCEQ, not the regional water planning process. However, the Brazos G RWPG assumes that any water appropriated by water right permits associated with this water management strategy will not impair the capability to impound and store water in surface water bodies such as sedimentation ponds, end lakes and other environmental features associated with mining and mining reclamation activities, when such are required by the Railroad Commission of Texas and other regulatory entities. This assumption is applicable only to runoff originating within the watershed that drains directly to each water body, and is not applicable to diversions from rivers or streams to maintain storage in the water bodies. Diversions of water from those water bodies for any reason are also specifically excluded from this assumption.



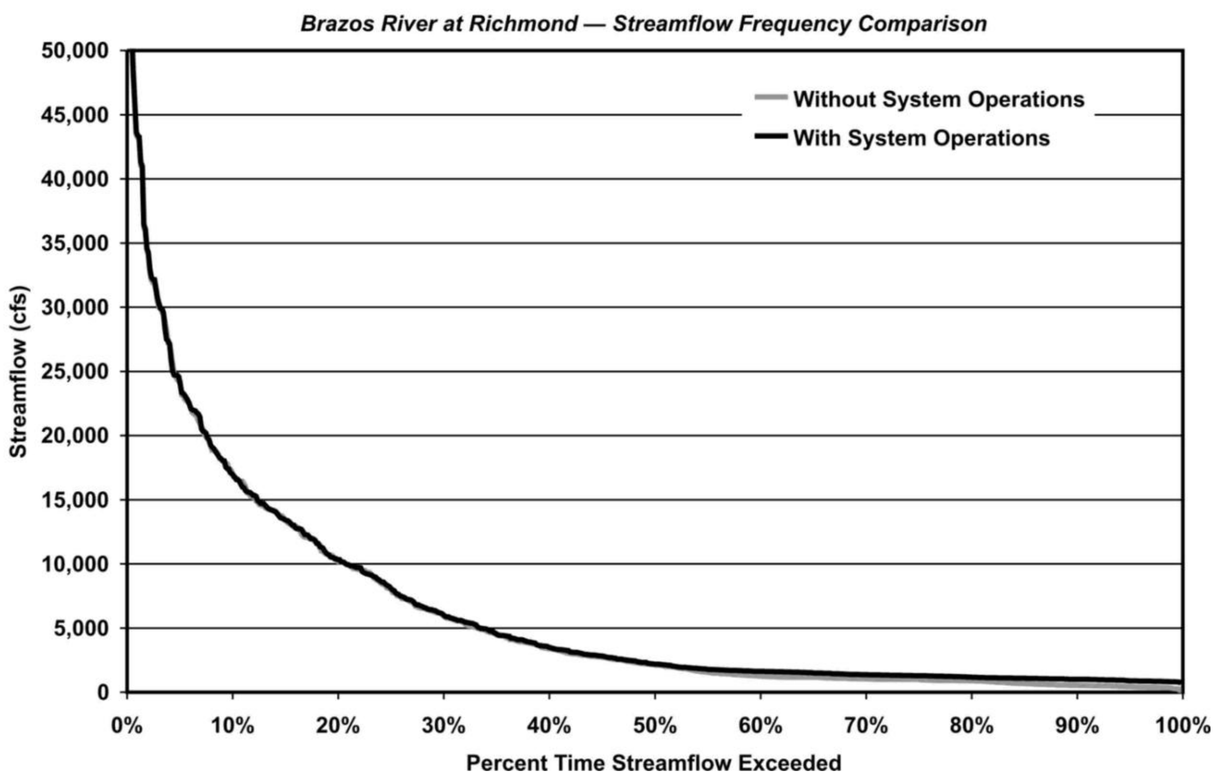
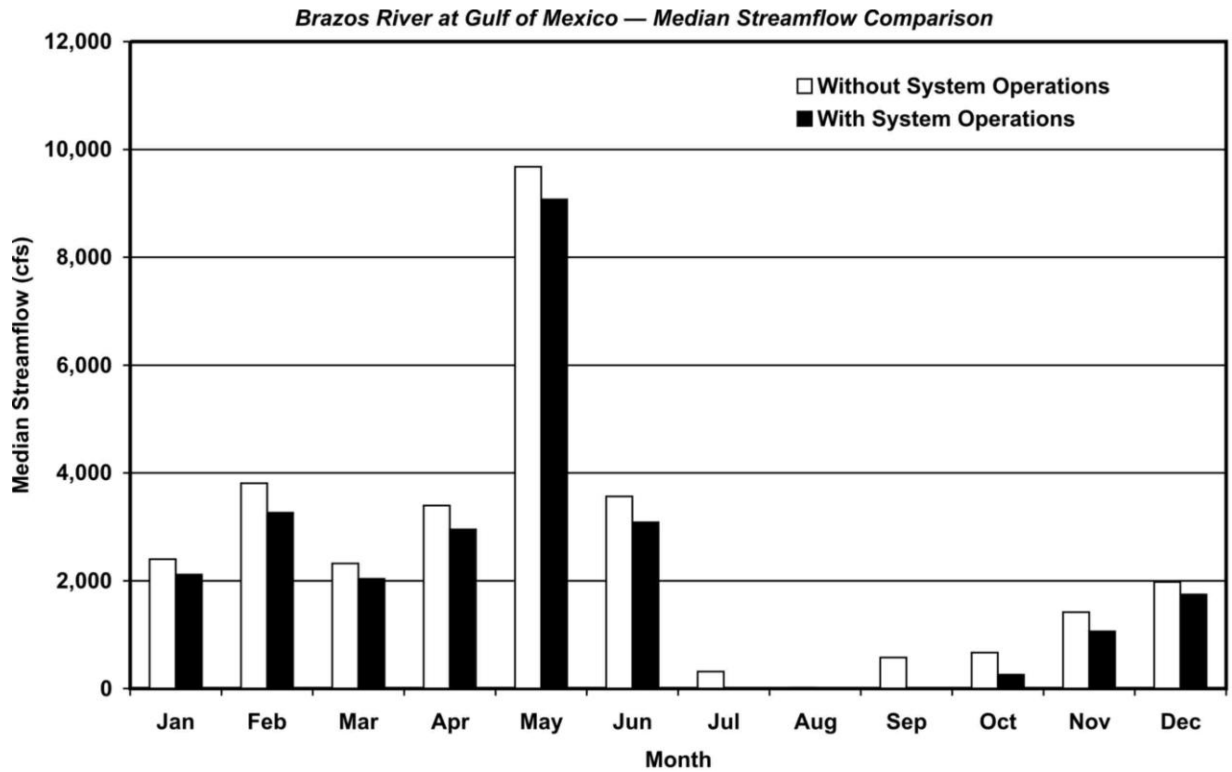


Figure 4B.4-4. BRA System Operations Streamflow Considerations at Brazos River at Richmond Control Point



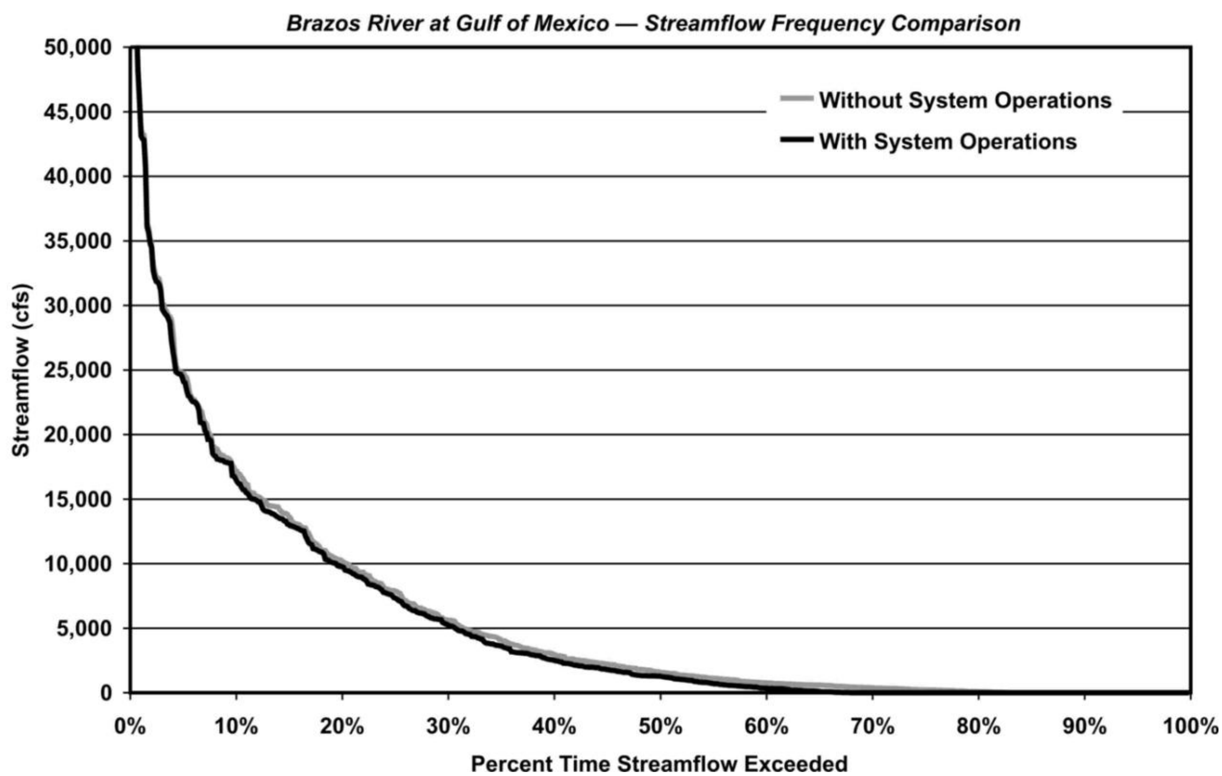


Figure 4B.4-5. BRA System Operations Streamflow Considerations at Brazos River at Gulf of Mexico Control Point

Table 4B.4-4.
Environmental Issues: BRA System Operations

Water Management Option	BRA System Operations
Implementation Measures	Each entity receiving the supply would have a water supply contract with the BRA.
Environmental Water Needs / Instream Flows	Possible low impacts. The primary sources of water are existing stored water and unappropriated flows diverted just upstream of the Gulf.
Bays and Estuaries	Possible low impact from reduced inflows to the Gulf.
Fish and Wildlife Habitat	Potential Impacts include constructing and maintaining easements for new pipelines or pump stations. Extent of impacts dependent on location and size of projects.
Cultural Resources	Possible low impact.
Threatened and Endangered Species	Potential Impacts include constructing and maintaining easements for new pipelines or pump stations. Extent of impacts dependent on location and size of projects.
Comments	Assumes infrastructure is needed to distribute purchased water to the entity in need.

Table 4B.4-5.
Comparison of BRA System Operations to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply: 1. Quantity 2. Reliability 3. Cost	 1. Sufficient to meet needs[1] 2. High reliability 3. Reasonable
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries 5. Threatened and Endangered Species 6. Wetlands	 1. Low impact 2. Low impact 3. Low impact 4. Low impact 5. Low impact 6. Low Impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None
[1] Significant quantity for regional use and Region H	

   c. TPWD Sand, Gravel, and Marl Permit for construction in state owned streambeds;
   d. NPDES Storm Water Pollution Prevention Plan;
   e. GLO easement for use of the state-owned streambed; and
   f. Section 404 certification from the TNRCC related to the Clean Water Act.
2. Permitting, at a minimum, will require these studies:
   a. Assessment of changes in instream flows in the Brazos River.
   b. Habitat mitigation plan.
   c. Environmental studies of potential impact on endangered species.
   d. Cultural resource studies and mitigation.
3. Land will need to be acquired through either negotiations or condemnation for pipeline and other facilities.

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4B.5 Groundwater/Surface Water Conjunctive Use

4B.5.1 Description of Strategy

Conjunctive use of surface water and groundwater resources for the Brazos G water plan features the use of surface water supplies during normal and wet periods and groundwater sources during droughts. Two conjunctive water management strategies are considered for the 2011 Brazos G water management plan. One is the use of Lake Granger and the Simsboro Aquifer to meet water shortages in Williamson County; and, the other is the use of Oak Creek Reservoir and the Dockum Aquifer to meet the City of Sweetwater's water demands. In these two cases, the firm yield of these surface water supplies is non existent or very limited during drought conditions. During these periods, the water stored in local aquifers is tapped to augment the surface water supplies, which together provides a meaningful firm yield.

4B.5.2 Lake Granger and Simsboro for Williamson County (Lake Granger Augmentation)

4B.5.2.1 Description of Option

Rapid population growth and development in Williamson County require additional water supplies throughout the planning period. The total need for new supplies in Williamson County is over 27,000 acft/yr by the year 2030, increasing to over 115,000 acft/yr by year 2060. Much of the increased demand is in the southwestern portion of the county in and adjoining the Cities of Cedar Park and Round Rock and extending along major highway corridors served by other potable water entities. This alternative will add 54,390 acft/yr by augmenting the long-term firm yield of Lake Granger with groundwater pumped from the Trinity Aquifer and the Carrizo-Wilcox Aquifer. In the initial phase of the project, water from the Trinity Aquifer in eastern Williamson County would be blended with treated water from the East Williamson County Regional Water Treatment Plant (EWCRWTP). In the second phase of the project, additional groundwater would be developed from the Carrizo-Wilcox Aquifer in areas east of Williamson County, in Milam, Lee and Burleson Counties. At this time specific locations for these supplies have not been identified. For the purposes of this plan, it is assumed that these supplies will come from Milam County.

Two alternatives have been previously studied for the second phase of the project. In the first alternative, referred to as the *Comingling Option*, Carrizo-Wilcox Aquifer water is first pumped into Lake Granger and comingled with natural runoff in the reservoir. The comingled water is subsequently diverted and all of the water is treated at the EWCRWTP. In the second alternative, referred to here as the *Bypass Option*, groundwater is blended with treated Lake Granger water rather than comingling the water in the reservoir. Because of concerns about blending groundwater in Lake Granger and the additional cost and treatment capacity associated with treating the blended water, current Brazos River Authority planning assumes that the Bypass Option will be used rather than the Comingling Option. Facilities for Phases 1 and 2 are depicted in Figure 4B.5-1. Concepts for this supply project are based on studies performed for the Brazos River Authority in 2005[1] and 2009[2].

4B.5.2.2 Available Yield

Using the Brazos G WAM, the firm yield of Lake Granger is projected to decline from the current yield of 18,007 acft/yr to 15,987 acft/yr in the year 2060. Reservoir sedimentation[3] is depleting conservation storage from its original permitted volume of 65,500 acft to a projected volume at year 2060 of 20,973 acft.

Water from the Trinity Aquifer in the Lake Granger area is relatively high in dissolved solids. This option envisions blending Trinity Aquifer water with treated water from the EWCRWTP to reduce dissolved solids concentration. A ratio of 2 parts Lake Granger water to 1 part Trinity Aquifer water should meet drinking water standards. As a result, the amount of water available from the Trinity Aquifer is limited by the yield of Lake Granger. Table 4B.5-1 shows the potential supply from the first phase of this project, which ranges from about 8,800 acft/yr of additional supply in 2010 to about 8,000 acft/yr in 2060.

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. Pending further study ASR is not included as an option in Phase I at this time.

[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] Sedimentation rate based on TWDB volumetric survey dated April 2002

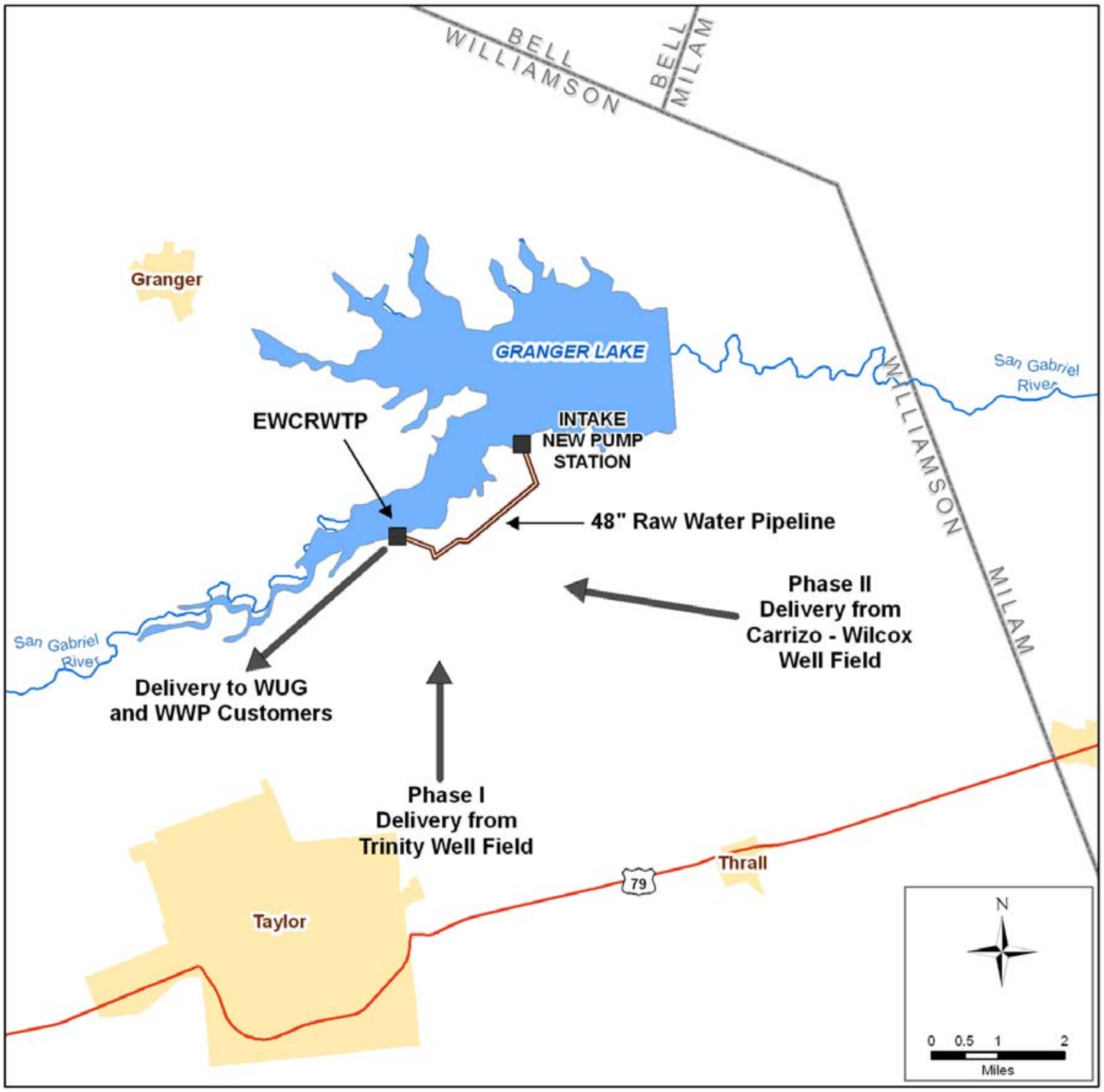

Figure 4B.5-1. Lake Granger Augmentation – Conjunctive Use with Trinity and Carrizo-Wilcox Aquifers

Table 4B.5-1
Potential Supply from First Phase of Lake Granger Augmentation Project
(Values in acft/yr)

Source	***2010***	***2020***	***2030***	***2040***	***2050***	***2060***
Granger Lake Firm Yield	17,670	17,334	16,997	16,660	16,324	15,987
Amount of Trinity Aquifer Groundwater	8,835	8,667	8,499	8,330	8,162	7,994
Total	26,505	26,001	25,496	24,990	24,486	23,981

The second phase of the project calls for overdrafting Lake Granger during times of high flow, utilizing interruptible surface water from the BRA System Operations Permit. Surface water supplies will be supplemented by water from the Carrizo-Wilcox Aquifer when interruptible water from Lake Granger is not available.

The conjunctive use project would develop a supply of 72,405 acft/yr, including supplies from the Trinity Aquifer. Of this amount, 18,015 acft/yr has been assigned to current and future needs for the City of Taylor, City of Hutto and the Jonah Water Special Utility District, leaving a supply of 54,390 acft/yr (46,390 acft/yr from Phase II conjunctive use plus 8,000 acft/yr from Phase I) for other future needs in Williamson County.

The Brazos G WAM was utilized to simulate operations of Lake Granger supplemented with the groundwater pumping. In the WAM it was assumed that all of the demand (less 8,000 acft/yr from the Trinity Aquifer) was taken from Lake Granger when the reservoir was full and spilling. When the reservoir is less than full demands are reduced as the storage in the reservoir declines. Figure 4B.5-2 shows the storage trace for Lake Granger modeled with these assumptions. The remaining demand is met by pumping from the Carrizo-Wilcox Aquifer. Using these assumptions, in 2060 the average pumping from the Carrizo-Wilcox Aquifer is 30,832 acft/yr with a maximum pumping of 58,459 acft/yr (Figure 4B.5-3).

4B.5.2.3 Environmental

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, and
- 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 4B.5-2.

4B.5.2.4 Engineering and Costing

Facilities for this option are shown in Tables 4B.5-3 and 4B.5-4. For costing purposes in this study 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.

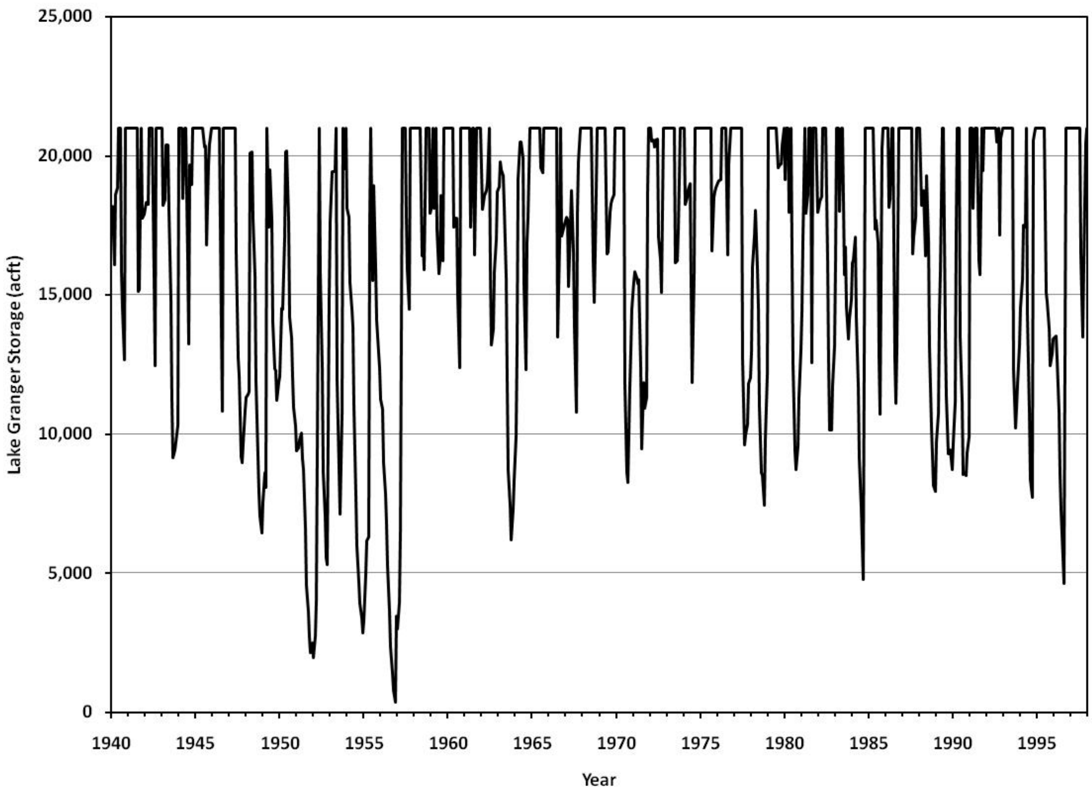

Figure 4B.5-2. Lake Granger Storage – 2060 Conditions

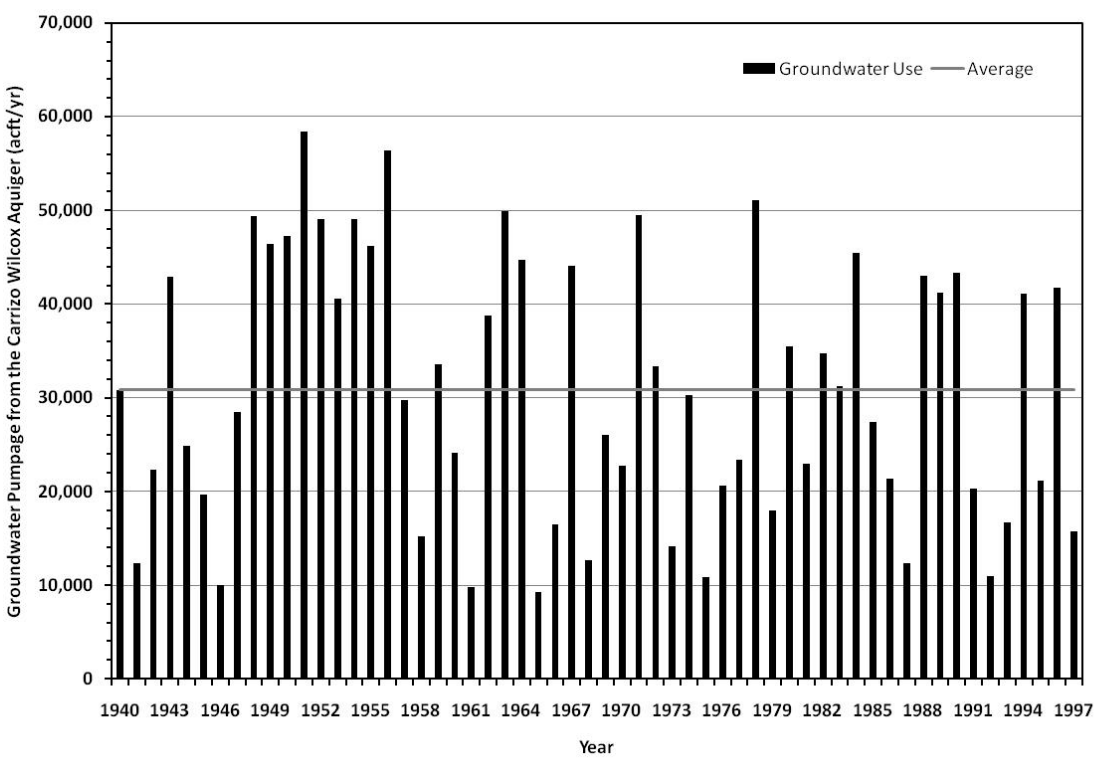

Figure 4B.5-3. Annual Carrizo-Wilcox Pumping – 2060 Conditions

Table 4B.5-2
Environmental Issues: Groundwater/Surface Water Conjunctive Use
(Lake Granger Augmentation)

Water Management Option	***Groundwater/Surface Water Conjunctive Use***
Implementation Measures	Construction of well fields, collection systems, pump stations, pipelines, and expansion of existing water treatment plant
Environmental Water Needs/Instream Flows	Possible impacts on instream flows
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Possible moderate impacts on riparian corridors and upland habitats depending on specific locations of pipelines
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible low impact
Comments	Assume institutional transfer agreements among water rights owners, suppliers, and users

For Phase I, the Trinity Aquifer well field is assumed to require six wells located near the EWCRWTP. Because there is little current use from Trinity Aquifer in this area, two test wells would be needed to verify productivity and water quality. Other facilities include a well field collection system, cooling towers (the water will most likely be hot), and expansions to the EWCRWTP. This option also requires construction of a new larger intake in Lake Granger, a new pump station and a 3.8-mile 48-inch raw water pipeline. The intake structure and raw water pipeline improvements are already underway by BRA, initially to replace an existing shallow-water intake structure that is subject to failure during both low lake conditions and high river flow events.

The total capital cost for Phase I is $77.6 million as shown in Table 4B.5-3. Additional costs for professional services, land acquisition, well mitigation, and interest during construction add $35.5 million for a total project cost of $113 million. Annual debt service on this principal amount, calculated on the basis of 6 percent interest for 20-year debt, is $9.9 million. Operation and maintenance costs for pumping, transmission, and treatment to deliver a total annual supply of 26,505 acft, added to the annual debt service, gives a total annual cost for the full project of $22.2 million. For Phase I, the unit cost of water is $838 per acft/yr or $2.57 per 1,000 gallons.

Table 4B.5-3.
Cost Estimate Summary for Phase I of Lake Granger Augmentation)
(2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Raw Water Intake & Pump Station	$10,710,000
Raw Water Pipeline (48 in. dia., 3.8 miles)	$6,365,000
Trinity Aquifer Well Field (6 wells)	$33,004,000
EWCRWTP Expansions (12.5 MGD)	$25,770,000
Transmission Pump Station(s)	$1,730,000
Total Capital Cost	**$77,579,000**
Engineering, Legal Costs and Contingencies	$27,949,000
Environmental & Archaeology Studies and Mitigation	$979,000
Land Acquisition and Surveying (37 acres)	$153,000
Interest During Construction (1.5 years)	$6,400,000
Total Project Cost	**$113,060,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$9,857,000
Operation and Maintenance	$5,639,000
Pumping Energy Costs ($ 0.09/kW-hr)	$6,723,000
Annual Groundwater Permitting and Acquisition Cost[1]	$0
Total Annual Cost	**$22,219,000**
Available Project Yield (acft/yr)	26,505
Annual Cost of Water ($ per acft)	$838
Annual Cost of Water ($ per 1,000 gallons)	$2.57

[1] No groundwater conservation district exists in Williamson County and no permitting costs are anticipated.

Phase II will provide an additional 46,390 acft/yr of supply. The location of the well field for Phase II has not been identified. For the purposes of this study, it is assumed that the well field will be located in Milam County, although all or part of the required well field may be located in Burleson, Lee or other counties to the east of Williamson County. Carrizo-Wilcox groundwater will be gathered by a well-field collection system and transported by parallel 36-inch and 48-inch pipelines (built in phases) to a blending facility near the EWCRWTP. Customers such as Chisholm Trail Special Utility District, Georgetown or Round Rock would need to build treated water pipelines from the delivery point to their respective retail systems.

The Phase II total capital cost is $275.4 million as shown in Table 4B.5-4. Additional costs for professional services, land acquisition, well mitigation, and interest during construction add $255.5 million for a total project cost of $530.9 million. Annual debt service for the groundwater rights acquisition ($100 million) calculated at 6 percent for 30 years is estimated at $7.26 million. This cost reflects acquisition of real property, not leasing or purchase of groundwater rights. Debt service on the remaining project costs calculated at 6 percent for 20 years is $37.6 million. Annual costs for the new annual supply of 46,265 acft, including regulatory groundwater withdrawal fees and annual debt service gives a total annual cost for the full project of $68.7 million. For Phase II, the unit cost of water is $1,484 per acft/yr or $4.55 per 1,000 gallons.

Costs shown are for the BRA to develop the supply. Costs for customers to utilize this supply would include a system rate cost for purchase of raw water that is not shown here. Individual water management strategies for WUGs and WWPs that would utilize these supplies will include the unit costs shown here, which will be assumed to reflect the total purchase cost of the treated water supply.

4B.5.2.5 Implementation Issues

Early significant activity toward implementation of this alternative has been accomplished by the Brazos River Authority via its ownership of Lake Granger water supply, application for a systems operation permit, ownership of the existing water treatment plant on Lake Granger, and pursuit of nearby groundwater supplies. Developing a suitable approach to the evaluated level of groundwater pumping requires additional cooperative agreements with local groundwater districts and landowners.

Table 4B.5-4
Cost Estimate Summary for Phase II of Lake Granger Augmentation)
(2008 Prices)

Item	*Estimated Costs for Facilities*
Capital Costs	
Carrizo-Wilcox Well Field (30 wells)	$30,839,000
Pipeline from Well Field to EWCRWTP (36 & 48 in. dia. each 44 miles)	$116,907,000
Blending Facility	$18,521,000
EWCRWTP Expansions (83 MGD)	$76,065,000
Transmission Pump Station(s)	$30,882,000
Treated Water Storage	$2,202,000
Total Capital Cost	**$275,416,000**
Engineering, Legal Costs and Contingencies	$106,917,000
Environmental & Archaeology Studies and Mitigation	$3,421,000
Land and/or Groundwater Rights Acquisition[1]	$100,000,000
Land Acquisition and Surveying	$4,123,000
Interest During Construction (3 years)	$40,991,000
Total Project Cost	**$530,868,000**
Annual Costs	
Debt Service for Infrastructure (6 percent, 20 years)	$37,565,000
Debt Service for Groundwater Rights Acquisition (6 percent, 30 years)	$7,265,000
Operation and Maintenance	$16,769,000
Pumping Energy Costs (@ 0.09 $/kW-hr)	$5,531,000
Annual Groundwater Permitting Cost (Assumed $55 per acft)	$1,546,000
Total Annual Cost	**$68,676,000**
Available Project Yield (acft/yr)	46,265
Annual Cost of Water ($ per acft)	$1,484
Annual Cost of Water ($ per 1,000 gallons)	$4.55

[1] Cost estimate provided by the BRA as estimated to acquire real property necessary to secure underlying groundwater rights.

This water supply option has been compared to the plan development criteria, as shown in Table 4B.5-5.

Table 4B.5-5.
Comparison of Lake Granger Augmentation to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low to moderate impact
3. Cultural Resources	3. Low 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

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

- Local groundwater district pumping permits as needed;
- TCEQ water rights permit (pending) for BRA System Operations (Phase II);
- U.S. Army Corps of Engineers Section 404 permits for pipeline stream crossings, discharges of fill into wetlands and waters of the U.S. for construction, and other activities;
- NPDES Stormwater Pollution Prevention Plans; and
- TP&WD Sand, Shell, Gravel, and Marl permit for construction in state-owned stream beds.

4B.5.3 Oak Creek Reservoir and Dockum Aquifer for City of Sweetwater

4B.5.3.1 Description of Option

The City of Sweetwater (Sweetwater) utilizes water supplies from the Oak Creek Reservoir in Coke County and the Champion Well Field. The wells are in the Dockum Aquifer in Nolan County. Prior to the drought beginning in 1998, the primary water supply was Oak Creek Reservoir and supplemental supplies from Lake Sweetwater, Lake Trammel and about eight wells in the Champion Well Field. Because of the 1998-2007 drought, the water supplies from the lakes diminished and finally disappeared. As a result, the City installed about 35 new wells to the Champion Well Field on an emergency basis. During the later part of the drought, groundwater from the Champion Well Field was the sole source of supply.

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 Engineering, Inc. (HDR). This study was partly funded by the City of 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 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 downsteam 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 as the primary water supply and Champion Well Field as the secondary water supply. Furthermore, the concept is to overdraft Oak Creek Reservoir when water is available, and to only use Champion Well Field for supplemental supplies, except when the reservoir's supplies become depleted from overdrafting or during severe droughts.

The locations of Champion Well Field, Oak Creek Reservoir and Sweetwater are shown in Figure 4B.5-4.

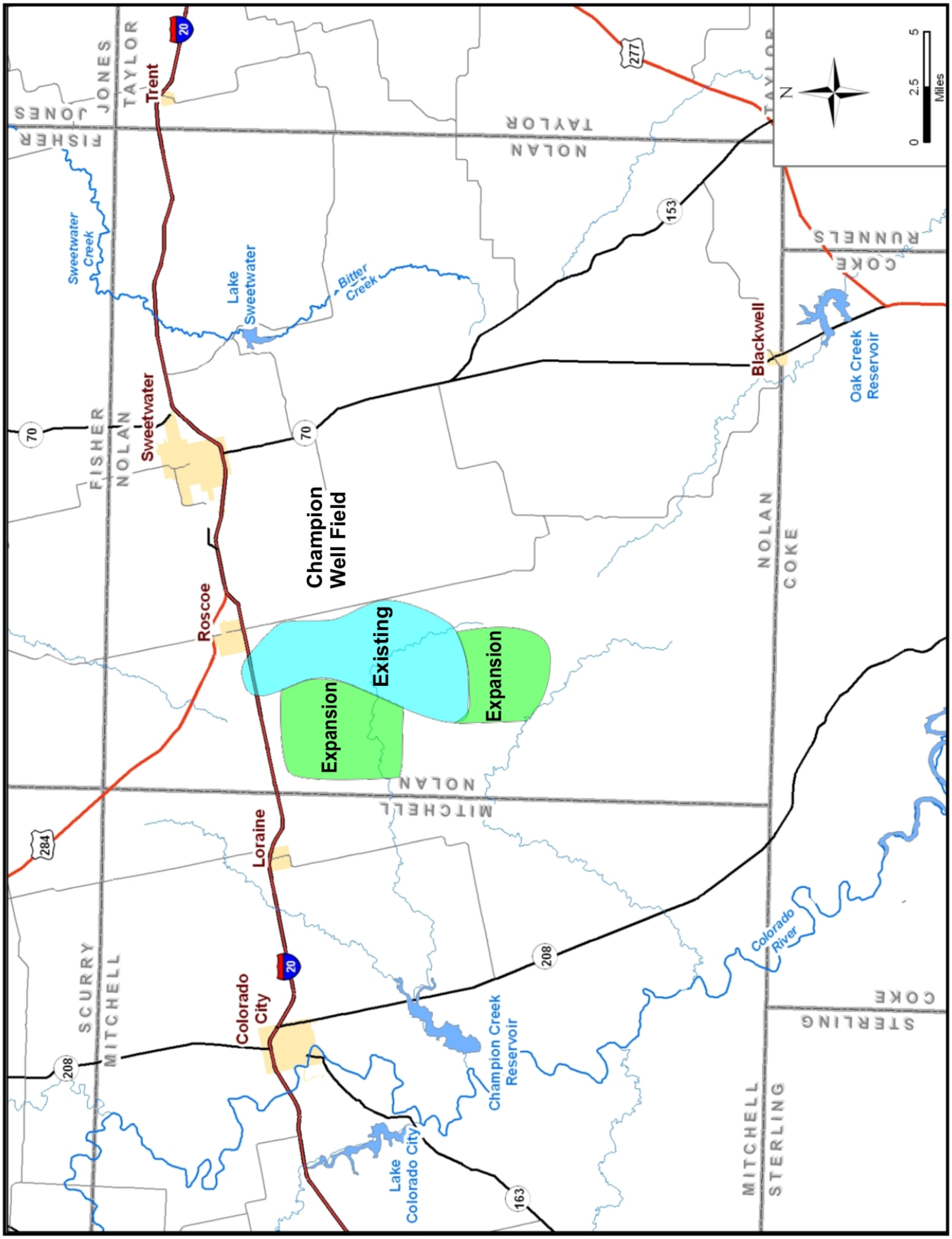

Figure 4B.5-4. Location of Champion Well Field

4B.5.3.2 Available Yield

A study utilizing the groundwater model developed for this study and well performance data from Sweetwater's production wells in the Champion Well Field suggests that: (1) the current well field could provide a long-term supply of about 2,000 acft/yr while allowing overdrafting by 2,500, 2,000 and 1,500 acft/yr for droughts lasting 1, 4, and 7 years respectively and (2) if the well field was expanded considerably to the south and west, the long-term supply would be about 3,000 acft/yr while allowing overdrafting by 3,500, 3,000 and 2,500 acft/yr for droughts lasting 1, 4 and 7 years respectively. An analysis of Sweetwater's demands and water supply contracts shows the peak demand during the planning period is 5,435 acft/yr in 2030 (Table C-52). A comparison of this demand with supplies from Champion Well Field shows that the existing well field is not capable of meeting this demand; however, the expanded well field could meet this demand for a 7-year drought. This 7-year drought is essentially equivalent to the duration of no yield from Oak Creek Reservoir recently experienced from 2001-2007.

At least three Water Availability Model (WAM) simulations have been made for the Oak Creek basin by consultants for Region F. They are called the Basin WAM, Run 3, and Mini-WAM. The first two simulations have a daily time step and end in 1998, thus they miss the apparent drought of record from 1998-2007. The Mini-WAM has monthly time intervals and ends in 2004. A comparison of the results of the Mini-WAM for Oak Creek Reservoir with historical results showed a reasonable match. For these reasons, the results from the Mini-WAM were used in this conjunctive use analysis.

A study was conducted to: (1) estimate the optimal maximum annual diversion rate from Oak Creek Reservoir and minimal annual pumping from Champion Well Field with a sensitivity analysis of a range of maximum annual diversion rates and (2) estimate the number of years when there is an insignificant amount of water in Oak Creek Reservoir for Sweetwater. The optimal diversion is a balance between maximizing the diversions from Oak Creek Reservoir, minimizing the amount of pumpage from Champion Well Field, and limiting the number of consecutive years when the Champion Well Field would need to be overdrafted. Figure 4B.5-6 shows the relationship between the maximum annual diversions from Oak Creek Reservoir and average annual diversions and pumpage. For this optimization, this figure shows maximum annual diversion from Oak Creek Reservoir would be about 3,300 acft/yr. Figure 4B.5-7 shows the relationship between the maximum annual diversions from Oak Creek Reservoir and the

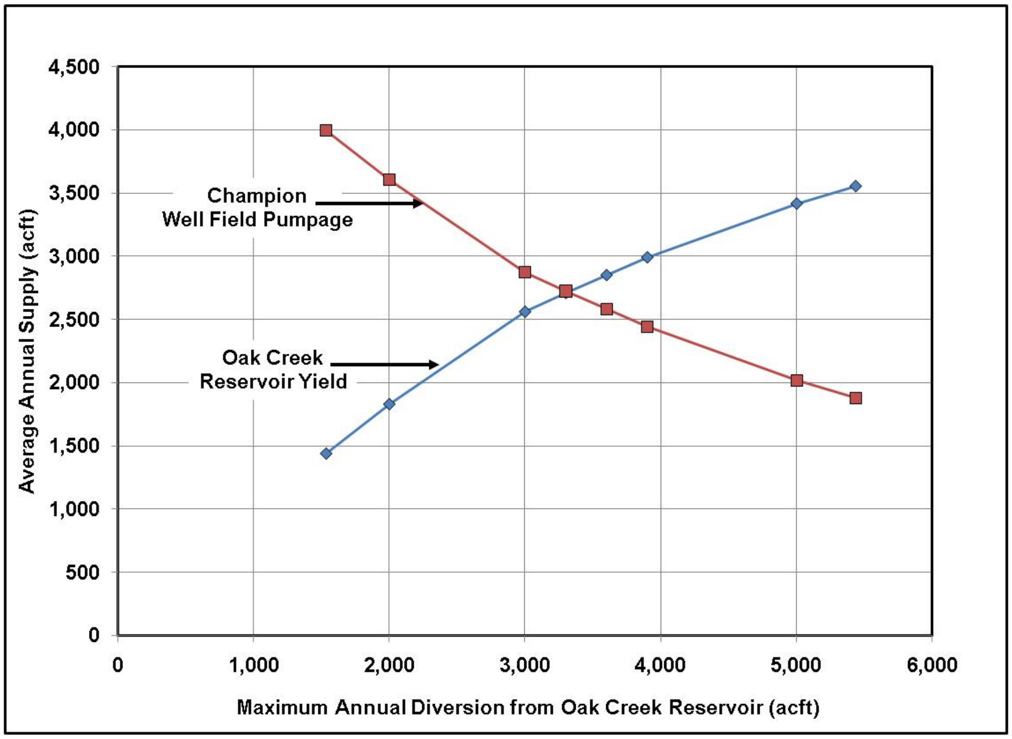

Figure 4B.5-6. Average Annual Oak Creek Reservoir Yield and Champion Well Field Pumpage with 1940-2007 Hydrologic Conditions

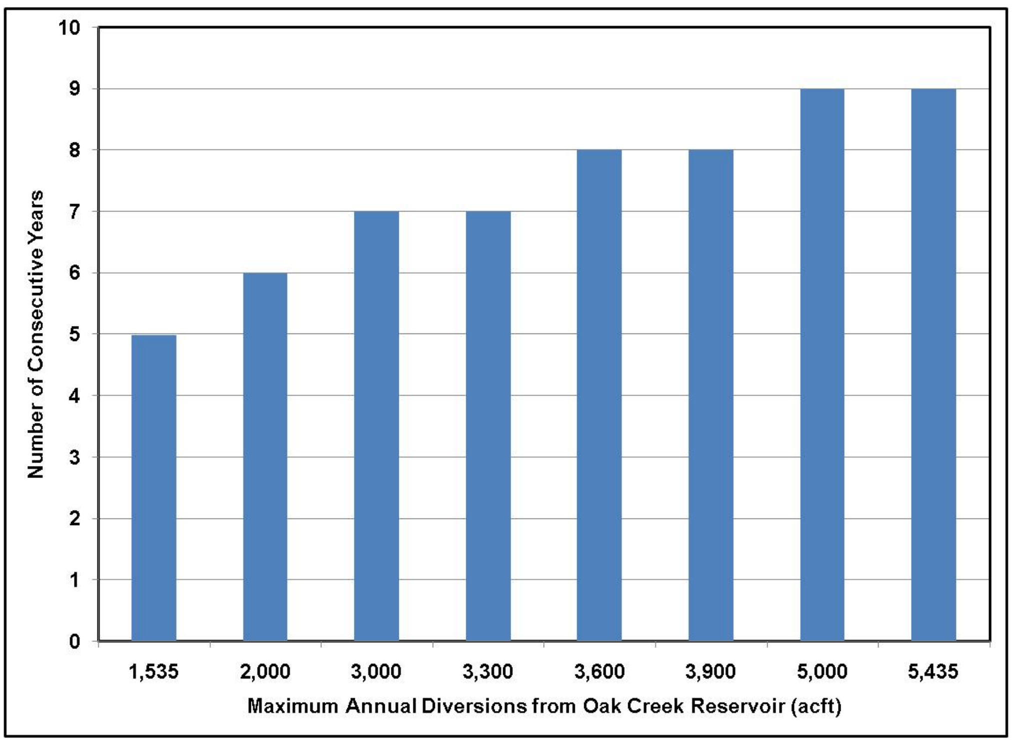

Figure 4B.5-7. Maximum Number of Consecutive Years with Little or No Supply from Oak Creek Reservoir with 1940-2007 Hydrologic Conditions

maximum number of consecutive years with little or no water supply from Oak Creek Reservoir. This figure shows a 7-year period of little or no water supply from Oak Creek when the maximum annual diversion rate is 3,000 and 3,300 acft/yr. This shortage can be accommodated by an expanded Champion Well Field. Figure 4B.5-8 shows the temporal distribution of annual diversions and annual pumpage for projected 2030 water demands. This figure shows that, by far, the worst drought condition for this conjunctive water management strategy since 1940 would have been for 2001-2007 conditions.

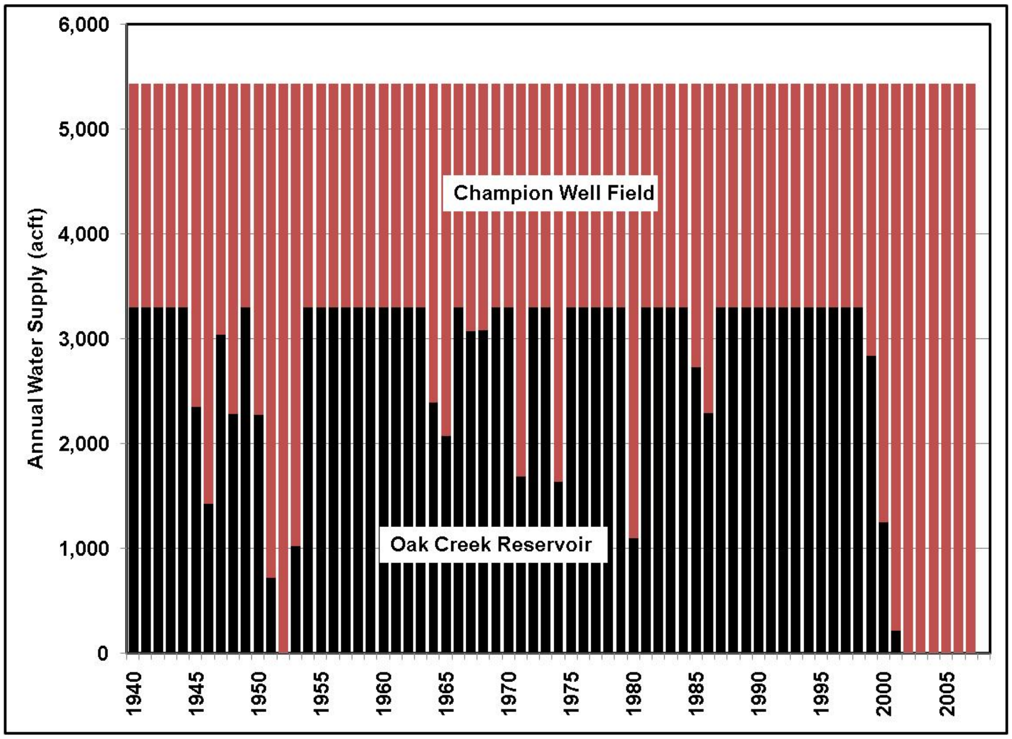

Figure 4B.5-8. Distribution of Water Sources for Sweetwater for 2030 Demands with 1940-2007 Hydrologic Conditions

4B.5.3.3 Environmental

Environmental impacts could include:

- Possible low impacts on instream flows due to slight decrease in groundwater discharges from the Dockum Aquifer; and
- A summary of environmental issues id presented in Table 4B.5-6.

Table 4B.5-6.
Summary of Environmental Impacts

Water Management Option	Groundwater/Surface Water Conjunctive Use
Implementation Measures	Construction of well field (26 wells) and collection pipeline (28-mile corridor)
Environmental Water Needs/Instream Flows	Possible very minor impacts on instream flows
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Possible very minor 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	Assumes subordination of water rights and purchase of groundwater leases

4B.5.3.4 Engineering and Costing

Based on the above analysis suggesting a withdrawal of 3,300 acft/yr from Oak Creek Reservoir when water is available, Champion Well Field would need to provide up to 5,345 acft/yr of water for 2030 demands and severe drought conditions. Assuming worst case conditions where these demands occur at the end of a 7-year drought, the existing wells in Champion Well Field would be capable of producing about 3,500 acft/yr (2,000 acft/yr while allowing an overdraft of 1,500 acft/yr during a 7-year drought) and a well field expansion would need to produce about 2,000 acft/yr for up to 7-years. With the existing and expanded well fields combined, the Champion Well Field capacity would be about 3,000 acft/yr while allowing for overdrafting of 3,500, 3,000 and 2,500 acft/yr for 1, 4, and 7 years, respectively. Thus, the capacity of the expansion to the Champion Well Field would be 1,000 acft/yr while allowing an overdraft of 1,000 acft/yr for up to 7 years. This analysis suggests that the well field expansion would result in a drought supply for this conjunctive management scenario of 2,000 acft/yr or 1.8 MGD. Allowing for peak seasonal demands, the expansion would need to have a capacity of about 3.6 MGD.

The average capacity of the new wells is estimated to be equivalent to the average capacity of the existing Champion Well Field wells, which is about 105 gallons per minute (gpm). Based on the expanded capacity requirements, the average well yield, and a contingency of about 10 percent, 26 new wells are needed. Water from the wells would be gathered by a 28-mile long well-field collection system and delivered to an existing ground storage tank and booster pump station within the existing Champion Well Field for transmission to Sweetwater for treatment and delivery to the distribution system.

For regional planning purposes, the new facilities include new wells and the collection pipelines. It's assumed that existing pump stations and pipelines for the delivery of this quantity of water and water treatment capacity are adequate for both Oak Creek Reservoir and Champion Well Field.

The total capital cost including wells, well-field collection system, and water system improvements is $9,993,000 as shown in Table 4B.5-7. The project costs, including capital and expenses for professional services, land acquisition, well mitigation, and interest during construction will be $15,015,000. Annual debt service on this principal amount, calculated on the basis of 6 percent interest for a 20-year loan is $1,309,000. Annual operation and maintenance costs for operating the well field, including groundwater leases at $50/acft, are $327,000. With a drought yield of 1,935 acft/yr, the unit cost of water is $849 per acft/yr or $2.61 per 1,000 gallons. If one considered the long-term average use of the well field expansion instead of drought conditions, the unit cost would be somewhat greater.

4B.5.3.5 Implementation Issues

Development of this water management strategy requires the subordination of the senior water rights that are downsteam of Oak Creek Reservoir and securing groundwater leases or property for wells. It would also require an engineering evaluation of the water transmission and water treatment facilities to accommodate the projected Brazos G demands for Sweetwater.

Requirements for permits to use groundwater, as well as for pipeline construction, will require permits as follow:

- Well construction and production permits from the Wes-Tex Groundwater Conservation District; and
- TCEQ approval for wells, water quality, and facilities.

Table 4B.5-7.
Cost Summary for Expansion of Champion Well Field
(September 2008 Prices)

Item	*Estimated Costs for Facilities*
Capital Costs	
Well Fields (26 wells) and Collection Pipelines (28 miles of 4-12 in-diameter)	$9,302,000
Water Treatment Plant	$0
Distribution	$691,000
Total Capital Cost	**$9,993,000**
Engineering, Legal Costs and Contingencies	$3,498,000
Environmental & Archaeology Studies and Mitigation	$726,000
Land Acquisition and Surveying (33 acres)	$220,000
Interest During Construction (1 years)	$578,000
Total Project Cost	**$15,015,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$1,309,000
Operation and Maintenance	
Wells and Collector Pipeline	$100,000
Water Treatment Plant	$0
Pumping Energy Costs (1,520,360 kW-hr @ 0.09 $/kW-hr)	$137,000
Purchase of Water (1,935 acft/yr @ 50 $/acft)	$97,000
Total Annual Cost	**$1,643,000**
Available Project Yield (acft/yr)	1,935
Annual Cost of Water ($ per acft)	$849
Annual Cost of Water ($ per 1,000 gallons)	$2.61

4B.6 Desalination

4B.6.1 Description of Options

Water demands in Johnson County are increasing at a very significant rate, while the existing supply from the Surface Water and Treatment System (SWATS) water treatment plant at Lake Granbury is near operational capacity, and withdrawals from the Trinity Aquifer are substantially exceeding its estimated long-term capacity. Two desalination options are being considered for Johnson County to meet part or all of these demands. These options are treating and delivering: (1) additional brackish surface water from Lake Granbury and (2) fresh to brackish groundwater from the Woodbine and Paluxy Aquifers in the northeastern part of the county. The surface water desalination project expands the potable water supply from Lake Granbury to most all major water utilities in the county. The groundwater desalination project is an option to treat and blend groundwater from the Paluxy and Woodbine Aquifers and is considered for the northeastern part of the county.

4B.6.2 Desalination of Lake Granbury Water for Johnson County Regional Plan

4B.6.2.1 Description of Option

In the mid-1980s, the population growth of Johnson County was projected to result in water demands that would exceed available supplies. One largely unused supply was Lake Granbury, which impounds slightly saline (brackish) water. A study of alternatives determined if it would be feasible to install a desalination plant on the lake, using either electrodialysis reversal (EDR) or reverse osmosis (RO) technology. The initial design and construction of the SWATS plant followed for a 3.5 MGD first phase of an ultimate 26 MGD system of a coupled conventional and desalination water treatment plant located on the shore of Lake Granbury. This capacity was increased to 15 MGD. Within the last few years, water demands have increased to the point that an expansion of this plant is being considered in the near future.

Currently, the BRA operates the SWATS plant near Lake Granbury to serve four wholesale customers. Johnson County Special Utility District, and City of Keene are in Johnson County, while Acton Municipal Utility District and the City of Granbury are in Hood County.

Most municipal water user groups in Johnson County are projected to be water short by 2060. The three greatest shortages are: Johnson County Special Utility District (16,664 acft/yr), Bethesda WSC (3,660 acft/yr), and City of Cleburne (1,954 acft/yr). The City of Burleson is not included because its water supply is expected to come from the Tarrant Regional Water District (TRWD). The combined municipal shortage for Johnson County in 2060, excluding Burleson, is about 23,600 acft/yr. Using a peaking factor of 2.0, the additional system capacity needed is 42 MGD.

Recognizing the substantial future water shortage in Johnson and Parker Counties, the Brazos River Authority (BRA) and the TRWD conducted a cooperative study[1] to explore the feasibility of developing regional facilities to help meet the growing water supply needs. For purposes of this plan, their option to expand SWATS (Scenario #1) is adjusted for this Brazos G option. Scenario #1 considered an expansion (new facilities that largely parallel the existing facilities) of an average of 15 MGD in 2020 and an additional expansion of 30 MGD in 2060, for a total of 45 MGD. In other units, Scenario # 1 provides an average water supply at build-out of 50,400 acft/yr and a peaking capacity of 90 MGD. For purposes of this analysis, the surface water desalination project is intended to meet Johnson County's long-term shortage of about 23,600 acft/yr.

Figure 4B.6-1 shows the locations of the existing SWAT facilities and pipelines planned for this option.

4B.6.2.2 Available Yield

In addition to current BRA supply at Lake Granbury, the expanded SWATS regional system could utilize additional raw water supplies from one or more of several possible sources: purchase of water from an entity that has unused supply (such as Luminant); enhancement of yield from an existing source, such as reallocation of storage at Lake Whitney; BRA System Operations; or negotiating a water trade among BRA customers to make additional water available in Lake Granbury.

[1] Freese and Nichols, Inc., "Regional Water Supply and Wastewater Service Study for Johnson and Parker Counties, Phase I," prepared for Brazos River Authority and Tarrant Regional Water District, April 2004.

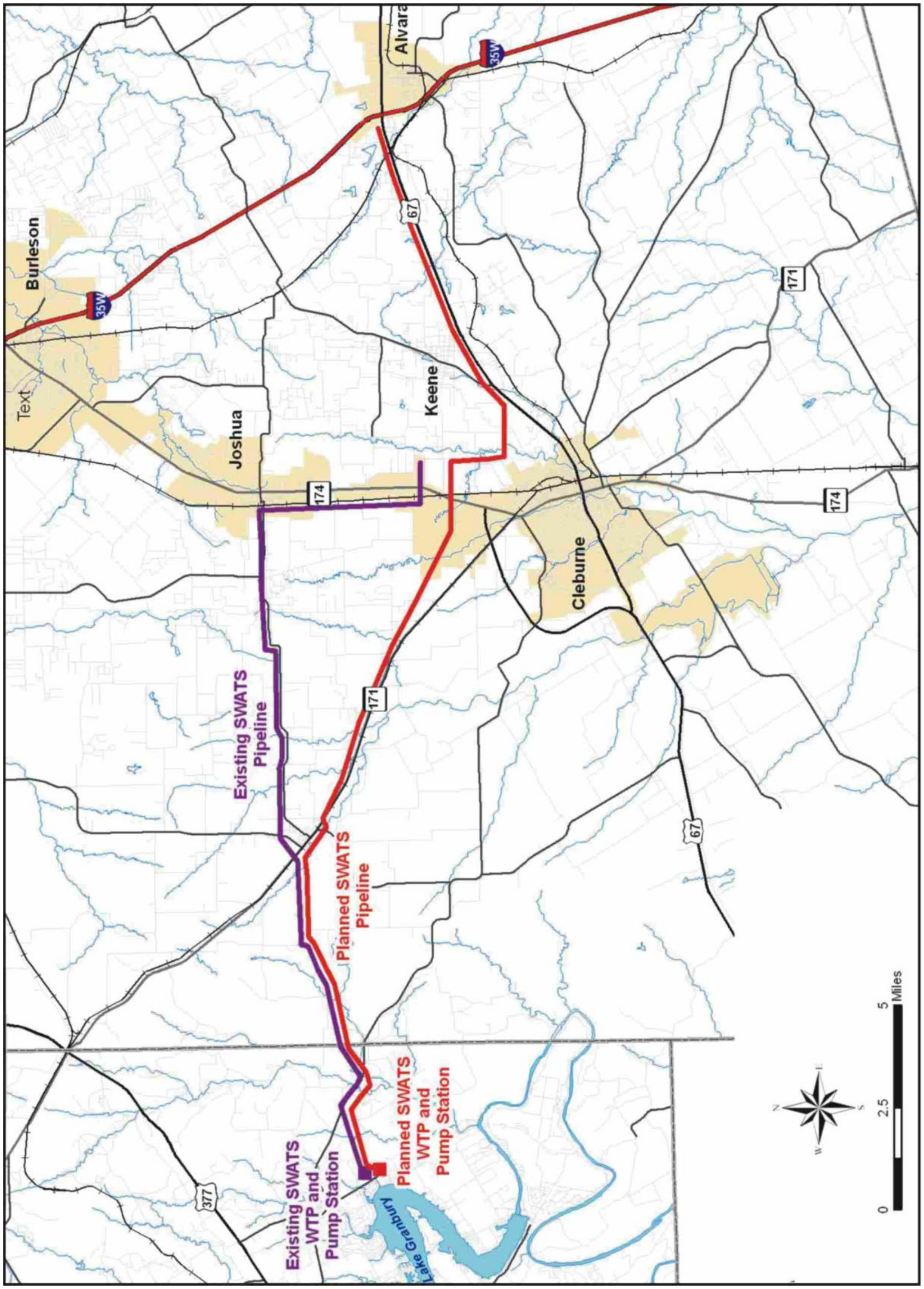

Figure 4B.6-1. Existing and Planned Facilities for SWATS Expansion in Johnson County

4B.6.2.3 Environmental Issues

The construction of a water supply project to supply water from Lake Granbury to Johnson County would involve relatively low environmental impacts:

- Reduced flows in the Brazos River below Lake Granbury could have a low impact on environmental water needs and instream flows.
- Pipeline construction effects on fish and wildlife habitat at creek and river crossings and on cultural resources would be low if inside existing highway right-of-way, possibly moderate if outside right-of-way.
- Brine disposal through blending of brine concentrate effluent would have possibly low impacts on Lake Granbury and other receiving streams.

4B.6.2.4 Engineering and Costing

The facilities needed to provide water for the long-term projected shortages in Johnson County by the Lake Granbury desalination project are:

- New raw water intake structure at Lake Granbury;
- Expanded SWATS water treatment plant (EDR or RO process preceded by a conventional water treatment plant);
- Treated water pump stations; and
- Water transmission pipelines to receiving entities.

The raw water intake, water treatment facilities, pump station, and transmission pipelines are all designed to be peaking facilities with a 50 MGD capacity and an average of delivery rate of 28,000 acft per year.

For purposes of this plan, the cooperative study's Scenario #1, which is an expansion of SWATS and delivery facilities, is adjusted for this Brazos G Lake Granbury desalination option. In developing the cost estimates for this option, the cost estimates for the Scenario #1 in the cooperative study were used as a basis and adjusted by reducing the capacity from 90 MGD to 50 MGD and updating costs to September 2008, as per regional water planning guidelines. Table 4B.6-1 summarizes the cost estimates for this water supply option. As shown in the table, the total project cost for the Lake Granbury Supply to Johnson County project is estimated to be $101,119,000, resulting in a unit cost of $932 per acft or $2.86 per 1,000 gallons. These costs include the purchase of raw water at the current BRA system price. Of importance, these costs are based on full utilization of the facility which does not occur until 2060. In the interim, with year 2030 as an example, the Johnson County shortage is estimated to be about 5,850 acft/yr. At this level of utilization, after debt service has been paid, the unit cost of water from these customers would be about $2,991 acft/yr or $9.18 per 1,000 gallons.

Table 4B.6-1.
Cost Estimate Summary
Lake Granbury Supply to Johnson County
September 2008 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (50 MGD)	$671,000
Transmission Pipeline (60 in dia., 0 miles)	$23,593,000
Transmission Pump Station(s)	$5,166,000
Water Treatment Plant (50 MGD)	$40,296,000
Total Capital Cost	**$69,726,000**
Engineering, Legal Costs and Contingencies	$23,224,000
Environmental & Archaeology Studies and Mitigation	$1,083,000
Land Acquisition and Surveying	$1,509,000
Interest During Construction	$5,577,000
Total Project Cost	**$101,119,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$8,590,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$382,000
Water Treatment Plant	$12,340,000
Pumping Energy Costs (36,133,333 kW-hr @ 0.09 $/kW-hr)	$3,252,000
Purchase of Water (28,000 acft/yr @ 54.5 $/acft)	$1,526,000
Total Annual Cost	**$26,090,000**
Available Project Yield (acft/yr)	28,000
Annual Cost of Water ($ per acft)	$932
Annual Cost of Water ($ per 1,000 gallons)	$2.86

4B.6.2.5 Implementation

The Lake Granbury water supply option has been compared to the plan development criteria, as shown in Table 4B.6-2, and the option meets each criterion.

Implementation will require these steps, in addition to development of the necessary supply from the BRA.

1. It will be necessary to obtain these permits:
    a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings
    b. General Land Office Sand and Gravel Removal Permits
    c. Texas Parks and Wildlife Department Sand, Gravel and Marl permit for river crossings
2. Right-of-Way and easement acquisition.
3. Crossings
    a. Highways and Railroads
    b. Creeks and Rivers
    c. Other Utilities
4. Financing
    a. Sponsoring entity must be identified and be able to incur debt to finance project.
    b. Participating entities must negotiate water purchase contract with BRA and establish rate structure.

The regulatory permits that are expected to be requirements specific to pipelines 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 pond construction; and other activities;
- National Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit for construction in state-owned streambed.

Table 4B.6-2.
Comparison of Lake Granbury Supply to Johnson County Option to Plan Development Criteria

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

4B.6.3 Brackish Groundwater Desalination for Northeast Johnson County

4B.6.3.1 Description of Option

This water supply option is targeted for the extreme northeastern part of Johnson County, as shown in Figure 4B.6-2. This option evaluates the use of groundwater from the Woodbine and Paluxy Aquifers[2,3,4,5] that ranges in salinity from fresh to brackish. Figure 4B.6-3 is a schematic of a hydrogeologic cross-section. In the target area, the Woodbine Aquifer is relatively shallow and confined. Wells are about 200 to 400 feet deep and produce about 75 gallons per minute (gpm). TWDB water quality data show very high concentrations of iron and manganese, which requires removal. Data on salinity indicate most wells have concentrations of total dissolved solids (TDS) concentration of 500 to 1,000 milligrams per Liter (mg/L). However, some wells have concentrations ranging up to 2,000 mg/L. Data from wells with multiple samples indicate that water quality can vary considerably over time. The underlying Paluxy Aquifer, which is the upper water-bearing zone of the Trinity Aquifer, is confined and well depths are expected to range from 800 to 900 feet. The capacity of high capacity wells is expected to be about 100 gpm. TWDB water quality data indicate that the water has moderate iron and manganese concentrations. The concentrations of TDS typically range from 500 to 1,000 mg/L; however, some samples indicate concentrations up to 1,200 mg/L.

4B.6.3.2 Available Yield

For Johnson County as a whole, the current withdrawals substantially exceed the estimated groundwater availability from the Trinity Aquifer. However, most of this pumpage is from the deep, most productive water-bearing units (Hensell and Hosston) and in the central and eastern parts of the county. Of considerable importance, the Paluxy Aquifer in this area is seldom used because higher yielding wells can be obtained in the deeper Hensell and Hosston and shallower supplies are available in the overlying Woodbine. For the Woodbine Aquifer, current

[2] Thompson, G.L., 1969, Ground-water resources in Johnson County, Texas: Texas Water Development Board Report 94.
[3] Klemt, W.B. and others, Ground-water resources of Part of Central Texas with Emphasis on the Antlers and Travis Peak Formations: Texas Water Development Board Report 195, v. I and II.
[4] Nordstrom, P.L., Occurrence, Availability, and Chemical Quality of Ground Water in the Cretaceous Aquifers of North-Central Texas: Texas Water Development Board Report 269, v. I and II.
[5] R.W. Harden & Associates, Inc., 2004, Northern Trinity/Woodbine Aquifer Groundwater Availability Model: Texas Water Development Board Contract Report

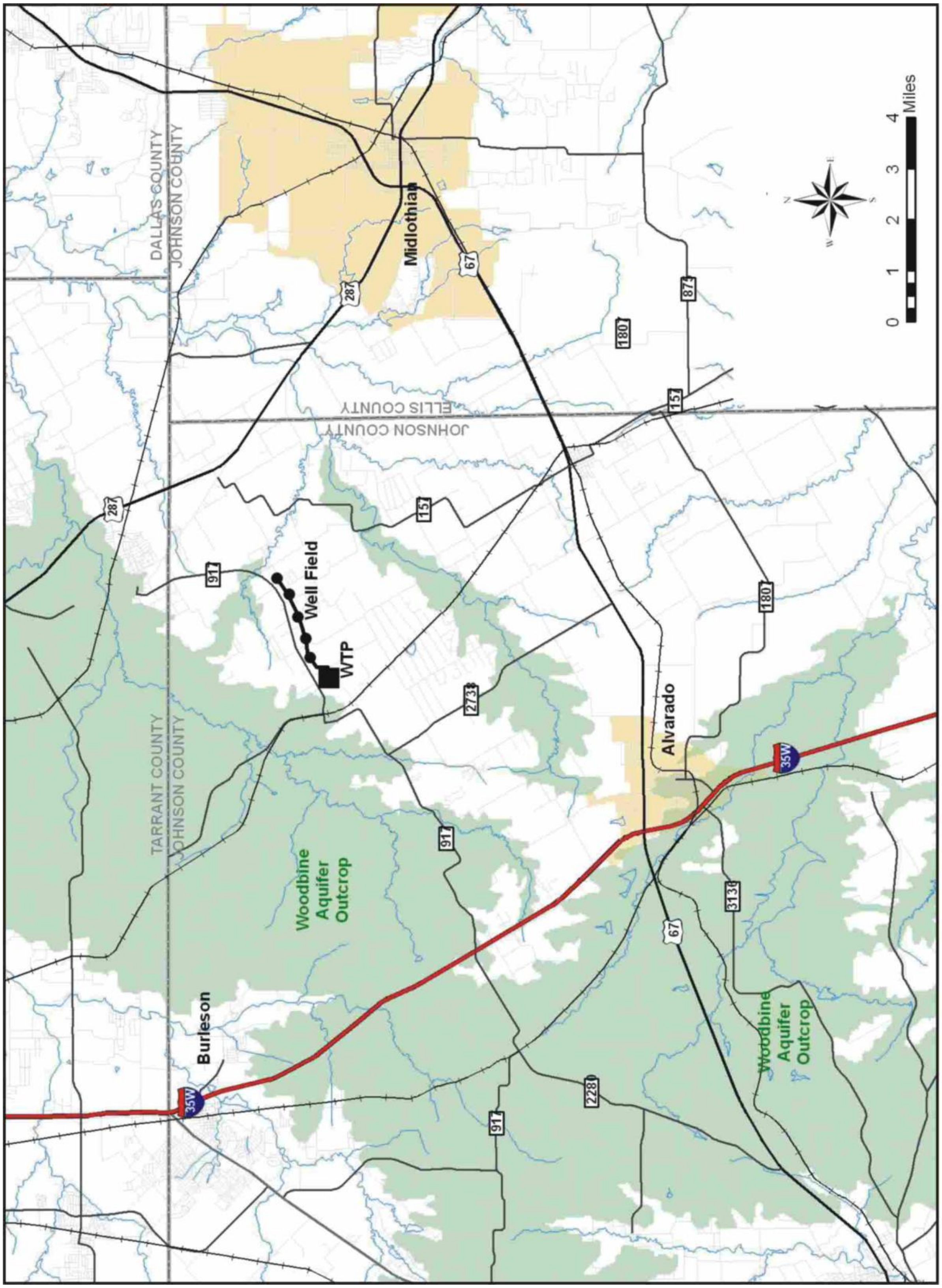

Figure 4B.6-2. Brackish Groundwater Desalination Option for Northeast Johnson County

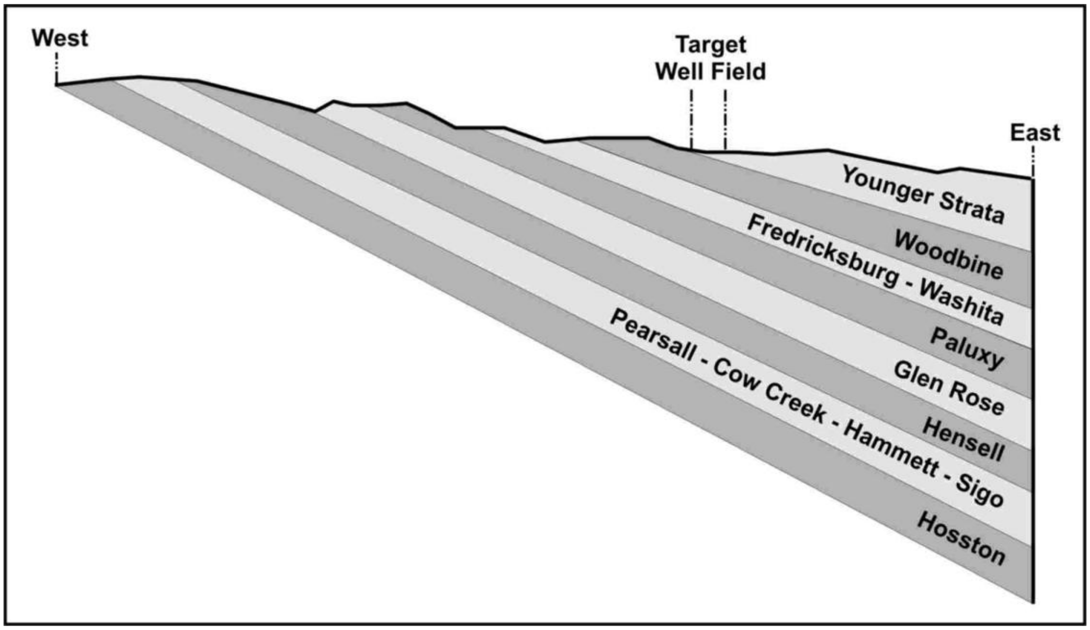

Figure 4B.6-3. Hydrogeologic Cross-Section

groundwater withdrawals are made by both local users and by distant water utilities. The planned well field is relatively close to the outcrop of the Woodbine area. Pumpage of an average 0.4 MGD from the Woodbine wells and 0.6 MGD from the Paluxy wells are not expected to significantly impact the other wells.

4B.6.3.3 Environmental Issues

The development of wells in the Paluxy and Woodbine Aquifers and the construction of wells, collector pipelines, and water treatment facilities would involve relatively low environmental impacts:

- Drawdown from wells is expected to have little or no effect on discharge to Walnut Creek or Mountain Creek.
- Construction of pipelines, wells and water treatment facilities would have little or no effect on wildlife habitat and would be in existing rights-of-way or in disturbed areas. No streams or wetlands are expected to be encountered.
- No brine concentration is expected to be produced.

4B.6.3.4 Engineering and Costing

For preliminary design, a Woodbine well and a Paluxy well would be constructed in a well yard and have a combined yield of 175 gpm. To provide a peak capacity of 1.0 MGD, five Woodbine and five Paluxy wells are needed. The planned site of the well field and water treatment plant is along Farm Road 917 and between the town of Lillian and the Johnson-Ellis County line. Five well yards are required and would be spaced about a half mile apart. Well depths are estimated to be about 300 and 800 feet for the Woodbine and Paluxy, respectively. The water treatment facility will be designed to remove the high iron and manganese concentrations and to blend water from the 10 wells producing brackish water and with other water in the distribution system. Thus, no desalination treatment or disposal of brine concentrate is expected to be required. The water treatment plant is planned to be located next to existing water mains and only limited water transmission and interconnect facilities are required.

The major facilities required are:

- Water Collection and Conveyance System:
  - Wells,
  - Pipelines from well fields to treatment plant,
  - Pump Station, and
  - Storage.
- Water Treatment:
  - Removal of iron and manganese concentrations, and
  - Blending of water from wells and from existing water distribution system.

Cost estimates are based on a peak capacity of 1.0 MGD with an average delivery of 560 acft/yr. These estimates include capital costs, annual debt service, operation and maintenance, power, land, and environmental mitigation for peak day delivery and are summarized in Table 4B.6-3. Water treatment costs are for removal of iron and manganese, filtration, blending, and disinfection. As shown, the project cost is estimated to be $5,683,000; and the annual costs, including debt service, operation and maintenance, and power, are estimated to be $731,000. This option produces potable water at an estimated cost of $1,305 per acft ($4.01 per 1,000 gallons).

4B.6.3.5 Implementation

The brackish groundwater supply option for northeast Johnson County has been compared to the plan development criteria, as shown in Table 4B.6-4, and the option meets each criterion.

Implementation will require these steps:

1. Acquisition of groundwater rights;
2. Right-of-way and easement for wells, pipelines, and water treatment plant; and
3. Financing and operations by a sponsoring entity, who must be identified.

Table 4B.6-3.
Cost Estimate Summary
Water Supply Project Option (Sept 2008 Prices)
Northeast Johnson County: Paluxy and Woodbine Wells, Blend with Other Water

Item	***Estimated Costs for Facilities***
Capital Costs	
Treated Water Transmission and Interconnect (12 in, 500 ft)	$597,000
Water Wells (5 Paluxy and 5 Woodbine)	$2,188,000
Well Field Collector Pipeline (8-12 in, 2 mi)	$303,000
Water Treatment Plants (Pretreatment Only)	$807,000
Total Capital Cost	**$3,895,000**
Engineering, Legal Costs and Contingencies	$1,362,000
Environmental & Archaeology Studies and Mitigation	$94,000
Land Acquisition and Surveying (32 acres)	$113,000
Interest During Construction (1 years)	$219,000
Total Project Cost	**$5,683,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$495,000
Operation and Maintenance	
Wells, Pipeline, Pump Station	$36,000
Water Treatment Plant	$161,000
Pumping Energy Costs (438810 kW-hr @ 0.09 $/kW-hr)	$39,000
Purchase of Water and Groundwater District Fees	$0
Total Annual Cost	**$731,000**
Available Project Yield (acft/yr)	560
Annual Cost of Water ($ per acft)	$1,305
Annual Cost of Water ($ per 1,000 gallons)	$4.01

Table 4B.6-4.
Comparison of Brackish Groundwater Option in Northeast Johnson County to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient only for local needs
2. Reliability	2. High
3. Cost	3. Moderately expensive
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. None
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

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4B.7 Augmentation of Millers Creek Reservoir

Augmentation of Millers Creek Reservoir was studied for the 2006 Brazos G Regional Water Plan. The 2006 Plan evaluated diverting water from nearby Lake Creek to Millers Creek Reservoir via a canal and, as an alternative, via a pipeline. The current evaluation updates the yields and costs for the previously considered options and also considers two additional options: construction of a new dam and reservoir on Millers Creek downstream of the existing reservoir and construction of the new reservoir along with the canal diversion from Lake Creek.

4B.7.1 Description of Canal 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, this strategy includes diverting water 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 4B.7-1.

Design parameters for the diversion canal were identified through the work conducted for the 2006 Plan. The maximum monthly depletion from Lake Creek, assuming the Lake Creek diversion is the most senior in the basin, was computed for the 2006 Plan 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 4B.7-2. 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.

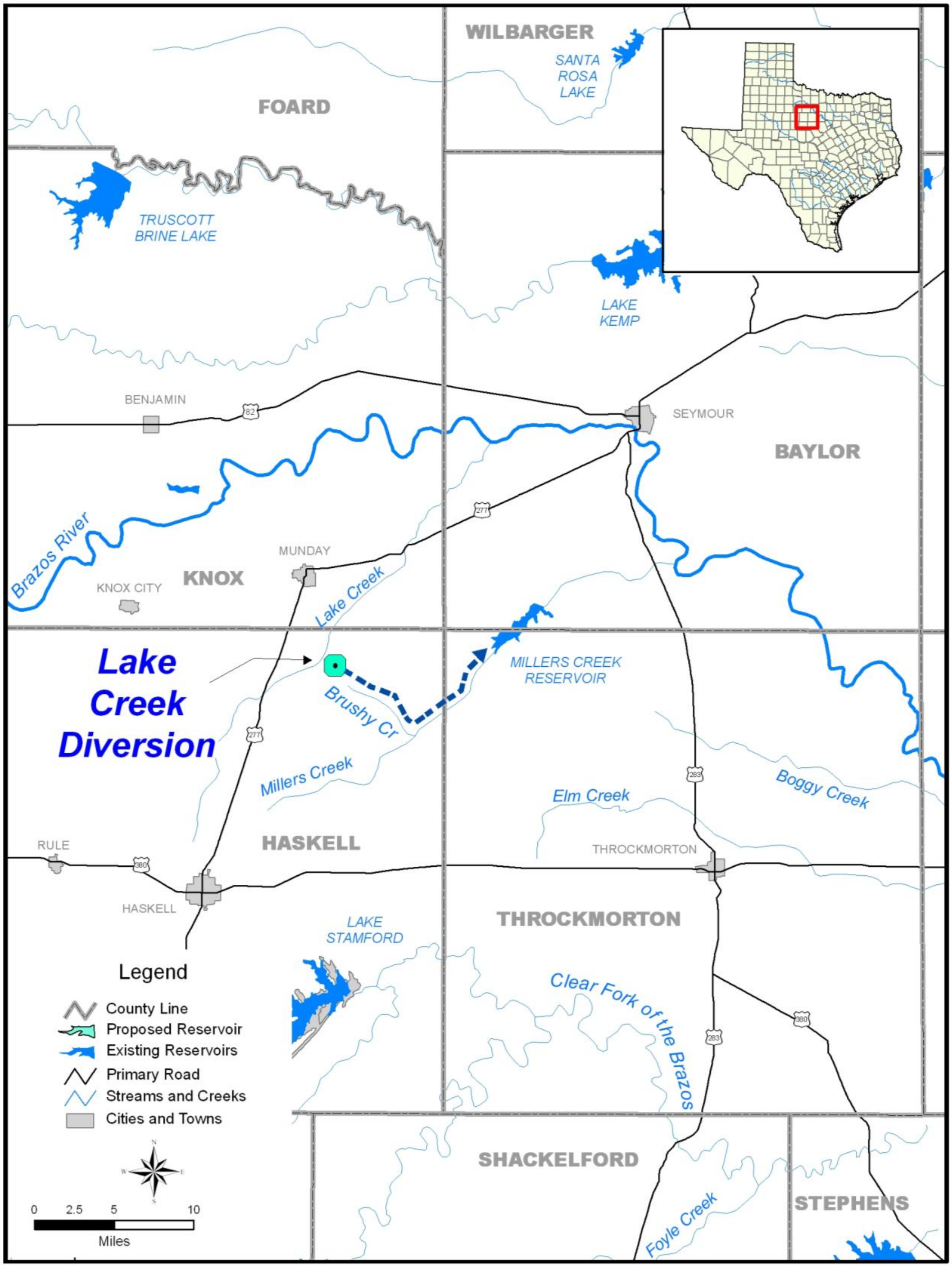


Figure 4B.7-1. Lake Creek Diversion to Millers Creek Reservoir

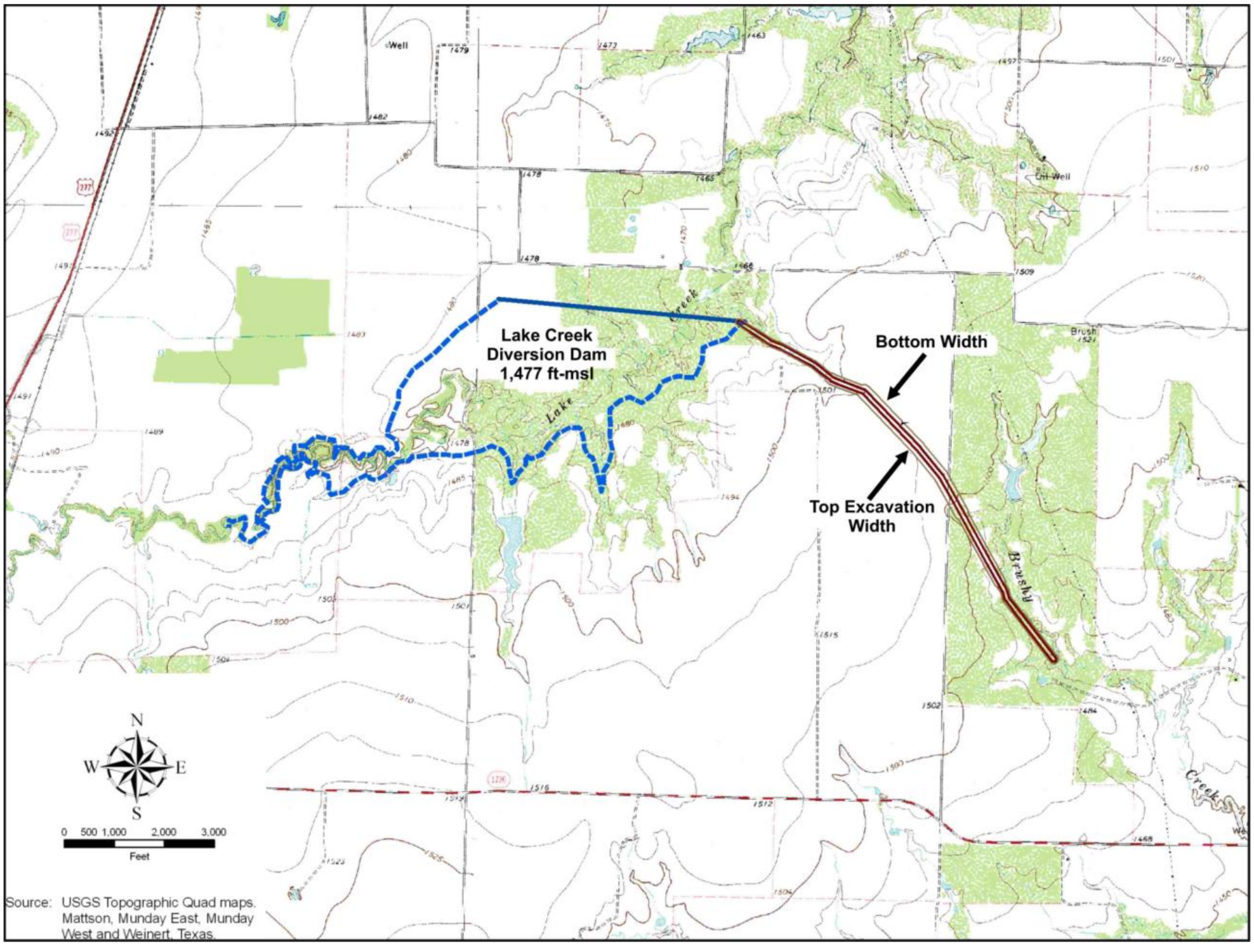


Figure 4B.7-2. Lake Creek Diversion Dam and Canal to Brushy Creek

4B.7.1.1 Available Yield

Water potentially available for impoundment into the Millers Creek Reservoir was estimated using the 2060 Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available for diversion from Lake Creek into the Millers Creek Reservoir without causing increased shortages to existing downstream rights. Safe yield was computed subject to Consensus Criteria for Environmental Flow Needs (CCEFN) instream flow requirements (Appendix H) at the Lake Creek Diversion. The streamflow statistics used to identify the Consensus Criteria pass through requirements for the Lake Creek Diversion were computed for the 2006 Brazos G Regional Plan and are shown in Table 4B.7-1.

Table 4B.7-1.
Daily Natural Streamflow Statistics
for the Lake Creek Diversion

Month	***Median Flows - Zone 1 Pass Through Requirements (cfs)***	***25th Percentile Flows - Zone 2 Pass Through Requirements (cfs)***
January	0.0	0.0
February	0.5	0.0
March	0.3	0.0
April	0.0	0.0
May	0.3	0.0
June	1.3	0.0
July	0.1	0.0
August	0.0	0.0
September	0.0	0.0
October	0.0	0.0
November	0.0	0.0
December	0.0	0.0
Zone 3 (7Q2) Pass-Through Requirement (cfs):		0

The calculated safe yield of the Millers Creek Reservoir with the Lake Creek diversion is 6,742 acft/yr, assuming subordination of Possum Kingdom Reservoir to the Millers Creek Reservoir and the Lake Creek diversion. The Lake Creek diversion increases the yield of the Millers Creek Reservoir over that of the existing reservoir alone by 6,257 acft/yr. Based on a delivery factor of 0.572 (from the Brazos G 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 3,579 acft/yr for costing purposes. Additional analysis would be required to refine this estimate of impact on Possum Kingdom Reservoir.

Figure 4B.7-1 illustrates the simulated Millers Creek Reservoir storage levels for the 1940 to 1997 historical period, subject to the safe yield of 6,742 acft/yr. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 92.8 percent of the time and above the Zone 3 trigger level (50 percent capacity) 99.6 percent of the time (all but 3 months of the simulation).

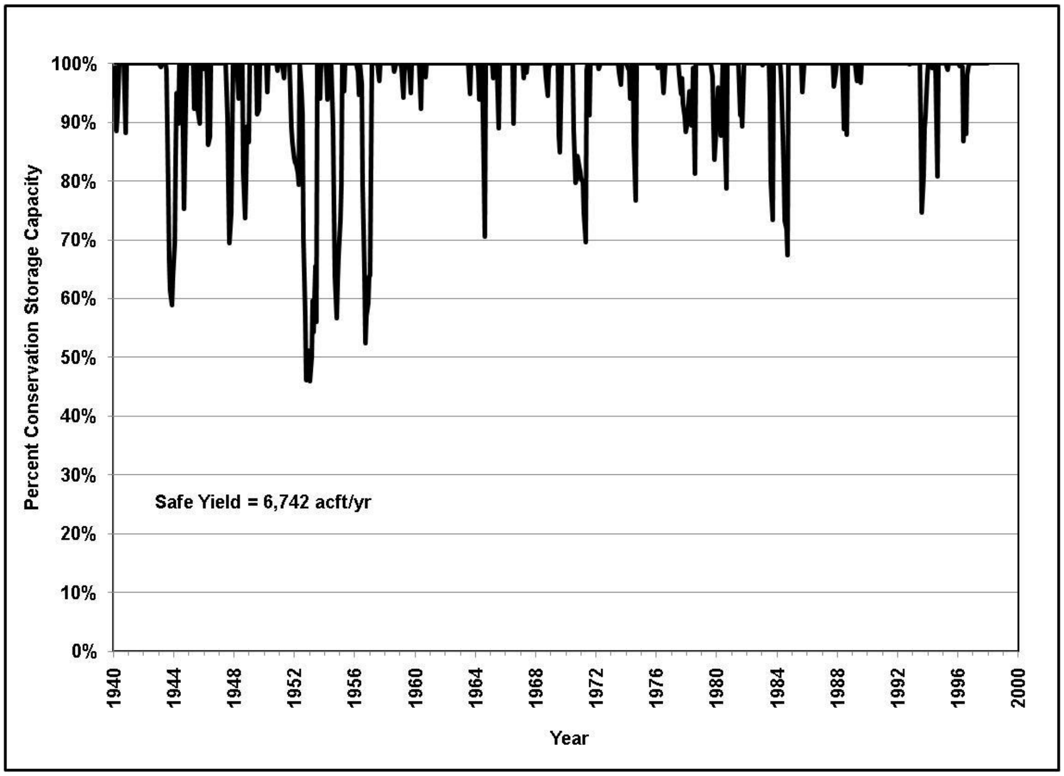
Figures 4B.7-3 and 4B.7-4 illustrate the changes in Lake Creek and Millers Creek median monthly streamflows caused by the project. The largest change as computed from the simulation results is a decline in median monthly streamflow in Lake Creek of 23 cfs in July. In Millers Creek, the model-computed median monthly stream flow below the dam is reduced to zero for all months but May and June with the project in place. The largest decrease in model-computed median monthly flow is 11 cfs, computed for the month of June. The decrease in median monthly flows is due to the subordination of Possum Kingdom Reservoir to Millers Creek Reservoir. Figures 4B.7-3 and 4B.7-4 also illustrate the Lake Creek and Millers Creek streamflow frequency characteristics with the project in place. In Lake Creek, the model-computed frequency of mean monthly flows below approximately 100 cfs is decreased. In Millers Creek, the model-computed frequency of monthly flows below approximately 110 cfs and above approximately 25 cfs is increased, while the frequency of those less than 25 cfs is decreased.

4B.7.1.2 Environmental Issues

The environmental issues associated with the four options for augmenting Millers Creek reservoir are discussed together in Section 4B.7.5.

4B.7.1.3 Engineering and Costing

The total estimated project cost for the channel dam and grass lined canal is $22.9 million. Capital costs were developed for the 2006 Brazos G Plan and have been updated to September 2008 dollars using the Engineering News Record (ENR) Construction Cost Index (CCI). 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 4B.7-2. The cost for the estimated additional safe yield increase of 6,257 acft/yr translates to an annual unit cost for raw water of $0.85 per 1,000 gallons, or $279/acft.



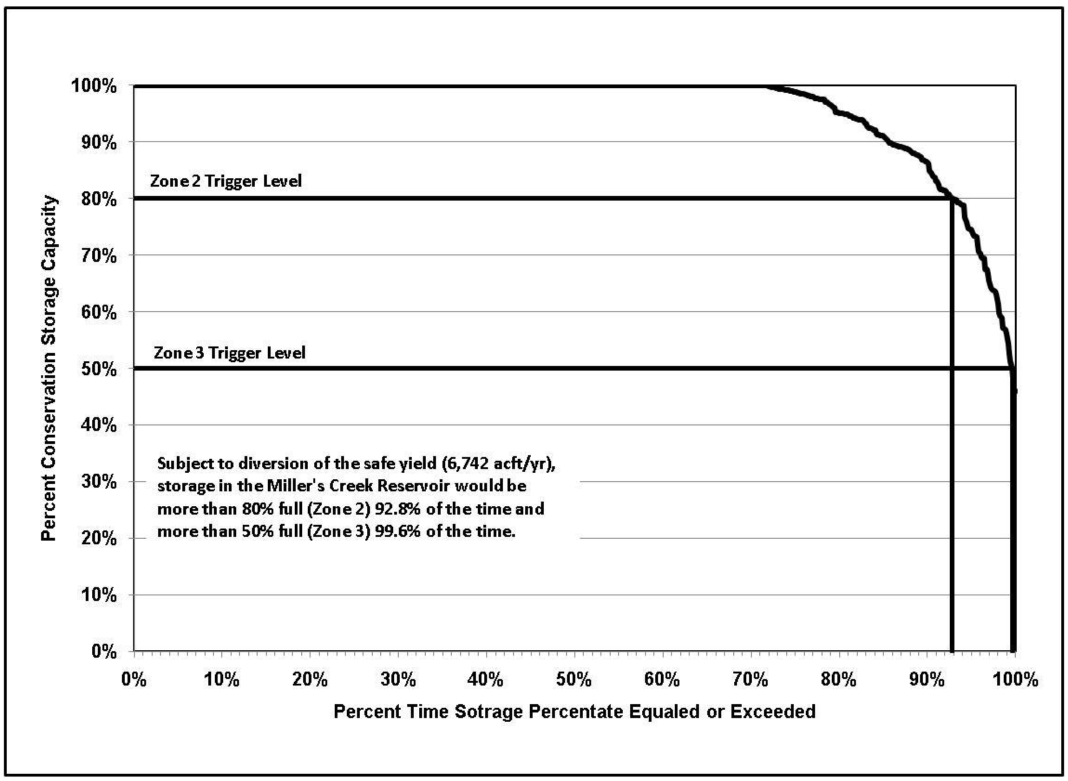


Figure 4B.7-3. Millers Creek Reservoir Storage Trace and Storage Frequency at Safe Yield

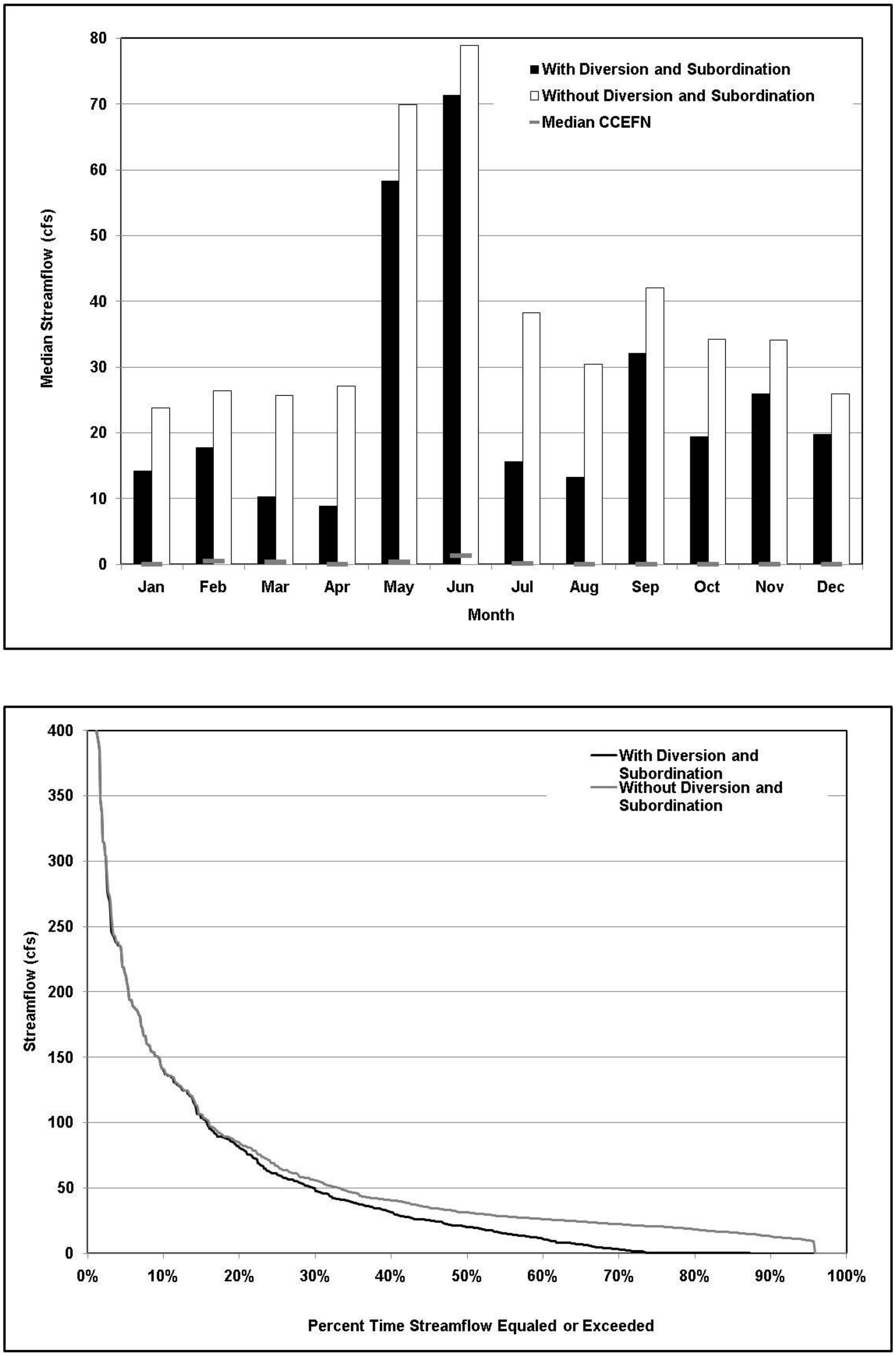
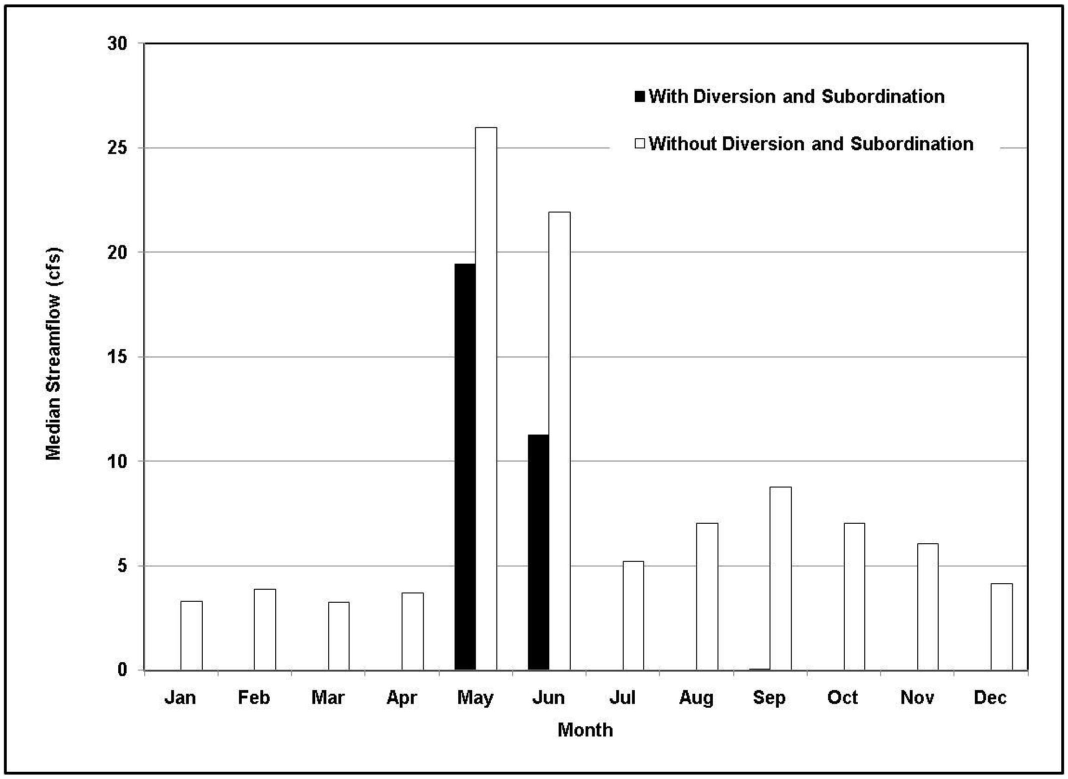


Figure 4B.7-4. Comparison of Median Monthly Streamflow and Streamflow Frequency Below Lake Creek Diversion Point With and Without Canal Diversion



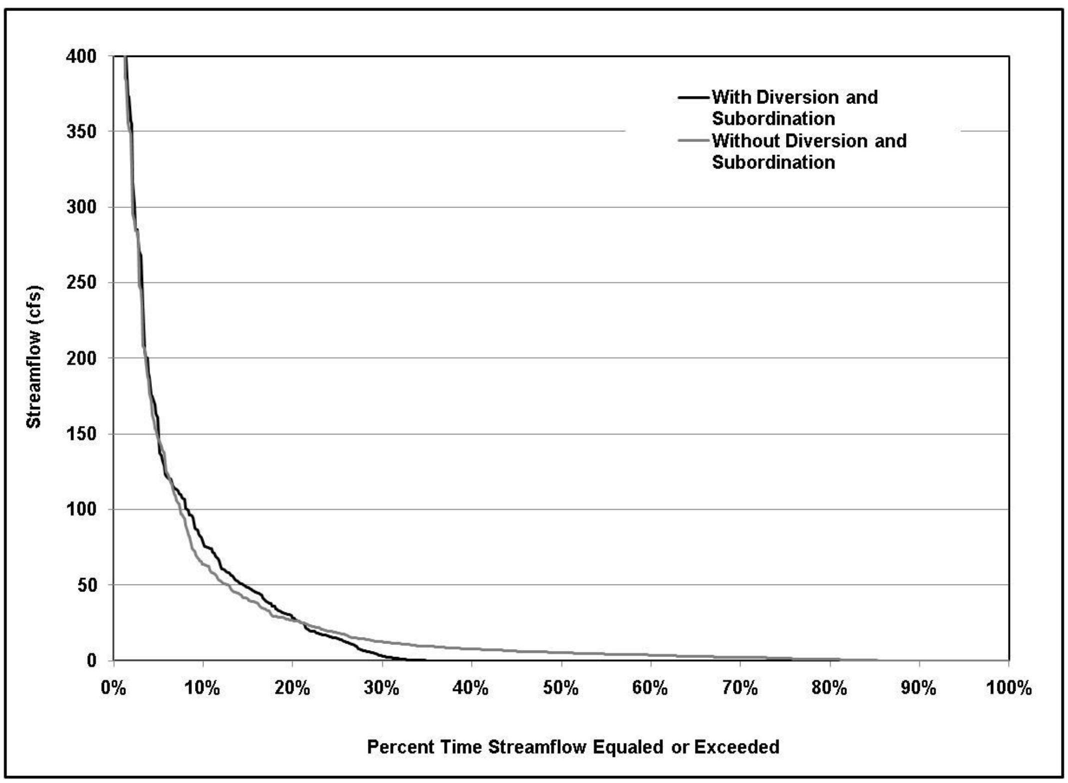


Figure 4B.7-5. Comparison of Median Monthly Streamflow and Streamflow Frequency Below Millers Creek Reservoir With and Without Canal Diversion

Table 4B.7-2.
Cost Estimate Summary for
Augmentation of Millers Creek Reservoir (Canal Option)
(September 2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Channel Dam, Reservoir (1,477 ft-msl), and Canal	$14,676,000
Total Capital Cost	**$14,676,000**
Engineering, Legal Costs and Contingencies	$5,136,000
Environmental & Archaeology Studies and Mitigation	$691,000
Land Acquisition and Surveying (491 acres)	$715,000
Interest During Construction (2 years)	$1,698,000
Total Project Cost	**$22,916,000**
Annual Costs	
Reservoir Debt Service (6 percent, 40 years)	$1,523,000
Operation and Maintenance	
Dam and Reservoir	$25,000
Purchase of Water (3,579 acft/yr @ 54.50 $/acft)	$195,000
Total Annual Cost	**$1,743,000**
Available Project Yield (acft/yr)	6,257
Annual Cost of Water ($ per acft)	$279
Annual Cost of Water ($ per 1,000 gallons)	$0.85

4B.7.1.4 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.7-3, and the option meets each criterion.

Table 4B.7-3.
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. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low to moderate impact
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. 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	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.7.1.4.1 *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.

4B.7.1.4.2 *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.

4B.7.1.4.3 *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.

4B.7.2 Description of Pipeline Option

Another option for augmenting Millers Creel Reservoir previously studied[1] and included in the 2006 Brazos G Plan is to divert water from Lake Creek through a 24-inch pipeline into Brushy Creek, which flows into Millers Creek and eventually into Millers Creek Reservoir, as shown in Figure 4B.7-2.

4B.7.2.1 Available Yield

The increase in Millers Creek Reservoir yield that could potentially be obtained with the pipe diversion was estimated using the 2060 Brazos G WAM. Subordination of Possum Kingdom Reservoir to both Millers Creek Reservoir and the Lake Creek diversion was assumed. An additional instream flow requirement of 5 cfs was added to the model at the Lake Creek

1 Freese & Nichols, Inc, "West Central Brazos River Basin Regional Water Treatment and Distribution Facility Plan," August 2004.

diversion point for consistency with previous work on the pipeline option. The capacity of the 24-inch pipe was assumed to be approximately 10 cfs or 7,200 acft/yr. As with the canal diversion, Possum Kingdom Reservoir was assumed to be subordinated to the Lake Creek diversion and to Millers Creek Reservoir.

The safe yield of Millers Creek Reservoir with the pipeline diversion was computed to be 4,076 acft/yr, which is an increase of 3,591 acft/yr over the model-computed safe yield of the existing reservoir alone. Based on a delivery factor for water flowing from Millers Creek reservoir to Possum Kingdom Reservoir of 0.572 (from the Brazos G WAM), the yield impact on Possum Kingdom Reservoir due to the pipe diversion and subordination was assumed to be 2,054 acft/yr for costing purposes. Additional analysis would be required to refine this estimate of impact on Possum Kingdom Reservoir.

4B.7.2.2 Environmental Issues

The environmental issues associated with the four options for augmenting Millers Creek reservoir are discussed together in Section 4B.7.5.

4B.7.2.3 Engineering and Costing

The total estimated project cost is $10.20 million for the diversion weir, intake canal, pipeline, and pump station. The annual project costs are estimated to be $1.16 million, including annual debt service, operation and maintenance, and annual payment to the Brazos River Authority for lost yield in Possum Kingdom. A summary of the project costs is presented in Table 4B.7-4. The cost for the estimated increase in Millers Creek Reservoir safe yield of 3,591 acft/yr translates to an annual unit cost for raw water of $0.99 per 1,000 gallons, or $324 per acft.

4B.7.2.4 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.7-5, and the option meets each criterion.

Table 4B.7-4.
Cost Estimate Summary for
Augmentation of the Millers Creek Reservoir (Pipeline Option)
September 2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Dam and Reservoir (Diversion Weir and Intake Canal)	$4,474,000
Intake and Pump Station	$1,726,000
Transmission Pipeline (24 in dia., 1.8 miles)	$768,000
Total Capital Cost	**$6,968,000**
Engineering, Legal Costs and Contingencies	$2,368,000
Environmental & Archaeology Studies and Mitigation	$44,000
Land Acquisition and Surveying (8 acres)	$61,000
Interest During Construction (2 years)	$757,000
Total Project Cost	**$10,198,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$402,000
Reservoir Debt Service (6 percent, 40 years)	372,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$57,000
Dam and Reservoir	25,000
Pumping Energy Costs	$196,000
Purchase of Water (2,054acft/yr @ $54.50/acft)	$112,000
Total Annual Cost	**$1,164,000**
Available Project Yield (acft/yr)	3,591
Annual Cost of Water ($ per acft)	$324
Annual Cost of Water ($ per 1,000 gallons)	$0.99

Table 4B.7-5.
Comparison of Augmentation to the 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. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low to moderate impact
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. 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	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.7.2.4.1 *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.

4B.7.2.4.2 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.

4B.7.2.4.3 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.

4B.7.3 Description of New Dam and Reservoir 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 4B.7-6 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 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.

[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.

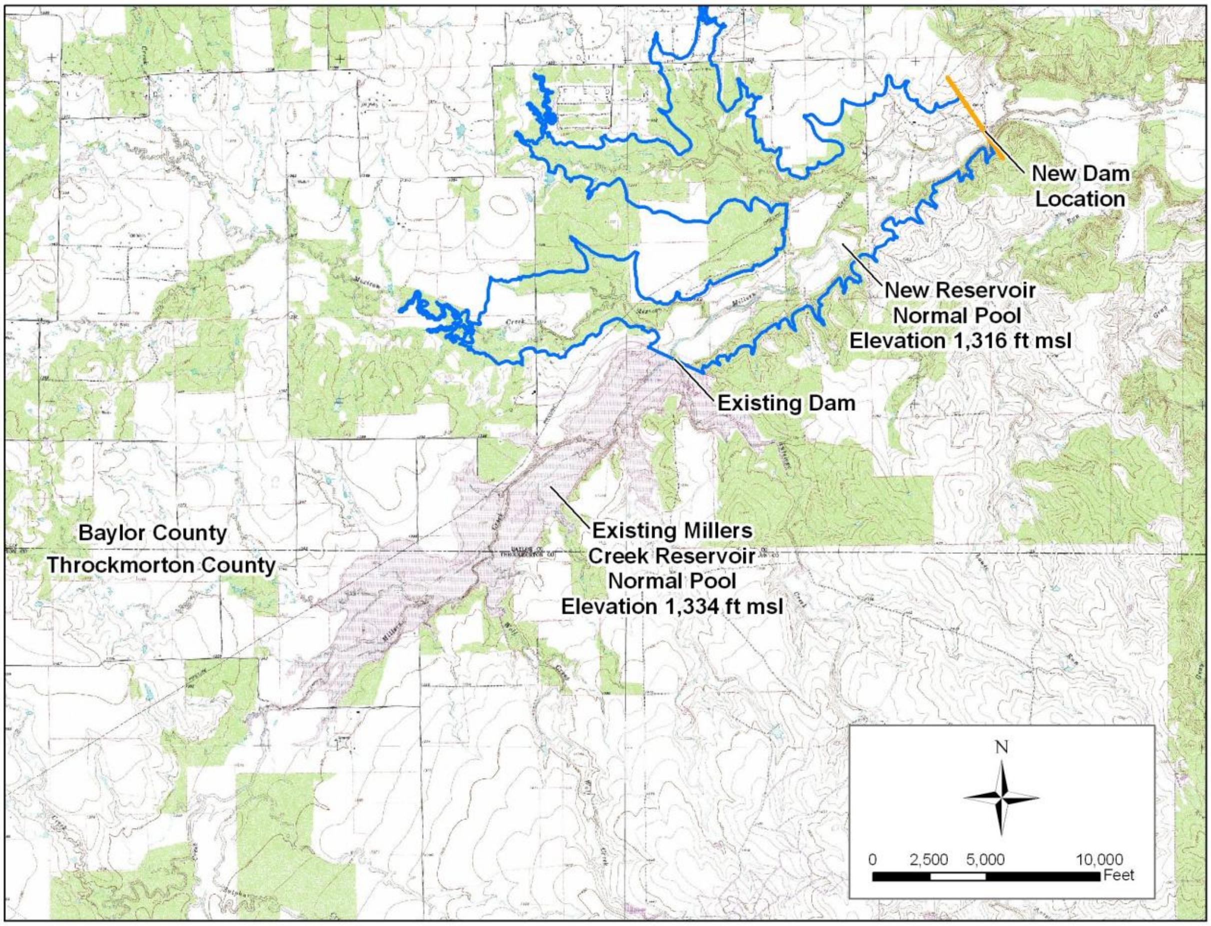


Figure 4B.7-6. New Reservoir Below Millers Creek Reservoir

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 2060 Brazos G WAM, which models existing reservoirs at their projected year 2060 capacity, is 14,674 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

[3] Texas Water Development Board, "Hydrographic Survey of Miller's Creek Reservoir," Prepared for North Central Texas Municipal Water Authority, March 2003.

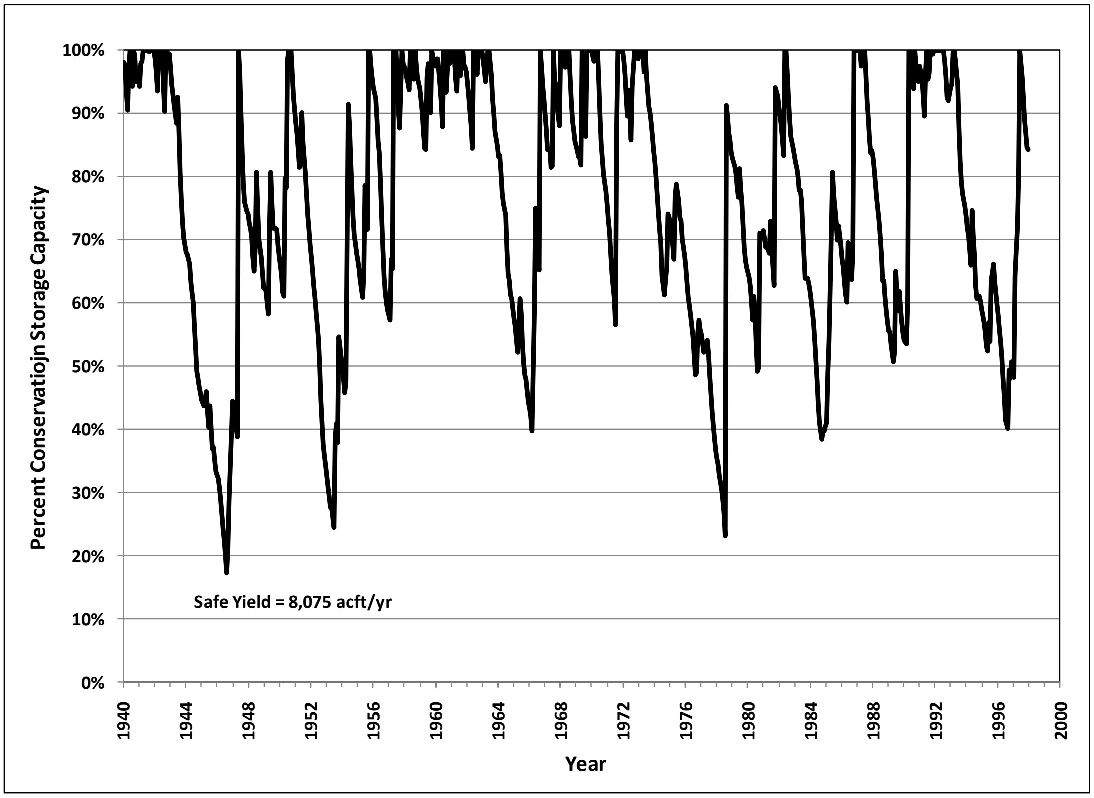
normal pool elevation. The study recommends a 20-foot embankment top width. A core trench having 1:1 side slopes and 20-foot bottom width extending to impervious material is also recommended by the study. The study recommends protection of the upstream face of the dam with 8 inches of gravel and 24 inches of riprap.

4B.7.3.1 Available Yield

The safe yield that would be available with construction of the new reservoir was estimated using the 2060 Brazos G WAM. Streamflow records for August 1963 through October 2009 at USGS Gauge 08082700, located on Millers Creek near Munday, Texas, approximately 11.7 miles upstream of the existing dam, were evaluated to identify the potential CCEFN requirements for the new reservoir. The gauged daily mean flows were scaled by the drainage area ratio to the new dam site, and the median, 25th percentile, and 7Q2 flows were computed. As the gage is upstream of the existing reservoir, the existing reservoir's impact on streamflow did not affect the computed streamflow statistics. All three of the CCEFN statistics were computed to be zero. Therefore, CCEFN requirements were not included in modeling the safe yield of the new reservoir. Subordination of Possum Kingdom Reservoir to both the existing and new Millers Creek reservoirs was assumed for the safe yield calculation.

The calculated safe yield of the new reservoir is 8,075 acft/yr, with the subordination and priority assumptions noted above. Along with a computed 1,420 acft/yr increase in the safe yield of the existing reservoir due to the subordination of Possum Kingdom Reservoir, the total increase in safe yield that would result from implementing this project is 9,495 acft/yr. Based on a delivery factor of 0.572, the yield impact on Possum Kingdom Reservoir was estimated to be 5,431 acft/yr for costing purposes. Additional analysis would be required to refine this estimate of impact on Possum Kingdom Reservoir. Figure 4B.7-7 shows the simulated storage levels of the new reservoir for the 1940 to 1997 historical period, subject to the safe yield of 8,075 acft/yr.

The effects of the new reservoir and subordination of Possum Kingdom reservoir on streamflow in Millers Creek below the new reservoir were computed from the 2060 Brazos G WAM simulation results. Figure 4B.7-8 shows the computed Miller's Creek median monthly streamflow and streamflow frequency characteristics downstream of the new reservoir. The computed median monthly stream flow is zero for each month of the year. The frequency



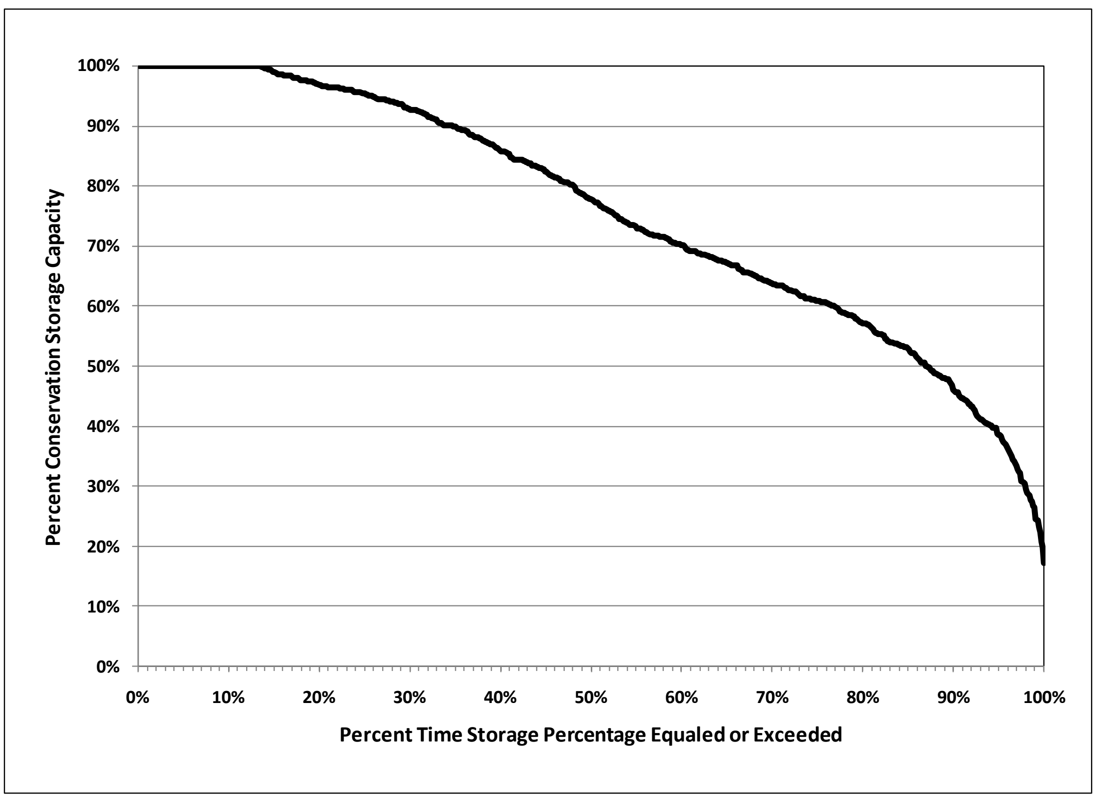


Figure 4B.7-7. New Reservoir Storage Trace and Storage Frequency at Safe Yield

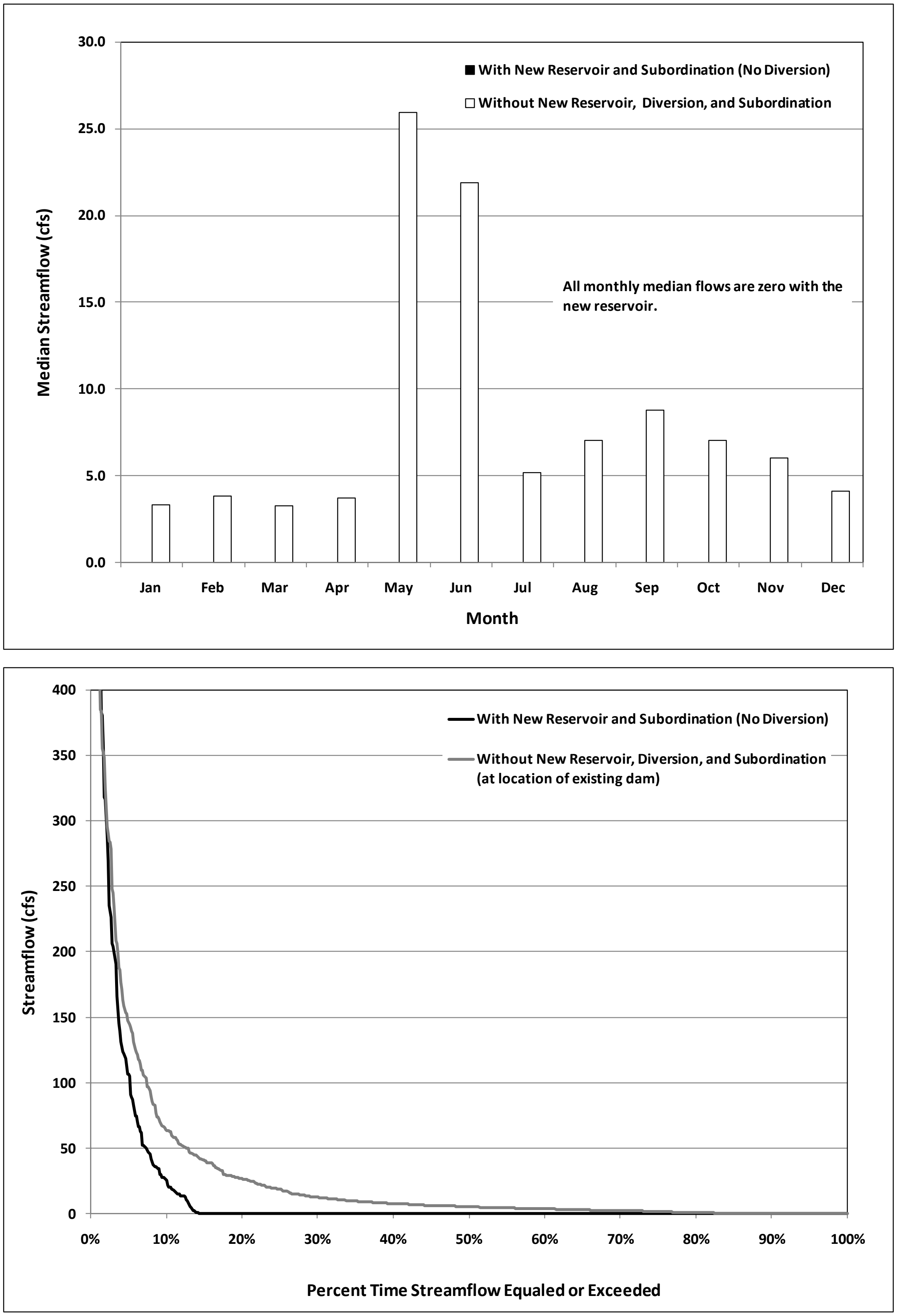


Figure 4B.7-8. Comparison of Millers Creek Median Monthly Streamflow and Streamflow Frequency With and Without New Reservoir

characteristics 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. A decrease in the frequency of mean monthly flows less than approximately 250 cfs is apparent in the frequency plot.

4B.7.3.2 Environmental Issues

The environmental issues associated with the four options for augmenting Millers Creek reservoir are discussed together in Section 4B.7.5.

4B.7.3.3 Engineering and Costing

Table 4B.7-6 summarizes estimated costs for the new dam and reservoir. The Freese, Nichols and Endress Study provides a preliminary cost estimate for construction of the new dam. The capital costs from this study were updated from 1967 to September 2008 values using the ENR CCI for inclusion in the present estimate. Other costs were computed based on standard regional planning methodologies.

The total estimated project cost for the new dam and reservoir is $24.0 million. The annual project costs are estimated to be $2.01 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 safe yield increase of 9,495 acft/yr translates to an annual unit cost for raw water of $0.65 per 1,000 gallons, or $212 per acft.

4B.7.3.4 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.7-7, and the option meets each criterion.

4B.7.3.4.1 <u>Potential Regulatory Requirements:</u>

- 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;

Table 4B.7-6.
Cost Estimate Summary for
Augmentation of the Millers Creek Reservoir
(New Dam and Reservoir Option)
(September 2008 Prices)

Item	*Estimated Costs for Facilities*
Capital Costs	
Dam and Reservoir (Conservation Pool 46,645 acft, 2,541 acres, 1,316 ft-msl)	$6,866,000
Relocations and Other	$460,000
Total Capital Cost	**$7,326,000**
Engineering, Legal Costs and Contingencies	$2,564,000
Environmental & Archaeology Studies and Mitigation	$5,340,000
Land Acquisition and Surveying (3,795 acres)	$5,529,000
Interest During Construction (2 years non-reservoir, 4 years reservoir)	$3,273,000
Total Project Cost	**$24,032,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$59,000
Reservoir Debt Service (6 percent, 40 years)	$1,553,000
Operation and Maintenance	
Dam and Reservoir	$103,000
Purchase of Water (5,431 acft/yr @ 54.50 $/acft)	$296,000
Total Annual Cost	**$2,011,000**
Available Project Yield (acft/yr)	9,495
Annual Cost of Water ($ per acft)	$212
Annual Cost of Water ($ per 1,000 gallons)	$0.65

Table 4B.7-7.
Comparison of New Dam and Reservoir
to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet some needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
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
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	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

- 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.

4B.7.3.4.2 *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.

4B.7.3.4.3 *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.

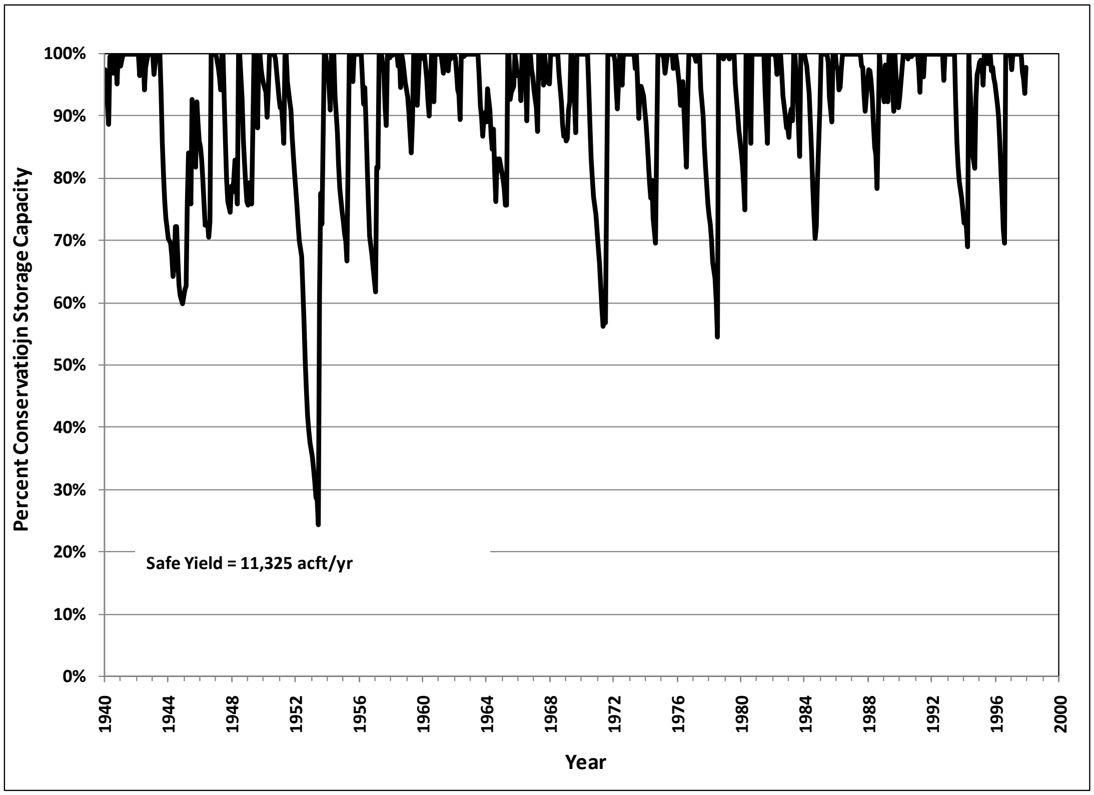
4B.7.4 Description of Combined Canal Diversion with New Dam and Reservoir

This option combines the canal diversion from Lake Creek to the existing Miller's Creek Reservoir described in Section 4B.7.1 with the new dam and reservoir described in Section 4B.7.3. 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, then passed through the existing reservoir to fill the new reservoir.

4B.7.4.1 Available Yield

The yield of the reservoir system including the existing Millers Creek Reservoir, new reservoir, and Lake Creek diversion canal was computed with the 2060 Brazos G WAM. Subordination of Possum Kingdom Reservoir to the existing Millers Creek Reservoir. Diversions from Lake Creek were subject to the CCEFN requirements discussed in Section 4B.7.1.1.

The safe yield of the new reservoir with the canal diversion and subordination assumptions noted above was computed to be 11,325 acft/yr, which is an increase of 3,250 acft/yr over the model-computed safe yield of the new reservoir alone (Section 4B.7.3.1). The estimated safe yield of the existing reservoir with the canal diversion is 6,742 acft/yr, or 6,257 acft more than the existing reservoir alone (Section 4B.7.1.1) and this yield estimate is not impacted by the new reservoir, as the new reservoir is assumed to be junior to the existing reservoir. Overall, the canal diversion, new reservoir, and subordination of Possum Kingdom Reservoir would increase the yield of the existing reservoir by an estimated 17,582 acft/yr. Based on a delivery factor of 0.572, the yield impact on Possum Kingdom Reservoir was estimated to be 10,057 acft/yr for costing purposes. Additional analysis would be required to refine this estimate of impact on Possum Kingdom Reservoir. Figure 4B.7-9 shows the simulated storage levels of the new reservoir for the 1940 to 1997 historical period, subject to the safe yield of 11,325 acft/yr.



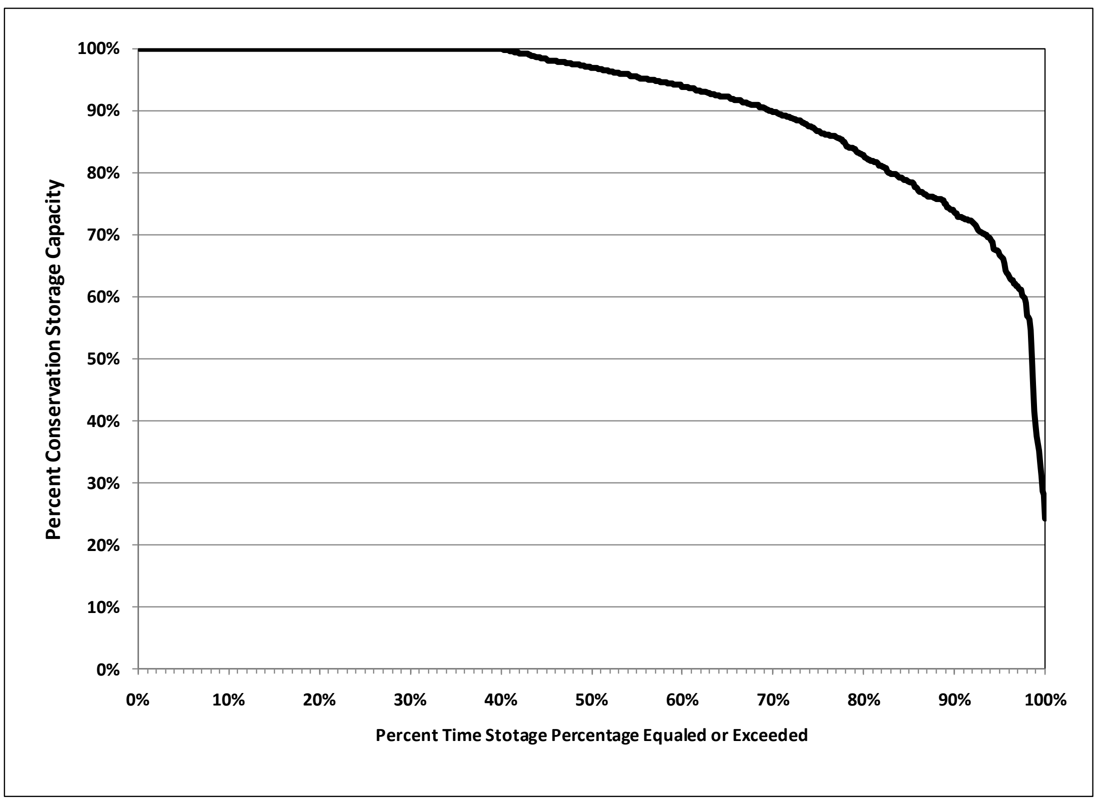


Figure 4B.7-9. New Reservoir Storage Trace and Storage Frequency at Safe Yield with Canal Diversion

Figures 4B.7-10 and 4B.7-11 illustrate the model-computed changes in Lake Creek and Millers Creek median monthly streamflow caused by the project. The median monthly streamflow in Lake Creek is reduced to nearly zero for all months but May and June. In Millers Creek, the model-computed median monthly stream flow below the dam is reduced to zero for all months. Figures 4B.7-10 and 4B.7-11 also illustrate the Lake Creek and Millers Creek streamflow frequency characteristics with the project in place. In Lake Creek, the model-computed frequency of mean monthly flows below approximately 250 cfs is decreased. 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. A decrease in the frequency of mean monthly flows less than 60 cfs is apparent in the frequency plot.

4B.7.4.2 Environmental Issues

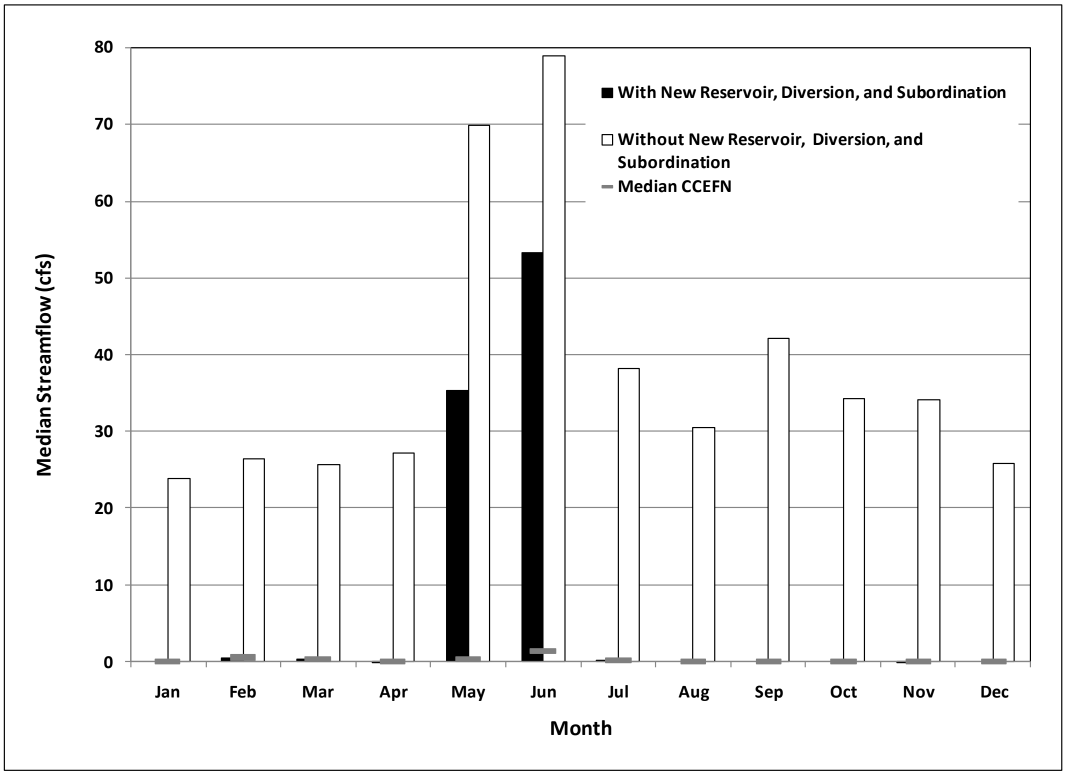
The environmental issues associated with the four options for augmenting Millers Creek reservoir are discussed together in Section 4B.7.5.

4B.7.4.3 Engineering and Costing

Table 4B.7-8 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 $46.9 million. The annual project costs are estimated to be $3.81 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 safe yield increase of 17,582 acft/yr translates to an annual unit cost for raw water of $0.67 per 1,000 gallons, or $217 per acft.

4B.7.4.4 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.7-9, and the option meets each criterion.



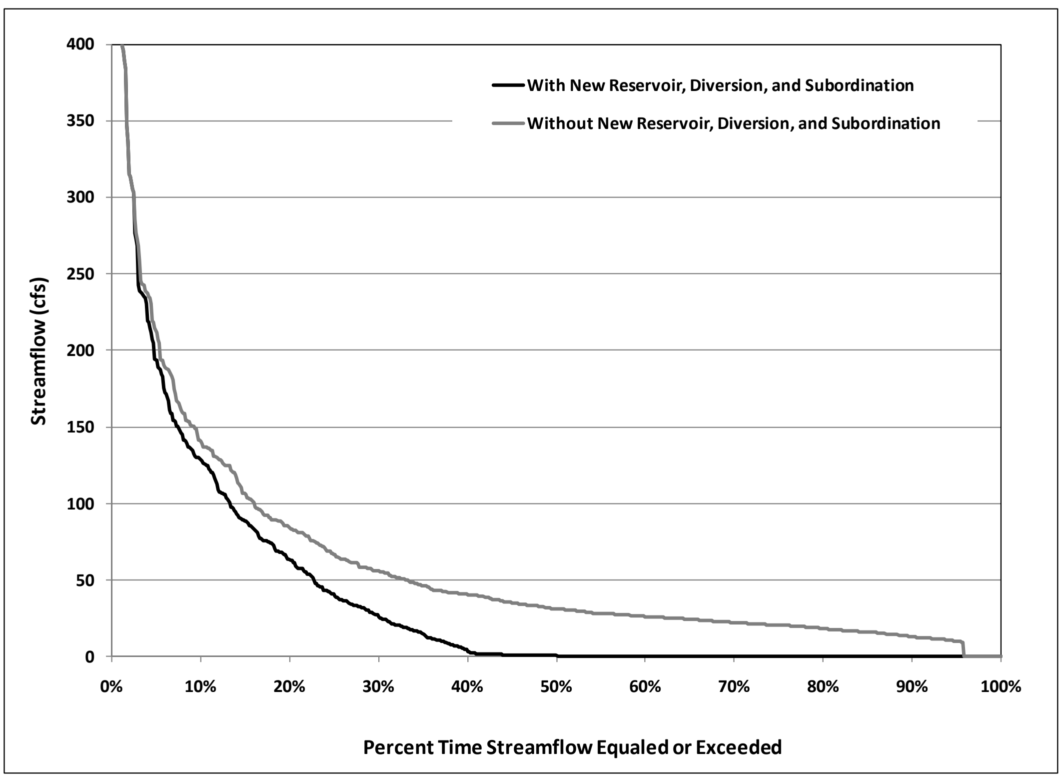
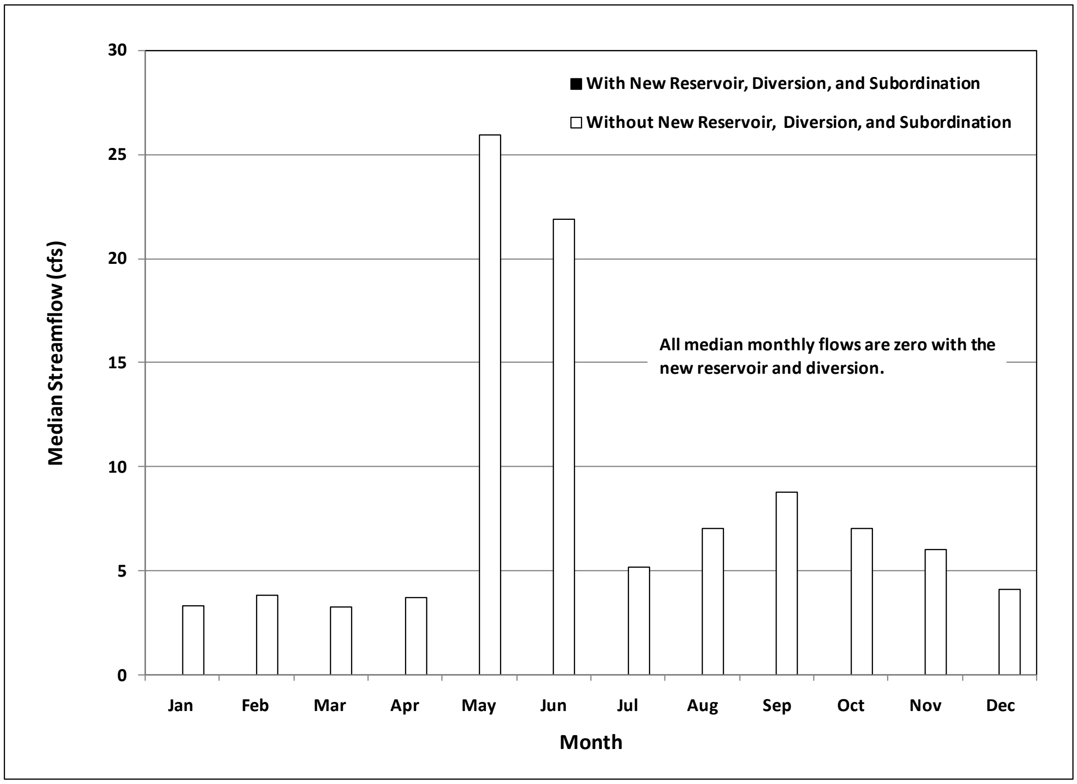


Figure 4B.7-10. Comparison of Median Monthly Streamflow and Streamflow Frequency Below Lake Creek Diversion Point With and Without New Reservoir and Canal Diversion



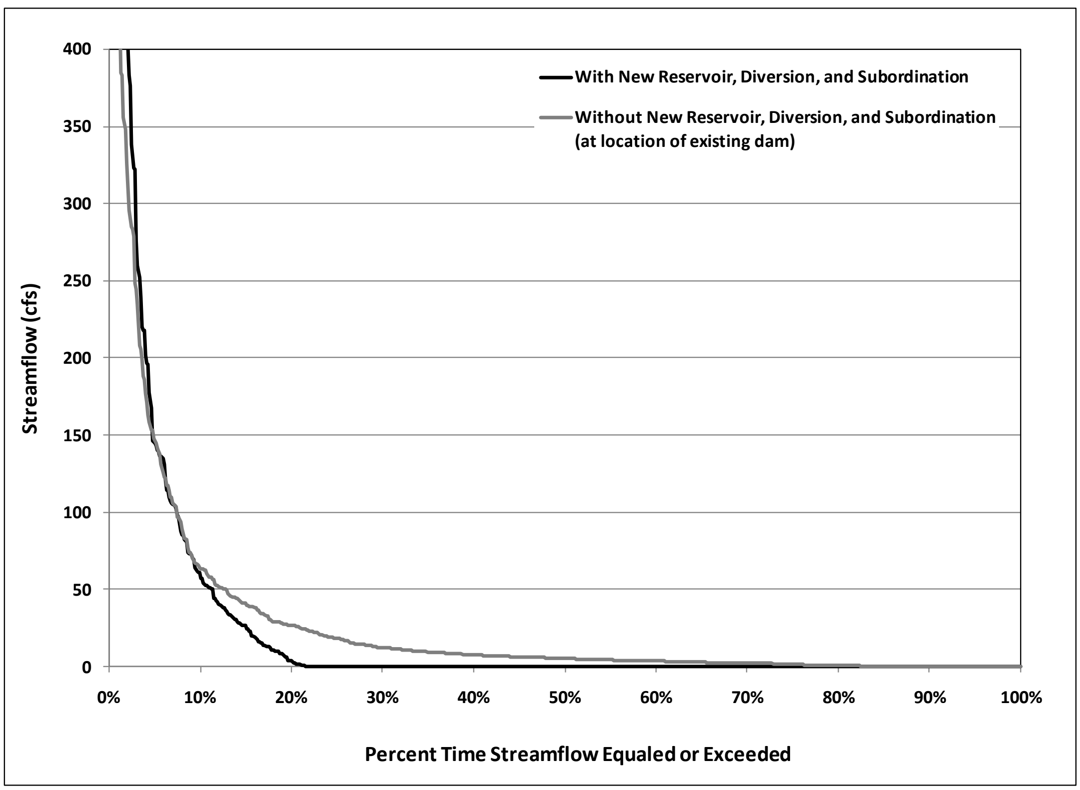


Figure 4B.7-11. Comparison of Millers Creek Median Monthly Streamflow and Streamflow Frequency With and Without New Reservoir and Canal Diversion

Table 4B.7-8.
Cost Estimate Summary for
Augmentation of the Millers Creek Reservoir
(Combined Canal Diversion with New Dam and Reservoir Option)

Item	***Estimated Costs for Facilities***
Capital Costs	
Canal, Dams, and Reservoirs	$21,542,000
Relocations and Other	$460,000
Total Capital Cost	**$22,002,000**
Engineering, Legal Costs and Contingencies	$7,700,000
Environmental & Archaeology Studies and Mitigation	$6,031,000
Land Acquisition and Surveying (4,286 acres)	$6,244,000
Interest During Construction (2 years non-reservoir, 4 years reservoir)	$4,971,000
Total Project Cost	**$46,948,000**
Annual Costs	
Dept Service (6 percent, 20 years)	$59,000
Reservoir Debt Service (6 percent, 40 years)	$3,076,000
Operation and Maintenance	
Dams and Reservoirs	$128,000
Purchase of Water (10,057 acft/yr @ 54.50 $/acft)	$548,000
Total Annual Cost	**$3,811,000**
Available Project Yield (acft/yr)	17,582
Annual Cost of Water ($ per acft)	$217
Annual Cost of Water ($ per 1,000 gallons)	$0.67

Table 4B.7-9.
Comparison of Combined Canal Diversion with New Dam and Reservoir to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet some needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
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
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	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.7.4.4.1 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.

4B.7.4.4.2 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.

4B.7.4.4.3 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.

4B.7.5 Environmental Issues

This water management strategy involves four possible scenarios:

(1) A diversion dam which will divert water from Lake Creek through a grass-lined canal into Brushy Creek and subsequently into Millers Creek Reservoir;

(2) The use of a pipeline instead of a canal to carry the diverted water from Lake Creek to Brushy Creek;

(3) Development of a new reservoir below Millers Creek Reservoir with no associated Lake Creek diversion; and

(4) Development of both the new reservoir and diversion of water from Lake Creek via a canal.

Both the Millers Creek Reservoir Augmentation Site, diversion canal and the new reservoir site lie within the Rolling Plains Ecological Region[4]. This region is located east of the High Plains, west of the West Cross Timbers and North Central Prairie, and north of the Edwards Plateau. It is characterized by nearly level to rolling topography, soft prairie sands and clays, juniper breaks, and midgrass prairie. The physiognomy of the region varies from open, short to tall, scattered to dense grasslands to savannahs with bunch grasses. Most of the plains are rangeland, but dryland 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

[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.

and subsequently decreased the value of the land for cattle production. Farming and grazing practices have also reduced the abundance and diversity of wildlife in the region.[5] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average precipitation ranges between 24 and 26 inches.[6]

The Seymour Aquifer, an unconsolidated sand and gravel aquifer, is the only major aquifer in the project area. It is formed by alluvial deposits in twenty counties in north central Texas. The Seymour aquifer consists mainly of the scattered erosional remnants of the Seymour Formation of Pleistocene age, which consists of clay, silt, sand, and gravel, that were deposited by eastward-flowing streams. The aquifer generally has less than 100 feet of saturated thickness, but it is an important source of water for domestic, municipal, and irrigation needs.[7]

The physiography of the region includes recharge sand, undissected red beds, loose surficial sand, flood prone areas, and severely eroded land.[8] Three major vegetation types occur within the general vicinity of the project area: Mesquite (*Prosopis glandulosa*) - Lotebush Shrub, Mesquite-Saltcedar (*Tamarix*) Brush/Woods, and Crops.[9] Variations of these primary types occur which involve changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Mesquite-Lotebush Shrub vegetational areas 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*),

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5 Telfar, Roy C. 1999. Vegetation Areas of Texas: concepts and Commentary. Journal of the Botanical Institute of Texas 3 (1).
6 Larkin, T.J. and Bomar, G.W., 1983, Climatic atlas of Texas: Texas Water Development Board Limited Publication 192, 151 p
7 Ashworth, John B and Janie Hopkins. 1995. Aquifers of Texas. Texas Water Development Board, Report 345. Austin, Texas.
8 Kier, R. S., L.E. Garner, and L.F. Brown, Jr. 1977. Land Resources of Texas [map]. Bureau of Economic Geology, University of Texas. Austin, Texas.
9 McMahan, Craig A., Roy G. Frye and Kirby L. Brown. 1984. The Vegetation Types of Texas Including Cropland. Texas Parks and Wildlife Department, Austin, Texas.

broom snakeweed (*Gutierrezia sarothrae*), and bitterweed (*Hymenoxys odorata*). Commonly associated plants of Mesquite-Saltcedar Brush/Woods are creosotebush (*Larrea tridentata*), cottonwood (*Populus deltoides*), desert willow (*Chilopsis linearis*), giant reed (*Arundo donax*), seepwillow (*Baccharis* sp.), common buttonbush (*Cephalanthus occidentalis*), whitethorn acacia (*Acacia constricta*), Australian saltbush (*Atriplex semibaccata*), fourwing saltbush (*Atriplex canescens*), lotebush, wolfberry (*Lycium berlandieri*), tasajillo, guayacan (*Guaiacum angustifolium*), alkali sacaton (*Sporobolus airoides*), Johnsongrass (*Sorghum halepense*), saltgrass (*Distichlis spicata*), cattail (*Typha* spp.), bushy bluestem (*Andropogon glomeratus*), and chino grama (*Bouteloua ramosa*). Crop vegetational areas include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

4B.7.5.1 Potential Impacts

4B.7.5.1.1 Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated at the existing Millers Creek Reservoir, and at the Lake Creek diversion point. The diversion would occur at an impoundment created by construction of a channel dam on Lake Creek. Water would be diverted from the Lake Creek impoundment via a canal or pipeline to Brushy Creek which feeds Millers Creek and Millers Creek Reservoir. Under a third option, a new dam and reservoir would be constructed downstream of the existing Miller's Creek Reservoir, providing additional storage of flows from Millers Creek. A fourth option would include construction of the diversion canal along with the new reservoir, providing additional storage of flows from Millers Creek and the Lake Creek diversion.

Tables 4B.7-10 and 4B.7-11 list the model-computed median monthly streamflows in Millers Creek just below the reservoir (below the new reservoir, if present for an option, otherwise below the existing reservoir), and in Lake Creek just below the diversion. The tables also provide the percentage change in median monthly streamflow for each augmentation option, as computed from the simulation results. These statistics 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

Table 4B.7-10.
Median Monthly Streamflow in Millers Creek

	Without Project	*With Canal Diversion*		*With Pipe Diversion*		*With New Reservoir*		*With New Reservoir and Canal Diversion*	
	Median Monthly Flow (cfs)	*Median Monthly Flow (cfs)*	*Flow Difference (With Project - Without) (%)*	*Median Monthly Flow (cfs)*	*Flow Difference (With Project - Without) (%)*	*Median Monthly Flow (cfs)*	*Flow Difference (With Project - Without) (%)*	*Median Monthly Flow (cfs)*	*Flow Difference (With Project - Without) (%)*
Jan	3.3	0.0	-100	0.0	-100	0.0	-100	0.0	-100
Feb	3.9	0.0	-100	0.0	-100	0.0	-100	0.0	-100
Mar	3.3	0.0	-100	0.0	-100	0.0	-100	0.0	-100
Apr	3.7	0.0	-100	0.0	-100	0.0	-100	0.0	-100
May	26.0	19.4	-25	18.1	-30	0.0	-100	0.0	-100
Jun	21.9	11.3	-49	11.6	-47	0.0	-100	0.0	-100
Jul	5.2	0.0	-100	0.0	-100	0.0	-100	0.0	-100
Aug	7.0	0.0	-100	0.0	-100	0.0	-100	0.0	-100
Sep	8.8	0.0	-100	0.0	-100	0.0	-100	0.0	-100
Oct	7.0	0.0	-100	0.0	-100	0.0	-100	0.0	-100
Nov	6.0	0.0	-100	0.0	-100	0.0	-100	0.0	-100
Dec	4.1	0.0	-100	0.0	-100	0.0	-100	0.0	-100

Table 4B.7-11.
Median Monthly Streamflow in Lake Creek Below Diversion

	Without Project	*With Canal Diversion*		*With Pipe Diversion*		*With New Reservoir*		*With New Reservoir and Canal Diversion*	
	Median Monthly Flow (cfs)	*Median Monthly Flow (cfs)*	*Flow Difference (With Project - Without) (%)*	*Median Monthly Flow (cfs)*	*Flow Difference (With Project - Without) (%)*	*Median Monthly Flow (cfs)*	*Flow Difference (With Project - Without) (%)*	*Median Monthly Flow (cfs)*	*Flow Difference (With Project - Without) (%)*
Jan	23.8	14.2	-40	14.9	-37	23.8	0	0.0	-100
Feb	26.4	17.8	-33	18.6	-30	26.4	0	0.5	-98
Mar	25.7	10.3	-60	17.0	-34	25.7	0	0.3	-99
Apr	27.1	8.8	-68	18.3	-32	27.1	0	0.0	-100
May	69.9	58.3	-17	66.4	-5	69.9	0	35.4	-49
Jun	78.9	71.3	-10	73.5	-7	78.9	0	53.2	-33
Jul	38.3	15.5	-59	28.6	-25	38.3	0	0.1	-100
Aug	30.4	13.3	-56	21.8	-29	30.4	0	0.0	-100
Sep	42.1	32.0	-24	35.3	-16	42.1	0	0.0	-100
Oct	34.2	19.4	-43	24.5	-28	34.2	0	0.0	-100
Nov	34.1	26.0	-24	28.1	-18	34.1	0	0.0	-100
Dec	25.9	19.7	-24	19.8	-23	25.9	0	0.0	-100

reservoir either with or without the canal diversion. Implementation of either of these options would reduce the median monthly flows for all months to zero based on the simulation results. In Lake Creek, the largest impact would occur for construction of the new dam and reservoir with the diversion canal. Under this scenario, the median monthly flow would be reduced by 98 to 100 percent for all months but May and June. 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. 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, 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.

4B.7.5.1.2 Threatened and Endangered Species

A total of 27 animal species could potentially occur within the vicinity of the project that are state or federally listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern according to county lists of rare species provided by the Texas Parks and Wildlife Department (TPWD) online (Table 4B.7-12). In addition to these county lists, the TPWD Natural Diversity Database (NDD) was reviewed for known occurrences of any federal or state listed species found within or near the project area. Listed species include three reptiles, 12 birds, eight mammals, two freshwater mussels, and two fish species. Two bird species and three mammal species which are federally-listed as endangered could occur (or historically occurred) in the project area. Bird species include the interior least tern (*Sterna antillarum athalassos*), and whooping crane (*Grus americana*). The interior least tern and whooping crane are seasonal migrants that could pass through the project area. Mammal species which area federally listed include the gray wolf (*Canis lupus*), red wolf (*Canis rufus*), and black-footed ferret (*Mustela nigripes*). Both the gray wolf and red wolf are considered to be extirpated within the project counties. Although the black-footed ferret (*Mustela nigripes*) historically occurred in the area, there have been no confirmed reports of this

Table 4B.7-12.
Potentially Occurring Species that are Rare or Federal and State Listed in Baylor, Haskell, and Throckmorton Counties

Scientific Name	Common Name	Federal/ State Status	Potential Occurrence
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/-	Migrant
Ammodramus bairdii	Baird's Sparrow	SOC	Migrant
Buteo regalis	Ferruginous Hawk	SOC	Migrant*
Haliaeetus leucocephalus	Bald Eagle	DL/T	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Charadrius montanus	Mountain Plover	SOC	Migrant*
Charadrius alexandrinus	Snowy plover	SOC	Migrant
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*
Charadrius alexandrines nivosus	Western Snowy Plover	SOC	Migrant
Grus americana	Whooping Crane	LE/E	Migrant
Plegadis chihi	White-faced Ibis	-/T	Migrant
Fishes			
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Mammals			
Mustela nigripes	Black-footed Ferret	LE/-	Extirpated
Cynomys ludovicianus	Black-tailed Prairie Dog	SOC	X
Myotis velifer	Cave Myotis Bat	SOC	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis lupus	Gray Wolf	LE/E	Extirpated
Corynorhinus townsendii pallescens	Pale Townsend’s big-eared bat	SOC	X
Canis rufus	Red Wolf	LE/E	Extirpated
Dipodomys elator	Texas kangaroo rat	-/T	X
Mussels			
Truncilla macrodon	Texas fawnsfoot	SOC	X
Tritogonia verrucosa	Pistolgrip	SOC	X
Reptiles			
Nerodia harteri	Brazos Water Snake	SOC/T	X
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X

(TPWD County List of Endangered, Threatened and Species of Concern, Baylor, Throckmorton and Haskell Counties, updated 6/25/09)

* Nesting migrant; may nest in the county. X = Occurs in county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; DL-De-listed Endangered/Threatened; C-Candidate, SOC-Species of Concern.

State Status: E-Listed as Endangered; T-Listed as Threatened; **SOC**-Species of Concern .

species in Texas since 1963.[10] These bird and mammal species are not anticipated to be directly affected by the proposed reservoir or diversion canal.

There are six additional species which are listed as threatened by the state of Texas within the project counties. These include the American peregrine falcon (*Falco peregrinus anatum*), bald eagle (*Haliaeetus leucocephalus*), white-faced ibis (*Plegadis chihi*), Texas kangaroo rat (*Dipodomys elator*), Brazos water snake (*Nerodia harteri*), and Texas horned lizard (*Phrynosoma cornutum*). The three state threatened bird species are migrants within the project area and are not anticipated to be adversely affected by the project. The Texas kangaroo rat lives on clay soils supporting sparse, short grasses and small scattered mesquite bushes. NDD occurrences of the Texas kangaroo rat are documented approximately 18 miles north of the project area. The Brazos water snake is known to inhabit rocky areas found within the Brazos River Basin. This species of snake has been reported by the NDD near Lake Stamford along Paint Creek approximately 20 miles southwest of the study area. Although suitable habitat for the state threatened Texas horned lizard may exist within the project area, no impact to this species is anticipated due to the abundance of similar habit near the project area.

A search of the Texas Wildlife Diversity Database (NDD)[11] revealed no documented occurrences of rare or listed species within the project vicinity (as noted on representative 7.5 minute quadrangle map(s) that include the project site). However there are two documented nesting colonies of the Great Blue Heron found located along Millers Creek which could be impacted by the proposed new reservoir below Millers Creek Reservoir. NDD information is based on the best data available to TPWD, however this does 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. No species specific surveys were conducted in the project area for this report.

A search of the Texas Wildlife Diversity Database (NDD)[12] revealed no documented occurrences of rare or listed species within the project vicinity (as noted on representative 7.5 minute quadrangle map(s) that include the project site). However there are two documented

[10] Campbell, Linda. 1995. Endangered and Threatened Animals of Texas. Texas Parks and Wildlife Department, Endangered Resources Branch. Austin, Texas.

[11] Texas Parks and Wildlife. 2009. Natural Diversity Database. Texas Parks and Wildlife. Austin, Texas. Received December 8, 2009.

[12] Texas Parks and Wildlife. 2009. Natural Diversity Database. Texas Parks and Wildlife. Austin, Texas. Received December 8, 2009.

nesting colonies of the Great Blue Heron found located along Millers Creek which could be impacted by the proposed new reservoir below Millers Creek Reservoir. NDD information is based on the best data available to TPWD, however this does 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. No species specific surveys were conducted in the project area for this report.

4B.7.5.1.3 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 minimum width of 131 feet and a maximum width of 287 feet. This would result in approximately 48 acres of impact to wildlife habitat. Vegetation found within the diversion canal ROW includes areas of cropland. Utilization of areas already impacted by agricultural uses generally reduces the overall habitat loss impact on species found within the project area. Impacts resulting from the use of a pipeline to transport the water from the diversion area rather than a canal would be fewer due to the fact that it would be buried and include only maintained ROW areas.

The addition of the new reservoir site below the existing Millers Creek Reservoir would involve the loss of approximately 2,541 acres of additional wildlife habitat at the normal pool elevation and approximately four stream miles of riparian habitat. Vegetation types found within this site include portions of Mesquite Lotebush Shrub, Mesquite Saltcedar Brush/Woods and Crop areas.

A number of vertebrate species would be expected to occur within the general vicinity of the project site as indicated by county occurrence records.[13] These include one species of salamander, five species of frogs and toads, three species of turtles, five species of lizards and

[13] Dixon, James R. and R. Kathryn Vaughan. 1998. *Amphibians and Reptiles of Texas Counties Checklist*. Texas A & M University, College Station, Texas.

skinks, and 17 species of snakes. Mammals expected to occur within the project area include the coyote (*Canis latrans*), common raccoon (*Procyon lotor*), white-tailed deer (*Odocoileus virginianus*), Texas mouse (*Peromyscus attwateri*), and plains pocket gopher (*Geomys bursarius*) among others.[14] A variety of bird and fish species would be expected to inhabit the site, with distributions and population densities limited by the types and quality of habitats available.

4B.7.5.1.4 Cultural Resources

A review of the Texas Historical Commission Texas Historic Sites Atlas data base indicated that there are no National Register Properties, Historical Markers, or cemeteries listed near any of the proposed project areas. A search of the Texas Archeological Sites Atlas database indicates that three archeological sites have been documented within the general vicinity of the proposed diversion canal. These sites, which lie outside the current project alignment, were recorded as prehistoric habitation sites. Two of these sites (41KX95 and 41HK1) were recommended for further testing in 1973. Prior to construction of the diversion canal or the new reservoir area, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any cultural resources are present within the area. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archeological and Historic Preservation Act (PL93-291).

4B.7.5.1.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would have an impact associated with lower streamflows 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.

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

4B.8 Aquifer Storage and Recovery (ASR)

In the development of Brazos G water management strategies, Aquifer Storage and Recovery (ASR) is considered for (1) the Seymour Aquifer in Knox and Haskell Counties where the aquifer is recharged with water from the Salt Fork Brazos River by infiltration and recovered with existing irrigation wells, and (2) the Trinity Aquifer in Johnson County where new, dual-purpose wells are used to inject potable water from the SWATS water treatment plant on Lake Granbury into the aquifer for storage and recovery by public supply wells.

The ASR management strategy is useful to water suppliers who periodically have surplus water and water shortages. For example, ASR can be used to inject and store water in aquifers during the fall, winter, and spring when demands are low and to recover the water during the summer when demands are high. This strategy better utilizes the available capacity of the water treatment plant and supply and transmission system, and commonly delays the need for expanding water treatment and distribution facilities. In most all cases, the water utility's operating plan would call for balancing injection and recovery or possibly recovering slightly less than the amount injected.

4B.8.1 Seymour Aquifer in Knox and Haskell Counties

4B.8.1.1 Description of Option

A proposed ASR water management option for irrigation water supplies in Knox and Haskell Counties is based on diverting a portion of runoff during relatively high flow conditions from the Salt Fork Brazos River to an off-channel reservoir for temporary storage, transporting the stored water to spreading basins in the target recharge area in the Seymour Aquifer, and recovering the water with existing irrigation wells. The project area was selected on the basis of the local proximity to a potentially suitable surface water reservoir for temporary storage, the Salt Fork Brazos River, and areas of the Seymour where the aquifer is rather thick and productive, water level declines are significant, and there is extensive agricultural irrigation with groundwater. The selected ASR area of the Seymour Aquifer is in a region along the Haskell-Knox County line and between the towns of Munday and Knox City; the selected off-channel reservoir is Lake Davis, which is located about 10 miles north of the ASR area. The Salt Fork Brazos River is between the off-channel reservoir and the target ASR area. The strategy is intended to supplement the natural recharge to the Seymour and benefit irrigated agriculture. This area is shown in Figure 4B.8.1-1.

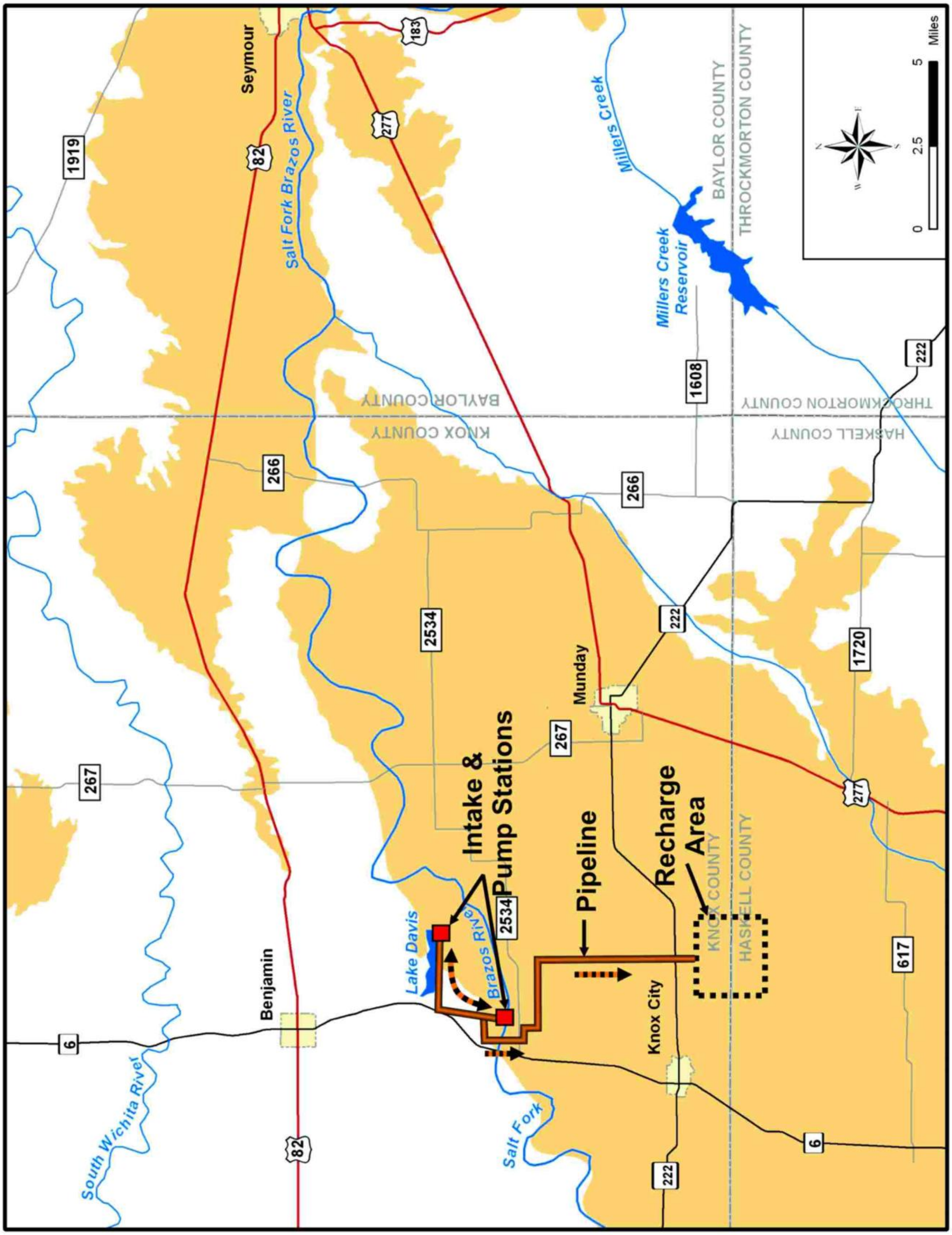

Figure 4B.8.1-1. Location and Features of Seymour ASR Project

4B.8.1.2 Available Yield

4B.8.1.2.1 Source and Supply of Surface Water

The source of water for the Seymour ASR project is the Salt Fork Brazos River. During seasons of high flow available water from the Salt Fork would be diverted to Lake Davis. During the September-April period, available water from Lake Davis would be delivered to the target area for recharging the Seymour Aquifer. The recharged water would be recovered from May through August for irrigation of crops.

The Brazos G WAM was used to evaluate the availability of water in the Salt Fork and potential operation of Lake Davis. Operational settings to the Brazos G WAM included:

- Possum Kingdom Lake is subordinated to Salt Fork Brazos River and Lake Davis;
- No diversions are made to ASR when there is less than 575 acft of storage in Lake Davis to protect irrigation uses from the reservoir;
- Adjustment of the water diversion patterns from Lake Davis to allow existing irrigation water rights to continue from May through August and ASR diversions from September through April;
- When water in the Salt Fork is available and needed by the ASR project, the filling rate of Lake Davis is 2,100 acft/month (equivalent of a 36-inch pipe transporting water at a velocity of 5 feet per second (fps) from the Salt Fork to Lake Davis);
- ASR diversions are limited to 1,125 acft/mo (9,000 acft/yr); and
- Lake Davis storage is considered to be under 2060 sedimentation conditions.

Figure 4B.8.1-2a shows the annual available flow from the Salt Fork to Lake Davis that is constrained by the capacity of the 36-inch pipeline, and Figure 4B.8.1-2b shows an additional constraint that is attributed to the available storage capacity of Lake Davis. The diversions shown in Figure 4B.8.2b represent the supply of water that is available from the Salt Fork, which averages about 5,980 acft/yr. The greatest annual diversion occurs in 1968 and is about 10,490 acft. For 3 years, no water was available for diversion to Lake Davis. Figure 4B.8.1-3 shows the annual diversions from Lake Davis to the ASR area. This chart shows that the average annual recharge was about 6,208 acft/yr, which is about 230 acft/yr greater than the diversions from the Salt Fork. This increase is attributed to runoff into Lake Davis.

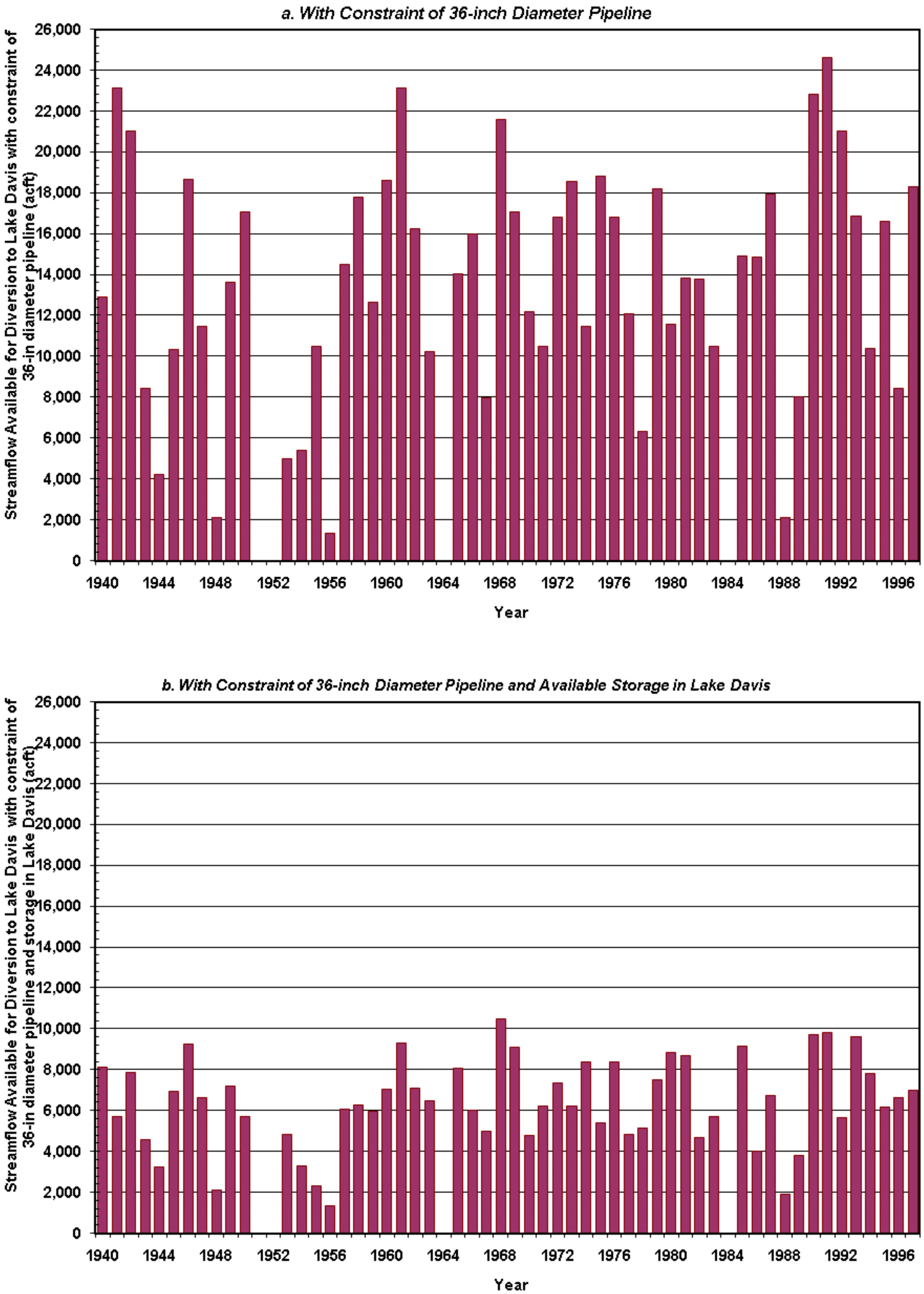

Figure 4B.8.1-2. Potential Annual Diversions from Salt Fork Brazos River for Storage in Lake Davis

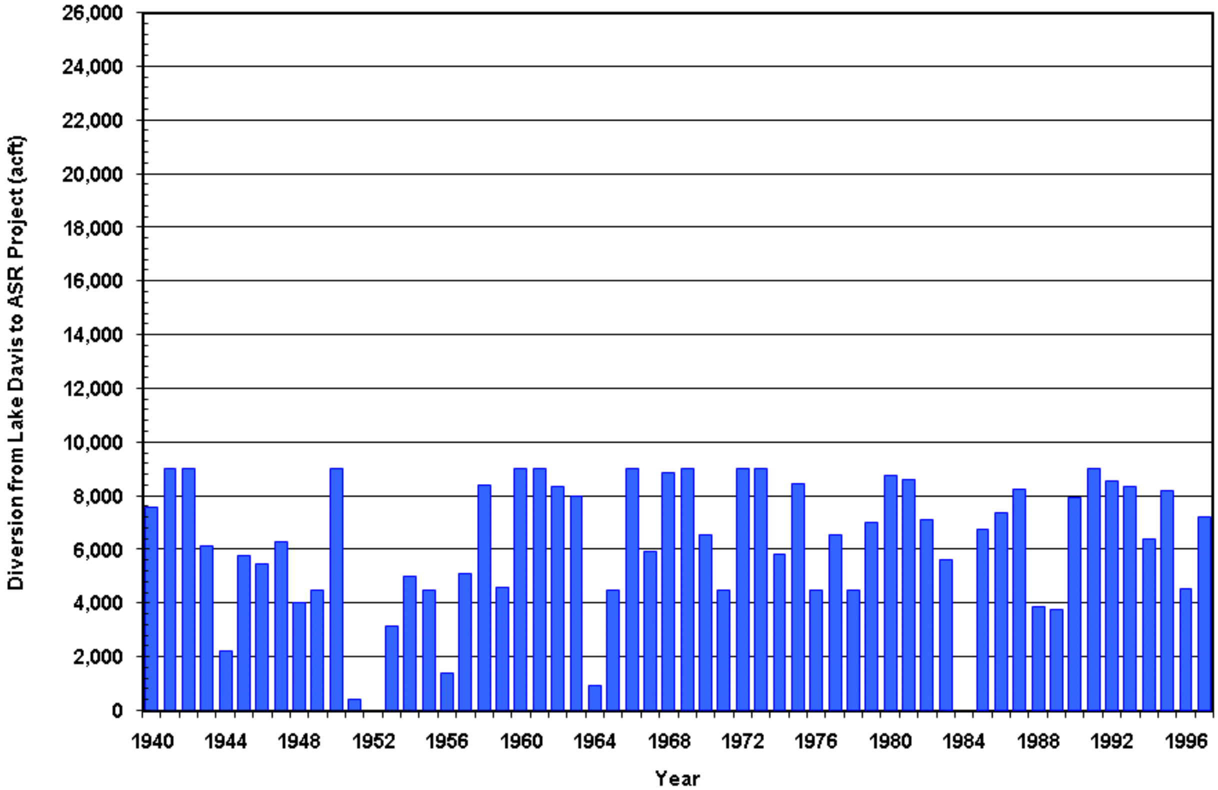

Figure 4B.8.1-3. Annual Availability of Water from Lake Davis for ASR Recharge

Water quality in the Salt Fork was considered in the study of the ASR system. For this analysis, chloride concentrations and streamflow records at USGS gaging station 08082000 Salt Fork Brazos River near Aspermont, Texas, were analyzed. Figure 4B.8.1-4 shows the concentration of chloride versus streamflow. The shaded area indicates the range of discharges at which the most scalping of high flows in the Salt Fork would occur. The chart shows that chloride concentration decreases significantly as discharge increases.

4B.8.1.2.2 Seymour Aquifer

The Seymour Aquifer is composed of alluvial clay, silt, sand, and gravel deposited during the Pleistocene era and can be up to several tens of feet thick. Originally, the geologic material was laid down as a continuous unit; however, natural erosion has dissected the geologic material into several disconnected "pods." The targeted ASR area is in a relatively large and hydraulically transmissive pod of the Seymour Aquifer and has been utilized for irrigation and local municipal supplies during the last several decades. Unconfined (water table) conditions exist throughout the aquifer. Infiltration of precipitation and excess irrigated water serve as the primary sources of recharge.

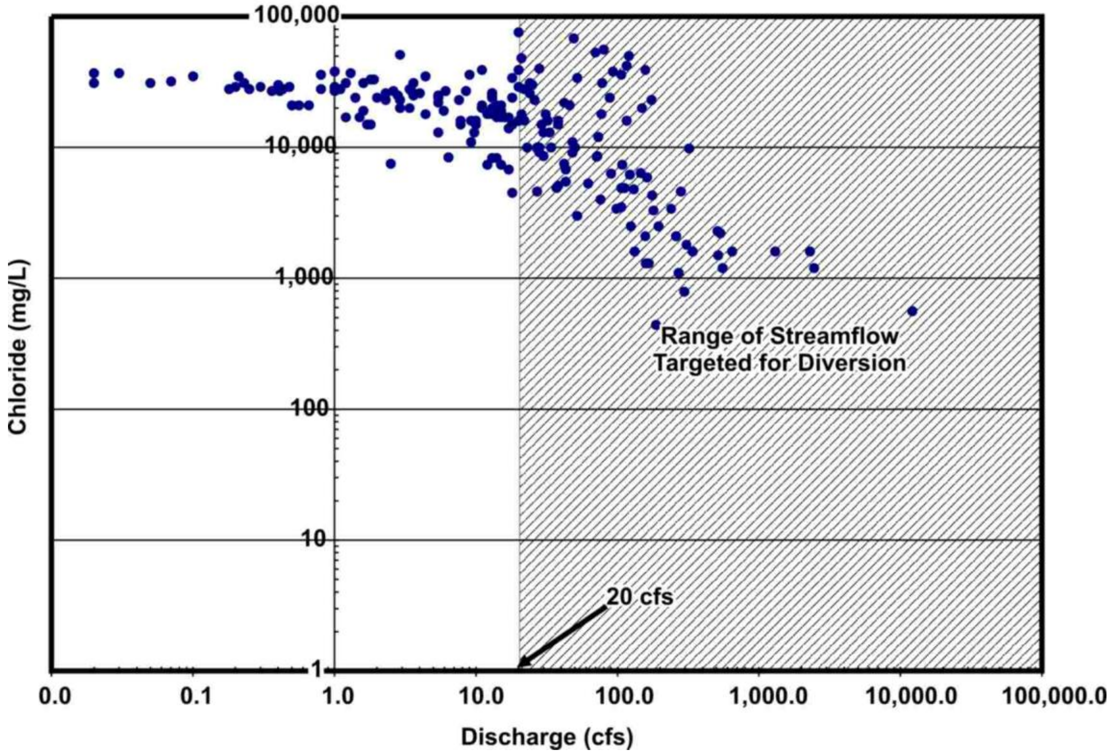

Figure 4B.8.1-4. Relation of Chloride Concentrations to Streamflow at 08082000 Salt Fork Brazos at Aspermont

Historical water level data in the vicinity of the target recharge area show significant declines in saturated thickness during the last 20 years. For example, a decline of about 30 feet was recorded between 1987 and 2003 at TWDB's monitoring well 2134902, which is near Knox City. This is about a 70 percent reduction in saturated thickness. These declines suggest that well yields from this area have declined in the past and, if the historical trend in declining water levels persists, well yield declines will continue. The reductions in saturated thickness also indicate that storage space for ASR recharge exists within the aquifer. Because the Seymour is an unconfined aquifer, any surplus recharge added through ASR must be contained within the sediment pore spaces.

4B.8.1.2.3 <u>Potential Seymour ASR Design</u>

The proposed method of recharge is using spreading basins instead of wells. The spreading basins are expected to be shallow swales in the more permeable areas, aligned along topographic contours. The spreading basins have the advantage of allowing the use of recharge water with some sediment concentrations, high application rates, and limited maintenance. It has the disadvantage of some water loss. This probably will be overcome with the retention of rainfall that may otherwise runoff. Site-specific information on soil infiltration characteristics and aquifer properties would be needed to design the recharge system and to identify the prime recovery wells.

4B.8.1.2.4 Important Seymour ASR Assumptions

Important issues relating to the applicability of a Seymour ASR project include seasonal recharge and recovery cycles and suitable quality and quantity of surface water for aquifer compatibility and local groundwater use.

The recovery cycle must soon follow the injection cycle, or the recharge may dissipate into the regional aquifer system. While benefiting the aquifer on a more regional basis, specific project benefits for participants may be minimal. Additional studies concerning water quality from the Salt Fork would need to be conducted if the project appears feasible from cost/benefit studies.

4B.8.1.3 Environmental Issues

Diversion facilities on the Salt Fork with a pump station and pipeline to Lake Davis and then to the recharge area, which would cover a relatively small surface area of 57 acres, would probably result in:

- Negligible impacts on environmental water needs, instream flows, and bays and estuaries;
- Improved fish and wildlife habitat conditions in Lake Davis;
- Low to moderate impacts to wildlife habitat along pipeline crossing of Salt Fork;
- Low to moderate impacts to fish and wildlife, including endangered species; and
- Low impacts on cultural resources.

4B.8.1.4 Engineering and Costing

The engineering facilities for the ASR project consist of an intake and pump station on the Salt Fork Brazos River, a 36-in pipeline to Lake Davis, an intake and pump station at Lake Davis, a 24-in pipeline from the river to the ASR recharge area, distribution pipelines to several delivery points, and swales in the fields. The 36-inch diameter pipeline from the Salt Fork to

Lake Davis would be used for filling the lake. The 24-inch diameter pipeline would be used to divert water from Lake Davis to the recharge area. The river intake and pump station would be located near State Hwy 6. The Lake Davis discharge, intake and pump station facilities would be located near the dam. The conceptual location of these facilities are shown in Figure 4B.8.1-1. The major facilities required for this option is:

- River Diversion to Off-Channel Storage:
  - River intake;
  - Pump station;
  - Pipeline; and
  - Outlet works.
- Lake Diversion to Recharge Area:
  - Lake intake;
  - Pump station;
  - Pipeline;
  - Outlet works; and
  - Terraces or swales.

Estimates were prepared for capital costs, annual debt service, operation and maintenance, water purchases, power, land, and environmental mitigation. These costs are summarized in Table 4B.8.1-1. Estimated costs do not include an annual payment to BRA for potential impacts to Possum Kingdom Reservoir yields. The project costs, including capital, are estimated to be $38,625,000. The annual costs, including debt service, operation and maintenance, and power are estimated to be $4,352,000. This water management option produces water at estimated costs of $701 per acft/yr for a long-term average delivery of 6,208 acft/yr. Because of the relatively large fixed cost, unit rates would be less for relatively wet conditions and more for relatively dry conditions.

4B.8.1.5 Implementation

Implementation of the described ASR water management strategy for the Seymour Aquifer includes the following issues:

- Availability of suitable water quantities and water quality from the Salt Fork Brazos River;
- Contractual arrangements can be made with owner of Lake Davis or another nearby reservoir for use of the unused storage capacity of the reservoir;
- Contractual arrangements with land owners where the infiltration basins are to be constructed;

Table 4B.8.1-1.
Cost Estimate Summary
Seymour Aquifer ASR Water Supply Project Option
September 2008 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (Salt Fork of the Brazos to Lake Davis)	$5,208,000
Intake and Pump Station (Lake Davis to Recharge Area)	$8,227,000
Transmission Pipeline (36 in dia., Salt Fork to Lake Davis)	$4,605,000
Transmission Pipeline (24 in dia., Lake Davis to Recharge Area)	$8,699,000
Recharge Area Preparations	$400,000
Total Capital Cost	**$27,139,000**
Engineering, Legal Costs and Contingencies	$8,833,000
Environmental & Archaeology Studies and Mitigation	$490,000
Land Acquisition and Surveying (72 acres)	$677,000
Interest During Construction (1 years)	$1,486,000
Total Project Cost	**$38,625,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$3,368,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$469,000
Pumping Energy Costs (5719276 kW-hr @ 0.09 $/kW-hr)	$515,000
Purchase of Water (acft/yr @ 0 $/acft)	$0
Total Annual Cost	**$4,352,000**
Available Project Yield (acft/yr)	6,208
Annual Cost of Water ($ per acft)	$701
Annual Cost of Water ($ per 1,000 gallons)	$2.15

- Pipeline right-of-way from Salt Fork diversion to Lake Davis, and from Lake Davis to ASR site;
- Entity who is willing and capable of funding and operating the facilities and capable of developing and administering a management plan to efficiently use the facilities and to balance injection and recovery cycles;
- Controlling the loss of the injected water by the participants in the project;
- Initial cost; and/or
- Experience in operating water facilities.

It will be necessary to obtain these permits:

- TCEQ water rights permit to divert from the Salt Fork Brazos River;
- U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings;
- General Land Office Sand and Gravel Removal Permits; and
- Texas Parks and Wildlife Department Sand, Gravel and Marl permit for river crossings.

The impacts of the ASR option for the Seymour Aquifer in Knox and Haskell Counties has been compared to the plan development criteria, as shown in Table 4B.8.1-2.

Table 4B.8.1-2.
Comparison of ASR –Seymour Option in Knox and Haskell Counties to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient in most years
2. Reliability	2. Low
3. Cost	3. Moderate to expensive for irrigation use
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. None
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• Potential negative impacts on water quality of Seymour; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is an attempt to meet agricultural irrigation needs
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.8.2 Trinity Aquifer in Johnson County

4B.8.2.1 Description of Option

For purposes of this option, the ASR project of the Trinity Aquifer in Johnson County considers the use of dual-purpose (ASR) wells to inject potable water into the aquifer for storage and recovery of the water at a later date. This strategy takes advantage of the unused capacity of the SWATS desalination water treatment plant during the fall, winter and spring. During these times, some or all the SWATS excess capacity is utilized and the treated water is transported by the existing pipeline to the ASR wells for storage. During summer when the demand exceeds supplies, the water is recovered. The location of the project facilities is shown in Figure 4B.8.2-1. New facilities required for this option are the ASR wells, well field collection pipelines and an interconnect between the pipeline and ASR well field.

The strategy is designed for Johnson County SUD (JCSUD), which now includes Johnson County FWSD#1. SWATS has a treatment capacity of 10.5 MGD, which is planned to be increased to 15.54 MGD by 2020. Of this supply, JCSUD currently has 5.90 MGD of capacity. With the 2020 expansion, JCSUD's share would be 8.73 MGD. The capacity of the water transmission pump station and pipeline is about 10.1 MGD. The customers on the transmission pipeline include JCSUD and the City of Keene. Keene's share of SWATS is 0.68 MGD for the current capacity and 1.00 MGD for the expansion. They lease 1.00 MGD of capacity in the pipeline and pump stations. In addition to SWATS, JCSUD also has a supply of water from the Trinity Aquifer. For planning purposes, the groundwater supply is 1,995 acft/yr.

The projected water demands for JCSUD increases from 8,036 acft/yr in 2010 to 24,506 acft/yr in 2060. A comparison of this demand and the groundwater and SWATS supplies are shown in Figure 4B.8.2-2. This illustrates that annual supplies are adequate to meet the annual demand through 2020. However, when considering the limitations on seasonal (monthly) supplies, the analyses suggest that the supplies are not adequate during June to September for 2010 and 2020, as shown in Figures 4B.8.2-3a and b, respectively. The available supplies from SWATS for JCSUD in 2010 and 2020 are shown in Figure 4B.8.2-4. However, this assumes a uniform monthly pattern of groundwater pumpage. During peak summer monthly demand periods, Trinity Aquifer pumping rates could be increased to meet the seasonal deficit, or water

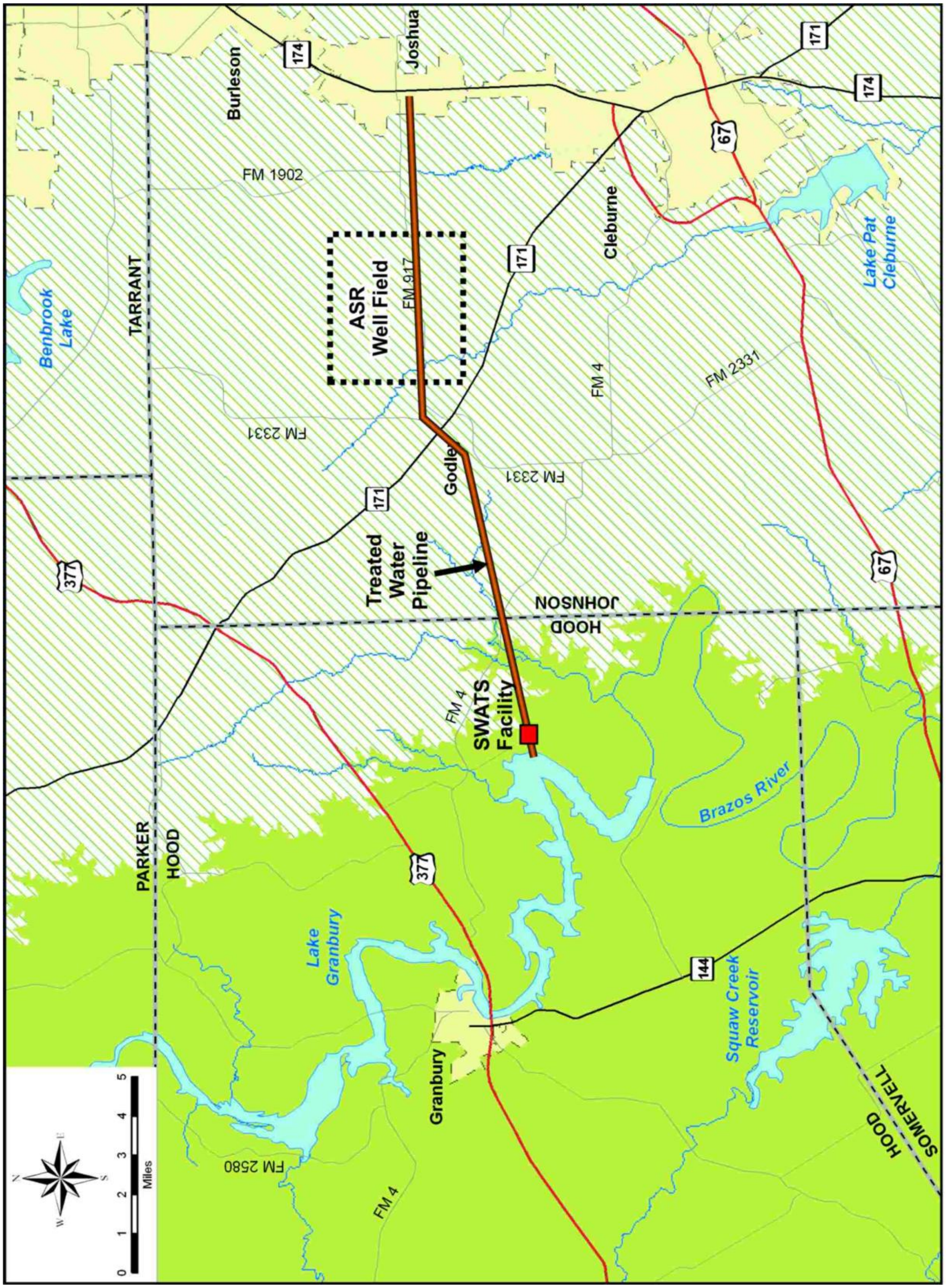

Figure 4B.8.2-1. Location of Johnson County ASR Project

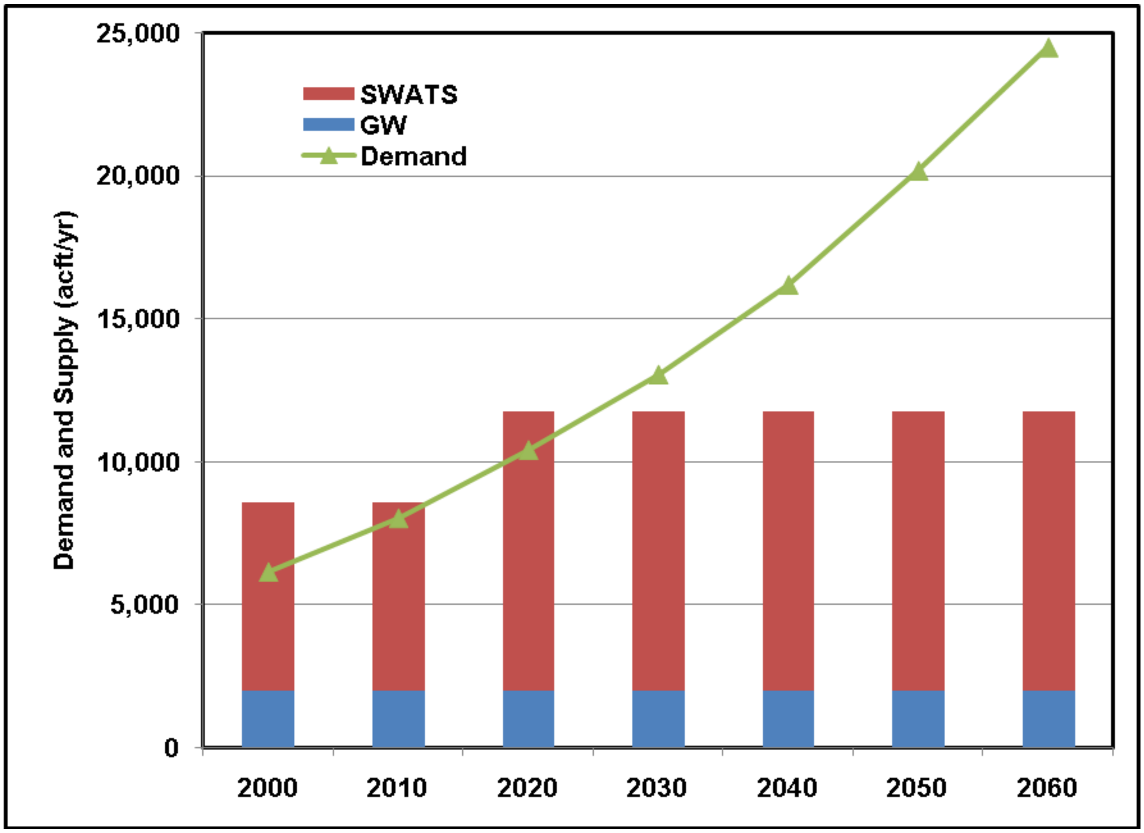

Figure 4B.8.2-2. Comparison of Johnson County SUD's Long-Term Water Demand and Existing Supplies

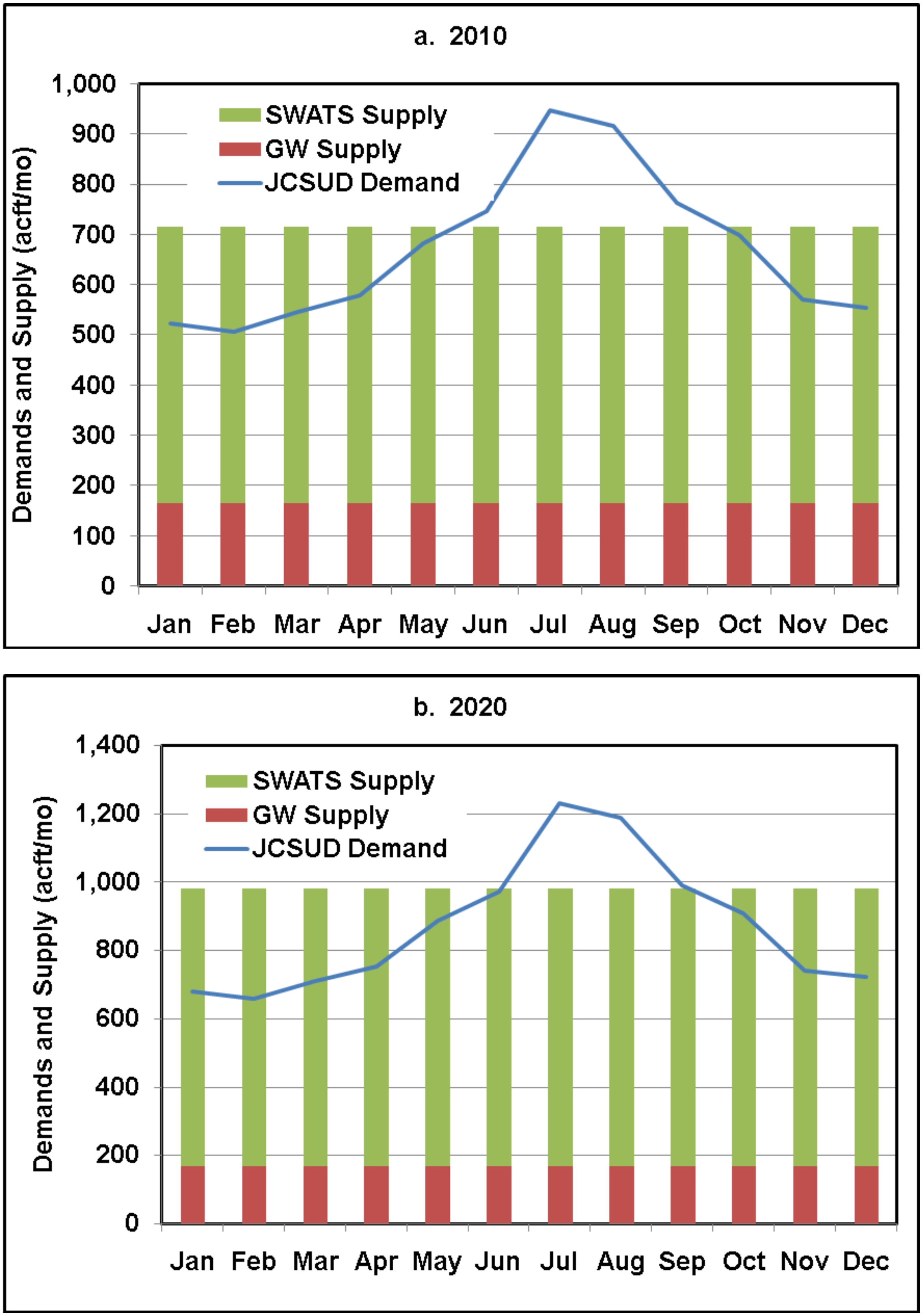

Figure 4B.8.2-3. Comparison of Johnson County SUD's Monthly Water Demand and Existing Supplies

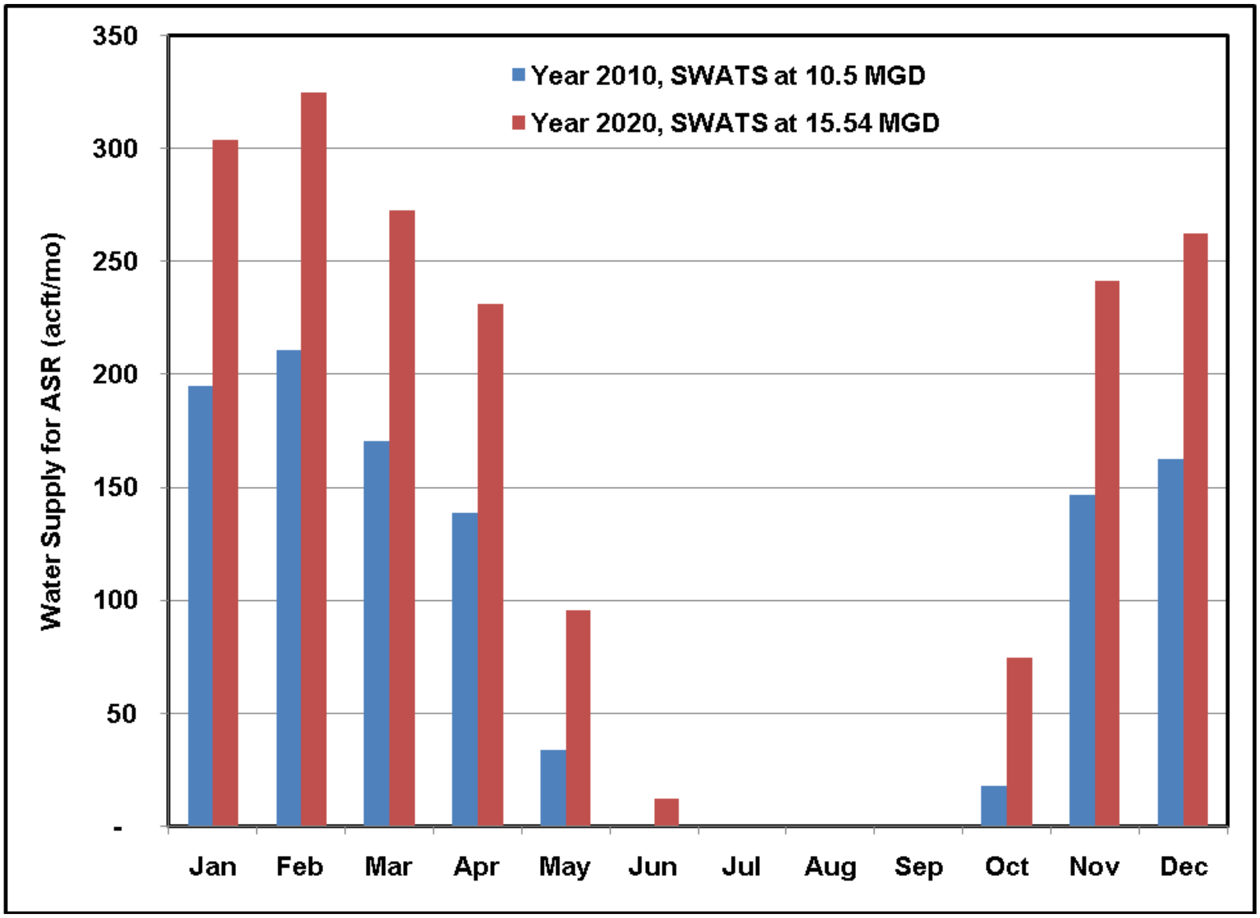

Figure 4B.8.2-4. Water Supply Availability for ASR in 2010 and 2020

recharged pursuant to this ASR project could be used. This analysis shows the total excess capacity of SWATS for JCSUD is 1,073 acft in 2010 and 1,815 acft in 2020. For operational purposes, the supply is limited to the minimum monthly supply from November-April. However, as shown in Figure 4B.8.2, the growth in annual water demands exceeds annual supplies before 2030.

The strategy is evaluated for two options. One is for 2010 conditions; and, the other is for 2020 conditions. The area selected for an ASR well field is located in the northeast part of the county between the towns of Godley and Joshua. For purposes of this study, it is assumed that SWATS water is chemically compatible with the Trinity Aquifer and native Trinity water.

4B.8.2.2 Available Yield

4B.8.2.2.1 <u>Trinity Aquifer System</u>

In Johnson County, the Trinity Aquifer system is composed of three sandy aquifer units that are confined and separated by relatively impermeable clay units. These aquifer units include, from youngest to oldest: the Paluxy, Hensell, and Hosston (Figure 4B.8.2-5). 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 County. 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 will be insignificant because the strategy for this project is to balance the injection and recovery of water stored from SWATS. In the short-term, the impact will be a noticeable, but temporary, rise in groundwater levels during the injection cycle and a similar decline during the recovery cycle.

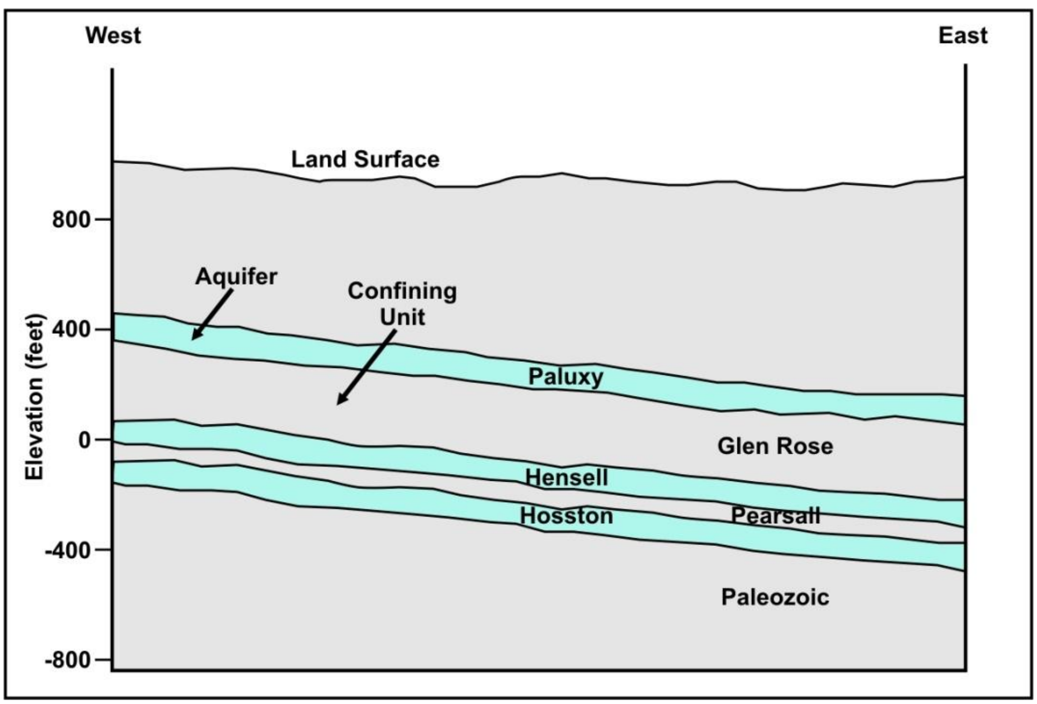

Figure 4B.8.2-5. Hydrogeologic Profile in ASR Well Field

4B.8.2.2.2 Potential Trinity ASR Well Field Design

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 test drilling and field testing program prior to implementation of an ASR system in the region.

Available records indicate that wells constructed in the area will average between 1,100 and 1,200 feet in depth. Based on existing wells in the area, the maximum injection and recovery rate of a well is about 250 gpm. Given these conditions, it is estimated that 8 wells, with a 10 percent contingency, is needed for the 2010 project, and 14 wells for the 2020 project. The ASR wells would be used for injection from November through April and for recovery from June through September. The wells would be idle for May and September. The well field design for the 2010 strategy has the wells spaced about 0.5 miles apart and parallel to the SWATS water transmission pipeline. For the 2020 strategy, the design divides the wells into two rows, one on each side of the pipeline and about 0.5 miles from the pipeline.

4B.8.2.2.3 Important Assumptions

Important issues relating to the applicability of a Johnson County ASR project include: (1) balanced annual injection and recovery cycles, (2) availability of suitable quality and quantity of water from SWATS, (3) the native aquifer water and imported water are chemically compatible, and (4) limited local groundwater use. Additional studies concerning compatibility of SWATS water and the Trinity Aquifer would need to be conducted to determine if the project is feasible.

4B.8.2.3 Environmental Issues

The development of ASR facilities in the Johnson County includes the construction of wells, collector pipelines, and water treatment facilities would involve relatively low environmental impacts:

- Operation of ASR wells is expected to have no effect on streams in the area; and
- Construction of wells, collector pipelines and pump station would have little or no effect on wildlife habitat or in disturbed areas. No streams or wetlands are expected to be encountered.

4B.8.2.4 Engineering and Costing

The ASR well field would be developed by constructing water wells capable of injection and recovery, well field pipelines for distribution and collection of water, terminal storage, and an interconnection. The well field is about midway between the towns of Godley and Joshua and is parallel to the SWATS pipeline, as shown earlier in Figure 4B.8.2-1. During the injection cycle, a terminal storage reservoir is needed to provide balancing storage between the pipeline and wells. The ASR (dual-purpose) wells would have to be constructed to public water supply standards. The wells would be spaced about 0.5 miles apart. Well pumps will be large enough to produce sufficient head to force the recovered water directly into the SWATS pipeline. The major facilities required for these options are:

- Well Field and interconnect to the SWATS pipeline along State FM 917:
  - Wells,
  - Pipelines,
  - Terminal Storage, and
  - Interconnect.

The project consists of two options. One is for the existing water treatment capacity of 10.5 MGD SWATS water plant, and the other is the expanded SWATS water plant with a capacity of 15.54 MGD, which is being considered for 2020. Considering the JCSUD water demands and the SWATS water treatment capacity, a system with a capacity to store and recovery 967 acft/yr for 2010 and 1,614 acft/yr for 2020 is planned. Water from the SWATS plant will only require operation and maintenance cost, which are estimated to be $1.15 per 1,000 gallons, because the debt service and raw water costs are part of existing contracts. There is sufficient existing capacity in the water transmission system from SWATS to JCSUD; thus, the only additional cost will be for power.

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 4B.8.2-1 for the 2010 and 2020 options. The annual costs, including debt service, operation and maintenance, and power, are estimated to be $1,500 per acft for the 2010 project and $1,512 per acft for the 2020 project. Later, as the JCSUD demand exceeds SWATS excess capacity, which will cause the amount of water available for ASR to decrease, the unit cost will increase.

Table 4B.8.2-1.
Cost Estimate Summary
Water Supply Project Option (Sept 2008 Prices)
Johnson County ASR Water Supply Project Option

Item	*2010 Project*	*2020 Project*
Capital Costs		
ASR Well Field (250 gpm, 1,200 ft deep wells)	$4,974,000	$8,705,000
Well Field Collector Pipelines (8-12 inch)	$882,000	$1,559,000
System Storage and Interconnections	$1,027,000	$1,454,000
Total Capital Cost	**$6,883,000**	**$11,718,000**
Engineering, Legal Costs and Contingencies	$2,409,000	$4,101,000
Environmental & Archaeology Studies and Mitigation	$302,000	$523,000
Land Acquisition and Surveying	$360,000	$623,000
Interest During Construction (1 years)	$399,000	$679,000
Total Project Cost	**$10,353,000**	**$17,644,000**
Annual Costs		
Debt Service (6 percent, 20 years)	$903,000	$1,538,000
Operation and Maintenance		
Intake, Pipeline, Pump Station	$69,000	$117,000
SWATS Water Treatment Plant	$311,000	$519,750
Pumping Energy Costs	$168,000	$266,000
Purchase of Raw Water	$0	$0
Total Annual Cost	**$1,451,000**	**$2,440,750**
Available Project Yield (acft/yr)	**967**	**1,614**
Annual Cost of Water ($ per acft)	**$1,500**	**$1,512**
Annual Cost of Water ($ per 1,000 gallons)	**$4.60**	**$4.64**

4B.8.2.5 Implementation

The ASR water management strategy described above has been compared to the plan development criteria, as shown in Table 4B.8.2-2, and the strategy meets each criterion. Implementation of the ASR water management strategy for Johnson County includes the following issues:

- Contractual arrangements can be made with the Brazos River Authority for an expansion of the SWAT facility;
- Permits from TCEQ for ASR operations and for storage of surface water in the Trinity Aquifer can be obtained;
- 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 injection and recovery cycles.

Table 4B.8.2-2.
Comparison of Johnson County ASR-Trinity Water Supply Project to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Improves balance of winter and summer demands
2. Reliability	2. High
3. Cost	3. Moderately expensive
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. None
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

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4B.9 Brush Control and Range Management

Brush control is a potential water management strategy that could possibly create additional water supply within the Brazos G Area. The Texas Brush Control Program, created in 1985 and operated by the Texas State Soil and Water Conservation Board (TSSWCB), serves to study and implement brush control programs in areas where brush is considered to be responsible for substantial water losses.

Brush control is a land management practice that converts land that is covered with brush, such as juniper and mesquite, to grasslands. The impact of these practices can increase water availability through reduced extraction of soil water for transpiration and increased recharge to shallow groundwater and emergent springs. To a lesser extent, there is the potential for increased runoff during rainfall and snowmelt events.

Research on brush control and water balance began in the 1920s, but the idea of brush control as a possible means of alleviating water scarcity in drought-prone western states started to take hold in the 1970s. Research and pilot studies have found that the control of brush species yields more water, but these increases are dependent upon rainfall variations and many other variables. To date, there has been mixed results regarding water production, but in general, the results indicate positive outcomes to carefully planned brush control.

One of the first studies on brush control was the federally sponsored Seco Creek Demonstration project in the Texas Hill Country. The findings from this study showed significant improvements in rangeland health and water quality and quantity of the underlying Edwards Aquifer. Following that study, significant state- support of brush control began with a feasibility study on the North Concho River Basin in 1998. Over the past 6 years, the State has authorized feasibility studies for the control of mesquite, juniper and mixed brush in 14 watersheds: North Concho, Main Concho, Twin Buttes/Lake Nasworthy, Upper Colorado, Canadian, Wichita, Pedernales, Edwards Aquifer, Nueces, Frio, Palo Pinto Lake, Lake Brownwood, Lake Phantom Hill and Lake Arrowhead. From these fourteen feasibility studies, three major state-supported brush control programs have been initiated in the North Concho, Upper Colorado and Pedernales River Basins. Each is administered by the TSSWCB.

In addition to State supported studies and programs, the Federal government, through the Corps of Engineers, is involved in brush control studies in the O.C. Fisher and Cibolo Creek watersheds. Both of these projects include brush control as part of environmental restoration and aquifer recharge enhancement efforts. Other efforts include salt cedar removal in the Colorado, Canadian and Pecos River Basins. Bio-control studies of salt cedar using Asian leaf beetles are also being conducted in these basins in conjunction with state and federal agencies.

Generally, brush control activities in Texas have been limited to feasibility studies with limited data collection from on-going brush programs. The results of the completed feasibility studies indicate increases in water production for all basins studied, with average annual water increases per acre treated ranging from 13,000 gallons in the Canadian Basin to 172,000 gallons in the Medina watershed (Edwards Aquifer). These calculations are based on comparisons of total water flow at the most downstream point of the watershed for conditions with and without brush. Estimates of long-term reliable supply from increased storage in reservoirs or aquifers are not reported in the studies.

The North Concho River Brush Control Project is one of the longer on-going brush programs in the state. From 1999 through 2003, over 207,000 acres of brush were cleared in the O.C. Fisher Reservoir watershed.[1] A total of 307,000 acres were targeted for removal by 2004. However, current drought conditions have limited removal efforts and basin-wide responses have been difficult to measure. In limited areas, the program is recording increased soil moisture after treatment and more frequent rainfall-runoff events, but it is difficult to assess the water supply benefits of brush control during drought. It appears that most of the water realized through brush removal is likely associated with increased soil moisture and/or contained in the shallow alluvial aquifer. There have been no significant increases in storage content in O.C. Fisher Reservoir since the program has been in place.

4B.9.1 Description of Brush Control Strategy

Virtually all of the renewable and sustainable water resources available for the Brazos G Area originate as precipitation within the boundaries of the region. The inflow from the upstream tributaries of the Brazos River is limited in amount and quality. The significant majority of this precipitation falls on agricultural lands, which includes crop land, improved pastures, improved range, native range, and other rural lands, such as rocky outcrops, heavy brush and trees, and other land that is not used for production. This water then infiltrates into the soil, runs off the land to nearby streams, or evaporates from localized ponding.

[1] Texas State Soil and Water Conservation Board, *Brush Control Program – 2003 Annual Report*, 2004.

Modification of the landscape has a significant impact on the partitioning of rainfall into runoff and infiltration, and ultimately the usability of this water. From a water yield standpoint, the ideal range (non-cropland) landscape has a good grass cover at all times of the year, whether the grass is alive or dormant. The grass retards surface runoff and allows more time for infiltration of the rainfall into the soil. The grass prevents sealing of the soil surface and the roots improve the soil structure, which also increases infiltration (water flow *into* the soil) and percolation (water flow *within* the soil). The active root zone of most grasses is easily within the top 3 feet of the soil, so the infiltrated soil water that is in excess to the storage capacity of the soil will percolate to the groundwater table. In aquifer outcrop areas, this percolation recharges the aquifer. If there is no aquifer, the shallow groundwater will emerge as springs and soil water movement into creek, stream, and river channels. This is the source of the highly desirable base flow of rivers that continuously recharge the reservoirs and provide wildlife habitat, livestock water, fish habitat, and recreational uses. Flash flood runoff does not contribute significantly to this base flow. The grass cover provides grazing for stock, which provides the economic incentive for the landowner to maintain the ranges in good condition.

The worst case from a water yield standpoint is a landscape that is covered with brush, such as juniper and mesquite. The grass cover is reduced under the brush (especially juniper) and, therefore, not fully effective in reducing runoff. The major impact of the brush, however, is the continuing extraction of soil water for transpiration long after the rainfall event has ended. Whereas most grasses have an effective rooting zone of 3 feet or less, mesquite can pull moisture from 10 to 20 feet and perhaps even more. Juniper is much shallower rooted, but will still extract moisture from below the grass root zone. Although each fair-sized shrub or small tree (10-foot diameter canopy) would only use 10 to 15 gallons of water a day, it would use the water every day and all of the water use for an area adds to a significant amount of groundwater consumed. Grass, with its much shallower root zone, is limited by the amount of soil water available for extraction.

Groundwater initially receives most of the additional water that is produced from brush removal, although surface water flows may be enhanced directly and indirectly following initial groundwater recharge. The rate of brush regrowth and brush control maintenance is important to maintaining stable, long-term water yield. Control methods that kill and remove the entire brush plant are more desirable than simply killing the brush. Water yield projections usually exceed actual results, and optimum results are achieved under optimum conditions.

There are three primary methods to remove upland brush: mechanical removal, chemical removal, and prescribed burning. Bio-control through Asian leaf beetles is limited to salt cedar removal, which generally occurs in riparian zones and lakes, and may be an option for some areas in the upper portion of the Brazos River. A brief description of each method is presented below.

4B.9.1.1 Mechanical Brush Control

A wide variety of mechanical brush control methods are available. The simplest is selective brush control with a hand axe and chain saw. Grubbing and piling is frequently done with a bulldozer. This may be either clear-cut or selective. Bulldozers and/or tractors may also be equipped with root plows, shears, or shredders. Two large bulldozers pulling large anchor chains stretched between them are capable of clearing low brush in swaths 100 foot or more in width at a time.

Moderate to heavy mesquite or cedar can be grubbed (bulldozer with a 3-foot-wide grubbing attachment) or root plowed for $100 to $165/acre. Two-way chaining can be effective on moderate to heavy cedar, but it often just breaks off mesquite and they re-sprout profusely from the bud zones below ground. Using hydraulic shears mounted on Bobcat loaders can be effective on blueberry juniper (a non-sprouting species) for a cost of $50 to $140/acre. If the shears are used on mesquite or redberry juniper one must spray the stump immediately with a herbicide, which will cost in the range of $0.10 to $0.30 per plant.

4B.9.1.2 Chemical Brush Control

Several herbicides are approved for brush control. The herbicides may be applied by applying a herbicide-water mixture from aircraft, from booms on tractor-pulled spray rigs, or from hand tanks. Some herbicides are also available in pellet form.

The herbicides Triclopyr (Remedy®) and Clopyralid methyl (Reclaim®) are approved herbicides for on-going TSSWCB brush programs. Arsenal is the herbicide typically used for removal of salt cedar. Chemical treatments with Remedy® and Reclaim® were shown to achieve about 70 percent root kill in studies around the state and in adjacent states. Commercial aerial applications in general are not as effective, which is most likely due to fewer controls. Timing is the key to successful chemical treatment. Soil temperature must be over 75°F at a depth of 12 to 18 inches, mesquite foliage must be dark green, and treatment is best conducted 42 to 63 days after bud break and 72 to 84 days after bud break. Other herbicide treatments are available, but many will achieve little root kill. Aerial spraying of brush such as mesquite costs about $25 per acre and is the same regardless of the plant density or canopy cover.

4B.9.1.3 Brush Control by Prescribed Burning

Prescribed burning is defined as the application of fire to a predetermined area. The burn is conducted under prescribed conditions of fine fuel load, weather, and season to specifically target desired effects. The purposes of prescribed burning include control or suppression of undesirable vegetation, to facilitate distribution of grazing and browsing animals, to improve forage production and/or quality, and to improve wildlife habitat.

Prescribed burning is estimated at $15 per acre for the TSSWCB programs. Actual costs will depend on how rocky the soils are and the amount of large brush to remove from the fire guards (i.e., a once-over pass with a maintainer versus clearing heavy brush with a bulldozer, then smoothing up the fire guard). Prescribed burning will only be effective under the right environmental conditions, and with an adequate amount of fine fuel (dead or dormant grasses). For successful burns, a pasture deferment is essential for part or all of the growing season prior to burning, and burned pastures must be rested after the burn. On average, a 12-month deferment is necessary, which may increase costs if a rancher cannot utilize the land for livestock grazing.

Burning rarely affects moderate to heavy stands of mature mesquite. Burning only topkills the smooth-bark mesquite plants, and they re-sprout profusely. For mesquite, fire only gives short-term suppression, and stimulates the development of heavier canopy cover than was present pre-burn. Burning is not usually an applicable tool in moderate to heavy cedar (juniper) because these stands suppress production of an adequate amount of grass for fine fuel. Burning can be excellent for controlling junipers over 4 feet tall, if done correctly. Prescribed burning is often not recommended for initial clearing of heavy brush due to the concern that the fire could become too hot and sterilize the soil. Burning is often used for maintenance of brush removal.

4B.9.1.4 Bio-Control of Brush

Bio-control of salt cedar is a relatively new technique to be used in Texas. This control method has been studied for nearly 20 years and there have been pilot studies in the Lake

Meredith watershed and most recently in the Colorado River Basin[2]. Research has shown that the Asian leaf beetle can consume substantial quantities of salt cedar in a relatively short time period, and generally does not consume other plants. Different subspecies of the Asian beetle appear to be sensitive to varying climatic conditions, and there is on-going research on appropriate subspecies for Texas. It is recommended that this control method be integrated with chemical and mechanical removal to best control re-growth. The cost per acre is unknown.

4B.9.1.5 Range Management for Brush Control

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.

4B.9.2 Brush Control in the Brazos G Area

In 1985, the TSSWCB in conjunction with the Texas Water Development Board developed a list of water supply reservoirs where brush control could possibly enhance water supplies.[3] This list was updated in 2001; 27 existing reservoirs, one potential new reservoir site and two river segments in Region G were identified as potentially benefiting from brush control. The complete list as included in the State Brush Control Plan is shown in Table 4B.9-1.

Considering these potential sources, the TSSWCB has sponsored two brush removal feasibility studies in the Brazos G Area including the Lake Fort Phantom Hill watershed[4] and Lake Palo Pinto watershed.[5] In addition, an independent study is currently being conducted in the Leon River watershed. This project, which includes federal and state participation, focuses on brush removal in Hamilton and Coryell Counties, upstream of Belton Lake.[6,7]

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[2] Colorado River Municipal Water District, *Annual Report*, 2003.

[3] Texas State Soil and Water Conservation Board, *State Brush Control Program*, 2003 Annual Report. http://www.tsswcb.state.us/programs/brush.html

[4] Brazos River Authority, *Fort Phantom Hill Reservoir Watershed, Brush Control Assessment and Feasibility Study*, prepared for the Texas State Soil and Water Conservation Board, 2003a.

[5] Brazos River Authority, *Palo Pinto Reservoir Watershed, Brush Control Assessment and Feasibility Study*, prepared for the Texas State Soil and Water Conservation Board, 2003b.

[6] Kiel, Simone, of Freese and Nichols, Inc., Memorandum documenting telephone conversation with Steve Manning, Central Texas Cattleman's Association, regarding the Leon River Restoration Project, December 11, 2003.

[7] Kiel, Simone, of Freese and Nichols, Inc., Memorandum documenting telephone conversation with Wayne Hamilton, Texas A&M, regarding the Leon River Project, January 20, 2004.

Table 4B.9-1.
Brazos G Water Supply Sources Identified in the State Brush Control Plan that Could Benefit from Brush Control

County	*Reservoir*	*Water Course*	*User*	*Comments*
Baylor	Miller's Creek	Miller's Creek	N. Central Texas MWA	Not more than 20% canopy
Bell	Lake Belton	Leon River	Bell Co. WCID	
Bosque	Bosque River	Bosque River	Meridian	
Bosque	Bosque River	Bosque River	Clifton	Proposed reservoir
Callahan	Lake Baird	Mexia Creek	Baird	
Callahan	Lake Clyde	N. Prong Pecan Bayou	Clyde	Brownwood Study - 2002
Eastland	Lake Cisco	Sandy Creek	Cisco	
Erath	Bailey's Lake	Kickapoo Creek	Lipan	
Erath	Thurber Lake	Gibson Creek	Thurber	Palo Pinto Study - 2002
Falls	Lake Marlin	Big Sandy Creek	Marlin	
Falls	Lake Rosebud	Pond Creek Tributary	Rosebud	
Hamilton	Proctor	Leon River	Hamilton	
Haskell	Lake Stamford	Paint Creek	Stamford	
Johnson	Lake Pat Cleburne	Nolan River	Cleburne	
Jones	Ft. Phantom Hill	Elm Creek	Abilene	Ft. Phantom Hill Study - 2002
Nolan	Lake Trammel	Sweetwater Creek	Sweetwater	
Nolan	Lake Sweetwater	Bitter Creek	Sweetwater	
Palo Pinto	Palo Pinto	Palo Pinto Creek	Palo Pinto MWD	Palo Pinto Study - 2002
Palo Pinto	Lake Mingus	Gibson Creek	Mingus	Palo Pinto Study - 2002
Palo Pinto	Tucker Lake	Russell Creek	Strawn	Palo Pinto Study - 2002
Shackelford	McCarty Lake	Salt Prong Hubbard Creek	Albany	
Somerville	Paluxy River	Paluxy River		
Stephens	Lake Daniel	Gonzales Creek	Breckenridge	Base flow decline
Stephens	Hubbard Creek	Hubbard Creek	W. Central Texas MWD	
Taylor	Lake Abilene	Elm Creek	Abilene	Ft. Phantom Hill Study - 2002
Taylor	Lake Kirby	Cedar Creek	Abilene	Ft. Phantom Hill Study - 2002
Taylor	Lake Lytle	Lytle Creek	Abilene	Ft. Phantom Hill Study - 2002
Williamson	Lake Georgetown	N. Fork san Gabriel	Brazos RA	
Young	Lake Graham	Salt Creek	Graham	
Young	Lake Whiskey Creek	Whiskey Creek	Newcastle	

The feasibility studies sponsored by the TSSWCB are modeling studies, while the Leon River Project includes the collection of field data for pre- and post-brush removal conditions. The data from the Leon River Project will be used to help quantify the impacts of brush removal; however, the data are not yet available. At this time, the best predictive tools available for evaluating a potential brush removal project are modeling studies utilizing the Soil and Water Assessment Tool (SWAT) model developed by the USDA Agricultural Research Service. The model simulates the change of brush into native grass and calculates new water yields after brush is removed over the simulation period from 1960 to 1999. The term “water yield” in the study reports represents average annual increases in stream flow measured at the most downstream point in the model and average annual recharge to aquifers.

This is different from the term “yield” that is used to describe the reliable supply from a reservoir or a stream. Reservoir yields were not determined in the TSSWCB-sponsored studies. To clarify this difference, the term “water production” will be used in this memorandum to describe results from the TSSWCB studies and the term “yield” will be used in discussing supply from a reservoir.

4B.9.3 TSSWCB Brush Control Feasibility Studies

The studies for the Lake Fort Phantom Hill and Lake Palo Pinto watersheds were conducted during fiscal years 2001 and 2002. Hydrologic, climate, soils, and vegetation data were collected for each watershed. These data were used to develop and calibrate the SWAT model. While calibration of the hydrologic portion of the SWAT model showed long-term mean correlation with downstream gages over selected time periods, there were some significant differences in monthly flows. Monthly flows particularly during drought periods are critical when determining increases in reservoir yield. Other assumptions in parameter selection and interactions between surface and groundwater also impact the modeling results.

The SWAT model for each watershed assumed 100 percent removal of heavy and moderate categories of brush. The removal of light brush was not modeled. Results show that average water production within these watersheds will increase with the implementation of brush managements programs. Water production during drought conditions is expected to be less. For Lake Fort Phantom Hill, the drought of record in the 1950s was not included in the simulation.

According to the Feasibility Study Report, data from 1950 through 1957 were not included because the drought of record during this time period skewed the data.[8]

Costs were developed as part of the feasibility studies for different methods of brush removal, which include initial brush removal and maintenance for 10 years. The most economical method as appropriate for the type of brush was used for cost estimating purposes. Costs were not developed for improved infrastructure to utilize the increased water production. The costs reported in this summary were obtained from the feasibility reports, and include landowner costs and State participation.

In the Lake Fort Phantom Hill study, 138,396 of the total 301,118 acres of the watershed were assumed to be treated during the simulation period. Model results showed implementing a brush control program could potentially increase the average annual water production by 111,000 gallons of water per acre treated.[7] This is equivalent to an additional average annual water production of 0.34 acre-feet per treated acre or an increase in water production in the entire watershed of 44,385 acre-feet per year. Treatment costs were estimated to range between $35.57 and $143.17 per acre depending on the brush type and treatment employed. Total costs for the program, with full implementation, were estimated at approximately $14.3 million with an assumed State participation cost share of $10.2 million. The cost per acre-foot of additional water production is estimated at $41.45. This includes both landowner and State participation costs. Landowner costs are estimated at an average of $30 per treated acre.[9] These costs, however, cannot be compared to costs for supply from additional reservoir yield.

For the Lake Palo Pinto watershed, there were similar findings. Calibration of the hydrologic portion of the SWAT model had varied results. There are no USGS monitoring stations historically or presently in operation upstream of Lake Palo Pinto, which provided little baseline data for model calibration. Considering these uncertainties, the study found that brush removal would generate an average annual water production of 0.55 acre-feet per treated acre. Assuming 139,425 of the total 296,400 acres of the Palo Pinto watershed were treated, the total

[8] Brazos River Authority, *Fort Phantom Hill Reservoir Watershed, Brush Control Assessment and Feasibility Study*, prepared for the Texas State Soil and Water Conservation Board, 2003a

[9] Brazos River Authority, *Fort Phantom Hill Reservoir Watershed, Brush Control Assessment and Feasibility Study*, prepared for the Texas State Soil and Water Conservation Board, 2003a

increase in water production would be 76,330 acre-feet per year. Treatment costs for the Palo Pinto watershed were estimated at $35.57 to $173.17 per acre. The cost share portion for landowners ranged from $17.09 per acre for treatment of moderate mesquite to $37.20 per acre for control of heavy Post/Shimmery Oak. The estimated total cost for the program is $18.2 million. This includes an assumed State participation cost of $14.3 million and landowner cost of $3.9 million. The total cost per acre-foot of additional water production is estimated at $30.65.[10]

4B.9.4 Potential Brush Control Project

Based on the findings of the feasibility studies and the high ranking by the TSSWCB, the Lake Fort Phantom Hill watershed was selected to evaluate the potential water supply benefits of a brush project in the watershed. This evaluation includes assumptions of landowner participation, brush removal percentages within each subbasin, and an assessment of increased monthly inflows to Lake Fort Phantom Hill.

While landowner support is assessed as high by the TSSWCB, the levels of participation assumed in the TSSWCB study (100 percent) will probably not be realized. Actual participation and removal percentages most likely will be less. For this project it was assumed that landowner participation would be approximately 50 percent of the total watershed. Subbasins with the highest amount of water generated from brush removal per acre were targeted for inclusion in the project. It was also assumed that 75 percent of the brush within the targeted subbasins would be removed. The subbasin data were obtained from the feasibility study and are shown in Table 4B.9-2.

To assess the potential water supply benefits, the SWAT model outputs for conditions with brush and without brush were obtained from the Blackland Research Center.[11] Monthly stream flows were extracted from the output files for both conditions. The differences in inflows between the brush and no brush simulations from SWAT were calculated. These increases in inflows were adjusted based on water production per acre treated to reflect a smaller project

[10] Brazos River Authority, *Palo Pinto Reservoir Watershed, Brush Control Assessment and Feasibility Study*, prepared for the Texas State Soil and Water Conservation Board, 2003b.

[11] Rosenthal, Wesley, Blackland Research Center, Texas A&M University. Reach files for SWAT model for Lake Fort Phantom Hill, e-mail correspondence to Simone Kiel, January 15, 2004.

scope. The "with brush" and adjusted "no brush" inflows were then input into a reservoir operation model to assess the potential increase in reservoir yield. The reservoir operation model computes the available supply through a mass-balance evaluation, considering inflows, reservoir area-capacity data, reservoir surface evaporation, and diversions. A monthly time step was used for the simulation.

Table 4B.9-2.
Subbasins Targeted for Potential Brush Control Project

Subbasin[1]	Total Area (acres)	Total Brush Area (acres)	Treated Brush (acres)	Increase in Water Yield (gal/ac/yr)
1	2,540	537	403	238,892
8	68	28	21	123,145
15	36,789	24,241	18,181	119,368
2	12,087	3,735	2,801	118,572
3	4,451	1,114	836	112,286
10	27,797	12,690	9,518	111,254
5	30,985	9,356	7,017	109,228
9	11,914	5,931	4,448	109,046
4	453	149	112	108,484
6	21,928	7,275	5,456	106,471
16	28,340	19,218	NI	104,404
14	23,069	12,073	NI	102,331
17	8,803	6,102	NI	97,874
7	12,483	4,431	NI	92,874
12	28,282	11,245	NI	91,332
11	38,084	14,597	NI	85,206
13	13,045	5,672	NI	82,080
Total - Watershed	301,118	138,394		1,912,847
Total - Project	149,012	65,056		1,256,746

[1]Listed in order of water production
NI – Not included in potential brush control project.

In this study, the "with brush" simulation is considered the baseline current condition. With these assumptions, the firm yield of Fort Phantom Hill with brush (using SWAT inflows) is 12,360 acre-feet per year. After implementing the brush control project, the firm yield of the reservoir is projected to be 15,000 acre-feet per year, an increase of 2,640 acre-feet per year. Diversions from the Clear Fork and Deadman Creek were not included in the study. The potential increase in reservoir yield that was computed is due solely to increases in watershed production.

Costs were assessed using the cost estimates developed for the feasibility study. These costs are based on the type of brush and removal methodology, and are unique to each subbasin. The total cost for the project as shown in Table 4B.9-3 was estimated at approximately $5 million. This includes costs typically attributed to the landowner, as well as State participation costs. To assess the cost per acre-foot of water generated from the brush control project, the total cost was amortized over a 10-year period at an annual interest rate of 6 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. With these assumptions, the cost per acre-foot of additional raw water in the lake is $257. Additional cost to maintain the level of brush removal will be needed after ten years. Cost per acre-foot of water may be less in subsequent decades if only maintenance activities are required.

Table 4B.9-3.
Costs for Potential Brush Control Project

Subbasin	*Treated Brush Area (acres)*	*State Cost per Treated Acre*	*State Cost*	*Estimated Rancher Cost*[1]	*Total Cost*
1	403	$59.38	$23,916	$11,277	$35,193
2	2,801	$59.62	$167,018	$78,435	$245,453
3	836	$62.71	$52,398	$23,394	$75,792
4	112	$72.68	$8,122	$3,129	$11,251
5	7,017	$64.36	$451,640	$196,476	$648,116
6	5,456	$78.62	$428,973	$152,775	$581,748
8	21	$82.71	$1,737	$588	$2,325
9	4,448	$82.50	$366,992	$124,551	$491,543
10	9,518	$73.43	$698,906	$266,490	$965,396
15	18,181	$78.78	$1,432,211	$509,061	$1,941,272
Totals	48,792		$3,631,913	$1,366,176	$4,998,089
Annual cost (amortized over 10 years)					$679,080
Increase in Safe Yield (acft/yr)					1,390
Cost/acft of water					$489
Cost/1,000 gal. of water					$1.50

[1]Rancher costs were estimated at $28 per acre. This corresponds to 20 to 30 percent of the total cost per acre. Recent changes to the brush control program rules limits State participation to 70 percent

The Brazos G RWPG has recommended that water supplies for reservoirs above Lake Possum Kingdom be evaluated on a safe yield basis. Using these guidelines, the increase in safe yield of Lake Fort Phantom Hill that is associated with a potential brush control program is 1,390 acre-feet per year. The total cost of the program remains the same, which results in a raw water cost of $489 per acre-foot or $1.50 per 1,000 gallons.

4B.9.5 Comparison of Findings to Other Studies

The SWAT model output under the "with brush" conditions should be similar to the inflows determined by the Brazos G WAM (Volume I, Section 3.2.1) under natural order analysis, i.e., not adhering to prior appropriation doctrine. Comparisons of the SWAT output to the WAM inflows found that the SWAT model underestimated the inflows into Lake Fort Phantom Hill in most years. The cumulative difference over time is about 339,000 acre-feet, which is shown on Figure 4B.9-1. Using the WAM inflows over the same period of record (1960-1997, with extended data for 1998 and 1999), the reservoir yield for Lake Fort Phantom Hill is 17,000 acre-feet per year. Recent data indicate that a new drought of record began in 1997 in the watershed. For the SWAT model inflows, the drought of record is in 1974, with other times of low content in 1981 and 1986. Application of the WAM through the drought of record period in the 1950s reduces the computed yield to 12,100 acre-feet per year.

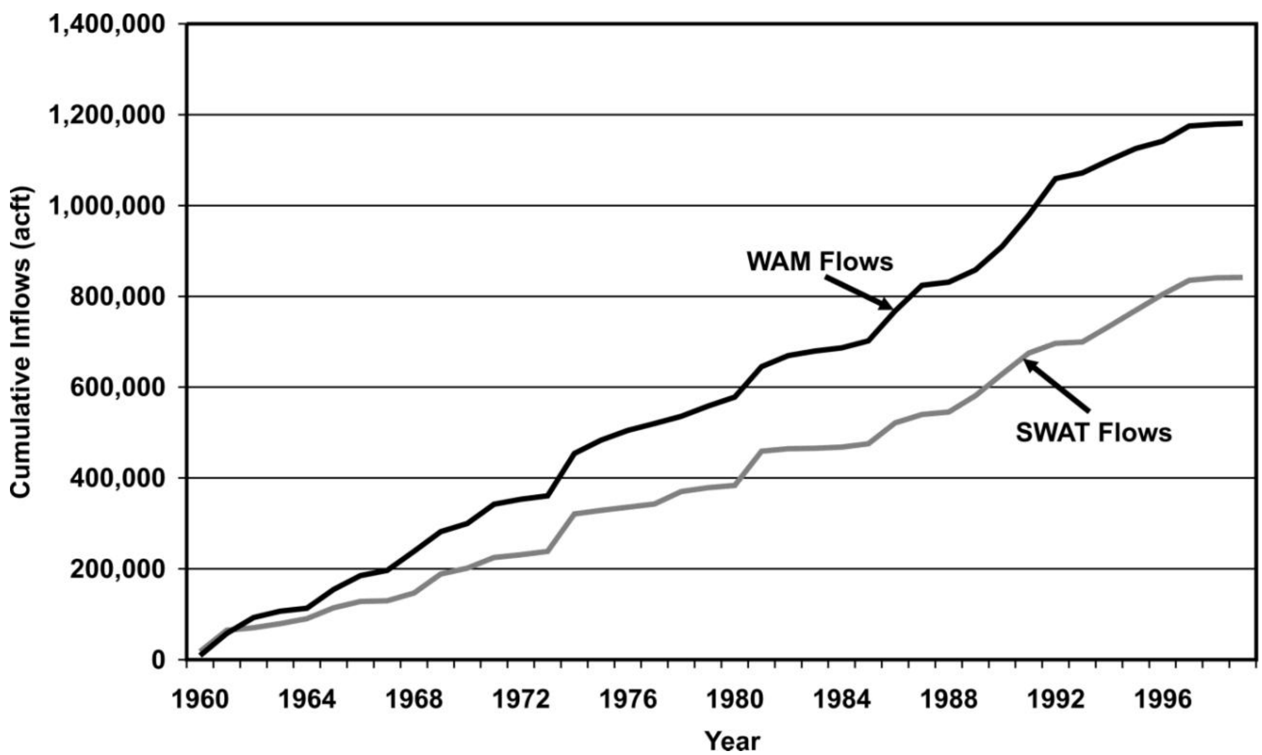

Figure 4B.9-1. Fort Phantom Hill Reservoir Cumulative Inflow Comparison

These factors indicate that the potential increase in reservoir yield would be less than indicated by the SWAT model because the SWAT model does not include the historical drought of record of the 1950s, or the potential new drought of record that started in the late 1990s. Increased inflows from brush removal during drought may be minimal and have little to no impact on firm available water supplies, except the initiation of drought flows would be somewhat delayed to the extent that additional water would be temporarily stored in shallow soils and aquifers and subsequently discharged to streams. Not until brush control has been completed within a basin and data have been collected for a sufficient length of time can the water supply benefits be truly quantified.

4B.9.6 Environmental Impacts of the Potential Brush Control Project

The central and western portions of the Lake Fort Phantom Hill Watershed Brush Control Study Area are within the Edwards Plateau Ecological Region, while the northern and eastern portions of the study area are within the Rolling Plains Ecological Region.[12] The physiography of the study area includes recharge sands, massive limestone, caliche with some soil cover, severely eroded lands, and undissected red beds.[13] Topography varies from rough, rolling hills to nearly level terrain. Soil types are diverse. The Tarrant-Tobosa association comprises well-drained upland soils that are very shallow to steep. These soils include very shallow to deep calcareous, clays 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.[14] Major aquifers that may be minimally represented in the study area include the Edwards-Trinity Aquifer in the western portion and the Trinity Aquifer in the eastern portion.[15] Climate is characterized as subtropical, sub humid, with hot summers and dry winters. Average annual precipitation ranges between 23 and 25 inches.[16]

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[12] 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.

[13] 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.

[14] Soil Conservation Service. *Soil Survey of Taylor County, Texas*. U.S. Department of Agriculture Soil Conservation Service, 1976.

[15] Texas Water Development Board. *Major Aquifers of Texas, 1990*. A map.

[16] Larkin, T.J., and G.W. Bomar. *Climatic Atlas of Texas*. Texas Department of Water Resources LP-192, 1983.

Vegetation and resulting wildlife habitats within these ecological regions have been greatly affected by anthropogenic factors 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 from the suppression of wild fires and intensive livestock grazing. Three major vegetation types now occur in the study area,[17] these include: Mesquite (*Prosopis glandulosa*)-Lotebush (*Ziziphus obtusifolia*) Shrub, Mesquite-Juniper (*Juniperus spp*.) Shrub, and Mesquite-Juniper-Live Oak (*Quercus fusiformis*) Brush. 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. Other major cover types include crops and developed urban areas. Major land uses in the area include cattle ranches and farms, oil fields, hunting leases, and minerals. [18]

A number of vertebrate species would be expected to occur within the study area as indicated by county occurrence records.[19] These include 1 species of salamander, 14 species of frogs and toads, 7 species of turtles, 12 species of lizards, and 34 species of snakes. Additionally, 79 species of mammals could occur within the study area or surrounding region[20] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the study area but with distributions and population densities limited by the types and quality of habitats available.

A total of 26 species could potentially occur in the study area that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern. This group includes 4 reptiles, 14 birds, 5 mammals, 1 fish species, and 2 plants (Table 4B.9-4). Five bird species and one mammal are federally-listed as threatened or endangered that could occur (or historically occurred) in the study area. These include the bald

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[17] 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.

[18] 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.

[19] Texas A&M University. *Texas Cooperative Wildlife Collection*. http://wfscnet.tamu.edu/tcwc/tcwc.htm Incorporates online checklists of amphibians and reptiles for counties based on information contained in: Dixon, J.R., and R.K. Vaughan. 1987. *Amphibians and Reptiles of Texas*. Texas A&M University Press. College Station Texas, 1998.

[20] Texas Tech University. *The Mammals of Texas – Online Edition*, 1997. http://www.nsrl.ttu.edu/tmot1/distribu.htm Incorporates information contained in: Davis, W.B., and D.J. Schmidly. 1994. *The Mammals of Texas*. Texas Parks and Wildlife Department. Austin, Texas.

Table 4B.9-4.
Federal and State-Listed Species, Candidate and Proposed Species for Listing, and Species of Concern for Counties in Fort Phantom Hill Brush Control Study Area

Scientific Name	Common Name	Federal/State Status	Callahan County	Jones County	Nolan County	Taylor County
Birds						
Falco peregrinus anatum	American Peregrine Falcon	DL/E	M	M	M	M
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	M	M	M	M
Ammodramus bairdii	Baird's Sparrow	SOC		M	M	M
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	M	M	M	M
Vireo atricapillus	Black-capped Vireo	LE/E	NM		NM	NM
Buteo regalis	Ferruginous Hawk	SOC		M	M	M
Sterna antillarum athalassos	Interior Least Tern	LE/E	M	M	M	M
Tympanuchus pallidicinctus	Lesser Prairie Chicken	C/SOC		R	R	
Charadrius montanus	Mountain Plover	PT/SOC	M	M	M	M
Charadrius melodus	Piping plover	FT w/CH	M	M	M	M
Charadrius aleMandrinus	Snowy Plover	SOC		M	M	
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	R	R	R	
Grus americana	Whooping Crane	LE/E	M	M	M	M
Buteo albonotatus	Zone-tailed Hawk	SOC/T				NM
Fishes						
Notropis buccula	Smalleye Shiner	C/SOC				R
Mammals						
Mustela nigripes	Black-footed Ferret	LE/E		R1	R1	
Cynomys ludovicianus	Black-tailed Prairie Dog	C/SOC		R	R	R
Myotis velifer	Cave Myotis Bat	SOC	R	R	R	R
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	R	R	R	R
Vulpes velox	Swift Fox	SOC		R	R	
Reptiles						
Nerodia harteri	Brazos Water Snake	SOC/T		R		
Holbrookia lacerata	Spot-tailed Earless Lizard	SOC				R
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	R	R	R	R
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	R	R	R	R
Plants						
Chamaesyce jejuna	Dwarf broomspurge	SOC			R	
Hexalectris warnockii	Warnock's coral root	SOC				R

Notes:

Federal Status: LE-Listed Endangered; LT-Listed Threatened; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations.)

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas.

Type of Occurrence: R - Resident; NM – Potential Nesting Migrant; M – Migrant, R1 – Historically occurred but now extirpated.

Source: Texas Parks and Wildlife Department, Texas Biological and Conservation Data System (TBCDS) 2004.

eagle (*Haliaeetus leucocephalus*), black-capped vireo (*Vireo atricapillus*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), whooping crane (*Grus americana*), and black-footed ferret (*Mustela nigripes*). The bald eagle, interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the area, but would not likely be directly affected by brush control practices. The black-footed ferret historically occurred in prairie dog towns, but is thought to be extirpated throughout its historical range in Texas.

Impacts of brush control could directly affect the black-capped vireo that nests in brush communities about 6 feet in height with about 30 to 60 percent canopy coverage.[21]

Impacts of brush control can positively or negatively affect the environment depending on the type of control method used, location, and extent of application. If brush removal is planned and implemented as part of a comprehensive range management strategy and is consistent with Section 5.5.3, Wildlife Considerations, of the State Brush Control Plan,[22] very positive environmental benefits can result. Properly planned and applied brush control using mechanical, chemical, or prescribed fire can enhance soil conditions, increase water tables, provide greater streamflow thus improving water quantity and quality, provide higher energy and nutrient inputs, increase vegetation diversity, and enhance the quality of wildlife habitat with resulting higher abundance and diversity of wildlife species. However, removal of established of brush on uplands or removal of riparian woody vegetation along stream courses without consideration of a comprehensive long term management strategy can be detrimental to wildlife and associated habitats. Other adverse impacts could occur depending on the type of control method employed.

Mechanical treatment using mechanized equipment to root plow, brush mow, bulldoze or scrape the ground surface could result in moderate to high levels of soil disturbance that could result in erosion and sedimentation into adjacent streams and water bodies. There would also be a change in vegetation communities toward earlier succession species. Soil disturbance would favor both re-establishment of both grasses and forbs (herbaceous) in addition to re-invasion of

[21] Campbell, Linda. *Endangered and Threatened Animals of Texas*. Texas Parks and Wildlife Department, Endangered Resources Branch, Austin, Texas, 1995.

[22] Texas State Soil and Water Conservation Board. *State Brush Control Plan*, 2002. http://www.tsswcb.state.tx.us/reports/brushplan2001.pdf

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. However, cultural and archeological surveys are not required for private property included in the State Brush Program. Some federal cost sharing programs may require archeological surveys.

The State Brush Program requires all participants to follow recommended practices in the application of herbicides. The two most commonly used herbicides in the State Program are Triclopyr (Remedy®) and Clopyralid methyl (Reclaim®). Both 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. Remedy® is toxic to aquatic organisms, while the toxicity of Reclaim® to birds, mammals and fish is low. A number of other herbicides are also toxic to aquatic life. There could also be effects to non-target plant species from broadcast applications.

The use of prescribed fire provides many ecological benefits. Historically, prairie wild fires were a major factor is suppressing invasion of woody vegetation among the prairie grassland communities. Other benefits include increased soil fertility through release of organic nutrients, stimulated growth of new plant material, and greater diversity of herbaceous plants tolerant to fire. Prescribed fire could adversely affect other vegetation such as damaging or killing established trees not intended for treatment, can be difficult to control if applied during the wrong season or during improper weather conditions, and could affect air quality regulated under federal and state laws. Environmental impacts are summarized in Table 4B.9-5.

4B.9.7 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 State Brush Control Plan. 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

Table 4B.9-5.
Environmental Impacts of Brush Control in Fort Phantom Hill Study Area

Type of Control [1]	*Implementation Measures*	*Aquatic Environments*	*Bays, Estuaries, Arms of Gulf of Mexico*	*Wildlife Habitat*	*Threatened/ Endangered Species*	*Cultural Resources*	*Threats to Natural Resources*
Mechanical	Removal of woody vegetation using mechanized equipment, e.g. root plowing, chaining, or brush mowing.	Possible moderate increase of in-stream flow from increased water yields in watershed with substantial removal[2].	No impact assuming any increase in streamflow is captured in downstream reservoirs.	High positive or negative impacts, depending on extent, timing, and location of removal; Positive impacts possible when properly planned & conducted according to Section 5.5.3 of the State Brush Control Plan.	Possible high positive or negative impacts to black-capped vireo nesting habitat, depending on extent, timing and location of removal.	Low adverse impacts from chaining & brush mowing; Moderate to high adverse impacts likely from root plowing, dozing or scraping.	Could mitigate declining water quantity & quality through increased streamflow, if properly applied.
Chemical	Removal of woody vegetation using application of herbicides.	Possible moderate increase of in-stream flow from increased water yields in watershed with substantial removal[2]. Variable impacts to aquatic organisms depending on toxicity of herbicide, and level of concentration to aquatic habitats[3].	No impact assuming any increase in streamflow is captured in downstream reservoirs.	High positive or negative impacts, depending on extent, timing, and location of applications and removal; Positive impacts possible when properly planned and conducted according to Section 5.5.3 of the State Brush Control Plan.	Possible high positive or negative impacts to black-capped vireo nesting habitat depending on extent, timing and location of removal.	Minimal or No Adverse Impacts.	Could mitigate declining water quantity & quality through increased streamflow, if properly applied.
Prescribed Fire	Removal of herbaceous and woody vegetation with managed, controlled fire.	Possible moderate increase of in-stream flow from increased water yields in watershed with substantial removal[2].	No impact assuming any increase in streamflow is captured in downstream reservoirs.	Generally moderate to high positive impacts to wildlife habitat.	Possible high positive or negative impacts to black-capped vireo nesting habitat depending on extent, timing and location of removal.	Minimal or No Adverse Impacts.	Could mitigate declining water quantity and quality through increased streamflow. Improved rangeland, if properly applied.

[1]Includes those practices eligible for cost-sharing under the State Brush Control Plan (2002).
[2]Studies show water yield maximized only through extensive control reducing brush coverage to less than 15 percent (Thurow, T.L., A.P. Thurow, and M.D. Garcia. "Policy prospects for brush control to increase off-site water yield." J. Range Manage. 53: 23-31, January 2000.)
[3]Many herbicides are toxic to fish and other aquatic organisms

wildlife and how the brush control will affect the value of the land for wildlife recreation purposes. In recent years, the value of ranch lands which have sufficient brush cover to support wildlife populations, particularly white-tailed deer, wild turkey, bobwhite and scaled quail, has increased at a faster rate than the value of those lands which are void of brush or woody vegetation. Consequently, many landowners can be expected to support brush control to the extent that it does not exclude wildlife populations.

Other implementation issues for land owner participation include the perceived economic benefit of brush control. If the land is currently not actively managed for ranching or wildlife recreation the owner may chose not to participate. Decreased profitability of sheep, goat and cattle grazing systems will influence the economics of brush control by ranchers, and consequently their willingness to participate. Research by Thurow, et al.[23] found that only about 66 percent of ranchers surveyed were willing to enroll their land in a similarly characterized program. Also, the size of the land tracts can affect the total amount of brush removed and the effectiveness of a program. Watersheds that contain many small tracts are less likely to have contiguous land owner participation that is needed to realize the water supply benefits associated with brush control.

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.[24] There may also be local and county regulations associated with burning practices.

No land acquisition or relocations would be required for this water management strategy.

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[23] Thurow, A., T. Thurow, and M. Garriga, "Modeling Texas Ranchers Willingness to Participate in a Brush Control Cost-Sharing Program to Improve Off-Site Water Yields," Journal of Agricultural and Resource Economics, (Manuscript submitted, Department of Rangeland Ecology and Management, Texas A&M University, College Station, TX), 1998.

[24] Texas Commission on Environmental Quality. Control of Air Emissions from Visible Emission and Particulate Matter. Chapter 11, Subchapter B, Outdoor Burning, Subsection 111.219, and 111.211. http://www.tnrcc.state.tx.us/oprd/rules/pdflib/111b.pdf , 2002.

4B.9.8 Conclusions

Due to the uncertainties with the modeling calibration and other assumptions in the SWAT model, the amount of reliable supply generated by a brush control project in the Brazos G Area is uncertain. The yields reported in this case study do not include the historical drought of the 1950s, or the drought that began in the late 1990s. The amount of reliable water that is available through increased reservoir yields through brush control is relatively low as compared to the water production rates reported in published studies, yet brush control may be a feasible strategy for some watersheds. The success of such a program for providing increased water supplies is dependent on increased surface water runoff and significant landowner participation. The true benefits of brush control might not lie with increased surface water runoff, but increased deep soil percolation and improved land management. Significant landowner participation will require adequate external funding on a continuous basis because the benefits of brush control are lost if the maintenance activities are not continued. Securing these funds will depend upon the success of on-going pilot studies and brush programs. Support of the on-going brush programs with continued data collection is necessary to demonstrate the realized water benefits of brush control. This strategy should be re-evaluated once the results of these programs have been quantified.

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4B.10 Weather Modification

Weather modification is a water management strategy currently used in Texas to increase precipitation released from clouds over a specified area typically during the dry summer months. The most common form of weather modification or rainfall enhancement is cloud seeding. Cloud seeding is used to enhance the natural process for the formation of precipitation in a select group of convective clouds. Convective clouds, also known as cumulus clouds, are responsible for producing the bulk of rainfall during any given year in Texas.[1] The cloud seeding process increases the availability of ice crystals, which bond with moisture in the atmosphere to form raindrops, by injecting a target cloud with artificial crystals, such as silver iodide. Specially equipped aircraft release the seeding crystals into clouds that are rich in supercooled droplets. The silver iodide crystals form water droplets from available moisture in the air. Droplets then collide with droplets transforming the ice crystal into a raindrop.

While weather modification is most often utilized as a water management strategy during the dry summers in West Texas, the amount of additional rainfall produced by cloud seeding in a drought year is much less. The water that cloud seeding produces during non-drought periods augments existing surface and groundwater supplies. It also reduces the reliance on other supplies for irrigation during times of normal and slightly below normal rainfall. However, not all of this water is available for water demands. Some of this precipitation is lost to evaporation, evapotranspiration, and local ponds. The amount of water made available to a specific entity from this strategy is difficult to quantify, yet there are regional benefits. Three major benefits associated with weather modification include:

- Improved rangeland and agriculture due to increased precipitation
- Greater runoff to streams and rivers due to higher soil moisture
- Groundwater recharge

One ongoing weather modification program is partially located in the Brazos G Area, the Colorado River Municipal Water District rain enhancement project. A second weather modification program, conducted by the West Central Texas Weather Modification Association, was started in 2001, but due to budgetary issues, was stopped after the 2003 season.

[1] Texas Department of Licensing and Regulation's Website http://www.license.state.tx.us/weather/weathermod.htm. October 5, 2004.

The Colorado River Municipal Water District (CRMWD) rain enhancement project is based in Big Spring and has been active since 1971. It seeds clouds in a 2.6 million acre target area. Even though Big Spring is located in Region F, the target area of the project is the area between the cities of Big Spring, Lamesa, Snyder, and Sweetwater. The City of Sweetwater and a small portion of the target area are located in Region G.

Both increased rainfall and higher cotton yields within the target area have been attributed to the CRMWD rain enhancement project during the life of the project. According to the CRMWD website, the precipitation data indicate a 35 percent average increase in rainfall at rainfall stations within the target area. This can be compared to a 12 percent average increase in rainfall at weather stations outside of the target area. Precipitation and crop yield data from more recent years indicate that cotton yields have increased an average of 44 percent for counties in the cloud seeding area. In addition, a 37 percent increase in production was also reported for counties downwind of seeding activities, whereas only a 6 percent increase was reported for counties upwind of the program[2].

The West Central Texas Weather Modification Association's program, sponsored by an alliance of nine counties and the City of Abilene, performed cloud seeding activities over 4.9 million acres in nine counties during the 2001 -2003 seasons. Five of these counties, including Nolan, Taylor, Callahan, Eastland, and Comanche, are located in Region G. The program conducted seeding activities between May 1 and September 30 of the year. The 2003 operating budget was $496,000, of which a portion was provided by a grant from the State of Texas[3].

Since the West Central Texas Weather Modification program was active for only three seasons, documented data are limited. According to Tom Mann of the West Central Texas Council of Governments, during the three years of the program, there was a 62 percent average increase in normal precipitation recorded that generated an average of 40,550 acre-feet of additional rainwater. Even though 2002 was a drought year in the study area, there were more opportunities for cloud seeding, which resulted in a higher yield from the program.

Successful rainfall enhancement programs can improve dryland farming, reduce irrigation for irrigated acres, improve forage and potentially increase runoff to local streams and reservoirs. According to the Texas Agricultural Statistics Service, within the West Central Texas

[2] Colorado River Municipal Water District's Weather Modification Program Website: http://www.crmwd.org/wxprog.htm. October 12, 2004.
[3] Kiel, Simone of Freese and Nichols, Inc., Email with Tom Mann, West Central Council of Governments, July 22, 2003.

target area there are over 51,500 acres of irrigated agriculture, 632,400 acres of dryland farming, and 355,000 head of cattle. A study by Texas A&M University on the economic impacts of weather modification found that an additional one inch of rainfall distributed evenly over the target area would result in over $10 million in benefits per year[4]. The increases in rainfall recorded to date, if distributed uniformly over the target area, correspond to 0.0068 inches in 2001 and 0.011 inches in 2002. In 2003, seeded clouds produced 1.5 inches more rainfall than similar unseeded clouds. While the economic benefits cannot be proportioned directly, the benefits associated with these levels of increased rainfall would be substantially less than $10 million.

The cost of operating the weather modification program is approximately 10 cents per acre. Benefits of the program are widespread and are difficult to quantify for specific entities within Region G. As such, weather modification is not recommended to meet a specific need at this time. However, if the West Central Texas Weather Modification program is reinstated, it is recommended that the counties in Region G within the target area support the program. This would allow additional data to be collected to determine if weather modification could be used as a long-term water management strategy in the region.

[4] Kiel, Simone of Freese and Nichols, Inc., Email with Tom Mann, West Central Council of Governments, September 2, 2003.

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4B.11 Interregional Water Management Strategies

4B.11.1 Trinity River Authority Reuse Supply through Joe Pool Lake

4B.11.1.1 Description of Option

The Trinity River Authority (TRA) owns and operates several wastewater treatment plants, and has plans to develop a number of direct and indirect reuse projects in the Trinity River Basin. The TRA could develop a project to supply indirect reuse water through Joe Pool Lake for use in Johnson County (Johnson County SUD). The wastewater effluent would be delivered from the TRA Central Wastewater Treatment Plant in Grand Prairie to Joe Pool Lake. The reuse portion of the project is assumed to be developed by TRA by 2020 in conjunction with the Dallas County Reuse Project for steam electric power. The description and costs for the portion of the project developed by TRA are discussed in the 2006 *Region C Water Plan*.[1] Johnson County SUD would develop the transmission and treatment facilities to use the water from Joe Pool Lake. A schematic of the proposed strategy is shown on Figure 4B.11-1. It is assumed that an existing intake structure on Joe Pool Lake can be utilized.

4B.11.1.2 Available Yield

Johnson County SUD would contract with the TRA for up to 20,000 acre-feet per year (acft/yr) of indirect reuse water for use in Johnson County. The pipeline and components from Joe Pool Lake to Johnson County would be sized for 36 million gallons per day (MGD) peak design capacity.

4B.11.1.3 Environmental

Environmental impacts could include:

- Possible low to moderate impacts on in-stream flows due to increased diversions.
- Possible moderate impacts to water quality in Joe Pool Lake. This can be mitigated with advanced treatment of the wastewater effluent.
- Possible low impacts on riparian corridors depending on specific locations of pipelines. Generally, it is assumed that pipelines can be routed to avoid environmentally sensitive areas.

A summary of environmental issues is presented in Table 4B.11-1.

[1] Freese and Nichols, January 2006, 2006 Region C Water Plan.

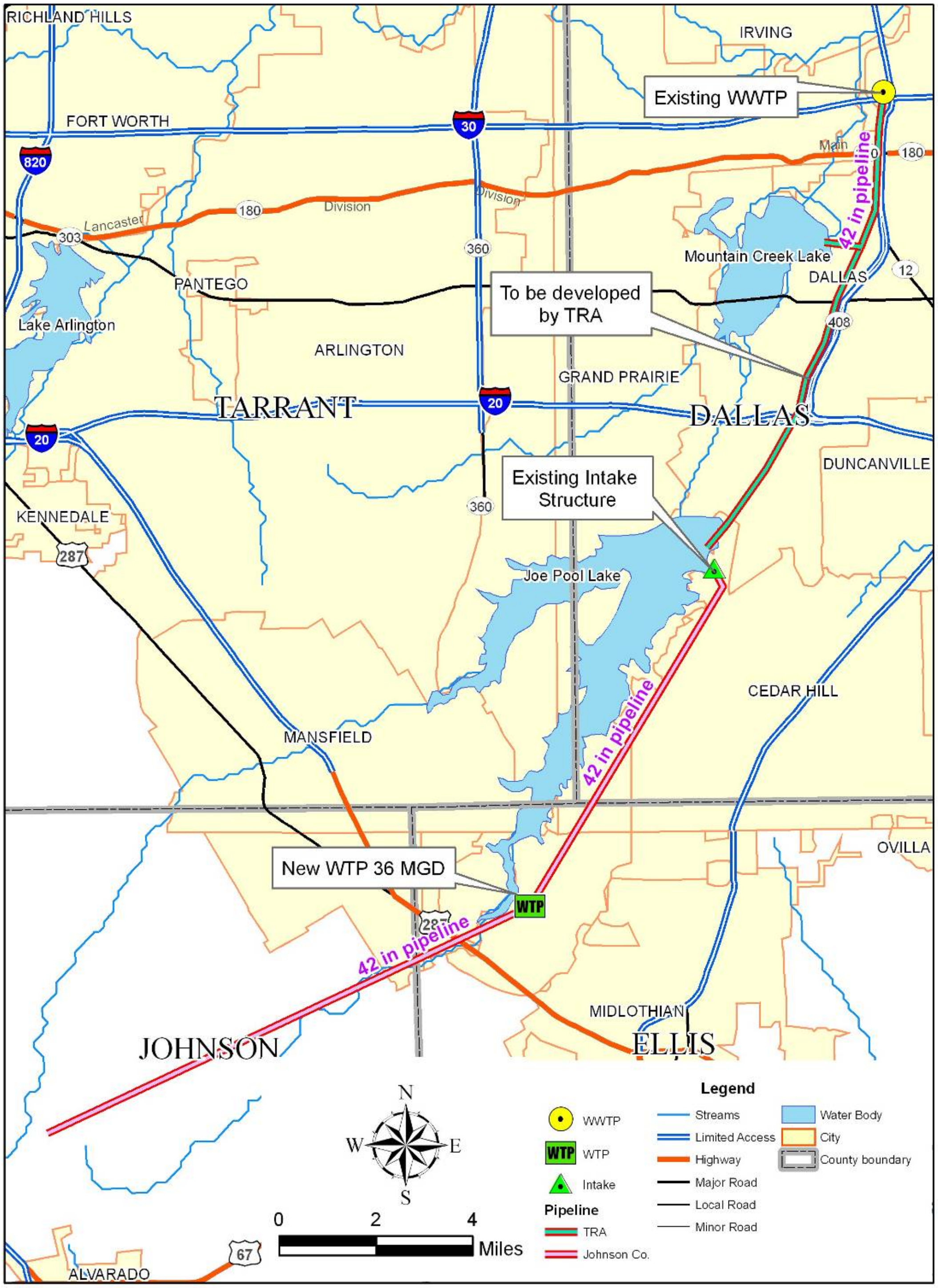

Figure 4B.11-1. TRA Reuse Project to Johnson County SUD

Table 4B.11-1.
Environmental Issues
TRA Reuse Supply to Johnson County SUD

Water Management Option	TRA Indirect reuse project to Johnson County SUD through Joe Pool Lake
Implementation Measures	Construction of pump stations, water treatment plant and approximately 20 miles of pipeline from Joe Pool Lake to Johnson County SUD. It is assumed that the infrastructure needed to move the wastewater effluent to Joe Pool Lake will be developed by TRA.
Environmental Water Needs / Instream Flows	Possible impacts on in-stream flows due to reuse of return flows. Cumulative impacts are expected to be minimal because as demands in the Dallas area increase, the net decrease in return flow due to reuse is negligible. Could impact water quality in Joe Pool Lake. This would be addressed during the reuse permitting process.
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Possible low to moderate impacts on riparian corridors and upland habitats depending on specific locations of pipelines.
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible to low impacts on endangered species depending on specific locations of pipelines
Comments	Will require indirect reuse permit and possible interbasin transfer permit from the Trinity to Brazos River Basin

4B.11.1.4 Engineering and Costing

Facilities required for Johnson County SUD to deliver treated water to its customers in Johnson County include:

- Water treatment plant;
- Pump station; and
- Transmission pipeline.

Facilities required to move treated wastewater effluent to Joe Pool Lake are assumed to be developed by TRA and are not considered here. Costs associated with the TRA portion of the project are reflected in the water purchase price to Johnson County SUD.

This strategy assumes that the existing intake structure and pump station at Joe Pool Lake is sufficient to move raw water through a 42-inch pipeline to a water treatment plant located at the upstream end of the lake. The water would be treated at a new 36 MGD conventional surface water plant, and then transported approximately 12 miles to Johnson County SUD's distribution system.

The total project costs including pump stations, pipeline, water treatment plant, and other project costs are $118,783,000. After taking into consideration debt service at 6 percent for 20 years, operation and maintenance, energy costs, and purchase of raw water on a wholesale basis at $166 per acft ($0.51 per 1,000 gallons), the total annual cost of the project is $19,151,000. This is a unit cost of $958 per acft ($2.94 per 1,000 gallons) for treated water. Table 4B.11-2 summarizes the cost estimate.

4B.11.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.11-3, and the option meets each criterion. To implement this option, TRA would need to obtain an indirect reuse permit to Joe Pool Lake. Currently this strategy is proposed to meet the needs of Johnson County SUD's customers in the Trinity River Basin. If this water is used for customers in the Brazos River Basin, an interbasin transfer permit will also be needed. Other permits that may be required as part of the construction are identified below.

4B.11.1.6 Regulatory Permits Required

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

4B.11.1.7 Mitigation Funding and Other

Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

4B.11.2 Regional Surface Water Supply to Williamson County from Lake Travis

4B.11.2.1 Description of Option

The Lower Colorado River Authority (LCRA) owns and operates five reservoirs which, along with Lake Austin, are known as the Highland Lakes. Two of the Highland Lakes, Lakes Buchanan and Travis, are water supply reservoirs and have dedicated conservation storage. The

Table 4B.11-2.
Summary of Costs for TRA Reuse Supply to Johnson County SUD

Item	***Estimated Costs for Facilities (Sept 2008)***
Capital Costs	
Raw Water Pipeline	$11,448,161
Treated Water Pipeline	$16,761,930
Right of Way Easements (ROW)	$2,426,000
Engineering & Contingencies (30%)	$8,463,027
Total Pipeline Cost	**$39,099,118**
WTP Pump Station	$4,221,000
Engineering & Contingencies (35%)	$1,477,350
Total Pump Station Cost	**$5,698,350**
Water Treatment Plant	$49,604,000
Engineering & Contingencies (35%)	$17,361,000
Total Water Treatment Plant Cost	**$66,965,000**
Permitting and Mitigation	$297,000
Interest during Construction (18 months)	$6,724,000
Total Project Cost	**$118,783,000**
Annual Costs	
Debt Service (6% for 20 years)	$10,356,000
Electricity	$432,000
Operation & Maintenance - Conveyance System	$388,000
Purchase water ($166 per acft)[1]	$3,320,000
Treatment Costs	$4,655,000
Total Annual Costs	**$19,151,000**
Total Project Yield (acft/yr)	**20,000**
Unit Costs (During Amortization)	
Per Acre-Foot	**$958**
Per 1,000 gallons	**$2.94**

1 - Cost to purchase reuse water is based on costs for TRA to develop the reuse project to Joe Pool Lake.

Table 4B.11-3.
Comparison of TRA Reuse Option to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply 1. Quantity 2. Reliability 3. Cost	 1. Sufficient quantities available 2. High reliability 3. Low to moderate
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries 5. Threatened and Endangered Species 6. Wetlands	 1. Possible low to moderate impact. Possible water quality impacts in Joe Pool Lake from discharge of treated effluent. This can be mitigated through treatment. 2. Low impact possible where new pipelines are constructed 3. Possible low impact 4. No substantial impact 5. No substantial impact 6. Low impact possible where new pipelines are constructed
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• No apparent negative impacts on agriculture or natural resources
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• May require interbasin transfer from the Trinity River Basin to supply customers in the Brazos River Basin. This would be an exempt IBT since Johnson County is partially located in the Trinity River Basin.
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

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), currently has contracts to supply water to two cities in Williamson County from Lake Travis. LCRA currently has contracts to provide 18,000 acft/yr of raw water to the City of Cedar Park, and 6,400 acft/yr of treated water to the City of Leander. The City of Round Rock has a contract with BRA for supply from the LCRA for 20,928 acft/yr of raw water but does not have the infrastructure to receive the water currently.

The cities of Round Rock, Cedar Park and Leander / LCRA 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 39.5 MGD of raw water. Portions of this project have been designed and are set to be constructed by 2010. 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 LCRA/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 raw water to Cedar Park's existing 26 MGD water treatment plant, LCRA/Leander's 12 MGD water treatment plant and 0.9 MGD to the Twin Creeks golf course.

The BCRUA will utilize the existing 30 MGD intake structure of the Cedar Park WTP initially, until a deep water 141.7 MGD intake structure can be constructed near Volente. The deep water intake will provide access to water during a severe drought. The floating intake conveys raw water through a new pipeline in an existing easement to the new regional water treatment plant to be located near the western edge of Cedar Park and Leander. A raw water transmission pipeline will be constructed to the new regional 105.8 MGD WTP. Treated water will then be 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 4B.11-2. The allocation of supplies for the proposed regional system is detailed in Table 4B.11-4.

4B.11.2.2 Available Yield

Under the provisions of HB 1437[2] 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. Currently, 21,528 acft/yr is committed. However, the 25,000 acft/yr allowed under HB 1437 does not meet the 2060 needs in Williamson County. Sufficient quantity of uncommitted stored water exists in the Highland Lakes to meet a large portion of Williamson County's projected 2060 shortages, and this supply option as conceptualized here is sized to meet 100 percent of the total 108,039 acft/yr of needs in the county. It requires that either

[2] House Bill 1437, 76th Session, Texas Legislature.

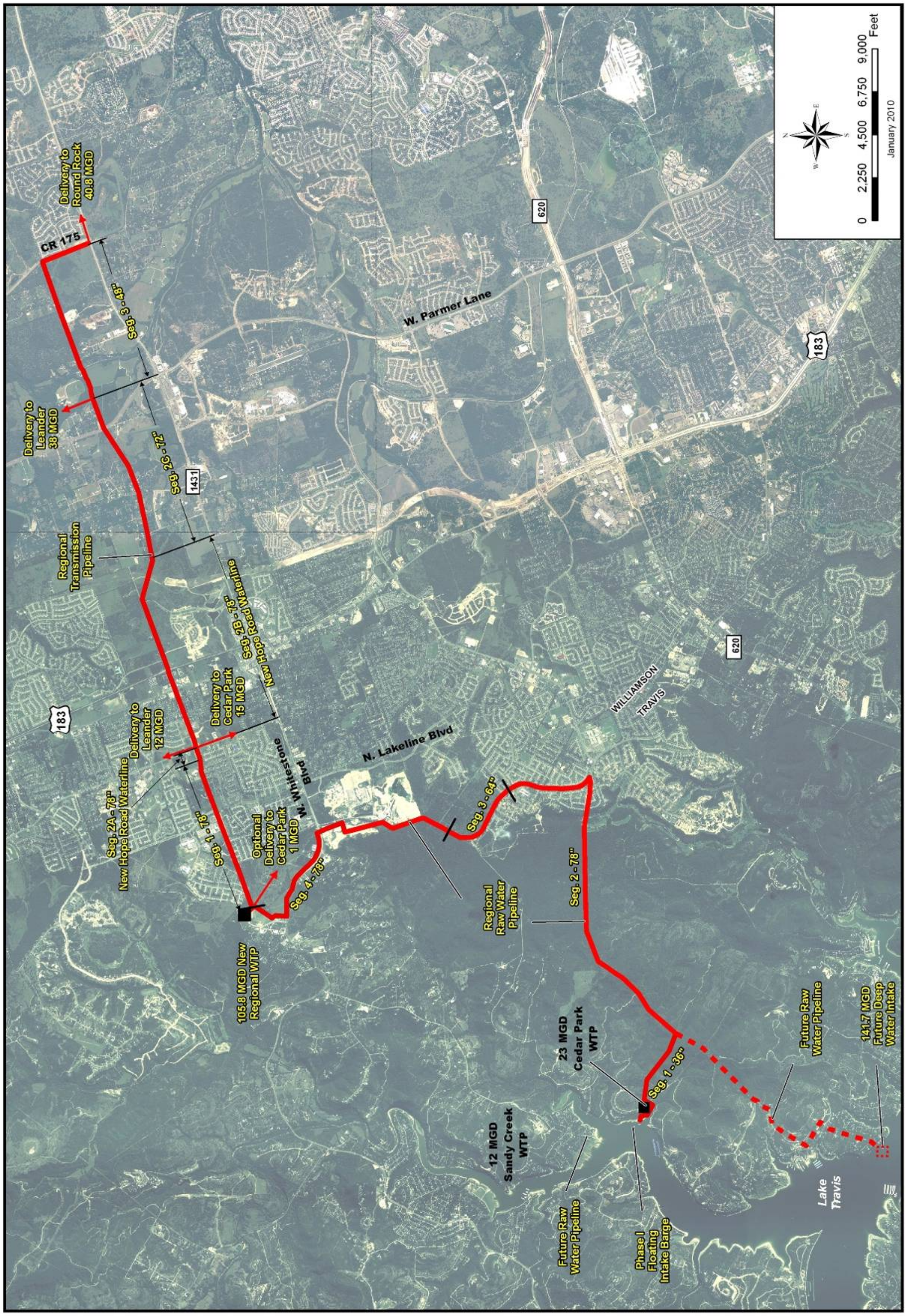

Figure 4B.11-2. BCRUA Water Supply Project

Table 4B.11-4.
Brushy Creek Regional Utility Authority System Participation

	Cedar Park	Round Rock	LCRA/ Leander	Total
Treated Water Allocation (acft/yr)	16,800	45,700	56,000	118,500
Treated Water %	14.18%	38.56%	47.26%	100%
With Deep Water Intake (acft/yr)	43,568	45,700	69,440	158,708
Deep Water Intake %	27.45%	28.79%	43.75%	100%

HB 1437 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 4B.11-5 presents the projected allocation of water under the original 25,000 acft/yr, and an additional allocation of water of 118,500 acft/yr. Currently, only 2,540 acft/yr of the HB 1437 water remains uncommitted. This plan assumes that the city of Round Rock will obtain the portion of the HB 1437 water currently allocated to Georgetown and the currently unallocated amount. Cedar Park and Liberty Hill would obtain additional supply above the original HB 1437 amount.

Table 4B.11-5.
Allocation of New Highland Lakes Supply in Williamson County

Entity	Current HB 1437 Allocation (acft/yr)	Projected HB 1437 Allocation (acft/yr)	Additional Highland Lakes Supply (acft/yr)	Total (acft/yr)
Cedar Park	0	0	16,800	16,800
Chisholm Trail SUD[1]	3,472	3,472	0	3,472
Liberty Hill	600	600	0	600
Round Rock	11,444	20,928	45,700	66,628
LCRA/Leander	0	0	56,000	56,000
Georgetown	6,944	0	0	0
Unallocated	3,472	0	0	0
Total	25,000	25,000	118,500	143,500

[1] Chisholm Trail SUD currently has expressed no plans to use this supply.

4B.11.2.3 Environmental

The construction of a new intake structure on Lake Travis and transmission pipeline to Williamson County would entail low to moderate environmental effects, depending on the quantity of water diverted, and the specific alignment of the pipelines.

- The diversion of up to 118,500 acft/yr or more could have a low impact below Lake Travis on environmental water needs, instream flows and Matagorda Bay, depending on the quantity and timing of diversions.
- The pipeline construction could have moderate to high impacts on karst invertebrates in Travis and Williamson Counties and other wildlife in the Travis County portion of route, where the pipeline would not follow existing highway rights-of-way.
- Low impacts could occur on three federally listed endangered bird species. Moderate to high impacts would be possible for seven federally listed endangered invertebrates.

4B.11.2.4 Engineering and Costing

The project is planned in three phases with the first to be completed by 2010 and the final phase to be completed by 2023. The first phase of the project will provide 30 MGD of treated water. Total projected costs for Phase I is $143,732,900

The major facilities needed to implement Phase I of this project are:

- Expansion of the raw water intake and pump station at Cedar Park Water Treatment Plant;
- Raw water transmission pipeline from Lake Travis to Regional Water Treatment Plant;
- Construction of a new 30 MGD water treatment plant; 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 70 MGD. Total projected cost for Phase II is $136,987,600. The major facilities planned for Phase II of the project are:

- Construction of a new deep water intake near Volente with a capacity of 105.9 MGD
- Raw water transmission pipelines from the deep water intake; and
- 40 MGD expansion of the regional water treatment plant constructed in Phase I.

The final phase of the project will increase the deep water intake capacity and regional water treatment plant to meet ultimate needs by 2050. Total projected costs for Phase III are $48,801,500. Major facilities include:

- Increase deep water intake capacity to 141.7 MGD
- 35.8 MGD expansion at the regional water treatment plant for total capacity of 105.8 MGD.

Costs for the regional system and the share of the facilities costs have been developed from the Cedar Park – Round Rock – LCRA/Leander Regional Water Supply Project Preliminary Engineering Report, January 2007 and are represented in Table 4B.11-6.

4B.11.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.11-7, 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.

4B.11.2.5.1 Requirements Specific to Pipelines

1. Necessary permits:
   a. U.S. Army Corps of Engineers Section 404 dredge and fill permit for stream crossings and lake intake impacting wetlands or navigable water of the United States.
   b. GLO Sand and Gravel Removal permits.
   c. TPWD Sand, Gravel and Marl permit for construction in state-owned streambeds.
2. Right-of-way and easement acquisition.
3. Crossings:
   a. Highways and Railroads.
   b. Creeks and Rivers.
   c. Other Utilities.
4. Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

Table 4B.11-6.
Summary of Costs for BCRUA Water Supply Project (Phases I- III)
September 2008 Prices

Item	*Estimated Costs for Facilities*	*Cedar Park*	*Round Rock (BRA/LCRA Alliance)*	*Leander/LCRA*
Capital Costs				
Floating Intake (30 MGD)	$5,173,000	$1,490,000	$1,339,000	$2,344,000
Deep Water Intake and Pump Station (141.7 MGD)	$41,362,000	$11,442,000	$11,709,000	$18,211,000
Raw Water Pipeline	$54,292,000	$10,459,000	$18,863,000	$24,970,000
Transmission Pipeline	$38,800,000	$1,649,000	$23,187,000	$13,964,000
Water Treatment Plant (105.8 MGD)	$116,674,000	$16,542,000	$44,993,000	$55,139,000
Total Capital Cost	**$256,301,000**	**$41,582,000**	**$100,091,000**	**$114,628,000**
Engineering, Legal Costs and Contingencies	$103,020,000	$16,986,000	$40,023,000	$46,010,000
Land Acquisition and Surveying	$4,398,000	$911,000	$1,485,000	$2,003,000
Interest During Construction (3 years)[1]	$14,550,000	$2,379,000	$5,665,000	$6,506,000
Total Project Cost	**$378,269,000**	**$61,858,000**	**$147,264,000**	**$169,147,000**
Annual Costs				
Debt Service (6 percent, 20 years)[2]	$32,979,000	$5,393,000	$12,839,000	$14,747,000
Operation and Maintenance				
Intake, Pipeline, Pump Station	$2,094,000	$424,000	$769,000	$901,000
Water Treatment Plant	$14,261,000	$2,022,000	$5,500,000	$6,740,000
Pumping Energy Costs (194,984,825 kW-hr @$0.09/kW-hr)	$17,549,000	$4,818,000	$5,053,000	$7,678,000
Purchase of Water ($157.5/acft)	$3,937,500	$0	$3,843,000	$94,500
Purchase of Water ($126/acft)	$5,292,000	$2,268,000	$0	$3,024,000
		-		-
Total Annual Cost	**$76,112,500**	**$14,925,000**	**$28,004,000**	**$33,184,500**
Available Project Yield (acft/yr)[3,4]	67,000	18,000	24,400	24,600
Annual Cost of Water ($ per acft)	$1,136	$829	$1,148	$1,349
Annual Cost of Water ($ per 1,000 gallons)	$3.49	$2.54	$3.52	$4.14

Costs developed from Cedar Park-Round Rock - LCRA/Leander Regional Water Supply Project, PER, Jan. 2007
1 - Interest during construction is calculated by phase and then summarized.
2 - Debt service is calculated by phase and summarized.
3 -Project yield includes the ultimate deep water intake capacity (141.7 MGD). Treated capacity is 105.8 MGD.
4 -Yield is limited to the available supply from the Highland Lakes

Table 4B.11-7.
Comparison of Lake Travis Supply to Williamson County Option to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Moderate to high impact along pipeline routes
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Moderate impact along pipeline routes
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Low to none
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Sales from LCRA to Cedar Park are exempted from interbasin transfer requirements
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

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4B.12 New Reservoirs

Over the majority of the last century, large on-stream reservoirs have been the backbone of the state's surface water supply resources as well as the planning for future supplies. Most of the sites in the state that are readily amenable to reservoir development have already been utilized. Many other sites that are amenable to reservoir development from a technical, or water supply, point of view have not been developed even though they have been studied for many years. These projects have regularly been mentioned in previous state water plans but have been unable to be developed due to permitting problems, environmental impacts, water quality, or cost considerations. Over the last 10 to 20 years, the development of major reservoirs has slowed considerably due to dramatically increased permitting requirements and increased environmental awareness. For these reasons any major reservoir should be considered only as a long-term solution, as the development time for the project, if it can be built at all, will probably be more than 10 years. Despite these recent impediments to development of on-stream reservoirs, these projects are an important option for development of water supplies to meet the state's needs.

Eleven potential new reservoirs were reviewed and are shown in Figure 4B.12-1. The projects listed are feasible and can provide significant additional water supply; however, as with any major reservoir projects, development of any of them will be challenging. The proposed reservoirs are:

(1) Cedar Ridge Reservoir in Shackelford, Haskell and Throckmorton Counties;
(2) South Bend Reservoir in Young County;
(3) Throckmorton Reservoir in Throckmorton County;
(4) Double Mountain Fork West Reservoir in Stonewall and Fisher Counties;
(5) Double Mountain Fork East Reservoir in Stonewall County;
(6) Turkey Peak Reservoir in Palo Pinto County;
(7) Little River Reservoir in Milam County;
(8) Millican Reservoir – Bundic Dam Site in Brazos, Madison, Leon, and Robertson Counties;
(9) Millican Reservoir – Panther Creek Dam Site in Brazos, Madison, Grimes, and Robertson Counties;
(10) Gibbons Creek Reservoir Augmentation in Grimes County; and
(11) Brushy Creek Reservoir in Falls County .

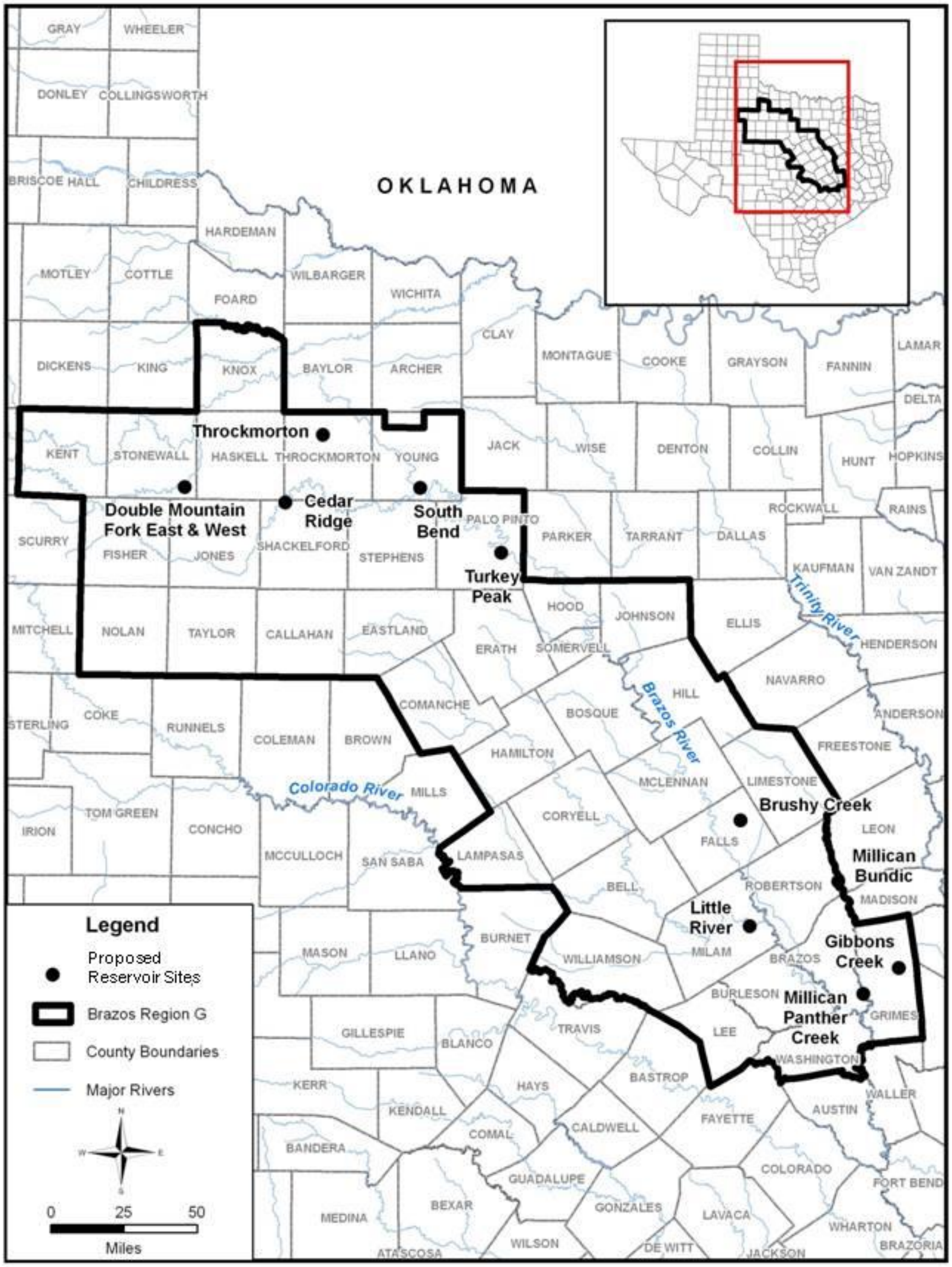

Figure 4B.12-1. New Reservoirs — Alternatives Reviewed

Each of the reservoirs is described briefly in the following sections. Except for updated hydrologic analyses, most of the information is updated from previous reports. A summary of all new reservoir yield and project costs are shown in Table 4B.12-1.

Table 4B.12-1.
Summary of New Reservoir Yield and Costs[1]

Reservoir	*Yield (acft/yr)*	*Total Project Cost*	*Total Annual Cost*	*Unit Cost per acft*	*Unit Cost per 1,000 gallons*
Cedar Ridge	23,380 (safe)	$285,214,000	$27,297,000	$1,168	$3.58
South Bend	64,500	$422,715,000	$31,314,000	$485	$1.49
Throckmorton	1,500 (safe)	$28,254,000	$2,086,000	$1,391	$4.27
Double Mtn. Fork (West)	34,775 (safe)	$151,456,000	$11,611,000	$334	$1.02
Double Mtn. Fork (East)	36,025 (safe)	$211,373,000	$16,132,000	$448	$1.37
Turkey Peak	7,600 (safe)	$50,227,000	$7,019,000	$924	$2.83
Little River (310 ft-msl)	71,275	$331,705,000	$23,349,000	$328	$1.01
Little River (330 ft-msl)	119,940	$556,520,000	$39,293,000	$328	$1.01
Millican-Bundic	36,990	$720,224,000	$52,951,000	$1,431	$4.39
Millican-Panther Creek	194,500	$1,159,907,000	$120,209,000	$618	$1.90
Gibbons Creek	3,870	$12,140,600	$918,723	$237	$0.73
Brushy Creek	2,090	$13,251,907	$951,739	$182	$0.73

[1] Costs shown are for raw water at the reservoir except where noted in the detailed strategy write ups.

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4B.12.1 Cedar Ridge Reservoir (formerly the Breckenridge Reservoir Cedar Ridge Site)

4B.12.1.1 Description of Option

The proposed Cedar Ridge Reservoir, analyzed in the 2001 Plan at the Breckenridge Reservoir Reynolds Bend site, and in 2006 as the Breckenridge Reservoir Cedar Ridge site, is located near the county lines of Throckmorton, Shackelford and Haskell Counties on the Clear Fork of the Brazos River, upstream from the mouth of Paint Creek about 50 miles north of the City of Abilene, as shown in Figure 4B.12.1-1. This project was studied in 1971 and most recently in 2009 for the City of Abilene by Enprotec/ Hibbs & Todd and HDR Engineering.[1] This report served as a source of some of the information contained in this write up. The proposed reservoir will contain approximately 227,127 acft of conservation storage and inundate 6,635 acres at the full conservation storage level of 1,489 ft-msl. The total drainage area at the Cedar Ridge Reservoir Site is approximately 2,748 sq. miles.

The water supply from this reservoir could be used to meet the various municipal shortages in the area and is projected to be part of the water supply plan for City of Abilene (Section 4C.38).

4B.12.1.2 Available Yield

Water supply potentially available from the impoundment in the proposed Cedar Ridge Reservoir was estimated using the Brazos G mini-WAM. The model utilized an updated January 1940 through June 2008 hydrologic period of record to account for the recent drought in the Upper Brazos Basin. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available from the Clear Fork of the Brazos River without causing increased shortages to existing downstream rights. Safe yield was computed subject to the reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the reservoir are shown in Table 4B.12.1-1.

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

[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.

The calculated safe yield of the Cedar Ridge Reservoir is 23,380 acft/yr, assuming subordination of Possum Kingdom Reservoir. The firm yield impact on Possum Kingdom, as defined in the inter-local agreement between the Brazos River Authority, the City of Abilene, and the WCTMWD from the operation of Cedar Ridge Reservoir has been determined to be 5,000 acft/yr.

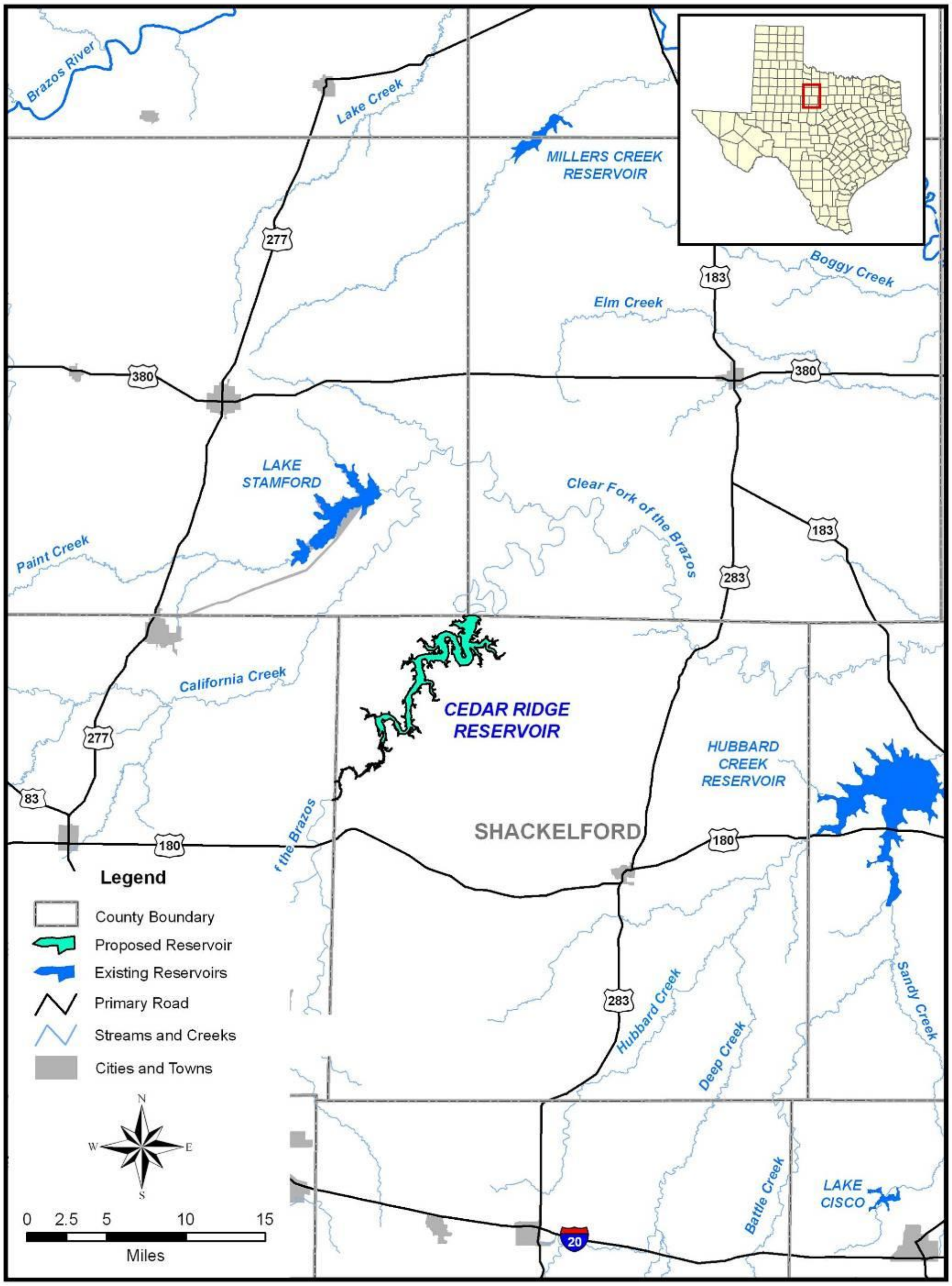


Figure 4B.12.1-1. Cedar Ridge Reservoir

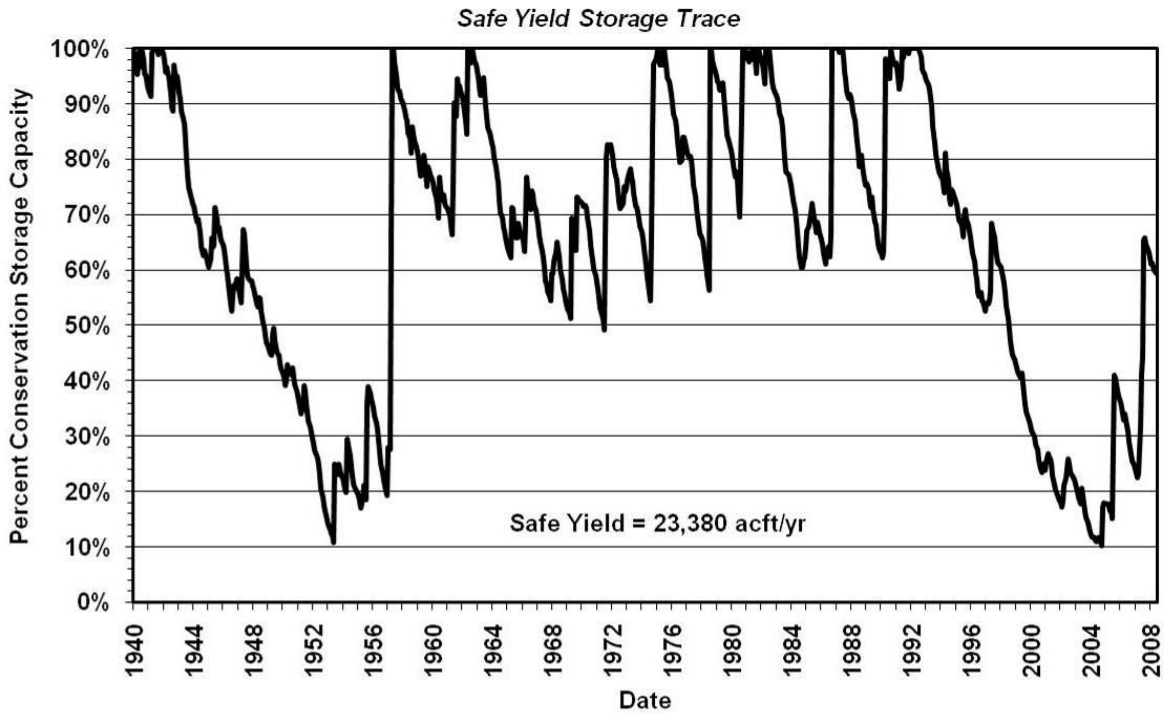
Table 4B.12.1-1.
Daily Natural Streamflow Statistics
for the Cedar Ridge Reservoir

Month	***Median Flows – Zone 1 Pass-Through Requirements (cfs)***	***25th Percentile Flows – Zone 2 Pass-Through Requirements (cfs)***
January	24.6	13.5
February	33.2	16.3
March	34.6	17.3
April	38.4	13.2
May	54.0	12.6
June	55.4	17.4
July	22.0	2.8
August	13.0	1.2
September	22.0	1.0
October	24.1	3.8
November	19.1	4.3
December	16.7	7.0
Zone 3 (7Q2) Pass-Through Requirement (cfs):		1.5

Figure 4B.12.1-2 illustrates the simulated Cedar Ridge Reservoir storage levels for the 1940 to 2008 historical period, subject to the safe yield of 23,380 acft/yr. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 32 percent of the time and above the Zone 3 trigger level (50 percent capacity) 79 percent of the time.

Figure 4B.12.1-3 illustrates the changes in Clear Fork streamflows caused by impounding the unappropriated waters of the Brazos River. The largest change would be a decline in median streamflow of about 40 cfs during May. Other significant declines would occur in June through October. During the months of January through April and December, there would be little change in streamflow because the reservoir would only rarely be able to impound water in excess of that required for downstream senior water rights and environmental needs.

Figure 4B.12.1-3 also illustrates the Clear Fork streamflow frequency characteristics with the Cedar Ridge Reservoir in place. At low flows, there is little difference with the project because the reservoir would typically be passing all, or nearly all, inflows in order to satisfy senior water rights and/or environmental constraints. There is a more pronounced difference at higher Brazos River flows, because in this range the reservoir would be able to impound water, since water rights and environmental needs would be satisfied more frequently.



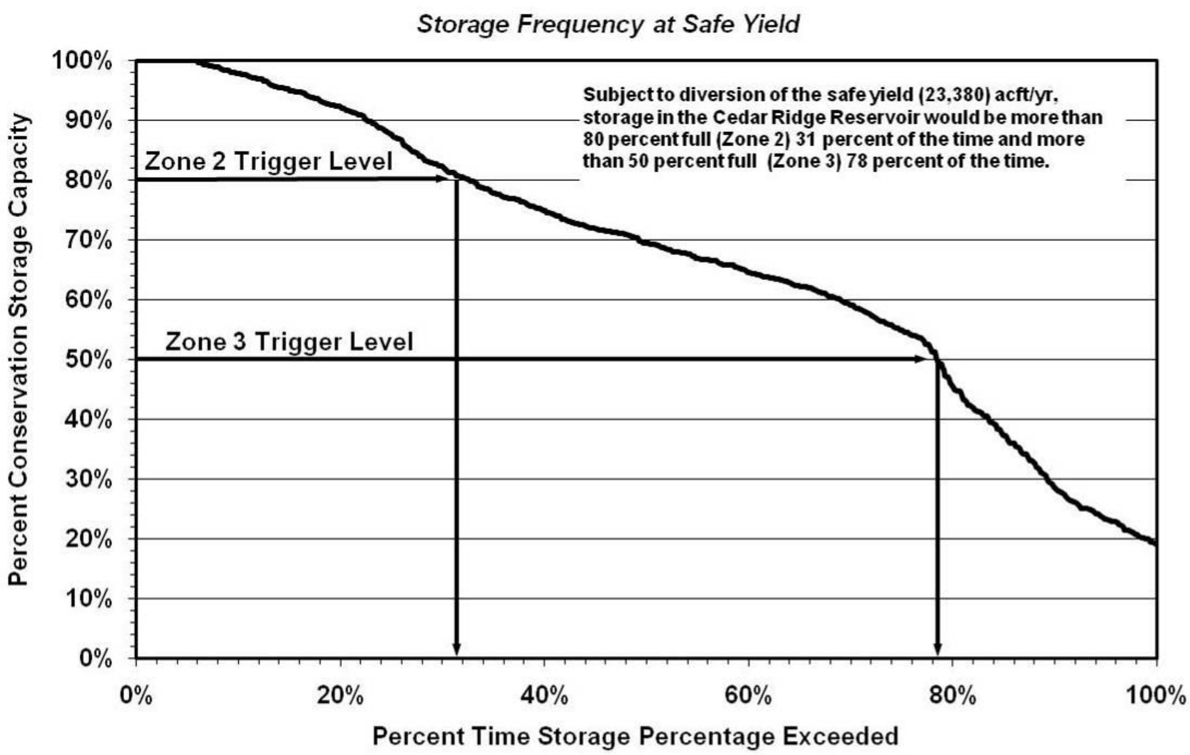
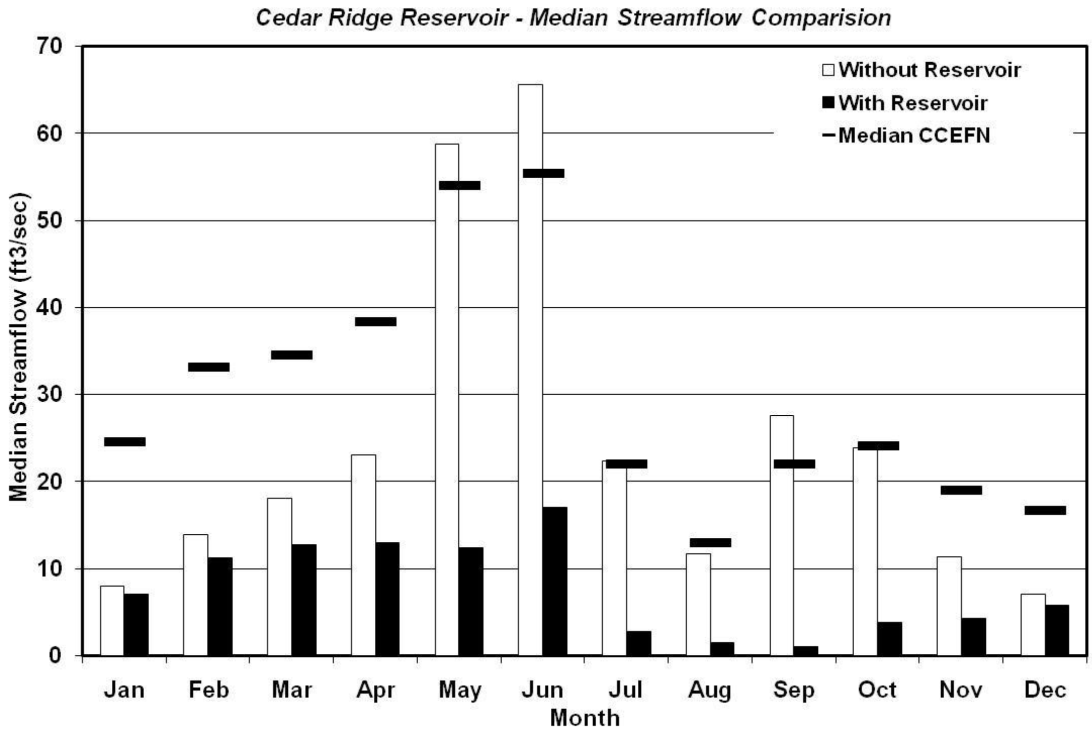


Figure 4B.12.1-2. Cedar Ridge Reservoir Storage Considerations



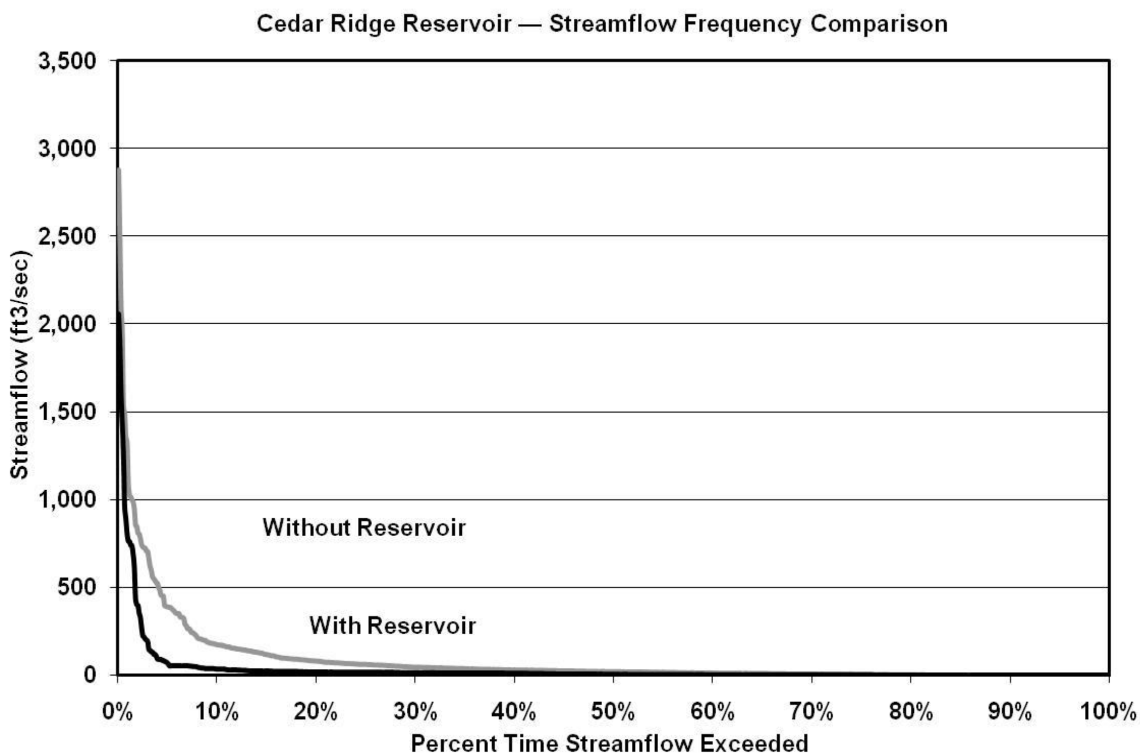


Figure 4B.12.1-3. Cedar Ridge Reservoir Streamflow Comparisons

4B.12.1.3 Environmental Issues

4B.12.1.3.1 *Existing Environment*

The Cedar Ridge Reservoir site in Jones, Throckmorton, Haskell, and Shackelford Counties lies within the Rolling Plains Ecological Region.[2] This region is located east of the High Plains, west of the West Cross Timbers and North Central Prairie, and north of the Edwards Plateau. It is characterized by nearly level to rolling topography, soft prairie sands and clays, and 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 dryland and irrigated crops are increasingly important. Poor range management practices of the past have increased the density of invasive 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.[3] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 23 and 25 inches.[4]

The Seymour Aquifer, an unconsolidated sand and gravel aquifer, is the only major aquifer in the project area. It is formed by isolated alluvial deposits in 20 counties in north central Texas. The Seymour Aquifer consists mainly of the scattered erosional remnants of the Seymour Formation of Pleistocene Age, which consists of clay, silt, sand, and gravel, that were deposited by eastward-flowing streams. The aquifer generally has less than 100 feet of saturated thickness, but it is an important source of water for domestic, municipal, and irrigation needs.[5]

The physiography of the region includes flood-prone areas, terraces, stair step topography, thin-bedded limestone, and undissected red beds.[6] The predominant soil associations in the project area are Palopinto-Throck and Clairmont-Grandfiled-Clearfork (Rowena-Leeray-Nuvalde and Lueders-Throck-Nukrum are in the area but not predominant).

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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] Telfair, R.C., "Texas Wildlife Resources and Land Uses," University of Texas Press, Austin, Texas, 1999.
[4] Larkin, T.J., and G.W. Bomar, "Climatic Atlas of Texas," Texas Department of Water Resources, Austin, Texas, 1983.
[5] United States Geological Service (USGS), *Ground Water Atlas of the United States*, http://capp.water.usgs.gov/gwa/index.html, 2009.
[6] 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.

Three major vegetation types occur within the general vicinity of the proposed project: Mesquite (*Prosopis glandulosa*)–Lotebush (*Ziziphus obtusifolia*) Shrub, Mesquite Brush, and crops.[7] 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 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 Mesquite Brush are narrowleaf yucca (*Yucca angustissima*), grassland pricklypear (*Opuntia cymochila*), juniper, red grama, Texas grama, sideoats grama, hairy grama, purple three-awn, Roemer three-awn (*Aristida purpurea* var. *roemeriana*), buffalograss, red lovegrass (*Eragrostis secundiflora*), gummy lovegrass (*Eragrostis curtipedicellata*), sand dropseed, tobosa, western ragweed (*Ambrosia cumanensis*), James rushpea (*Caesalpinia jamesii*), scurfpea (*Psoralidium* sp.), and wild buckwheat (*Eriogonum* sp.). 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.

4B.12.1.3.2 Potential Impacts

4B.12.1.3.2.1 Aquatic Environments including Bays and Estuaries

The anticipated impact of this project would be lower variability in and significant reductions in quantity of median monthly flows. The difference in variability of monthly flows would be a factor of approximately 2.3 (measured by comparing variances of monthly flows from 1940-2008 with and without the project in place; sample variance without project =5.66 x 10^4; sample variance with project =2.42 x 10^4). Variability in flow is important to the instream

[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.

biological community as well as riparian species and this reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing habitat suitability for others. Reductions in the quantity of median monthly flow downstream of the project would range from 1.0 cfs (12 percent) in January to 48.5 cfs (74 percent) in May, as shown in Table 4B.12.1-2. The highest percent reductions (>85 percent) would be in July through September while December through February would have much lower reductions in median monthly streamflows (<20 percent). These lower flows would have substantial impacts on the instream biological community in areas downstream of the project site. Substantial reductions in July, August, and September would be particularly detrimental as a result of high temperatures and the high likelihood of impairment of other water quality parameters during that time of year. Despite these reductions, the frequency of low-flow conditions (>85 percent exceedance) would not be affected by this project. Streamflow would decrease to 0.73 cfs for 16 percent of the time and would cease for 8.9 percent of the time with or without the project.

Table 4B.12.1-2.
Median Monthly Streamflow: Cedar Ridge Reservoir

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	8.0	7.1	1.0	12%
February	13.9	11.3	2.6	19%
March	18.1	12.8	5.3	29%
April	23.0	13.0	10.0	44%
May	58.7	12.4	46.4	79%
June	65.6	17.1	48.5	74%
July	22.3	2.8	19.5	88%
August	11.7	1.5	10.2	87%
September	27.6	1.0	26.6	96%
October	23.9	3.8	20.1	84%
November	11.4	4.3	7.1	63%
December	7.0	5.8	1.3	18%

Although there would be impacts on the biological community 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 inflows to the estuary. As a new reservoir without a current operating permit, the Cedar Ridge Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

4B.12.1.3.2.2 Threatened and Endangered Species

A total of 28 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.12.1-3). This group includes 2 reptiles, 14 birds, 7 mammals, and 2 fish and 3 mollusk species. Four bird species federally-listed as threatened or endangered could occur in the project area. These include the black-capped vireo (*Vireo atricapillus*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), and whooping crane (*Grus americana*). The interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir. Three mammals, the black-footed ferret (*Mustela nigripes*), gray wolf (*Canis lupus*), and red wolf (*Canis rufus*), are federally-listed as endangered; all are extirpated from the project area. In December 2009 the Texas Parks and Wildlife Department listed 15 freshwater mollusks as threatened. This list includes two species that may occur in the project area, the smooth pimpleback (*Quadrula houstonensis*) and the Texas fawnsfoot (*Truncilla macrodon*).

A search of the Texas Wildlife Diversity Database[8] revealed the documented occurrence of the Brazos water snake (*Nerodia harteri*) within the vicinity of the proposed Cedar Ridge Reservoir (as noted on representative 7.5-minute quadrangle map(s) that include the project site). These data are not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or 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.

[8] Texas Parks and Wildlife Department (TPWD), Texas Wildlife Diversity Database, 2004.

Table 4B.12.1-3.
Potentially Occurring Species that are
Rare or Federal- and State-Listedat the Cedar Ridge Reservoir Site,
Jones, Throckmorton, Haskell, and Shackelford Counties

Scientific Name *Common Name*	*Federal Listing/State Listing*	*Jones County*	*Throckmorton County*	*Haskell County*	*Shackelford County*
Birds					
Falco peregrinus anatum *American Peregrine Falcon*	DL/T	Migrant	Migrant	Migrant	Migrant
Falco peregrinus tundrius *Arctic Peregrine Falcon*	DL	Migrant	Migrant	Migrant	Migrant
Ammodramus bairdii *Baird's Sparrow*	SOC	Migrant	Migrant	Migrant	Migrant
Haliaeetus leucocephalus *Bald Eagle*	DL/T	Migrant	Migrant	Migrant	Migrant
Vireo atricapillus *Black-capped Vireo*	LE/E	—	—	—	Migrant
Buteo regalis *Ferruginous Hawk*	SOC	X	—	—	—
Sterna antillarum athalassos *Interior Least Tern*	LE/E		—	Migrant*	Migrant*
Charadrius montanus *Mountain Plover*	SOC	Migrant*	Migrant*	Migrant*	Migrant*
Falco peregrines *Peregrine Falcon*	DL/T	Migrant	Migrant	Migrant	Migrant
Charadrius melodus *Piping Plover*	LT		—	—	Migrant
Charadrius alexandrines *Snowy Plover*	SOC	Migrant			
Charadrius alexandrines nivosus *Western Snowy Plover*	SOC	Migrant	—	Migrant	—
Athene cunicularia hypugaea *Western Burrowing Owl*	SOC	Migrant	Migrant*	Migrant*	Migrant*
Grus Americana *Whooping Crane*	LE/E	Migrant	Migrant	Migrant	Migrant
Fishes					
Notropis oxyrhyncus *Sharpnose Shiner*	C/SOC	X	X	X	—
Notropis buccula *Smalleye Shiner*	C/SOC	X	X	X	X
Mammals					
Mustela nigripes *Black-footed Ferret*	LE/E	Extirpated	—	Extirpated	—
Cynomys ludovicianus *Black-tailed Prairie Dog*	SOC	X	X	X	X
Myotis velifer *Cave Myotis Bat*	SOC	X	X	X	X

Table 4B.12.1-3 (Concluded)

Scientific Name ***Common Name***	***Federal Listing/State Listing***	***Jones County***	***Throckmorton County***	***Haskell County***	***Shackelford County***
Canis lupus *Gray Wolf*	LE/E	Extirpated	Extirpated	Extirpated	Extirpated
Corynorhinus townsendii pallescens *Pale Townsend's Big-eared Bat*	SOC	—	—	X	—
Spilogale putorius interrupta *Plains Spotted Skunk*	SOC	X	X	X	X
Canis rufus *Red Wolf*	LE/E	X	Extirpated	Extirpated	Extirpated
Mollusks					
Tritogonia verrucosa *Pistolgrip*	SOC	X	X	X	X
Quadrula houstonensis *Smooth Pimpleback*	SOC/T	—	—	—	X
Truncilla macrodon *Texas fawnsfoot*	SOC/T	X	X	X	X
Reptiles					
Nerodia harteri *Brazos Water Snake*	SOC/T	X	X	X	X
Phrynosoma cornutum *Texas Horned Lizard*	SOC/T	—	X	X	X

X = Occurs in county; — = does not occur in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; DL-Delisted Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: Texas Parks and Wildlife Department (TPWD) Annotated County List of Rare Species for Throckmorton County (2009), Annotated County List of Rare Species for Jones County (2009), Annotated County List of Rare Species for Haskell County (2009), and Annotated County List of Rare Species for Shackelford County (2009); TPWD Texas Wildlife Diversity Database (2009), United States Fish and Wildlife Service (USFWS), Federally-listed as Threatened and Endangered Species of Texas, December 15, 2009.

4B.12.1.3.2.3 Wildlife Habitat

Approximately 6,635 acres below 1,489 feet are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 30 acres of Grasses/Forbs, 4,040 acres of Mesquite Brush, and 2,565 acres of Mesquite-Lotebush Shrub.

A number of vertebrate species would be expected to occur within the Cedar Ridge Reservoir site as indicated by county occurrence records.[9] These include 11 species of frogs and toads, 6 species of turtles, 10 species of lizards and skinks, and 31 species of snakes. Additionally, 78 species of mammals could occur within the site or surrounding region,[10] as well

[9] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," Texas Cooperative Wildlife Collection, 1998.

[10] 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.

as 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.

4B.12.1.3.2.4 Cultural Resources

A search of Texas Historical Commission Geographic Information Systems data indicates that there are no cemeteries, historical markers, or properties or sites listed on the National Registry of Historic Places located within the proposed inundation area or within one-mile. It is likely that there are sites listed in the Archeological Sites Atlas database within the vicinity of the Cedar Ridge Reservoir site. A search of data housed at the Texas Archeological Research Laboratory should be completed. 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 these sites or any other cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places 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).

4B.12.1.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower streamflows, declining water quality, and reduced inflows to reservoirs. This project would contribute to lower streamflow below the reservoir, particularly in the months of July, August and September. Lower flows could result in declining water quality with respect to lower dissolved oxygen, and higher concentration of any existing stream pollutants. Reduced streamflow may impact populations of the Brazos water snake within the conservation pool and downstream of the reservoir area.

4B.12.1.4 Engineering and Costing

The proposed Cedar Ridge Reservoir includes the construction of an earthen dam, principal spillway, emergency spillway, and appurtenant structures. eHT and HDR Engineering recently completed a study[11] of the proposed Cedar Ridge Reservoir and estimated the project would cost approximately $139.8 million for raw water at the reservoir. This includes the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. Added to this cost are facilities to deliver the water to the City of Abilene through a pipeline and for additional treatment capacity that would be needed by the City to fully utilize the Cedar Ridge supply. A more detailed listing of the various components of the cost estimate is provided in Table 4B.12.1-4. The annual project costs for the combined project are estimated to be $27 million, which includes annual debt service, operation and maintenance, and an annual payment to the Brazos River Authority for lost yield in Possum Kingdom. The cost for the estimated 1-yr safe yield of 23,380 acft/yr translates to an annual unit cost of raw water of $3.58 per 1,000 gallons, or $1,168 per acft.

4B.12.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.12.1-5, and the option meets each criterion.

A summary of the implementation steps for the project is presented below.

4B.12.1.5.1 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.

4B.12.1.5.2 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;

[11] eHT and HDR Engineering, Op. Cit., November 2009.

Table 4B.12.1-4.
Cost Estimate Summary for
Cedar Ridge Reservoir
(September 2008 Prices)

Cost Estimate Summary Water Supply Project Option Sept 2008 Prices Cedar Ridge Reservoir	
Item	***Estimated Costs for Facilities***
Capital Costs	
Dam and Reservoir (Conservation Pool 227,127 acft, 6,635 acres, 1489 ft.	$65,538,000
Intake and Pump Station (20.9 MGD)	$12,197,000
Transmission Pipeline (36 in dia., 29 miles)	$35,566,000
Water Treatment Plant (13.9 MGD)	$24,226,000
Total Capital Cost	**$149,027,000**
Engineering, Legal Costs and Contingencies	$55,398,000
Environmental & Archaeology Studies and Mitigation	$30,842,000
Land Acquisition and Surveying (16,314 acres)	$24,519,000
Interest During Construction (3 years)	$25,428,000
Total Project Cost	**$285,214,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$11,337,000
Reservoir Debt Service (6 percent, 40 years)	$10,314,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$661,000
Dam and Reservoir	$983,000
Water Treatment Plant	$2,013,000
Pumping Energy Costs (19,067,256 kW-hr @ 0.09 $/kW-hr)	$1,716,000
Purchase of Water (5000 acft/yr @ 54.5 $/acft)	$273,000
Total Annual Cost	**$27,297,000**
Available Project Yield (acft/yr)	23,380
Annual Cost of Water ($ per acft)	$1,168
Annual Cost of Water ($ per 1,000 gallons)	$3.58

Table 4B.12.1-5.
Comparison of Cedar Ridge Reservoir to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable 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. Negligible impact
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	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

- 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.

4B.12.1.5.3 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.

4B.12.2 South Bend Reservoir

4B.12.2.1 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 4B.12.2-1. The reservoir would capture flow from both streams, with an estimated capacity of up to 771,604 acft from the 13,168-square mile drainage area. The dam would be an earthfill embankment that would extend approximately 2.8 miles across the Brazos River at an elevation of 1,090 ft-msl and inundate 29,877 surface acres.

There are some water-short entities in the area that could benefit from the construction of the reservoir, but the majority of the water would have its greatest usefulness as part of the BRA System. Some of the water-short communities in the area would include Tolar, Oak Trail Shores Subdivision, and some smaller water supply corporations. Other non-municipal shortages identified in the area include mining in Stephens County.

4B.12.2.2 Available Yield

Water potentially available for impoundment in the proposed South Bend Reservoir was estimated using an updated version of the Brazos G mini-WAM. The model utilized an updated January 1940 through June 2008 hydrologic period of record to account for the recent drought in the Upper Brazos Basin. Estimates of the water availability in the Brazos River Basin were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available from the Brazos River without causing increased shortages to downstream rights. Firm yield was computed subject to the reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the reservoir are shown in Table 4B.12.2-1.

Since the South Bend Reservoir is of a significant size and geographically close to Possum Kingdom Reservoir, it was analyzed both as a stand alone reservoir and acting as part of a system with Possum Kingdom Reservoir. The stand alone firm yield of South Bend Reservoir is 64,500 acft/yr. Preliminary analysis indicate that as much as 147,000 acft/yr of supply could be made available by operating South Bend as part of the BRA system in conjunction with

Possum Kingdom Reservoir. The results presented in the remainder of this section are for the stand alone yield scenario of South Bend Reservoir.

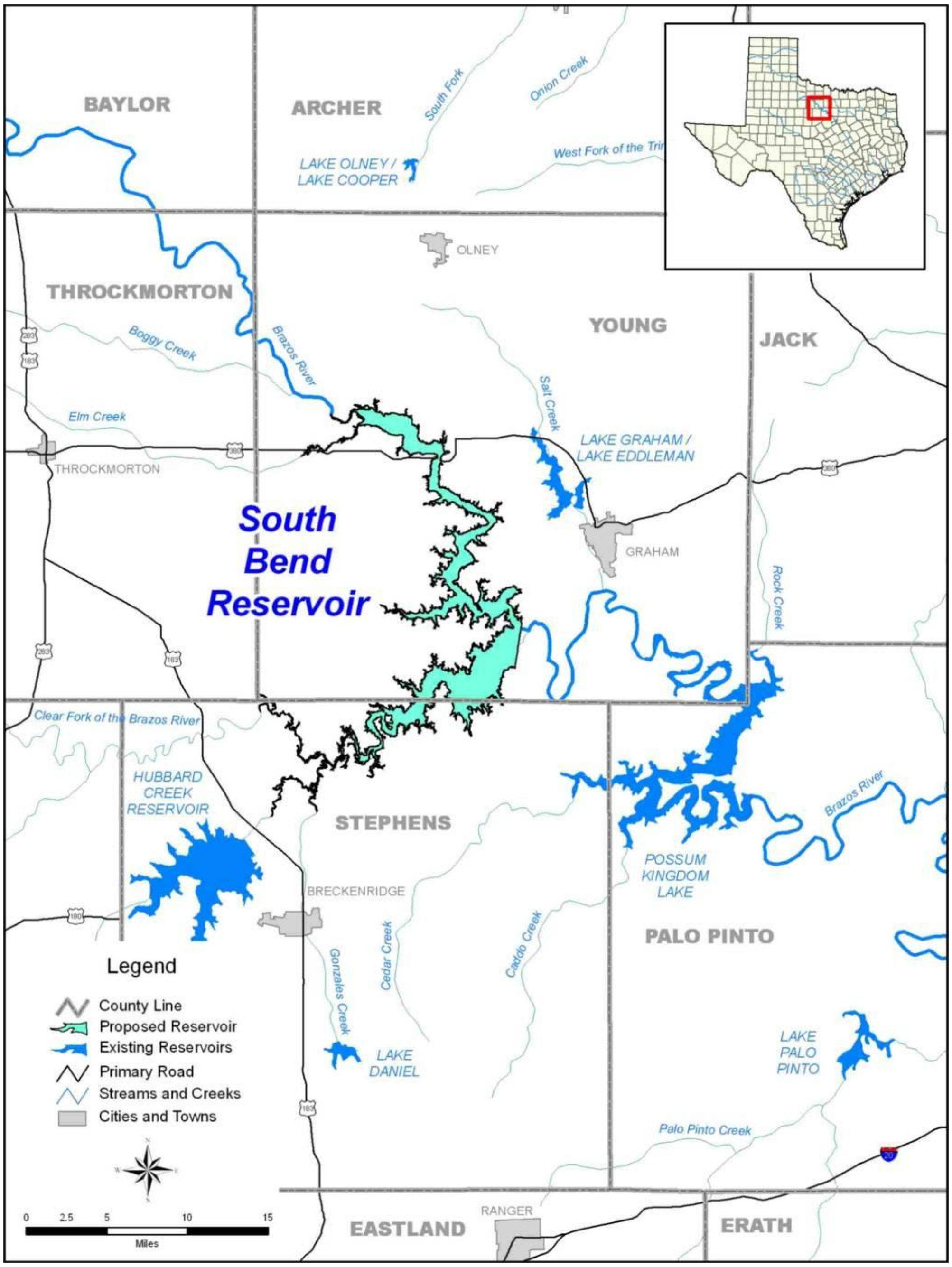


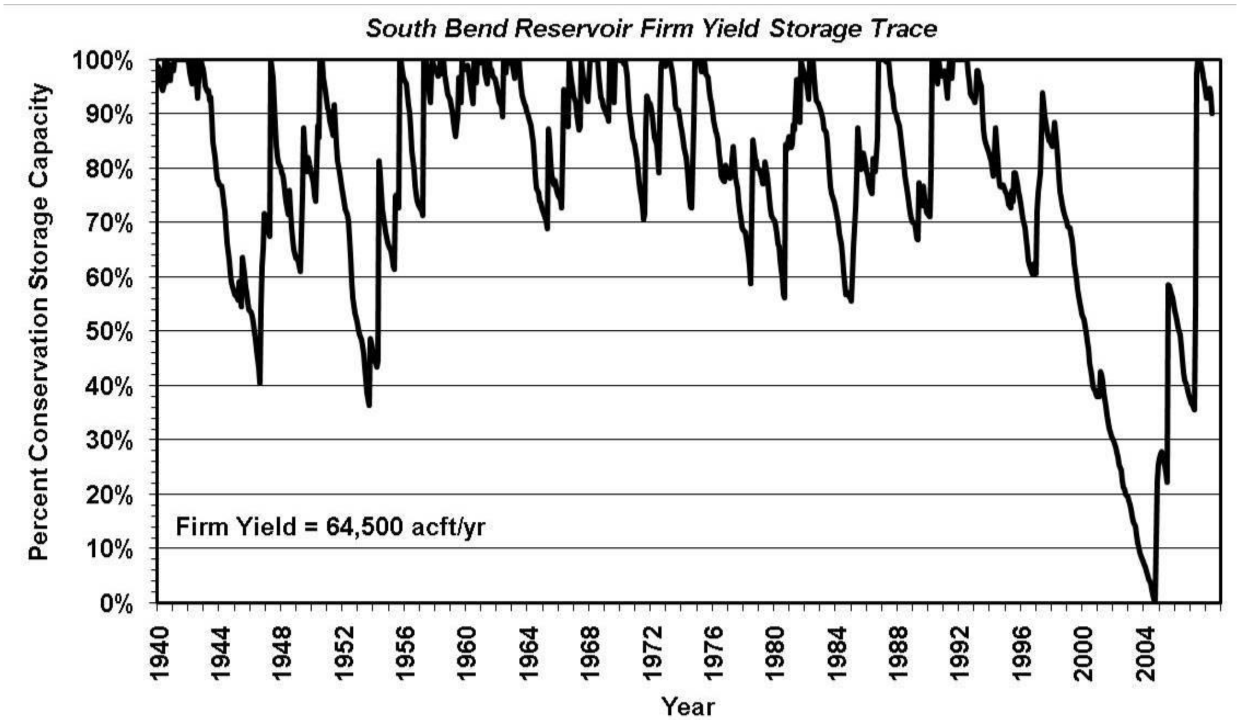
Figure 4B.12.2-1. South Bend Reservoir

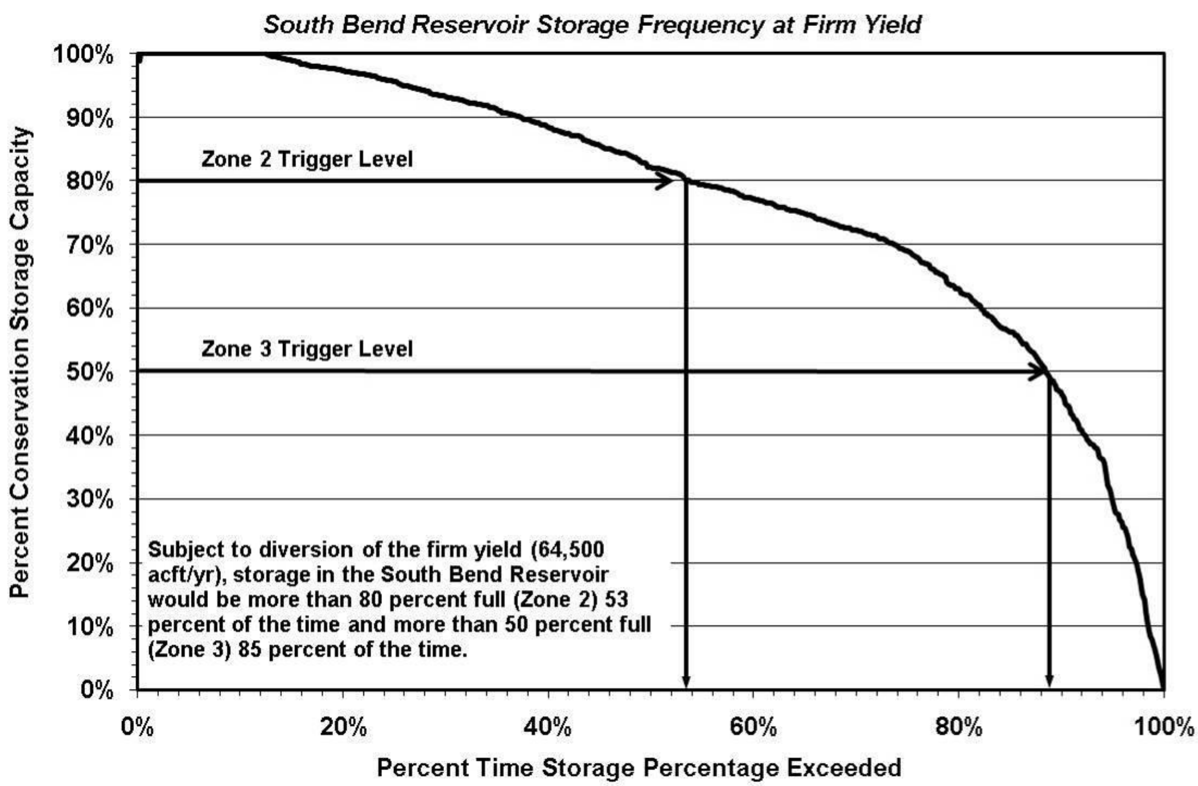
Table 4B.12.2-1.
Daily Natural Streamflow Statistics for the South Bend Reservoir

Month	***Median Flows – Zone 1 Pass Through Requirements (cfs)***	***25th Percentile Flows – Zone 2 Pass Through Requirements (cfs)***
January	122.2	40.8
February	149.5	52.9
March	161.4	51.3
April	126.5	49.3
May	163.0	51.3
June	54.8	18.0
July	10.9	2.9
August	3.0	0.4
September	7.2	1.2
October	9.3	1.5
November	32.9	10.7
December	63.7	21.1
Zone 3 (7Q2) Pass-Through Requirement (cfs):		1.56

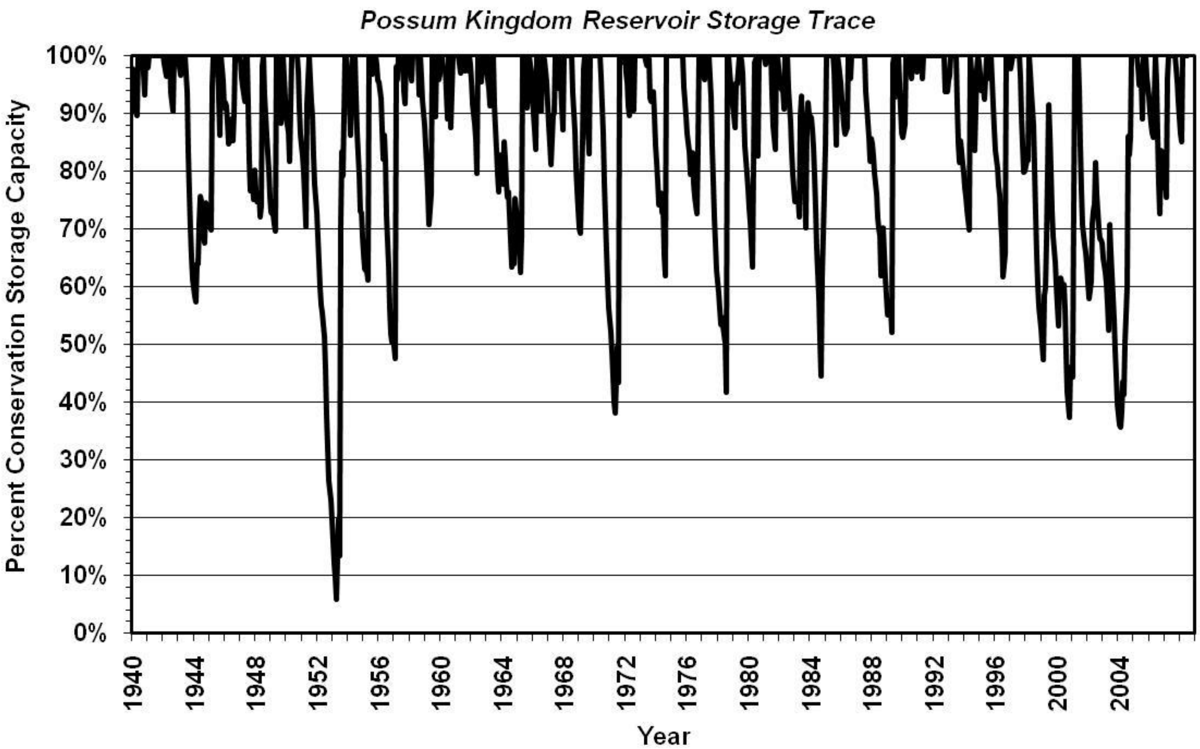
Figure 4B.12.2-2 illustrates simulated South Bend Reservoir storage levels for the 1940 to 2008 historical period, subject to the firm yield in South Bend Reservoir of 64,500 acft/yr and diversions from Possum Kingdom Reservoir that meet the BRA's downstream main stem contractual committments. Operated as part of the BRA System, Possum Kingdom was operated to meet specific contracts as well as supplement other BRA contractual commitments. As allowed by the BRA's water rights in Possum Kingdom, these downstream diversions are often in excess of the authorized diversion amount of 230,750 acft/yr. Simulated reservoir contents in South Bend remain above the Zone 2 trigger level (80 percent capacity) 53 percent of the time and above the Zone 3 trigger level (50 percent capacity) 87 percent of the time.

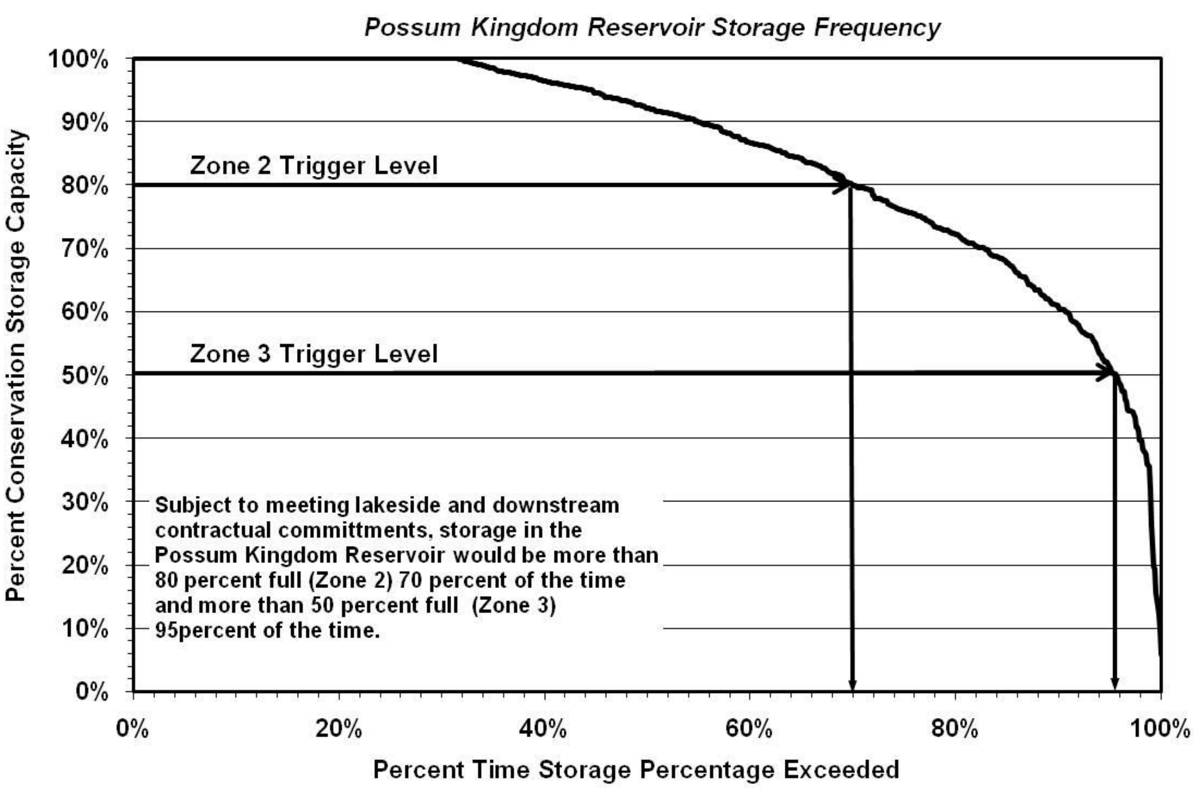
Figure 4B.12.2-3 illustrates simulated Possum Kingdom Reservoir storage levels for the same historical period, subject to the downstream main stem contractual committments. Simulated reservoir contents in Possum Kingdom remain above the Zone 2 trigger level (80 percent capacity) 70 percent of the time and above the Zone 3 trigger level (50 percent capacity) 95 percent of the time. However, as a current permitted project, Possum Kingdom is not required to operate to meet CCEFN flow requirements.





4B.12.2-2. South Bend Reservoir Storage Considerations





4B.12.2-3. Possum Kingdom Reservoir Storage Considerations

Figure 4B.12.2-4 illustrates the changes in Brazos River streamflows caused by impounding the unappropriated waters of the Brazos and Clear Fork of the Brazos Rivers. The greatest change in flow would occur in the spring and summer months of May and June. The largest decline occurs in May, where the median streamflow is reduced by 260 cfs. During the winter months, there would be little change in streamflow because the reservoir would only rarely be able to impound flows in excess of those required for downstream senior water rights and environmental needs.

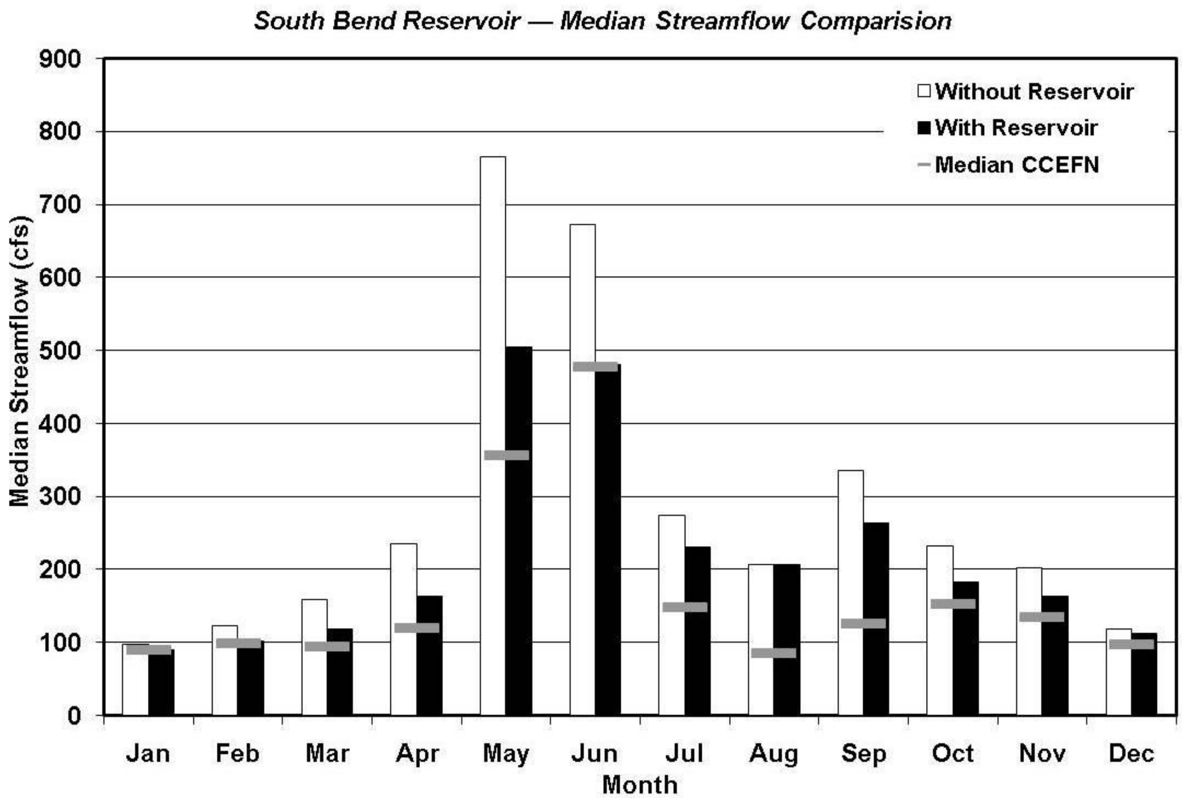
4B.12.2.3 Environmental Issues

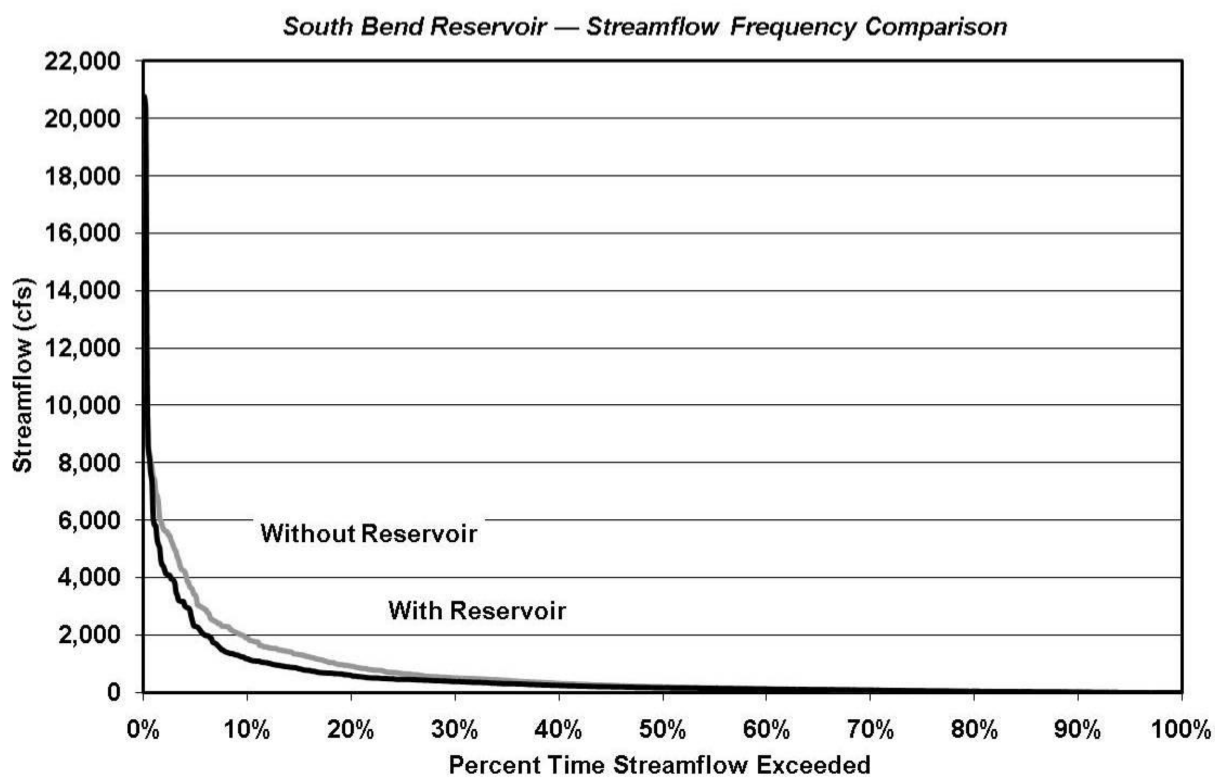
4B.12.2.3.1 Existing Environment

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.[12] 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.[13] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 28 and 32 inches.[14] The project area lies between the Seymour and Trinity major aquifers, but is underlain by no major or minor aquifers.[15]

The physiography of the region includes clay mud and sandstone, ceramic clay and lignite/coal, hard sandstone, mud, and mudstone (undifferentiated), hard sandstone and conglomerate (undifferentiated), terraces, and flood-prone areas. The topography ranges from

[12] 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.
[13] Telfair, R.C., "Texas Wildlife Resources and Land Uses," University of Texas Press, Austin, Texas, 1999.
[14] Larkin, T.J., and G.W. Bomar, "Climatic Atlas of Texas," Texas Department of Water Resources, Austin, Texas, 1983.
[15] United States Geological Service (USGS), *Ground Water Atlas of the United States*, http://capp.water.usgs.gov/gwa/index.html, 2004.





4B.12.2-4. South Bend Reservoir Streamflow Comparisons

rolling hills and prairie to steeply to moderate sloping hills and rugged hills and scarps. There are also flat areas and local shallow depressions in flood-prone areas along waterways.[16] The predominant soil associations in the project area are the Clearfork-Clairemont, Bastrop-Minwells, and Bonti-Truce-Bluegrove associations in Stephens County. 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. The Bonti-Truce-Bluegrove association consists of moderately deep and deep, gently sloping to hilly, loamy soils, most of which are flaggy or stony and underlain by sandstone or shale, on uplands.[17]

Three major vegetation types occur within the general vicinity of the proposed project: Mesquite (*Prosopis glandulosa*)-Lotebush (*Ziziphus obtusifolia*) Shrub, Post Oak (*Quercus stellata*) Parks/Woods, and Live Oak (*Q. virginiana*)-Mesquite-Ashe Juniper (*Juniperus ashei*) Parks.[18] 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

[16] 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.
[17] Cyprian, T.E., *Soil Survey of Stephens County, Texas*, United States Department of Agriculture Soil Conservation Service in cooperation with Texas Agricultural Experiment Station, 1994.
[18] 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.

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*).

4B.12.2.3.1 Potential Impacts

4B.12.2.3.1.1 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 (measured by comparing sample variances of all monthly flows from 1940-2004 and predicted flows over that same time period with the project in place; sample variance without project $=9.89 \times 10^4$; sample variance with project $=9.45 \times 10^4$) would probably not have much impact on the instream biological community or riparian species. The decrease in monthly median flow values would range from 0 cfs (0 percent) in August to 260 cfs (34 percent) in May, as shown in Table 4B.12.2-2. The highest reductions (>20 percent) would occur in May,July, and September. Despite relatively large differences in median flow values, this project would have no effect on the frequency of low-flow conditions; the 85 percent exceedance value would be approximately 39 cfs without the proposed reservoir in place and 34 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.

Table 4B.12.2-2.
Median Monthly Streamflow: South Bend Reservoir

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	96.8	90.5	6.3	7%
February	123.0	101.4	21.6	18%
March	158.2	117.9	40.3	25%
April	234.5	163.5	71.0	30%
May	764.6	504.7	259.9	34%
June	671.9	480.8	191.1	28%
July	274.3	230.4	43.9	16%
August	207.0	207.0	0.0	0%
September	334.7	263.4	71.3	21%
October	232.8	182.9	49.9	21%
November	202.1	163.7	38.4	19%
December	118.7	111.9	6.8	6%

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 greater. 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.

4B.12.2.3.1.2 Threatened & Endangered Species

A total of 24 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.12.2-3). This group includes two reptiles, 11 birds, 6 mammals, 2 mollusks, 2 fish, and 1 plant species. Additionally, two of the state- and federally-listed mammals, the gray wolf (*Canis lupus*) and the red wolf (*Canis rufus*) are extripated within

Table 4B.12.2-3.
Potentially Occurring Species that are Rare or Federal- and State-Listed for Stephens and Young Counties – South Bend Reservoir Site

Scientific Name	Common Name	Federal/State Status	Stephens County	Young County
Birds				
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL	Migrant	Migrant
Ammodramus bairdii	Baird's Sparrow	SOC	Migrant	Migrant
Haliaeetus leucocephalus	Bald Eagle	DL/T	Migrant	Migrant
Vireo atricapillus	Black-capped Vireo	LE/E	Migrant	—
Dendroica chrysoparia	Golden-cheeked Warbler	LE/E	Migrant	Migrant
Ammodramus henslowii	Henslow's Sparrow	SOC	—	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*	Migrant*
Charadrius montanus	Mountain Plover	SOC	Migrant*	Migrant*
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant	Migrant
Fishes				
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	—	X
Notropis buccula	Smalleye Shiner	C/SOC	X	X
Mammals				
Cynomys ludovicianus	Black-tailed Prairie Dog	SOC	—	X
Myotis velifer	Cave Myotis Bat	SOC	—	X
Canis lupus	Gray Wolf	LE/E	Extirpated	Extirpated
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X	X
Canis rufus	Red Wolf	LE/E	Extirpated	Extirpated
Dipodomys elato	Texas Kangaroo Rat	SOC/T	—	X
Mollusks				
Tritogonia verrucosa	Pistolgrip	SOC	X	X
Truncilla macrodon	Texas Fawnsfoot	SOC/T	X	X
Plants				
Yucca necopina	Glen Rose Yucca	SOC	—	X
Reptiles				
Nerodia harteri	Brazos Water Snake	SOC/T	X	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X	X

X = Occurs in county; — = does not occur in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be Delisted (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-Delisted Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed)

Sources: Texas Parks and Wildlife Department (TPWD) Annotated County List of Rare Species for Young and Stephens Counties (2009); TPWD Texas Wildlife Diversity Database (2009), United States Fish and Wildlife Service (USFWS), Federally-listed as Threatened and Endangered Species of Texas, August 27, 2009.

the state. Four bird species federally-listed as threatened or endangered could occur in the project area. These include the black-capped vireo (*Vireo atricapillus*), golden-cheeked warbler (*Dendroica chrysoparia*), interior least tern (*Sterna antillarum athalassos*), and whooping crane (*Grus americana*). The interior least tern and whooping crane are seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir. The Texas fawnsfoot (*Truncilla macrodon*) is a freshwater mussed listed as threatened by the state which may occur within the project area.

A search of the Texas Natural Diversity Database[19] 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 1 mile north of the project site; the other is located within 5 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.

4B.12.2.3.1.3 Wildlife Habitat

Approximately 29,877 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 9,143 acres of Cropland, 2,788 acres of Grassland, 11,590 acres of Mesquite Shrub/Brush, 1,938 acres of Post Oak-Mesquite Woods, 3,434 acres of mixed Riparian Brush/Woods, and 984 acres of exposed streambed.

A number of vertebrate species would be expected to occur within the South Bend Reservoir site as indicated by county occurrence records.[20] These include 11 species of frogs and toads, 7 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[21] in

[19] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, *Element of Occurrence Records*, August 25, 2009.
[20] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," http://wfscnet.tamu.edu/tcwc/Herps_online/CountyRecords.htm accessed September 2, 2009.
[21] 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.

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.

4B.12.2.3.1.4 Cultural Resources

A search of the Texas Historical Commission's online database indicates 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 indicates 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).

4B.12.2.3.1.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and 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.

4B.12.2.4 Engineering and Costing

A cost estimate for the proposed South Bend Reservoir was made in 1991. This estimate was updated for the 2006 Brazos G Regional Water Plan and now to September 2008 prices for the current plan. The cost details are shown in Table 4B.12.2-4. The total project costs are estimated to be $422,715,000. The cost for the estimated increase in system yield of 64,500 acft/yr, translates to an annual unit cost of raw water at the reservoir of $1.49 per 1,000 gallons, or $485 per acft. The annual project costs are estimated to be $31.3 million; this includes annual debt service, and operation and maintenance costs.

The total project cost reported in the 2006 Water plan was $259 million; the current plan costs are an estimated to be $423 million. In addition to inflation, cost differences are due to different methodology used in the 2006 and 2011 plans to calculate Engineering, Legal Costs and Contingencies and Environmental & Archaeology Studies and Mitigation.

The annual unit cost of water has increased from $418 per acft ($1.28 per 1,000 gallons) in the 2006 plan to $485 per acft ($1.49 per 1,000 gallons) in the current plan. The increase in yield from the 2006 plan has mitigated the some of the increase in costs from inflation and changes in methodology.

4B.12.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.12.2-5, and the option meets each criterion.

Implementation of the South Bend Reservoir would encounter difficult permitting constraints, as would be typical for any major reservoir. In addition, the water would likely require significant treatment due to water quality concerns. The level of dissolved solids, if used in the area, would require additional treatment similar to the SWATS plant for Lake Granbury water. The portion of the available supply used within the overall BRA system would not necessarily need demineralization treatment.

Table 4B.12.2-4.
Cost Estimate Summary for
South Bend Reservoir
(September 2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Dam and Reservoir (Conservation Pool 771604 acft, 29877 acres, 1090 ft. msl)	$108,862,000
Relocations & Other	$48,893,000
Total Capital Cost	**$157,755,000**
Engineering, Legal Costs and Contingencies	$55,214,000
Environmental & Archaeology Studies and Mitigation	$74,398,000
Land Acquisition and Surveying (52877 acres)	$77,042,000
Interest During Construction (4 years)	$58,306,000
Total Project Cost	**$422,715,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$6,675,000
Reservoir Debt Service (6 percent, 40 years)	$23,006,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$0
Dam and Reservoir	$1,633,000
Water Treatment Plant	$0
Pumping Energy Costs (0 kW-hr @ 0.09 $/kW-hr)	$0
Purchase of Water (acft/yr @ $/acft)	$0
Total Annual Cost	**$31,314,000**
Available Project Yield (acft/yr)	64,500
Annual Cost of Water ($ per acft)	$485
Annual Cost of Water ($ per 1,000 gallons)	$1.49

Table 4B.12.2-5.
Comparison of South Bend 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. Moderate
B. Environmental factors	
1. Environmental Water Needs	1. Moderate to High 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. 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	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

A summary of the implementation steps for the project is presented below.

4B.12.2.5.1 *Potential Regulatory Requirements*

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for structures placed in navigable waters of the U.S. (Section 10 of Rivers and Harbors Act) or 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.

4B.12.2.5.2 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.

4B.12.2.5.3 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.

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4B.12.3 Throckmorton Reservoir

4B.12.3.1 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 4B.12.3-1. 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.

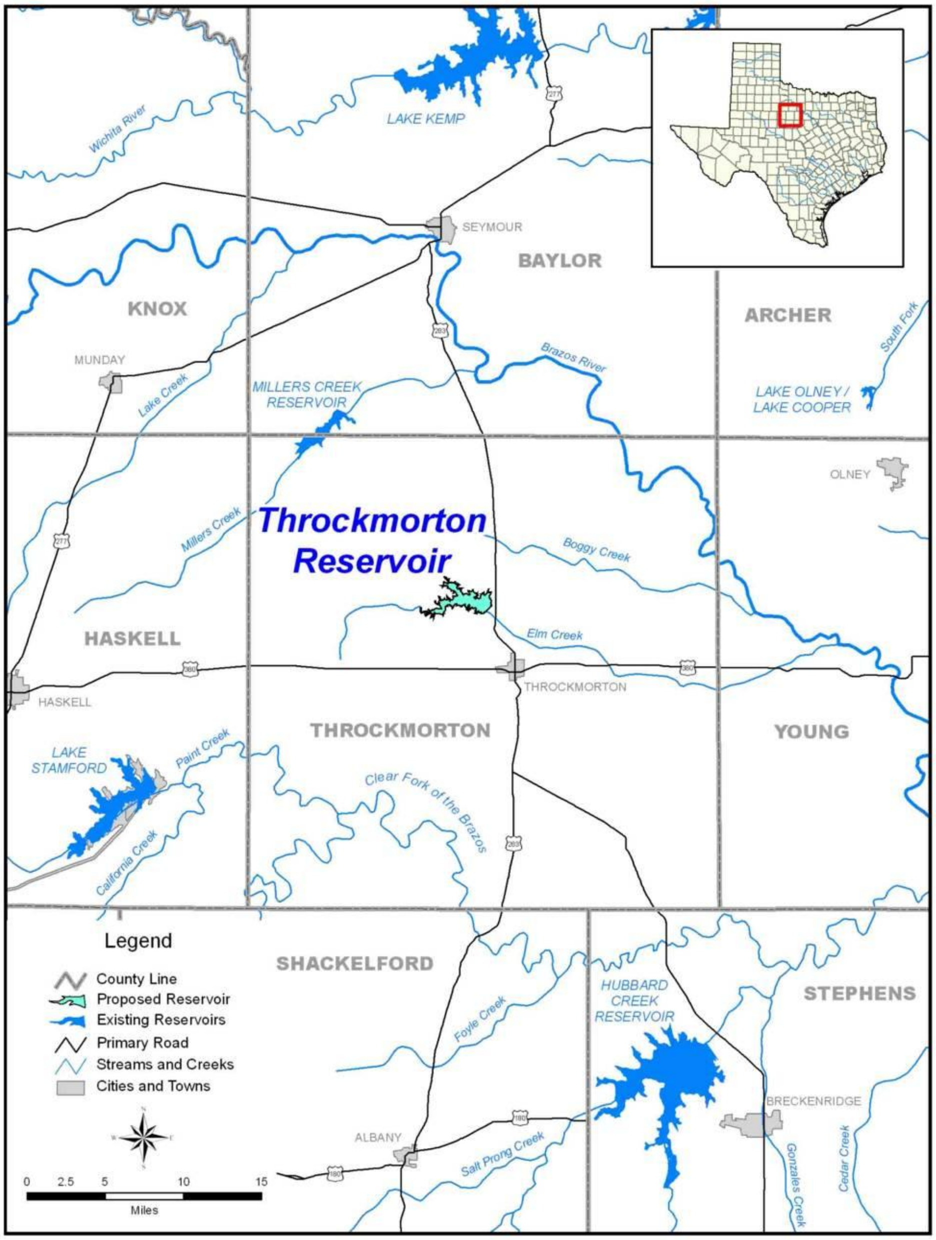


Figure 4B.12.3-1. Throckmorton Reservoir

4B.12.3.2 Available Yield

Water potentially available for impoundment in the proposed Throckmorton Reservoir was estimated using an updated version of the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available from North Elm Creek without causing increased shortages to existing downstream rights. Safe yield was computed subject to the reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the reservoir are shown in Table 4B.12.3-1.

The calculated safe yield of Throckmorton Reservoir is 1,500 acft/yr, assuming subordination of Possum Kingdom Reservoir. According to the Brazos G WAM, channel losses between Throckmorton Reservoir and Possum Kingdom Lake are about 18%. Therefore, the impact on the yield of Possum Kingdom is less than the gain of supply at Throckmorton. The firm yield of Possum Kingdom is reduced by an estimated 120 acft/yr.

Table 4B.12.3-1.
Daily Natural Streamflow Statistics
for Throckmorton Reservoir

Month	*Median Flows - Zone 1 Pass Through Requirements (ft^3/sec)*	*25th Percentile Flows - Zone 2 Pass Through Requirements (ft^3/sec)*
January	2.0	1.1
February	1.9	1.1
March	2.3	0.7
April	2.1	0.8
May	6.5	1.2
June	10.0	3.0
July	2.6	0.5
August	1.3	0.1
September	2.3	0.2
October	3.4	0.7
November	3.0	0.9
December	2.3	1.1
Zone 3 (7Q2) Pass-Through Requirement (ft^3/sec):		0

Figure 4B.12.3-2 illustrates the simulated Throckmorton Reservoir storage levels for the 1940 to 2004 historical period, subject to the safe yield of 1,500 acft/yr. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 64 percent of the time and above the Zone 3 trigger level (50 percent capacity) 94 percent of the time.

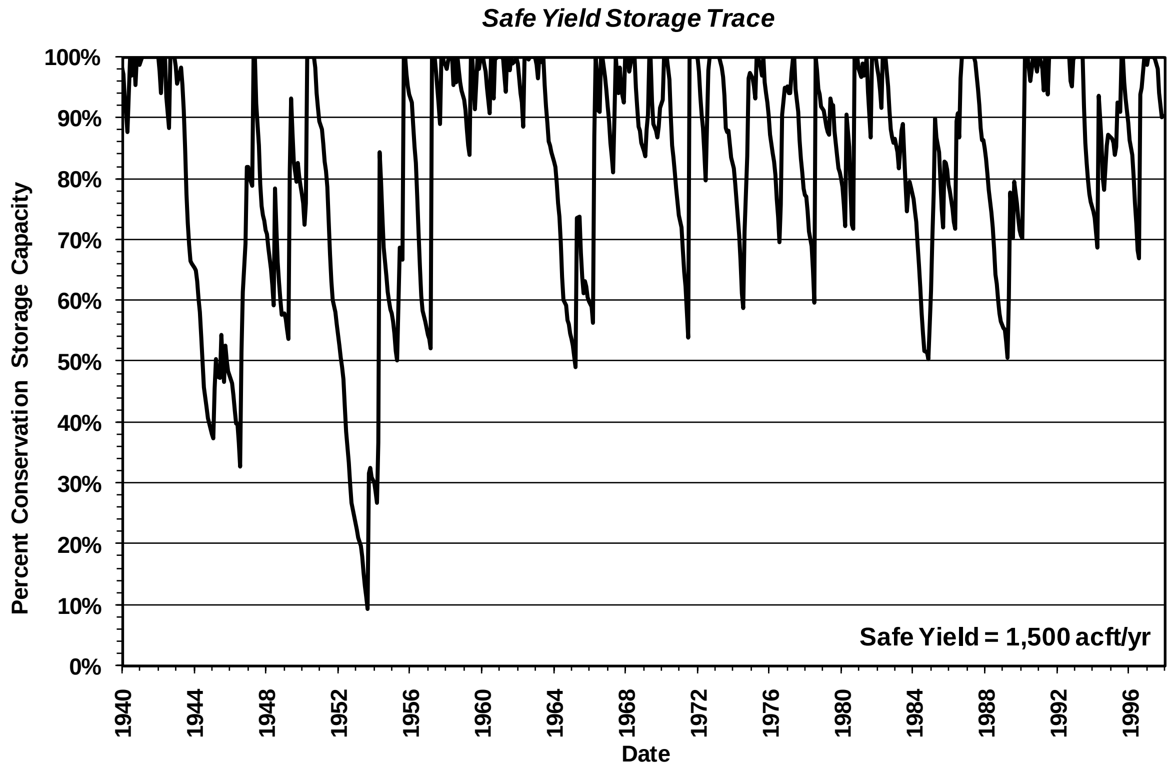
Figure 4B.12.3-3 illustrates the changes in North Elm Fork streamflows caused by impounding unappropriated water. The largest changes would be declines in median streamflow of 17.1 cfs during May (72 percent reduction) and 16.8 cfs during June (77 percent reduction). Streamflow is reduced greater than 50 percent in all months but January, February, and December. Figure 4B.12.3.2-2 also illustrates the North Elm Creek streamflow frequency characteristics with the Throckmorton Reservoir in place.

4B.12.3.3 Environmental Issues

4B.12.3.3.1 Existing Environment

The Throckmorton Reservoir site in Throckmorton County is within the Rolling Plains Ecological Region[22]. 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 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 dryland and irrigated crops are increasingly important. Poor range management practices of the past have increased the density of invasive 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[23]. The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation is approximately 27 inches.[24]

[22] 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.
[23] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.
[24] Texas State Climatologist, Texas *Temperature, Freeze, Growing Season and Precipitation Records by County*, Compilation of data from 1971-2000. Texas A&M University, College Station, 2004.



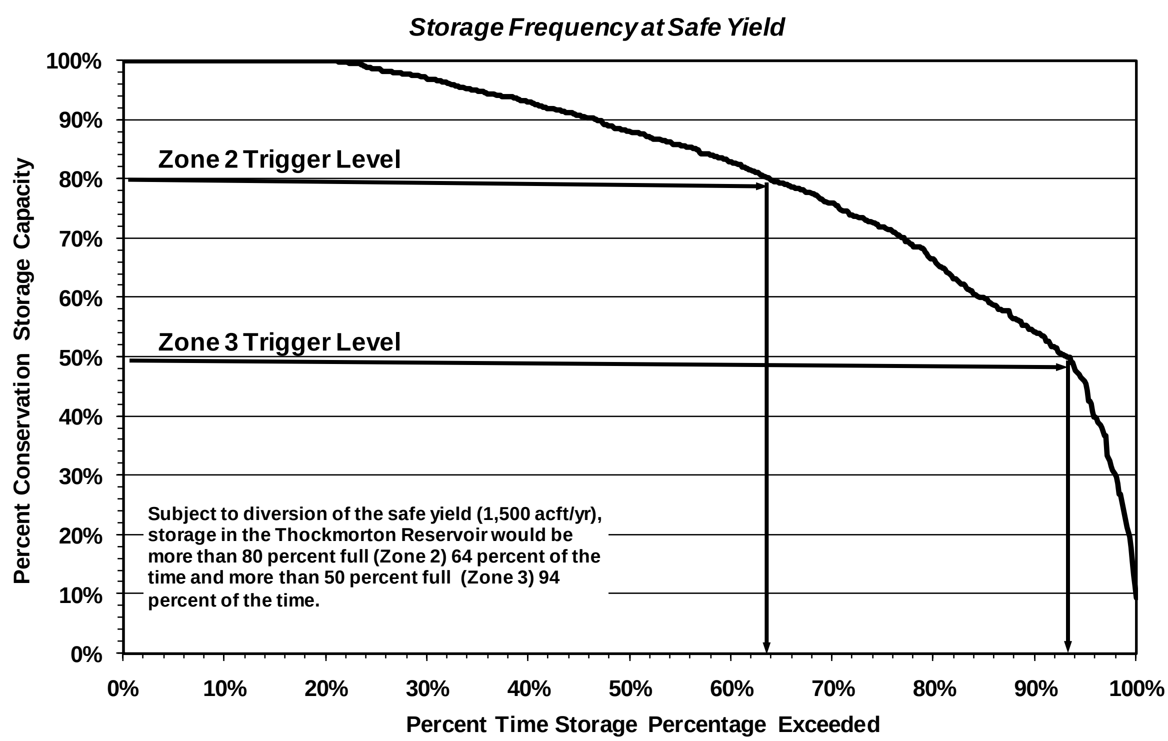
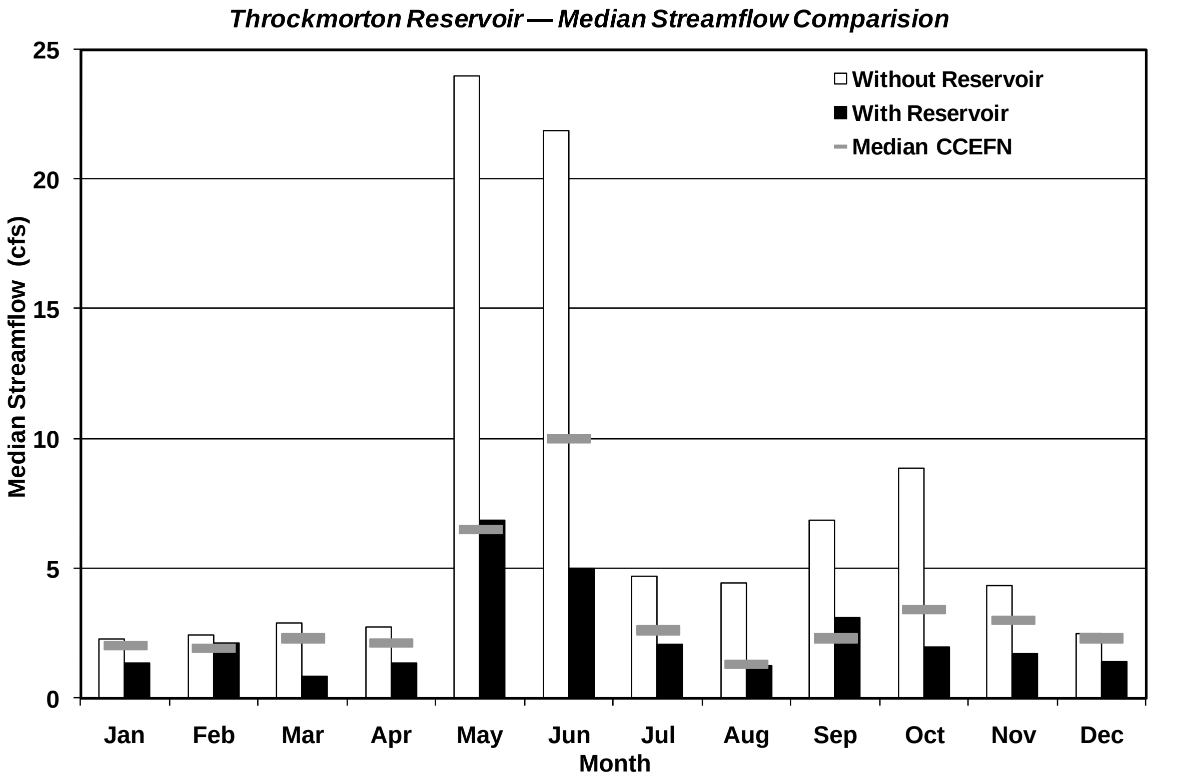


Figure 4B.12.3-2. Throckmorton Reservoir Storage Considerations



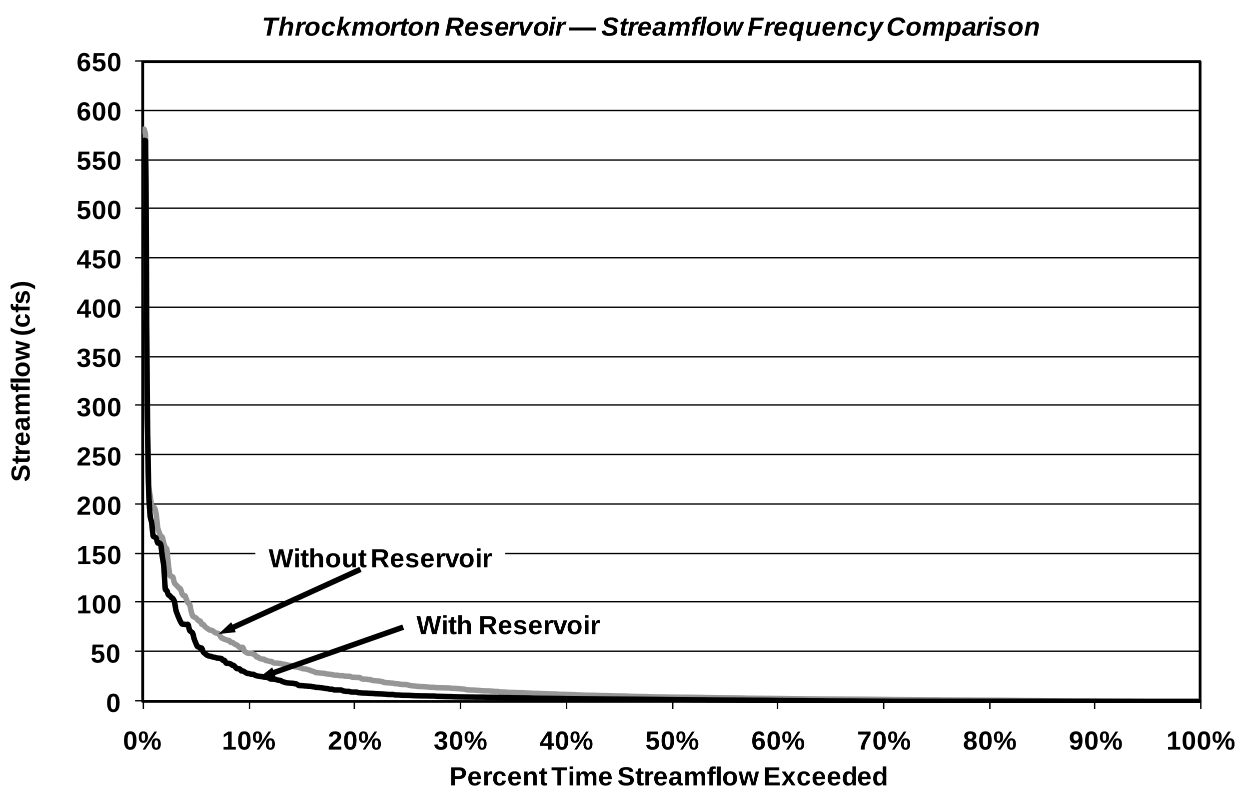


Figure 4B.12.3-3. Throckmorton Reservoir Streamflow Comparisons

The Seymour aquifer, an unconsolidated sand and gravel aquifer, is the only major aquifer in the project area.[25] It is formed by isolated alluvial deposits in 20 counties in north central Texas. The Seymour aquifer consists mainly of the scattered erosional remnants of the Seymour Formation of Pleistocene age, which consists of clay, silt, sand, and gravels that were deposited by eastward-flowing streams. The aquifer generally has less than 100 feet of saturated thickness, but it is an important source of water for domestic, municipal, and irrigation needs.[26]

The physiography of the region includes clay mud and sandstone, terraces, stair step topography, and flood-prone areas. The topography ranges from flat to rolling to steeply sloped, with benches in some areas and local shallow depressions in flood zones along waterways.[27] The predominant soil associations in the project area are the Clearfork-Gageby and Lueders-Throck-Owens associations. Clearfork-Gageby soils are very deep, nearly level or very gently sloping, loamy soils on flood plains. Lueders-Throck-Owens soils are very shallow to deep, gently undulating or undulating, loamy and clayey upland soils.[28]

Two major vegetation types occur within the general vicinity of the proposed project: Mesquite (*Prosopis glandulosa*)–Lotebush Shrub, and crops.[29] 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*),

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

[26] United States Geological Service (USGS), *Ground Water Atlas of the United States*, http://capp.water.usgs.gov/gwa/index.html, 2004.

[27] 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.

[28] Cyprian, T.E., *Soil Survey of Throckmorton County, Texas*, United States Department of Agriculture, Natural Resources Conservation Service, in cooperation with Texas Agricultural Experiment Station, 2004.

[29] 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.

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.

4B.12.3.3.2 Potential Impacts

4B.12.3.3.2.1 Aquatic Environments including Bays & Estuaries

The anticipated impact of this project would be minimal reduction in variability and substantial reductions in quantity of median monthly flows. The slight reduction in variability of monthly flow values (measured by comparing sample variances of all monthly flows from 1940-2004 and predicted flows over that same time period with the project in place; sample variance without project =6.94 x 10^6; sample variance with project =5.14 x 10^6) 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 0.3 cfs (14 percent) in February to 17.1 cfs (72 percent) in May, as shown in Table 4B.12.3-2. The highest reductions (>75 percent) would occur in June and October, and all months except January, February, and December would be reduced by at least 50 percent. This project would also result in a higher frequency of low-flow conditions. Without the project, the monthly flow would be less than .71 cfs only 15 percent of the time (85 percent exceedance value), and would be less than 0.10 cfs 15 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 the summer months when flows are already historically low and water chemistry conditions are the most stressful for aquatic species (e.g., high temperatures and high nutrient growth).

Although there would be biological impacts in the immediate vicinity of the project site and downstream, it is not likely that this project, alone, would have a substantial influence on total discharge in the Brazos River or to freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflow to the estuary. As a new reservoir without a current operating permit, the Throckmorton Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

Table 4B.12.3-2.
Median Monthly Streamflow for Throckmorton Reservoir

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	2.3	1.3	0.9	42%
February	2.4	2.1	0.3	14%
March	2.9	0.8	2.1	72%
April	2.7	1.4	1.4	50%
May	24.0	6.8	17.1	72%
June	21.8	5.0	16.8	77%
July	4.7	2.0	2.6	56%
August	4.4	1.2	3.2	72%
September	6.8	3.1	3.7	55%
October	8.9	1.9	6.9	78%
November	4.3	1.7	2.6	61%
December	2.5	1.4	1.1	44%

4B.12.3.3.2.2 Threatened & Endangered Species

A total of 18 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.12.3-3). This group includes two reptiles, seven birds, five mammals, two mollusks, and two fish species. Two listed species, the gray wolf (*Canis lupus*) and the red wolf (*Canis rufus*) have been extirpated from the project area. The whooping crane (*Grus Americana*) is the only federally-listed threatened or endangered bird potentially occurring in the project area. The whooping crane is a seasonal migrant that could pass through the project area but would not likely be directly affected by the proposed reservoir. Two mollusks, the pistolgrip (*Tritogonia verrucosa*) and the Texas fawnsfoot (*Truncilla macrodon*) and two fishes the smalleye shiner (*Notropis buccula)* and the sharpnose shiner (*Notropis oxyrhincus*) potentially occur in the project area; the Texas fawnsfoot is state listed as threatened and the other three species are candidates for federal listing.

A search of the Texas Natural Diversity Database[30] maintained by TPWD revealed the documented occurrence of one colonial water bird rookery within approximately 2.5-miles of the

[30] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, *Element of Occurrence Records*, August 25, 2009.

Table 4B.12.3-3.
Potentially Occurring Species that are Rare or Federal- and State-Listed for Throckmorton County - Throckmorton Reservoir Site

Scientific Name	***Common Name***	***Federal/ State Status***	***Potential Occurrence***
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL	Migrant
Ammodramus bairdii	Baird's Sparrow	SOC	Migrant
Haliaeetus leucocephalus	Bald Eagle	DL/T	Migrant
Charadrius montanus	Mountain Plover	SOC	Migrant*
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*
Grus Americana	Whooping Crane	LE/E	Migrant
Fishes			
Notropis oxyrhincus	Sharpnose Shiner	C/SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Mammals			
Cynomys ludovicianus	Black-tailed Prairie Dog	SOC	X
Myotis velifer	Cave Myotis Bat	SOC	X
Canis lupus	Gray Wolf	LE/E	Extirpated
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E	Extirpated
Mollusks			
Tritogonia verrucosa	Pistolgrip	SOC	X
Truncilla macrodon	Texas Fawnsfoot	SOC/T	X
Reptiles			
Nerodia harteri	Brazos Water Snake	SOC/T	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X

X = Occurs in county. * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations.)

SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas.

Sources: Texas Parks and Wildlife Department (TPWD) Annotated County List of Rare Species for Throckmorton County (2009); TPWD Texas Wildlife Diversity Database (2009), United States Fish and Wildlife Service (USFWS), Federally-listed as Threatened and Endangered Species of Texas, September 8, 2009.

proposed Throckmorton Reservoir (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.

4B.12.3.3.2.3 Wildlife Habitat

Approximately 1,160 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 1,118 acres of Mesquite-Lotebush Shrub, and 42 acres of Mesquite-Saltcedar Brush.

A number of vertebrate species would be expected to occur within the Throckmorton Reservoir site as indicated by county occurrence records.[31] 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 [32] 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.

4B.12.3.3.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that no archeological sites have been documented within the general vicinity of the proposed reservoir. However, the area has never been surveyed by a professional archeologist and the absence of documented sites may reflect the lack of investigation rather than the absence of archeological sites. Prior to reservoir inundation the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within

[31] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," http://wfscnet.tamu.edu/tcwc/Herps_online/CountyRecords.htm accessed September 2, 2009.
[32] Davis, W.B., and D.J. Schmidly, *The Mammals of Texas – Online Edition*, Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

the 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).

4B.12.3.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased adverse effects on stream flow below the reservoir site 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.

4B.12.3.4 Engineering and Costing

Construction of the Throckmorton Reservoir project will cost approximately $28.3 million. This includes the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $2.09 million; this includes annual debt service and operation and maintenance. The cost for the available project safe yield of 1,500 acft/yr translates to an annual unit cost of raw water of $4.27 per 1,000 gallons, or $1,391/acft. A summary of the cost estimate is provided in Table 4B.12.3-4. Costs shown herein are for raw water supply at the reservoir and include no transmission, local distribution, or treatment costs.

4B.12.3.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.12.3-5, and the option meets each criterion.

Table 4B.12.3-4.
Cost Estimate Summary for
Throckmorton Reservoir
(September 2008 Prices)

Item	*Estimated Costs for Facilities*
Capital Costs	
Dam and Reservoir	$13,411,000
Total Capital Cost	**$13,411,000**
Engineering, Legal Costs and Contingencies	$4,694,000
Environmental & Archaeology Studies and Mitigation	$4,050,000
Land Acquisition and Surveying	$4,050,000
Interest During Construction (2 years)	$2,049,000
Total Project Cost	**$28,254,000**
Annual Costs	
Reservoir Debt Service (6 percent, 40 years)	$1,878,000
Operation and Maintenance	$201,000
Purchase of Water (120 acft/yr @ $54.50 per acft)	7,000
Total Annual Cost	**$2,086,000**
Available Project Safe Yield (acft/yr)	1,500
Annual Cost of Water ($ per acft)	$1,391
Annual Cost of Water ($ per 1,000 gallons)	$4.27

Table 4B.12.3-5.
Comparison of Throckmorton Reservoir
to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable 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. 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 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

4B.12.3.5.1 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.

4B.12.3.5.2 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.

4B.12.3.5.3 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.

4B.12.4 Double Mountain Fork Reservoir (East and West Sites)

4B.12.4.1 Description of Options

The Double Mountain Fork Reservoir is a proposed new reservoir on the Double Mountain Fork of the Brazos River, which has been proposed for construction at two alternative sites (East and West Sites). The two sites are less than 30 river miles apart from each other as shown on (Figure 4B.12.4-1). This project is a potential source of water for Stonewall County and other counties in west central Texas.

The West Site will be located in Jones and Stonewall Counties, about 18 miles southwest of the City of Aspermont. The proposed west site has a storage capacity of 215,254 acft, covering 6,632 acres. The proposed conservation pool elevation is 1,790 feet. The drainage area at this location is 1,669 square miles.

The East Site is located about 30 river miles downstream of the west site, between Highway 83 and FM 1835, with a drainage area of 1,937 square miles. The storage capacity of the east site is 280,814 acft, with a surface area of 10,814 acres at the proposed conservation pool elevation of 1,667 feet. Preliminary studies have indicated that the east site may have some potential problems with land acquisition. If the east site needs to be relocated 5 to 10 miles downstream, it is expected that this change would have no significant impact on the firm yield.

The Stonewall County area has a great deal of gypsum in the soil. Gypsum is soluble in water and can make a reservoir site unsuitable to build a dam. The reservoir locations considered were chosen to avoid the presence of gypsum in the vicinity of the dam. However, more detailed soil investigations are required to ensure the foundation conditions are suitable for a dam. If necessary, the sites may be relocated to a suitable soil without having a significant impact on the yield.

4B.12.4.2 Available Yield

Water potentially available for impoundment in the proposed Double Mountain Fork Reservoirs (East and West) was estimated using the Brazos G WAM and a reservoir water budget analysis. Safe yield calculations were calculated using the updated Brazos G WAM with 2060 sediment conditions for the January 1940 to December 1997 hydrololgic period and a spreadsheet model with a hydrologic extension from January 1998 through September 2004 to

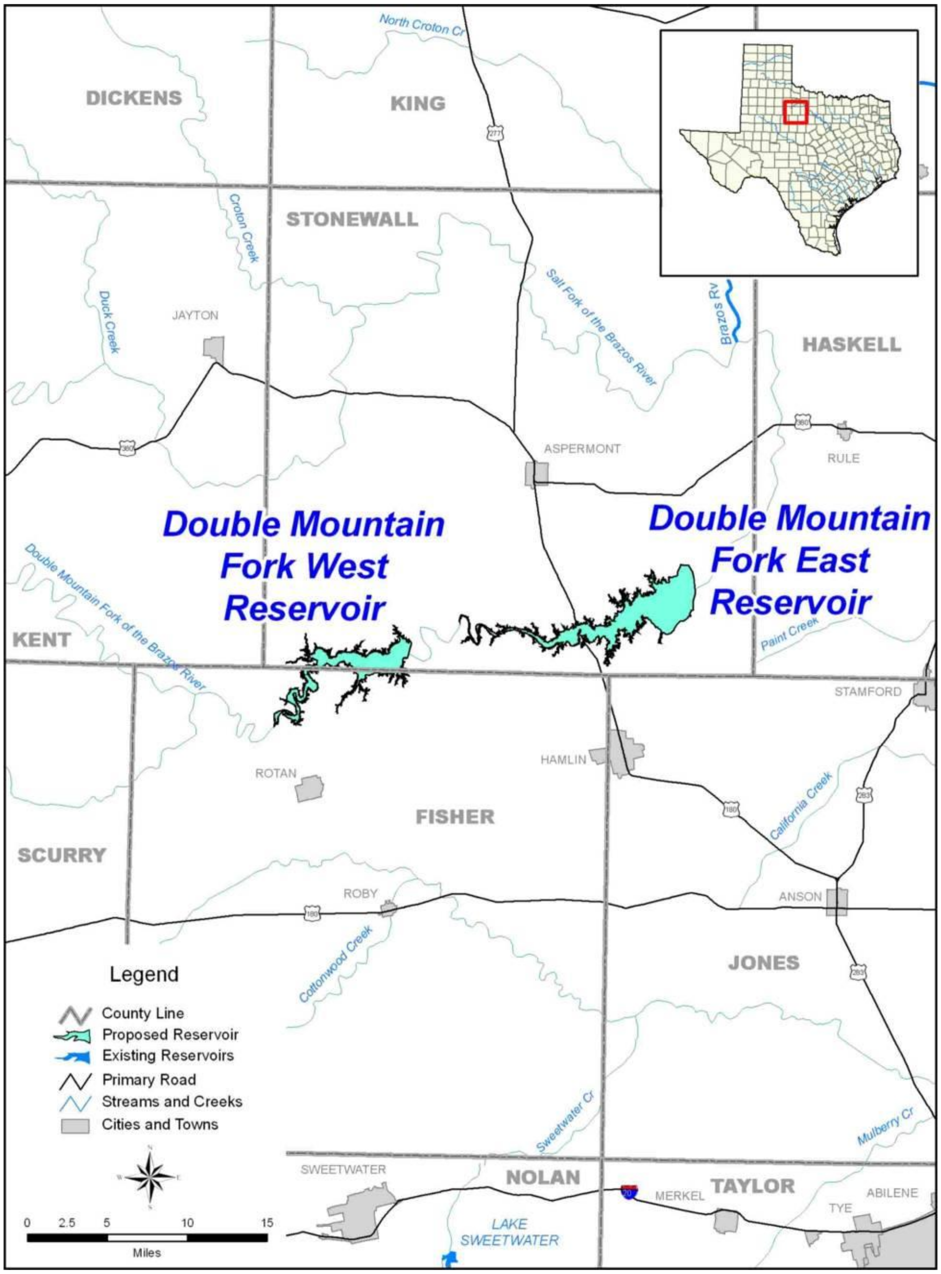


Figure 4B.12.4-1. Double Mountain Fork Reservoir (East and West Sites)

account for the recent drought in the Upper Brazos Basin. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available from the Double Mountain Fork of the Brazos River without causing increased shortages to existing downstream rights. Safe yield was computed subject to the reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the

Consensus Criteria pass through requirements for the east and west reservoirs, respectively, are shown in Tables 4B.12.4-1 and 4B.12.4-2.

The calculated safe yield of the East Site is 36,025 acft/yr and the calculated safe yield of the West Site is 34,775 acft/yr; both safe yields assume subordination of Possum Kingdom Reservoir. The yield impact on Possum Kingdom due to the East Site is estimated to be 4,450 acft/yr and the yield impact on Possum Kingdom due to the West Site is estimated to be 3,250 acft/yr.

Figures 4B.12.4-2 and 4B.12.4-3 illustrates the simulated Double Mountain Fork Reservoirs (East and West) storage levels for the 1940 to 2004 historical period, subject to the safe yield of 36,025 acft/yr for the East Site and 34,775 acft/yr for the West Site. For the East Site, simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 51 percent of the time and above the Zone 3 trigger level (50 percent capacity) 87 percent of the time. For the West Site, simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 64 percent of the time and above the Zone 3 trigger level (50 percent capacity) 92 percent of the time.

Figures 4B.12.4-4 and 4B.12.4-5 illustrates the changes in Double Mountain Fork streamflows caused by impounding the unappropriated water at both reservoir sites. Median streamflows are reduced significantly due to the reservoir. These figures also illustrate the Double Mountain Fork streamflow frequency characteristics with the East Site and West Site reservoirs in place.

4B.12.4.3 Environmental Issues – East Site

4B.12.4.3.1 Existing Environment

The Double Mountain Fork East Reservoir site in Stonewall County is within the Rolling Plains Ecological Region.[33] This region is located east of the High Plains, west of the West Cross Timbers and North Central Prairie, and north of the Edwards Plateau. It is characterized by nearly level to rolling topography, soft prairie sands and clays, juniper breaks and midgrass prairie. The region varies from open, short to tall, scattered to dense grasslands to savannahs

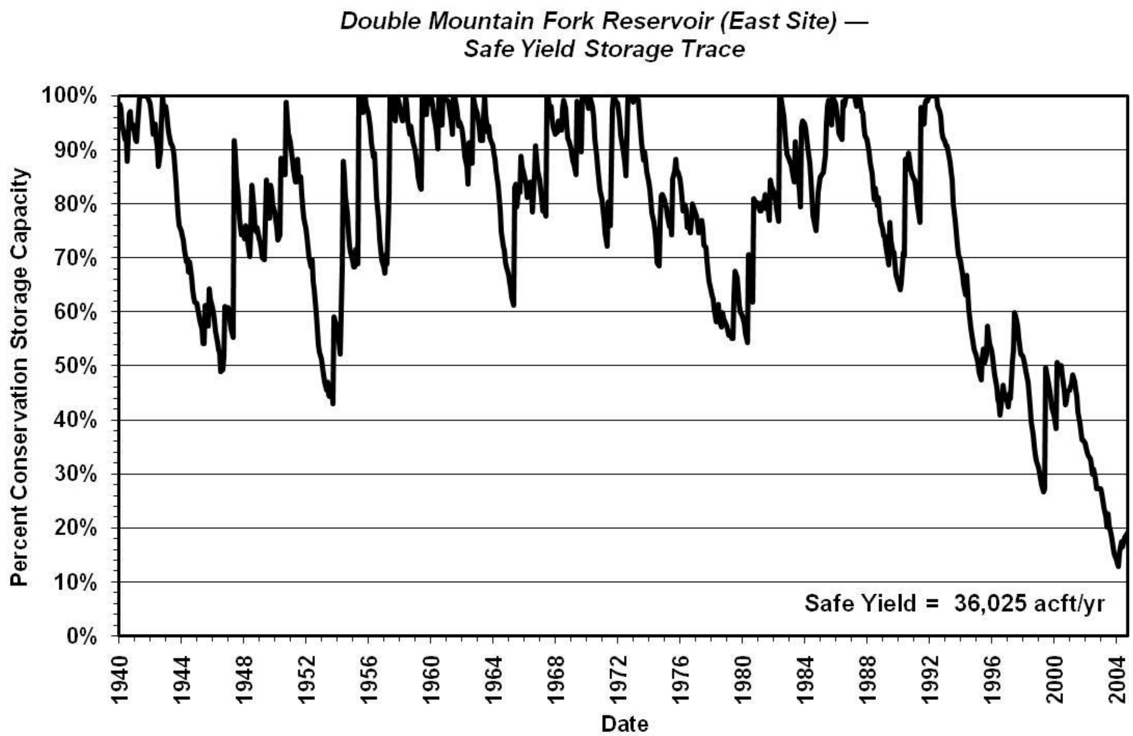
[33] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, *Vegetational Areas of Texas*, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.

Table 4B.12.4-2.
Daily Natural Streamflow Statistics
for the Double Mountain Fork Reservoir – East Site

Month	***Median Flows - Zone 1 Pass Through Requirements (ft³/sec)***	***25th Percentile Flows - Zone 2 Pass Through Requirements (ft³/sec)***
January	7.3	1.9
February	7.2	1.4
March	4.6	0.6
April	4.0	0.5
May	24.9	1.3
June	38.8	5.4
July	8.5	0.7
August	5.9	0.2
September	14.9	0.4
October	10.9	1.0
November	9.5	1.0
December	8.4	2.1
Zone 3 (7Q2) Pass-Through Requirement (ft³/sec):		0

Table 4B.12.4-3.
Daily Natural Streamflow Statistics
for the Double Mountain Fork Reservoir – West Site

Month	***Median Flows - Zone 1 Pass Through Requirements (ft³/sec)***	***25th Percentile Flows - Zone 2 Pass Through Requirements (ft³/sec)***
January	6.4	1.3
February	6.5	0.8
March	3.8	0.3
April	3.9	0.3
May	23.6	1.0
June	39.4	5.3
July	8.7	0.6
August	5.7	0.2
September	14.4	0.4
October	10.6	0.7
November	8.1	0.5
December	7.8	1.4
Zone 3 (7Q2) Pass-Through Requirement (ft³/sec):		0



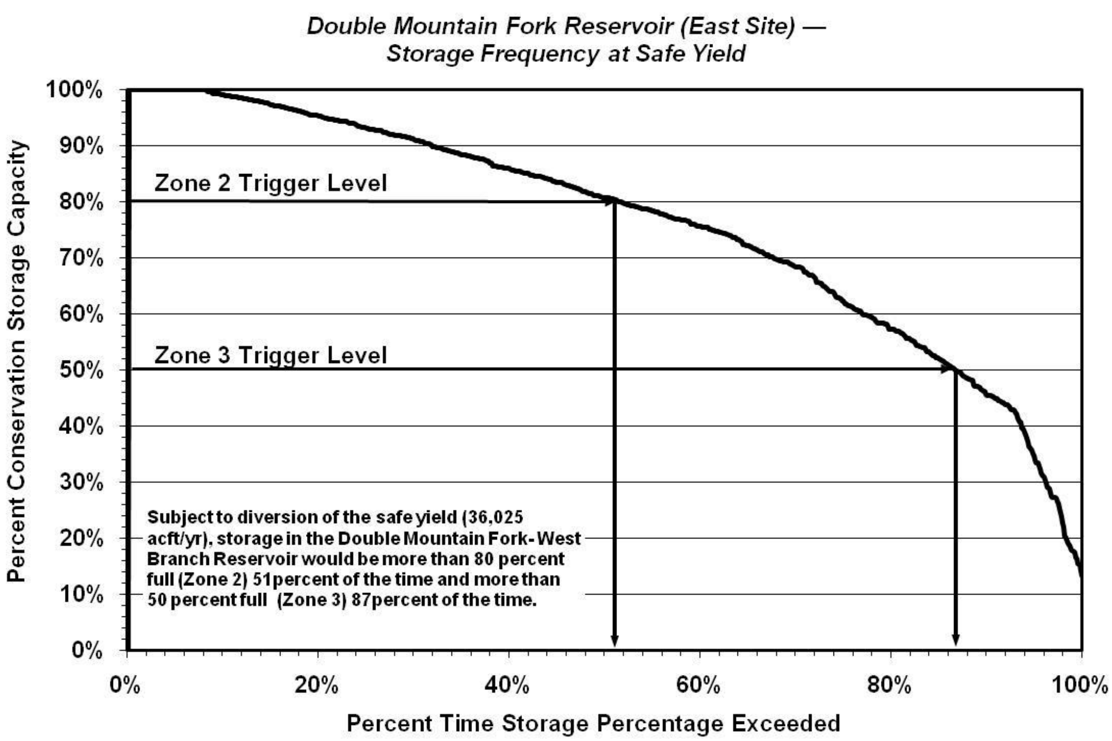
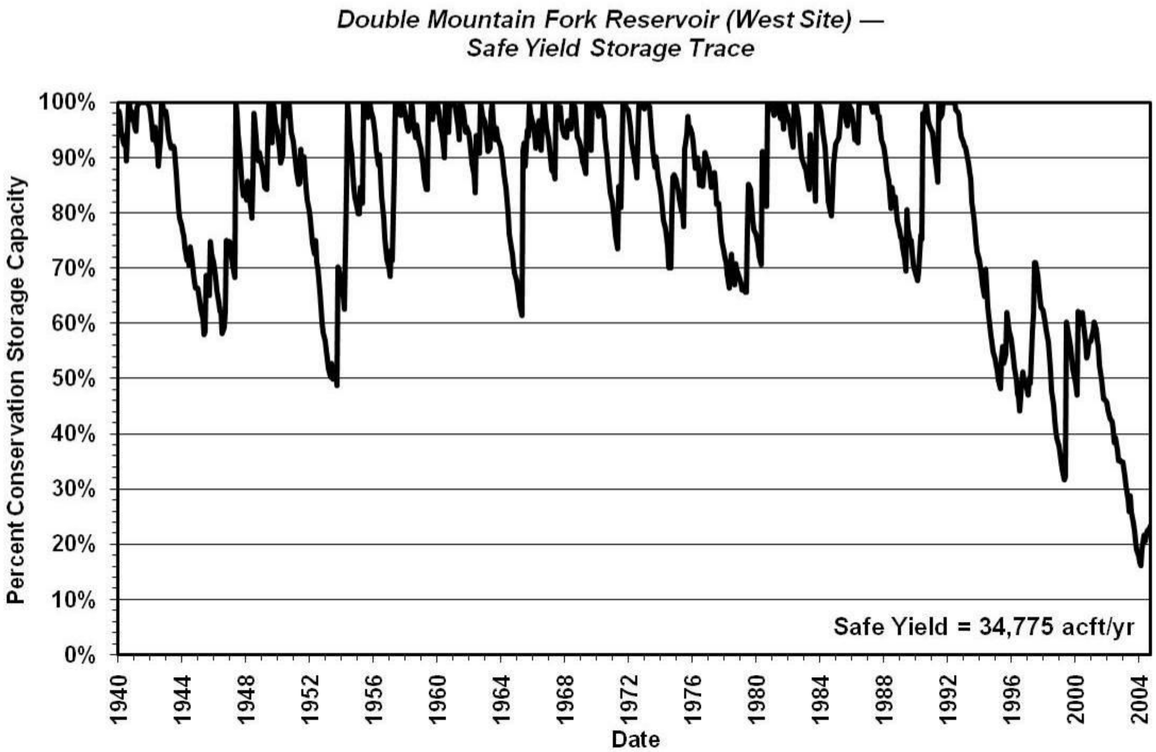


Figure 4B.12.4-2. Double Mountain Fork Reservoir (East Site) Storage Considerations



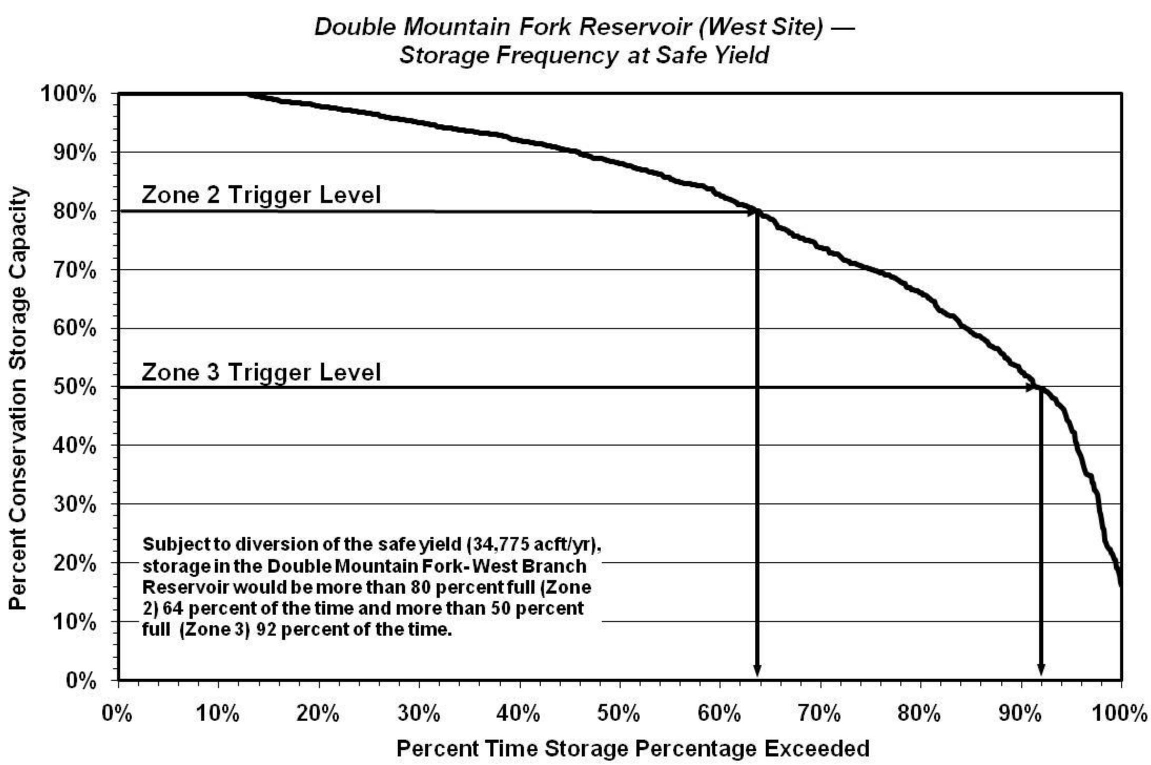
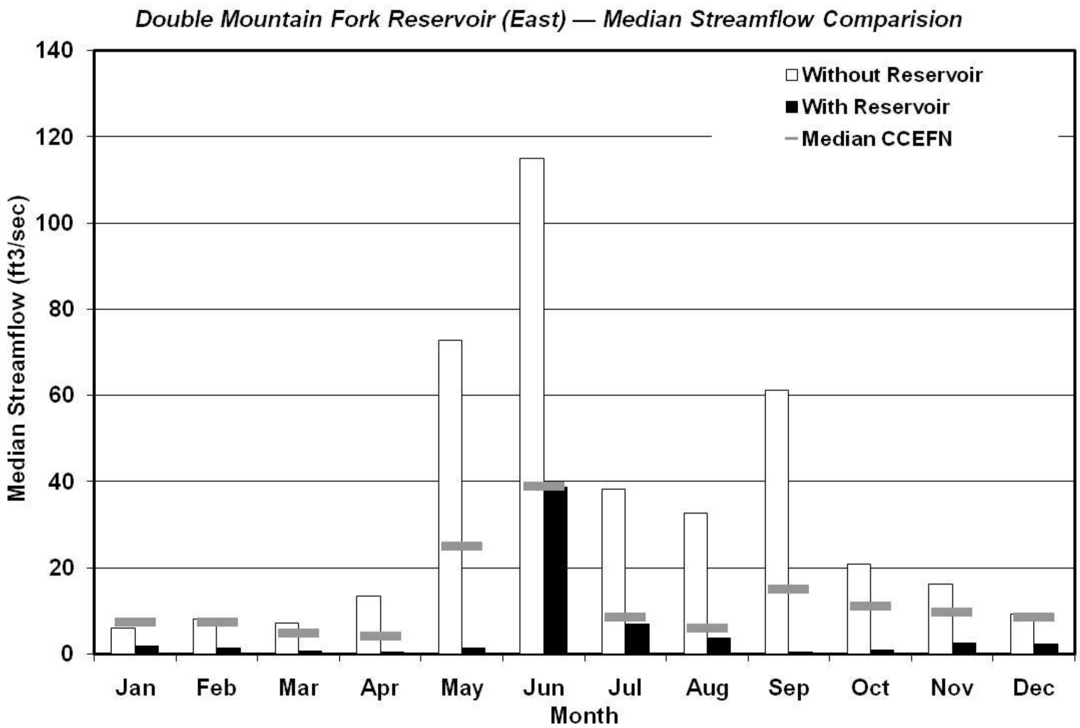


Figure 4B.12.2-3. Double Mountain Fork Reservoir (West Site) Storage Considerations



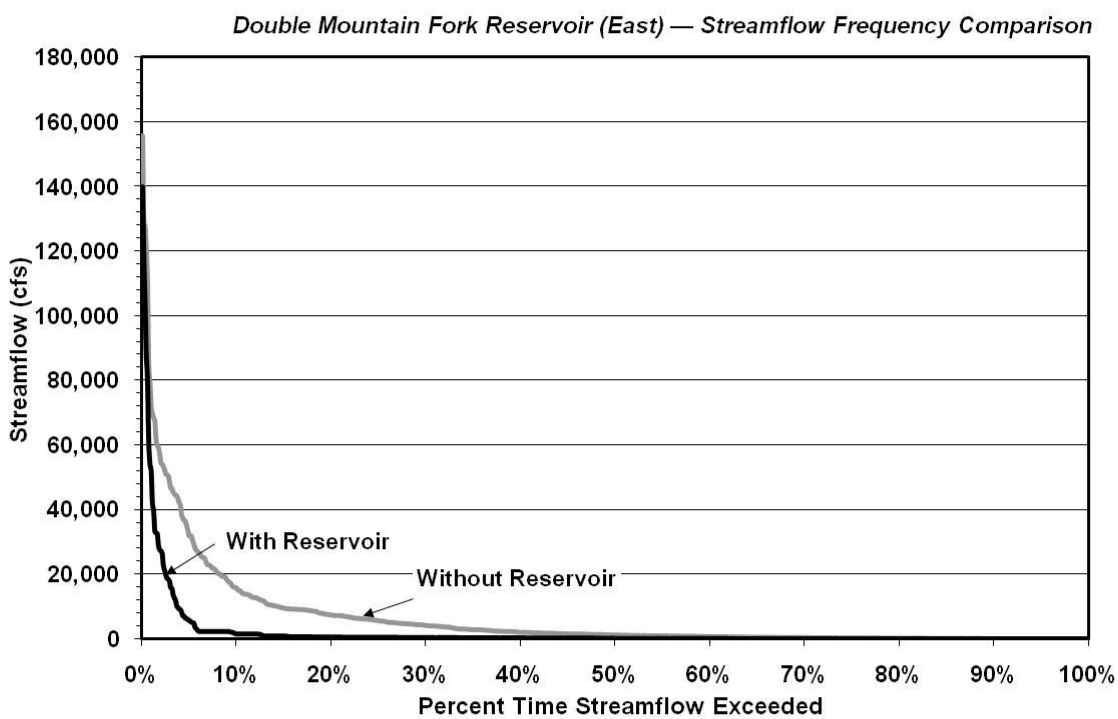
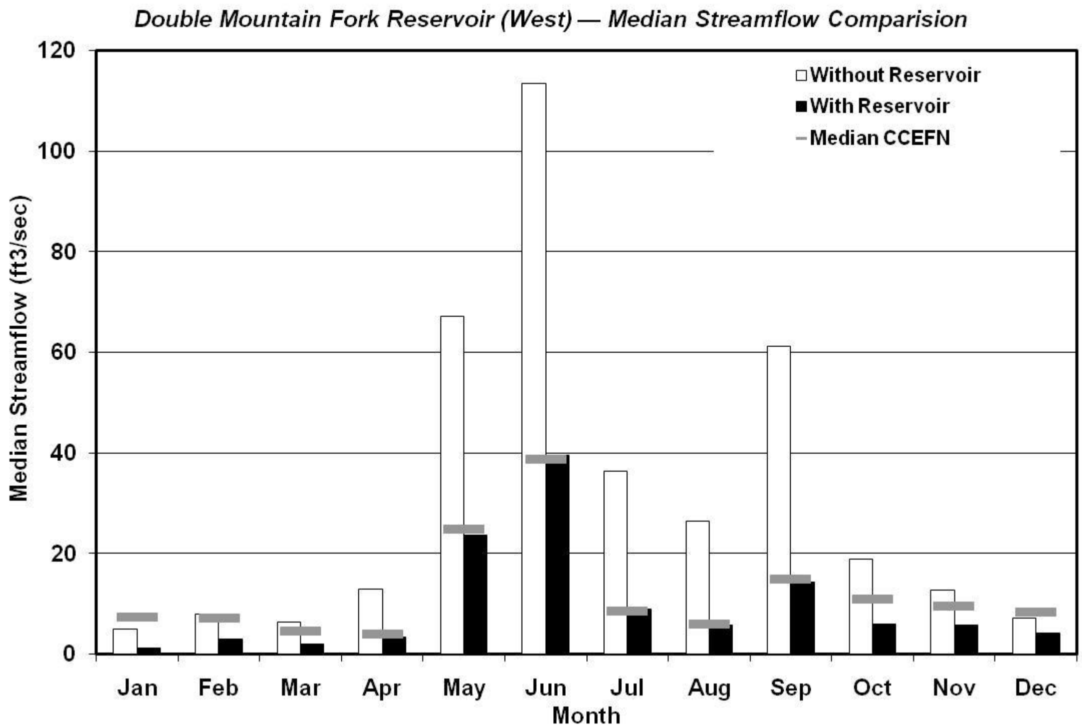


Figure 4B.12.4-4. Double Mountain Fork Reservoir (East Site) Streamflow Comparison



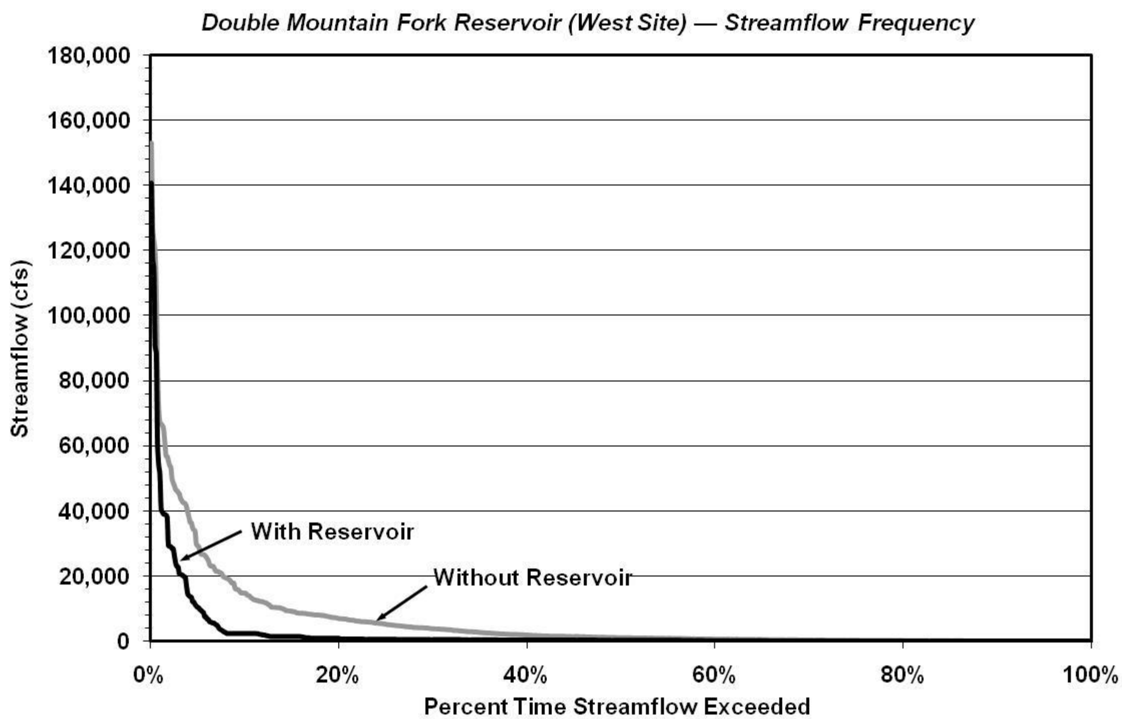


Figure 4B.12.4-5. Double Mountain Fork Reservoir (West Site) Streamflow Comparison

to savannahs with bunch grasses. Most of the plains are rangeland, but dryland and irrigated crops are increasingly important. Poor range management practices of the past have increased the density of invasive 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.[34] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 23 and 25 inches.[35]

The Seymour Aquifer, an unconsolidated sand and gravel aquifer, is the only major aquifer in the project area. It is formed by isolated alluvial deposits in 20 counties in north central Texas. The Seymour aquifer consists mainly of the scattered erosional remnants of the Seymour Formation of Pleistocene age, which consists of clay, silt, sand, and gravel that were deposited by eastward-flowing streams. The aquifer generally has less than 100 feet of saturated thickness, but it is an important source of water for domestic, municipal, and irrigation needs.[36]

The physiography of the region includes hard sandstone, mud, and mudstone (undifferentiated), gypsiferous red beds with dolomite, terraces, severely eroded land, undissected red beds, and flood-prone areas. In some areas, the topography is steeply sloped, with densely dissected gullies and low hills in severely eroded areas. There are also local shallow depressions in flood-prone areas along waterways.[37] The predominant soil associations in the project area are the Owens-Cottonwood and Rotan-Frankirk associations. The Owens-Cottonwood association consists of very shallow to shallow, gently to strongly sloping soils on uplands. These soils are very slowly to moderately permeable and well drained. Cottonwood soils are calcareous loam underlain by gypsum; and Owens soils are calcareous clay underlain by shaly clay. The Rotan-Frankirk association consists of deep, nearly level to gently sloping soils on uplands that formed in either ancient alluvial outwash (Rotan) or calcareous, loamy alluvium (Frankirk). These clay and clay loam soils are moderately slowly permeable and well drained.[38]

Four major vegetation types occur within the general vicinity of the proposed project: Mesquite (*Prosopis glandulosa*)–Lotebush Brush/Shrub, Mesquite-Juniper (*Juniperus*) Brush,

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[34] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.
[35] Larkin, T.J., and G.W. Bomar, *Climatic Atlas of Texas*, Texas Department of Water Resources, Austin, Texas, 1983.
[36] United States Geological Service (USGS), *Ground Water Atlas of the United States*, http://capp.water.usgs.gov/gwa/index.html, 2004.
[37] 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.
[38] Goerdel, A.R., and L. Watson, *Soil Survey of Stonewall County, Texas*, United States Department of Agriculture, Soil Conservation Service, in cooperation with Texas Agricultural Experiment Station, 1975.

Mesquite-Saltcedar (*Tamarix*) Brush/Woods, and crops.[39] 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 Brush/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*). Commonly associated plants of Mesquite-Juniper Brush are lotebush, shin oak (*Quercus havardii*), sumac (*Rhus* spp.), Texas pricklypear (*Opuntia engelmannii*), tasajillo, kidneywood (*Eysenhardtia texana*), agarito, yucca, Lindheimer silktassel (*Garrya ovata*), catclaw (*Acacia* sp.), Mexican persimmon (*Diospyros texana*), sideoats grama, three-awn (*Aristida* sp.), Texas grama, hairy grama, curly-mesquite (*Hilaria belangeria*), buffalograss, and hairy tridens (*Erioneuron pilusum*). Commonly associated plants of Mesquite-Saltcedar Brush/Woods are creosotebush (*Larrea tridentata*), cottonwood (*Populus deltoides*), desert willow (*Chilopsis linearis*), giant reed (*Arundo donax*), seepwillow (*Baccharis* sp.), common buttonbush (*Cephalanthus occidentalis*), whitethorn acacia (*Acacia constricta*), Australian saltbush (*Atriplex semibaccata*), fourwing saltbush (*Atriplex canescens*), lotebush, wolfberry (*Lycium berlandieri*), tasajillo, guayacan (*Guaiacum angustifolium*), alkali sacaton (*Sporobolus airoides*), Johnsongrass (*Sorghum halepense*), saltgrass (*Distichlis spicata*), cattail (*Typha* spp.), bushy bluestem (*Andropogon glomeratus*), and chino grama (*Bouteloua ramosa*). 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.

[39] 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.

4B.12.4.3.2 Potential Impacts

4B.12.4.3.2.1 Aquatic Environments including Bays & Estuaries

The anticipated impact of this project would be lower variability in and substantial reductions in quantity of median monthly flows. The difference in variability of monthly flows would be a factor of approximately 2.3 (measured by comparing sample variances of all monthly flows from 1940-2004 and predicted flows over that same time period with the project in place; sample variance without project=23.15 x 10^7; sample variance with project=10.14 x 10^7). Variability in flow is important to the instream biological community as well as riparian species and this reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing habitat suitability for others. In addition to reduced variability, there would be substantial reductions in the quantity of median monthly flow downstream of the project. These reductions would range from 4.1 cfs (69 percent) in January to 76.1 cfs (66 percent) in June, as shown in Table 4B.12.4-3. The decrease in monthly median flow values at the project site would be greater than 90 percent for five months (March, April, May, September, October) and approximately 66 percent or greater in all months. This project would also result in a higher frequency of low-flow conditions. Without the project, the monthly flows would be less than 2.02 cfs only 15 percent of the time (85 percent exceedance value), but the 85 percent exceedance value with the project in place would be 0.2 cfs. These reductions in flow would have substantial impacts on the instream biological community, including reduced habitat available for spawning fish in the spring and an increased likelihood of high water temperatures and impairment of other water quality parameters in the summer.

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 downstream locations on the Brazos River (this site is near the headwaters). It is also unlikely that this project would have an impact on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows to the estuary. As a new reservoir without a current operating permit, the Double Mountain Fork East Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

Table 4B.12.4-3.
Median Monthly Streamflow: Double Mountain Fork East Reservoir

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	6.0	1.9	4.1	69%
February	8.1	1.4	6.7	82%
March	7.2	0.6	6.6	92%
April	13.5	0.5	13.0	96%
May	72.8	1.3	71.5	98%
June	114.9	38.8	76.1	66%
July	38.3	6.9	31.4	82%
August	32.6	3.6	29.0	89%
September	61.3	0.4	60.9	99%
October	20.9	1.0	19.9	95%
November	16.3	2.6	13.7	84%
December	9.3	2.4	6.9	75%

4B.12.4.3.2.2 Threatened and Endangered Species

A total of 20 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.12.4-4). This group includes 2 reptiles, 10 birds, 6 mammals, and 2 fish species. Two listed species, the black-footed ferret (*Mustela nigripes*) and the gray wolf (*Canis lupus*) have been extirpated from the project area. The whooping crane (*Grus americana*) is the only federally-listed threatened or endangered bird potentially occurring in the project area. The whooping crane is a seasonal migrant that could pass through the project area but would not likely be directly affected by the proposed reservoir. Two fishes, the smalleye shiner (*Notropis buccula*) and the sharpnose shiner (*Notropis oxyrhincus*) potentially occur in the project area; these species are candidates for federal listing.

Table 4B.12.4-4.
Potentially Occurring Species that are Rare or Federal- and State-Listed for Stonewall County - Double Mountain Fork Reservoir East Site

Scientific Name	*Common Name*	*Federal/State Status*	*Potential Occurrence*
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL	Migrant
Ammodramus bairdii	Baird's Sparrow	SOC	Migrant
Haliaeetus leucocephalus	Bald Eagle	DL/T	Migrant
Buteo regalis	Ferruginous Hawk	SOC	Migrant
Charadrius montanus	Mountain Plover	SOC	Migrant*
Charadrius alexandrinus	Snowy Plover	SOC	Migrant
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*
Charadrius alexandrines nivosus	Western Snowy Plover	SOC	Migrant
Grus americana	Whooping Crane	LE/E	Migrant
Fishes			
Notropis buccula	Smalleye Shiner	C/SOC	X
Notropis oxyrhincus	Sharpnose Shiner	C/SOC	X
Mammals			
Mustela nigripes	Black-footed Ferret	LE/E	Extirpated
Cynomys ludovicianus	Black-tailed Prairie Dog	SOC	X
Myotis velifer	Cave Myotis Bat	SOC	X
Canis lupus	Gray Wolf	LE/E	Extirpated
Corynorhinus townsendii pallescens	Pale Townsend's Big-eared Bat	SOC	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Reptiles			
Nerodia harteri	Brazos Water Snake	SOC/T	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X

* Nesting migrant; may nest in the county.
X = Occurs in county.
Federal Status: LE-Listed Endangered; LT-Listed Threatened; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations.) SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).
State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas. SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: Texas Parks and Wildlife Department (TPWD) Annotated County List of Rare Species for Stonewall County (2009); TPWD Texas Wildlife Diversity Database (2009), United States Fish and Wildlife Service (USFWS), Federally-listed as Threatened and Endangered Species of Texas, August 27, 2009.

A search of the Texas Natural Diversity Database40 maintained by the TPWD revealed no documented occurrences of rare or listed species within the vicinity of the proposed Double Mountain Fork East Reservoir site (as noted on representative 7.5 minute quadrangle map(s) that include the project site). This is based on the best information available to TPWD. However, this does 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.

4B.12.4.3.2.3 Wildlife Habitat

Approximately 10,814 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 1,274 acres of crops, 2,623 acres of Mesquite-Juniper Brush, 5,541 acres of Mesquite-Lotebush Brush/Shrub, 711 acres of Mesquite-Salt Cedar Brush/Woods, and 665 acres of exposed streambed.

A number of vertebrate species could occur within the Double Mountain Fork Reservoir East site as indicated by county occurrence records.[41] These include 8 species of frogs and toads, 3 species of turtles, 7 species of lizards and skinks, and 15 species of snakes. Additionally, 64 species of mammals could occur within the site or surrounding region[42] 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.

4B.12.4.3.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates 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

[40] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, *Element of Occurrence Records*, August 25, 2009.
[41] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," http://wfscnet.tamu.edu/tcwc/Herps_online/CountyRecords.htm accessed September 2, 2009.
[42] 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.

reservoir inundation the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archeological and Historic Preservation Act (PL93-291).

4B.12.4.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased adverse effects on stream flow below the reservoir site as a reduction in the quantity of median monthly flow is projected downstream, but the reservoir would trap and/or dilute pollutants, providing some positive benefits to water quality immediately downstream. These benefits could be offset, however, 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.

4B.12.4.4 Environmental Issues – West Site

4B.12.4.4.1 Existing Environment

The Double Mountain Fork West Reservoir site in Fisher and Stonewall Counties is within the Rolling Plains Ecological Region.[43] This region is located east of the High Plains, west of the West Cross Timbers and North Central Prairie, and north of the Edwards Plateau. It is characterized by nearly level to rolling topography, soft prairie sands and clays, juniper breaks and midgrass prairie. The physiognomy of the region varies from open, short to tall, scattered to dense grasslands to savannahs with bunch grasses. Most of the plains are rangeland, but dryland and irrigated crops are increasingly important. Poor range management practices of the past have increased the density of invasive plant species and have decreased the value of the land for

[43] 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.

cattle production. Farming and grazing practices have also reduced the abundance and diversity of wildlife in the region.[44] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 23 and 25 inches.[45]

The Seymour Aquifer, an unconsolidated sand and gravel aquifer, is the only major aquifer in the project area. It is formed by isolated alluvial deposits in 20 counties in north central Texas. The Seymour aquifer consists mainly of the scattered erosional remnants of the Seymour Formation of Pleistocene age, which consists of clay, silt, sand, and gravel, that were deposited by eastward-flowing streams. The aquifer generally has less than 100 feet of saturated thickness, but it is an important source of water for domestic, municipal, and irrigation needs.[46]

The physiography of the region includes loose surficial sand, gypsiferous red beds with dolomite, dissected red beds, terraces, severely eroded land, and flood-prone areas. The topography ranges from flat to rolling and steeply sloped, with densely dissected gullies and low hills in severely eroded areas and local shallow depressions in flood-prone areas along waterways.[47] The predominant soil associations in the project area are the Quinlan-Woodward, Paducah-Obaro, Carey-Woodward, and Spur-Yahola associations. The Quinlan-Woodward association consists of shallow to deep, sloping to moderately steep, loamy soils over sandstone and packsand. These soils are moderately to moderately rapidly permeable and well drained. The Paducah-Obaro association consists of deep and moderately deep, nearly level to gently sloping, loamy upland soils over sandstone. These soils are moderately permeable and well drained. The Carey-Woodward association consists of gently sloping to moderately sloping, deep and moderately deep, loamy soils on uplands cut by many drainageways. Spur-Yahola soils are nearly level, deep, moderately fine- and medium-textured, moderately permeable soils of the bottomland. These soils are moderately permeable and well drained.[48,49]

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[44] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.

[45] Larkin, T.J., and G.W. Bomar, *Climatic Atlas of Texas*, Texas Department of Water Resources, Austin, Texas, 1983

[46] United States Geological Service (USGS), *Ground Water Atlas of the United States*, http://capp.water.usgs.gov/gwa/index.html, 2004.

[47] 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.

[48] Schwartz, R.L., *Soil Survey of Fisher County, Texas*, United States Department of Agriculture, Soil Conservation Service, in cooperation with Texas Agricultural Experiment Station, 1992.

[49] Goerdel, A.R., and L. Watson, *Soil Survey of Stonewall County, Texas*, United States Department of Agriculture, Soil Conservation Service, in cooperation with Texas Agricultural Experiment Station, 1975.

Four major vegetation types occur within the general vicinity of the proposed project: Mesquite (*Prosopis glandulosa*)–Lotebush (*Ziziphus obtusifolia*) Brush, Mesquite-Lotebush Shrub, Mesquite-Saltcedar (*Tamarix* sp.) Brush/Woods, and crops[50]. Both the Mesquite–Lotebush Brush and Mesquite–Lotebush Shrub vegetation types consist of the following commonly associated plants: yucca (*Yucca* spp.), skunkbush sumac (*Rhus trilobata*), agarito (*Berberis trifoliolata*), elbowbush (*Forestiera angustifolia*), juniper (*Juniperus* sp.), tasajillo (*Opuntia leptocaulis*), cane bluestem (*Bothriochloa barbinodis*), silver bluestem (*Bothriochloa saccharoides*), little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), Texas grama (*Bouteloua rigidiseta*), sideoats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua hirsuta*), red grama (*Bouteloua trifida*), tobosagrass (*Pleuraphis mutica*), buffalograss (*Buchloe dactyloides*), Texas wintergrass (*Nasella leucotricha*), purple three-awn (*Aristida purpurea*), Engelmann daisy (*Engellmania peristena*), broom snakeweed (*Gutierrezia sarothrae*), and bitterweed (*Hymenoxys odorata*). Commonly associated plants of Mesquite-Saltcedar Brush/Woods are creosotebush (*Larrea tridentata*), cottonwood (*Populus deltoides*), desert willow (*Chilopsis linearis*), giant reed (*Arundo donax*), seepwillow (*Baccharis* sp.), common buttonbush (*Cephalanthus occidentalis*), whitethorn acacia (*Acacia constricta*), Australian saltbush (*Atriplex semibaccata*), fourwing saltbush (*Atriplex canescens*), lotebush, wolfberry (*Lycium berlandieri*), tasajillo, guayacan (*Guaiacum angustifolium*), alkali sacaton (*Sporobolus airoides*), Johnsongrass (*Sorghum halepense*), saltgrass (*Distichlis spicata*), cattail (*Typha* spp.), bushy bluestem (*Andropogon glomeratus*), and chino grama (*Bouteloua ramosa*). The crops cover type consists of 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.

4B.12.4.4.2 Potential Impacts

4B.12.4.4.2.1 Aquatic Environments including Bays and Estuaries

The potential impacts of this project were evaluated in two locations, at the proposed reservoir site and at a gage location on the Brazos River, near Aspermont. The anticipated impact of this project would be lower variability in and substantial reductions in quantity of median monthly flows in both locations. The difference in variability of monthly flows at the

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[50] 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.

proposed project site would be a factor of approximately 1.9 (measured by comparing sample variances of all monthly flows from 1940-2004 and predicted flows over that same time period with the project in place; sample variance without project =2.14 x 10^8; sample variance with project =1.14 x 10^8). The difference in variability of monthly flow in the Brazos River would be a factor of approximately 1.7 (sample variance without project =2.70 x 10^8; sample variance with project =1.59 x 10^8). 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.

At the project site, reductions in median monthly flows would range from 2.9 cfs (59 percent) in January to 74.0 cfs (65 percent) in June, as shown in Table 4B.12.4-5. No median monthly flows would be reduced by more than 78% percent and only four months would be decreased more than 70 percent. In the Brazos River, reductions would range from 0.8 cfs (17 percent) in January to 70.1 cfs (56 percent) in June, with the greatest percentage reduction (69 percent) in September (Table 4B.12.4-6). Reductions in median monthly flow values would be greater than 60 percent in April, May, July, August, and September. This project would also result in a higher frequency of low-flow conditions at the project site. Without the project, the 85 percent exceedance value would be 1.51 cfs, but would be only 0.29 cfs with the project in place. The 85 percent exceedance values would be 1.61 and 1.27 in the Brazos River without and with the project, respectively. These reductions in flow at the project site would have substantial impacts on the instream biological community, including reduced habitat available for spawning fish in the spring and an increased likelihood of high water temperatures and impairment of other water quality parameters in the summer. However, the potential impacts of the reservoir would be greatest at the project site and reduced in downstream locations where additional flow inputs would moderate the effects.

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 downstream locations the Brazos River (this site is near the headwaters). It is also unlikely that this project would have an impact on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows to the estuary. As a new reservoir without a current operating permit, the Double Mountain Fork

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

Table 4B.12.4-5.
Median Monthly Streamflow: Double Mountain Fork West Reservoir

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	5.0	2.1	2.9	59%
February	8.0	3.0	5.0	63%
March	6.3	2.1	4.2	67%
April	12.9	3.5	9.4	73%
May	67.2	23.6	43.6	65%
June	113.5	39.5	74.0	65%
July	36.4	9.0	27.4	75%
August	26.4	5.7	20.7	78%
September	61.2	14.3	46.9	77%
October	18.9	5.9	13.0	69%
November	12.8	5.8	7.0	55%
December	7.2	4.1	3.1	43%

Table 4B.12.4-6.
Median Monthly Streamflow: Brazos River Gage Near Aspermont

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	5.2	4.4	0.8	17%
February	7.6	5.9	1.7	22%
March	6.2	3.7	2.5	40%
April	12.8	5.1	7.7	60%
May	94.2	33.8	60.4	64%
June	124.6	54.5	70.1	56%
July	38.2	15.0	23.2	61%
August	30.7	11.5	19.2	62%
September	85.5	26.3	59.2	69%
October	21.4	12.3	9.1	43%
November	13.6	8.5	5.1	37%
December	8.0	7.0	1.0	12%

4B.12.4.4.2.2 Threatened & Endangered Species

A total of 22 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.12.4-7). This group includes two reptiles, ten birds, six mammals, and two fish species. Two listed species the black-footed ferret (Mustela nigripes) and the gray wolf (Canis lupus) have been extirpated from the project area. The whooping crane (*Grus americana*) is the only federally-listed threatened or endangered bird potentially occurring in the project area. The whooping crane is a seasonal migrant that could pass through the project area but would not likely be directly affected by the proposed reservoir. Two fishes, the smalleye shiner (*Notropis buccula*) and the sharpnose shiner (*Notropis oxyrhincus*) potentially occur in the project area; these species are candidates for federal listing.

A search of the Texas Natural Diversity Database51 maintained by the TPWD revealed no documented occurrences of rare or listed species within the vicinity of the proposed Double Mountain Fork West Reservoir site (as noted on representative 7.5 minute quadrangle map(s) that include the project site). This is based on the best information available to TPWD. However, this does 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.

4B.12.4.4.2.3 Wildlife Habitat

Approximately 6,632 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 1,175 acres of crops, 2,890 acres of Mesquite-Lotebush Brush, 1,046 acres of Mesquite-Lotebush Shrub, 1,089 acres of Mesquite-Salt Cedar Brush/Woods, and 432 acres of exposed streambed.

A number of vertebrate species could occur within the Double Mountain Fork Reservoir West site as indicated by county occurrence records.[52] These include 9 species of frogs and

[51] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, *Element of Occurrence Records*, August 25, 2009.
[52] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," http://wfscnet.tamu.edu/tcwc/Herps_online/CountyRecords.htm accessed September 2, 2009.

Table 4B.12.4-7.
Potentially Occurring Species that are Rare or Federal- and State-Listed for Stonewall and Fisher Counties - Double Mountain Fork Reservoir West Site

Scientific Name	Common Name	Federal/ State Status	Fisher County	Stonewall County
Birds				
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL	Migrant	Migrant
Ammodramus bairdii	Baird's Sparrow	SOC	Migrant	Migrant
Haliaeetus leucocephalus	Bald Eagle	DL/T	Migrant	Migrant
Buteo regalis	Ferruginous Hawk	SOC	Migrant	Migrant
Charadrius montanus	Mountain Plover	SOC	Migrant*	Migrant*
Charadrius alexandrinus	Snowy Plover	SOC	Migrant	Migrant
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*	Migrant*
Charadrius alexandrines nivosus	Western Snowy Plover	SOC	Migrant	__
Grus americana	Whooping Crane	LE/E	Migrant	Migrant
Fishes				
Notropis buccula	Smalleye Shiner	C/SOC	X	X
Notropis oxyrhincus	Sharpnose Shiner	C/SOC	X	X
Mammals				
Mustela nigripes	Black-footed Ferret	LE	Extirpated	Extirpated
Cynomys ludovicianus	Black-tailed Prairie Dog	SOC	X	X
Myotis velifer	Cave Myotis Bat	SOC	X	X
Canis lupus	Gray Wolf	LE/E	Extirpated	Extirpated
Corynorhinus townsendii pallescens	Pale Townsend's Big-eared Bat	SOC	X	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X	X
Reptiles				
Nerodia harteri	Brazos Water Snake	SOC/T	-	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X	X

* Nesting migrant; may nest in the county.

X = Occurs in county; - Does not occur in county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations.) SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed.)

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas.

SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: Texas Parks and Wildlife Department (TPWD) Annotated County List of Rare Species for Stonewall and Fisher Counties (2009); TPWD Texas Wildlife Diversity Database (2009), United States Fish and Wildlife Service (USFWS), Federally-listed as Threatened and Endangered Species of Texas, August 25, 2009.

toads, 5 species of turtles, 10 species of lizards and skinks, and 17 species of snakes. Additionally, 64 species of mammals could occur within the site or surrounding region[53] 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.

4B.12.4.4.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that one archeological site has been documented within the general vicinity of the proposed reservoir. This site lies outside the currently proposed reservoir location. The site (41SN1) was recorded as an historic occupation with associated graves in 1970 and was recommended for further testing and excavation. Prior to reservoir inundation, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any other cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archeological and Historic Preservation Act (PL93-291).

4B.12.4.4.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased adverse effects on stream flow below the reservoir site as a reduction in the quantity of median monthly flow is projected downstream, but the reservoir would trap 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.

[53] 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.

4B.12.4.5 Engineering and Costing

Construction of the Double Mountain Fork East Reservoir project will cost approximately $211.4 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 $16.1 million; this includes annual debt service and operation and maintenance. The cost for the available project safe yield of 36,025 acft/yr translates to an annual unit cost of raw water of $1.37 per 1,000 gallons, or $448/acft. A summary of the cost estimate is provided in Table 4B.12.4-8. Costs shown herein are for raw water supply at the reservoir and include no transmission, local distribution, or treatment costs.

Construction of the Double Mountain Fork West Reservoir project will cost approximately $151.5 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 $11.6 million; this includes annual debt service and operation and maintenance. The cost for the available project safe yield of 34,775 acft/yr translates to an annual unit cost of raw water of $1.02 per 1,000 gallons, or $334/acft. A summary of the cost estimate is provided in Table 4B.12.4-9. Costs shown herein are for raw water supply at the reservoir and include no transmission, local distribution, or treatment costs.

4B.12.4.6 Implementation Issues (East and West Sites)

Both sites have been compared to the plan development criteria as shown in Table 4B.12.4-10 and both sites meet each criteria.

4B.12.4.6.1 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 structures placed in navigable waters of the U.S. (Section 10 of Rivers and Harbors Act) or 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.

Table 4B.12.4-8.
Cost Estimate Summary for
Double Mountain Fork Reservoir (East Site)
(September 2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Dam and Reservoir	$122,716,000
Total Capital Cost	**$122,716,000**
Engineering, Legal Costs and Contingencies	$42,951,000
Environmental & Archaeology Studies and Mitigation	$10,010,000
Land Acquisition and Surveying	$10,010,000
Interest During Construction (3 years)	$25,686,000
Total Project Cost	**$211,373,000**
Annual Costs	
Reservoir Debt Service (6 percent, 40 years)	$14,048,000
Purchase of Water (4,450 acft/yr @ $54.50 per acft)	$243,000
Operation and Maintenance	$1,841,000
Total Annual Cost	**$16,132,000**
Available Project Safe Yield (acft/yr)	36,025
Annual Cost of Water ($ per acft)	$448
Annual Cost of Water ($ per 1,000 gallons)	$1.37

Table 4B.12.4-9.
Cost Estimate Summary for
Double Mountain Fork Reservoir (West Site)
(September 2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Dam and Reservoir	$91,199,000
Total Capital Cost	**$91,199,000**
Engineering, Legal Costs, and Contingencies	$31,920,000
Environmental & Archaeology Studies and Mitigation	$4,966,000
Land Acquisition and Surveying	$4,966,000
Interest During Construction (3 years)	$18,405,000
Total Project Cost	**$151,456,000**
Annual Costs	
Reservoir Debt Service (6 percent, 40 years)	$10,066,000
Purchase of Water (3,250 acft/yr @ $54.50 per acft)	$177,000
Operation and Maintenance	$1,368,000
Total Annual Cost	**$11,611,000**
Available Project Safe Yield (acft/yr)	34,775
Annual Cost of Water ($ per acft)	$334
Annual Cost of Water ($ per 1,000 gallons)	$1.02

Table 4B.12.4-10.
Comparison of Double Mountain Fork Reservoir (East and West Sites) 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. 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 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

4B.12.4.6.2 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; 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.

4B.12.4.6.3 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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4B.12.5 Turkey Peak Reservoir

4B.12.5.1 Description of Option

The Lake Palo Pinto dam was initially constructed in 1963 and 1964 with a conservation pool level of 863.0 feet above mean sea level (ft-msl) and deliberate impoundment began in April 1964. In 1966 the conservation storage level was raised four feet to 867.0 ft-msl. In the early 1980s, the Palo Pinto County Municipal Water District No. 1(District) became concerned about the capacity of Lake Palo Pinto and in 1985, a volumetric survey of Lake Palo Pinto was performed. This survey determined the reservoir's conservation capacity to be 27,650 acft or about 63 percent of its authorized storage. In 2007, an additional volumetric survey was performed by the Texas Water Development Board and this survey determined the reservoir's capacity to be 27,215 acft [54] (about 62 percent of its authorized storage). Based on the June 2007 TWDB survey, Lake Palo Pinto's conservation pool has an average depth of only 12.5 feet. The reservoir currently inundates 2,176 acres at its conservation level. The Turkey Peak Reservoir project is currently being pursued by the District to recover the lost storage in Lake Palo Pinto as authorized under Certificate of Adjudication 12-4031.

The proposed Turkey Peak Reservoir is located on Palo Pinto Creek immediately downstream of Lake Palo Pinto, as shown in Figure 4B.12.5-1. The Turkey Peak Reservoir is located approximately 2 miles northwest of the City of Santo, approximately 1,000 feet upstream from the bridge over Palo Pinto Creek on FM4. The conservation capacity of Turkey Peak Reservoir is 22,577 acft and covers 648 acres, resulting in an average reservoir depth of 35 ft.

The normal pool elevation of the Turkey Peak Reservoir will be 867 ft-msl, the same as Lake Palo Pinto. A portion of the existing dam and spillway at Lake Palo Pinto will be removed and the two reservoir pools will be connected above an elevation of 860 ft-msl. Below this elevation a pipe will connect both pools as shown in Figure 4B.12.5-2 and the two pools can be operated either as a single reservoir or as separate reservoirs. The combined Turkey Peak/Palo Pinto Reservoir will initially contain approximately 49,792 acft of conservation storage and inundate 2,824 acres at its conservation storage level of 867 ft-msl.

[54] Texas Water Development Board, Volumetric and Sediment Survey of Lake Palo Pinto, June 2007.

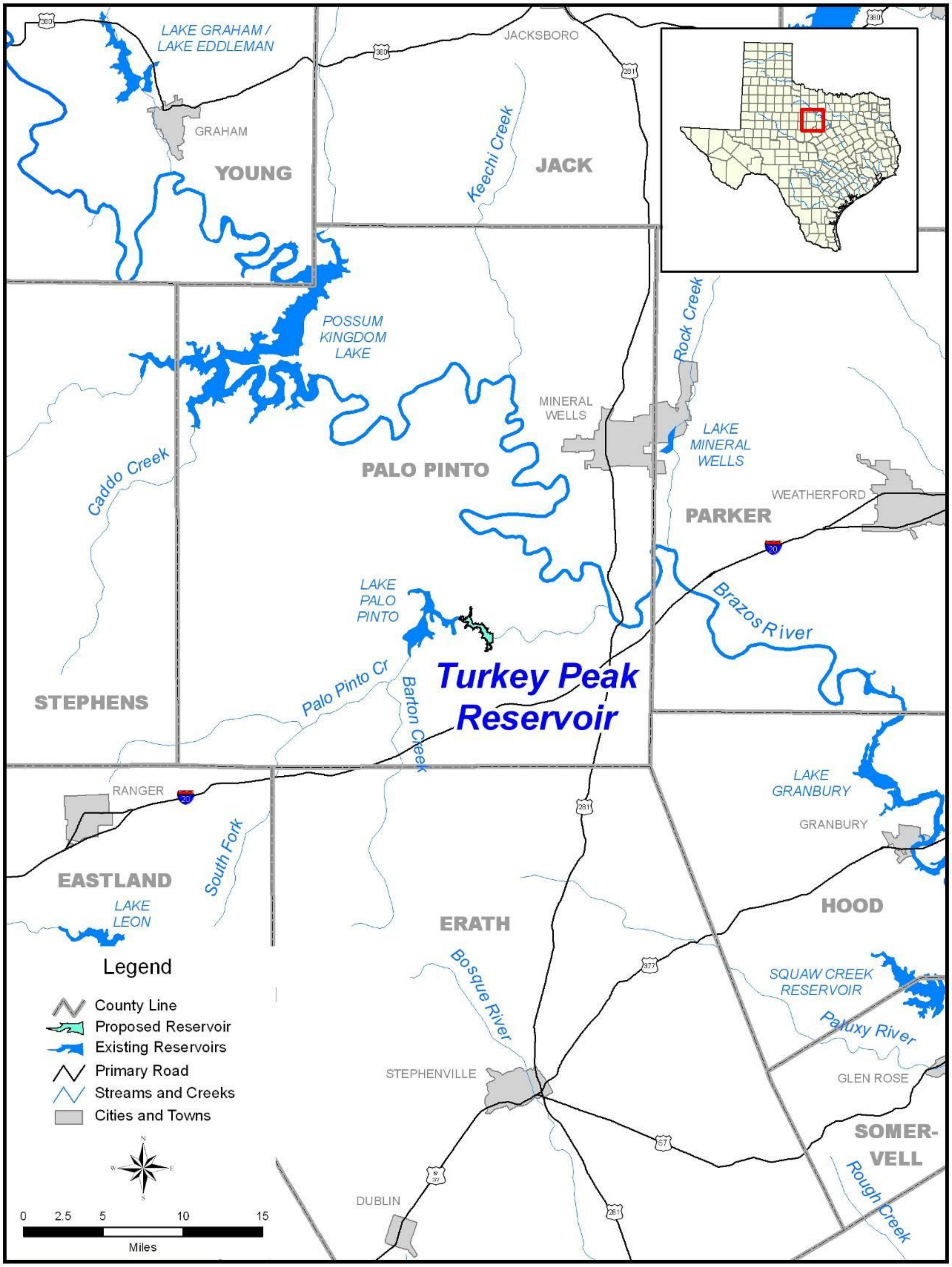


Figure 4B.12.5-1. Turkey Peak Reservoir

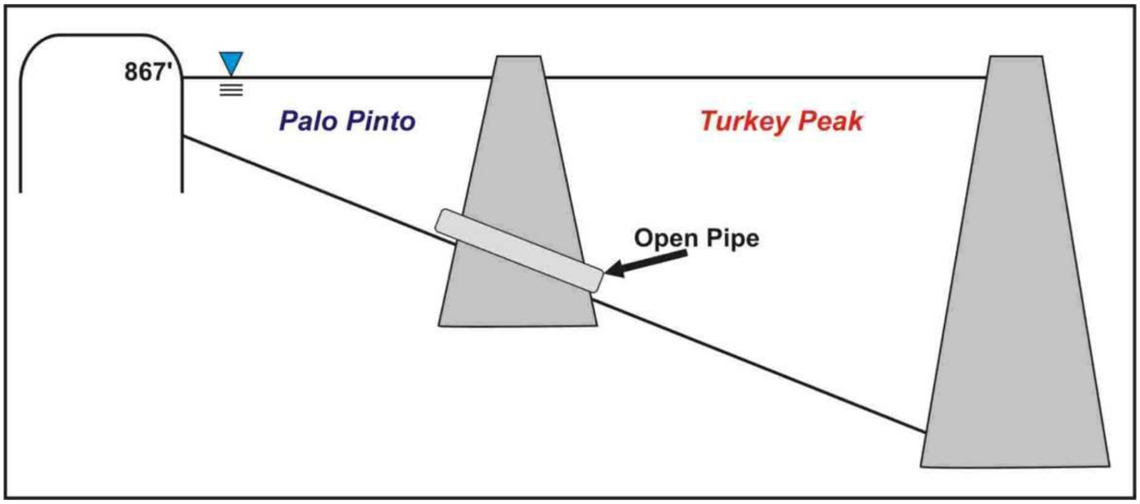


Figure 4B.12.5-2. Combined Turkey Peak/Palo Pinto Reservoir

The Turkey Peak Reservoir will increase storage by 83 percent (as compared to Lake Palo Pinto), while only inundating an additional 20 percent of the surface area of the existing Lake Palo Pinto. Because Turkey Peak Reservoir is significantly deeper than Lake Palo Pinto, there is a 695 acre reduction (20 percent) in the surface area of the combined reservoirs when compared to raising the conservation level of Lake Palo Pinto by 5.5 feet (and storing 44,100 acft, its current permit authorization). This results in a significant reduction in reservoir evaporation between the two alternative configurations. The District has completed feasibilitystudies of the project and is moving forward with the permitting and preliminary engineering phase of the project. The District selected the Turkey Peak project instead of the Lake Palo Pinto Off-Channel Reservoir project because of lower unit water costs and to avoid an endangered species (Golden-cheeked Warbler).

4B.12.5.2 Available Yield

Water potentially available for impoundment in the proposed Turkey Peak/Palo Pinto Reservoir was estimated using the TCEQ Brazos WAM. The reservoir was modeled by combining the 2060 storage capacity of Lake Palo Pinto with the proposed storage capacity of Turkey Peak Reservoir. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The Brazos G WAM was not used to generate these results, as the studies performed by the District are more detailed and contain assumptions consistent with the

Brazos G modeling assumptions. This project is being pursued to recover lost storage in Lake Palo Pinto and to increase the reliability of the supply as currently authorized by the District's Certificate of Adjudication. Therefore the need to apply the Brazos G WAM specifically to this project was not required. Model runs performed by the District indicate that streamflow available from the Brazos River Basin will be available without causing increased shortages to existing downstream water rights.

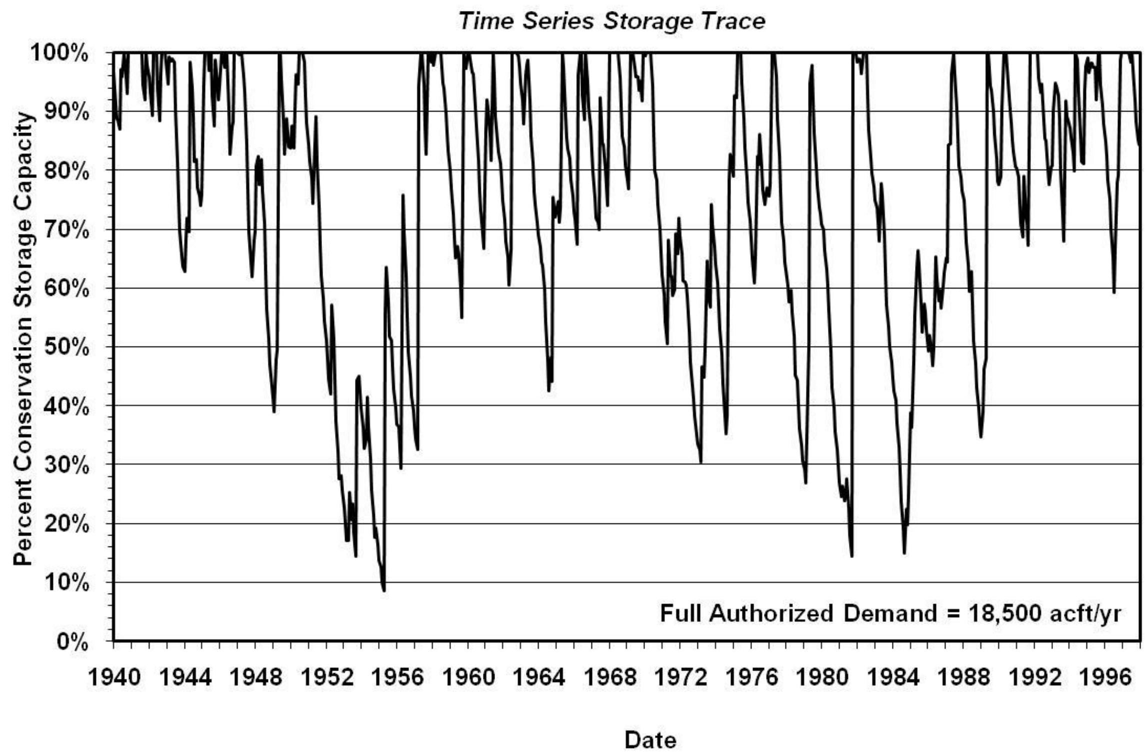
The water availability analysis performed by the District indicates that the Turkey Peak/Palo Pinto Reservoir is capable of supplying the District's current authorization of 18,500 acft/yr. The District operates using a 6-month safe yield, which for the combined project is 14,260 acft/yr in 2060. The 2060 stand-alone 6-month safe yield of Lake Palo Pinto, adjusted for channel losses, is 6,660 acft/yr. Therefore, the additional safe yield attributed to Turkey Peak Reservoir in 2060 is 7,600 acft/yr.

Figure 4B.12.5-3 illustrates the simulated Turkey Peak/Palo Pinto Reservoir storage levels for the 1940 to 1997 historical period, subject to the authorized demand of 18,500 acft/yr. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 52 percent of the time and above the Zone 3 trigger level (50 percent capacity) 80 percent of the time.

Figure 4B.12.5-4 illustrates the Palo Pinto Creek streamflow characteristics with the Turkey Peak Reservoir in place with a minimum flow release of 8 cfs[55]. The median streamflow in Palo Pinto Creek would be increased in all months.

Figure 4B.12.5-4 also illustrates the Palo Pinto Creek streamflow frequency characteristics with the Palo Pinto/Turkey Peak Reservoir in place. While median monthly streamflows are reduced by the project, there is a minimal difference in streamflow frequencies in Palo Pinto Creek with the project

[55] A water right permit application has been filed by the District at TCEQ for the Turkey Peak permit which includes an 8 cfs minimum flow release.



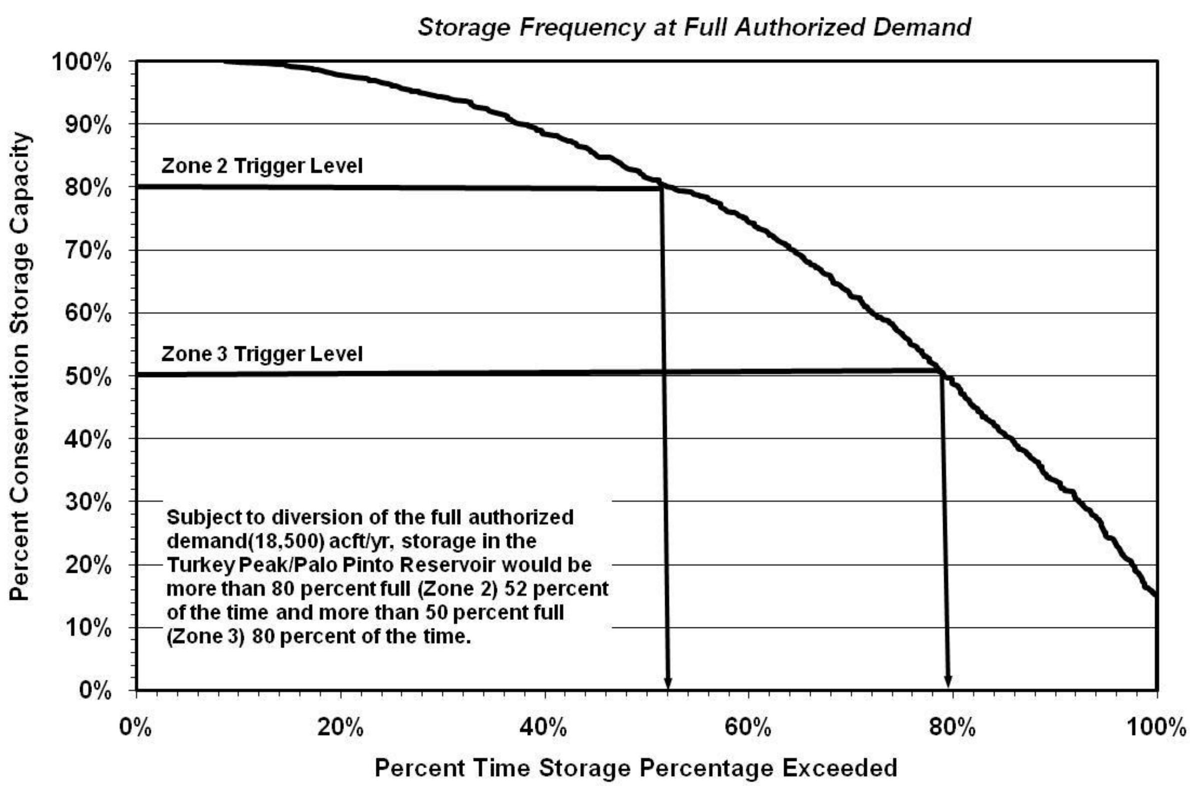
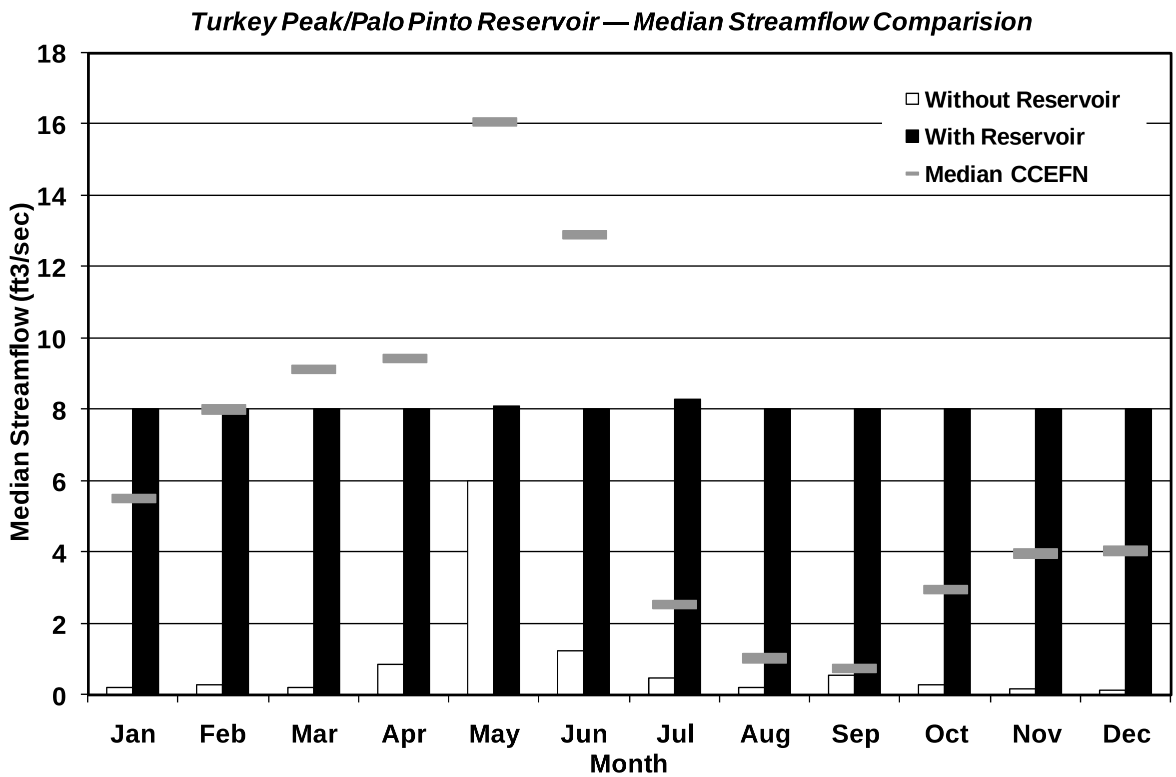


Figure 4B.12.5-3. Turkey Peak/Palo Pinto Reservoir Storage Considerations



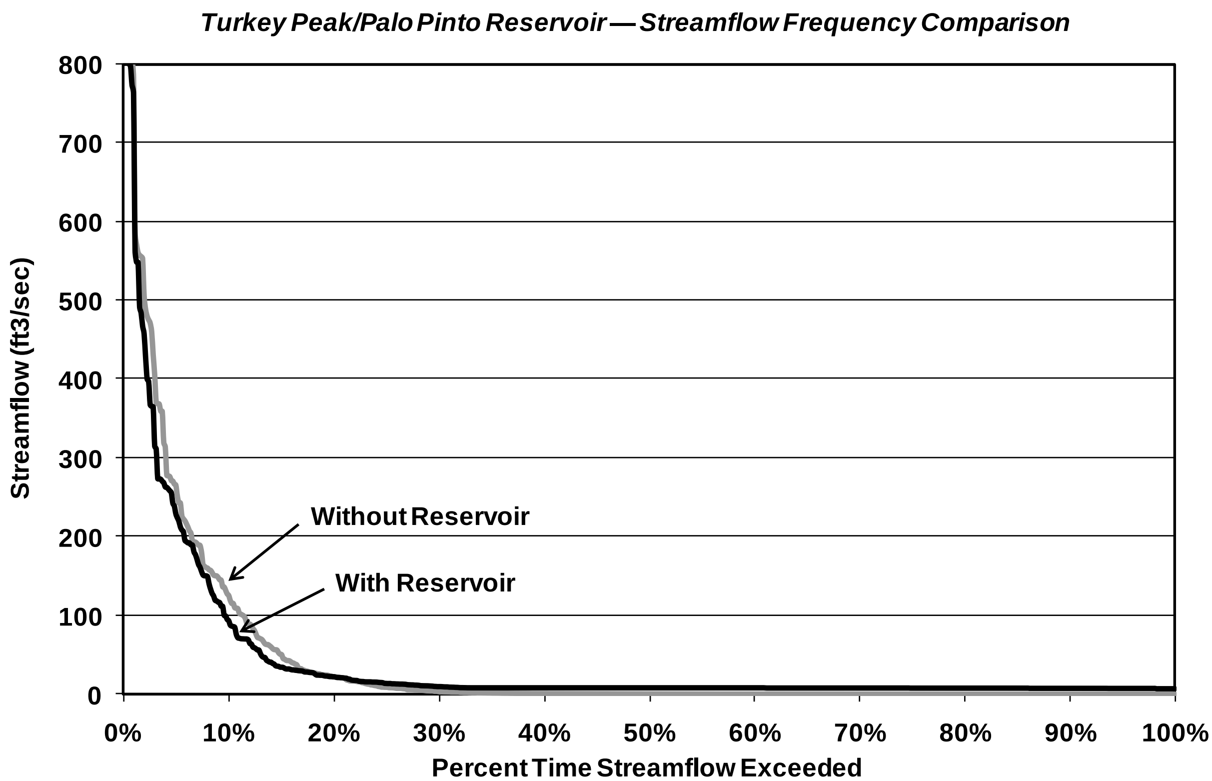


Figure 4B.12.5-4. Turkey Peak/Palo Pinto Reservoir Streamflow Comparisons

4B.12.5.3 Environmental Issues

4B.12.5.3.1 Existing Environment

The Turkey Peak Reservoir site in Palo Pinto County is within the Cross Timbers Ecoregion.[56] 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.[57] 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.[58] 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.[59]

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.[60] 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.[61]

According to The Vegetation Types of Texas, two major vegetation types occur in the general vicinity of the proposed project: Ashe Juniper Parks/Woods and Oak-Mesquite-Juniper

[56] 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).
[57] Telfair, R.C., "Texas Wildlife Resources and Land Uses," University of Texas Press, Austin, Texas, 1999.
[58] Larkin, T.J., and G.W. Bomar, "Climatic Atlas of Texas," Texas Department of Water Resources, Austin, Texas, 1983.
[59] Texas Water Development Board (TWDB), Major and Minor Aquifers of Texas; Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.
[60] 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.
[61] 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.

Parks/Woods.[62] Variations of these primary types occur within the region, which reflect changes in the composition of woody and herbaceous species and physiognomy. Ashe Juniper Parks/Woods, which occur principally on the slopes of hills in Palo Pinto County, usually include the following commonly associated plants: live oak, 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, 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*), sideoats grama, curly mesquite (*Hilaria belangeri*), and Texas wintergrass.

4B.12.5.3.2 Potential Impacts

4B.12.5.3.2.1 Aquatic Environments including Bays & Estuaries

This project will assure a minimum flow of 8 cfs in Palo Pinto Creek downstream of the new project. Currently there is no requirement for the District to make minimum flow releases and about 10 percent of the time over the past 11 years, the District has closed the gate resulting in no flow being released. The Turkey Peak project will assure minimum flows in Palo Pinto Creek as the District has included an 8 cfs minimum flow request in their permit application.

It is not likely that this projectwill have a substantial influence on total discharge in downstream locations on the Brazos River including freshwater inflows to the Brazos River estuary.

[62] 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.

4B.12.5.3.2.2 Threatened & Endangered Species

A total of 20 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.12.5-1). This group includes two reptiles, nine birds, three mammals, three mollusks, and three fish species. Inclusion in Table 4B.12.5-1 does not mean that a species will occur within the study area but only acknowledges the potential for its occurrence in Palo Pinto County. On-site evaluations by qualified biologists are required to confirm the occurrence of sensitive species or habitats.

The Migratory Bird Treaty Act protects most bird species, including, but not limited to, cranes, ducks, geese, shorebirds, hawks, and songbirds. Migratory bird pathways, stopover habitats, wintering areas, and breeding areas may occur within and adjacent to the project area, and may be associated with wetlands, ponds, shorelines, riparian corridors, fallow fields and grasslands, and woodland and forested areas. Although reservoir construction would remove some habitats utilized by certain migratory bird species, it would create more habitats for others. It is anticipated that the reservoir would reach its full capacity in one to three years. This transition from terrestrial to aquatic habitat would allow time for migratory species to acclimate to the altered condition within the project area and movement of non-aquatic species to similar areas nearby.

Four bird species federally listed as threatened or endangered may occur in the project vicinity. These include the black-capped vireo (*Vireo atricapillus*), golden-cheeked warbler (*Dendroica chrysoparia*), interior least tern (*Sterna antillarum athalassos*), and whooping crane (*Grus americana*). These bird species are all seasonal migrants that could pass through the project area. The black-capped vireo only nests in dense underbrush in semi-open woodlands having distinct upper and lower stories. The interior least tern typically nests on bare or sparsely vegetated areas associated with streams or lakes, such as sand and gravel bars, beaches, islands, and salt flats. Unvegetated bars within wide river channels or open flats along lake or reservoir shorelines are preferred and provide nesting habitat and access to adjacent open water for foraging for this tern. The main whooping crane flock nests in Canada and migrates annually to their wintering grounds in and around the Aransas National Wildlife Refuge near Rockport on

Table 4B.12.5-1
Potentially Occurring Species that are Rare or Federal and State Listed at the Turkey Peak Reservoir Site, Palo Pinto County

Scientific Name	***Common Name***	***Federal/State Status***	***Potential Occurrence***
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/	Migrant
Haliaeetus leucocephalus	Bald Eagle	DL/T	Migrant
Vireo atricapillus	Black-capped Vireo	LE/E	Migrant*
Dendroica chrysoparia	Golden-cheeked Warbler	LE/E	Migrant*
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Charadrius montanus	Mountain Plover	SOC	Migrant*
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant
Fishes			
Micropterus treculii	Guadalupe bass	SOC	X
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Mammals			
Canis lupus	Gray Wolf	LE/E	Extirpated
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E	Extirpated
Mollusks			
Tritogonia verrucosa	Pistolgrip	SOC	X
Arcidens confragosus	Rock pocketbook	SOC	X
Truncilla macrodon	Texas fawnsfoot	T	X
Reptiles			
Nerodia harteri	Brazos Water Snake	T	X
Phrynosoma cornutum	Texas Horned Lizard	T	X

X = Occurs in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; C-Candidate ; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: TPWD, Annotated County List of Rare Species for Palo Pinto County, (5/4/09)

the Texas coast. Whooping cranes occasionally utilize wetlands as an incidental rest stop during this migration. Habitat elements particularly attractive to the black-capped vireo, interior least tern, and whooping crane do not appear to be present on or adjacent to the proposed reservoir site, although migrants are possible.

The golden-cheeked warbler is the only federally-listed avian species with potential to utilize the proposed reservoir site for nesting. Juniper-oak woodlands found on canyon slopes may provide the isolated woodland habitat of deciduous oaks and mature junipers required by this migratory songbird. A detailed field survey for this species was conducted by qualified personnel in March–May 2006, and no sightings or detections of the warbler were documented.[63] 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 Reservoir area (unlike the Off-Channel Reservoir project) was not likely to support this species.[64]

Avian species listed by the State of Texas as endangered or threatened include the peregrine falcon (*Falco peregrinus*) and bald eagle (*Haliaeetus leucocephalus*). The peregrine falcon includes two subspecies which migrate across the state from more northern breeding areas in the U.S. and Canada to winter along the coast. Bald eagles are listed as threatened in Texas and occur as winter migrants. The majority of nesting bald eagle pairs currently reported are found along major rivers and near reservoirs in eastern Texas. Bald eagles are opportunistic predators, feeding primarily on fish captured in the shallow water of both lakes and streams or scavenged food sources. These birds may utilize tall trees near perennial water as roosting or nesting sites. Although the bald eagle could use either Lake Palo Pinto or Possum Kingdom Reservoir for foraging or nesting, the species has not been reported in the region. It is not expected that either bird species would be directly affected by the proposed reservoir construction at the Turkey Peak site.

The Texas horned lizard (*Phrynosoma cornutum*), Texas fawnsfoot (*Truncilla macrodon*), and Brazos water snake (*Nerodia harteri*), state threatened species, and the plains spotted skunk (*Spilogale putorius interrupta*), a species of concern, are possible inhabitants of the reservoir site or its adjacent upland pastures. Texas horned lizards inhabit deserts and grasslands in semi-arid to arid landscapes with sparse vegetation and gravelly soils. Their habitat must contain a stable population of harvester ants, the primary prey of the horned lizard, which make up the majority of its diet. Patchy environments that contain bare areas mixed with patches of vegetation are ideal to attract harvester ants and Texas horned lizards. This species could be displaced within the areas that will be gradually inundated. Relocation would then be possible into similar and acceptable habitat available adjacent to the project area.

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

Several species of freshwater mussels including the Texas fawnsfoot (*Truncilla macrodon*) have been listed as threatened by the state of Texas. USFWS is also considering listing a number of mussel species as endangered or threatened. 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.

The Brazos water snake 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 twice by TPWD near Palo Pinto Creek. It has been observed at the mouth of Coffee Creek, approximately 0.4 mile downstream of the confluence of Palo Pinto Creek and the Brazos River, and roughly 4 miles downstream of this same confluence along the margins of the Brazos River. Surveys for the Brazos water snake along Palo Pinto Creek within the Turkey Peak Reservoir site and downstream were undertaken in 2009. There were no sightings of the snake during these surveys. In any case, 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 is generally found in open fields, prairies, and croplands. Vegetation within the project area generally consists of moderately dense mixed deciduous woodlands in the canyons, with pastures or pecan orchards in the floodplains. It is expected that if the plains spotted skunk is present in the project area, the gradual transition to an aquatic system could displace these species. However, the project area is rural, and similar suitable habitats exist adjacent to the project area; therefore, it is anticipated that the spotted skunk could relocate to those areas if necessary.

The gray wolf (*Canis lupus*) and red wolf (*Canis rufus*) are two state and federally listed endangered mammals which historically lived in Palo Pinto County. These two species are now considered to be extinct within this region of the state.

The sharpnose shiner (*Notropis oxyrhynchus*) and the smalleye shiner (*Notropis buccula*) are two small, slender minnows endemic to the Brazos River Basin. In 2002, both species were placed on the U.S. Fish and Wildlife Service list as potential candidates for federal protection. 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. Additionally, the existing channel dam constructed in the mid 1960's would likely restrict upstream movement of the minnows. The study area lies downstream of any recently recorded occurrences for these species; therefore the occurrence of either cyprinid species is unlikely.

Information received from the TPWD Texas Natural Diversity Database[65] revealed no documented occurrences of endangered or threatened species within or near the proposed Turkey Peak Reservoir. 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.

4B.12.5.3.2.3 Wildlife Habitat

Palo Pinto County is included in the Texan Biotic Province as delineated by Blair and modified by TPWD. [66] 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.

[65] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, Received June 5, 2008.
[66] Blair, W. Frank. 1950. "The Biotic Provinces of Texas," Texas Journal of Science 2 (1):93-117, modified by TPWD GIS lab.

Within this province, western species tend to encroach into open habitats, and eastern species intrude along the many wooded drainageways extending through the landscape. The Texan Biotic Province supports 49 species of mammals, 39 species of snakes, 16 species of lizards, two types of terrestrial turtles, 18 types of toads and frogs (anurans), five species of salamander (urodeles), and an undetermined number of bird species.

Approximately 648 acres are estimated to be inundated by the reservoir. Areas of wildlife habitat that will be impacted include approximately 328 acres of Juniper Woodland, 161 acres of Oak Mesquite-Juniper Parks, 88 acres of Grassland, and 72 acres of Riparian Woods.

4B.12.5.3.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that 99 archeological sites have been documented within the general vicinity of the proposed reservoir. Researchers from the University of Texas recorded 49 of these sites as part of the Village Bend archeological survey in 1980. These sites, which lie outside the currently proposed reservoir, represent a variety of historic and prehistoric site types.

A Phase IA cultural resource assessment was conducted for the proposed development of the Turkey Peak Reservoir project site in January 2009. This initial Phase 1A study was performed to determine the appropriate inventory and evaluation studies necessary to assure proper assessment of all potential impacts by this project as required by federal laws and regulations. Research revealed that there were no previously documented archeological sites found in the proposed reservoir area. Three existing structures within the reservoir area were considered for architectural assessment; however none met the requirements for Natural Register eligibility. Consequently no mitigation is recommended for any of these sites. No State Historical markers, Recorded Texas Historic Landmarks, cemeteries, or NRHP- listed properties were found to be listed within the Turkey Peak reservoir project area.

Prior to reservoir inundation, the project must be coordinated with the Texas Historical Commission and a cultural resources survey is planned to be conducted to determine if any cultural resources are present within the conservation pool. Any cultural resources identified during the survey will 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).

4B.12.5.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2. This project will likely have little adverse effects on stream flow below the reservoir site. Although there could be a small reduction in median monthly flows, the project will assure a minimum flow of 8 cfs to Palo Pinto Creek and eliminate the periods of no flow which occur today. Additionally the reservoir would trap and/or dilute pollutants, providing some positive benefits to water quality immediately downstream. Dissolved oxygen levels on Palo Pinto Creek are expected to be slightly improved as the District will construct a multi-level outlet tower which will always release water to Palo Pinto Creek from the top 30 feet of the reservoir pool. This will be an improvement from current conditions as the existing outlet pipe at Lake Palo Pinto is 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.

4B.12.5.4 Engineering and Costing

Cost estimates for the Turkey Peak/Palo Pinto Reservoir were originally prepared by HDR Engineering in 2001[67] and those costs were updated for this study to reflect current September 2008 costs. The capital cost, approximately $32.8 million, are associated with the relocation of FM 4, the construction of a new bridge and road at the existing dam and spillway at Lake Palo Pinto and the construction of the new dam and spillways along with modifications to the existing dam and spillway. The total project cost is approximately $50.2 million (Table 4B.12.5-2). This includes the costs for construction, , land acquisition, resolution of conflicts, environmental permitting and mitigation, engineering, mapping and surveying, utility relocations, design, TxDOT plan review, and construction phase services.

[67] HDR Engineering, “Yield Studies for Lake Palo Pinto and the Proposed Turkey Peak Reservoir”, June 2001.

Table 4B.12.5-2.
Cost Estimate Summary for
Turkey Peak/Lake Palo Pinto Reservoir
(September 2008 Prices)

Item	*Estimated Costs for Facilities*
Total Capital Cost	**$32,817,000**
Total Project Cost	**$50,227,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$1,401,000
Reservoir Debt Service (6 percent for 40 years)	$2,270,000
Operation and Maintenance	
Dam and Reservoir	$3,348,000
Total Annual Cost	**$7,019,000**
Available Project Yield (acft/yr)	**7,600**
Annual Cost of Water ($ per acft)	**$924**
Annual Cost of Water ($ per 1,000 gallons)	**$2.83**

The annual project costs are estimated to be about $7 million; this includes annual debt service, operation and maintenance. The cost for the estimated increase in system yield of 7,600 acft/yr translates to an annual unit cost of raw water of $2.83 per 1,000 gallons, or $924/acft. Costs shown herein are for raw water supply at the reservoir and do not include treatment or transmission costs. The permitting, land acquisition and design phases of the project is scheduled to be completed sometime between 2012 and 2015. The construction phase of the project could begin sometime aftr 2012. Because of conflicts between the location of the new dam and the existing location of FM 4, the start of work for the new dam and spillways will need to be delayed until the work associated with the reloaction or closure of FM 4 is completed. Based on the sequencing of the construction contracts, construction is estimated to be completed between 2016 and 2020.

4B.12.5.5 Implementation Issues

This water supply option has been compared to the plan development criteria as shown in Table 4B.12.5-3, and the options meets each criterion. A summary of the implementation steps for the project is presented below.

Table 4B.12.5-3.
Comparison of Turkey Peak Reservoir to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable to High
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impact
2. Habitat	2. Moderate 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	• 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	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.12.5.5.1 *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 (TPDES) 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.

4B.12.5.5.2 *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.

4B.12.5.5.3 *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.

4B.12.6 Little River Reservoir

4B.12.6.1 Description of Option

The proposed new reservoir on the Little River would be located on the main stem of the Little River just upstream from its confluence with the Brazos River near the City of Cameron, as shown in Figure 4B.12.6-1. The smaller, at elevation 310 ft-msl, would provide a surface area of 20,690 acres and a storage volume of about 321,000 acft (Appendix N). The larger, full development of the site would represent a surface elevation of 330 ft-msl, with a surface area of 35,590 acres and a storage volume of about 877,770 acft.

The project would have its greatest usefulness as part of the BRA system, meeting water needs in Williamson County, Brazos County, or downstream in Region H.

4B.12.6.2 Available Yield

Water potentially available for impoundment in the proposed Littler River Reservoir was estimated using the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available from the Little River without causing increased shortages to existing downstream rights. Firm yield was computed subject to the Little River Reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the Little River are shown in Table 4B.12.6-1.

The available firm yield of the proposed reservoir is relatively large, since about a quarter of the approximately 7,584 square mile drainage area is uncontrolled. For the smaller size reservoir (310' elevation), the estimated yield is about 71,275 acft/yr. The fully developed site (330' elevation) would have a yield of about 119,940 acft/yr.

Figure 4B.12.6-2 illustrates the simulated Little River Reservoir storage levels at both elevations (310' and 330') for the 1940 to 1997 historical period, subject to the firm yields of 71,275acft/yr and 119,940 acft/yr, respectively. For the 310' elevation reservoir, the simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 70 percent of the time and above the Zone 3 trigger level (50 percent capacity) 91 percent of the time. For the 330' elevation reservoir, the simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 74 percent of the time and above the Zone 3 trigger level (50 percent capacity) 91 percent of the time.

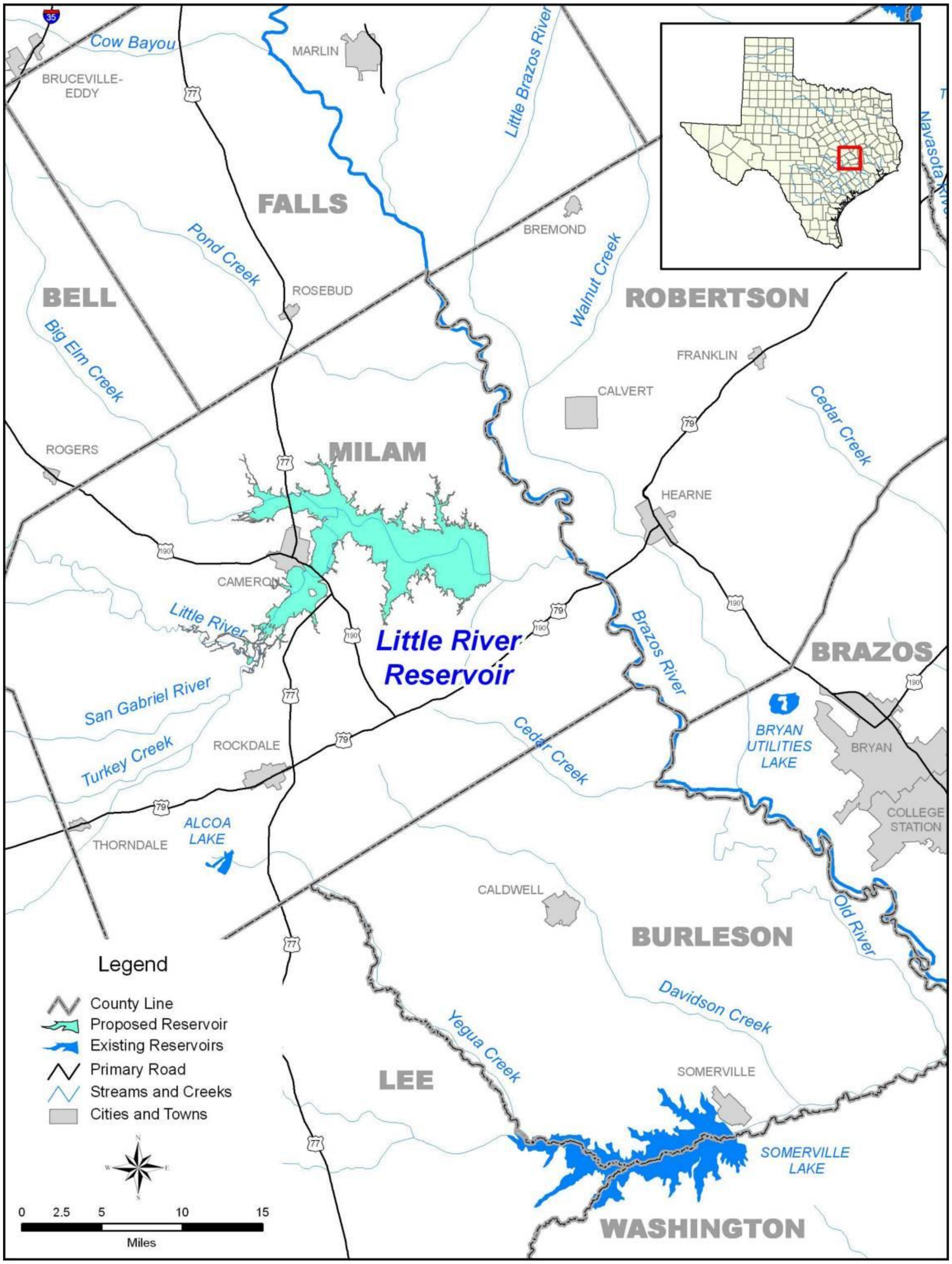


Figure 4B.12.6-1. Little River Reservoir

Table 4B.12.6-1.
Daily Natural Streamflow Statistics
for the Little River Reservoir

Month	***Median Flows - Zone 1 Pass Through Requirements (ft^3/sec)***	***25th Percentile Flows - Zone 2 Pass Through Requirements (ft^3/sec)***
January	519	195
February	738	245
March	752	280
April	1,034	308
May	2,128	556
June	1,404	445
July	511	184
August	258	101
September	245	101
October	275	89
November	383	143
December	450	180
Zone 3 (7Q2) Pass-Through Requirement (ft^3/sec):		72

Figure 4B.12.6-3 illustrates the Little River streamflow characteristics and streamflow frequency characteristics at both elevations (310’ and 330’) with the Little River Reservoir in place. The proposed project at either conservation pool will have only a moderate impact on the streamflow since most the inflows will have to be passed to satisfy downstream senior water rights and/or environmental flows. Firm yield was computed subject to the Little River Reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass through requirements for the Little River are shown in Table 4B.12.6-1.

The effect of sedimentation on the firm yield for both conservation pool elevations (310’ and 330’) was determined over a 60-year period. The rate of sediment production for the proposed Little River Reservoir was estimated based on available data from the Soil Conservation Service and from volumetric surveys in surrounding reservoirs (Appendix N). It

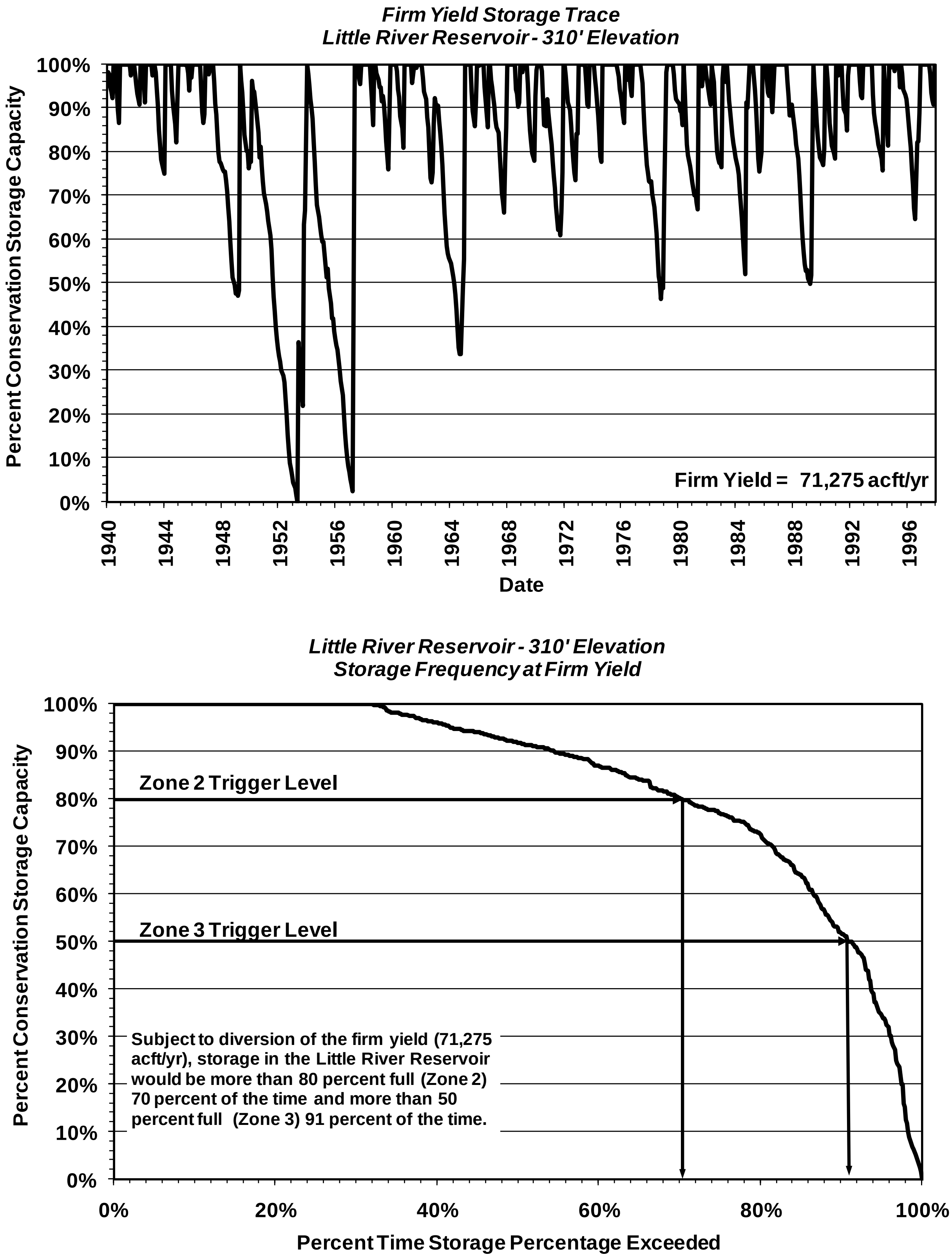
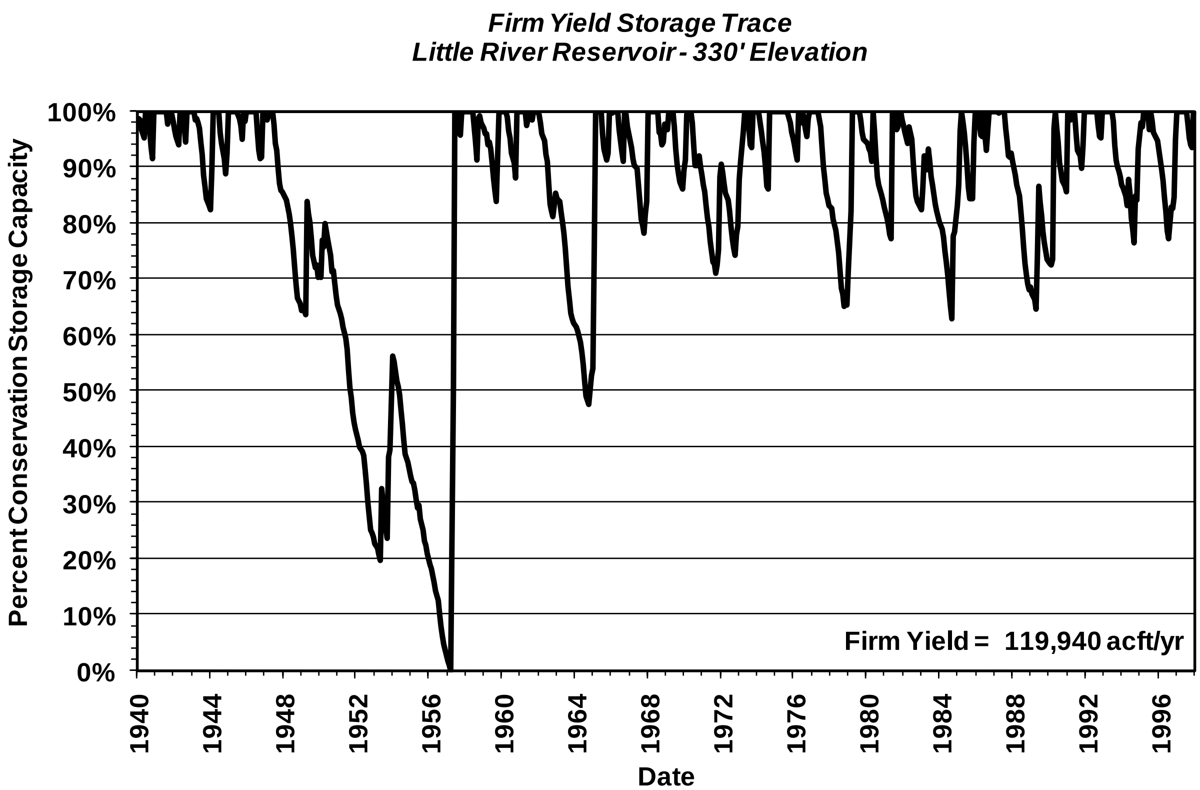


Figure 4B.12.6-2. Little River Reservoir Storage Considerations at 310' & 330' Elevation



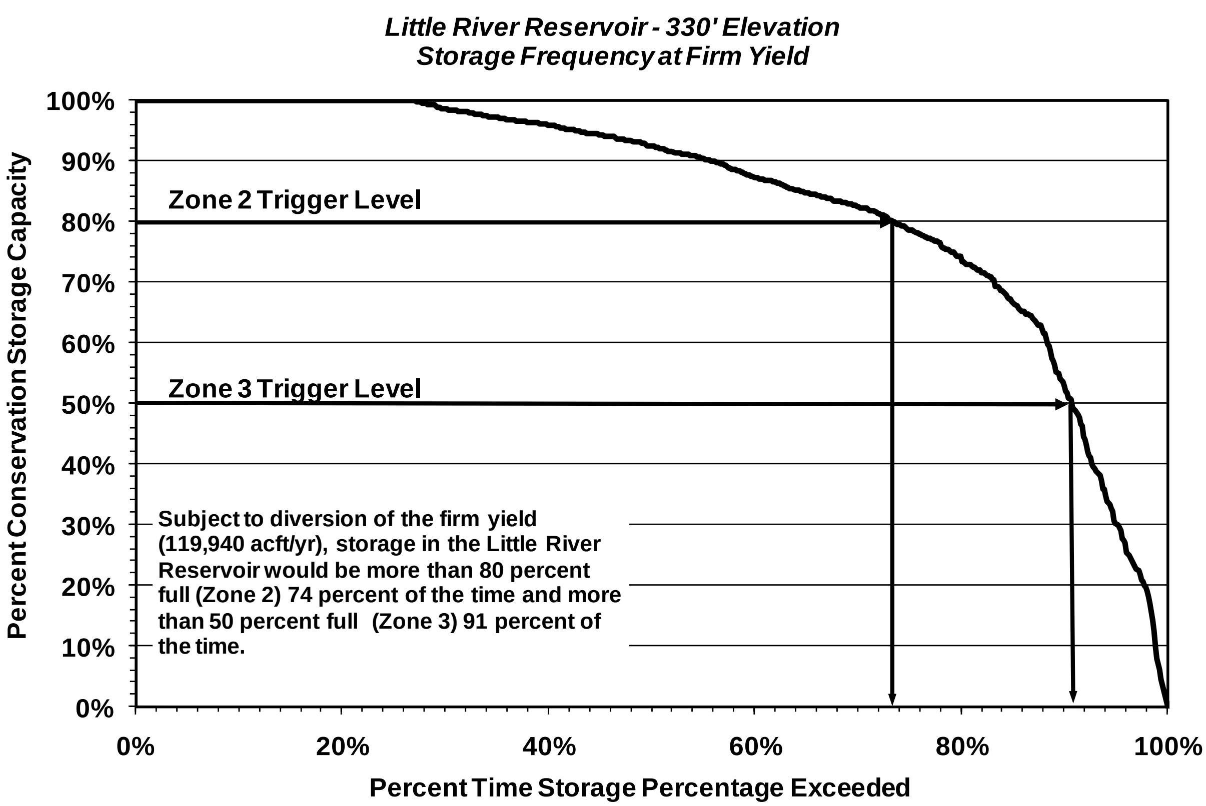
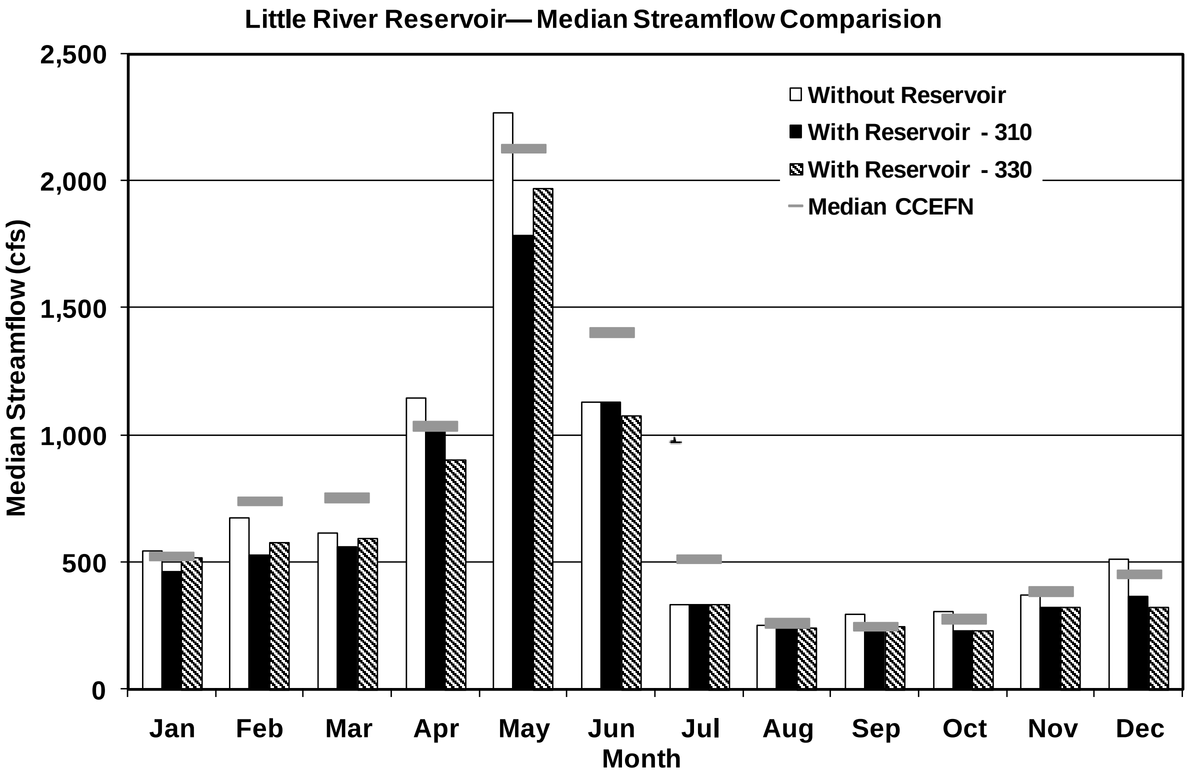


Figure 4B.12.6-2. Little River Reservoir Storage Considerations at 310' & 330' Elevation (Concluded)



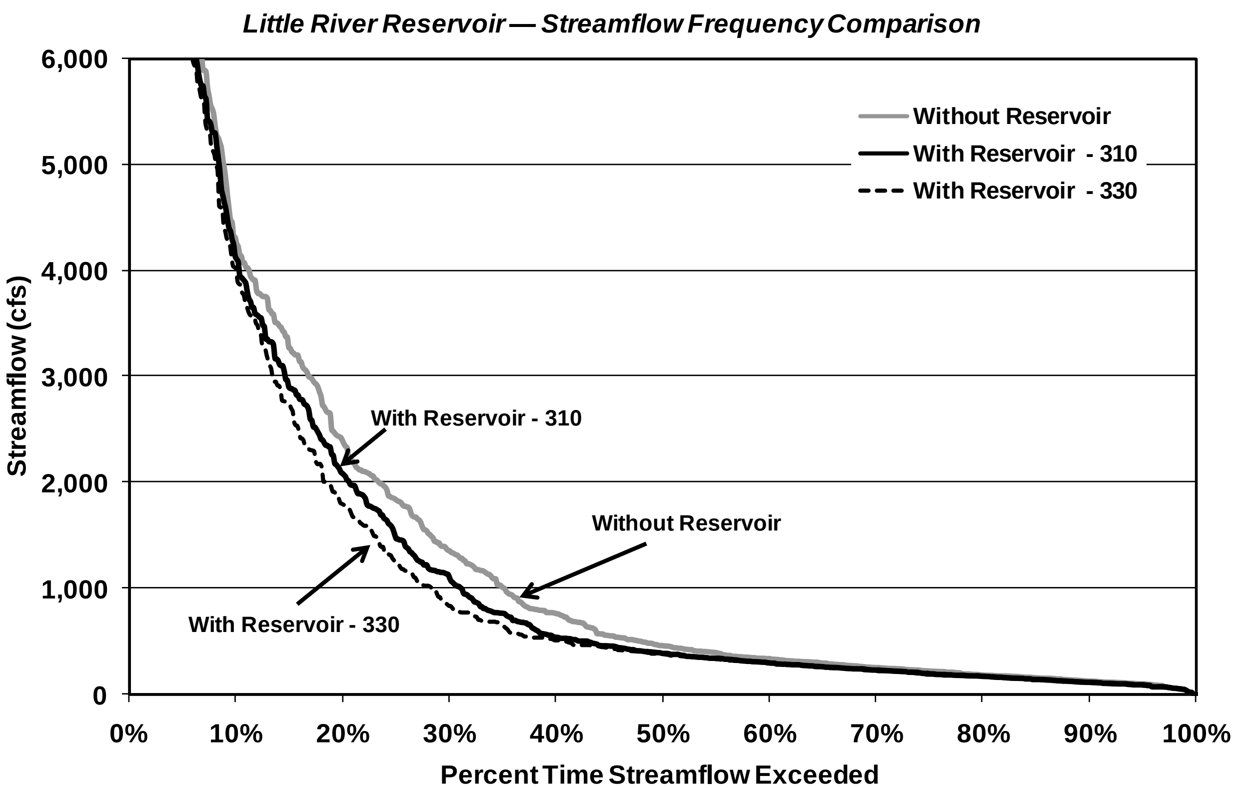


Figure 4B.12.6-3. Little River Streamflow Comparison

was determined that the firm yield of the 330 ft-msl elevation reservoir would be reduced by 5,365 acre-feet/year (4% of the initial value) over 60 years. The firm yield of the 310 ft-msl elevation reservoir would be reduced by 18,050 acre-feet or by 25% of the initial value. The critical drought period for the 330 ft-msl elevation option is April 1947 to March 1957. This period is 5-years longer than the critical period for the 310 ft-msl elevation option. Table 4B.12.6-2 summarizes the impact of sedimentation on the firm yield of the reservoir. Note that the values shown in Table 4B.12.6-2 are based on the sedimentation rates presented in Appendix N. Differences in firm yield values shown here and in Appendix N are due to updates to the Brazos G WAM between the 2006 and 2011 Plans.

Table 4B.12.6-2. Impact of Sedimentation on Firm Yields of the Little River Reservoir

Conservation Pool	Initial Firm Yield (acft/yr)	Firm Yield after 60 Years (acft/yr)	Loss of Yield (acft/yr)
330 ft-msl	119,940	114,575	5,365
310 ft-msl	71,275	53,225	18,050

4B.12.6.3 Environmental Issues (Normal Pool Elevation = 310 ft-msl)

4B.12.6.3.1 Existing Environment

The proposed Little River Reservoir site (normal pool at 310 ft-msl) in Milam County is in a transitional zone with the Blackland Prairies Ecological Region to the west and the Post Oak Savannah Ecological Region to the east.[68] This region is characterized by level to rolling topography, with interspersed grassland and woodland, with soils ranging from the deep, fertile, black soils of the Blackland Prairies region to the shallow, nearly impervious clay pan of the Post Oak Savannah region. The original physiognomy of the region varied from medium to tall broad-leaved deciduous and some needle-leaved evergreen trees to medium-tall dense grasslands with scattered open groves of deciduous trees in minor prairies.[69] The climate is characterized as subtropical humid with warm summers. Average annual precipitation ranges between 36 and 40

[68] 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
[69] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.

inches.[70] The Carrizo-Wilcox Aquifer is the only major aquifer underlying in the project area, though the downdip portion of the Trinity Aquifer lies nearby to the west.[71] The Queen City and Brazos River Alluvium minor aquifers are to the south and east of the project area, respectively.

The physiography of the region includes ceramic clay and lignite/coal, recharge sands, limestone sand and gravel, expansive clay mud, terraces, and flood-prone areas. The topography is flat to rolling with local escarpments, with local shallow depressions in flood-prone areas along waterways.[72] The predominant soil types in the project area are primarily sandy loams and loamy sands, with a small amount of silty clay.[73]

Three major vegetation types occur within the general vicinity of the proposed project: Post Oak Woods/Forest, Post Oak Woods, Forest, and Grassland Mosaic, and crops.[74] 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. Post Oak Woods/Forest and the Post Oak Woods, Forest, and Grassland Mosaic could include the following commonly associated plants: blackjack oak (*Quercus marilandica*), eastern redcedar (*Juniperus virginiana*), mesquite (*Prosopis glandulosa*), black hickory (*Carya texana*), live oak (*Q. virginiana*), sandjack oak (*Q. incana*), cedar elm (*Ulmus crassifolia*), hackberry (*Celtis* spp.), yaupon (*Ilex vomitoria*), poison oak (*Toxicodendron pubescens*), American beautyberry (*Callicarpa americana*), hawthorn (*Crataegus* spp.), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus* spp.), coralberry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium* var. *scoparium*), silver bluestem (*Bothriochloa saccharoides*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida* spp.), spranglegrass (*Chasmanthium sessiliflorum*), and tickclover (*Desmodium* spp.). Crops include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

[70] Larkin, T.J., and G.W. Bomar, *Climatic Atlas of Texas*, Texas Department of Water Resources, Austin, Texas, 1983.
[71] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.
[72] 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.
[73] Soil Conservation Service (NRCS), *Soil Survey for Milam County, Texas,* Soil Conservation Service, United States Department of Agriculture, 1979.
[74] 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.

4B.12.6.3.2 Potential Impacts

4B.12.6.3.2.1 Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated with the proposed reservoir maintained at 310 feet (ft) above sea level and a diversion of 71,275 acre-feet of water per year. Overall, this alternative would have little influence on variability of monthly flows and result in a moderate reduction in quantity of median monthly flows in the Little River. The minimal reduction in variability of monthly flow values (measured by comparing sample variances of all monthly flows from 1940-1997 and predicted flows over that same time period with each alternative in place; sample variance without project $=2.95 \times 10^{10}$; sample variance with project at 310-ft elevation $=2.82 \times 10^{10}$) would probably not have much impact on the instream biological community or riparian species.

The reduction in the quantity of median monthly flow for the 310-ft elevation reservoir in the area of the project would range from 0 cfs in June and July to 480 cfs (21 percent) in May, as shown in Table 4B.12.6-3. The highest percent reduction (28 percent) would occur in December, while the lowest (<3 percent) would occur during the summer months of June, July and August. The change in low-flow conditions (85% exceedance values) would also be minimal. Without the project, the 85% exceedance value for monthly flow would be 156 cfs while under this alternative the value would be 141 cfs. Overall, these reductions in flow should not have substantial impacts on the biological community since the highest reductions are anticipated in fall and winter. Reductions during these months are less critical than during spring and summer when flows are naturally lower and many aquatic species spawn.

Any reduction in discharge associated with this reservoir alternative in the Little River would have minimal influence on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows into the estuary. As a new reservoir without a current operating permit, the Little River Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

Table 4B.12.6-3.
Median Monthly Streamflow: Little River Reservoir at 310-ft elevation

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	542.6	461.7	81.0	15%
February	675.0	524.0	151.0	22%
March	610.3	560.7	49.6	8%
April	1,143.3	1,020.8	122.5	11%
May	2,265.7	1,785.7	480.0	21%
June	1,128.1	1,128.1	0.0	0%
July	331.6	331.6	0.0	0%
August	247.5	243.0	4.5	2%
September	291.6	248.5	43.1	15%
October	304.2	225.7	78.5	26%
November	371.2	321.2	49.9	13%
December	510.0	365.8	144.1	28%

4B.12.6.3.2.2 Threatened & Endangered Species

According to county occurrence records,[75] a total of 27 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern. This group includes one amphibian, four reptiles, eight birds, three mammals, four fish species, five mollusks and two plant species (Table 4B.12.6-4). One federally endangered mammal, the red wolf (*Canis rufus*) has been extirpated. One amphibian, two bird species, and one plant species federally-listed as threatened or endangered could occur in the project area. These include the Houston toad (*Bufo houstonensis*), interior least tern (*Sterna antillarum athalassos*), whooping crane (*Grus americana*), and Navasota ladies'-tresses (*Spiranthes parksii*). Habitat for the Houston toad includes pine and/or oak woodlands underlain by pockets of deep sandy soils with temporary pools of water available for breeding.[76] The Houston toad inhabits pools and stock tanks in areas with a sandy substrate. The interior least tern and whooping crane are seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir. Navasota Ladies'-tresses occurs on upland margins of intermittent, minor tributaries in association with post oak, blackjack oak, and yaupon.

[75] Texas Parks and Wildlife Department (TPWD), Annotated County List of Rare Species for Milam County, June 25, 2009.
[76] U.S. Fish and Wildlife Service, *The Endangered Houston Toad*, http://ifw2es.fws.gov/HoustonToad/, 2004.

Table 4B.12.6-4. Potentially Occurring Species that are Rare or Federal- and State-Listed for Milam County - Little River Reservoir Site

Scientific Name	***Common Name***	***Federal/State Status***	***Potential Occurrence***
Amphibians			
Bufo houstonensis	Houston Toad	LE/E	X
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL	Migrant
Haliaeetus leucocephalus	Bald Eagle	DL/T	X
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant
Mycteria americana	Wood Stork	SOC/T	Migrant
Fishes			
Cycleptus elongatus	Blue Sucker	SOC/T	X
Micropterus treculi	Guadalupe Bass	SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Mammals			
Myotis velifer	Cave Myotis Bat	SOC	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E	Extirpated
Mollusks			
Quincuncina mitchelli	False Spike Mussel	SOC/T	X
Tritogonia verrucosa	Pistolgrip	SOC	X
Arcidens confragosus	Rock Pocketbook	SOC	X
Quadrula houstonensis	Smooth Pimpleback	SOC/T	X
Truncilla macrodon	Texas Fawnsfoot	SOC/T	X
Reptiles			
Macrochelys temminckii	Alligator Snapping Turtle	SOC/T	X
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X
Plants			
Spiranthes parksii	Navasota ladies'-tresses	LE/ E	X
Polygonella parksii	Parks' jointweed	SOC	X

X = Occurs in county, - does not occur in county, * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations.) SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas.

SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: Texas Parks and Wildlife Department (TPWD) Annotated County List of Rare Species for Milam County (May 4, 2009); TPWD Texas Wildlife Diversity Database (2009); USFWS – Endangered Species List – List of Species by County August 27, 2009.

A search of the Texas Natural Diversity Database77 maintained by TPWD revealed two documented occurrences of rookeries within 0.5 to 1-mile of the proposed Little River Reservoir (as noted on representative 7.5 minute quadrangle map(s) that include the project site). Both rookeries are described by TPWD as nesting colonies of the great egret, little blue heron, and cattle egret; one of the rookeries also has had nesting snowy egrets. Navasota ladies'-tresses have been documented within 2.5 miles of the proposed reservoir. 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.

4B.12.6.3.2.3 Wildlife Habitat

Approximately 20,687 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 16,493 acres of cropland, 549 acres of Post Oak Woods, and 3,645 acres of mixed Riparian Forest. Some new shoreline and wetland habitat would be created that would be associated with the land-water interface. Vegetation would change from streamside plant species adapted to short-term inundation and over bank flooding, to aquatic or semi-aquatic species adapted to hydric or semi-hydric conditions along the shoreline.

A number of vertebrate species could occur within the vicinity of the Little River Reservoir site as indicated by county occurrence records.[78] These include four species of salamanders and newts, 16 species of frogs and toads, 9 species of turtles, the American alligator, 10 species of lizards and skinks, and 21 species of snakes. Additionally, 54 species of mammals could occur within the site or surrounding region[79] 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.

[77] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, *Element of Occurrence Records*, August 25, 2009.
[78] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," http://wfscnet.tamu.edu/tcwc/Herps_online/CountyRecords.htm accessed September 2, 2009.
[79] Davis, W.B., and D.J. Schmidly, *The Mammals of Texas – Online Edition*, Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

The habitat value of occurring cover types has been estimated based on methodology developed by the Texas Parks and Wildlife Department[80] and other previous information.[81] Based on these estimates, preliminary mitigation requirements to compensate or offset the loss of inundated habitats are summarized in Table 4B.12.6-5.

4B.12.6.3.2.4 Cultural Resources

A search of the Texas Historical Commission's online database indicates that one Official State Historical Marker is located within the proposed reservoir footprint. This marker, erected in 1936, commemorates the landing of the steamboat Washington in the winter of 1850-1851. The Washington was the "first, last and only" steamboat to navigate the Little River. At least seven cemeteries are mapped within the proposed reservoir. These include: Turnham-McCown Cemetery, Old City Cemetery, Milam Grove Cemetery, Pebble Grove Cemetery, Coxes Providence Community Cemetery, Story Cemetery, and Oxsheer-Smith Cemetery. No properties listed in the National Register of Historic Places (NRHP) or State Archeological Landmarks (SALs) occur within the proposed reservoir footprint.

A total of 102 archeological sites have been documented within the general vicinity of the proposed reservoir. These sites represent a variety of historic and prehistoric site types. Five of these sites (41MM12, 41MM13, 41MM14, 41MM130, and 41MM292) occur within the proposed reservoir's normal pool at elevation 310 ft-msl. Four of the five sites within the normal pool are recorded as prehistoric artifact scatters and/or prehistoric occupation sites. The remaining site (41MM13) is recorded as a prehistoric occupation site and historic artifact scatter. Espey Huston & Associates recommended site 41MM13 for further testing in 1979. A total 22 prehistoric archeological sites have been documented along Cannonsnap Creek in the immediate vicinity of the proposed reservoir site. While these sites do not appear to occur within the normal pool, it is considered likely that similar sites (or undocumented components of these previously recorded sites) may exist within the proposed reservoir.

[80] Texas Parks and Wildlife Departement (TPWD), *Wildlife Habitat Appraisal Procedure*. PWD RP N7100-145, http://www.tpwd.state.tx.us/conserve/whap/mainwhap.html, 1995.
[81] Texas Parks and Wildlife Department (TPWD), *Texas Water and Wildlife*, PWD-BK-7100-147, 1990

Table 4B.12.6-5.
Estimated Mitigation Requirements for Cover Types Inundated by the Proposed Little River Reservoir (Normal Pool Elevation = 310 ft-msl)

Cover Type	*Acres Lost*	*Habitat Quality Rating*[1]	*Habitat Units Lost*[2]	*Potential HQ Gain*[3]	*Compensation Acreage Requirements*[4]
Mixed Riparian Forest	3,645	0.75	2, 733.8	0.25	10,935
Post Oak Woods	549	0.58	318.4	0.42	758
Crops	16,493	0.20	3,298.6	0.80	4,123
Total	**20,687**		**6,350.8**		**15,816**

[1]Habitat Quality Ratings extrapolated from ratings of similar habitats within the same general region conducted by TPWD (1990).

[2]Values represent the product of Acres Lost multiplied by Habitat Quality Rating.

[3]Represents future maximum gain in habitat value (1.0 - Habitat Quality Rating Value) through intensive management of a mitigation area with similar baseline habitat value.

[4]Represents compensation required to fully offset loss of the cover type (Habitat Units lost ÷ Potential HQ gain); calculations derived from TPWD (1995); federal/state permits historically have required compensation only for jurisdictional waters of the U.S., including wetlands.

Prior to reservoir inundation, a cultural resources survey must be conducted to determine if any other cultural resources are present within the normal pool. Any cultural resources identified during survey will need to be formally 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 (APE) 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).

4B.12.6.3.2.5 Threats to Natural Resources

Identified threats to natural resources were identified in Section 1.7 as lower stream flows, declining water quality, and reduced inflows to reservoirs. This project is expected to have slight effects on the variability of median monthly flows, and not substantially change low flow conditions (flows exceeded 85% of the time). It is unlikely this project would have any substantial influence on total discharge in the Brazos River, freshwater inflows to the Brazos River estuary, or water quality downstream.

4B.12.6.3.3 Mineral Rights

Without researching courthouse deeds, the ownership of minerals contained within the footprint of the proposed Little River Reservoir normal pool elevation of 310 ft above sea level is unknown. However, according to known oil, gas, and other mineral recovery sites mapped from databases maintained by the Texas Railroad Commission[82], there is one gas well, one shut-in (not producing) oil well, one oil/gas well, and six dry holes located within the 310 ft-msl elevation footprint of the reservoir. (Table 4B.12.6-6).

Table 4B.12.6-6.
Oil and Gas Wells in the Little River Reservoir Footprint
(310 ft-msl Pool Elevation)

Type of Well	*Total Number*
Gas Well	1
Shut-In Oil Well	1
Oil/Gas Well	1
Dry Hole	6
Source: Railroad Commission of Texas, 2005.	

4B.12.6.3.3.1 Mitigation Costs for Minerals

Plugging Existing Wells

As noted in Table 4B.12.6-6 the Texas Railroad Commission reports one gas well, one shut-in oil well, one oil/gas well, and six dry holes located within the 310 ft-msl elevation footprint of the proposed Little River Reservoir. Assuming the dry holes are properly plugged, the development of the proposed reservoir would require the plugging of three existing wells.

Estimated costs for plugging these wells is available from the Railroad Commission's state-funded well plugging program. This program was established to locate, prioritize, and plug wells that have been abandoned by non-compliant oil and gas operators that may pose a risk to the environment or public safety. The program has, as of March 2003, plugged a total of 162 abandoned wells in Milam County, Texas at a cost of $317,069.11 or an average of $1,957 per well (TRC, 2003). At an estimated cost of $1,957 per well, plugging the three wells in the reservoir footprint would cost about $5,871.

[82] Texas Railroad Commission (TRC), Mineral Recovery Databases, 2005

Raising Existing Wells and Relocating Storage Tanks

Another mitigation option would be to raise existing wells and relocate storage tanks out of the reservoir footprint. Although costs for this option have not been explicitly estimated, this option would result in oil and gas production facilities remaining on the surface of the reservoir – an outcome most project sponsors would probably seek to avoid.

Acquisition of Mineral Rights

Reservoir project sponsors could acquire the mineral rights for the property to be inundated. Texas law holds that the mineral estate is dominant over the surface estate.[83] This rule has serious implications for surface owners who are not mineral owners. Texas courts have held that mineral leases are not mere rental agreements as the name implies. Instead, they are actually deeds granting limited ownership rights to mineral lessees for as long as the lease continues. Thus, during the tenure of a lease, the mineral lessee enjoys the same rights to use the surface as any other mineral owner.

These property rights can be stated in the following way: mineral lessees can use as much of the surface as is *reasonably necessary* for mineral exploration and production. This privilege springs from the executed mineral lease. Independent permission from the surface owner is not necessary. No responsibility exists for restoring the surface or for paying surface damages. Liability arises only when the lessee goes beyond what is reasonably necessary or negligently injures the surface. The oil company or other entity leasing the minerals is the *lessee* and the mineral owner is the *lessor*.[84] The cost of mineral right acquisition would have to be estimated from a detailed examination of the Milam County Tax Office appraisals for the affected properties. This appraisal project would be undertaken at a latter stage of the project development, but the costs to acquire mineral rights in an actively producing region could be substantial.

[83] Fambrough, J., *Subdivision Drill Sites***,** *A Reprint from the Real Estate Center Journal,* Texas A&M University, Publication 690, November 1997.

[84] Fambrough, J., *Minerals, Surface Rights and Royalty Payments. A Reprint from the Real Estate Center Journal*, Texas A&M University, Technical Report 840, November 1996.

Lignite Resources

Approximately 6,400 acres of the proposed reservoir at the 310 ft-msl pool elevation are underlain by lignite resources,[85] about 31% of the 20,687-acre footprint. This would imply acquisition of the mineral rights for the 6,400 acres affected. The cost of mineral right acquisition would require an appraisal study that, as in the case of oil and gas resources, would be undertaken at a latter stage of the project development. The presence of lignite resources in addition to oil and gas resources would, however, increase the cost of mineral rights substantially.

Sand and Gravel Resources

A search of the TxDOT Aggregate Quarry and Pit Safety Program Inventory File (TxDOT 2005) for pits and quarries in Milam County indicated two active aggregate quarries. This data were not sufficient to confirm whether these quarries were located within the reservoir footprint.

4B.12.6.3.4 Socioeconomic Effects

This section characterizes the potential socioeconomic effects of the proposed Little River Reservoir at a 310 ft-msl pool elevation on the local economy in terms of: (1) impact on the tax base; (2) impacts to the local county economy from changes in the tax base; (3) revenue and employment effects from potential recreational businesses; and (4) loss of crop value.

4B.12.6.3.4.1 Impact on the Tax Base of Milam County

At an elevation of 310 ft-msl the proposed Little River Reservoir would inundate an area of 20,685 acres in east-central Milam County between the City of Cameron and the confluence of the Little River and the Brazos River. The area proposed for inundation includes 16,493 acres of cropland, 3,645 acres of mixed riparian forests, and 549 acres of Post Oak woods. The impact on the Milam County tax base can, in principle, be estimated as the net effect of: (1) the loss of property tax revenue to local jurisdictions from the conversion of the reservoir footprint to public (tax exempt) ownership, assuming that the project sponsors will be public entities; and (2) the

[85] Henry, C.D. and J.M. Basciano, *Environmental Geology of the Wilcox Group Lignite Belt: East Texas. Report of Investigation* No. 98, Bureau of Economic Geology, University of Texas at Austin. 1979

increase in value of property along the shoreline of the proposed reservoir, assuming that the shoreline will remain largely in private ownership. An estimate of increased values around the proposed reservoir would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

Estimates of total market value (land and improvements) and total appraised value by county are available from the Texas Association of Counties' County Information Project.[86] For Milam County, the average market value of land and improvements was $2,491 per acre and the average appraised value was $1,711 per acre in 2003. If this average can be taken as an upper limit to the per acre appraised value of the 20,685 acres that would be required for the proposed Little River Reservoir at a 310 ft-msl pool elevation, then the total appraised value that would be lost in Milam County for taxation is $35,392,035 in 2003 dollars.

4B.12.6.3.4.2 Impacts to the Local Economy from Changes in the Tax Base

A total loss of $35,392,035 of tax base in Milam County represents a reduction of about 3% from the 2003 total appraised value of $1,119,106,754. Neglecting the possibility of increased appraised value from the lake front property created by the reservoir, a reduction of the Milam County tax base of 3% would not imply the need for a substantial increase in local taxes or decrease in the provision of public services and would not therefore, in itself, create a substantial negative impact on the regional economy.

In addition, if the possibility of increased value arising from the creation of water front property were considered, depending upon assumptions, the net effect of the proposed reservoir on the Milam County tax base could even be positive. But, as noted above, an estimate of increased values would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

4B.12.6.3.4.3 Revenue and Employment Effects from Potential Recreational Businesses

Potential sales, income, and jobs effects in Milam County arising from recreational benefits associated with the development of the proposed reservoir are estimated by comparing the proposed reservoir to estimated impacts in 1996 for similar reservoirs in the Brazos G Area

[86] Texas Association of Counties, County Information Project. http://www.county.org/resources/countydata/, 2004.

that were documented in a study contracted by the Corps of Engineers.[87] Seven reservoirs in the Brazos G Area were analyzed as potentially representative of the proposed reservoir: (1) Belton Lake; (2) Somerville Lake; (3) Stillhouse Hollow Reservoir; (4) Waco Lake; (5) Whitney Lake; (6) Granger Lake; and (7) Lake Georgetown. Granger Lake is the closest to the proposed site in Milam County, but at 4,400 surface acres it is much smaller than the proposed Little River Reservoir at a normal pool elevation of 310 ft-msl. Whitney Lake, at normal pool elevation, covers 23,500 surface acres, relatively close to the size (20,687 acres) of the Little River Reservoir at the normal pool elevation of 310 ft-msl. Table 4B.12.6-7 presents estimates of total annual recreational spending, direct and total sales (output) effects, direct and total income effects, and direct and total job effects for the surrounding regions.

Size, proximity to urban areas and available facilities are variables that certainly affect the visitation, spending and resulting economic effects at these reservoirs. At a 310 ft-msl pool elevation, the effects of the proposed Little River Reservoir are estimated as the average of those for Whitney Lake (closest in size) and Granger Lake (closest in location). This estimate assumes that the proposed Little River Reservoir will be characterized by approximately the same level of recreational facilities as the average of Whitney and Granger Lakes. Table 4B.12.6-8 presents these estimates for the proposed Little River Reservoir.

These estimates suggest that recreational activity at the proposed reservoir would have substantial positive economic effects on the surrounding region in Milam County. Total annual spending is estimated at $12,995,000, total sales effects at $15,200,000, total income effects at $8,110,000, and total jobs created at 406.

4B.12.6.3.4.4 <u>Loss of Crop Value</u>

The proposed Little River Reservoir at pool elevation of 310 ft-msl would inundate a total of 20,687 acres in eastern Milam County. Approximately 16,493 acres of Cropland,

[87] Propst, D. B., D. J. Stynes, W. Chang, and R. Jackson, *Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996.* U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. Technical Report R-98-1, September 1998.

Table 4B.12.6-7
Estimates of Annual Recreational Spending, Sales, Income and Job Effects on Surrounding Region for Selected U.S. Corps of Engineers Projects in the Brazos G Area, 1996

Project	*Total Spending (1996 $)*	*Direct Sales Effects (1996 $)*	*Total Sales Effects (1996 $)*	*Direct Income Effects (1996 $)*	*Total Income Effects (1996 $)*	*Direct Jobs Effects (Number of Jobs)*	*Total Jobs Effects (Number of Jobs)*
Belton Lake	22,760,000	14,050,000	22,210,000	7,420,000	12,010,000	510	655
Somerville Lake	18,850,000	12,180,000	19,410,000	6,290,000	10,220,000	416	538
Stillhouse Hollow Reservoir	5,550,000	3,640,000	6,030,000	1,890,000	3,180,000	121	163
Waco Lake	19,540,000	13,010,000	23,140,000	7,010,000	12,600,000	442	616
Whitney Lake	19,780,000	12,860,000	23,650,000	6,790,000	12,660,000	442	629
Granger Lake	6,210,000	4,070,000	6,750,000	2,110,000	3,560,000	136	182
Lake Georgetown	10,550,000	6,920,000	11,460,000	3,590,000	6,050,000	230	309

Source: Propst, D. B., D. J. Stynes, W. Chang, R. Jackson, "Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996", U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report R-98-1, September 1998.

Table 4B.12.6-8.
Estimates of Annual Recreational Spending, Sales, Income and Job Effects on Surrounding Region for the Proposed Little River Reservoir (310 ft-msl) in Milam County

Project	*Total Spending (1996 $)*	*Direct Sales Effects (1996 $)*	*Total Sales Effects (1996 $)*	*Direct Income Effects (1996 $)*	*Total Income Effects (1996 $)*	*Direct Jobs Effects (Number of Jobs)*	*Total Jobs Effects (Number of Jobs)*
Whitney Lake	19,780,000	12,860,000	23,650,000	6,790,000	12,660,000	442	629
Granger Lake	6,210,000	4,070,000	6,750,000	2,110,000	3,560,000	136	182
Proposed Little River 310' (Average of Whitney and Granger Lakes)	12,995,000	8,465,000	15,200,000	4,450,000	8,110,000	289	406

Sources: HDR Engineering, Inc. and Hicks & Company, 2004; Propst, D. B., D. J. Stynes, W. Chang, R. Jackson, "Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996", U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report R-98-1, September 1998; Texas Parks and Wildlife Department, http://www.tpwd.state.tx.us/fish/infish/lakes/granger/lake_id.htm; U.S. Army Corps of Engineers, Fort Worth District, http://www.swf-wc.usace.army.mil/whitney/pages/

549 acres of Post Oak Woods, and 3,645 acres of mixed Riparian Forest would be included in the inundated area. The 1997 Census of Agriculture[88] reports harvested cropland and market value of crops sold in Milam County. The majority of harvested acreage (almost entirely dryland) included hay, sorghum, cotton, and corn. The value per acre for harvested cropland (all crops) for Milam County in 1997 was $139. Using this value per acre of cropland and the expected loss of 16,493 acres of cropland to the proposed reservoir yields a rough estimate for total annual loss of crop value of $2,292,527.

4B.12.6.4 Environmental Issues (Normal Pool Elevation = 330 ft-msl)

4B.12.6.4.1 Description of Existing Environment

The proposed Little River Reservoir site (normal pool at 330 ft above mean sea level) in Milam County is in a transitional zone with the Blackland Prairies Ecological Region to the west and the Post Oak Savannah Ecological Region to the east.[89] This region is characterized by level to rolling topography, with interspersed grassland and woodland, with soils ranging from the deep, fertile, black soils of the Blackland Prairies region to the shallow, nearly impervious clay pan of the Post Oak Savannah region. The original physiognomy of the region varied from medium to tall broad-leaved deciduous and some needle-leaved evergreen trees to medium-tall dense grasslands with scattered open groves of deciduous trees in minor prairies.[90] The climate is characterized as subtropical humid with warm summers. Average annual precipitation ranges between 36 and 40 inches.[91] The Carrizo-Wilcox Aquifer is the only major aquifer underlying in the project area, though the downdip portion of the Trinity Aquifer lies nearby to the west.[92] The Queen City and Brazos River Alluvium minor aquifers are to the south and east of the project area, respectively.

The physiography of the region includes ceramic clay and lignite/coal, recharge sands, limestone sand and gravel, expansive clay mud, terraces, and flood-prone areas. The topography is flat to rolling with local escarpments, with local shallow depressions in flood-prone areas

[88] U. S. Department of Agriculture, *Census of Agriculture, Highlights of Agriculture: 1997 and 1992, Milam County, Texas*; http://www.nass.usda.gov/census/census97/highlights/tx/txc166.txt, 1997.
[89] 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.
[90] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.
[91] Larkin, T.J., and G.W. Bomar, *Climatic Atlas of Texas*, Texas Department of Water Resources, Austin, Texas, 1983.
[92] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.

along waterways.[93] The predominant soil types in the project area are primarily sandy loams and loamy sands, with a small amount of silty clay.[94]

Three major vegetation types occur within the general vicinity of the proposed project: Post Oak Woods/Forest, Post Oak Woods, Forest, and Grassland Mosaic, and crops.[95] 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. Post Oak Woods/Forest and the Post Oak Woods, Forest, and Grassland Mosaic could include the following commonly associated plants: blackjack oak (*Quercus marilandica*), eastern redcedar (*Juniperus virginiana*), mesquite (*Prosopis glandulosa*), black hickory (*Carya texana*), live oak (*Q. virginiana*), sandjack oak (*Q. incana*), cedar elm (*Ulmus crassifolia*), hackberry *(Celtis* spp.), yaupon (*Ilex vomitoria*), poison oak (*Toxicodendron pubescens*), American beautyberry (*Callicarpa americana*), hawthorn (*Crataegus* spp.), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus* spp.), coralberry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium* var. *scoparium*), silver bluestem (*Bothriochloa saccharoides*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida* spp.), spranglegrass (*Chasmanthium sessiliflorum*), and tickclover (*Desmodium* spp.). Crops include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

4B.12.6.4.2 Potential Impacts

4B.12.6.4.2.1 Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated with the proposed reservoir maintained at 330 feet (ft) above sea level and a diversion of 119,940 acre-feet of water per year. Overall, this alternative would have little influence on variability of median monthly flows, similar to the 310-ft elevation alternative, but would result in a greater reduction in quantity of monthly flows in the Little River compared with that alternative. The minimal reduction in variability of monthly flow values (measured by comparing sample variances of all monthly

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[93] 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.
[94] Soil Conservation Service (SCS), *Soil Survey of Milam County*, United States Department of Agriculture Soil Conservation Service in Cooperation with Texas Agricultural Experiment Station, 1925.
[95] 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.

flows from 1940-1997 and predicted flows over that same time period with each alternative in place; sample variance without project =2.95×10^{10}; sample variance with 330-ft elevation = 2.65×10^{10}) would probably not have much impact on the instream biological community or riparian species.

The reduction in the quantity of median monthly flow for the 330-ft elevation option in the area of the project would range from 0 cfs in July to 295.9 cfs (13 percent) in May, as shown in Table 4B.12.6-9. The highest percent reduction (36 percent) would occur in December, while the lowest (<2 percent) would occur during the months of March, July, and August. The change in low-flow conditions (85% exceedance values) would also be minimal. Without the project, the 85% exceedance value for monthly flow would be 156 cfs while under this alternative the value would be 141 cfs. The highest reductions are anticipated in fall and winter, which is less critical than reductions in spring and summer since many species spawn in the spring and summer flows are naturally lower and more susceptible to deterioration of water quality. Overall, the reductions in flow would be greater under this alternative than under the 310-ft elevation alternative, but should not have substantial impacts on the biological community.

Table 4B.12.6-9.
Median Monthly Streamflow: Little River Reservoir at 330-ft Elevation

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	542.6	519.4	23.2	4%
February	675.0	577.4	97.6	14%
March	610.3	595.8	14.4	2%
April	1,143.3	904.9	238.4	21%
May	2,265.7	1,969.8	295.9	13%
June	1,128.1	1,077.3	50.8	5%
July	331.6	331.6	0.0	0%
August	247.5	243.0	4.5	2%
September	291.6	244.8	46.8	16%
October	304.2	231.1	73.1	24%
November	371.2	321.2	49.9	13%
December	510.0	324.1	185.9	36%

Any reduction in discharge associated with this alternative for this project in the Little River would have minimal influence on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows into the estuary. As a new reservoir without a current operating permit, the Little River Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

4B.12.6.4.2.2 Wildlife Habitat

Approximately 35,586 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 25,344 acres of Cropland, 1,390 acres of Post Oak Woods, and 8,852 acres of mixed Riparian Forest. Some new shoreline and wetland habitat would be created that would be associated with the land-water interface. Vegetation would change from streamside plant species adapted to short-term inundation and over bank flooding, to aquatic or semi-aquatic species adapted to hydric or semi-hydric conditions along the shoreline.

A number of vertebrate species could occur within the vicinity of the Little River Reservoir site as indicated by county occurrence records.[96] These include four species of salamanders and newts, 16 species of frogs and toads, nine species of turtles, the American alligator, 10 species of lizards and skinks, and 21 species of snakes. Additionally, 54 species of mammals could occur within the site or surrounding region[97] 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.

The habitat value of occurring cover types has been estimated based on methodology developed by the Texas Parks and Wildlife Department[98] and other previous information.[99] Based on these estimates, preliminary mitigation requirements to compensate or offset the loss of inundated habitats are summarized in Table 4B.12.6-10.

[96] Texas A&M University (TAMU), *County Records for Amphibians and Reptiles*, Texas Cooperative Wildlife Collection, 1998.
[97] 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.
[98] Texas Parks and Wildlife Department (TPWD), "Wildlife Habitat Appraisal Procedure," PWD RP N7100-145 (2/95), <http://www.tpwd.state.tx.us/conserve/whap/mainwhap.html>, 1995.
[99] TPWD, "Texas Water and Wildlife," PWD-BK-7100-147-5/90, 1990.

Table 4B.12.6-10.
Estimated Mitigation Requirements for Cover Types Inundated by the Proposed Little River Reservoir (Pool level at 330 ft-msl)

Cover Type	Acres Lost	Habitat Quality Rating[1]	Habitat Units Lost[2]	Potential HQ Gain[3]	Compensation Acreage Requirements[4]
Mixed Riparian Forest	8,852	0.75	6,639	0.25	26,556
Post Oak Woods	1,390	0.58	806.2	0.42	1,920
Crops	25,344	0.2	5,068.8	0.8	6,336
Total	**35,586**		**12,514**		**34,812**

[1]Habitat Quality Ratings extrapolated from ratings of similar habitats within the same general region conducted by TPWD (1990).

[2]Values represent the product of Acres Lost multiplied by Habitat Quality Rating.

[3]Represents future maximum gain in habitat value (1.0 - Habitat Quality Rating Value) through intensive management of a mitigation area with similar baseline habitat value.

[4]Represents compensation required to fully offset loss of the cover type (Habitat Units lost ÷ Potential HQ gain); calculations derived from TPWD (1995); federal/state permits historically have required compensation only for jurisdictional waters of the U.S., including wetlands.

4B.12.6.4.2.3 *Threatened and Endangered Species*

According to county occurrence records,[100] a total of 26 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern. This group includes one amphibian, four reptiles, eight birds, two mammals, four fish species, five mollusks and two plant species (Table 4B.12.6-4). Additionally, one federally endangered mammal, the red wolf (*Canis rufus*) has been extirpated. One amphibian, two bird species, and one plant species federally-listed as threatened or endangered could occur in the project area. These include the Houston toad (*Bufo houstonensis*), interior least tern (*Sterna antillarum athalassos*), whooping crane (*Grus americana*), and Navasota ladies'-tresses (*Spiranthes parksii*). Habitat for the Houston toad includes pine and/or oak woodlands underlain by pockets of deep sandy soils with temporary pools of water available for breeding.[101] The Houston toad inhabits pools and stock tanks in areas with a sandy substrate. The interior least tern and whooping crane are seasonal migrants that could pass through the project area but would not likely be directly

[100] Texas Parks and Wildlife Department (TPWD), Annotated County List of Rare Species for Milam County, June 25, 2009.
[101] U.S. Fish and Wildlife Service, *The Endangered Houston Toad*, http://ifw2es.fws.gov/HoustonToad/, 2004.

affected by the proposed reservoir. Navasota Ladies'-tresses occurs on upland margins of intermittent, minor tributaries in association with post oak, blackjack oak, and yaupon.

A search of the Texas Natural Diversity Database[102] maintained by TPWD revealed two documented occurrences of rookeries within 0.5 to one-mile of the proposed Little River Reservoir (as noted on representative 7.5 minute quadrangle map(s) that include the project site). Both rookeries are described by TPWD as nesting colonies of the great egret, little blue heron, and cattle egret; one of the rookeries also has had nesting snowy egrets. Navasota ladies'-tresses have been documented within 2.5 miles of the proposed reservoir. 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.

4B.12.6.4.2.4 Cultural Resources

The potential cultural resources constraints for the Little River Reservoir at the 330 ft-msl normal pool elevation are essentially identical to those of the reservoir alternative at the 310 ft-msl normal pool elevation. A search of the Texas Archeological Sites Atlas database indicates that 102 archeological sites have been documented within the general vicinity of the proposed reservoir. These sites represent a variety of historic and prehistoric site types. Five of these sites (41MM12, 41MM13, 41MM14, 41MM130, and 41MM292) occur within the proposed reservoir's conservation pool. Four of the five sites within the conservation pool are recorded as prehistoric artifact scatters and/or prehistoric occupation sites. The remaining site (41MM13) is recorded as a prehistoric occupation site and historic artifact scatter. Espey Huston & Associates recommended site 41MM13 for further testing in 1979. A total of 22 archeological sites have been documented along Cannonsnap Creek in the immediate vicinity of the proposed reservoir. These sites do not appear to be within the proposed conservation pool; however, it is considered likely that similar sites (or undocumented components of these previously recorded sites) may exist within the proposed reservoir.

[102] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, *Element of Occurrence Records*, August 25, 2009.

One Official State Historical Marker is located within the footprint of the proposed reservoir. This marker, erected in 1936, commemorates the landing of the steamboat Washington in the winter of 1850-1851. The Washington was the “first, last and only” steamboat to navigate the Little River. At least seven cemeteries are mapped within the proposed reservoir. These include: Turnham-McCown Cemetery, Old City Cemetery, Milam Grove Cemetery, Pebble Grove Cemetery, Coxes Providence Community Cemetery, Story Cemetery, and Oxsheer-Smith Cemetery. No properties listed in the National Register of Historic Places (NRHP) or State Archeological Landmarks (SALs) occur within the proposed reservoir footprint.

Prior to reservoir inundation, a cultural resources survey must be conducted to determine if any other cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be formally 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).

4B.12.6.4.2.5 Threats to Natural Resources

Identified threats to natural resources were identified in Section 1.7.3.2 as lower stream flows, declining water quality, and reduced inflows to reservoirs. This project is expected to have slight effects on the variability of median monthly flows, and not substantially change low flow conditions (flows exceeded 85% of the time). It is unlikely this project would have any substantial influence on total discharge in the Brazos River, freshwater inflows to the Brazos River estuary, or water quality downstream.

4B.12.6.4.3 Mineral Rights and Oil and Gas Wells

Without researching courthouse deeds, the ownership of minerals contained within the proposed normal pool elevation of 330 ft-msl is unknown. However, according to known oil, gas, and other mineral recovery sites mapped from databases maintained by the Texas Railroad Commission,[103] there is one gas well, two shut-in oil wells, two oil/gas wells, 12 permitted

[103] Texas Railroad Commission (TRC), Mineral Recovery Databases, 2005.

locations, 44 oil wells, six plugged oil wells, and 14 dry holes located within the reservoir footprint (Table 4B.12.6-11).

Table 4B.12.6-11.
Oil and Gas Wells in the Little River Reservoir Footprint
(330 ft-msl Pool Elevation)

Type of Well	***Total Number***
Gas Well	1
Shut-In Oil Well	2
Oil/Gas Well	2
Pemitted Location	12
Oil Well	44
Plugged Oil Well	6
Dry Hole	14
Source: Texas Railroad Commission, 2005.	

4B.12.6.4.3.1 Mitigation Costs for Minerals

Plugging Existing Wells

As noted in Table 4B.12.6-11, the Texas Railroad Commission reports 44 oil wells, 2 oil/gas wells, 1 gas well, 2 shut-in oil wells, 6 plugged oil wells, 14 dry holes and 12 permitted locations in the Little River footprint at a normal pool elevation of 330 ft-msl. Assuming the dry holes are properly plugged, the development of the proposed reservoir would require the plugging of 49 existing wells.

Estimated costs for plugging these wells is available from the Railroad Commission's state-funded well plugging program. This program was established to locate, prioritize, and plug wells that have been abandoned by non-compliant oil and gas operators that may pose a risk to the environment or public safety. The program has, as of March 2003, plugged a total of 162 abandoned wells in Milam County, Texas at a cost of $317,069 or an average of $1,957 per well.[104] At an estimated cost of $1,957 per well, plugging the 49 wells in the 330 ft-msl reservoir footprint would cost about $95,893.

[104] Texas Railroad Commission (TRC), http://www.rrc.state.tx.us/news-releases/2003/030328a.html, 2003.

Raising Existing Wells and Relocating Storage Tanks

Another mitigation option to resolve the conflict would be to raise existing wells and relocate storage tanks out of the reservoir footprint. Although costs for this option have not been explicitly estimated, this option would result in oil and gas production facilities remaining on the surface of the reservoir – an outcome most project sponsors would probably seek to avoid.

Acquisition of Mineral Rights

Reservoir project sponsors could acquire the mineral rights for the property to be inundated. Texas law holds that the mineral estate is dominant over the surface estate.[105] This rule has serious implications for surface owners who are not mineral owners. Texas courts have held that mineral leases are not mere rental agreements as the name implies. Instead, they are actually deeds granting limited ownership rights to mineral lessees for as long as the lease continues. Thus, during the tenure of a lease, the mineral lessee enjoys the same rights to use the surface as any other mineral owner.

These property rights can be stated in the following way: mineral lessees can use as much of the surface as is *reasonably necessary* for mineral exploration and production. This privilege springs from the executed mineral lease. Independent permission from the surface owner is not necessary. No responsibility exists for restoring the surface or for paying surface damages. Liability arises only when the lessee goes beyond what is reasonably necessary or negligently injures the surface. The oil company or other entity leasing the minerals is the *lessee* and the mineral owner is the *lessor*.[106] The cost of mineral right acquisition would have to be estimated from a detailed examination of the Milam County Tax Office appraisals for the affected properties. This appraisal project would be undertaken at a latter stage of project development, but it is safe to say that costs to acquire mineral rights in an actively producing region could be substantial.

[105] Fambrough, J., *Subdivision Drill Sites, A Reprint from the Real Estate Center Journal,* Texas A&M University, Publication 690, November 1997.
[106] Fambrough, J., *Minerals, Surface Rights and Royalty Payments. A Reprint from the Real Estate Center Journal*, Texas A&M University, Technical Report 840, November 1996

Lignite Resources

Approximately 7,680 acres of the proposed reservoir at the 330 ft-msl normal pool elevation are underlain by lignite resources,[107] about 22 % of the 35,586 acre footprint. The only practical resolution of this conflict would be the acquisition of the mineral rights for the 7,680 acres affected. The cost of mineral right acquisition would require an appraisal project that, as in the case of oil and gas resources, would be undertaken at a latter stage of the project development. The presence of lignite resources in addition to oil and gas resources would, however, increase the cost of mineral rights acquisition.

Sand and Gravel Resources

A search of the TxDOT Aggregate Quarry and Pit Safety Program Inventory File[108] for pits and quarries in Milam County indicated two active quarries. This data were not sufficient to confirm whether these quarries were located within the reservoir footprint.

4B.12.6.4.4 Socioeconomic Effects

This section characterizes the potential socioeconomic effects of the proposed Little River Reservoir at a 330 ft-msl normal pool elevation in terms of: (1) impact on the tax base; (2) impacts to the local county economy from changes in the tax base; (3) revenue and employment effects from potential recreational businesses; and (4) loss of crop value.

Impact on the Tax Base of Milam County

At an elevation of 330 ft-msl, the proposed Little River reservoir would inundate an area of 35,586 acres in east-central Milam County between the City of Cameron and the confluence of the Little River and the Brazos River. The area proposed for inundation includes 25,344 acres of cropland, 8,852 acres of mixed riparian forests, and 1,390 acres of Post Oak woods.

The impact on the local Milam County tax base can, in principle, be estimated as the net effect of: (1) the loss of property tax revenue to local jurisdictions from the conversion of the reservoir footprint to public (tax exempt) ownership, assuming that the project sponsors will be

[107] Henry, C.D. and J.M. Basciano, *Environmental Geology of the Wilcox Group Lignite Belt: East Texas*. Report of Investigation No. 98, Bureau of Economic Geology, University of Texas at Austin. 1979.
[108] Texas Department of Transportation (TxDOT), Aggregate Quarry and Pit Safety Program Inventory File, 2005

public entities; and (2) the increase in value of property along the shoreline of the proposed reservoir, assuming that the shoreline will remain largely in private ownership. This estimate would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

Estimates of total market value (land and improvements) and total appraised value by county are available from the Texas Association of Counties' County Information Project.[109] For Milam County, the average market value of land and improvements was $2,491 per acre and the average appraised value was $1,711 per acre in 2003. If this average can be taken as an upper limit to the per acre appraised value of the 35,586 acres that will be required for the proposed reservoir at the 330 ft-msl normal pool elevation, then the total appraised value that would be lost in Milam County for taxation is $60,887,646 in 2003 dollars.

Impacts to Local Economy from Changes in the Tax Base

A total loss of $60,887,646 of tax base in Milam County represents a reduction of about 5.4 % from the 2003 total appraised value of $1,119,106,754. Neglecting the possibility of increased appraised value from the lake front property created by the reservoir, a reduction of the Milam County tax base of 5.4 % would not imply the need for a substantial increase in local taxes or decrease in the provision of public services and would therefore not, in itself, create a substantial negative impact on the local or regional economy. In addition, if the possibility of increased value arising from the creation of water front property were considered, depending upon assumptions, the net effect of the reservoir on the Milam County tax base could even be positive. But, as noted above, an estimate of increased values would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

Revenue and Employment Effects from Potential Recreational Businesses

Potential sales, income, and jobs effects in Milam County arising from recreational benefits associated with the development of the proposed reservoir are estimated by comparing the proposed reservoir to estimated impacts in 1996 for similar reservoirs in the Brazos G Area

[109] Texas Association of Counties, County Information Project. http://www.county.org/resources/countydata/, 2004.

that were documented in a study contracted by the Corps of Engineers.[110] Seven reservoirs in the Brazos G Area were analyzed as potentially representative of the proposed reservoir: (1) Belton Lake; (2) Somerville Lake; (3) Stillhouse Hollow Reservoir; (4) Waco Lake; (5) Whitney Lake; (6) Granger Lake; and (7) Lake Georgetown. Granger Lake is the closest to the proposed site in Milam County, but at 4,400 surface acres, it is much smaller than the proposed Little River Reservoir at the 330 ft-msl normal pool elevation. Table 4B.12.6-12 presents estimates of annual total spending, direct and total sales (output) effects, direct and total income effects and direct and total job effects for the surrounding regions.

Table 4B.12.6-12.
Estimates of Annual Recreational Spending, Sales, Income and Job Effects on Surrounding Region for Selected U.S. Corps of Engineers Projects in the Brazos G Area, 1996

Project	Total Spending (1996 $)	Direct Sales Effects (1996 $)	Total Sales Effects (1996 $)	Direct Income Effects (1996 $)	Total Income Effects (1996 $)	Direct Jobs Effects (Number of Jobs)	Total Jobs Effects (Number of Jobs)
Belton Lake	22,760,000	14,050,000	22,210,000	7,420,000	12,010,000	510	655
Somerville Lake	18,850,000	12,180,000	19,410,000	6,290,000	10,220,000	416	538
Stillhouse Hollow Reservoir	5,550,000	3,640,000	6,030,000	1,890,000	3,180,000	121	163
Waco Lake	19,540,000	13,010,000	23,140,000	7,010,000	12,600,000	442	616
Whitney Lake	19,780,000	12,860,000	23,650,000	6,790,000	12,660,000	442	629
Granger Lake	6,210,000	4,070,000	6,750,000	2,110,000	3,560,000	136	182
Lake Georgetown	10,550,000	6,920,000	11,460,000	3,590,000	6,050,000	230	309

Source: Propst, D. B., D. J. Stynes, W. Chang, R. Jackson, “Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996”, U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report R-98-1, September 1998.

Size, proximity to urban areas, and available facilities are variables that certainly affect the visitation, spending and resulting economic effects at these reservoirs. At a normal pool elevation of 330 ft-msl the proposed Little River Reservoir would have a surface area of 35,586 acres, about 75% more than at a pool elevation of 310 ft-msl. A larger reservoir would logically

[110] Propst, D. B., D. J. Stynes, W. Chang, and R. Jackson, Estimating *the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996.* U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. Technical Report R-98-1, September 1998.

have correspondingly larger economic effects. To estimate the higher economic effects of the larger reservoir alternative, Corps of Engineers estimates for recreational effects at a larger lake in the Fort Worth District, Lake Lewisville (29,592 acres), were averaged with Granger Lake and results shown in Table 4B.12.6-13**.**

These estimates suggest that recreational activity at the 330 ft-msl normal pool elevation for the proposed reservoir would have substantially larger positive economic effects on the surrounding region in Milam County than at the 310 ft-msl normal pool elevation. Total annual spending at the higher elevation is estimated at $21,315,000, total sales effects at $26,405,000, total income effects at $15,080,000 and total jobs created at 541.

Table 4B.12.6-13.
Estimates of Annual Recreational Spending, Sales, Income and Job Effects on Surrounding Region for the Proposed Little River Reservoir (330 ft-msl) in Milam County

Project	*Total Spending (1996 $)*	*Direct Sales Effects (1996 $)*	*Total Sales Effects (1996 $)*	*Direct Income Effects (1996 $)*	*Total Income Effects (1996 $)*	*Direct Jobs Effects (Number of Jobs)*	*Total Jobs Effects (Number of Jobs)*
Lewisville Lake	36,420,000	27,830,000	46,060,000	16,020,000	26,600,000	653	900
Granger Lake	6,210,000	4,070,000	6,750,000	2,110,000	3,560,000	136	182
Proposed Little River 330' (Average of Lewisville and Granger Lakes)	21,315,000	15,950,000	26,405,000	9,065,000	15,080,000	395	541

Sources: HDR Engineering, Inc. and Hicks & Company, 2004; Propst, D. B., D. J. Stynes, W. Chang, R. Jackson, "Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996", U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report R-98-1, September 1998; Texas Parks and Wildlife Department, http://www.tpwd.state.tx.us/fish/infish/lakes/granger/lake_id.htm; Texas Parks and Wildlife, Freshwater Fishing, http://www.tpwd.state.tx.us/fish/infish/lakes/lewisvll/lake_id.htm

Loss of Crop Value

The proposed Little River Reservoir at the 330 ft-msl normal pool elevation would inundate a total of 35,586 acres in eastern Milam County. Approximately 25,344 acres of Cropland, 1,390 acres of Post Oak Woods, and 8,852 acres of mixed Riparian Forest would be included in the inundated area. The 1997 Census of Agriculture[111] reports harvested cropland and market value of crops sold in Milam County. The majority of harvested acreage (almost entirely dryland) included hay, sorghum, cotton, and corn. The value per acre for harvested cropland (all crops) in 1997 was $139. Using this value per acre of cropland and the expected

[111] U. S. Department of Agriculture, *Census of Agriculture, Highlights of Agriculture: 1997 and 1992, Milam County, Texas*; http://www.nass.usda.gov/census/census97/highlights/tx/txc166.txt, 1997.

loss of 25,344 acres of cropland within the normal pool elevation of 330 ft-msl yields an estimate for total annual loss of crop value of $3,522,816, substantially higher than for the 310 ft-msl pool elevation alternative.

4B.12.6.5 Engineering and Costing

Construction of the Little River Reservoir at a normal pool elevation of 310 ft-msl will cost approximately $331.7 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 $23.3 million; this includes annual debt service and operation and maintenance. The cost for the available project yield of 71,275 acft/yr translates to an annual unit cost of raw water of $1.01 per 1,000 gallons, or $328/acft. A summary of the cost estimate is provided in Table 4B.12.6-14. Costs shown herein are for raw water supply at the reservoir and include no transmission, local distribution, or treatment costs

Construction of the Little River Reservoir at a normal pool elevation of 330 ft-msl will cost approximately $556.5 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 $39.3 million; this includes annual debt service and operation and maintenance. The cost for the available project yield of 119,940 acft/yr translates to an annual unit cost of raw water of $1.01 per 1,000 gallons, or $328/acft. A summary of the cost estimate is provided in Table 4B.12.6-15. Costs shown herein are for raw water supply at the reservoir and include no transmission, local distribution, or treatment costs.

4B.12.6.6 Implementation Issues (Normal Pool Elevations 310 ft-msl and 330 ft-msl)

This option has been compared to the plan development criteria as shown in Table 4B.12.6-16.

4B.12.6.6.1 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 structures placed in navigable waters of the U.S. (Section 10 of Rivers and Harbors Act) or 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);

Table 4B.12.6-14
Cost Estimate Summary for
Little River Reservoir (Normal Pool Elevation = 310 ft-msl)
(September 2008 Prices)

Item	***Estimated Costs***
Capital Costs	
Dam and Reservoir (Conservation Pool 321,000 acft, 20687 acres, 310 ft-msl)	$86,953,000
Total Capital Cost	**$86,953,000**
Engineering, Legal Costs and Contingencies	$30,434,000
Environmental & Archaeology Studies and Mitigation	$84,489,000
Land Acquisition and Surveying (31,000 acres)	$84,489,000
Interest During Construction (4 years)	$45,340,000
Total Project Cost	**$331,705,000**
Annual Costs	
Reservoir Debt Service (6 percent, 40 years)	$22,045,000
Operation and Maintenance	$1,304,000
Total Annual Cost	**$23,349,000**
Available Project Yield (acft/yr)	71,275
Annual Cost of Water ($ per acft)	$328
Annual Cost of Water ($ per 1,000 gallons)	$1.01

Table 4B.12.6-15.
Cost Estimate Summary for
Little River Reservoir (Normal Pool Elevation = 330 ft-msl)
(September 2008 Prices)

Item	***Estimated Costs***
Capital Costs	
Dam and Reservoir (Conservation Pool 930,460 acft, 35,463.5 acres, 330 ft-msl)	$153,812,000
Total Capital Cost	**$153,812,000**
Engineering, Legal Costs and Contingencies	$53,834,000
Environmental & Archaeology Studies and Mitigation	$136.402,000
Land Acquisition and Surveying (53,200 acres)	$136,402,000
Interest During Construction (4 years)	$76,070,000
Total Project Cost	**$556,520,000**
Annual Costs	
Reservoir Debt Service (6 percent, 40 years)	$36,986,000
Operation and Maintenance	$2,307,000
Total Annual Cost	**$39,293,000**
Available Project Yield (acft/yr)	119,940
Annual Cost of Water ($ per acft)	$328
Annual Cost of Water ($ per 1,000 gallons)	$1.01

Table 4B.12.6-16.
Comparison of Little River Reservoir (310 ft and 330 ft elevations) 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. 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 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

- 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.

4B.12.6.6.2 *State and Federal Permits will 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.

4B.12.6.6.3 *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;
- Possible relocations of residences, utilities, roads, oil and gas production and storage facilities, or other structures; and
- Possible acquisition of mineral rights.

4B.12.7 Millican Reservoir – Bundic Site

4B.12.7.1 Description of Option

Studies for development of a new reservoir on the Navasota River have been conducted by the U.S. Army Corps of Engineers (USCOE) since the mid-1940s. The proposed Millican Reservoir has been evaluated by the USCOE for the purposes of flood control, water supply, hydropower generation, and recreation. Many different sites have been studied along the Navasota River at various sizes and configurations.

Following completion of studies in the 1960s, the U.S. Congress authorized Millican Reservoir in 1968 as the first unit of a two-stage reservoir development. A second reservoir, Navasota Reservoir, located upstream of Millican Reservoir, was also authorized. Since the original authorization in 1968, concerns have evolved regarding the loss of large lignite and oil and gas resources that would occur by construction of Millican Reservoir. In addition, conditions in the Brazos River Basin changed including the construction of Lake Limestone and two power generation plants, Gibbons Creek and Twin Oaks. In 1980, the USCOE restudied the Millican Reservoir Project. As part of the study, detailed plans of alternative reservoir sites were evaluated including:

- Authorized Dam Site (Conservation Storage = 754,000 acft);
- Panther Creek Dam Site (Conservation Storage = 1,973,000 acft);
- Panther Creek Dam Site (Conservation Storage = 587,000 acft); and
- Bundic Dam Site (Conservation Storage = 228,000 acft).

The results of the 1980 study found that the Bundic Site provided the maximum benefits and the plan for the Millican Reservoir was reformulated to be the Bundic Site. However, a Reevaluation Study was performed by the USCOE in 1985, which recommended the Panther Creek Dam Site instead of the Bundic Site. The results of the 1980 and 1985 studies on Millican Reservoir by the USCOE show that both the Panther Creek and Bundic Dam Sites are the two sites that are most feasible for reservoir development. However, only the Bundic Dam Site (Millican-Bundic Reservoir) is discussed in this current Regional Water Plan.

The Millican-Bundic Reservoir is on the Navasota River located between SH 21 and US 79, approximately 19 miles northeast of the City of Bryan, as shown in Figure 4B.12.7-1.

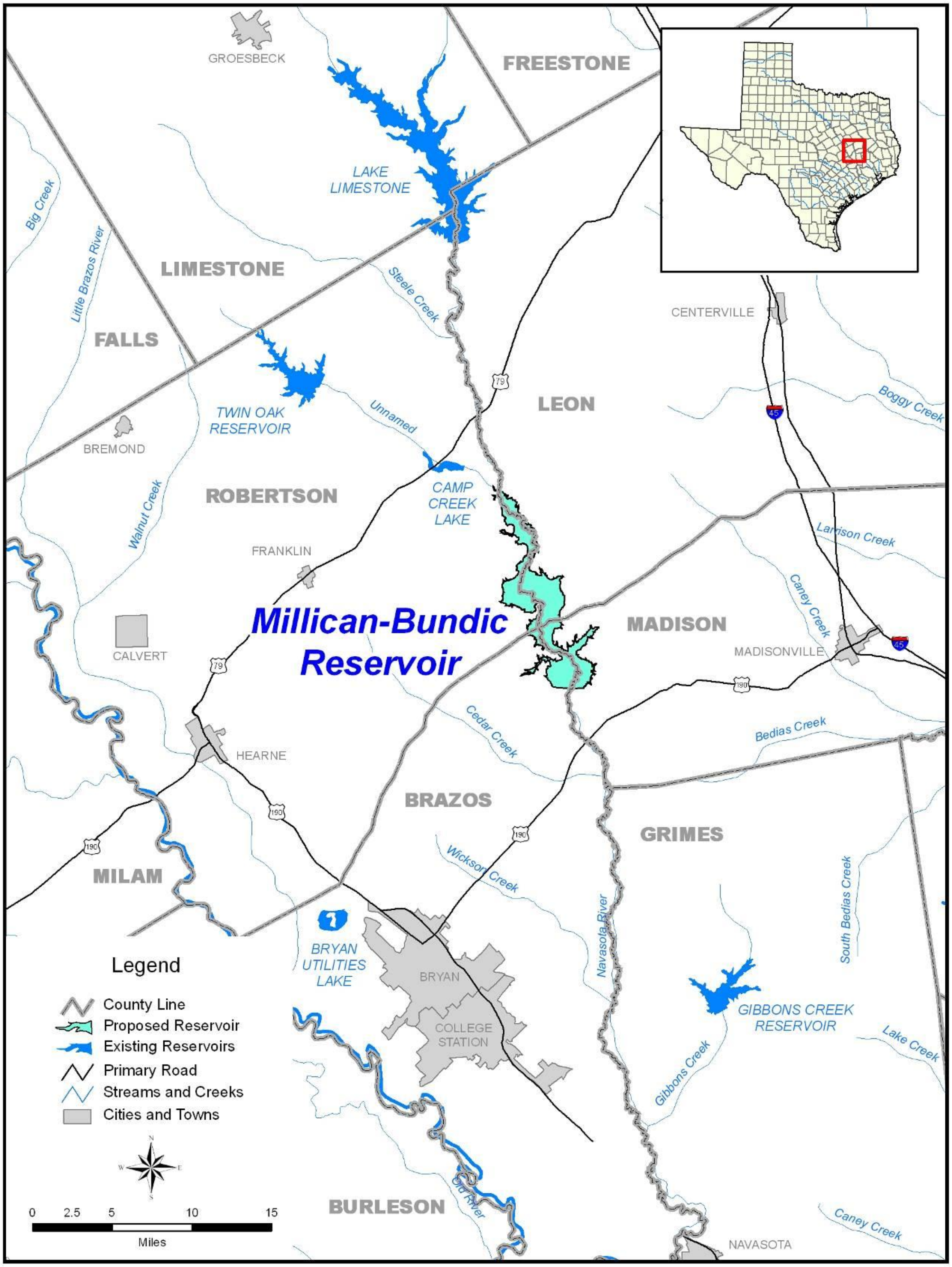


Figure 4B.12.7-1. Millican-Bundic Reservoir

Based on the USCOE study results, this reservoir would be constructed for the purposes of water supply and recreation. Flood control storage and hydropower generation were not found to be economically justified. The proposed reservoir will contain approximately 205,760 acft of conservation storage and inundate 14,630 acres at the full conservation storage level of 277 ft-msl. It would be formed by a dam about 2 miles long (10,400 feet).

The Millican-Bundic Reservoir could potentially provide surface water to the Brazos County and Grimes County area as well as meet downstream water supply needs in Region H.

4B.12.7.2 Available Yield

Water potentially available for impoundment in the proposed Millican-Bundic Reservoir was estimated using the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available from the Navasota River without causing increased shortages to existing downstream rights. Firm yield was computed subject to the reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the reservoir are shown in Table 4B.12.7-1.

Table 4B.12.7-1.
Daily Natural Streamflow Statistics
for the Millican-Bundic Reservoir

Month	Median Flows – Zone 1 Pass-Through Requirements (cfs)	25th Percentile Flows – Zone 2 Pass-Through Requirements (cfs)
January	122.2	40.8
February	149.5	52.9
March	161.4	51.3
April	126.5	49.3
May	163.0	51.3
June	54.8	18.0
July	10.9	2.9
August	3.0	0.4
September	7.2	1.2
October	9.3	1.5
November	32.9	10.7
December	63.7	21.1
Zone 3 (7Q2) Pass-Through Requirement (cfs):		0.82

Figure 4B.12.7-2 illustrates the simulated Millican-Bundic Reservoir storage levels for the 1940 to 1997 historical period, subject to the firm yield in the reservoir of 36,990 acft/yr. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 66 percent of the time and above the Zone 3 trigger level (50 percent capacity) 90 percent of the time.

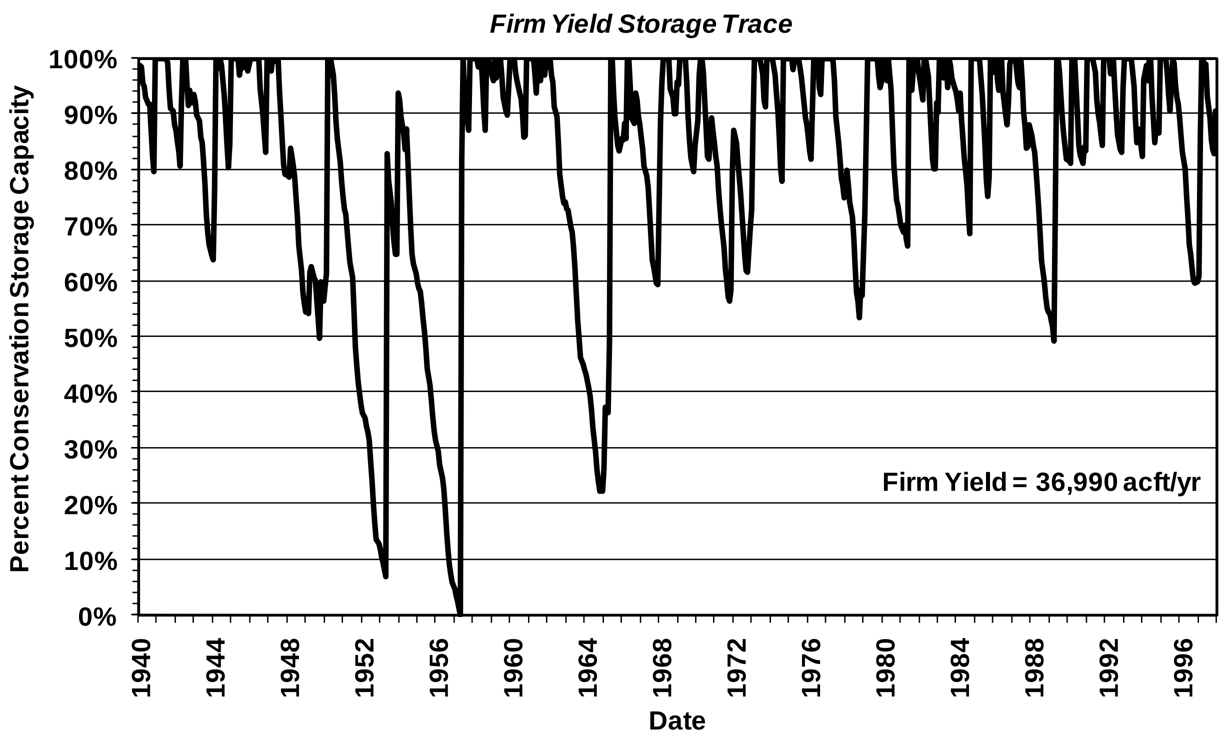
Figure 4B.12.7-3 illustrates the changes in streamflows caused by impounding the unappropriated waters of the Navasota River. The largest change would be a decline in median streamflow of 200 cfs during February. Other significant declines would occur in January, March, and May. During the months of August-October, there would be little change in streamflow because the reservoir would only rarely be able to impound water in excess of that required for downstream senior water rights and environmental needs.

4B.12.7.3 Environmental Issues

4B.12.7.3.1 Description of Existing Environment

The Bundic Site of the proposed Millican Reservoir lies within the Post Oak Savannah Ecological Region[112] in Brazos, Leon, Madison, and Robertson Counties. This region is characterized as a narrow, highly irregular oak belt that consists of intermingled forest, woodland, and savannah. It is located between the East Texas Pine-Hardwood Forest to the east, Blackland Prairies to the west, and the Coastal Prairie and South Texas Brushlands to the south. The original physiognomy of the region was medium to tall broad-leaved deciduous and some needle-leaved evergreen trees. The shallow, nearly impervious clay pan of the Post Oak Savannah region causes the soil to be arid.[113] The climate is characterized as subtropical humid, with warm summers. Average annual precipitation ranges between 36 and 40 inches.[114] The Queen City and Sparta minor aquifers underlie the study area, and the Gulf Coast major aquifer lies south of the study area but does not underlie it.[115]

[112] 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.
[113] Telfair, R.C., "Texas Wildlife Resources and Land Uses," University of Texas Press, Austin, Texas, 1999.
[114] Larkin, T.J., and G.W. Bomar, "Climatic Atlas of Texas," Texas Department of Water Resources, Austin, Texas, 1983.
[115] Texas Water Development Board (TWDB), Major and Minor Aquifers of Texas; Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.



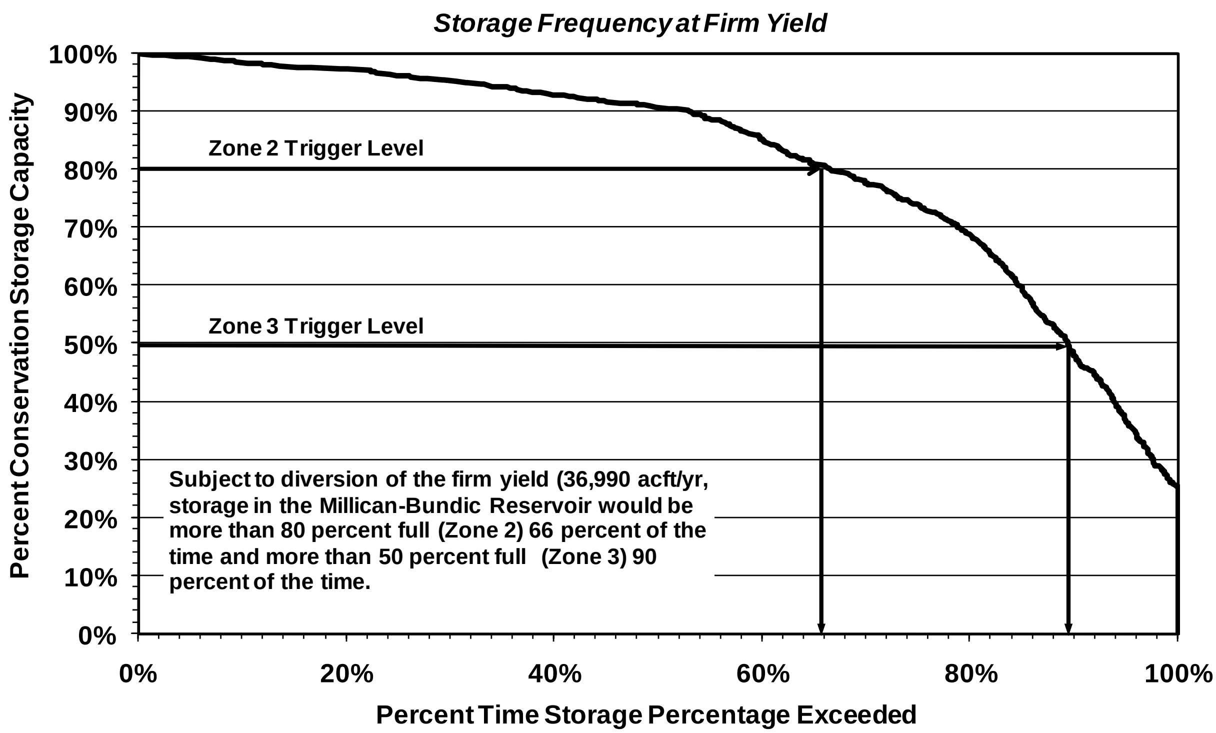
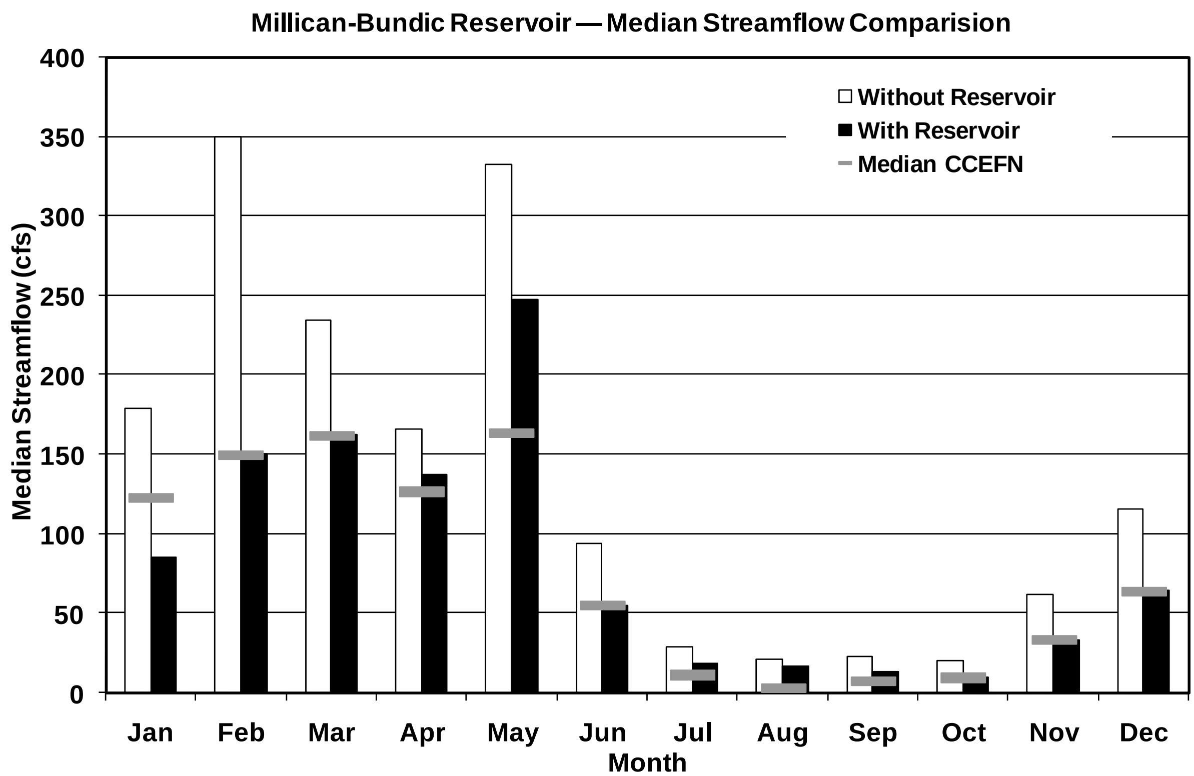


Figure 4B.12.7-2. Millican-Bundic Reservoir Storage Considerations



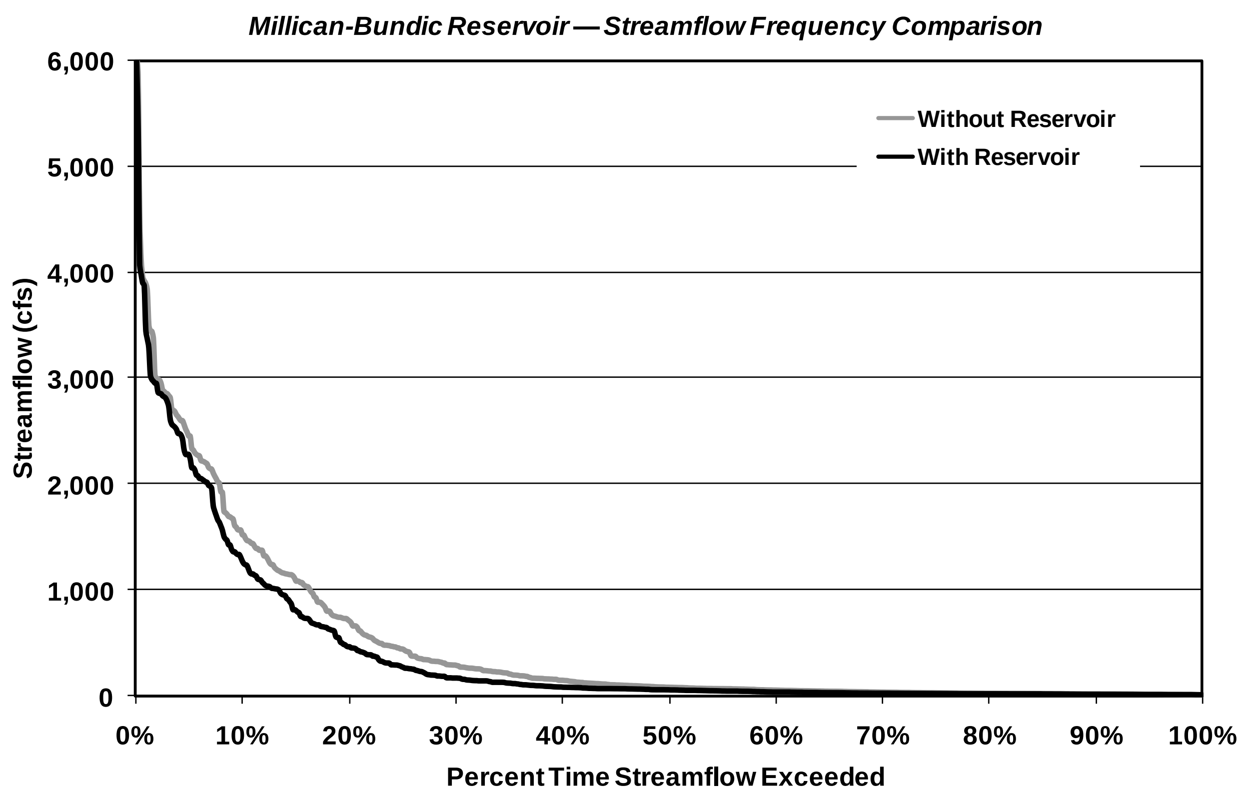


Figure 4B.12.7-3. Millican-Bundic Reservoir Storage Considerations

The physiography of the study area includes recharge sand, secondary aquifers, greensand-ironstone, siliceous sand and gravel, terraces, and flood-prone areas. The topography ranges from flat to rolling, with local escarpments in recharge sands and shallow depressions in flood-prone areas along waterways, to steeply sloped greensand-ironstone areas.[116] The predominant soil associations in the study area are the Tabor-Gredge-Rader and Sandow (Brazos County), Gladewater-Kaufman and Hatliff-Nahatche (Leon County), and Gladewater and Gowker-Nahatche (Madison and Robertson Counties). The Tabor-Gredge-Rader association consists of nearly level to moderately sloping, very deep, loamy soils that are well drained or moderately well drained, in areas of oak savannahs. Sandow soils are nearly level, very deep, loamy soils that are moderately well drained and occur in frequently flooded areas on bottomland.[117] Gladewater-Kaufman soils are nearly level, deep, clayey soils that are very poorly drained to somewhat poorly drained. Hatliff-Nahatche soils are nearly level, deep, loamy soils that are moderately well drained and somewhat poorly drained.[118] Gladewater soils are nearly level, clayey soils that are poorly drained and occur primarily on floodplains. Gowker-Nahatche soils are nearly level, loamy soils that are moderately well drained and somewhat poorly drained and occur primarily on floodplains.[119]

Three major vegetation types occur within the general vicinity of the proposed project: Post Oak (*Quercus stellata*) Woods, Forest, and Grassland Mosaic, Post Oak Woods/Forest, and Water Oak (*Q. nigra*)-Elm (*Ulmus* spp.)-Hackberry (*Celtis* spp.) Forest.[120] 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. Post Oak Woods/Forest and Post Oak Woods, Forest, and Grassland Mosaic could include the following commonly associated plants: blackjack oak (*Quercus marilandica*), eastern redcedar (*Juniperus virginiana*), mesquite (*Prosopis glandulosa*), black hickory (*Carya texana*), live oak (*Q. virginiana*),

[116] 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.
[117] Natural Resources Conservation Service (NRCS), "Soil Survey of Brazos County, Texas," United States Department of Agriculture in cooperation with Texas Agricultural Experiment Station, 2002.
[118] Neitsch, C.L., J.J. Castille, and M.R. Jurena, "Soil Survey of Leon County, Texas," United States Department of Agriculture in cooperation with Texas Agricultural Experiment Station, 1989.
[119] Neitsch, C.L., "Soil Survey of Madison County, Texas," United States Department of Agriculture in cooperation with Texas Agricultural Experiment Station, 1994.
[120] 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.

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* spp.), coralberry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium*), silver bluestem (*Bothriochloa saccharoides*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida* spp.), spranglegrass (*Chasmanthium sessiliflorum*), and tickclover (*Desmodium* spp.). Water Oak-Elm-Hackberry Forest could include the following commonly associated plants: cedar elm, American elm (*Ulmus americana*), willow oak (*Q. phellos*), southern red oak (*Q. falcata*), white oak (*Q. alba*), black willow (*Salix nigra*), cottonwood (*Populus deltoides*), red ash (*Fraxinus pennsylvanica*), sycamore (*Platanus occidentalis*), pecan (*Carya illinoinensis*), bois d'arc (*Maclura pomifera*), flowering dogwood (*Cornus florida*), dewberry, coralberry, dallisgrass (*Paspalum dilatatum*), switchgrass (*Panicum virgatum*), rescuegrass (*Bromus catharticus*), bermudagrass (*Cynodon dactylon*), eastern gamagrass (*Tripsacum dactyloides*), Virginia wildrye (*Elymus virginicus*), Johnsongrass (*Sorghum halepense*), giant ragweed (*Ambrosia trifida*), and Leavenworth eryngo (*Eryngium leavenworthii*).

4B.12.7.3.2 *Potential Impacts*

4B.12.7.3.2.1 *Aquatic Environments including Bays & Estuaries*

The anticipated impact of this project would be minimal influence on the variability of monthly flows but moderate reductions in the quantity of median monthly flows. The minimal reduction in variability of monthly flow values (measured by comparing sample variances of all monthly flows from 1940-1997 and predicted flows over that same time period with the project in place; sample variance without project =2.39 x 10^9; sample variance with project =2.06 x 10^9) would probably not have much impact on the instream biological community or riparian species. The reduction in the quantity of median monthly flow in the area of the project would range from 4.1 cfs (20 percent) in August to 199.9. cfs (57 percent) in February, as shown in Table 4B.12.7-2. The highest reductions (>50 percent) would occur in January, February, and October, while the lowest (20 percent or less) would occur in April and August. This project would also result in a slightly higher frequency of low-flow conditions. Without the project, the 85 percent exceedance value would be 18 cfs, and it would be 15 cfs with the project in place. These reductions in flow could have moderate impacts on the instream biological community.

However, minimal reductions in the spring and summer will lessen impacts during critical times when many species spawn and when water quality conditions are highly susceptible to streamflow reductions.

Table 4B.12.7-2.
Median Monthly Streamflow: Millican-Bundic Reservoir

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	178.6	84.8	93.8	53%
February	350.0	150.1	199.9	57%
March	234.4	162.0	72.4	31%
April	165.5	137.4	28.2	17%
May	332.3	247.0	85.3	26%
June	94.0	55.0	39.0	41%
July	28.5	18.4	10.0	35%
August	20.9	16.8	4.1	20%
September	22.8	13.3	9.5	42%
October	19.7	9.5	10.2	52%
November	62.0	33.1	29.0	47%
December	115.6	63.9	51.7	45%

Although there may be moderate biological impacts in the Navasota River in the immediate vicinity of the project site and downstream, it is unlikely 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 have impacts on freshwater inflows to the estuary. As a new reservoir without a current operating permit, the Millican Lake Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

4B.12.7.3.2.2 *Wildlife Habitat*

Approximately 14,630 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 4,086 acres of Grasses/Forbs, 1,334 acres of Post Oak Woods, and 9,210 acres of mixed Bottomland Hardwood Forest. Some new shoreline and wetland habitat would be created that would be associated with the land-water interface. Vegetation would change from streamside plant species adapted to short-term inundation and over bank flooding, to aquatic or semi-aquatic species adapted to hydric or semi-hydric conditions along the shoreline.

A number of vertebrate species could occur within the Millican-Bundic Reservoir Site as indicated by county occurrence records.[121] These include 6 species of salamanders, 22 species of frogs and toads, 14 species of turtles, 1 alligator species, 11 species of lizards and skinks, and 33 species of snakes. Additionally, 60 species of mammals could occur within the site or surrounding region[122] 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.

The habitat value of occurring cover types has been estimated based on methodology developed by the Texas Parks and Wildlife Department (TPWD)[123] and other previous information.[124] Based on these estimates, preliminary mitigation requirements to compensate or offset the loss of inundated habitats are summarized in Table 4B.12.7-3.

Table 4B.12.7-3.
Estimated Mitigation Requirements for Cover Types
Inundated by the Proposed Millican Reservoir (Bundic Site)

Cover Type	*Acres Lost*	*Habitat Quality Rating*[1]	*Habitat Units Lost*[2]	*Potential HQ Gain*[3]	*Compensation Acreage Requirements*[4]
Mixed Bottomland Hardwood Forest	9,210	0.63	5,802.3	0.37	15,682
Grasses/Forbs	4,086	0.33	1,348.4	0.67	2,013
Post Oak Woods	1,334	0.39	520.3	0.61	853
Total	14,630		7,670.9		18,548

1 Habitat Quality Rating values from TPWD (1990).
2 Values represent the product of Acres Lost multiplied by Habitat Quality Rating.
3 Represents future maximum gain in habitat value (1.0 – Habitat Quality Rating Value) through intensive management of a mitigation area with similar baseline habitat value.
4 Represents compensation required to fully offset loss of the cover type (Habitat Units Lost ÷ Potential HQ Gain); calculations derived form TPWD (1995); federal/state permits historically have required compensation only for jurisdictional waters of the U.S., including wetlands.

121 Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, *Element of Occurrence Records*, August 25, 2009.
122 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.
123 Texas Parks and Wildlife Department (TPWD), "Wildlife Habitat Appraisal Procedure," PWD RP N7100-145 (2/95), <http://www.tpwd.state.tx.us/conserve/whap/mainwhap.html>, 1995.
124 TPWD, "Texas Water and Wildlife," PWD-BK-7100-147-5/90, 1990.

4B.12.7.3.2.3 Threatened & Endangered Species

According to county occurrence records[125] a total of 44 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.12.7-4). This group includes one amphibian, 3 reptiles, 8 birds, 3 fish species, 3 insect species, four mammals, 13 mollusks, and 9 plant species. The federally endangered red wolf (*Canis rufus*) is listed as extirpated within the region. One amphibian species, two bird species, one mammal, and two plant species federally-listed as threatened or endangered could occur in the study area. These include the Houston toad (*Bufo houstonensis*), interior least tern (*Sterna antillarum athalassos*), whooping crane (*Grus americana*), Louisiana black bear (*Ursus americanus lutealus*) large-fruited sand verbena (*Abronia macrocarpa*), and Navasota ladies'-tresses (*Spiranthes parksii*). The interior least tern, and whooping crane are seasonal migrants that could pass through the study area but would not likely be directly affected by the proposed reservoir. The Louisiana black bear is a transient in the study area.

A search of the Texas Natural Diversity Database[126] maintained by the TPWD revealed the documented occurrence of the federally-endangered Houston toad, large-fruited sand verbena, and Navasota Ladies'-tresses within the vicinity of the site (as noted on representative 7.5-minute quadrangle map(s) that include the project site). Although not federal- or state-listed as endangered or threatened, species of concern documented within the vicinity of the site include the sandhill woolywhite (*Hymenopappus carrizoanus*), and Parks' Jointweed (*Polygonella parksii*). Other documented sensitive species include the Centerville Brazos-mint (*Brazoria pulcherrima*), Mohlenbrock's umbrella-sedge (*Cyperus grayioides*), and the crawfish frog (*Rana areolata*). Additionally, two colonial water bird nesting rookeries were also documented near the vicinity of the 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 will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

[125] TPWD, "Annotated County List of Rare Species for Brazos, Leon, Madison, and Robertson Counties," 2009.
[126] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, *Element of Occurrence Records*, August 25, 2009.

Table 4B.12.7-4. Potentially Occurring Federal-and State-Listed Species (Including Species of Concern) for Brazos, Leon, Madison, and Robertson Counties - Millican-Bundic Reservoir

Scientific Name	*Common Name*	*Federal/ State Status*	*Brazos County*	*Leon County*	*Madison County*	*Robertson County*
Amphibians						
Bufo houstonensis	Houston Toad	LE/E	X	X	—	X
Birds						
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant	Migrant	Migrant	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL	Migrant	Migrant	Migrant	Migrant
Aimophila aestivalis	Bachman's Sparrow	SOC/T	—	Migrant*	Migrant*	—
Haliaeetus leucocephalus	Bald Eagle	DL/T	Migrant*	Migrant*	Migrant*	Migrant*
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant	Migrant	Migrant	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*	Migrant*	Migrant*	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant	Migrant	Migrant	Migrant
Mycteria americana	Wood Stork	SOC/T	Migrant	Migrant	Migrant	Migrant
Fishes						
Cycleptus elongatus	Blue sucker	SOC/T	X	—	—	X
Notropis buccula	Smalleye Shiner	C/SOC	X	—	—	X
Notropis oxyrhincus	Sharpnose Shiner	C/SOC	X	—	—	X
Insects						
Procloeon texanum	A Mayfly	SOC	X	—	—	—
Gomphus modestus	Gulf Coast Clubtail	SOC	X	—	—	—
Neurocordulia molesta	Smoky Shadowfly	SOC	X	—	—	—
Mammals						
Ursus americanus luteolus	Louisiana Black Bear	LT/T	Transient	Transient	Transient	Transient
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X	X	X	X
Canis rufus	Red Wolf	LE/E	Extirpated	Extirpated	Extirpated	Extirpated
Myotis austroriparius	Southeastern Myotis Bat	SOC	—	X	X	—
Mollusks						
Strophitus undulates	Creeper (Squawfoot)	SOC	—	X	X	—
Quincuncina mitchelli	False Spike Mussel	SOC/T	X	—	—	X
Truncilla donaciformis	Fawnsfoot	SOC	—	X	X	—
Villosa lienosa	Little Spectaclecase	SOC	—	X	X	—
Pleurobema riddellii	Louisiana Pigtoe	SOC/T	—	X	X	—
Tritogonia verrucosa	Pistolgrip	SOC	X	X	X	X
Arcidens confragosus	Rock Pocketbook	SOC	X	X	X	X

Table 4B.12.7-4 (Concluded)

Scientific Name	Common Name	Federal/ State Status	Brazos County	Leon County	Madison County	Robertson County
Lampsilis satura	Sandbank Pocketbook	T	—	X	X	—
Quadrul houstonensis	Smooth Pimpleback	SOC/T	X	X	X	X
Truncilla macrodon	Texas Fawnsfoot	SOC/T	X	—	—	X
Potamilus amphichaenus	Texas Heelsplitter	SOC/T	—	X	X	—
Fusconaia askewi	Texas Pigtoe	SOC/T	—	X	X	—
Fusconaia flava	Wabash Pigtoe	SOC	—	X	X	—
Reptiles						
Macrochelys temminckii	Alligator Snapping Turtle	SOC/T	X	X	X	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X	X	X	X
Crotalus horridus	Timber/Canebrake Rattlesnake	SOC/T	X	X	X	X
Plants						
Liatris cymosa	Branched Gay-feather	SOC	X	—	X	—
Xyris chapmanii	Chapman's Yellow-eyed Grass	SOC	—	X	—	—
Abronia macrocarpa	Large-fruited Sand Verbena	LE/E	—	X	—	X
Spiranthes parksii	Navasota Ladies'-tresses	LE/E	X	X	X	X
Polygonella parksii	Parks' jointweed	SOC	—	X	—	X
Hymenopappus carrizoanus	Sandhill woolywhite	SOC	—	X	—	X
Eriocaulon körnickianum	Small-headed pipewort	SOC	X	—	—	—
Thalictrum texanum	Texas meadow-rue	SOC	X	—	—	—
Chloris texensis	Texas windmill-grass	SOC	X	—	—	—

X = Occurs in county; — = does not occur in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be Delisted (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-Delisted Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: Texas Parks and Wildlife Department (TPWD) Annotated County List of Rare Species for Brazos, Leon, Madison, and Robertson Counties (2009); TPWD Texas Wildlife Diversity Database (2009), USFWS Endangered Species List – List of species by county for Texas, August 27, 2009.

Habitat for the Houston toad includes pine and/or oak woodlands underlain by pockets of deep sandy soils, with temporary pools of water available for breeding.[127] Large-fruited sand verbena, which flowers from April through June and sometimes as late as October, is typically found in deep, somewhat excessively drained sandy soils in openings in post oak woodlands, sometimes in active sand blowouts. Navasota ladies'-tresses, which flowers in late October through early November, is typically found in the margins and openings of post oak woodlands in sandy loams along intermittent tributaries of rivers and streams.[128]

[127] U.S. Fish and Wildlife Service, "The Endangered Houston Toad," http://ifw2es.fws.gov/HoustonToad/, 2004.
[128] Op. Cit.

4B.12.7.3.2.4 Cultural Resources

A search of the Texas Historical Commission's online database indicates that no properties listed on the National Register of Historic Places, State Archeological Landmarks, Recorded Texas Historic Landmarks, or Official State Historical Markers occur within the proposed reservoir site. At least two cemeteries, the Burns Cemetery and the Anderson Cemetery, are mapped within the proposed reservoir site.

A total of 56 archeological sites have been documented within the general vicinity of the proposed reservoir. Prewitt and Associates, Inc. recorded 53 of these sites in 1981 as part of an archeological survey of proposed reservoir alternatives. These sites, which represent a variety of historic and prehistoric site types, may be impacted by reservoir inundation. These sites must be reassessed in coordination with the Texas Historical Commission relative to their eligibility for inclusion in the National Register of Historic Places or as State Archeological Landmarks. Additionally, a cultural resources survey must be conducted for any areas within the proposed reservoir that were not included in the previous survey efforts to determine if cultural resources are present. Any cultural resources identified during survey will need to be formally 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).

4B.12.7.3.2.5 Threats to Natural Resources

Identified threats to natural resources were identified in Section 1.7.3.2 as lower streamflows, declining water quality, and reduced inflows to reservoirs. This project is expected to have slight effects on the variability of median monthly flows, but median monthly low flows (flows exceeded 85 percent of the time) would decline by about 39 percent. However, it is unlikely this project would have any substantial influence on total discharge in the Brazos River, freshwater inflows to the Brazos River estuary, or water quality downstream.

4B.12.7.3.4 Mineral Rights and Oil and Gas Wells

Without researching courthouse deeds, the ownership of minerals contained within the footprint of the proposed Millican-Bundic Reservoir is unknown. However, according to known oil, gas, and other mineral recovery sites mapped from databases maintained by the Texas Railroad Commission,[129] there is one oil well, two plugged oil wells, and four dry holes within the reservoir footprint (Table 4B.12.7-5).

Table 4B.12.7-5. Oil and Gas Wells in the Footprint of the Millican-Bundic Reservoir

Type of Well	*Total Number*
Oil Well (Bottom)	1
Plugged Oil Well	2
Dry Hole	4
Source: Railroad Commission of Texas, 2005.	

4B.12.7.3.5 Mitigation Costs for Minerals

4B.12.7.3.5.1 Plugging Existing Wells

As noted in Table 4B.12.7-5, the Texas Railroad Commission[130] reports that within the footprint of the Millican-Bundic Reservoir, there are two plugged oil wells, one oil-producing well and four dry holes. Assuming that the dry holes are properly plugged, the development of the proposed Millican-Bundic Reservoir would require the plugging of one existing well.

Estimated costs for plugging these wells are available from the Railroad Commission's state-funded well plugging program. This program was established to locate, prioritize, and plug wells that have been abandoned by non-compliant oil and gas operators that may pose a risk to the environment or public safety. Based on data obtained from a nearby county (Milam County), the average cost to plug an abandoned well in 2003 was about $1,957.00[131]

4B.12.7.3.5.2 Raising Existing Wells and Relocating Storage Tanks

Another mitigation option would be to raise existing wells and relocate storage tanks out of the reservoir footprint. Although costs for this option have not been explicitly estimated, this option would result in oil and gas production facilities remaining on the surface of the reservoir – an outcome most project sponsors would probably seek to avoid.

[129] Texas Railroad Commission (TRC), Mineral Recovery Databases, 2005.
[130] Ibid.
[131] TRC, http://www.rrc.state.tx.us/news-releases/2003/030328a.html, 2003.

4B.12.7.3.5.3 Acquisition of Mineral Rights

Reservoir project sponsors could acquire the mineral rights for the property to be inundated. Texas law holds that the mineral estate is dominant over the surface estate.[132] This rule has serious implications for surface owners who are not mineral owners. Texas courts have held that mineral leases are not mere rental agreements as the name implies. Instead, they are actually deeds granting limited ownership rights to mineral lessees for as long as the lease continues. Thus, during the tenure of a lease, the mineral lessee enjoys the same rights to use the surface as any other mineral owner.

These property rights can be stated in the following way: mineral owners or lessees can use as much of the surface as is reasonably necessary for mineral exploration and production. This privilege springs from the executed mineral lease. Independent permission from the surface owner is not necessary although surface use agreements to minimize impacts of mineral recovery may be executed between the owner of the surface and the owner or lessee of the mineral rights. In the absence of a surface use agreement, or regulations established by the Texas Railroad Commission, no responsibility exists for restoring the surface or for paying surface damages. Liability arises only when the lessee goes beyond what is reasonably necessary or negligently injures the surface. The oil company or other entity leasing the minerals is the lessee and the mineral owner is the lessor.[133] The cost of mineral right acquisition would have to be estimated from a detailed examination of the Brazos, Leon, Madison and Robertson County Tax Offices appraisals for the affected properties. Although this appraisal project would be undertaken at a latter stage of project development, costs to acquire mineral rights in an actively producing region could be substantial.

4B.12.7.3.5.4 Lignite Resources

Kaiser[134] has identified lignite resources of the Yegua Formation occurring in Madison County. These resources are indicated to be east and south of the proposed Millican-Bundic Reservoir footprint, but are close enough to warrant a site-specific investigation of potential occurrence to be undertaken at a latter stage of the project development.

[132] Fambrough, J., "Minerals, Surface Rights and Royalty Payments," A Reprint from the Real Estate Center Journal, Texas A&M University, November 1996 Technical Report 840, 1996.
[133] Fambrough, J., "Subdivision Drill Sites," A Reprint from the Real Estate Center Journal, Texas A&M University, November 1997, Publication 690, 1997.
[134] Kaiser, W.R. 1974. Texas Lignite: Near-Surface and Deep-Basin Resources, Report of Investigation No. 79, Bureau of Economic Geology, University of Texas at Austin.

4B.12.7.3.5.5 Sand and Gravel Resources

A search of the TxDOT Aggregate Quarry and Pit Safety Program Inventory File[135] for pits and quarries in the counties of Leon, Robertson, Madison, and Brazos indicated six active quarries. The data were not sufficient to confirm whether any of these quarries were located within the reservoir footprint.

4B.12.7.3.5.6 Socio-economic Effects

This section characterizes the potential socioeconomic effects of the proposed reservoir in terms of: (1) impact on the tax base; (2) impacts to the local county economy from changes in the tax base; (3) revenue and employment effects from potential recreational businesses; and (4) loss of crop value.

4B.12.7.3.6 Impact on the Tax Base in Leon, Robertson, Madison, and Brazos Counties

The proposed Millican-Bundic Reservoir would inundate an area of 14,630 acres along the Navasota River in Leon (4,453 acres), Robertson (3,469 acres), Madison (3,295 acres) and Brazos (3,414 acres) Counties. The area proposed for inundation includes 9,210 acres of mixed bottomland hardwood forest, 4,086 acres of grasses and forbs, and 1,334 acres of Post Oak woods.

The impact on the local tax base can, in principle, be estimated as the net effect of: (1) the loss of property tax revenue to local jurisdictions from the conversion of the reservoir footprint to public (tax exempt) ownership, assuming that the project sponsors will be public entities; and (2) the increase in value of property along the shoreline of the proposed reservoir, assuming that the shoreline will remain largely in private ownership. An estimate of increased property values around the proposed reservoir would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

Estimates of total market value (land and improvements) and total appraised value by county are available from the Texas Association of Counties' County Information Project.[136] These estimates are used below to derive potential reductions to the affected counties' appraised values that would result from the acquisition of land for the proposed reservoirs by a public (tax exempt) sponsor.

[135] Texas Department of Transportation (TxDOT), Aggregate Quarry and Pit Safety Program Inventory File, 2005.

4B.12.7.3.6.1 Leon County

For Leon County, the average market value of land and improvements was $2,128/acre and the average appraised value was $1,271/acre in 2003. Taking this as representative of the appraised value of land at the proposed reservoir site in the southern part of the county, then for the 4,453 acres of land proposed for the Millican-Bundic Reservoir in Leon County, the estimated loss of appraised value of land in Leon County available for taxation is $5,659,763 in 2003 dollars.

4B.12.7.3.6.2 Brazos County

For Brazos County, the average market value of land and improvements was $18,925/acre and the average appraised value was $16,396/acre in 2003. This average, however, includes urban land in Bryan and College Station and would not be representative of the value of land at the proposed reservoir site in the northern part of the county. Therefore, the average appraised value per acre from Leon County ($1,271) in 2003 was used as a more appropriate upper limit to the per-acre appraised value of the 3,414 acres in Brazos County that will be required for the proposed Millican-Bundic Reservoir[137] indicates $1,271/acre would be a reasonable upper limit for the appraised value of most land in northern Brazos County). This per-acre value would imply that the total appraised value that will be lost in Brazos County for taxation is $4,339,194 in 2003 dollars.

4B.12.7.3.6.3 Madison County

For Madison County, the average market value of land and improvements was $2,083/acre and the average appraised value was $1,219/acre in 2003. Taking this as representative of the appraised value of land at the proposed reservoir site in the western part of the county, then for the 3,295 acres of land proposed for the Millican-Bundic Reservoir in Madison County, the estimated loss of appraised value available for taxation is $4,016,605 in 2003 dollars.

4B.12.7.3.6.4 Robertson County

For Robertson County, the average market value of land and improvements was $2,513/acre and the average appraised value was $1,805/acre in 2003. Taking this as

[136] Texas Association of Counties, County Information Project, http://www.county.org/resources/countydata/, 2004.
[137] Personal communication with G.L Winn, Chief Appraiser, Brazos County Appraisal District, 2005.

representative of the appraised value of land at the proposed reservoir site in the eastern part of the county, then for the 3,469 acres of land proposed for the Millican-Bundic Reservoir in Robertson County, the estimated loss of appraised value available for taxation is $6,261,545 in 2003 dollars.

4B.12.7.3.7 Impacts to the Local County Economies from Changes in the Tax Base

4B.12.7.3.7.1 Leon County

A total loss of $5,659,763 of tax base in Leon County represents a reduction of less than 1 percent from the 2003 total appraised value of $878,480,040. Neglecting the possibility of increased appraised value from the lake front property created by the reservoir, a reduction of the Leon County tax base of less than 1 percent would not imply the need for a substantial increase in local taxes or decrease in the provision of public services and would not therefore, in itself, create a substantial negative impact on the regional economy. In addition, if the possibility of increased value arising from the creation of water front property were considered, depending upon assumptions, the net effect of the reservoir on the Leon County tax base could even be positive. But, as noted above, an estimate of increased values would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

4B.12.7.3.7.2 Brazos County

A total loss of $4,339,194 of tax base in Brazos County represents a reduction of less than one-tenth of 1 percent from the 2003 total appraised value of $6,190,931,875. Neglecting the possibility of increased appraised value from the lake front property created by the reservoir, a reduction of the Brazos County tax base of less than one-tenth of 1 percent would not imply the need for a substantial increase in local taxes or decrease in the provision of public services and would not therefore, in itself, create a substantial negative impact on the regional economy. In addition, if the possibility of increased value arising from the creation of water front property were considered, depending upon assumptions, the net effect of the reservoir on the Brazos County tax base could even be positive. But, as noted above, an estimate of increased values would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

4B.12.7.3.7.3 Madison County

A total loss of $4,016,605 of tax base in Madison County represents a reduction of about 1 percent from the 2003 total appraised value of $369,105,924. Neglecting the possibility of increased appraised value from the lake front property created by the reservoir, a reduction of the Madison County tax base of 1 percent would not imply the need for a substantial increase in local taxes or decrease in the provision of public services and would not therefore, in itself, create a substantial negative impact on the regional economy. In addition, if the possibility of increased value arising from the creation of water front property were considered, depending upon assumptions, the net effect of the reservoir on the Madison County tax base could even be positive. But, as noted above, an estimate of increased values would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

4B.12.7.3.7.4 Robertson County

A total loss of $6,261,545 of tax base in Robertson County represents a reduction of less than 1 percent from the 2003 total appraised value of $1,000,124,980. Neglecting the possibility of increased appraised value from the lake front property created by the reservoir, a reduction of the Robertson County tax base of less than 1 percent would not imply the need for a substantial increase in local taxes or decrease in the provision of public services and would not therefore, in itself, create a substantial negative impact on the regional economy. In addition, if the possibility of increased value arising from the creation of water front property were considered, depending upon assumptions, the net effect of the reservoir on the Robertson County tax base could even be positive. But, as noted above, an estimate of increased values would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

4B.12.7.3.8 Revenue and Employment Effects from Potential Recreational Businesses

Potential sales, income, and jobs effects arising from recreational benefits associated with the development of the proposed Millican-Bundic Reservoir are estimated by comparing the proposed reservoir to estimated impacts for similar reservoirs in the Brazos G Region presented in the Corps of Engineers study cited above.[138] Seven reservoirs in the Brazos G Region were analyzed as potentially representative of the proposed reservoir: (1) Belton Lake; (2) Somerville Lake; (3) Stillhouse Hollow Reservoir; (4) Waco Lake; (5) Whitney Lake; (6) Granger Lake; and (7) Lake Georgetown.

Table 4B.12.7-6 presents estimates of annual total spending, direct and total sales (output) effects, direct and total income effects and direct and total job effects for the surrounding regions.

Size, proximity to urban areas and available facilities are variables that certainly affect the visitation, spending and resulting economic effects at these reservoirs. As a rough approximation, economic effects for the proposed Millican-Bundic Reservoir are estimated as the average of those for Belton Lake (closest in size) and Somerville Lake (closest in location). This estimate assumes that the proposed Millican-Bundic Reservoir will be characterized by approximately the same level of recreational facilities as the average of Belton and Somerville Lakes.

Table 4B.12.7-7 presents these estimates for the proposed Millican-Bundic Reservoir. The proposed Millican-Bundic Reservoir would have a surface area of 14,630 acres, comparable to both Somerville and Belton Lakes.

These estimates suggest that economic effects from recreational activity at the proposed reservoir would have positive economic effects on the surrounding region in Brazos, Leon, Robertson, and Madison Counties. These effects are comparable in magnitude to those expected

[138] Propst, D. B., D. J. Stynes, W. Chang, and R. Jackson. 1998. Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996. U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report R-98-1, September 1998.

for the proposed Little River 330' Reservoir. Total annual spending is estimated at $20,805,000, total sales effects at $20,810,000, total income effects at $11,115,000 and total jobs created at 597.

Table 4B.12.7-6.
Estimates of Annual Recreational Spending, Sales, Income and Job Effects on Surrounding Region for Selected U.S. Corps of Engineers Projects in the Brazos G Area, 1996

Project	Total Spending (1996 $)	Direct Sales Effects (1996 $)	Total Sales Effects (1996 $)	Direct Income Effects (1996 $)	Total Income Effects (1996 $)	Direct Jobs Effects (Number of Jobs)	Total Jobs Effects (Number of Jobs)
Belton Lake	22,760,000	14,050,000	22,210,000	7,420,000	12,010,000	510	655
Somerville Lake	18,850,000	12,180,000	19,410,000	6,290,000	10,220,000	416	538
Stillhouse Hollow Reservoir	5,550,000	3,640,000	6,030,000	1,890,000	3,180,000	121	163
Waco Lake	19,540,000	13,010,000	23,140,000	7,010,000	12,600,000	442	616
Whitney Lake	19,780,000	12,860,000	23,650,000	6,790,000	12,660,000	442	629
Granger Lake	6,210,000	4,070,000	6,750,000	2,110,000	3,560,000	136	182
Lake Georgetown	10,550,000	6,920,000	11,460,000	3,590,000	6,050,000	230	309

Source: Propst, D. B., D. J. Stynes, W. Chang, R. Jackson, "Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996", U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report R-98-1, September 1998.

Table 4B.12.7-7.
Estimates of Annual Recreational Spending, Sales, Income and Job Effects on Surrounding Region for the Proposed Millican-Bundic Reservoir in Brazos, Leon, Robertson and Madison Counties

Project	Total Spending (1996 $)	Direct Sales Effects (1996 $)	Total Sales Effects (1996 $)	Direct Income Effects (1996 $)	Total Income Effects (1996 $)	Direct Jobs Effects (Number of Jobs)	Total Jobs Effects (Number of Jobs)
Belton Lake	22,760,000	14,050,000	22,210,000	7,420,000	12,010,000	510	655
Somerville Lake	18,850,000	12,180,000	19,410,000	6,290,000	10,220,000	416	538
Proposed Millican-Bundic Reservoir (average of Belton and Somerville Lakes)	20,805,000	13,115,000	20,810,000	6,855,000	11,115,000	463	597

Sources: HDR Engineering, Inc. and Hicks & Company, 2004; Propst, D. B., D. J. Stynes, W. Chang, R. Jackson, "Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996", U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report R-98-1, September 1998; U.S. Army Corps of Engineers, http://www.swf-wc.usace.army.mil/belton/Lkmap.htm; U.S. Army Corps of Engineers, http://swf67.swf-wc.usace.army.mil/SOMERVILLE/lakeinfo.htm

4B.12.7.3.9 Loss of Crop Value

Based on evaluation of existing aerial photography, no substantial acreage of intensively managed row crops occurs with the reservoir footprint. Therefore, no substantial loss of value of agricultural row crops or intensively managed agricultural land is expected. Among the 14,630 acres potentially inundated by the reservoir, approximately 4,086 acres or 28 percent includes grasslands that comprise of a mixture of non-native and native grassland species, a portion of which is used for livestock grazing and/or hay production. However, the value of these grasslands could not be determined because they could not be differentiated from other non-agricultural grasslands at this level of photographic analysis. Forested lands would also have value for timber production, but this would be highly variable depending on species composition and size. Estimates of the value of timber resources would be determined from site evaluations in later studies.

4B.12.7.4 Engineering and Costing

The proposed Millican-Bundic Reservoir project includes the construction of an earth dam, principal spillway, emergency spillway, and appurtenant structures. Project cost estimates were prepared by the USCOE in 1982. These project cost estimates were updated to September 2008 prices. The total project cost for the Bundic Dam Site is estimated to be $720.2 million. This cost is based on a federal project and some federal participation in the project would be anticipated. The cost details are shown in Table 4B.12.7-8. The annual project costs are estimated to be $53 million; this includes annual debt service, and operation and maintenance. The cost for the estimated firm yield of 36,990 acft/yr, translates to an annual unit cost of raw water at the reservoir of $4.39 per 1,000 gallons, or $1,431 per acft.

The total project cost reported in the 2006 Water Plan was $464.7 million and the current plan costs have increased to an estimated $720.2 million. These increases are due to inflation between 2002 and 2008 and differences in methodology used to compute land acquisition, environmental studies, and mitigation costs.

The annual unit cost of water has increased from $913 per acft ($2.80 per 1,000 gallons) in the 2006 Plan to $1,431 per acft ($4.39 per 1,000 gallons) in the current plan.

Table 4B.12.7-8.
Cost Estimate Summary for
Millican-Bundic Reservoir
(September 2008 Prices)

Item	*Estimated Costs for Facilities*
Capital Costs	
Dam and Reservoir (Conservation Pool 205,760 acft, 14,630 acres, 277 ft-msl)	$338,928,000
Total Capital Cost	**$338,928,000**
Engineering, Legal Costs and Contingencies	$118,625,000
Environmental & Archaeology Studies and Mitigation	$81,299,000
Land Acquisition and Surveying (14,630 acres)	$82,030,000
Interest During Construction (4 years)	$99,342,000
Total Project Cost	**$720,224,000**
Annual Costs	
Reservoir Debt Service (6 percent for 40 years)	$47,867,000
Operation and Maintenance	
Dam and Reservoir	$5,084,000
Total Annual Cost	**$52,951,000**
Available Project Yield (acft/yr)	36,990
Annual Cost of Water ($ per acft)	$1,431
Annual Cost of Water ($ per 1,000 gallons)	$4.39

4B.12.7.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.12.7-9, and the option meets each criterion.

Table 4B.12.7-9.
Comparison of Millican-Bundic Reservoir to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient quantity[1]
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impact
2. Habitat	2. Moderate impact
3. Cultural Resources	3. Moderate to High impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. 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	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

[1] Significant quantity available for regional use and Region H.

4B.12.7.5.1 Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for structures placed in navigable waters of the U.S. (Section 10 of Rivers and Harbors Act) or 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.

4B.12.7.5.2 *State and Federal Permits will 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.

4B.12.7.5.3 *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;
- Possible relocations of residences, utilities, roads, oil and gas production and storage facilities, or other structures; and
- Possible acquisition of mineral rights.

4B.12.8 Millican Reservoir – Panther Creek Site

4B.12.8.1 Description of Option

Studies for development of a new reservoir on the Navasota River have been conducted by the U.S. Army Corps of Engineers (USACE) since the mid-1940s. The proposed reservoir, Millican Reservoir, has been evaluated by the USACE for the purposes of flood control, water supply, hydropower generation, and recreation. Many different sites have been studied along the Navasota River, as well as various sizes and configurations.

Following completion of studies in the 1960s, the U.S. Congress authorized Millican Reservoir in 1968 as the first unit of a two-stage reservoir development. A second reservoir, Navasota Reservoir, located upstream of Millican Reservoir, was also authorized. Since the original authorization in 1968, concerns have evolved regarding the loss of large lignite and oil and gas resources that would occur by construction of Millican Reservoir. In addition, conditions in the Brazos River Basin had changed including the construction of Lake Limestone and two power generation plants, Gibbons Creek and Twin Oaks. In 1980, the USACE performed a re-study of the Millican Reservoir Project. As part of the study, detailed plans of alternative reservoir sites were evaluated including:

- Authorized Dam Site (Conservation Storage = 754,000 acft);
- Panther Creek Dam Site (Conservation Storage = 1,973,000 acft);
- Panther Creek Dam Site (Conservation Storage = 587,000 acft); and
- Bundic Dam Site (Conservation Storage = 228,000 acft).

The results of the 1980 study found that the Bundic Site provided the maximum benefits and the plan for the Millican Reservoir was reformulated to be the Bundic Site. However, a Reevaluation Study was performed by the USACE again in 1985. The 1985 study recommended the Panther Creek Site, with a conservation storage of 1,973,000 acft, instead of the Bundic Site. The results of the 1980 and 1985 studies on Millican Reservoir by the USACE show that the Panther Creek and Bundic Sites are the two alternative sites that are most feasible for implementation.

The Panther Creek Site is a large impoundment on the Navasota River, located about 13 miles southeast of the City of Bryan (Figure 4B.12.8-1). Based on the USACE study results, the reservoir would be constructed for the purposes of water supply, hydropower

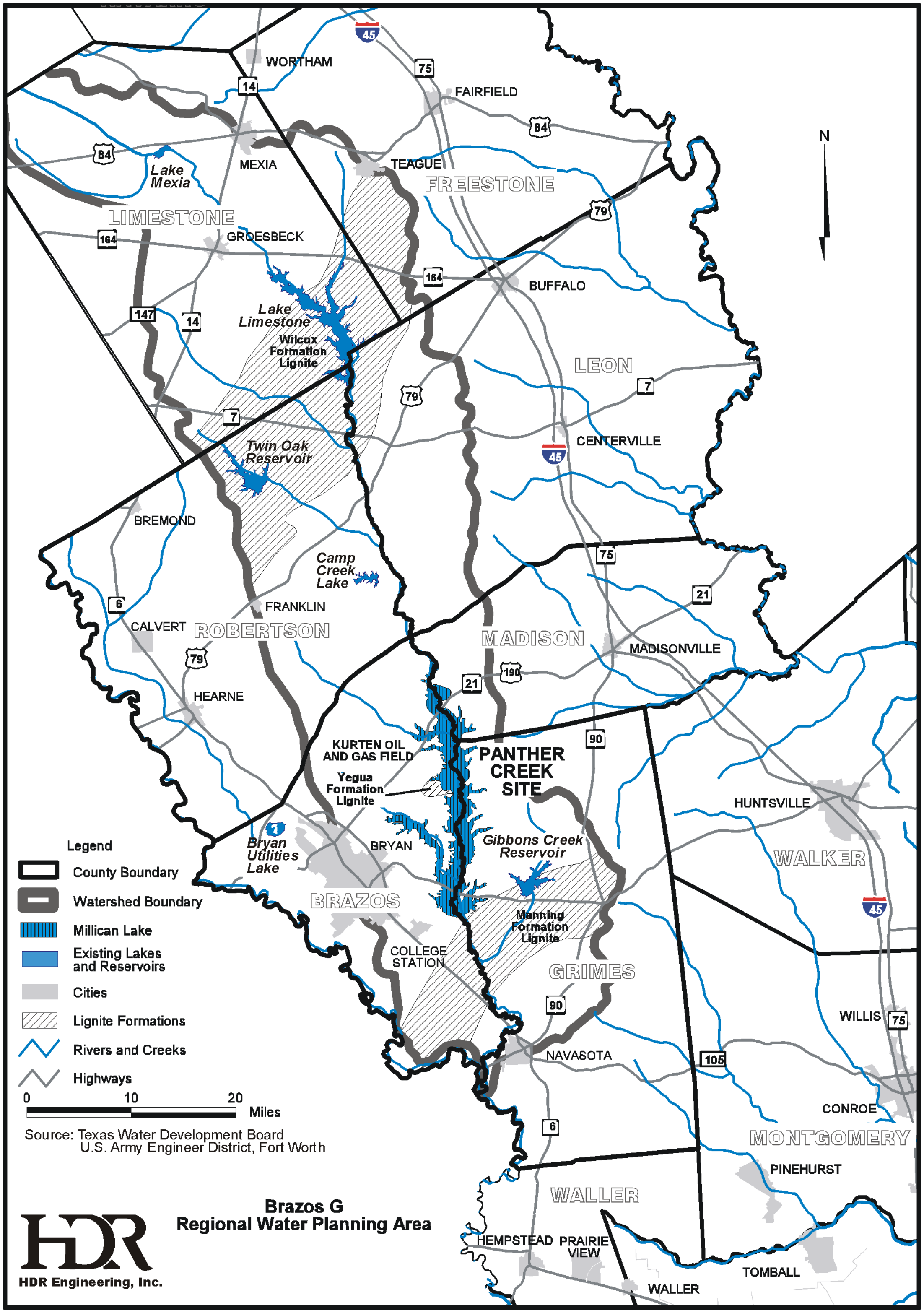


Figure 4B.12.8-1. Millican Reservoir — Panther Creek Site

generation, and recreation. Flood control storage was found by the USACE to not be economically justified, however, the reservoir would still provide some flood control benefits downstream. According to the 1985 USACE study, the proposed reservoir would be formed by a dam that is over 4 miles long (23,050 feet) and would have conservation storage of 1,973,000 acft at the conservation pool elevation of 263 ft-msl. HDR recalculated the reservoir elevation-area-capacity relationship using USGS 10 ft vertical interval topography. At the conservation pool elevation (263 ft-msl), the updated Panther Creek Site would encompass 71,032 acres and have a storage capacity of 2,044,563 acft. The large area of inundation of the reservoir impacts natural resources in the area, including portions of the Yegua lignite formation, Kurten oil and gas field, and bottomland hardwood forest.

The Millican Reservoir - Panther Creek Site could potentially provide surface water to the Brazos and Grimes County area as well as meeting downstream water supply needs including those from the growing Houston metropolitan area. The Millican Reservoir – Panther Creek Site could also be incorporated into the BRA System providing a large supply to meet downstream demands, which could free up BRA system water out of upper basin reservoirs and make it available for local uses.

4B.12.8.2 Available Yield

Water potentially available for impoundment in the proposed Millican Reservoir – Panther Creek Site was estimated using the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record with 2060 sediment conditions. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available from the Navasota River without causing increased shortages to existing downstream rights. Firm yield was computed subject to the Millican Reservoir – Panther Creek Site having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the Navasota River are shown in Table 4B.12.8-1.

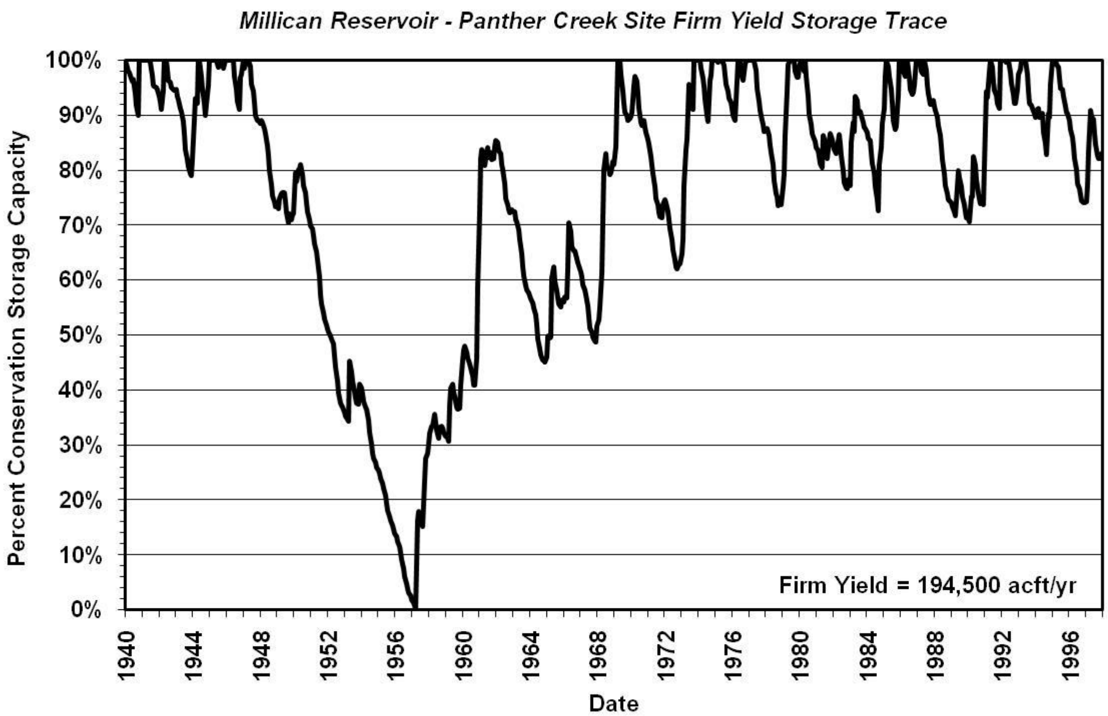
The firm yield of the Millican Reservoir - Panther Creek Site is estimated to be 194,500 acft/yr. The 1985 USACE study estimated a firm yield of 235,000 acft/yr. The reduction in yield is most likely due to updates in the Brazos G WAM and variations in modeling techniques.

Table 4B.12.8-1.
Daily Natural Streamflow Statistics
for the Millican Reservoir – Panther Creek Site

Month	***Median Flows - Zone 1 Pass Through Requirements (ft^3/sec)***	***25th Percentile Flows - Zone 2 Pass Through Requirements (ft^3/sec)***
January	157.7	52.6
February	192.9	68.3
March	208.2	66.3
April	163.2	63.7
May	210.3	66.2
June	70.7	23.2
July	13.6	3.6
August	3.8	0.5
September	9.4	1.5
October	12.0	2.0
November	42.5	13.8
December	82.2	27.3
Zone 3 (7Q2) Pass-Through Requirement (ft^3/sec):		1.1

Figure 4B.12.8-2 illustrates simulated Millican Reservoir – Panther Creek Site storage levels for the 1940 to 1997 historical period and storage frequencies subject to the firm yield of 194,500 acft/yr. Simulated reservoir contents in the reservoir remain above the Zone 2 trigger level (80 percent capacity) 57 percent of the time and above the Zone 3 trigger level (50 percent capacity) 83 percent of the time.

Figure 4B.12.8-3 illustrates the changes in Brazos River streamflows caused by impounding the unappropriated waters of the Navasota River. The greatest changes in flow would occur in the spring and summer months from January to June. The largest decline occurs in February, where the median streamflow is reduced by 406 cfs. The Navasota River streamflow frequency comparison illustrates the significant decrease in streamflow at the reservoir site resulting from project implementation.



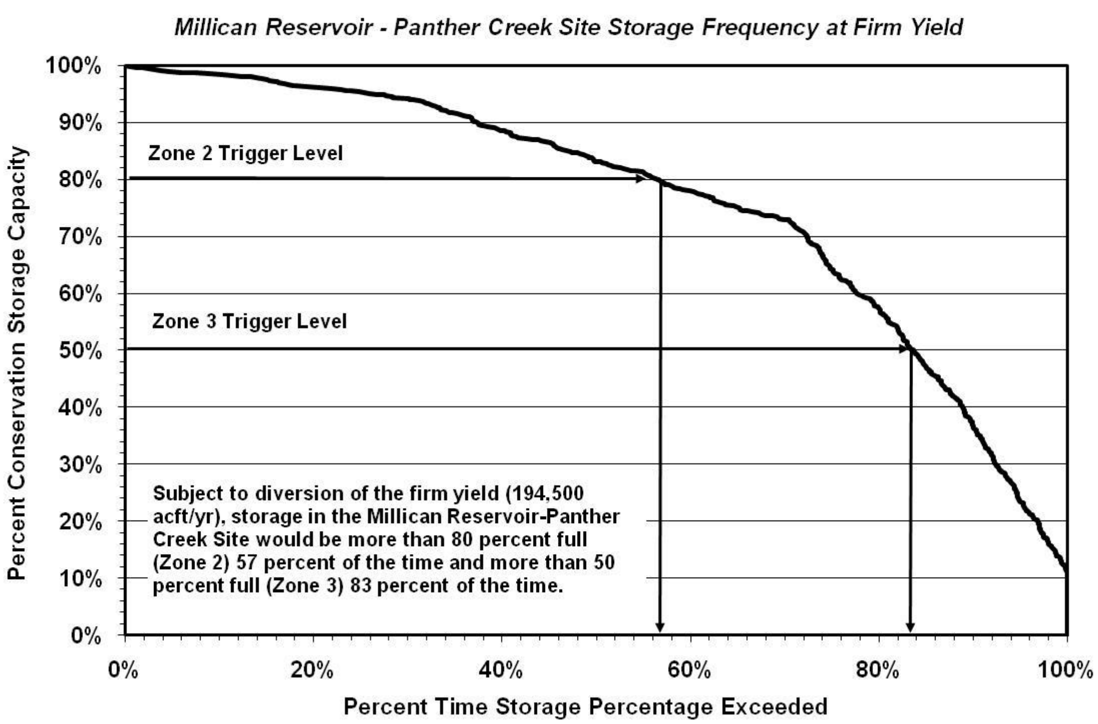
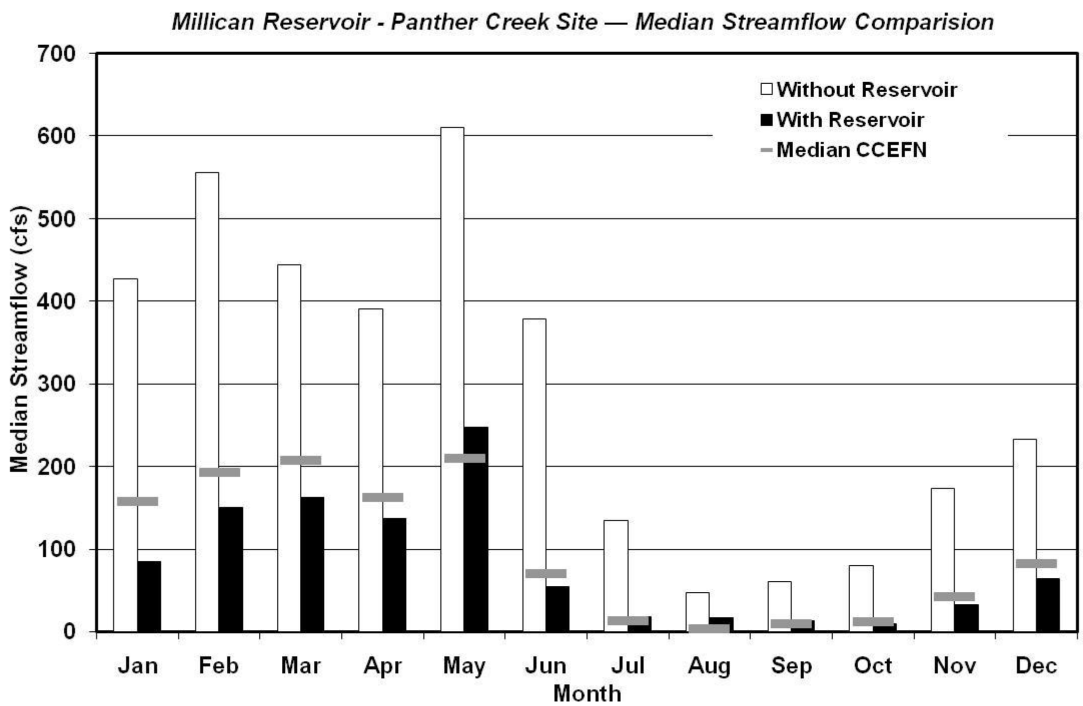


Figure 4B.12.8-2. Millican Reservoir – Panther Creek Site Storage Considerations



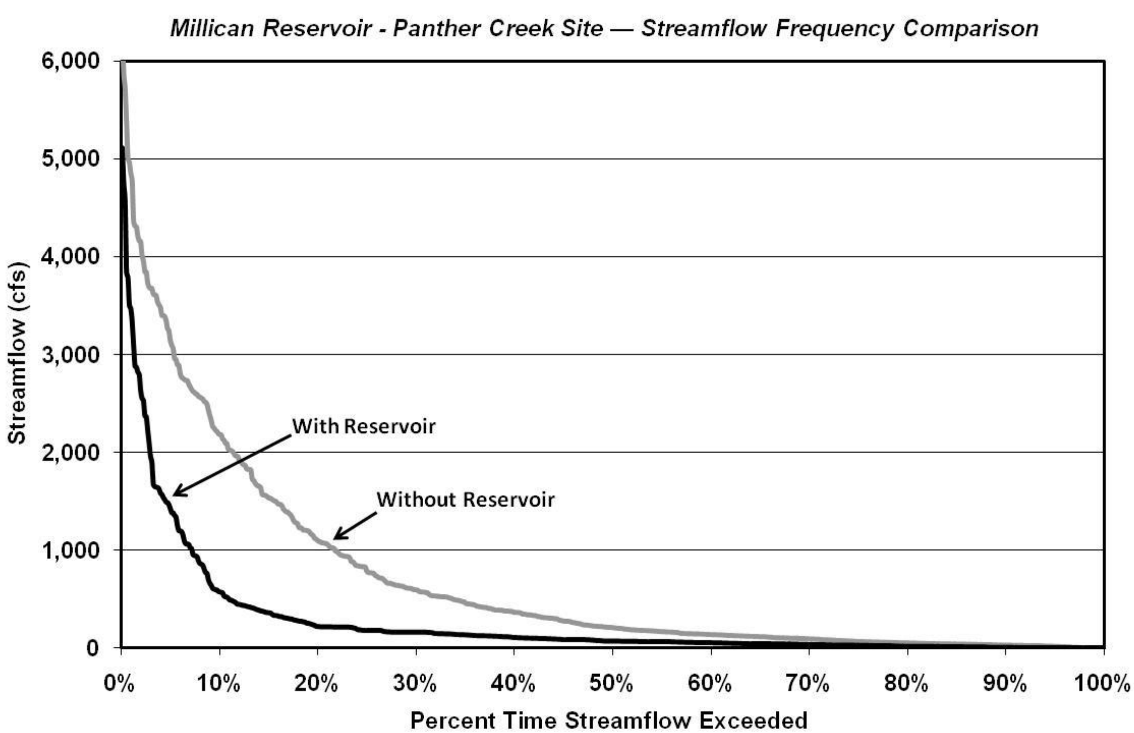


Figure 4B.12.8-3. Navasota River Streamflow Comparisons

4B.12.8.3 Environmental Issues

4B.12.8.3.1 Existing Environment

The Millican Reservoir – Panther Creek Site involves dam construction and inundation of over 100 square miles. The proposed reservoir site along the Navasota River is located within Robertson, Leon, Madison, Grimes and Brazos counties. The site is on the ecotone between the Blackland Prairies and the Oak Woods and Prairies ecoregions[139] and is within the Texan biotic province.[140] The site is within the Gulf Coastal Plains physical region which is characterized by rolling to hilly topography, with a heavy growth of pine and hardwood trees. Soils range from the deep, fertile, black soils of the Blackland Prairies region to the sandy soils of the Oak Woods and Prairies region. The climate is characterized as subtropical humid, with warm summers. Average annual precipitation is approximately 40-42 inches.[141] The Carrizo Aquifer is the only major aquifer underlying the project area.[142]

The proposed Millican Reservoir – Panther Creek Site is within the Texas Claypan Area.[143] Soils in the project area formed on nearly level to sloping plains dissected by perennial streams and their tributaries. Large floodplains and stream terraces are associated with meandering river systems. Over most of the area, soils have well-developed, clayey, subsoil horizons with sandy and loamy surface textures. Woodtell, Edge, Crockett and Straber soils occur on interstream divides and ridges, and Tabor soils are on stream terraces. Padina and Silstid soils have sandy surface layers more than 20 inches thick. Edge-Tabor-Silstid series soils are present in the project area.

Vegetation within the project area includes post oak woods, forest and grassland mosaic, post oak woods/forests, and water oak-elm-hackberry forests[144]. Post oak woods, forest and grassland mosaic and Post Oak woods and forests could include the following commonly

[139] TPWD, "Texas Partners in Flight; Ecological Region 7 – Edwards Plateau"http://www.tpwd.state.tx.us/huntwild/wild/birding/pif/assist/pif_regions/region_7.phtml accessed November 30, 2009.
[140] Blair, W.F., "The Biotic Provinces of Texas, "Tex. J. Sci. 2:93-117, 1950.
[141] Texas Water Development Board (TWDB). *Precipitation Polygon GIS Layer*.
[142] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.
[143] USDA – NRCS, 2008. *General Soil Map of Texas*, produced from the NRCS STATSGO 2004 database. GeneratedSeptember 25, 2008.
[144] 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.

associated plants: Blackjack oak (*Quercus marilandica*), eastern redcedar (*Juniperus viginiana*), mesquite (*Prosopis glandulosa*), black hickory (*Carya texana*), live oak (*Q. fusiformis*), sandjack oak (*Q. incana*), cedar elm (*Ulmus crassifolia*), hackberry (*Celtis reticulata*), yaupon (*Ilex vomitoria*), poison oak (*Rhus toxicodendron-radicans*), American beautyberry (*Callicarpa americana*), hawthorn (*Crateagus texana*), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus trivialis*), coral-berry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida purpurea*), sprangle-grass (*Chasmanthium latifolium*), and tickclover (*Desmodium paniculatum*). Commonly associated plants in the wateroak-elm-hackberry forest include: Cedar elm, American elm (*Ulmus americana*), willow oak (*Q. phellos*), southern red oak (*Q. buckleyi*), white oak (*Q. alba*), black willow (*Salix nigra*), cottonwood (*Populus deltoides*), red ash (*Fraxinus pennsylvanica*), sycamore (*Platanus occidentalis*), pecan (*Carya illinoensis*), bois d'arc (*Maclura pomifera*), flowering dogwood (*Cornus florida*), dewberry, coral-berry, dallisgrass (*Paspalum dilatum*), switchgrass (*Panicum virgatum*), rescuegrass (*Bromus catharticus*), bermudagrass (*Cynodon dactylon*), eastern gamagrass (*Tripsacum dactyloides*), Virginia wildrye (*Elymus virginicus*), Johnsongrass (*Sorghum halepense*), giant ragweed (*Ambrosia trifida*), yankeeweed (*Eupatorium compositifolium*), Leavenworth eryngo (*Eryngium leavenworthii*).

4B.12.8.3.2 Potential Impacts

4B.12.8.3.2.1 Aquatic Environments

It is anticipated that there would be a reduction in the quantity of median monthly flows below the dam as shown in Table 4B.12.8-2. Median monthly flows would be reduced in all months of the year with a low of a 60 percent reduction in May, when flows are typically high, to a high of an 88 percent reduction in October, when flows are typically lower. The difference in variability of monthly flow conditions below the dam might also be expected. Variability in flow is important to the instream biological community as well as riparian species and a reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing suitability for others.

Table 4B.12.8-2.
Median Monthly Streamflow: Millican Reservoir – Panther Creek Site

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	428	85	343	80%
February	556	150	406	73%
March	445	162	283	64%
April	391	137	253	65%
May	610	247	363	60%
June	379	55	324	85%
July	135	18	117	86%
August	48	17	31	65%
September	60	13	47	78%
October	81	10	71	88%
November	173	33	140	81%
December	233	64	169	73%

4B.12.8.3.2.2 Threatened & Endangered Species

A total of 49 species that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern could potentially occur within the vicinity of the Millican Reservoir – Panther Creek Site. This group includes one amphibian, 11 birds, 3 fishes, 3 insects, 4 mammals, 13 mollusks, 4 reptiles, and 10 plant species (Table 4B.12.8-3). Three bird species federally-listed as threatened or endangered could possibly occur within the project area. These include the Least Tern, Red-cockaded Woodpecker and Whooping Crane. The Least Tern and Red-Cockaded Woodpecker may breed and forage within the vicinity of the site but have very specific habitat requirements. The Whooping Crane is a seasonal migrant that could pass through the project area. The federally-endangered Houston toad requires sandy substrate and pooled water including ephemeral pools and stock tanks. The federally-threatened Louisiana black bear is possible in the area as a transient in bottomland hardwoods and large tracts of inaccessible forest land; the federally-endangered red wolf has been extirpated. Two plant species of potential occurrence, Navasota ladies' tresses and large-fruited sand-verbena, are federally endangered. Both plant

Table 4B.12.8-3.
Potentially Occurring Species that are Rare or Federal- and State-Listed in Brazos, Grimes, Leon, Madison and Robertson Counties

Scientific Name	*Common Name*	*Federal/State Status*	*Potential Occurrence*
Amphibians			
Bufo houstonensis	Houston Toad	LE/E	X
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/SOC	Migrant
Aimophila aestivalis	Bachman's Sparrow	T	Resident
Haliaeetus leucocephalus	Bald Eagle	DL/T	Resident
Ammodramus henslowii	Henslow's Sparrow	SOC	Resident
Sterna antillarum	Least Tern	LE/E	Resident Breeder
Falco peregrinus	Peregrine Falcon	DL/T	Migrant
Picoides borealis	Red-Cockaded Woodpecker	LE/E	Resident
Plegadis chihi	White-Faced Ibis	T	Resident
Grus Americana	Whooping Crane	LE/E	Migrant
Mycteria americana	Wood Stork	T	Migrant
Fishes			
Cycleptus elongates	Blue Sucker	T	X
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Insects			
Procloeon texanum	A Mayfly	SOC	X
Gomphus modestus	Gulf Coast Clubtail	SOC	X
Neurocordulia molesta	Smoky Shadowfly	SOC	X
Mammals			
Ursus americanus luteolus	Louisiana Black Bear	LT/T	Transient
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E	Extirpated
Myotis austroriparius	Southeastern Myotis Bat	SOC	X
Mollusks			
Strophitus undulates	Creeper (Squawfoot)	SOC	X
Quincuncina mitchelli	False Spike Mussel	SOC/T	X
Truncilla donaciformis	Fawnsfoot	SOC	X
Villosa lienosa	Little Spectaclecase	SOC	X
Pleurobema riddellii	Louisiana Pigtoe	SOC/T	X

Table 4B.12.8-3 (Concluded)

Scientific Name	***Common Name***	***Federal/State Status***	***Potential Occurrence***
Tritogonia verrucosa	Pistolgrip	SOC	X
Arcidens confragosus	Rock Pocketbook	SOC	X
Lampsilis satura	Sandbank Pocketbook	T	X
Quadrula houstonensis	Smooth Pimpleback	SOC/T	X
Truncilla macrodon	Texas Fawnsfoot	SOC/T	X
Potamilus amphichaenus	Texas Heelsplitter	SOC/T	X
Fusconaia askewi	Texas Pigtoe	SOC/T	X
Fusconaia flava	Wabash Pigtoe	SOC	X
Reptiles			
Macrochelys temminckii	Alligator Snapping Turtle	T	X
Pituophis ruthveni	Louisiana Pine Snake	C//T	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X
Plants			
Liatris cymosa	Branched Gay-Feather	SOC	X
Xyris chapmanii	Chapman's Yellow-Eyed Grass	SOC	X
Abronia macrocarpa	Large-Fruited Sand-Verbena	LE/E	X
Agalinis navasotensis	Navasota False Foxglove	SOC	X
Spiranthes parksii	Navasota Ladies'-Tresses	LE/E	X
Polygonella parksii	Parks' Jointweed	SOC	X
Hymenopappus carrizoanus	Sandhill Woollywhite	SOC	X
Eriocaulon koernickianum	Small-Headed Pipewort	SOC	X
Thalictrum texanum	Texas Meadow-Rue	SOC	X
Chloris texensis	Texas Windmill-Grass	SOC	X

X = Occurs in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be Delisted (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-Delisted Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: TPWD, *Annotated County List of Rare Species for Brazos County,* 2009. TPWD, *Annotated County List of Rare Species for Leon County,* 2009. TPWD, *Annotated County List of Rare Species for Grimes County,* 2009. TPWD, *Annotated County List of Rare Species for Madison County,* 2009. TPWD, *Annotated County List of Rare Species for Robertson County,* 2009. TPWD Texas Wildlife Diversity Database (2009), United States Fish and Wildlife Service (USFWS), *Federally-listed as Threatened and Endangered Species of Texas*, November 30, 2009.

species have restricted habitats requiring sandy soils and openings in post oak woodlands. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

The species listed by USFWS, and TPWD, as endangered, threatened, or species of concern with potential to occur in the subject counties are listed in Table 4B.12.8-3. The Texas Natural Diversity Database, maintained by TPWD, documents the occurrence of rare species within the state. There are documented occurrences of threatened, endangered or rare species and habitats within the proposed reservoir site (as noted on representative 7.5-minute quadrangle map(s) that include the project site), and in the surrounding vicinity. The endangered Houston toad and Navasota ladies'-tresses, the rare branched gay-feather and sandhill woollywhite, three colonial waterbird rookeries, and three rare plant series have all been documented within the proposed inundation area. Additionally, there have been documented occurrences of the endangered large-fruited sand verbena, the state threatened timber (canebrake) rattlesnake, active bald eagle nests, and three other rare plants within the vicinity of the project area. 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.

4B.12.8.3.2.3 Wildlife Habitat

The primary impacts that would result from construction and operation of the proposed Millican Reservoir – Panther Creek Site include conversion of existing habitats and land uses within the conservation pool to open water. Nearly 100 square miles of deciduous forest land, mixed rangeland, cropland and pasture below 273 ft-msl would be permanently inundated and converted to open water upon reservoir filling[145].

[145] USGS, 1990. "A Land Use and Land Cover Classification System for Use with Remote Sensor Data," Reston, VA 1990.

A number of vertebrate species could occur within the project area as indicated by county occurrence records.[146] These include six species of salamanders, 22 species of frogs and toads, 15 species of turtles, 11 species of lizards and skinks, 33 species of snakes, and the American alligator. Additionally, approximately 54 species of mammals could occur within the site or surrounding region[147] as well as an undetermined number of bird species. A variety of fish and invertebrate species would be expected to inhabit the river, streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

4B.12.8.3.2.4 Cultural Resources

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available GIS datasets from the Texas Historical Commission (THC), it appears six documented cemeteries are within the proposed inundation area; Stick, Wixon Creek, Anderson, Trant, Martins Prairie and Jarvis Farm Graves Cemeteries. No historic markers or historic places are within the proposed inundation area. There are four historical markers within two miles of the proposed inundation area as well as many cemeteries. Considering 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 whether 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 cultural resources.

4B.12.8.3.2.5 Threats to Natural Resources

This project would alter the habitat along the Navasota River changing from primarily a bottomland hardwood system to an impounded system. Bottomland hardwoods are extensive in the project area and are important habitats for a variety of species including migratory birds. Species dependent upon flowing water would also be adversely impacted by impoundment.

[146] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," Accessed online http://wfscnet.tamu.edu/tcwc/Herps_online/CountyRecords.htm December 2, 2009.
[147] 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.

Furthermore, there would likely be adverse effects on stream flow below the dam. Decreased stream flow would contribute to declines in dissolved oxygen and higher temperatures during summer periods. Additional impacts would be expected to terrestrial wildlife, potentially including some threatened or endangered species, which would be displaced during reservoir filling.

4B.12.8.4 Engineering and Costing

The proposed Millican Reservoir - Panther Creek Site project includes the construction of an earth dam, principal spillway, emergency spillway, and appurtenant structures. Project cost estimates were prepared by the USACE in 1982. These project cost estimates were updated to September 2008 prices. The total project cost for the Panther Creek Site is estimated to be $1,159,907,000. The annual project costs are estimated to be $82,488,000; this includes annual debt service and operation and maintenance. These costs are based on a federal project and some federal participation in the project would be anticipated. The 1985 study estimated that the federal cost share for the Panther Creek Site would be 11.4 percent and the non-federal cost share would be 88.6 percent. The project cost estimates for the Panther Creek Site are presented in Table 4B.12-4. The project costs include the cost for the raw water facilities and excludes any water treatment and treated water transmission. Based on the total annual costs of the project and the water supply yield, the unit cost of raw water from the reservoir is estimated to be $424 per acft ($1.30 per 1,000 gallons).

4B.12.8.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.12.8-5, and the option meets each criterion.

Implementation of the Millican Reservoir – Panther Creek Site project will require permits from various state and federal agencies, land acquisition, and design and construction of the facilities. There are a number of constraints that have to be overcome to implement the project including many environmental issues and financial issues. A summary of the implementation steps for the project is presented below.

4B.12.8.5.1 Potential Regulatory Requirements:

- TCEQ Water Right and Storage permit (re-authorization);
- 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;
- NPDES Storm Water Pollution Prevention Plan;
- GLO easement for use of the state-owned streambed; and
- Section 404 certification from the TNRCC related to the Clean Water Act.

4B.12.8.5.2 State and Federal Permits may require the following studies and plans:

- Assessment of changes in instream flows in the Navasota River.
- Habitat mitigation plan including mitigation for wetlands, bottomland hardwoods, and endangered species.
- Environmental studies.
- Cultural resource studies.
- Mitigation Funding:
- Acquisition of land for mitigation, either through eminent domain or market transactions;
- Cultural resources mitigation, including possibly extensive data recovery;
- Acquisition of rights-of-way and easements;
- Crossings of roads, railroads, creeks, rivers and other utilities;
- Possible relocations, including residences and other structures, affected utilities and roads, etc.

4B.12.8.5.3 Acquisition Issues:

- Land will need to be acquired through either negotiations or condemnation from multiple landowners. The reservoir area for the Panther Creek Site includes significant lignite formations (estimated 450,000,000 tons) as well as oil and gas fields (oil production of over 372,000 barrels per year).
- Funding of the project will require a substantial commitment from a non-federal sponsor.

Table 4B.12.8-4.
Cost Estimate Summary for
Millican Reservoir – Panther Creek Site
(September 2008 Prices)

Item	***Estimated Costs***
Capital Costs	
Dam & Reservoir	$399,757,000
Total Capital Cost	**$399,757,000**
Engineering, Legal Costs, and Contingencies	$87,487,000
Environmental & Archaeological Studies and Mitigation	$19,715,000
Land Acquisition and Surveying (71,200 acres)	$399,218,000
Interest During Construction	$253,730,000
Total Project Cost	**$1,159,907,000**
Annual Costs	
Reservoir Debt Service	$77,087,000
Operation and Maintenance	$5,401,000
Total Annual Cost	**$82,488,000**
Available Project Yield (acft/yr)	**194,500**
Annual Cost of Water ($ per acft) Raw Water	**$424**
Annual Cost of Water ($ per 1,000 gallons) Raw Water	**$1.30**

Table 4B.12.8-5.
Comparison of Millican Reservoir – Panther Creek Site to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply: 1. Quantity 2. Reliability 3. Cost	 1. Significant quantity[1] 2. High reliability 3. Reasonable
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries	 1. High impact 2. High impact 3. High impact 4. 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	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None
[1] Significant quantity available for regional use and Region H	

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4B.12.9 Gibbons Creek Reservoir Expansion

4B.12.9.1 Description of Option

The Texas Municipal Power Agency (TMPA) owns and operates Gibbons Creek Reservoir in Grimes County, 20 miles east of Bryan/College Station near the town of Carlos (Figure 4B.12.9-1). The reservoir is used to provide cooling water to the Gibbons Creek Steam-electric Station, a lignite coal-fired power plant. TMPA holds Certificate of Adjudication (CA) 12-5311 and Amendment 12-5311A for impoundment of 32,084 acre-feet (acft) of water at a normal maximum operating level of 247 ft-msl. TMPA is authorized to divert, circulate, and re-circulate as much water as necessary, of which not more than 9,740 acre-feet per year (acft/yr) may be consumptively used, for industrial (forced evaporative cooling and power plant operation) purposes. TMPA also holds Certificate of Adjudication 12-5307 for diversion from the Navasota River for subsequent use in Gibbons Creek Reservoir. As flows are not always available to the Navasota diversion right, TMPA has contracted with the Brazos River Authority (BRA) to provide 3,600 acft/yr (4,800 maximum in 1 year) from Lake Limestone.

TMPA is considering the possibility of raising the level of Gibbons Creek Reservoir in order to secure additional supply for future power plant expansions. Gibbons Creek Dam is a 1.25-mile long earthen embankment constructed across the confluence of Gibbons and Sulphur Creeks. This water supply option involves increasing the reservoir storage capacity and the firm yield from the reservoir by raising the elevation of the conservation pool by 4 feet from elevation 247 ft-msl to elevation 251 ft-msl. This would increase the storage in Gibbons Creek Reservoir from 32,084 acft to 44,334 acft, based on the original elevation-storage capacity relationship for the reservoir.

Raising the reservoir would involve increasing the effective dam crest elevation by installing a parapet wall along the upstream face, modifying the emergency spillway, modifying or replacing the spillway gates, and modifying the spillway piers. Engineering considerations for this project are discussed in Section 4B.12.9.4.

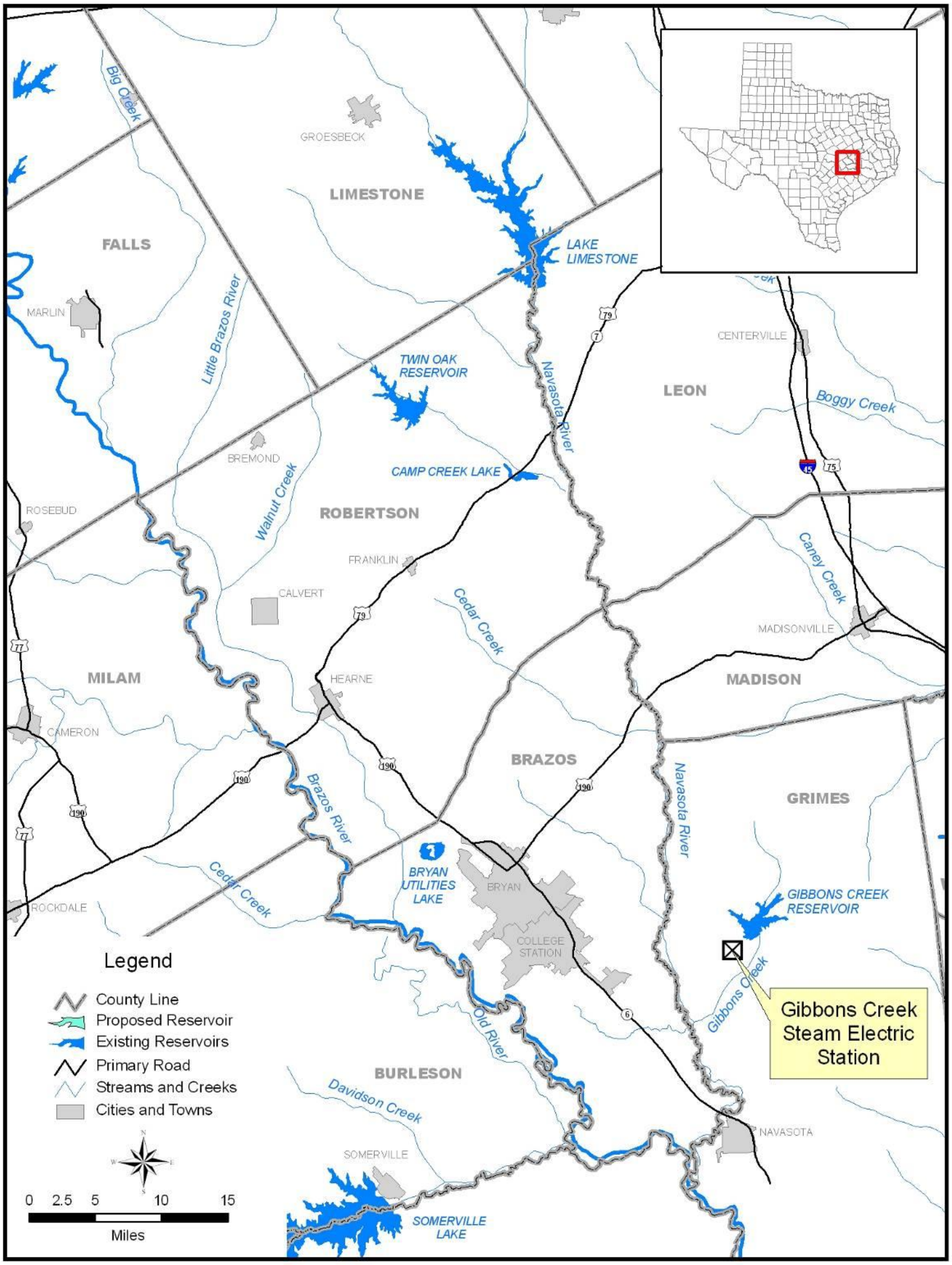


Figure 4B.12.9-1. Project Location and Vicinity Map

4B.12.9.2 Available Yield

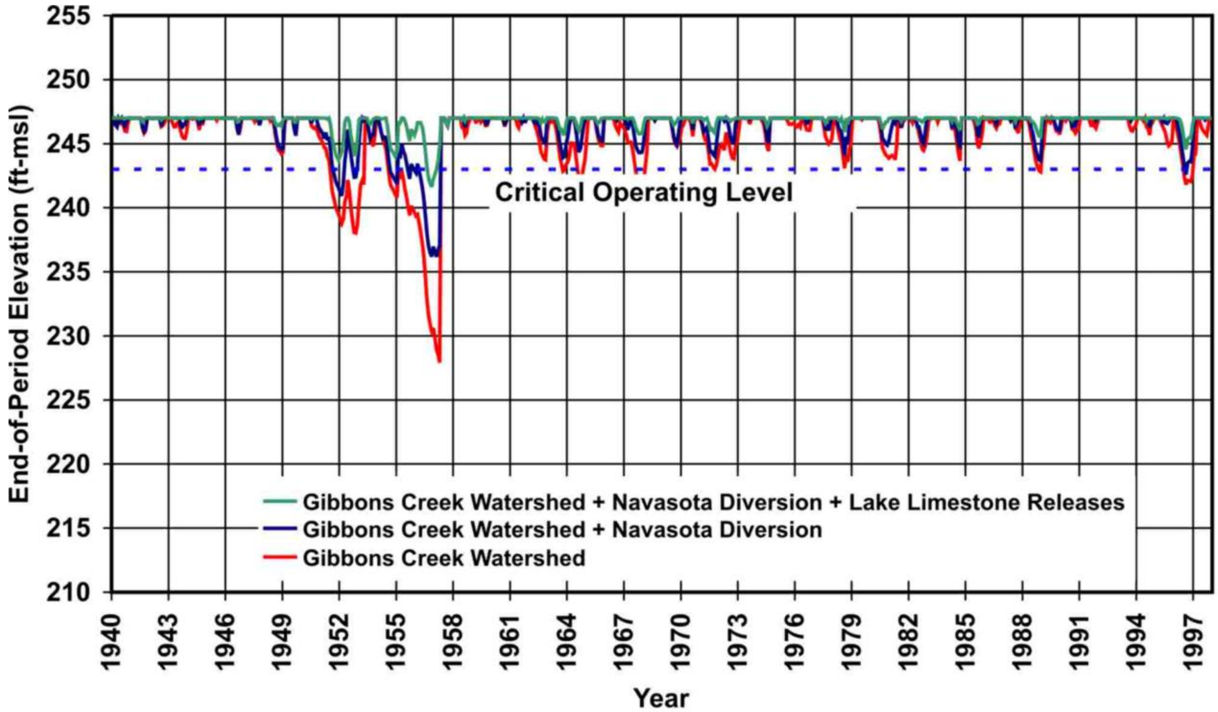
TMPA has is currently studying this strategy for increasing their supply out of Gibbon Creek Reservoir. The following information is summarized from a May 2005 technical memorandum developed as part of TMPA's ongoing study efforts. The existing Gibbons Creek Reservoir was evaluated under three alternative water supply scenarios including:

- Water available from the Gibbons Creek watershed only;
- Water available from the Gibbons Creek watershed, supplemented with diversions from the Navasota River under CA 12-5307; and
- Water Available from the Gibbons Creek watershed, supplemented with diversions from the Navasota River and releases from Lake Limestone.

For each of these scenarios, the BWAM was modified to implement the current restrictions defined in the certificates of adjudication, as well as reflect TMPA's current infrastructure. Under CA 12-5307, the total permitted annual diversion from the Navasota River is limited to 6,000 acft. The releases from Lake Limestone were limited to a maximum 1 year volume of 4,800 acft in accordance with the BRA contract. The total monthly diversion rate from both sources was limited to a combined 1,400 acft per month, which is the approximate capacity of the Navasota River Diversion Facility.

For the analysis of the existing system, the reservoir was first modeled under a strict application of the water rights as included in the TCEQ model. The reservoir was operated under its currently authorized consumptive use of 9,740 acft/yr with no critical operating level in the reservoir defined. Therefore, the water level in the reservoir was allowed to drop without any restrictions that might otherwise be implemented in the actual management of the system. These model simulations attempted to maintain the reservoir at its existing conservation capacity of 32,084 acft at an elevation of 247 ft-msl.

As shown in Figure 4B.12.9-2, the authorized use from the reservoir is firm under all three scenarios. However, in each simulation the reservoir water level drops below elevation 243 ft-msl, which is the estimated critical operating level for the steam-electric plant. The TMPA has determined that this is the minimum level to which the reservoir can drop and still maintain efficient cooling properties. The reservoir stays full approximately 40% of the time with water from its drainage area only, but when supplemented with water from the Navasota River and Lake Limestone releases, the reservoir maintains its 32,084 acft impoundment approximately 75% of the time.



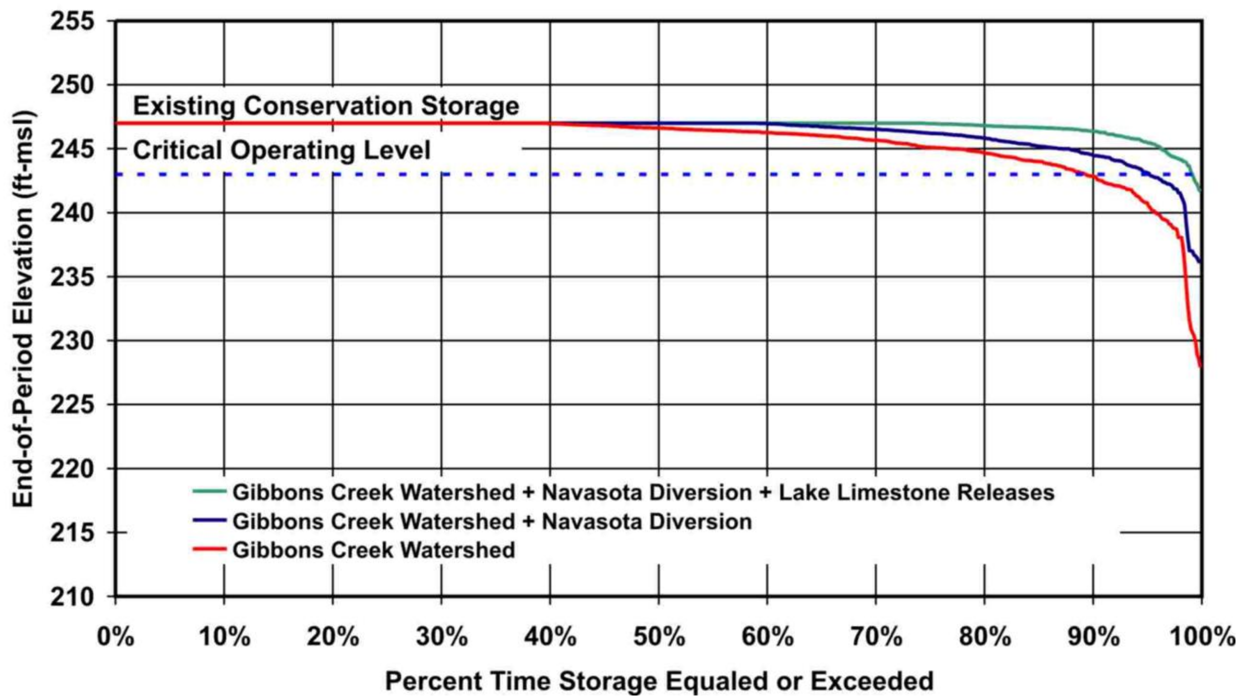


Figure 4B.12.9-2. Monthly End-of-Period Storage for Gibbons Creek Reservoir Operated at Existing Capacity (247 ft-msl), with No Critical Operating Limit Imposed (Authorized Consumptive Demand of 9,740 acft/yr)

A second set of model runs were developed to simulate the existing system with critical operating levels imposed. For these runs, the reservoir was operated under a firm yield basis while not allowing the water level to drop below elevation 243 ft-msl when subjected to each of the three previously described scenarios. The storage traces and frequency plots for these model runs are provided in Figure 4B.12.9-3. The yields for each simulation are also shown in these figures and reveal that the permitted consumptive use of 9,740 acft/yr is not firm under any of the three operating scenarios. These yields represent the amount that could be reliably consumed on an annual basis from the reservoir without dropping below the critical operating level of 243 ft-msl. The reservoir stays full approximately 58% to 83% of the time with the yields ranging from 980 acft/yr when water is obtained from the reservoir's watershed only, to a maximum of 6,310 acft/yr when the BRA Lake Limestone contract is utilized in conjunction with the Navasota River diversion right.

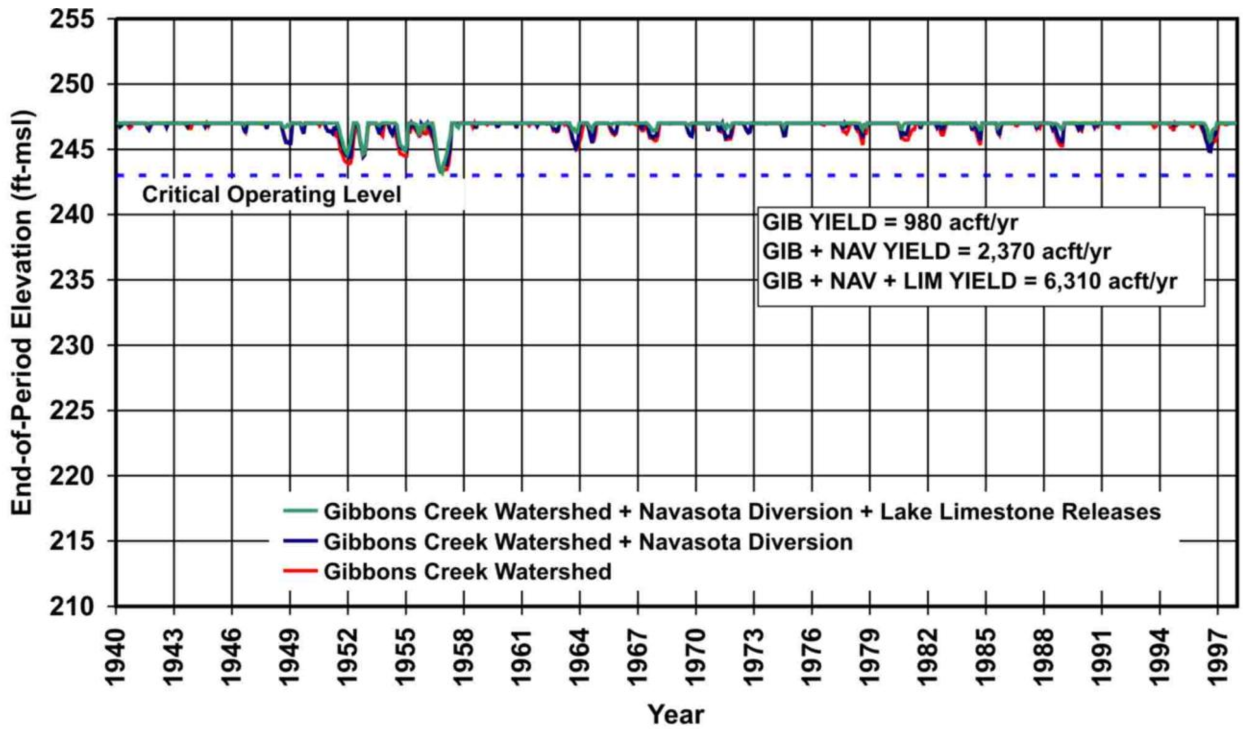
This alternative strategy evaluated the firm yield increase provided by raising the conservation pool level of Gibbons Creek Reservoir 4 feet and increasing the storage capacity by approximately 12,000 acft to 44,334 acft at elevation 251 ft-msl. The firm yield of the raised reservoir would be increased to 10,180 acft/yr, which is slightly greater than the permitted consumptive use of 9,740 acft/yr. However, as shown in Figure 4C.12.9-4, the authorized consumptive use is firm only when the BRA Lake Limestone contract is utilized.

4B.12.9.3 Environmental Issues

4B.12.9.3.1 Existing Environment

The Gibbons Creek Reservoir expansion project involves raising the level of the reservoir 4 feet, from elevation 247 ft-msl to elevation 251 ft-msl. This change would increase the storage capacity of the reservoir and inundate forested habitat at several locations around the reservoir's current perimeter. The existing reservoir lies within the Post Oak Savannah Vegetational Area[148] and is within the Texan biotic province.[149] The reservoir is within the Interior Coastal Plain Physiographic Province, which is characterized by parallel ridges and valleys of unconsolidated

[148] Gould, Frank W. 1975. The Grasses of Texas. Texas A&M University Press, College Station, Texas.
[149] Blair, W.F., "The Biotic Provinces of Texas", Tex. J. Sci. 2:93-117, 1950.



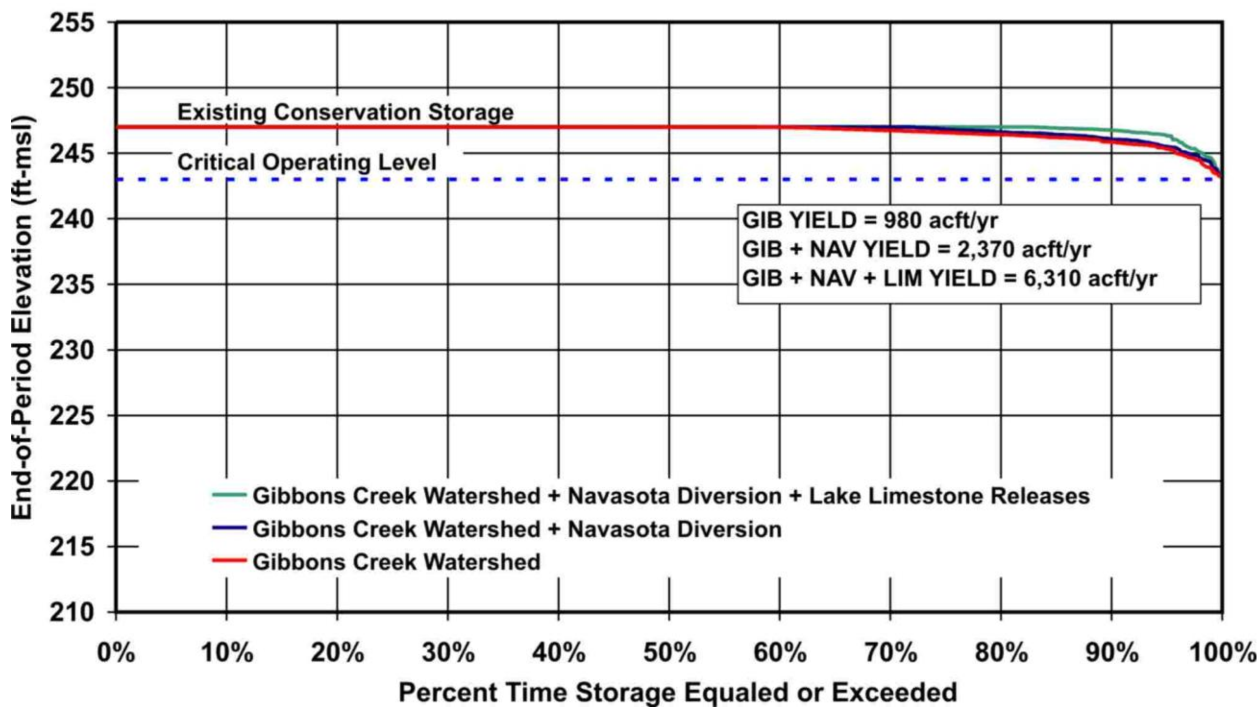


Figure 4B.12.9-3. Monthly End-of-Period Storage for Gibbons Creek Reservoir Operating at Existing Capacity (247 ft-msl), with Critical Operating Limit Imposed

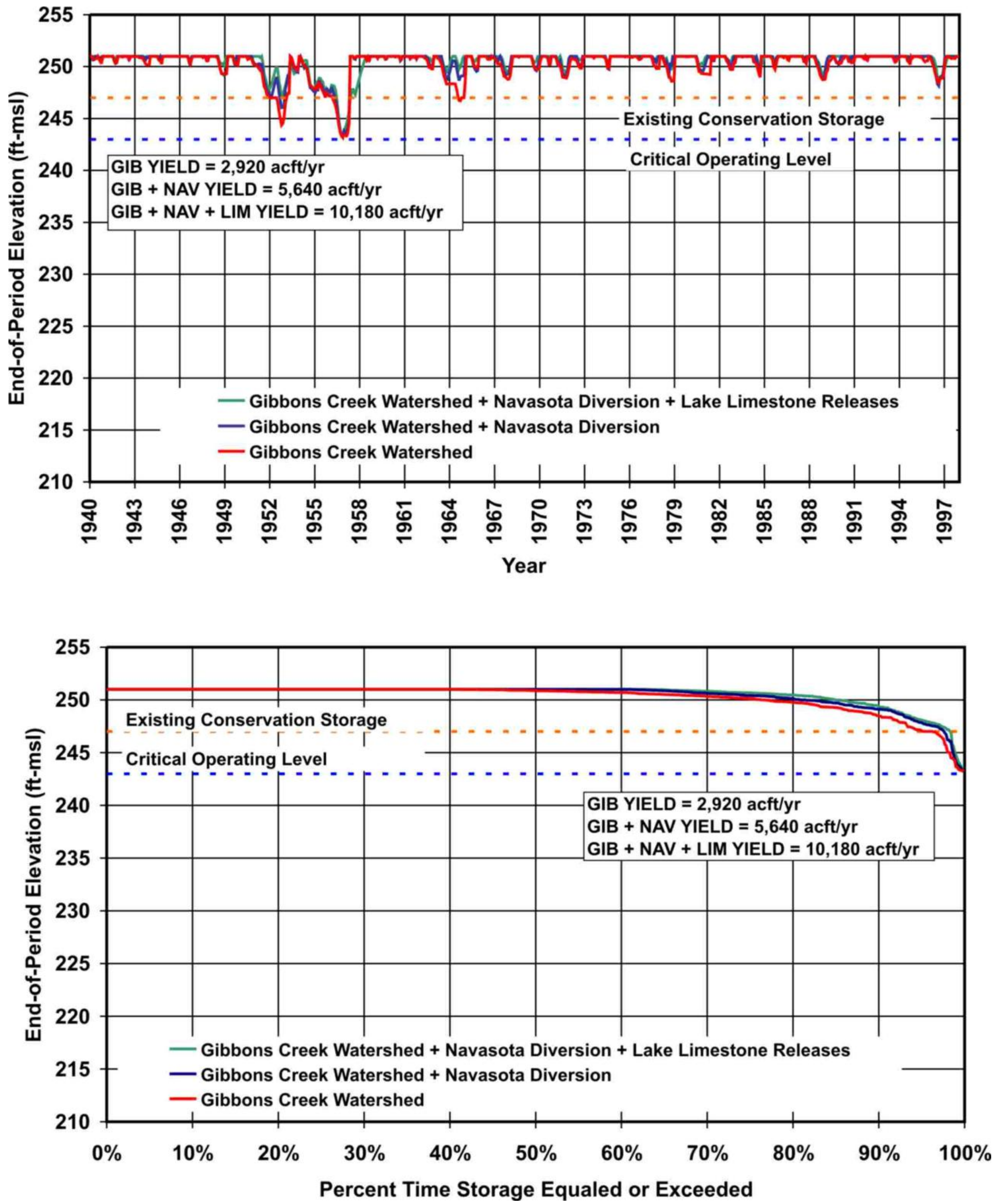


Figure 4B.12.9-4. Monthly End-of-Period Storage for Gibbons Creek Reservoir Operated at Proposed Capacity (251 ft-msl), with Critical Operating Limit Imposed

sands and muds with an elevation range from 300 to 800 meters.[150] The climate is characterized as subtropical humid, with warm summers. Average annual precipitation is approximately 42-44 inches.[151]

Gibbons Creek Reservoir is located within the Texas Claypan Area.[152] Soils in the project area formed on nearly level to sloping plains dissected by perennial streams and their tributaries. Large floodplains and stream terraces are associated with meandering river systems. Over most of the area, soils have well-developed, clayey, subsoil horizons with sandy and loamy surface textures. Woodtell, Edge, Crockett and Straber soils occur on interstream divides and ridges, and Tabor soils are on stream terraces. Padina and Silstid soils have sandy surface layers more than 20 inches thick. Edge-Tabor-Silstid series soils are present in the project area.

Vegetation within the project area includes post oak woods, forest and grassland mosaic, and pine-hardwood forests.[153] Post oak woods, forest and grassland mosaic could include the following commonly associated plants: Blackjack oak (*Quercus marilandica*), eastern redcedar (*Juniperus viginiana*), mesquite (*Prosopis glandulosa*), black hickory (*Carya texana*), live oak (*Q. fusiformis*), sandjack oak (*Q. incana*), cedar elm (*Ulmus crassifolia*), hackberry (*Celtis reticulata*), yaupon (*Ilex vomitoria*), poison oak (*Rhus toxicodendron-radicans*), American beautyberry (*Callicarpa americana*), hawthorn (*Crateagus texana*), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus trivialis*), coral-berry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida purpurea*), sprangle-grass (Chasmanthium latifolium), and tickclover (Desmodium paniculatum).

Commonly associated plants in the pine-hardwood forest include: shortleaf pine (*Pinus echinata),* water oak (*Quercus nigra*), winged elm (*Ulmus alata*), beech (*Fagus* spp.), and magnolia (*Magnolia* spp.). Understory plants include American beautyberry (*Callicarpa americana*), flowering dogwood (*Cornus florida*), yaupon (*Ilex vomitoria*), and sassafras (*Sassafras officinale*). Groundcovers such as poison ivy (*Toxicodendron radicans*), greenbriar (*Smilax* spp.), and blackberry (*Rubus* spp.) are common within the area.

[150] Bureau of Economic Geology. 1996. Physiographic Map of Texas. The University of Texas, Austin, Texas.
[151] Texas Water Development Board (TWDB). *Precipitation Polygon GIS Layer*.
[152] USDA – NRCS, 2008. *General Soil Map of Texas*, generated from the NRCS STATSGO 2004 database, September 25, 2008.
[153] 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.

4B.12.9.3.2 Potential Impacts

4B.12.9.3.2.1 Aquatic Environments

While not presented in the modeling simulation provided by TMPA, it is anticipated that there would be a slight reduction in the quantity of median monthly flows below the dam. Since a significant portion of the inflow into the reservoir comes from supplemental sources on the Navasota River and TMPA generally operates to keep the reservoir full, maximizing spills, the reductions are expected to be negligible.

4B.12.9.3.2.2 Threatened & Endangered Species

A total of 29 species that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern could potentially occur within the vicinity of Gibbons Creek Reservoir. This group includes 10 birds, 2 fishes, 4 mammals, 5 mollusks, 4 reptiles, and 4 plant species (Table 4B.12.9-1). Three bird species federally-listed as threatened or endangered could possibly occur within the project area. These include the Interior Least Tern, Red-cockaded Woodpecker and Whooping Crane. The Interior Least Tern and Red-Cockaded Woodpecker may breed and forage within the vicinity of the site but have very specific habitat requirements. The Whooping Crane is a seasonal migrant that could pass through the project area. The federally-threatened Louisiana black bear is possible in the area as a transient in bottomland hardwoods and large tracts of inaccessible forest land; the federally-endangered red wolf has been extirpated. One plant species of potential occurrence, the Navasota ladies' tresses, is federally endangered. This plant species has restricted habitats requiring sandy soils and openings in post oak woodlands. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

4B.12.9.3.2.3 Wildlife Habitat

The primary impact that would result from increasing the conservation level of Gibbons Creek Reservoir includes the conversion of existing habitats and land uses of approximately 160 acres surrounding the existing reservoir to open water. Post oak woods/forest and grassland, and pine-hardwood areas between elevations 247 and 251 ft-msl would be permanently inundated. This area is currently within the existing flood pool of Gibbons Creek Reservoir.

Table 4B.12.9-1.
Potentially Occurring Species that are Rare or Federal- and State-Listed in Grimes County

Scientific Name	*Common Name*	*Federal/State Status*	*Potential Occurrence*
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/SOC	Migrant
Haliaeetus leucocephalus	Bald Eagle	DL/T	Resident
Ammodramus henslowii	Henslow’s Sparrow	SOC	Resident
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant
Falco peregrinus	Peregrine Falcon	DL/T	Migrant
Picoides borealis	Red-Cockaded Woodpecker	LE/E	Resident
Plegadis chihi	White-Faced Ibis	T	Resident
Grus Americana	Whooping Crane	LE/E	Migrant
Mycteria americana	Wood Stork	T	Migrant
Fishes			
Cycleptus elongates	Blue Sucker	T	X
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Mammals			
Ursus americanus luteolus	Louisiana Black Bear	LT/T	Transient
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E	Extirpated
Myotis austroriparius	Southeastern Myotis Bat	SOC	X
Mollusks			
Quincuncina mitchelli	False Spike Mussel	T	X
Tritogonia verrucosa	Pistolgrip	SOC	X
Arcidens confragosus	Rock Pocketbook	SOC	X
Quadrula houstonensis	Smooth Pimpleback	T	X
Truncilla macrodon	Texas Fawnsfoot	T	X
Reptiles			
Macrochelys temminckii	Alligator Snapping Turtle	T	X
Pituophis ruthveni	Louisiana Pine Snake	C//T	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X
Plants			
Liatris cymosa	Branched Gay-Feather	SOC	X
Agalinis navasotensis	Navasota False Foxglove	SOC	X
Spiranthes parksii	Navasota Ladies’-Tresses	LE/E	X
Thalictrum texanum	Texas Meadow-Rue	SOC	X

X = Occurs in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be Delisted (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-Delisted Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: TPWD, *Annotated County List of Rare Species for Grimes County,* January 2010.

A number of vertebrate species could occur within the project area, as indicated by county occurrence records.[154] These include 55 reptile and amphibian species which include salamanders, frogs and toads, turtles, lizards and skinks, snakes, and the American alligator. Additionally, approximately 54 species of mammals could occur within the site or surrounding region,[155] as well as an undetermined number of bird species. A variety of fish and invertebrate species likely inhabit the existing reservoir, but distributions and population densities may be limited by the types and quality of habitats available.

4B.12.9.3.2.4 Cultural Resources

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available GIS datasets from the Texas Historical Commission (THC), no historic markers, cemeteries, or historic places are within the proposed additional reservoir inundation area.

4B.12.9.3.2.5 Threats to Natural Resources

This project would alter the habitat along the current boundary of Gibbons Creek Reservoir from primarily a bottomland hardwood system to an impounded system. Bottomland hardwoods are extensive in the project area and are important habitats for a variety of species including migratory birds. Additional impacts would be expected to terrestrial wildlife, potentially including some threatened or endangered species, which would be displaced during additional reservoir filling.

4B.12.9.4 Engineering and Costing

Increasing the conservation pool level of Gibbons Creek Reservoir by 4 feet would necessitate raising the top of dam elevation in order to safely pass the probable maximum flood. Given the increasing rate of storage with increasing reservoir pool elevation, it was assumed that

[154] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," Accessed online http://wfscnet.tamu.edu/tcwc/Herps_online/CountyRecords.htm December 2, 2009.
[155] Davis, W.B., and D.J. Schmidly, "The Mammals of Texas – Online Edition," Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

the top of dam would need to be raised 3 feet. Detailed flood hydrology and hydraulic analyses would be required to refine the top of dam elevation. The dam would be raised using a concrete parapet wall along the upstream edge of the dam crest. The road on top of the dam crest would not be raised. The downstream face of this wall would be shaped to serve as a traffic barrier for vehicles driven on the dam crest. The existing soil cement slope protection along the upstream face of the wall that is disturbed by construction would need to be replaced with lean concrete or cement-treated materials. Repairs to the road along the top of the dam and repaving it with a single chip-seal coat would complete the dam crest work.

The entire “footprint” of the emergency spillway would be raised 4 feet using earth fill to keep the frequency of engagement the same. A portion of the overflow crest would be protected using some form of armor, such as concrete pavers or gabions. The remainder of the raised and disturbed area would be revegetated using a turf reinforcement mat and native grasses. An existing boat ramp and associated park facilities in the vicinity of the emergency spillway would also need to be relocated to higher ground.

Two possible approaches exist for raising the service spillway gates 4 feet: (1) either modify and strengthen the existing gates, or (2) replace the gates entirely. In either case, modifications would be required to the trunnion and trunnion anchorage in order to resist the additional loads, and new hoists and hoist platforms would likely be necessary to lift the additional weight of the gates. Because the tops of the existing gates were previously raised approximately 2 feet and the lower portions of the existing gates are likely not designed to handle any additional hydrostatic loads, 4 feet would be added to the bottom of the gates rather than the top. To perform the modification, the gates would be rotated 4 feet open and new skin plates, vertical purlins, horizontal girders, and radial struts would be added to the bottom of the gates. New hoist brackets would also be added to the bottom of the gates. With this approach the existing portions of the gates would carry essentially the same hydrostatic loads as before. Due to the new geometry, however, it is likely that additional diagonal braces will be required above the existing top radial struts. Such gate modifications are complicated and the costs would likely be equivalent to simply replacing the existing gates.

The hot canal and weir system that is used to return hot water from the power plant to the middle fork of the reservoir would also need to be raised. The concrete walls for the weir and wing walls would be scabbed onto and raised 4 feet. Concrete buttresses of some form would probably be required to stabilize the higher walls. The canal levees would be raised 4 feet using local earth fill material.

The estimated capital costs for the major construction items associated with expanding Gibbons Creek Reservoir are listed in Table 4B.12.9-2. The total construction cost is estimated to be $7,456,000. Considering other costs such as engineering, legal, and financing, the total project cost of expanding Gibbons Creek Reservoir is estimated to be $12,140,600, with an annual cost (debt service and O&M) of $918,723 based on 6 percent interest and 40-year financing. The project would provide an additional firm yield of 3,870 acft/yr of water, for an annual unit cost of $237/acft.

Table 4B.12.9-2. Cost Estimate Summary for Gibbons Creek Reservoir Expansion (September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Raise Dam Crest	$1,050,000
Modify Emergency Spillway	$2,125,000
Modify Service Spillway	$2,119,000
Modify Hot Canal Weir and Levees	$1,418,000
Relocate Boat Ramp and Park Facilities	$66,000
Unlisted Design Items (10%)	$678,000
Total Capital Cost	**$7,456,000**
Engineering, Legal Costs, and Contingencies	$2,609,600
Environmental & Archaeological Studies and Mitigation	$800,000
Land Acquisition and Surveying	$808,000
Interest During Construction	$467,000
Total Project Cost	**$12,140,600**
Annual Costs	
Reservoir Debt Service	$751,587
Operation and Maintenance	$111,840
Total Annual Cost	**$918,723**
Available Project Yield (acft/yr)	**3,870**
Annual Cost of Water ($ per acft) Raw Water	**$237**
Annual Cost of Water ($ per 1,000 gallons) Raw Water	**$0.73**

4B.12.9.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.12.9-3, and the option meets each criterion.

Implementation of the Gibbons Creek Reservoir Expansion project will require permits from state and federal agencies, land and easement acquisitions, and design and construction of the facilities. The number of constraints to implement this expansion project would be significantly reduced as compared to the development of a new reservoir because of existing land ownership and the nature of the project. A summary of the implementation steps for the project is presented below.

1. It will be necessary to obtain these permits:
   a. TCEQ Water Right and Storage permit (re-authorization);
   b. TCEQ Dam Safety Program permit for construction of the dam and spillway modifications;
   c. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for reservoirs impacting wetlands or navigable waters of the U.S;
   d. NPDES Storm Water Pollution Prevention Plan administered by TCEQ;
   e. Section 401certification from the TCEQ related to the Clean Water Act.
2. Permitting, at a minimum, will require these studies:
   a. Habitat mitigation plan including mitigation for wetlands and endangered species.
   b. Environmental studies.
   c. Cultural resource studies.
   d. Mitigation Funding:
      - Acquisition of land for mitigation, either through eminent domain or market transactions;
      - Possible relocations, including residences and other structures, affected utilities and roads, etc.
3. The TMPA owns land to elevation 250 ft-msl and flood easement to elevation 255 ft-msl surrounding the reservoir. Land will need to be acquired to elevation 251 ft-msl and additional flood easement may need to be acquired above elevation 255 ft-msl through either negotiations or condemnation from multiple landowners.
4. Funding of the project will require a substantial commitment from a non-federal sponsor.

Table 4B.12.9-3.
Comparison of Gibbons Creek Reservoir Expansion Project to Plan Development Criteria

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

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4B.12.10 Brushy Creek Reservoir

4B.12.10.1 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, which is a tributary to the Brazos River. The proposed reservoir is located approximately 26 miles to the southeast of the City of Waco and 8 miles to the east of the City of Marlin (Figure 4B.12.10-1). This project was suggested as a water management strategy in the 2001 and 2006 Brazos G Regional Water Plans. Other studies include the 1984 *Final Watershed Plan and Environmental Impact Statement for the Big Creek Watershed for Falls, Limestone, and McLennan Counties*[156] and the 2008 *Reservoir Site Protection Study*[157] The proposed reservoir has a storage capacity of 6,560 acre-feet at the permitted conservation storage level of 380.5 feet above mean sea level (ft-msl). At conservation storage level the reservoir will inundate an area of approximately 697 acres. The land required to create the reservoir has already been acquired by the City of Marlin.

The Brushy Creek Reservoir is authorized by Certificate of Adjudication 12-4355, as amended. The certificate also authorizes New Marlin Reservoir and Marlin City Lake which impound 3,135 and 791 acre-feet of water, respectively. Marlin City Lake is used as a sedimentation basin. The City of Marlin is allowed to divert 4,000 acre-feet per year from New Marlin Reservoir and/or Brushy Creek Reservoir for municipal purposes, plus 2,000 acre-feet for municipal purposes and 2,000 acre-feet for industrial purposes from the Brazos River between October and April. A continuous release of 0.1 cfs must be made from Brushy Creek Reservoir to maintain instream flows. Table 4B.12.10-1 is a summary of the authorizations made by Certificate No. 12-4355.

[156] 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.

[157] 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.

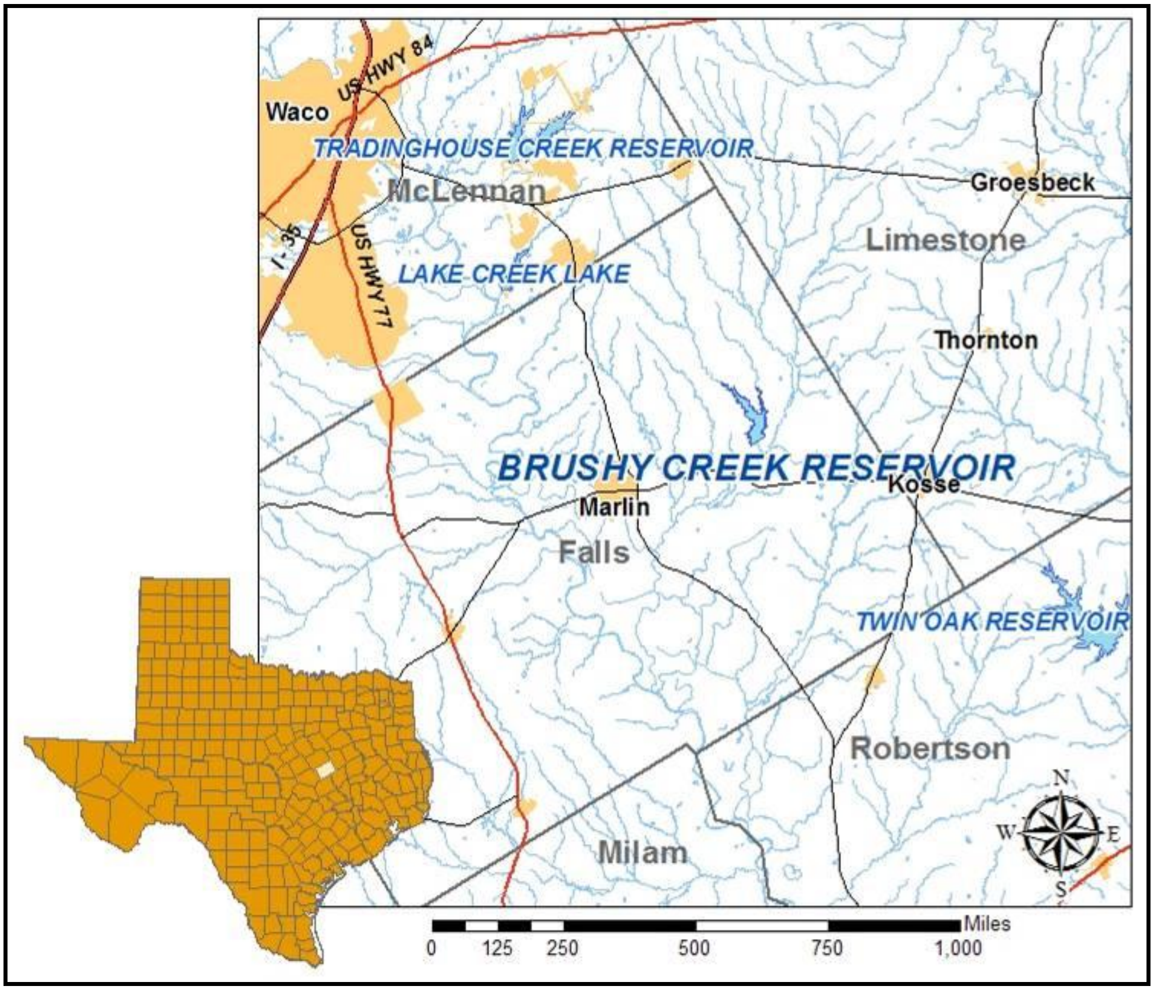

Figure 4B.12.10-1. Location of Brushy Creek Reservoir

Table 4B.12.10-1.
Summary of Authorizations Made by Water Right

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

4B.12.10.2 Available Yield

The firm yield of Brushy Creek Reservoir was calculated using the Brazos G WAM with 2060 sedimentation conditions. The simulation is performed using the Water Rights Analysis Package (WRAP) with a monthly time step and a period-of-analysis from January 1940 to December 1997. Table 4B.12.10-2 shows the elevation-area-capacity relationship for Brushy Creek Reservoir.

Table 4B.12.10-2.
Elevation-Area-Capacity Relationship for Brushy Creek Reservoir

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

* Authorized conservation pool elevation

The firm yield was computed for the authorized storage capacity of Brushy Creek Reservoir, which is 6,560 acre-feet, subject to a minimum required instream flow release of 0.1 cfs as specified in Special Condition G of Certificate of Adjudication 12-4355. Based on the premises and assumptions reflected in the model, the firm yield for Brushy Creek Reservoir is 2,090 acre-feet per year.

Figure 4B.12.10-2 shows the simulated storage in Brushy Creek Reservoir assuming an annual diversion amount equal to the firm yield. The storage frequency curve for these conditions is presented in Figure 4B.12.10-3.

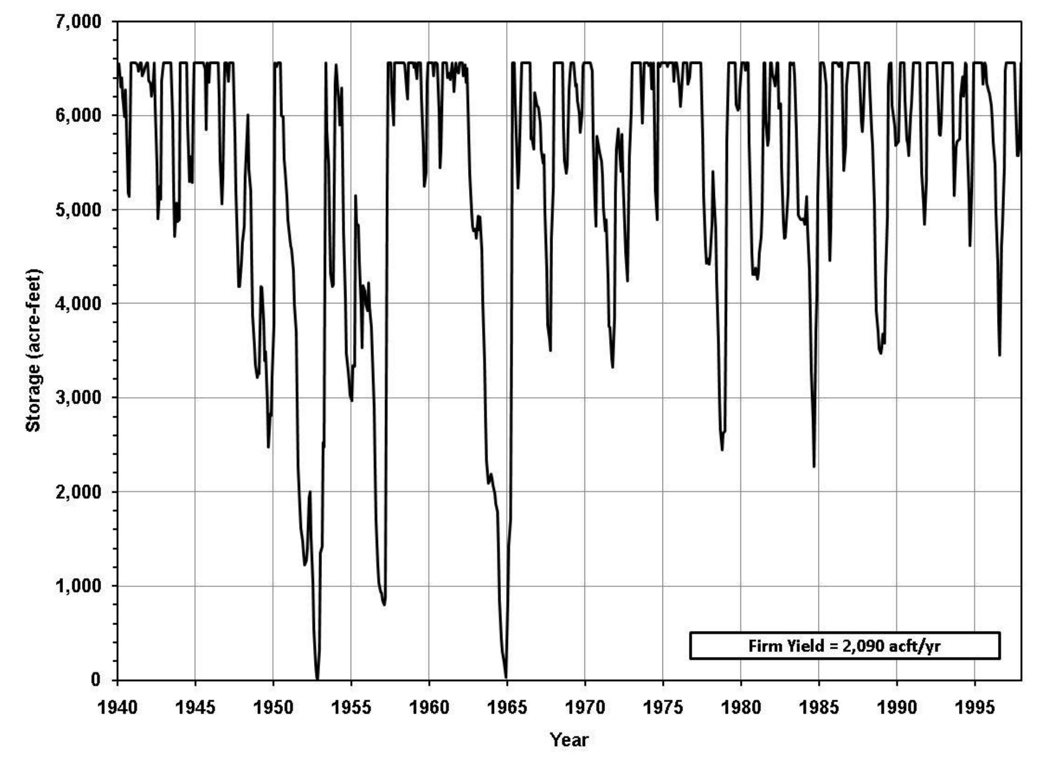

Figure 4B.12.10-2. Simulated Storage in Brushy Creek Reservoir

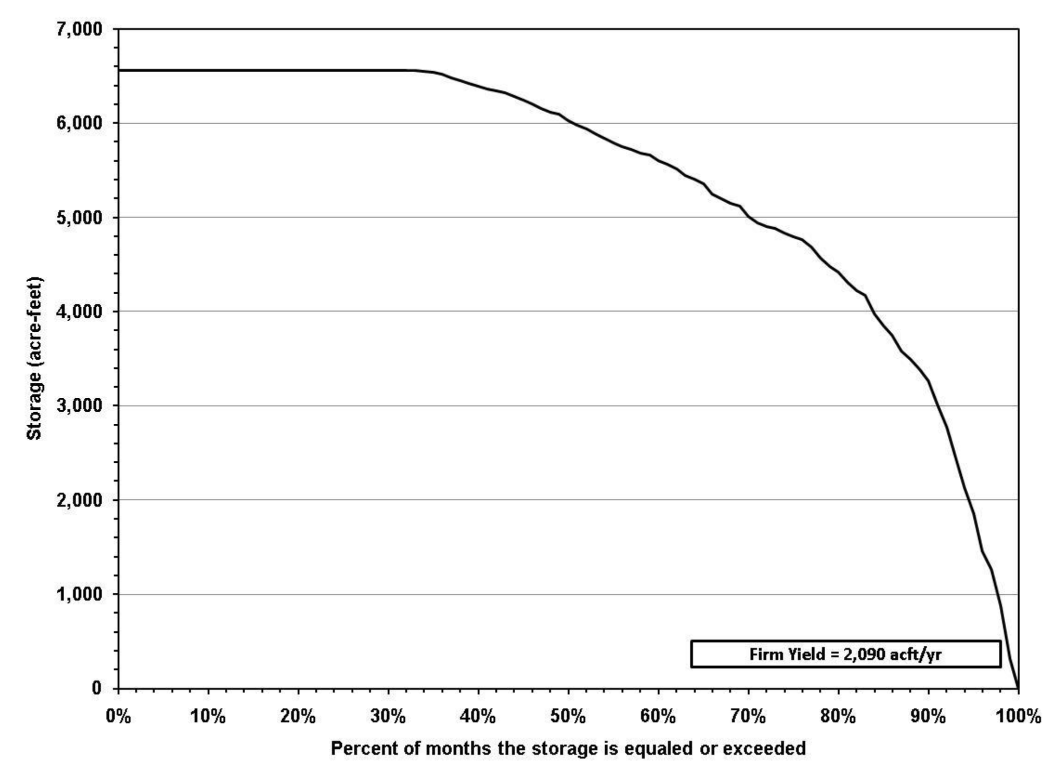

Figure 4B.12.10-3. Storage Frequency Curve for Brushy Creek Reservoir

4B.12.10.3 Environmental Issues

4B.12.10.3.1 Existing Environment

The proposed Brushy Creek Reservoir site in Falls County lies within the Texas Blackland Prairies Ecological Region. 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.

Landcover is dominated by agricultural lands (41%) and deciduous forest (35%). Grasslands cover approximately 17% and the remaining 7% is shrubland. The climate is characterized as subtropical humid, most noted for warm summers. On average, precipitation ranges from 36 to 38 inches per year.

There are no major aquifers beneath the project site, however, the Trinity Aquifer is located 5miles to the northwest and the Carrizo Aquifer is seven miles to the southeast of the proposed reservoir site.

4B.12.10.3.1 Potential Impacts

4B.12.10.3.1.1 Aquatic Environments including Bays & 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. Assuming annual diversions equal to the permitted amounts (Table 4B.12.10-3), these reductions could range from 2.3 cfs (96 percent) in September to 7.8 cfs (71 percent) in June. The highest percent reductions (>95 percent) could be from September through December. The lowest percent reduction occurs in May (27 percent). Figure 4B.12.10-4 shows that without the reservoir, streamflow would likely cease 11% of the time. With the reservoir, streamflow will likely persist because a minimum release of 0.1 cfs is required to maintain instream flows. Without the required instream flow releases, streamflow would likely cease 49% 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 4B.12.10-3.
Median Monthly Streamflow for Brushy Creek Reservoir

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	7.7	1.0	6.8	88
February	6.6	0.2	6.5	98
March	7.2	2.2	5.0	70
April	6.7	1.7	5.0	75
May	15.6	11.4	4.2	27
June	11.0	3.2	7.8	71
July	4.1	0.1	4.0	98
August	3.7	0.8	2.9	78
September	2.4	0.1	2.3	96
October	2.6	0.1	2.5	96
November	3.3	0.1	3.2	97
December	7.0	0.1	6.9	99

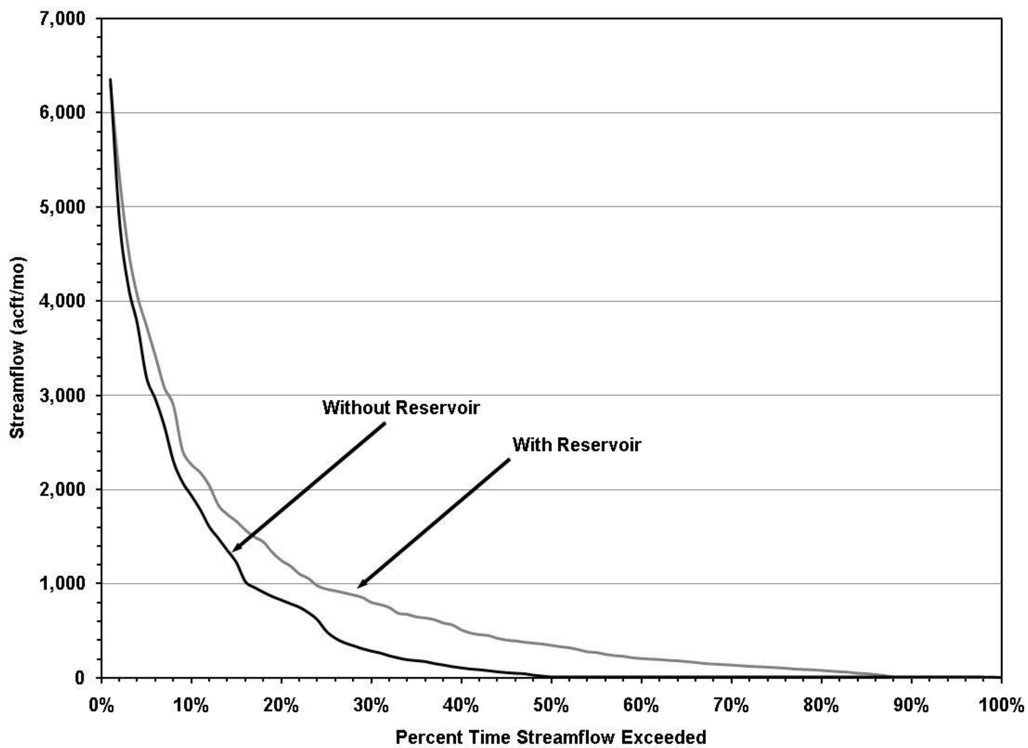

Figure 4.12.10-4. Brushy Creek Reservoir Streamflow Frequency Comparison

4B.12.10.3.1.2 Threatened & Endangered Species

The Brushy Creek Reservoir site would be located in Falls County, Texas. There are 24 species that are state or federally-listed as rare, threatened, or endangered that could potentially occur within Falls County (Table 4B.12.10-4).[158] The list contains 10 birds, 2 fish species, 3 mammals, 5 mollusks, and 4 reptiles. Two bird species that could potentially occur in the vicinity of the site are federally-listed as endangered. They are the whooping crane (*Grus americana*) and the interior least tern (*Sterna antillarum athalassos*). Because these two birds are seasonal migrants, they are not likely to be impacted by the proposed project.

The information in Table 4B.12.10-4 does not confirm nor deny the presence of the species in the project area. On-site evaluations by qualified biologists are required to confirm the presence of species. A site protection study sponsored by TWDB did not identify any endangered species in the basin (TWDB, 2008). An environmental impact statement conducted in 1984 found that “the project will not affect any known threatened or endangered species” (USDA, 1984).

4B.12.10.3.1.3 Wildlife Habitat

The quality of wildlife habitat in the Brushy Creek area has been impacted due to aggressive brush eradication efforts and the conversion of native habitats into agricultural lands. Construction of Brushy Creek Reservoir and surrounding flood-retarding structures could impact approximately 3,454 acres of wildlife habitat. Another 4,018 acres would be located within the detention pool, buffer, or flowage easement areas and would likely not be impacted (USDA, 1984). The reservoir would inundate approximately 697 acres of land at conservation capacity. Of the land to be inundated, approximately 269 acres are upland deciduous forest, 235 acres are agricultural lands, and the remainder is grasslands or shrubland.

[158] TPWD, 2009. Rare, Threatened, and Endangered Species of Texas by County Database. Texas Parks and Wildlife Department (TPWD). Accessed October 2009.

Table 4B.12.10-4.
Potentially Occurring Rare, Threatened or Endangered Species
Listed in Falls County

Scientific Name	*Common Name*	*Federal Status*	*State Status*
Birds			
Ammodramus henslowii	Henslow's Sparrow	Rare	Rare
Athene cunicularia hypugaea	Western Burrowing Owl	Rare	Rare
Falco peregrinus	Peregrine Falcon	Delisted	Threatened
Falco peregrinus anatum	American Peregrine Falcon	Delisted	Threatened
Falco peregrinus tundrius	Arctic Peregrine Falcon	Delisted	Rare
Grus americana	Whooping Crane	Endangered	Endangered
Haliaeetus leucocephalus	Bald Eagle	Delisted	Threatened
Mycteria americana	Wood Stork	Rare	Threatened
Plegadis chihi	White-faced Ibis	Rare	Threatened
Sterna antillarum athalassos	Interior Least Tern	Endangered	Endangered
Fishes			
Notropis buccula	Smalleye shiner	Candidate for Listing	Rare
Notropis oxyrhynchus	Sharpnose shiner	Candidate for Listing	Rare
Mammals			
Canis rufus	Red wolf	Endangered	Endangered
Myotis velifer	Cave myotis bat	Rare	Rare
Spilogale putorius interrupta	Plains spotted skunk	Rare	Rare
Mollusks			
Arcidens confragosus	Rock pocketbook	Rare	Rare
Quadrula houstonensis	Smooth pimpleback	Rare	Threatened
Quincuncina mitchelli	False spike mussel	Rare	Threatened
Tritogonia verrucosa	Pistolgrip	Rare	Rare
Truncilla macrodon	Texas fawnsfoot	Rare	Threatened
Reptiles			
Crotalus horridus	Timber/Canebrake rattlesnake	Rare	Threatened
Macrochelys temminckii	Alligator snapping turtle	Rare	Threatened
Phrynosoma cornutum	Texas horned lizard	Rare	Threatened
Thamnophis sirtalis annectens	Texas garter snake	Rare	Rare

4B.12.2.3.1.4 Cultural Resources

A cultural resource surface survey of the Brushy Creek Reservoir area was conducted in 1978[159]. 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[160]. 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).

4B.12.10.4 Engineering and Costing

Due to the history of detailed studies on the Brushy Creek reservoir the cost estimate presented below in Table 4B.12.10-5 contains a greater level of detail than the typical water management strategy evaluation. The proposed Brushy Creek Reservoir includes the construction of a rolled earth embankment, a principal spillway, and an emergency spillway. Table 4B.12.10-5 shows the estimated costs for the Brushy Creek Reservoir, including the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and engineering services. The unit costs used in this study are based on the Reservoir Site Protection Study (TWDB, 2008) 2005 prices adjusted to September 2008 prices using a multiplier of 1.17 based on the Construction Cost Index (CCI). The price of land per acre is

[159] Nunley, 1978. *Archeological Survey of Portions of Big Creek Watershed, Falls, Limestone and McLennan Counties, Texas*. Nunley Multimedia Productions, Miscellaneous Papers, No. 2, Dallas.
[160] 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.

estimated as the percent between minimum and maximum land values for river properties in Falls County based on Texas Rural Land Value Trends 2005 and 2008 developed by Texas A&M Real Estate Center. However, the inclusion of land prices in this cost estimate may be unnecessary since the City of Marlin has already purchased the land needed to build the reservoir for around $1 million.

Given these assumptions, the estimated cost of the project is $13.3 million (September 2008 prices). The annual costs of the project, which include debt service and operation and maintenance, are estimated to be $0.95 million. With a projected firm yield of 2,090 acre-feet per year by 2060, the annual unit cost of raw water will be $1.40 per 1,000 gallons ($455 per acre-foot). Without the floodwater component, the unit cost is $0.73 per 1,000 gallons ($182 per acre-foot).

4B.12.10.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.12.10.5-6, and the option meets each criterion.

A summary of the implementation steps for the project is presented below.

4B.12.10.5.1 Potential Regulatory Requirements:

- U.S. Army Corps of Engineers Permits will be required for structures placed in navigable waters of the U.S. (Section 10 of Rivers and Harbors Act) or 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.

Table 4B.12.10-5.
Cost Estimate Summary for Brushy Creek Reservoir
(September 2008 Prices)

Item	Quantity	Unit	Unit Cost	Cost
Mobilization (5%)	1	LS		$215,636
Foundation:				
Cutoff excavation	61,832	CY	$2.95	$182,404
Channel cleanout excavation & foundation preparation	29,000	CY	$2.95	$85,550
Compacted fill - cutoff trench	61,832	CY	$2.95	$182,404
Subtotal - foundation construction				$450,359
Embankment:				
Clearing & grubbing	40	AC	$2,340	$93,600
Compacted fill	579,789	CY	$2.95	$1,710,378
Riprap & bedding	12,500	TON	$76.00	$950,000
Topsoil & grassing	50	AC	$5,265	$263,250
Fencing	14,190	LF	$4.70	$66,693
Subtotal - Embankment construction				$3,083,921
Emergency Spillway:				
Excavation - emergency spillway	110,000	CY	$2.95	$324,500
Subtotal - Emergency Spillway Construction				$324,500
Principal Spillway:				
Reinforced concrete				
7' x 7' box culvert conduit	290	CY	$470	$136,300
Anti-seep collars	39	CY	$470	$18,330
Riser	81	CY	$470	$38,070
Footing	31	CY	$470	$14,570
St. Anthony Falls basin	490	CY	$470	$230,300
Slide gate	1	EA	$7,020	$7,020
Trash rack	1	EA	$9,360	$9,360
Subtotal - Principal Spillway Construction				$453,950
Subtotal - Dam Construction				$4,312,729
Clearing Reservoir	175	AC	$1,170	$204,750
Subtotal - Dam & Reservoir Construction				$4,733,116
Engineering & Contingencies (35% Dam & Reservoir)				$1,656,591
Total - Dam & Reservoir Construction				$6,389,706
Conflicts (Relocations):				
12.5 kilovolt distribution line	1	LS	$35,100	$35,100
69 kilovolt transmission line	1	LS	$315,900	$315,900
Close county roads 182 & 182A	1	LS	$175,500	$175,500
Water lines	1	LS	$93,600	$93,600
TXDOT Highway 147	1	LS	$2,925,000	$2,925,000
Subtotal - Conflicts				$3,545,100
Engineering & Contingencies (35% Conflicts)				$1,240,785
Land Purchase (1,812 acres previously purchased)	1812	AC		
Environmental Studies & Mitigation				$918,625
Construction Total				$12,094,216
Interest during Construction				$1,157,691
Total Cost				$13,251,907
Annual Costs				
Debt Service (6% for 40 years)				$880,742
Operation & Maintainance (1.5% of Dam & Spillway Costs)				$70,997
Total Annual Costs				$951,739
Firm Yield (acre-feet per year)				2,090
Unit Cost: City Share (40%) & NRCS Share (60%)				
Unit Cost of Water with NRCS floodwater component				
Per acre-foot				$455
Per 1,000 gallons				$1.40
Unit Cost of Water without NRCS floodwater component (City's Share)				
Per acre-foot				$182
Per 1,000 gallons				$0.73

Table 4B.12.10-6.
Comparison of Brushy Creek 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. Moderate
B. Environmental factors	
1. Environmental Water Needs	1. Moderate to High 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. 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	• 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

4B.12.10.5.2 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.

4B.12.10.5.3 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.

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4B.13 Off-Channel Reservoirs

4B.13.1 Introduction

Implementation of off-channel reservoirs is becoming more common as increasing environmental constraints limit the development of major on-channel reservoirs. The concept of an off-channel reservoir is to divert water from a primary stream during high flows to storage in a reservoir constructed on a smaller tributary stream. Stored water in the off-channel reservoir is used to provide a firm supply of water when flow is not available from the primary stream during drought periods. Off-channel reservoirs have been implemented in Texas in the past, primarily for industrial and steam electric purposes. Examples of existing off-channel reservoirs in the Brazos G Area include Lake Alcoa, Tradinghouse Creek Reservoir (Texas Utilities), Lake Creek Reservoir (Texas Utilities), City of Robinson, and the City of Clifton. A summary of each of these projects is presented in Table 4B.13.1-1.

Table 4B.13.1-1.
Summary of Existing Off-Channel Reservoirs in the Brazos G Area

Owner	*Off-Channel Reservoir*	*Authorized Storage (acft)*	*Primary Stream for Diversion*
Alcoa	Lake Alcoa	15,650	Little River
Texas Utilities	Tradinghouse Creek Reservoir	37,800	Brazos River
Texas Utilities	Lake Creek Reservoir	8,500	Brazos River
City of Robinson	Robinson Off-Channel Reservoir	8,037	Brazos River
City of Clifton	Clifton Off-Channel Reservoir	2,000	North Bosque River

While providing a firm supply during drought times when run-of-the-river diversions are not available, off-channel reservoirs also provide other advantages, including:

- Less environmental impact than an on-channel reservoir as the site of the off-channel reservoir can be located to minimize environmental impacts;
- Off-channel reservoirs also generally offer a lower cost for storage because the reservoir is typically sited on a small tributary which reduces the size of the dam and spillway facilities;
- Opportunities to phase construction of the facilities as water demands increase in order to lower the initial cost of the supply system; and
- A pumping schedule can be developed to produce the optimal water quality from the primary stream.

The primary disadvantage of an off-channel reservoir is the requirement for a pump station and pipeline system to divert water from the primary stream to the off-channel reservoir site, which causes operation and maintenance costs to be generally higher than operation and maintenance of an on-channel reservoir.

Several locations in the Brazos G Region offer the potential for development of an off-channel reservoir as a source of water supply (Figure 4B.13.1-1). These locations include:

1. City of Groesbeck in Limestone County;
2. Wheeler Branch Off-Channel Reservoir in Somervell County (recently constructed),
3. Peach Creek Lake in Brazos County,
4. Little River Off-Channel Reservoir in Milam County, and
5. Lake Palo Pinto Off-Channel Reservoir in Palo Pinto County
6. Coryell County Reservoir in Coryell County

Each of the reservoirs is described briefly in the following sections. A summary of all the proposed off-channel reservoir yields and project costs is shown in Table 4B.13.1-2.

Table 4B.13.1-2.
Summary of Off-Channel Reservoir Yields and Costs

Reservoir	***Yield (acft/yr)***	***Total Project Cost***	***Total Annual Cost***	***Unit Cost per acft***	***Unit Cost per 1,000 gallons***
Groesbeck (w/ Navasota River Diversion)	1,755	$10,412,000	$991,000	$565	$1.73
Wheeler Branch[1] (w/ Paluxy River Diversion)	1,800	Constructed since 2006 Plan			
Peach Creek (w/ Navasota River Diversion)	4,240	$40,643,000	$3,727,000	$879	$2.70
Little River (108”) (w/ Little River Diversion)	27,225	$137,356,000	$11,875,000	$436	$1.34
Lake Palo Pinto (w/ Lake Palo Pinto Diversion)	3,110	$25,399,000	$2,501,700	$804	$2.47
Coryell County Reservoir	3,365	$37,489,000	$3,387,000	$1,007	$3.09

[1] This project has been constructed and implemented by the Somervell County Water District (SCWD) since completion of the 2006 Plan.

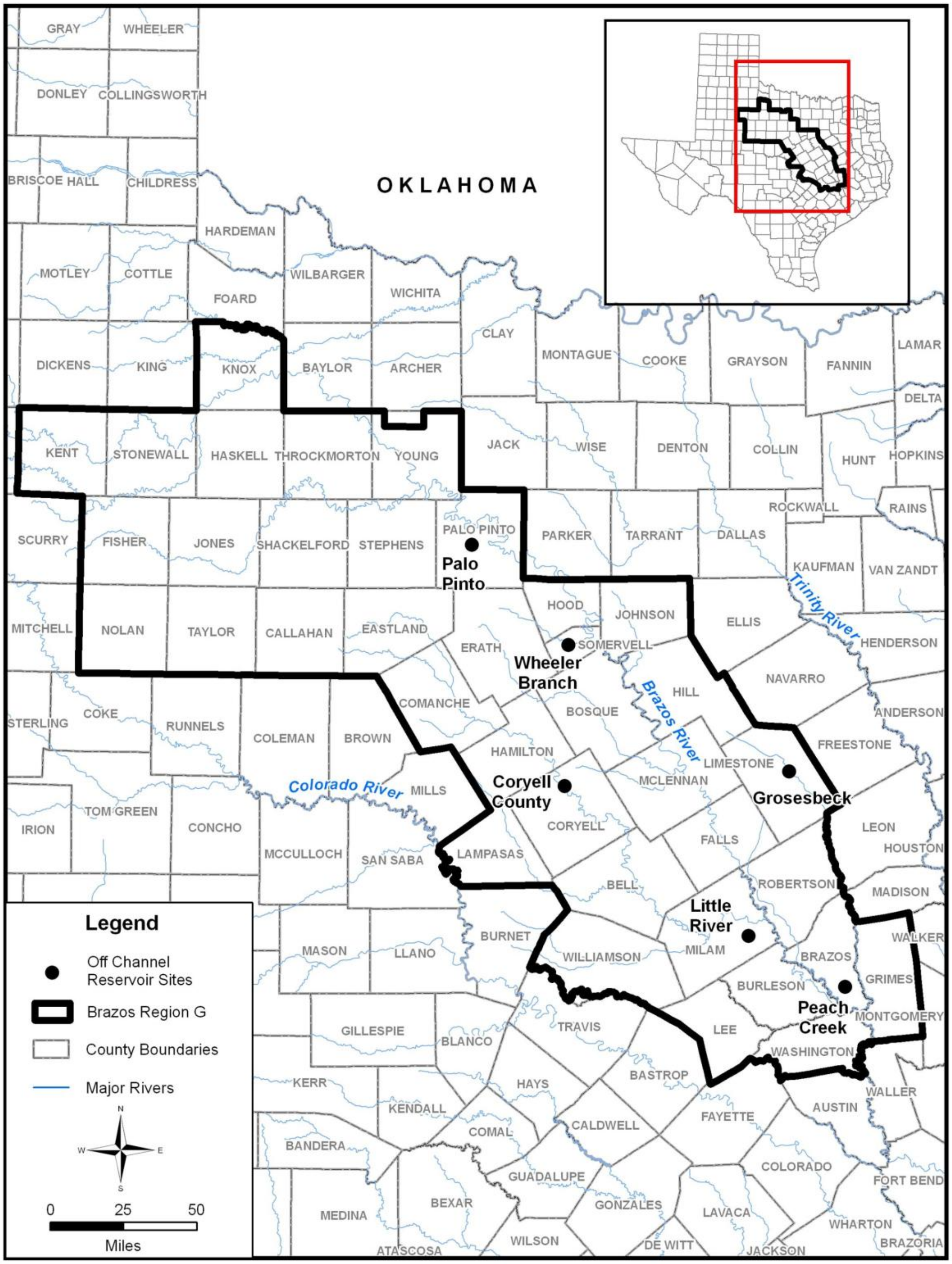

Figure 4B.13.1-1. Off-Channel Reservoir Location Map

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4B.13.2 City of Groesbeck Off-Channel Reservoir

4B.13.2.1 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 Figures 4B.13.2-1 and 4B.13.2-2. The City of Groesbeck uses surface water directly from the Navasota River and has water rights on the Navasota River that authorize diversion of 2,500 acft/yr and storage of 500 acft with a priority of June 1921. This water right is one of the more senior water rights in the Brazos River Basin.

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

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

A yield analysis of Springfield Lake was performed to determine what the reliable supply to Groesbeck would be with its diversion rights from the Navasota River and storage in Springfield Lake. The shallow depth of about four feet and effective surface area of 500 acres of Springfield Lake results in the reservoir being very inefficient. In comparison, net evaporation

[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.

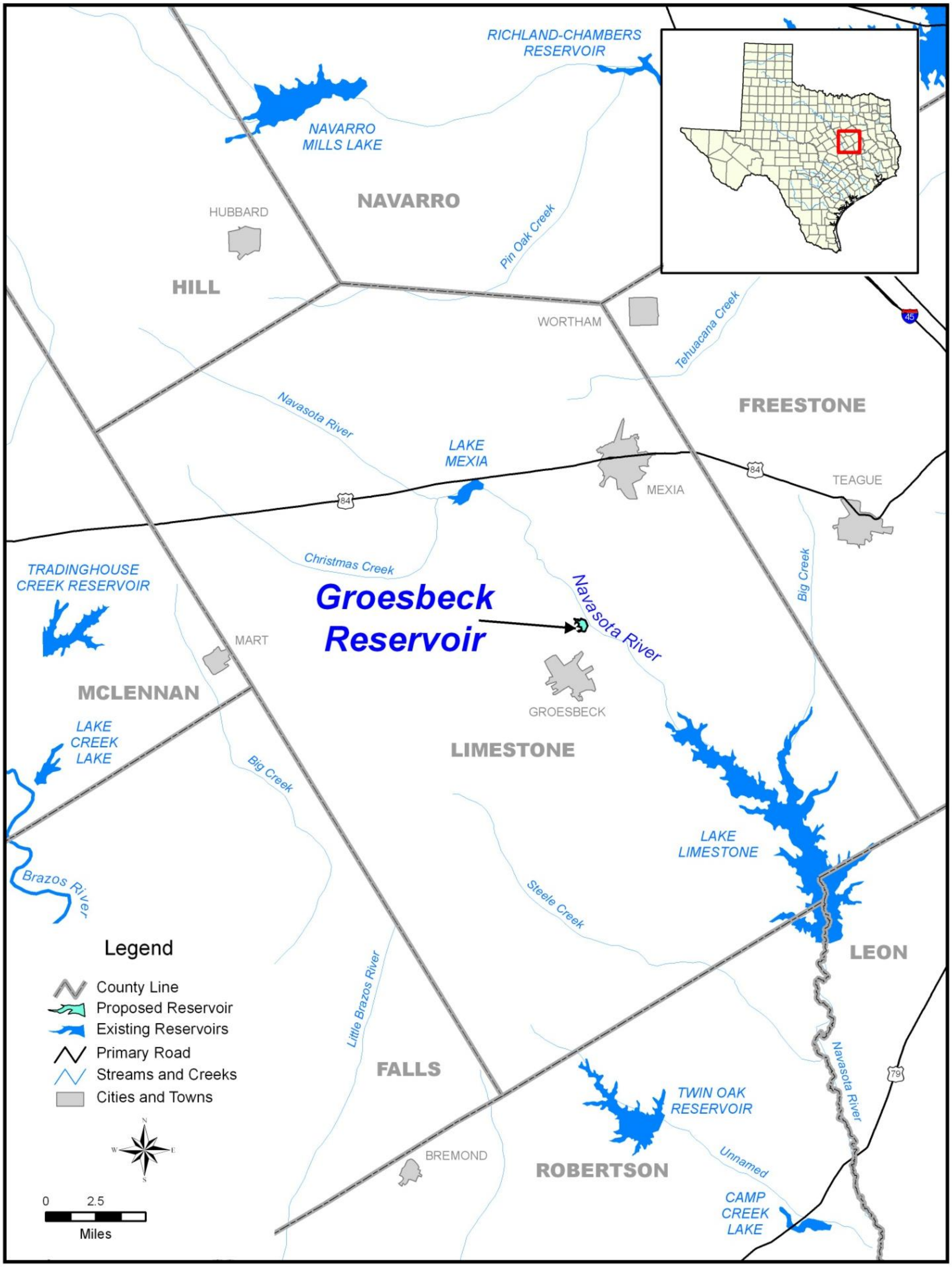


Figure 4B.13.2-1. Groesbeck Off-Channel Reservoir

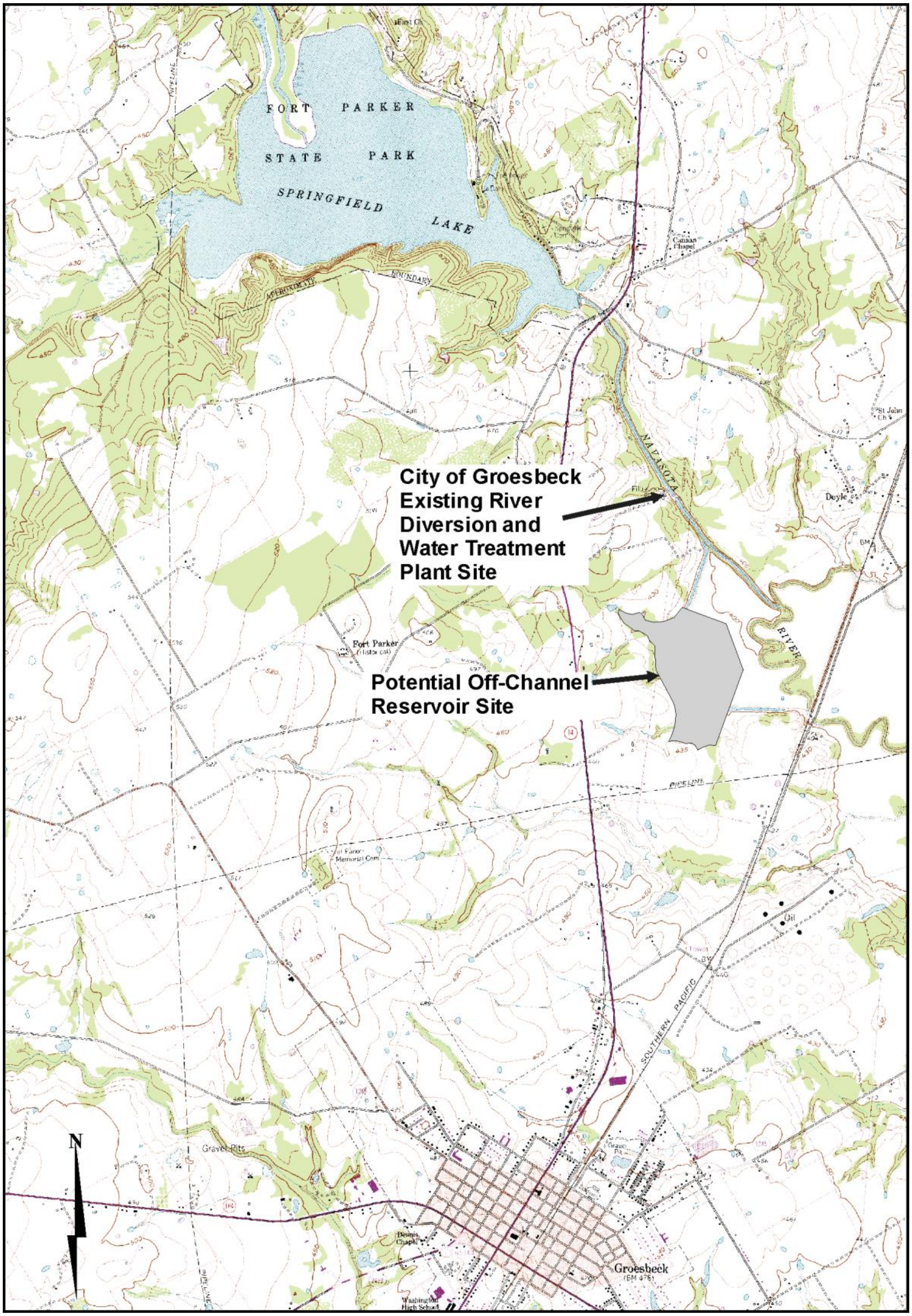


Figure 4B.13.2-2. Groesbeck Off-Channel Reservoir rates during the extended drought periods of the 1950s were as high as 4.2 feet annually, which would severely deplete the reservoir storage without any diversions by the City. The yield analysis showed that the firm yield of the City's water right, supplemented with storage from Springfield Lake, was less than 200 acft/yr. The City of Groesbeck's water use in 2000 was 782 acft. The Brazos G WAM modeling results indicate that the seniority of the city's right allows it to make a minimum annual diversion of 1,142 acft/yr. This is substantially less than the authorized diversion of 2,500 acft/yr, and there are months during the simulation when the full monthly diversion is not met. As the city's demands grow, additional storage or a supplemental supply of water will be needed.

Various alternatives to supplement the City's supply are available. These alternatives include construction of an off-channel reservoir along the Navasota River to store water for use during drought periods, development of groundwater in the Carrizo-Wilcox Aquifer east of the City, and purchase of water from Lake Limestone, located downstream of the City. The off-channel reservoir alternative appears to be an economical solution to provide the City with a firm water supply, as the storage can be developed near the City's existing river diversion and water treatment facilities. A potential off-channel storage site along the Navasota River is shown in Figure 4B.13.2-2. The dam would be an earthfill embankment that would extend approximately 1,500 feet and provide a conservation storage capacity of 2,317 acft at an elevation 420 ft-msl; the reservoir would inundate 146 surface acres. The reservoir would impound flows diverted from the Navasota River. All flows from the small watershed above the reservoir would be passed.

The city's senior water right with a diversion of 2,500 acft/yr and a priority of June 1921 would be used to divert water from the Navasota River to the off-channel reservoir. The city would then divert water from the reservoir for municipal use. This will allow an increase in the city's current minimum annual diversion of 1,142 acft/yr by providing an increase in storage of available flows for use during drought periods. Additionally, since the city's water right is senior to Lake Limestone, water would not need to be purchased from BRA to compensate for losses in Lake Limestone's yield from a subordination agreement.

4B.13.2.2 Available Yield

Water potentially available for impoundment in the proposed Groesbeck Off-Channel Reservoir was estimated using the Brazos G WAM. The model utilized a January 1940 through

December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available for diversion from the Navasota River into the Groesbeck Off-Channel Reservoir without causing increased shortages to existing downstream rights. Because this project makes the most efficient use of the existing senior water right, no instream flow restrictions were modeled as part of this right. The off-channel reservoir was also modeled such that it has no naturalized flow contributing from its own drainage area.

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 1968 to 2009 for the Navasota River at Groesbeck indicates that on average, only 7.6 days per month exceed the required streamflow of 16.2 cfs. Therefore, it is assumed that the transmission system will only operate 7.6 days per month and transfer a maximum of 237 acft/mo of flow from the Navasota River. Figure 4B.13.2-3 illustrates the annual diversion amount under firm yield conditions from the Navasota River used to refill storage. On average, 2,065 acft/yr of water would be diverted.

The calculated firm yield of the Groesbeck Off-Channel Reservoir is 1,755 acft/yr Figure 4B.13.2-4 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. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 61 percent of the time and above the Zone 3 trigger level (50 percent capacity) 86 percent of the time.

Figure 4B.13.2-5 illustrates the change in streamflows in the Navasota River caused by the project. Streamflow changes from the diversions to the off-channel reservoir are negligible for all months. From July through November, there is little or no water available in the stream. During January, March, April, June, and December, there are small increases in streamflow from the implementation of the off-channel reservoir. This increase is a result of bypassing flows in the Navasota River for diversion due to the off-channel reservoir storage being at full capacity;

whereas, the existing run-of-river water right would have diverted flows. Figure 4B.13.2-5 also illustrates the Navasota River streamflow frequency characteristics with the Groesbeck Off-Channel Reservoir in place. There is little impact on flows due to the reservoir.

4B.13.2.3 Environmental Issues

4B.13.2.3.1 Existing Environment

The City of Groesbeck Off-Channel Reservoir site in Limestone County lies in a transitional zone with the Blackland Prairies Ecological Region to the west and the Post Oak Savannah Ecological Region to the east.[2] This region is characterized by level to rolling

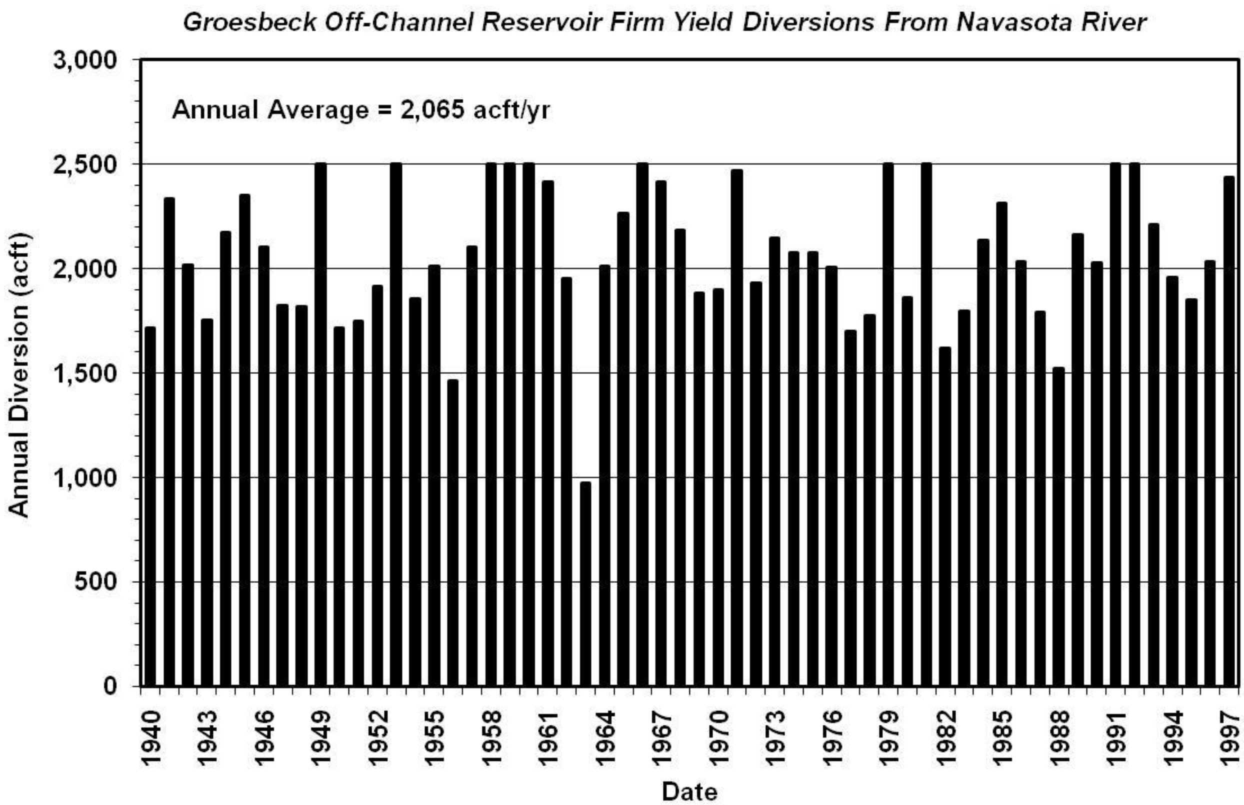
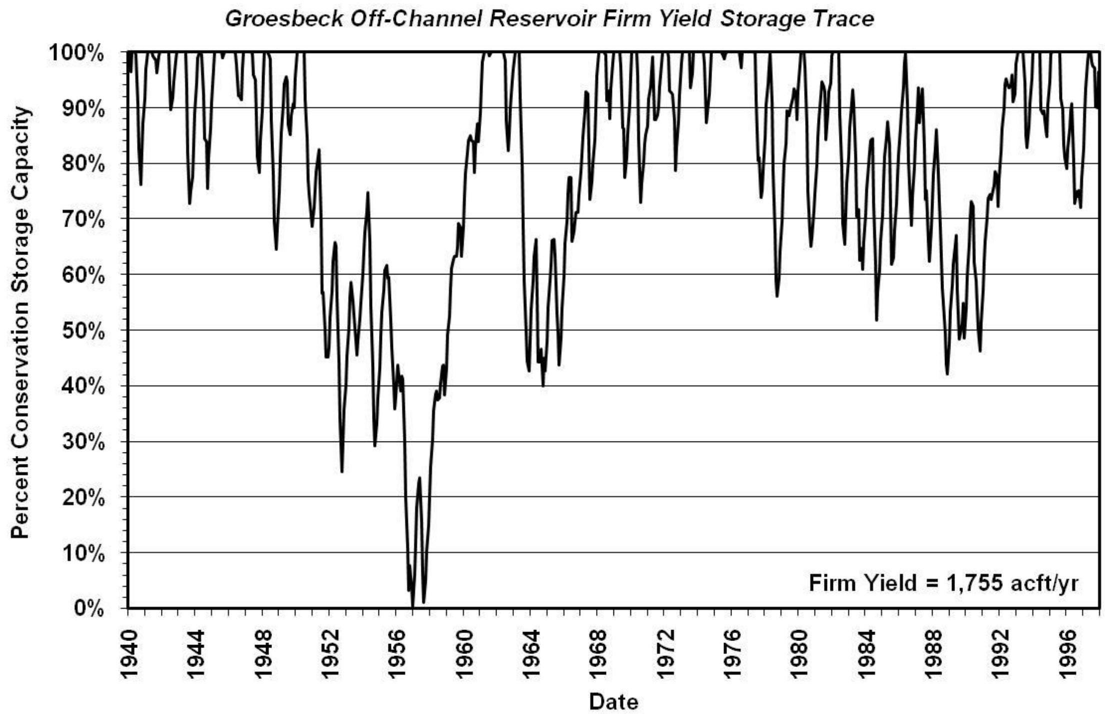


Figure 4B.13.2-3. Groesbeck Off-Channel Reservoir Firm Yield Diversions from the Navasota River

[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.



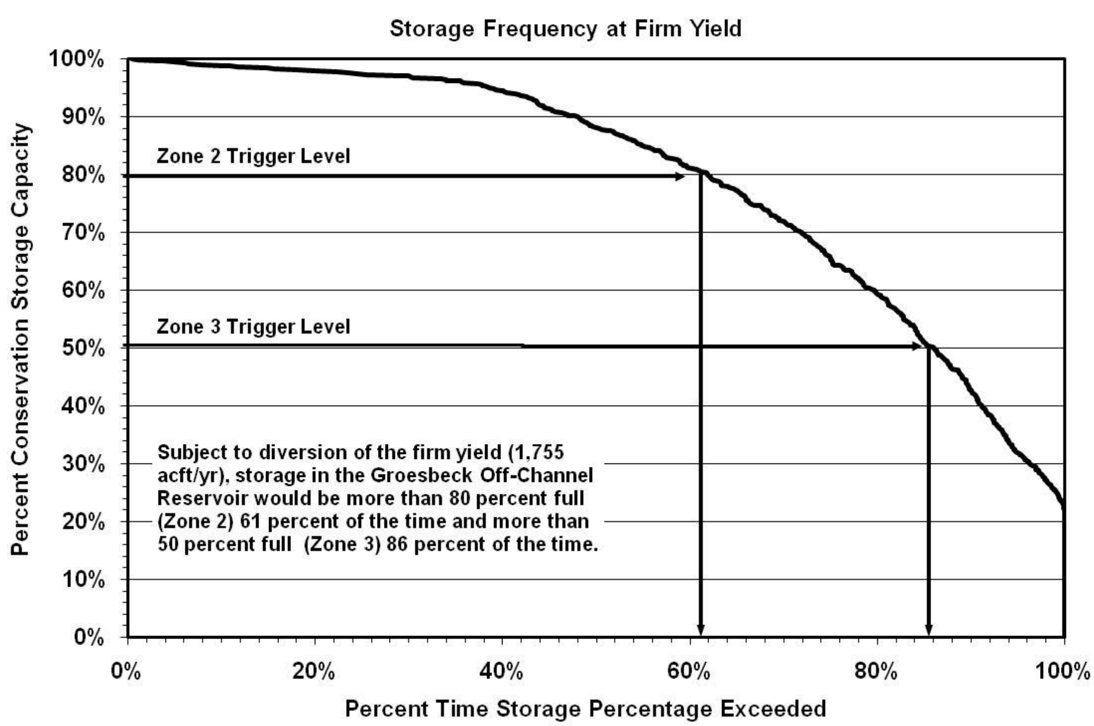
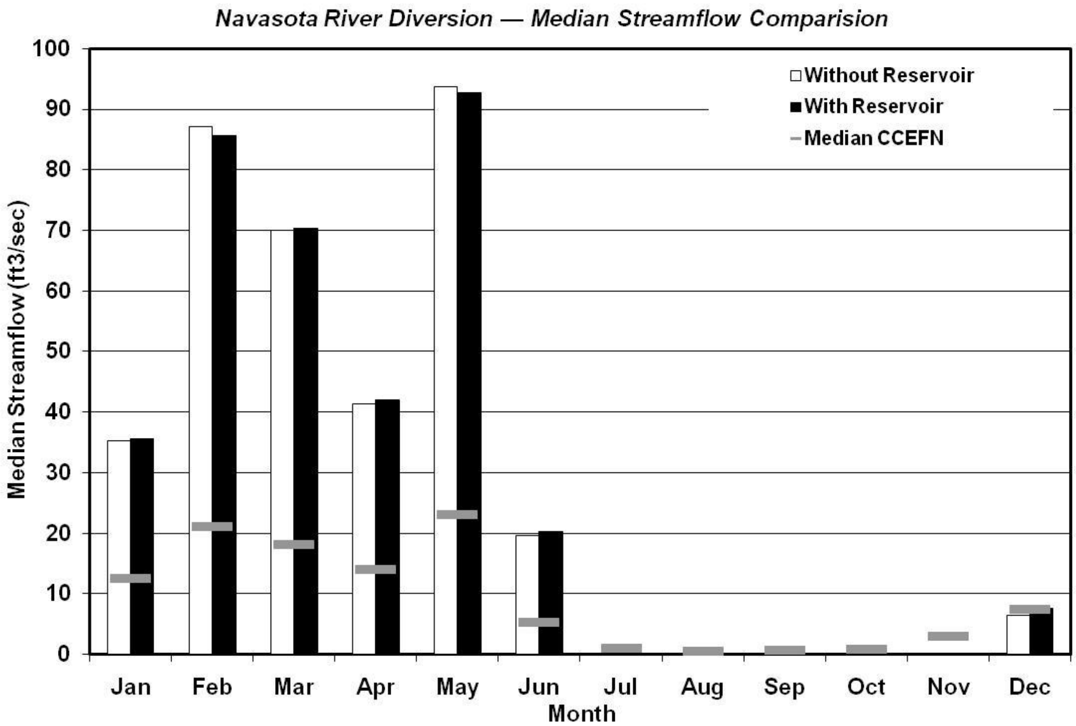


Figure 4B.13.2-4. Groesbeck Off-Channel Reservoir Storage Considerations



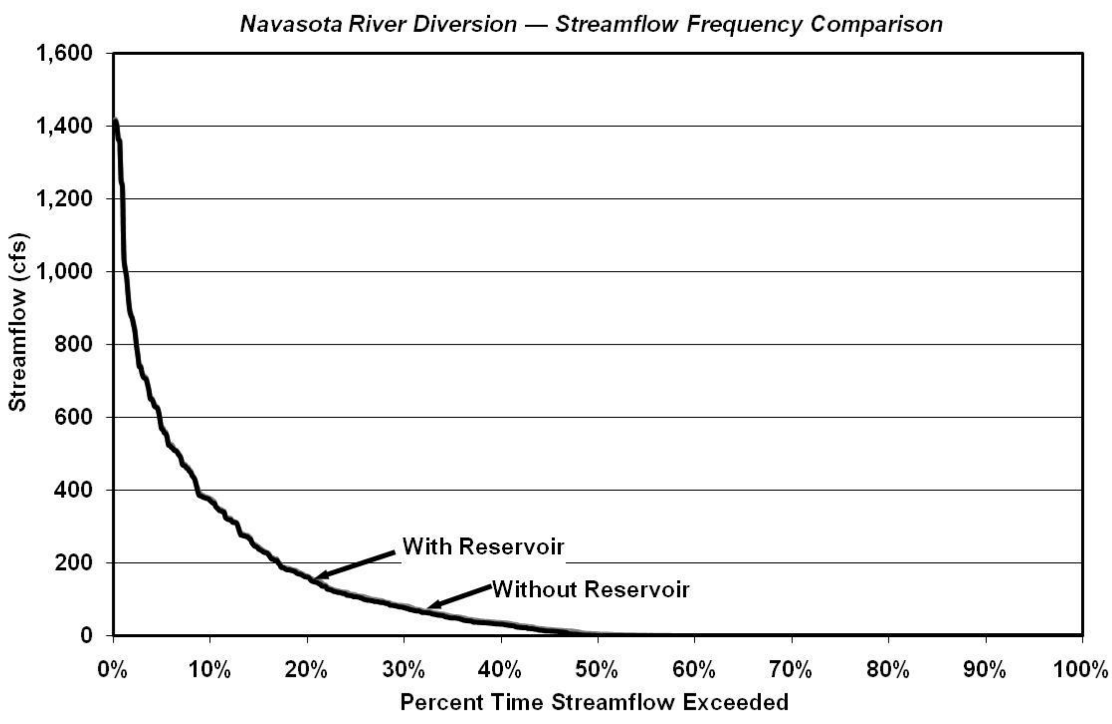


Figure 4B.13.2-5. Groesbeck Off-Channel Reservoir and Navasota River Diversion Streamflow Comparisons

topography, with interspersed grassland and woodland, with soils ranging from the deep, fertile, black soils of the Blackland Prairies region to the shallow, nearly impervious clay pan of the Post Oak Savannah region. The original physiognomy of the region varied from medium to tall broad-leaved deciduous and some needle-leaved evergreen trees to medium-tall dense grasslands with scattered open groves of deciduous trees in minor prairies.[3] The climate is characterized as subtropical humid, with warm summers. Average annual precipitation ranges between 36 and 40 inches.[4] The Carrizo-Wilcox Aquifer is the only major aquifer underlying the project area.[5]

The physiography of the region includes greensand-ironstone, undifferentiated sand and mud, terraces, and flood-prone areas. The topography ranges from steep slopes to low rolling hills and prairies, with some flat areas and local shallow depressions in flood-prone areas along waterways.[6] The predominant soil associations in the project area are Axtell-Rader and Whitesboro. The Axtell series consists of very deep, moderately well drained, very slowly permeable soils on Pleistocene terraces. The soil formed in slightly acid to alkaline clayey sediments. Slopes are dominantly 0 to 5 percent, but range up to 12 percent.[7,8]

Three major vegetation types occur within the general vicinity of the project: Elm-Hackberry (*Ulmus-Celtis*) Woods, Other Native and/or Introduced Grasses, and crops.[9] 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. 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.),

[3] Telfair, R.C., "Texas Wildlife Resources and Land Uses," University of Texas Press, Austin, Texas, 1999.
[4] Larkin, T.J., and G.W. Bomar, "Climatic Atlas of Texas," Texas Department of Water Resources, Austin, Texas, 1983.
[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.
[6] 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.
[7] Schappert, Phil., *The Stengl-Lost Pines Biological Station Soil Profiles*, http://www.sbs.utexas.edu/philjs/Stengl/soil/axtell.html, 1998.
[8] Baker, F.E., *Soil Survey of Bastrop County, Texas*, Soil Conservation Service, United States Department of Agriculture, Washington, D.C., 1979.
[9] 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.

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*). Commonly associated plants of Other Native and/or Introduced Grasses are mixed native or introduced grasses and forbs on grassland sites or mixed herbaceous communities resulting from the clearing of woody vegetation, which are subject to change due to brushy re-growth. 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.

4B.13.2.3.2 Potential Impacts

4B.13.2.3.2.1 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. The difference in variability of monthly flow conditions at the proposed project site would be a factor of approximately 2.0 (measured by comparing sample variances of all monthly flows from 1940-1997 and predicted flows over that same time period with the project in place; sample variance without project =7,159; sample variance with project =3,536). The difference in variability of monthly flow values in the Navasota River diversion site would be negligible (sample variance without project =1.69 x 10^8; sample variance with project =1.70 x 10^8). 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 February and May and would be less than 1.45 cfs, as shown in Table 4B.13.2-1. All other months would have little or no reduction in median monthly flow at the diversion. Because low-flows occur frequently without the project in place, the addition of this project would have minimal impact on these low-flow conditions. At the Navasota River diversion site, the 85 percent exceedance values would be 0.003 cfs without the project and zero cfs without the project.

Table 4B.13.2-1.
Median Monthly Streamflow: Navasota River Diversion Site

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	35.18	35.52	-0.33	-1%
February	87.14	85.69	1.45	2%
March	70.01	70.40	-0.39	-1%
April	41.35	41.95	-0.60	-1%
May	93.71	92.70	1.02	1%
June	19.56	20.24	-0.68	-3%
July	0.01	0.00	0.01	100%
August	0.00	0.00	0.00	0%
September	0.01	0.00	0.01	100%
October	0.02	0.00	0.02	100%
November	0.04	0.03	0.04	100%
December	6.36	7.57	-1.20	-19%

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.

4B.13.2.3.2.2 Threatened & Endangered Species

A total of 22 species are designated for Limestone County which are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern. This group includes 4 reptiles, 7 birds, 3 mammals, 5 mussels, 1 fish species and 2 plant species (Table 4B.13.2-2). Four bird species federally-listed as threatened or endangered could possibly occur within the project area. These include the interior least tern

Table 4B.13.2-2.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the City of Groesbeck Off-Channel Reservoir Site, Limestone County

Scientific Name	***Common Name***	***Federal/State Status***	***Potential Occurrence***
Birds			
Falco peregrinus anatum	AmericanPeregrine Falcon	DL/T	Migrant
Haliaeetus leucocephalus	Bald Eagle	DL/T	Resident
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*
Plegadis chihi	White-faced Ibis	SOC/T	Migrant
Grus Americana	Whooping Crane	LE/E	Migrant
Mycteria Americana	Wood Stork	T	Migrant
Fishes			
Notropis buccula	Smalleye Shiner	C/SOC	X
Mammals			
Canus rufus	Red wolf	LE/E	Historic
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Mollusks			
Quadrula mitchelli	False spike mussel	T	X
Tritogonia verrucosa	Pistolgrip	SOC	X
Arcidens confragosus	Rock pocketbook	SOC	X
Quadrula houstonensis	Smooth pimpleback	T	X
Truncilla macrodon	Texas fawnsfoot	T	X
Reptiles			
Macrochelys temminckii	Alligator snapping turtle	T	X
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X
Plants			
Eriocaulon koernickianum	Small-headed pipewort	SOC	X
Spiranthes parksii	Navasota ladies'-tresses	LE/E	X

X = Occurs in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be Delisted (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-Delisted Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: TPWD, *Annotated County List of Rare Species for Limestone County,* Updated 2/2/2010. TPWD Texas Wildlife Diversity Database (2009), United States Fish and Wildlife Service (USFWS), *Federally-listed as Threatened and Endangered Species of Texas*, August 2, 2010.

(*Sterna antillarum athalassos*), and whooping crane (*Grus americana*). Although the interior least tern, and whooping crane are seasonal migrants that could pass through the project area, they are not anticipated to be directly affected by the proposed reservoir.

A search of the Texas Natural Diversity Database[10] revealed the documented occurrence of the bald eagle within the vicinity of the proposed Groesbeck Off-Channel Reservoir (as noted on representative 7.5-minute quadrangle map(s) that include the project site). These data are not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or 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.

4B.13.2.3.2.3 Wildlife Habitat

Approximately 146 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 107 acres of Grasses/Forbs, and 39 acres of Elm/Hackberry Woods.

A number of vertebrate species could occur within the City of Groesbeck Reservoir site as indicated by county occurrence records.[11] These include 3 species of salamanders, 14 species of frogs and toads, 10 species of turtles, the American alligator, 11 species of lizards and skinks, and 19 species of snakes. Additionally, 54 species of mammals could occur within the site or surrounding region[12] as well as 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.

4B.13.2.3.2.4 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

[10] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, September 10, 2009.
[11] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," Texas Cooperative Wildlife Collection, 1998.
[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.

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 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).

4B.13.2.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and 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.

4B.13.2.4 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 15.7 cfs;
- 5,280 feet of raw water pipeline (24-inch diameter) from the pump station to the off-channel reservoir;
- Pump station at the off-channel reservoir site with a capacity of 4 cfs;
- 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 4B.13.2-3. The proposed Groesbeck Off-Channel Reservoir project would cost approximately $10.4 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 $991,000. This includes annual debt service, operation and maintenance, and pumping energy costs.

The total annual cost reported in the 2006 Water plan was $866,000; the current plan costs are estimated at $991,000. The increase in 2011 estimated costs are due to the higher pumping energy costs and decrease in debt service length from 30 years to 20 years.

The annual unit cost of water has decreased significantly from $912 per acft ($2.80 per 1,000 gallons) in the 2006 plan to $565 per acft ($1.73 per 1,000 gallons) in the current plan. The decrease in unit cost is due to the increase of yield from the project made possible by assuming that the City's senior diversion right can be used to make flows available from the Navasota River.

4B.13.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.13.2-4, and the option meets each criterion.

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.

Table 4B.13.2-3
Cost Estimate Summary for
Groesbeck Off-Channel Reservoir
(September 2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Dam and Reservoir (Conservation Pool 2317 acft, 146 acres, 420 ft. msl)[1]	$3,192,000
Intake and Pump Station at Navasota River Diversion Site (10 MGD)	$1,631,000
Transmission Pipeline to Off-Channel Reservoir (24 in dia., 5,280 ft)	$407,000
Transmission Pump Station at Off-Channel Reservoir (3 MGD)	$1,063,000
Transmission Pipeline to WTP (12 in dia., 3,500 ft)	$171,000
Total Capital Cost	**$6,464,000**
Engineering, Legal Costs and Contingencies	$2,233,000
Environmental & Archaeology Studies and Mitigation	$461,000
Land Acquisition and Surveying (155 acres)	$482,000
Interest During Construction (2 years)	$772,000
Total Project Cost	**$10,412,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$423,000
Reservoir Debt Service (6 percent, 40 years)	$370,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$73,000
Dam and Reservoir	$48,000
Pumping Energy Costs (857,942 kW-hr @ 0.09 $/kW-hr)[2]	$77,000
Total Annual Cost	**$991,000**
Available Project Yield (acft/yr)	1,755
Annual Cost of Water ($ per acft)	$565
Annual Cost of Water ($ per 1,000 gallons)	$1.73

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

[2] Includes the power cost for pumping water from the Navasota River to the off-channel reservoir and water from the off-channel reservoir to the water treatment plant.

Table 4B.13.2-4
Evaluations of Groesbeck Off-Channel Reservoir Option to Enhance Water Supplies

Impact Category	***Comment(s)***
A. Water Supply 1. Quantity 2. Reliability 3. Cost	 1. Sufficient to meet needs 2. High reliability 3. Reasonable (moderate to high)
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries 5. Threatened and Endangered Species 6. Wetlands	 1. Negligible impact 2. Negligible impact 3. Low impact 4. Negligible impact 5. Low impact 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

4B.13.2.5.1 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.

4B.13.2.5.2 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.

4B.13.2.5.3 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.

4B.13.3 Wheeler Branch Off-Channel Reservoir

4B.13.3.1 Description of Option

The Wheeler Branch Off-Channel Reservoir was a proposed new reservoir on the Wheeler Branch, a tributary of the Paluxy River, about two miles north of the City of Glen Rose in Somervell County (Figure 4B.13.3-1) for the 2006 Brazos G Regional Water Plan and the 2007 State Water Plan. Since the completion of the 2006 Plan, this project has been constructed and implemented by the Somervell County Water District (SCWD).

The project impounds water from the Wheeler Branch watershed as well as diverts water from the Paluxy River during periods of flow in excess of downstream needs. The reservoir has a conservation storage capacity of 4,118 acft and a drainage area of 1.6 square miles. Waters from the Paluxy River are transported into the reservoir through a 36-inch pipeline and pump station system that has a capacity of 50 cfs. The diversion point on the Paluxy River has a drainage area of 428 square miles.

The water right for this reservoir (Permit 5744) was approved by the TCEQ on September 11, 2002 with a priority date of June 17, 2001.[13] This water right authorizes an annual diversion of up to 5,000 acft from the Paluxy River at a maximum rate of 50 cfs and a diversion of 2,000 acft/yr from the reservoir for municipal use. SCWD has an agreement with the Brazos River Authority that subordinates the Authority's water right in Lake Whitney to the Wheeler Branch Off-Channel Reservoir. The calculated firm yield, from the 2006 Brazos G Plan, of the Wheeler Branch Off-Channel Reservoir is 1,800 acft/yr. The yield is constrained by the capacity of a 36-inch diameter pipeline.

The 2006 Plan was amended to include a treatment and transmission system for the Somervell County Water District to utilize supplies from the reservoir (see Volume II, Section 4B.21).

[13] TCEQ Database of Water Rights as of September 24, 2004.

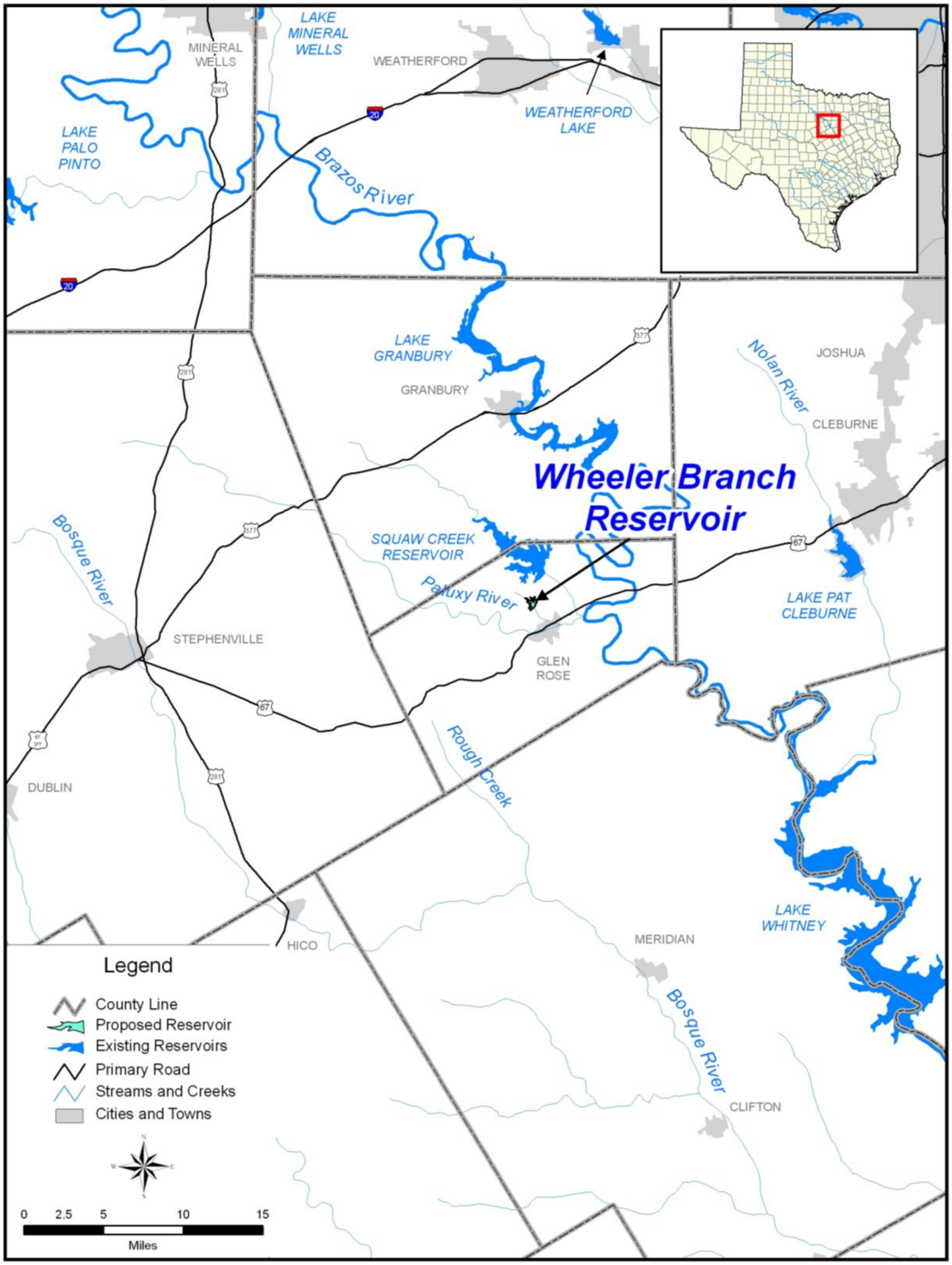


Figure 4B.13.3-1. Wheeler Branch Off-Channel Reservoir

4B.13.4 Peach Creek Off-Channel Reservoir

4B.13.4.1 Description of Option

The proposed Peach Creek Off-Channel Reservoir is located on Peach Creek, a tributary of the Navasota River in the Brazos County, about 10 miles southeast of the Bryan-College Station area (Figure 4B.13.4-1). The total reservoir storage capacity at a normal pool elevation of 240 feet-msl is 14,641 acft and the reservoir will inundate approximately 1,045 acres of land. The contributing drainage area is approximately 17 square miles. The project is proposed with a diversion from the Navasota River through a 60-inch pipeline and 1,400 HP pump station with a 100 cfs capacity to supplement local runoff from the Peach Creek watershed. The Navasota River diversion has a drainage area of 1,933 square miles. The reservoir is a potential source of water supply for Brazos County.

4B.13.4.2 Available Yield

Water potentially available for impoundment in the proposed Peach Creek Off-Channel Reservoir was estimated using the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available for diversion from the Navasota River into the Peach Creek Off-Channel Reservoir without causing increased shortages to downstream rights. Firm yield was computed subject to the reservoir and Navasota River diversion having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H).

The calculated firm yield of the Peach Creek Off-Channel Reservoir is 4,240 acft/yr. This yield is obtained by assuming that only unappropriated flows in the Navasota River are available for pumping at a maximum rate of 100 cfs through a 60-inch diameter pipeline. The firm yield of the reservoir may increase if water is purchased from Lake Limestone to supplement local runoff with a larger pumping capacity. The 2006 Region G plan reported a firm yield of 3,980 acft/yr.

The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the off-channel reservoir and the Navasota River diversion are shown in Tables 4B.13.4-1 and 4B.13.4-2.

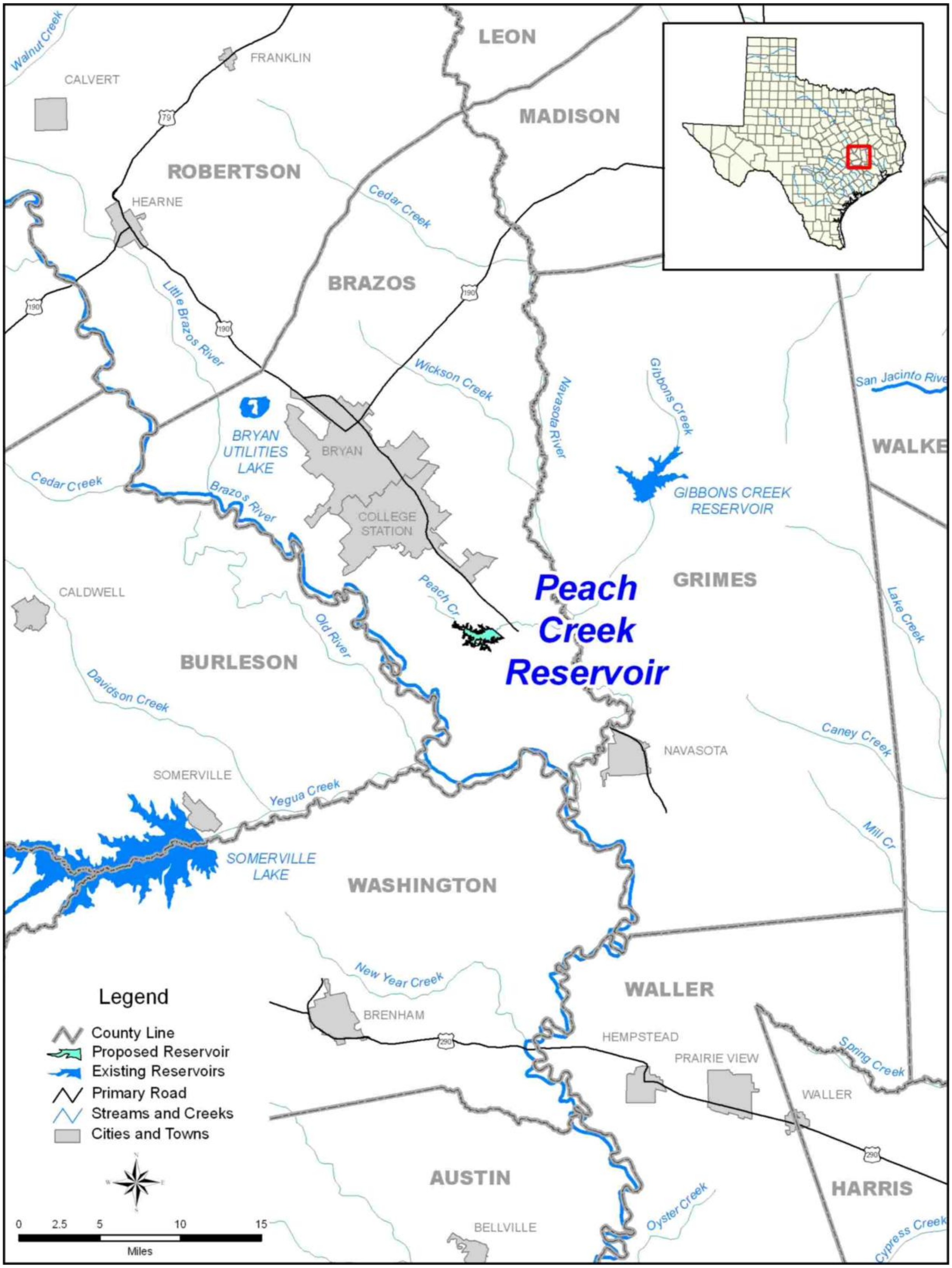


Figure 4B.13.4-1. Peach Creek Reservoir

Table 4B.13.4-1. Daily Natural Streamflow Statistics for the Peach Creek Off-Channel Reservoir

Month	***Median Flows - Zone 1 Pass Through Requirements (cfs)***	***25th Percentile Flows - Zone 2 Pass Through Requirements (cfs)***
January	6.4	2.4
February	7.0	2.8
March	6.7	2.3
April	5.2	1.9
May	7.6	0.9
June	6.5	1.8
July	3.8	1.6
August	1.8	0.7
September	1.9	0.7
October	1.4	0.4
November	3.4	1.2
December	4.1	1.6
Zone 3 (7Q2) Pass-Through Requirement (cfs):		0.5

Table 4B.13.4-2. Daily Natural Streamflow Statistics for the Navasota River Diversion

Month	***Median Flows - Zone 1 Pass Through Requirements (cfs)***	***25th Percentile Flows - Zone 2 Pass Through Requirements (cfs)***
January	294	132
February	390	163
March	351	124
April	320	126
May	422	115
June	216	69
July	127	53
August	60	21
September	69	18
October	61	21
November	132	55
December	226	89
Zone 3 (7Q2) Pass-Through Requirement (cfs):		8

Figure 4B.13.4-2 illustrates the simulated Peach Creek Off-Channel Reservoir storage contents for the 1940 to 1997 historical period, subject to the firm yield of 4,240 acft/yr and based on delivery of Navasota River diversions via a 60-inch pipeline. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 81 percent of the time and above the Zone 3 trigger level (50 percent capacity) 96 percent of the time.

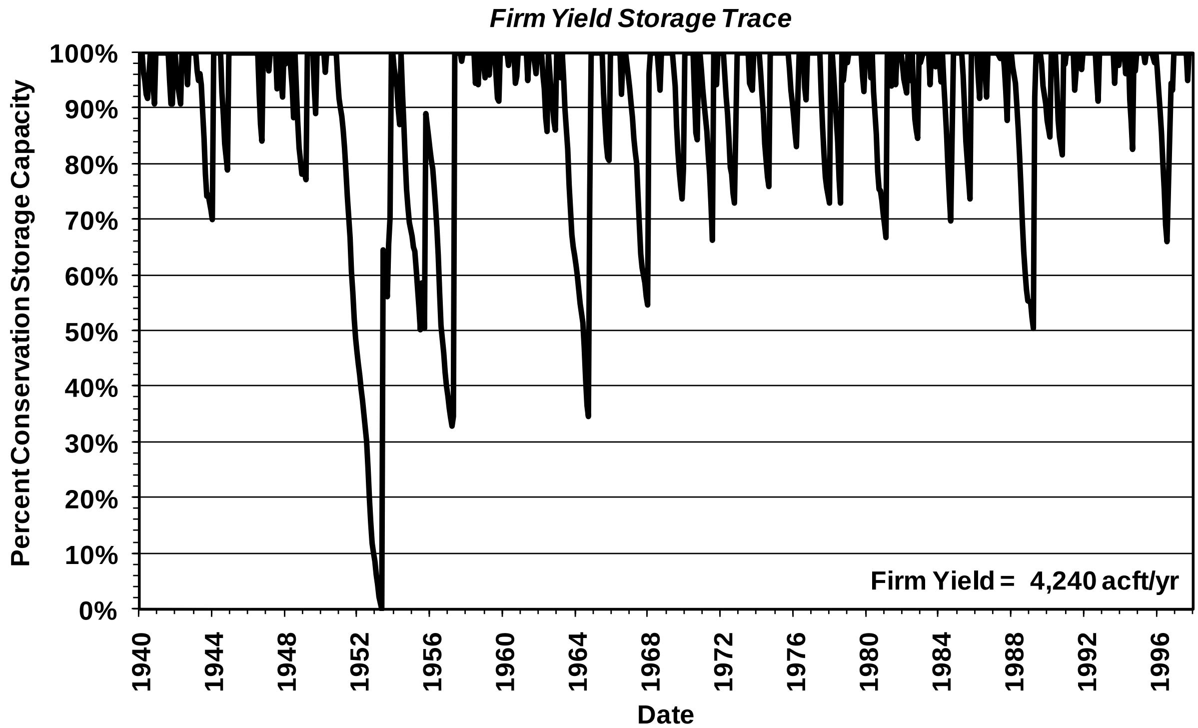
Figure 4B.13.4-3 illustrates the changes in Peach Creek and Navasota River streamflows caused by the project. There is about a 50 percent reduction in median streamflows in Peach Creek and minimal changes in the Navasota River streamflow due to the project. Figure 4B.13.4-3 also illustrates the streamflow frequency characteristics with the Peach Creek Reservoir in place.

4B.13.4.3 Environmental Issues

4B.13.4.3.1 Existing Environment

The Peach Creek Off-Channel Reservoir site in Brazos County is within the Post Oak Savannah Ecological Region.[14] This region is characterized as a narrow, highly irregular oak belt that consists of intermingled forest, woodland, and savannah. It is located between the East Texas Pine-Hardwood Forest to the east, Blackland Prairies to the west, and the Coastal Prairie and South Texas Brushlands to the south. The original physiognomy of the region included medium to tall broad-leaved deciduous trees and some needle-leaved evergreens. In the northern and eastern areas, these trees are interspersed with open areas of grasses and forbs, however in the southern and western areas, areas of trees are often found clumped or in solid stands. The shallow, nearly impervious clay pan of the Post Oak Savannah region causes the soil to be arid.[15] The climate within this area is characterized as subtropical humid, with warm summers and an average annual precipitation which ranges between 36 and 40 inches.[16] Aquifers which underlie the area include the Queen City, Sparta, and Yegua Jackson minor aquifers. A major aquifer, the Gulf Coast, lies south of the project area but does not underlie it.[17]

[14] 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
[15] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.
[16] Larkin, T.J., and G.W. Bomar, *Climatic Atlas of Texas*, Texas Department of Water Resources, Austin, Texas, 1983.
[17] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.



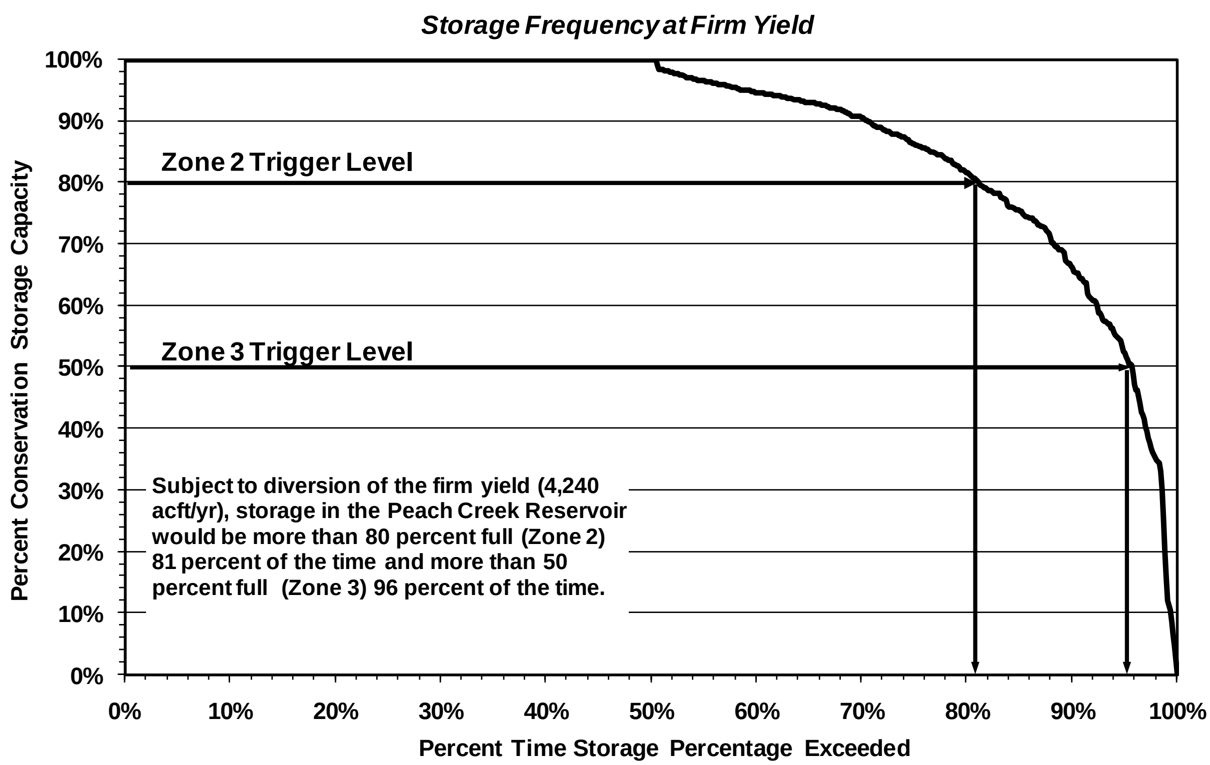
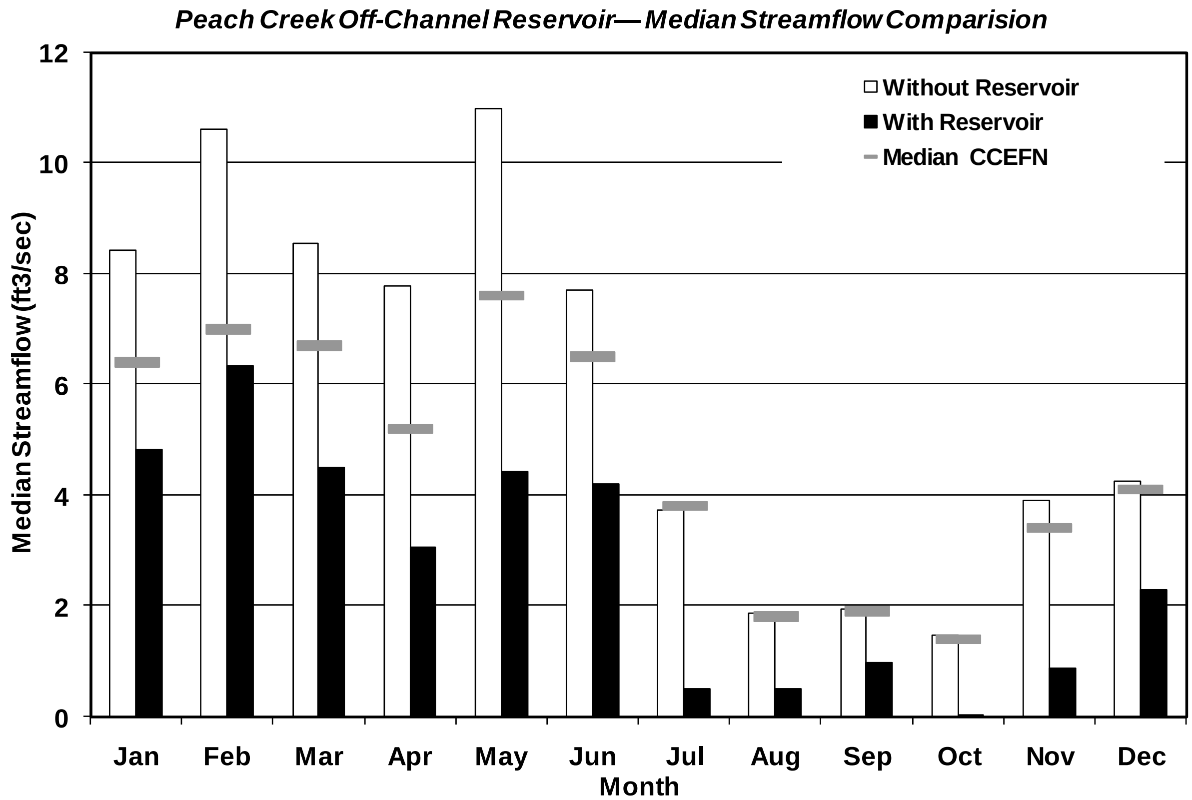


Figure 4B.13.4-2. Peach Creek Off-Channel Reservoir Storage Considerations



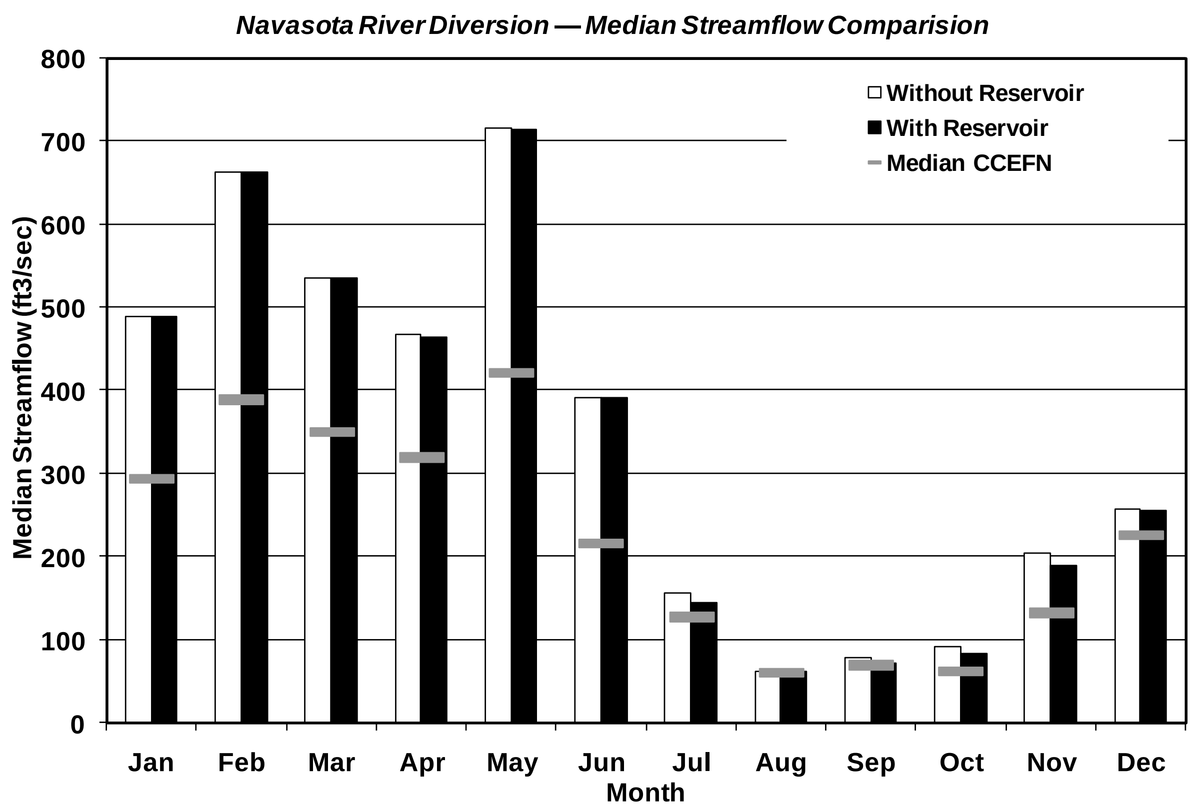
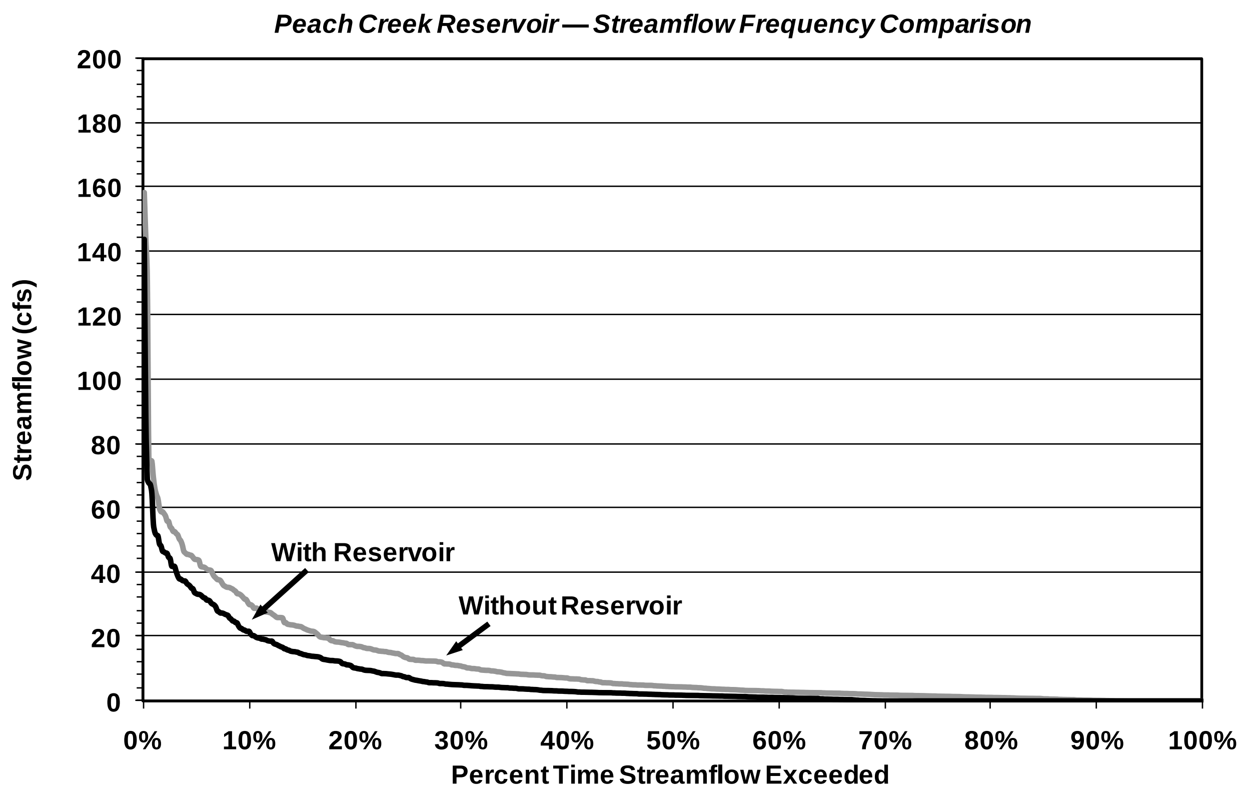


Figure 4B.13.4-3. Peach Creek Off-Channel Reservoir and Navasota River Diversion Streamflow Comparison



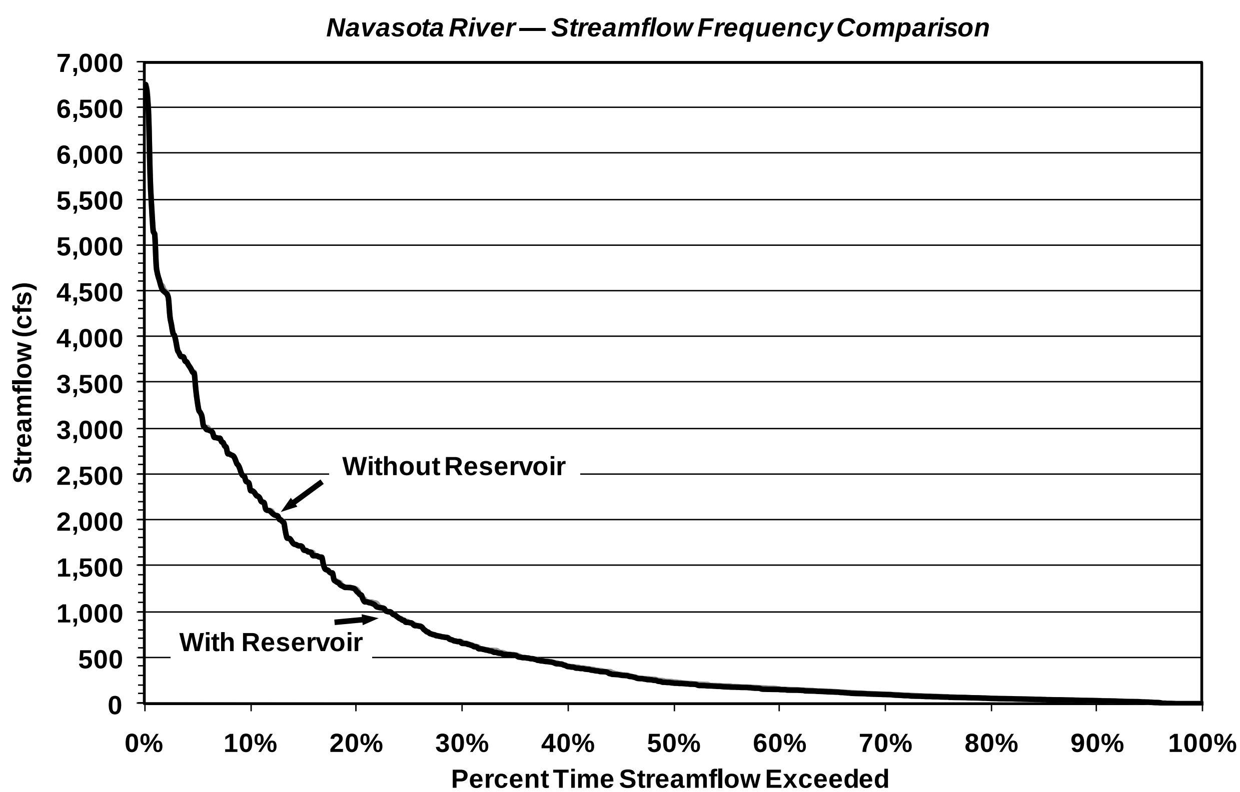


Figure 4B.13.4-3. Peach Creek Off-Channel Reservoir and Navasota River Diversion Streamflow Comparison (Concluded)

The physiography of the region includes sand and mud with lignite and bentonite, and flood-prone areas. The topography is low to moderately rolling with local shallow depressions in flood-prone areas along waterways.[18] The predominant soil associations in the project area are the Burlewash-Singleton and Sandow associations. Burlewash-Singleton soils are gently sloping to moderately sloping, moderately deep, loamy soils that are well drained or moderately well drained and occur in oak savannahs. Sandow soils are nearly level, very deep, loamy soils that are moderately well drained and occur in frequently flooded areas on bottom land.[19]

Three major vegetation types which occur within the general vicinity of the proposed project include: Post Oak (*Quercus stellata*) Woods/Forest, Water Oak (*Q. nigra*)–Elm (*Ulmus* sp.) –Hackberry (*Celtis* sp.) Forest, and crops[20]. 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. Areas of Post Oak Woods/Forest could include the following commonly associated plants: blackjack oak (*Quercus marilandica*), eastern redcedar (*Juniperus virginiana*), mesquite (*Prosopis glandulosa*), black hickory (*Carya texana*), live oak (*Q. virginiana*), sandjack oak (*Q. incana*), cedar elm (*Ulmus crassifolia*), hackberry *(Celtis* spp.), yaupon (*Ilex vomitoria*), poison oak (*Toxicodendron pubescens*), American beautyberry (*Callicarpa americana*), hawthorn (*Crataegus* spp.), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus* spp.), coralberry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium* var. *scoparium*), silver bluestem (*Bothriochloa saccharoides*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida* spp.), spranglegrass (*Chasmanthium sessiliflorum*), and tickclover (*Desmodium* spp.). Water Oak-Elm-Hackberry Forest could include the following commonly associated plants: cedar elm, American elm (*Ulmus americana*), willow oak (*Quercus phellos*), southern red oak (*Q. falcata*), white oak (*Q. alba*), black willow (*Salix nigra*), cottonwood (*Populus deltoides*), red ash (*Fraxinus pennsylvanica*), sycamore (*Platanus occidentalis*), pecan (*Carya illinoinensis*), bois d'arc (*Maclura pomifera*), flowering dogwood

[18] 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.
[19] Natural Resources Conservation Service (NRCS), *Soil Survey of Brazos County, Texas*, United States Department of Agriculture, in cooperation with Texas Agricultural Experiment Station, 2002.
[20] 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.

(*Cornus florida*), dewberry, coralberry, dallisgrass (*Paspalum dilatatum*), switchgrass (*Panicum virgatum*), rescuegrass (*Bromus catharticus*), bermudagrass (*Cynodon dactylon*), eastern gamagrass (*Tripsacum dactyloides*), Virginia wildrye (*Elymus virginicus*), Johnsongrass (*Sorghum halepense*), giant ragweed (*Ambrosia trifida*), and Leavenworth eryngo (*Eryngium leavenworthii*). 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.

4B.13.4.3.2 Potential Impacts

4B.13.4.3.2.1 Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated in two locations, at the proposed reservoir site and in the Navasota River where water will be pumped and diverted to the project site. The potential impacts of this project would differ in the two locations. In the diversion site on the Navasota River, very little impact is predicted in terms of a reduction in flow variability or reduction in the quantity of median monthly flows. At the proposed reservoir site, there would be lower flow variability and substantial reductions in quantity of median monthly flows. The difference in variability of monthly flow conditions at the proposed project site would be a factor of approximately 1.7 (measured by comparing sample variances of all monthly flows from 1940-2004 and predicted flows over that same time period with the project in place; sample variance without project =9.85 x 10^5; sample variance with project =5.90 x 10^5) while the difference in variability of monthly flow values in the Navosota River diversion site would be negligible (sample variance without project =4.413 x 10^9; sample variance with project =4.412 x 10^9). 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.

The reductions in median monthly flows at the project site would range from 1 cfs (50 percent) in September to 6.5 cfs (60 percent) in May, as shown in Table 4B.13.4-3. The greatest reductions (>50 percent) would occur in April, May, and July through November. February has the lowest percent reduction (40 percent) at the proposed reservoir site. In the Navasota River, the reduction in median monthly flows would range from 0 cfs in January through March, June,

Table 4B.13.4-3.
Median Monthly Streamflow:
Peach Creek Reservoir

Month	***Without Project (cfs)***	***With Project (cfs)***	***Difference (cfs)***	***Percent Reduction***
January	8.4	4.8	3.6	43%
February	10.6	6.3	4.3	40%
March	8.5	4.5	4.0	47%
April	7.8	3.1	4.7	61%
May	11.0	4.4	6.5	60%
June	7.7	4.2	3.5	46%
July	3.7	0.5	3.2	87%
August	1.9	0.5	1.4	73%
September	1.9	1.0	1.0	50%
October	1.5	0.0	1.4	98%
November	3.9	0.9	3.0	78%
December	4.2	2.3	2.0	46%

Table 4B.13.4-4.
Median Monthly Streamflow:
Diversion Site in Navasota River

Month	***Without Project (cfs)***	***With Project (cfs)***	***Difference (cfs)***	***Percent Reduction***
January	489.2	489.2	0.0	0%
February	662.4	662.4	0.0	0%
March	534.2	534.2	0.0	0%
April	466.9	463.0	3.9	1%
May	716.2	714.4	1.8	0%
June	391.1	391.1	0.0	0%
July	156.4	144.4	12.1	8%
August	61.0	61.0	0.0	0%
September	77.3	70.8	6.5	8%
October	90.6	83.1	7.5	8%
November	204.5	188.4	16.1	8%
December	256.6	255.7	0.9	0%

and August to 16.1 cfs (8 percent) in November, as shown in Table 4B.13.4-4. There would be virtually no reduction in seven months of the year. July and September through November would have consequential decreases in median monthly flow. This project would also result in a higher frequency of low-flow conditions at the project site. Without the project, the monthly flows would be less than 0.68 cfs only 15 percent of the time (85 percent exceedance value), but the monthly flows would be 0 cfs for 30 percent of the time with the project in place. The 85 percent exceedance value would be 46 and 44 cfs in the Navasota River without and with the project, respectively. These reductions in flow at the project site would have substantial impacts on the instream biological community, particularly during the summer months when streams are more susceptible to a reduction in water quality conditions (e.g., high temperatures and high nutrient growth).

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

4B.13.4.3.2.2 Threatened & Endangered Species

A total of 31 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.13.4-5). This group includes one amphibian, three reptiles, three insects, eight birds, three mammals, three fish species, five mollusk species, and five plant species. Two bird species, one amphibian, two mammal species, and one plant species federally-listed as threatened or endangered could occur (or historically occurred) in the project area. These include the interior least tern (*Sterna antillarum athalassos*), whooping crane (*Grus americana*), Houston toad (*Bufo houstonensis*), Louisiana black bear (*Mustela nigripes*), red wolf (*Canis rufus*), and Navasota ladies'-tresses (*Spiranthes parksii*). The interior least tern and whooping crane are seasonal migrants that could pass through the project area, but would not

Table 4B.13.4-5.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the Peach Creek Off-Channel Reservoir Site, Brazos County

Scientific Name	*Common Name*	*Federal/State Status*	*Potential Occurrence*
Amphibians			
Bufo houstonensis	Houston Toad	LE/E	X
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/SOC	Migrant
Haliaeetus leucocephalus	Bald Eagle	DL/T	Resident
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant
Falco peregrinus anatum	Peregrine Falcon	DL/T	Migrant
Grus americana	Whooping Crane	LE/E	Migrant
Mycteria americana	Wood Stork	SOC/T	Migrant
Fishes			
Cycleptus elongatus	Blue Sucker	SOC/T	X
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Insects			
Procloeon texanum	*A mayfly*	*SOC*	*X*
Gomphus modestus	*Gulf Coast clubtail*	*SOC*	*X*
Neurocordulia molesta	*Smoky shadowfly*	*SOC*	*X*
Mammals			
Ursus americanus luteolus	*Louisiana Black Bear*	*LT/T*	*Historic*
Spilogale putorius interrupta	*Plains Spotted Skunk*	*SOC*	*X*
Canis rufus	*Red wolf*	*LE/E*	*Historic*
Mollusks			
Quincuncina mitchelli	*False spike mussel*	*T*	*X*
Tritogonia verrucosa	*Pistolgrip*	*SOC*	*X*
Arcidens confragosus	*Rock pocketbook*	*SOC*	*X*
Quadrula houstonensis	*Smooth pimpleback*	*T*	*X*
Truncilla macrodon	*Texas fawnsfoot*	*T*	*X*
Reptiles			
Macroclemys temminckii	Alligator Snapping Turtle	SOC/T	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X

Table 4B.13.4-5 (Concluded)

Scientific Name	***Common Name***	***Federal/State Status***	***Potential Occurrence***
Plants			
Liatris cymosa	Branched gay-feather	SOC	X
Spiranthes parksii	Navasota ladies'-tresses	LE/ E	X
Eriocaulon koernickianum	Small-headed pipewort	SOC	X
Thalictrum texanum	Texas meadow rue	SOC	X
Chloris texensis	Texas windmill-grass	SOC	X

* Nesting migrant; may nest in the county.

X= Occurs in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations.) SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas.

SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: Texas Parks and Wildlife Department (TPWD), Annotated County List of Rare Species for Brazos County (Revised 2/2/2010); TPWD, Texas Conservation and Biological Data System (TCBDS) 2009.

likely be directly affected by the project. Although the state threatened bald eagle is known to nest in the Navasota River Basin, there are no known nesting sites in or near the project area. The Houston toad prefers deep sands for burrowing and upland ponds and depressions for breeding. Navasota Ladies'-tresses occur on upland margins of intermittent, minor tributaries in association with post oak, blackjack oak, and yaupon. Although historically occurring, populations of black bear and red wolf no longer occur within the region.

A search of the Texas Natural Diversity Database[21] revealed numerous documented occurrences of the endangered Navasota ladies tresses (*Spriranthes parksii*), in addition to limited occurrences of two species of concern, branched gay-feather (*Liatris cymosa*), and Texas Meadow-rue (*Thalictrum texanum*), within the project vicinity (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

[21] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, September 10, 2009.

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.

4B.13.4.3.2.3 *Wildlife Habitat*

Approximately 1,045 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 178 acres of Grasses/Forbs, 756 acres of Post Oak Woods, and 111 acres of Riparian Woods.

A number of vertebrate species could occur within the Peach Creek off-channel reservoir site as indicated by county occurrence records.[22] These include 5 species of salamanders and newts, 18 species of frogs and toads, 14 species of turtles, the American alligator, 11 species of lizards and skinks, and 31 species of snakes. Additionally, 54 species of mammals could occur within the site or surrounding region[23] 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.

4B.13.4.3.2.4 *Cultural Resources*

A search of the Texas Archeological Sites Atlas database indicates that 126 archeological sites have been documented within the general vicinity of the proposed reservoir. Prewitt and Associates, Inc. recorded 23 of these sites in 1981 as part of an archeological survey of proposed reservoir alternatives. Researchers from the University of Texas documented 26 of these sites as part of a preliminary investigation of the area proposed for Millican Lake in 1973. An additional 22 sites have been recorded during surveys on behalf of the Texas Municipal Power Agency in advance of various electrical transmission lines and proposed lignite mines. Thirteen sites have been recorded during surveys of proposed facilities for Texas A&M University. The sites recorded on behalf of the Texas Municipal Power Agency and Texas A&M University lie outside the currently proposed reservoir location. The sites documented in the area represent a variety of historic and prehistoric site types. Prior to reservoir inundation, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be

[22] Texas A&M University (TAMU), *County Records for Amphibians and Reptiles*, Texas Cooperative Wildlife Collection, 1998.
[23] 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.

conducted to determine if these sites or any other cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archeological and Historic Preservation Act (PL93-291).

4B.13.4.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased adverse effects on stream flow below the reservoir site, but the reservoir would trap sediment and/or dilute pollutants, providing some positive benefits to water quality downstream. These benefits could be offset by declines in dissolved oxygen through decreased flows and higher temperatures immediately downstream during summer periods. The project is expected to have negligible impacts to stream flow and water quality in the Navasota and Brazos Rivers.

4B.13.4.4 Engineering and Costing

Construction of the Peach Creek Reservoir project will cost approximately $40.6 million. This includes the construction of the dam, pumping facilities, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $3.7 million; this includes annual debt service and operation and maintenance. The cost for the available project yield of 4,240 acft/yr translates to an annual unit cost of raw water of $2.70 per 1,000 gallons, or $879/acft. A summary of the cost estimate is provided in Table 4B.13.4-6. Costs shown herein are for raw water supply at the reservoir and include no transmission, local distribution, or treatment costs.

4B.13.4.5 Implementation Issues

This option has been compared to the plan development criteria as shown in Table 4B.13.4-7.

Table 4B.13.4-6.
Cost Estimate Summary for
Peach Creek Reservoir
(September 2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Raw Water Pumping Facilities	$18,595,000
Dam and Reservoir	$6,595,000
Total Capital Cost	**$25,190,000**
Engineering, Legal Costs and Contingencies	$7,887,000
Environmental & Archaeology Studies and Mitigation	$2,309,000
Land Acquisition and Surveying	$2,309,000
Interest During Construction (2 years)	$2,948,000
Total Project Cost	**$40,643,000**
Annual Costs	
Debt Service (6% for 20 years)	$2,225,000
Reservoir Debt Service (6 percent, 40 years)	$1,005,000
Operation and Maintenance	$497,000
Total Annual Cost	**$3,727,000**
Available Project Yield (acft/yr)	4,240
Annual Cost of Water ($ per acft)	$879
Annual Cost of Water ($ per 1,000 gallons)	$2.70

Note

- Raw water pumping facilities include a raw water intake and pump station (100 cfs, 1,400 HP), 22,000 feet raw water pipeline (60-inch diameter) from the river to the off-channel reservoir.
- Includes the power cost for pumping water from the Navasota River to the off-channel reservoir.

Table 4B.13.4-7.
Evaluations of Peach Creek Off-Channel Reservoir Option to Enhance Water Supplies

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

4B.13.4.5.1 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 (NPDES) 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.

4B.13.4.5.2 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.

4B.13.4.5.3 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.

4B.13.5 Little River Off-Channel Reservoir

4B.13.5.1 Description of Option

The Little River Off-Channel Reservoir is a proposed new reservoir on Beaver Creek, a tributary to the Little River. The reservoir site is located in Milam County, east of the City of Cameron, as shown in Figure 4B.13.5-1. The project would impound water from the Beaver Creek watershed as well as divert water from the Little River during periods of flow in excess of downstream needs. The dam would be an earthfill embankment that would extend approximately 1-mile across the Beaver Creek valley and provide a conservation storage capacity of 155,812 acft at an elevation 400 ft-msl; the reservoir would inundate 4,343 surface acres.

4B.13.5.2 Available Yield

Water potentially available for impoundment in the proposed Little River Off-Channel Reservoir was estimated using the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available for diversion from the Little River into the Little River Off-Channel Reservoir without causing increased shortages to downstream rights. Firm yield was computed subject to the reservoir and Little River diversion having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H).

Various maximum diversion capacities associated with potential pipeline sizes (64-inch, 72-inch, 90-inch, 108-inch, and 120-inch diameter pipelines) were considered. Figure 4B.13.5-2 illustrates the Little River Off-Channel Reservoir yield for each of the pipeline diameters considered. The greatest incremental benefit in yield occurs with the 90-inch and 108-inch pipeline sizes.

The calculated firm yield of the Little River Off-Channel Reservoir is 27,225 acft/yr. The yield is constrained by the capacity of a 108-inch diameter pipeline. The available firm yield is significant since there is a substantial watershed for the Little River (7,500 square miles) that is uncontrolled. The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the off-channel reservoir and the Little River diversion are shown in Tables 4B.13.5-1 and 4B.13.5-2.

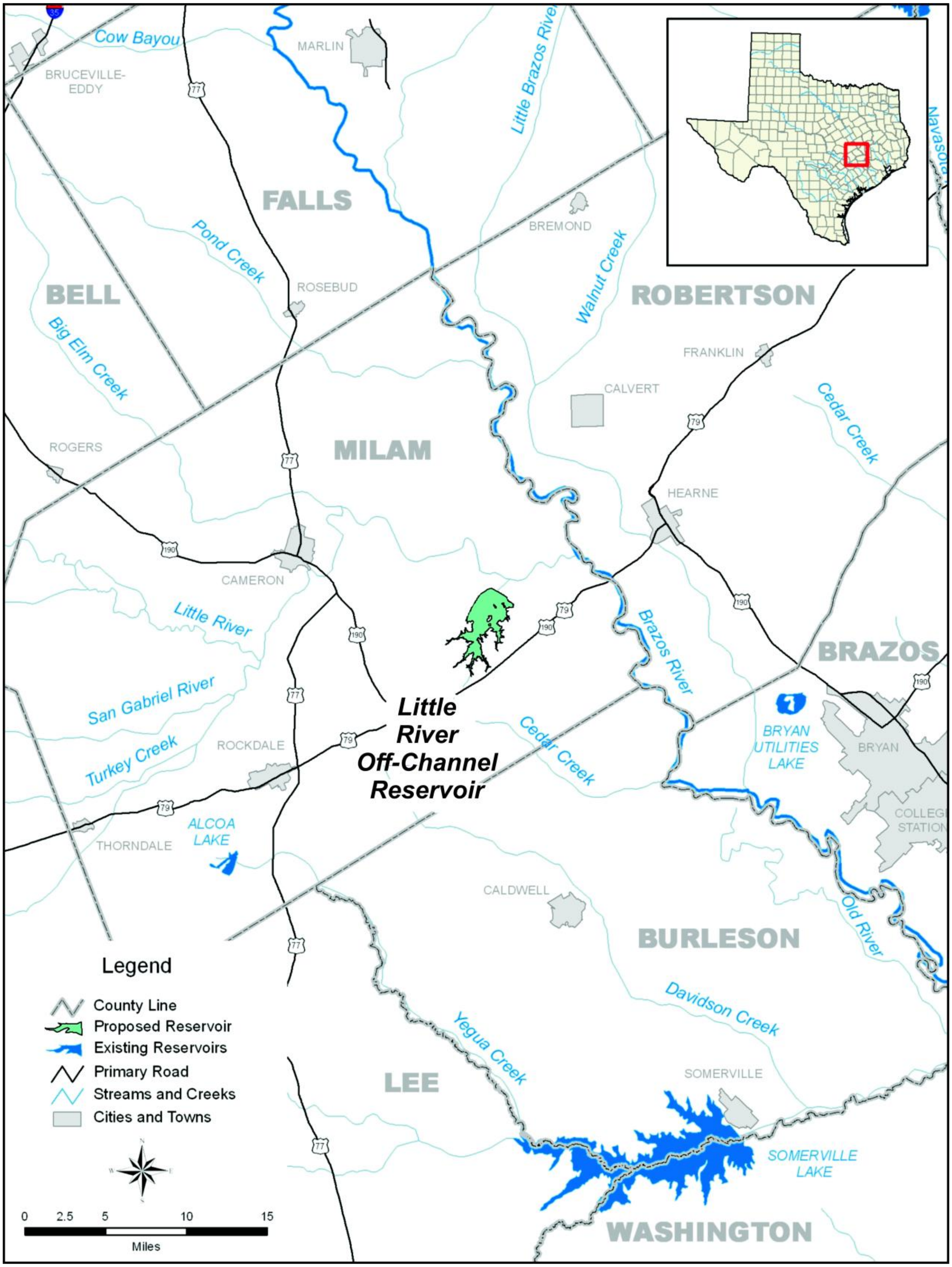


Figure 4B.13.5-1. Little River Off-Channel Reservoir

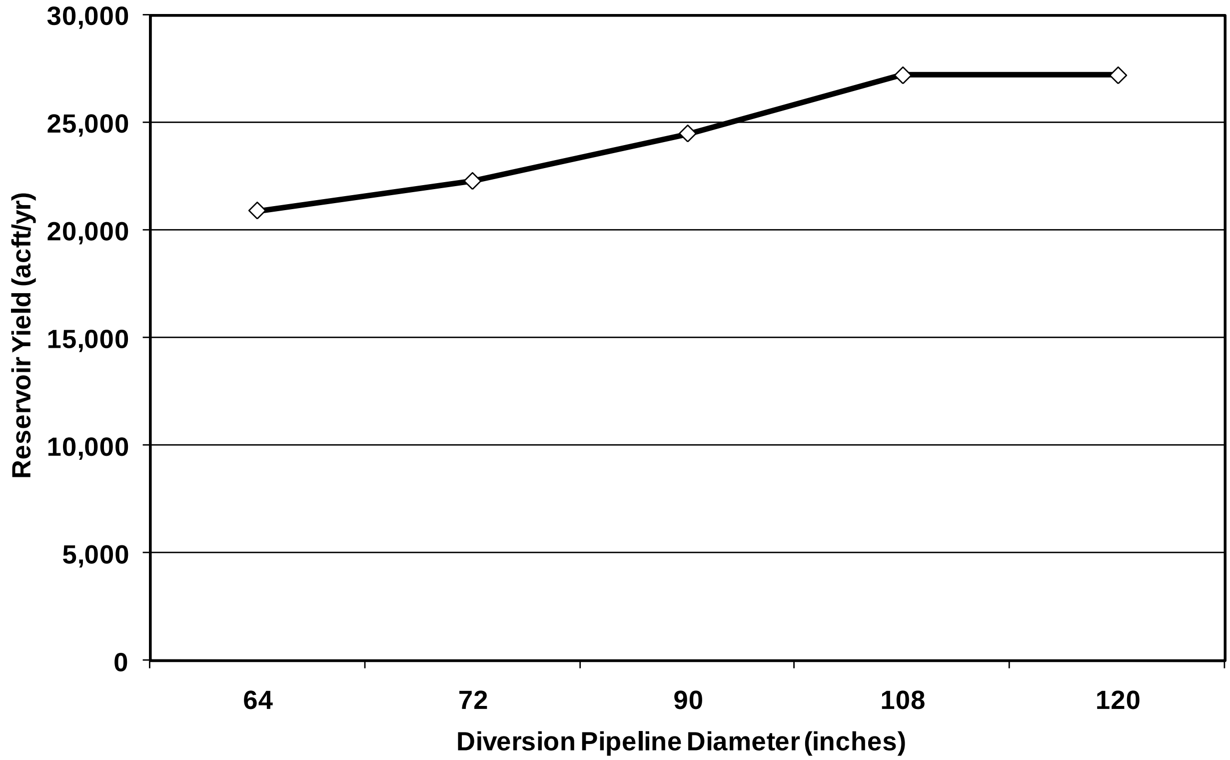


Figure 4B.13.5-2. Water Available from Little River Diversion into the Little River Off-Channel Reservoir

Figure 4B.13.5-3 illustrates the simulated Little River Off-Channel Reservoir storage contents for the 1940 to 1997 historical period, subject to the firm yield of 27,225 acft/yr and based on delivery of Little River diversions via a 108-inch pipeline. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 82 percent of the time and above the Zone 3 trigger level (50 percent capacity) 96 percent of the time.

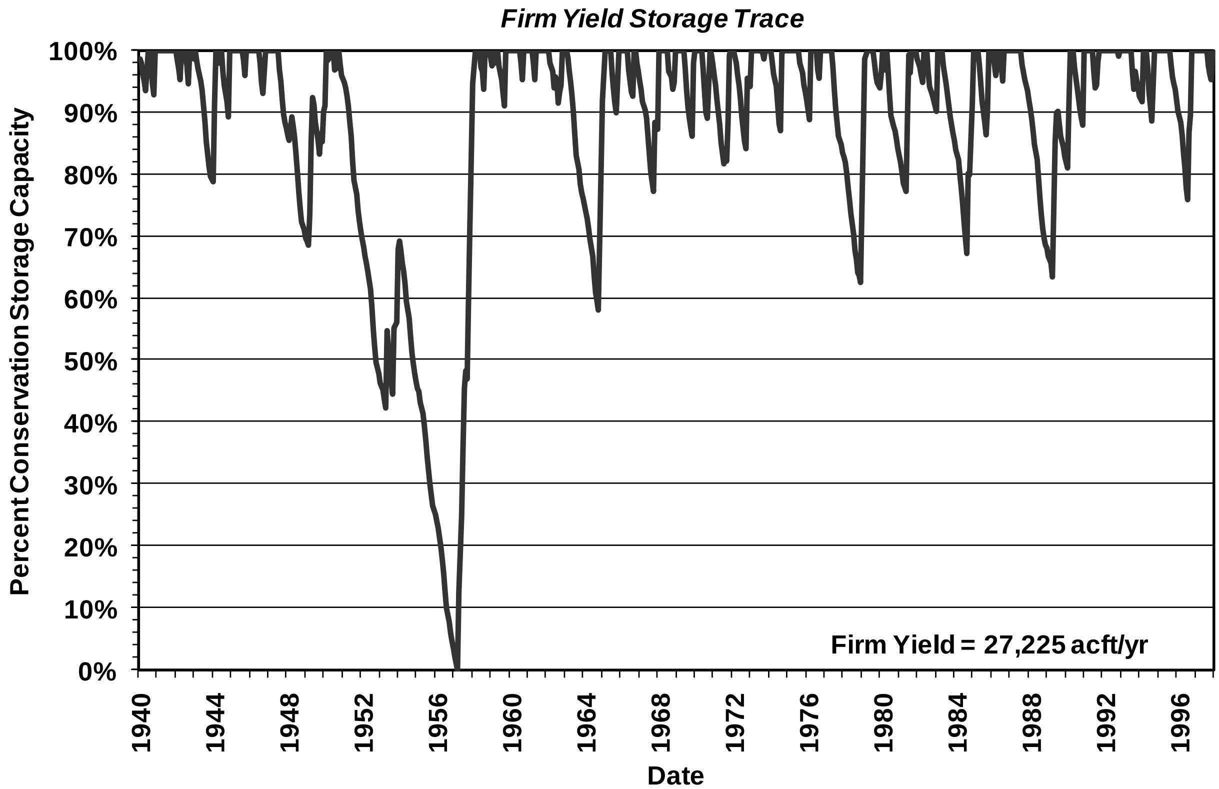
Figure 4B.13.5-4 illustrates the changes in streamflows at the reservoir location and the Little River caused by the project. There are significant changes in streamflow at the reservoir location due to the project; however, there are minimal changes in Little River streamflow due to the project. The largest decline in monthly median streamflow on the Little River (95 cfs) occurs in February. Figure 4B.13.5-4 also illustrates the streamflow frequency characteristics at the reservoir location and the Little River with the project in place. There is little difference in streamflow on the Little River with the project because the Little River diversion would be required to pass substantial inflows in order to satisfy senior water rights and/or environmental flow requirements.

Table 4B.13.5-1.
Daily Natural Streamflow Statistics
for the Little River Off-Channel Reservoir

Month	Median Flows – Zone 1 Pass-Through Requirements (cfs)	25th Percentile Flows – Zone 2 Pass-Through Requirements (cfs)
January	2.7	0.6
February	2.8	1.0
March	3.0	0.9
April	2.4	0.4
May	4.5	1.2
June	3.1	0.5
July	1.7	0.3
August	1.1	0.3
September	0.8	0.1
October	0.7	0.0
November	1.5	0.6
December	2.2	0.7
Zone 3 (7Q2) Pass-Through Requirement (cfs):		0.0

Table 4B.13.5-2.
Daily Natural Streamflow Statistics
for the Little River Diversion

Month	Median Flows – Zone 1 Pass-Through Requirements (cfs)	25th Percentile Flows – Zone 2 Pass-Through Requirements (cfs)
January	466.9	190.9
February	787.9	257.1
March	761.7	269.5
April	925.0	263.2
May	1547.1	514.2
June	1022.5	317.8
July	441.0	154.5
August	244.0	92.2
September	250.9	66.9
October	268.8	76.5
November	405.3	142.5
December	494.1	165.3
Zone 3 (7Q2) Pass-Through Requirement (cfs):		54.6



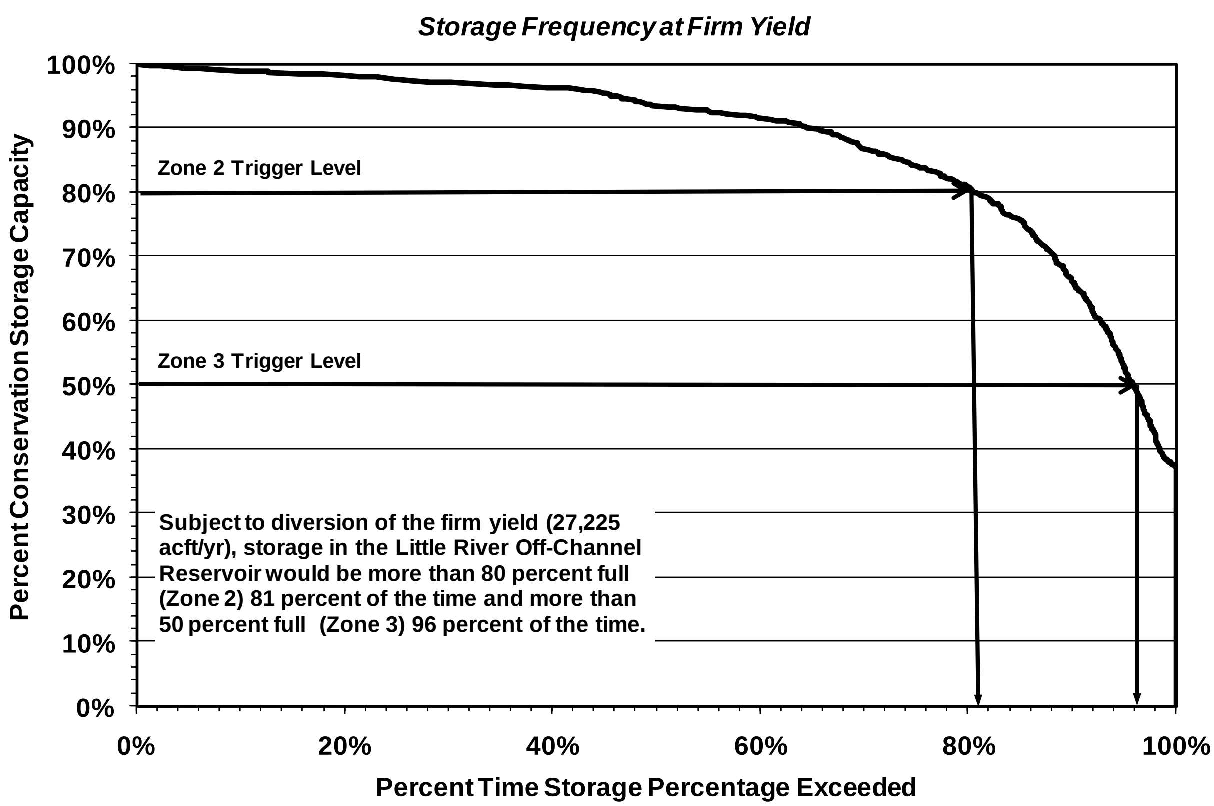
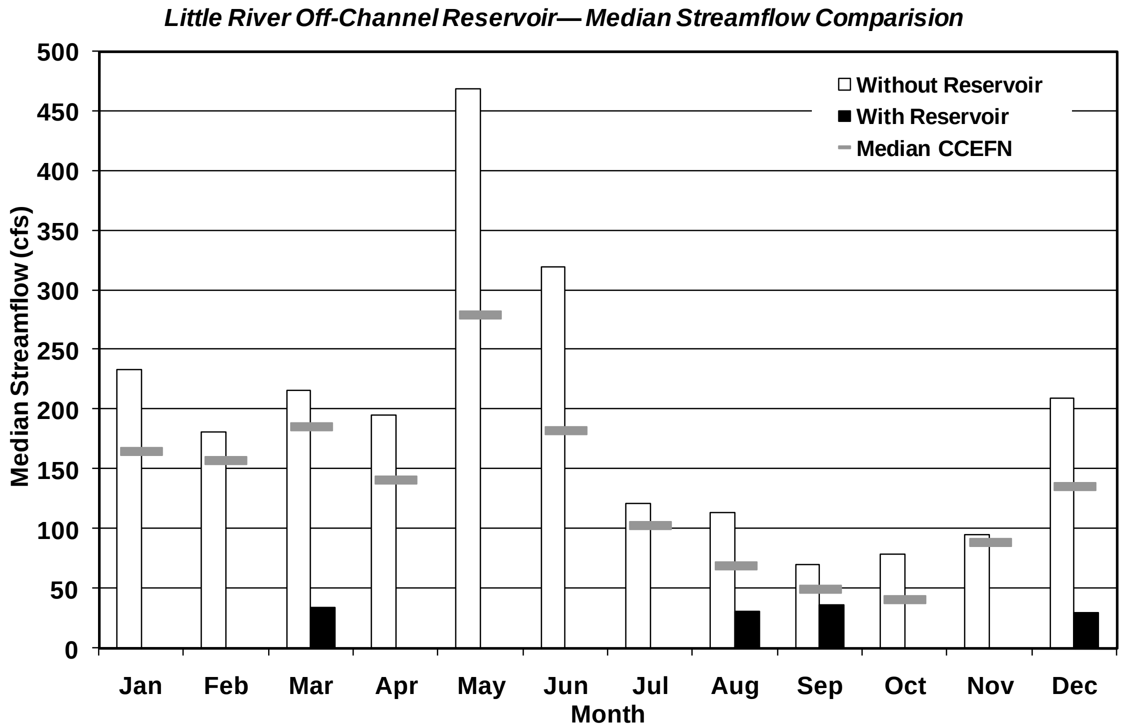


Figure 4B.13.5-3. Little River Off-Channel Reservoir Storage Considerations



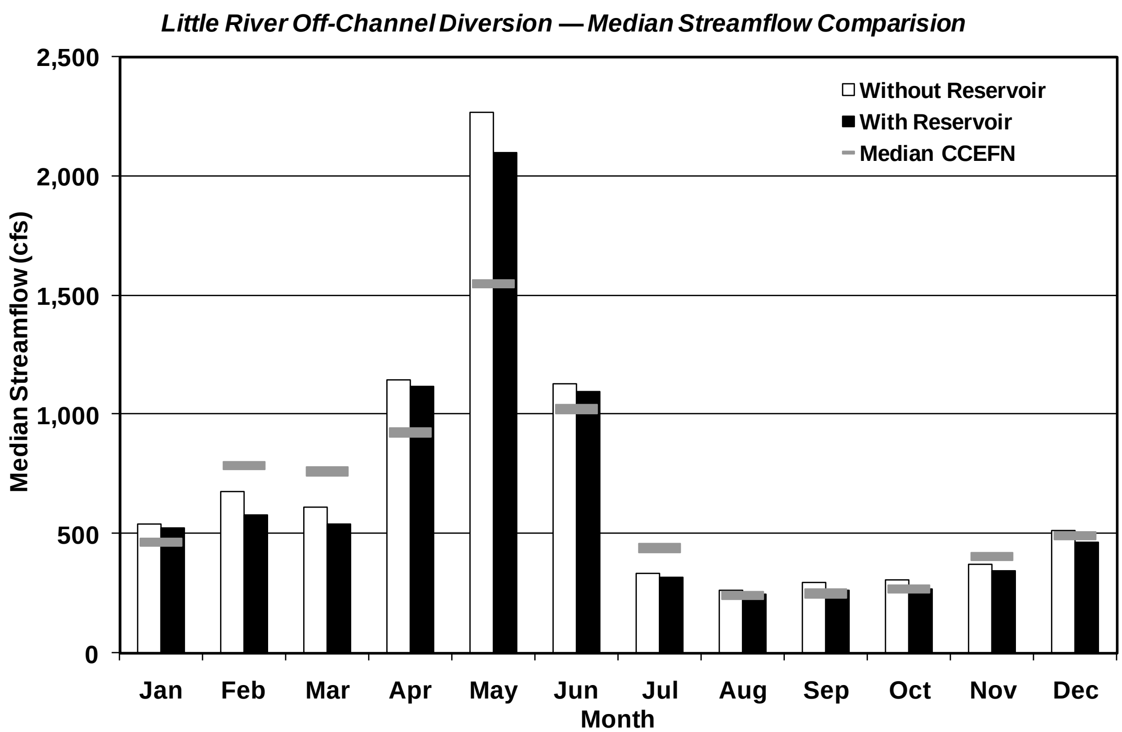
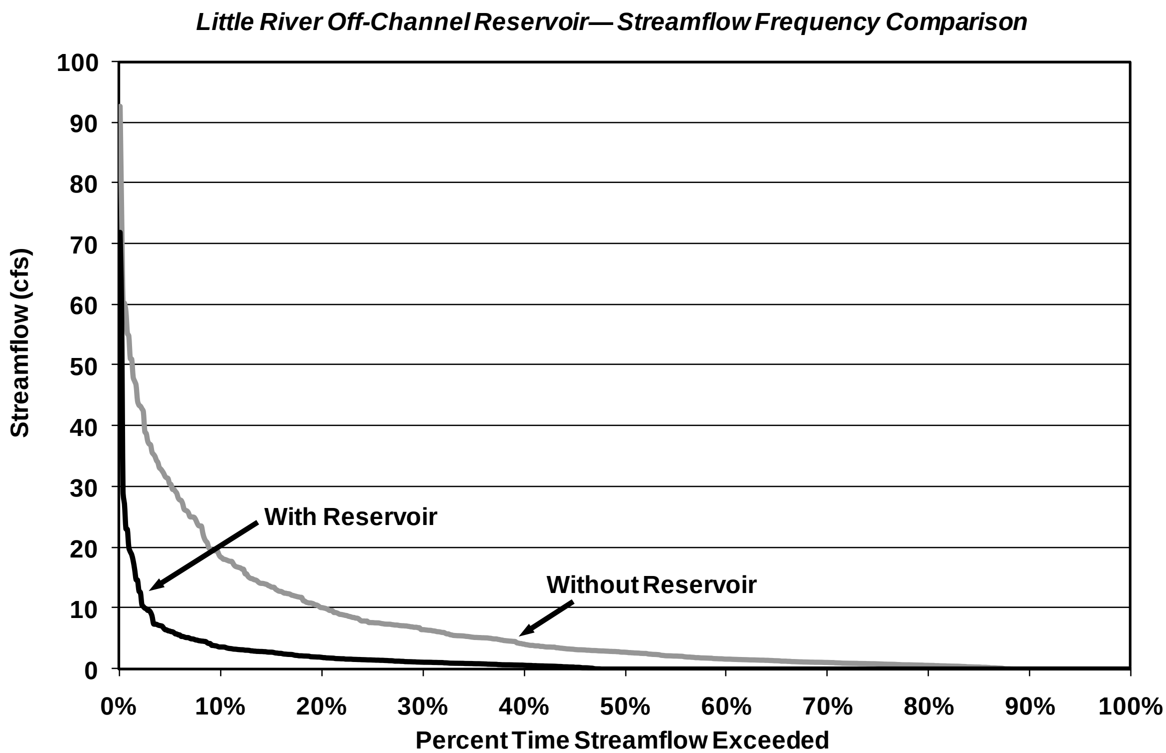


Figure 4B.13.5-4. Little River Diversion and Reservoir Streamflow Comparison



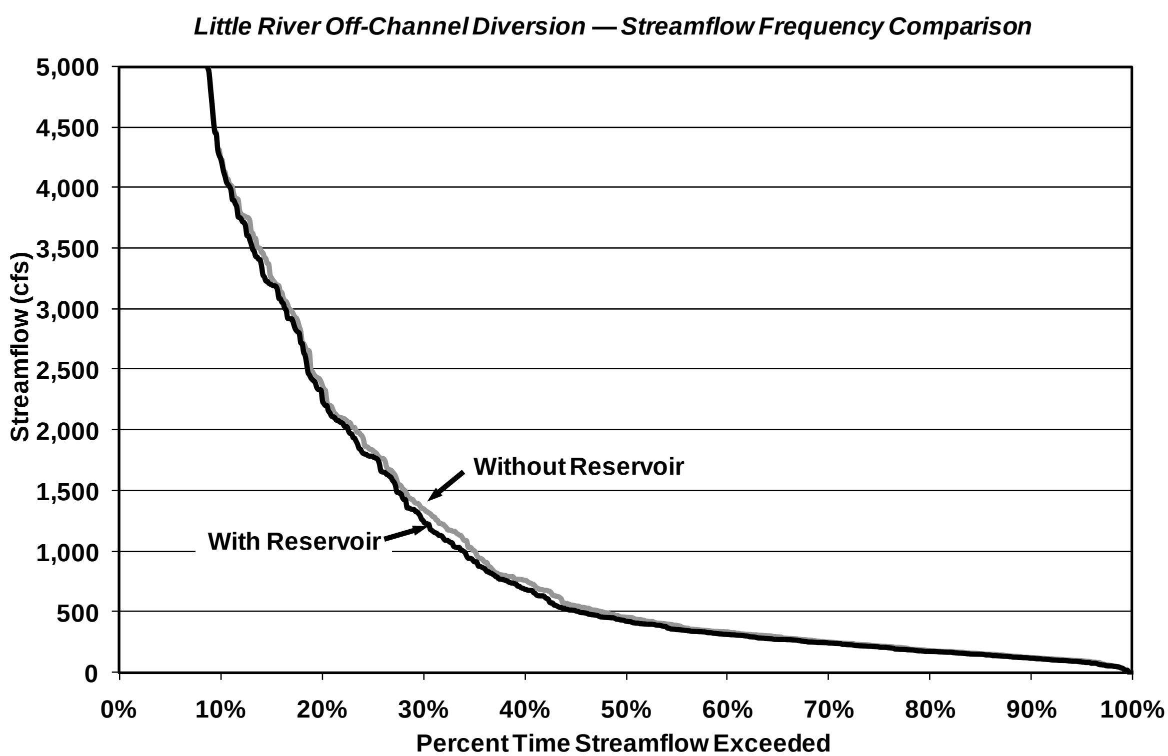


Figure 4B.13.5-4. Little River Diversion and Reservoir Streamflow Comparison (Concluded)

4B.13.5.3 Environmental Issues

4B.13.5.3.1 Existing Environment

The Little River Off-Channel Reservoir site in Milam County is within the Post Oak Savannah Ecological Region.[24] This region is characterized as a narrow, highly irregular oak belt that consists of intermingled forest, woodland, and savannah. It is located between the Pine-Hardwood Forest to the east, Blackland Prairies to the west, and the Coastal Prairie and South Texas Brushlands to the south. The original physiognomy of the region included medium to tall broad-leaved deciduous trees and some needle-leaved evergreens. In the northern and eastern areas, these trees are interspersed with open areas of grasses and forbs, but in the southern and western areas, trees are clumped or in solid stands. The shallow, nearly impervious clay pan of the Post Oak Savannah region causes the soil to be arid.[25] The climate is characterized as subtropical humid, with warm summers. Average annual precipitation ranges between 36 and 40 inches.[26] The Carrizo-Wilcox Aquifer is the only major aquifer underlying the project area.[27] The Queen City and Brazos River Alluvium minor aquifers are to the south and east of the project area, respectively.

The physiography of the region includes ceramic clay and lignite/coal, recharge sands, expansive clay mud, and flood-prone areas. The topography is flat to rolling with local escarpments, with local shallow depressions in flood-prone areas along waterways.[28] The predominant soil types in the project area are primarily sandy loams and loamy sands, with a small amount of silty clay.[29]

Three major vegetation types occur within the general vicinity of the proposed project: Post Oak Woods/Forest, Post Oak Woods, Forest, and Grassland Mosaic, and crops.[30] Variations

[24] 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.
[25] Telfair, R.C., "Texas Wildlife Resources and Land Uses," University of Texas Press, Austin, Texas, 1999.
[26] Larkin, T.J., and G.W. Bomar, "Climatic Atlas of Texas," Texas Department of Water Resources, Austin, Texas, 1983.
[27] Texas Water Development Board (TWDB), Major and Minor Aquifers of Texas; Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.
[28] 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.
[29] Soil Conservation Service (NRCS), *Soil Survey for Milam County, Texas*, Soil Conservation Service, United States Department of Agriculture, 1979.
[38] McMahan, C.A., R.F. Frye, and K.L. Brown, "The Vegetation Types of Texas," Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

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. Post Oak Woods/Forest and the Post Oak Woods, Forest, and Grassland Mosaic could include the following commonly associated plants: blackjack oak (*Quercus marilandica*), eastern redcedar (*Juniperus virginiana*), mesquite (*Prosopis glandulosa*), black hickory (*Carya texana*), live oak (*Q. virginiana*), sandjack oak (*Q. incana*), cedar elm (*Ulmus crassifolia*), hackberry (*Celtis* spp.), yaupon (*Ilex vomitoria*), poison oak (*Toxicodendron pubescens*), American beautyberry (*Callicarpa americana*), hawthorn (*Crataegus* spp.), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus* spp.), coralberry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium* var. *scoparium*), silver bluestem (*Bothriochloa saccharoides*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida* spp.), spranglegrass (*Chasmanthium sessiliflorum*), and tickclover (*Desmodium* spp.). Crops include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

4B.13.5.3.2 Potential Impacts

4B.13.5.3.2.1 Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated in two locations, at the proposed reservoir site and in the Little 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 Little River, very little impact is predicted in terms of a reduction in flow variability or quantity of median monthly flows. But in the proposed project site, there would be dramatic reductions in both flow variability and the quantity of median monthly flows. The difference in variability of monthly flow conditions at the proposed project site would be a factor of approximately 7.5 (measured by comparing sample variances of all monthly flows from 1940-1997 and predicted flows over that same time period with the project in place; sample variance without project =43.25×10^4; sample variance with project =5.54×10^4). The difference in variability of monthly flow values in the Little River diversion site would be negligible (sample variance without project =2.95×10^{10}; sample variance with project =2.93×10^{10}). 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.

The reduction in the median monthly flow at the reservoir site would range from 0.6 cfs (48 percent) in September to 7.6 cfs (100 percent) in May, as shown in Table 4B.13.5-3. Median monthly flow would be reduced to zero (100 percent reduction) during 8 months of the year at the proposed reservoir site. At the diversion site, reductions in median monthly flow would range from 12.3 cfs (4 percent) in July to 170.5 cfs (8 percent) in May, as shown in Table 4B.13.5-4. Reductions would be 10 percent or less during 8 months of the year. This project would have minimal effects on the frequency of low-flow conditions at the proposed reservoir site. Without the project, 85 percent exceedance value of monthly flows would be 0.33 cfs; with the project in place, this value would be 0 cfs. At the diversion site, the 85 percent exceedance values would be 156 cfs without and 152 cfs with the project in place. Because of the number of months with zero flow values, this project is anticipated to have substantial impacts on the instream biological community at the proposed reservoir site; however, there would be minimal impacts in the Little River diversion site.

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, in which case there would be minimal influence on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows into the estuary. As a new reservoir without a current operating permit, the Little River Off-Channel Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

4B.13.5.3.2.2 Threatened & Endangered Species

A total of 28 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern. This group includes 1 amphibian, 4 reptiles, 8 birds, 3 mammals, 5 fish species, 5 mollusks, and 2 plant species (Table 4B.13.5-5). One

Table 4B.13.5-3.
Median Monthly Streamflow: Little River Off-Channel Reservoir

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	3.8	0.0	3.8	100%
February	3.3	0.0	3.3	100%
March	3.5	0.6	2.9	84%
April	3.3	0.0	3.3	100%
May	7.6	0.0	7.6	100%
June	5.4	0.0	5.4	100%
July	2.0	0.0	2.0	100%
August	1.8	0.5	1.3	73%
September	1.2	0.6	0.6	48%
October	1.3	0.0	1.3	100%
November	1.6	0.0	1.6	100%
December	3.4	0.5	2.9	86%

Table 4B.13.5-4.
Median Monthly Streamflow: Little River Diversion Site

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	541.5	522.3	19.2	4%
February	673.7	578.8	94.9	14%
March	609.3	537.1	72.2	12%
April	1142.2	1114.5	27.7	2%
May	2265.7	2095.2	170.5	8%
June	1129.0	1094.5	34.5	3%
July	330.1	317.8	12.3	4%
August	263.2	244.0	19.2	7%
September	292.2	259.8	32.4	11%
October	303.9	268.8	35.1	12%
November	371.4	343.8	27.6	7%
December	510.1	460.8	49.3	10%

Table 4B.13.5-5. Potentially Occurring Species that are Rare or Federal- and State-Listed at the Little River Off-Channel Reservoir Site, Milam County

Scientific Name	*Common Name*	*Federal/State Status*	*Potential Occurrence*
Amphibians			
Bufo houstonensis	Houston Toad	LE/E	X
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL	Migrant
Haliaeetus leucocephalus	Bald Eagle	DL/T	Resident
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant
Mycteria americana	Wood Stork	SOC/T	Migrant
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Resident
Fishes			
Anguilla rostrata	American Eel	SOC	X
Cycleptus elongatus	Blue Sucker	SOC/T	X
Micropterus treculi	Guadalupe Bass	SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Mammals			
Myotis velifer	Cave Myotis Bat	SOC	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E	Historic
Mollusks			
Quadrula mitchelli	False spike mussel	T	X
Tritogonia verrucosa	Pistolgrip	SOC	X
Arcidens confragosus	Rock pocketbook	SOC	X
Quadrula houstonensis	Smooth pimpleback	T	X
Truncilla macrodon	Texas fawnsfoot	T	X
Reptiles			
Macrochelys temninckii	Alligator snapping turtle	T	X
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X
Plants			
Spiranthes parksii	Navasota ladies'-tresses	LE/ E	X
Polygonella parksii	Parks' jointweed	SOC	X

X = Occurs in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: TPWD, Annotated County List of Rare Species for Milam County (2/2/2010); TPWD, Texas Natural Diversity Data System (TNDD), September 10, 2009.

amphibian, two bird species, and one plant species federally-listed as threatened or endangered could occur in the project area. These include the Houston toad (*Bufo houstonensis)*, interior least tern (*Sterna antillarum athalassos*), whooping crane (*Grus americana*), and Navasota ladies'-tresses (*Spiranthes parksii*). The interior least tern, and whooping crane are seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir. The Navasota Ladies'-tresses occur on upland margins of intermittent, minor tributaries in association with post oak, blackjack oak, and yaupon.

A search of the Texas Natural Diversity Database[31] revealed documented occurrences of Navasota ladies'-tresses an endangered species and Park's jointweed, a species of concern, within two miles of the proposed Little River Off-Channel Reservoir (as noted on representative 7.5-minute quadrangle map(s) that include the project site). These data are not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or 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.

4B.13.5.3.2.3 Wildlife Habitat

Approximately 4,343 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 2,215 acres of Mixed Grassland, 1,839 acres of Post Oak Woods, and 289 acres of Mixed Riparian Woods/Forest.

A number of vertebrate species could occur within the Little River Off-Channel Reservoir site as indicated by county occurrence records.[32] These include four species of salamanders and newts, 16 species of frogs and toads, nine species of turtles, the American alligator, 10 species of lizards and skinks, and 21 species of snakes. Additionally, 54 species of mammals could occur within the site or surrounding region[33] 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.

[31] Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, September 10, 2009.
rks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.
tiles," Texas Cooperative Wildlife Collection, 1998.
[33] Davis, W.B., and D.J. Schmidly, "The Mammals of Texas – Online Edition," Texas Tech University,

4B.13.5.3.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that 31 archeological sites have been documented within the general vicinity of the proposed reservoir. Nineteen of these sites were recorded by private individuals or by university research programs for academic purposes. All of these sites lie outside the currently proposed reservoir location. These sites represent a variety of historic and prehistoric site types. In addition, Pin Oak Cemetery may lie within the reservoir site. Prior to reservoir inundation, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archeological and Historic Preservation Act (PL93-291).

4B.13.5.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased adverse effects on stream flow below the reservoir site, but the reservoir would trap sediment and/or dilute pollutants, providing some positive benefits to water quality downstream. These benefits could be offset by declines in dissolved oxygen through decreased flows and higher temperatures immediately downstream of the reservoir during summer periods. The project is expected to have negligible impacts to the stream flow and water quality in the Little River and Brazos River.

4B.13.5.4 Engineering and Costing

A cost estimate for the proposed Little River Off-Channel Reservoir was made utilizing available mapping and information. The total project is estimated to cost $137.4 million for construction of the dam, reservoir, river intake and pump station, and raw water pipeline from the Little River to the reservoir site. The annual project costs are estimated to be $11.9 million; this includes annual debt service, operation and maintenance, and pumping energy costs. A summary of the project costs is presented in Table 4B.13.5-6. The cost for the estimated firm yield of 27,225 acft/yr translates to an annual unit cost for raw water of $1.34 per 1,000 gallons, or $436/acft.

The total project cost reported in the 2006 Water Plan was $96.5 million; the current plan costs are estimated to be $137.4 million. In addition to inflation, some of the cost differences are due to increased land costs and different methodology used to calculate Environmental & Archaeology Studies and Mitigation.

The annual cost of water has increased from $250/acft ($0.77 per 1,000 gallons) in the 2006 Plan to $436/acft ($1.34 per 1,000 gallons) in the current plan.

4B.13.5.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.13.5-7, and the option meets each criterion.

This Implementation of the Little River Off-Channel Reservoir will require permits from various state and federal agencies, land acquisition, and design and construction of the facilities. A summary of the implementation steps for the project is presented below.

4B.13.5.5.1 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.

4B.13.5.5.2 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;

Table 4B.13.5-6.
Cost Estimate Summary for
Little River Off-Channel Reservoir
(September 2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Dam and Reservoir (Conservation Pool: 155,812 acft, 4,343 acres, 400 ft-msl)	$36,022,000
Intake and Pump Station (205.5 MGD)	$21,341,000
Transmission Pipeline (108-in dia., 1 mile)	$3,292,000
Relocations & Other	$141,000
Total Capital Cost	**$60,796,000**
	$21,114,000
Engineering, Legal Costs and Contingencies	
Environmental & Archaeology Studies and Mitigation	$19,570,000
Land Acquisition and Surveying (4,348 acres)	$19,804,000
Interest During Construction (4 years)	$16,072,000
Total Project Cost	**$137,356,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$3,082,000
Reservoir Debt Service (6 percent for 40 years)	$6,779,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$566,000
Dam and Reservoir	$540,000
Pumping Energy Costs (10,087,646 kWh @ 0.06 $/kWh)	$908,000
Total Annual Cost	**$11,875,000**
Available Project Yield (acft/yr)	**27,225**
Annual Cost of Water ($ per acft)	**$436**
Annual Cost of Water ($ per 1,000 gallons)	**$1.34**

Table 4B.13.5-7.
Comparison of Little River Off-Channel Reservoir Option to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient to meet some needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low to moderate impact
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. 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	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

- 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.

4B.13.5.5.3 *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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4B.13.6 Lake Palo Pinto Off-Channel Reservoir

4B.13.6.1 Description of Option

During the early 1980s and after the occurrence of low lake levels, the Palo Pinto County Municipal Water District No. 1 (District) became concerned about the capacity of Lake Palo Pinto and a volumetric survey of the lake was performed in 1985 by HDR Engineering, Inc. (HDR). This survey determined the reservoir's conservation capacity to be 27,650 acft or about 16,450 acft less than the authorized capacity of 44,100 acft. A second volumetric survey was conducted in 1988 by the Texas Water Development Board (TWDB). This survey confirmed the results of the 1985 survey and determined the reservoir's capacity to be 27,590 acft. This survey also determined the reservoir has an average conservation pool depth of only 12.5 feet. In the late 1980's the District became further concerned about the potential loss of water supply releases along the 16 miles of Palo Pinto Creek between Lake Palo Pinto and the District's channel reservoir on Palo Pinto Creek. The results of a 1989 channel loss study revealed that between 500 and 2,000 acft of water are lost annually to Palo Pinto Creek and the channel reservoir.

In 2004, the Brazos Electric Power Cooperative (BEPC) approached the District about their need for additional water. The District re-initiated previous investigations of alternatives to restore the capacity of Lake Palo Pinto and increase its yield. The District authorized a study to evaluate the feasibility of additional water supply options.[34] In 2006, the District undertook a subsurface geotechnical investigation to determine dam and reservoir feasibility of the Wilson Hollow off-channel reservoir site in addition to an environmental study to determine if endangered species were present.

In the 2001 Brazos G Regional Water Plan (2001 Plan), the Turkey Peak Reservoir was included as the Recommended Water Management Strategy (WMS) for the District. In the 2006 Brazos G Regional Water Plan (2006 Plan) and the 2007 State Water Plan, the Wilson Hollow (Off-channel Reservoir) Water Management Strategy (WMS) replaced the Turkey Peak Reservoir WMS as a Recommended WMS due to its lower estimated cost in 2005. The Turkey Peak Reservoir was included in the 2006 Plan as an Alternative WMS. However, following the completion of the 2006 geotechnical and environmental studies (which determined that an

[34] HDR Engineering, Inc. "Reconnaissance Report for Off-Channel Reservoir Project for Palo Pinto County Municipal Water District No. 1", April 2005.

endangered species was present at the Wilson Hollow site and that the project would also cost more than originally estimated due to geologic conditions), in 2008 the District requested the Brazos G Regional Planning Group to approve the substitution of the Turkey Peak Reservoir WMS for the Wilson Hollow (Off-channel Reservoir) WMS as the Recommended WMS in the State Water Plan. This substitution request was officially approved by the TWDB on August 25, 2008. The Palo Pinto Off-Channel Reservoir (Wilson Hollow Site) remains an alternative WMS to meet the needs of the District.

The proposed off-channel reservoir is located approximately 1.6 miles north of Lake Palo Pinto at Wilson Hollow, as shown in Figures 4B.13.6-1 and 4B.13.6-2. The proposed dam would be an earthfill embankment that would extend approximately 1,550 feet and provide an initial conservation storage capacity of 10,000 acft with a surface area of 182 acres at an elevation of 1,088 ft-msl. This site can be expanded to store up to 22,000 acft depending on the growth of the District and the future needs of the BEPC.

The proposed off-channel reservoir would be filled by natural drainage and by pumping water from Lake Palo Pinto when it is spilling or nearly full. As shown in Figure 4B.13.6-2, water would be pumped 1.9 miles via a 36-inch pipeline to the off-channel reservoir from Lake Palo Pinto at a new 27 MGD intake site located at the northeast corner of the lake. When the level of Lake Palo Pinto is lowered due to drought conditions, water would be released by gravity from the off-channel reservoir to Lake Palo Pinto to increase its supply capability. When both the off-channel reservoir and Lake Palo Pinto are at their conservation elevations, 1,088 ft-msl and 867 ft-msl respectively, the combined storage capacity in 2060 would be approximately 31,426 acft. This is less than the District's authorized storage capacity of Lake Palo Pinto of 44,100 acft.

4B.13.6.2 Available Yield

Water potentially available for diversion in the proposed Lake Palo Pinto Off-Channel Reservoir was estimated using the Texas Water Development Board's (TWDB) reservoir operation model, SIMYLD-II. Using this model, Lake Palo Pinto and the proposed off-channel reservoir were evaluated as a reservoir system subject to a set of operational rules. These operational rules attempted to maintain Lake Palo Pinto above elevation 864 ft-msl for as long as possible while still meeting the municipal diversions of the District at the diversion dam

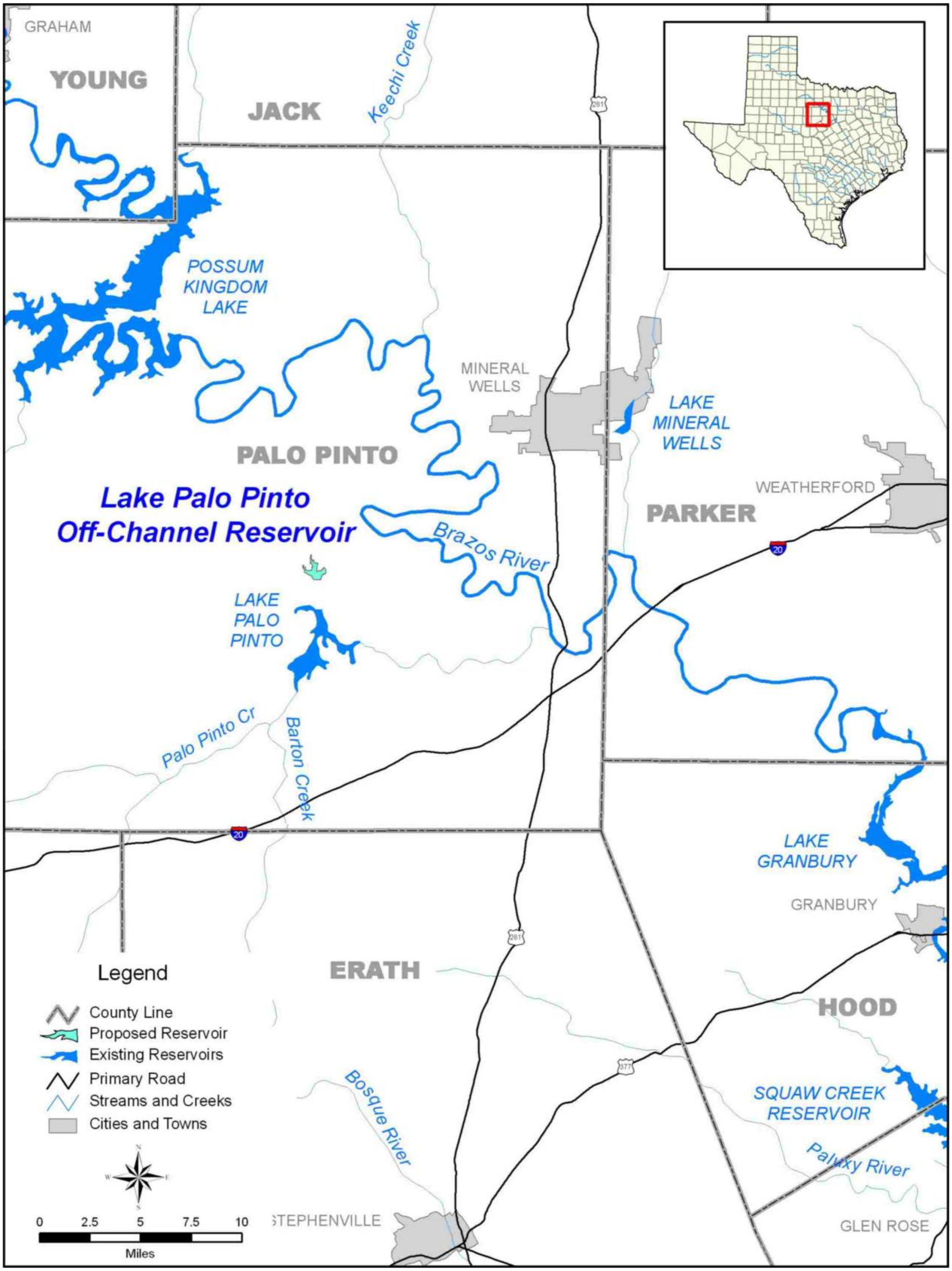

Figure 4B.13.6-1. Lake Palo Pinto Off-Channel Reservoir

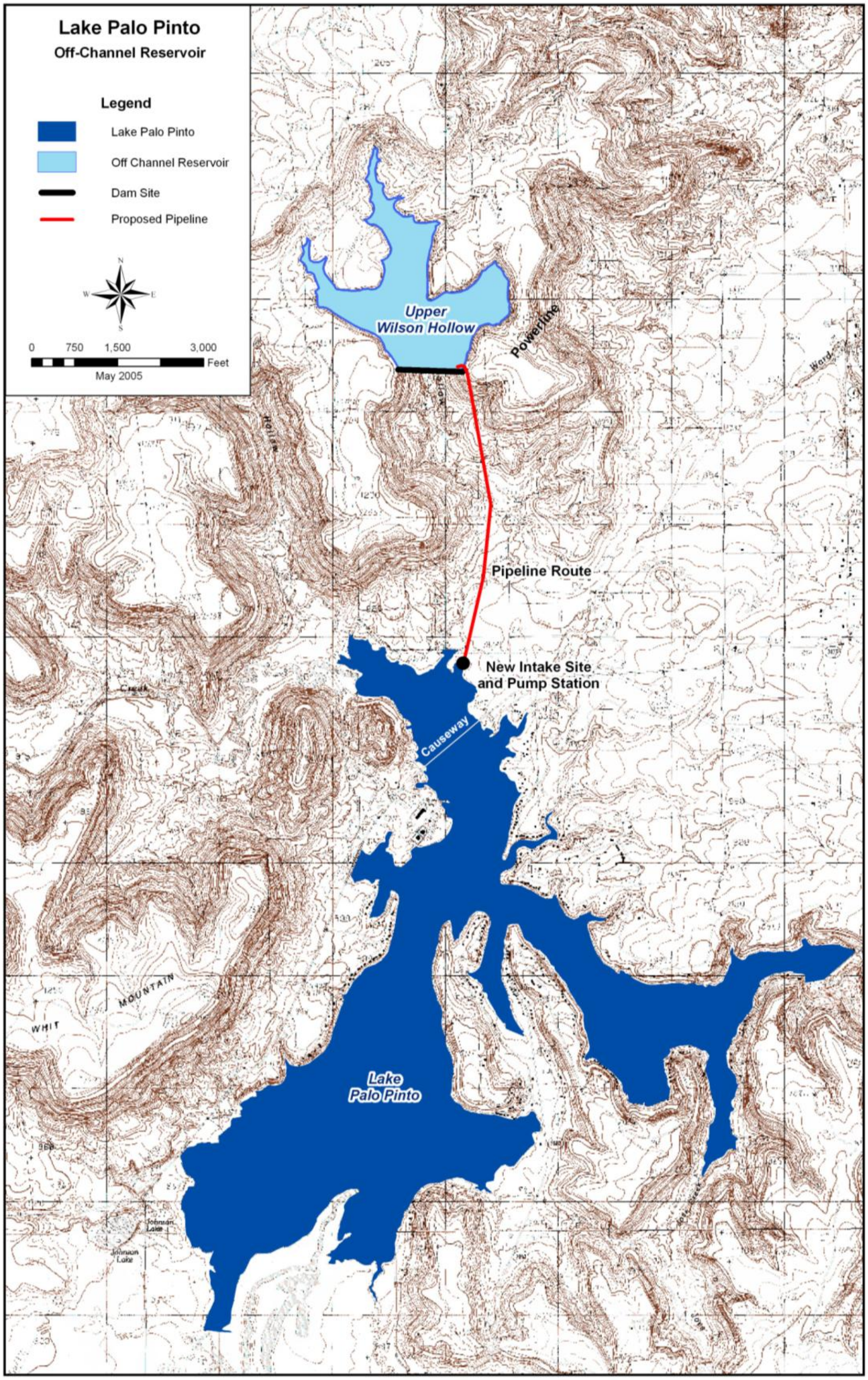

Figure 4B.13.6-2. Lake Palo Pinto Off-Channel Reservoir located downstream of Lake Palo Pinto. The model utilized a January 1948 through December 2001 hydrologic period of record.[35,36] The water availability analysis was not updated for the 2011 Regional water plan, as no significant changes occurred requiring updating of the SIM-YLD model.

As reported in the 2006 Brazos G Regional Water Plan, the calculated 2060 safe yield (with a 6-month storage reserve) for the Lake Palo Pinto and off-channel reservoir system is 9,770 acft/yr. The 2006 plan reported a 2060 stand alone safe yield of Lake Palo Pinto as 6,660 acft/yr. Therefore, the additional yield to the system attributed to the Lake Palo Pinto Off-Channel Reservoir is 3,110 acft/yr. Figure 4B.13.6-3 illustrates the Lake Palo Pinto and Off-Channel Reservoir storage levels for the 1948-2001 historical period, subject to the safe yield demand of 9,770 acft/yr. Figure 4B.13.6-4 compares the storage in Lake Palo Pinto at existing conditions (standalone) with the storage when the lake is operated with the Off-Channel Reservoir. The figure shows that when operated with the proposed Off-channel Reservoir, the lake levels in Lake Palo Pinto are stabilized and more water is available in the drier years compared to Lake Palo Pinto operated independently.

Since both the combined storage and diversion amounts for the Lake Palo Pinto and off-channel reservoir are within the limits of the District's existing water rights, and the off-channel reservoir is proximate to Lake Palo Pinto, this proposed project could be implemented within the existing water rights held by the District (storage capacity and diversion) and will have little or no change to streamflow beyond those already caused by the District's water rights when fully utilized.

[35] HDR Infrastructure, Inc. "Yield Studies of Lake Palo Pinto and Turkey Peak Reservoir," Palo Pinto County Municipal Water District Number One, March 1986.
[36] HDR Engineering, Inc. "Yield Studies for Lake Palo Pinto and the Proposed Turkey Peak Reservoir," Palo Pinto County Municipal Water District Number One, June 2001.

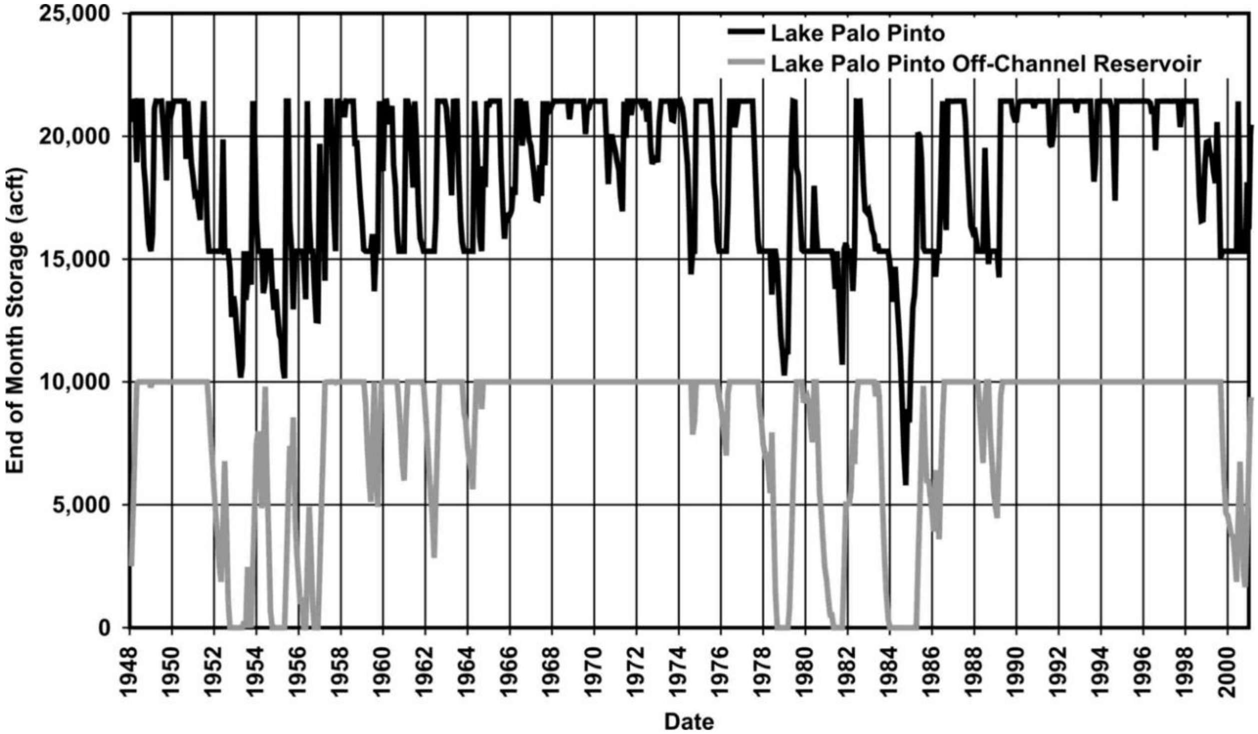

Figure 4B.13.6.-3. Monthly Lake Palo Pinto and Lake Palo Pinto Off-Channel Reservoir Storage for 1948-2001 Period of Record

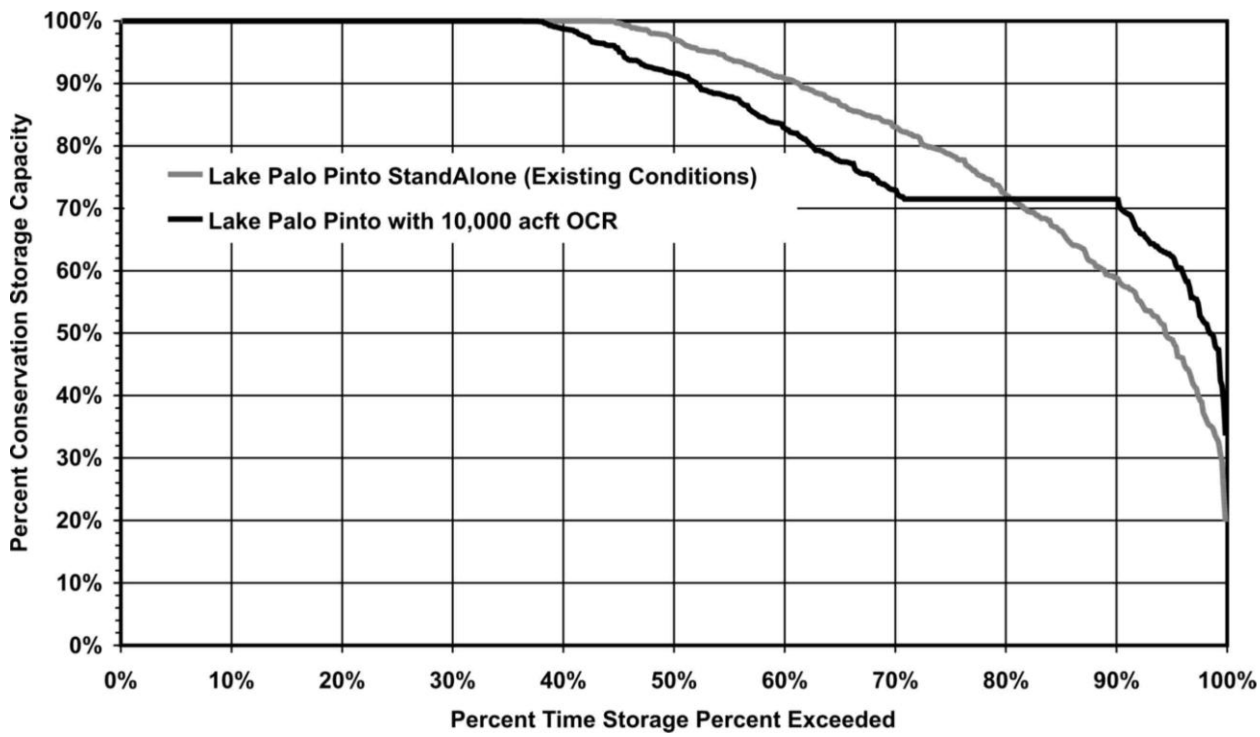

Figure 4B.13.6-4. Comparison of Lake Palo Pinto Storage when Operated With and Without Lake Palo Pinto Off-Channel Reservoir

4B.13.6.3 Environmental Issues

4B.12.6.3.1 Existing Environment

The Lake Palo Pinto Off-Channel Reservoir site in central Palo Pinto County is within the Cross Timbers and Prairies Ecological Region.[37] This complex transitional area of prairie dissected by parallel timbered strips is located in north-central Texas west of the Blackland Prairies and east Rolling Plains Ecological regions, 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.[38] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 28 and 32 inches.[39] No major or minor aquifers underlie the project area; 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.[40]

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.[41] The predominant soil associations in the project area are the Palopinto-Set-Hensley, Bosque-Santo and Bonti-Truce-Shatruce associations. The Palopinto-Set-Hensley association is characterized by shallow and deep, nearly level to steep, loamy, clayey and stony soils found on upland areas. 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.[42]

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[37] 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.
[38] Telfair, R.C., "Texas Wildlife Resources and Land Uses," University of Texas Press, Austin, Texas, 1999.
[39] Larkin, T.J., and G.W. Bomar, "Climatic Atlas of Texas," Texas Department of Water Resources, Austin, Texas, 1983.
[40] Texas Water Development Board (TWDB), Major and Minor Aquifers of Texas; Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.
[41] 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.
[42] 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.

The major vegetation type surrounding the entirety of the proposed project consists of the Ashe Juniper (*Juniperus ashei*) Parks/Woods.[43] Variations of this primary vegetation type may involve changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. The proposed Lake Palo Pinto Off-Channel Reservoir lies within the Wilson Hollow canyon north of Lake Palo Pinto along a second-order stream, Wilson Creek, a minor headwater tributary to the reservoir. The canyon cross section is V-shaped with steep slopes variably incised into a sandstone escarpment composed of Turkey Creek Sandstone.[44] The lower half of the canyon is typically obstructed or braided by accumulations of relatively unsorted sediment ranging in size from silty sand to boulders. Dry pools, or short stream reaches exhibiting features such as bank undercutting and thin algal crusts on rocks, were observed at numerous locations along the canyon.

The irregular, relatively steep canyon slopes that cap the escarpment are densely wooded throughout the canyon with post oak (*Quercus stellata*), blackjack oak (*Q. marylandica*) and Ashe juniper with Texas ash (*Fraxinus texana*), scrub oak (*Q. sinuata*), and honey mesquite (*Prosopis glandulosa*) also present in small numbers. Woodlands on the steeper slopes generally have open canopies and relatively dense ground covers of small junipers, oaks, Opuntia cacti, and grasses. Where the slopes are less steep (and the trees more mature) a primarily post oak forest with a closed canopy and open understory has developed. Post and blackjack oaks account for at least 70% of the canopy coverage in the canyon, with ashe juniper accounting for most of the remainder. The riparian zone is not well developed or defined, generally corresponding to the canyon bottom floodway. This area is characterized by deep colluvial soils (i.e., a loose deposit of rocky materials that accumulate at the base of slopes by force of gravity and erosion) and more gentle slopes than are present on the valley walls. Overstory and shrub vegetation along the floodway includes post oak, blackjack oak, scrub oak, live oak (*Q. virginiana*), hackberry (*Celtis laevigata*), cedar elm, green ash (*F. pennslyvanica*), Texas ash, pecan (*Carya illinoiensis*), cottonwood (*Populus deltoides*), honey mesquite, Ashe juniper, prairie sumac (*Rhus lanceolata*), youpon (*Ilex vomitoria*), prickley pear (*Opuntia lindheimeri*), pencil cactus (*O. leptocaulis*), buttonbush (*Cephalanthus occidentalis*), American beautyberry (*Callicarpa americana*), and greenbriar (*Smilax* spp.). Although numerous large trees are present, the

[43] 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.
[44] Bureau of Economic Geology (BEG). 1972. Geologic Atlas of Texas, Abilene Sheet. The University of Texas at Austin. Austin, Texas.

floodway vegetation commonly consists of a mosaic of shrubby thickets of small Ashe junipers or saplings of the dominant tree species, and clearings where a variety of grasses dominated ground cover.

4B.12.6.3.2 Potential Impacts

4B.12.6.3.2.1 Threatened & Endangered Species

A total of 20 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.13.6-1). This group includes two reptiles, nine birds, three mammals, three mollusks, and three fish species. Inclusion in Table 4B.13.6-1 does not mean that a species will occur within the study area but only acknowledges the potential for its occurrence in Palo Pinto County. On-site evaluations by qualified biologists are required to confirm the occurrence of sensitive species or habitats.

The Migratory Bird Treaty Act protects most bird species, including, but not limited to, cranes, ducks, geese, shorebirds, hawks, and songbirds. Migratory bird pathways, stopover habitats, wintering areas, and breeding areas may occur within and adjacent to the project area, and may be associated with wetlands, ponds, shorelines, riparian corridors, fallow fields and grasslands, and woodland and forested areas. If the off-channel option was employed, reservoir construction would remove some habitats utilized by certain migratory bird species, it would create more habitats for others. This transition from a terrestrial to an aquatic ecosystem would allow time for migratory species to acclimate to the altered condition within the project area and movement of non-aquatic species to similar areas nearby.

Four bird species federally listed as threatened or endangered may occur in the project vicinity. These include the black-capped vireo, golden-cheeked warbler, interior least tern, and whooping crane. These bird species are all seasonal migrants that could pass through the project area. The black-capped vireo only nests in dense underbrush in semi-open woodlands having distinct upper and lower stories. The interior least tern typically nests on bare or sparsely vegetated areas associated with streams or lakes, such as sand and gravel bars, beaches, islands, and salt flats. Unvegetated bars within wide river channels or open flats along lake or reservoir shorelines are preferred and provide nesting habitat and access to adjacent open water for feeding.

Table 4B.13.6-1.
List of Rare or Federal- and State-Listed Species of Potential Occurrence
Lake Palo Pinto Off-Channel Reservoir Site, Palo Pinto County

Scientific Name	***Common Name***	***Federal/State Status***	***Potential Occurrence***
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/	Migrant
Haliaeetus leucocephalus	Bald Eagle	DL/T	Migrant
Vireo atricapillus	Black-capped Vireo	LE/E	Migrant*
Dendroica chrysoparia	Golden-cheeked Warbler	LE/E	Migrant*
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Charadrius montanus	Mountain Plover	SOC	Migrant*
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant
Fishes			
Micropterus treculii	Guadalupe bass	SOC	X
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Mammals			
Canis lupus	Gray Wolf	LE/E	Extirpated
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E	Extirpated
Mollusks			
Tritogonia verrucosa	Pistolgrip	SOC	X
Arcidens confragosus	Rock pocketbook	SOC	X
Truncilla macrodon	Texas fawnsfoot	T	X
Reptiles			
Nerodia harteri	Brazos Water Snake	T	X
Phrynosoma cornutum	Texas Horned Lizard	T	X

X = Occurs in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; C-Candidate ; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: TPWD, Annotated County List of Rare Species for Palo Pinto County, (1/15/2010)

The whooping crane spends the winter on the Texas Coast at Aransas National Wildlife Refuge near Rockport, and breeds in the wetlands of Wood Buffalo National Park in northern Canada. Whooping cranes occasionally utilize wetlands as an incidental rest stop during their migration throughout the central portion of Texas. Habitat elements particularly attractive to the black-capped vireo, interior least tern, and whooping crane do not appear to be present on or adjacent to this potential reservoir site, although migrants are possible.

Of the aforementioned federally-listed avian species, the golden-cheeked warbler (GCW) does utilize the proposed reservoir site for nesting, as the juniper-oak woodland habitats on the canyon slopes and the riparian floodplain along Wilson Creek is representative of fairly high quality GCW habitat. Several detailed presence/absence field surveys of the Wilson Hollow canyon was conducted by qualified personnel in March-May 2006. A total of 139 GCW detections including observations of 121 males, 7 females and 11 juveniles were made during 7 site visits totaling slightly over 40 hours of total survey time.[45] Fifty-eight of the GCW observations or 42% of the birds sighted during the study were recorded within the boundaries of the reservoir survey area. Between 12 and 14 individual GCW territories were mapped across the Wilson Hollow study area with most extending beyond the boundary of the study area.[46]

Avian species listed by the State of Texas as endangered or threatened include the peregrine falcon and bald eagle. The peregrine falcon includes two subspecies which migrate across the state from more northern breeding areas in the U.S. and Canada to winter along the coast. Bald eagles are listed as threatened in Texas and occur as winter migrants. The majority of nesting bald eagle pairs currently reported are found along major rivers and near reservoirs in eastern Texas. Bald eagles are opportunistic predators, feeding primarily on fish captured in the shallow water of both lakes and streams or scavenged food sources. These birds may utilize tall trees near perennial water as roosting or nesting sites. Although the bald eagle could use the nearby reservoirs (Lake Palo Pinto or Possum Kingdom Reservoir) for foraging or nesting, the species has not been reported in the region. It is not expected that either bird species would be directly affected by the proposed Lake Palo Pinto Off-Channel Reservoir site.

The Texas horned lizard, a state threatened species, and the plains spotted skunk, a species of concern, are possible inhabitants of the reservoir site or its adjacent upland pastures.

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

Texas horned lizards inhabit deserts and grasslands in semi-arid to arid landscapes with sparse vegetation and gravelly soils. Their habitat must contain a stable population of harvester ants, which make up the majority of its diet. They typically inhabit relatively flat, open areas with light ground vegetation cover but can be found in elevations up to 6,000 ft on a variety of soil types. This species could be displaced within the areas that will be gradually inundated. Relocation would then be possible into similar and acceptable habitat available adjacent to the project area. The plains spotted skunk is generally found in open fields, prairies, and croplands. Vegetation within the project area generally consists of moderately dense mixed deciduous woodlands in the canyons, with pastures or pecan orchards in the floodplains. It is expected that if the plains spotted skunk is present in the proposed reservoir area, the gradual transition to an aquatic system could displace these species. However, the project area is rural, and similar suitable habitats exist adjacent to the project area; therefore, it is anticipated that the spotted skunk could relocate to those areas if necessary.

The gray wolf and red wolf are two state and federally listed endangered mammals which historically lived in Palo Pinto County. These two species are now considered to be extinct within this region of the state.

The Brazos water snake, a threatened species, and two small, slender minnow species of concern, the sharpnose shiner and the smalleye shiner, are aquatic species endemic to the Brazos River Basin. The Brazos water snake is usually found in shallow rocky riffle areas along river channels that have a gently sloping rocky shoreline free of vegetation and in reservoir environments with similar habitat characteristics. Occurrences of the Brazos water snake have been documented twice by TPWD near Palo Pinto Creek. In 2002, the two species of fish were placed on the U.S. Fish and Wildlife Service list as potential candidates for federal protection due to the decline of suitable habitat through the construction of dams along the Brazos River and several of its major tributaries. General habitat associations for these sympatric fish species include relatively shallow water of moderate currents flowing through broad and open sandy channels. No evidence of persistent water was observed in Wilson Creek; therefore, the occurrence of either the Brazos water snake or the two cyprinid species is highly unlikely.

Freshwater mussels are sensitive barometers of environmental quality. When terrestrial or aquatic ecological conditions degrade or are modified, native unionid mussels (Family Unionidae) are often the first organisms to decline or vanish. In December 2009, the TPWD placed 15 of the 50 known Texas freshwater mussel species on the state threatened list. The

Texas fawnsfoot, found on the Palo Pinto County list, is known only in the Brazos River downstream of Possum Kingdom Lake. The lack of permanent water in Wilson Creek would preclude this species or other freshwater mussels from inhabiting the study area.

Other than the known presence of GCW individuals, habitat and territories within Wilson Hollow and the immediate vicinity, a search of the Texas Natural Diversity Database[47] revealed no other documented occurrences of endangered or threatened species within or near the proposed Lake Palo Pinto Off-Channel Reservoir site. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area.

4B.12.6.3.2.3 Wildlife Habitat

Palo Pinto County is included in the Texan Biotic Province as delineated by Blair[48] and modified by TPWD. This province includes bands of prairie and woodland that begin in South Central Texas and run north to Kansas. The Texan Biotic Province constitutes a broad ecotone between the forests in the eastern portion of this region and the western grasslands. Although varied, the vertebrate community within the area of the proposed reservoir includes no true endemic species. The wildlife habitat types of the study area coincide closely with the major plant community types present. The mountains and associated vegetation areas within Palo Pinto County are similar to that of the Edwards Plateau; therefore the wildlife habitats and species of the study area represent a mixture of those typical of the surrounding areas.

Within this province, western species tend to encroach into open habitats, and eastern species intrude along the many wooded drainageways extending through the landscape. The Texan Biotic Province supports 49 species of mammals, 39 species of snakes, 16 species of lizards, two types of terrestrial turtles, 18 types of toads and frogs (anurans), five species of salamander (urodeles), and an undetermined number of bird species.

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47 Texas Parks and Wildlife Department (TPWD), Texas Natural Diversity Database, Received June 5, 2008.
[48] Blair, W. Frank. 1950. "The Biotic Provinces of Texas," Texas Journal of Science 2 (1):93-117.

4B.12.6.3.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that 99 archeological sites have been documented within the general vicinity of the proposed off-channel reservoir. Researchers from the University of Texas recorded 49 of these sites as part of the Village Bend archeological survey in 1980. These sites, which lie outside the currently proposed reservoir, represent a variety of historic and prehistoric site types.

Prior to reservoir inundation, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any other cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archeological and Historic Preservation Act (PL93-291).

4B.12.6.3.2.5 Threats to Natural Resources

This project would reduce streamflow below the reservoir site during storm events but would increase streamflow when water is released to Lake Palo Pinto. As the reservoir would trap and/or dilute pollutants, it would provide some positive benefits to water quality immediately downstream. Dissolved oxygen levels would be maintained by the installation of a multi-level outlet tower at the new reservoir which would always release water from the top 30 feet of the reservoir conservation pool. The project is expected to have negligible impacts to total discharge downstream and overall water quality in the Brazos River.

A series of avian surveys conducted by Loomis-Austin[49] indicated the wooded ravine and riparian floodplain areas in the Wilson Hollow canyon and close proximity are currently used by the federally protected golden-cheeked warbler, with a total of 139 individuals being observed during March, April and May 2006.

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

4B.13.6.4 Engineering and Costing

Cost estimates for the Lake Palo Pinto Off-Channel Reservoir were originally prepared by HDR Engineering Inc. in April, 2005 for the District.[50] For consistency with the regional water planning guidelines, these costs were adjusted to September 2008 prices using a ratio derived from Engineering News Record Construction Cost Indexes. The estimated construction cost of the Lake Palo Pinto Off-Channel Reservoir is approximately $25.4 million. This includes the construction of the dam, land acquisition, resolution of conflicts, geotechnical investigation, environmental permitting and mitigation, and technical services.

The annual costs are estimated to be $2.5 million; this includes annual debt service, operation and maintenance, and pumping energy costs. The cost for the estimated increase in system yield of 3,110 acft/yr translates to an annual unit cost of raw water of $2.47 per 1,000 gallons, or $804/acft. A summary of the cost estimate is provided in Table 4B.13.6-2.

4B.13.6.5 Implementation Issues

This option has been compared to the plan development criteria as shown in Table 4B.13.6-3.

4B.13.6.5.1 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 (NPDES) 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.

4B.13.6.5.2 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;

[50] HDR Engineering, Inc. "Reconnaissance Report for Off-Channel Reservoir Project for Palo Pinto County Municipal Water District No. 1", April 2005.

Table 4B.13.6-2.
Cost Estimate Summary for
Lake Palo Pinto Off-Channel Reservoir
(September 2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Dam and Reservoir (Conservation Pool 10,000 acft, 182 acres, 1,088 ft-msl_	$9,395,000
Outlet Works/Intake Tower	$526,000
Pump Station & Pipeline	$5,844,000
Relocations and Other	$381,000
Total Capital Cost	**$16,146,000**
Mobilization (5%)	$788,000
Construction Contingencies (12%)	$2,032,000
Land and Easements	$931,000
Engineering, Geotechnical, Legal, & Financing	$2,845,000
Environmental and Archaeological	$907,000
Interest During Construction (18 months)	$1,419,000
Pumping Costs to Fill Initial Reservoir	$331,170
Total Project Cost	**$25,399,000**
Annual Costs	
Debt Service (6%, 30 years)	$2,214,300
Operation and Maintenance	$181,000
Pumping Energy Cost (Avg. Annual)	$106,400
Total Annual Cost	**$2,501,700**
Available Project Yield (acft/yr)	3,110
Annual Cost of Water ($ per acft)	$804
Annual Cost of Water ($ per 1,000 gallons)	$2.47

Table 4B.13.6-3.
Evaluations of Lake Palo Pinto Off-Channel Reservoir Option to Enhance Water Supplies

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate)
B. Environmental factors	
1. Environmental Water Needs	1. Negligible impact
2. Habitat	2. High impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. High 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

- 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.

4B.13.6.5.3 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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4B.13.7 Coryell County Off-Channel Reservoir

4B.13.7.1 Description of Option

The Coryell County Off-Channel Reservoir is a proposed new reservoir adjacent to Cowhouse Creek, northwest of South Purmela, as shown in Figures 4B.13.7-1 and 4B.13.7-2. While there are no current water needs from entities in the county, the off-channel reservoir would provide water for projected future shortages.

The off-channel reservoir will impound diversions made from Cowhouse Creek directly below the proposed dam location illustrated in Figure 4B.13.7-2. The reservoir will consist of a 4,767 ft earthfill embankment dam on the Cowhouse Creek tributary stream with a crest elevation at 1,080 ft-msl. The dam will allow for a 5 ft vertical freeboard and create a conservation pool elevation of 1,075 ft-msl. At conservation pool elevation, the reservoir will have a storage capacity of 15,380 acft and inundate 445 surface acres. All flows from the small contributing drainage area above the reservoir would be passed.

In order for the project to provide a sufficient yield to be cost effective, the Brazos River Authority would likely subordinate their water right at Lake Belton to the Coryell County Off-Channel Reservoir diversions from Cowhouse Creek. Without subordination, the unappropriated flows in Cowhouse Creek available for diversion would not be sufficient enough to maintain adequate water levels in the off-channel reservoir for a viable project.

4B.13.7.2 Available Yield

Water potentially available for impoundment in the proposed Coryell Off-Channel Reservoir was estimated using the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available for diversion from Cowhouse Creek into the Coryell Off-Channel Reservoir without causing increased shortages to existing downstream rights. Firm yield was computed subject to a priority calls agreement with Lake Belton.

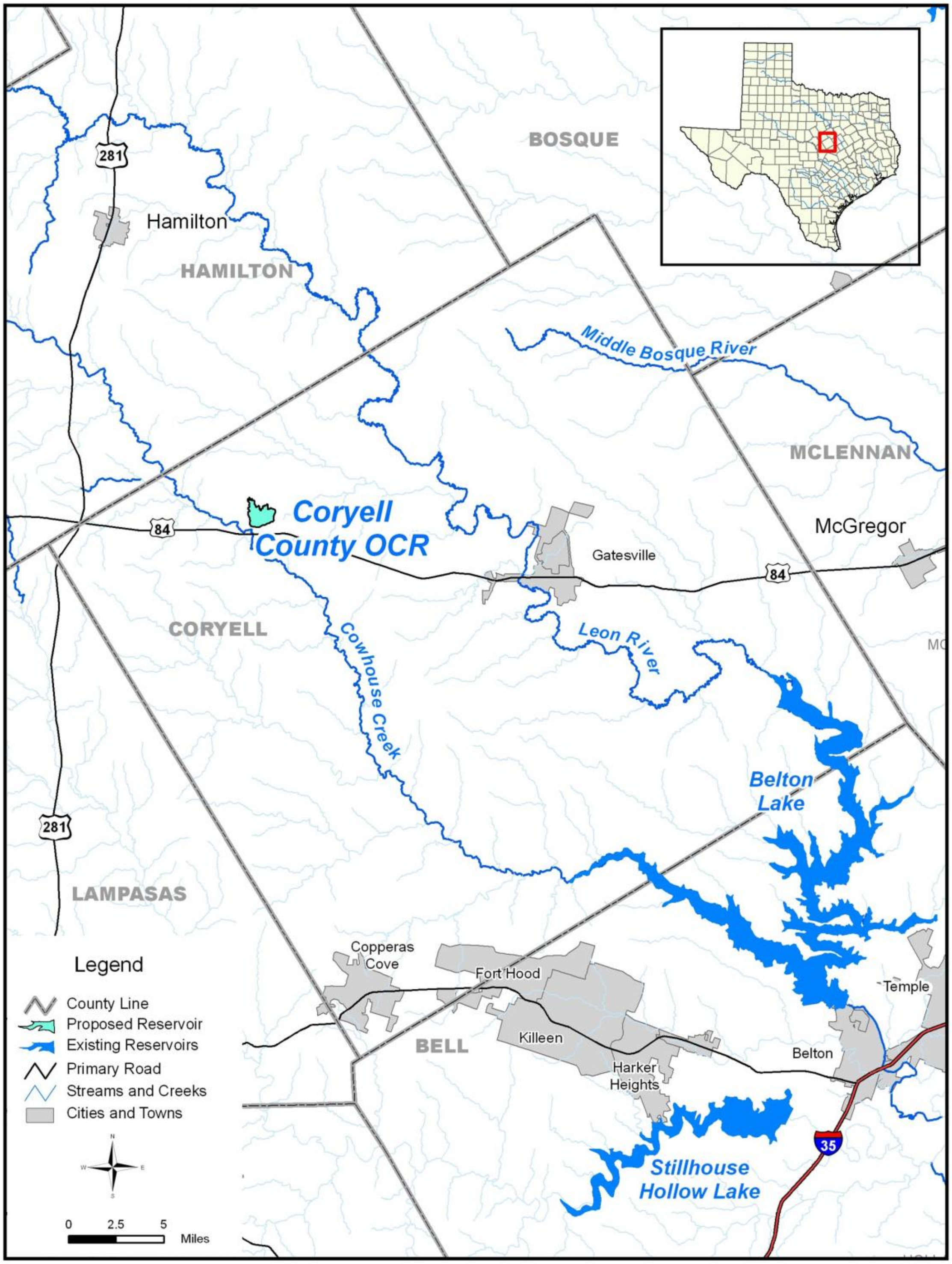


Figure 4B.13.7-1. Coryell County Off-Channel Reservoir

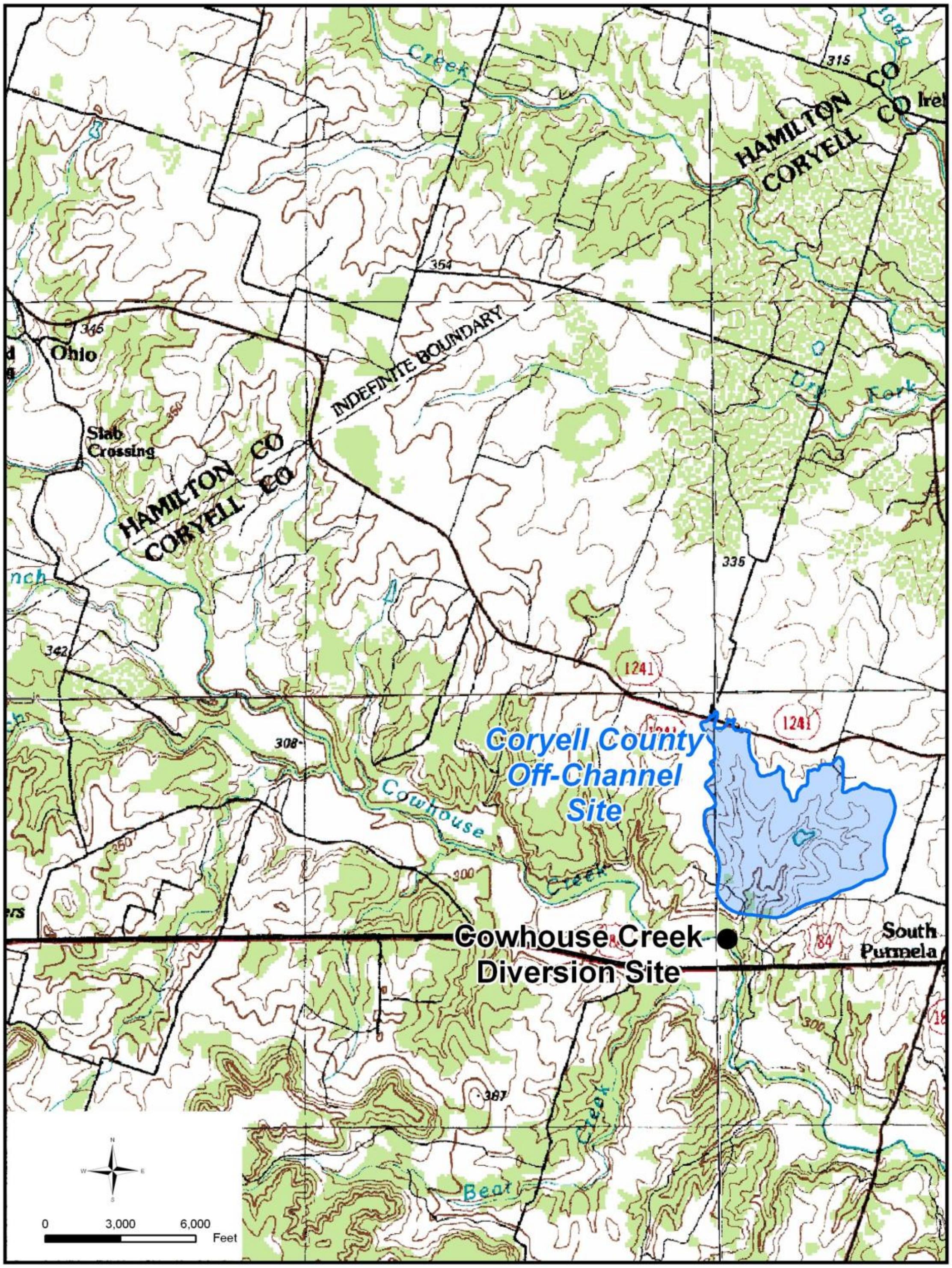


Figure 4B.13.7-2. Coryell County Off-Channel Reservoir

Lake Belton is firm at its authorized diversion of 112,257 acft/yr. When Lake Belton was subordinated to the Cowhouse Creek diversions for the off-channel reservoir, there was no impact to the reservoir's ability to meet its authorized diversions and it remained firm. The ability of Lake Belton to remain firm is a result of it being modeled as part of the BRA system contracts to meet downstream needs. Therefore, to estimate a yield impact from subordination, Lake Belton was modeled as being fully utilized in meeting BRA contracts, firm yield demand. This approach to modeling Lake Belton produces a yield impact of 897 acft/yr due to subordination.

Cowhouse Creek diversions were required to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the Cowhouse Creek diversions are shown in Table 4B.13.7-1. The off-channel reservoir was also modeled such that it has no naturalized flow contributing from its own drainage area. Therefore, no Consensus Criteria pass-through requirements were required at the off-channel reservoir site.

A 675 ft, 36-inch diameter pipeline would be used to divert 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 2007 at Cowhouse Creek near Pidcoke, TX. The estimated streamflow indicates that on average, only 5.3 days per month exceed the required streamflow of 50.0 cfs. Therefore, it is assumed that the transmission system will only operate 5.3 days per month and transfer a maximum of 520 acft/mo of flow from Cowhouse Creek. Figure 4B.13.7-3 illustrates the annual diversion amount from Cowhouse Creek required to refill storage under firm yield conditions. On average, 3,820 acft/yr of water would be diverted.

The calculated firm yield of the Coryell County Off-Channel Reservoir is 3,365 acft/yr Figure 4B.13.7-4 illustrates the simulated Coryell County Off-Channel Reservoir storage levels

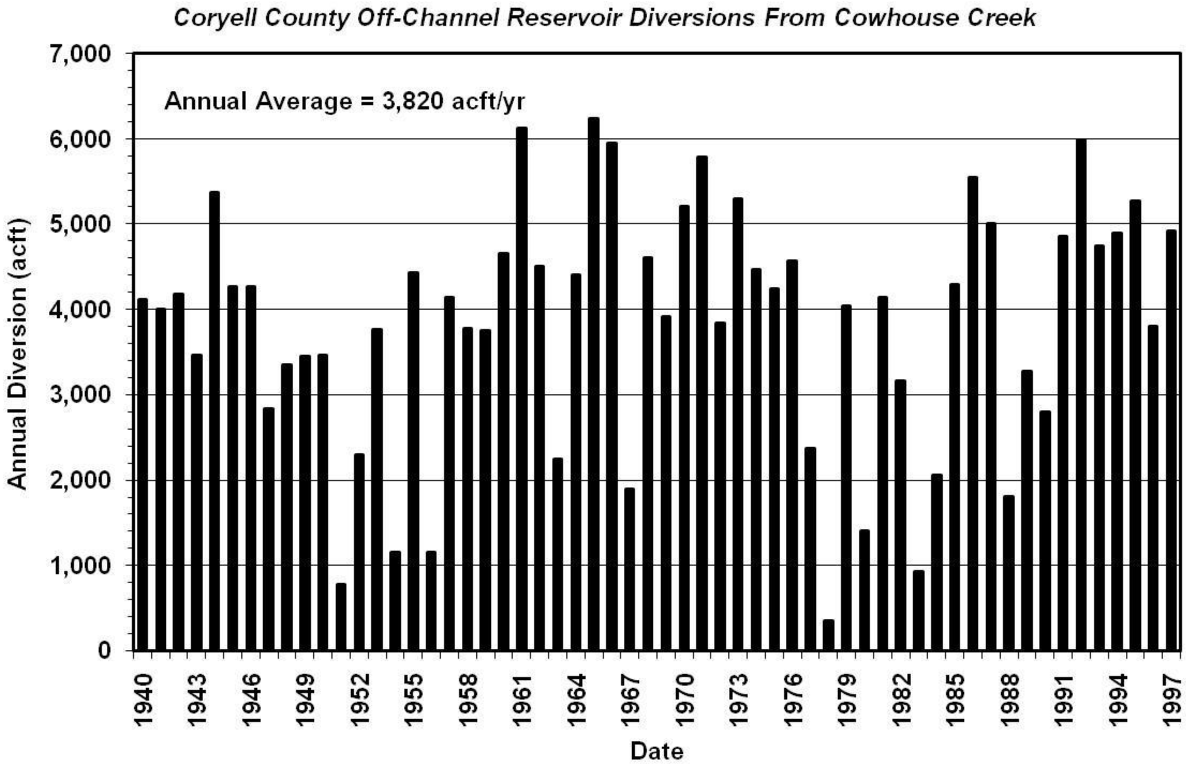


Figure 4B.13.7-3. Coryell County Off-Channel Reservoir Firm Yield Diversions from Cowhouse Creek

for the 1940 to 1997 historical period, subject to the firm yield of 3,365 acft/yr and assuming subordination of Lake Belton and delivery of Cowhouse Creek diversions via a 36-inch pipeline. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 26 percent of the time and above the Zone 3 trigger level (50 percent capacity) 57 percent of the time.

Table 4B.13.7-1.
Daily Natural Streamflow Statistics
for Cowhouse Creek

Month	***Median Flows – Zone 1 Pass-Through Requirements (cfs)***	***25th Percentile Flows – Zone 2 Pass-Through Requirements (cfs)***
January	5.2	0.8
February	7.3	1.2
March	12.1	2.7
April	15.8	2.5
May	20.6	3.3
June	12.1	2.1
July	2.6	0.1
August	0.5	0.0
September	0.9	0.0
October	1.3	0.0
November	2.1	0.1
December	3.9	0.4
Zone 3 (7Q2) Pass-Through Requirement (cfs):		0.0

Figure 4B.13.7-5 illustrates the change in streamflows in Cowhouse Creek caused by the project. The largest change in the Navasota River would be a decline in median streamflow of 9.39 cfs during February. Figure 4B.13.7-5 also illustrates the Cowhouse Creek streamflow frequency characteristics with the Coryell County Off-Channel Reservoir in place. There is little impact on flow frequencies due to the reservoir.

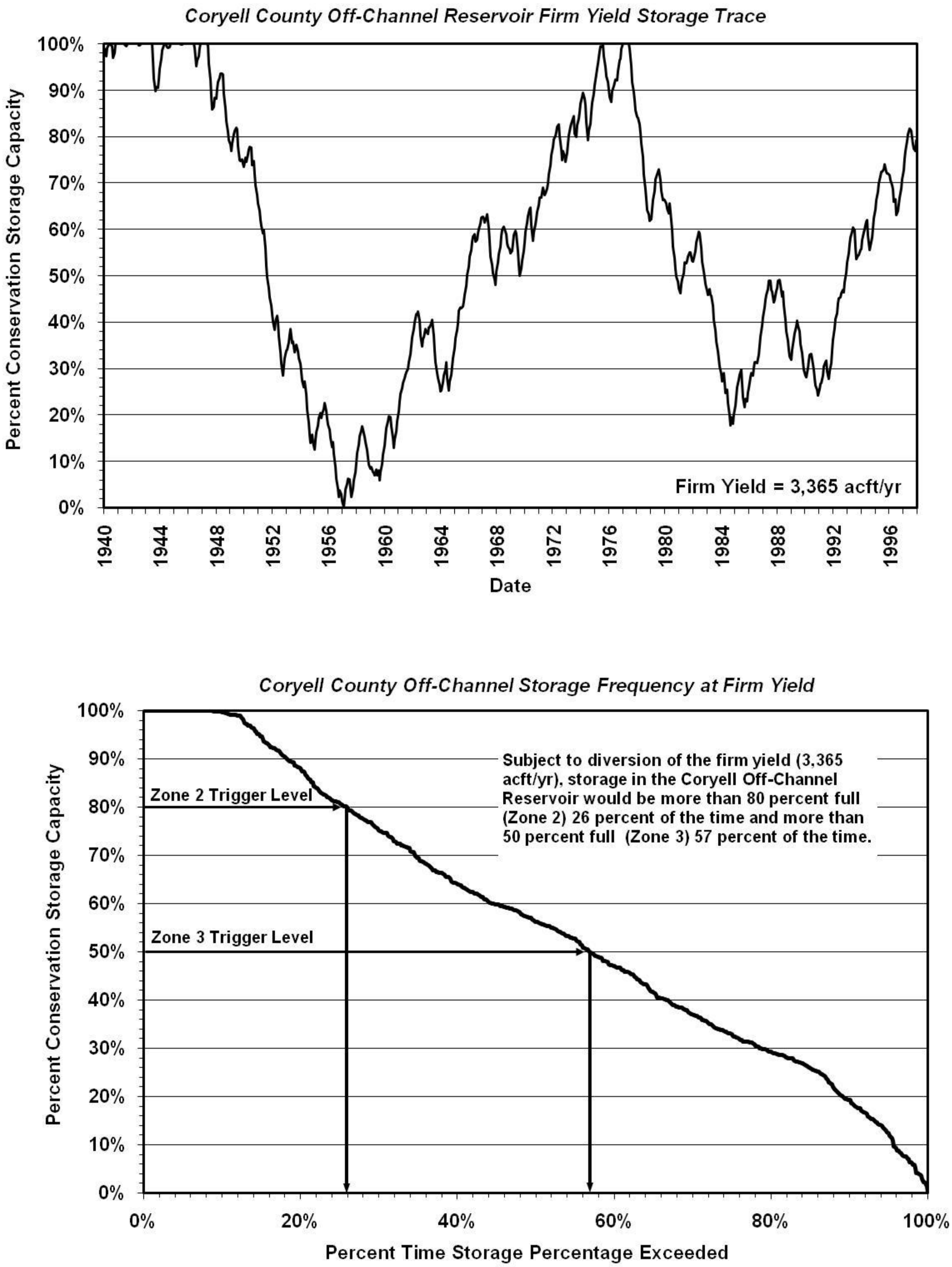
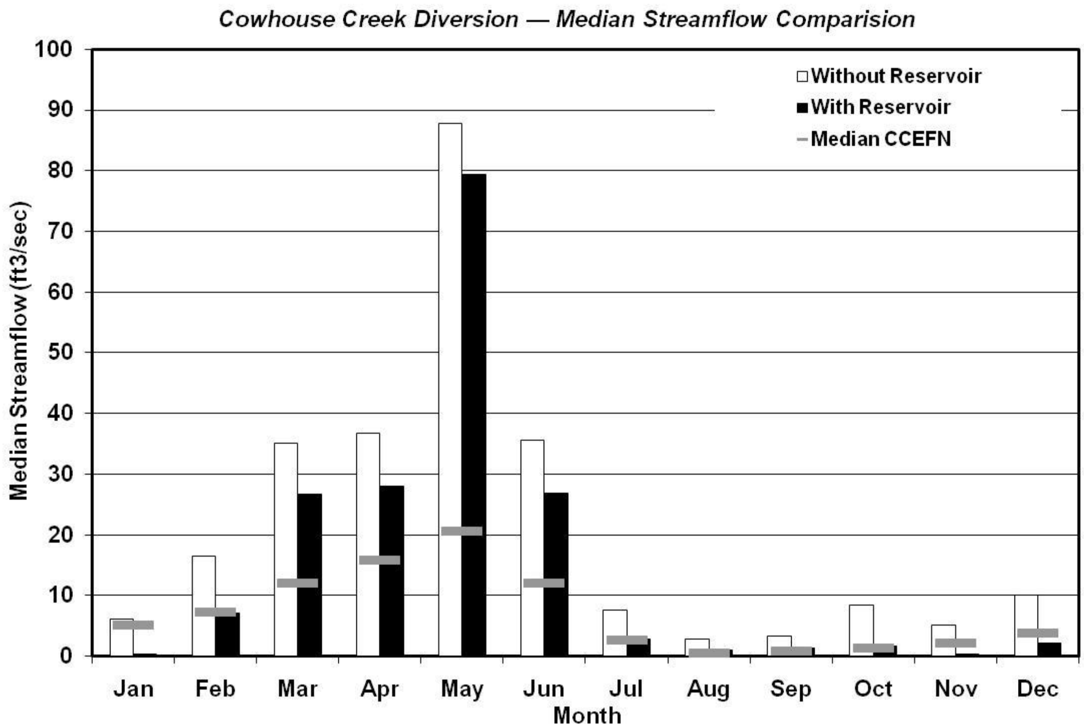


Figure 4B.13.7-4. Coryell County Off-Channel Reservoir Storage Considerations



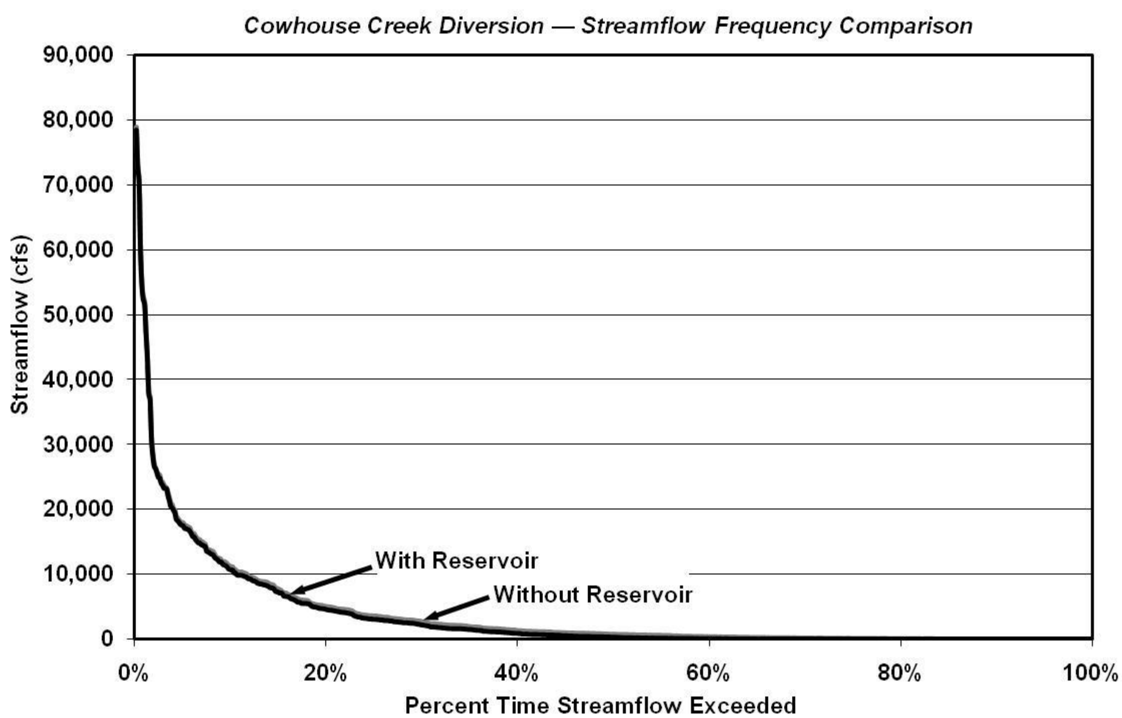


Figure 4B.13.7-5. Cowhouse Creek Diversion Streamflow Comparisons

4B.13.7.3 Environmental Issues

4B.13.7.3.1 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 east of Cowhouse Creek. The proposed OCR site is located in northwestern Coryell County. The site is on the ecotone between the Blackland Prairies and the Edwards Plateau ecoregions[51] and is within the Balconian biotic province.[52] This region is characterized by rolling to hilly topography, with interspersed grassland and woodland, with soils ranging from the deep, fertile, black soils of the Blackland Prairies region to the shallow, dry limestone of the Edwards Plateau region. The climate is characterized as subtropical humid, with warm summers. Average annual precipitation is approximately 33 inches.[53] The Trinity Aquifer is the only major aquifer underlying the project area.[54]

A Custom Soil Resource Report was completed for the Coryell County OCR site[55]. According to this report, nine soil types underlie the site. Nuff very stoney, silty clay loam with 2 to 6 percent slopes, are the most abundant soils in the project area. These soils, typically found on backslopes of ridges, are well drained and consist of a surface layer covered with cobbles, stones or boulders underlain by silty clay loam. Doss-Real complex, 1-8 percent slopes, occupy backslopes of ridges. This complex is well drained and has a very low available water capacity. The complex consists of clay loam to very gravelly clay loam. Bosque clay loam, 0 to 1 percent slopes, rarely flooded, Cho clay loam, 1 to 3 percent slopes, Cisco fine sandy loam, 1 to 5 percent slopes, moderately eroded, and Wise clay loam, 3 to 5 percent slopes, moderately eroded, each comprise approximately 10 percent of the site. The Bosque soils within the site occur on floodplains, are well drained, have a high available water capacity and consist of clay loam. The Cho clay loam soils in the project area are present on ridges, are well drained and have a very low available water capacity. These soils are clay loam at the surface, underlain by

[51] TPWD, "Texas Partners in Flight; Ecological Region 7 – Edwards Plateau"http://www.tpwd.state.tx.us/huntwild/wild/birding/pif/assist/pif_regions/region_7.phtml accessed July 20, 2009.
[52] Blair, W.F., "The Biotic Provinces of Texas, "Tex. J. Sci. 2:93-117, 1950.
[53] The Dallas Morning News, 2008, "Texas Almanac 2008-2009." Texas A&M University Press Consortium, College Station, Texas.
[54] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.
[55] NRCS. "Custom Soil Resource Report for Coryell County, Texas – Coryell County Off-Channel Site. October 6, 2009.

cemented material and gravelly 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. Clay loam is present in the middle layers of these Cisco soils. Wise clay loam soils in the project area are found on ridges, are well drained and have a low available water capacity. These soils are comprised of clay loam at the surface, underlain by silty clay loam and stratified very fine sandy loam to silty clay loam. Additionally, Lewisville clay loam, 1 to 3 percent slopes, Real-rock outcrop complex, 12 to 40 percent slopes and Seawillow clay loam, 3 to 5 percent slopes comprise smaller portions of the project area.

Vegetation within the project area is primarily silver bluestem-Texas wintergrass grassland with a smaller area of oak-mesquite-juniper parks and woods[56]. Silver bluestem-Texas wintergrass grasslands could include the following commonly associated plants: little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), Texas grama (*Bouteloua rigidiseta*), three-awn (*Aristida sp.*) , hairy grama (*Bouteloua hirsute*), tall dropseed (*Sporobolus asper*), buffalograss (*Buchloe dactyloides*), windmillgrass (*Chloris verticillata*), hairy tridens (*Erioneuron pilosum*), tumblegrass (*Schedonnardus paniculatus*), western ragweed (*Ambrosia psilostachya*), broom snakeweed (*Gutierrezia sarothrae*), Texas bluebonnet (*Lupinus texensis*), live oak (*Quercus fusiformis*), post oak (*Q. stellata*) and mesquite (*Prosopis glandulosa*). Commonly associated plants in the oak-mesquite-juniper parks and 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*).

4B.13.7.3.2 Potential Impacts

4B.13.7.3.2.1 Aquatic Environments including Bays & 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

[56] 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.

Table 4B.13.7-2. Median monthly flows are expected to be reduced in all months of the year with a low of a 10 percent reduction expected in May, when flows are typically high, to a high of 93 to 95 percent reduction in median monthly flows expected in November and January, respectively. The difference in variability of monthly flow conditions at the diversion point might also be expected. Variability in flow is important to the instream biological community as well as riparian species and a reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing suitability for others.

Table 4B.13.7-2.
Median Monthly Streamflow: Cowhouse Creek Diversion Site

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	6.05	0.30	5.75	95%
February	16.54	7.15	9.39	57%
March	35.09	26.61	8.48	24%
April	36.75	28.01	8.74	24%
May	87.89	79.43	8.46	10%
June	35.56	26.77	8.78	25%
July	7.64	2.77	4.87	64%
August	2.78	0.91	1.87	67%
September	3.29	1.29	2.00	61%
October	8.38	1.72	6.66	80%
November	5.15	0.37	4.78	93%
December	10.10	2.12	7.98	79%

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, 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.

4B.13.7.3.2.2 Threatened & Endangered Species

A total of 24 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern. This group includes nine birds, two fishes, one insect, three mammals, five mollusks, three reptiles, and one plant species (Table 4B.13.7-3). Three bird species federally-listed as threatened or endangered could possibly occur within the project area. These include the Black-capped Vireo (*Vireo atricapilla*), Golden-cheeked Warbler (*Dendroica chrysoparia*) and whooping crane (*Grus americana*). The Black-capped Vireo and Golden-cheeked Warbler are present in central Texas during the breeding season and have very specific habitat requirements. The whooping crane is a seasonal migrant that could pass through the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

The species listed by USFWS, and TPWD, as endangered or threatened with potential habitat in Coryell County are listed in Table 4B.13.7-3. The Texas Natural Diversity Database, maintained by TPWD, documents the occurrence of rare species within the state. There are no documented occurrences of threatened, endangered or rare species within the proposed OCR site (as noted on representative 7.5-minute quadrangle map(s) that include the project site). The closest documented occurrence is of the endangered Black-capped Vireo, approximately 5.0 miles southwest from the site[57]. There are no other documented occurrences of rare, threatened or endangered species near the proposed OCR 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 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.

4B.13.7.3.2.3 Wildlife Habitat

The primary impacts that would result from construction and operation of the proposed Coryell County OCR include conversion of existing habitats and land uses within the conservation pool to open water. Approximately 445 acres of cropland and pasture and mixed

[57] TPWD, 2009. Element of Occurrence Record – Texas Natural Diversity Database. Obtained from Texas Parks and Wildlife Department October 20, 2009.

Table 4B.13.7.3-2.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the Coryell County Off-Channel Reservoir Site, Coryell County

Scientific Name	*Common Name*	*Federal/State Status*	*Potential Occurrence*
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/T	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL	Migrant
Haliaeetus leucocephalus	Bald Eagle	DL/T	Resident
Vireo atricapilla	Black-capped Vireo	LE/E	Resident Breeder
Dendroica chrysoparia	Golden-cheeked Warbler	LE/E	Resident Breeder
Charadrius montanus	Mountain Plover	SOC	Migrant*
Falco peregrinus	Peregrine Falcon	DL/T	Migrant
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*
Grus Americana	Whooping Crane	LE/E	Migrant
Fishes			
Micropterus treculii	Guadalupe Bass	SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Insects			
Taeniopteryx starki	Leon River winter stonefly	SOC	X
Mammals			
Myotis velifer	Cave Myotis Bat	SOC	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E	Extirpated
Mollusks			
Quincuncina mitchelli	False Spike Mussel	T	X
Tritogonia verrucosa	Pistolgrip	SOC	X
Arcidens confragosus	Rock Pocketbook	SOC	X
Quadrula houstonensis	Smooth Pimpleback	T	X
Truncilla macrodon	Texas Fawnsfoot	T	X
Reptiles			
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X
Plants			
Croton alabamensis var. texensis	Texabama croton	SOC	X

X = Occurs in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be Delisted (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-Delisted Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: TPWD, *Annotated County List of Rare Species for Coryell County,* 2010. TPWD Texas Wildlife Diversity Database (2009), United States Fish and Wildlife Service (USFWS), *Federally-listed as Threatened and Endangered Species of Texas*, 2010.

rangeland below 1,075 ft-msl would be permanently inundated and converted to open water upon reservoir filling[58].

A number of vertebrate species could occur within the Coryell County OCR site as indicated by county occurrence records.[59] These include 15 species of frogs and toads, 5 species of turtles, 8 species of lizards and skinks, and 22 species of snakes. Additionally, 55 species of mammals could occur within the site or surrounding region[60] as well as 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.

4B.13.7.3.2.4 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, no documented cemeteries, historic markers, or historic places are within the proposed inundation area; the John Paney Bertrand historical marke and the Smith Cemetery are located approximately 1.25 miles to the southeast. Considering 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 Texas Historical Commission regarding whether 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 cultural resources.

4B.13.7.3.2.5 Threats to Natural Resources

This project would likely increase adverse effects on stream flow 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 wildlife within the proposed OCR area that would be displaced during reservoir

[58] USGS, 1990. "A Land Use and Land Cover Classification System for Use with Remote Sensor Data," Reston, VA 1990.
[59] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," Accessed online http://wfscnet.tamu.edu/tcwc/Herps_online/CountyRecords.htm November 10, 2009.
[60] 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.

filling. The project is expected to have negligible impacts to the stream flow and water quality in the Brazos River.

4B.13.7.4 Engineering and Costing

The potential off-channel reservoir project for Coryell County would require additional facilities to divert water from Cowhouse Creek to the off-channel reservoir site. 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 49.5 cfs (32 MGD);
- 675 feet of raw water pipeline (36-inch diameter) from the pump station to the off-channel reservoir;
- Off-channel dam including spillway, intake tower, and 445 acres of land for the reservoir.

A summary of the total project cost in September 2008 dollars is presented in Table 4B.13.7-4. The proposed Coryell County Off-Channel Reservoir project would cost approximately $37.5 million for surface water supply facilities. This includes the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The project costs also include the cost for the raw water facilities to convey surface water from the Cowhouse Creek diversion site to the off-channel reservoir. Costs associated with the transmission and treatment of raw water stored in the off-channel reservoir to future customers is not included. The annual project costs are estimated to be $3,387,000. This includes annual debt service, operation and maintenance, pumping energy costs, and purchase of water from BRA for compensation of yield impacts to Lake Belton.

The off-channel project will be able to provide raw water prior to treatment and transmission of treated water to entities in Coryell County at a unit cost of $1,007 per acft or $3.09 per 1,000 gallons.

Table 4B.13.7-4.
Cost Estimate Summary for
Coryell County Off-Channel Reservoir
(September 2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Off-Channel Storage (Conservation Pool 15,380 acft, 445 acres, 1,075 ft. msl)[1]	$15,747,000
Intake and Pump Station at Cowhouse Creek Diversion Site (32 MGD)	$8,348,000
Transmission Pipeline to Off-Channel Reservoir (36 in dia., 675 ft)	$125,000
Total Capital Cost	**$24,220,000**
Engineering, Legal Costs and Contingencies	$8,471,000
Environmental & Archaeology Studies and Mitigation	$1,221,000
Land Acquisition and Surveying (447 acres)	$1,223,000
Interest During Construction (2 years)	$2,354,000
Total Project Cost	**$37,489,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$1,038,000
Reservoir Debt Service (6 percent, 40 years)	$1,700,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$210,000
Dam and Reservoir	$236,000
Pumping Energy Costs (1,711,600 kW-hr @ 0.09 $/kW-hr)	$154,000
Purchase of Water (897 acft/yr @ 54.50 $/acft)	$49,000
Total Annual Cost	**$3,387,000**
Available Project Yield (acft/yr)	3,365
Annual Cost of Water ($ per acft)	$1,007
Annual Cost of Water ($ per 1,000 gallons)	$3.09

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

4B.13.7.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.13.7-5, and the option meets each criterion.

Table 4B.13.7-5. Evaluations of Coryell County Off-Channel Reservoir Option to Enhance Water Supplies

Impact Category	*Comment(s)*
A. Water Supply 1. Quantity 2. Reliability 3. Cost	 1. Sufficient to meet needs 2. High reliability 3. Reasonable (moderate to high)
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries 5. Threatened and Endangered Species 6. Wetlands	 1. Negligible impact 2. Negligible impact 3. Low impact 4. Negligible impact 5. Low impact 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.

4B.13.7.5.1 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.

4B.13.7.5.2 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.

4B.13.7.5.3 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.

4B.14 Interconnection of Regional and Community Systems

4B.14.1 Bosque County Regional Project

4B.14.1.1 Description of Option

In the 2006 Plan, several entities in Bosque County were projected to have water shortages in the year 2060 including the cities of Meridian, Walnut Springs, and Valley Mills and the County-Other entities. Current estimates indicate that three of these entities have adequate supplies while Valley Mills is projected to have a supply need of 12 acft in 2060. In an attempt to address the previously estimated shortage, the Brazos River Authority, Texas Water Development Board, and the Cities of Clifton and Meridian jointly sponsored a study[1] to determine the regional water needs and to evaluate existing and proposed water facilities. According to the study, water shortages in 2030 are: Childress WSC, 0.19 MGD; Meridian, 0.12 MGD; Valley Mills, 0.17 MGD; and Walnut Springs, 0.06 MGD. These quantities are approximately equal to the 2060 shortages determined by the 2006 BGRWPG. The study evaluated four alternatives are described below in Table 4B.14.1-1.

Table 4B.14.1-1.
Alternative Description

Alternative	*Description*
No. 1	The Clifton WTP provides water solely to the Meridian
No. 2	Meridian builds WTP to serve its own users.
No. 3	Subregional water systems are built at Meridian (Northern) and Clifton (Southern) for all participants.
No. 4	Clifton WTP is expanded and becomes a regional facility for all participants.

The study recommended Alternative 4 on the basis of construction costs and unit water costs. For purposes of this water management strategy, the participating water utilities include: Clifton, Childress WSC, Meridian, Valley Mills, and Walnut Springs.

Clifton has recently implemented a surface water supply project to meet its water supply needs. The fourth alternative expands the city's system into a regional facility. This expansion

[1] Carter-Burgess, "Bosque County Regional Water Treatment and Distribution Facilities Plan," Final Report to the Brazos River Authority, March 2004.

would include a pump station and pipelines to the four participants. Figure 4B.14.1-1 shows the planned interconnection of the four water utilities with the regional facility at Clifton.

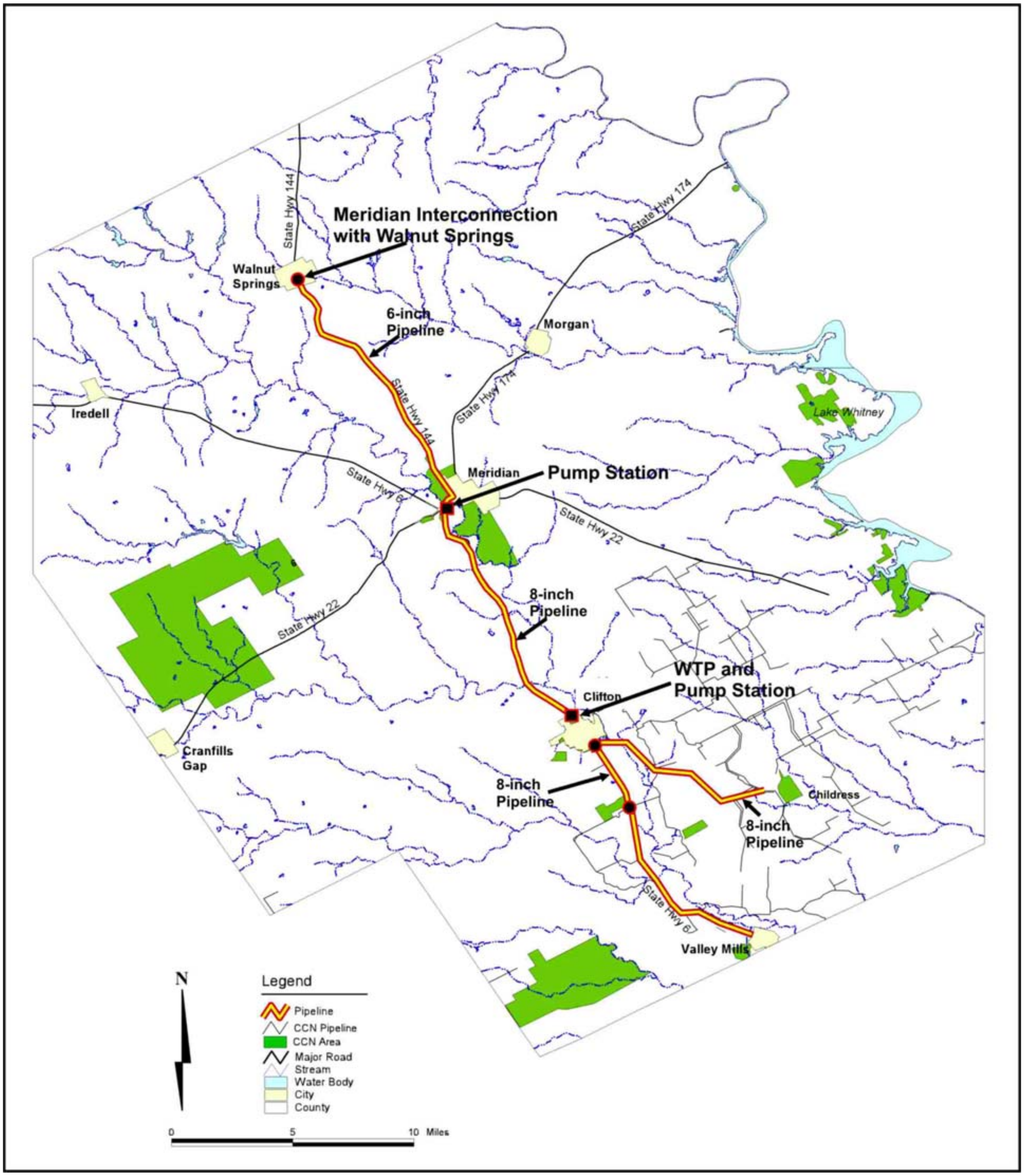


Figure 4B.14.1-1. Interconnection of Bosque County Systems

4B.14.1.2 Available Yield

The yield of the City of Clifton's surface water system (Bosque River diversion into an off-channel reservoir) is currently 405 acft/yr, but future enlargement of the reservoir could increase the yield to 1,777 acft/yr. Based on projected demands, Clifton would have up to 760 acft/yr of supply available to sell in 2060 if its current water treatment plant were expanded and the reservoir were enlarged. This strategy, as formulated, would provide a total of 604 acft/yr to the four WUGS (213 acft/yr to Childress WSC; 134 acft/yr to Meridian; 190 acft/yr to Valley Mills; and 67 acft/yr to Walnut Springs). Estimates of available groundwater supplies from the Trinity Aquifer in Bosque County are substantially greater than those estimated for the 2006 Plan. This increase in available groundwater supplies has eliminated projected shortages for all four entities, except for a small need for Valley Mills which can be accommodated by advanced conservation (Table 4B.2-2). 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.

Note that the cities of Clifton and Meridian have recently completed a treated water pipeline from Clifton to Meridian. If needs develop more rapidly than projected for Clifton or the four utilities, the Clifton off-channel reservoir could be enlarged to increase the firm yield.

4B.14.1.3 Environmental

Environmental impacts could include:

- Possible low to moderate impacts on in-stream flows due to increased diversions.
- Possible moderate impacts on endangered species depending on specific locations of pipelines.
- Possible moderate impacts on riparian corridors depending on specific locations of pipelines.

A summary of environmental issues is presented in Table 4B.14.1-2.

Table 4B.14.1-2.
Environmental Issues
Interconnection of City of Clifton System to Surrounding Communities

Water Management Option	Interconnection of City of Clifton System to Surrounding Communities
Implementation Measures	Construction of pump stations, storage tanks and approximately 45 miles of pipelines between City of Clifton and surrounding communities
Environmental Water Needs / Instream Flows	Possible impacts on in-stream flows but within existing flow regimes allowed by current permits
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 moderate impacts on endangered species, including Black-capped vireo and Golden-cheeked warbler, depending on specific locations of pipelines
Comments	Assumes institutional transfer agreements with 45 miles of pipeline and construction of associated facilities

4B.14.1.4 Engineering and Costing

The City of Clifton, which has developed a new surface water supply, is used as an example of expanding and interconnecting its system into a regional and community system. The following facilities would be needed to connect the City of Clifton to Childress WSC, Meridian, Valley Mills, and Walnut Springs:

- Expansion Clifton’s Water Treatment Plant and Ground Storage;
- Treated Water Pump Station at Clifton and Meridian;
- Treated Water Storage Tank for Pump Station;
- Treated Water Transmission Pipelines; and
- Possible enlargement of off-channel storage if total needs develop more rapidly than projected.

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 a distribution point in the Childress WSC and Valley Mills, and to a pump station at Meridian. From the Meridian pump station, treated water would be pumped to a distribution point in the Meridian and Walnut Springs systems.

The costs for four participating communities in Bosque County to connect to the City of Clifton’s water system are summarized in Table 4B.14.1-3. The capital and other project costs are derived from the Carter-Burgess study and have been updated to September 2008 prices. For consistency with other water management strategies, the annual costs are based on HDR’s cost guide for regional planning studies. The total project cost, including capital, engineering, legal costs, contingencies, environmental studies, land acquisition and surveying, for the regional interconnections are: Childress, $3,022,000; Meridian, $2,974,000; Valley Mills, $5,150,000; and Walnut Springs, $5,247,000.

Table 4B.14.1-3.
Cost Estimate Summary
Bosque County – Interconnection of Clifton, Childress WSC, Meridian, Valley Mills and Walnut Springs.
September 2008 Prices

Item	*Cost of Supply*			
	Childress WSC	***Meridian***	***Valley Mills***	***Walnut Springs***
Capital Costs				
Transmission Pipeline	$1,487,000	$1,650,000	$2,927,000	$2,587,000
Transmission Pump Station(s)	$244,000	$172,000	$273,000	$1,010,000
Water Treatment Plant (Clifton Regional)	$427,000	$302,000	$478,000	$151,000
Total Capital Cost	**$2,158,000**	**$2,124,000**	**$3,678,000**	**$3,748,000**
Engineering (15%)	$324,000	$319,000	$552,000	$562,000
Contingency (25%) [1]	$540,000	$531,000	$920,000	$937,000
Total Project Cost	**$3,022,000**	**$2,974,000**	**$5,150,000**	**$5,247,000**
Annual Costs				
Debt Service (6 percent, 20 years)	$263,000	$259,000	$449,000	$457,000
Operation and Maintenance				
Pipeline and Pump Station	$28,000	$27,000	$47,000	$67,000
Water Treatment Plant	$62,000	$39,000	$56,000	$20,000
Pumping Energy Costs(@ 0.09 $/kW-hr)	$7,000	$3,000	$6,000	$2,000
Total Annual Cost	**$360,000**	**$328,000**	**$558,000**	**$546,000**
Available Project Yield (acft/yr)	**213**	**134**	**190**	**67**
Annual Cost of Water ($ per acft)	**$1,690**	**$2,448**	**$2,937**	**$8,149**
Annual Cost of Water ($ per 1,000 gallons)	**$5.19**	**$7.51**	**$9.01**	**$25.01**

1 - Includes costs for Environmental, Archaeology, Mitigation, Land and Interest during construction.

Taking into consideration debt service on a 20-year loan, operation and maintenance costs, and pumping energy costs, the annual costs are: Childress, $360,000; Meridian, $328,000; Valley Mills, $558,000; and Walnut Springs, $546,000. On the basis water supplies listed above, the unit costs per 1,000 gallons of treated water are: Childress, $5.19; Meridian, $7.51; Valley

Mills, $9.01; and Walnut Springs, $25.01. These costs reflect full development and use of the regional system, assuming enlargement of Clifton's off-channel reservoir is unnecessary.

4B.14.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.14.1-4, and the option meets each criterion.

Table 4B.14.1-4.
Comparison of Bosque County Interconnections Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply 1. Quantity 2. Reliability 3. Cost	 1. Sufficient to meet needs 2. High reliability 3. High
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries 5. Threatened and Endangered Species 6. Wetlands	 1. Low impact 2. Low impact 3. Low impact 4. Negligible impact 5. Low impact 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

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; and

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

Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

4B.14.2 West Central Brazos Water Distribution System

4B.14.2.1 Description of Option

The West Central Brazos Water Distribution System (WCBWDS) is a relatively unused system that could potentially provide raw water to a large portion of the upper Brazos River Basin area. The WCBWDS pipeline facilities, which are owned by the Brazos River Authority (BRA), consist of an intake and pump station on Possum Kingdom Reservoir, several miles of 8-inch through 36-inch pipeline and an intermediate pump station east of Breckenridge. The facilities currently provide raw water for industrial use to the area west of Possum Kingdom.

The Authority has received requests from numerous area water suppliers interested in purchasing raw water from Possum Kingdom Lake that could be conveyed through the WCBWDS facilities. Abilene, Albany, Breckenridge, Eastland County WSD, Graham, Shackelford WSC, Stephens Regional SUD (previously named Stephens County Rural WSC) and West Central Texas MWD have all expressed interest in obtaining water from the BRA. As part of the West Central Brazos Study[2], a hydraulic analysis of the WCBWDS was conducted and improvements were identified to move water to different participants. Three scenarios were evaluated: 1) near-term requests, 2) long-term requests and 3) long-term requests with a potential request from Abilene. These amounts from the West Central Brazos Study are shown in Table 4B.14.2-1.

The hydraulic study found that with only pump station improvements and some additional pipeline capacity, the WCBWDS facilities could have sufficient capacity to serve the existing customers and the near-term requests for water. With the addition of a booster station and a 27-inch parallel pipeline, the facilities could serve additional supply to West Central Texas MWD, Eastland County WSD, the City of Graham, and the City of Albany. Extensive improvements would be necessary to provide supply to the City of Abilene, although facilities

[2] Freese and Nichols, *West Central Brazos River Basin Regional Water Treatment and Distribution Facility Plan,* August 2004.

are in place from the WCBWDS intake all the way to Abilene. Without considering Abilene, the WCBWDS pipeline could provide water to 20 or more entities.

Table 4B.14.2-1. Demands for WCBWDS Hydraulic Analyses

Scenario	Water User	Demand (MGD)	Total Demand (MGD)
	Existing Industrial Demands	2.11	
1	Near-Term Requests	6.43	8.54
	Shackelford		
	Breckenridge		
	Stephens Regional SUD		
	Throckmorton		
	Mining		
2	Long-Term Requests	18.96	27.51
	Albany		
	WCTMWD		
	Eastland County WSD		
	Graham		
	Stephens Regional SUD		
3	Abilene	26.78	54.29

For the 2011 Plan, the transport of water from Possum Kingdom Reservoir using the WCBWDS was considered for the Midway Group participants. The group includes Shackelford Water Supply Corporation (WSC), Stephens Regional SUD, the City of Throckmorton and the City of Breckenridge.

4B.14.2.2 Description of Midway Group Option using the WCBWDS

The Midway Group provides much of the water in Shackelford, Stephens and Throckmorton Counties. Primary water sources for the group include Hubbard Creek Reservoir, Lake Daniel, Lake Throckmorton and a contract with the City of Albany, which receives water from Hubbard Creek Lake and Lake McCarty. Under current contractual and physical constraints all of the Midway group (except Shackelford WSC which is not a WUG) have sufficient supplies to meet TWDB demand projections, but are limited in their capability to accommodate demands that are substantially greater than TWDB projections. Additionally encountering a drought worse than the drought of record could reduce available supplies to less than projected demands.

To meet potential needs of the Midway Group, this strategy proposes to transport water from Possum Kingdom Reservoir to the Stephens Regional SUD water treatment facility near Breckenridge via the WCBWDS, and distributed using existing facilities, upgraded proposed facilities and new facilities to increase supplies and service currently unserved areas. Figure 4B.14.2-1 presents a general schematic of the proposed improvements required for this strategy.

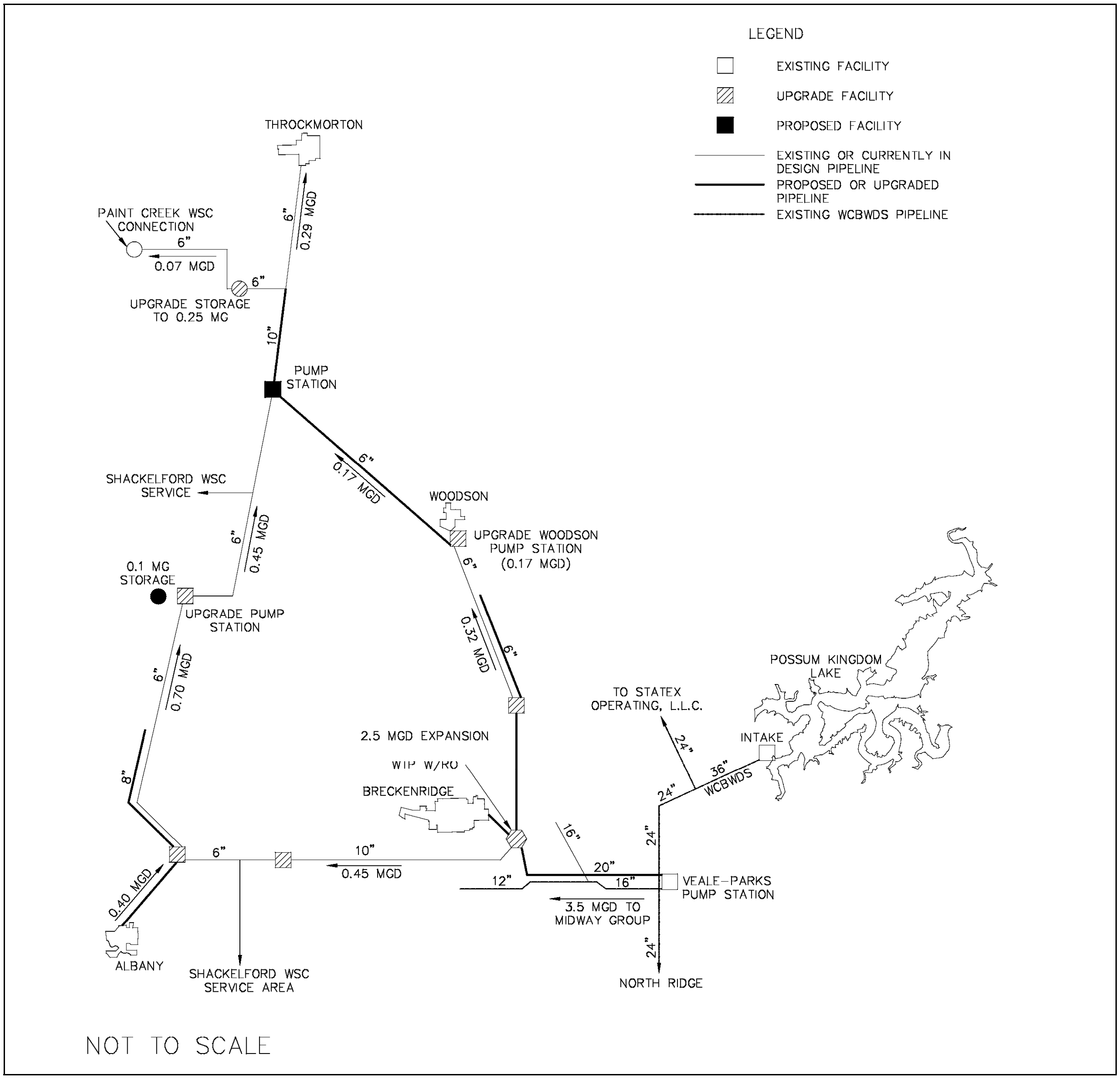


Figure 4B.14.2-1. Schematic of Midway Group Interconnections Using the WCBWDS Facilities

4B.14.2.3 Available Yield

This strategy assumes that the Midway Group participants would contract with the BRA for a total raw water supply of 2,000 acft/yr. Assuming 30 percent of this supply is lost as reject water during treatment (desalination), the available treated supply is approximately 1,400 acft/yr. The total projected demand for the group is over 2,169 acft/yr in 2010, reducing to 1,818 acft/yr by 2060 due to declining populations and conservation in the water demands.

The WCBWSD would be used to move the 2,000 acft/yr of water from Possum Kingdom Lake to the regional water treatment plant. Hydraulic analyses of this pipeline found that a new 20-inch pipeline and some pump station improvements were needed to meet the peak demands of the Authority's current customers and the Midway Group. To treat the water, the existing water treatment plant at Breckenridge would be expanded with a 2.5 MGD microfiltration and reverse osmosis facility. Alternatively, a new water treatment plant could be built solely for treating water from Possum Kingdom Reservoir. The reject water could possibly be discharged to evaporation beds, brine disposal well, to the WCBWDS pipeline for delivery to on-going oil field water flood operations, or other means. Details of the proposed upgrades are shown on Figure 4B.14.2-1 and available supplies to each participant are discussed below.

- **Throckmorton County.** This strategy proposes to supply the city of Throckmorton with 193 acft/yr (200 gpm) through upgrading Shackelford WSC's planned expansion into Throckmorton County and utilizing existing and new water lines in Stephens Regional SUD system. To meet the City's full demands (232 acft/yr in 2010), a new water line from the water treatment plant to Throckmorton would be needed. This scenario assumes that Throckmorton will continue to use some water from existing supplies.
- **Shackelford County.** Of the remaining supply, approximately 250 acft/yr of treated water would be provided to Shackelford WSC, 400 acft/yr to Stephens Regional SUD and 550 acft/yr to Breckenridge to supplement current contracted supplies. The water for Shackelford WSC would be taken south of Breckenridge and transported through the WSC's system to a proposed in-line pump station on Highway 180. The water would then be conveyed to the WSC's office pump station where it could be blended with water from the city of Albany and transported to an existing booster pump station near Ft. Griffin. From there, water would be distributed to Shackelford's customers and the City of Throckmorton. This scenario requires approximately 11.5 miles of upgrades to existing or planned water lines, upgrades of 5 pump stations and several new facilities. Some of these improvements are already proposed to serve retail customers of Shackelford WSC.
- **Stephens County.** Stephens Regional SUD would take treated water directly from the new regional water treatment plant. New connections to their existing distribution facilities would be needed. Some upgrades to Stephens Regional SUD system as

shown on Figure 4B.14.2-1 are also necessary to move water to Throckmorton and expand service to retail customers. These improvements include nearly 13 miles of new 6-inch pipeline and upgrades to Stephens Regional SUD's two existing pump stations. No additional improvements are proposed for the existing Breckenridge facilities.

4B.14.2.4 Environmental

The environmental impacts are expected to be low for the transmission improvements and system upgrades. Most of the upgrades are to existing or proposed pipelines. It is assumed that new pipelines can be routed around environmentally sensitive areas, if needed. Environmental impacts for the reject water from the treatment facility could be low to moderate, depending on the selected disposal method. Further study is needed on the disposal options and potential impacts. There would be minimal impacts to Possum Kingdom Reservoir from this strategy. The quantity of water represents a small amount of the total yield of the reservoir, and would have little impact on water levels.

A summary of environmental issues is presented in Table 4B.14.2-2.

Table 4B.14.2-2.
Environmental Issues
Midway Group Option using the WCBWDS

Water Management Option	Infrastructure improvements to supply water from Possum Kingdom Reservoir to entities in Stephens, Shackelford and Throckmorton Counties (Midway Group).
Implementation Measures	Upgrading of existing pipelines and pump stations to move water from a regional water treatment plant near Breckenridge to users in a 3-county area. Includes 2.5 MGD expansion of water treatment plant with microfiltration to treat brackish water from Possum Kingdom Reservoir.
Environmental Water Needs / Instream Flows	Negligible impacts to Possum Kingdom Reservoir. Potential impacts to water quality if brine effluent is discharged to surface water streams.
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Negligible impact from upgrade of infrastructure since most of the infrastructure is in place. Possible low to moderate impacts if brine effluent is discharged to surface water streams.
Cultural Resources	Negligible impact
Threatened and Endangered Species	Negligible to moderate impacts on threatened or endangered species depending on specific locations of pipelines and disposal option of brine effluent.
Comments	Impacts from brine discharge will be evaluated and mitigated during the permitting process.

4B.14.2.5 Engineering and Costing

Facilities required for the Midway Option using the WCBWDS to deliver treated water to its customers in Stephens, Shackelford, and Throckmorton Counties include:

- Water treatment plant expansion (with microfiltration),
- Pump station upgrades,
- Transmission pipeline, and
- Elevated storage tank upgrades.

The total capital costs for this strategy are estimated at $22.5 million, which includes upgrades to the WCBWDS pipeline and a 2.5 MGD water treatment facility. The cost for treated water would be $6.28 per 1,000 gallons. This does not include power costs to move the water to Throckmorton or other water suppliers' customers. The capital and annual costs are shown in Table 4B.14.2-3.

Table 4B.14.2-3.
Estimated Cost for the Midway Group Interconnections
(September 2008 Dollars)

Item	*Estimated Costs for Facilities*
Capital Costs	
Intake and Pump Station (MGD)	$1,150,000
Upgrade existing and new Transmission Pipeline (29 miles)	$4,563,000
Water Treatment Plant (2.5 MGD)	$8,948,000
Relocations & Other	$601,000
Total Capital Cost	**$15,262,000**
Engineering, Legal Costs and Contingencies	$5,118,000
Environmental & Archaeology Studies and Mitigation	$761,000
Land Acquisition and Surveying (12 acres)	$48,000
Interest During Construction (1.5 years)	$1,272,000
Total Project Cost	**$22,461,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$1,958,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$74,000
Water Treatment Plant	$724,000
Pumping Energy Costs (0 kW-hr @ 0.09 $/kW-hr)	$0
Purchase of Water (2000 acft/yr @ 54.5 $/acft)	$109,000
Total Annual Cost	**$2,865,000**
Available Project Yield (acft/yr)	1,400
Annual Cost of Water ($ per acft)	$2,046
Annual Cost of Water ($ per 1,000 gallons)	$6.28

4B.14.2.6 Implementation Issues

Note that the Stephens Regional SUD completed a pilot study in September 2007 and is pursuing development of a 1 MGD treatment facility near Breckenridge. This is smaller than envisioned in this update to the West Central Brazos study and its impacts to this overall project have not been determined.

This water supply option has been compared to the plan development criteria, as shown in Table 4B.14.2-4, and the option meets each criterion. A major issue facing this option is that full participation of the identified entities may be critical to having an economically feasible project. Utilization of the WCBWDS will require infrastructure improvements that will need to be financed by the water users. Significant increases in the cost of water associated with the infrastructure improvements and water purchase can impede implementation, especially for smaller entities with limited financial resources.

Table 4B.14.2-4.
Comparison of Midway Group Interconnections to Plan Development Criteria

Impact Category	*Comments*
A. Water Supply	
1. Quantity	1. Sufficient quantities available
2. Reliability	2. High reliability
3. Cost	3. Moderate
B. Environmental factors	
1. Environmental Water Needs	1. Possible low to moderate impact, depending on disposal method for brine effluent
2. Habitat	2. Low impact possible where new pipelines are constructed
3. Cultural Resources	3. Possible low impact
4. Bays and Estuaries	4. No substantial impact
5. Threatened and Endangered Species	5. Possible low to moderate impact, depending on disposal method for brine effluent
6. Wetlands	6. Low impact possible where new pipelines are constructed
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	No apparent negative impacts on agriculture or natural resources
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet demand
F. Requirements for Interbasin Transfers	No interbasin transfer required
G. Third Party Social and Economic Impacts from Voluntary Redistribution	No anticipated third party impacts

The other major implementation issue is the potential water quality concerns associated with the treatment and disposal of the elevated salts in the water from Possum Kingdom Reservoir. The Midway Group Regional WTP is proposed to treat Possum Kingdom water using reverse osmosis (or other comparable method). This will generate a brine reject stream that will require disposal. Options considered include discharge to the Brazos River, deep well injection, oil field flooding, or evaporation ponds. Depending on the disposal option, the cost of disposal and the time needed to obtain necessary permits will vary. For any discharge to state waters, a Texas Pollutant Discharge Elimination System Permit would be needed. This permit is issued by the TCEQ and requires demonstration of no to low impacts to the water quality of the receiving stream. Permits for deep well injection are granted by the TCEQ for municipal and manufacturing wastes or by the Railroad Commission of Texas for oil and gas operations. The permitting process through TCEQ for deep well injection can be costly and take several years. Options for salt water disposal through the oil and gas industry either by injection or oil field flood are likely to be easier to implement, but these options require willing oil/gas participation with appropriate facilities. One implementation issue associated with evaporation ponds or drying beds is available space. For small-scale projects, this may be an option, but large scale projects will generate considerable amounts of brine requiring significant area for effective evaporation.

Mitigation requirements would vary depending on impacts. Mitigation is expected to be negligible for the infrastructure improvements. Mitigation requirements associated with the disposal of the brine effluent are unknown.

4B.14.3 Interconnection of City of Abilene System with City of Sweetwater

4B.14.3.1 Description of Option

To provide additional supply to meet the projected water needs of the City of Sweetwater, an interconnection between Sweetwater and Abilene is proposed. The City of Sweetwater would purchase treated water from the City of Abilene through a 16-inch diameter pipeline from Abilene’s Northeast Water Treatment Plant. Figure 4B.14.3-1 shows the major components of the system as well as the pipeline alignment.

An alternative would be to share a raw water pipeline from Abilene with a planned power plant in Nolan County, and treat the supply at Sweetwater’s water treatment plan (Volume I, Section 4C.26.6). This would decrease costs for all participants, but is not evaluated here.

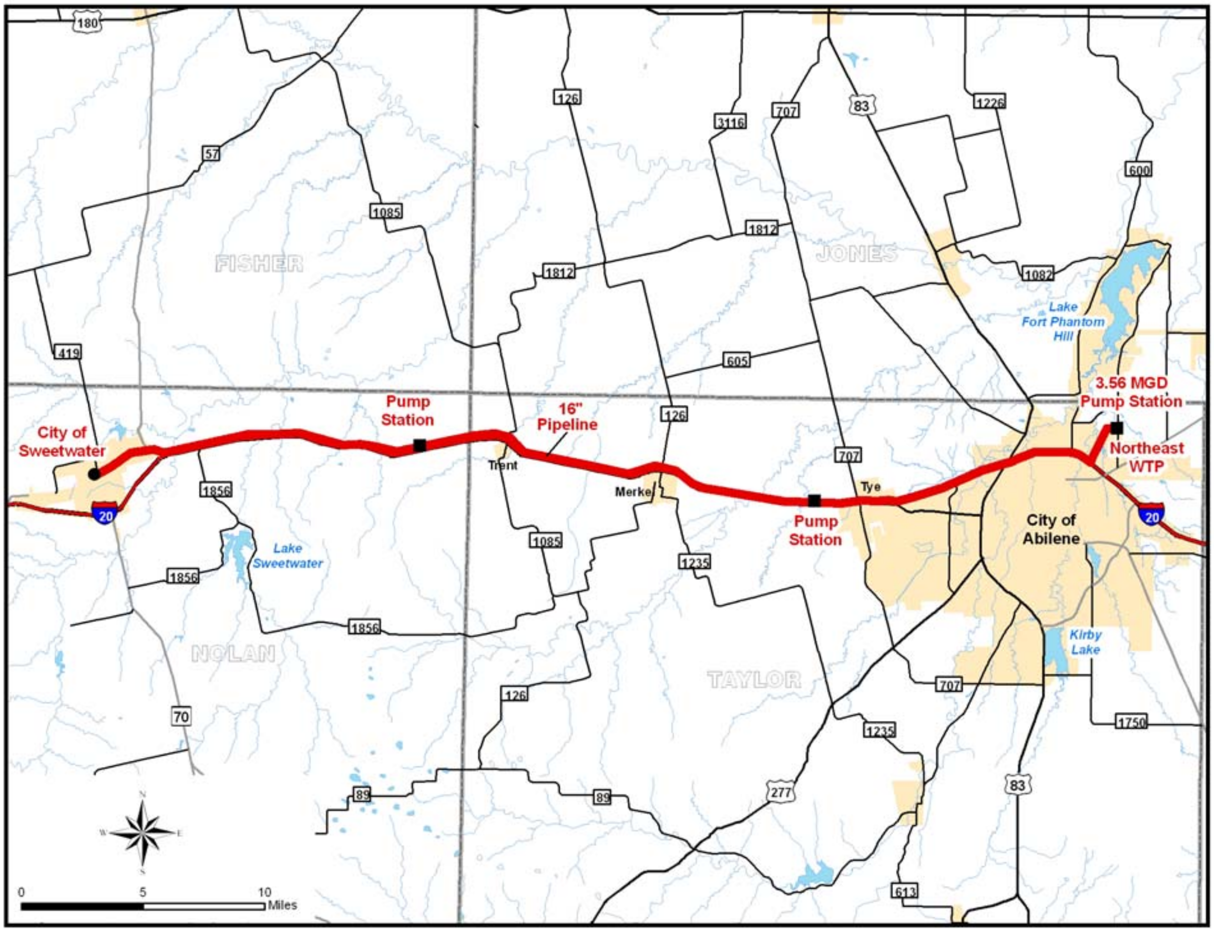


Figure 4B.14.3-1. Treated Water Pipeline from Abilene to Sweetwater

4B.14.3.2 Available Yield

The City of Sweetwater would contract with Abilene for delivery of up to 4,000 acft/yr of treated water. Delivery of the treated water is assumed to be uniform; therefore, the pipeline and components are not sized to accommodate peaking requirements.

4B.14.3.3 Environmental

Environmental impacts could include:

- Possible low impacts on instream flows due to increased diversions; and
- Possible low to moderate impacts on riparian corridors depending on specific locations of the pipeline.

A summary of environmental issues is presented in Table 4B.14.3-1.

Table 4B.14.3-1.
Environmental Issues
Interconnection of City of Abilene System with City of Sweetwater

Water Management Option	Interconnection of City of Abilene System with City of Sweetwater
Implementation Measures	Construction of a 45-mile pipeline between City of Abilene System and City of Sweetwater
Environmental Water Needs / Instream Flows	Possible low impacts on in-stream flows but within existing flow regimes allowed by current permits
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Possible moderate impacts on riparian corridors if pipeline does not occur within existing rights-of-way
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible impact
Comments	Assumes institutional transfer agreements for sale of water

4B.14.3.4 Engineering and Costing

Facilities required for the City of Sweetwater to receive treated water from Abilene include:

- Pump stations, and
- Transmission pipeline.

The system facilities include a 3.75-MGD pump station located near Abilene's Northeast Water Treatment Plant. From this pump station, a 16-inch, approximately 45-mile pipeline, transports water to the vicinity of Sweetwater's existing water treatment plant via two booster stations.

The total capital costs including pump stations, pipeline, valves, and encasements are $32,264,000. Including the project costs of engineering, legal costs, contingencies, environmental studies, land acquisition, surveying, and interest during construction, the total project cost comes to $46,964,000. After taking into consideration annual costs including debt service at 6 percent for 20 years, operation and maintenance, energy costs, and purchase of treated water on a wholesale basis at $1,007 per acft ($3.09 per 1,000 gallons), the total annual cost of the project is $9,461,000. This is a unit cost of $2,365 per acft ($7.26 per 1,000 gallons) for treated water. Table 4B.14.3-2 provides a summary of the project cost estimate.

Table 4B.14.3-2.
Cost Estimate Summary
Interconnection of Abilene and Sweetwater Systems
September 2008 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (3.75 MGD)	$4,398,000
Transmission Pipeline (16 in dia., 45 miles)	$21,417,000
Transmission Pump Station(s)	$6,449,000
Total Capital Cost	**$32,264,000**
Engineering, Legal Costs and Contingencies	$10,221,000
Environmental & Archaeology Studies and Mitigation	$1,116,000
Land Acquisition and Surveying (168 acres)	$1,556,000
Interest During Construction (1 year)	$1,807,000
Total Project Cost	**$46,964,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$4,095,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$479,000
Pumping Energy Costs (9,543,084 kW-hr @ 0.09 $/kW-hr)	$859,000
Purchase of Water (4,000 acft/yr @ 1,007 $/acft)	$4,028,000
Total Annual Cost	**$9,461,000**
Available Project Yield (acft/yr)	4,000
Annual Cost of Water ($ per acft)	$2,365
Annual Cost of Water ($ per 1,000 gallons)	$7.26

[1] Based upon a wholesale rate of $3.09 per 1,000 gallons of treated water. The actual rate would be negotiated.

4B.14.3.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.14.3-3, and the option meets each criterion.

Table 4B.14.3-3.
Comparison of Interconnecting Abilene System with Sweetwater Option to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. 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	• Water supply being redistributed is not needed by seller; no third party impact

4B.14.3.5.1 Regulatory Permits Required

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.

4B.14.3.5.2 Mitigation Funding and Other

Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

4B.14.4 Interconnection of Central Texas WSC with Salado WSC

4B.14.4.1 Description of Option and Costing

The 2006 Plan indicated that Salado WSC was projected to have a water shortage starting in 2020 (100 acft/yr) through 2060 (400 acft/yr). Updated needs analysis indicates that Salado WSC has adequate water supplies. However, this strategy has been evaluated as an alternative for the 2011 Plan. A potential solution to provide additional supplies is a purchase of wholesale treated water from Central Texas WSC. Specific information from Central Texas WSC regarding future interconnection plans is pending. The Central Texas WSC wholesale treated water cost for new customers is $2.10 per 1,000 gallons. For costing purposes, facility and operational costs are assumed to be included in this rate. The annual cost per decade is shown in Table 4B.14.4-1.

Table 4B.14.4-1.
Cost Estimate Summary
Interconnection of Central Texas WSC with Salado WSC

Year:	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*	*2060*
Demand (acft/yr):	0	0	100	250	300	350	400
Cost:	$0	$0	$68,424	$171,062	$205,273	$239,486	$273,697

4B.14.4.2 Available Yield

This water management strategy does not increase supply in the Brazos G Area, but increases utilization of existing reservoir (Lake Stillhouse Hollow) supplies.

4B.14.4.3 Environmental

Environmental impacts could include:

- Possible low to moderate impacts on in-stream flows due to increased diversions.
- Probable low impacts on endangered species depending on specific locations of facilities used to interconnect the systems.

- Probable low impacts on riparian corridors depending on specific locations of pipelines.

A summary of environmental issues is presented in Table 4B.14.4-2.

Table 4B.14.4-2
Environmental Issues
Interconnection of Central Texas WSC with Salado WSC

Water Management Option	*Interconnection of Central Texas WSC with Salado WSC*
Implementation Measures	Construction of pump stations, storage tanks and pipelines
Environmental Water Needs / Instream Flows	Possible impacts on in-stream flows but within existing flow regimes allowed by current permits
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Possible moderate impacts on riparian corridors and upland habitats depending on specific locations of facilities
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible low impacts on endangered species, depending on specific locations of facilities
Comments	Assumes institutional transfer agreements and construction of associated facilities

4B.14.4.4 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.14.4-3, and the option meets each criterion.

The Central Texas WSC and Salado WSC must negotiate a water service contract, likely based on an individual cost of service study.

Requirements specific to pipelines needed to link existing sources to users will include:

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

Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

Table 4B.14.4-3
Interconnection of Central Texas WSC with Salado WSC to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply 1. Quantity 2. Reliability 3. Cost	 1. Sufficient to meet needs 2. High reliability 3. Reasonable
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries 5. Threatened and Endangered Species 6. Wetlands	 1. Low impact 2. Low impact 3. Low impact 4. Negligible impact 5. Negligible impact 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 shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.14.5 Potential Purchase and Use of Water from Possum Kingdom Reservoir

4B.14.5.1 Description of Option

The City of Abilene is evaluating potential sources of raw water to supplement their existing surface water supplies. Despite recent recovery, little rainfall and increasing populations over the last decade have driven Texas deeper and deeper into drought conditions. Particularly in West Texas, cities and towns are evaluating new sources to plan for their future water needs. One such possibility for Abilene is purchasing water from the Brazos River Authority (BRA) at Possum Kingdom Reservoir. This alternative has been explored in varying detail several times over the last 25 years. A general study was last performed in 2008 by HDR Engineering, Inc. (HDR), in conjunction with Enprotec/Hibbs & Todd, Inc. (eHT), and Lockwood, Andrews, and Newnam, Inc. (LAN)[3]. The 2008 study concluded that it was feasible to use Possum Kingdom Lake as a source of raw water supply for the City of Abilene.

[3] *Evaluation of Cedar Ridge Reservoir and Possum Kingdom Lake Water Supply Options for the City of Abilene.* HDR Engineering, Inc. Enprotec/Hibbs & Todd, Inc. Prepared for the City of Abilene. April 2008.

On March 10, 2005, Abilene entered into an Interlocal Agreement with the BRA and the West Central Texas Municipal Water District (WCTMWD) to address existing and future water supplies. The Interlocal Agreement provides the City of Abilene and/or the WCTMWD the option to purchase up to 20,000 acre-feet (acft) per year of BRA System Water, diverted from Possum Kingdom Reservoir. The option is for a period of 10-years from the March 10, 2005 effective date of the Interlocal Agreement, at no cost. At the expiration of the 10-year period, the option to purchase up to 20,000 acre-feet can be extended for a second 10-year period at a cost established under terms of the Agreement. Provisions of the Interlocal Agreement also allow additional extensions of the option to purchase (beyond the second 10-year term) "by mutual agreement." If exercised, the option to purchase would be converted into a standard, long-term water purchase agreement with the BRA.

4B.14.5.2 Possum Kingdom Reservoir

Possum Kingdom Reservoir lies approximately 80 miles east of Abilene, predominantly in Palo Pinto, Stephens, and Young Counties. The reservoir was created with BRA's construction of Morris Sheppard Dam in 1941. According to the BRA, Possum Kingdom Reservoir has a current conservation capacity of 556,220 acre feet and a conservation surface area of 17,800 acres. Normal pool level is approximately 1000 feet above mean sea level (ft-msl). There are approximately 310 miles of shoreline encompassing the long and meandering reservoir. The reservoir is a major component of BRA's basin-wide water supply system.

A hydroelectric power plant located at the Morris Sheppard Dam is capable of generating 22,500 kilowatts of electrical energy from two turbine units. The two turbines are powered by water supplied from two 12-foot diameter pen-stocks having a combined discharge rate of approximately 3,000 cubic feet per second (cfs). The hydro power operations are permitted and regulated by the Federal Energy Regulatory Commission (FERC). The electricity produced from this plant is primarily used for peaking conditions, mostly in the summer months.

In the earlier years of the operation of the system, water from the reservoir was used almost exclusively for rice crop irrigation along the Texas coast. That use has dwindled, and other users have contracted for the available supply. The City of Abilene could acquire a portion of the available supply through a standard, long-term water purchase agreement with the BRA.

4B.14.5.3 Water Quality

Possum Kingdom Reservoir historically has had elevated levels of chlorides, sulfates and total dissolved solids (TDS). These constituents are typically much higher than other area lakes and also higher than current Federal and State drinking water standards. Table 4B.14.5-1 shows median concentrations of chlorides, sulfates, and TDS in Possum Kingdom Reservoir for the 1996 to 2001 period in comparison to maximum limits allowed by current Texas drinking water standards (Texas Administrative Code 30 TAC §290.118(b)).

Table 4B.14.5-1.
Possum Kingdom Reservoir Water Quality
(1996 – 2001)

Constituent	***Median Concentration (mg/L)***	***Texas Drinking Water Standard (mg/L)***
Chlorides	909	300
Sulfates	369	300
Total Dissolved Solids	1,894	1,000

Chloride data from September 1997 to July 2007 as measured at TCEQ sampling site #11866 located in the lower body of the lake near Johnson Bend, are presented in Figure 4B.14.5-1. This figure shows that the median chloride level increased to about 1,060 mg/L during this recent timeframe. With the secondary contaminant level for chlorides in Texas currently set at 300 milligrams per liter (mg/L), the data clearly indicate that any water treatment facility processing this supply source for potable water use must include demineralization.

4B.14.5.4 Water Treatment Facilities

Prior water planning efforts reviewed various treatment and conveyance scenarios for delivering Possum Kingdom water to the City of Abilene. While the option of expanding the City's existing WTPs is feasible, there appear to be several benefits to implementing a new plant near the lake. First, there are a number of communities located along the Possum Kingdom – Abilene corridor that could potentially take advantage of this project and purchase water from the City of Abilene. Previous studies have identified a regional group (Midway Group) of communities that is interested in obtaining treated water. A second benefit of strategically locating the plant next to the lake is the ability to return brackish reject water from the treatment process back into the lake, an option that is not economically available at other potential plant locations. Alternate waste disposal methods, such as deep well injection and evaporation ponds would be significantly more expensive than a direct discharge. Lastly, treating the water prior to transmission eliminates conveyance of the reject water component (approximately 25% of the raw water volume) over a distance of nearly 80 miles. As the quantity of water to be conveyed reduces, so too can the diameter of the pipeline. Savings would be realized in the lower material cost of the smaller pipe diameter with less corrosion protection, and the lower energy costs associated with pumping the reduced quantity of water.

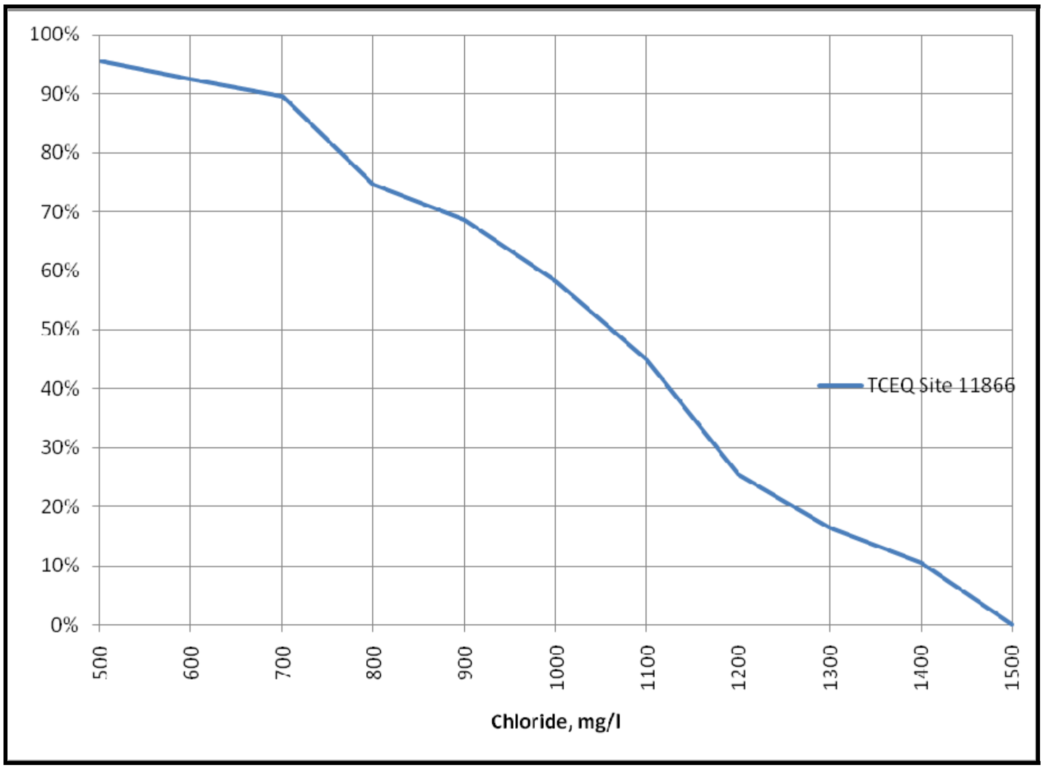


Figure 4B.14.5-1. Exceedance Frequencies for Chloride Concentrations, Possum Kingdom Lake (TCEQ Site 11866: 1997 to 2007)

4B.14.5.4.1 *<u>Treatment Objectives and Process Description</u>*

The finished water quality from the proposed WTP must meet Federal Primary and Secondary Standards, and Texas Commission on Environmental Quality (TCEQ) standards from its *Chapter 290 – Public Drinking Water, Subchapter D: Rules and Regulations for Public Water Systems* and *Subchapter F: Drinking Water Standards*. For this water source, a conventional treatment process would address potability and bacteriological quality requirements, but would not effectively remove the dissolved solids. Reverse Osmosis (RO) is considered to be an effective advanced treatment step for a water source of this quality. Several RO facilities are currently successfully treating the raw water from Possum Kingdom Lake, one of which has since the early 1980s.

With the inclusion of a RO treatment train, the volume of concentrated brine waste, or reject water, must be recognized. Current operating data for a plant on Possum Kingdom Lake operated by the Possum Kingdom Water Supply Corporation (PKWSC) indicate approximately 23% of the total raw water is brackish reject water that is disposed of back into the Lake. Given the above, and allowing an additional 3% water consumption for other process water uses within the WTP, results in a total 26% reduction from gross raw water to net finished water. If the total 20,000 acre-feet of option water were to be utilized, the raw water supply, waste, and net potable water produced would be proportioned as shown in Table 4B.14.5-2.

Table 4B.14.5-2.
WTP Gross/Waste/Net Volumes

Component	*acft/yr*	*MGD*
Total Raw Water Supply	20,000	17.85
RO Reject & Waste	5,200	4.65
Net Potable Water	14,800	13.20

The proposed WTP process is anticipated to consist of a conventional treatment train with coagulation/sedimentation and micro-filtration in advance of the RO membranes to remove the larger particulates and achieve a partial level of treatment. A portion of the filtered water from the conventional treatment train can be blended with the RO permeate to attain the required finished water quality, thereby optimizing the RO equipment capacity. A preliminary schematic diagram of the treatment process is presented as Figure 4B.14.5-2, and the primary process flow streams are summarized in Table 4B.14.5-3. This summary is based on use of the total 20,000 acft of supply; alternate, lower capacity scenarios would be proportioned commensurately.

Process wastewater from the treatment process, predominantly consisting of RO reject water, will have significantly elevated levels of chloride, sulfate, and TDS, and must be disposed of properly. Based on recent Possum Kingdom Lake water quality data, the water treatment volumes described above, and a projected dissolved solids removal rate of 95%, the range of concentrations of these constituents in the waste stream has been estimated as follows:

- Chloride 1,990 to 3,636 mg/L
- Sulfate 1,330 to 2,070 mg/L
- TDS 5,635 to 8,675 mg/L

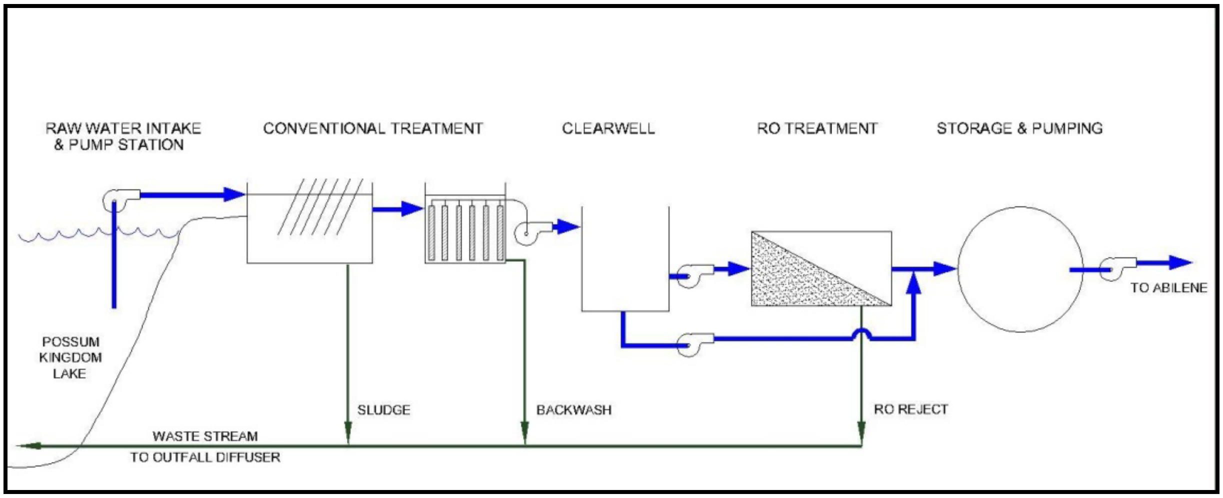


Figure 4B.14.5-2. Preliminary WTP Flow Schematic

Table 4B.14.5-3.
Preliminary WTP Process Summary

Process Stream	***Flow Rate (MGD)***	***% Raw***	***Blend Streams (MGD)***	***Blend Ratios***
Conventional Train Feed	17.85	100%		
Filtered Water to Blend	-1.96	11%	1.96	14.85%
Backwash & Process Water	-0.54	3%		
Net, RO Feed Water	15.35	89%		
RO reject	-4.11	23%		
Net, RO Permeate	11.24	67%	11.24	85.15%
Total Finished Water	13.20	78%	13.20	

The most cost effective means of disposal is to return the brine flow back into the lake. Other disposal methods such as evaporation ponds or deep well injection entail significant capital and/or operation and maintenance costs, and are not preferable for this project. Disposal of the waste stream in Possum Kingdom Lake will require a discharge permit and approval by TCEQ. A preliminary analysis of the impact of this discharge on the water quality of the lake with respect to TCEQ criteria was performed. This analysis projects the not-to-exceed effluent discharge concentrations for chloride, sulfate, and TDS to be 4,300 mg/L, 1,200 mg/L, and 10,000 mg/L, respectively, indicating that the anticipated sulfate levels in the waste stream would require additional analysis in order to be permitted by the TCEQ. The analysis is based on a simplified dispersion model, however, and it might be possible to use more complex techniques to show that enhanced dispersion or diffusion would allow higher concentrations If not, additional treatment may be required to reduce brine concentrations to acceptable levels.

4B.14.5.4.2 Water Treatment Plant Siting

The destination of water delivery favors a WTP site on the southwest side of Possum Kingdom Lake. The most cost-effective option for the proposed raw water intake and pumping facility appears to be the joint use of the existing BRA West Central Brazos (WCB) Water Distribution System intake located in this area. Fortunately, there appear to be many suitable locations for siting of the proposed WTP near the existing intake site. Much of the land adjacent to Park Road 33 and Pump Station Road is owned by the BRA. Advantages of this particular area include the following:

- Level or slightly rolling terrain,
- Minimal clearing required,
- Close proximity to electricity,
- Close proximity to intake structure,
- BRA owned property, and
- Considerable distance to existing homes.

A map of the general area in the vicinity of the WCB intake, showing the relationship of the potential site location and transmission line is presented in Figure 4B.14.5-4.

4B.14.5.4.3 Raw Water Intake

The proposed WTP intake must be sized and configured to convey the required volume of raw water from the lake to the WTP site. The intake should be in close proximity to the WTP site, have reasonable access to electrical power and roads, and be configured for operation over a conservatively-projected range of lake levels. The existing WCB pump station, with the appropriate capacity upgrades, appears to be adequate. This intake site is located on the Little Caddo Creek arm on the southwest portion of the lake. The intake is situated at the end of Pump Station Road which intersects Park Road 33 approximately 2.5 miles southwest of the Possum

Kingdom State Park entrance. The BRA provided information from an assessment of the intake prepared by Freese & Nichols, Inc. which supports a field evaluation performed by eHT. The WCB intake is in good overall condition but would need modifications and additions to adequately serve as the intake and raw water pump station for this project.

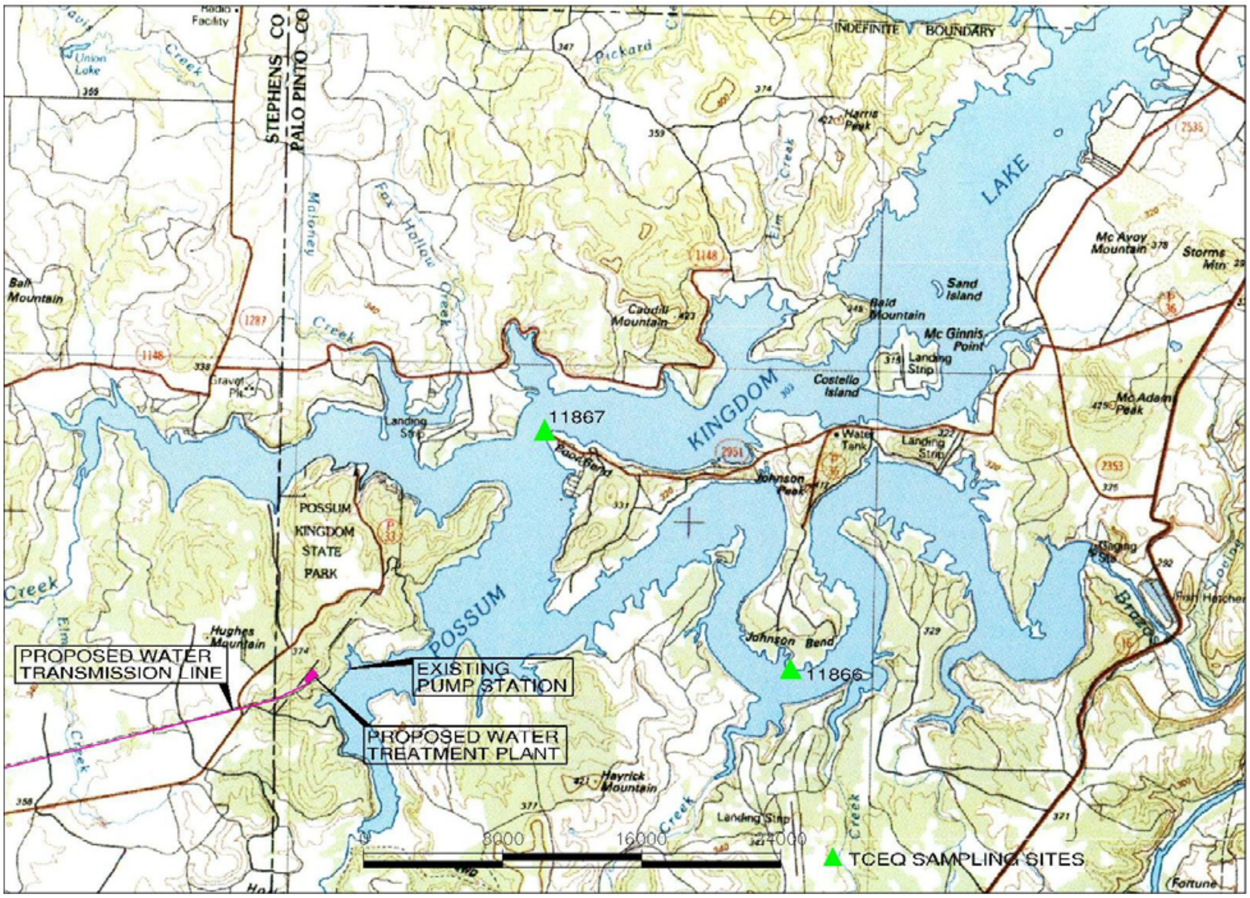


Figure 4B.14.5-4. Proposed WTP Site and Existing Intake Area Map

Expansion or additional use of the WCB intake will require coordination with and approval from the BRA and FERC. The City would need to work with the BRA to determine the extent of necessary improvements, determine joint-use versus separate facilities, and develop a lease agreement that addresses operation and maintenance responsibilities and allocation of costs. BRA has indicated that it would support the City's efforts and assist in the coordination with FERC if joint-use of the existing intake is implemented.

In general, principal modifications to the WCB intake would include raw water pumps installed in the existing structure, discharge piping and control valving, a pipe bridge to the structure, electrical and controls for the pumps, and a motor control center (MCC) building to support the City's pumping infrastructure. Based on the August 7, 2007, excerpt of the Freese & Nichols, Inc. "Assessment of Funding Requirements for the BRA Repair and Replacement Fund" pertaining to the WCB intake, several other capacity and Operation & Maintenance (O&M) improvements have been identified for implementation over the next several years. It is assumed that, if the City of Abilene pursues this option, the City would need to participate in the cost of improvements to shared components of the facility.

The Water Availability Model (WAM) for the Clear Fork portion of the Brazos River has been updated through 2006 to support the City's regional planning efforts. Figure 4B.14.5-5, below, presents a comparison of modeled elevations for Possum Kingdom Lake for currently-permitted diversions versus year 2060 projected full-use diversions. A review of mapped contours of the lake in the vicinity of the WCB intake indicates the elevation of the bottom of the lake to be in the range of 960 ft-msl – 970 ft-msl. This would allow pump operation down to approximately elevation 980 with the proper pump setting. Referencing this lake level to the WAM Brazos G 2060 elevation/frequency curve indicates the water level would be adequate for normal pump operations approximately 94% of the time.

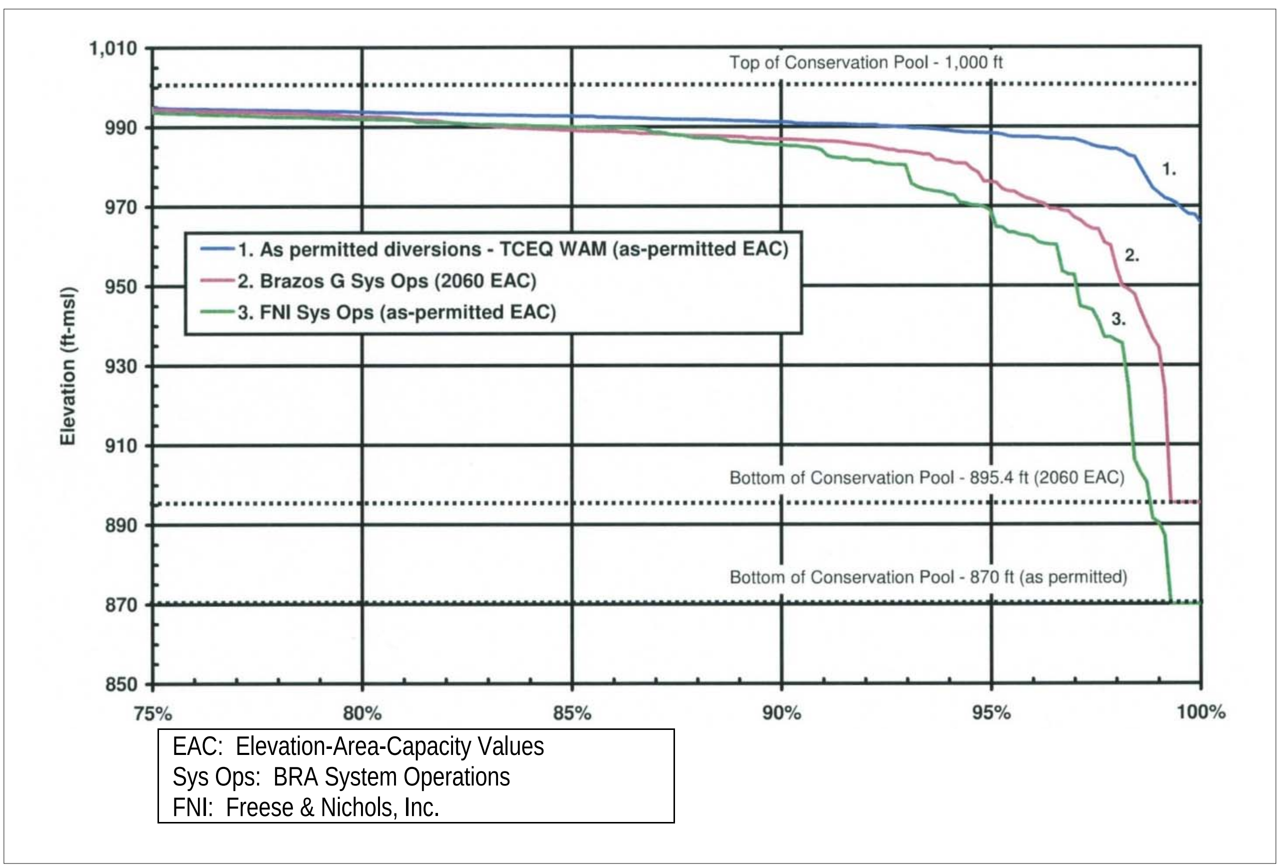


Figure 4B.14.5-5. Possum Kingdom Lake Elevation-Frequency Simulations

4B.14.5.5 Treated Water Transmission

As presented above, the net finished potable water production associated with a 20,000 acft raw water supply volume is projected to be 14,800 acft, or 13.20 MGD. The transmission system is sized to convey this volume with a potential 5% downtime, resulting in an effective transmission capacity of 13.91 MGD, or 9,660 gpm. The system would begin at a high service pump station at the WTP site, and include booster stations at strategic locations to convey the water to Abilene. The point of delivery is Abilene's distribution system on the northeast side of the City.

The layout and configuration of the transmission system requires that consideration be given to topography, system hydraulics, easement/right-of-way issues, and constructability. The terrain is somewhat challenging in that a wide range of elevations are encountered from a lake level of 1000 feet above mean sea level to a high point at approximately 1950 feet above mean sea level. The character of the surface and sub-surface soils will have a direct impact on the cost of construction.

Formations expected to be encountered in trenching range from the most stubborn limestone and sandstone to more moderate soils such as mudstone and shale to the most forgiving soils like sand and alluvium. A preliminary geological review of the project corridor suggests that approximately half of the pipeline length is limestone or sandstone. The other half is a combination of mainly mudstone, shale, alluvium, and deposits.

The evaluated transmission pipeline alignment is shown in Figure 4B.14.5-6 (System Layout). The proposed alignment follows the alignment of existing water transmission facilities, with the intent to utilize existing easements and minimize new easement acquisition. The proposed route would utilize two existing easements that could provide right-of-way for approximately half of the length of the transmission pipeline. One easement was first established by the Texas Pacific Oil Company, Inc., later acquired by the Kerr-McGee Company, and was most recently acquired by the BRA. This easement contains an existing 36" pipeline which is still used for secondary recovery operations in oil fields located west of Breckenridge and in some areas south of Eliasville. BRA has incorporated this facility into their WCB system. This easement, with some limitations, could be used up to a point between US Highway 180 and State Highway 717, northeast of Breckenridge. Based on correspondence with the BRA, the existing easements on several of the parcels along this route will require landowner approval for

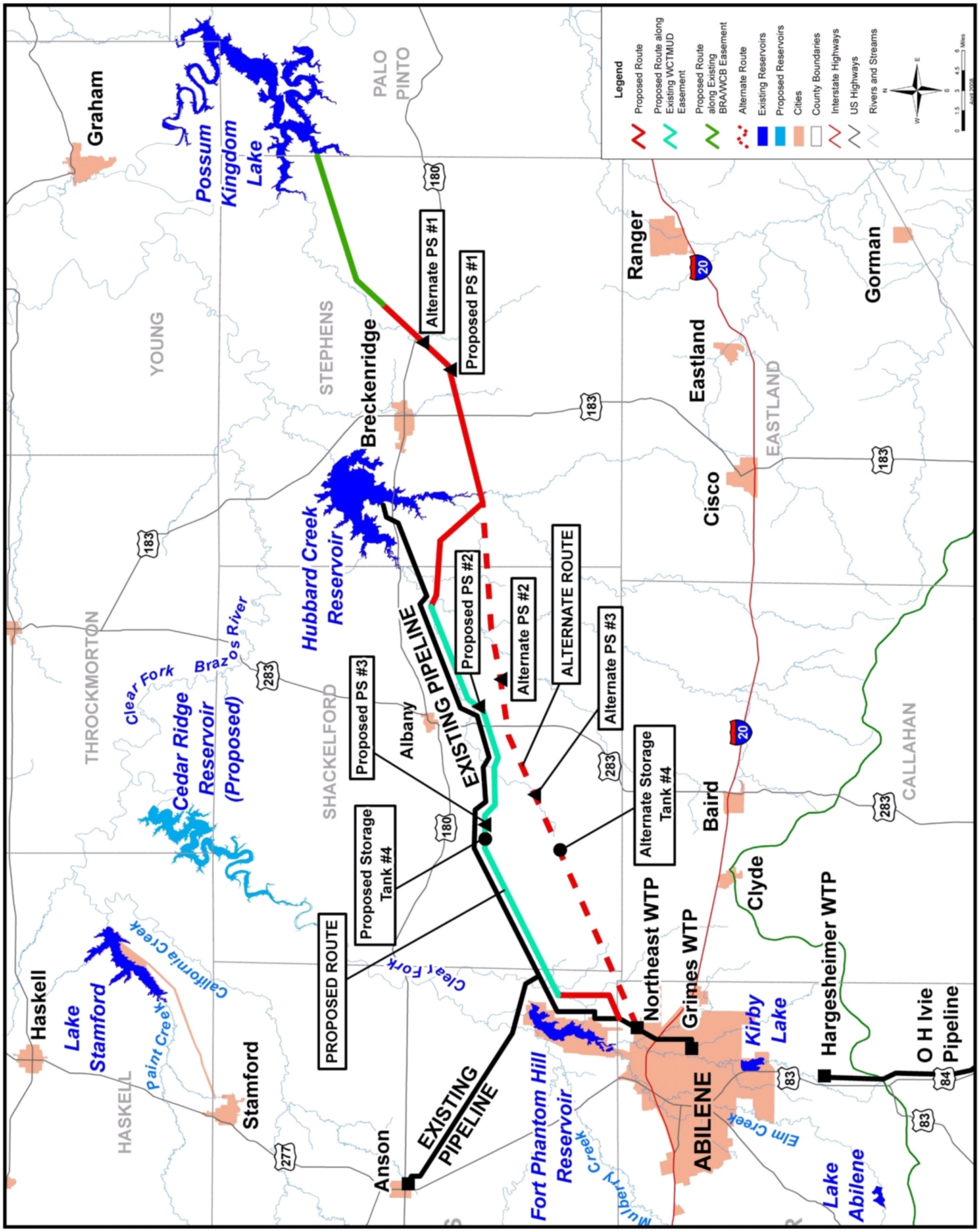


Figure 4B.14.5-6. Proposed Transmission System additional pipelines to be installed and/or easement rights to be assigned. The second easement, owned by the West Central Texas Municipal Water District (WCTMWD), begins at Hubbard Creek Reservoir and generally runs southwest toward Abilene. It is a 100 foot-wide easement containing two existing raw water lines. One line runs down the center of the easement and the other lies approximately 30 feet to the north. The route of the proposed transmission line between the BRA/WCB easement and the WCTMWD easement avoids the developed fringes east and south of Breckenridge, and the southern extremities of Hubbard Creek Reservoir. Total length of the transmission pipeline would be about 77 miles.

A preliminary hydraulic analysis was performed for the transmission system route to size piping, locate and determine operating requirements for pump stations, and review pipe pressure conditions. Figure 4B.14.5-7 presents hydraulic profiles for the proposed route, and display the ground profile, and hydraulic grade line (HGL). The analysis indicates that a 36" transmission line will be required to efficiently convey the treated water volume associated with the 20,000 acft supply (conveying 13.91 MGD of potable water). Three booster pump stations, in addition to the intake and high service pump station will provide sufficient energy to overcome the elevation changes throughout the proposed pipeline route. Operating conditions for the pump stations are summarized in Table 4B.14.5-4.

Each pump station would include a 750,000 gallon ground storage tank for pump suction and flow balancing. The topography along the last quarter of the corridor favors the provision of an "elevated" ground storage tank at the high point in the system that would allow gravity feed into the City.

4B.14.5.6 Environmental Issues

4B.14.5.6.1 Existing Environment

The City of Abilene is evaluating the possibility of utilizing water from Possum Kingdom Reservoir to supplement their existing surface water supplies. The proposed management strategy would include the addition of a new water treatment plant and upgrading of an existing pump station on the southwest side of Possum Kingdom Reservoir, an approximately eighty mile pipeline system used to convey the water to Abilene, and the addition of three booster pump stations. The proposed pipeline will connect at Abilene's existing distribution system located on the northeast side of the City.

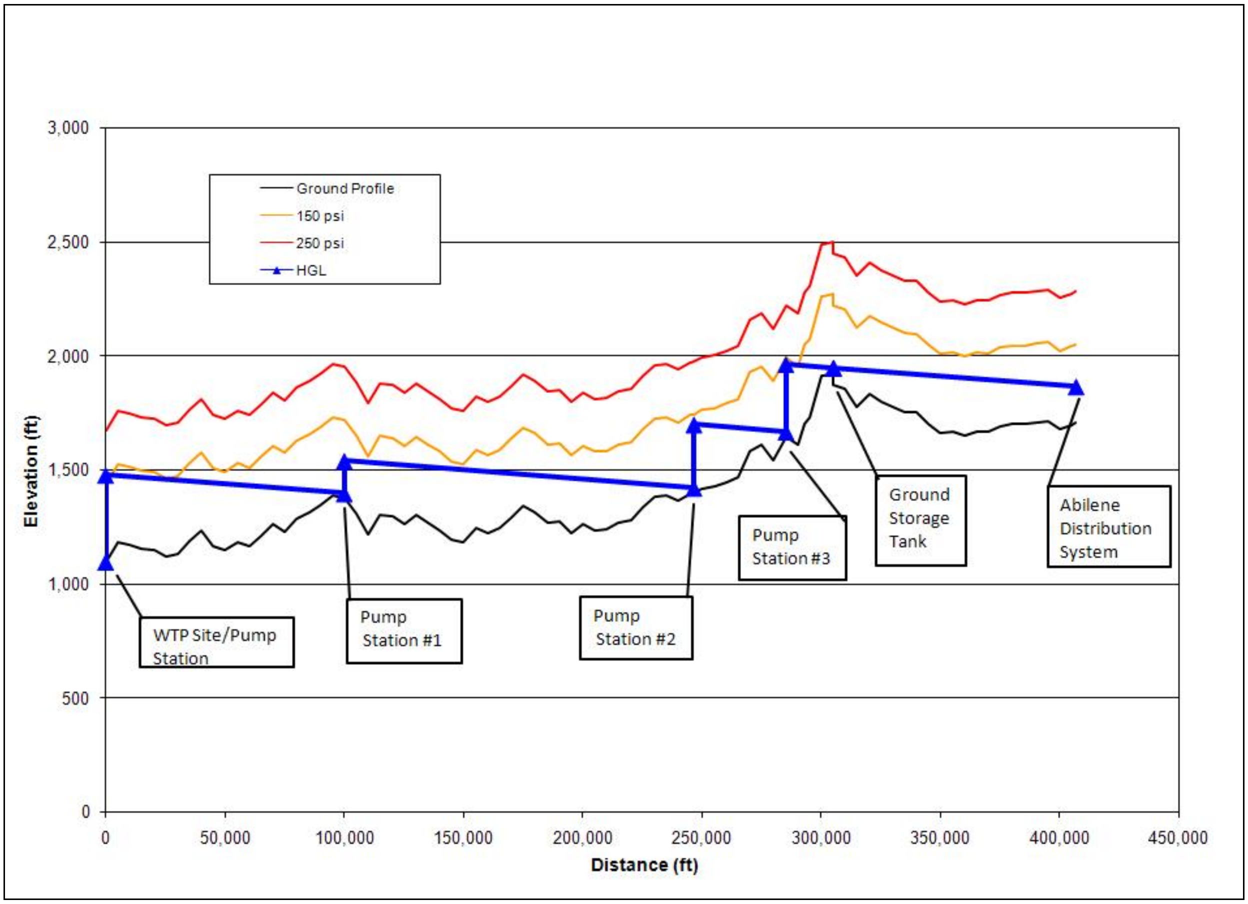


Figure 4B.14.5-7. Hydraulic Profile of Transmission System Proposed Route

Table 4B.14.5-4.
Transmission System Pump Station Requirements

Facility	***Station Capacity (gpm)***	***Discharge Pressure (psi)***	***Power (HP)***
WTP Pump Station	9,700	165	1,378
Booster PS #1	9,700	72	629
Booster PS #2	9,700	130	1,099
Booster PS #3	9,700	245	1,159

The primary environmental issues related to this project are the development of a new pipeline route, addition of three new pump stations, development of new brackish water treatment facilities, disposal of brackish reject water, and integration into the existing pipeline system.

The proposed route includes a total length of approximately 77 miles, and follows the alignment of existing water transmission facilities for approximately half of its route. The use of existing right-of-way (ROW) areas would result in minimal vegetation clearing for those areas and minimize the amount of habitat which would be impacted by the pipeline.

The development of the three booster pump stations along with their associated 750,000 gallon ground storage tanks, and the addition of upgrades to the existing intake and pump station located at PKL will impact relatively small areas of existing habitat.

Plans to process the brackish water found in Possum Kingdom Reservoir at a new water treatment plant could result in the reintroduction of the brackish reject water into the lake. Possible impacts to existing species found near or within Possum Kingdom Reservoir should be carefully evaluated if this option is selected. Alternative methods suggested for the disposal of brackish reject water include deep well injection or the use of evaporation ponds. Either of these alternate methods would be expected to have a more limited impact on existing area species.

4B.14.5.6.2 Project Area Overview

The project area is located in the North-Central Plains Physiographic Province. This area is locally characterized by limestones, sandstones and shales arranged in low north-south ridges. The geologic structure within this area is tilted to the west, with elevation levels ranging from 900 to 3,000 feet above mean sea level.

4B.14.5.6.3 Vegetation and Wildlife Habitats

The study area encompasses two vegetational areas; the western portion of the project is located within the Rolling Plains and the eastern portion within the Cross Timbers and Prairies.[4] The Rolling Plains vegetational area is located between the High Plains, and Cross Timbers and Prairies vegetational areas of northern Texas and contains areas of nearly level to rolling plain with moderate to rapid surface drainage. The original prairie vegetation found within the Rolling Plains Vegetational Area included medium-tall grassland with a sparse shrub cover. The dominant vegetation currently found includes native grasses such as little bluestem

[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.

(*Schizachyrium scoparium* var. *frequens*), blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), Indiangrass (*Sorghastrum nutans*), sand bluestem (*Andropogon gerardii* var. *paucipilus*), and various forbes.

Within areas of sandier soils with broad rolling relief you will find shin oak (*Quercus sinuata* var. *breviloba*) grasslands, with additional groups of various oaks occurring in the mixed grass prairie. In areas containing clay and clay loam soils the predominant vegetation is the mesquite savannah grasslands. These usually occur on flat to gently rolling lands and are characterized by an open canopy of larger mesquite trees, a midstory composed of shrubs such as lotebush (*Zizyphus obtusifolia*), succulents including prickly pears (*Opuntia* spp.), and ephedra (*Ephedra* spp.), and an understory of grasses and forbs.

Historically these natural communities were maintained by a combination of severe weather events, drought and fire. Invasion of the rangeland areas in this region by annual and perennial forbs, legumes, and woody species has been facilitated by historic livestock grazing practices and a lack of naturally occurring fire in the area.

The Cross Timbers and Prairies vegetational area is a transitional area between the Blackland Prairies to the east and the Rolling Plains to the west. The original climax vegetation of this area was primarily composed of grasses such as big bluestem (*Andropogon gerardii* var. *gerardii*), little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and Canada wildrye (*Elymus canadensis*). At one time this area also contained significant amounts of forbes such as western ragweed (*Ambrosia psilostachya*), littlesnout sedge (*Carex microrhyncha*), heath aster (*Aster ericoides*), gayfeathers (*Liatris* spp.) and sageworts (*Artemisia* spp.).

As a result of historical misuse and cultivation, the uplands within this area now contain scrub oak (*Quercus* sp.), mesquite (*Prosopis glandulosa*), and Ashe juniper (*Juniperus ashei*), with mid- and short-grass understories. Hardwoods such as pecan (*Carya illinoensis*), oak, and elm (*Ulmus* sp.) are the traditional primary bottomland trees, but have commonly been invaded by mesquite.

Faunal species found within the project area include those suited to a semi-arid environment. Riparian zones located along the Brazos River, and streams and their tributaries contain important wildlife habitat for the region and support populations of white-tailed deer (*Odocoileus virginianus)* and Rio Grande turkeys (*Meleagris gallopavo intermedia)*. Bobwhites

(*Colinus virginianus),* scaled quail (*Callipepla squamata*), mourning dove (*Zenaida macroura*), and a variety of song birds, small mammals, waterfowl, shorebirds, reptiles, and amphibians are found in this region. Mammals which occur principally in the plains area of Texas include the Texas kangaroo rat (*Dipodomys elator),* Texas mouse (*Peromyscus attwateri*), prairie vole (*Microtus ochrogaster*), and plains pocket mouse (*Perognatus flavescents*).[5] Larger mammals found in the region include the coyote (*Canis latrans),* and ringtail (*Bassariscus astusus).* Bison (*Bos bison),* and black-footed ferrets (*Mustela nigripes*) are historically associated with this area.

4B.14.5.6.4 County Listed Species

In Jones, Taylor, Shackelford, Stephens, and Palo Pinto Counties there may occur ten state-listed endangered or threatened species and seven federally-listed endangered or threatened wildlife species, according to the county lists of rare species published by the TPWD. A list of these species, their preferred habitat and potential occurrence in the five county areas is provided in Table 4B.14.5-5.

Inclusion in Table 4B.14.5-5 does not imply that a species will occur within the project area, but only acknowledges the potential for occurrence in the project area counties. A more intensive field reconnaissance would be necessary to confirm and identify specific suitable habitat that may be present in the project area.

The proposed projects occur primarily in areas which have been previously developed and used for farming and ranching activities for an extended period of time. Disturbance within these areas due to construction of the pipeline route and other facilities needed for this project is anticipated to have minimal effect on the existing environment. Although the use of deep well injection methods or evaporation ponds for disposal of the brackish reject water is not anticipated to impact existing terrestrial species, impacts from the disposal of this water into Possum Kingdom Reservoir or surface water streams should be carefully monitored in order to minimize any impacts this may have on aquatic species. Impacts to any federally listed threatened or endangered species, its habitat, or designated habitat, or to any state endangered species would depend on the specific location of the pipeline route and the disposal option chosen for the brackish reject water. The presence or absence of potential habitat within an area does not confirm the presence or absence of a listed species. No species specific surveys were conducted in the project area for this report.

[5] Davis, W. B. and D. J. Schmidly. 1994. The Mammals of Texas. Texas Parks and Wildlife Department, Austin,TX

Table 4B.14.5-5.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the Abilene Possum Kingdom Site, Jones, Taylor, Stephens, Palo Pinto, and Shackelford Counties

Common Name	Scientific Name	Summary of Habitat Preference	Potential Occurrence in Project Area	Federal Status	State Status
Peregrine falcon	*Falco peregrinus anatum* (American)	Open county; cliffs	Nesting/Migrant	DL	T
	Falco peregrinus tundrius (Arctic)	Open county; cliffs	Nesting/Migrant	DL	—
Baird's Sparrow	*Ammodramus bairdii*	Shortgrass prairie with scattered low bushes and matted vegetation, migratory in western half of state	Migrant	—	—
Bald Eagle	*Haliaeetus leucocephalus*	Found primarily near rivers and large lakes, nests in tall trees or cliffs near water	Resident	DL	T
Black-capped Vireo	*Vireo atricapilla*	Oak-juniper woodlands with distinctive patchy, two-layered aspect; shrub and tree layer with open, grassy spaces.	Migrant	LE	E
Ferruginous Hawk	*Buteo regalis*	Found in open country, primarily prairies and plains, nests in tall trees along streams or slopes	Resident	—	—
Golden-cheeked Warbler	*Dendroica chrysoparia*	Juniper-oak woodlands; dependent on Ashe juniper for long fine bark strips, only available from mature trees, used in nest construction.	Migrant	LE	E
Interior Least Tern	*Sterna antillarum athalassos*	Subspecies is listed only when found more than 50 miles from a coastline; nests along sand and gravel bars within braided streams and rivers.	Migrant	LE	E
Mountain plover	*Charadrius montanus*	Breeding, nesting on shortgrass prairie.	Resident	—	—
Snowy plover	*Charadrius alexandrinus*	Potential migrant, wintering along the coast	Migrant	—	—
Western burrowing owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie.	Resident	—	—
Western Snowy Plover	*Charadrius alexandrinus nivosus*	Potential migrant; wintering along the coast.	Potential Migrant	—	—
Whooping crane	*Grus Americana*	Winters in coastal marshes	Migrant	LE	E
Black-footed ferret	*Mustela nigripes*	Extirpated, inhabited prairie dog towns in the general area	Historic	LE	—
Black-tailed prairie dog	*Cynomys ludovicianus*	Found in dry, flat, short grasslands with low, relatively sparse vegetation, including areas overgrazed by cattle; lives in large family groups.	Resident	—	—
Cave myotis bat	*Myotis velifer*	Colonial and cave-dwelling, also roosts in rock crevices, old buildings, carports, and under bridges	Resident	—	—
Gray wolf	*Canis lupus*	Extirpated; formerly known throughout the western two-thirds of the state in forests, brushlands, or grasslands.	Historic	LE	E
Plains spotted skunk	*Spilogale putorius interrupta*	Open fields, and prairies.	Resident	—	—

Table 4B.14.5-5 (Concluded)

Common Name	***Scientific Name***	***Summary of Habitat Preference***	***Potential Occurrence in Project Area***	***Federal Status***	***State Status***
Red wolf	*Canis rufus*	Extirpated	Historic	LE	E
Guadalupe bass	*Micropterus treculii*	Endemic to perennial streams of the Edward's Plateau region.	Resident	—	—
Sharpnose shiner	*Notropis oxyrhynchus*	Endemic to Brazos River drainage, found in large turbid rivers, with the bottom a combination of sand, gravel, and clay-mud.	Resident	C	—
Smalleye shiner	*Notropus buccula*	Endemic to upper Brazos River system and its tributaries: medium to large prairie streams with sandy substrate and turbid to clear warm water.	Resident	C	—
Brazos water snake	*Nerodia harteri*	Found in the upper Brazos River drainage; in shallow water with rocky bottom and on rocky portions of banks.	Resident	—	T
Pistolgrip	*Tritogonia verrucosa*	Found on stable substrate, rock, hard mud, silt, and soft bottoms, often buried deeply; east and central Texas, Red through San Antonio River basins.	Aquatic Resident	—	—
Rock pocketbook	*Arcidens confragosus*	Mud, sand, and gravel substrates of medium to large rivers in standing or slow flowing water, may tolerate moderate currents and some reservoirs, east Texas, Red through Guadalupe River basins.	Aquatic Resident	—	—
Smooth pimpleback	*Quadrula houstonensis*	Small to moderate streams and rivers as well as moderate size reservoirs; mixed mud, sand, and fine gravel, lower Trinity, Brazos, and Colorado River basins.	Aquatic Resident	—	T
Texas fawnsfoot	*Truncilla macrodon*	Little known; possibly rivers and larger streams, and intolerant of impoundment; possibly sand, gravel, and perhaps sandy-mud bottoms in moderate flows; Brazos and Colorado River basins.	Aquatic Resident	—	T
Spot-tailed earless lizard	*Holbrookia lacerate*	Open prairie-brushland.	Resident	—	—
Texas horned lizard	*Phrynosoma cornutum*	Varied; sparsely vegetated uplands, grass, cactus, and brush.	Resident	—	T
Warnock's coral-root	*Hexalectric warnockii*	Lives in leaf litter and humus in oak-juniper woodlands on shaded slopes and intermittent, rocky creekbeds in canyons.	Resident	—	—

Source: TPWD, Annotated County List of Rare Species, Jones, Taylor, Shackelford and Stephen Counties updated June 25, 2009. Palo Pinto County updated May 4, 2009.

DL Federally Delisted LE Federally listed endangered PDL Proposed for Federal Delisting LT Federally listed threatened
C Candidate species for Federal Listing
--- Not Listed but Rare E State Endangered T State Threatened

4B.14.5.6.5 Wetland Areas

Potential wetland impacts are expected to include pipeline crossings of rivers, and streams, and areas near existing reservoirs. The additional pump stations, water treatment plant, and water transmission pipeline systems should be sited in such a way as to avoid or minimize impacts to these sensitive resources. Potential impacts can be minimized by right-of-way selection and appropriate construction methods, including erosion controls and revegetation procedures. Compensation for net losses of wetland would be required where impacts are unavoidable.

4B.14.5.6.6 Cultural Resources

A review of the Texas Historical Commission Texas Historic Sites Atlas data base indicated that there are no National Register Properties, cemeteries or historical markers listed near any of the proposed project areas.

A cultural resource survey of the proposed WTP and pump station sites along with the pipeline route will need to be performed consistent with requirements of the Texas Antiquities Commission.

4B.14.5.6.7 Summary of Overall Possible Impacts

Because of the relatively small areas involved, construction and maintenance of the additional pump stations and wastewater treatment plant are not expected to result in substantial environmental impacts. Use of the proposed pipeline route would substantially reduce the amount of impact to existing habitats by utilizing already disturbed ROW areas.

Where environmental resources (e.g., endangered species habitat and cultural resource sites) could be impacted by infrastructure, adjustments in facility siting and pipeline alignment should generally be sufficient to avoid or minimize adverse effects. Mitigation requirements would vary depending on the impacts, but could possibly include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

4B.14.5.7 Engineering and Costing

Project cost projections were prepared using the "Studies Level Engineering and Costing Methodology" spreadsheet templates developed by HDR. Cost tables were updated to September 2008 with energy cost set at $0.09 per kWh, to be consistent with State regional water planning efforts. Cost projections were prepared for the Possum Kingdom option using the proposed alignment described above. The Cost summary is included in Table 4B.14.5-6.

As projected, a comparison of the City's future water needs versus existing supplies indicates a deficit of approximately 12,400 acft per year based on 1-year safe yields at 2060. These projected needs could be met with the facilities sized as described above, with a 16%

Table 4B.14.5-6.
Cost Estimate Summary for
Water Supply Project Option
(September 2008)

Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (17.85 MGD)	$2,494,000
Transmission Pipeline (36 in dia., 77 miles)	$71,284,000
Transmission Pump Station(s)	$13,698,000
Two Water Treatment Plants (17.85 MGD - Conventional and 11.24 MGD - RO)	$42,762,000
Total Capital Cost	**$130,238,000**
Engineering, Legal Costs and Contingencies	$42,019,000
Environmental & Archaeology Studies and Mitigation	$2,073,000
Land Acquisition and Surveying (171 acres)	$1,546,000
Total Project Cost	**$189,947,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$16,560,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$1,083,000
Water Treatment Plant	$4,353,000
Pumping Energy Costs (25010885 kW-hr @ 0.09 $/kW-hr)	$2,248,000
Purchase of Water (20000 acft/yr @ 75 $/acft)	$1,500,000
BRA-WCB easement lease	$3,000
Intake lease payment to BRA	$5,000
Total Annual Cost	**$25,752,000**
Available Project Yield (acft/yr)	12,400
Annual Cost of Water ($ per acft)	$2,077
Annual Cost of Water ($ per 1,000 gallons)	$6.37

reserve capacity margin, which is considered reasonable and appropriate. Operating and maintenance production costs are projected based on the 12,400 acft per year water needs. The total project cost for treatment and delivery of 12,400 acft of potable Possum Kingdom Lake water to the City of Abilene (using the alignment cost in Table 4B.14.5-6) is $175,876,000. The associated debt service and annual operating cost are projected at $24,526,000, yielding a finished water cost of $1,978 per acft, or $6.07 per thousand gallons.

4B.14.5.8 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.14.5-7, and the option meets each criterion.

Table 4B.14.5-7.
Comparison of Potential Purchase and Use of Water from Possum Kingdom Reservoir to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply 1. Quantity 2. Reliability 3. Cost	 1. Sufficient to meet needs 2. High reliability 3. Reasonable
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries 5. Threatened and Endangered Species 6. Wetlands	 1. Low impact 2. Low impact 3. Low impact 4. Negligible impact 5. Low impact 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

The participating entities must negotiate a regional water service contract to build and operated the system and to equitably share costs. This would probably include the need for a cost of service study.

Requirements specific to pipelines needed to link existing sources to users will include:

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

Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

4B.15 Carrizo-Wilcox Aquifer Development

The development of the Carrizo-Wilcox Aquifer option involves pumping the aquifer and transporting the water to municipal and industrial users in Williamson and Brazos Counties. The required facilities for each of the two areas are a well field, pipelines, pump stations, and storage facilities. Water treatment to remove possible iron and manganese constituents would be required for the Williamson County option, while only disinfection and cooling would be required for Brazos County.

The Carrizo-Wilcox Aquifer System in Central Texas is capable of producing large quantities of fresh water from the Simsboro and Carrizo Formations.[1,2] The aquifer is primarily used for domestic, livestock, public supplies, and some industrial purposes (mining and power plants). The largest municipal pumpage to date is from the Simsboro for public supply in the Bryan-College Station area, which began over 50 years ago. Other significant pumping is in Milam and Robertson Counties for mining and steam electric purposes and is also from the Simsboro. Water level changes experienced to date are mainly limited to artesian pressure declines in the vicinity of pumping centers. Little or no change in water tables in outcrop (recharge) areas has been observed.

Groundwater availability in the Brazos, Burleson, and Lee Counties is based on a potential consensus by representatives in GMA-12 area. A discussion on the revisions from the 2006 Plan is presented in a Memo to the Brazos G Regional Planning Ground on April 8, 2009. A comparison of the groundwater availability of the Carrizo-Wilcox Aquifer in the 2006 and 2011 Plans for the three counties is presented in Table 1.

Table 1.
Groundwater Availability in Carrizo-Wilcox Aquifer

County	2006 Plan	2011 Plan	Change (2011-2006)
Brazos	53,000	57,156	4,156
Burleson	44,000	35,482	-8,518
Lee	45,000	27,533	-17,467

[1] Thorkildsen, D. and Price, R. D., 1991, "Groundwater Resources of the Carrizo-Wilcox Aquifer in the Central Texas Region," Texas Water Development Board (TWDB) Report 332.
[2] Kelley, V.A., and others, 2004, "Groundwater Availability Models for the Queen City and Sparta Aquifers", prepared for Texas Water Development Board by Intera, Inc, The University of Texas Bureau of Economic Geology and R.J. Brandes Co.

According to the information from GMA-12 representatives, the 2011 availability in Lee County is sufficient to accommodate an 18,000 acft/yr project. In Burleson County, there is a supply of about 31,000 acft/yr. The availability in Brazos County considers the growth in demands for Bryan, College Station, Texas A&M, and other in-county demands. For purposes of the Williamson County strategy, about 22,000 acft/yr will come from Burleson County and about 13,000 acft/yr from Lee County. Accordingly, these new demands are consistent with the 2011 Plan groundwater availability estimates. Finally, any development must address the permitting requirements of wells and export of groundwater by the respective groundwater conservation districts (GCD).

Regulations on the development of groundwater and the export of groundwater have been established for Lee County by the Lost Pines GCD; Milam and Burleson Counties by the Post Oak Savannah GCD; and Brazos and Robertson Counties by the Brazos Valley GCD. Well spacing and export requirements are to be addressed in the permitting process.

4B.15.1 Williamson County

4B.15.1.1 Description of Option

This option is an alternative to the Lake Granger Conjunctive Use Project that is planned to meet Williamson County's shortfall from 2050 to 2060. This maximum shortfall is estimated to be 35,000 acft/yr. Groundwater from the Carrizo-Wilcox Aquifer from a well field crossing the Lee-Burleson County line would be supplied to Williamson County, including the cities of Georgetown, Hutto, Round Rock, and Weir, the utility districts of Chisholm Trail, Jerrell-Schwertner, and Jonah, and county-other and manufacturing. The option is presented at uniform delivery of 31.2 MGD and at a peak-day delivery of 62.4 MGD. For purposes of this assessment, peak day demand is assumed to be 2.0 times the average day demand. The location of the Williamson County Project is shown in Figure 4B.15-1.

4B.15.1.2 Available Yield

The proposed well field is southeast of the Mexia-Talco Fault Zone and about midway between the outcrops of the Carrizo Aquifer and the downdip extent of freshwater. At this location, large capacity wells can be developed in both the Simsboro and Carrizo Aquifers.

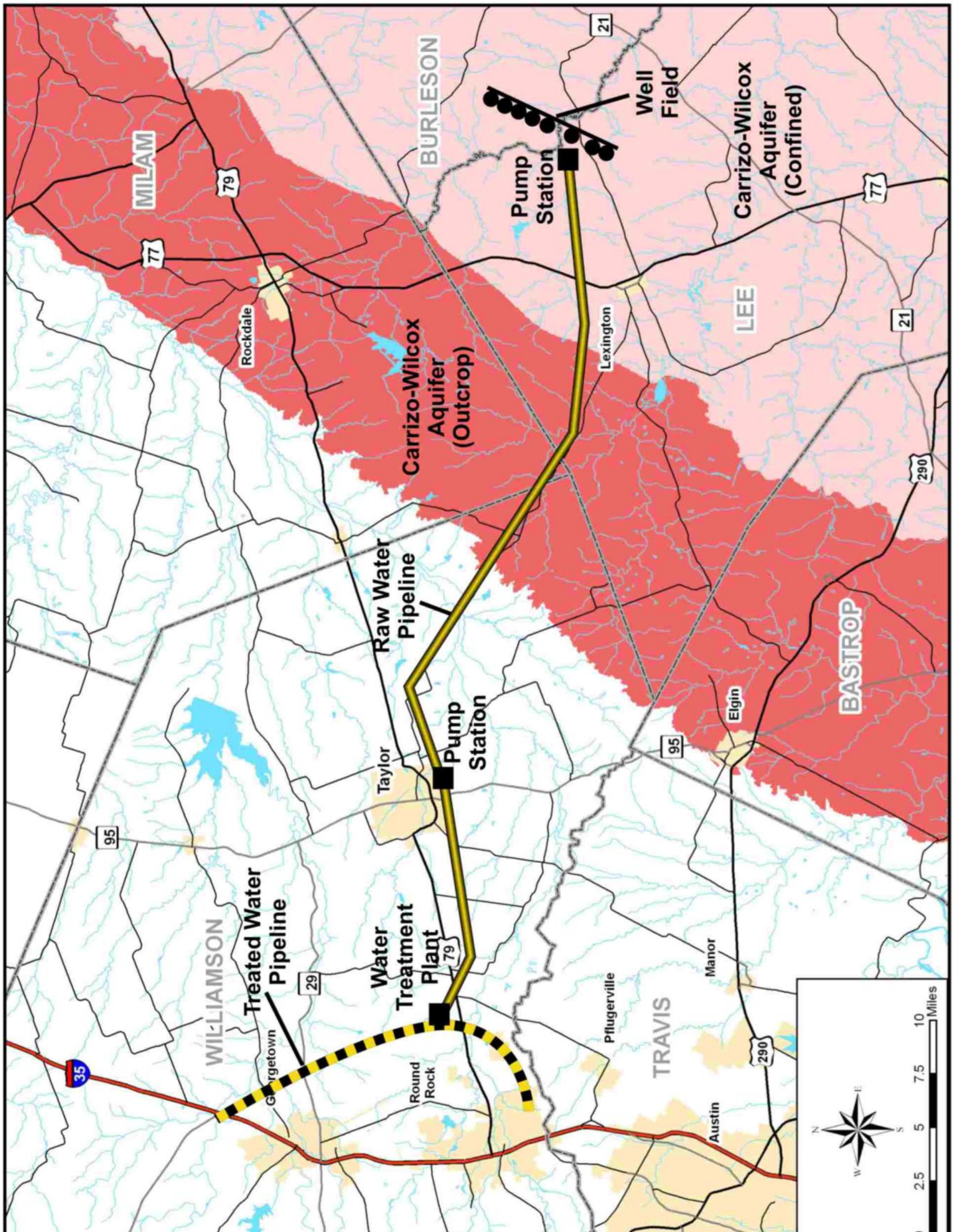


Figure 4B.15-1. Location of Carrizo-Wilcox Water Supply for Williamson County

Simsboro wells would be about 2,500 feet deep and are expected to yield 2,100 gpm. Carrizo wells would be about 900 feet deep and are expected to yield about 1,000 gpm. For a uniform delivery rate at 35,000 acft/yr (31.2 MGD), eight well yards consisting of a Simsboro well and a Carrizo well, producing at 4.4 MGD, are required for the design capacity and a 10 percent contingency. For a well field to meet the peak day demand of 62.4 MGD, 16 well yards would be required. The well yards would be spaced at about 3,000-foot intervals. About a third of the well field would be in Lee County and the remaining two-thirds would be in Burleson County, as shown in Figure 4B.15-1.

4B.15.1.3 Environmental Issues

New and/or expanded well fields in the Carrizo-Wilcox Aquifer in Lee and Burleson Counties, including storage facilities, pump stations and a 60-mile pipeline to Williamson County, and about 25 miles of treated water pipelines could possibly involve the following impacts:

- Impact on environmental water needs and instream flows over the Carrizo-Wilcox would possibly be low, if quantity withdrawn is relatively small. Potential increase in return flows to Brazos River. Base flows would decrease by less than 50 cfs across the outcrop in the Brazos River Basin from pumping of the full availability estimate.
- Possible low beneficial impact on bays and estuaries from increased return flows to Brazos River.
- Probable low impact on fish and wildlife habitat in general, including one amphibian and two plant species, all federally listed.
- Possible low impact on cultural resources.
- Unknown impacts of proposed well field on Houston toad habitat.
- Water level declines would be less than those estimated for pumping of full availability, as shown in Appendix B (Volume I).

4B.15.1.4 Engineering and Costing

The planned site of the well field is along a northeast-southwest line between US 77 and TX 36 and straddling the Lee-Burleson County line. A raw water pipeline would deliver the Carrizo and Simsboro water to a water treatment plant in Williamson County. From there, treated water pipelines would deliver water to individual water utilities.

The major facilities required are:

- Water Collection and Conveyance System:
  - Wells,
  - Pipelines,

  - Pump Station, and
  - Storage.
- Transmission System:
  - Storage,
  - Pipeline, and
  - Pump Station.
- Water Treatment:
  - Removal of iron and manganese concentrations may be required.

Two facility options are evaluated, one for a uniform delivery rate of 31.2 MGD and the other for a peak delivery rate of 62.4 MGD.

Cost estimates were computed for capital costs, annual debt service, operation and maintenance, power, land, and environmental mitigation for uniform and peak day delivery. These costs are summarized in Table 4B.15-1. Treatment costs are for removal of iron, manganese, and possibly hydrogen sulfide by aeration and/or oxidation and filtration. The project costs, including capital, are estimated to be $145,721,000 and $257,884,000 for the uniform and peak delivery options, respectively. As shown, the annual costs, including debt service, operation and maintenance, and power, are estimated to be $29,475,000 and $46,383,000 for the uniform and peak day options, respectively. This option produces potable water at an estimated cost of $842 per acft ($2.58 per 1,000 gallons) and $1,325 per acft ($4.07 per 1,000 gallons), respectively.

4B.15.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.15-2, and the option meets each criterion.

The development of additional groundwater in the Carrizo and Simsboro Aquifers in Lee and Burleson Counties must address several issues. Major issues include:

- Competition with others for groundwater in the area.
- Purchase of groundwater rights.
- Impact on water levels in the aquifer. Anticipated pumping is less than the water availability estimates, but significant water level declines may trigger reductions in production permits with the Lost Pines and Post Oak Savannah Groundwater Conservation Districts.

Table 4B.15-1.
Cost Estimate Summary
Carrizo-Wilcox: Williamson County Option
September 2008 Prices

Item	***Uniform Option***	***Peaking Option***
Capital Costs		
Transmission Pipeline	$91,176,000	$158,438,000
Transmission Pump Stations	$18,908,000	$27,348,000
Well Field and Collection Pipeline	$28,884,000	$60,191,000
Water Treatment Plant (Level 1)	$6,753,000	$11,907,000
Total Capital Cost	**$145,721,000**	**$257,884,000**
Engineering, Legal Costs and Contingencies	$46,444,000	$82,338,000
Environmental & Archaeology Studies and Mitigation	$1,407,000	$1,506,000
Land Acquisition and Surveying (308 acres)	$2,763,000	$2,878,000
Interest During Construction (2 years)	$15,707,000	$27,569,000
Total Project Cost	**$212,042,000**	**$372,175,000**
Annual Costs		
Debt Service (6 percent, 20 years)	$18,487,000	$32,448,000
Operation and Maintenance		
Intake, Pipeline, Pump Station	$1,641,000	$2,814,000
Water Treatment Plant	$2,203,000	$4,236,000
Pumping Energy Costs ($0.09/kWh)	$4,519,000	$4,260,000
Purchase of Water (35,000 acft/yr @ $75/acft)	$2,625,000	$2,625,000
Total Annual Cost	**$29,475,000**	**$46,383,000**
Available Project Yield (acft/yr)	**35,000**	**35,000**
Annual Cost of Water ($ per acft)	**$842**	**$1,325**
Annual Cost of Water ($ per 1,000 gallons)	**$2.58**	**$4.07**

Table 4B.15-2.
Comparison of Carrizo-Wilcox:
Williamson County Option to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High
3. Cost	3. Low to moderate
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact; possible affect on several species
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

The regulatory permits that are expected to be requirements specific to wells and pipelines include:

- Regulations and permits by the groundwater conservation districts (Lost Pines and Post Oak Savannah).
- U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the pipelines impacting wetlands or navigable waters of the United States.
- General Land Office easement for use of state-owned land.
- Texas Parks and Wildlife Department Sand, Gravel, and Marl permit for construction in state-owned streambeds.

- Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

4B.15.2 Brazos County

4B.15.2.1 Description of Option

This Carrizo-Wilcox development option for Bryan and College Station is planned to meet their need for additional water by expanding their Simsboro Aquifer well fields. This shortfall totals about 11,200 acft/yr by 2060. Groundwater from the Simsboro Aquifer, which is the main water-bearing zone of the Wilcox Formation, would come from a well field in the extreme western part of the county (Figure 4B.15-2).

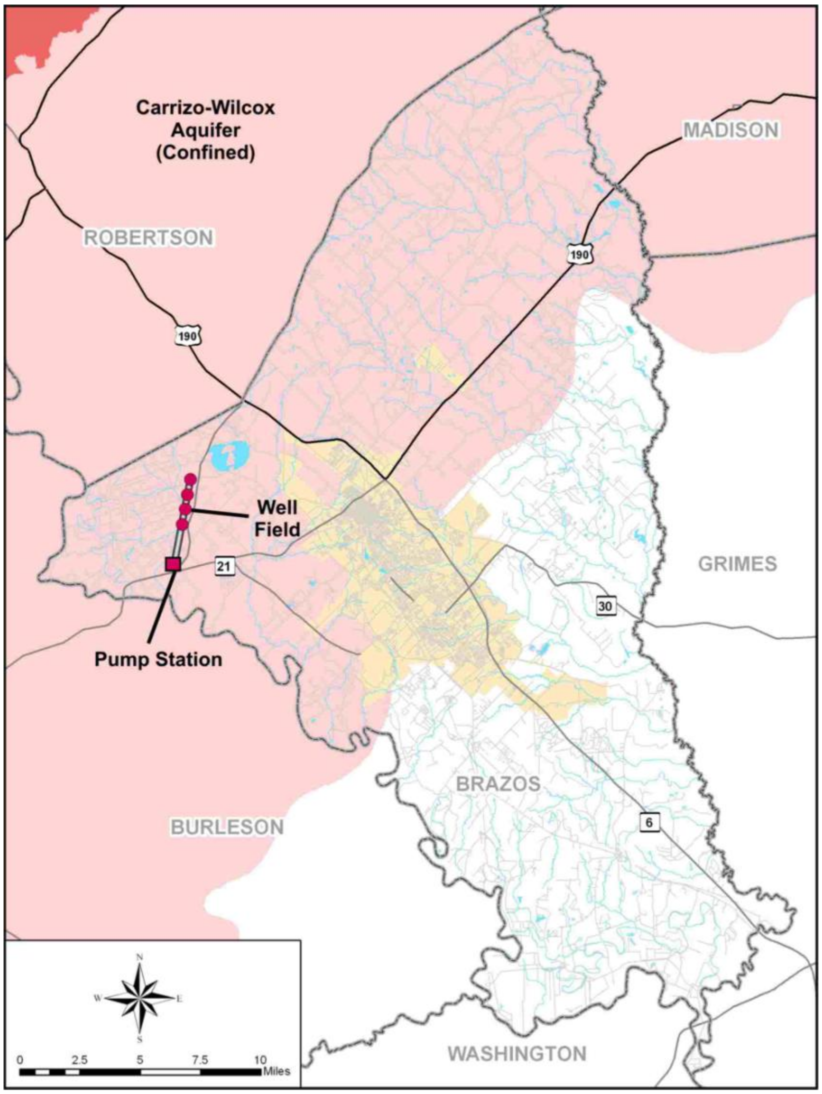


Figure 4B.15-2. Location of Carrizo-Wilcox Water Supply for Brazos County

The option is presented at two delivery capacities. One is for a uniform delivery of water and the other is sized to meet peak day demands. For purposes of this assessment, peak day demand is 2.0 times the average day demand.

4B.15.2.2 Available Yield

Previous studies[3,4] and the ones conducted for Brazos G indicate that this quantity of water from the Simsboro part of the Carrizo-Wilcox Aquifer is available for development. In this area, Simsboro wells average 2,800 feet in depth and commonly yield 2,100 gpm. For planning purposes, the maximum annual production of water from the Brazos County well field is 11,200 acft/yr. For the uniform water delivery option, five wells would be required when considering a contingency of one well. A well field sized to provide a peak day delivery rate would require a peak production rate of 20.0 MGD. This demand would require eight wells. The estimated well spacing would be similar to existing wells in the area (i.e., 2,000 to 2,500 feet). The location of the proposed well field is in Brazos County and is shown in Figure 4B.15-2.

4B.15.2.3 Environmental Issues

New and/or expanded well fields in the Carrizo-Wilcox Aquifer in Brazos Counties, include wells, storage facilities, pump stations and a 3-mile pipeline to existing or planned pipelines. This development is expected to have the following environmental impacts:

- Impact on environmental water needs and instream flows over the Carrizo-Wilcox would possibly be low. Potential increase in return flows to Brazos River downstream of Bryan-College Station. Base flows would decrease by less than 50 cfs across the outcrop in the Brazos Basin from pumping at the full estimated availability.
- Possible low beneficial impact on bays and estuaries from increased return flows to Brazos River.
- Probable low impact on fish and wildlife habitat in general, including one amphibian and two plant species, all federally listed.
- Possible low impact on cultural resources.
- Water level declines would be less than those estimated for pumping of full availability, as shown in Appendix B (Volume I).

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[3] Thorkildsen, D. and R.D. Price, Op. Cit., 1991.
[4] Muller, D.A. and R.D. Price, Op. Cit., 1979.

4B.15.2.4 Engineering and Costing

For the Brazos County option, groundwater would be developed from a well field along a north-south line about 5 miles west of Bryan. Water treatment would require cooling and disinfection. The location is subject to adjustment, due to future expansions of adjoining well fields.

The major facilities required for these options are:

- Wells,
- Pipelines,
- Storage,
- Booster Station, and
- Water Treatment Plant.

These facilities are designed for a uniform delivery rate of 10.0 MGD and a peak delivery rate of 20.0 MGD. The approximate location of these facilities is shown in Figure 4B.15-2.

Estimates were prepared for capital costs, annual debt service, operation and maintenance, water purchases, power, land, and environmental mitigation. These costs are summarized in Table 4B.15-3. The project costs, including capital, are estimated to be $28,101,000 and $51,856,000 for the uniform and peak delivery options, respectively. The annual costs, including debt service, operation and maintenance, and power, are estimated to be $4,410,000 and $7,270,000 for base and peak options, respectively. This water management option produces water at estimated costs of $394 and $649per acft for base and peak options, respectively.

4B.15.2.5 Implementation Issues

The development of additional groundwater in the Carrizo and Simsboro Aquifers in Brazos County must address several issues, including:

- Impact on water levels in the aquifer. Anticipated pumping in combination with current supplies is less than the water availability estimates presented in Section 3.4 and Appendix B, and water level declines would be less than those projected under a full availability analysis.
- Possibly purchase of groundwater rights.
- Competition with others for groundwater in the area.
- Regulations and permits by the Brazos Valley Groundwater Conservation District.

- Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

This water supply option has been compared to the plan development criteria, as shown in Table 4B.15.2-4, and the option meets each criterion.

Table 4B.15-3.
Cost Estimate Summary
Carrizo-Wilcox Well Field: Brazos County Option
September 2008 Prices

Item	*Uniform Option*	*Peaking Option*
Capital Costs		
Transmission Pipeline	$2,306,000	$3,623,000
Transmission Pump Stations	$3,996,000	$6,025,000
Well Field and Collection Pipeline	$10,196,000	$21,967,000
Water Treatment Plant (Level 1)	$3,357,000	$4,955,000
Total Capital Cost	**$19,855,000**	**$36,570,000**
Engineering, Legal Costs and Contingencies	$6,834,000	$12,618,000
Environmental & Archaeology Studies and Mitigation	$111,000	$158,000
Land Acquisition and Surveying (308 acres)	$220,000	$515,000
Interest During Construction (2 years)	$1,081,000	$1,995,000
Total Project Cost	**$28,101,000**	**$51,856,000**
Annual Costs		
Debt Service (6 percent, 20 years)	$2,450,000	$4,521,000
Operation and Maintenance		
Intake, Pipeline, Pump Station	$218,000	$395,000
Water Treatment Plant	$895,000	$1,510,000
Pumping Energy Costs ($0.09/kWh)	$847,000	$844,000
Total Annual Cost	**$4,410,000**	**$7,270,000**
Available Project Yield (acft/yr)	**11,200**	**11,200**
Annual Cost of Water ($ per acft)	**$394**	**$649**
Annual Cost of Water ($ per 1,000 gallons)	**$1.21**	**$1.99**

Table 4B.15-4.
Comparison of Carrizo-Wilcox:
Brazos County Option to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Low to moderate
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact; possible affect on one endangered species
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

4B.16 Voluntary Redistribution

4B.16.1 Description of Option

For the purposes of this discussion, “voluntary redistribution” is defined as an entity in possession of water rights or water purchase contracts freely selling, leasing, giving, or otherwise providing water to another entity. Typically, the entity providing the water has determined that it does not need the water for the duration of the transfer. The water could be transferred for a set period of years or permanently.

Voluntary redistribution is nothing new to Texas or to the Brazos G Area, and is essentially a water purchase. Typical examples of voluntary redistribution occurring in the region are the sale of water by entities such as the BRA, City of Waco, LCRA, and the City of Abilene through purchase contracts. The most common water sales occur when cities such as Waco or Abilene sell water to their surrounding communities.

Voluntary redistribution has many benefits over other supply options because it avoids implementation issues associated with new reservoir projects such as environmental, local impacts, and large capital costs. Most importantly, redistribution of water makes use of existing resources and provides a more immediate source of water.

4B.16.2 Available Supply and Shortages

The first step towards voluntary distribution is determining where water supplies are available and are projected to be available for some future period. Water available for the voluntary redistribution option was identified for municipal and industrial uses only.

As potential sources of water for voluntary redistribution are identified, it is important to remember that the redistribution of water is voluntary. No entity is required to participate. For this reason, entities with available water will not be specifically identified in this analysis, and the quantity of unused water is aggregated on a county-wide basis.

The amount of water available for municipal use was determined from the projected demands and supplies. Each municipal water user group was examined for water that is projected to be in excess of projected demands.

4B.16.2.1 Available Municipal Supplies

The municipal water supplies available as a potential source for voluntary redistribution are approximately 98,645 acft/yr and 66,880 acft/yr, in 2030 and 2060, respectively. The total municipal need for the region in 2030 and 2060 is 80,358 acft/yr and 194,433 acft/yr, respectively. It is important to note that municipal voluntary redistribution is typically only feasible when an entity with a projected shortage is located in close proximity to an entity with a projected surplus. The projected municipal shortages and the amount of water available for transfer within each county are shown for 2030 and 2060 in Table 4B.16-1.

4B.16.2.2 Available Industrial Supply

Industrial uses include manufacturing, steam-electric, and mining. The industrial water supplies available as a potential source for voluntary redistribution are approximately 133,420 acft/yr and 113,192 acft/yr, in 2030 and 2060, respectively. The total industrial need for the region in 2030 and 2060 is 97,953 acft/yr and 151,084 acft/yr, respectively. The projected industrial shortages and the amount of water available for transfer are shown by county for 2030 and 2060 in Table 4B.16-2.

4B.16.3 Environmental Issues

No substantial environmental impacts are anticipated, as available water resources identified for this option are from existing supplies. A summary of the few environmental issues that might arise for this alternative are presented in Table 4B.16-3.

4B.16.4 Engineering and Costing

A cost estimate to this option cannot be fully assessed. Many unknowns exist including the price of the water, potential costs of new pipelines or water treatment facilities, and the proximity of the water needs to the water supply.

Potential costs of purchasing and using water available from voluntary redistribution are listed below:

- Cost of raw water;
- Treatment costs;
- Conveyance costs;
- Engineering costs of designing and constructing treatment and conveyance systems; and
- Additional costs required by water supplier. Many times when the water supplier is a city, water will be sold for 1.5 times the price of water sold within the city limits.

Table 4B.16-1.
Municipal Needs/Available Supplies for Voluntary Redistribution

County	Shortages 2030 (acft/yr)	Shortages 2060 (acft/yr)	Available Supplies 2030 (acft/yr)	Available Supplies 2060 (acft/yr)
Bell	487	3,841	10,613	7,816
Bosque	2	64	850	604
Brazos	68	5,882	8,475	5,648
Burleson	10	22	2,027	1,777
Callahan	242	232	796	895
Comanche	0	0	394	482
Coryell	72	2,262	3,148	2,108
Eastland	193	81	1,471	1,715
Erath	0	0	4,262	2,478
Falls	2,299	2,763	1,006	1,084
Fisher	0	0	490	547
Grimes	760	1,112	1,296	1,201
Hamilton	0	0	832	886
Haskell	508	472	50	92
Hill	316	823	4,069	2,780
Hood	3,566	6,740	3,807	380
Johnson	5,890	23,640	7,672	4,389
Jones	2,912	2,723	461	622
Kent	95	57	8	21
Knox	484	466	0	2
Lampasas	0	0	4,027	3,543
Lee	480	797	776	459
Limestone	2,944	3,722	2,126	1,316
McLennan	341	1,745	17,733	11,616
Milam	485	617	2,291	2,377
Nolan	3,435	3,117	263	327
Palo Pinto	1,590	2,588	1,413	974
Robertson	0	0	2,727	2,738
Shackelford	15	0	449	737
Somervell	26	77	2,057	2,038
Stephens	0	0	1,112	1,286
Stonewall	0	0	143	193
Taylor	19,317	17,982	614	660
Throckmorton	23	0	45	84
Washington	0	0	1,074	863
Williamson	33,797	112,609	8,339	625
Young	0	0	1,730	1,518

Table 4B.16-2.
Industrial Needs/Available Supplies for Voluntary Redistribution

County	Shortages		Available Supplies	
	2030 (acft/yr)	2060 (acft/yr)	2030 (acft/yr)	2060 (acft/yr)
Bell	4,296	7,102	319	44
Bosque	735	5,461	535	173
Brazos	0	0	16,936	16,799
Burleson	0	0	121	21
Callahan	0	0	5	0
Comanche	0	0	58	54
Coryell	0	0	15	7
Eastland	0	0	702	683
Erath	0	0	25	1
Falls	0	0	75	83
Fisher	0	0	314	250
Grimes	16,699	23,199	245	135
Hamilton	0	0	4	1
Haskell	0	0	523	269
Hill	0	0	1,338	1,311
Hood	0	0	47,012	42,530
Johnson	7,797	8,888	55	27
Jones	0	0	14,102	13,909
Kent	0	0	474	502
Knox	0	0	2	2
Lampasas	135	169	94	105
Lee	0	0	3	0
Limestone	39	17,645	880	765
McLennan	0	0	18,377	13,272
Milam	70	2,000	3,398	442
Nolan	20,108	20,172	270	0
Palo Pinto	0	0	11,334	9,922
Robertson	0	16,485	2,803	11
Shackelford	0	0	51	51
Somervell	35,505	35,392	919	937
Stephens	8,473	9,253	52	49
Stonewall	0	0	178	178
Taylor	0	0	27	0
Throckmorton	0	0	6	0
Washington	0	0	151	2
Williamson	4,097	5,318	0	0
Young	0	0	12,018	10,658

Table 4B.16-3.
Environmental Issues: Voluntary Redistribution

Water Management Option	***Voluntary Redistribution***
Implementation Measures	Voluntary Redistribution or water purchase from an entity with available water supply to entities in need of water. Terms of the contract would be drawn up on a case by case basis.
Environmental Water Needs / Instream Flows	Possible low impacts. The primary source of water identified as available to this option is stored in existing reservoirs.
Bays and Estuaries	No substantial impact identified.
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 impacts of 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.

Table 4B.16-4 lists estimates of costs of voluntary redistribution. The raw water purchase price is estimated to be between $54.50 and $126 per acft, reflecting the price of raw water from the BRA (System Rate) and LCRA respectively. The total potential cost of water from voluntary redistribution, assuming existing infrastructure is adequate, is $652 to $1,500 per acft, or $2.00 to $4.57 per 1,000 gallons. Specific costs involving the selling and conveyance of treated water to water user groups which would require additional transmission infrastructure are detailed in Volume II, Section 4B.17.

Table 4B.16-4.
Potential Annual Costs of Water from Voluntary Redistribution
(i.e., Water Purchase)

Raw Water Purchase[1] ($/acft)	***Treatment ($/acft)***	***Conveyance ($/acft)***	***Potential Total Cost ($/acft)***
$54.50 to $126	$597 to $1000	$0 to $374	$652 to $1,500 ($2.00 to $4.57/1,000 gallons)

[1] Based on raw water costs from BRA (System Rate) and LCRA of $54.50 and $126 per acft, respectively.

4B.16.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.16-5, and the option meets each criterion.

An issue facing redistribution is appropriate compensation for the entity or individual that owns the water right or contract for water. If an entity has arranged through contracts to have more water than they currently need or may need in the study period, they should be compensated for the expense and upkeep of any facilities and purchase contracts already in place.

The following issues should be considered when negotiating a voluntary redistribution agreement:

- Quantity of water to be redistributed;
- Location of excess water supply in relation to buyer with need;
- Necessary water treatment and distribution facilities;
- Determination of fair market value;
- Consideration of how existing contracts will effect the sale or lease;
- Length of agreement;
- Drought contingencies;
- Protections needed by entity providing water;
- Protections needed by entity needing water;
- Enforcement of protections; and
- Other conditions specific to buyer and seller.

Table 4B.16-5.
Comparison of Voluntary Redistribution Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Significant quantities available in parts of the region
2. Reliability	2. High reliability
3. Cost	3. Low to moderate
B. Environmental factors	
1. Environmental Water Needs	1. Possible low impact
2. Habitat	2. Low impact possible where new pipelines are constructed
3. Cultural Resources	3. Possible low impact
4. Bays and Estuaries	4. No substantial impact
5. Threatened and Endangered Species	5. 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	• Could affect agriculture if supplies converted to M&I; beneficial effect on natural resources by avoiding need for new projects
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	• Supplies considered are excess to 30-year needs; no anticipated third party effects

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4B.17 Miscellaneous Strategies

4B.17.1 Strategy Overview

Miscellaneous Strategies represent 54 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 Sections 4B water management strategies. Strategies were developed to overcome the water shortages identified between 2010 and 2060 after other specific water management strategies including conservation were applied for all WUGs. The combined strategies applied to the WUGs should be adequate to provide for 105% of the water demand of the WUG. The WUGs with Miscellaneous Strategies are organized by county and are detailed in Section 4B.17.3

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 Section 4B.1.4 and are priced in September 2008 dollars. Debt service is calculated at 6% 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.

4B.17.2 Implementation Issues

The miscellaneous strategies for each WUG were evaluated and determined based on plan development criteria. Groundwater, surface water and reuse water supplies are projected to be adequate to implement these miscellaneous strategies. Environmental impacts will need to be mitigated to protect instream flow requirements, habitat, cultural resources, threatened and endangered species and wetlands. Generally, it is assumed that pipelines can be routed to avoid environmentally sensitive areas. Strategies were considered to meet municipal and industrial shortages in the planning area and will not have an apparent negative impact on other state water resources, or on agriculture and natural resources. The strategies do not require interbasin transfers.

Some of the miscellaneous strategies are feasible only if other recommended strategies are implemented. Other considerations for implementation of the miscellaneous strategies are summarized below:

In general, any development of additional groundwater in the Brazos G Area must address several issues including:

- Competition with others for groundwater in the area.
- Purchase of groundwater rights.
- Impact on water levels in the aquifer which could trigger reduction in production permits from the regulating Groundwater Conservation District.

The regulatory permits that are expected to be requirements specific to wells and pipelines include:

- Regulations and permits by the groundwater conservation districts.
- U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the pipelines impacting wetlands or navigable waters of the United States.
- General Land Office easement for use of state-owned land.
- Texas Parks and Wildlife Department Sand, Gravel, and Marl permit for construction in state-owned streambeds.
- Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

4B.17.3 Miscellaneous Pipelines, Pump Stations, and Groundwater Options by County

4B.17.3.1 Bell County

WUG: Bell County Steam-Electric
Strategy: Reuse Supply from the City of Temple
Source: City of Temple WWTP
Facilities: Storage tank, pump station, and pipeline
Total Capital Cost: $12,045,000
Total Project Cost: $17,404,000
Total Annual Cost: $3,375,000
Available Project Yield: 8,407 acft/yr
Annual Cost of Water: $ 401 per acft/yr or $ 1.23 per 1,000 gal

This project will include a 14 mile 20 inch diameter pipeline to convey water from the City of Temple WWTP to future steam-electric facilities. The wholesale unit cost of reuse water from Temple is estimated at $138/acft, based on an existing contract between Temple and Panda Power.

4B.17.3.2 Bosque County

WUG: Bosque County Steam-Electric
Strategy: BRA System Operation
Source: BRA - Lake Whitney
Facilities: Intake, pump station, and transmission pipeline
Total Capital Cost: $17,125,000
Total Project Cost: $24,725,000
Total Annual Cost: $3,307,000
Available Project Yield: 5,222 acft/yr
Annual Cost of Water: $ 633 per acft/yr or $ 1.94 per 1,000 gal

This project will include an 18 mile 18 inch diameter pipeline to convey water between Lake Whitney and future steam-electric sites.

4B.17.3.3 Brazos County

WUG: College Station
Strategy: Delivery of BRA System Operations Supply
Source: BRA System Operations
Facilities: Intake, pump stations, transmission pipeline and WTP
Total Capital Cost: $16,841,000
Total Project Cost: $23,954,000
Total Annual Cost: $3,226,000
Available Project Yield: 2,500 acft/yr
Annual Cost of Water: $ 1,290 per acft/yr or $ 3.96 per 1,000 gal

This project will include a 3.6 mile 12 inch diameter pipeline to convey water from a diversion point on the Brazos River to College Station. Water will be purchased from BRA and be treated at a new 2.2 MGD Conventional WTP and 1.1 MGD desalination WTP.

WUG: Wickson Creek SUD
Strategy: Purchase Water from City of Bryan
Source: City of Bryan
Facilities: Pump station, storage tank, and transmission pipeline
Total Capital Cost: $894,000
Total Project Cost: $1,201,000
Total Annual Cost: $394,000
Available Project Yield: 1,500 acft/yr
Annual Cost of Water: $ 263 per acft/yr or $ 0.81 per 1,000 gal

This project will include an interconnection between the City of Bryan and Wickson Creek SUD including 600 feet of 12 inch diameter pipeline, a pump station and storage tank. Water will be purchased from City of Bryan at an estimated wholesale rate of $167/acft. Project costs to be shared between Bryan and the SUD.

4B.17.3.4 Coryell County

WUG: Gatesville
Strategy: Coryell County Reservoir (BRA System)
Source: Coryell County Off-Channel Reservoir
Facilities: Intake, pump stations, transmission pipeline and WTP
Total Capital Cost: $16,257,000
Total Project Cost: $23,532,000
Total Annual Cost: $4,338,000
Available Project Yield: 1,500 acft/yr
Annual Cost of Water: $ 2,892 per acft/yr or $ 8.87 per 1,000 gal

This project will include an intake and WTP sized to meet Gatesville and Coryell County Other 2060 demands. The 15 mile 12 inch diameter pipeline will convey water from Coryell County Reservoir to Gatesville along Hwy 84. Estimated wholesale water cost is $1,007/acft based on Volume II, Section 4B.13.7

WUG: Coryell County Other
Strategy: Coryell County Reservoir (BRA System)
Source: Coryell County Off-Channel Reservoir
Facilities: Intake, pump station, and transmission pipeline
Total Capital Cost: $19,440,000
Total Project Cost: $28,356,000
Total Annual Cost: $5,308,000
Available Project Yield: 1,865 acft/yr
Annual Cost of Water: $ 2,846 per acft/yr or $ 8.73 per 1,000 gal

This project will include a 22 mile 12 inch diameter pipeline to convey water from Coryell County Reservoir to Coryell County Other along FM 1690 to Izoro and Harmon Rd to Pidcoke. Estimated wholesale water cost is $1,007/acft based on Volume II, Section 4B.13.7

4B.17.3.5 Eastland County

WUG: Rising Star
Strategy: Water Supply from Connection to Westbound WSC
Source: Eastland, Cisco and Groundwater
Facilities: Transmission pipeline
Total Capital Cost: $167,000
Total Project Cost: $262,000
Total Annual Cost: $262,000
Available Project Yield: 150 acft/yr
Annual Cost of Water: $ 1,747 per acft/yr or $ 5.36 per 1,000 gal

This project will include a 0.5 mile 6 inch diameter pipeline to interconnect the City of Rising Star with the Westbound WSC. A treated water rate of $1,490/acft is applied to the base cost of this project.

4B.17.3.6 Falls County

WUG: City of Marlin
Strategy: Brushy Creek Reservoir
Source: Brushy Creek Reservoir
Facilities: Intake, pump station, and transmission pipeline
Total Capital Cost: $4,391,000
Total Project Cost: $6,459,000
Total Annual Cost: $1,013,000
Available Project Yield: 2,090 acft/yr
Annual Cost of Water: $485 per acft/yr or $1.49 per 1,000 gal

Costs to construct the Brushy Creek Reservoir are found in Volume II, Section 4B.12.10. In addition to the cost of the reservoir, this project will include an intake, pump station and a 6.8 mile 14 inch diameter pipeline to convey water between the reservoir and the City of Marlin,. Annual costs include the annual unit cost for the City of Marlin's portion of the reservoir costs ($182/acft).

WUG: West Brazos WSC
Strategy: Purchase Water from City of Waco
Source: City of Waco
Facilities: Pump Stations, transmission pipeline, and two storage tanks.
Total Capital Cost: $6,601,000
Total Project Cost: $10,452,000
Total Annual Cost: $1,466,000
Available Project Yield: 450 acft/yr
Annual Cost of Water: $ 3,258 per acft/yr or $10 per 1,000 gal

This project will include a 23 mile 8 inch diameter pipeline to convey water between the City of Waco and The City of Chilton (approx. location of center of West Brazos WSC).

4B.17.3.7 Grimes County

WUG: Grimes County Steam-Electric
Strategy: Additional Gulf Coast Aquifer Development
Source: Jackson, Carrizo
Facilities: Well Field, collection pipes, and pump stations
Total Capital Cost: $21,781,000
Total Project Cost: $31,630,000
Total Annual Cost: $3,574,000
Available Project Yield: 5,600 acft/yr
Annual Cost of Water: $638 per acft/yr or $1.96 per 1,000 gal

This project will include ten 300 gpm wells drilled to 500 ft and five 800 gpm wells drilled to 2,000 ft. Other costs include 18.5 miles of well field piping and groundwater leases estimated at $40/acft.

WUG: Grimes County Steam-Electric
Strategy: Purchase Reuse Water from College Station and Bryan
Source: Bryan-College Station Reuse Water
Facilities: Pump Stations, Storage Tank, and Transmission Pipeline
Total Capital Cost: $23,422,000
Total Project Cost: $33,647,000
Total Annual Cost: $7,743,000
Available Project Yield: 11,000 acft/yr
Annual Cost of Water: $ 704 per acft/yr or $ 2.16 per 1,000 gal

This project will include a 27 mile 27 inch diameter pipeline to convey water between a College Station/Bryan WWTP and Steam Electric facilities in Grimes County. A wholesale unit cost of the reuse water from College Station / Bryan is $350/acft.

4B.17.3.8 Hill County

WUG: White Bluff Community WS
Strategy: BRA System Operation
Source: BRA Systems - Lake Whitney
Facilities: **Intake**, Pump Station, Transmission Pipeline, and WTP
Total Capital Cost: $6,533,000
Total Project Cost: $9,277,000
Total Annual Cost: $1,288,000
Available Project Yield: 600 acft/yr
Annual Cost of Water: $ 2,147 per acft/yr or $ 6.59 per 1,000 gal

This project will include a 2 mile 6 inch diameter pipeline and 1 MGD WTP to treat and transport water from Lake Whitney to the White Bluff Community WS.

WUG: Woodrow-Osceola WSC
Strategy: BRA System Operation
Source: Lake Whitney - BRA
Facilities: Intake, Pump Station, Transmission Pipeline, and WTP
Total Capital Cost: $4,744,000
Total Project Cost: $7,231,000
Total Annual Cost: $819,000
Available Project Yield: 150 acft/yr
Annual Cost of Water: $ 5,460 per acft/yr or $ 16.75 per 1,000 gal

This project will include a 11 mile 6 inch diameter pipeline and a 0.3 MGD WTP to treat and convey water between Lake Whitney and Woodrow-Osceola WSC.

4B.17.3.9 Hood County

WUG: City of Lipan
Strategy: Trinity Aquifer Development
Source: Trinity Aquifer
Facilities: Well Field, collection pipes, and pump stations
Total Capital Cost: $5,614,000
Total Project Cost: $8,524,000
Total Annual Cost: $916,000
Available Project Yield: 685 acft/yr
Annual Cost of Water: $ 1,337 per acft/yr or $4.10 per 1,000 gal

This project will include nine 100 gpm wells drilled to 300 ft as well as 7 miles of well field piping, distribution system improvements, and groundwater leases estimated at $40/acft.

WUG: City of Tolar
Strategy: Trinity Aquifer Development
Source: **Trinity** Aquifer
Facilities: Well Field, collection pipes, transmission and treatment
Total Capital Cost: $829,000
Total Project Cost: $1,286,000
Total Annual Cost: $134,000
Available Project Yield: 150 acft/yr
Annual Cost of Water: $ 893 per acft/yr or $2.74 per 1,000 gal

This project will include two 150 gpm wells drilled to 500 ft as well as 1 mile of transmission pipeline, disinfection treatment, and distribution system improvements.

WUG: Oak Trail Shores Subdivision
Strategy: Purchase Water from City of Granbury
Source: City of Granbury
Facilities: Storage Tank, Pump Station, and Transmission Pipeline
Total Capital Cost: $1,502,000
Total Project Cost: $2,416,000
Total Annual Cost: $638,000
Available Project Yield: 390 acft/yr
Annual Cost of Water: $ 1,636 per acft/yr or $ 5.02 per 1,000 gal

This project will include a 5 mile 6 inch diameter pipeline to convey treated water between the City of Granbury and the Oak Trail Shores Subdivision. Wholesale treated water from Granbury estimated at $1,000/acft.

4B.17.3.10 Johnson County

WUG: Bethany WSC
Strategy: Purchase water from Johnson County SUD
Source: Mansfield
Facilities: Pump Station and Transmission Pipeline
Total Capital Cost: $552,000
Total Project Cost: $693,000
Total Annual Cost: $1,107,000
Available Project Yield: 1,120 acft/yr
Annual Cost of Water: $ 988 per acft/yr or $ 3.03 per 1,000 gal

This project will include a connection using 12 inch diameter pipeline to convey treated water between Johnson County SUD and Bethany WSC. Wholesale treated water cost from Johnson County SUD is estimated at $928/acft. Costs are based Bethany WSC cost estimates.

WUG: Bethesda WSC
Strategy: Contract with City of Arlington
Source: Richard Chambers / Cedar Creek Reservoirs
Facilities: Pump Station and Transmission Pipeline
Total Capital Cost: $10,478,000
Total Project Cost: $16,334,000
Total Annual Cost: $2,357,000
Available Project Yield: 1,248 acft/yr
Annual Cost of Water: $ 1,889 per acft/yr or $ 5.80 per 1,000 gal

This project will include a 9 mile 20 inch diameter pipeline to convey treated water between the City of Arlington and Bethesda WSC. Wholesale treated water cost from City of Arlington is estimated at $651.6/acft. Costs are based on the *Water Supply Study for Ellis County, Johnson County, Southern Dallas County, and Southern Tarrant County* dated April 2009.

WUG: Cleburne
Strategy: Additional BRA supply through system operations – firm up existing BRA contract supplies
Source: Lake Granbury - BRA System
Facilities: Intake, pump stations, and transmission pipeline
Total Capital Cost: $9,337,000
Total Project Cost: $14,086,000
Total Annual Cost: $1,443,000
Available Project Yield: 1,530 acft/yr
Annual Cost of Water: $ 943 per acft/yr or $ 2.89 per 1,000 gal

This project will include a 21 mile 12 inch diameter pipeline to convey water from Lake Granbury along FM 2331, to US Hwy 67 into Cleburne.

WUG: Godley
Strategy: Purchase from BRA SWATS
Source: BRA SWATS - Lake Granbury
Facilities: Storage Tank, Pump Station, and Transmission Pipeline
Total Capital Cost: $4,160,000
Total Project Cost: $6,651,000
Total Annual Cost: $1,100,000
Available Project Yield: 375 acft/yr
Annual Cost of Water: $ 2,933 per acft/yr or $ 9 per 1,000 gal

This project will include a 15 mile 8 inch diameter pipeline to convey treated water between the BRA SWATS and the City of Godley. Wholesale treated water cost at the SWATS plant is $1,218/acft.

WUG: Johnson County SUD
Strategy: Infrastructure project for City of Mansfield water
Source: Mansfield from Tarrant Regional MWD (Lake Benbrook)
Facilities: Pump Station and Transmission Pipeline
Total Capital Cost: $18,018,000
Total Project Cost: $27,182,000
Total Annual Cost: $9,359,000
Available Project Yield: 10,080 acft/yr
Annual Cost of Water: $ 928 per acft/yr or $ 2.85 per 1,000 gal

This project will include a 13 mile 30 inch diameter pipeline to convey treated water between the City of Mansfield and Johnson County SUD. Wholesale treated water cost at the Mansfield WTP is estimated at $652/acft. Costs are based on the *Water Supply Study for Ellis County, Johnson County, Southern Dallas County, and Southern Tarrant County* dated April 2009.

WUG: Johnson County SUD
Strategy: Purchase water from the City of Grand Prairie
Source: Grand Prairie from Tarrant Regional MWD
Facilities: Pump Station and Transmission Pipeline
Total Capital Cost: $24,056,000
Total Project Cost: $35,646,000
Total Annual Cost: $8,016,000
Available Project Yield: 6,726 acft/yr
Annual Cost of Water: $ 1,192 per acft/yr or $ 3.66 per 1,000 gal

This project will include a 14 mile 30 inch diameter pipeline to convey treated water between the City of Grand Prairie and Johnson County SUD. Wholesale treated water cost from Grand Prairie is estimated at $652/acft. Costs are based on the *Water Supply Study for Ellis County, Johnson County, Southern Dallas County, and Southern Tarrant County* dated April 2009.

WUG: Keene
Strategy: BRA System Operation
Source: BRA System Operation through the BRA SWATS plant
Facilities: Pump station and transmission pipeline
Total Capital Cost: $1,847,000
Total Project Cost: $3,062,000
Total Annual Cost: $481,000
Available Project Yield: 157 acft/yr
Annual Cost of Water: $ 3,064 per acft/yr or $ 9.4 per 1,000 gal

This project will include an 8 mile 6 inch diameter pipeline to convey water between the BRA SWATS plant to the City of Keene. Wholesale treated water cost at the BRA SWATS plant is estimated at $1,218/acft.

WUG: Parker WSC
Strategy: Trinity Aquifer Development
Source: Trinity Aquifer
Facilities: Well Field, collection pipes, transmission and treatment
Total Capital Cost: $1,386,000
Total Project Cost: $2,045,000
Total Annual Cost: $214,000
Available Project Yield: 160 acft/yr
Annual Cost of Water: $ 1,338 per acft/yr or $4.10 per 1,000 gal

This project will include two 200 gpm wells drilled to 1,600 ft as well as 0.5 mile of transmission pipeline, disinfection treatment, and distribution system improvements.

4B.17.3.11 Lampasas County

WUG: Lampasas County Manufacturing
Strategy: Purchase Water from City of Lampasas
Source: City of Lampasas
Facilities: Storage Tank, Pump Station, and Transmission Pipeline
Total Capital Cost: $604,000
Total Project Cost: $971,000
Total Annual Cost: $246,000
Available Project Yield: 165 acft/yr
Annual Cost of Water: $ 1,491 per acft/yr or $ 4.57 per 1,000 gal

This project will include a 2 mile 6 inch diameter pipeline to convey water from the City of Lampasas to manufacturing sites within Lampasas County.

4B.17.3.12 Lee County

WUG: Aqua WSC
Strategy: Additional Carrizo Aquifer Development
Source: Carrizo-Wilcox Aquifer
Facilities: Well Field, transmission and treatment
Total Capital Cost: $916,000
Total Project Cost: $1,364,000
Total Annual Cost: $177,000
Available Project Yield: 403 acft/yr
Annual Cost of Water: $ 439 per acft/yr or $1.35 per 1,000 gal

This project will include one 500 gpm well drilled to 1,000 ft as well as 0.5 mile of transmission pipeline, disinfection treatment, and distribution system improvements.

WUG: Lee County WSC
Strategy: Additional Carrizo Aquifer Development
Source: Carrizo-Wilcox Aquifer
Facilities: Well Field, collection piping and treatment
Total Capital Cost: $1,524,000
Total Project Cost: $2,166,000
Total Annual Cost: $335,000
Available Project Yield: 806 acft/yr
Annual Cost of Water: $ 416 per acft/yr or $1.28 per 1,000 gal

This project will include two 500 gpm wells drilled to 500 ft as well as one mile of collection piping, disinfection treatment, and distribution system improvements.

4B.17.3.13 Limestone County

WUG: Bistone MWSD
Strategy: Carrizo-Wilcox Aquifer Development
Source: Carrizo-Wilcox Aquifer
Facilities: Well Field, collection pipes, transmission and treatment
Total Capital Cost: $14,045,000
Total Project Cost: $18,458,000
Total Annual Cost: $2,024,000
Available Project Yield: 3,600 acft/yr
Annual Cost of Water: $ 562 per acft/yr or $1.73 per 1,000 gal

This project will include eight 450 gpm wells drilled to 650 ft, as well as well field collection piping, 5.5 miles of 12 inch diameter transmission pipeline, storage tank and water treatment plant improvements.

WUG: City of Kosse
Strategy: Carrizo-Wilcox Aquifer Development
Source: Carrizo-Wilcox Aquifer
Facilities: Well Field, transmission and treatment
Total Capital Cost: $1,612,000
Total Project Cost: $2,386,000
Total Annual Cost: $237,000
Available Project Yield: 100 acft/yr
Annual Cost of Water: $ 2,370 per acft/yr or $7.27 per 1,000 gal

This project will include two 100 gpm wells drilled to 500 ft, eight miles of 4 - 6 inch diameter transmission pipeline, disinfection treatment pump station and elevated storage tank.

WUG: Limestone County Manufacturing
Strategy: Carrizo-Wilcox Aquifer Development
Source: Carrizo-Wilcox Aquifer
Facilities: Well Field, transmission and treatment
Total Capital Cost: $237,000
Total Project Cost: $347,000
Total Annual Cost: $40,000
Available Project Yield: 75 acft/yr
Annual Cost of Water: $540 per acft/yr or $1.66 per 1,000 gal

This project will include one 100 gpm well drilled to 250 ft, 0.25 mile of 4 inch diameter transmission pipeline, and disinfection treatment.

4B.17.3.14 McLennan County

WUG: Chalk Bluff WSC
Strategy: Trinity Aquifer Development
Source: Trinity Aquifer
Facilities: Well Field, collection pipes, and treatment
Total Capital Cost: $1.909,000
Total Project Cost: $2,707,000
Total Annual Cost: $287,000
Available Project Yield: 230 acft/yr
Annual Cost of Water: $ 1,248 per acft/yr or $3.83 per 1,000 gal

This project will include two 200 gpm wells drilled to 2,125 ft, one mile of 6 inch collection piping, disinfection treatment and distribution system improvements.

WUG: Cross Country WSC
Strategy: Water Supply from City of Waco
Source: City of Waco
Facilities: Transmission pipeline and pump station
Total Capital Cost: $2,307,000
Total Project Cost: $3,545,000
Total Annual Cost: $674,000
Available Project Yield: 333 acft/yr
Annual Cost of Water: $ 2,023 per acft/yr or $ 6.2 per 1,000 gal

This project will include a 6 mile 6 inch diameter pipeline to convey treated water from the City of Waco to Cross Country WSC along FM 2490. Wholesale treated water rate from Waco is $979/acft.

WUG: Hallsburg
Strategy: Water Supply from City of Waco
Source: City of Waco
Facilities: Transmission pipeline and pump station
Total Capital Cost: $652,000
Total Project Cost: $1,028,000
Total Annual Cost: $138,000
Available Project Yield: 49 acft/yr
Annual Cost of Water: $ 3,643 per acft/yr or $ 11.18 per 1,000 gal

This project will connect into the 6 inch diameter transmission line from Waco to Mart along Hwy 6 to deliver treated water 3 miles to Hallsburg along FM 3222. Costs include a portion of the main transmission and pump station from Waco to Mart . Wholesale treated water cost is $979/acft from City of Waco.

WUG: Mart
Strategy: Water Supply from City of Waco
Source: City of Waco
Facilities: Transmission pipeline and pump station
Total Capital Cost: $5,144,000
Total Project Cost: $6,960,000
Total Annual Cost: $1,093,000
Available Project Yield: 300 acft/yr
Annual Cost of Water: $ 3,643 per acft/yr or $ 11.18 per 1,000 gal

This project will include a 15 mile 6 inch diameter pipeline to convey treated water from the City of Waco to Mart along Hwy 6 and Hwy 164. Wholesale treated water cost is $979/acft from City of Waco.

WUG: North Bosque WSC
Strategy: Water Supply from City of Waco
Source: City of Waco
Facilities: Transmission pipeline and pump station
Total Capital Cost: $1,133,000
Total Project Cost: $1,793,000
Total Annual Cost: $361,000
Available Project Yield: 194 acft/yr
Annual Cost of Water: $ 1,861 per acft/yr or $ 5.71 per 1,000 gal

This project will interconnect with the City of Waco's 30 in diameter pipeline at the intersection of Hwy 6 and FM 185. The new transmission line will include a 4 mile 6 inch diameter pipeline to convey treated water to North Bosque service area along Hwy 6. Wholesale treated water cost is $979/acft from City of Waco.

WUG: Riesel
Strategy: Water Supply from City of Waco
Source: City of Waco
Facilities: Transmission pipeline and pump station
Total Capital Cost: $840,000
Total Project Cost: $1,326,000
Total Annual Cost: $179,000
Available Project Yield: 38 acft/yr
Annual Cost of Water: $3,643 per acft/yr or $ 11.18 per 1,000 gal

This project will connect into the 6 inch diameter transmission line from Waco to Mart along Hwy 6/ Hwy 164 to deliver treated water 3.7 miles to Riesel. Costs include a portion of the main transmission and pump station from Waco to Mart. Wholesale treated water cost is $979/acft from City of Waco.

WUG: Western Hills WSC
Strategy: Trinity Aquifer Development
Source: Trinity Aquifer
Facilities: Well Field, transmission and treatment
Total Capital Cost: $713,000
Total Project Cost: $1,073,000
Total Annual Cost: $129,000
Available Project Yield: 198 acft/yr
Annual Cost of Water: $652 per acft/yr or $2.00 per 1,000 gal

This project will include one 250 gpm well drilled to 1,150 ft, 0.5 mile of 6 inch diameter transmission pipeline, disinfection treatment and distribution system improvements.

4B.17.3.15 Milam County

WUG: Southwest Milam WSC
Strategy: Additional Carrizo-Wilcox Aquifer Development
Source: Carrizo-Wilcox
Facilities: Well Field, transmission and treatment
Total Capital Cost: $2,413,000
Total Project Cost: $3,502,000
Total Annual Cost: $440,000
Available Project Yield: 966 acft/yr
Annual Cost of Water: $ 455 per acft/yr or $1.40 per 1,000 gal

This project will include two 1,000 gpm wells drilled to 1,000 ft, one mile of 12 inch diameter transmission pipeline, disinfection treatment and distribution system improvements.

WUG: Milam County Steam-Electric
Strategy: Additional Carrizo-Wilcox Aquifer Development
Source: Carrizo-Wilcox
Facilities: Well Field and transmission
Total Capital Cost: $2,201,000
Total Project Cost: $3,160,000
Total Annual Cost: $365,000
Available Project Yield: 1,613 acft/yr
Annual Cost of Water: $ 226 per acft/yr or $0.69 per 1,000 gal

This project will include two 1,000 gpm wells drilled to 1,000 ft and 1.5 mile of 12 – 16 inch diameter transmission pipeline.

WUG: Milam County Mining
Strategy: Additional Carrizo-Wilcox Aquifer Development
Source: Carrizo-Wilcox
Facilities: Well Field and transmission
Total Capital Cost: $490,000
Total Project Cost: $715,000
Total Annual Cost: $72,000
Available Project Yield: 100 acft/yr
Annual Cost of Water: $ 719 per acft/yr or $2.21 per 1,000 gal

This project will include one 150 gpm well drilled to 1,000 ft and 0.5 mile of 4 inch diameter transmission pipeline.

4B.17.3.16 Nolan County

WUG: Sweetwater
Strategy: Alternative**:** Purchase Raw Water from City of Abilene
Source: City of Abilene
Facilities: Intake, Two Pump Stations, Three Storage Tanks, and Transmission Pipeline
Total Capital Cost: $26,731,000

Total Project Cost: $39,172,000
Total Annual Cost: $5,007,000
Available Project Yield: 4,000 acft/yr
Annual Cost of Water: $ 1,258 per acft/yr or $ 3.84 per 1,000 gal

This project will include a 41 mile 16 inch diameter pipeline to convey water between Abilene and Sweetwater along I-20. Wholesale raw water cost from Abilene is estimated at $100/acft

WUG: Nolan County Mining
Strategy: Water Supply from Edwards-Trinity (Plateau) Aquifer
Source: Edwards-Trinity
Facilities: Well Field and transmission
Total Capital Cost: $463,000
Total Project Cost: $679,000
Total Annual Cost: $67,000
Available Project Yield: 114 acft/yr
Annual Cost of Water: $ 588 per acft/yr or $1.80 per 1,000 gal

This project will include two 1,000 gpm wells drilled to 300 ft and 0.5 mile of 4 inch diameter transmission pipeline.

WUG: Nolan County Steam-Electric
Strategy: Water Supply from City of Abilene
Source: City of Abilene
Facilities: Pump Station, Two Booster Pumps, Three Storage Tanks, and Transmission Pipeline
Total Capital Cost: $65,169,000
Total Project Cost: $91,940,000
Total Annual Cost: $14,574,000
Available Project Yield: 20,000 acft/yr
Annual Cost of Water: $ 729 per acft/yr or $ 2.24 per 1,000 gal

This project will include a 43 mile 36 inch diameter pipeline to convey raw water between Abilene and Nolan County Steam Electric facilities located in the Sweetwater vicinity along I-20.

4B.17.3.17 Palo Pinto County

WUG: City of Strawn
Strategy: Water Supply from Eastland County WSD
Source: Eastland County WSD
Facilities: Transmission Pipeline and Pump Station
Total Capital Cost: 3,192,000
Total Project Cost: 5,158,000
Total Annual Cost: 775,000
Available Project Yield: 200
Annual Cost of Water: $3,875 per acft/yr or $11.89 per 1,000 gal

This project will include a 13 mile 4 inch diameter pipeline to convey water from Ranger to Strawn along Interstate 20 and Highway 16.

4B.17.3.18 Robertson County

WUG: Robertson County Steam-Electric
Strategy: Purchase of Reuse Water from Walnut Creek Mine
Source: Walnut Creek Mine
Facilities: Storage Tank, Pump Station, and Transmission Pipeline
Total Capital Cost: $16,179,000
Total Project Cost: $23,126,000
Total Annual Cost: $7,117,000
Available Project Yield: 15,479 acft/yr
Annual Cost of Water: $ 460 per acft/yr or $ 1.41 per 1,000 gal

This project will include a 15 mile 30 inch diameter pipeline to convey water from the Walnut Creek Mine WWTP to steam-electric facilities in Robertson County.

4B.17.3.19 Williamson County

WUG: Blockhouse MUD
Strategy: Increase Supply from Cedar Park
Source: Cedar Park – Highland Lakes
Facilities: Transmission pipeline and pump station
Total Capital Cost: $1,586,000
Total Project Cost: $2,291,000
Total Annual Cost: $1,964,000 (assuming full implementation initially)
Available Project Yield: 2,100 acft/yr
Annual Cost of Water: $ 935 per acft/yr or $ 2.87 per 1,000 gal (assuming full implementation initially)

This project will include a 1.5 mile 10 inch diameter pipeline to convey water from the Lake Travis regional water line to Blockhouse MUD along North Bell Blvd. The wholesale treated water rate from Cedar Park is estimated at $829/acft.

WUG: Brushy Creek MUD
Strategy: Rehabilitate Existing Wells
Source: NA
Facilities: NA
Total Capital Cost: $260,000
Total Project Cost: $350,000 (per Brushy Creek MUD)
Total Annual Cost: $33,000
Available Project Yield: 1,100 acft/yr
Annual Cost of Water: $30 per acft/yr or $0.09 per 1,000 gal

This project will rehabilitate existing wells to increase capacity by 1,100 acft/yr.

WUG: Chisholm Trail SUD
Strategy: Transmission from Round Rock
Source: Highland Lakes (LCRA through the Brushy Creek RUA)
Facilities: Transmission pipeline and pump station
Total Capital Cost: $9,086,000
Total Project Cost: $13,264,000
Total Annual Cost: $5,460,000
Available Project Yield: 3,472 acft/yr
Annual Cost of Water: $1,573 per acft/yr or $4.83 per 1,000 gal

This project will include a 13 mile 16 inch diameter pipeline to convey water between Round Rock and Chisholm Trail SUD north to Hwy 263 to FM 2338. Wholesale treated water cost from Round Rock is estimated at $1,148/acft.

WUG: City of Florence
Strategy: Trinity Aquifer Development
Source: Trinity Aquifer
Facilities: Well Field, transmission and treatment
Total Capital Cost: $1,087,000
Total Project Cost: $1,648,000
Total Annual Cost: $191,000
Available Project Yield: 322 acft/yr
Annual Cost of Water: $ 593 per acft/yr or $1.82 per 1,000 gal

This project will include two 200 gpm wells drilled to 750 ft, one mile of 4 inch diameter transmission pipeline and distribution system improvements.

WUG: Liberty Hill
Strategy: Purchase water from City of Leander
Source: Leander – Highland Lakes
Facilities: Transmission pipeline and pump station
Total Capital Cost: $5,986,000
Total Project Cost: $8,691,000
Total Annual Cost: $1,723,000
Available Project Yield: 1,800 acft/yr
Annual Cost of Water: $ 2,872 per acft/yr or $ 8.81 per 1,000 gal (1st 600 acft with debt service for full project from 2010 to 2020)

$1,425 per acft/yr or $ 4.37 per 1,000 gal (next 1,200 acft without debt service from 2030 to 2050)

This project will include an 8 mile 12 inch diameter pipeline to convey water from Leander to Liberty Hill along Highways 183 and 29. The wholesale unit cost of treated water varies from $1,380/acft for the first 600 acft to $1,348/acft for the remaining 1,200 acft.

WUG: Williamson County-Other
Strategy: Trinity Wells
Source: Trinity Aquifer
Facilities: Well Field, transmission and treatment
Total Capital Cost: $1,294,000
Total Project Cost: $1,995,000
Total Annual Cost: $216,000
Available Project Yield: 280 acft/yr
Annual Cost of Water: $ 770 per acft/yr or $2.36 per 1,000 gal

This project will include two 200 gpm wells drilled to 750 ft, two miles of 4 inch diameter transmission pipeline and distribution system improvements.

WUG: Multiple WUGs in Williamson County
Strategy: EWCRWTS Supply to Williamson County
Source: BRA (Lake Granger)
Facilities: Transmission Pipelines and Pump Stations
Total Capital Cost: $29,733,000
Total Project Cost: $44,706,000
Total Annual Cost: $7,844,000
Available Project Yield: 8,847 acft/yr
Annual Cost of Water: $887 per acft/yr or $2.72 per 1,000 gal

This project will include a 40 mile pipe network to convey water from the BRA's EWCRWTS at Lake Granger to area WUGs. WUGs that will receive water from this project include the following:

- City of Bartlett,
- City of Granger,
- City of Hutto (via City of Taylor),
- City of Jarrell,
- Jarrell-Schwertner WSC,
- Jonah Water SUD,
- City of Thrall,
- City of Weir,
- Center Texas WSC, and
- Williamson County Other.

The pipe network will originate at the EWCRWTS located on the south shore of Lake Granger. An approximately 830 horse power pump station will be located at the treatment plant; existing plant capacity is assumed to be adequate (i.e., costs for treatment plant expansion are not included). A 24-inch line will extend west along FM 1331 from the pump station to SH 95. From the intersection of FM 1331 and SH 95, a 24-inch line will extend northward along SH 95 through the Cities of Granger and Bartlett, and terminate in the City of Holland. Central Texas WSC will be supplied at the terminus of the line in Holland. In addition to Granger, Bartlett, and Central Texas WSC, the City of Jarrell, Jarrell-Schwertner WSC, and Jonah SUD will be served by the line located along SH 95. A 6-inch line will extend eastward from Taylor to Thrall along U.S. Highway 79. For cost estimating purposes, it is assumed that existing transmission capacity from the FM 1331 – SH 95 intersection to Taylor is sufficient to convey the required supplies for Hutto and Thrall to Taylor. Hutto will be supplied at Taylor through existing infrastructure. Lastly, a 14-inch spur line will extend westward from SH 95 along SH 29 to the intersection of County Road 120. An approximately 270 horse power booster station will be included on this line. A 6-inch line will extend northward along County Road 120 to serve the City of Weir. The 14-inch line and pump station provide sufficient capacity so that the line can be extended westward along SH 29 across Interstate 35 to meet needs of Chisholm Trail SUD, which are project to occur in 2050, as part of the BRA Lake Granger Augmentation Project.

Costs for the EWCRWTS are based on construction of the facilities described above. The unit water cost is based on the total project cost and the total volume of water delivered. This cost is applied to each WUGs receiving water from the project, except as noted in the Williamson County Plan discussion.

WUG: City of Round Rock, Williamson County Other, Chisholm Trail SUD
Strategy: Lake Granger Augmentation – Conjunctive Use
Source: Lake Granger
Facilities: Water Treatment Plant Expansion, Transmission Pipeline and Pump Station

Total Capital Cost:	$152,108,000
Total Project Cost:	$229,822,000
Total Annual Cost:	$33,212,000
Available Project Yield:	38,394 acft/yr
Annual Cost of Water:	$865 per acft/yr or $2.65 per 1,000 gal

This project will include a 65.5 MGD expansion to the BRA's EWCRWTS at Lake Granger and a 25 mile 48 inch diameter pipeline to convey water from the treatment plant to Round Rock. In addition, the project will include extending the 14-inch EWCRWTS pipeline located along SH 29 10 miles to the west, crossing Interstate 35, to serve Chisholm Trail SUD.

4B.17.4 Water Treatment Plants

There are a total of ten water user groups and or wholesale water providers that will require a water treatment plant expansion 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 as described in Volume I, Section 3. Table 4B.17-1 summarizes water treatment plant strategies. This table includes only the water treatment plant strategies that are not included in any of the other Section 4B water management strategy evaluations.

Table 4B.17-1.
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
Temple	Phase I expansion (14 MGD)	7,840	$16,393,000	$23,017,000	$3,681,000	$470	$1.44
Temple	Phase II expansion (14 MGD)	7,840	$16,277,000	$22,853,000	$5,678,000	$362	$1.11
Granbury	Expand WTP by 14 MGD	7,840	$22,303,000	$31,314,000	$4,622,000	$590	$1.81
Cleburne	Expand WTP by 5 MGD	2,800	$9,936,000	$13,951,000	$1,814,000	$648	$1.99
Johnson County SUD[1]	Expand BRA SWATS by 5.66 MGD	3,170	$23,284,000	$33,320,000	$4,778,000	$1,218	$3.74
Stamford	Expand WTP by 6 MGD	3,360	$9,730,000	$13,662,000	$1,958,000	$583	$1.79
Jayton	New WTP (0.4 MGD)	224	$2,508,000	$3,522,000	$488,000	$2,179	$6.68
Robinson	Expand WTP by 2 MGD	1,120	$3,243,000	$4,554,000	$653,000	$583	$1.79
[2]Palo Pinto County MWD No. 1	New WTP (15 MGD)	8,400	$25,514,000	$35,822,000	$5,268,000	$627	$1.92
Albany	Expand WTP by 0.1 MGD	56	$162,000	$228,000	$32,663	$583	$1.79
Georgetown	Expand WTP by 7.2 MGD	4,032	$8,431,000	$11,838,000	$1,893,000	$469	$1.44
Georgetown	Expand WTP by 11.1 MGD	6,216	$12,998,000	$18,249,000	$3,950,000	$384	$1.18
Georgetown	Expand WTP by 12.7 MGD	7,112	$14,697,000	$20,635,000	$5,162,000	$297	$0.91
Abilene	Expand WTP by 23.2 MGD	12,992	$35,116,000	$49,304,000	$7,424,000	$571	$1.75

1 - Implementation of this strategy will also affect cost of water to Keene, Acton MUD and Granbury

2 - City of Mineral Wells may also have partial ownership in this WTP

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4B.18 Reallocation of Storage in Federal Reservoirs

4B.18.1 BRA Reservoirs Excluding Lake Aquilla[1]

4B.18.1.1 Description of Option[2]

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. In 2008, the USACE in conjunction with the Brazos River Authority (BRA) published a feasibility study of reallocating flood control storage to water supply storage for nine lakes in the Brazos River Basin: Lake Aquilla, Lake Belton, Lake Georgetown Lake Granger, Lake Proctor, Lake Somerville, Stillhouse Hollow, Lake Waco and Lake Whitney. 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.

4B.18.1.2 Available Yield from Reallocation in Federal Reservoirs Excluding Lake Aquilla

The USACE study evaluated four alternatives for each reservoir:

- Alternative #1 – Elevation corresponding to half the maximum discretionary authority as described in Alternative #2 below.
- Alternative #2 – Elevation corresponding to the maximum discretionary authority (defined as the authority given to the chief of Engineers to make allocation adjustments without additional authorization by Congress, which is 50,000 acft or fifteen percent of total authorized storage whichever, is less).
- Alternative #3 – Elevation corresponding to one foot above the elevation determined for Alternative # 2.
- Alternative #4 –Thirty percent of the authorized flood control pool storage, rounded to the nearest foot.

[1] U.S. Army Corps of Engineers, Fort Worth District, *DRAFT Information Paper (FSM Document) for Brazos River Basin Systems Assessment Feasibility Study Phase I*, July 2008.
[2] U.S. Army Corps of Engineers, Fort Worth District, *DRAFT Information Paper (FSM Document) for Brazos River Basin Systems Assessment Feasibility Study Phase I*, July 2008.

Results of the yield analysis, excluding Lake Aquilla, which has been selected for further evaluation during this planning cycle using slightly different criteria, are shown in Table 4B.18.1.2-1. The yields in Table 4B. 18.1.2-1 use both the USACE SUPER model and the TCEQ Brazos WAM. The SUPER program operates using a daily time step simulating the operation of a multi-purpose system of reservoirs over a historical period. SUPER has a limited number of other demands in the Brazos Basin and operates from upstream to downstream. The Brazos Water Availability Model (WAM) Run 3 is specifically designed to model the priority system used for Texas water rights. The priority system assigns each diversion and storage right a priority date. For older water rights, the priority date is based on the time of first use. For newer water rights, the priority date is based on the date that the permit application was approved by the state. In the Brazos WAM, water is distributed based on the priority of the water right, as well as the geographic location of the right. Water rights with older priority dates are allocated water before water rights with newer priority dates. The yields using the Brazos WAM assume that the additional supply from the reservoir above current permitted amounts has the most junior priority date. As a result, the additional yield is last in line when water is allocated by the model. The BrazosWAM also has all water rights operating at their full permitted amounts. These differences in the models, as well as differences in hydrology and other data, explain the difference between the yields using SUPER and the yield using the Brazos WAM.

The USACE study did not identify any clear candidates for reallocation, nor did the USACE exclude any of the nine reservoirs from further consideration. Based on the upcoming need for additional water and the limited economical alternatives, the USACE selected Lake Aquilla for further study in the second phase of the study. The reallocation strategy described in this plan will focus on reallocation of Lake Aquilla. Other reservoirs may be considered for reallocation in future planning cycles.

Table 4B.18.1.2-1
Yield Increase from Reallocation from 2008 USACE Study

Reservoir	Scenario	Top of Conservation Pool		Surface Area (acres)	COE SUPER Model Yield (acft/yr)	BWAM 3 Yield[a] (acft/yr)
		Elevation (feet)	Storage (acft)			
Belton	Existing	594	435,225	12,135	129,714	101,102
	Alternative 1	596	460,576	12,903	132,118	101,150
	Alternative 2	598	484,958	13,262	134,302	101,150
	Alternative 3	599	498,307	13,437	135,263	101,150
	Alternative 4	606	599,309	15,173	142,670	104,750
Georgetown	Existing	791	36,904	1,287	16,590	11,516
	Alternative 1	796	43,864	1,490	17,138	11,510
	Alternative 2	803	54,434	1,751	17,955	11,810
	Alternative 3	804	56,202	1,786	18,067	11,810
	Alternative 4	809	66,509	1,980	18,799	12,220
Granger	Existing	504	52,525	4,064	22,821	16,988
	Alternative 1	507	68,280	5,020	26,287	17,240
	Alternative 2	510	82,864	5,708	29,661	17,420
	Alternative 3	511	88,681	5,927	30,018	17,450
	Alternative 4	514	109,419	6,760	31,354	17,970
Proctor	Existing	1162	55,457	4,537	29,107	19,537
	Alternative 1	1167	81,362	5,760	33,205	20,150
	Alternative 2	1171	105,097	6,639	37,267	20,150
	Alternative 3	1172	111,848	6,863	38,089	20,150
	Alternative 4	1177	150,542	8,140	40,155	20,150
Somerville	Existing	238	147,104	11,555	44,690	42,338
	Alternative 1	240	171,034	12,520	48,140	44,410
	Alternative 2	242	197,094	13,540	50,588	46,410
	Alternative 3	243	210,924	14,120	51,877	47,720
	Alternative 4	245	240,279	15,230	54,629	48,790
Stillhouse Hollow	Existing	622	227,825	6,484	73,760	63,008
	Alternative 1	625	247,630	6,780	75,550	64,320
	Alternative 2	629	277,488	7,260	77,746	66,330
	Alternative 3	630	284,956	7,377	78,312	66,330
	Alternative 4	638	345,329	8,240	82,933	70,200
Waco[b]	Original	455	144,830	8,437	83,564	Not evaluated[c]
	Existing	462	199,227	8,437	94,727	
	Alternative 1	463	207,751	8,611	95,802	
	Alternative 2	473	307,560	11,309	104,931	
Whitney[d]	Existing	533	554,203	23,220	143,668	34,380
	Alternative 1	534	578,088	24,210	161,366	40,570
	Alternative 2	535	602,623	24,860	178,380	46,990
	Alternative 3	536	627,768	25,430	190,181	46,990
	Alternative 4	545	883,518	31,190	312,228	72,060

Notes

a Yields calculated in USACE study using the TCEQ Brazos WAM Run 3. These yields do not necessarily match yields used by the Brazos G Water Planning Group.

b A portion of the flood storage in Lake Waco has already been reallocated. The conservation elevation of the reservoir was raised from 455 feet to 462 feet in 2003.

c Brazos WAM yields for Lake Waco were not determined in the USACE study.

d COE SUPER utilized full reservoir storage to compute yield while the BWAM3 Yield was computed using only the TCEQ-authorized portion.

4B.18.2 Lake Aquilla

4B.18.2.1 Description of the Lake Aquilla Option

Figure 4B.18.2.1-1 is an aerial map of Lake Aquilla showing the water surface area at the four alternative pool elevations discussed in Section. According to a March 2008 volumetric survey of Lake Aquilla, at the current conservation elevation of 537.5 feet, the lake has 44,566 acft of storage and a surface area of 3,066 acres[3] (Table 4B.18.2.1-1). The flood storage in the reservoir extends up to an elevation of 556.0 feet.

Table 4B.18.2.1-1
Lake Aquilla Characteristics,[4]

Owner	***U.S. Army Corps of Engineers***
Water Supply Contract	
Owner	Brazos River Authority
Storage amount	52,400 acft
Texas Water Right	
Number	CA 12-5158
Owner	Brazos River Authority
Diversion	13,896 acft/yr
Storage	52,400 acft
Priority date	October 25, 1976
Flood Pool	
Top elevation	556 ft
Storage	93,634 acft
Conservation Pool	
Top elevation	537.5 ft
Surface area	3,066 ac
Storage	44,566ac-ft
Sediment Pool	
Top elevation	503 ft
Storage	106 ac-ft

In 2009, the USACE updated the yield available from Lake Aquilla with reallocation using the 2008 volumetric survey[5]. The 2009 yield study used slightly different reallocation

[3] Texas Water Development Board, *Volumetric Survey of Aquilla Lake March 2008 Survey*, April 2009.
[4] Certificate of Adjudication 12-5158.
[5] United States Army Corps of Engineers, *Aquilla Lake Reallocation Study Critical Period Dependable Yield Determination (Current sedimentation conditions), DRAFT version 1.1*, March 2009.

scenarios than those used in the 2008 USACE study and did not include an evaluation using the TCEQ Brazos WAM.

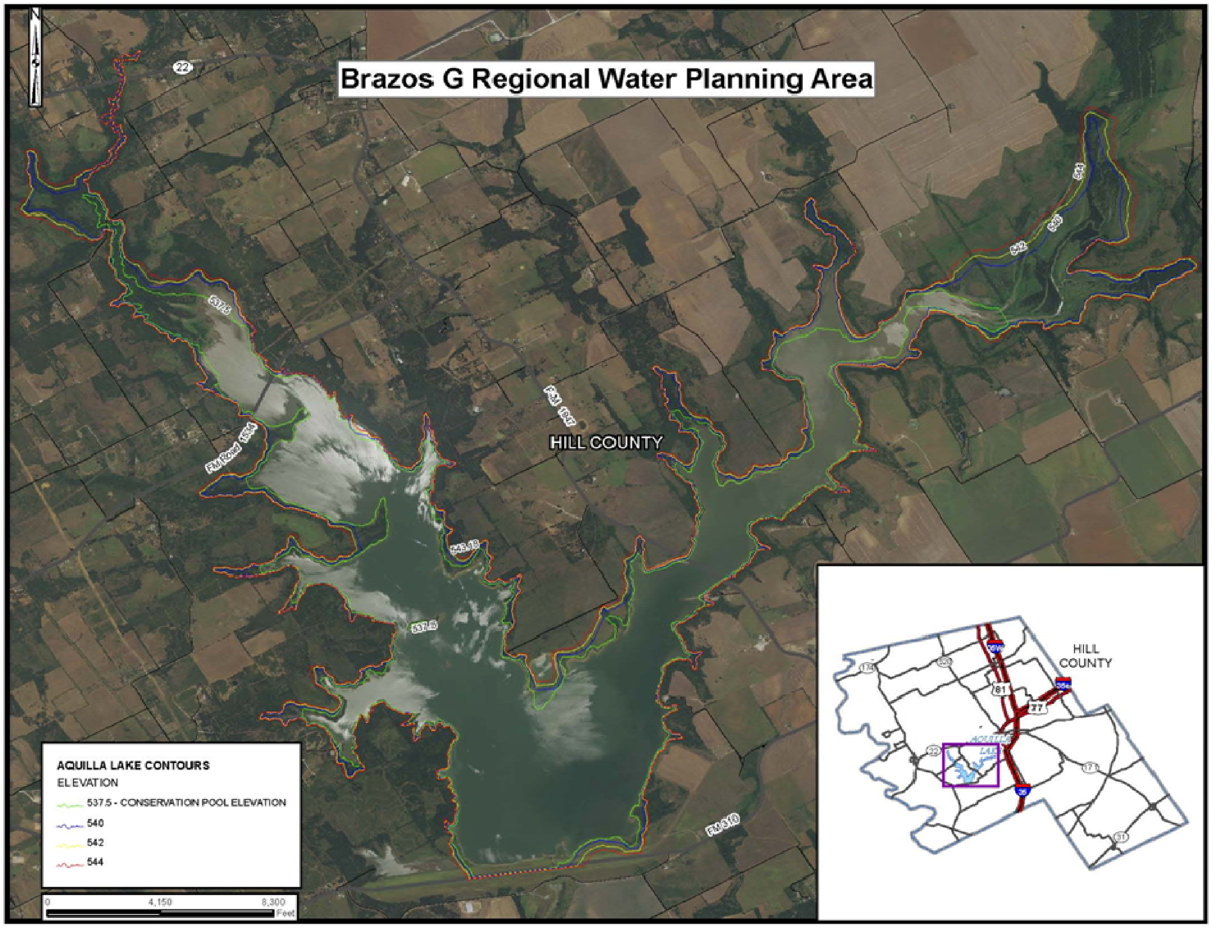

Figure 4B.18.2.1-1 Aerial map of Lake Aquilla

4B.18.2.2 Available Yield

As part of this plan, updated yields using the Brazos G WAM were performed using the same storage elevations as the 2009 USACE study as shown below:

- Existing – Current conservation storage elevation of 537.5 ft-msl;
- Scenario 1 – Raise conservation elevation to 540.0 feet, an increase of 2.5 ft-msl;
- Scenario 2 – Raise conservation elevation to 542.0 feet, an increase of 4.5 ft-msl; and
- Scenario 3 – Raise conservation elevation to 544.0 feet, an increase of 6.5 ft-msl.

Figure 4B.18.2.1-1 shows the elevation contours for the four proposed conservation storage elevations. Table 4B.18.2.2-1 is a summary of the yield studies, and Figure 4B.18.2.2-1 shows the relationship of yield to conservation storage elevation.

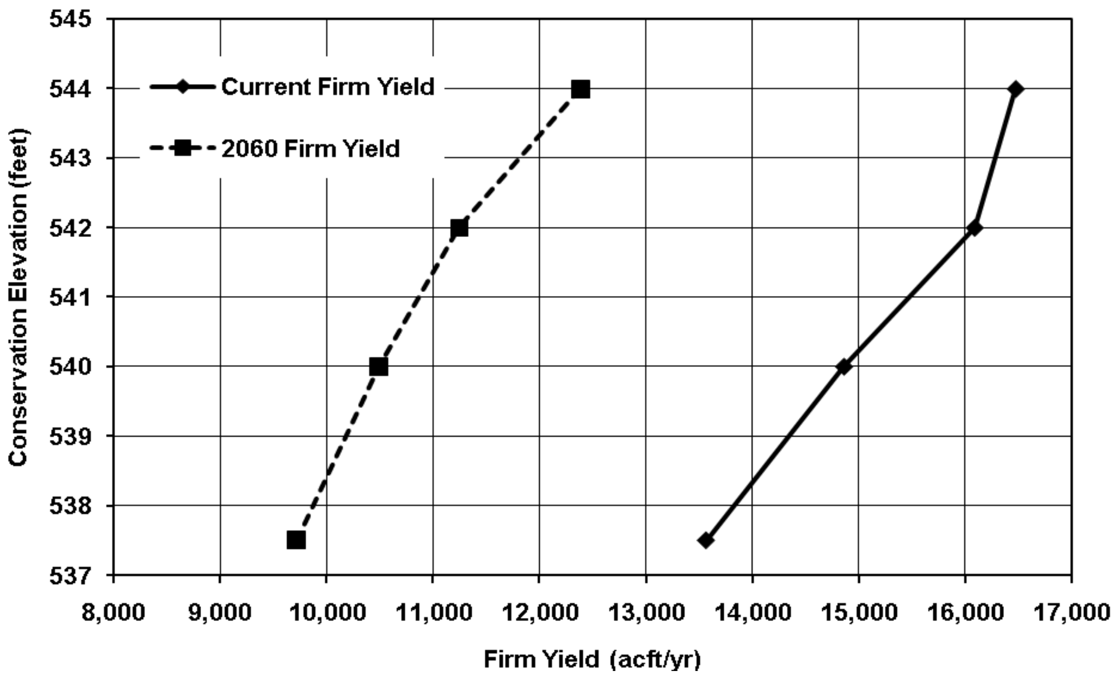

Figure 4B.18.2.2-1. Current and 2060 Yield vs. Storage Elevation for Lake Aquilla

Currently the USACE has the discretion to reallocate up to 50,000 acft or 15 percent of the total authorized storage, whichever is less. In the case of Lake Aquilla, this discretionary authority corresponds to about 14,000 acft. The yield increase of the reservoir with only the discretionary authority is currently about 2,300 acft/yr declining to 1,400 acft/yr in 2060. Additional reallocation of flood storage to conservation storage requires the approval of the U.S. Congress. Scenario 1 is within the discretionary authority of the USACE. Scenario 2 corresponds to the discretionary authority of rounding up to the nearest whole foot, and would probably require congressional approval. Scenario 3 is well above the discretionary authority and would require the approval of Congress.

By 2060 the estimated storage of Lake Aquilla decreases to 20,437 acft - slightly less than half of the current storage.[6] The calculated firm yield in 2060 from the Brazos G WAM at the current conservation storage of elevation 537.5 ft-msl is 9,713 acft/yr. In Scenario 2 (elevation 542.0 ft-msl) the yield of Lake Aquilla is 11,248 acft/yr, resulting in 1,535 acft of additional yield in 2060. This is a 16 percent increase over the current yield. Figure 4B.18.2.2-2

[6] The estimated 2060 storage does not account for recently-revised sedimentation rates based on updated 2008 TWDB volumetric survey.

and Figure 4B.18.2.2-3 show the storage trace in the year 2060 for Lake Aquilla under existing conditions and with Scenario 2, respectively.

Table 4B.18.2.2-1
Comparison of Firm Yield of Lake Aquilla with Flood Storage Reallocation using Brazos G WAM for Current and 2060 Conditions

Scenario	Top of Conservation Elevation (feet)	Current Conditions			2060 Conditions		
		Storage (acft)	Firm Yield (acft/yr)	Yield Increase (acft/yr)	Storage (acft)	Firm Yield (acft/yr)	Yield Increase (acft/yr)
Existing	537.50	44,566	13,565		20,437	9,713	-
Scenario 1	540.00	52,659	14,861	1,296	28,530	10,488	775
Scenario 2	542.00	59,650	16,086	2,521	35,521	11,248	1,535
Scenario 3	544.00	68,144	16,472	2,907	44,011	12,392	2,679

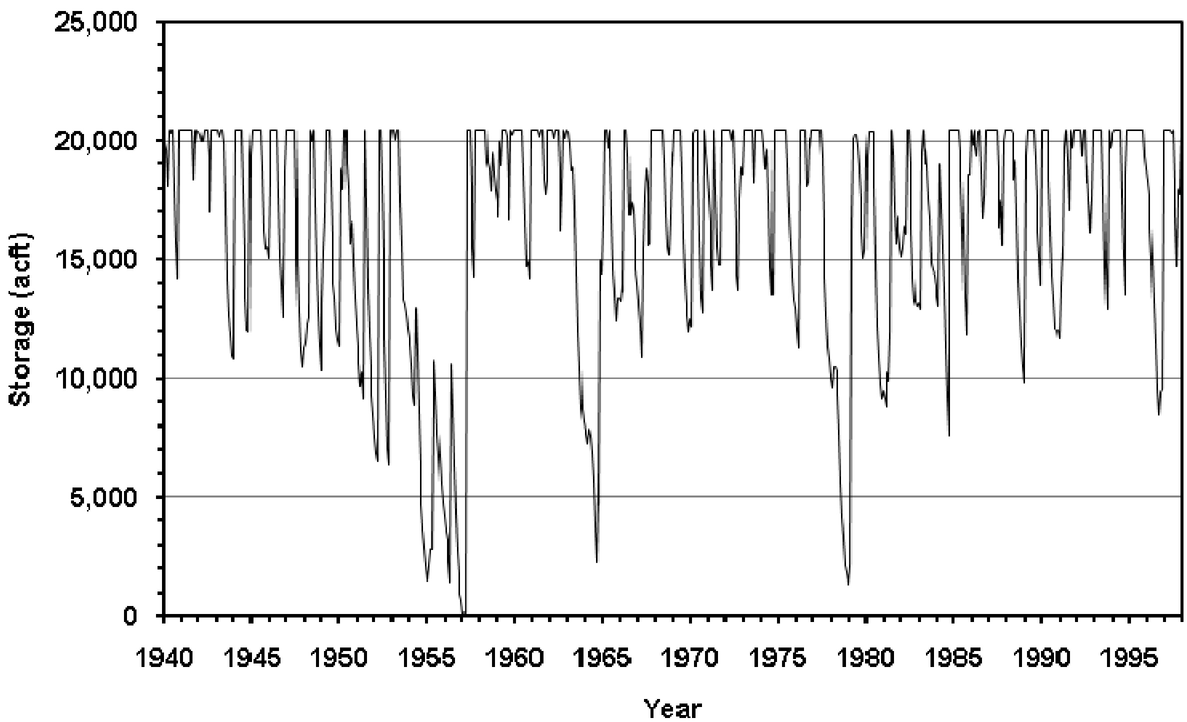

Figure 4B.18.2.2-2. 2060 Lake Aquilla Storage Trace, Current Conservation Elevation (537.5 ft-msl)

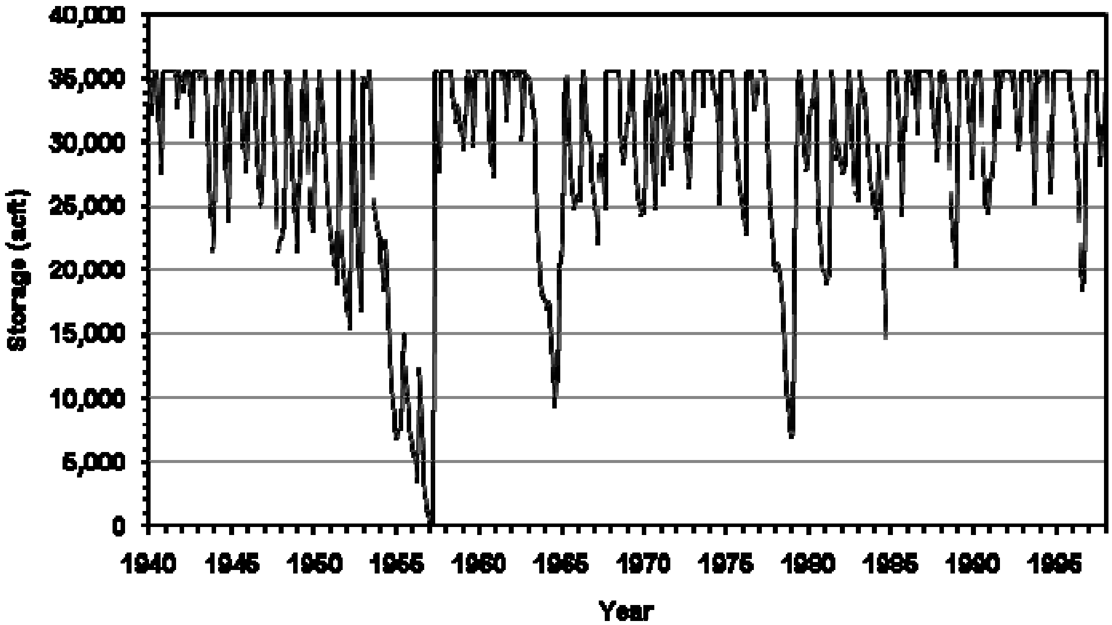

Figure 4B.18.2.2-3. 2060 Lake Aquilla Storage Trace, Alternative 2 (Conservation Elevation at 542 ft-msl)

4B.18.2.3 Environmental Issues

The greatest impact on the environment from the reallocation of storage in Lake Aquilla is the loss of terrestrial habitat due to higher lake levels. Table 4B.18.2.3-1 compares the water surface area at conservation elevation under current conditions to the three storage alternatives described above. In Alternative 3, the maximum reallocation scenario considered for this strategy, the reservoir will inundate an additional 947 acres at conservation. All of the land up to the flood pool elevation around Lake Aquilla is owned by the USACE. The USACE manages the area around the lake as a wildlife management area.

Table 4B.18.2.3-1
Comparison of Water Surface Areas with Reallocation

Scenario	*Elevation (feet)*	*Surface Area (ac)*	*Change in Surface Area (ac)*
Existing	537.5	3,066	–
Alternative 1	540.0	3,388	322
Alternative 2	542.0	3,613	547
Alternative 3	544.0	4,013	947

Wetlands and bottomland hardwoods located in the upper reaches of the lake will be impacted by raising the conservation elevation. Endangered and threatened species reported in Hill County include the whooping crane, black-capped vireo, and golden-cheeked warbler. Species which are candidates for listing are the smalleye shiner and sharpnose shiner. The USACE did not encounter any habitats that appeared suitable for the black-capped vireo or golden-cheeked warbler in the affected area. It is possible that whooping cranes may temporarily use the affected habitat during their annual migration, but an encounter would be rare. The USACE did not find evidence of either the smalleye shiner or sharpnose shiner within the study area.

4B.18.2.4 Engineering and Costing

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 three telephone lines, seven electric lines, three water lines, two petroleum product pipelines and 18 roads. Another cost is the mitigation of the loss of terrestrial habitat, which is potentially high for this project. Studies on the slope stability, seepage, flood impacts and environmental impacts are included in the estimate. Improvements to Lake Aquilla dam to store the additional capacity may be identified in these studies, and an estimate of the cost of these improvements is included in the estimate. The capital costs for the reallocation of storage to an elevation of 542 ft-msl is $4.04 million. Detailed costs are shown in Table 4.B.18.2.4-1.

4B.18.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.18.2.5-1, and the option meets each criterion.

Seepage concerns have been expressed in the past for Lake Aquilla dam. For the re-allocation of storage to take place an evaluation of foundation seepage, slope stability and instrumentation may be required. The studies along with additional instrumentation are included in the cost estimate. The habitat lost to inundation will need to be mitigated and securing mitigation property may be an issue. If Alternatives 2 or 3 are chosen, Congressional authorization for the project will be required.

Table 4B.18.2.4-1
Cost Estimate Summary for Lake Aquilla Pool Reallocation
(September 2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Improvements to Dam	$1,550,000
Relocations	$2,490,000
Total Capital Cost	**$4,040,000**
Engineering, Legal Costs and Contingencies	$1,414,000
Environmental & Archaeology Studies and Mitigation	$5,325,000
Slope stability, seepage and geotechnical studies	$210,000
Interest During Construction (12 months)	$458,000
Total Project Cost	**$11,447,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$832,000
Total Annual Cost	**$832,000**
Available Project Yield (acft/yr)	2,050
Annual Cost of Water ($ per acft)	$406
Annual Cost of Water ($ per 1,000 gallons)	$1.25

Table 4B.18.2.5-1
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 due to frequent hydropower releases from Lake Whitney
2. Habitat	2. Low (540 ft) to moderate (544 ft) impacts on bottomland hardwood and fish and wildlife resources. Lake sedimentation may create significant amounts of shallow wetlands that might benefit migratory water fowl.
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Low impact due to distance from coast
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low (540 ft) to moderate (544 ft) impacts on wetlands
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• 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

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);
- 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
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- Texas General Land Office Easement if State-owned land or water is involved; and

- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

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

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

Land Acquisition Issues:

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

4B.19 Control of Naturally Occurring Salinity

4B.19.1 Characterization of Salinity in the Brazos River

4B.19.1.1 Sources

Natural salt pollution has been recognized as the most serious and widespread water quality problem in the Brazos River Basin. No other pollution source, man-made or natural, has had the impact of the natural salt sources located in the upper basin. However, as the Brazos River flows to the Gulf, inflows from tributaries decrease the concentration of dissolved minerals and salts, which in turn improves the quality of water.

The primary sources of the natural salt pollution in the Brazos River Basin are northwest of the City of Abilene, principally in the watersheds of the Salt and Double Mountain Forks of the Brazos River, which are within the Brazos G Area (Figure 4B.19.1-1).

A substantial part of the salt load in the Brazos River is contributed by Croton Creek and Salt Croton Creek, according to various reports.[1,2,3,4,5,6,7] The natural salt pollution producing area is a semi-arid region of salt and gypsum encrusted hills and canyon-like stream valleys. The area is studded with salt springs and seeps. The highly erodible floodplain material in this region is continually washed away as the streams cut their way down to rock or other impervious base. This bedrock provides a cap over a brine aquifer that underlies this entire region of Texas and parts of Arkansas, Oklahoma, and Kansas. In areas where the erosion process has continued for centuries, the streambed has spread out to form large flats. Wherever there is a joint of fracture in the stream bedrock material, the highly mineralized water seeps to the surface under artesian pressure. Massive salt flats, often 400 to 500 acres in size, are formed by this process. Salt and other minerals are also leached out of the adjacent floodplain material that surrounds the salt flats

[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.

and streams. The Brazos River receives a tremendous salt load when local rainfall is sufficient to dissolve the deposited salt and wash it out of the salt flats.

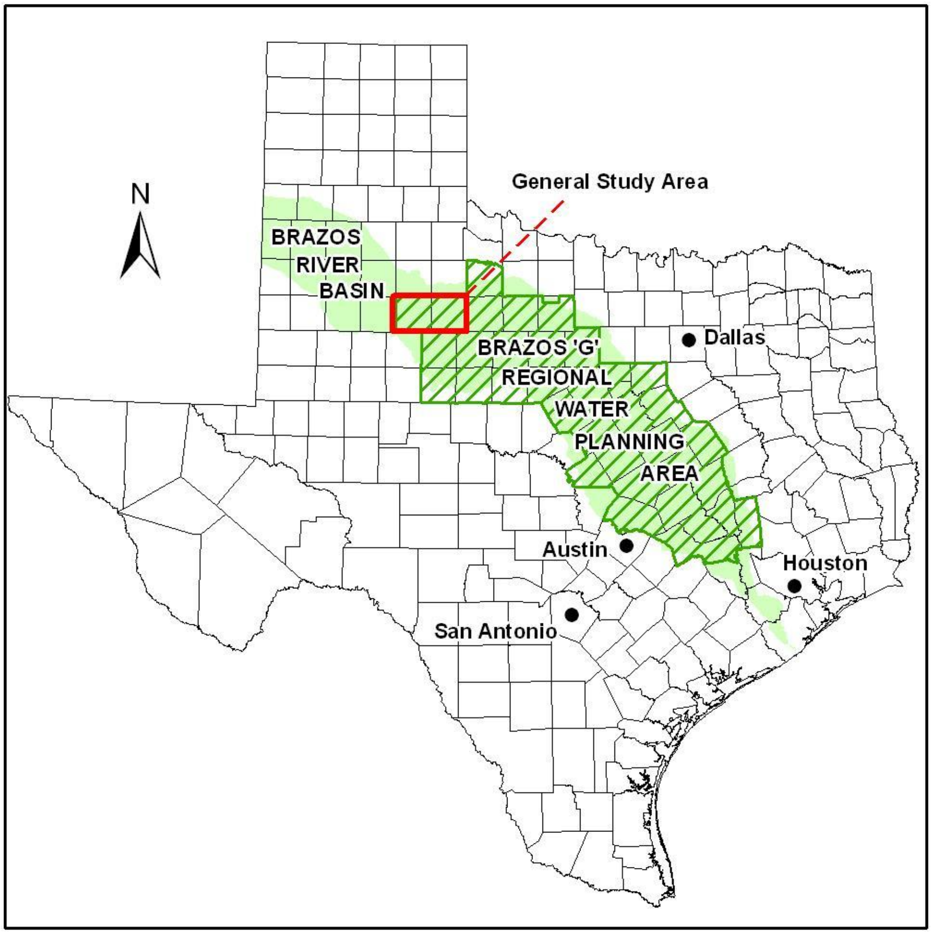

Figure 4B.19.1-1. Salinity Control Study Area

4B.19.1.2 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

[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.

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 (Table 4B.19.1-1, excerpted from Wurbs et. al. (1993)). The 26 gages were chosen based on their record durations and their locations, which are mapped in Figure 4B.19.1-2. This section highlights data and findings from the Ganze and Wurbs (1989) and Wurbs et. al. (1993) studies.

Table 4B.19.1-2 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 4B.19.1-3, also excerpted from Wurbs et. al. (1993), lists the mean discharges and TDS, Cl, and SO_4 loads at 12 of the 26 gages based on available data from the 1964 through 1986 period. The table provides data from similar time periods to facilitate comparisons.

The data in the Tables 4B.19.1-2 and 4B.19.1-3 indicate that much of the salinity in the watershed originates above the Seymour gage. A decrease in concentration with distance down the main stem of the Brazos is evident, as tributaries having lower salinity concentrations join the main stem. Based on the data in Table 4B.19.1-3, 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 4B.19.1-4 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 4B.19.1-1.
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
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.

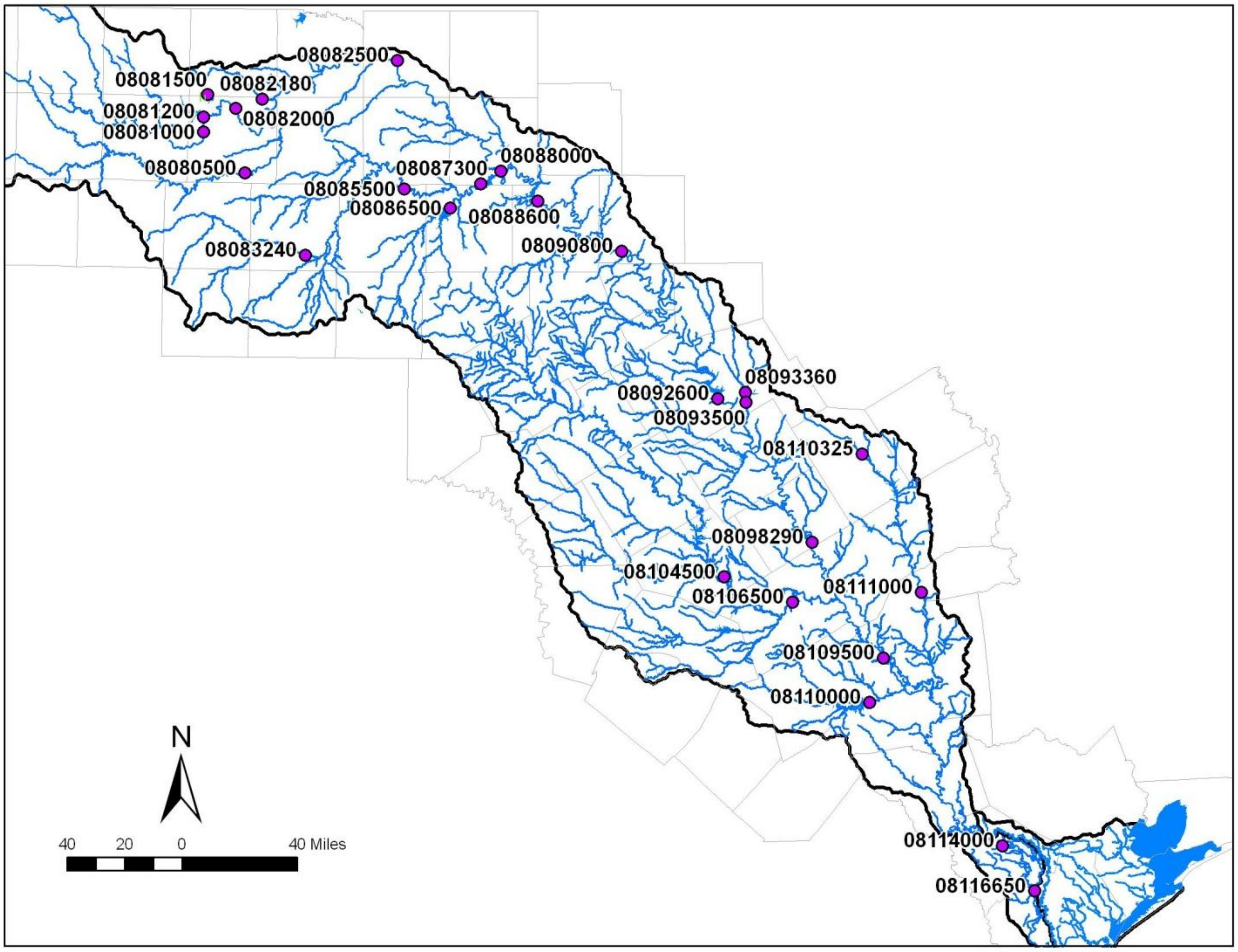

Figure 4B.19.1-2. Selected USGS Water Quality Monitoring Stations

Table 4B.19.1-2.
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
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 4B.19.1-3.
Mean Discharges, Loads and Concentrations at Selected Stations 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 4B.19.1-4.
Ranges in Monthly Mean Salinity Concentration for Water Years 1964 through 1986

Abbreviated Station Name	Tributary	Con-stituent	Minimum Monthly Mean Concen-tration (mg/L)[1]	Date of Minimum Monthly Mean Concen-tration (mg/L)[1]	Maximum Monthly Mean Concen-tration (mg/L)[1]	Date of Maximum Monthly Mean Concen-tration (mg/L)[1]	Ratio of Maximum to Minimum
Seymour	Main Stem	TDS	618	Aug 1964	15,400	May 1984	24.92
Seymour	Main Stem	Cl	190	Jun 1975	7,740	May 1984	40.74
Seymour	Main Stem	SO_4	112	Nov 1963	2,225	Mar 1976	19.87
Richmond	Main Stem	TDS	153	Nov 1984	978	Oct 1978	6.39
Richmond	Main Stem	Cl	28	Nov 1984	355	Oct 1978	12.68
Richmond	Main Stem	SO_4	24	Dec 1965	185	Oct 1963	7.71

[1]Source: Wurbs, R.A., A.S. Karama, I. Saleh, and C.K. Ganze, "Natural Salt Pollution and Water Supply Reliability in the Brazos River Basin," Texas Water Resources Institute, 1993.

Based on arithmetic averages of the monthly mean concentrations for each month of the year in the 1964 through 1986 analysis period, Wurbs et. al. (1993) also found that seasonal fluctuations in salinity concentrations were greater at the Seymour gage than at the gages located below the reservoirs. The month having the maximum average monthly mean concentrations of all three salinity parameters at Seymour is February. Table 4B.19.1-5 lists the range of the arithmetic averages of the monthly mean concentrations at the Seymour, Whitney, and Richmond gages. Of the three gages listed in Table 4B.19.1-5, the variation is least at the Whitney gage, which is likely due to the effects of the reservoir. With regard to trends over time, Wurbs et al. (1993) found that any trends or long term changes in salinity concentrations are very small relative to the random variability in the data.

Table 4B.19.1-5.
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.

4B.19.1.3 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 Figures 4B.19.1-3 through 4B.19.1-7.

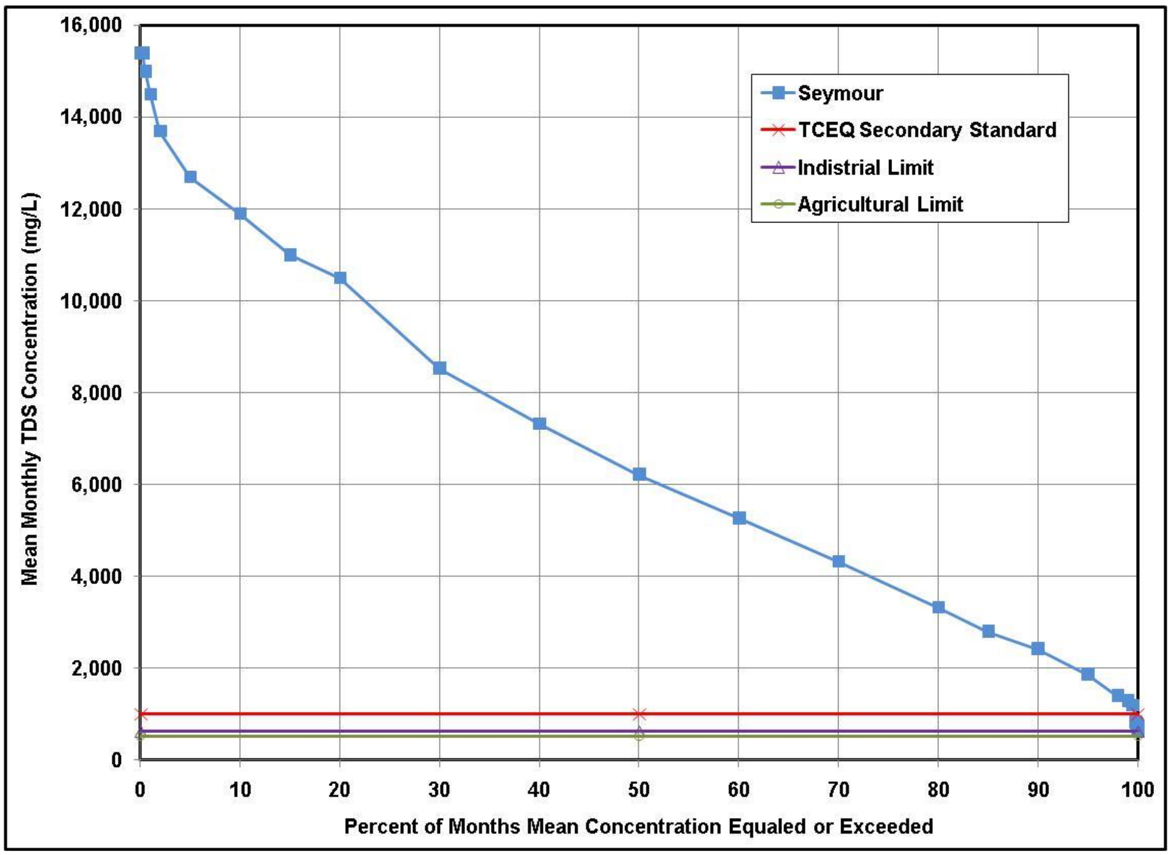

Figure 4B.19.1-3. TDS Concentration-Duration Curve at Seymour

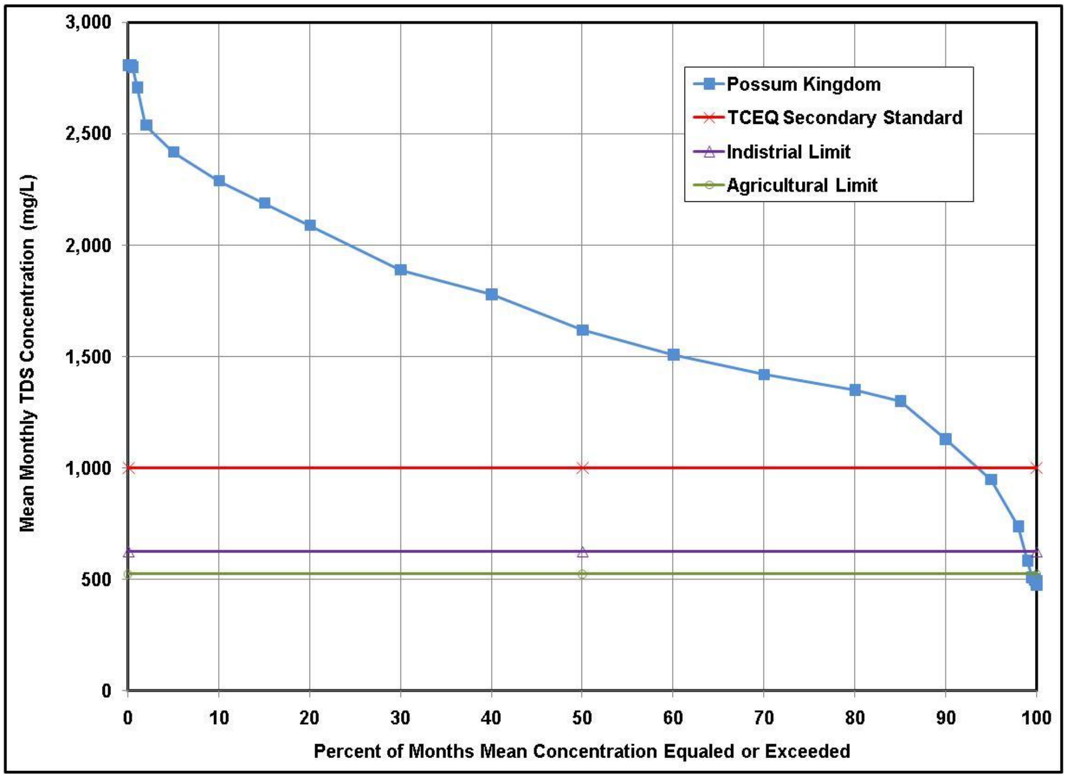

Figure 4B.19.1-4. TDS Concentration-Duration Curve at Possum Kingdom

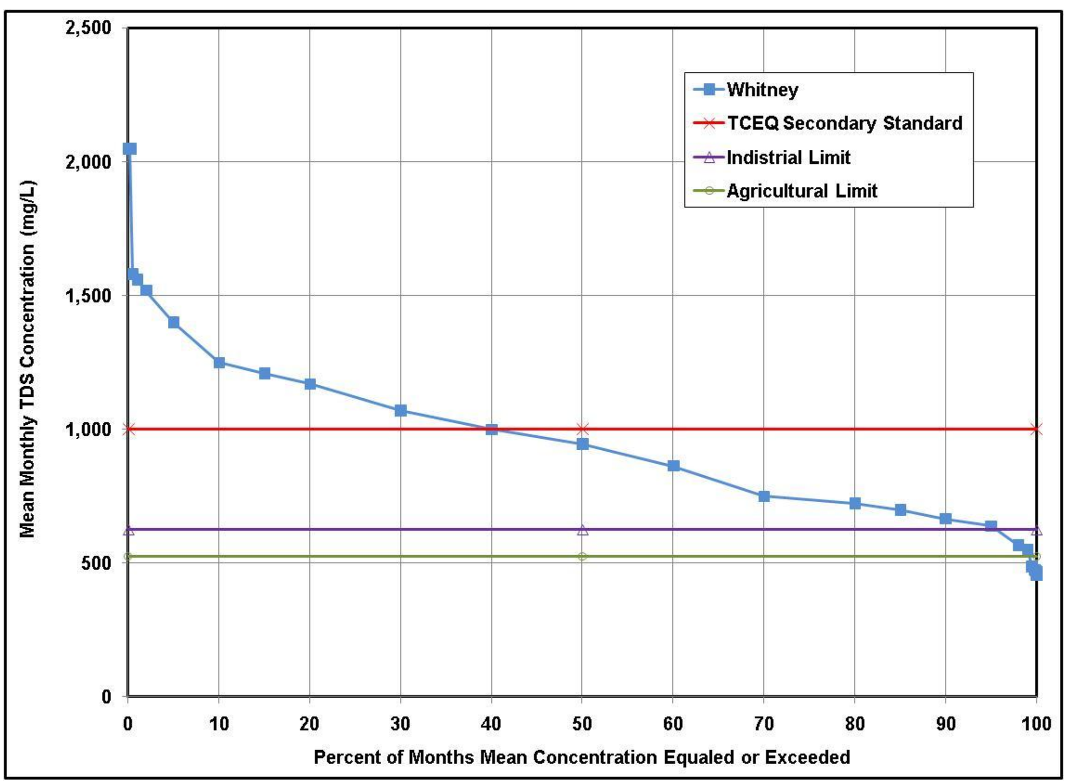

Figure 4B.191-5. TDS Concentration-Duration Curve at Whitney

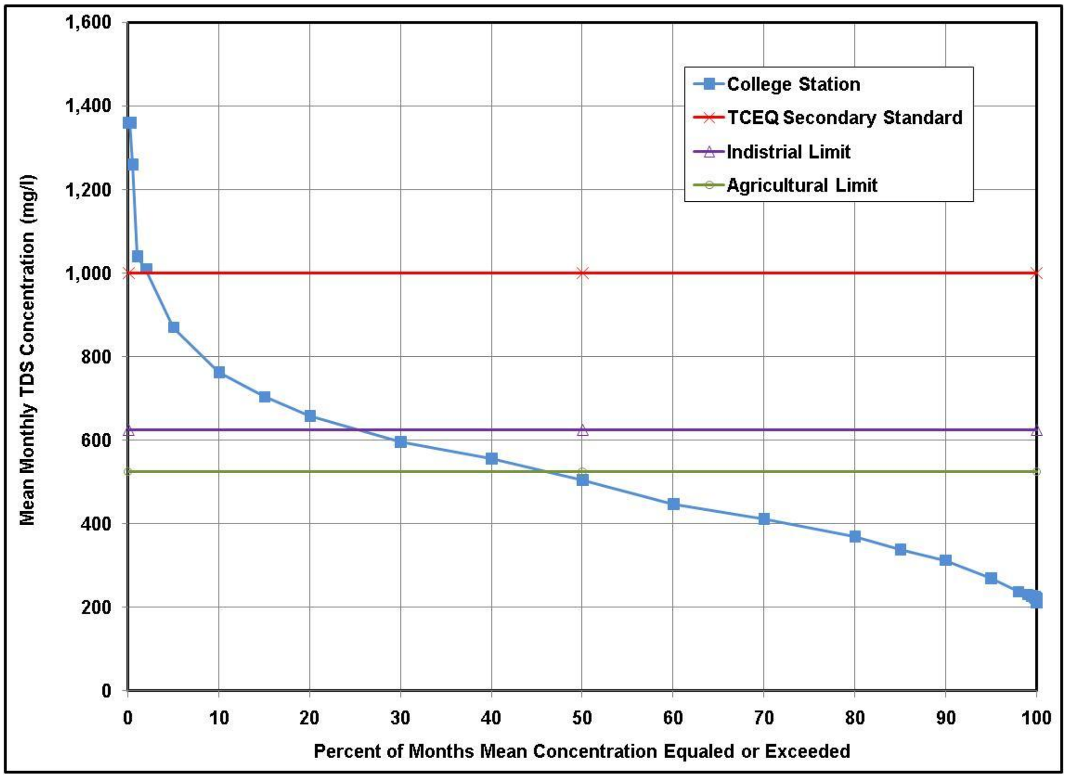

Figure 4B.19-6. TDS Concentration-Duration Curve at College Station

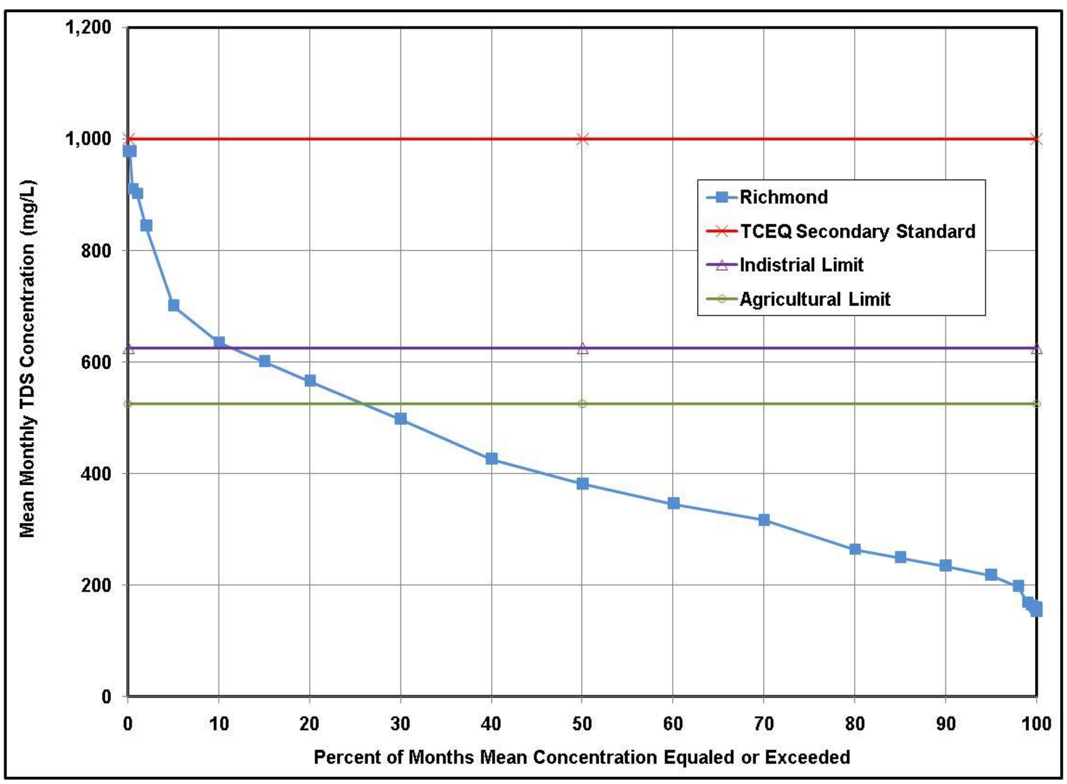

Figure 4B.19-7. TDS Concentration-Duration Curve at Richmond

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 4B.19.1-2 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 4B.19.1-6 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 4B.19.1-7 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, Figures 4B.19.1-3 through 4B.19.1-7 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.

[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.

Table 4B.19.1-6.
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 4B.19.1-7.
Irrigation Water Quality Guidelines

Degree of Restriction on Use	***TDS Concentration (mg/L)***
None	< 450
Slight to Moderate	450 – 2,000
Severe	> 2,000
Source: Ayers, R.S., and D.W. Westcot, "Water Quality for Agriculture," Food and Agricultural Organization of the United Nations, Irrigation and Drainage Paper No. 29, rev. 1, 1985, as cited in U.S. Department of Agriculture Natural Resources Conservation Service. Part 623 National Engineering Handbook, Chapter 2, "Irrigation Water Requirements," 1993.	

Water quality requirements for industrial usage vary widely depending upon the industrial process.[12] A 625 mg/L TDS limit is assumed here. The limit is derived from a desirable chloride concentration for water used in cooling towers of less than 200 mg/L. Based on the USGS water quality data, mean chloride concentration as a percentage of mean TDS concentration in the Brazos River ranges from 23% at Richmond to 41% at Seymour. Using the midpoint of this range, 32%, as a representative percentage of TDS that is chloride, a 200 mg/L chloride limit equates to a 625 mg/L TDS limit (200/.32 = 625). Figures 4B.19.1-3 through 4B.19.1-7 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.

[12] Ibid.

4B.19.2 Description of Salinity Control Project

Three salinity control project options were studied in the 2001 Brazos G Regional Water Plan. All three options included brine recovery well fields that penetrate the saline aquifer, lowering the piezometric surface of the water table, thereby eliminating brine springs and seeps in the area. Option 1 involved disposal of the recovered brine in a deep well injection system. Option 2 involved disposal of the brine in Kiowa Peak Reservoir, which would serve as a permanent impoundment for the recovered brine. Option 3, which has evolved into the project studied further herein, would convey the recovered brine to a brine utilization and management complex (BUMC) where it would be converted into marketable sodium chloride (NaCl) salt products. Stonewall, Garza, and Kent Counties have formed a local government corporation called the Salt Fork Water Quality (SFWQ) Corporation to work on advance planning for the project in cooperation with the Brazos River Authority.

The currently proposed project configuration is shown in Figure 4B.19.2-1. Key project components are located in Kent and Stonewall counties and include three brine recovery well fields, a brine conveyance pipeline, and the BUMC. The brine recovery well fields would be located adjacent to salt springs contributing flows to Salt Croton Creek (Dove Creek Salt Flat / Panther Canyon Area), Croton Creek (Short Croton Salt Flat), and Salt Creek. Test wells have been drilled in all three well fields. A test well at the Salt Creek field is currently producing brine that is being sold to Oxy-Permian Corporation.[13] Six-inch spur and 12-inch trunk lines would convey the brine from the well fields to the BUMC, which would employ solar evaporation ponds to recover the salt from solution. A total of approximately 37.5 miles of 12-inch line and 17.5 miles of 6-inch line would be installed. The pipe material would be carbon steel with epoxy coating. Three pump stations, located in the vicinity of the well fields, would be included in the transmission system. The BUMC would be located in Kent County approximately 16 miles southwest of Jayton and 29 miles north of Snyder. Costing and environmental information are also included in the present evaluation for a rail spur running along State Highway 208 from the BUMC to the BNSF Railroad line in Snyder. The rail spur would facilitate long distance shipping of salt products. Although the rail spur is preliminarily evaluated herein, the associated initial capital costs and potential benefits of access to a broader geographical market compared to trucking are still under consideration.

[13] Rodgers, R.W., "Natural Chloride Salt Pollution Control in the Upper Brazos River Basin," prepared for the Salt Fork Water Quality District, Stonewall, Kent, and Garza Counties, Texas, 2008.

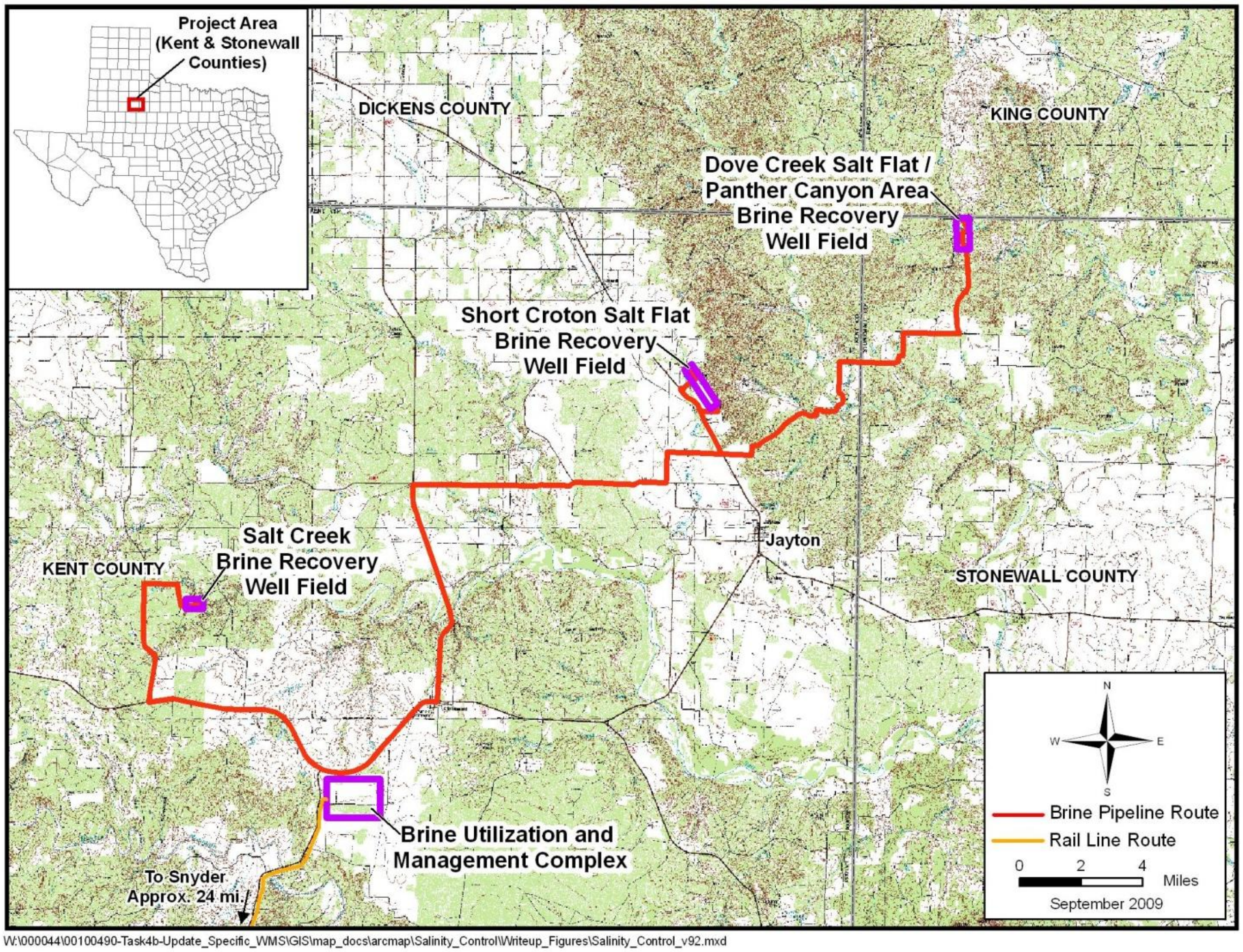

Figure 4B.19.2-1. Project Layout Map

Most of the brine pumped from the well fields would be evaporated to make salt. There is a possibility that some fresh water could be condensed as a byproduct. Brine that is not evaporated would be used in liquid form as "ten-pound brine" for oil and gas operations. Sales of salt and liquid brine would produce revenues to help cover annual costs.

As an alternative configuration of the proposed project, the feasibility of using smaller evaporation units closer to the recovery wells is being evaluated by the SFWQ Corporation. Salt would be collected from these units and shipped by truck. A second variation of the project would include, in addition to the previously described components, capturing brine in North Croton Creek and piping it to a disposal reservoir in the Wichita River basin.[14] The U.S. Army Corps of Engineers' salinity control project in the Wichita River Basin includes the existing Truscott Brine Disposal Lake and project plans have included the Crowell Brine Lake. As

[14] Denny, K. and J. Dougherty, Verbal communication, September 2009.

information for the two variations of the project has not been developed in comparable detail to the components previously described, these variations are not evaluated further herein.

4B.19.3 Evaluation of the Potential Effectiveness of the Salinity Control Project

4B.19.3.1 Modeling Approach

The approach to evaluating the potential effectiveness of the salinity control project involved modeling TDS concentrations in the Brazos River Basin for the hydrologic, water use, and reservoir operating policies of the 2060 Brazos G Water Availability Model (WAM). Model simulations were developed to represent conditions with and without the salinity control project, and the resulting TDS concentration frequency data were compared. Work by Wurbs and Lee (2009)[15] provided salinity input data used in the modeling.

4B.19.3.1.1 Brazos WAM WRAP-SALT Input File

Wurbs and Lee (2009)[16] used the USGS 1964-1986 sampling data to develop a TDS budget for the Brazos Basin. The budget provided estimates of TDS loads and concentrations that Wurbs and Lee then applied in preparing an input file for the WRAP-SALT[17] software. WRAP-SALT is the salinity modeling component of the Water Rights Analysis Package (WRAP).[18] The program computes loads and concentrations of conservative water quality constituents based on scenarios of water use, reservoir operating policies, and salinity control measures. The Brazos WAM is implemented with the WRAP-SIM component of WRAP and provides the water quantity data that are necessary for execution of WRAP-SALT. The Wurbs and Lee (2009) input file is designed for use with the various versions of the Brazos WAM.

Table 4B.19.3-1 provides a summary of the Wurbs and Lee (2009) TDS budget. Water volumes, TDS loads, and TDS concentrations of inflows to the Brazos River system and losses from the system are summarized in the table by their mean values over the 1964 through 1986 water year period. The inflow values are summarized at five control points representing five USGS gaging stations, and the losses are summarized at the three major main stem reservoirs

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[15] Wurbs, R.A. and C. Lee, "Salinity Budget and WRAP Salinity Simulation Studies of the Brazos River/Reservoir System," Texas Water Resources Institute Technical Report No. 352, July 2009.
[16] Ibid.
[17] Wurbs, R.A, "Salinity Simulation with WRAP," Texas Water Resources Institute Technical Report No. 317, July 2009.
[18] Wurbs, R.A, "Water Rights Analysis Package (WRAP) Modeling System Reference Manual," Texas Water Resources Institute Technical Report No. 255, August 2008.

(Possum Kingdom, Granbury, and Whitney). The losses represent removal of salinity from the system that is not associated with a particular water management practice.

Wurbs and Lee (2009) used the TDS budget in developing the WRAP-SALT input file. The 197,402 tons/month mean net TDS inflow less losses in Table 4B.19.3-1 is the mean TDS load of the river flows at the Richmond gage as entered in the WRAP-SALT input file. The actual mean load at the Richmond gage (Table 4B.19-3) 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 Granbury. These loads are not subtracted out of the load entered into the input file because the software computes the actual values of these loads for the water management strategies being modeled.

Components of the total Basin load are introduced at various locations throughout the Basin in the salinity simulation based on information provided by the Brazos WAM WRAP-SALT input file. The salinity computations are carried out from upstream to downstream. TDS loads entering the system at the Seymour control point and inflow concentrations entering at the Cameron control point define upstream boundaries of the salinity simulation. These boundaries are the loads and concentrations associated with total regulated flows at the Seymour and Cameron control points, respectively. The Little River is the largest low salinity tributary of the Brazos River. Although the Brazos WAM contains control points located upstream of the boundaries and computes water quantities above these points, the salinity simulation does not extend above the Seymour gage on the Brazos River and the Cameron gage on the Little River.

In addition to defining the boundary conditions, the WRAP-SALT input file defines the TDS concentrations for incremental inflows that occur throughout the Basin below the boundaries. The incremental inflow concentrations are defined at several control points. These concentrations are then automatically repeated by the model at all control points located above the given control point until a control point is encountered for which a different incremental inflow concentration is defined. Thus, incremental inflow concentrations are applied to all incremental inflows entering the model below the upstream boundaries.

Table 4B.19.3-1.
TDS Budget Summary

Location	***Brazos WAM Control Point ID***	***USGS Gage 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						
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 4B.19.3-2 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 4B.19.3-2.
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 4B.19.3-1 shows losses from the system that are not associated with a particular water management practice. To account for these losses in the WRAP-SALT simulations, the input file includes coding to reduce inflow loads to the Lake Possum Kingdom, Granbury, and Whitney control points by 17.42%, 6.59%, and 3.00% respectively. These losses are not repeated at any other control points.

The WRAP-SALT simulation requires as input initial storage contents and TDS concentrations for each reservoir located below the upstream boundaries. In both the Brazos WAM and the salinity simulation, all reservoirs are assumed to be full at the beginning of the simulation period. Possum Kingdom Lake, Lake Granbury, and Lake Whitney are assigned initial TDS concentrations of 1,626 mg/L, 1,302 mg/L, and 1,062 mg/L, respectively. These values are the mean 1964 through 1986 TDS concentrations for each lake as computed in the salinity budget. Reservoirs upstream of Possum Kingdom, Granbury, and Whitney are assigned initial TDS concentrations of 800 mg/L, 400 mg/L, and 300 mg/L respectively. Reservoirs upstream of the Brazos River at the Gulf of Mexico and below Whitney are assigned initial TDS concentrations of 250 mg/L.

4B.19.3.1.2 Adaptation of Brazos WAM WRAP-SALT Input File to Salinity Control Project

Wurbs and Lee (2009) used WRAP-SALT with the input file described in the previous section to assess the salinity reduction that would be achieved by construction of salinity control impoundments on Croton Creek, Salt Croton Creek, and North Croton Creek. The impoundment project has been previously studied by the U.S. Army Corps of Engineers.[19,20] Wurbs and Lee (2009) modeled the impacts of the impoundments by assuming that all flows and loads entering the system above the impoundments would be removed. A similar approach was used in the present study to assess the effects of the groundwater pumping salinity control project.

Table 4B.19-10 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

[19] U.S. Army Corps of Engineers Fort Worth District, "Natural Salt Pollution Control Study, Brazos River Basin, Texas," Volumes 1-4, 1973.
[20] U.S. Army Corps of Engineers, Fort Worth District, "Brazos Natural Salt Pollution Control, Brazos River Basin, Texas, Design Memorandum No. 1, General Phase 1 – Plan Formulation," 1983.

Table 4B.19-10 have complete water year 1964 through 1986 records. The table therefore provides 1969 through 1977 means that are based on measured data as well as 1964 through 1986 means that are based on records which were filled as necessary by regression analysis.

To model the affects of the salinity control impoundments, Wurbs and Lee (2009) reduced TDS loads at the Seymour gage in the WRAP-SALT input file using the information provided in Table 4B.19-10. 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 4B.19-9 shows the location of the proposed brine recovery well fields in relation to major brine springs and USGS stream gages. Previous work has indicated that the proposed brine recovery well system will reduce the TDS loads in the Brazos River above Possum Kingdom Lake by 41%.[21] If the Dove Creek Salt Flat / Panther Canyon Area well field eliminated the TDS load from Salt Croton Creek and the Short Croton Salt Flat well field eliminated the TDS load from Croton Creek, an average of 901 tons per day would be eliminated from the system, based on the 1964 through 1986 mean TDS loads (Table 4B.19-10 and Figure 4B.19-9). The TDS load of Salt Creek is approximately 10% of the load of the Salt Fork of the Brazos River near Peacock,[22] or approximately 68 tons per day based on the 1964 through 1986 mean load at the gage near Peacock (Table 4B.19.3-3 and Figure 4B.19.3-1). 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.

[21] James, W.P., "Water Quality Improvement along the Brazos River," prepared for the Salt Fork Water Quality District, Stonewall, Kent, and Garza Counties, Texas, Open-file Report, 2007.
[22] Rodgers, R.W., "Natural Chloride Salt Pollution Control in the Upper Brazos River Basin," prepared for the Salt Fork Water Quality District, Stonewall, Kent, and Garza Counties, Texas, 2008.

Table 4B.19.3-3.
Flows and Loads in the Upper Brazos River Basin

USGS Gaging Station	*USGS Gage ID*	*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.						

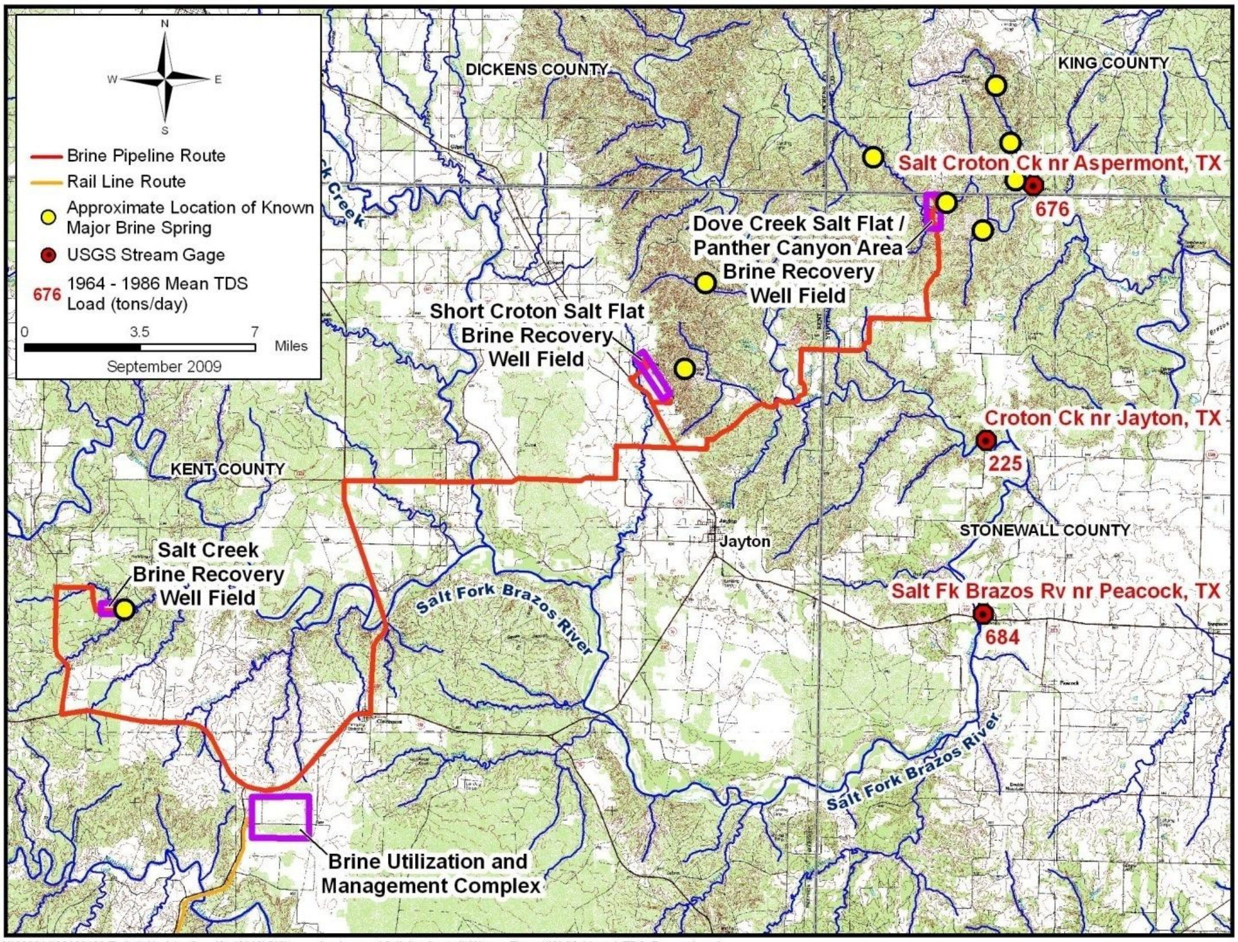

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Figure 4B.19.3-1 Well Fields and TDS Loads

It has been proposed that a total groundwater pumping rate of 500 gallons per minute (gpm) would effectively lower the piezometric surface on the brine aquifer such that the Dove Creek Salt Flat / Panther Canyon Area springs will cease to flow.[23] If the other two well fields were pumped at a similar rate, the total rate of groundwater pumping would be approximately 1% of the discharge of the Brazos River at Seymour. Given that a portion of this discharge would be lost to natural process in the channel between the springs and the Seymour gage, it was assumed for modeling purposes that the flow removed by the well fields would constitute an inconsequential fraction of the total discharge of the Brazos River at Seymour, and therefore the discharge at Seymour was not reduced in the model. As further justification for this assumption,

[23] James, W.P., "Chloride Concentration in the Possum Kingdom Reservoir," prepared for the Salt Fork Water Quality District, Stonewall, Kent, and Garza Counties, Texas, Open-file Report, 2005 cited in Rodgers, R.W., "Natural Chloride Salt Pollution Control in the Upper Brazos River Basin," prepared for the Salt Fork Water Quality District, Stonewall, Kent, and Garza Counties, Texas, 2008.

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 be flushed out within a finite time period. Previous work by others has indicated that significant improvement in water quality of the Brazos River would occur within three to five years of implementation of the brine recovery well system, depending on the amount of rainfall that occurs in the watershed.[24] It was also assumed that brine discharges from existing desalination plants do not contribute a significant amount of additional salinity to the system; desalination discharges were therefore not explicitly modeled.

Two other assumptions in the approach are highlighted by Wurbs and Lee (2009). First, the approach assumes that there are no natural salinity losses occurring between the sources and the Seymour gage. Second, the WRAP-SALT program assumes that salinity load losses due to flow volume losses in the channel are linearly proportional to the volume losses. Wurbs and Lee (2009) note that underestimation of natural load losses would tend to cause overestimation in the effectiveness of salinity control measures.

The first assumption noted by Wurbs and Lee (2009) appears to be reasonable, as the sum of the mean 1964 through 1986 TDS loads at the Double Mountain Fork of the Brazos River near Aspermont (USGS gage 08080500), the Salt Fork of the Brazos River near Aspermont (USGS Gage 08082000), and North Croton Creek near Knox City (USGS Gage 08082180) is 2,451 tons per day (580 tons per day plus 1,660 tons per day plus 211 tons per day from Tables 4B.19-3 and 4B.19-10), 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.

[24] James, W.P., "Water Quality Improvement along the Brazos River," prepared for the Salt Fork Water Quality District, Stonewall, Kent, and Garza Counties, Texas, Open-file Report, 2007.

4B.19.3.2 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 2060 version of the Brazos G WAM, which models reservoirs at their projected year 2060 capacity. Tables 4B.19.3-4 and 4B.19.3-5 and Figures 4B.19.3-10 through 4B.19.3-7 summarize the results of the WRAP-SALT analysis at key locations in the Brazos River Basin. The tables and figures provide concentration duration curves for regulated outflows from the Seymour, Bryan, and Richmond model control points and reservoir storage concentrations at Possum Kingdom Lake, Lake Granbury, and Lake Whitney. The concentration-duration curves are based on the monthly concentration output for the 696 months of the 1940 through 1997 Brazos WAM simulation period.

Tables 4B.19.3-4 and 4B.19.3-5 provide monthly mean TDS concentrations at each location, computed as the arithmetic average of the concentrations for the 696 simulation periods. The last row in Table 4B.19.3-5 lists the percent reductions in the monthly mean concentrations that result from the project. The reduction percentages show that the effects of the project are most pronounced at the upstream model limit (Seymour), and diminish with distance downstream. Wurbs and Lee (2009) explain that this is due to the effects of load losses in the channel and reservoirs.[25] The 40% reduction in mean TDS concentration at Seymour is expected, as the load reduction at this point is established as a model boundary condition. Reductions in mean concentrations of 29% to 24% are computed at the three reservoirs. Further down the basin, the reduction in mean concentration decreases to 11% at Bryan and 9% at Richmond.

Table 4B.19.3-6 lists exceedence frequencies without and with the salinity control project for the water quality limits discussed in Section 4B.19.1.3. The data are based on the model-predicted concentration-duration curves presented in Tables 4B.19.3-4 and 4B.19.3-5 and Figures 4B.19.3-2 through 4B.19.3-7. The water quality limits are plotted in Figures 4B.19.3-2 through 4B.19.3-7 for comparison to the concentration-duration curves. The effects of the project are demonstrated by the reduction in the percentage of months in which a water quality limit is

[25] Wurbs, R.A. and C. Lee, "Salinity Budget and WRAP Salinity Simulation Studies of the Brazos River/Reservoir System," Texas Water Resources Institute Technical Report No. 352, July 2009.

Table 4B.19.3-4.
Model-Predicted TDS Concentration-Duration Curves Without Project

Percent Equaled or Exceeded	*Seymour (mg/L)*	*Possum Kingdom Lake (mg/L)*	*Lake Granbury (mg/L)*	*Lake Whitney (mg/L)*	*Bryan (mg/L)*	*Richmond (mg/L)*
0.01	19,603	4,324	24,290	2,998	2,028	2,124
0.05	19,603	4,324	24,290	2,998	2,028	2,124
0.1	19,603	4,324	24,290	2,998	2,028	2,124
0.2	18,998	3,959	17,635	2,779	1,995	2,117
0.5	17,045	3,364	6,146	2,232	1,896	1,973
1	14,952	3,333	4,427	1,862	1,823	1,718
2	13,948	3,228	3,378	1,668	1,718	1,473
5	12,485	2,669	2,659	1,542	1,439	1,164
10	11,259	2,427	2,213	1,337	1,164	895
15	10,458	2,236	1,991	1,234	1,011	750
20	9,723	2,121	1,820	1,165	882	660
30	8,140	2,020	1,592	1,036	716	544
40	7,225	1,899	1,438	975	586	439
50	6,044	1,776	1,316	906	468	346
60	4,948	1,662	1,158	841	320	290
70	4,083	1,532	991	778	216	234
80	2,984	1,328	795	712	164	189
85	2,606	1,213	613	653	145	160
90	2,112	1,015	300	590	110	134
95	1,566	719	0	472	78	104
98	601	364	0	199	45	72
99	0	163	0	70	23	44
99.5	0	27	0	2	10	27
99.8	0	0	0	0	5	2
99.9	0	0	0	0	3	0
99.95	0	0	0	0	1	0
99.99	0	0	0	0	0	0
100	0	0	0	0	0	0
Mean	**6,398**	**1,751**	**1,374**	**936**	**551**	**449**

Table 4B.19.3-5.
Model-Predicted TDS Concentration-Duration Curves With Project

Percent Equaled or Exceeded	*Seymour (mg/L)*	*Possum Kingdom Lake (mg/L)*	*Lake Granbury (mg/L)*	*Lake Whitney (mg/L)*	*Bryan (mg/L)*	*Richmond (mg/L)*
0.01	11,762	2,883	13,488	2,397	2,045	2,124
0.05	11,762	2,883	13,488	2,397	2,045	2,124
0.1	11,762	2,883	13,488	2,397	2,045	2,124
0.2	11,399	2,700	10,363	2,182	1,998	2,079
0.5	10,227	2,413	4,557	1,702	1,871	1,812
1	8,971	2,322	3,461	1,611	1,808	1,602
2	8,369	2,176	2,573	1,213	1,718	1,326
5	7,491	1,813	1,856	1,099	1,341	1,005
10	6,755	1,654	1,559	969	1,049	816
15	6,275	1,589	1,472	911	887	673
20	5,834	1,510	1,361	865	787	591
30	4,884	1,426	1,157	799	614	465
40	4,335	1,359	1,041	748	507	387
50	3,626	1,272	948	693	380	317
60	2,968	1,183	867	646	275	266
70	2,450	1,092	757	609	191	220
80	1,790	964	591	552	154	183
85	1,563	891	452	515	134	160
90	1,267	751	218	478	108	136
95	940	559	0	406	81	104
98	360	274	0	215	42	61
99	0	84	0	128	20	39
99.5	0	5	0	4	7	19
99.8	0	0	0	0	4	2
99.9	0	0	0	0	2	0
99.95	0	0	0	0	1	0
99.99	0	0	0	0	0	0
100	0	0	0	0	0	0
Mean	**3,839**	**1,241**	**1,000**	**715**	**493**	**408**
Percent Reduction in Mean	**40**	**29**	**27**	**24**	**11**	**9**

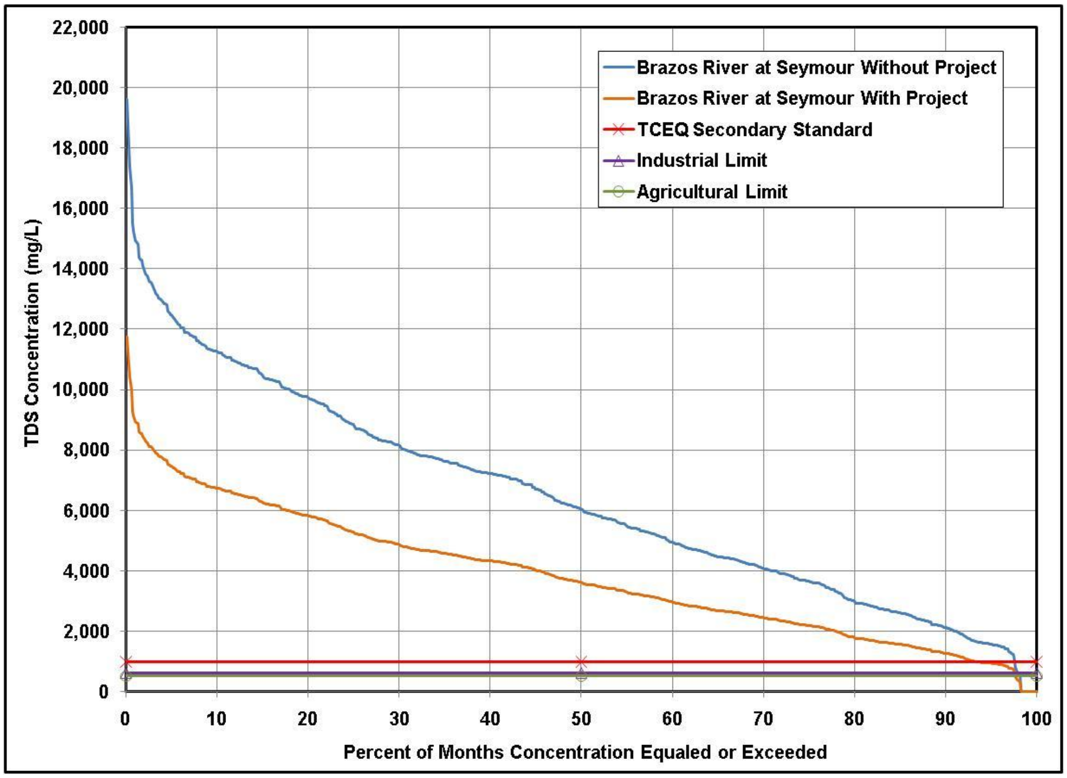

Figure 4B.19.3-2. Model-Predicted TDS Concentration-Duration Curve at Seymour

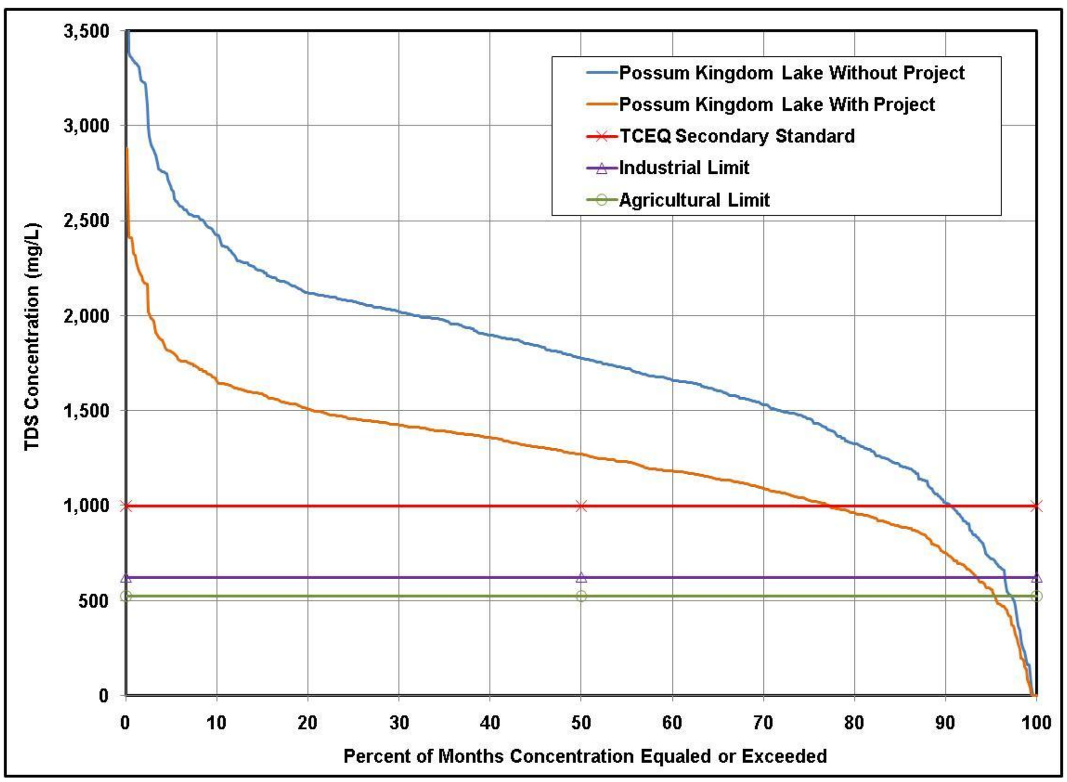

Figure 4B.19.3-3. Model-Predicted TDS Concentration-Duration Curve at Possum Kingdom Lake

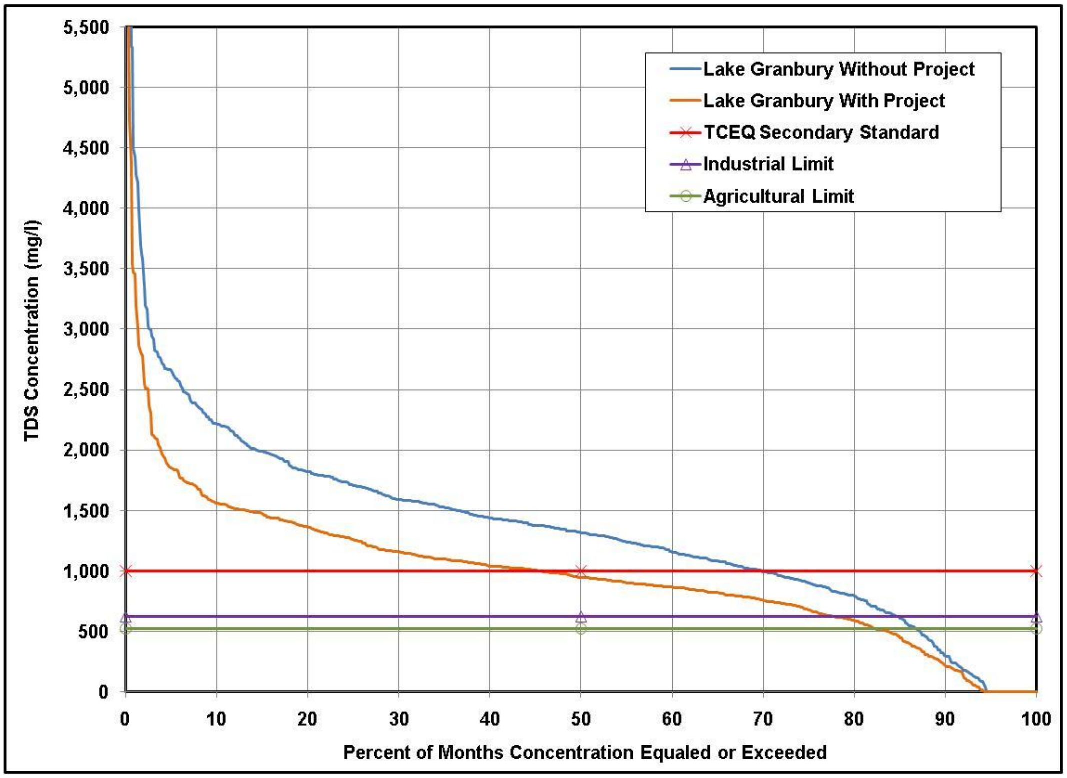

Figure 4B.19.3-4. Model-Predicted TDS Concentration-Duration Curve at Lake Granbury

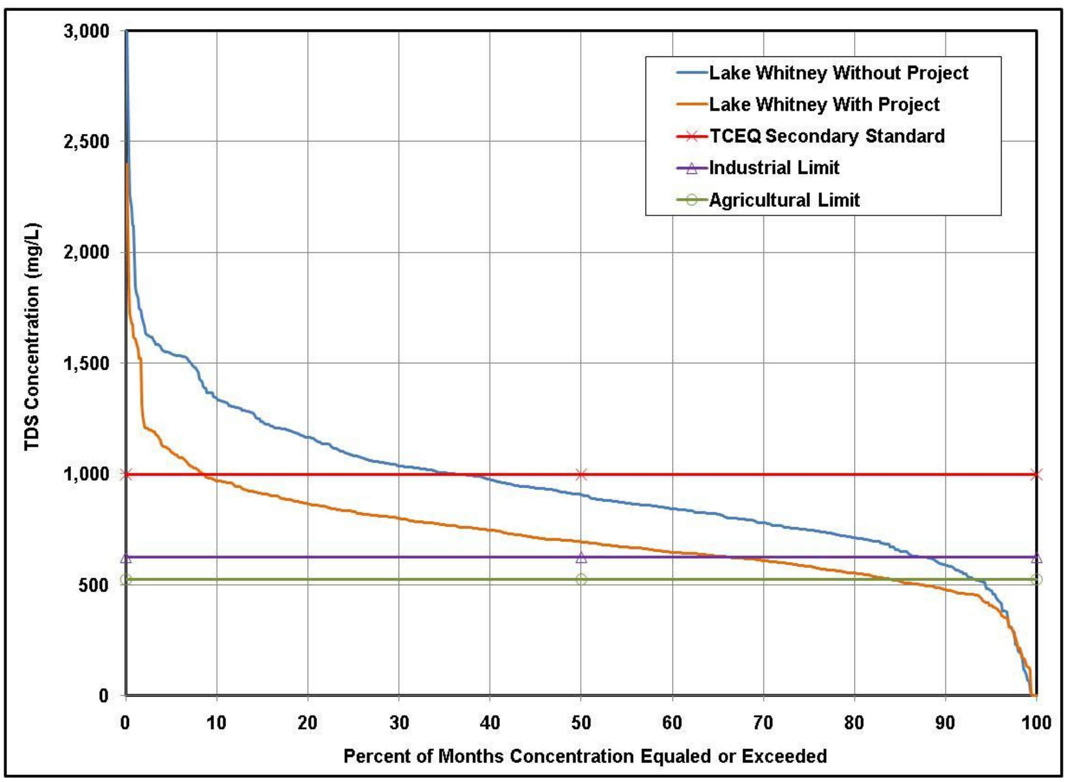

Figure 4B.19.3-5. Model-Predicted TDS Concentration-Duration Curve at Lake Whitney

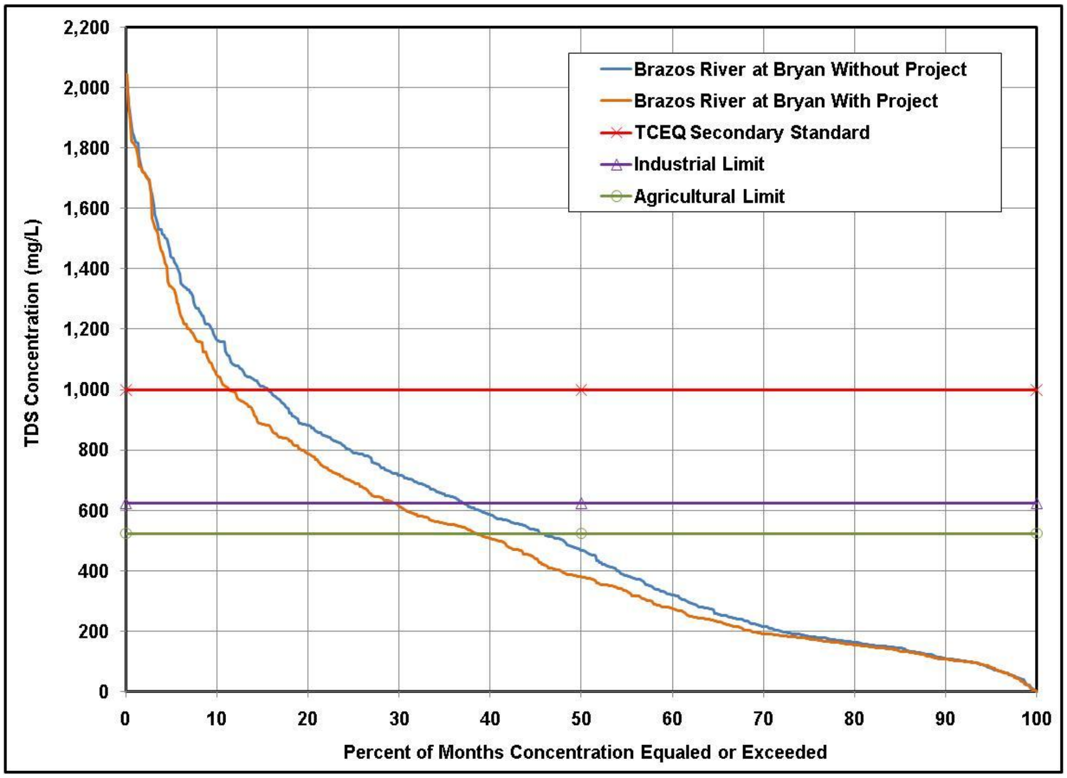

Figure 4B.19.3-6. Model-Predicted TDS Concentration-Duration Curve at Bryan

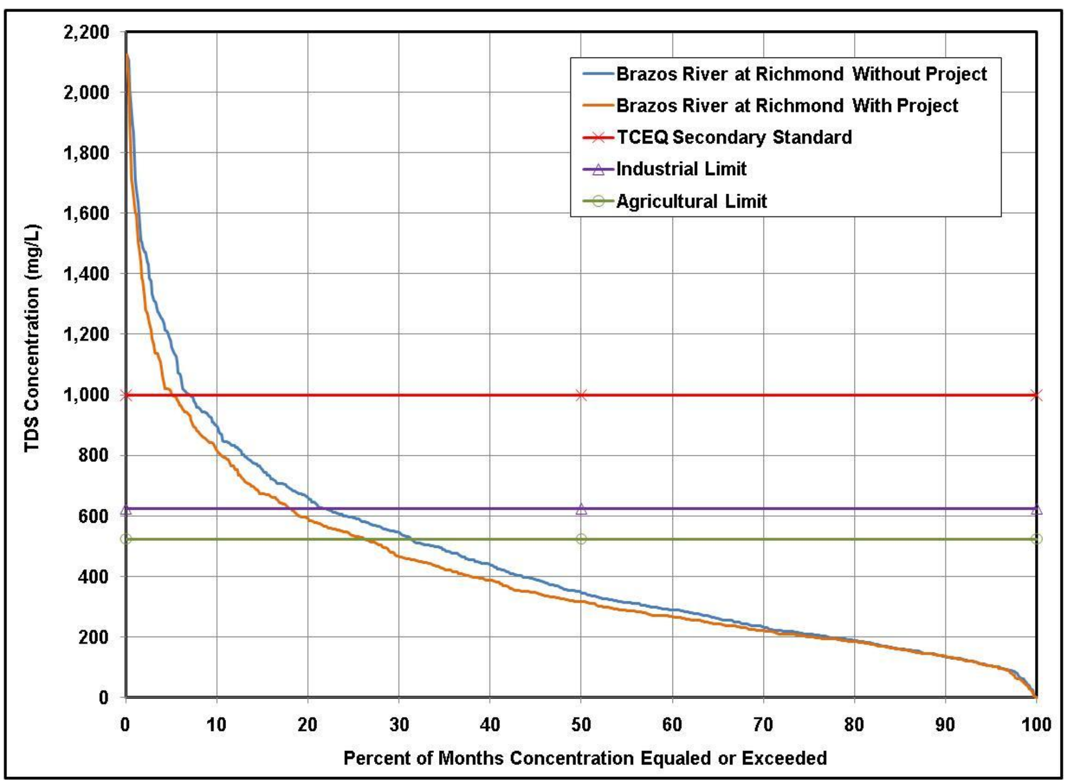

Figure 4B.19.3-7. Model-Predicted TDS Concentration-Duration Curve at Richmond

Table 4B.19.3-6.
Model-Predicted Exceedence 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	93.2	77.3	45.5	8.5	11.4	5.1
Agricultural	525	97.7	95.4	82.2	83.9	38.2	26.1
Industrial	625	97.6	93.4	77.6	65.9	29.3	17.9

exceeded. For example, the percentage of months in which the TCEQ secondary TDS standard is equaled or exceeded in Lake Whitney is reduced by approximately 28% (36.2% - 8.5% = 27.7%). Of the locations shown in Table 4B.19.3-6, Lake Whitney is the location with the greatest reduction in time exceeding the TCEQ standard. The greatest reduction in time exceeding the agricultural and industrial limits is also seen in Lake Whitney, where 9% and 21% reductions, respectively, are computed.

The TDS concentration frequency results for the without project scenario can be compared to the concentration frequency curves developed by Wurbs et. al.[26] from the stream gage data and presented in Section 4B.19.1.3. 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 2060 Brazos G WAM, and conditions that actually existed during the 1964 through 1986 data collection period. The 1964 through 1986 dataset shows that

[26] Wurbs, R.A., A.S. Karama, I. Saleh, and C.K. Ganze, "Natural Salt Pollution and Water Supply Reliability in the Brazos River Basin," Texas Water Resources Institute, 1993.

the TCEQ standard was equaled or exceeded 99.7%, 93.6%, 40.0%, and 0% of the time at Seymour, below Possum Kingdom Lake, below Lake Whitney, and at Richmond respectively. In the model results, the TCEQ standard is exceeded 97.6%, 90.5%, 36.2% and 7.0% of the time at comparable locations. Although the exceedence frequencies for the observed and modeled datasets are different (as would be expected), the relative similarities in the frequencies provide some confidence that the model produces reasonable results.

4B.19.3.3 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. See Section 4C.38.3 for more information on the BRA plan.

4B.19.4 Environmental Issues

The proposed project area is located in the upper Brazos River Basin east of the Llano Estacado Region within portions of Kent, King, and Stonewall counties in north-central Texas. The primary environmental issues related to the development of the salt control water management option is the construction of the brine pipeline, development of the brine well fields, evaporation facilities and pump stations, and creation of the railroad spur and its amenities.

4B.19.4.1 Environmental Setting

The study area is located in the Southwestern Tablelands Ecological Region as designated by the Texas Parks and Wildlife Department (TPWD).[27] This region is characterized by canyons, mesas, badlands, and dissected river breaks. Little cropland occurs within this area, with much of the region consisting of sub-humid grassland and semiarid rangeland. Vegetation within this area is characterized by grama-buffalograss with some mesquite-buffalograss in the southeast portion of the Region, juniper-scrub oak-midgrass savannah on escarpment bluffs, and midgrass prairie with low oak brush along portions of some rivers. This region is bordered on the south by the Edwards Plateau Ecological Region and on the west by the High Plains Ecological Region.

[27] Texas Parks and Wildlife Department, 2005.

The study area is located in the Rolling Plains Vegetational area.[28] This area is characterized gently rolling hills with rangelands that are dissected by streams and rivers which flow from west to east. Vegetation within this area is characterized by mixed and short grass prairies, shinnery oak grasslands, and mesquite savannah grasslands. Within this area redberry juniper, mesquite, and Eastern red cedar are considered aggressive invasive species.

The original prairie vegetation found within the Rolling Plains Vegetational Area included medium-tall grassland with a sparse shrub cover. The dominant vegetation within this area is native grasses including little bluestem (*Schizachyrium scoparium* var. *frequens*), blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), Indiangrass (*Sorghastrum nutans*), and sand bluestem (*Andropogon gerardii* var. *paucipilus*, and various forbes. Within areas of sandier soils with broad rolling relief you will find shin oak (*Quercus sinuata* var. *breviloba*) grasslands, with additional groups of various oaks occurring in the mixed grass prairie. In areas containing clay and clay loam soils the predominant vegetation is the mesquite savannah grasslands. These usually occur on flat to gently rolling lands and are characterized by an open canopy of larger mesquite trees, a midstory composed of shrubs such as lotebush (*Zizyphus obtusifolia*), succulents including prickly pears (*Opuntia* spp.) and ephedra, and an understory of grasses and forbs. Bottomland areas found along larger streams contain American elm (*Ulmus Americana),* button willow (*Cephalanthus occidentalis),* pecan (*Carya illinoensis)* and cottonwood (*Populus* spp.). Historically these natural communities were maintained by a combination of severe weather events, drought and fire. Invasion of the rangeland areas in this region by annual and perennial forbs, legumes, and woody species has been facilitated by historic livestock grazing practices and a lack of naturally occurring fire in the area. The limestone ridges and steep terrains of this area produce a greater diversity of woody plants and wildlife habitat than would normally be expected within this area.

The natural region of the proposed project area, as described by TPWD in the Vegetation Types of Texas, indicates that along the proposed brine pipeline route vegetation is generally characterized as mesquite-lotebush shrub and mesquite-lotebush brush.29 Pockets of Harvard Shin Oak-mesquite brush are also found within the area, along with limited areas of crops. The majority of land found near the project area is currently used as rangeland with limited areas of dryland and irrigated crops and pastures. Land use is expected to remain primarily rural in the

[28] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, "Vegetational areas of Texas," TX Agri. Ext. Serv. L-492.
[29] Texas Parks and Wildlife Department, "The Vegetation Types of Texas," Austin, Texas, 1984.

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.

4B.19.4.2 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 the proposed project area to determine if any threatened or endangered species or critical habitats for these species are present. Table 4B.19.4-1 lists plant, wildlife and fish species possibly found within Kent, King, and Stonewall counties that are considered by U.S Fish and Wildlife Service (FWS) or the Texas Parks and Wildlife Department (TPWD) to be endangered, threatened or rare. The primary sources used to develop this list were the annotated county lists provided by the TPWD for the three-county project area.

Twenty-two threatened, endangered or rare species have either been reported from this area or have some possibility of occurrence. Inclusion in Table 4B.19.4-1 does not mean that a species will occur within the project area, but only acknowledges the potential for occurrence in the three project area counties.. The following paragraphs present distributional data concerning each federally listed or state-listed endangered or threatened species, along with a brief evaluation of the potential for the species to occur within the project area.

Table 4B.19.4-1.
Threatened, Endangered and Rare Species of
Kent, King, and Stonewall Counties, Texas 2009

Species Name		Occurrence in County	Federal Status	State Status
BIRDS				
Peregrine Falcon (*Falco peregrinus*)	American Peregrine Falcon (*Falco peregrinus anatum*)	Year round resident and local breeder in west Texas.	DL	T
	Arctic Peregrine Falcon (*Falco peregrinus tundrius*)	Potential migrant.	DL	___
Baird's Sparrow (*Ammodramus bairdii*)		Found in shortgrass prairie with scattered low bushes and matted vegetation.	___	___
Bald Eagle (*Haliaeetus leucocephalus*)		Found primarily near seacoasts, rivers, and large lakes; nests in tall trees or on cliffs near water; communally roosts in winter.	DL	T
Ferruginous Hawk (*Buteo regalis*)		Lives in open country, primarily prairies, plains, and badlands; nests in tall trees along streams or on steep slopes, cliff ledges, river-cut banks, hillsides, power line towers.	___	___
Mountain Plover (*Charadrius montanus*)		Breeding species: nests on high plains or shortgrass prairie, on ground in shallow depression; nonbreeding: shortgrass plains and bare, dirt (plowed) fields; primarily insectivorous.	___	___
Snowy Plover (*Charadrius alexandrinus*)		Formerly an uncommon breeder in the Panhandle; potential migrant.	___	___
Western Burrowing Owl (*Athene cunicularia hypugaea*)		Open grasslands, especially prairie, plains, and savanna, sometimes in open areas such as vacant lots near human habitation or airports; nests and roosts in abandoned burrows and man-made structures.	___	___
Western Snowy Plover (*Charadrius alexandrines nivosus*)		Uncommon breeder in the Panhandle; potential migrant which winters along the coast.	___	___
Whooping Crane (*Grus americana*)		Potential migrant; winters in and around Aransas National Wildlife Refuge and migrates to Canada for breeding.	LE	E
FISHES				
Sharpnose shiner (*Notropis oxyrhynchus*)		Endemic to Brazos River drainage, found in large turbid rivers with a bottom composed of a combination of sand, gravel and clay-mud.	C	___
Smalleye shiner (Notropis buccula)		Endemic to upper Brazos river system and its tributaries (Clear Fork and Bosque), found in medium to large prairie streams with sandy substrate and turbid to clear warm water.	C	___
MAMMALS				
Black-footed Ferret (*Mustela nigripes*)		Extirpated in Texas; former inhabitant of prairie dog towns in the general area.	LE	___
Black-tailed Prairie Dog (*Cynomys ludovicianus*)		Prefers dry, flat, short grasslands with low, relatively sparse vegetation, including areas overgrazed by cattle; lives in large family groups.	___	___

Table 4B.19.4-1 (Concluded)

Species Name	***Occurrence in County***	***Federal Status***	***State Status***
Cave Myotis Bat (*Myotis velifer*)	Roosts colonially in caves, rock crevices, old buildings, carports, under bridges, nests; roosts in clusters of up to thousands of individuals; hibernates in limestone caves of Edwards Plateau and gypsum caves of Panhandle during winter; opportunistic insectivore.	___	___
Gray wolf (*Canis lupus*)	Extirpated; formerly known throughout the western two-thirds of the state.	LE	E
Pale Townsend's big-eared bat (*Corynorhinus townsendii pallescens*)	Roosts in caves, abandoned mine tunnels and old buildings, hibernates in groups during winter.	___	___
Plains Spotted Skunk (*Spilogale putorius interrupta*)	Catholic in habitat; open fields, prairies, croplands, fence rows, farmyards, forest edges, and woodlands; prefers wooded, brushy areas and tallgrass prairie.	___	___
Texas kangaroo rat (Dipodomys elator)	Mostly in association with scattered mesquite shrubs and sparse, short grasses in areas underlain by firm clay soils; along fencerows adjacent to cultivated fields/roads; burrows into soil with openings usually at base of mesquite or shrub.	___	T
REPTILES			
Brazos water snake *(Nerodia harteri)*	Upper Brazos River drainage; in shallow water with rocky bottom and on rocky portions of banks.	___	T
Texas Horned Lizard (*Phrynosoma cornutum*)	Open, arid and semi-arid regions with sparse vegetation, which could include grass, cactus, scattered brush or scrubby trees.	___	T

Status Key: LE Federal Endangered LT Federal Threatened DL Federal Delisted C Federal Candidate Species
E State Endangered T State Threatened -- Rare, but with no regulatory listing status
TPWD County Species Lists revised 6/24/2009.

Two species listed in Table 4B.19.4-1 are considered endangered by both the FWS and TPWD. These are the Whooping Crane (*Grus Americana*) and the grey wolf (*Canis lupus*). The grey wolf is considered extirpated in Texas and subsequently will not occur within the project area. Portions of North Texas including the Panhandle lie within the migratory corridor the whooping cranes follow in route to and from their nesting grounds in Wood Buffalo National Park in northwestern Canada. This species is known to stop during migration at locations in Oklahoma, Kansas, and Nebraska. There have been only a few scattered confirmed ground sightings of whooping cranes within Texas with the exception of their salt marsh wintering grounds along the Texas Coastal Bend. Although these birds might occur as possible vagrants during migration periods, the likelihood of incidence within the project area is remote.

The black-footed ferret (*Mustela nigripes*), federally listed as endangered, is considered extirpated in Texas due to the decline of available shortgrass prairie habitat and reduction in the black-tailed prairie dog (*Cynomys ludovicianus*) population, a species that the ferret is heavily dependent on for survival. Although their historic range included the High Plains, Rolling Plains and Trans-Pecos regions of North America, the last reported Texas sightings of the black-footed ferret were on the western edge of the Texas Panhandle in Dallam County in 1953 and Bailey County in 1963.[30] This species is not expected to be impacted by the proposed project.

Historically, the smalleye shiner and the sharpnose shiner, both federal species of concern, were found throughout the Brazos River Watershed and several of its major tributaries. They are considered at this time to be stable in the upper Brazos River Basin, but their number has declined in the middle and lower reaches of the Basin. The most serious issues threatening these species are the effects of impoundments and degradation of water quality. Current information indicates that the shiner population within the Upper Brazos drainage upstream of Possum Kingdom Reservoir is apparently stable, whereas the population within the Lower Brazos River Basins may only exist in remnant areas of suitable habitat, or may be completely extirpated.

These two cyprinid species evolved to prosper in the saline and turbid conditions naturally occurring in the Brazos River Basin. The salinity control project proposed for the Upper Brazos River would convert the natural saline waters to a quality possibly available for human consumption, and would modify the waters chemical characteristics thought to be conducive to preferred shiner habitat.

After a review of the habitat requirements for each listed species, it is expected that this project will have no adverse effect on any federally listed threatened or endangered species, its habitat, or designated habitat, nor would it adversely affect any state endangered species. Although suitable habitat for the state threatened Texas horned lizard may exist within the project area, no impact to this species is anticipated due to the small area utilized by the wells and new desalinization water plant, and the abundance of similar habit near the project area. The presence or absence of potential habitat does not confirm the presence or absence of a listed species. No species specific surveys were conducted in the project area for this report.

[30] Davis, W. B. and D. J. Schmidly,. "The Mammals of Texas," Texas Parks and Wildlife Department, Austin, Texas, 1994.

4B.19.4.3 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.[31] Factors influencing the suitability of the area for this type of production include land cost, soil type, rainfall amounts, wind velocity and direction, susceptibility to flooding, possible endangered species habitat, availability of workers, and ease of transportation of products.

4B.19.4.4 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 (Figure 4B.19-8).

The brine pipeline would begin at the Salt Creek Brine Recovery Well Field and follow Ranch Road (RR) 1081 south for approximately 6 miles, it would then turn east along U.S. Highway (US) 380 for approximately 7 additional miles and intersect with a connection to the solar salt facility. The pipeline would then continue east for approximately 5 additional miles along US 380, turn north along State Highway (SH) 208 for 7 miles, and then travel east paralleling RR 2320 and Farm to Market (FM) 1228 for 11 additional miles. A small portion of Kent County Roads (CR) 165 and 161 are then followed before the pipeline turns in a northwesterly direction along SH 70 for about 5 miles, terminating at the Short Croton Salt Flat Brine Recovery Well Field. From the intersection of SH 70 and CR 160 the pipeline travels northwest along CR 160, CR 350 and unnamed roadways for approximately 14 miles terminating at the Dove Creek Salt Flat/ Panther Canyon Area Brine Recovery Well Field in Stonewall County.

[31] 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 which are located within the pipeline right-of-way could potentially be affected by this project, and floodplains could possibly suffer a temporary change in drainage patterns. Potential wetland impacts are expected to primarily include pipeline stream and river crossings, which can be minimized by right-of-way selection and appropriate construction methods, including erosion controls and revegetation procedures. This pipeline could potentially traverse approximately eighteen stream crossings, a number of which are unnamed tributaries. Major water bodies crossed by this pipeline could include Salt Creek, T-O Creek, Duck Creek, Little Duck Creek, Croton Creek, and the Salt Fork Brazos River. Impacts to wetlands from construction possibly include destruction or alteration of vegetation/habitat along the right-of-way (ROW) and within the well field areas. Compensation for net losses of wetlands would be required where impacts are unavoidable.

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.

4B.19.5 Engineering and Costing

4B.19.5.1 Project Costs

Tables 4B.19.5-1 and 4B.19.5-2 summarize estimated costs for the brine collection and transmission system and the BUMC, respectively. The capital costs, engineering costs, and land acquisition costs were provided by the SFWQ Corporation's consultants, other costs were estimated for preparation of the regional water plan. The consultants assumed engineering and contingencies at 40% of total capital costs for the brine collection and transmission system and 35% of the total capital costs for the BUMC. Environmental and Archaeology Studies and Mitigation costs were estimated as being equal to the land acquisition costs. A two-year construction period was assumed for computing interest during construction.

Table 4B.19.5-1.
Cost Estimate Summary — Brine Collection and Transmission System
September 2008 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Collection Wells	$1,040,000
Gathering Lines and Appurtenances	$198,000
Brine Transmission Pipeline (carbon steel with epoxy coating)	$16,609,000
Pump Stations, Emergency Generators, Gate Valves, etc.	$780,000
Electrical Power Infrastructure	$300,000
Total Capital Cost	**$18,927,000**
Engineering and Contingencies (40%)	$9,335,000
Environmental & Archaeology Studies and Mitigation	$2,410,000
Land Acquisition	$2,410,000
Interest During Construction (2 years)	$2,647,000
Total Project Cost	**$35,729,000**
Annual Costs	
Debt Service (6%, 20 years)	$3,115,000
Operation and Maintenance	$0
Total Annual Cost	**$3,115,000**

Table 4B.19.5-2.
Cost Estimate Summary — Brine Utilization and Management Complex
September 2008 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Equipment, Machinery, Site Work, and Onsite Rail	$29,126,000
Rail Extension to BNSF Tracks at Snyder	$29,000,000
Solar Ponds	$21,800,000
Electrical Power Infrastructure	$635,000
Total Capital Cost	**$80,561,000**
Engineering and Contingencies (35%)	$32,365,000
Environmental & Archaeology Studies and Mitigation	$2,563,000
Land Acquisition	$2,563,000
Interest During Construction (2 years)	$9,445,000
Total Project Cost	**$127,497,000**
Annual Costs	
Debt Service (6%, 20 years)	$11,116,000
Operation and Maintenance	$0
Total Annual Cost	**$11,116,000**

The operation and maintenance costs in Tables 4B.19.5-1 and 4B.19.5-2 are zero. The SFWQ Corporation's consultants have prepared a pro forma analysis indicating that revenue from salt sales would cover well field, pipeline, and BUMC operation and maintenance costs. It is anticipated that once the project was constructed, a salt company would operate and maintain the facilities and generate sufficient revenue such that operation and maintenance costs to the public would be zero. The SFWQ Corporation's consultants have also assumed that right of way costs for the brine transmission pipeline would be negligible; the pipeline would run within existing county road right of ways and the counties are participants in the project.

Overall, the estimated combined capital cost for the brine collection and transmission system and the BUMC is $99,488,000. The estimated combined total project cost for the brine collection and transmission system and the BUMC is $163,226,000, and the estimated combined annual cost is $14,231,000.

4B.19.5.2 Comparison of Desalination Costs With and Without Salinity Control Project

This section reviews the effectiveness of the salinity control project in reducing desalination costs in the Brazos River Basin. The cost of municipal desalination treatment with and without the salinity control project is compared to the cost of implementing the project.

Although the TCEQ TDS secondary standard is 1,000 mg/L, the costs presented herein assume that the desalination is implemented to reduce TDS concentrations to 500 mg/L. Actual acceptable TDS limits for water supply systems are case specific. Systems that have not historically been exposed to TDS concentrations as high as 1,000 mg/L may be subject to corrosion issues with introduction of water having a 1,000 mg/L TDS concentration. The 500 mg/L treatment level was assumed as a limit that would generally be acceptable for new supplies.

Concentration-duration curves for TDS based on WRAP-SALT modeling with the 2060 Brazos G WAM are presented in Tables 4B.19.3-4 and 4B.19.3-5 and Figures 4B.19.3-2 through 4B.19.3-7 (Section 4B.19.3.2). The tables and figures compare TDS concentrations of regulated outflows from the Seymour, Bryan, and Richmond model control points and reservoir storage TDS concentrations at Possum Kingdom Lake, Lake Granbury, and Lake Whitney with and without the salinity control project. TDS is an indicator of the levels of chlorides and dozens of other dissolved ions that would be removed by the salinity control project and desalination treatment. The with-project concentration-duration curves are representative of a point in the future when the benefits of the project are fully realized and residual salt has been washed from the upland stream beds and from downstream lakes.

The estimated costs of desalination treatment at Seymour, Possum Kingdom Lake, Lake Granbury, Lake Whitney, Bryan, and Richmond with and without implementing the salinity control project are included in Tables 4B.19.5-3 through 4B.19.5-8, respectively. The desalination cost estimates are based upon producing 10 MGD of treated water and the 90th percentile (10% equaled or exceeded) and 50th percentile (median) TDS concentrations at each location as shown by the concentration-duration curves. The desalination costs reflect the impact of TDS on both the plant capital and the operating and maintenance costs. Capital costs are based on the 90th percentile TDS concentrations and operating and maintenance costs are based on the 50th percentile TDS concentrations. Surface water must undergo conventional treatment prior to desalination. For the purpose of comparing treatment costs for various TDS concentrations, values shown are for the desalination component only. Costs common to conventional water treatment plants are omitted. Omitted costs include intakes, pump stations, conventional pretreatment, clearwell storage, and others.

Based on the cost estimates shown in Tables 4B.19.5-3 through 4B.19.5-8, 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 $6,488,103, or $579 per acft on a unit cost basis. With the salinity control project, the estimated annual cost of desalination at Seymour is $5,559,467, or $496 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 $83 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 $53, $62, and $75 per acft, respectively. Downstream of the Lakes, at Bryan and Richmond, the estimated desalination treatment savings as a result of implementing the salinity control project on a unit cost basis is $23 and $26 per acft, respectively.

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 4B.19.5-9 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 4B.19.5-9 also includes the unit cost of desalination treatment with and without the project. The total annual cost to desalinate water contracted or permitted for municipal use without the project is estimated to be $99,716,390. With the project, the total annual cost of desalination treatment is estimated to be $84,726,703. Therefore, implementation of the project results in reduced annual desalination costs of $14,989,687.

Table 4B.19.5-3
Estimated Incremental Cost of Desalination at Seymour with and without Implementation of Salinity Control Project

Item	No Salinity Control	With Salinity Control	Difference
90th Percentile TDS	11,259	6,755	
50th Percentile TDS	6,044	3,626	
% of Water Desalinated	100%	94%	
Capital Costs			
RO Desalination Plant (10 MGD)[1]	$17,554,000	$15,928,000	$1,626,000
Concentrate Disposal	$10,017,495	$7,424,015	$2,593,481
Total Capital Cost	**$27,571,495**	**$23,352,015**	**$4,219,481**
Engineering, Legal Costs and Contingencies (35%)	$9,650,000	$8,173,000	$1,477,000
Interest During Construction (1 years)	$1,654,000	$1,401,000	$253,000
Total Project Cost	**$38,875,495**	**$32,926,015**	**$5,949,481**
Annual Costs			
Debt Service (6%, 30 years)	$3,389,000	$2,871,000	$518,000
Operation and Maintenance			
Desalination Water Treatment Plant	$2,679,208	$2,334,942	$344,265
Concentrate Disposal	$419,895	$353,525	$66,371
Total			
Total Annual Cost	**$6,488,103**	**$5,559,467**	**$928,636**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$579**	**$496**	**$83**
Annual Cost of Water ($ per 1,000 gallons)	**$1.78**	**$1.52**	**$0.25**

[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 4B.19.5-4
Estimated Incremental Cost of Desalination at Possum Kingdom Lake with and without Implementation of Salinity Control Project

Item	***No Salinity Control***	***With Salinity Control***	***Difference***
90th Percentile TDS	2,427	1,654	
50th Percentile TDS	1,776	1,272	
% of Water Desalinated	81%	72%	
Capital Costs			
RO Desalination Plant (10 MGD)[1]	$13,662,000	$12,524,000	$1,138,000
Concentrate Disposal	$5,753,374	$4,778,676	$974,698
Total Capital Cost	**$19,415,374**	**$17,302,676**	**$2,112,698**
Engineering, Legal Costs and Contingencies (35%)	$6,795,000	$6,056,000	$739,000
Interest During Construction (1 years)	$1,165,000	$1,038,000	$127,000
Total Project Cost	**$27,375,374**	**$24,396,676**	**$2,978,698**
Annual Costs			
Debt Service (6%, 30 years)	$2,387,000	$2,127,000	$260,000
Operation and Maintenance			
Desalination Water Treatment Plant	$1,890,016	$1,604,030	$285,986
Concentrate Disposal	$273,970	$227,556	$46,414
Total			
Total Annual Cost	**$4,550,986**	**$3,958,586**	**$592,400**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$406**	**$353**	**$53**
Annual Cost of Water ($ per 1,000 gallons)	**$1.25**	**$1.08**	**$0.16**

[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 4B.19.5-5.
Estimated Incremental Cost of Desalination at Lake Granbury with and without Implementation of Salinity Control Project

Item	*No Salinity Control*	*With Salinity Control*	*Difference*
90th Percentile TDS	2,213	1,559	
50th Percentile TDS	1,316	948	
% of Water Desalinated	79%	70%	
Capital Costs			
RO Desalination Plant (10 MGD)[1]	$13,433,000	$12,285,000	$1,148,000
Concentrate Disposal	$4,930,380	$3,792,600	$1,137,780
Total Capital Cost	**$18,363,380**	**$16,077,600**	**$2,285,780**
Engineering, Legal Costs and Contingencies (35%)	$6,427,000	$5,627,000	$800,000
Interest During Construction (1 years)	$1,102,000	$965,000	$137,000
Total Project Cost	**$25,892,380**	**$22,669,600**	**$3,222,780**
Annual Costs			
Debt Service (6%, 30 years)	$2,257,000	$1,976,000	$281,000
Operation and Maintenance			
Desalination Water Treatment Plant	$1,651,090	$1,296,779	$354,311
Concentrate Disposal	$234,780	$180,600	$54,180
Total			
Total Annual Cost	**$4,142,870**	**$3,453,379**	**$689,491**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water ($ per acft)	**$370**	**$308**	**$62**
Annual Cost of Water ($ per 1,000 gallons)	**$1.13**	**$0.95**	**$0.19**

[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 4B.19.5-6.
Estimated Incremental Cost of Desalination at Lake Whitney with and without Implementation of Salinity Control Project

Item	No Salinity Control	With Salinity Control	Difference
90^{th} Percentile TDS	1,337	969	
50^{th} Percentile TDS	906	693	
% of Water Desalinated	65%	51%	
Capital Costs			
RO Desalination Plant (10 MGD)[1]	$11,622,000	$9,954,000	$1,668,000
Concentrate Disposal	$3,565,044	$2,275,560	$1,289,484
Total Capital Cost	**$15,187,044**	**$12,229,560**	**$2,957,484**
Engineering, Legal Costs and Contingencies (35%)	$5,315,000	$4,280,000	$1,035,000
Interest During Construction (1 years)	$911,000	$734,000	$177,000
Total Project Cost	**$21,413,044**	**$17,243,560**	**$4,169,484**
Annual Costs			
Debt Service (6%, 30 years)	$1,867,000	$1,503,000	$364,000
Operation and Maintenance			
Desalination Water Treatment Plant	$1,225,444	$812,761	$412,684
Concentrate Disposal	$169,764	$108,360	$61,404
Total			
Total Annual Cost	**$3,262,208**	**$2,424,121**	**$838,088**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water Treatment ($ per acft)	**$291**	**$216**	**$75**
Annual Cost of Water Treatment ($ per 1,000 gallons)	**$0.89**	**$0.66**	**$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 4B.19.5-7.
Estimated Incremental Cost of Desalination at Bryan with and without Implementation of Salinity Control Project

Item	No Salinity Control	With Salinity Control	Difference
90^{th} Percentile TDS	1,164	1,049	
50^{th} Percentile TDS	468	380	
% of Water Desalinated	60%	55%	
Capital Costs			
RO Desalination Plant (10 MGD)[1]	$11,025,000	$10,431,000	$594,000
Concentrate Disposal	$1,517,040	$1,137,780	$379,260
Total Capital Cost	**$12,542,040**	**$11,568,780**	**$973,260**
Engineering, Legal Costs and Contingencies (35%)	$4,390,000	$4,049,000	$341,000
Interest During Construction (1 years)	$753,000	$694,000	$59,000
Total Project Cost	**$17,685,040**	**$16,311,780**	**$1,373,260**
Annual Costs			
Debt Service (6%, 30 years)	$1,542,000	$1,422,000	$120,000
Operation and Maintenance			
Desalination Water Treatment Plant	$567,079	$444,126	$122,953
Concentrate Disposal	$72,240	$54,180	$18,060
Total			
Total Annual Cost	**$2,181,319**	**$1,920,306**	**$261,013**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water Treatment ($ per acft)	**$195**	**$171**	**$23**
Annual Cost of Water Treatment ($ per 1,000 gallons)	**$0.60**	**$0.53**	**$0.07**

[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.

[2] With salinity control project, raw water quality at Lake Whitney meets or exceeds the secondary drinking water standard for TDS. No desalination treatment is needed.

Table 4B.19.5-8. Estimated Incremental Cost of Desalination at Richmond with and without Implementation of Salinity Control Project

Item	*No Salinity Control*	*With Salinity Control*	*Difference*
90th Percentile TDS	895	816	
50th Percentile TDS	346	317	
% of Water Desalinated	47%	41%	
Capital Costs			
RO Desalination Plant (10 MGD)[1]	$9,435,000	$8,623,000	$812,000
Concentrate Disposal	$1,517,040	$1,137,780	$379,260
Total Capital Cost	**$10,952,040**	**$9,760,780**	**$1,191,260**
Engineering, Legal Costs and Contingencies (35%)	$3,833,000	$3,416,000	$417,000
Interest During Construction (1 years)	$657,000	$586,000	$71,000
Total Project Cost	**$15,442,040**	**$13,762,780**	**$1,679,260**
Annual Costs			
Debt Service (6%, 30 years)	$1,346,000	$1,200,000	$146,000
Operation and Maintenance			
Desalination Water Treatment Plant	$567,079	$444,126	$122,953
Concentrate Disposal	$72,240	$54,180	$18,060
Total			
Total Annual Cost	**$1,985,319**	**$1,698,306**	**$287,013**
Water Treated Annually (acft/yr)	**11,202**	**11,202**	
Annual Cost of Water Treatment ($ per acft)	**$177**	**$152**	**$26**
Annual Cost of Water Treatment ($ per 1,000 gallons)	**$0.54**	**$0.47**	**$0.08**

[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.

[2] With salinity control project, raw water quality at Lake Whitney meets or exceeds the secondary drinking water standard for TDS. No desalination treatment is needed.

Table 4B.19.5-9.
Estimation of the Total Annual Cost of Desalination Treatment within the Brazos River Basin

	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	$579	$496	$0	$0	$0
Possum Kingdom Lake to Above Lake Granbury	3,298	$406	$353	$1,338,988	$1,164,194	$174,794
Lake Granbury to Above Lake Whitney	35,644	$370	$308	$13,188,280	$10,978,352	$2,209,928
Lake Whitney to Above Bryan	18,975	$291	$216	$5,521,725	$4,098,600	$1,423,125
Bryan to Above Richmond	19,935	$195	$171	$3,887,325	$3,408,885	$478,440
Richmond to Gulf of Mexico	428,136	$177	$152	$75,780,072	$65,076,672	$10,703,400
Total	505,988			$99,716,390	$84,726,703	$14,989,687

[1] Includes Brazos River Authority Contract amounts and TNRCC Water Rights for municipal use.

Comparing the desalination cost savings to the total annual cost of the project, $14,231,000 from Section 4B.19.5.1, shows that the project is marginally cost effective. The cost savings exceeds the annual cost of the project by approximately $759,000 or about 5%. Additional benefits (although not quantified here) would accrue for industrial users and irrigation users. Furthermore, as the amount of water contracted or permitted for municipal use increases in the future, the desalination costs savings due to the project as computed in Table 4B.19.5-9 would increase, while the project cost would not.

The results of the present desalination cost evaluation are subject to the modeling assumptions discussed in Section 4B.19.3.1.2. 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.

4B.19.6 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.19.6-1.

4B.19.6.1 Regulatory Permits Required

Development of the BUMC may require the following permits:

- U.S. Army Corps of Engineers 404 dredge and fill permit(s) for discharges of fill into wetlands and waters of the United States for evaporation pond construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan;
- GLO Easement for use of State-owned land; and
- TPWD Sand, Shell, Gravel and Marl Permit for construction in state-owned streambeds.

Permitting will require the following studies and plans:

- Habitat mitigation plan;
- Environmental study of potential impact on endangered species;
- Cultural resources study; and
- Other studies.

4B.19.6.2 Mitigation Funding and Other

The salinity control project will increase the usability of main stem Brazos River water throughout the Region. Distribution of project costs to beneficiaries will not be straightforward. 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.

Table 4B.19.6-1.
Comparison of Salinity Control Project to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply:	
1. Quantity	1. No increase in water supply
2. Reliability	2. Not a reliable water supply, although does increase reliable usage of existing and future main stem supplies.
3. Cost	3. Not applicable
B. Environmental Factors:	
1. Environmental Water Needs	1. Low to moderate impact
2. Habitat	2. Moderate to high impact on some species
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Negligible impact
C. Impact on Other State Water Resources	• Beneficial impact on water quality in much of the Brazos River Basin; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Overall positive impact on agriculture and natural resources
E. Equitable Comparison of Strategies Deemed Feasible	• Not considered for water supply. Possible significant benefit on basin water quality.
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.20 BRA Reservoir Connections

4B.20.1 Lake Aquilla Augmentation

4B.20.1.1 Description of Option

Lake Aquilla is located southwest of the City of Hillsboro in Hill County. The reservoir is owned by the U.S. Army Corps of Engineers (USACE) and is part of the Brazos River Authority (BRA) System. The reservoir provides water for the cities of Hillsboro, Cleburne and Milford and for Brandon-Irene WSC, Files Valley WSC, and Lake Whitney Water Company. The yield of Lake Aquilla will not be able to completely supply the future needs of these entities. Options to supplement supplies at Lake Aquilla are being evaluated and include both reallocation of flood pool to conservation pool storage, as well as building a pipeline from Lake Whitney to Lake Aquilla. The City of Cleburne has contracts with the BRA totaling 9,700 acre-feet per year with a Lake Whitney diversion location, but does not currently have the infrastructure to access this water. The pipeline option would allow Cleburne access to its Lake Whitney water and could supplement other Lake Aquilla water users as well. The total supply for the project will be 14,700 acft/yr (9,700 acft/yr for the City of Cleburne and up to 5,000 acft/yr for others). The supplemental water for the project will come from a combination of existing BRA rights and the BRA System Operation Permit.

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,[1] 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 load reduced by advanced treatment.

Two options have been considered for this strategy as described below.

- Option A takes water from Lake Whitney, treats the water to remove TDS, and discharges the water into Lake Aquilla.
- Option B is similar to Option A except that instead of discharging the water into Lake Aquilla the water is taken to a common delivery point where the City of Cleburne and others can access the water. For this study, this delivery point is assumed to be near the existing intake structures and pump stations owned by the City of Cleburne and the Aquilla Water Supply District.

[1] Brazos River Authority, Proposed Transportation of Raw Water from Lake Whitney to Lake Aquilla, 2009.

Both options include advanced treatment to remove dissolved solids from a portion of the water from Lake Whitney. Approximately 70 to 85 percent of the water will need to be treated to remove sufficient salt loads to maintain acceptable water quality.[2]

4B.20.1.2 Available Yield

The supply from Lake Aquilla without this strategy is estimated to be 12,528 acft/yr in 2000 and 9,713 ac-ft/yr in 2060. This project would provide 14,700 acft/yr of additional supply to the area, with 9,700 acft/yr going to the City of Cleburne and 5,000 acft/yr for others. Water would come from a combination of stored water from Lake Whitney, releases from upstream BRA reservoirs, and coordinated operation of run-of-the-river supplies authorized under the System Operation Permit.

4B.20.1.3 Environmental Issues

For Option A, the primary environmental concern with transporting water from Lake Whitney to Lake Aquilla is the high TDS content of the Brazos River main stem. In addition to the TDS content of the main stem of the Brazos River, the possibility that changes in the temperature, salinity and other factors could trigger golden algae blooms in Lake Aquilla exists. Treatment of the water may be sufficient to address these issues. Additional studies will be required to evaluate the impact of blending the treated water in Lake Aquilla. If these studies indicate that blending water in Lake Aquilla has unacceptable environmental risk, then Option B should be selected.

Another potential concern is the return of reject brine from treatment to Lake Whitney. Lake Whitney is a very large reservoir with more than 550,000 acft of storage[3] and a significant amount of flow-through due to hydropower operations. As a result, the return of reject water to the reservoir should have minimal impact on water quality. Additional studies may be required to verify this assumption. If brine reject cannot be returned to the reservoir, deep-well injection or evaporation ponds could be used to dispose of the reject. These options will add to the cost of the project.

The locations of facilities and pipeline routes have not been identified at this time. It is expected that pipelines and pump stations can be located to avoid sensitive habitats. Endangered

[2] Freese and Nichols INC. Memorandum Report on Lake Whitney Development, October 5, 2009
[3] Texas Water Development Board: *Volumetric Survey of Lake Whitney, June 2005 Survey*, September 2006.

and threatened species reported in Hill County (Federal[4] and Texas Listings[5]) include the American peregrine falcon (*Falco peregrinus anatum*), bald eagle *Haliaeetus lecocephalus*), black-capped vireo (*Vireo atricapilla*), Brazos water snake (*Nerodia harteri*), golden-cheeked warbler (*Dendroica chrysoparia*), interior least tern (*Sterna antillarum athalassos*), peregrine falcon (*Falco peregrinus*), red wolf (*Canis rufus*), Texas horned lizard (*Phrynosoma cornutum*), timber/canebrake rattlesnake (*Crotalus horridus*), smooth pimpleback (*Quadrula houstonensis*), Texas fawnsfoot (*Truncilla macrodon*), white-faced ibis (*Plegadis chihi*), whooping crane (*Grus Americana*), and wood stork (*Mycteria Americana*) . Species which are candidates for listing are the smalleye shiner (*Notropis buccula*) and sharpnose shiner (*Notropis oxyrhynchus*).

In Option A, water delivered into Lake Aquilla is expected to be withdrawn almost immediately by users. Therefore there is little expected change in Lake Aquilla elevations.

The project is expected to have low to medium impacts on environmental flows and no impacts on bays and estuaries.

4B.20.1.4 Engineering and Costing

Two strategies were evaluated for transport of water by pipeline from Lake Whitney to Lake Aquilla. Both include pretreatment of Lake Whitney water before it is discharged to Lake Aquilla. Option A calls for an intake and pump station at Lake Whitney, approximately 7 miles of 30-inch pipe, membrane treatment facilities, and a discharge structure in Lake Aquilla. Reject water from membrane treatment is returned to Lake Whitney. The total capital cost for Option A is $46.4 million with total annual costs of $9.1 million. A breakdown of the cost for Option A is provided in Table 4B.20.1.4-1.

Option B is similar to Option A, except that instead of discharging into Lake Aquilla an additional 5.6 miles of pipeline carries water to a common delivery point near the existing intake and pump stations for the City of Cleburne and the Aquilla Water Supply District. Facilities include an intake and pump station on Lake Whitney, membrane treatment facilities, 12.6 miles of 30-inch pipe, and a connection for water users. The total capital cost for Option B is $51.8 million with total annual costs of $11.1 million. A summary of the costs for Option B is provided in Table 4B.20.1.4-2.

[4] U.S. Fish and Wildlife Service (USFWS). 2009. Endangered Species List. Southwest Region Ecological Services. http://www.fws.gov/southwest/es/EndangeredSpecies/lists/ListSpecies.cfm

[5] Texas Parks and Wildlife Department (TPWD). 2009. Annotated County Lists of Rare Species. http://gis2.tpwd.state.tx.us/ReportServer$GIS_EPASDE_SQL/Pages/ReportViewer.aspx?%2fReport+Project2%2fReport5&rs:Command=Render&county=Hill

Option A is the more cost-effective of the two options. In addition, because the water will be delivered to Lake Aquilla, customers will be able to access the water anywhere a suitable intake can be located in the reservoir. Costs for Option B, which only has one location for delivery to customers, are higher. However, environmental concerns may cause Option B to be the preferred option. Additional studies will be required before finalizing the delivery option.

The existing pipeline for the City of Cleburne will not have sufficient capacity to use all of the contracted supply from the BRA. A 31-mile 24-inch pipeline paralleling the existing Barkman Pipeline will give the city sufficient capacity to access all of its water from Lakes Aquilla and Whitney. Table 4B.20.1.4-3 shows the costs for the parallel pipeline. The parallel pipeline will be required for both Options A and B.

Table 4B.20.1.4-1
Cost Estimate for Lake Aquilla Augmentation Option A

Item	*Estimated Costs for Facilities*
Capital Costs	
Raw Water Intake and Pump Stations (20 MGD)	$13,710,000
RO Desalination Treatment (10.97 MGD)	$20,624,000
Concentrate Disposal (4.59 MGD, 18 in. dia. 1 mile)	$2,000,000
Ground Storage Tank (2, 1.5 MGD)	$1,500,000
Transfer Pump Station (13 MGD)	$2,750,000
Transmission Pipeline (30 in. dia, 7 miles)	$5,842,000
Total Capital Cost	**$46,426,000**
Engineering, Legal Costs and Contingencies	$16,787,000
Land Acquisition and Surveying	$1,536,000
Total Project Cost	**$64,749,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$5,645,000
Operation & Maintenance	
Intake, Pipeline, Pump Station	$663,000
Treatment Plant	$654,116
Pumping Energy Costs ($0.09 kwh)	$2,092,959
Total Annual Cost	**$9,055,075**
Available Project Yield (acft/yr)	14,700
Annual Cost of Water ($ per acft)	$616
Annual Cost of Water ($ per 1,000 gallons)	$1.89

Table 4B.20.1.4-2
Cost Estimate for Lake Aquilla Augmentation Option B

Item	***Estimated Costs for Facilities***
Capital Costs	
Raw Water Intake and Pump Stations (20 MGD)	$13,710,000
RO Desalination Treatment (10.97 MGD)	$20,624,000
Concentrate Disposal (4.6 MGD, 18 in. dia. 1 mile)	$2,000,000
Ground Storage Tank (2, 1.5 MGD)	$2,250,000
Transfer Pump Station (13.1 MGD)	$2,750,000
Transmission Pipeline (30 in dia, 12.6 miles)	$10,450,000
Total Capital Cost	**$51,784,000.0**
Construction Services Legal and Contingencies (35%)	$18,818,000
Land Acquisition and Surveying (20 acres)	$1,981,000
Total Project Cost	**$72,583,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$6,328,000
Operation & Maintenance	
Intake, Pipeline, Pump Station	$663,025
Treatment Plant	$654,116
Pumping Energy Cost ($0.09 kwh)	$2,092,959
Total Annual Cost	**$11,055,242**
Available Project Yield (acft/yr)	14,700
Annual Cost of Water ($ per acft)	$752
Annual Cost of Water ($ per 1,000 gallons)	$2.31

Table 4B.20.1.4-3
Cost Estimate for Parallel Pipeline from Lake Aquilla to the City of Cleburne

Item	***Estimated Costs for Facilities***
Capital Costs	
New Aquilla Lake Intake and Pump Station (10 MGD)	$7,686,000
Transmission Pipeline (24 in. dia, 31.2 miles)	$20,655,000
Booster Pump Station (13.4 MGD)	$3,833,000
Total Capital Cost	**$32,174,000**
Engineering, Legal Costs and Contingencies	$11,950,000
Land Acquisition & Surveying (20 acres)	$1,970,000
Total Project Cost	**$46,094,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$4,019,000
Operation & Maintenance	
Intake, Pipeline, Pump Station	$663,025
Treatment Plant	$654,116
Pumping Energy Cost ($0.09 kwh)	$826,993
Total Annual Cost	**$6,163,134**
Available Project Yield (acft/yr)	14,700
Annual Cost of Water ($ per acft)	$419
Annual Cost of Water ($ per 1,000 gallons)	$1.29

4B.20.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.20.1.5-1, and the option meets each criterion.

A summary of the implementation steps for the project is presented below.

- Agreement between BRA and the City of Cleburne on pipeline route, delivery point, and cost sharing.
- Pilot study to evaluate RO treatment of Lake Whitney water.
- Agreement with USACE for discharge into Lake Aquilla (Option A).
- Analysis of potential impact of blending Lake Whitney water in Lake Aquilla and disposal of brine reject.

Potential Regulatory Requirements:

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

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

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

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 4B.20.1.5-1
Comparison of Transportation of Raw Water from Lake Whitney to Lake Aquilla to Plan Development Criteria

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

4B.20.2 Lake Belton to Lake Stillhouse Hollow Pipeline

4B.20.2.1 Description of Option

A pipeline is proposed to connect Lake Belton to Lake Stillhouse Hollow (Figure 4B.20.2.1-1). 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 Lampasas and Leon Rivers join southeast of the City of Belton to form the Little River. A small tributary of the Leon, Nolan Creek, is located between the two reservoirs. The reservoirs are owned by the U.S. Army Corps of Engineers (USACE) 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. 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 4B.20.2.1-1 summarizes storage and diversion information for the reservoirs.

The Lake Belton to Lake Stillhouse Hollow pipeline project is primarily designed to delay the need for development of new sources of water by utilizing currently unused Lake Belton water in the decades prior to 2060. With the implementation of this pipeline, the combined supplies from the three reservoirs can meet existing contract demands until approximately 2060. The proposed pipeline could transfer up to 30,000 acft/yr to Lake Stillhouse Hollow. From Lake Stillhouse Hollow, some of the Lake Belton water could be transferred to Lake Georgetown via the existing Williamson County Regional Raw Water Pipeline. The Lake Belton to Lake Stillhouse Hollow Pipeline will allow the BRA to operate these three lakes as a system, increasing the reliability of the supplies to the area.

At this time the location of facilities and a pipeline route for this project have not been identified. 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 lower part of the reservoir.

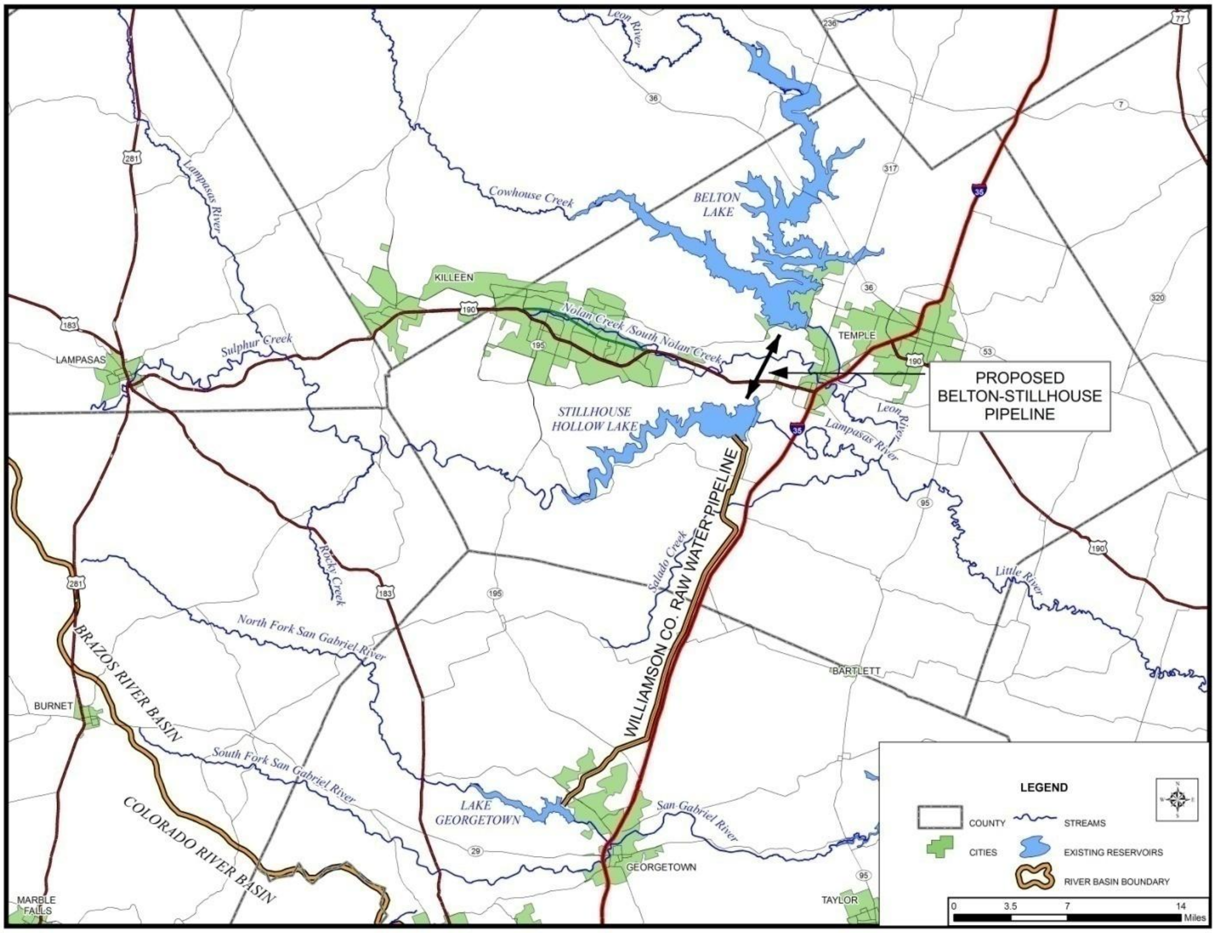

Figure 4B.20.2.1-1. Proposed connection between Lakes Belton and Stillhouse Hollow

Table 4B.20.2.1-1
Diversion and Storage Data for Lakes Belton, Stillhouse Hollow and Georgetown

Reservoir Name	***Water Right***	***Authorized Storage (acft)***	***Authorized Priority Diversion (acft/yr)***	***Priority Date***
Belton	CA 12-5160	457,600	100,257	12/16/1963
Stillhouse Hollow	CA 12-5161	235,700	67,768	12/16/1963
Georgetown	CA 12-5162	37,100	13,610	2/12/1968
CA – Certificate of Adjudication				

4B.20.2.2 Available Yield

The project is expected to deliver up to 30,000 acft/yr from Lake Belton to Lake Stillhouse Hollow. The increased efficiency of operation could increase the yield of the reservoirs by about 2,600 acft/yr, although the primary benefit of the pipeline will be the delay in developing expensive new sources of water to meet anticipated future demands. The supply for this project is authorized under the existing BRA water rights for Lakes Belton and Stillhouse Hollow and its System Order.

Figure 4B.20.2.2-1 shows simulated storage traces for Lake Stillhouse Hollow operating under 2060 conditions with and without the Lake Belton to Lake Stillhouse Hollow pipeline. Figure 4B.20.2.2-2 shows the exceedance frequency for the same data. Figures 4B.20.2.2-3 and 4B.20.2.2-4 shows simulated 2060 storage traces and exceedance frequency for Lake Georgetown, respectively. Storage traces were estimated using the Brazos G WAM. Demands are based on BRA contracts assigned to Lake Stillhouse Hollow and Lake Georgetown. Pumping is initiated from Lake Belton when Lake Stillhouse Hollow has less than 130,000 acft in storage. Note that without the proposed pipeline there would be insufficient supplies to meet demands during a repeat of the 1950s drought. Figures 4B.20.2.2-5 and 4B.20.2.2-6 show the storage traces and exceedance frequencies for Lake Belton, respectively. Without the pipeline over 50,000 acft of water is in storage at Lake Belton’s lowest point in the simulation. The proposed Lake Belton to Lake Stillhouse Hollow pipeline would allow the BRA to use the water left in storage to meet demands at the other two reservoirs.

4B.20.2.3 Environmental Issues

The intake and discharge structures could have low to moderate environmental impacts depending on the final location of the structures. The pipeline route is expected to avoid sensitive areas, so the construction and operation of the pipeline is expected to have low environmental impacts.

Figures 4B.20.2.2-2, 4B.20.2.2-4, and 4B.20.2.2-6 show that the pipeline has a minimal impact on the frequency of time that these reservoirs are full and spilling. This is because pumping does not occur until Lake Stillhouse Hollow has been drawn down significantly. Because the frequency and volume of spills are about the same with and without the pipeline, the project has minimal impact on instream flows or bays and estuaries.

Lakes Belton and Stillhouse Hollow are located in adjacent watersheds on tributaries of the Little River that join a short distance below the reservoirs. Both reservoirs are expected to have similar biological communities and water quality. There are no anticipated impacts associated with blending water for the two reservoirs, although this may need to be verified by additional studies.

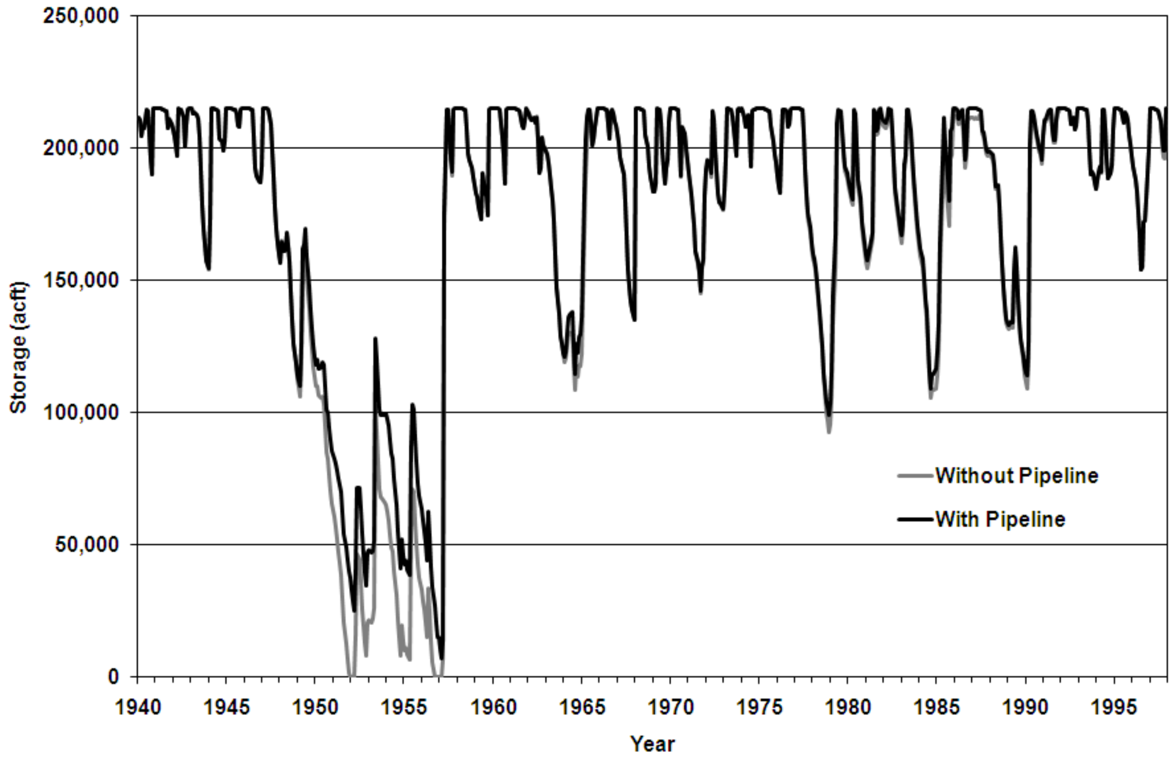

Figure 4B.20.2.2-1. 2060 Lake Stillhouse Hollow Storage With and Without Proposed Lake Belton to Lake Stillhouse Hollow Pipeline

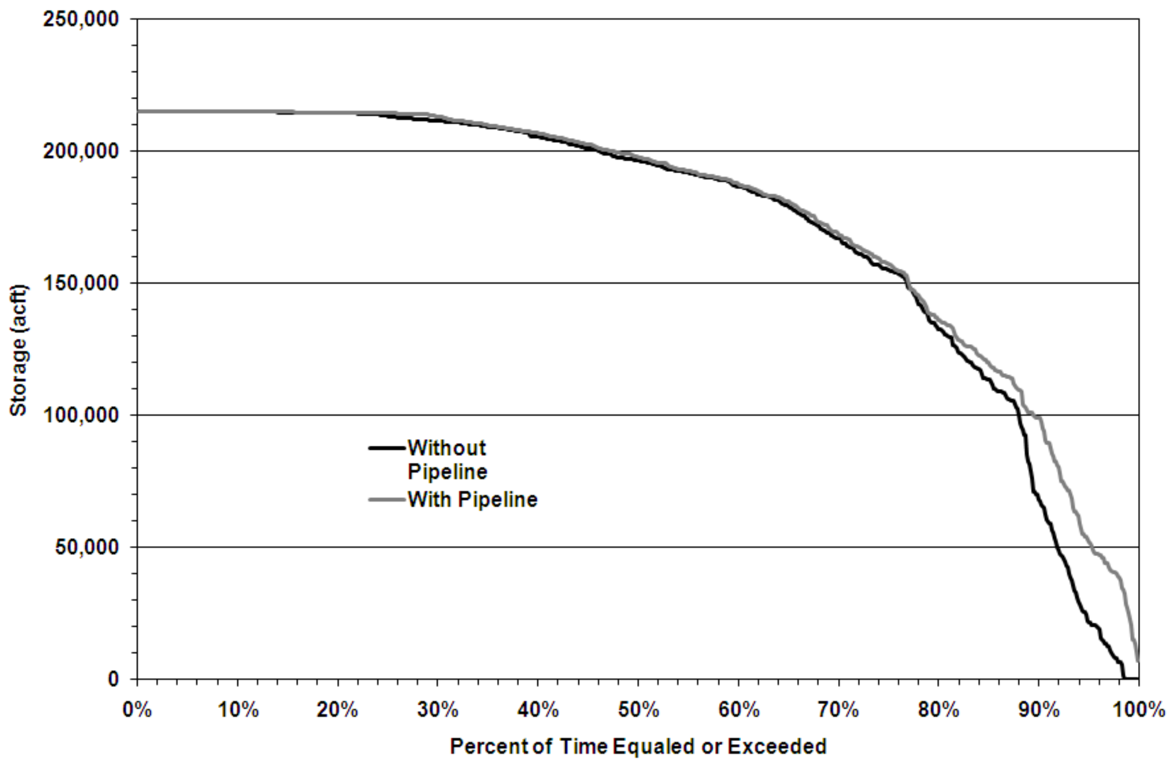

Figure 4B.20.2.2-2. 2060 Lake Stillhouse Hollow Storage Exceedance Frequency With and Without Proposed Lake Belton to Lake Stillhouse Hollow Pipeline

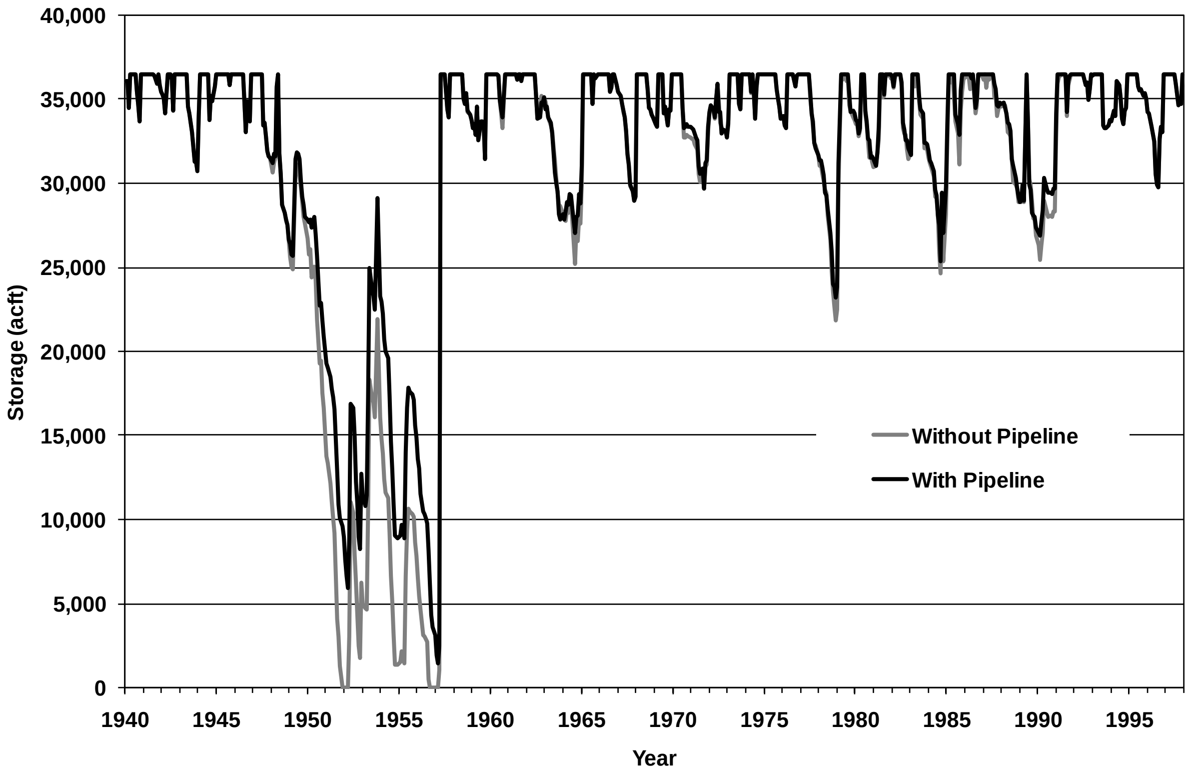

Figure 4B.20.2.2-3. 2060 Lake Georgetown Storage With and Without Proposed Lake Belton to Lake Stillhouse Hollow Pipeline

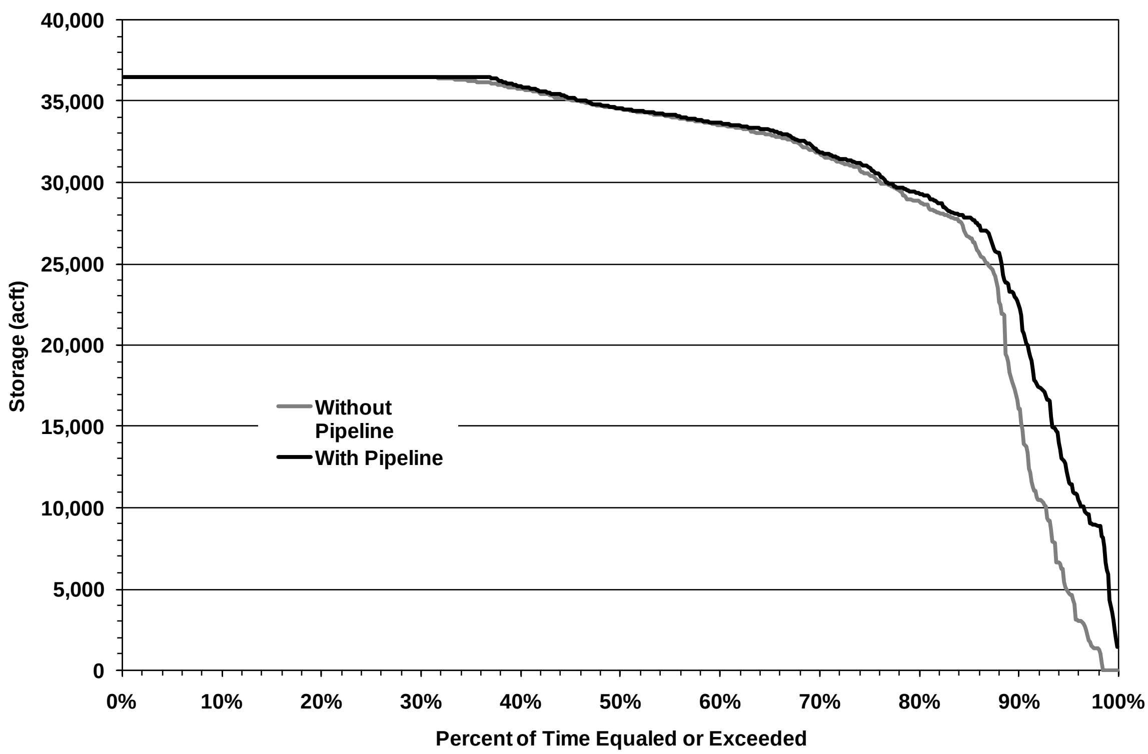

Figure 4B.20.2.2-4. 2060 Lake Georgetown Storage Exceedance Frequency With and Without Proposed Lake Belton to Lake Stillhouse Hollow Pipeline

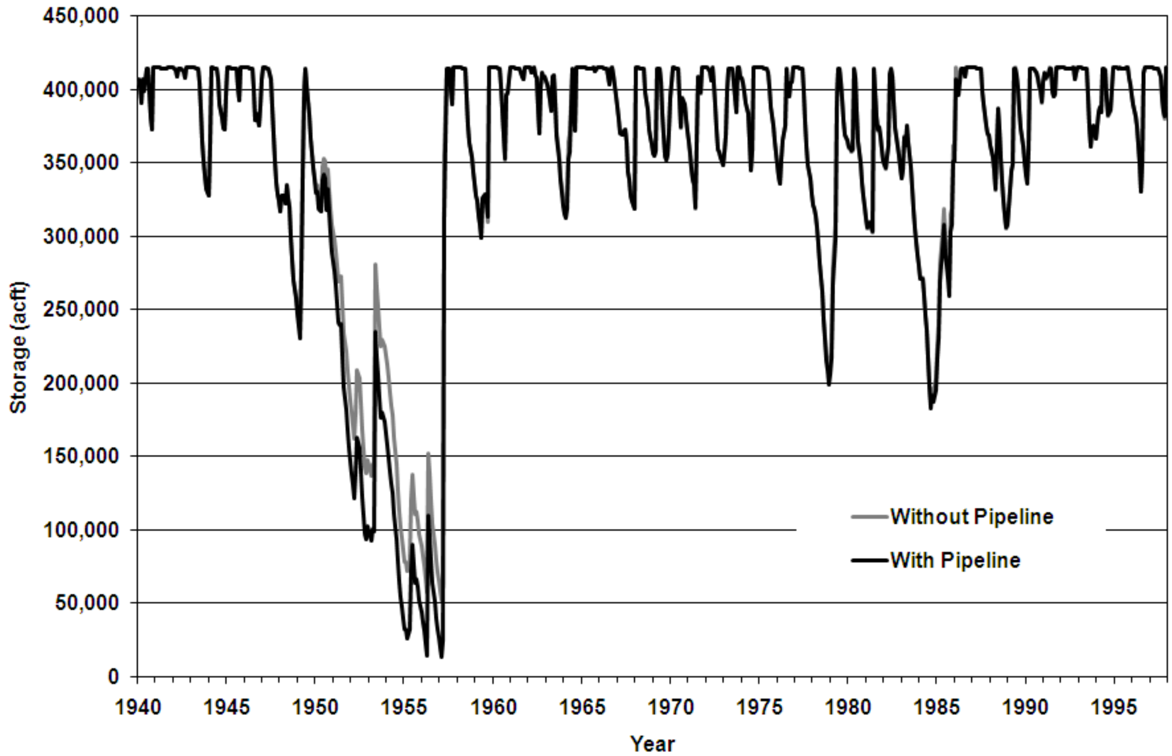

Figure 4B.20.2.2-5. 2060 Lake Belton Storage
With and Without Proposed Lake Belton to Lake Stillhouse Hollow Pipeline

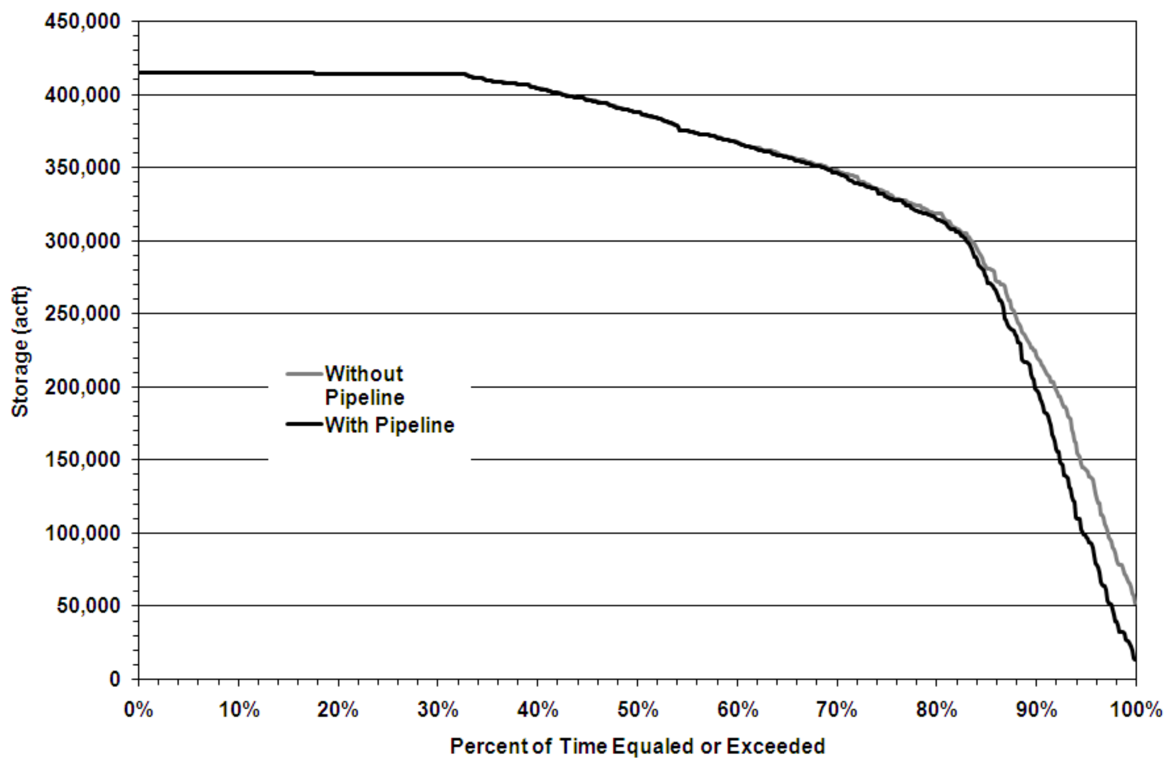

Figure 4B.20.2.2-6. 2060 Lake Belton Storage Exceedance Frequency
With and Without Proposed Lake Belton to Lake Stillhouse Hollow Pipeline

4B.20.2.4 Engineering and Costing

A specific location for facilities and a pipeline route has not been determined at this time. 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 4B.20.2.4-1 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 $25.9 million. Total project costs, including engineering, contingency permitting, mitigation and interest during construction are an additional $10.1 million for a total project cost of $36.0 million. Annual costs, including debt service, power cost and operation and maintenance are approximately $4.5 million per year. The resulting unit costs are $150 per acre-foot or $0.46 per thousand gallons.

4B.20.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.20.2.5-1, and the option meets each criterion.

A summary of the implementation steps for the project is presented below.

- Agreement with USCOE for discharge into Lake Stillhouse Hollow.
- Possible analysis of potential impact of blending Lake Belton water in Lake Stillhouse Hollow.

Potential Regulatory Requirements:

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

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

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

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions 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 4B.20.2.4-1
Cost Estimate for Lake Belton to Lake Stillhouse Hollow Pipeline

Item	*Estimated Costs for Facilities*
Capital Costs	
Intake & Pump Station (33 MGD)	$15,300,000
Transmission Pipeline (6.8 mi, 48 in. dia.)	$10,466,000
Discharge Structure	$94,000
Total Capital Cost	**$25,860,000**
Engineering, Legal Costs and Contingencies	$8,407,000
Environmental & Archeological Studies and Mitigation	$343,000
Interest During Construction	$1,428,000
Total Project Cost	**$36,038,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$3,142,000
Operation & Maintenance	
Intake, Pipeline, Pump Station	$580,000
Pumping Energy Costs ($0.09 kwh)	$781,000
Total Annual Cost	**$4,503,000**
Available Project Yield (acft/yr)	30,000
Annual Cost of Water ($ per acft)	$150
Annual Cost of Water ($ per 1,000 gallons)	$0.46

Table 4B.20.2.5-1
Comparison of Lake Belton to Lake Stillhouse Hollow Pipeline to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply 1. Quantity 2. Reliability 3. Cost	 1. Sufficient to meet needs 2. High reliability 3. Reasonable
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries 5. Threatened and Endangered Species 6. Wetlands	 1. Low to medium impact 2. Low impact 3. Low impact 4. Low impact due to distance from coast 5. Low impact 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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4B.21 2006 Plan Amendments

Several entities requested amendments to the 2006 Plan following its adoption, so that the plan would better reflect their specific water supply initiatives. The strategies in these amendments are also recommended water management strategies in the 2011 Plan. The cost estimates for these strategies were updated to second quarter 2008 dollars before inclusion in the plans for water user groups and wholesale water providers (Volume I, Section 4C). The plan amendments as adopted by the Brazos G RWPG and approved by the TWDB are included here, in the following sections.

4B.21.1 City of Cleburne Amendment

4B.21.2 City of Granbury Amendment

4B.21.3 Palo Pinto County MWD No. 1 Amendment

4B.21.4 Somervell County MWD Amendment

4B.21.5 Somervell County Steam-Electric (Luminant) Amendment

4B.21.6 City of Waco (WMARSS) Amendment

4B.21.7 Johnson County Special Utility District Amendment

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4B.21.1 City of Cleburne Amendment

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BRAZOS G
WATER PLANNING GROUP

BRAZOS RIVER AUTHORITY, Administrative Agent
P.O. Box 7555 ◆ Waco, Texas 76714-7555
(254) 761-3100 ◆ Fax (254) 761-3204

June 4, 2008

To: Interested Parties

Re: Amendment to the 2006 Brazos G Regional Water Plan related to Additional Water Management Strategies for the City of Cleburne

The Brazos G Regional Water Planning Group hereby amends the 2006 Brazos G Regional Water Plan as follows:

1. **Recommend the New West Loop Reuse Line as a Recommended Water Management Strategy for the City of Cleburne.**
   The City of Cleburne is expanding its reuse system, and is pursuing development of the New West Loop Reuse Line to supply various reuse customers.

2. **Recommend the Phase I Lake Whitney Water Supply Project as a Recommended Water Management Strategy for the City of Cleburne.**
   The City of Cleburne has purchased raw water supply from the Brazos River Authority (Lake Whitney) and is developing the infrastructure necessary to utilize that supply.

The revised plan for the City of Cleburne is shown in Attachment A. A detailed technical evaluation of these amendments is included in Attachment B.

4C.17.5 City of Cleburne

4C.17.5.1 Description of Supply

The City of Cleburne obtains its water supply from Lake Pat Cleburne, Lake Aquilla, and groundwater from the Trinity Aquifer. The City of Cleburne is projected to have a surplus of 1,791 acft/yr in the year 2030 and a shortage of 2,853 acft/yr in the year 2060.

4C.17.5.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended to meet the projected shortage of the City of Cleburne:

- Conservation
- Reuse (The City has implemented a reuse program, which it has committed to expanding.)
- Lake Whitney Supply – The project will develop 9,700 acre-feet per year of undeveloped water supply from Lake Whitney contracted to the City through the Brazos River Authority. This project would develop part of Cleburne's remaining contractual commitment for water from the Brazos river authority, beyond the 5,300 acre-feet per year currently available from Lake Aquilla. The project would require a deep water intake, diversion pump station to take water out of Lake Whitney, an advanced water treatment facility for the Lake Whitney water, blending tanks, a booster pump station , and a pipeline to connect the Lake Whitney supply to the existing Barkman Pipeline for delivery to Cleburne , and all associated appurtenances for a fully functional and operational water supply delivery and treatment system. This project would supply the City of Cleburne and Johnson County mining, manufacturing, steam electric, and irrigation water though Cleburne.
- Optimization of the surface water supplies from Lake Pat Cleburne, Lake Aquilla, Lake Whitney and any other future water supply through planned expansions of the City's existing water treatment plant – The first phase project would expand the existing water treatment plant by 5 MGD to meet projected peak-day needs and to supply treated water to City customers. This project would supply the City of Cleburne and Johnson county mining, manufacturing, steam electric and irrigation water through Cleburne.

4C.17.5.3 Costs

Costs of the Recommended Plan for the City of Cleburne.

a. Conservation
- Cost Source: Volume II, Section 4B.2.1
- Date to be Implemented: before 2010
- Annual Cost: $195,700 (maximum annual cost in 2020)

b. Reuse Strategy 1 – Expanded Use of Existing System:
- Cost Source: Strategy Evaluation (Section 4B.3)
- Date to be Implemented: before 2010
- Annual Cost: $1,512,090 (Based on unit costs from Section 4B.3)

c. Reuse Strategy 2 – New West Loop Reuse Line:
- Cost Source: City of Cleburne
- Date to be Implemented: before 2010
- Total Project Cost: $7,384,900
- Annual Cost: $853,900

d. Phase I Lake Whitney Water Supply Project:
- Cost Source: City of Cleburne
- Date to be Implemented: before 2010, with future phases
- Total Project Cost : $42,221,700 (Phase I)
- Annual Cost: $4,690,100 (Phase I)

Table 4C.17-6.
Recommended Plan Costs by Decade for the City of Cleburne

Plan Element	2010	2020	2030	2040	2050	2060
Projected Surplus/(Shortage) (acft/yr)	4,225	3,013	1,791	483	(1,051)	(2,853)
Conservation						
Supply From Plan Element (acft/yr)	229	515	454	413	416	473
Annual Cost ($/yr)	$87,020	$195,700	$172,520	$156,940	$158,080	$179,740
Unit Cost ($/acft)	$530	$530	$530	$530	$530	$530
Reuse Strategy 1 – Expanded Use of Existing System						
Supply From Plan Element (acft/yr)	351	351	351	351	1,051	2,853
Annual Cost ($/yr)	$186,030	$186,030	$186,030	$186,030	$557,030	$1,512,090
Unit Cost ($/acft)	$530	$530	$530	$530	$530	$530
Reuse Strategy 2 – New West Loop Reuse Line						
Supply From Plan Element (acft/yr)[1]	1,680	1,680	1,680	1,680	1,680	1,680
Annual Cost ($/yr)	$853,900	$853,900	$853,900	$853,900	$853,900	$853,900
Unit Cost ($/acft)	$508	$508	$508	$508	$508	$508
Phase I Lake Whitney Water Supply Project						
Supply From Plan Element (acft/yr)[1]	2,128	2,128	2,128	2,128	2,128	2,128
Annual Cost ($/yr)	$4,69,100	$4,69,100	$4,69,100	$4,69,100	$4,69,100	$4,69,100
Unit Cost ($/acft)	2,554	2,554	2,554	2,554	2,554	2,554

Note 1: 90 % Treatment Recovery Rate with blending

Request for Amendment to the Region G Water Plan to Add Development of the City of Cleburne Water Supply Projects to Meet Projected Water Supply Shortages

1. Background

The *2006 Brazos G Regional Water Plan* recommended two water management strategies. They are conservation and reuse. The City will continue to pursue both of these strategies.

The City commissioned a long-range water supply study that was completed in January 2008. The study showed that the City of Cleburne may have significant increases in industrial demand over the next few years which were not identified in the 2006 Brazos G Regional Water Plan, in particular:

- Brazos Electric Power Company has indicated that they intend to construct Phase II of their existing power plant in Cleburne in the 2013 to 2015 period. This would increase Cleburne's average-day demand by 1.1 to 2.2 MGD, depending on the Phase II unit capacity.
- Representatives of the oil and gas industry have asked Cleburne for water to develop natural gas wells. They are seeking an average of 1.5 MGD for the next few years, with lower amounts needed in the future.
- Other industries currently located in Cleburne have indicated that they expect significant increases in their demands, and the City continues to attract new industries as well.

Municipal demands are also increasing due to growing population. This growth in demand requires that Cleburne develop substantial new supplies in the next few years.

The recommended plan developed in the January 2008 study addressed both the immediate additional water needs and a long-term sustainable supply. The major components of the plan are:

- Optimization of the surface water supplies from Lake Pat Cleburne and Lake Aquilla through planned expansions of the City's existing water treatment plant;
- Maintaining the groundwater for supplemental and peak usage;
- Expanding the reuse wastewater facilities for industrial applications;
- Developing Lake Whitney as a long-term sustainable water supply for the City;

- Continuing the City's Water Conservation Program to preserve water resources.

The Texas Water Development Board at a funding pre-application meeting on April 14, 2008 determined that the water treatment plant expansion and developing Lake Whitney as a long-term sustainable water supply for the City of Cleburne are not specifically included in the 2006 Brazos G Regional Water Plan and thus are not currently eligible for Water Infrastructure funding. Following the April 14, 2008 meeting the City of Cleburne requested that the Brazos G Regional Water Planning Group amend the 2006 Brazos G Regional Water Plan to add the water treatment plant expansion and development of Lake Whitney BRA contracted water supply.

2. Amendment Request

The City of Cleburne respectfully requests that the *2006 Brazos G Regional Water Plan* be amended to add the following City of Cleburne's water management strategies, which include:

- Develop the New West Loop Reclaimed Water Line (reuse of wastewater) and Pump Station. This project would develop a reclaimed water pipeline on the west side of the City, which would join the existing east reclaimed water line serving the Brazos Electric Power Plant (Steam Electric) to form a looped system. This line would supply reclaimed water for oil and gas development (Mining), irrigation use by major water users, and industrial use (Manufacturing) by the existing James Hardie manufacturing plant and others. This project would supply the City of Cleburne and Johnson County mining, manufacturing, steam electric and irrigation water through Cleburne. While an expanded reuse program is identified for Cleburne, this project is not specifically identified as a water management strategy for the City in the 2006 Brazos G Regional Water Plan.
- Complete a 5 MGD expansion of the existing water treatment plant. This project would increase the capacity of the existing water treatment plant to meet projected peak-day needs and to supply treated water from existing and future raw water supply sources. This project would supply the City of Cleburne and Johnson County mining, manufacturing, steam electric and irrigation water through Cleburne.
- Complete the 1.9 MGD Phase I Lake Whitney Water Supply Project. This project would develop part of Cleburne's remaining contractual commitment for water from

the Brazos River Authority (beyond the 4.73 MGD [5,300 acre-feet per year] currently available from Lake Aquilla). The project would require a deep water intake, diversion pump station to take water out of Lake Whitney, an advanced water treatment facility for the Lake Whitney water, blending tanks, a booster pump station, and a pipeline to connect the Lake Whitney supply to the existing Barkman Pipeline for delivery to Cleburne, and all associated appurtenances for a fully functional and operational water supply delivery and treatment system. This project would supply the City of Cleburne and Johnson County mining, manufacturing, steam electric and irrigation water through Cleburne.

The City believes that this amendment meets the Texas Water Development Board criteria for a minor amendment to the *2006 Brazos G Regional Water Plan*, as laid out in Texas Administrative Code Rule 357.16:

- It does not result in over allocation of an existing or planned source of water. The amendment does not change the allocation of any source of supply. The project develops, in phases, the current BRA contracted amount of 9,700 acre-feet per year and does not rely on any new allocations.
- It does not relate to a new reservoir. The amendment only relates to the development of treatment and transmission facilities.
- It does not have a significant impact on instream flows, environmental flows, or freshwater flows to bays and estuaries.
- It does not have a significant impact on water planning or previously adopted management strategies.
- It does not delete or change any legal requirements of the plan.

If the Brazos G Regional Planning Group or the Texas Water Development Board determines that the requested amendment cannot be processed as a minor amendment, the City requests that it be processed as a major amendment.

3. Description of Strategy

The City of Cleburne currently obtains its water supply from four sources:

- Lake Pat Cleburne;
- Lake Aquilla and the associated Barkman Pipeline;

- Seven groundwater wells in the Trinity Sands Aquifer;
- Direct reuse of treated wastewater for industrial supplies.

The main source of Cleburne's existing water supply is Lake Pat Cleburne which has 5,760 acre-feet per year of adjudicated municipal water rights. The certificate of adjudication was amended in January 2002 to authorize the City to use the bed and banks of Lake Pat Cleburne to deliver 5,300 acre-feet per year of water from Lake Aquilla and 4,700 acre-feet per year of water from Lake Whitney.

It is estimated that the yield of Lake Pat Cleburne will decrease by about 0.29 MGD between 2006 to the year 2050.

The supply available from Lake Aquilla may decrease significantly over the same period. If the yield of Lake Aquilla decreases as indicated by recent BRA analysis, Cleburne (and other holders of contracts for water from the Lake) will not be able to divert the full contracted amount as a reliable supply.

Annual Average Day Supply Capability of the Existing Water Sources

	2006 (MGD)	**2050 (MGD**
Lake Pat Cleburne	4.66	4.38
Lake Aquilla (BRA Contract)	4.73	3.57
Groundwater	1.0	1.0
Direct Reuse of Treated Wastewater	0.6	5.0

The current existing water supply is 10.98 MGD and the current projected drought condition demand is 11.38 MGD.

To meet the existing and long-term water supply need it will be necessary to develop the Lake Whitney BRA contracted water supply. Cleburne has an existing contract with BRA for use of as much as 15,000 acre-feet per year of water from the Brazos River Authority. BRA has indicated that the 15,000 acre-feet per year can be supplied from any part of its system (subject to availability) and Cleburne is currently using 5,300 acre-feet per year from Lake Aquilla.

Based on preliminary examination of the Lake Whitney reservoir topography, an intake and pump station from Lake Whitney could be located on the eastern shore of the lake. Other diversion locations may be evaluated and other future take points identified. Lake Whitney water would be treated at an advanced water treatment plant located on the eastern shore. The water would not be disinfected to meet drinking water standards, but the TDS and chlorides would be reduced to match the target water quality in Lake Pat Cleburne and Lake Aquilla. The partially treated water would then be blended with Lake Aquilla water in the Barkman pipeline and pumped to the City's treatment plant or Lake Pat Cleburne for rediversion and treatment. Future options may include full treatment at the take point.

4. Available Supply

The City of Cleburne has a water right for 5,760 acre-feet per year for municipal use and 240 acre-feet per year for irrigation from Lake Pat Cleburne. The City has contracted for 15,000 acre-feet from BRA of which 5,300 acre-feet per year is supplied from Lake Aquilla and the remaining 9,700 acre-feet per year will be supplied from Lake Whitney. The proposed project which is the subject of this amendment will make this 9,700 acre-feet per year available as a reliable water supply for the City of Cleburne.

Environmental

Environmental impacts could include:

- Possible minor impacts on riparian corridors, depending on location of connecting pipelines and treatment plant.
- Other possible minor impacts from pipeline construction. 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.
- Intake and Pump Station could potentially have Section 404 permit environmental considerations from the Corps of Engineers regarding construction disturbance of Lake Whitney. All necessary permits and environmental documentation will be acquired.

A summary of environmental issues is presented in Table 1.

Table 1
Environmental Issues:
City of Cleburne Water Supply Project

Water Management Option	Cleburne Water Supply Project
Implementation Measures	Expand the existing water treatment plant by 5 MGD, construction of a Lake Whitney Pump Station, advanced treatment plant and pipeline.
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, possible minor impact on aquatic life from lake pump station.
Cultural Resources	Possible low impact.
Threatened and Endangered Species	Possible low impact.

5. Engineering and Costing

Figures 1 and 2 show the facilities required to develop the City of Cleburne Water Project. Water from Lake Whitney will be treated at an advanced water treatment plant on the eastern shore and blended to a target level. The brine waste will be disposed of in a TCEQ permitted Class I disposal well, other options for brine disposal may be evaluated. The blended water will be pumped to the Barkman pipeline and diverted to the City’s water treatment plant or Lake Pat Cleburne.

Table 2 summarizes the capital costs for Phase I of the project.

Table 2
Cost Estimate Summary for City of Cleburne
Water Supply Project
(2007 Prices)

LAKE WHITNEY DIVERSION – TDS SCALPING OPTION (PHASE I)

	Item Description	Units/Size	Unit Price ($ 2007)	Estimated Amount ($2007)	Estimated Amount ($2002)
	Capital Costs:				
1.	Deep Water Intake	Platform Design		$ 11,750,000	$ 10,138,000
2.	Raw Water Pump Station	4.2 MGD	4,700 ac.ft./yr.	Included in Item #1	
3.	Electrical Service	1000 Hp	LS	$ 1,750,000	$ 1,509,900
4.	Feed Tank	0.5 MG		$ 300,000	$ 258,800
5.	Pre-Treatment – MF/UF	1.75 MGD		$ 1,750,000	$ 1,509,900
6.	Transfer Tank	0.5 MG		$ 300,000	$ 258,800
7.	Desalination Treatment – RO	1.75 MGD		$ 2,500,000	$ 2,157,000
8.	Transfer Tank	0.5 MG		$ 300,000	$ 258,800
9.	Chemical Facilities and Administration	1.9 MGD		$ 225,000	$ 194,100
10.	Transfer Pumps	1.9 MGD		$ 475,000	$ 409,800
11.	Concentrate Disposal	0.50 MGD			$ 1,509,900
	Brine Concentrator		LS	$ 1,750,000	$ 1,509,900
	Disposal Well		LS	$ 1,750,000	
12.	Transmission Pipeline	8 miles/18 inch	$95/ft	$ 4,012,800	$ 3,462,300
13.	Meters and Connections	LS		$ 50,000	$ 43,100
14.	Land Acquisition	10 Acres	$25,000/Ac	$ 250,000	$ 215,700
15.	Easements	30 ft. wide	$0.21660/SF	$ 274,476	$ 236,800
16.	Permitting				
	404 Permit (Individual Permit)			$ 90,000	$ 77,700
	Mitigation			$ 150,000	$ 129,400
	Threatened/Endangered species habitat assessment			$ 10,000	$ 8,600
	Cultural resources survey			$ 20,000	$ 17,300
	Environmental Assessment for 404 Permit			$ 250,000	$ 215,700
	Archaeological Assessment			$ 75,000	$ 64,700
	TPWD Sand, Gravel, & Marl Permit			$ 10,000	$ 8,600
	GLO Grant of Easement			$ 15,000	$ 12,900
	Permitting "Bed and Banks" through Lake Pat Cleburne			$ 85,000	$ 73,300
	TCEQ Disposal Well Class I Permit			$ 250,000	$ 215,700
	Sub-Total			$ 28,392,276	$ 24,497,200
17.	Engineering, Legal and Contingencies	30%		$ 8,517,683	$ 7,349,200
	Total Capital Cost			**$ 36,909,958**	**$ 31,846,400**
	Annual Costs				
1.	Debt Service (5.50 percent, 20 years)			$ 3,088,625	$ 2,664,900
2.	Raw Water Purchase (20 year present worth)			$ 271,425	$ 234,200
3.	Operation and Maintenance				
	Pump Station & Transmission			$ 415,297	$ 358,300
	Water Treatment			$ 1,416,656	$ 1,222,300
4.	Brine Disposal			$ 198,332	$ 171,100
5.	Pumping			$ 45,491	$ 39,300
	Total Annual Phase I			**$ 5,435,826**	**$ 4,690,100**
	Cost per 1000 Gallons Phase I			**$ 7.84**	**$ 6.76**
	Cost per Acre-Ft. Phase I			**$ 2,554.10**	**$ 2,204**
	Treated Water Produced Phase I			**1.9 MGD**	**1.9 MGD**

Note : 2007 Costs were reduced to 2002 Costs using 3 % Inflation per year over 5 years.

Table 2 (Continued)
Cost Estimate Summary for City of Cleburne
5 MGD Water Treatment Plant Expansion
(2007 Prices)

WATER TREATMENT PLANT EXPANSION – 5 MGD

Item Description	Units/Size	Unit Price	Estimated Amount ($ 2007)	Estimated Amount ($ 2002)
Capital Costs:				
1. Water Treatment Plant Expansion	5 MGD	LS	$ 8,000,000	$ 6,902,500
2. Improvements to Sludge Handling	5 MGD	LS	$ 750,000	$ 647,100
3. Miscellaneous Improvements & Pumping		LS	$ 500,000	$ 431,400
Sub-Total			**$ 9,250,000**	**$ 7,981,000**
Engineering, Legal & Contingencies		**30%**	**$ 2,775,000**	**$ 2,394,300**
Total			**$ 12,025,000**	**$ 10,375,300**
Unit Cost @2.5 MGD Average: $/1000 gallons			**$1.98**	**$ 1.71**
Unit Cost $ per gallon capacity			**$2.41**	**$ 2.08**

Note: 2007 Costs were reduced to 2002 Costs using 3% Inflation per year over 5 years.

Table 2 (Continued)
Cost Estimate Summary for City of Cleburne
New West Loop Reuse Pipeline
(2007 Prices)

WASTEWATER REUSE

New West Loop Reuse Line
New 16" direct wastewater reuse line from WWTP west and looping to meet existing line at Brazos Electric.
Reuse water could be provided for irrigation to Municipal Golf Course (beyond 24 acre-feet from Lake Pat Cleburne).
Hill County College, Walls Hospital and a substantial volume to James Hardie.

Construction Items	Total Units	Unit Cost(s)	2007 Cost	2002 Cost
New 16" reuse pipeline	56505	$ 95	$ 5,367,975	$ 4,631,600
Pump Station – Installed	1	$ 450,000	$ 450,000	$ 388,300
Meter	1	$ 50,000	$ 50,000	$ 43,100
Storage Tank – standpipe	1	$ 400,000	$ 400,000	$ 431,400
Easements	30' Wide	$ 6.50	$ 339,030	$ 292,500
Sub-Total			**$ 6,607,005**	**$ 5,700,600**
Engineering & Contingencies (@30% of sub-total			$ 1,982,102	$ 1,710,200
Total Capital Cost			**$ 8,559,107**	**$ 7,384,900**
Debt Service 20 years @ 5.5 %			$ 716,200	$ 618,000
Annual Pumping Cost	**Unit Cost(s)**	**Total Units**	**2007 Cost**	**2002 Cost**
1.5 MGD @ 500 TDH, 200 Hp	$0.09 Per kW-H	1,307,000 kW-H	$ 117,630	$ 101,500
Annual O&M Cost				
1% of Pipeline Cost (Includes Chlorine & Normal)	$64,416	1	$ 64,416	$ 55,600
2.5% of Pump Station Cost	$13,500	1	$ 13,500	$ 11,600
Total O&M cost			$ 77,916	$ 67,200
Total Annual Cost (Capital + O&M)			**$ 989,662**	**$ 853,900**
Cost/1000 gallons (Based on 1.5MGD)			**$1.81**	**$ 1.56**

Note : 2007 Costs were reduced to 2002 Costs using 3% Inflation per year over 5 years.

Table 3 summarizes the capital costs for the recommended short-term Water Supply Projects for Cleburne.

Table 3
Recommended Short-Term Projects for Cleburne

Project Description	Estimated Supply (MGD)	Estimated Capital Cost
West Side Reuse Line and Pump Station	2.4	$8,600,000
5 MGD Water Treatment Plant Expansion	-	$12,025,000
1.9 MGD Lake Whitney project Phase I	1.9	$36,910,000
TOTAL	4.3	$57,535,000

Table 3 shows the estimated cost of each of these projects and the supply available from them. The three projects would supply a total of about 4.3 mgd for Cleburne (although supplies from the reuse pipeline would continue to grow over time), and the total estimated capital cost (at 2007 prices) is $57,535,000.

Cleburne will also have to develop additional supplies to meet long-term demands beyond 2020. At this time, it is not clear what Cleburne's best options to meet demands beyond 2020 will be, but the following steps could meet currently forecast demands:

- Complete Water Treatment Plant expansions as needed (5 MGD expansions forecast for 2024, 2034, 2043 and 2050)
- Develop Lake Whitney Phase 2 (2021)
- Develop indirect reuse in Lake Pat Cleburne (2027)
- Develop Lake Whitney Phase 3 or other supply source (2031)

6. Implementation Issues

This project could be developed in cooperation with the Brazos River Authority to provide a regional surface water supply. Other implementation issues will include financing and Section 404 permitting. As shown in Table 4, this water management strategy has been compared to the plan development criteria.

7. Potential Regulatory Requirements

Implementation of this water management strategy will require the following permits for pipeline and lake pump station construction:

- U.S. Army Corps of Engineers Section 404 permit for intake and pipeline stream crossings and discharges of fill into wetlands and waters of the U.S. during construction.
- NPDES Stormwater Pollution Prevention Plans.
- Possibly TP&WD Sand, Shell, Gravel, and Marl permits for construction in state-owned stream beds.

Table 4
Comparison of City of Cleburne Water Supply Project to Plan Development Criteria

Impact category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient for local needs.
2. Reliability	2. High.
3. Cost	3. Relatively high, but reasonable compared to other similar systems.
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.

4B.21.2 City of Granbury Amendment

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BRAZOS G
WATER PLANNING GROUP

BRAZOS RIVER AUTHORITY, Administrative Agent
P.O. Box 7555 υ Waco, Texas 76714-7555
(254) 761-3100 υ Fax (254) 761-3204

April 15, 2009

To: Interested Parties

Re: Amendment to the 2006 Brazos G Regional Water Plan related to the City of Granbury Surface Water Treatment Plant

The Brazos G Regional Water Planning Group hereby amends the 2006 Brazos G Regional Water Plan as follows:

1. **Recommend the City of Granbury Surface Water Treatment Plant as a Recommended Water Management Strategy for the City of Granbury.** The City of Granbury is replacing its existing treatment plant to improve treatment capability and increase treatment capacity.

The revised plan for the City of Granbury (Section 4C.16.2) is shown in Attachment A. A detailed technical evaluation of this amendment is included in Attachment B.

4C.16.2 City of Granbury

4C.16.2.1 Description of Supply

The City of Granbury obtains its water supply from groundwater from the Trinity Aquifer and from surface water from Lake Granbury. No shortages are projected for the City of Granbury. However, the City of Granbury is planning to construct a new surface water treatment plant with increased capacity to replace the aging plant currently in operation on Lake Granbury.

4C.16.2.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended to supplement existing supplies for the City of Granbury:

- City of Granbury Surface Water Treatment Plant – the project will treat raw water from Lake Granbury and deliver treated water to City of Granbury customers.

4C.16.2.3 Costs

Costs of the Recommended Plan for the City of Granbury.

a. City of Granbury Surface Water Treatment Plant:
   - Cost Source: Cost estimate from strategy evaluation
   - Date to be Implemented: before 2010 with future phases
   - Total Project Cost: $48,511,660 (all phases)
   - Annual Cost: $1,650,430 (Phase 1 Only)
   -

Table 4C.16-2.
Recommended Plan Costs by Decade for City of Granbury Surface Water Treatment Plant

Plan Element	***2010***	***2020***	***2030***	***2040***	***2050***	***2060***
Projected Surplus/(Shortage) (acft/yr)	5,731	5,290	4,888	4,451	3,901	3,252
City of Granbury Surface Water Treatment Plant						
	Phase 1	Phase 2		Phase 3	Phase 4	
Supply From Plan Element (acft/yr)	1,680	5,040	5,040	6,720	8,400	8,400
Annual Cost ($/yr)	$1,650,430	$4,100,365	$4,100,365	$4,434,360	$3,985,010	$3,985,010
Unit Cost ($/acft)	$982	$814	$814	$660	$474	$474

Request for Amendment to the 2006 Brazos G Regional Water Plan to Add Development of the City of Granbury Surface Water Treatment Plant

1. Background

The *2006 Brazos G Regional Water Plan* does not include specific water management strategies or water supply plans for the City of Granbury as the City is not expected to have a water shortage. The City is predicted to have a surplus of 4,888 acre-feet per year in 2030 and 3,252 acre-feet per year in 2060. However the City's existing water treatment plant is over 30 years old and cannot treat enough water requiring the City to purchase treated water from the Brazos River Authority Surface Water and Treatment System (SWATS) plant. The City wishes to build a new water treatment plant which will provide improved treatment capability as well as increased treatment capacity. This new water treatment plant will allow the City to meet all of the customer demands without purchasing water from other providers.

Because the City of Granbury's new surface water treatment plant is not specifically included in the *2006 Brazos G Regional Water Plan* the project is not currently eligible for Water Infrastructure funding. Alva Cox, director of public works of the City of Granbury, wrote to Scott Mack, Chair of the Brazos G Regional Water Planning Group, requesting an amendment to the *2006 Brazos G Regional Water Plan* to add the development of the City of Granbury Surface Water Treatment Plant.

2. Amendment Request

The City of Granbury requests that the *2006 Brazos G Regional Water Plan* be amended to add the proposed City of Granbury Surface Water Treatment Plant, which includes:

- Development of a 1.5 MGD Micro-Filtration and Reverse Osmosis water treatment plant and raw water intake and later expansion.
- Development of a 500,000 gallon ground storage tank at the plant site.
- Future expansions to the plant up to 7.5 MGD.

The City believes that this amendment meets the Texas Water Development Board criteria for a minor amendment to the *2006 Brazos G Regional Water Plan*, as laid out in Texas Administrative Code Rule 357.16:

- It does not result in over allocation of an existing or planned source of water. The amendment does not change the allocation of any source of supply.
- It does not relate to a new reservoir. The amendment only relates to the development of treatment facilities.
- It does not have a significant impact on instream flows, environmental flows, or freshwater flows to bays and estuaries.
- It does not have a significant impact on water planning or previously adopted management strategies.
- It does not delete or change any legal requirements of the plan.

If the Brazos G Regional Water Planning Group or the Texas Water Development Board determines that the requested amendment cannot be processed as a minor amendment, the City requests that it be processed as a major amendment.

3. Description of Strategy

The City of Granbury currently obtains its water supply from groundwater in the Trinity Aquifer as well as surface water from Lake Granbury. Groundwater is supplied by wells in the Trinity Aquifer. Surface water is supplied from the water rights in Lake Granbury through treatment of water at the City's 0.5 MGD water treatment plant. Additional supply comes from purchase of finished water from the BRA SWATS plant. As the City's WTP was constructed over 30 years ago, it has become dilapidated and the City intends to demolish the existing 0.5 MGD plant and construct a new 1.5 MGD WTP, which will be expandable to 7.5 MGD in the future. The City will utilize the new treatment plant to provide base-load (average day) supplies, and will gradually phase out of its capacity in the SWATS plant. Peak-day supplies will be provided by SWATS capacity until phased out and existing groundwater wells.

4. Available Supply

The City of Granbury has contracted with the BRA for 10,800 acre-feet per year from Lake Granbury, of which approximately 1,904 acre-feet per year is currently treated at the BRA SWATS plant. The proposed City of Granbury Surface Water Treatment Plant, which is the subject of this amendment, will initially treat 1.5 MGD and be expandable to 7.5 MGD of potable water. Once the plant is constructed the city will begin to gradually decrease supplies treated at the SWATS plant. Water supply for the new plant will come from the city's contracted amount of 10,800 acre-feet per year from Lake Granbury.

5. Environmental

Environmental impacts could include:

- Possible minor impacts on riparian corridors.

The minor impacts during construction of the raw water intake will be minimized to the extent possible by implementing an effective SWPPP and proper revegetation of the area after construction. A summary of environmental issues is presented in Table 1.

Table 1
Environmental Issues:
City of Granbury Water Supply Project

Water Management Option	City of Granbury Surface Water Treatment Plant
Implementation Measures	Construction of a 1.5 mgd water treatment plant, pump station, and ground storage tank.
Environmental Water Needs/Instream Flows	Negligible impact.
Bays and Estuaries	Negligible impact.
Fish and Wildlife Habitat	Possible minor impacts on riparian corridors, during construction of the raw water intake.
Cultural Resources	Possible low impact.
Threatened and Endangered Species	Possible low impact.

6. Engineering and Costing

Water from Lake Granbury will be treated at the water treatment plant and distributed to the city by a system of pump stations, ground and elevated storage tanks, and pipelines. Phase 1 will include a 1.5 mgd water treatment plant and 500,000 gallon ground storage tank.

Table 2 summarizes the capital costs for Phase 1, which total $8,944,100 using the second quarter 2002 costs to be consistent with costs shown in the *2006 Brazos G Regional Water Plan.*

Table 2
Cost Estimate Summary for
City of Granbury Water Supply Project Phase 1
(Second Quarter 2002 Prices and 2009 Prices)

Item	Estimated Cost for Facilities (2002 $)	Estimated Cost for Facilities (2009 $)
Capital Costs		
New 1.5 MGD Water Treatment Plant (Including High Service Pump Station (HSPS))	$ 8,537,550	$ 10,500,000
500,000 Gallon Ground Storage Tank	$ 406,550	$ 500,000
Total Capital Costs	**$ 8,944,100**	**$ 11,000,000**
Contingencies	$ 1,341,620	$ 1,650,000
Engineering, Permitting, Survey, and Geotech	$ 1,512,370	$ 1,860,000
Interest During Construction (1 year)	$ 473,470	$ 565,325
Total Project Costs	**$ 12,271,560**	**$ 15,075,325**
Annual Costs		
Debt Service (6 percent for 30 years)	$ 890,920	$ 1,094,470
Operation and Maintenance (Including Plant Pumping Costs & HSPS Maintenance)	$ 720,300	$ 885,870
HSPS Energy Costs (653,496 kWh @ $0.06/kWh)	$ 39,210	$ 52,280
Total Annual Costs	**$ 1,650,430**	**$ 2,032,620**
Available Project Yield (ac-ft/yr)	**1,680**	**1,680**
Annual Cost of Water ($ per ac-ft)	**$ 982**	**$ 1,210**
Annual Cost of Water ($ per 1,000 gallons)	**$ 3.02**	**$ 3.71**

Notes:
1. 2009 Costs were reduced to 2002 Costs using 3% Inflation per year over 7 years.
2. 2009 Power Costs are based on $0.08/kWh. 2002 costs are based on $0.06/kWh.

Professional services, contingencies, and interest during construction will add $3,327,460, for a total project cost of $12,271,560. (At 2009 prices, the estimated cost is $15,075,325.) With 6 percent interest and 30-year bonds, the annual debt service is $890,920. Operation and maintenance costs for pumping, transmission, and treatment add $759,510 per year, for a total annual cost of $1,650,430 (at 2002 prices) for delivery of 1,680 acre-feet. The cost of treated water delivered is $982 per acre-foot, or $3.02 per thousand gallons.

Table 3 summarizes the capital costs for expansions to the plant in Phases 2 through 4. Phases 2 will total $14,635,800 (2002 dollars). Professional services, contingencies, and interest during construction will add $5,132,035, for a total project cost of $19,767,835. (At 2009 prices, the estimated cost is $24,311,700.) With 6 percent interest and 30-year bonds, the annual debt service is $1,435,145. Phase 3 capital costs will total $7,317,900 (2002 dollars). Professional services, contingencies, and interest during construction will add $2,565,985, for a total project cost of $9,882,985. (At 2009 prices, the estimated cost is $12,155,850.) With 6 percent interest and 30-year bonds, the annual debt service is $717,505. Operation and maintenance costs for pumping, transmission and treatment will increase as each expansion is brought on-line. Costs for Phase 2 will add $1,774,300 per year, and will increase up to $2,789,120 in Phase 4. Total annual costs will be $4,100,365 (at 2002 prices) for Phase 2 and will increase up to $3,985,010 (at 2002 prices) for Phase 4. The Phase 2 expansion to the plant will increase the supply by 3,360 acre-feet, and Phase 4 & 5 expansion will increase the available supply by 1,680 acre-feet. The cost of treated water delivered is $814 per acre-foot or $2.50 per thousand gallons, $660 per acre-foot or $2.03 per thousand gallons, and $474 per acre-foot or $1.45 per thousand gallons for Phase 2, Phase 3, and Phase 4, respectively.

Table 3
Cost Estimate Summary for
City of Granbury Water Supply Project Phases 2 through 5
(Second Quarter 2002 Prices and 2009 Prices)

Item	Estimated Cost for Facilities (2002 $)	Estimated Cost for Facilities (2009 $)
PHASE 2 (4.5 MGD)		
Capital Costs		
3 MGD Expansion to Water Treatment Plant (Including Expansion to HSPS)	$ 14,635,800	$ 18,000,000
Total Capital Costs	**$ 14,635,800**	**$ 18,000,000**
Contingencies	$ 2,357,990	$ 2,900,000
Engineering, Permitting, Survey, and Geotech	$ 2,032,750	$ 2,500,000
Interest During Construction (1 year)	$ 741,295	$ 911,700
Total Project Costs	**$ 19,767,835**	**$ 24,311,700**

Table 3 (Continued)

Annual Costs				
Debt Service (6 percent for 30 years)	$	1,435,145	$	1,765,030
Debt Service of Phase 1	$	890,920	$	1,094,470
Operation and Maintenance (Including Plant Pumping Costs & HSPS Maintenance)	$	1,656,670	$	2,037,475
HSPS Energy Costs (1,960,488 kWh @ $0.06/kWh)	$	117,630	$	156,840
Total Annual Costs	**$**	**4,100,365**	**$**	**5,053,815**
Available Project Yield (ac-ft/yr)		**5,040**		**5,040**
Annual Cost of Water ($ per ac-ft)	**$**	**814**	**$**	**1,003**
Annual Cost of Water ($ per 1,000 gallons)	**$**	**2.50**	**$**	**3.08**
PHASE 3 (6 MGD)				
Capital Costs				
1.5 MGD Expansion to Water Treatment Plant (Including Expansion to HSPS)	$	7,317,900	$	9,000,000
Total Capital Costs	**$**	**7,317,900**	**$**	**9,000,000**
Contingencies	$	1,178,995	$	1,450,000
Engineering, Permitting, Survey, and Geotech	$	1,016,375	$	1,250,000
Interest During Construction (1 year)	$	370,615	$	455,850
Total Project Costs	**$**	**9,882,985**	**$**	**12,155,850**
Annual Costs				
Debt Service (6 percent for 30 years)	$	717,505	$	882,515
Debt Service of Phase 2	$	1,435,145	$	1,765,030
Operation and Maintenance (Including Plant Pumping Costs & HSPS Maintenance)	$	2,124,870	$	2,613,295
HSPS Energy Costs (2,613,984 kWh @ $0.06/kWh)	$	156,840	$	209,120
Total Annual Costs	**$**	**4,434,360**	**$**	**5,469,960**
Available Project Yield (ac-ft/yr)		**6,720**		**6,720**
Annual Cost of Water ($ per ac-ft)	**$**	**660**	**$**	**814**
Annual Cost of Water ($ per 1,000 gallons)	**$**	**2.03**	**$**	**2.50**
PHASE 4 (7.5 MGD)				
Capital Costs				
1.5 MGD Expansion to Water Treatment Plant (Including Expansion to HSPS)	$	4,878,600	$	6,000,000
Total Capital Costs	**$**	**4,878,600**	**$**	**6,000,000**
Contingencies	$	780,580	$	960,000
Engineering, Permitting, Survey, and Geotech	$	683,000	$	840,000
Interest During Construction (1 year)	$	247,100	$	303,900
Total Project Costs	**$**	**6,589,280**	**$**	**8,103,900**

Table 3 (Continued)

Annual Costs				
Debt Service (6 percent for 30 years)	$	478,385	$	588,345
Debt Service of Phase 3	$	717,505	$	882,515
Operation and Maintenance (Including Plant Pumping Costs & HSPS Maintenance)	$	2,593,070	$	3,189,120
HSPS Energy Costs (3,267,480 kWh @ $0.06/kWh)	$	196,050	$	261,400
Total Annual Costs	**$**	**3,985,010**	**$**	**4,921,380**
Available Project Yield (ac-ft/yr)		**8,400**		**8,400**
Annual Cost of Water ($ per ac-ft)	**$**	**474**	**$**	**586**
Annual Cost of Water ($ per 1,000 gallons)	**$**	**1.45**	**$**	**1.80**

Notes:

1. 2009 Costs were reduced to 2002 Costs using 3% Inflation per year over 7 years.
2. 2009 Power Costs are based on $0.08/kWh. 2002 costs are based on $0.06/kWh.

Table 4 summarizes the capital costs for the City of Granbury Water Supply Project. The construction of the new water treatment plant and expansions would supply a total of about 7.5 MGD for the City of Granbury and the total estimated capital cost will be $48,511,660.

Table 4
Capital Cost Summary for City of Granbury Water Supply Project
(Second Quarter 2002 Prices)

Project Description	Estimated Supply	Estimated Capital Costs
Phase 1 - New Water Treatment Plant	1.5 MGD	$12,271,560
Phase 2 - Water Treatment Plant Expansion	3.0 MGD	$19,767,835
Phase 3 - Water Treatment Plant Expansion	1.5 MGD	$9,882,985
Phase 4 - Water Treatment Plant Expansion	1.5 MGD	$6,589,280
Total	**7.5 MGD**	**$48,511,660**

7. Implementation Issues

The City of Granbury will encounter implementation issues including financing and Section 404 permitting. As shown in Table 5, this water management strategy has been compared to the plan development criteria.

8. Potential Regulatory Requirements

Implementation of this water management strategy will require the following permits for construction of the treatment plant and raw water intake:

- U.S. Army Corps of Engineers Section 404 permit for raw water intake construction.
- NPDES Stormwater Pollution Prevention Plans.
- Possibly TP&WD Sand, Shell, Gravel, and Marl permits for construction in state owned stream beds.

Table 5
Comparison of City of Granbury Water Supply Project to Plan Development Criteria

Impact category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient for local needs.
2. Reliability	2. High.
3. Cost	3. Relatively high, but reasonable compared to other treatment plants.
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.

4B.21.3 Palo Pinto County MWD No. 1 Amendment

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BRAZOS G
WATER PLANNING GROUP

BRAZOS RIVER AUTHORITY, Administrative Agent
P.O. Box 7555 υ Waco, Texas 76714-7555
(254) 761-3100 υ Fax (254) 761-3204

June 4, 2008

To: Interested Parties

Re: Amendment to the 2006 Brazos G Regional Water Plan related to the Palo Pinto County Municipal Water District No. 1

The Brazos G Regional Water Planning Group hereby amends the 2006 Brazos G Regional Water Plan as follows:

1. **Substitute Turkey Peak Reservoir for the Lake Palo Pinto Off-Channel Reservoir as the Recommended Water Management Strategy for the Palo Pinto County Municipal Water District No. 1, and Designate the Lake Palo Pinto Off-Channel Reservoir as an alternative water management strategy.**
   The Palo Pinto County Municipal Water District No. 1 has completed geotechnical, costing and environmental studies of the proposed Lake Palo Pinto Off-Channel Reservoir (Wilson Hollow site), and determined that Turkey Peak Reservoir is the preferred project. Both projects were evaluated during the development of the 2006 Brazos G Regional Water Plan, and Turkey Peak Reservoir was identified as an alternative to the Lake Palo Pinto Off-Channel Reservoir. Pursuant to 31 TAC §357.7(a)(7)(H), Turkey Peak Reservoir is substituted as the recommended water management strategy for the Palo Pinto County Municipal Water District No. 1, and the Lake Palo Pinto Off-Channel Reservoir is designated as an alternative water management strategy.

The revised plan for the Palo Pinto County Municipal Water District No. 1 is shown in Attachment A.

4C.38.10 Palo Pinto County Municipal Water District No. 1

4C.38.10.1 Description of Supply

Palo Pinto County MWD No. 1 obtains its water supply from Lake Palo Pinto. Based on the available surface water supply, Palo Pinto County MWD No. 1 is projected to have a surplus of 396 acft/yr in the year 2010 and a shortage of 1,821 acft/yr in the year 2060.

4C.38.10.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended to meet the projected shortage of the Palo Pinto County MWD No. 1:

- **Turkey Peak Reservoir (Volume II, Section 4B.12.5)**
  This project would restore permitted storage in the Lake Palo Pinto System, thus restoring existing permitted yield.
- **Alternative: Lake Palo Pinto Off-Channel Reservoir (Volume II, Section 4B.13.6)**

4C.38.10.3 Costs

Costs of the Recommended Plan for the Palo Pinto County MWD No. 1.

a. Turkey Peak Reservoir:
   - Cost Source: Volume II, Section 4B.12.5
   - Date to be Implemented: before 2020
   - Total Project Cost: $46,150,000
   - Annual Cost: $3,401,000

Table 4C.38-8.
Recommended Plan Costs by Decade for the Palo Pinto County MWD No. 1

Plan Element	*2010*	*2020*	*2030*	*2040*	*2050*	*2060*
Projected Surplus/(Shortage) (acft/yr)	396	(59)	(492)	(879)	(1,328)	(1,821)
Turkey Peak Reservoir						
Supply From Plan Element (acft/yr)	—	8,648	8,648	8,648	8,648	8,648
Annual Cost (million $/yr)	—	$3.401	$3.401	$3.401	$3.401	$3.401
Unit Cost ($/acft)	—	$393	$393	$393	$393	$393

4B.21.4 Somervell County MWD Amendment

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BRAZOS G
WATER PLANNING GROUP

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(254) 761-3100 υ Fax (254) 761-3204

June 4, 2008

To: Interested Parties

Re: Amendment to the 2006 Brazos G Regional Water Plan related to the Somervell County Water Supply Project

The Brazos G Regional Water Planning Group hereby amends the 2006 Brazos G Regional Water Plan as follows:

1. **Recommend the Somervell County Water Supply Project to Meet Future Water Supply Needs for Various Entities in Somervell County.** The Somervell County Water District has recently completed the Wheeler Branch Off-Channel Reservoir Project, which is a recommended water management strategy to meet County-Other municipal needs in Somervell County. The Somervell County Water Supply Project will treat raw water from the Wheeler Branch Reservoir and transmit the treated supply to various customers of the Somervell County Water District, specifically the City of Glen Rose, various customers included in County-Other, and Steam-Electric demands (process water and potable supply at the Comanche Peak Station), as shown in Attachment A, which is the revised plan for Somervell County. A detailed technical evaluation of the water management strategy is included in Attachment B.

4C.30 Somervell County Water Supply Plan

Table 4C.30-1 lists each water user group in Somervell County and their corresponding surplus or shortage in years 2030 and 2060. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 4C.30-1.
Somervell County Surplus/(Shortage)

Water User Group	Surplus/(Shortage)[1] 2030 (acft/yr)	2060 (acft/yr)	Comment
City of Glen Rose	38	37	Projected surplus
County-Other	(231)	(260)	Projected shortage – see plan below
Manufacturing	(4)	(7)	Projected shortage – see plan below
Steam-Electric	25,570	25,510	Projected surplus
Mining	(94)	(85)	Projected shortage – see plan below
Irrigation	945	953	Projected surplus
Livestock	0	0	Supply equals demand

[1] From Tables C-59 and C-60, Appendix C – Comparison of Water Demands with Water Supplies to Determine Needs.

4C.30.1 The City of Glen Rose

4C.30.1.1 Description of Supply

The City of Glen Rose obtains groundwater from the Trinity Aquifer. No shortage is projected for the City of Glen Rose. However, Glen Rose may obtain supplemental surface water supplies from the Somervell County Water Supply Project.

4C.30.1.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended to supplement existing supplies for the City of Glen Rose:

- Somervell County Water Supply Project – the project will treat raw water from Wheeler Branch Off-Channel Reservoir and transmit the treated water to customers of the Somervell County Water District.

4C.30.1.3 Costs

Costs of the Somervell County Water Supply Project are discussed in Section 4C.30.2.3 below.

Table 4C.30-1.
Recommended Plan Costs by Decade for the City of Glen Rose

Plan Element	*2010*	*2020*	*2030*	*2040*	*2050*	*2060*
Projected Surplus/(Shortage) (acft/yr)	57	46	38	36	36	37
Somervell County Water Supply Project (Phases 1 – 4)*						
Supply From Plan Element (acft/yr)	340	340	340	340	340	340
Annual Cost ($/yr)	$808,188	$808,188	$808,188	$143,974	$143,974	$143,974
Unit Cost ($/acft)	$2,377	$2,377	$2,377	$423	$423	$423
Somervell County Water Supply Project (Phases 5 – 13)*						
Supply From Plan Element (acft/yr)	–	–	260	260	260	260
Annual Cost ($/yr)	–	–	$249,488	$249,488	$249,488	$44,402
Unit Cost ($/acft)	–	–	$960	$960	$960	$171

* Note: This supply is from the Wheeler Branch Reservoir, which has been implemented. The project is for development of treatment and transmission facilities.

4C.30.2 County-Other

4C.30.2.1 Description of Supply

Somervell County-Other obtains its water supply from groundwater from the Trinity Aquifer. Based on the available groundwater supply, Somervell County-Other is projected to have a shortage of 231 acft/yr in the year 2030 and 260 acft/yr in the year 2060.

4C.30.2.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended to meet the projected shortage of Somervell County-Other:

- Wheeler Branch Off-Channel Reservoir – the project has obtained a water rights permit from the TCEQ and is projected to be completed by 2010
- Somervell County Water Supply Project – the project will treat raw water from Wheeler Branch Off-Channel Reservoir and transmit the treated water to customers of the Somervell County Water District.

- Conservation was also considered; however, the County-Other's per capita use rate is below the selected target rate of 140 gpcd.

4C.30.2.3 Costs

Costs of the Recommended Plan for Somervell County-Other.

a. Wheeler Branch Off-Channel Reservoir:
   - Cost Source: Volume II, Section 4B.13.3
   - Date to be Implemented: before 2010
   - Total Project Cost: $27,195,000
   - Annual Cost: $2,117,000

b. Somervell County Water Supply Project:
   - Cost Source: Somervell County Water District
   - Date to be Implemented: before 2010, with future phases
   - Total Project Cost: $87,226,800 (Phases 1 – 13). (Excluding retail distribution, the cost is $35,159,900.(
   - Annual Cost: $7,659,700 (Phases 1 – 13). (Excluding retail distribution, the annual cost is $3,109,800.)

Table 4C.30-2.
Recommended Plan Costs by Decade for Somervell County-Other

Plan Element	*2010*	*2020*	*2030*	*2040*	*2050*	*2060*
Projected Surplus/(Shortage) (acft/yr)	(133)	(189)	(231)	(251)	(257)	(260)
Wheeler Branch Off-Channel Reservoir						
Supply From Plan Element (acft/yr)	1,800	1,800	1,800	1,800	1,800	1,800
Annual Cost ($/yr)	$2,117,000	$2,117,000	$2,117,000	$2,117,000	$2,117,000	$2,117,000
Unit Cost ($/acft)	$1,176	$1,176	$1,176	$1,176	$1,176	$1,176
Somervell County Water Supply Project (Phases 1 – 4)*						
Supply From Plan Element (acft/yr)	200	200	200	200	200	200
Annual Cost ($/yr)	$475,405	$475,405	$475,405	$84,690	$84,690	$84,690
Unit Cost ($/acft)	$2,377	$2,377	$2,377	$423	$423	$423
Somervell County Water Supply Project (Phases 5 – 13)*						
Supply From Plan Element (acft/yr)	–	–	516	516	516	516
Annual Cost ($/yr)	–	–	$495,138	$495,138	$495,138	$88,120
Unit Cost ($/acft)	–	–	$960	$960	$960	$171

* Note: This supply is from the Wheeler Branch Reservoir, which has been implemented. The project is for development of treatment and transmission facilities.

4C.30.3 Manufacturing

4C.30.3.1 Description of Supply

Somervell County Manufacturing obtains its water supply from groundwater from the Trinity Aquifer. Based on the available groundwater supply, Somervell County Manufacturing is projected to have a shortage of 4 acft/yr in the year 2030 and 7 acft/yr in the year 2060.

4C.30.3.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended to meet the projected shortage of Somervell County Manufacturing:

- Conservation, and
- Purchase water from the City of Glen Rose.

4C.30.3.3 Costs

Costs of the Recommended Plan for Somervell County Manufacturing.

a. Conservation:
   - Date to be Implemented: before 2010
   - Annual Cost: Not determined

b. Water Supply from City of Glen Rose:
   - Cost Source: estimated wholesale treated water rate
   - Date to be Implemented: By year 2010
   - Annual Cost: $16,161 in 2060

   The annual cost was calculated by multiplying the Manufacturing projected supply from this strategy by an estimated wholesale water rate of $162/acft.

Table 4C.30-3.
Recommended Plan Costs by Decade for Somervell County Manufacturing

Plan Element	2010	2020	2030	2040	2050	2060
Projected Surplus/(Shortage) (acft/yr)	(2)	(3)	(4)	(5)	(6)	(7)
Conservation						
Supply From Plan Element (acft/yr)	0	0	1	1	1	1
Annual Cost ($/yr)	—	—	—	—	—	—
Unit Cost ($/acft)	—	—	—	—	—	—
Water Supply from City of Glen Rose						
Supply From Plan Element (acft/yr)	10	10	10	10	10	10
Annual Cost ($/yr)	$16,161	$16,161	$16,161	$16,161	$16,161	$16,161
Unit Cost ($/acft)	$162	$162	$162	$162	$162	$162

4C.30.4 Steam-Electric

4C.30.4.1 Description of Supply

Somervell County Steam-Electric is projected to have a surplus of water through 2060. Potable water for plant staff and high-quality process water for boiler feed at the Comanche Peak Steam Electric Station is currently provided from local groundwater. When the Somervell County Water Supply Project is developed, some potable water and process water for the plant will be obtained from the project.

4C.30.4.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended to supplement existing supplies for Somervell County Steam-Electric:

- Somervell County Water Supply Project – the project will treat raw water from Wheeler Branch Off-Channel Reservoir and transmit the treated water to customers of the Somervell County Water District.
- Conservation was also considered; however, the Somervell County Steam-Electric is already exercising substantial conservation.

4C.30.4.3 Costs

Costs of the Somervell County Water Supply Project are discussed in Section 4C.30.2.3 above.

Table 4C.30-4.
Recommended Plan Costs by Decade for Somervell County Steam-Electric

Plan Element	2010	2020	2030	2040	2050	2060
Projected Surplus/(Shortage) (acft/yr)						
Somervell County Water Supply Project (Phases 1 – 4)*						
Supply From Plan Element (acft/yr)	300	300	300	300	300	300
Annual Cost ($/yr)	$713,107	$713,107	$713,107	$127,036	$127,036	$127,036
Unit Cost ($/acft)	$2,377	$2,377	$2,377	$423	$423	$423
Somervell County Water Supply Project (Phases 5 – 13)*						
Supply From Plan Element (acft/yr)	–	–	184	184	184	184
Annual Cost ($/yr)	–	–	$176,561	$176,561	$176,561	$31,423
Unit Cost ($/acft)	–	–	$960	$960	$960	$171

* Note: This supply is from the Wheeler Branch Reservoir, which has been implemented. The project is for development of treatment and transmission facilities.

4C.30.5 Mining

4C.30.5.1 Description of Supply

Somervell County Mining obtains its water supply from groundwater from the Trinity Aquifer. Based on the available groundwater supply, Somervell County Mining is projected to have a shortage of 94 acft/yr in the year 2030 and 85 acft/yr in the year 2060.

4C.30.5.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended to meet the projected shortage of Somervell County Mining:

- Conservation, and
- Voluntary Redistribution from Steam-Electric.

4C.30.5.3 Costs

Costs of the Recommended Plan for Somervell County Mining.

a. Conservation:
  - Date to be Implemented: before 2010
  - Annual Cost: Not determined

b. Voluntary Redistribution from Steam-Electric:
  - Cost Source: assumed unit cost for raw water transfer between entities
  - Date to be Implemented: before 2010
  - Unit Cost: $75/acft
  - Annual Cost: $11,250

Table 4C.30-4.
Recommended Plan Costs by Decade for Somervell County Mining

Plan Element	*2010*	*2020*	*2030*	*2040*	*2050*	*2060*
Projected Surplus/(Shortage) (acft/yr)	(106)	(98)	(94)	(91)	(88)	(85)
Conservation						
Supply From Plan Element (acft/yr)	9	14	19	19	18	18
Annual Cost ($/yr)	—	—	—	—	—	—
Unit Cost ($/acft)	—	—	—	—	—	—
Voluntary Redistribution from Steam-Electric						
Supply From Plan Element (acft/yr)	150	150	150	150	150	150
Annual Cost ($/yr)	$11,250	$11,250	$11,250	$11,250	$11,250	$11,250
Unit Cost ($/acft)	$75	$75	$75	$75	$75	$75

4C.30.6 Irrigation

Somervell County Irrigation is projected to have a surplus of water through 2060 and no changes in water supply are recommended.

4C.30.7 Livestock

No shortages are projected for Somervell County Livestock and no changes in water supply are recommended.

Request for Amendment to the Region G Water Plan to Add Development of the Somervell County Water Supply Project

1. Background

The *2006 Brazos G Regional Water Plan* included the Wheeler Branch Off-Channel Reservoir as a water management strategy to address water supply needs in Somervell County. The Somervell County Water District has now constructed the reservoir and the associated raw water supply facilities. To make a potable water supply available for use in Glen Rose and Somervell County, the District now wishes to develop a water treatment plant and a transmission system to deliver water to wholesale and retail customers.

Luminant Power owns and operates the Comanche Peak Steam Electric Generating Station in Somervell County. Luminant would like to purchase water from the Somervell County Water District to provide potable water for the plant and high quality process water.

The Texas Water Development Board has determined that the treatment plant and transmission system needed to implement the Somervell County Water Project are not consistent with the *2006 Brazos G Regional Water Plan*. On March 24, 2008, Kevin Taylor, general manager of the Somervell County Water District, wrote to Scott Mack, Chair of the Brazos G Water Planning Group, requesting an amendment to the *2006 Brazos G Regional Water Plan* to add the development of the Somervell County Water Supply Project.

2. Amendment Request

The Somervell County Water District asks that the *2006 Brazos G Regional Water Plan* be amended to add the Somervell County Water Project, which includes:

- Development of a water treatment plant and high service pump station and later expansion.
- Development of transmission facilities to deliver water to wholesale and retail customers.
- Use of the water to meet municipal, manufacturing, steam electric generation, mining, irrigation, and livestock needs in Somervell County.

The District believes that this amendment meets the Texas Water Development Board criteria for a minor amendment to the *2006 Brazos G Regional Water Plan*, as laid out in Texas Administrative Code Rule 357.16:

- It does not result in over allocation of an existing or planned source of water. The amendment does not change the allocation of any source of supply.
- It does not relate to a new reservoir. The amendment only relates to the development of treatment and transmission facilities.
- It does not have a significant impact on instream flows, environmental flows, or freshwater flows to bays and estuaries.
- It does not have a significant impact on water planning or previously adopted management strategies.
- It does not delete or change any legal requirements of the plan.

If the Brazos G Regional Planning Group or the Texas Water Development Board determines that the requested amendment cannot be processed as a minor amendment, the District requests that it be processed as a major amendment.

3. Description of Strategy

Somervell County currently obtains all of its water supply from the Trinity Aquifer. As indicated in the U.S. Corps of Engineers "Department of the Army Evaluation and Decision Document" for the Section 404 permit obtained for Wheeler Branch Reservoir [Corps of Engineers, 2005]:

> "The Trinity aquifer is heavily used and is currently being over-drafted in Somervell County…. Measurements by the Texas Water Development Board (TWDB) show that water levels of the Glen Rose municipal well No. 2 have declined by over 130 feet since 1974. The current need for municipal water in Somervell County is approximately 1,000 acre-feet per year and is projected to increase to approximately 2,500 acre-feet per year by 2050. According to Senate Bill One evaluations, the current available municipal supply in the county is 773 acre-feet per year. To meet future demands, the county would need to develop approximately 2,000 acre-feet of additional supply by 2050. This amount would enable the District to meet all anticipated needs of Glen Rose through 2050 and about 70 percent of the expected requirements for the remainder of the county."

The development of the proposed treatment and transmission facilities is necessary to allow use of this surface water supply and relieve overuse of groundwater in this growing county.

Figure 1.1 is a map showing Phases 1 though 4 of the proposed Somervell County Water Supply Project. This part of the project is planned for development in the near future (completion shortly after 2010). Figure 1.2 shows the entire proposed project, including Phases 5 through 13, which are planned for future development. Figures 1.1 and 1.2 are at the end of this memorandum.

Phases 1 through 4 include development of a 1.5 mgd water treatment plant below the Wheeler Branch Dam, along with a transmission system to deliver the treated water to wholesale customers and some retail customers. Phases 5 through 13 include expansion of the plant to 5 mgd and development of the remaining transmission facilities needed to serve the entire county.

4. Available Supply

The Somervell County Water District has a water right for 2,000 acre-feet per year from the Wheeler Branch Reservoir. The District has a subordination agreement with the Brazos River Authority that makes the 2,000 acre-feet per year available on a reliable basis. The proposed Somervell County Water Project, which is the subject of this amendment, will make 2,000 acre-feet pear year available as potable water (840 acre-feet per year from Phases 1 through 4 and 1,160 acre-feet per year from Phases 5 through 13).

5. Environmental

Environmental impacts could include:

- Possible minor impacts on 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 1.

Table 1
Environmental Issues:
Somervell County Water Supply Project

Water Management Option	Somervell County Water Supply Project
Implementation Measures	Construction of a 5.0 mgd water treatment plant, pump stations, ground and elevated storage tanks, and pipelines (156.2 miles)
Environmental Water Needs/Instream Flows	Negligible impact.
Bays and Estuaries	Negligible impact.
Fish and Wildlife Habitat	Possible minor impacts on riparian corridors, depending on specific location of pipelines.
Cultural Resources	Possible low impact.
Threatened and Endangered Species	Possible low impact.

6. Engineering and Costing

Figures 1 and 2 show the facilities required to develop the Somervell County Water Project. Water from Wheeler Branch Reservoir will be 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. Phases 1 through 4 will include a 1.5 mgd water treatment plant and high service pump station, 1 booster pump station, 2 ground storage tanks, 1 elevated tank, and 30.5 miles of pipeline ranging from 6 inches to 18 inches in diameter. Phases 5 through 13 will include expanding the water treatment plant and high service pump station to 5.0 mgd, 5 booster pump stations, 4 ground storage tanks, 4 elevated tanks, and 125.7 miles of pipeline ranging from 6 inches to 12 inches in diameter.

Table 2 summarizes the capital costs for Phases 1 through 4, which total $17,099,200 using the 2002 costs assumed in the *2006 Brazos G Regional Water Plan.*

Table 2
Cost Estimate Summary for
Somervell County Water Supply Project Phases 1 through 4
(Second Quarter 2002 Prices and 2008 Prices)

Item	Estimated Cost for Retail Facilities (2002 $)	Estimated Cost for Wholesale Facilities (2002 $)	Estimated Cost for Facilities (2002 $)	Estimated Cost for Facilities (2008 $)
Capital Costs				
6" WL and Appurtenances	$ 315,100	$ -	$ 315,100	$ 376,200
8" WL and Appurtenances	$ 663,300	$ 187,900	$ 851,200	$ 1,016,400
10" WL and Appurtenances	$ -	$ 488,300	$ 488,300	$ 583,000
12" WL and Appurtenances	$ 447,700	$ 3,697,900	$ 4,145,600	$ 4,950,000
16" WL and Appurtenances	$ -	$ 2,726,900	$ 2,726,900	$ 3,256,000
18" WL and Appurtenances	$ -	$ 323,400	$ 323,400	$ 386,100
Boring and Casing	$ 167,500	$ 376,900	$ 544,400	$ 650,000
Installation through Rock	$ 70,400	$ 511,000	$ 581,400	$ 694,200
Pavement Repair	$ 32,200	$ 202,300	$ 234,500	$ 280,000
New 1.5 MGD Water Treatment Plant	$ -	$ 4,187,500	$ 4,187,500	$ 5,000,000
1.5 MGD HSPS	$ -	$ 418,800	$ 418,800	$ 500,000
Ground Storage Tanks	$ -	$ 837,500	$ 837,500	$ 1,000,000
Elevated Storage Tanks	$ -	$ 1,046,900	$ 1,046,900	$ 1,250,000
Booster Pump Station	$ -	$ 397,800	$ 397,800	$ 475,000
Total Capital Costs	**$ 1,696,200**	**$ 15,403,000**	**$ 17,099,200**	**$ 20,416,900**
Contingencies	$ 339,200	$ 3,080,600	$ 3,419,800	$ 4,083,380
Engineering, Permitting, Survey, and Geotech	$ 305,300	$ 2,772,500	$ 3,077,800	$ 3,675,042
Land Costs	$ 47,100	$ 262,800	$ 309,900	$ 370,000
Power Supply Costs	$ -	$ 128,100	$ 128,100	$ 152,919
Interest During Construction (1 year)	$ 101,800	$ 924,200	$ 1,025,900	$ 1,225,014
Total Project Costs	**$ 2,489,600**	**$ 22,571,200**	**$ 25,060,800**	**$ 29,923,300**
Annual Costs				
Debt Service (6 percent for 30 years)	$ 181,000	$ 1,641,000	$ 1,822,000	$ 2,175,000
Operation and Maintenance	$ 37,700	$ 338,400	$ 376,000	$ 449,000
Energy Costs (319,800 kWh @ $0.06/kWh)	$ 1,903	$ 17,285	$ 19,188	$ 25,584
Total Annual Costs	**$ 220,600**	**$ 1,996,700**	**$ 2,217,200**	**$ 2,649,600**
Available Project Yield (ac-ft/yr)		**840**	**840**	**840**
Annual Cost of Water ($ per ac-ft)		**$ 2,377**	**$ 2,640**	**$ 3,154**
Annual Cost of Water ($ per 1,000 gallons)		**$ 7.30**	**$ 8.10**	**$ 9.68**

Notes:
1. 2008 Costs were reduced to 2002 Costs using 3% Inflation per year over 6 years.
2. 2008 Power Costs are based on $0.08/kWh. 2002 power costs are $0.06/kWh.

Professional services, land costs, power supply costs, contingencies, and interest during construction will add $7,961,500, for a total project cost of $25,060,800. (At 2008 prices, the estimated cost is $29,923,300.) With 6 percent interest and 30-year bonds, the annual debt service is $1,822,000. Operation and maintenance costs for pumping, transmission, and treatment add $395,200 per year, for a total annual cost of $2,217,200 (at 2002 prices) for delivery of 840 acre-feet. The cost of treated water delivered is $2,640 per acre-foot, or $8.10 per thousand gallons. This relatively high cost is associated with the development of a new surface water supply system for a relatively small volume of water. The cost of treated water delivered considering only wholesale facilities is $2,377 per acre-foot, or $7.30 per thousand gallons.

Table 3 summarizes the capital costs for Phases 5 through 13, which total $42,263,100 using the 2002 costs assumed in the *2006 Brazos G Regional Water Plan.* Professional services, land costs, power supply costs, contingencies, and interest during construction will add $19,902,900, for a total project cost of $62,166,000. (At 2008 prices, the estimated cost is $74,228,100.) With 6 percent interest and 30-year bonds, the annual debt service is $4,519,000. Operation and maintenance costs for pumping, transmission and treatment add $923,500 per year, for a total annual cost of $5,442,500 (at 2002 prices) for delivery of 1,160 acre-feet. The cost of treated water delivered is $4,692 per acre-foot, or $14.40 per thousand gallons. This cost is associated with the development of a retail distribution system in a rural environment, where a lot of pipeline is needed per customer. Most of the costs of Phases 5 through 13 are associated with the retail distribution system, since Glen Rose and the Comanche Peak Steam Electric Station are the only significant wholesale customers in the county. The wholesale costs are $960 per acre-foot, or $2.95 per thousand gallons. Of course, it is possible that other wholesale customers will develop before the system is actually built.

Table 3
Cost Estimate Summary for
Somervell County Water Supply Project Phases 5 through 13
(Second Quarter 2002 Prices and 2008 Prices)

Item	Estimated Cost for Retail Facilities (2002 $)	Estimated Cost for Wholesale Facilities (2002 $)	Estimated Cost for Facilities (2002 $)	Estimated Cost for Facilities (2008 $)
Capital Costs	$ 2,846,700	$ -	$ 2,846,700	$ 3,399,000
6" WL and Appurtenances	$ 14,572,300	$ 845,700	$ 15,418,000	$ 18,409,600
8" WL and Appurtenances	$ 2,197,200	$ -	$ 2,197,200	$ 2,623,500
10" WL and Appurtenances	$ 4,666,900	$ 176,900	$ 4,843,800	$ 5,783,600
12" WL and Appurtenances	$ 1,423,800	$ 50,300	$ 1,474,000	$ 1,760,000
Boring and Casing	$ 1,554,600	$ -	$ 1,554,600	$ 1,856,200
Installation through Rock	$ 853,000	$ 82,100	$ 935,100	$ 1,116,500
Pavement Repair	$ -	$ 5,862,500	$ 5,862,500	$ 7,000,000
Water Treatment Plant Expansion to 5 MGD	$ -	$ 963,100	$ 963,100	$ 1,150,000
HSPS Expansion to 5 MGD	$ 213,600	$ -	$ 213,600	$ 255,000
Flow Control Valves	$ 1,549,400	$ -	$ 1,549,400	$ 1,850,000
Ground Storage Tanks	$ 3,643,100	$ -	$ 3,643,100	$ 4,350,000
Elevated Storage Tanks	$ 762,100	$ -	$ 762,100	$ 910,000
Booster Pump Station	**$ 34,282,600**	**$ 7,980,500**	**$ 42,263,100**	**$ 50,463,400**
Total Capital Costs				
	$ 6,856,500	$ 1,596,100	$ 8,452,600	$ 10,092,680
Contingencies	$ 6,170,900	$ 1,436,500	$ 7,607,400	$ 9,083,412
Engineering, Permitting, Survey, and Geotech	$ 210,400	$ 920,200	$ 1,130,600	$ 1,350,000
Land Costs	$ -	$ 176,600	$ 176,600	$ 210,850
Power Supply Costs	$ 2,057,000	$ 478,800	$ 2,535,800	$ 3,027,804
Interest During Construction (1 year)	**$ 49,577,400**	**$ 12,588,700**	**$ 62,166,000**	**$ 74,228,100**
Total Project Costs				
Annual Costs				
Debt Service (6 percent for 30 years)	$ 3,604,000	$ 915,000	$ 4,519,000	$ 5,396,000
Operation and Maintenance	$ 743,700	$ 188,400	$ 872,300	$ 1,113,000
Energy Costs (852,700 kWh @ $0.06/kWh)	$ 41,501	$ 9,661	$ 51,162	$ 68,216
Total Annual Costs	**$ 4,389,200**	**$ 1,113,100**	**$ 5,442,500**	**$ 6,577,200**
Available Project Yield (ac-ft/yr)		**1160**	**1160**	**1160**
Annual Cost of Water ($ per ac-ft)		**$ 960**	**$ 4,692**	**$ 5,670**
Annual Cost of Water ($ per 1,000 gallons)		**$ 2.95**	**$ 14.40**	**$ 17.40**

Notes:

1. 2008 Costs were reduced to 2002 Costs using 3% Inflation per year over 6 years.
2. 2008 Power Costs are based on $0.08/kWh. 2002 costs are based on $0.06/kWh.

7. Implementation Issues

The Somervell County Water District will need to reach agreements with the City of Glen Rose and Comanche Peak Steam Electric Station as wholesale customers to implement this water management strategy. Other implementation issues will include financing and Section 404 permitting. As shown in Table 4, this water management strategy has been compared to the plan development criteria.

8. 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.
- NPDES Stormwater Pollution Prevention Plans.
- Possibly TP&WD Sand, Shell, Gravel, and Marl permits for construction in state-owned stream beds.

Table 4
Comparison of Somervell County Water Supply Project to Plan Development Criteria

Impact category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient for local needs.
2. Reliability	2. High.
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.

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4B.21.5 Somervell County Steam-Electric (Luminant) Amendment

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BRAZOS G
WATER PLANNING GROUP

BRAZOS RIVER AUTHORITY, Administrative Agent
P.O. Box 7555 υ Waco, Texas 76714-7555
(254) 761-3100 υ Fax (254) 761-3204

July 9, 2008

To: Interested Parties

Re: Amendments to the 2006 Brazos G Regional Water Plan related to Steam Electric Water Demands in Somervell County

Brazos G Regional Water Planning Group has recommended to the Texas Water Development Board to amend the Steam-Electric demand in Somervell County as follows:

1. **Increased Steam Electric Demands in Somervell County**
   Due to plans by Luminant Power to develop two new 1,700 MW nuclear generating units adjacent to the existing Comanche Peak Station, consumptive Steam Electric water demands in Somervell County will increase from 23,200 acre-feet per year (acft/yr) to 84,817 acft/yr, an increase of 61,617 acft/yr.

The Brazos G Regional Water Planning Group hereby amends the 2006 Brazos G Regional Water Plan as follows:

1. **Recommended Strategy to Supply Increased Steam Electric Demands in Somervell County**
   Supplies available for Steam Electric uses in Somervell County total 48,810 acft/yr in 2010, and will decrease to 48,710 acft/yr by 2060. Increased Steam Electric water demands will create a need (shortage) for an additional 36,107 acft/yr by 2060. The Brazos G Regional Water Planning Group recommends the water management strategy titled "Somervell County Steam Electric Supply from the Brazos River Authority", as shown in Attachment A, which is the revised plan for Somervell County Steam Electric Demands. Attachment B presents a detailed technical evaluation of the recommended strategy.

4C.30 Somervell County Water Supply Plan

Table 4C.30-1 lists each water user group in Somervell County and their corresponding surplus or shortage in years 2030 and 2060. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 4C.30-1.
Somervell County Surplus/(Shortage)

Water User Group	Surplus/(Shortage)[1] 2030 (acft/yr)	Surplus/(Shortage)[1] 2060 (acft/yr)	Comment
City of Glen Rose	38	37	Projected surplus
County-Other	(231)	(260)	Projected shortage – see plan below
Manufacturing	(4)	(7)	Projected shortage – see plan below
Steam-Electric	(36,047)	(36,107)	Projected shortage – see plan below
Mining	(94)	(85)	Projected shortage – see plan below
Irrigation	945	953	Projected surplus
Livestock	0	0	Supply equals demand

[1] From Tables C-59 and C-60, Appendix C – Comparison of Water Demands with Water Supplies to Determine Needs.

4C.30.1 The City of Glen Rose

4C.30.1.1 Description of Supply

The City of Glen Rose obtains groundwater from the Trinity Aquifer. No shortage is projected for the City of Glen Rose. However, Glen Rose may obtain supplemental surface water supplies from the Somervell County Water Supply Project.

4C.30.1.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended to supplement existing supplies for the City of Glen Rose:

- Somervell County Water Supply Project – the project will treat raw water from Wheeler Branch Off-Channel Reservoir and transmit the treated water to customers of the Somervell County Water District.

4C.30.1.3 Costs

Costs of the Somervell County Water Supply Project are discussed in Section 4C.30.2.3 below.

Table 4C.30-1.
Recommended Plan Costs by Decade for the City of Glen Rose

Plan Element	2010	2020	2030	2040	2050	2060
Projected Surplus/(Shortage) (acft/yr)	57	46	38	36	36	37
Somervell County Water Supply Project (Phases 1 – 4)*						
Supply From Plan Element (acft/yr)	340	340	340	340	340	340
Annual Cost ($/yr)	$808,188	$808,188	$808,188	$143,974	$143,974	$143,974
Unit Cost ($/acft)	$2,377	$2,377	$2,377	$423	$423	$423
Somervell County Water Supply Project (Phases 5 – 13)*						
Supply From Plan Element (acft/yr)	–	–	260	260	260	260
Annual Cost ($/yr)	–	–	$249,488	$249,488	$249,488	$44,402
Unit Cost ($/acft)	–	–	$960	$960	$960	$171

* Note: This supply is from the Wheeler Branch Reservoir, which has been implemented. The project is for development of treatment and transmission facilities.

4C.30.2 County-Other

4C.30.2.1 Description of Supply

Somervell County-Other obtains its water supply from groundwater from the Trinity Aquifer. Based on the available groundwater supply, Somervell County-Other is projected to have a shortage of 231 acft/yr in the year 2030 and 260 acft/yr in the year 2060.

4C.30.2.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended to meet the projected shortage of Somervell County-Other:

- Wheeler Branch Off-Channel Reservoir – the project has obtained a water rights permit from the TCEQ and is projected to be completed by 2010
- Somervell County Water Supply Project – the project will treat raw water from Wheeler Branch Off-Channel Reservoir and transmit the treated water to customers of the Somervell County Water District.

- Conservation was also considered; however, the County-Other's per capita use rate is below the selected target rate of 140 gpcd.

4C.30.2.3 Costs

Costs of the Recommended Plan for Somervell County-Other.

a. Wheeler Branch Off-Channel Reservoir:
- Cost Source: Volume II, Section 4B.13.3
- Date to be Implemented: before 2010
- Total Project Cost: $27,195,000
- Annual Cost: $2,117,000

b. Somervell County Water Supply Project:
- Cost Source: Somervell County Water District
- Date to be Implemented: before 2010, with future phases
- Total Project Cost: $87,226,800 (Phases 1 – 13). (Excluding retail distribution, the cost is $35,159,900.)
- Annual Cost: $7,659,700 (Phases 1 – 13). (Excluding retail distribution, the annual cost is $3,109,800.)

Table 4C.30-2.
Recommended Plan Costs by Decade for Somervell County-Other

Plan Element	*2010*	*2020*	*2030*	*2040*	*2050*	*2060*
Projected Surplus/(Shortage) (acft/yr)	(133)	(189)	(231)	(251)	(257)	(260)
Wheeler Branch Off-Channel Reservoir						
Supply From Plan Element (acft/yr)	1,800	1,800	1,800	1,800	1,800	1,800
Annual Cost ($/yr)	$2,117,000	$2,117,000	$2,117,000	$2,117,000	$2,117,000	$2,117,000
Unit Cost ($/acft)	$1,176	$1,176	$1,176	$1,176	$1,176	$1,176
Somervell County Water Supply Project (Phases 1 – 4)*						
Supply From Plan Element (acft/yr)	200	200	200	200	200	200
Annual Cost ($/yr)	$475,405	$475,405	$475,405	$84,690	$84,690	$84,690
Unit Cost ($/acft)	$2,377	$2,377	$2,377	$423	$423	$423
Somervell County Water Supply Project (Phases 5 – 13)*						
Supply From Plan Element (acft/yr)	–	–	516	516	516	516
Annual Cost ($/yr)	–	–	$495,138	$495,138	$495,138	$88,120
Unit Cost ($/acft)	–	–	$960	$960	$960	$171

* Note: This supply is from the Wheeler Branch Reservoir, which has been implemented. The project is for development of treatment and transmission facilities.

4C.30.3 Manufacturing

4C.30.3.1 Description of Supply

Somervell County Manufacturing obtains its water supply from groundwater from the Trinity Aquifer. Based on the available groundwater supply, Somervell County Manufacturing is projected to have a shortage of 4 acft/yr in the year 2030 and 7 acft/yr in the year 2060.

4C.30.3.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended to meet the projected shortage of Somervell County Manufacturing:

- Conservation, and
- Purchase water from the City of Glen Rose.

4C.30.3.3 Costs

Costs of the Recommended Plan for Somervell County Manufacturing.

a. Conservation:
   - Date to be Implemented: before 2010
   - Annual Cost: Not determined

b. Water Supply from City of Glen Rose:
   - Cost Source: estimated wholesale treated water rate
   - Date to be Implemented: By year 2010
   - Annual Cost: $16,161 in 2060

   The annual cost was calculated by multiplying the Manufacturing projected supply from this strategy by an estimated wholesale water rate of $162/acft.

Table 4C.30-3.
Recommended Plan Costs by Decade for Somervell County Manufacturing

Plan Element	2010	2020	2030	2040	2050	2060
Projected Surplus/(Shortage) (acft/yr)	(2)	(3)	(4)	(5)	(6)	(7)
Conservation						
Supply From Plan Element (acft/yr)	0	0	1	1	1	1
Annual Cost ($/yr)	—	—	—	—	—	—
Unit Cost ($/acft)	—	—	—	—	—	—
Water Supply from City of Glen Rose						
Supply From Plan Element (acft/yr)	10	10	10	10	10	10
Annual Cost ($/yr)	$16,161	$16,161	$16,161	$16,161	$16,161	$16,161
Unit Cost ($/acft)	$162	$162	$162	$162	$162	$162

4C.30.4 Steam-Electric

4C.30.4.1 Description of Supply

Somervell County Steam-Electric obtains its water supply from Squaw Creek Reservoir and from the Brazos River Authority from Lake Granbury. Somervell County Steam-Electric is projected to have a shortage of 36,047 acft/yr in 2030 and 36,107 acft/yr in 2060. Potable water for plant staff and high-quality process water for boiler feed at the Comanche Peak Steam Electric Station is currently provided from local groundwater. When the Somervell County Water Supply Project is developed, some potable water and process water for the plant will be obtained from the project. Additional future water supplies will come from additional water supply from the Brazos River Authority.

4C.30.4.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended to supplement existing supplies for Somervell County Steam-Electric:

- Somervell County Steam Electric Supply from the Brazos River Authority.
- Somervell County Water Supply Project – the project will treat raw water from Wheeler Branch Off-Channel Reservoir and transmit the treated water to customers of the Somervell County Water District.

- Conservation was also considered; however, the Somervell County Steam-Electric is already exercising substantial conservation.

4C.30.4.3 Costs

Cost of the Recommended Plan for Somervell County Steam-Electric:

a. Water Supply from the Somervell County Steam Electric Supply from the Brazos River Authority:
   - Cost Source: Strategy Evaluation of Proposed Amendment
   - Date to be Implemented: By year 2020
   - Annual Cost: $15,980,000 in 2030

b. Costs of the Somervell County Water Supply Project are discussed in Section 4C.30.2.3 above.

Table 4C.30-4.
Recommended Plan Costs by Decade for Somervell County Steam-Electric

Plan Element	*2010*	*2020*	*2030*	*2040*	*2050*	*2060*
Projected Surplus/(Shortage) (acft/yr)	25,610	(36,027)	(36,047)	(36,067)	(36,087)	(36,107)
Somervell County Steam Electric Supply from the Brazos River Authority						
Supply From Plan Element (acft/yr)	–	103,717	103,717	103,717	103,717	103,717
Annual Cost (million $/yr)	–	$15.98	$15.98	$15.98	$8.44	$8.44
Unit Cost ($/acft)	–	$154	$154	$154	$81	$81
Somervell County Water Supply Project (Phases 1 – 4)*						
Supply From Plan Element (acft/yr)	300	300	300	300	300	300
Annual Cost ($/yr)	$713,107	$713,107	$713,107	$127,036	$127,036	$127,036
Unit Cost ($/acft)	$2,377	$2,377	$2,377	$423	$423	$423
Somervell County Water Supply Project (Phases 5 – 13)*						
Supply From Plan Element (acft/yr)	–	–	184	184	184	184
Annual Cost ($/yr)	–	–	$176,561	$176,561	$176,561	$31,423
Unit Cost ($/acft)	–	–	$960	$960	$960	$171

* Note: This supply is from the Wheeler Branch Reservoir, which has been implemented. The project is for development of treatment and transmission facilities.

4C.30.5 Mining

4C.30.5.1 Description of Supply

Somervell County Mining obtains its water supply from groundwater from the Trinity Aquifer. Based on the available groundwater supply, Somervell County Mining is projected to have a shortage of 94 acft/yr in the year 2030 and 85 acft/yr in the year 2060.

4C.30.5.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended to meet the projected shortage of Somervell County Mining:

- Conservation, and
- Voluntary Redistribution from Steam-Electric.

4C.30.5.3 Costs

Costs of the Recommended Plan for Somervell County Mining.

a. Conservation:
   - Date to be Implemented: before 2010
   - Annual Cost: Not determined

b. Voluntary Redistribution from Steam-Electric:
   - Cost Source: assumed unit cost for raw water transfer between entities
   - Date to be Implemented: before 2010
   - Unit Cost: $75/acft
   - Annual Cost: $11,250

Table 4C.30-4.
Recommended Plan Costs by Decade for Somervell County Mining

Plan Element	*2010*	*2020*	*2030*	*2040*	*2050*	*2060*
Projected Surplus/(Shortage) (acft/yr)	(106)	(98)	(94)	(91)	(88)	(85)
Conservation						
Supply From Plan Element (acft/yr)	9	14	19	19	18	18
Annual Cost ($/yr)	—	—	—	—	—	—
Unit Cost ($/acft)	—	—	—	—	—	—
Voluntary Redistribution from Steam-Electric						
Supply From Plan Element (acft/yr)	150	150	150	150	150	150
Annual Cost ($/yr)	$11,250	$11,250	$11,250	$11,250	$11,250	$11,250
Unit Cost ($/acft)	$75	$75	$75	$75	$75	$75

4C.30.6 Irrigation

Somervell County Irrigation is projected to have a surplus of water through 2060 and no changes in water supply are recommended.

4C.30.7 Livestock

No shortages are projected for Somervell County Livestock and no changes in water supply are recommended.

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Somervell County Steam Electric Supply from the Brazos River Authority

1.0 Description of Option

Luminant Power (formerly Texas Utilities or TXU) operates the Comanche Peak Station, which consists of two nuclear generating units located in Somervell County near Glen Rose, Texas. Water used to cool the two existing units is diverted from Squaw Creek Reservoir, supplemented with diversions from Lake Granbury, which is owned and operated by the Brazos River Authority (BRA). Water is diverted from Lake Granbury into Squaw Creek Reservoir, and circulated through the generating units prior to being discharged back into Squaw Creek Reservoir, and subsequently to the Brazos River via Squaw Creek.

Luminant is planning to build two additional 1,700 MW nuclear generating units at the Comanche Peak site, and intends to cool those units with additional water obtained from the BRA, diverted near the existing location on the southwest shore of Lake Granbury. Water would be pumped through two new pipelines into cooling towers at the new generating units. Blowdown from the cooling towers would be discharged back into Lake Granbury at a location downstream from the intake location. The two new units would operate independent and separate from the two existing units, and will not involve Squaw Creek Reservoir. The addition of the two generating units to Luminant's plans creates an additional Steam-Electric water demand in Somervell County that was not considered in the 2006 Brazos G Regional Water Plan.

Water would be delivered to the units separately through two, new 42-inch diameter pipelines. Similarly, blowdown water from the cooling towers would be returned through two, new 36-inch diameter pipelines. All new pipelines will be placed into or adjacent to the right-of-way for the existing pipelines between Lake Granbury and Squaw Creek Reservoir. The new pipelines would then be routed around the southern extent of Squaw Creek Reservoir to the new generating units on property currently owned by Luminant. The pipelines would be approximately 12 miles long. The approximate routes are shown in Figure 1. The route of the pipeline for discharge of blowdown flows might vary depending on the ultimate discharge location selected.

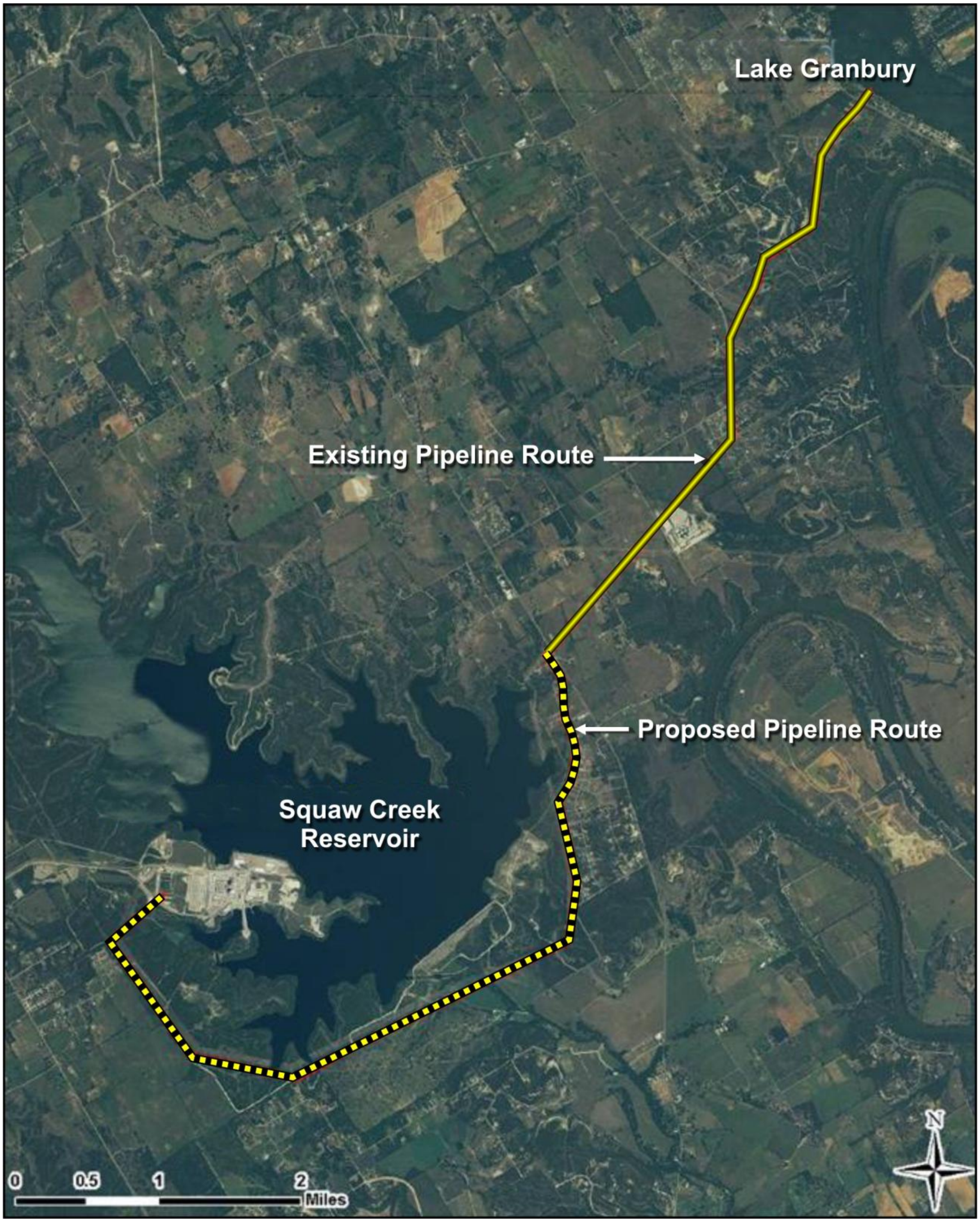

Figure 1. Luminant Pipeline Route.

1.1 Available Yield

Luminant's preliminary engineering has determined that annual diversions totaling 103,717 acre-feet per year (acft/yr) will be needed from Lake Granbury. Luminant currently holds contracts for water supply from the BRA totaling 27,447 acft/yr that have not yet been assigned to any current Luminant facility. Luminant would utilize this existing contractual supply plus an additional 76,270 acft/yr of new contractual water from the BRA. The BRA and Luminant have identified the pending BRA System Operations Permit as the source of supply for this new contractual water.

Analysis regarding the availability of this water supply from the BRA System was determined using the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized in the 2006 Brazos G Regional Water Plan. The following modifications to the Brazos G WAM were made to evaluate the supply available to the proposed new diversion from Lake Granbury and to estimate its impacts downstream:

(1) The methodology for modeling the existing Luminant diversion from Lake Granbury to Squaw Creek Reservoir was modified to more accurately depict actual operations. Previously, only the consumptive use was modeled as a diversion from Lake Granbury. This was modified to include diversions from Lake Granbury being discharged into Squaw Creek Reservoir, with actual consumptive use occurring from Squaw Creek Reservoir. Any unused diversions from Lake Granbury are allowed to spill from Squaw Creek Reservoir and contribute to flows downstream on the Brazos River via Squaw Creek.

(2) The diversion location for the unassigned contractual supply (27,447 acft/yr) from the BRA was moved from Possum Kingdom Reservoir to Lake Granbury.

(3) Additional supply to Luminant (76,270 acft/yr) from the pending BRA System Operations Permit was placed at Lake Granbury.

(4) Return flows representing the discharge of cooling tower blowdown into Lake Granbury were added. These are estimated by Luminant to be 42,100 acft/yr.

(5) Four water supply diversions totaling 31,106 acft/yr were included, which would utilize supply from the pending BRA System Operations Permit. These diversions

are included as water management strategies to meet future needs in the 2006 Brazos G Regional Water Plan. Previous analyses of potential supplies available from the BRA System Operations Permit included 10 potential new diversions totaling 65,482 acft/yr in Brazos G. Not all of these 10 diversions were ultimately recommended as water management strategies in the 2006 Plan. Only those four diversions recommended as water management strategies in the 2006 Plan were included in this analysis.

During development of the 2006 Brazos G and Region H Regional Water Plans, the supply from the BRA System to Brazos G and Region H was apportioned as shown in Table 1. The supplies shown in Table 1 are in addition to those supplies for which the BRA had already committed contractually at the time the 2006 plans were developed and may not necessarily reflect current BRA contractual commitments.

Table 1.
Assignment of Uncontracted BRA Supplies Between Brazos G and Region H.

	Region G	*Region H*	*Total*
Uncontracted BRA Supply from Existing Sources	31,955	29,000	60,955
Allens Creek Reservoir Supply	0	99,650	99,650
BRA System Operations Supply	63,510	120,000	183,510
Total Additional Supply from BRA	95,465	248,650	344,115
Note: All values are in acre-feet per year.			

This assignment was negotiated between Brazos G and Region H, and is considered a conservative estimate of supplies that might be available from the BRA System. Actual supplies available to Brazos G and Region H from the BRA System are likely greater, and will depend upon diversion rights granted in the pending BRA System Operations Permit and the diversion locations of future BRA contractual commitments.

For purposes of determining whether sufficient supply is available from the BRA System to meet the additional Luminant diversion from Lake Granbury and what effect, if any, this would have on supplies available to Region H, the model was operated to meet the Brazos G supply requirements first, with any remaining supply available from the BRA System assigned to a lower basin diversion to represent supplies available to Region H.

Table 2 summarizes these analyses, and compares these analyses to the original Brazos G WAM analysis of the BRA System Operations Permit completed during the development of the 2006 Brazos G Regional Water Plan, and to the supplies assigned to Brazos G and Region H for the 2006 plans.

Table 2.
Summary of Supplies Available to Brazos G and Region H.

Diversions/Returns	***Original Brazos G WAM Analysis***	***Brazos G/Region H Assignment***	***Somervell County Strategy Evaluation***
Brazos G WUG Strategies	65,482	95,465	31,106
New Luminant Diversion	–	–	76,270
Luminant Return	–	–	(42,100)
Total Brazos G Supply	65,482	95,465	65,276
Lower Basin Supply (Region H)	264,000	248,650	258,750

As shown in Table 2, the total supply available to Brazos G from the BRA System when the Luminant strategy is 65,276 acft/yr. This is approximately equal to the supply delineated in the original Brazos G analysis of supplies that might be used to meet ten individual WUG needs. However, the placement of the recommended four WUG diversions in conjunction with the Luminant strategy reduces the efficiency of the BRA System and reduces lower basin (Region H) supplies from 264,000 acft/yr to 258,750 acft/yr. This is still a greater supply than originally apportioned to Region H during development of the 2006 plans.

In summary, there is sufficient supply available from the BRA System to meet the Steam-Electric demands of the proposed Luminant strategy. Based upon actual recommended water management strategies in the 2006 Brazos G Regional Water Plan, the proposed supply to Luminant will not reduce supplies to Region H below what was originally assumed available during development of the 2006 Region H Water Plan.

As the 2006 Brazos G Regional Water Plan already considers this supply from Lake Granbury, there is little to no change in projected Lake Granbury storage or storage in other reservoirs constituting the BRA System. Figures 2 through 5 illustrate changes in monthly flows resulting from this strategy being implemented in the 2006 Brazos G Regional Water Plan. In the figures, the "Implemented Plan" conditions are projected flows at the subject locations assuming implementation of the 2006 Brazos G Plan. The "Implemented Plan w/Luminant" conditions are projected flows assuming implementation of the 2006 Brazos G Plan with the addition of the Luminant diversion from Lake Granbury.

1.2 Environmental Issues

1.2.1 Existing Environment

The pipeline's project area in Hood and Somervell Counties lies within the Cross Timbers and Prairie Ecological Region encompassing all or portions of 35 counties situated in north-central Texas.[1] This complex transitional area of prairie dissected by parallel timbered strips is located in the central portion of the area between three other ecological regions, the Blackland Prairie immediately to the east, the Edwards Plateau and Llano Uplift to the south and the Rolling Plains to the west. 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 28 and 32 inches.[3]

Hood and Somervell counties are located primarily over the outcrops of the Trinity Aquifer, the only major groundwater resource in the two-county area. The Trinity Aquifer is composed of interbedded sandstone, sand, limestone, and shale of Cretaceous Age. This aquifer consists of the Antlers Formation, the Twin Mountains Formation, the Paluxy Formation and the Glen Rose Formation. The Paluxy Formation and the Glen Rose Formation constitute the majority of the outcropping units along the pipeline right-of-way[4]. The Paluxy Formation is

[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] Bureau of Economic Geology (BEG). "Geologic Atlas of Texas, Dallas Sheet. The University of Texas. 1972, Revised 1988.

characterized by fine-grained, compact, friable, very fine to medium-grained white quartz sand interbedded with sandy, silty, calcareous, or waxy clay and shale. The saturated thickness of this formation can vary considerably and is an important regional water-yielding source providing water for rural domestic and livestock uses in addition to a municipal and industrial water supply.[5] The Glen Rose Formation is predominately limestone with smaller amounts of shale, sandy shale, clay sandstone, marl, and anhydrite. Typical thickness of the Glen Rose ranges from 40 to 200 feet with an approximate thickness of 1,500 feet.[6, 7] Locally, groundwater usage is exclusively for rural domestic and livestock needs. No minor aquifers underlie the project area.

The physiography of the region includes hard sandstone, mud, and mudstone (undifferentiated), ceramic clay and lignite/coal, terraces, and flood-prone areas. The topography ranges from flat to rolling, and from steeply to moderately sloped, with local shallow depressions in flood-prone areas along waterways.[8] The predominant soil associations in the project area are Tarrant-Purves, Windthorst-Duffau and Frio-Bosque. The Tarrant-Purves association consists of very shallow to shallow, undulating to hilly, upland clayey soils formed in limestone on ridgetops and hillsides. The Windthorst-Duffau association is characterized by deep, gently sloping to sloping, loamy and sandy soils formed in loamy sediments or in stratified clayey, sandy, or weakly cemented sandstone along shallow upland valleys and foot slopes. The Frio-Bosque association contains deep, nearly level, clayey and loamy soils, found on floodplains of streams that form over limestone.[9]

[5] Klemt,W.B., R.D. Perkins and H.J. Alvarez. "Ground-water Resources of Part of Central Texas with Emphasis on the Antlers and Travis Peak Formations, Volume 1. Texas Water Development Board Report 195. 1975.
[6] Baker, B., G. Duffin, R. Flores, and T. Lynch. "Evaluation of Water Resources in Part of North-Central Texas. Texas Water Development Board Report 318. 1990.
[7] Nordstrom, P.L. "Occurrence, Availability, and Chemical Quality of Ground Water in the Cretaceous Aquifers of North-Central Texas, Volume 1. Texas Water Development Board Report 269. 1982.
[8] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., "Land Resources of Texas." Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.
[9] Coburn, W.C. *Soil Survey of Hood and Somervell Counties, Texas*, United States Department of Agriculture, Soil Conservation Service, in cooperation with Texas Agricultural Experiment Station, 1978.

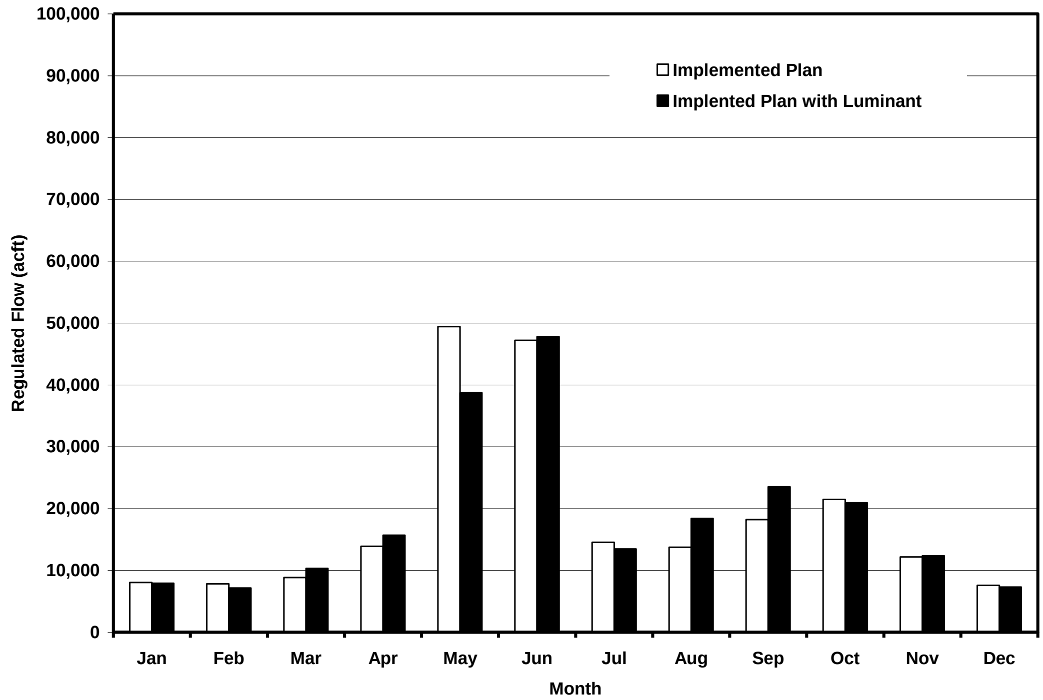

Figure 2. Monthly Median Flows in the Brazos River at Glen Rose.

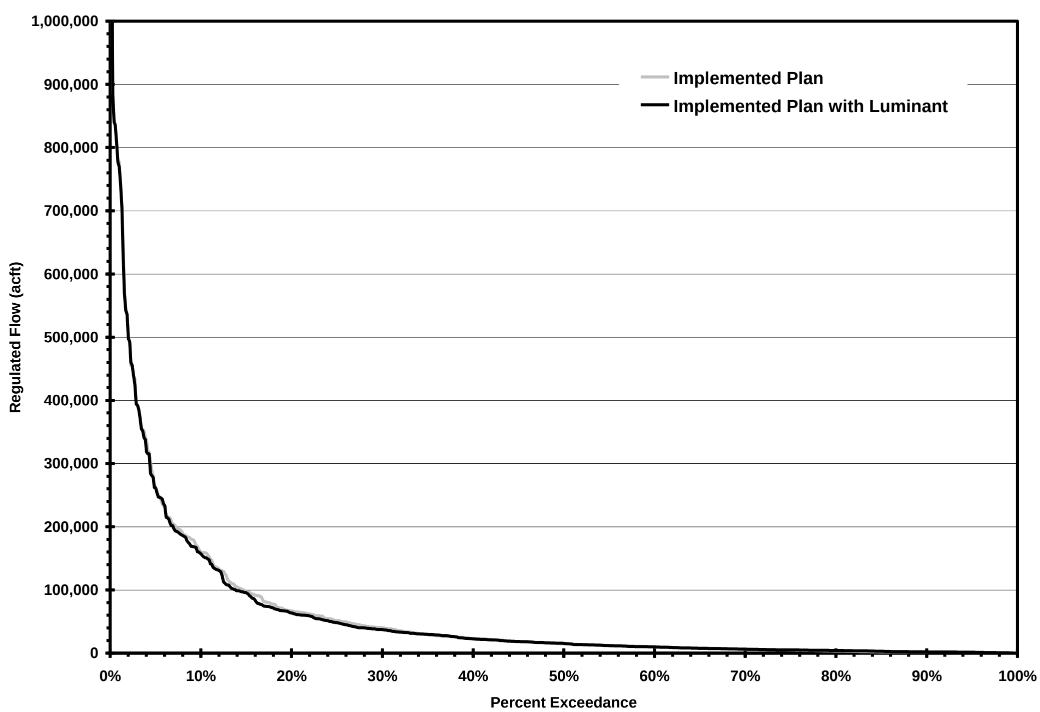

Figure 3. Monthly Flow Frequency in the Brazos River at Glen Rose.

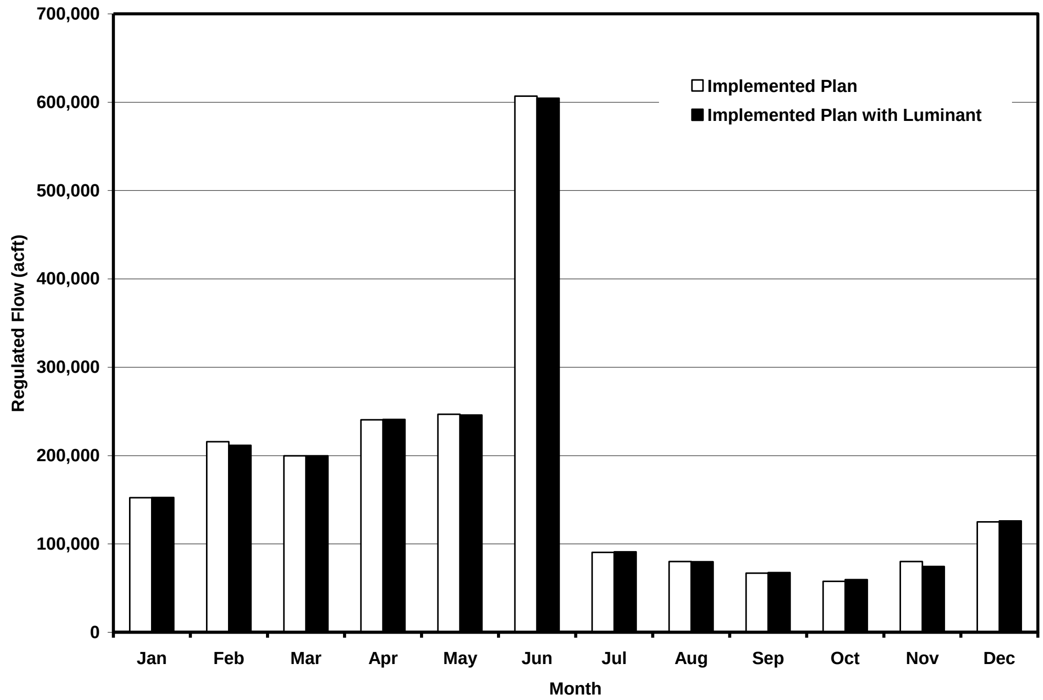

Figure 4. Monthly Median Flows in the Brazos River at Richmond.

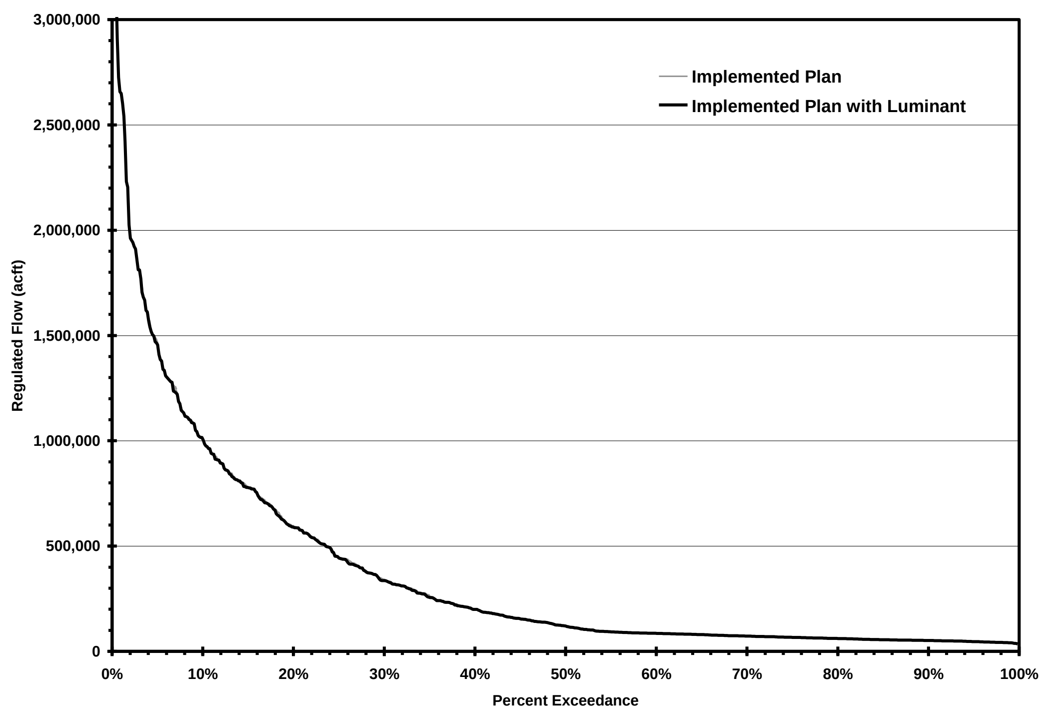

Figure 5. Monthly Flow Frequency in the Brazos River at Richmond.

1.2.1.1 Vegetation Types

Two major vegetation types occur within the general vicinity of the proposed project: Silver Bluestem (*Bothriochloa saccharoides*)–Texas Wintergrass (*Stipa leucotricha*) Grassland and Oaks-Mesquite-Juniper (*Quercus-Prosopis-Juniperus*) Parks/Woods.[10] Variations of these primary types can occur that may involve changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Silver Bluestem–Texas Wintergrass Grassland could include the following commonly associated plants: little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), Texas grama (*Bouteloua rigidiseta*), three-awn (*Aristida* spp.), hairy grama (*Bouteloua hirsuta*), tall dropseed (*Sporobolus cryptandrus*), buffalograss (*Buchloe dactyloides*), windmillgrass, (*Chloris* spp.), hairy tridens (*Tridens pilosum*), tumblegrass (*Schedonnardus paniculatus*), western ragweed (*Ambrosia psilostachya*), broom snakeweed (*Xanthocephalum* spp.), Texas bluebonnet (*Lupinus texensis*), live oak (*Quercus virginiana*), post oak (*Quercus stellata*), and mesquite (*Prosopis glandulosa*). Commonly associated plants of Oaks-Mesquite-Juniper Parks/Woods are post oak, Ashe juniper (*Juniperus ashei*), shin oak (*Quercus sinuata* var. *breviloba*), Texas oak (*Quercus texana*), blackjack oak (*Quercus marilandica*), live oak, cedar elm, agarito (*Berberis trifoliolata*), soapberry (*Sapindus saponaria*), sumac (*Rhus* spp.), hackberry (*Celtis* spp.), Texas pricklypear (*Opuntia lindheimeri*), Mexican persimmon (*Diospyros virginiana*), purple three-awn (*Aristida purpurea*), hairy grama, Texas grama, sideoats grama, curly mesquite (*Hilaria belangeri*), and Texas wintergrass (*Nasella leucotricha*).

1.2.1.2 Wildlife Species and Habitat

A number of vertebrate species would be expected to occur near the project area as indicated by occurrence records for Hood and Somervell counties.[11] These include one species of salamander, 16 species of frogs and toads, seven species of turtles, 11 species of lizards and skinks, and 29 species of snakes. Additionally, 65 species of mammals could occur within the site or surrounding region,[12] as well as an undetermined number of bird species.

[10] McMahan, C.A., R.F. Frye, and K.L. Brown, "The Vegetation Types of Texas," Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.
[11] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," Texas Cooperative Wildlife Collection, 1998.
[12] Davis, W.B., and D.J. Schmidly, "The Mammals of Texas – Online Edition," Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

The wildlife habitat types of the project area coincide closely with the major plant community types present. The major habitat divisions are forested (upland woodlands and bottomland woodlands), non-forested (savannah, native and improved pastureland, hayfields, forage crops and right-of-ways), aquatic (marshes, ponds, small streams, and major surface-water developments including Lake Granbury and Squaw Creek Reservoir). The upland forested areas are usually dominated by Ashe juniper, cedar elm (*Ulmus crassifolia*), Texas oak, post oak, mesquite and blackjack oak. Some common wildlife species known to occur within this community type include wild turkey (*Meleagris gallopavo*), American robin (*Turdus migratorius*), Carolina chickadee (*Poecile carolinensis*), downy woodpecker (*Picoides pubescens*), turkey vulture (Cathartes aura), blue jay (*Cyanocitta cristata*), northern cardinal (*Cardinalis cardinalis*), and red-bellied woodpecker (*Melanerpes carolinus*). Additional species of potential occurrence include the white-tailed deer, striped skunk (*Mephitis mephitis*), Virginia opossum (*Didelphis virginiana*), eastern fox squirrel (*Sciurus niger*), nine-banded armadillo (*Dasypus novemcinctus*), white-footed mouse (*Peromyscus leucopus*), Texas spiny lizard (*Sceloporus olivaceus*), eastern yellow-bellied racer (*Coluber constrictor*), Texas rat snake (*Elaphe obsoleta*), western diamondback rattlesnake (*Crotalus atrox*), mourning dove (*Zenaida macroura*), tufted titmouse (*Baeolophus bicolor*), rufous-crowned sparrow (*Aimophila ruficeps*), and the painted bunting (*Passerina ciris*).

Bottomland/riparian forested areas occur in topographic lowlands along major streams and along tributaries at higher elevations. Overstory species include cedar elm, Texas sugarberry (*Celtis laevigata*), pecan (*Carya illinoinensis*), walnut (*Juglans* spp.), American elm (*Ulmus americana*), slippery elm (*Ulmus rubra*), eastern cottonwood (*Populus deltoides*), and scattered Ashe juniper. Terrestrial wildlife species typical of this habitat include beaver (*Castor canadensis*), white-tailed deer, northern raccoon (*Procyon lotor*), black vulture (*Coragyps atratus*), American robin, Carolina chickadee, turkey vulture, northern cardinal and red-bellied woodpecker, Virginia opossum, white-footed mouse, wild turkey, eastern screech-owl (*Megascops asio*), yellow-billed cuckoo (*Coccyzus americanus*), pileated woodpecker, Carolina wren (*Thryothorus ludovicianus*), summer tanager (*Piranga rubra*), eastern pewee (*Contopus virens*), Barn owl (*Tyto alba*), fox squirrel, Texas rat snake, woodhouse's toad (*Bufo woodhousei*), eastern gray treefrog (*Hyla versicolor*), and Strecker's chorus frog (*Pseudacris streckeri*).

The savannah community is a type of grassland with an open tree canopy that forms approximately 10 to 50 percent crown cover. Scattered trees that make up the canopy in these stands typically include Ashe juniper, honey mesquite (*Prosopis glandulosa*), cedar elm, post oak and plateau oak (*Quercus fusiformis*). Dominant grasses and weedy herbaceous species include coastal bermudagrass (*Cynodon dactylon*), little bluestem (*Schizachyrium scoparium*), Indian grass (*Sorghastrum nutans*), sideoats grama, Texas grama, Texas wintergrass and hairy grama (*Bouteloua hirsuta*). Faunal species inhabiting the savannah community may include the turkey vulture, northern mockingbird ((*Mimus polyglottos*), dark-eyed junco, American kestrel (*Falco sparverius*), loggerhead shrike (*Lanius ludovicianus*), song sparrow (*Melospiza melodia*), mourning dove, Virginia opossum, eastern cottontail (*Sylvilagus floridanus*), nine-banded armadillo, hispid cotton rat (Sigmodon hispidus), plains harvest mouse (*Reithrodontomys montanus*), ornate box turtle (*Terrapene ornata*), Great Plains skink (*Eumeces obsoleta*), Texas rat snake, western diamondback snake, woodhouses' toad, bobwhite (*Colinus virginianus*) red-tailed hawk (*Buteo jamaicensis*), and eastern meadowlark (*Sturnella magna*).

The pastureland community includes native and improved pastures, hayfields, forage crops, and right-of-ways. Improved or managed pastureland is typically dominated by forage crops including bahiagrass (*Paspalum notatum*) and/or bermudagrass. Periodically kleingrass (*Panicum coloratum*) is planted for hay and as a forage grass. Unimproved pastureland and right-of-way areas consist of a variety of grasses, forbs, and woody species. Common grasses found throughout these habitats include little bluestem, sideoats grama, and Indiangrass. Wildlife species that may inhabit the community pastureland include most of those also occurring in the savannah habitat.

Aquatic habitats within the project area right-of-way consist primarily of stock ponds, unnamed tributaries to the Brazos River, Squaw Creek and its tributaries, Squaw Creek Reservoir and Lake Granbury. Plant species common to this habitat may include rushes (*Scirpus* spp.), sedges (*Carex* spp. and *Cyperus* spp.), spikesedges (*Eleocharis* spp.), and cattails (*Typha* spp.). Aquatic fauna may include the belted kingfisher (*Megaceryle alcyon*), great blue heron (*Ardea herodias*), lesser scaup (*Aythya affinis*), beaver, raccoon, and cricket frogs (*Acris* spp.), Virginia opossum, bullfrog (*Rana catesbeiana*), pied-billed grebe (*Podilymbus podiceps*), blue-winged teal (*Anas discors*), and the American widgeon (*Mareca americana*).

1.2.1.3 Aquatic Habitat

The project area is located within the middle segment of the Brazos River Basin in North-Central Texas. All surface drainage in the vicinity of the proposed pipeline follows a general east and southeast course toward the river. As previously mentioned, the major aquatic environments include reservoirs, intermittent streams and small surface water impoundments (stock ponds). The principal tributaries to the Brazos River that will be crossed by the pipeline include Squaw Creek, Panther Branch and several unnamed drainage systems that have direct communication with the main channel of the Brazos River. Distributions and population densities of aquatic assemblages are limited by the types and quality of habitats available. Aquatic biota in most of the project-area streams and ponds is probably severely restricted because of the lack of permanent water.

1.2.2 Potential Impacts

Luminant is proposing to construct two 36-inch diameter and two 42-inch diameter pipelines. The proposed pipelines will tie into Lake Granbury and terminate at the Comanche Peak Station. The entire proposed pipeline alignment, located on the Acton, Nemo, and Hill City 7.5 minute U.S. Geological Survey (USGS) topographic quadrangle maps, is approximately 63,000 feet long. The majority of the pipeline route between Lake Granbury and the vicinity of Squaw Creek Reservoir will parallel an existing pipeline ROW. Approximately half of the new pipeline, positioned along the south and southwest portion of Squaw Creek Reservoir, will be on Luminant property. The final alignment of the proposed pipeline(s) will be selected to avoid or minimize environmental impacts.

1.2.2.1 Vegetation

The anticipated impact of this project to vegetation resulting from site preparation and construction is the removal of existing woody vegetation from the areas required for the ROW. The greatest amount of vegetation clearing would be required in forested areas, while minimal clearing would be necessary in pasturelands. The only land lost to cultivation will be that occurring within the pipeline corridor easement.

Potential for regulatory wetlands is the greatest along the tributaries crossed by the pipeline route. Field investigations would be required to delineate the full extent of waters of the U.S., including wetlands, within the ROW. The United State Army Corps of Engineers

(USACE), Fort Worth District, has the primary regulatory authority for enforcing Section 404 of the Clean Water Act (CWA) requirements. The USACE would provide a verification of the delineation and make the final jurisdictional determination for waters of the U.S. in the ROW during permit negotiations.

1.2.2.2 Wildlife

The impact of construction of the proposed project on terrestrial wildlife and wildlife habitats would vary depending upon the timing of construction and types of construction techniques used, as well as on the requirements of each species and the habitat present where various project components would be constructed. In general, impact on terrestrial wildlife in the area for the new pipeline would be short term and minimal because no sensitive habitats would be affected (as indicated by Luminant based upon field investigations), and much of the area affected by construction would be allowed to revert to the pre-construction habitat type following construction.

Native wildlife habitat adjacent to the proposed project site has been eliminated by prior construction activities as the current ROW vegetation is a mowed grass field. The maintained grassy areas do not provide sufficient habitat to support diverse wildlife populations.

Due to the disturbed nature of the ROW from prior commercial activity associated with the Comanche Peak Station and because the site is mowed on a regular basis, the number and diversity of mammal, bird, reptile, and amphibian species are low and limited. Some species such as rodents, rabbits, lizards and insects may be affected by the construction due to alteration in habitat and direct contact with construction equipment. Those species common along the ROW are well adapted to life within this area and may move away during construction and return once the pipeline has been covered. However, the long-terms effects will be minimal.

The pipeline site is located in the North American flyway and many neo-tropical migrants pass over this area annually. Development of a construction schedule should be timed to minimize impacts to migratory birds during the major fall and spring migrations.

1.2.2.3 Threatened and Endangered Species

A total of 25 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 3). This group includes three reptiles, ten birds, two mammals, three mollusks, and two fish species. Four bird species federally-listed as threatened or endangered could occur in the project area. These include the black-capped vireo (*Vireo atricapillus*), golden-cheeked warbler (*Dendroica chrysoparia*), interior least tern (*Sterna antillarum athalassos*), and whooping crane (*Grus americana*). These four birds are all seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed pipeline crossing.

A search of the Texas Wildlife Diversity Database (TXNDD)[13] revealed six documented occurrences of the golden-cheeked warbler, six occurrences of the black-capped vireo, one documented occurrence each for the Brazos water snake (*Nerodia harteri*), Comanche Peak prairie-clover (*Dalea reverchonii*), and Glen Rose yucca (*Yucca necopina*) within the project vicinity as noted on representative 7.5-minute quadrangle maps (Nemo, Granbury, Hill City, Acton) that include the project site. The TXNDD has documented a waterbird colony (i.e., rookery) along Squaw Creek and Panther Branch near the upper end of Squaw Creek Reservoir and northwest of the proposed pipeline ROW. The two plant species of concern currently have no regulatory listing status and it is not anticipated that construction activity would create any adverse impact to these species. Confirmed habitat for the golden-cheeked warbler and the black-capped vireo is found 1 mile southwest of the proposed corridor, however, no impacts to these species are expected. The Brazos water snake is known to reside in the Brazos River in the vicinity of the proposed pipeline but is not likely to be found in the streams along the pipeline route due to lack of suitable habitat.

These data are not a representative inventory of rare resources or sensitive sites. Although based on the best information available to Texas Parks and Wildlife Department (TPWD), these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. Luminant Power has indicated that on-site evaluations have been conducted to investigate the occurrence of sensitive species or habitats, but the results of those evaluations are not yet available. The results of these evaluations will be described in the proposed facility's Construction and Operation License Application (COLA) to be submitted to the Nuclear Regulatory Commission (NRC).

[13] Texas Parks and Wildlife Department (TPWD), Texas Wildlife Diversity Database, February 28, 2008.

1.2.2.4 Aquatic Environments

The potential impacts of this water management strategy were evaluated at two gage locations on the Brazos River: (1) near Glen Rose downstream of the proposed pipeline and (2) near Richmond in the lower portion of the watershed. Monthly streamflows at these two sites are presented in Figures 2 through 5, and Tables 4 and 5. The anticipated impact of this water management strategy on overall flows would be minor when addressed from the perspective of the existing 2006 plan. In general, flows downstream of Lake Granbury, as measured by the Glen Rose gage, would generally be somewhat less than those without the new Luminant diversion; however, flows would increase in some months. These differences are due to how the BRA system of reservoirs responds in the modeling of the BRA System Operations Plan to meet shifting water needs. There would be little difference in flows at the Richmond gage.

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 where additional flow inputs would moderate the effects. No impacts on endangered or threatened aquatic fauna are anticipated.

Table 3.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the Luminant Pipeline, Hood and Somervell Counties

Scientific Name	Common Name	Federal/State Status	Hood County	Somervell County
Birds				
Falco peregrinus anatum	American Peregrine Falcon	DL/E	Migrant	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant	Migrant
Haliaeetus leucocephalus	Bald Eagle	DL/T	Migrant	Migrant
Vireo atricapillus	Black-capped Vireo	LE/E	Migrant	Migrant
Dendroica chrysoparia	Golden-cheeked Warbler	LE/E	Migrant	Migrant
Ammodramus bairdii	Baird's Sparrow	SOC	Migrant	—
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*	Migrant*
Charadrius montanus	Mountain Plover	SOC	Migrant*	Migrant*
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant	Migrant
Fishes				
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X	X
Notropis buccula	Smalleye Shiner	C/SOC	X	X
Mammals				
Ursus americanus	Black Bear	T/SA;NL/T	X	—
Canis lupus	Gray Wolf	LE/E	Extirpated	Extirpated
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X	X
Canis rufus	Red Wolf	LE/E	Extirpated	Extirpated
Mollusks				
Tritogonia verrucosa	Pistolgrip	SOC	X	X
Arcidens confragosus	Rock pocketbook	SOC	X	X
Truncilla macrodon	Texas fawnsfoot	SOC	X	X
Reptiles				
Nerodia harteri	Brazos Water Snake	SOC/T	X	X
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X	X
Crotalus horridus	Timber/Canebrake rattlesnake	SOC/T	X	X
Plants				
Dalea reverchonii	Comanche Peak Prairie-Clover	SOC	X	—
Yucca necopina	Glen Rose Yucca	SOC	X	X

X = Occurs in county; — = does not occur in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; T/SA- Listed Threatened on Basis of Similarity of Appearance; DL-Delisted Endangered/Threatened; NL-Not Listed; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed)

Sources: Texas Parks and Wildlife Department (TPWD) Annotated County List of Rare Species for Hood and Somervell Counties (2007); TPWD Texas Wildlife Diversity Database (2008), United States Fish and Wildlife Service (USFWS), Federally-listed as Threatened and Endangered Species of Texas, February 5, 2008.

1.2.2.5 Cultural Resources

An archeological survey and results of machine-assisted deep testing were provided by Luminant. This work was accomplished between February 11 and 15, 2008, to identify and assess any cultural resources that might be present within all areas to be impacted by the construction of the proposed pipeline. Field investigations entailed an intensive pedestrian surface survey with the excavation of several shovel test pits in surface soil areas along the segments of alternate routes positioned south of Squaw Creek Reservoir and deep trench assessment using a backhoe in five areas across the flood plain of Squaw Creek below the Squaw Creek Reservoir Dam. Ten areas of archeological interest previously identified during a reconnaissance were revisited for evaluation. These sites were determined to be either sufficiently removed from the proposed corridor area or were of little archeological value. Two new areas of archeological interest were encountered during this survey but were not considered to have substantial archeological significance. The entire project area surveyed has been

Table 4.
Median Monthly Streamflow: Brazos River Gage near Glen Rose

Month	*2006 Brazos G Plan (acft/mo)*	*2006 Plan with Luminant (acft/mo)*	*Difference (acft/mo)*	*Percent Reduction*
January	8,042	7,907	-135	-1.7%
February	7,831	7,132	-699	-8.9%
March	8,842	10,314	1,472	16.6%
April	13,891	15,670	1,779	12.8%
May	49,414	38,737	-10,677	-21.6%
June	47,185	47,792	607	1.3%
July	14,535	13,460	-1,074	-7.4%
August	13,732	18,388	4,656	33.9%
September	18,216	23,495	5,279	29.0%
October	21,460	20,929	-532	-2.5%
November	12,161	12,350	189	1.6%
December	7,584	7,309	-275	-3.6%

Table 5.
Median Monthly Streamflow: Brazos River Gage at Richmond

Month	2006 Brazos G Plan (acft/mo)	2006 Plan with Luminant (acft/mo)	Difference (acft/mo)	Percent Reduction
January	152,353	152,461	108	0.1%
February	215,567	211,630	-3,937	-1.8%
March	199,589	199,589	0	0.0%
April	240,376	240,841	465	0.2%
May	246,759	245,815	-944	-0.4%
June	606,834	604,515	-2,319	-0.4%
July	90,396	90,927	531	0.6%
August	79,916	79,782	-134	-0.2%
September	66,929	67,512	584	0.9%
October	57,516	59,533	2,016	3.5%
November	79,934	74,373	-5,561	-7.0%
December	124,910	125,850	941	0.8%

extremely disturbed by previous construction and land clearing activities. Sediments along Squaw Creek exceeded the maximum depth of the proposed waterline set at 6 feet but showed no indications of containing buried archeological deposits.

Additionally, a records search of the Texas Archeological Sites Atlas database was conducted on February 20, 2008 to determine the density of archeological sites documented within a 1,000-feet wide corridor (500 feet on either side of the proposed pipeline route) extending approximately 12 miles from Lake Granbury and ending at the Comanche Peak Station. After a review of the United States Geological Survey (USGS) 7.5-minute topographic quadrangle maps for Acton, Hill City and Nemo, the results reveal that one archeological site has been documented within the 500 feet boundary east of the proposed pipeline crossing in Hood County. Site 41SV55 was recorded in 1974 by Southern Methodist University (SMU) and consisted of a prehistoric scatter of lithics and burned rock that had been disturbed by agricultural plowing and vandalism. The present condition of this site is unknown and the site file located at the Texas Archeological Research Laboratory (TARL) consists of location data only. Several other recorded sites appear to lie within 0.31 miles (0.5 kilometers) of the currently proposed route.

None of the cultural resources directly along the pipeline corridor or within the Area of Potential Effect (APE) have potential for significant or important research value nor do they qualify for inclusion applicable to National Register of Historic Places (NRHP) significance criteria or listing as a State Archeological Landmark (SAL). No further archeological investigations are recommended. However, prior to construction of new pipeline, the project must be coordinated with the Texas Historical Commission (THC) to obtain clearance.

Coordination with the THC is ongoing. Based on survey results, Luminant has indicated that there are no significant findings along the pipe line routes. Cultural resources that occur on public lands or within the APE 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).

1.2.2.6 Threats to Natural Resources

Threats to natural resources include potentially lower streamflows downstream of Lake Granbury, potentially increased salinity levels (total dissolved solids, TDS) in Lake Granbury, and potentially increased temperatures. Downstream flows will be largely unaffected by the addition of the Luminant diversion.

Blowdown water from the cooling towers that would be returned to Lake Granbury will contain essentially the same mass load of TDS as the water originally diverted, but in greater concentrations due to the forced loss of water during the cooling process. In order to obtain a Texas Pollutant Discharge Elimination System (TPDES) discharge permit from the Texas Commission on Environmental Quality, Luminant will likely be required to treat the blowdown water by removing dissolved solids. For this reason, it is assumed that Luminant will be required to treat the blowdown water sufficiently so as to not create salinity levels in Lake Granbury that would constitute a threat to natural resources. The required treatment to remove dissolved solids is not included in this analysis.

Increased temperature in Lake Granbury could pose a threat to natural resources. The blowdown water to be discharged into Lake Granbury will be hotter than the ambient water temperature. Analyses provided by Luminant indicate that this temperature increase would dissipate quickly, and therefore will not increase the overall water temperature in Lake Granbury.

1.3 Engineering and Costing

Summaries of project costs for the diversion and blowdown pipelines are shown in Tables 6 and 7. The total project is estimated to cost $103.9 million for construction of the intake, pump stations, and transmission pipelines necessary to divert supply from Lake Granbury and return the blowdown water back to the reservoir. The annual project costs are estimated to be $15.98 million; this includes annual debt service, operation and maintenance, and annual payment to the Brazos River Authority for the water supply.

1.4 Implementation Issues

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

Table 6.
Cost Estimate Summary
Somervell County Steam Electric Supply from the Brazos River Authority
(Second Quarter 2002 Prices)
Cooling Tower Supply Pipeline

Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (92.6 MGD)	$22,318,000
Transmission Pipeline (42 in dia., 12 miles)	$25,548,000
Total Capital Cost	**$47,866,000**
Engineering, Legal Costs and Contingencies	$15,476,000
Environmental & Archaeology Studies and Mitigation	$602,000
Land Acquisition and Surveying (121 acres)	$265,000
Interest During Construction (2 years)	$5,137,000
Total Project Cost	**$69,346,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$5,038,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$813,000
Pumping Energy Costs (59775328 kW-hr @ 0.06 $/kW-hr)	$3,587,000
Purchase of Water (76270 acft/yr @ 45.75 $/acft)	$3,489,000
Total Annual Cost	**$12,927,000**
Available Project Yield (acft/yr)	103,717
Annual Cost of Water ($ per acft)	$125
Annual Cost of Water ($ per 1,000 gallons)	$0.38

Table 7.
Cost Estimate Summary
Somervell County Steam Electric Supply from the Brazos River Authority
(Second Quarter 2002 Prices)
Cooling Tower Blowdown Pipeline

Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (37.6 MGD)	$3,333,000
Transmission Pipeline (36 in dia., 12.6 miles)	$20,469,000
Total Capital Cost	**$23,802,000**
Engineering, Legal Costs and Contingencies	$7,307,000
Environmental & Archaeology Studies and Mitigation	$634,000
Land Acquisition and Surveying (92 acres)	$265,000
Interest During Construction (2 years)	$2,561,000
Total Project Cost	**$34,569,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$2,511,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$288,000
Pumping Energy Costs (4297887 kW-hr @ 0.06 $/kW-hr)	$258,000
Total Annual Cost	**$3,057,000**
Available Project Yield (acft/yr)	42,100
Annual Cost of Water ($ per acft)	$73
Annual Cost of Water ($ per 1,000 gallons)	$0.22

Note: Costs related to treatment of blowdown water (desalination) are not considered.

Table 8.
Comparison of Somervell County Steam Electric Supply from the Brazos River Authority to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low to moderate impact
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• Low to moderate impact on salinity levels in Lake Granbury, depending on TPDES discharge permit requirements; 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 industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

1.4.1 Potential Regulatory Requirements

- Texas Commission on Environmental Quality (TCEQ) System Operations Permit will need to be obtained by the Brazos River Authority;
- 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;
- TCEQ-administered TPDES discharge permit for return of blowdown water to Lake Granbury;
- 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.

1.4.2 State and Federal Permits may Require the Following Studies and Plans

- Environmental impact or assessment studies. Luminant indicates that that these studies have been completed, with the final report under preparation;
- 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. Luminant indicates that these studies have been completed and contemplate that no further action will be required.

1.4.3 Land Acquisition Issues

- Additional width of easement on land not owned by Luminant may be required.

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4B.21.6 City of Waco (WMARSS) Amendment

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BRAZOS G
WATER PLANNING GROUP

BRAZOS RIVER AUTHORITY, Administrative Agent
P.O. Box 7555 ט Waco, Texas 76714-7555
(254) 761-3100 ט Fax (254) 761-3204

April 15, 2009

To: Interested Parties

Re: Amendment to the 2006 Brazos G Regional Water Plan related to Additional Water Management Strategies for the City of Bellmead, Hewitt, Lacy-Lakeview, Lorena and Waco.

The Brazos G Regional Water Planning Group hereby amends the 2006 Brazos G Regional Water Plan as follows:

1. **Recommend the WMARSS Bellmead/Lacy-Lakeview Reuse Project as a Recommended Water Management Strategy for the Cities of Bellmead and Lacy-Lakeview.**

WMARSS is expanding its reuse system, and is pursuing development of the Bellmead/Lacy-Lakeview Reuse Project to supply various reuse customers within the Cities of Bellmead and Lacy-Lakeview.

2. **Recommend the WMARSS Bull Hide Creek Reuse Project as a Recommended Water Management Strategy for the Cities of Lorena and Hewitt.**

WMARSS is expanding its reuse system, and is pursuing development of the Bull Hide Creek Reuse Project to supply various reuse customers within the Cities of Lorena and Hewitt.

3. **Recommend the WMARSS Flat Creek Reuse Project as a Recommended Water Management Strategy for the City of Waco.**

WMARSS is expanding its reuse system, and is pursuing development of the Flat Creek Reuse Line to supply various reuse customers within the City of Waco.

The request to amend the 2006 Plan is included as Attachment A. The revised plans for the Cities of Bellmead, Hewitt, Lacy-Lakeview, Lorena and Waco are shown in Attachment B. Detailed technical evaluations of the projects comprising these amendments are included as Attachments C, D and E.

Request for Amendment to the 2006 Brazos G Regional Water Plan to Add Development of the Bellmead/Lacy-Lakeview, Bull Hide Creek, and Flat Creek Reuse Projects to Supplement Water Supplies in McLennan County

Background

On behalf of the member cities of the Waco Metropolitan Area Sewerage System (WMARSS), the City of Waco requests amendments to the *2006 Brazos G Regional Water Plan* and the *2007 State Water Plan* to incorporate three specific reuse projects that WMARSS is pursuing. The projects will provide reclaimed water from the existing WMARSS Central WWTP and the proposed WMARSS Bull Hide Creek WWTP. The projects will be capable of supplying the cities of Bellmead, Hewitt, Lacy-Lakeview, Lorena and Waco with Type 1 reuse water for industrial uses and landscape irrigation at existing or future parks, schools, ball fields, and other green spaces. This supply would decrease demands on the Trinity Aquifer groundwater and surface water supplies held by the Cities of Waco and Lorena.

Amendment Request

The City of Waco respectfully requests that the *2006 Brazos G Regional Water Plan* be amended to add the following reuse water management strategies:

- **WMARSS Bellmead/Lacy-Lakeview Reuse**

  The reclaimed water line and pump station project would provide the Cities of Bellmead and Lacy-Lakeview with up to 2 MGD (2,242 acft/yr) of reclaimed water from the WMARSS Central WWTP.

- **WMARSS Bull Hide Creek Reuse**

  The Bull Hide Creek project would provide the Cities of Hewitt and Lorena with up to 1.5 MGD (1,681 acft/yr) of treated effluent from the proposed WMARSS Bull Hide Creek WWTP.

- **WMARSS Flat Creek Reuse**

  The WMARSS Flat Creek Reuse project would provide the City of Waco with up to 7 MGD (7,847 acft/yr) of reclaimed water from the existing WMARSS Central WWTP.

These reuse projects are reflected in revised individual water supply plans for each city, as shown in the amended Sections 4C.24.1, 4C.24.9, 4C.24.10, 4C.24.11, 4C.24.18 and 4C.38.17 of the *2006 Brazos G Regional Water Plan*.

4C.24.1 City of Bellmead

4C.24.1.1 Description of Supply

The City of Bellmead obtains its water supply from groundwater from the Trinity Aquifer. The City of Bellmead also has contracted with the City of Waco for supplemental surface water supply from Lake Waco. No shortages are projected for the City of Bellmead; however, the City of Waco and the City of Bellmead are currently negotiating a contract for water supply in order to reduce Bellmead's dependence on Trinity Aquifer groundwater. The purchase of supplemental reuse water from WMARSS is also recommended to reduce demands on Trinity Aquifer groundwater.

4C.24.1.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended for the City of Bellmead:

- Purchase water from the City of Waco. In order to reduce demands on the Trinity Aquifer, provide for future growth, and coordinate with the City of Waco's plans, water purchased from the City of Waco is in excess of projected future demands for this WUG.
- Purchase reuse water from WMARSS (Bellmead/Lacy-Lakeview Reuse). The reuse supply will reduce demands 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

4C.24.1.3 Costs

Costs of the Recommended Plan for the City of Bellmead.

a. Water Supply from City of Waco:
   - Date to be Implemented: before 2010
   - Unit Cost: assumed unit cost of $815/acft ($2.50/1,000 gallons) for wholesale treated water, including transmission costs
   - Annual Cost: $2,609,630

b. Reuse Water Supply from WMARSS (Bellmead/Lacy-Lakeview Reuse)
   - Date to be Implemented: before 2010
   - Unit Cost: assumed unit cost of $240/acft ($0.74/1,000 gallons) for wholesale treated reuse water, including transmission costs
   - Annual Cost: $269,000

Table 4C.24-2.
Recommended Plan Costs by Decade for the City of Bellmead

Plan Element	2010	2020	2030	2040	2050	2060
Projected Surplus/(Shortage) (acft/yr)	113	113	113	113	113	113
Water Supply from City of Waco						
Supply From Plan Element (acft/yr)	2,622	2,751	2,873	2,984	3,065	3,202
Annual Cost ($/yr)	$2,136,930	$2,242,065	$2,341,495	$2,431,960	$2,497,975	$2,609,630
Unit Cost ($/acft)	$815	$815	$815	$815	$815	$815
Reuse Water Supply (WMARSS Bellmead/Lacy-Lakeview Reuse)						
Supply From Plan Element (acft/yr)	1,121	1,121	1,121	1,121	1,121	1,121
Annual Cost ($/yr)	$269,000	$269,000	$269,000	$269,000	$269,000	$269,000
Unit Cost ($/acft)	$240	$240	$240	$240	$240	$240

4C.24.9 City of Hewitt

4C.24.9.1 Description of Supply

The City of Hewitt obtains its water supply from groundwater from the Trinity Aquifer. The City also has contracted with the City of Waco for supplemental surface water supply from Lake Waco. No shortages are projected for the City of Hewitt, however, purchase of supplemental reuse water from WMARSS is recommended to reduce demands on water supplied by the City of Waco and groundwater from the Trinity Aquifer.

4C.24.9.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended for the City of Hewitt:

- Purchase reuse water from WMARSS (Bull Hide Creek Reuse). The reuse supply will reduce demands 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

4C.24.9.3 Costs

Costs of the Recommended Plan for the City of Hewitt

a. Reuse Water Supply from WMARSS (Bull Hide Creek Reuse)
   - Date to be Implemented: before 2010
   - Unit Cost: assumed unit cost of $798/acft ($2.45/1,000 gallons) for wholesale treated reuse water, including transmission costs
   - Annual Cost: $984,000

Table 4C.24-2.
Recommended Plan Costs by Decade for the City of Hewitt

Plan Element	2010	2020	2030	2040	2050	2060
Projected Surplus/(Shortage) (acft/yr)	123	123	123	123	123	123
Reuse Water Supply (WMARSS Bull Hide Creek Reuse)						
Supply From Plan Element (acft/yr)	1,233	1,233	1,233	1,233	1,233	1,233
Annual Cost ($/yr)	$984,000	$984,000	$984,000	$984,000	$984,000	$984,000
Unit Cost ($/acft)	$798	$798	$798	$798	$798	$798

4C.24.10 City of Lacy-Lakeview

4C.24.10.1 Description of Supply

The City of Lacy-Lakeview obtains its water supply from the City of Waco. No shortages are projected for the City of Lacy-Lakeview, however, purchase of supplemental reuse water from WMARSS is recommended to reduce demands on water supplied by the City of Waco.

4C.24.10.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended for the City of Lacy-Lakeview:

- Purchase reuse water from WMARSS (Bellmead/Lacy-Lakeview Reuse). The reuse supply will reduce demands 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

4C.24.10.3 Costs

Costs of the Recommended Plan for the City of Lacy-Lakeview

a. Reuse Water Supply from WMARSS (Bellmead/Lacy-Lakeview Reuse)
   - Date to be Implemented: before 2010
   - Unit Cost: assumed unit cost of $240/acft ($0.74/1,000 gallons) for wholesale treated reuse water, including transmission costs
   - Annual Cost: $269,000

Table 4C.24-2.
Recommended Plan Costs by Decade for the City of Lacy-Lakeview

Plan Element	*2010*	*2020*	*2030*	*2040*	*2050*	*2060*
Projected Surplus/(Shortage) (acft/yr)	0	0	0	0	0	0
Reuse Water Supply (WMARSS Bellmead/Lacy-Lakeview Reuse)						
Supply From Plan Element (acft/yr)	1,121	1,121	1,121	1,121	1,121	1,121
Annual Cost ($/yr)	$269,000	$269,000	$269,000	$269,000	$269,000	$269,000
Unit Cost ($/acft)	$240	$240	$240	$240	$240	$240

4C.24.11 City of Lorena

4C.24.11.1 Description of Supply

The City of Lorena obtains its water supply from groundwater from the Trinity Aquifer and run-of-river rights. No shortages are projected for the City of Lorena, however, purchase of supplemental reuse water from WMARSS is recommended to reduce demands on water supplied by the run-of-river rights and groundwater from the Trinity Aquifer.

4C.24.11.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended for the City of Lorena:

- Purchase reuse water from WMARSS (Bull Hide Creek Reuse). The reuse supply will reduce demands 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

4C.24.11.3 Costs

Costs of the Recommended Plan for the City of Lorena

a. Reuse Water Supply from WMARSS (Bull Hide Creek Reuse)
   - Date to be Implemented: before 2010
   - Unit Cost: assumed unit cost of $798/acft ($2.45/1,000 gallons) for wholesale treated reuse water, including transmission costs
   - Annual Cost: $357,000

Table 4C.24-2.
Recommended Plan Costs by Decade for the City of Lorena

Plan Element	2010	2020	2030	2040	2050	2060
Projected Surplus/(Shortage) (acft/yr)	662	623	591	556	534	498
Reuse Water Supply (WMARSS Bull Hide Creek Reuse)						
Supply From Plan Element (acft/yr)	448	448	448	448	448	448
Annual Cost ($/yr)	$357,000	$357,000	$357,000	$357,000	$357,000	$357,000
Unit Cost ($/acft)	$798	$798	$798	$798	$798	$798

4C.24.18 City of Waco

The City of Waco obtains its water supply from surface water from Lake Waco, for which it owns water rights. The City supplies several neighboring communities and projected wholesale water sales are projected to cause a shortage before 2050. Refer to Section 4C.38.17 for the City's plan as a Wholesale Water Provider. The City of Waco's plan as a Wholesale Water Provider has been amended.

4C.38.17 City of Waco (Wholesale Water Provider)

4C.38.17.1 Description of Supply

The City of Waco obtains its water supply from surface water from Lake Waco, in which it owns water rights, and from Lake Brazos on the Brazos River. The City supplies several neighboring communities and has sufficient water supply to meet its municipal and regional needs through the year 2030, but is projected to experience shortages prior to year 2050. The City has demonstrated a commitment to provide regional water supply in McLennan County, and could extend regional water supplies beyond the 2060 planning horizon by actively pursuing a reuse program. The City has recently entered into a contract to supply up to 16,000 acft of reuse water per year to LS Power to provide cooling water for steam electric power generation, and is exploring other potential reuse water sales.

4C.38.17.2 Water Supply Plan

The Brazos G RWPG recommends that the City of Waco continue to pursue direct and indirect reuse as a water management strategy in order to diversify and extend regional water supplies in the McLennan County area. Accordingly, the following water supply plan is recommended for the City of Waco:

- **Develop Reuse Supplies to Extend Lake Waco and Trinity Aquifer Supplies.**

4C.38.17.3 Costs

Costs of the Recommended Plan for the City of Waco.

a. WMARSS Reuse Water Supply (Flat Creek Reuse):
   - Cost Source: Evaluation of strategy evaluation added through plan amendment, adjusted for cost of purchased water
   - Date to be Implemented: ongoing

b. Other WMARSS Reuse Water Supply:
   - Cost Source: Volume II, Section 4B.3
   - Date to be Implemented: ongoing
   - Unit Cost: Unit costs range widely, depending upon quantity used and type of use:
     - $1,025/acft (average) for small-quantity municipal irrigation use
     - $111/acft for industrial use (steam-electric)
     - Based here on a projected average of $200/acft.

Table 4C.38-12.
Recommended Plan Costs by Decade for the City of Waco

Plan Element	2010	2020	2030	2040	2050	2060
Projected Surplus/(Shortage) (acft/yr)	28,072	23,619	7,729	2,235	(4,612)	(11,941)
Reuse Water Supply (WMARSS Flat Creek Reuse)						
Supply From Plan Element (acft/yr)[1]	5,319	6,918	7,847	7,847	7,847	7,847
Annual Cost ($/yr)	$1,140,000	$1,204,000	$1,241,000	$1,241,000	$1,241,000	$1,241,000
Unit Cost ($/acft)	$214.35	$174.03	$158.16	$158.16	$158.16	$158.16
Other WMARSS Reuse Water Supply						
Supply From Plan Element[1] (acft/yr)	--	--	420	1,817	2,705	4,009
Annual Cost ($/yr)	--	--	$84,000	$363,500	$541,000	$801,800
Unit Cost ($/acft)	--	--	$200.00	$200.00	$200.00	$200.00

[1] Remaining projected WMARSS flows available after meeting the demands of LS Power Station (Section 4B.3.1.9) and other WMARSS reuse projects.

WMARSS Bellmead/Lacy-Lakeview Reuse

Description of Option

The Waco Metropolitan Area Regional Sewerage System (WMARSS) is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the Cities of Bellmead and Lacy-Lakeview. This option consists of an integrated reuse project to deliver Type 1 reuse water from the existing WMARSS Central Wastewater Treatment Plant (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 1.

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 is divided equallty 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; and
- Possible negative impact to fish and wildlife habitat with substantially reduced stream flows.

A summary of environmental issues is presented in Table 1.

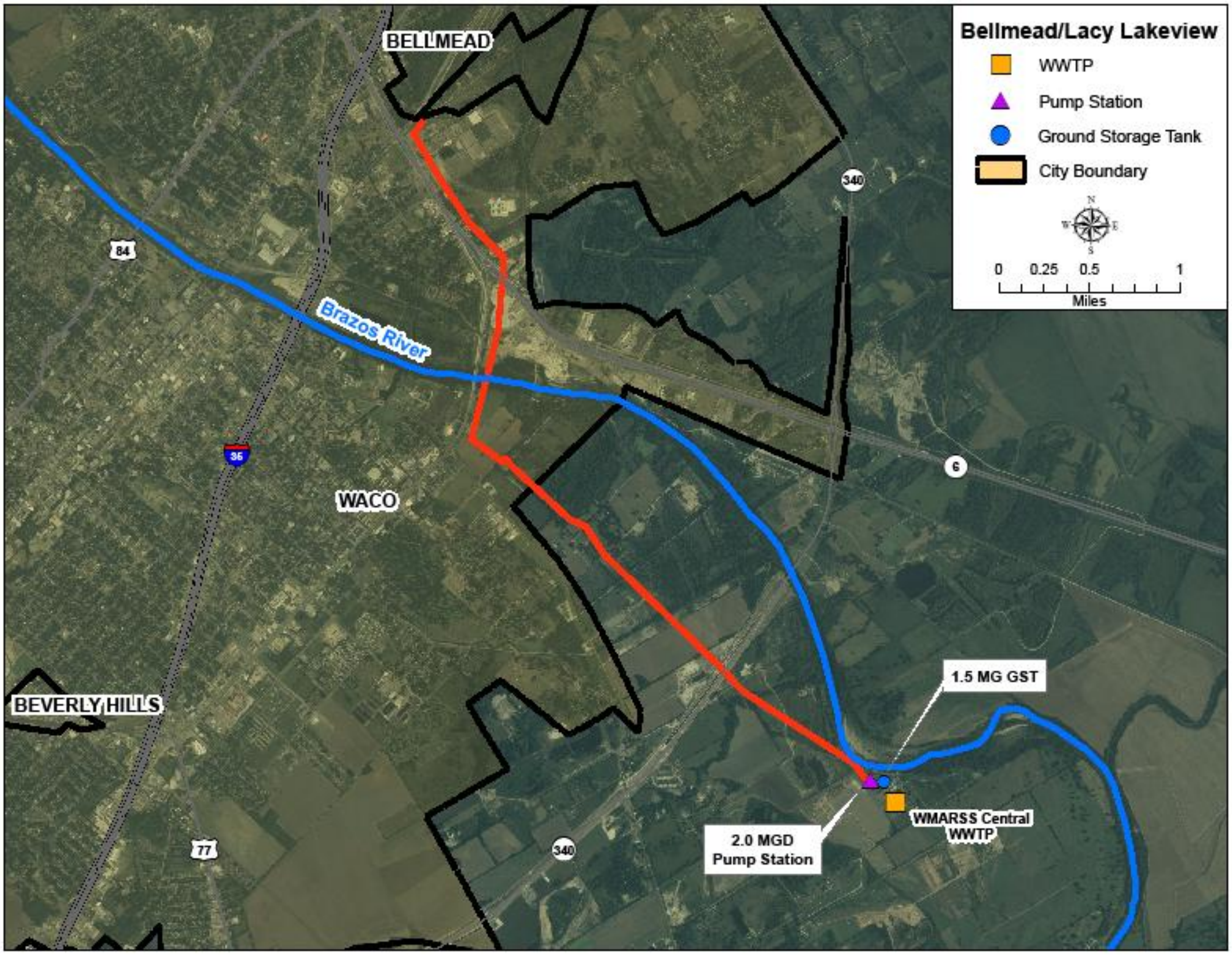

Figure 1. WMARSS Bellmead/Lacy-Lakeview Reuse

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

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

Costs presented in Table 3 provide the total option costs for developing a wastewater reuse supply for Bellmead and Lacy-Lakeview. The project will have an estimated total capital cost of $3,354,000 and an annual cost of $538,000. This cost translates to a $240 per acft or $0.74 per 1,000 gallons unit cost of the reuse water.

The cost to each City for the use of the reclaimed water from the Bellmead/Lacy-Lakeview Project is shown in Table 4. The costs are divided between the cities based on the quantity of water supplied to each.

Table 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 20-inch pipe; from WMARSS Central WWTP to I-35 Pump Station
Available Project Yield	2.0 MGD (2,242 acft/yr); total yield for all Bellmead/Lacy-Lakeview projects supplied

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 5, 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 transmission facilities to the ultimate points of end use.

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

Table 3.
Cost Estimate Summary
WMARSS Bellmead/Lacy Lakeview Reuse
Second Quarter 2002 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Pump Station (2.0 MGD)	$817,000
Ground Storage Tank (1.5 MG)	$780,000
Transmission Pipeline (12 in dia., 5 miles)	$1,757,000
Total Capital Cost	**$3,354,000**
Engineering, Legal Costs and Contingencies	$1,086,000
Environmental & Archaeology Studies and Mitigation	$121,000
Land Acquisition and Surveying (22 acres)	$169,000
Interest During Construction (1 year)	$190,000
Total Project Cost	**$4,920,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$357,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$46,000
Pumping Energy Costs (770,073 kW-hr @ 0.06 $/kW-hr)	$46,000
Purchase of Water (2,242 acft/yr @ 39.75 $/acft)	$89,000
Total Annual Cost	**$538,000**
Available Project Yield (acft/yr)	2,242
Annual Cost of Water ($ per acft)	$240
Annual Cost of Water ($ per 1,000 gallons)	$0.74

Table 4.
Cost to each City
WMARSS Bellmead and Lacy-Lakeview Reuse

City	Reuse Water Demand (acft/yr)	Unit Cost ($/acft)	Annual Cost ($/yr)
City of Bellmead	1,121	$240	$269,000
City of Lacy Lakeview	1,121	$240	$269,000
Total	**2,242**		**$538,000**

Table 5.
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. Highly reliable
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

WMARSS Bull Hide Creek Reuse

Description of Option

The Waco Metropolitan Area Regional Sewerage System (WMARSS) is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the Cities of Hewitt and Lorena. This option consists of an integrated reuse project to deliver Type 1 reuse water from the proposed WMARSS Bull Hide Creek Wastewater Treatment Plant 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 1.

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 proposed 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 planned 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; and
- Possible negative impact to fish and wildlife habitat due to reduced stream flows.

A summary of environmental issues is presented in Table 1.

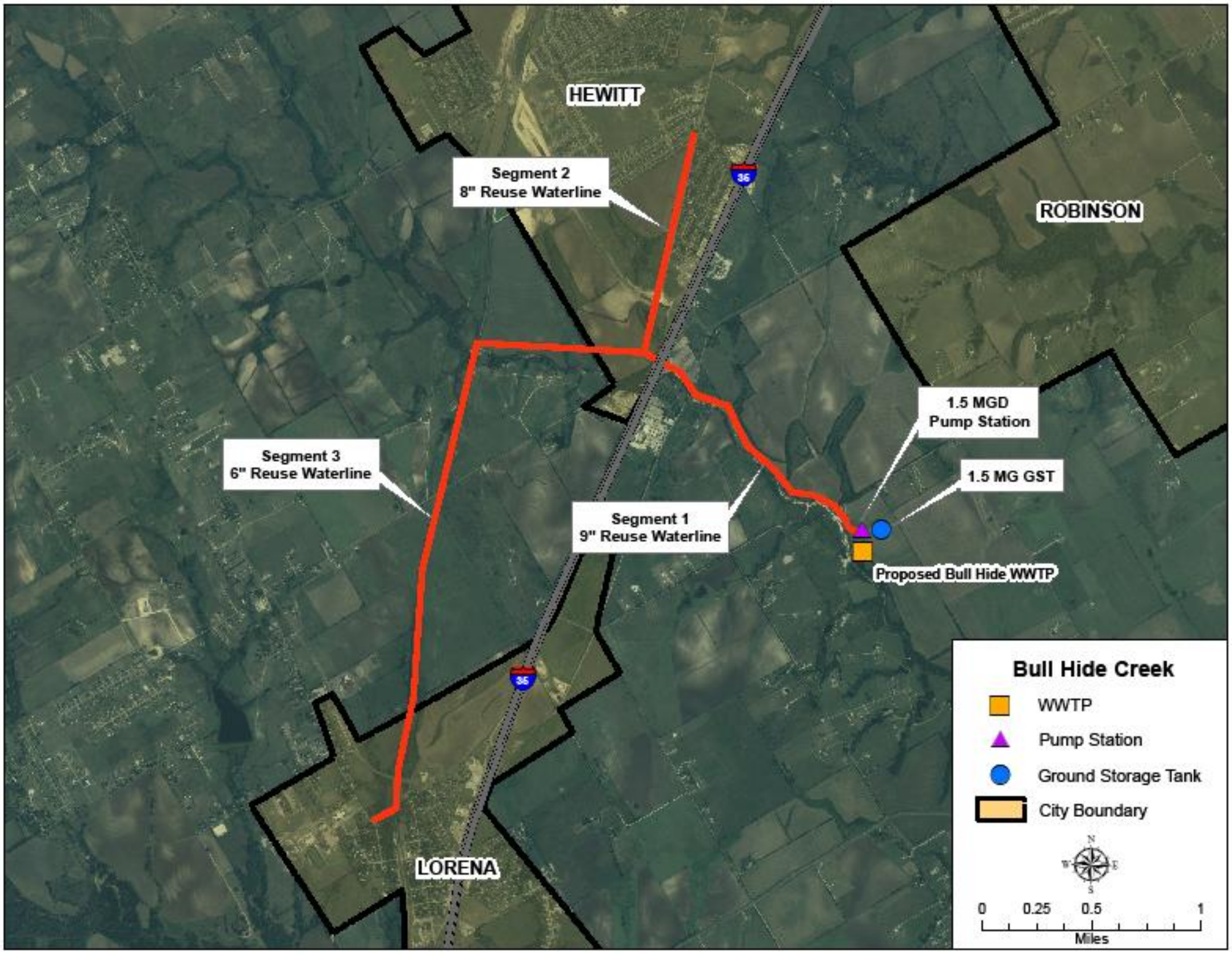

Figure 1. WMARSS Bull Hide Creek Reuse

Table 1.
Environmental Issues: WMARSS Bull Hide Creek Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible negative impact to fish and wildlife habitat due to reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible impact
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 2. The project requires a 1.5 MGD pump station along with a 1.5 MG storage tank located at the proposed WMARSS Bull Hide Creek WWTP site. The transmission pipeline system is separated into three separate components. The first segment is a 9-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.

Costs presented in Table 3 provide the total option costs for developing a wastewater reuse supply for Hewitt and Lorena. The project will have an estimated total capital cost of $11,207,000 and an annual cost of $1,341,000. This cost translates to a $798 per acft or $2.45 per 1,000 gallons unit cost of the reuse water.

The cost to each City for the use of the reclaimed water from the Bull Hide Creek WWTP is shown in Table 4. The costs are divided between the cities based on the quantity of water supplied to each.

Table 2.
Required Facilities – WMARSS Bull Hide Creek Reuse

Facility	Description
WWTP	1.5 MGD proposed WMARSS Bull Hide Creek WWTP
Pump Stations	129 HP at proposed 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 Central WWTP
Pipelines	Segment 1; 1.3 miles of 9-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

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 5, 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.

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

Table 3.
Cost Estimate Summary
WMARSS Bull Hide Creek Reuse
Second Quarter 2002 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Waste Water Treatment Plant (1.5 MGD)	$8,534,000
Intake and Pump Station (1.5 MGD)	$817,000
Ground Storage Tank (1.5 MG)	$780,000
Segment 1 Transmission Pipeline (9 in dia., 1.3 miles)	$383,000
Segment 2 Transmission Pipeline (8 in dia., 1.0 miles)	$177,000
Segment 3 Transmission Pipeline (6 in dia., 3.0 miles)	$516,000
Total Capital Cost	**$11,207,000**
Engineering, Legal Costs and Contingencies	$3,869,000
Environmental & Archaeology Studies and Mitigation	$139,000
Land Acquisition and Surveying (25 acres)	$192,000
Interest During Construction (1 years)	$617,000
Total Project Cost	**$16,024,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$1,164,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$39,000
Water Treatment Plant	$23,000
Pumping Energy Costs (802,985 kW-hr @ 0.06 $/kW-hr)	$48,000
Purchase of Water (1,681 acft/yr @ 39.75 $/acft)	$67,000
Total Annual Cost	**$1,341,000**
Available Project Yield (acft/yr)	1,681
Annual Cost of Water ($ per acft)	$798
Annual Cost of Water ($ per 1,000 gallons)	$2.45

Table 4.
Cost to each City
WMARSS Bull Hide Creek Reuse

City	Reuse Water Demand (acft/yr)	Unit Cost ($/acft)	Annual Cost ($/yr)
City of Hewitt	1,233	$798	$984,000
City of Lorena	448	$798	$357,000
Total	**1,681**		**$1,341,000**

Table 5.
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. Highly reliable
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

WMARSS Flat Creek Reuse

Description of Option

The Waco Metropolitan Area Regional Sewerage System (WMARSS) is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the City of Waco. This option consists of an integrated reuse project to deliver Type 1 reuse water from the existing WMARSS Central Wastewater Treatment Plant 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 1.

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. 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 will supply 16,000 acft/yr (14.3 MGD) of the treated effluent from the WMARSS system to the Sandy Creek Project (LS Power) (Section 4B.3.1.9 of the 2006 Plan). An additional 3,920 acft/yr (3.5 MGD) would be supplied through the Bullhide Creek and Bellmead/Lacy Lakeview reuse projects. The Year 2000 estimated effluent from WMARSS is 24,575 acft/yr (21.92 MGD) (Table 3.2-1 of the 2006 Plan). The Year 2060 estimated effluent from WMARSS is 31,779 acft/yr (28.4 MGD) (Section 4B.3 of the 2006 Plan). Assuming simultaneous implementation of the other reuse projects, potential available supply from the Flat Creek Reuse Project would be 5,319 acft/yr in 2010, 6,918 acft/yr in 2020, and the full 7,847 acft/yr (7 MGD) capacity sometime prior to 2030.

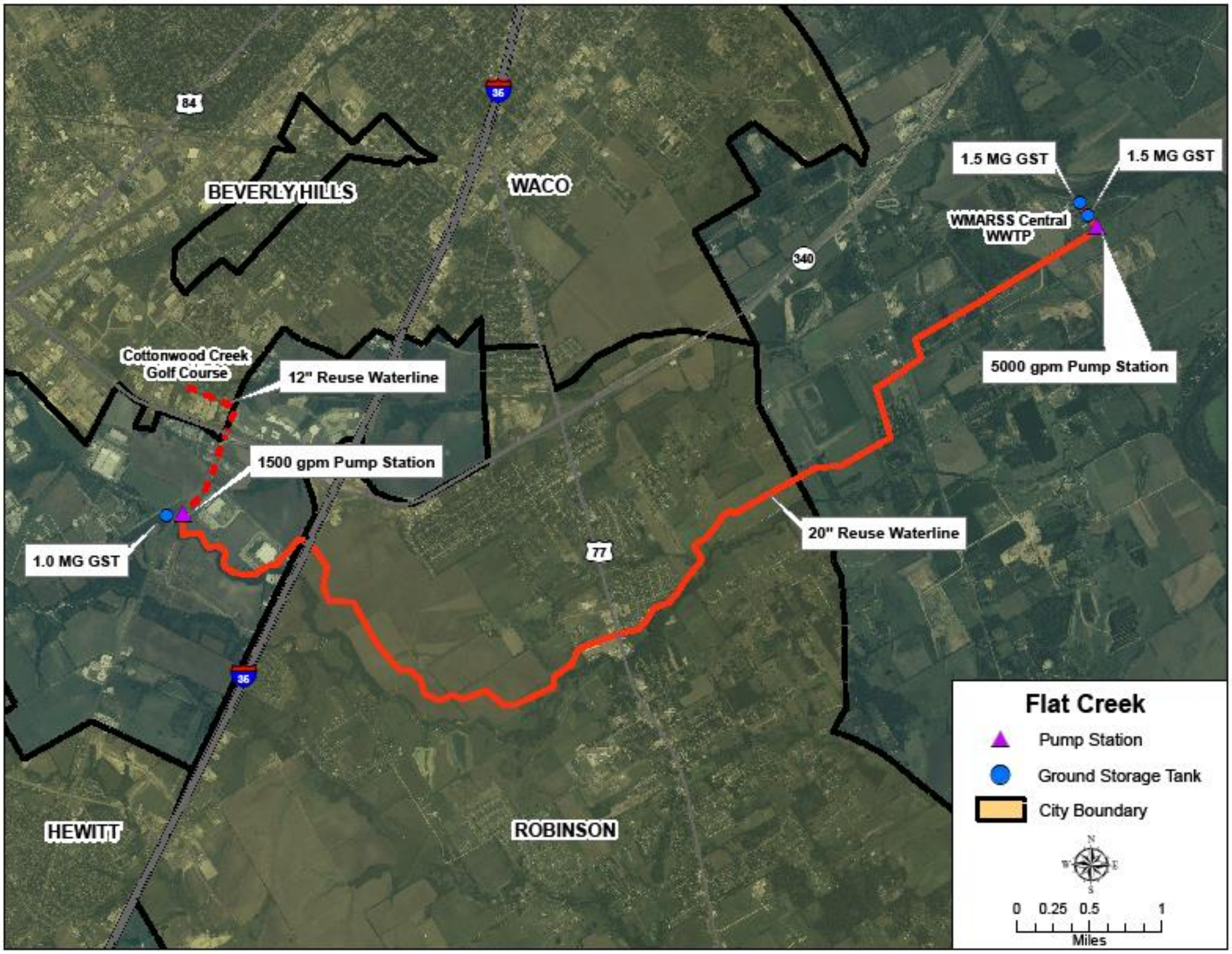

Figure 1. WMARSS Flat Creek Reuse

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; and
- Possible negative impact to fish and wildlife habitat due to reduced stream flows.

A summary of environmental issues is presented in Table 1.

Table 1.
Environmental Issues: WMARSS Flat Creek Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible negative impact to fish and wildlife habitat due to reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible impact
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 2. The project requires a 7 MGD pump station along with two 1.5 MG storage tanks located at the WMARSS Central WWTP. A 51,000 ft, 20-inch diameter pipe connects the pump station 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 diamater pipe to Cottonwood Creek Golf Course for irrigation purposes.

Table 2.
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	51,000 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 provide the total option costs for developing a wastewater reuse supply for Waco and Cottonwood Creek Golf Course. The project will have an estimated total capital cost of $6,298,000 and an annual cost of $1,241,000. This cost translates to a $158.15 per acft or $0.49 per 1,000 gallons unit cost of the reuse water, upon utilization of the full 7 MGD (7,847 acft/yr).

Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4, 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;
- NPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

Table 3.
Cost Estimate Summary
WMARSS Flat Creek Reuse
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities 2Q 2002 Prices***
Intake and Pump Station @ WMARSS (3,000 gpm)	$1,126,000
Ground Storage Tank @ WMARSS (1.5 MG)	$684,000
Transmission Pipeline (20 in dia., 51,000 feet)	$2,087,000
Transmission Pipeline (12 in dia., 6,720 feet)	$332,000
Pump Station @ I-35 (1,500 gpm)	$805,000
Second Ground Storage Tank @ WMARSS (1.5 MG)	$684,000
Ground Storage Tank @ I-35 (1 MG)	$580,000
Total Capital Cost	**$6,298,000**
Engineering, Legal Costs and Contingencies	$2,084,000
Environmental & Archaeology Studies and Mitigation	$36,000
Land Acquisition and Surveying (13 acres)	$49,000
Interest During Construction (1 years)	$339,000
Total Project Cost	**$8,806,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$640,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$86,000
Pumping Energy Costs (3,384,493 kW-hr @ 0.06 $/kW-hr)	$203,000
Purchase of Water (7,847 acft/yr @ 39.75 $/acft)	$312,000
Total Annual Cost	**$1,241,000**
Available Project Yield (acft/yr)	7,847
Annual Cost of Water ($ per acft)	$158.16
Annual Cost of Water ($ per 1,000 gallons)	$0.49

Table 4.
Comparison of Flat Creek Reuse Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply: 1. Quantity 2. Reliability 3. Cost	 1. Sufficient for intended uses 2. Highly reliable 3. Reasonable
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries	 1. Reduces instream flows—possible low impact 2. Possible low impact 3. None or low impact 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

4B.21.7 Johnson County Special Utility District Amendment

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BRAZOS G
WATER PLANNING GROUP

BRAZOS RIVER AUTHORITY, Administrative Agent
P.O. Box 7555 υ Waco, Texas 76714-7555
(254) 761-3100 υ Fax (254) 761-3204

February 3, 2010

To: Interested Parties

Re: Amendment to the 2006 Brazos G Regional Water Plan: **Johnson County SUD Supply from Mansfield**.

The Brazos G Regional Water Planning Group hereby amends the 2006 Brazos G Regional Water Plan as follows:

1. **Recommend the Johnson County SUD Supply from Mansfield Project as a Recommended Water Management Strategy for Johnson County SUD.**

The Johnson County SUD is pursuing the construction of potable water transmission facilities to supply treated Trinity Basin water from a connection with the City of Mansfield.

The request to amend the 2006 Plan is included as Attachment A. The revised plan for Johnson County SUD is shown in Attachment B. A detailed technical evaluation of the project is included as Attachment C.

Johnson County Special Utility District

"Quality and Service since 1965"

November 10, 2009

Chairman
Brazos G Regional Water Planning Group
c/o Mr. Trey Buzzbee
Brazos River Authority
P.O. Box 7555
Waco, TX 76714

Dear Group Members,

Johnson County Special Utility District (JCSUD) is requesting an amendment to the 2006 Brazos G Regional Water Plan.

The amendment is sought for a project to assure future supplies of treated surface water for the customers residing in the JCSUD service area. As presently written, the 2006 Brazos G Regional Water Plan does not include the project.

The project that will form the basis of the amendment, entitled "Trinity Basin Transmission Facilities" will help JCSUD accomplish the following goals:

- Conserve highly stressed groundwater supplies
- Make potable water supplies from the Trinity Basin available for future growth
- Allow JCSUD to meet customer needs through the year 2028

The amendment is required to obtain funding through the Texas Water Development Board (TWDB) for constructing the project.

We request that this proposed amendment be placed on the agenda and considered by the planning group at its November 2009 meeting. At the meeting JCSUD will outline the amendment's purpose and scope to the members and answer questions. Due to time constraints, however, the full body of the amendment will not be available in time for the November 12th meeting. JCSUD therefore requests that the Board take the request under advisement, await the full amendment request in two weeks from Thursday the 12th of November and then begin the review and approval process, hopefully ending with Brazos G passing it along to the TWDB with a supportive endorsement.

We request that when received and reviewed by the Brazos G group, they pass the request along with their support to the Texas Water Development Board as soon as possible. We understand that this will entail a delay until the January meeting for full Board approval.

Respectfully Yours,

John M. Sewell

John M. Sewell, P.E.

2849 Hwy. 171 South • P.O. Box 509 • Cleburne, TX 76033-0509
(817) 760-5200 • Fax (817) 760-5238

4C.17.9 Johnson County SUD (Formerly Johnson County Rural WSC)

4C.17.9.1 Description of Supply

Johnson County SUD (which remains Johnson County Rural WSC in the TWDB database) obtains its water supply from groundwater from the Trinity Aquifer, and a contract with the Brazos River Authority for water from Lake Granbury through the SWATS system. Johnson County SUD is projected to have a shortage of 2,456 acft/yr in the year 2030, and a shortage of 13,252 acft/yr in the year 2060.

4C.17.9.2 Water Supply Plan

Working within the planning criteria established by the Brazos G RWPG and TWDB, the following water supply plan is recommended to meet the projected shortage of Johnson County SUD:

- Conservation,
- Supply from the City of Mansfield, and
- Purchase water from the Trinity River Authority Joe Pool Reservoir Reuse Project.
- Alternatives to this plan are additional use of Lake Granbury supply (Volume II, Section 4B.6.1) and Aquifer Storage and Recover (ASR) in the Trinity Aquifer (Volume II, Section 4B.8.2).

4C.17.9.3 Costs

Costs of the Recommended Plan for Johnson County SUD.

a. Conservation:
   - Cost Source: Volume II, Section 4B.2.1
   - Date to be Implemented: before 2010
   - Annual Cost: maximum of $1,820,960 in 2060

b. Supply from the City of Mansfield:
   - Cost Source: Amendment to the 2006 Brazos G Plan
   - Date to be Implemented: before 2020
   - Total Project Cost: $12,745,000
   - Annual Cost: $11,292,113

c. Reuse from Trinity River Authority (Joe Pool Reservoir):
   - Cost Source: Volume II, Section 4B.11.1
   - Date to be Implemented: before 2030

- Total Project Cost: $79,257,000
- Annual Cost: $12,003,200

Table 4C.17-10.
Recommended Plan Costs by Decade for Johnson County SUD

Plan Element	2010	2020	2030	2040	2050	2060
Projected Surplus/(Shortage) (acft/yr)	2,284	39	(2,456)	(5,431)	(9,212)	(13,252)
Conservation						
Supply From Plan Element (acft/yr)	423	1,307	1,883	2,761	3,941	4,792
Annual Cost ($/yr)	$160,740	$496,660	$715,540	$1,049,180	$1,497,580	$1,820,960
Unit Cost ($/acft)	$380	$380	$380	$380	$380	$380
Supply from the City of Mansfield						
Supply From Plan Element (acft/yr)	—	10,082	10,082	10,082	10,082	10,082
Annual Cost ($/yr)		$11,292,113	$11,292,113	$11,292,113	$10,366,200	$10,366,200
Unit Cost ($/acft)		$1,120	$1,120	$1,120	$1,028	$1,028
Reuse from Trinity River Authority (Joe Pool Reservoir)						
Supply From Plan Element (acft/yr)	—	—	20,000	20,000	20,000	20,000
Annual Cost ($/yr)			$12,003,200	$12,003,200	$12,003,200	$12,003,200
Unit Cost ($/acft)			$600	$600	$600	$600

Johnson County SUD Supply from the City of Mansfield

Description of Option

Johnson County Special Utility District (JCSUD) is currently pursuing the construction of potable water transmission facilities to supply treated Trinity Basin water to its customers, as show in Figure 1. The facilities will transmit water taken from a connection with the City of Mansfield in accordance with the terms of a recently completed contract between the City and JCSUD. The transmission facilities will ultimately be capable of transmitting the maximum allowed daily demand of 9.0 million gallons per day (MGD), or 10,082 acre-feet per year (acft/yr) of treated potable water to the JCSUD system. The project will consist of:

- A new pump station and 1.0 million gallon (MG) ground storage tank.
- A 30-inch diameter transmission line.
- Associated branch lines (12-inch and 16-inch diamerters) to transmit water to pumping stations.

Available Supply

The project will make 10,082 acft/yr available from the Trinity Basin.

Environmental Issues

Possible environmental impacts attending the construction of the transmission facilities include effects upon endangered species, riparian corridors, wetlands, cultural resources, habitat or undisturbed archeological sites. These aspects of the project will be the subject of requisite studies and assessments; should any areas of concern be identified, all reasonable and approved mitigation measures will be implemented. A summary of environmental issues is shown in Table 1.

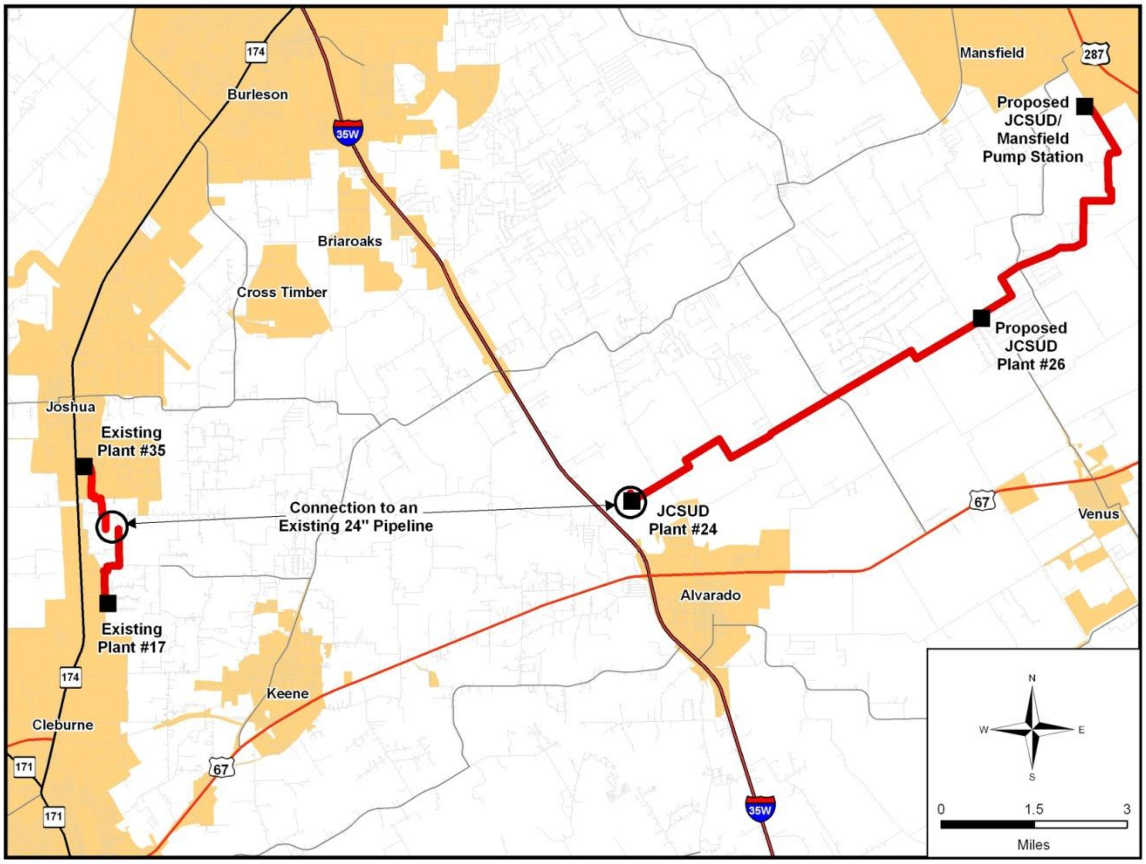

Figure 1. Johnson County SUD Transmission Facilities from the City of Mansfield

Table 1.
Environmental Issues: Johnson County SUD Supply from the City of Mansfield

Implementation Measures	Development of transmission pipelines, ground storage tanks and pump stations
Environmental Water Needs / Instream Flows	Possible low impact as this supply is already permitted
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible low impact related to the pipeline corridors
Cultural Resources	Possible low impact related to the pipeline corridors
Threatened and Endangered Species	Negligible impact

Implementation Issues

Regulatory permits for construction of the proposed facilities may be required. Quite possibly, at least one Texas Parks and Wildlife Department (TP&WD) Sand, Shell, Gravel and Marl permit for construction in state-owned stream beds will be required. In addition, an effective Storm Water Pollution Prevention Program (SW3P) including proper re-vegetation of the area after construction will be implemented as required throughout the project's locations. A U.S. Army Corps of Engineers 404 permit may also be required.

Another regulatory issue to be resolved is that of inter-basin transfer of Trinity River Basin surface water to the Brazos River Basin. Permitted through the Texas Commission for Environmental Quality (TCEQ), the impact of inter-basin transfer issues will be determined in part upon current water rights held by the Tarrant Regional Water District and the additional fact that the JCSUD service area includes parts of both river basins.

Engineering and Costing

The required improvements and costs to implement JCSUD's strategy are summarized in Table 2. The project requires a 9 MGD pump station along with a 1.0 MG storage tank. Transmission pipelines of 30-inch (66,000 linear feet), 16-inch (7,700 linear feet) and 12-inch (6,800 linear feet) diameters will be required.

The project will have an estimated total project cost of $12,745,040 and an annual cost of $11,292,113. Most of the annual cost is related to the purchase of treated water from the City of Mansfield. This annual cost translates to a $1,120 per acft or $3.44 per 1,000 gallons unit cost.

Table 2.
Cost Estimate Summary
Johnson County SUD Supply from the City of Mansfield
Second Quarter 2002 Prices

Item	Estimated Costs for Facilities 2Q 2002 Prices
9 MGD Pump Station and 1 MG Ground Storage Tank	$2,619,958
Transmission Pipeline (30-in dia, 66,000 feet)	$6,189,930
Transmission Pipeline (16-in dia., 7,700 feet)	$417,912
Transmission Pipeline (12 in dia., 6,800 feet)	$291,254
Total Capital Cost	**$9,519,054**
Engineering, Environmental, Archeology, Mitigation	$1,034,643
Bonds	$224,304
Land Acquisition and Legal	$383,985
Contingencies	$1,583,054
Total Project Cost	**$12,745,040**
Annual Costs	
Debt Service (6 percent, 30 years)	$925,913
Operation and Maintenance	
Intake, Pipeline, Pump Station	$190,381
Pumping Energy Costs (2,610,500 kW-hr @ 0.06 $/kW-hr)	$156,630
Purchase Treated Water (10,082 acft/yr @ $993.77/acft)	$10,019,189
Total Annual Cost	**$11,292,113**
Available Project Yield (acft/yr)	10,082
Annual Cost of Water ($ per acft)	$1,120
Annual Cost of Water ($ per 1,000 gallons)	$3.44

Note: Total project, O&M, pumping energy, and purchase costs provided by Johnson County SUD.