8 Aquifer Storage and Recovery (ASR)

8.1 City of Bryan ASR

8.1.1 Description

The City of Bryan (Bryan) currently has 12 water supply wells in the Simsboro and Sparta Aquifers with a combined permitted supply of 33,540 acft/yr. Eleven of these wells are permitted under historical use with an annual permitted production amount of 28,702 acft/yr. The current capacity of these wells is limited to 20,167 acft/yr. According to the City of Bryan's engineering consultant, the total current annual water supply based on permitted amounts meets the City's annual supply needs until 2056; however, pumping capacity from these wells prevents them from meeting the maximum day demands beyond 2040. Additionally, the Brazos County Modeled Available Groundwater (MAG) developed for the City of Bryan only allows for a supply of 16,792 acft/yr in 2020. Although the MAG allowable supply increases over time (maxing out at the pumping capacity of 20,167 acft/yr by 2040), the supply is not enough to meet demands beyond 2030.

Using TWDB methodology, the calculated total water supply, total water demand and water balance (surplus and shortage) is presented in Table 8.1-1 by decade. This analysis shows Bryan will need an additional 19,650 acft/yr by 2070. A groundwater strategy that is described in Section 5.1 will provide 17,474 acft/yr from the Carrizo Aquifer in Brazos and Robertson Counties. Remaining supplies will be developed by the ASR strategy.

An ASR conjunctive use strategy was developed to meet demands out to 2070 that includes ASR and production wells. A spreadsheet model was developed that simulates the storage and use of ASR water to determine when ASR wells and additional production wells are needed over time.

The ASR aspect of this conjunctive use strategy would fully utilize the MAG or well capacities by pumping at the allowable rate or capacities year-round. During times when water demand is less than the amount of water being produced from the production wells, the excess water would be directed from the City's Well Field Pump Station to a new ASR well field for aquifer storage. This water would be recovered from the ASR wells when Bryan's demand exceeds the allowable use from the MAG or when peak day use exceeds the current system capacity. The recovered water would be delivered back to the Well Field pump station for cooling and disinfection and then into the distribution system. Additional production wells are added over time according to the modeling. The model was also used to determine when each of the ASR wells in the proposed ASR well field would need to come online.

This conjunctive use strategy requires four new ASR wells and four recovery wells. The ASR strategy will make available 14,626 acft/yr of the City's supplies that are not currently accessible. The modeling of the strategy is discussed further in Section 8.1.2.

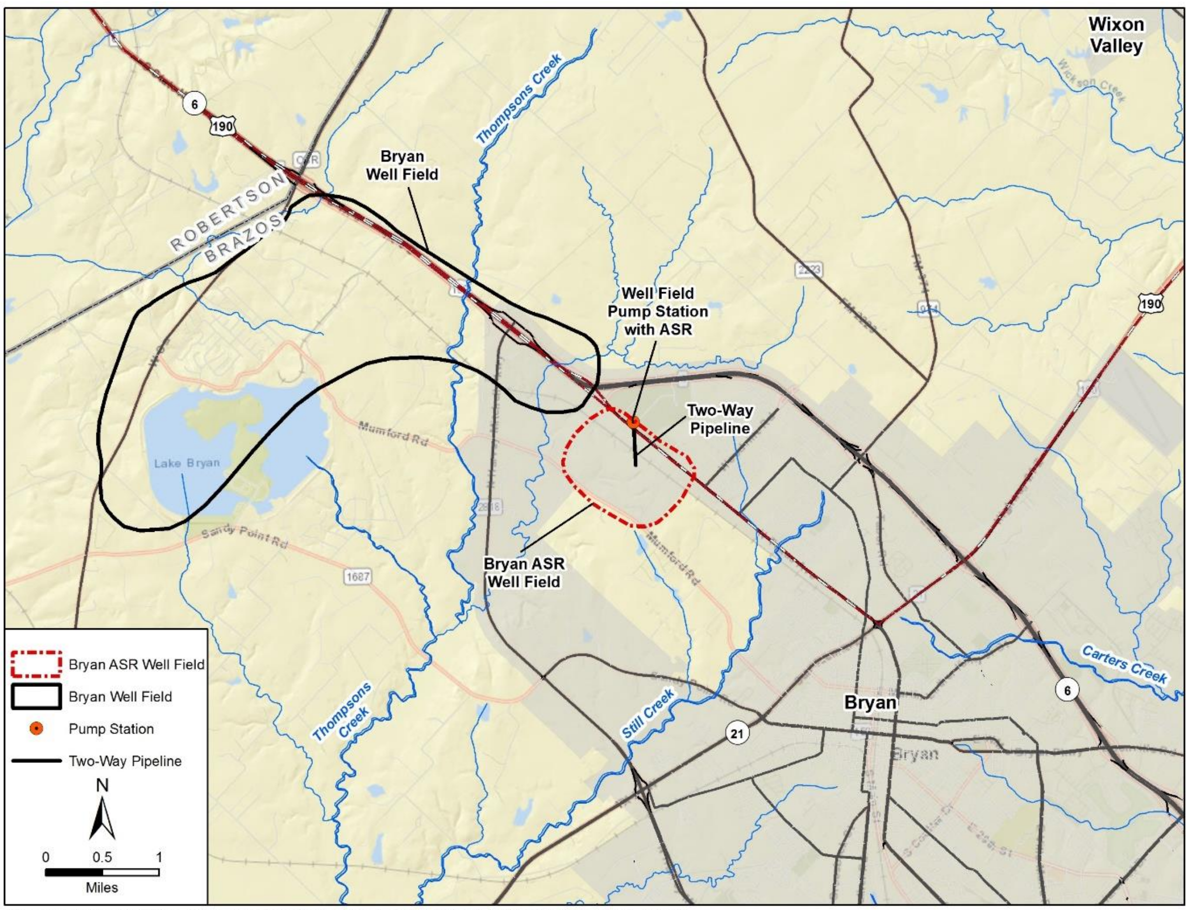
In addition to the wells required for this strategy, two-way pipelines between the ASR well field and the Well Field Pump Station, an ASR pump station at Well Field Pump Station, and an interconnect into the storage tanks are needed. A map showing the locations of the well fields is shown in Figure 8.1-1. For the purposes of this strategy, the target aquifer for storing the water is the brackish water zone of the Simsboro unit of the Wilcox Group.

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

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

1 - Includes sales to other entities.

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



Document Path: \\dalctxsrv01\Texas_GIS_Projects\10029705_036_Brazos_G_2021_Plan\Map_Docs\MXDs\ASR_Strategy\Bryan_ASR.mxd

8.1.2 Modeling and Available Supply

A probabilistic model was developed by consultants to the City of Bryan that simulates water demand over the available hydrologic record (1948 to 2014) to determine when ASR water may be stored or used. This model was used to determine how much water could be stored over time starting in 2020 and then adding production and ASR wells so as not to completely deplete the ASR supply out to 2070.

The first step in developing the model was to determine a relationship between current water demand and hydrologic conditions to simulate the monthly variations in demand. Water production data from 2000 to 2014 was converted to per capita demand and related to variables including precipitation, evaporation, and temperature. Evaporation was found to be the best indicator of water demand when considering each variable individually. The relationship was improved slightly by adding precipitation. Different relationships were then developed for each season or month to further improve the prediction.

Evaporation was the best indicator, but records from TWDB in the region are only available back to 1954. It was important to include the 1950's drought in the simulation; therefore, temperature data was used to extend the record. A relationship between evaporation and temperature was developed using all available data from 1954 to 2014. This relationship was used to extend the evaporation time series back to 1948.

Figure 8.1-2 shows a scatter plot of the production-based demand versus the final modeled demand based on the relationship developed between per capita demand and evaporation and precipitation for monthly values from 2000 to 2014.

Using the demand relationship that was developed, per capita water demand was predicted on a monthly time step from 1948 to 2014 using the available and extended evaporation and precipitation data. The Brazos G population projections were applied to the predicted monthly per capita water demands. Each decade was simulated over the entire period of record to determine the likelihood of ASR storage or use. It was found that water is likely to accumulate given 2020 and 2030 demands. By 2040, ASR water would likely be used at a greater rate than could be accumulated without adding additional supply. This agrees with the deficit predictions shown in Table 8.1-1.

To determine how much water is likely to be available through ASR over time as population increases, the median value of ASR storage or use on an annual basis was extracted for each of the simulated decades. These median storage/use values were applied to each decade from 2020 to 2070, and values between each decade were linearly interpolated. The cumulative volume was then calculated over time applying an unrecoverable (loss) factor of 10 percent. This analysis was used to determine how long the ASR supply would last given the MAG predicted supplies. Next, additional production wells and ASR wells were added to the strategy when needed to avoid depleting the supply and/or creating deficits. The resulting graph of cumulative supply is shown in Figure 8.1-3. The inflection points at 2030, 2040, and 2050 indicate when increases in the MAG allowed for additional pumping.

Figure 8.1-2. Fit of Demand Model

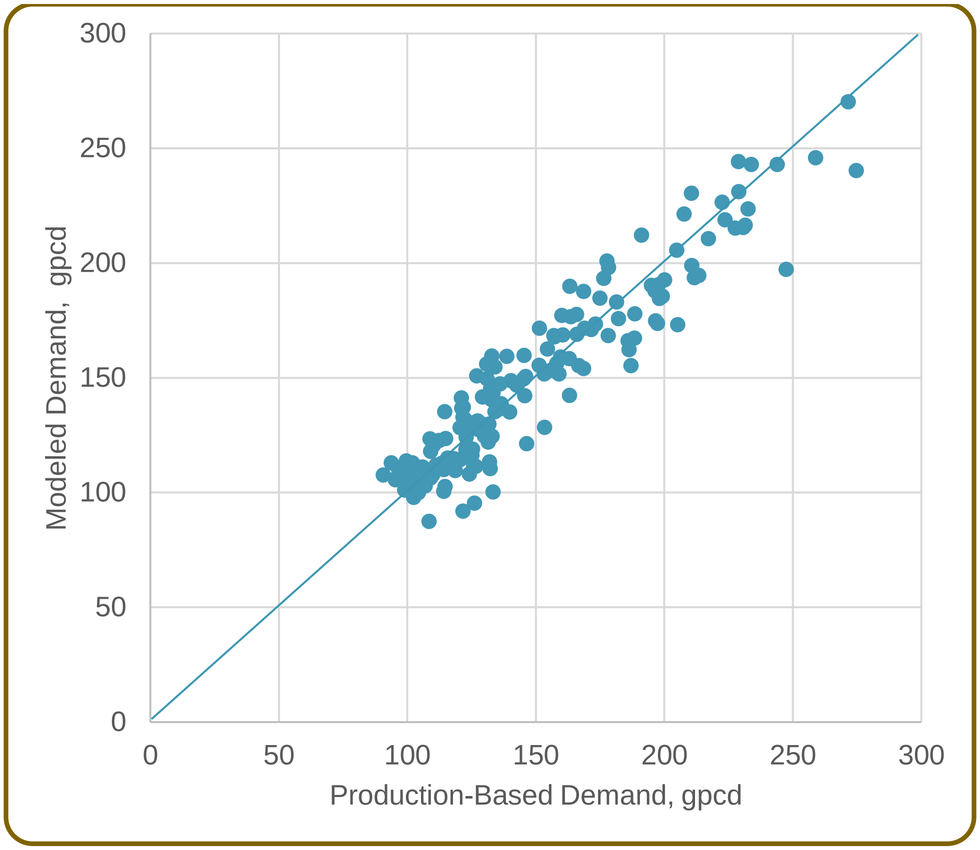
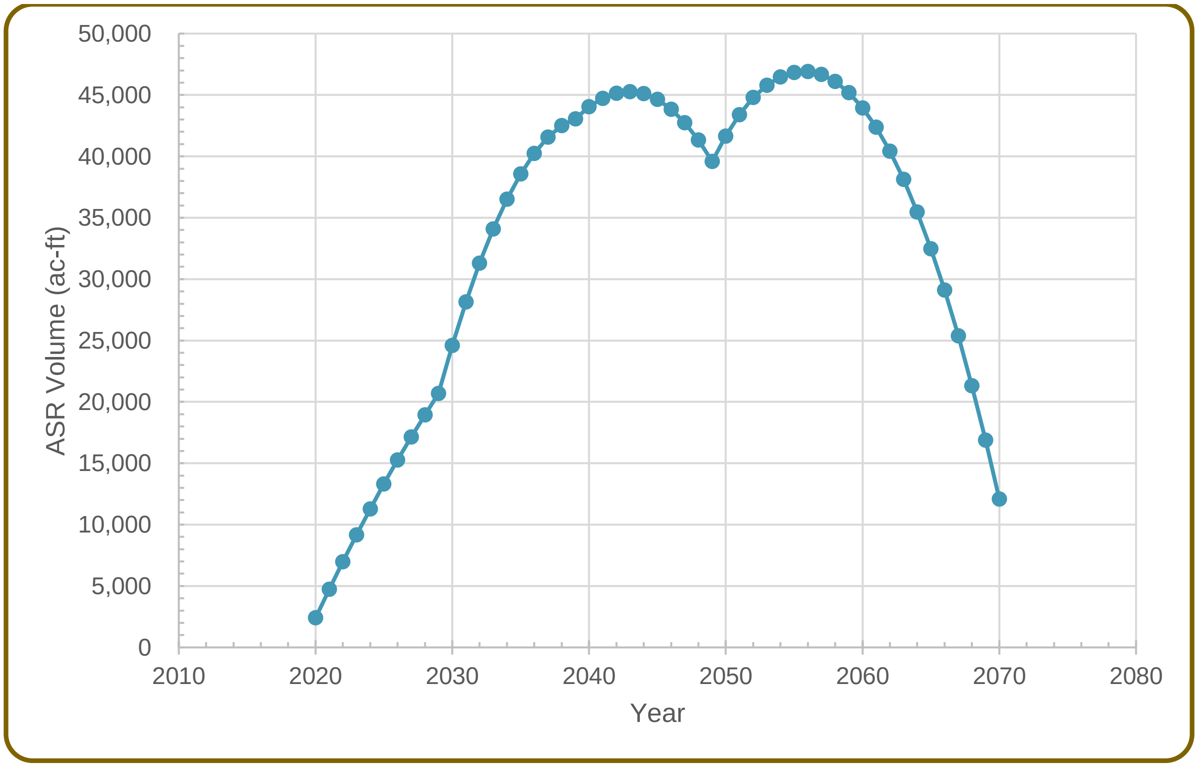


Figure 8.1-3. Time series Plot of ASR Recoverable Volume

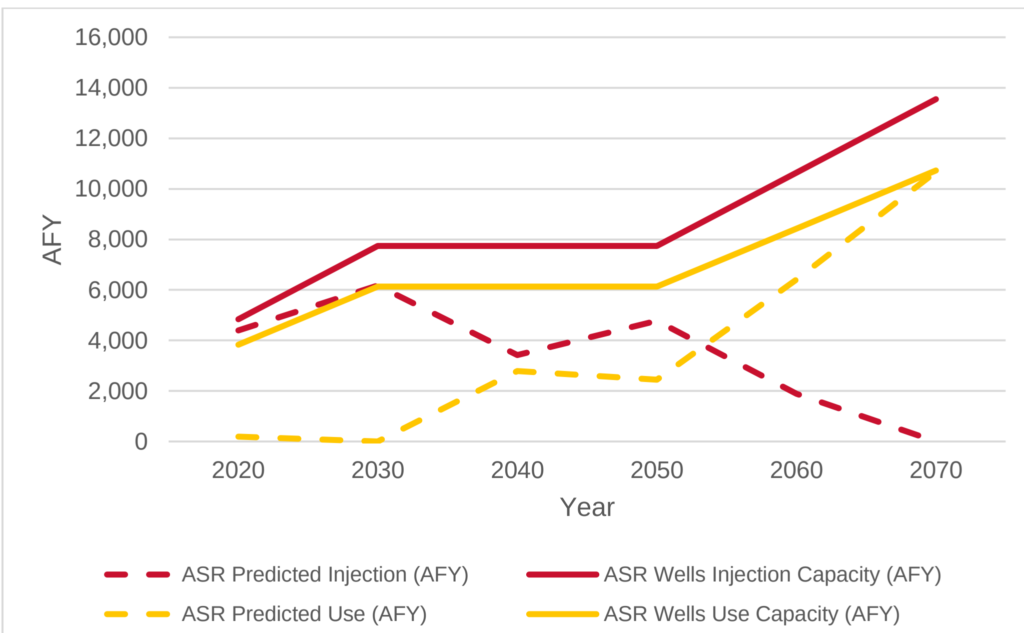


8.1.3 Infrastructure Timing

The modeling results show that by starting ASR in 2020, Bryan's current water production well infrastructure is sufficient until 2050. It is recommended that Bryan construct two new production wells in Brazos County by 2050. Each new production well is assumed to have a rated capacity of 3,000 gpm. Production estimates assume that the wells need to meet a maximum day factor of 2 and that the wells are 95 percent reliable.

Results from the modeling were used to determine the timing of ASR wells. For each simulated decade, the maximum annual amount stored and used was compared to the total ASR injection and use capacities, respectively. The ASR injection capacity is assumed to be 60 percent of the rated production capacity of the well. The use capacity assumes the same factors as for the production wells. Figure 8.1-4 shows the model predicted ASR injection and ASR use versus the ASR injection capacity and ASR use capacity. Predicted ASR use decreases each decade that additional production is recommended and increases in other decades. Predicted ASR injection follows opposite trends. To meet the predicted ASR injection and ASR use needs, Bryan should begin storing ASR water using Well #10 and one new ASR well prior to 2020. Then one new ASR well is needed each in 2030, 2060, and 2070. Additionally, piloting of Well #10 as an ASR well should begin as soon as possible.

Figure 8.1-4. ASR Injection, Capacity and Use Curves over Time



8.1.4 ASR Aquifer

The target area for ASR wells near Bryan is over the Carrizo-Wilcox aquifer. Major water-bearing formations in the Carrizo-Wilcox consist of the Carrizo Sands and Simsboro Formation. The wells would be installed in the Simsboro, which is 450 ft thick. Bryan's current wells are in the Sparta and Simsboro and are about 600 and 2,800 ft deep, respectively. High capacity Simsboro wells typically yield up to 3,000 gallons per minute (gpm). The water temperature for Simsboro wells in this locale is about 115 deg F and requires cooling before discharging into the distribution system.

The groundwater supply for the ASR project is currently permitted with the Brazos Valley Groundwater Conservation District.

8.1.5 Environmental Issues

Environmental issues for the proposed City of Bryan ASR Project are described below. This project includes the pumping of existing production wells nearly year round and utilizing any excess water for aquifer storage. This water would be recovered, disinfected and distributed later when needed for public use. This project would include the development of an ASR well field, additional well field distribution and collection pipelines, a new two-way transmission pipeline, a water treatment plant for disinfection and an interconnect. Implementation of this project would require field surveys by qualified professionals to document vegetation/habitat types, waters of the U.S. including wetlands, and cultural resources that may be impacted. Where impacts to protected species habitat or significant cultural resources cannot be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. The project sponsor would also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to wetland areas and compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

The pipelines and wells needed for the ASR project's well field would occur in close proximity to Still Creek and a tributary of Still Creek which includes several small stock ponds/impoundment areas. Coordination with the U.S. Army Corps of Engineers would be required for construction within any waters of the U.S. Any impacts from this proposed project which would result in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

The project occurs within the East Central Texas Plains Ecoregion[1] and lies within the Texan Biotic Province.[2] Vegetation types within the City of Bryan ASR well field area and transmission pipelines as described by the Texas Parks and Wildlife Department (TPWD)[3] include urban and other areas. These areas include portions of the city and wooded areas adjacent to cleared pasture areas. Avoidance of riparian areas near the creeks, impounded areas or heavily wooded areas would help minimize potential impacts to existing area species from project construction activities.

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

[1] Griffith Glenn, Sandy Bryce, James Omernik, and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality.

[2] Blair, W. Frank. 1950. The Biotic Provinces of Texas. Texas Journal of Science 2(1):93-117.

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

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

Because the project will use previously allocated water from existing wells to inject into the aquifer no significant impacts to existing stream flows or aquatic species are anticipated. Potential impacts to listed species within the project area are anticipated to include disturbance of existing habitat resulting from the construction of well fields and their associated pipelines, transmission pipelines and a new water treatment plant. However, most of these disturbances would be minimized by the small areas generally required for well field and pipeline construction. After construction is completed most of the disturbed areas will return to their previous habitat types excluding areas where maintenance activities are required.

A survey of the project area would be required prior to project construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291).

Based on the review of publically available Geographic Information System (GIS) records obtained from the Texas Historical Commission, there are no State Historic Sites, National Register Properties or Districts, or cemeteries within the project area. However five historical markers occur near the proposed pipeline route from the ASR well field to the Tabor Road pump station. A review of archaeological resources in the proposed project area should be conducted during the project planning phase. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., municipality), they will be required to coordinate with the Texas Historical Commission prior to project construction.

8.1.6 Engineering and Costing

This ASR conjunctive use strategy recommends a total of four recovery wells and four storage and recovery (ASR) wells. The timing of the recovery and ASR wells is summarized in Table 8.1-2.

Table 8.1-2. Timing of ASR Wellfield Infrastructure

Year	Recovery Wells	ASR Wells
2020		1
2030		1
2040		
2050	1	
2060	1	1
2070	2	1

Available records indicate that the ASR wells in the Simsboro, where proposed, would average about 3,200 ft deep. A typical injection and recovery rate is estimated to be 1,800 gpm and 3,000 gpm, respectively. The well field design has the wells spaced about 1,320 ft apart. The annual yield of the ASR and recovery wells is around 14,626 acft.

The major facilities required for these projects include:

- Pump station,
- Pipeline,
- ASR and Recovery wells,
- Collector pipelines, and
- Disinfection water treatment, and
- Interconnect.

Estimates were prepared for capital and project costs, annual debt service, operation and maintenance, power, land, and environmental mitigation. These costs are summarized in Table 8.1-3. The annual costs, including debt service, operation and maintenance, and power, is estimated to be $445 per acft.

8.1.7 Implementation

Implementation of the ASR conjunctive use water management strategy for Bryan includes the following issues:

- Acquiring permits from TCEQ for ASR construction and operations;
- Initial cost; and
- Development of a management and implementation of plan to efficiently balance utilization of production and ASR wells.

This water supply option has been compared to the plan development criteria, as shown in Table 8.1-4, and the option meets each criterion.

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

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

Table 8.1-4. Comparison of City of Bryan ASR to Plan Development Criteria

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

8.2 City of College Station ASR

8.2.1 Description

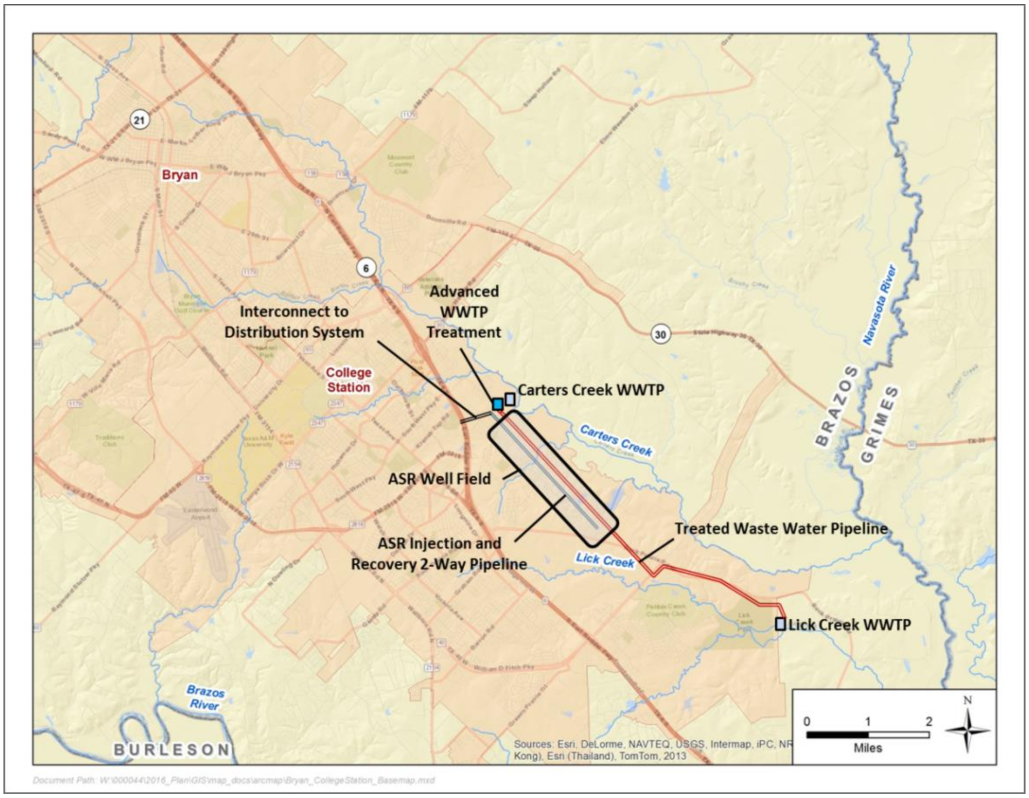
The concept for the City of College Station (College Station) ASR project is to:

- Utilize existing wastewater effluent as the source of water for ASR. For 2013-20017 the average effluent discharges from Carters Creek WWTP and Lick Creek WWTP were 6.07 and 1.17 million gallons per day (MGD), respectively.
- A new Advance Water Treatment Plant (AWTP) would be located near the Carters Creek WWTP. Effluent from the smaller Lick Creek WWTP would be transported to the AWTP through a new pipeline.
- The AWTP would treat the wastewater effluent with: (1) Low Pressure Membrane, (2) Reverse Osmosis, and (3) Oxidation before the water would be recharged.
- New Sparta and Queen City ASR wells would be located southeast of the AWTP. The Sparta and Queen City wells would be about 1,700 and 2,225 ft deep, respectively. An estimated 20 wells would be required at 10 sites.
- The recharge cycle of ASR would occur from October to March. Recovery would occur from April to September to supplement summer peaking demands.
- Recovered water would be disinfected before being delivered to the existing potable water distribution system.

A schematic showing the location of the project is shown in Figure 8.2-1. New facilities required for this option are the ASR wells, well field distribution and collection pipelines, pump station and wastewater transmission pipeline from Lick Creek WWTP and Carters Creek WWTP, advanced water treatment plant, interconnects between AWTP and the ASR well field and the AWTP and College Station's distribution system, a two-way pipeline between the AWTP and the ASR well field, and a chlorine disinfection facility.

For purposes of this ASR project, an assumed supply of 6.5 MGD of treated wastewater would be made available for storage in the ASR project during the months of October to March and recovery would be at a rate up to 6.5 MGD during April to September.

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



8.2.2 Available Yield

The target area for ASR wells in College Station's project area has four minor and major aquifers, including, from youngest to oldest: Jackson-Yegua, Sparta, Queen City, and Carrizo-Wilcox. Water-bearing formations in the Carrizo-Wilcox consist of the Carrizo Sands and Simsboro Formation. A geologic profile showing the approximate depth and thickness of the geologic formations is shown in Figure 8.2-2. The Jackson Group and Yegua Formation, called the Jackson-Yegua Aquifer, are the shallowest, but rather poor productivity limits well capacity. The Sparta Sands are about 250 ft thick and extend from about 1,450 to 1,700 ft below land surface. The Queen City Sands appear to be about 425 ft thick and range in depth from about 1,800 to 2,225 ft. The Carrizo Sands appear to be about 100 ft thick. The Simsboro is estimated to be about 450 ft thick and extend from about 4,500 to 4,950 ft below land surface.

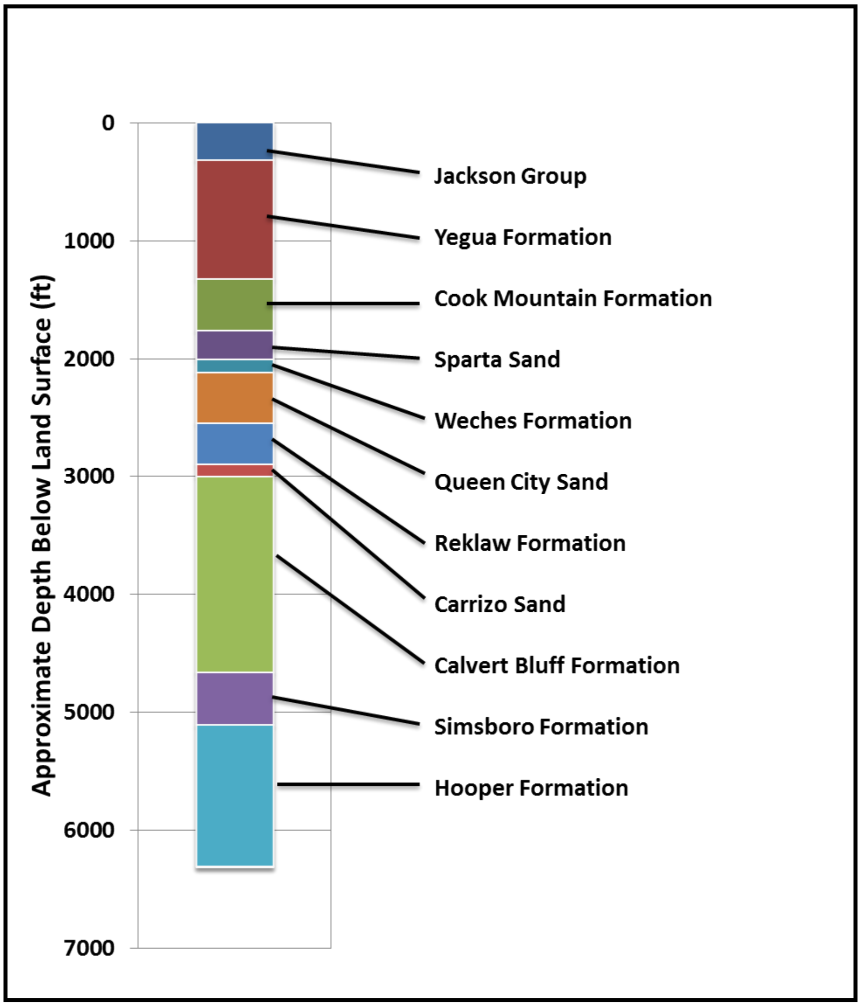
Electric geophysical logs[1] for a geologic cross-section suggest that the Sparta and Queen have rather extensive sands with fresh to brackish water. Electric geophysical logs[2] for another geologic cross-section provide picks for the Simsboro Formation. These logs suggest that the water quality in the Simsboro is brackish to saline. Native groundwater temperatures at these depths for the Sparta, Queen City, and Simsboro at these locations are about 95, 105, and 150 deg F, respectively. For purposes of this study, the Sparta and

[1] Follett, C.R., 1974, Ground-water resources of Brazos and Burleson Counties, Texas: Texas Water Development Board Report 185.

[2] Thorkildsen, D., and Price, R.D., 1991, Ground-water resources of the Carrizo-Wilcox Aquifer in the Central Texas Region: Texas Water Development Board Report 332.

Queen City Aquifers were selected for the storage because of depths and native groundwater temperature. This approach allows two wells to be constructed at each well site. Average well yields for both formations are estimated to be 300 gpm. One advantage of this well field is that there are few, if any, water wells in the target water-bearing zones.

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



8.2.3 Environmental Issues

Environmental issues for the proposed College Station ASR Project are described below. This project includes the development of an ASR well field, additional well field distribution and collection pipelines, a pump station and wastewater transmission pipeline, an advanced water treatment plant, and interconnects to existing transmission pipelines. The water source for this project would be existing wastewater effluent from local wastewater treatment plants which would be treated at a new AWTP planned near the existing Carters Creek WWTP. In addition, effluent water from the Lick Creek WWTP would be transported through a pipeline to the new AWTP for treatment and injection into the ASR wells. Recovered water from the ASR would be treated before delivery to the existing water distribution system. Implementation of this project would require field surveys by qualified professionals to document vegetation/habitat types, waters of the U.S. including wetlands, and cultural resources that may be impacted. Where impacts to protected species habitat or significant cultural resources cannot be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. The project sponsor would also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to wetland areas and compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

The pipelines and wells needed for the ASR project well field would occur in close proximity to Carters, Bee, Lick and Alum Creeks. Coordination with the U.S. Army Corps of Engineers would be required for construction within any waters of the U.S. Any impacts from this proposed project which would result in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

The project occurs within the East Central Texas Plains Ecoregion[3] and lies within the Texan Biotic Province.[4] Vegetation types within the ASR well field area and transmission pipelines as described by the Texas Parks and Wildlife Department (TPWD)[5] include Post Oak Woods, Forest, and Post Oak Woods, Forest and Grassland Mosaic areas. These areas include portions which have been developed or disturbed and now include homes, business, and farms. Avoidance of riparian areas near the creeks or heavily wooded areas would help minimize potential impacts to existing area species from project construction activities.

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

Because the project will use treated existing wastewater effluent to inject into the aquifer no significant impacts to existing stream flows or aquatic species are anticipated. Potential impacts to listed species within the project area are anticipated to include disturbance of existing habitat resulting from the construction of well fields and their associated pipelines, transmission pipelines and a new water treatment plant. However most of these disturbances would be minimized by the small areas generally required for well field and pipeline construction. After construction is completed the majority of the disturbed areas will return to their previous habitat condition excluding the AWTP site or areas where maintenance activities are required.

A survey of the project area would be required prior to project construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered

3 Griffith Glenn, Sandy Bryce, James Omernik, and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality.

4 Blair, W. Frank. 1950. The Biotic Provinces of Texas. Texas Journal of Science 2(1):93-117.

5 McMahan, Craig A., Roy G. Frye and Kirby L. Brown. 1984. The Vegetation Types of Texas. Wildlife Division, Texas Parks and Wildlife Department, Austin, Texas.

species with potential to occur in the project area should be initiated early in project planning.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291).

Based on the review of publicly available Geographic Information System (GIS) records obtained from the Texas Historical Commission, there are no State Historic Sites, National Register Properties or Districts, cemeteries or Historical Markers within the project area. A review of archaeological resources in the proposed project area should be conducted during the project planning phase. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction.

8.2.4 Engineering and Costing

Available records indicate that the ASR well depths in the Sparta and Queen City in an area southeast of College Station would average about 1,700 and 2,225 ft. A typical recharge and recovery rate is estimated to be 300 gpm. For a 7 MGD injection rate, 10 Sparta and 10 Queen City wells would be required. The wells would be spaced about 1,000 ft apart.

The major facilities required for these projects include:

- Pump Station at Lick Creek WWTP,
- Advance Water Treatment Plant,
- Pump Station at AWTP for distribution to ASR wells and existing distribution system,
- ASR well field,
- Collector pipelines,
- Transmission pipeline between AWTP and distribution system,
- Interconnect to existing distribution system, and
- Chlorine disinfection water treatment plant.

Estimates were prepared for capital and project costs, annual debt service, operation and maintenance, power, land, and environmental mitigation. These costs are summarized in Table 8.2-1. The annual costs, including debt service, operation and maintenance, and power, is estimated to be $3,277 per acft.

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

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

8.2.5 Implementation

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

- Acquiring permits from the Brazos Valley Groundwater Conservation District;
- Acquiring permits from TCEQ for Advanced Water Treatment Plant and ASR facilities construction and operations;
- Chemical and geochemical compatibility of native aquifer water and materials and imported water are chemically compatible;
- Lack of experience to develop confidence in the ability to inject and recover water from an aquifer, which includes the uncertainty about the compatibility of the injected water with native groundwater and aquifer materials;
- Initial and operational cost; and
- Development of a management plan to efficiently use the ASR wells with a balance of injection and recovery cycles.

This water supply option has been compared to the plan development criteria, as shown in Table 8.2-2, and the option meets each criterion.

Table 8.2-2. Comparison of College Station ASR Option to Plan Development Criteria

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

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8.3 Lake Georgetown ASR

8.3.1 Description of Option

The concept for the Lake Georgetown ASR project is to:

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

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

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

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

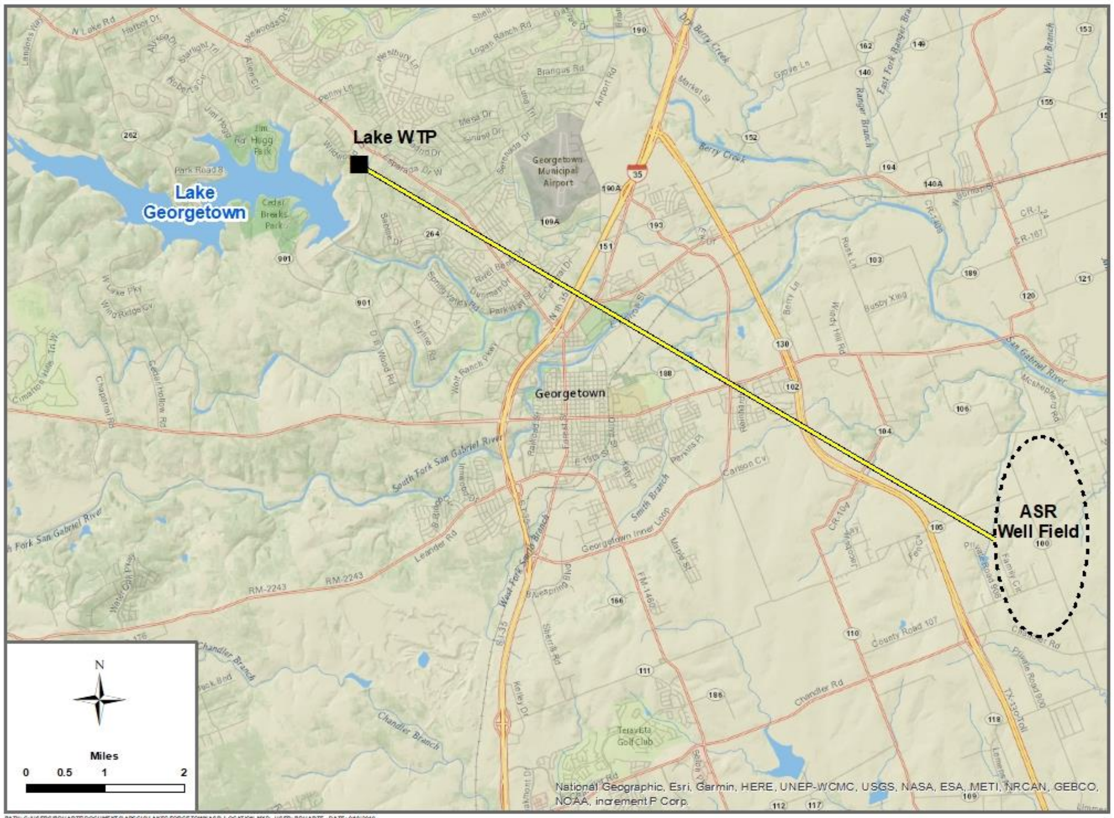
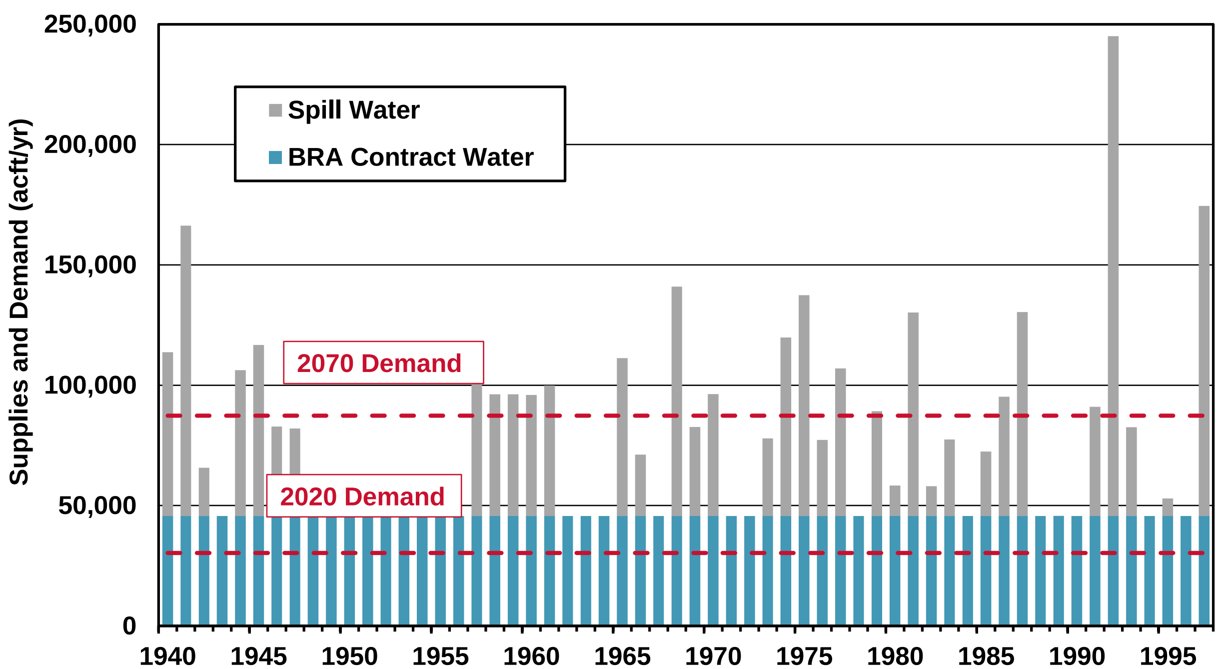


Figure 8.3-2. Lake Georgetown Water Supplies and Projected Demand



8.3.2 Available Yield

In Williamson County, the Lower Trinity Aquifer system is a productive ground water formation. In general, the most hydraulically transmissive (i.e., sand-rich) portions occur around 3,300 ft deep, and wells are expected to have yields from 800-2,000 gpm. For purposes of this analysis, the ASR wells were assumed to have a capacity of 1,500 gpm (200 acft/mo) during recovery and 1,200 gpm (160 acft/mo) during injection. The nearby production wells are assumed to have a capacity of 1,500 gpm (200 acft/mo). The long-term impact on the Trinity Aquifer is considered to be minimal on a county-wide basis because the strategy for this project is to balance the recharge and recovery of water. However, there is expected to be local variations in groundwater levels due to varying times of recharge and recovery and the location of ASR and nearby production wells.

The TCEQ Brazos Water Availability Model (WAM) Run 3 with Senate Bill 3 (SB3) environmental flow standards was used to determine the average magnitude and timing of Lake Georgetown overflow. This average modeled overflow along with BRA contractual water supply and projected municipal water demands serve as the basis for estimating ASR availability at Lake Georgetown, as shown in Table 8.3-1. Under the assumptions and constraints detailed in Table 8.3-2, an average of approximately 10,200 acft/yr are available for recharge from 2020 through 2079.

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

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

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

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

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

Table 8.3-1. Lake Georgetown ASR Availability

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

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

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

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

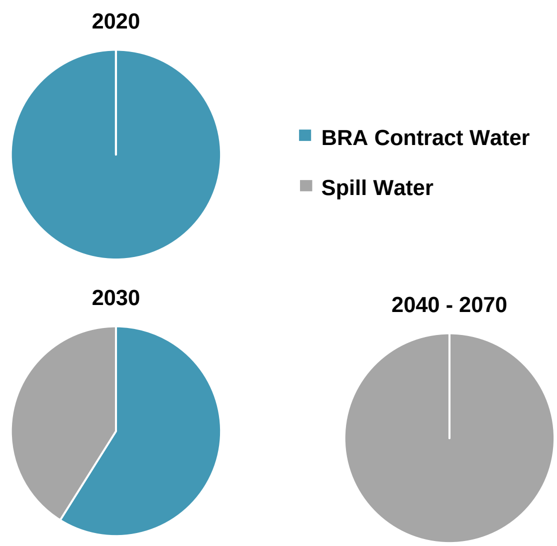


Figure 8.3-4. Simulated Timeline of Recharge by Planning Decade

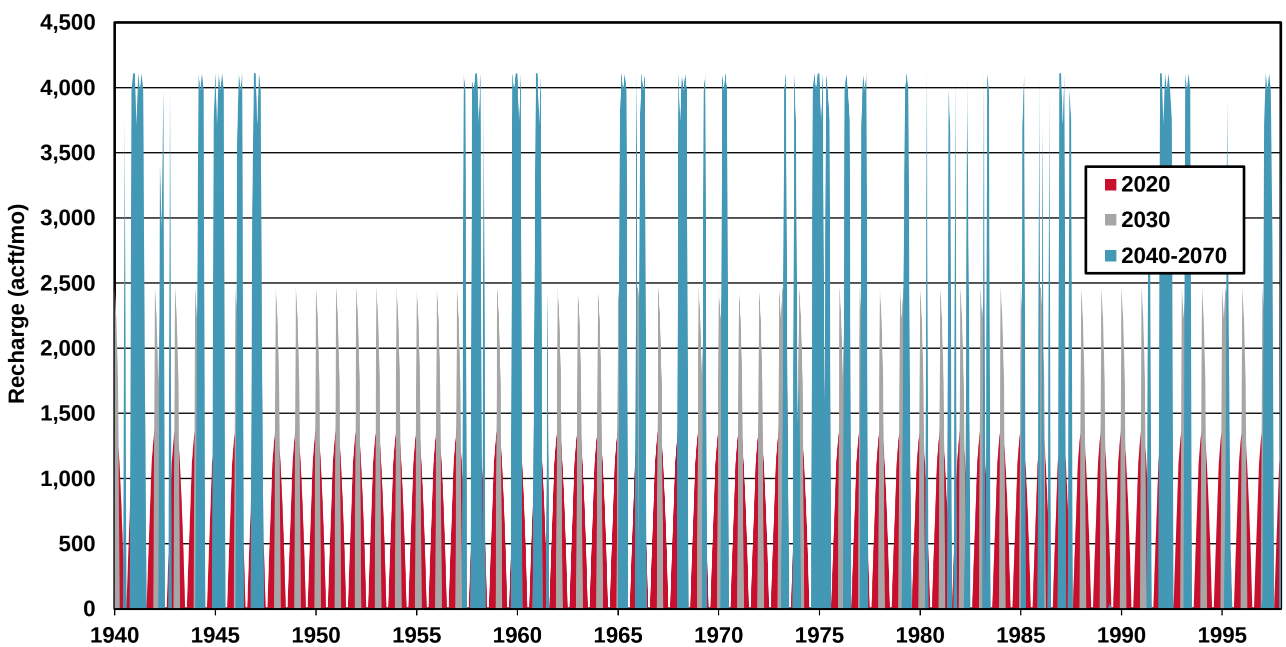
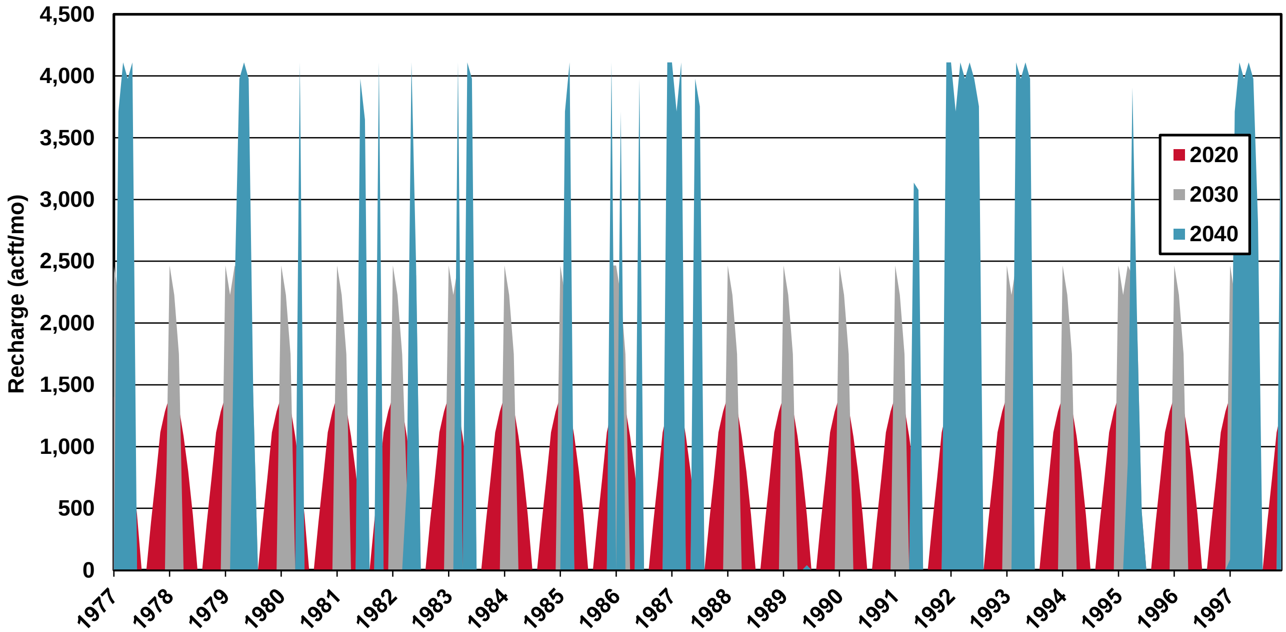


Figure 8.3-5. Zoomed-In Simulated Timeline of Recharge by Planning Decade



8.3.3 Environmental Issues

Environmental issues for the proposed Lake Georgetown ASR Project in Williamson County are described below. This project includes the development of a well field, production wells, well field distribution and collection pipelines, and an interconnect to a water treatment plant east of Lake Georgetown. Implementation of this project would require field surveys by qualified professionals to document vegetation/habitat types, waters of the U.S. including wetlands, and cultural resources that may be impacted. Where impacts to protected species habitat or significant cultural resources cannot be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. The project sponsor would also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to wetland areas and compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

The pipelines and wells needed for the Lake Georgetown ASR project well field would occur in close proximity to Lake Georgetown, a number of tributaries to the San Gabriel River, and the San Gabriel River, a Traditional Navigable Water. Coordination with the U.S. Army Corps of Engineers would be required for construction within any waters of the U.S. Any impacts from this proposed project which would result in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit 12 for Utility Line Activities.

The project occurs within the Cross Timbers and Prairies and Blackland Prairies Ecoregions[1] and lies within the Texan Biotic Province.[2] Vegetation types within the Lake

[1] Griffith Glenn, Sandy Bryce, James Omernik, and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality.

[2] Blair, W. Frank. 1950. The Biotic Provinces of Texas. Texas Journal of Science 2(1):93-117.

Georgetown ASR well field area as described by the Texas Parks and Wildlife Department (TPWD)[3] includes disturbed or tame grasslands, floodplain deciduous shrubland, floodplain hardwood forest, floodplain herbaceous vegetation, riparian deciduous shrubland, evergreen shrubland, riparian hardwood evergreen forest, riparian hardwood forest, riparian herbaceous vegetation, evergreen motte and woodland, hardwood motte and woodland, savanna grassland, deciduous woodland, juniper shrubland, mesquite shrubland, crops, urban high intensity cover, and urban low intensity cover. Avoidance of riparian areas near creeks and other relatively undisturbed natural habitats within the well field areas would help minimize potential impacts to existing area species.

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

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

No significant impacts to existing stream flows or aquatic species are anticipated. Potential impacts to listed species within the project area are anticipated to include disturbance of existing habitat resulting from the construction of well fields and their associated pipelines. However, these disturbances would be minimized by the small areas generally required for well field and pipeline construction. After construction is completed most of the disturbed areas will return to their previous habitat condition, excluding areas where maintenance activities are required.

Element occurrence records for the Coffin Cave mold beetle and western hog-nosed skunk intersect the proposed project area. A survey of the project area would be required prior to well field and pipeline construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291).

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

Based on the review of publically available Geographic Information System (GIS) records obtained from the Texas Historical Commission, there are no State Historic Sites, National Register Properties, National Register Districts, cemeteries or Historical Markers within the potential well field or pipeline area. Avoidance of any cultural resource areas discovered during project surveys should be possible by careful selection of the areas for well sites and their associated pipelines. A review of archaeological resources in the proposed project area should be conducted during the project planning phase. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction.

8.3.4 Engineering and Costing

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

The major facilities required for these projects include:

- ASR wells,
- Well field collector and transmission pipelines,
- Chlorination facility, and
- Water treatment plant interconnect and upgrades.

Estimates were prepared for capital and project costs, annual debt service, operation and maintenance, power, land, and environmental mitigation. These costs are summarized in Table 8.3-3.

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

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

8.3.5 Implementation

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

- Regulations (30 Texas Administrative Code Section 331.19(a) “Injection Into or Through the Edwards Aquifer”) currently do not allow injection of water through wells that transect the environmentally sensitive Edwards Aquifer in Williamson County and special legislative consideration is likely necessary to allow this project to proceed;
- Agreements between BRA and participants;
- Acquiring permits from TCEQ for ASR construction and operations and for storage of surface water in the Trinity Aquifer;
- Chemical and geochemical compatibility of native aquifer water and materials and imported water are chemically compatible;
- Lack of experience to develop confidence in the ability to inject water from a lake, which includes the uncertainty about the compatibility of the injected water with native groundwater and aquifer materials and failure of the ASR well;
- Controlling the loss of the injected water to others;
- Initial cost;
- Ability to add ASR wells as needed as the frequency of recharge events decreases and the magnitude increases;
- Ability to increase WTP capacity as needed to reflect changes in recharge events;
- Experience in operating the facilities; and
- Development of a management plan to efficiently use the ASR wells.

This water supply option has been compared to the plan development criteria, as shown in Table 8.3-4, and the option meets each criterion.

Table 8.3-4. Comparison of Lake Georgetown ASR Option to Plan Development Criteria

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

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8.4 Lake Granger ASR

8.4.1 Description of Option

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

- Supply local Lake Granger demands of 13,015 acft/yr, referred to herein as the "base rights."
- Overdraft Lake Granger to supply an additional 11,900 acft/yr, and recharge up to 11,520 acft/yr, when available.
- Install new Trinity Aquifer ASR and production wells and associated infrastructure.
- Operate the recharge cycle of ASR system when the reservoir is at greater than 70% capacity. Recover stored water with ASR and production wells when reservoir level drops to a volume equivalent to one-year supply of the lakeside demands.

New facilities required for this option are ASR wells (dual-purpose wells that are designed for injection and recovery), production wells to provide additional recovery capacity, well field distribution and collection pipelines, and interconnect to the water treatment plant. The general location of the proposed ASR and production well field, pipeline, and East Williamson County Regional Water Treatment Plant (EWCRWTP) are shown in Figure 8.4-1.

Operation of Lake Granger and the ASR project will be controlled by the available storage in the reservoir. When reservoir storage is at 70% (35,531 acft) or greater, water from the reservoir (stored water and inflows) will be used to meet the base rights and the additional yield created by the project (overdraft of Lake Granger), and supply water to the ASR system for recharge. When storage drops below 70%, diversion to the ASR project ceases, and reservoir storage and inflows are used to meet the base rights and additional yield. As storage drops below a volume equivalent to one year of the base rights (13,015 acft), reservoir storage and inflows are constrained to meet only the existing demand from base rights and water stored in the ASR project is used to meet the additional yield. If necessary, the ASR storage is also used to supplement the base rights. A schematic showing the operation of the project is shown in Figure 8.4-2.

Figure 8.4-1. Lake Granger ASR Project Location

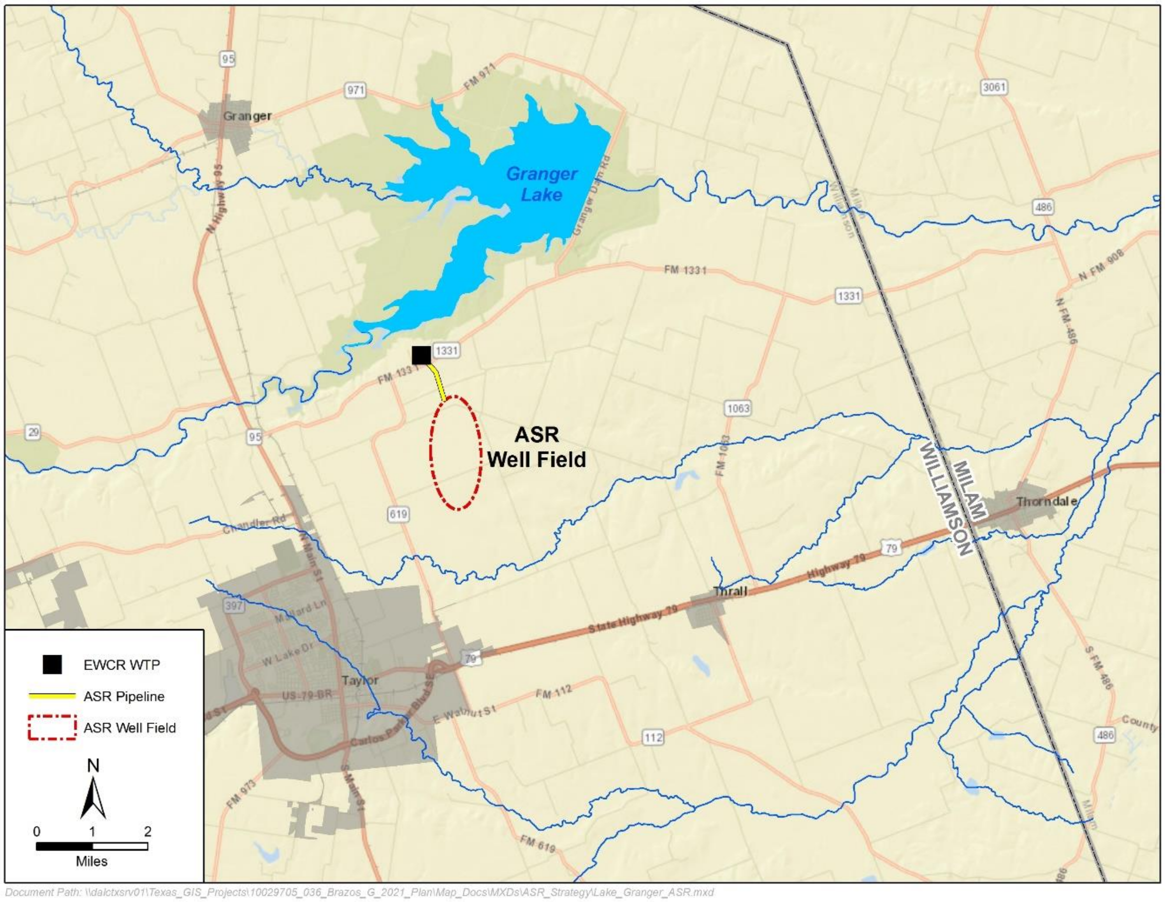
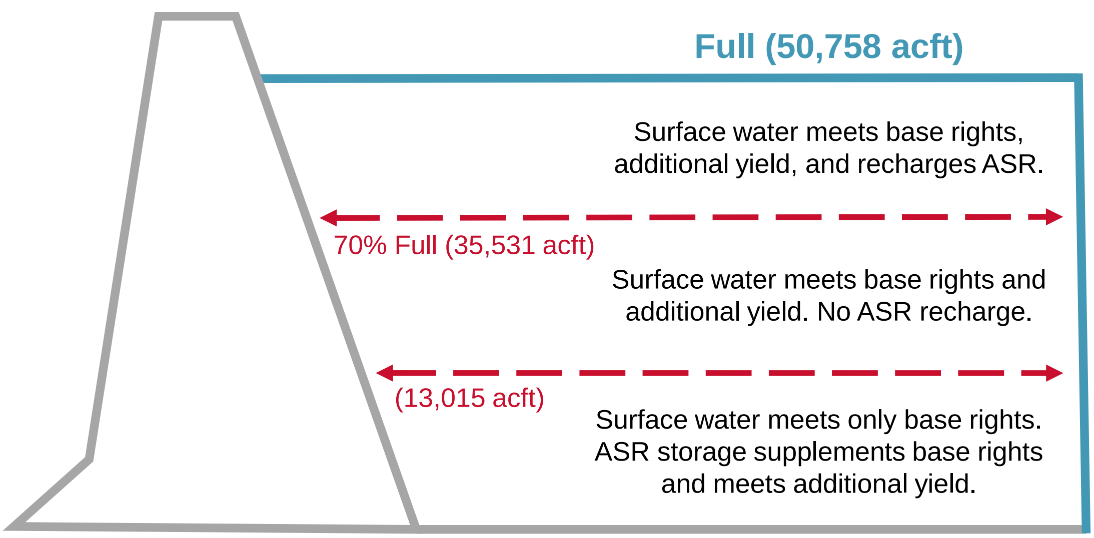


Figure 8.4-2. Operational Schematic of Lake Granger and ASR Project



8.4.2 Available Yield

In Williamson County, the Lower Trinity Aquifer system is a productive ground water formation. In general, the most hydraulically transmissive (i.e., sand-rich) portions occur around 3,300 ft deep, and wells are expected to have yields from 800-2,000 gpm. For purposes of this analysis, the ASR wells were assumed to have a capacity of 1,200 gpm (160 acft/mo) during injection and 1,500 gpm (200 acft/mo) during recovery. The nearby production wells are assumed to have a capacity of 1,500 gpm (200 acft/mo). The long-term impact on the Trinity Aquifer is considered to be minimal on a county-wide basis because the strategy for this project is to balance the recharge and recovery of water. However, there is expected to be local variations in groundwater levels due to varying times of recharge and recovery and the location of ASR and nearby production wells.

The TCEQ Brazos Water Availability Model (WAM) Run 3 with Senate Bill 3 (SB3) environmental flow standards was used to determine the potential additional yield that could be reliably supplied by conjunctive operation of Lake Granger with the proposed ASR well field. The ASR well field was assumed to require 6,200 acft of dead storage and was capped for analysis purposes at 80,000 acft of stored ASR water, including dead storage. The model was run with year 2020 sediment conditions for Lake Granger. The additional reliable yield available through the proposed conjunctive operation with the ASR well field was determined to be 11,900 acft/yr, increasing the total BRA water supply from Lake Granger to about 25,000 acft/yr. Figure 8.4-3 shows the annual source of diversions (Lake Granger or ASR storage) over the modeled time period. Figure 8.4-4 shows the combined storage trace for both Lake Granger and the ASR facility.

A storage frequency plot of Lake Granger with and without the ASR system illustrates the effect that conjunctive use has on the reservoir (Figure 8.4-5). As would be expected, Lake Granger would be full less often under the increased demands of the additional firm supply and diversions to the ASR facility. Under conjunctive operation of the reservoir and ASR system, the reservoir supplies the existing and additional firm yield roughly 90% of the time, and is able to contribute to ASR storage about 60% of the time. A storage trace of Lake Granger alone, shown in Figure 8.4-6, illustrates a chronological record of the simulated lake levels and a visual representation of how long the lake would be under various operating conditions for this conjunctive use project.

This additional, interuptible surface water supplied from Lake Granger for this strategy would be authorized by the BRA's System Operations Permit.

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

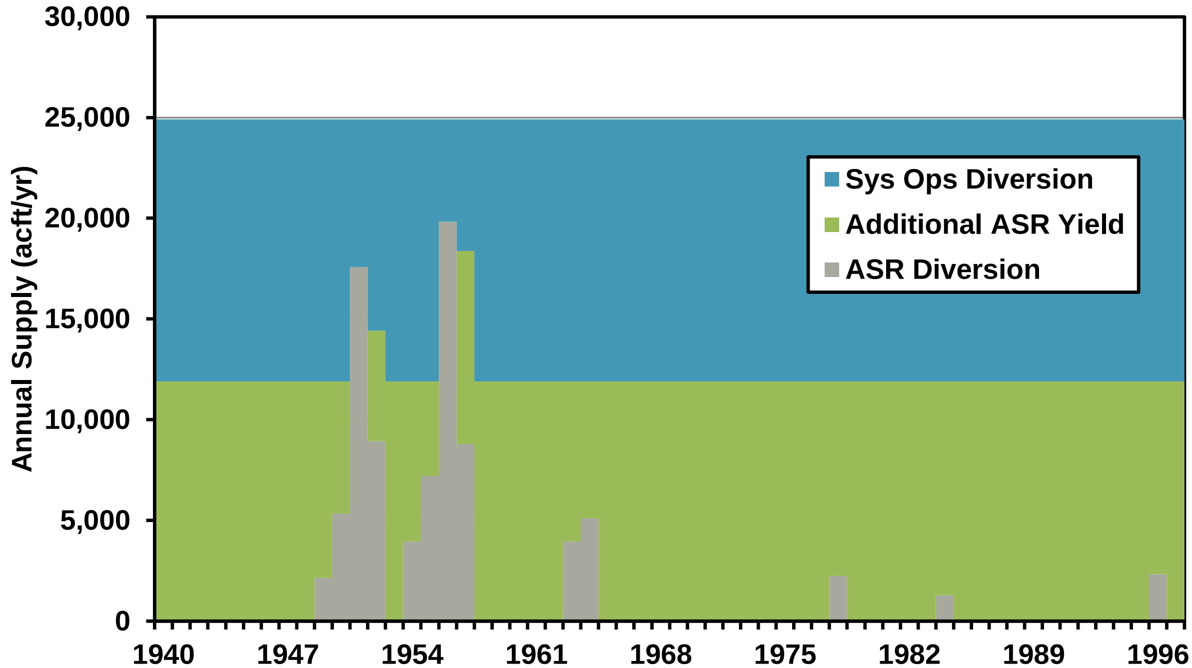


Figure 8.4-4. Combined System Storage for Lake Granger and ASR

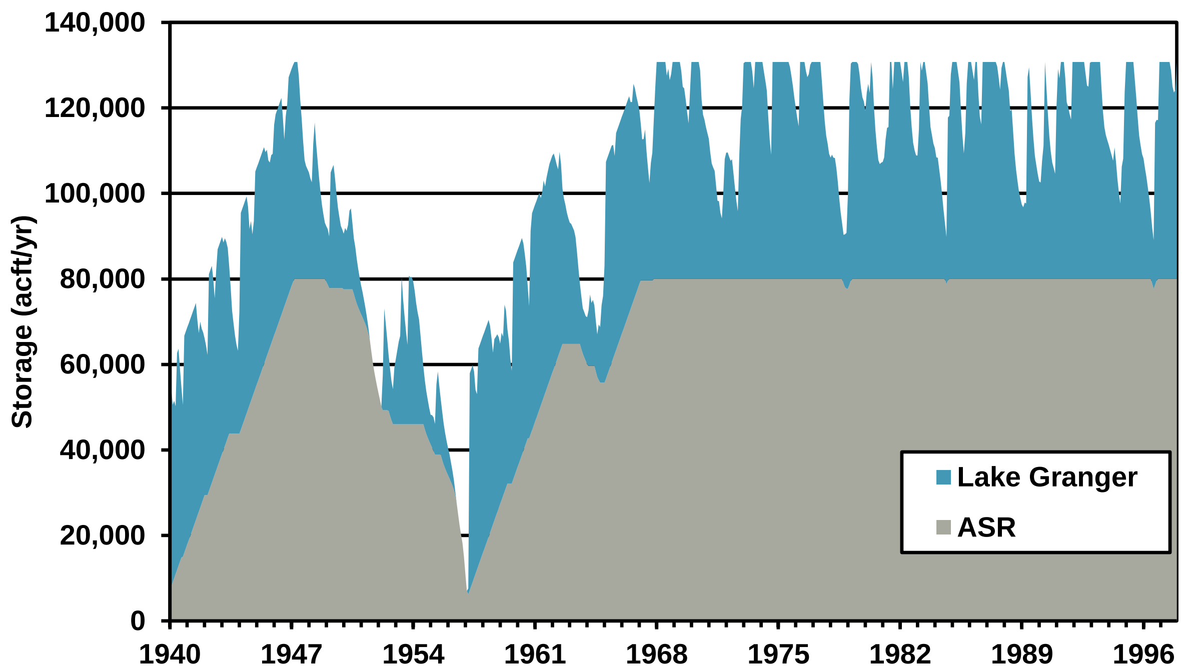


Figure 8.4-5. Lake Granger Storage Frequency

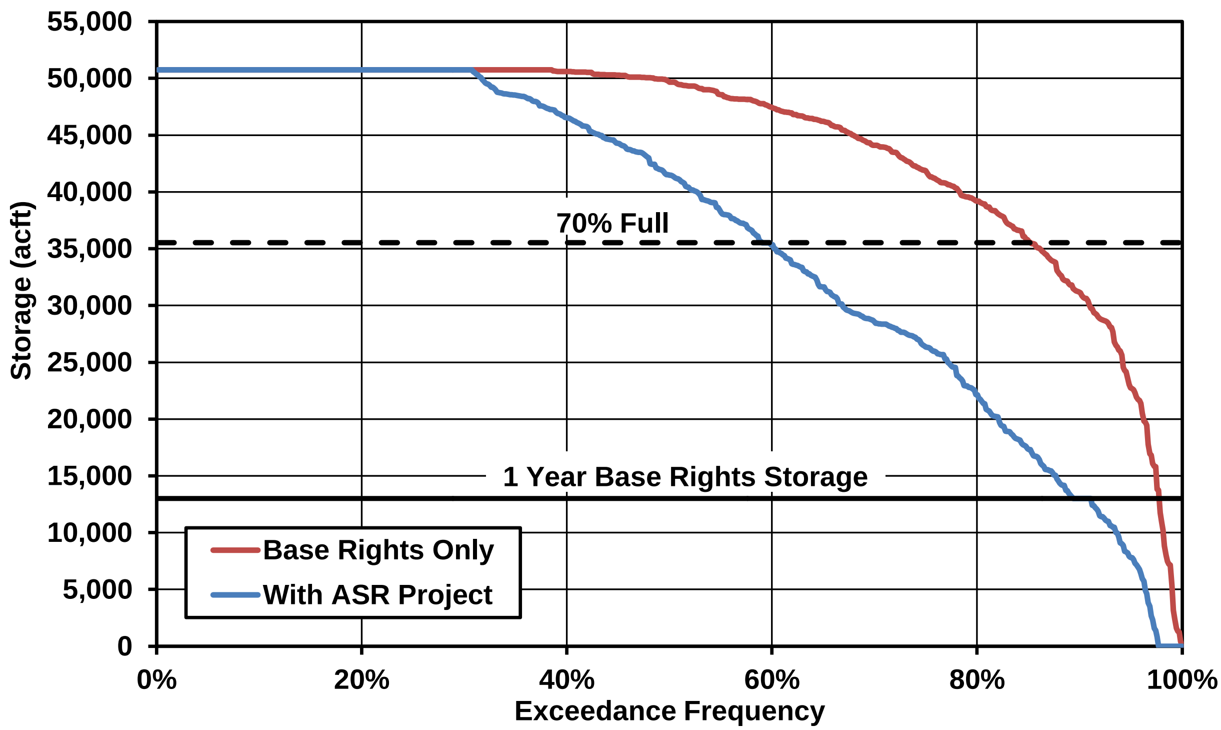
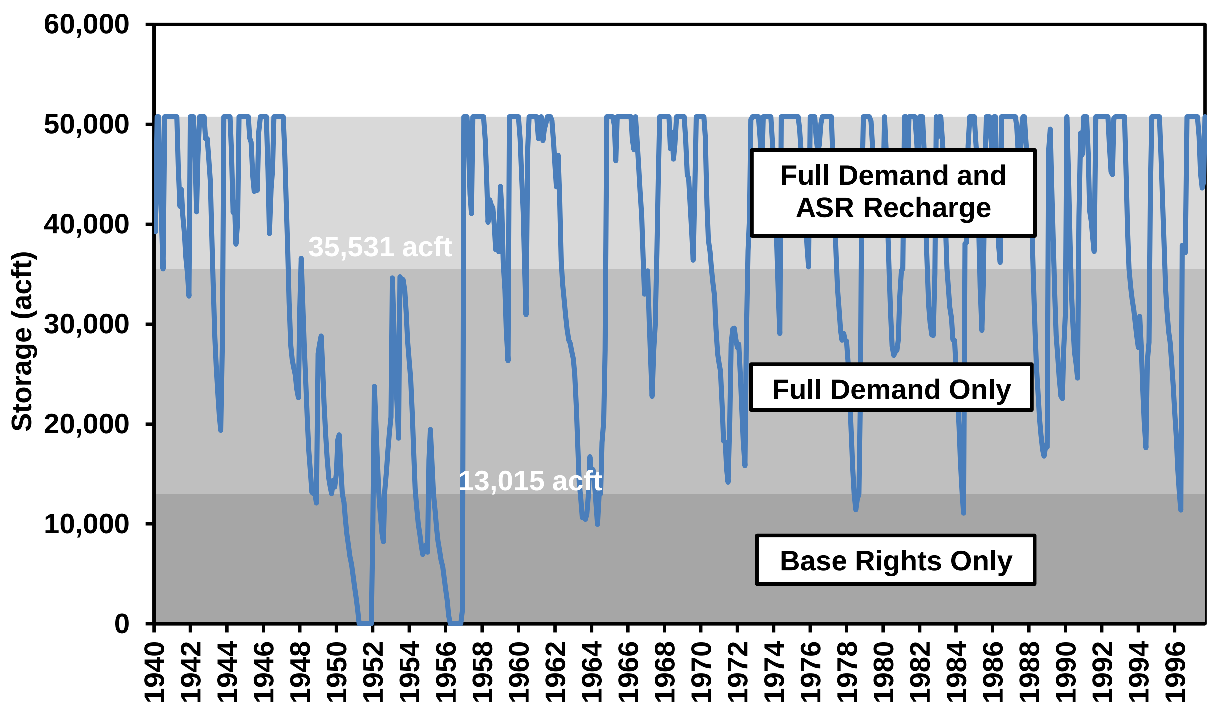


Figure 8.4-6. Lake Granger Storage Trace Operated Conjunctively with ASR Project



8.4.3 Environmental Issues

Environmental issues for the proposed Lake Granger ASR Project in Williamson County are described below. This project includes the development of an ASR well field, production wells, well field distribution and collection pipelines, and an interconnect to an existing water treatment plant. Implementation of this project would require field surveys by qualified professionals to document vegetation/habitat types, waters of the U.S. including wetlands, and cultural resources that may be impacted. Where impacts to protected species habitat or significant cultural resources cannot be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. The project sponsor would also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to wetland areas and compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

The pipelines and wells needed for the Lake Granger ASR project well field would occur near Lake Granger, Pecan Creek and a tributary of Turkey Creek. Coordination with the U.S. Army Corps of Engineers would be required for construction within any waters of the U.S. Any impacts from this proposed project which would result in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

The project occurs within the Texas Blackland Prairies Ecoregion[1] and lies within the Texan Biotic Province.[2] Vegetation types within the ASR well field area as described by the Texas Parks and Wildlife Department (TPWD)[3] as crops. Avoidance of riparian areas near creeks and other relatively undisturbed natural habitats within the well field areas would help minimize potential impacts to existing area species.

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

Information received from the TPWD Texas Natural Diversity Database (TXNDD) shows documented occurrences of two species of concern, the mountain plover and Texas garter snake within three miles of the project area.

Since the project will result in an equal exchange of water to the aquifer, no significant impacts to existing stream flows or aquatic species are anticipated. Potential impacts to listed species within the project area are anticipated to include disturbance of existing habitat resulting from the construction of well fields and their associated pipelines.

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[1] Griffith Glenn, Sandy Bryce, James Omernik, and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality.

[2] Blair, W. Frank. 1950. The Biotic Provinces of Texas. Texas Journal of Science 2(1):93-117.

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

However, these disturbances would be minimized by the small areas generally required for well field and pipeline construction. After construction is completed the majority of the disturbed areas will return to their previous habitat condition, excluding areas where maintenance activities are required.

A survey of the project area would be required prior to well field and pipeline construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291).

Based on the review of publicly available Geographic Information System (GIS) records obtained from the Texas Historical Commission, there are no State Historic Sites, National Register Properties, National Register Districts, cemeteries or Historical Markers within the potential well field or pipeline area. Avoidance of any cultural resource areas discovered during project surveys should be possible by careful selection of the areas for well sites and their associated pipelines. A review of archaeological resources in the proposed project area should be conducted during the project planning phase. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction.

8.4.4 Engineering and Costing

Available records indicate that Trinity Aquifer wells in eastern Williamson County average 3,300 feet deep. For an 11,900 acft/yr ASR system in Williamson County that accommodates existing water rights and operational constrains on Lake Granger, there is a considerable imbalance between peak injection water supply and peak recovery demands. In consideration of this imbalance, six (6) ASR wells are able to meet the peak injection rates, and 22 wells are required for recovery and production. Sixteen of the wells would be nearby production (recovery-only) wells, and six would be dual-purpose ASR wells. The number of wells is based on an assumption that an ASR well's recharge rate is 1,200 gpm, and ASR and production wells have a recovery capacity of 1,500 gpm. The water will be pumped from the well field to the EWDRWTP through a 30", 1.4 miles long, two-way transmission pipeline. The existing pump station at the treatment plant would deliver the treated water to the ASR well field and through transmission pipelines to east Williamson County.

The major facilities required for these projects include:

- ASR and production wells,
- Well field collector and transmission pipelines, and
- Water treatment plant interconnect and upgrades.

Estimates were prepared for capital and project costs, annual debt service, operation and maintenance, power, land, and environmental mitigation. These costs are summarized in Table 8.4-1.

The cost estimate below assumes that only the six ASR wells and associated pipelines and connections would be required in an initial phase. Subsequent phases are assumed to occur after a cumulative 10 years and 15 years, where eight recover-only wells would be constructed in each of the two later phases. The second phase includes only these additional wells, while the final phase considers the eight recover-only wells plus associated well field pipelines. The timing for the construction of the recovery wells could vary considerably from these assumptions because the wells would not be constructed until needed to produce peak demands of previously stored ASR water during a prolonged drought period. The annual costs, including debt service, operation and maintenance, and power, are estimated to be $271 per acft during the third phase.

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

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

8.4.5 Implementation

Implementation of the Lake Granger ASR strategy for BRA includes the following issues:

- Agreements between BRA and participants;
- Acquiring permits from TCEQ for ASR construction and operations and for storage of surface water in the Trinity Aquifer;
- Chemical and geochemical compatibility of native aquifer water and materials and imported water are chemically compatible;
- Lack of experience to develop confidence in the ability to inject water from a lake, which includes the uncertainty about the compatibility of the injected water with native groundwater and aquifer materials and failure of the ASR well;
- Controlling the loss of the injected water to others;
- Initial cost;
- Ability to add recovery wells as needed as reservoir reaches critical levels;
- Experience in operating the facilities; and
- Development of a management plan to efficiently use the ASR wells.

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

Table 8.4-2 Comparison of Lake Granger ASR Option to Plan Development Criteria

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

8.5 Johnson County SUD and Acton MUD ASR

8.5.1 Description of Option

The concept for the Johnson County and Acton MUD ASR project is:

- Utilize existing surface water rights in Lake Granbury that are owned by the BRA and purchased by Johnson County SUD (JCSUD) and Acton MUD (AMUD). JCSUD and AMUD supply contracts from Lake Granbury are 9,210 and 7,000 acft/yr, respectively.
- Utilize Brazos Regional Public Utility Agency (BRPUA) water treatment facility, which has a total rated production capacity of 13 million gallons a day (MGD). JCSUD and AMUD are the owners of BRPUA.
- For Johnson County participants, new Trinity Aquifer ASR wells would be located in central Johnson County and near the existing treated water pipeline between Lake Granbury and existing customers. Recovery of the water would be by participant's water wells. This procedure is considered an indirect transfer water from JCSUD to participants. Unlike traditional ASR projects where the injected water would be recovered by the same well, the indirect transfer would involve an accounting process within Johnson County where water would be stored in the Trinity Aquifer by JCSUD and credited to a participant's allocation. The participants would pay JCSUD for the raw water, water treatment, water transmission, recharge wells, and associated facilities and operations.
- For AMUD, new Trinity Aquifer ASR wells would be located near their existing treated water pipeline between Granbury and their distribution system.
- The recharge cycle of ASR would occur from October to May and would coincide when there is excess capacity in the BRPUA WTP. For Johnson County participants, recovery could be at any time, but typically would be during the summer when demand is relatively high. For AMUD, recovery would be during June-September. The recovered water would be discharged back into the treated water pipeline for eventual distribution to participants along with other supplies from the BRPUA WTP.

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

JCSUD's water supplies include groundwater, purchased surface water in Lake Granbury and other purchased surface water. These projected supplies and demands are illustrated in Figure 8.5-2. As indicted in Figure 8.5-2, JCSUD's water supplies exceed demands through 2070.

AMUD's water supplies include groundwater and purchased surface water in Lake Granbury. These projected supplies and demands are illustrated in Figure 8.5-3. Also, shown in this figure is a 1,400 acft/yr supply from the ASR project. This supply is derived from an estimate of excess capacity in the BRPUA WTP during low water demand months.

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

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

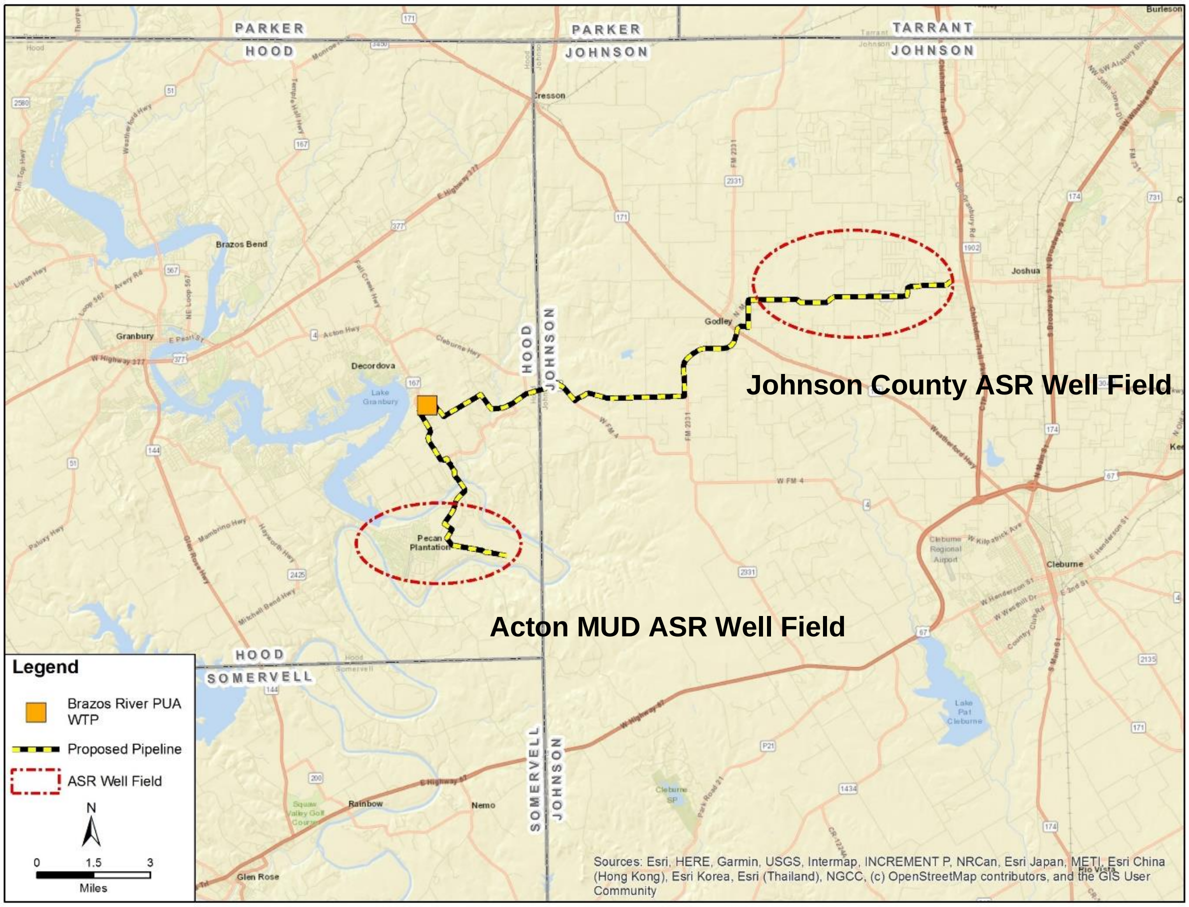


Figure 8.5-2. Water Supplies and Demand for JCSUD

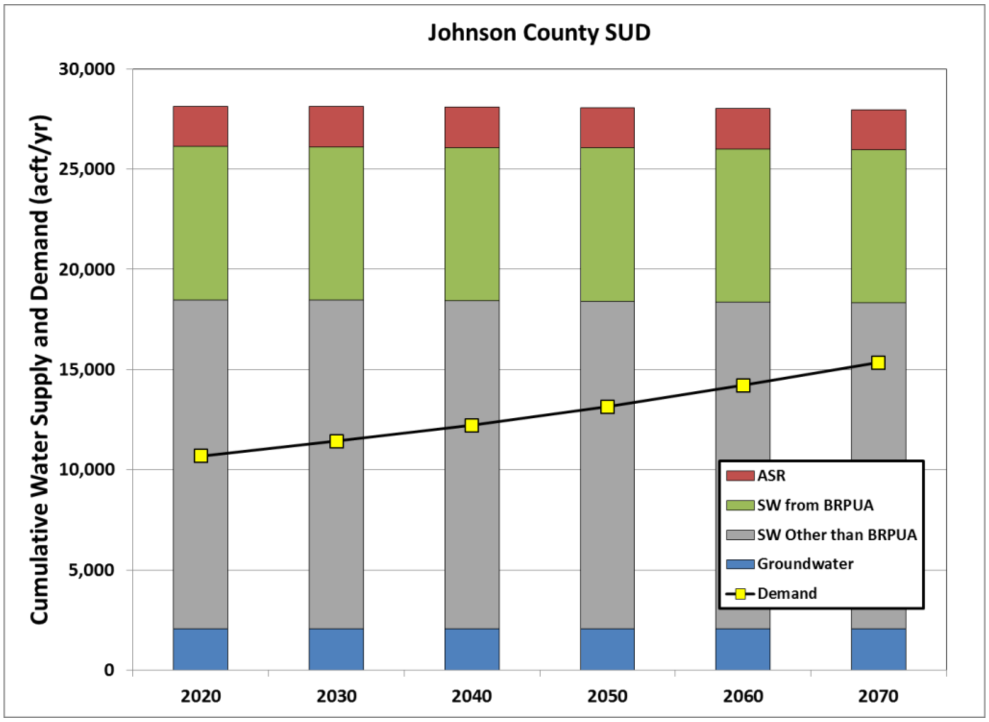
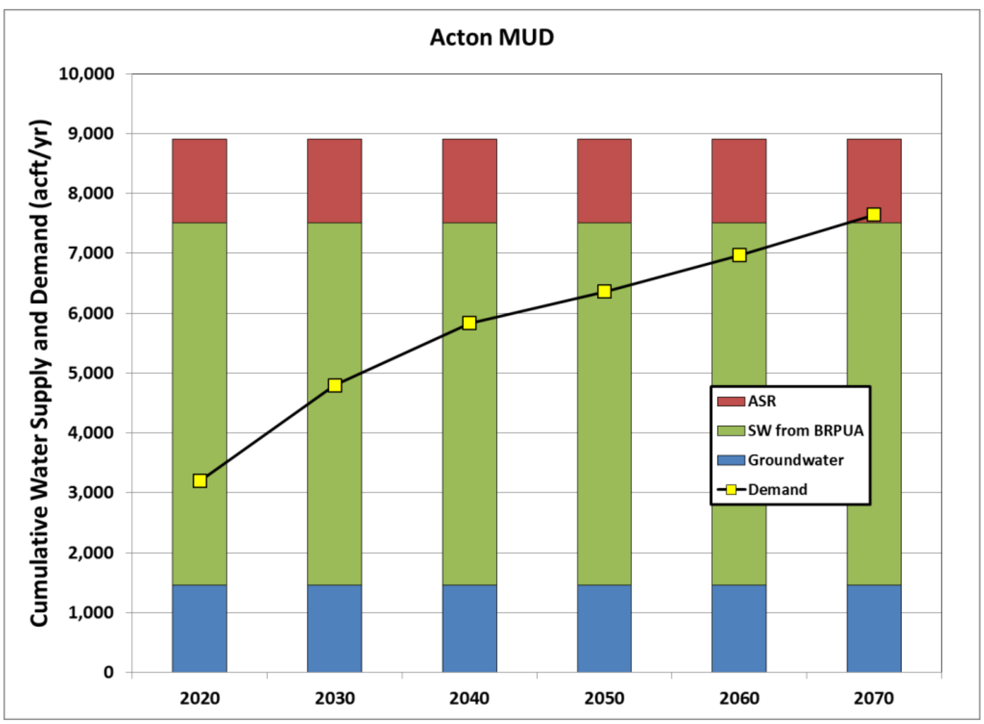


Figure 8.5-3. Water Supplies and Demand for AMUD

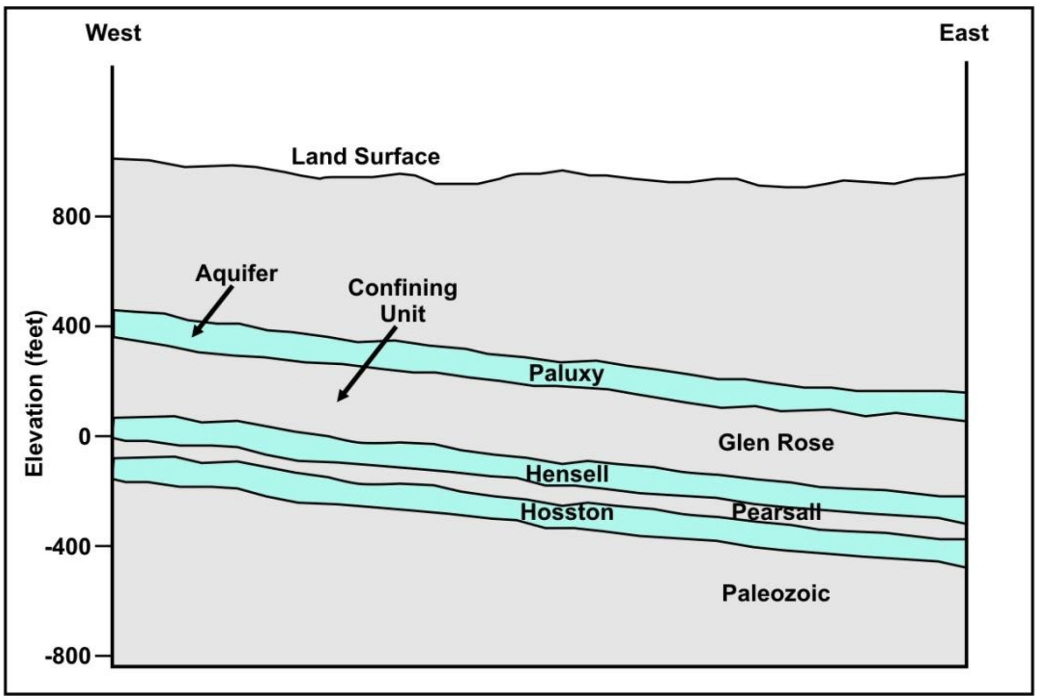


8.5.2 Available Yield

In Johnson and Hood Counties, the Trinity Aquifer system is composed of three sandy aquifer units that are confined and separated by nearly impermeable clay units. These aquifer units include, from youngest to oldest: the Paluxy, Hensell, and Hosston (Figure 8.5-4). In the proposed ASR well field, the water-bearing units are confined with artesian pressures generally rising several hundred feet above the top of the aquifer(s). The geometry and hydraulic properties of the hydrogeologic units of the Trinity Aquifer units vary throughout Johnson and Hood Counties. In general, the most hydraulically transmissive (i.e., sand-rich) portions of the units vary from 50 to 100 feet in thickness. High-capacity production wells typically yield from 150 to 250 gallons per minute (gpm).

The long-term impact on the Trinity Aquifer is considered insignificant because the intent for this project is to balance the recharge and recovery of water. In the short-term, the impact will be a noticeable, but temporary, rise in groundwater levels during the recharge cycle and a similar decline during the recovery cycle.

Figure 8.5-4. Hydrogeological Profile in ASR Well Field



8.5.3 Environmental Issues

Environmental issues for the proposed Johnson County and Acton MUD project are described below. This project includes the development of two ASR well fields, one along the border of Hood and Johnson Counties south of Granbury and the second west of Joshua in Johnson County. Additional well field distribution and collection pipelines and interconnects to existing transmission pipelines would also be required for the project. Implementation of this project would require field surveys by qualified professionals to document vegetation/habitat types, waters of the U.S. including wetlands, and cultural resources that may be impacted. Where impacts to protected species habitat or significant cultural resources cannot be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. The project sponsor would also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to wetland areas and compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

The pipelines and wells needed for the Acton MUD ASR well field would occur in close proximity to the Brazos River. The Texas Parks & Wildlife Department (TPWD) has identified a number of stream segments throughout the state as ecologically significant on the basis of biological function, hydrologic function, riparian conservation, exceptional aquatic life uses, and/or threatened or endangered species. The portion of the Brazos River near the proposed ASR well field is listed by the TPWD as ecologically significant. This segment of the Brazos River is considered to have outstanding wildlife values, high water quality, exceptional aquatic life, and high aesthetic value. Coordination with the U.S. Army Corps of Engineers would be required for construction within any waters of the U.S. Any impacts from this proposed project which would result in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

The project occurs within the Central Oklahoma/Texas Plains Ecoregion[1] and lies within the Texan Biotic Province.[2] Vegetation types within the Johnson County ASR well field as described by the Texas Parks and Wildlife Department (TPWD)[3] includes areas of crops, and Post Oak Woods, Forest and Grassland Mosaic. The Acton MUD ASR well field occurs primarily within the Oak-Mesquite-Juniper Parks/Woods vegetation type but also contains a small area of Bluestem grassland vegetation type in the southeastern section of the area. Both well field areas contain large areas that have been developed or disturbed and include homes, business, and farms. Avoidance of the remaining areas of riparian and woods habitat within the well field areas would help minimize potential impacts to existing area species.

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

Because the project will result in an equal exchange of water to the aquifer, no significant impacts to existing stream flows or aquatic species are anticipated. Potential impacts to listed species within the project area are anticipated to include disturbance of existing habitat resulting from the construction of well fields and their associated pipelines. However, these disturbances will be minimized by the small areas generally needed for well field and pipeline construction. After construction is completed most of the disturbed

1 Griffith Glenn, Sandy Bryce, James Omernik, and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality.

2 Blair, W. Frank. 1950. The Biotic Provinces of Texas. Texas Journal of Science 2(1):93-117.

3 McMahan, Craig A., Roy G. Frye and Kirby L. Brown. 1984. The Vegetation Types of Texas. Wildlife Division, Texas Parks and Wildlife Department, Austin, Texas.

areas will return to their previous condition excluding areas where maintenance activities are required.

A survey of the project area would be required prior to well field and pipeline construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291).Based on the review of publically available Geographic Information System (GIS) records obtained from the Texas Historical Commission, there are no State Historic Sites, National Register Properties, or National Register Districts within the well field areas. However, one Historical Marker and one cemetery are located within the Johnson County ASR well field area and one cemetery occurs within the Acton MUD ASR well field area. Avoidance of these cultural resource areas should be possible by careful selection of the areas for well sites and their associated pipelines. A review of archaeological resources in the proposed project area should be conducted during the project planning phase. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction.

8.5.4 Engineering and Costing

The actual number of wells and land required for the well field is dependent upon local depth to water, and the thickness and character of sands present at each well field site. This site-specific information would need to be acquired through a research or a test drilling and field-testing program prior to implementation of an ASR system in the region.

Available records indicate that wells in central Johnson County average between 1,100 and 1,200 feet deep. Near AMUD wells typically are 500-600 ft deep. Based on existing wells in central Johnson County, the maximum recharge and recovery rate is 250 gpm. For a 3,574 acft/yr system in Johnson County, 27 ASR wells are required. For a 2,526acft/yr system for AMUD, 13 ASR wells are required. The ASR wells would be used for recharge from October through May and for recovery from June through September. The well field design has the wells spaced about 1,000 feet apart and in the vicinity of the treated water transmission pipeline. The relatively close well spacing is based on seasonal ASR operations.

The major facilities required for these projects include:

- ASR wells,
- Collector Pipelines,
- Pump Stations
- Terminal Storage, and
- Interconnect.

Estimates were prepared for capital and project costs, annual debt service, operation and maintenance, power, land, and environmental mitigation. These costs are summarized in Table 8.5-1 and Table 8.5-2 for the Johnson County and Acton MUD projects, respectively. The annual costs, including debt service, operation and maintenance, and power, are estimated to be $633 per acft for the Johnson County project and $662 per acft for the AMUD project.

Table 8.5-1 Johnson County SUD ASR Cost Summary

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

Table 8.5-2 Acton MUD ASR Cost Summary

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

8.5.5 Implementation

Implementation of the ASR water management strategy for Johnson County and Acton MUD includes the following issues:

- Permits from TCEQ for ASR construction and operations and for storage of surface water in the Trinity Aquifer can be obtained;
- Chemical and geochemical compatibility of native aquifer water and materials and imported water are chemically compatible;
- Lack of experience to develop confidence in the ability to inject and recover water from an aquifer, which includes the uncertainty about the compatibility of the injected water with native groundwater and aquifer materials;
- Controlling the loss of the injected water to others;
- Initial cost;

- Experience in operating the facilities; and
- Development of a management plan to efficiently use the ASR wells with a balance of recharge and recovery cycles.

This water supply option has been compared to the plan development criteria, as shown in Table 8.5-3, and the option meets each criterion.

Table 8.5-3. Comparison of Johnson County SUD and Acton MUD ASR Options to Plan Development Criteria

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

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8.6 Trinity ASR in McLennan County

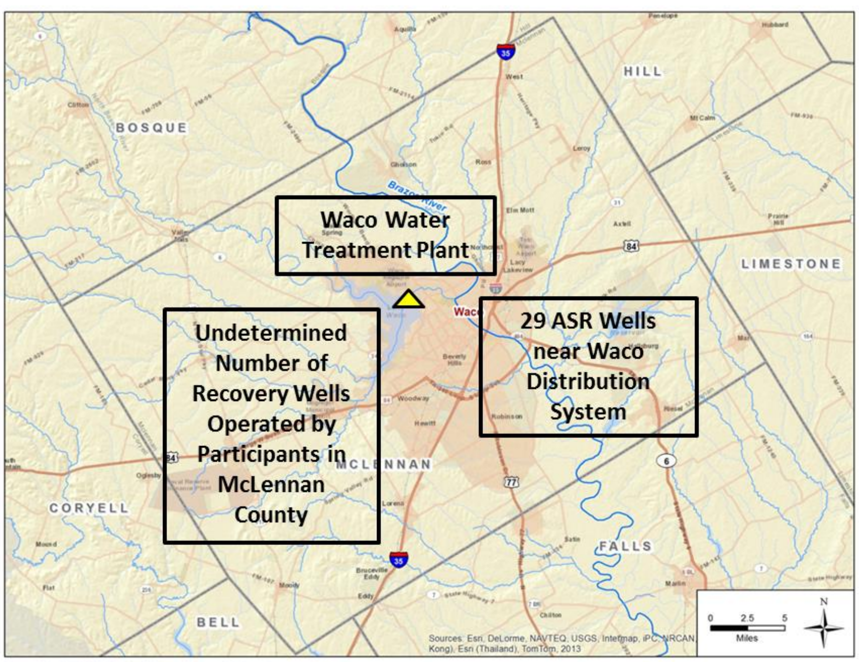
8.6.1 Description of Option

The concept for the Waco and McLennan County ASR project is to:

- Utilize existing surface water rights in Lake Waco that are owned by the City of Waco (Waco).
- More fully utilize Waco's water treatment plant (WTP) capacity of 50,400 acft/yr.
- Install new Trinity Aquifer ASR wells that would be located in the vicinity of Waco's distribution system where there is sufficient capacity to deliver additional treated water to the ASR wells. Recovery of the water would be by participant's existing or new water wells at locations other than the ASR wells. This would be water indirectly transferred from Waco to participants. Unlike traditional ASR projects where the recharged water would be recovered by the same well, the indirect transfer would involve an accounting process within McLennan County where water stored by Waco would be credited to a participant. The participants would pay Waco for the water right, water treatment, water transmission, recharge wells, and associated facilities and operations.
- Operate the ASR injection cycle from October to May which coincides when there is excess treatment capacity. Recovery could be at any time, but typically would be during the summer when demands are relatively high.

A schematic showing the location of the project is shown in Figure 8.6-1. New facilities required for this option are the ASR wells, well field distribution and collection pipelines and interconnects between the pipeline and ASR well fields.

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



8.6.2 Available Yield

The projected water supplies for Waco if unconstrained by water treatment capacity, and demands are illustrated in Figure 8.6-2. For purposes of this proposed ASR project, an assumed supply of 1,000 acft/mo would be made available to the ASR project during the eight months of October to May when Waco's demands are relatively low (see Figure 8.6-3). This 8,000 acft/yr supply is derived from an estimate of excess capacity in the Waco WTP during low water demand months and would not require an expansion of the WTP.

In McLennan County, the Trinity Aquifer system is composed of three sandy aquifer units that are confined and separated by nearly impermeable clay units. These aquifer units include, from youngest to oldest: the Paluxy, Hensell, and Hosston. The target unit is the Hosston. In general, the most hydraulically transmissive (i.e., sand-rich) portions of the unit vary from 100-200 feet in thickness and high-capacity production wells typically have yields from 350-450 gpm.

The long-term impact on the Trinity Aquifer is considered to be insignificant on a county-wide basis because the strategy for this project is to balance the recharge and recovery of water. However, there is expected to be local variations in groundwater level changes due to varying locations of recharge and recovery.

8.6.3 Environmental Issues

Environmental issues for the proposed Waco and McLennan County ASR Project are described below. This project includes the development of an ASR well field and additional well field distribution and collection pipelines and interconnects to existing transmission pipelines. Additional wells would need to be developed by individuals intending to utilize the stored water if existing wells are not available. Implementation of this project would require field surveys by qualified professionals to document vegetation/habitat types, waters of the U.S. including wetlands, and cultural resources that may be impacted. Where impacts to protected species habitat or significant cultural resources cannot be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. The project sponsor would also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to wetland areas and compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

The pipelines and wells needed for the Waco and McLennan County ASR project well field would occur in close proximity to the Brazos River. Coordination with the U.S. Army Corps of Engineers would be required for construction within any waters of the U.S. Any impacts from this proposed project which would result in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

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

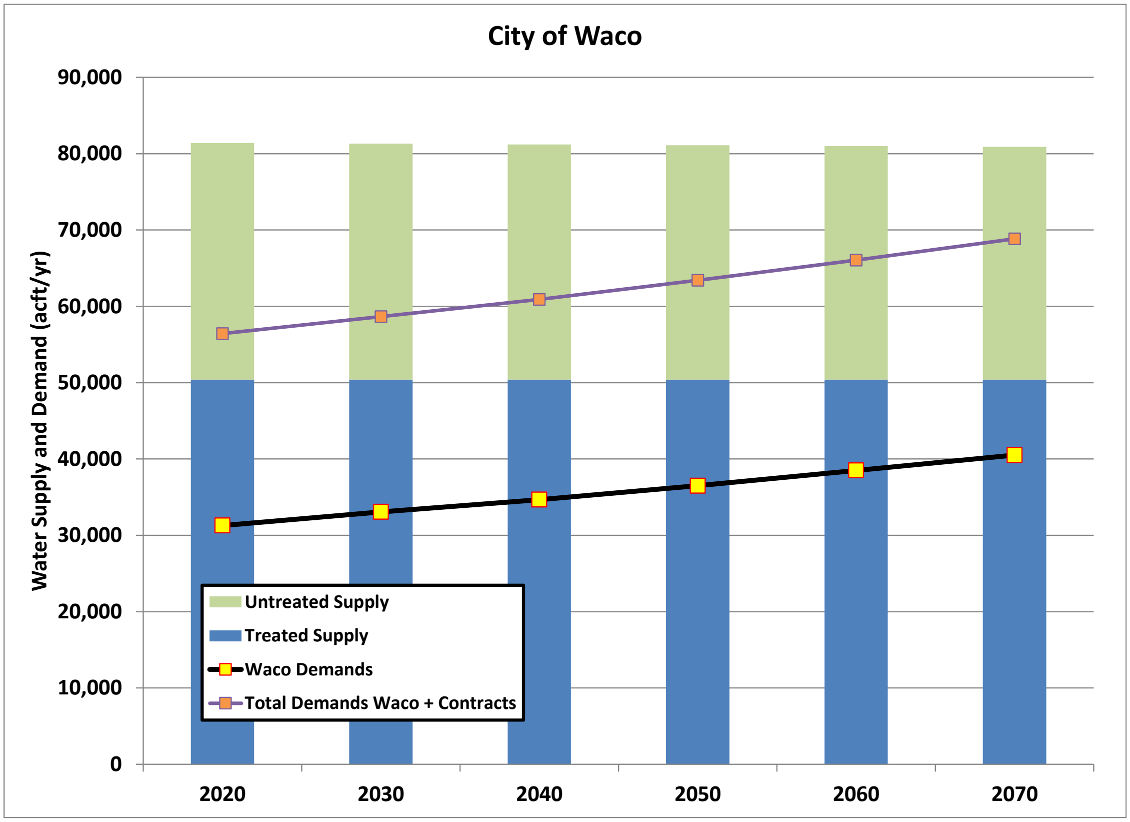
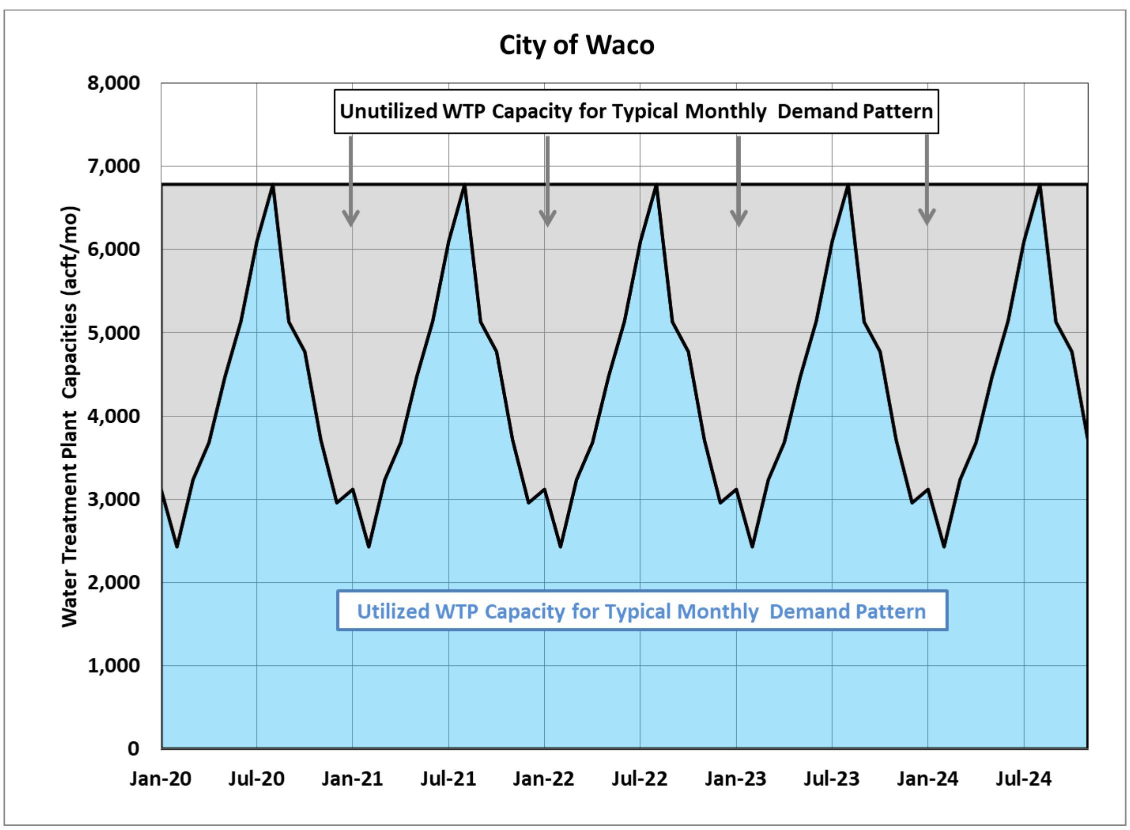


Figure 8.6-3. Water Treatment Capacity and Utilization of Waco's WTP



The project occurs within portions of the Central Oklahoma/Texas Plains, Texas Blackland Prairies and Edwards Plateau Ecoregions[1] and lies within the Texan Biotic Province.[2] Vegetation types within the Waco and McLennan County ASR well field area as described by the Texas Parks and Wildlife Department (TPWD)[3] includes crops, and urban areas. The majority of these areas have been developed or disturbed and now include homes, business, and farms. Avoidance of riparian areas near the Brazos River and other relatively undisturbed natural habitats within the well field areas would help minimize potential impacts to existing area species.

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

Because the project will result in an equal exchange of water to the aquifer, no significant impacts to existing stream flows or aquatic species are anticipated. Potential impacts to listed species within the project area are anticipated to include disturbance of existing habitat resulting from the construction of well fields and their associated pipelines. However, these disturbances would be minimized by the small areas generally required for well field and pipeline construction. After construction is completed the majority of the disturbed areas will return to their previous habitat condition excluding areas where maintenance activities are required.

A survey of the project area would be required prior to well field and pipeline construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291).

Based on the review of publically available Geographic Information System (GIS) records obtained from the Texas Historical Commission, there are no State Historic Sites, three National Register Properties, three National Register Districts, 24 cemeteries and 47 Historical Markers within the potential well field area. The National Register Properties and Districts occur within the northwest corner of the well field area within the City of Waco. Avoidance of these cultural resource areas should be possible by careful selection of the

[1] Griffith Glenn, Sandy Bryce, James Omernik, and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality.

[2] Blair, W. Frank. 1950. The Biotic Provinces of Texas. Texas Journal of Science 2(1):93-117.

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

areas for well sites and their associated pipelines. A review of archaeological resources in the proposed project area should be conducted during the project planning phase. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction.

8.6.4 Engineering and Costing

Available records indicate that wells in central McLennan County average between 1,800 and 2,200 feet deep. A typical recharge rate is estimated to be 300 gpm and a recovery rate of 400 gpm. For an 8,000 acft/yr ASR system in McLennan County, 29 ASR wells are required.

The major facilities required for these projects include:

- ASR wells (injection wells), and
- SCADA and interconnections at each well site.

Estimates were prepared for capital and project costs, annual debt service, operation and maintenance, power, land, and environmental mitigation. These costs are summarized in Table 8.6-1. The annual costs, including debt service, operation and maintenance, and power, are estimated to be $645 per acft. The costs do not include any compensation to the City of Waco for use of their surface water right. Costs include the energy cost associated with pumping water through the pipeline and the power connection costs for each well.

8.6.5 Implementation

Implementation of the ASR water management strategy for Waco and McLennan County includes the following issues:

- Agreements between Waco and participants;
- Acquiring permits from the McLennan County Groundwater Conservation District;
- Acquiring permits from TCEQ for ASR construction and operations and for storage of surface water in the Trinity Aquifer;
- Chemical and geochemical compatibility of native aquifer water and materials and imported water are chemically compatible;
- Lack of experience to develop confidence in the ability to inject water from an aquifer, which includes the uncertainty about the compatibility of the injected water with native groundwater and aquifer materials and failure of the ASR well;
- Controlling the loss of the injected water to others;
- Initial cost;
- Experience in operating the facilities; and
- Development of a management plan to efficiently use the ASR wells.

This water supply option has been compared to the plan development criteria, as shown in Table 8.6-2, and the option meets each criterion.

Table 8.6-1. Cost Estimate Summary: McLennan County ASR Project Option

Item	Estimated Costs for Facilities
Well Fields (Wells, Pumps, and Piping)	$36,220,000
Integration, Relocations, & Other	$8,554,000
TOTAL COST OF FACILITIES	**$44,774,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$15,671,000
Environmental & Archaeology Studies and Mitigation	$78,000
Land Acquisition and Surveying (76 acres)	$404,000
Interest During Construction (3% for 3 years with a 0.5% ROI)	$5,027,000
TOTAL COST OF PROJECT	**$65,954,000**
ANNUAL COST	
Debt Service (3.5 percent, 20 years)	$4,641,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$448,000
Pumping Energy Costs (864,877 kW-hr @ 0.08 $/kW-hr)	$69,000
TOTAL ANNUAL COST	**$5,158,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1	**8,000**
Annual Cost of Water ($ per acft)	**$645**
Annual Cost of Water ($ per 1,000 gallons)	**$1.98**

Table 8.6-2. Comparison of Bryan ASR Option to Plan Development Criteria

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

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