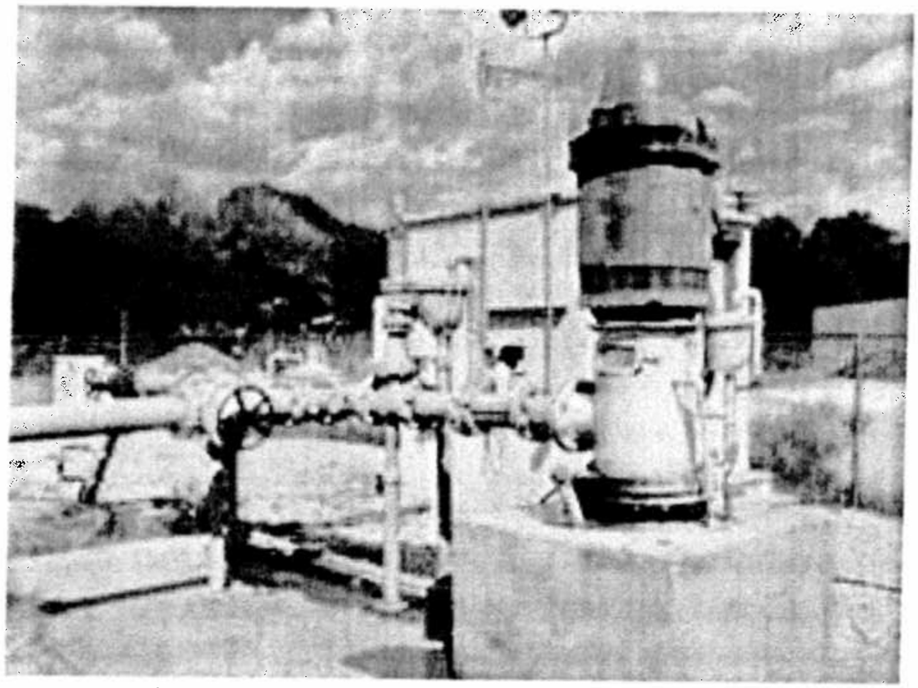
An Assessment of Aquifer Storage and Recovery in Texas



Report

by

Malcolm Pirnie, Inc
ASR Systems, LLC
Jackson, Sjoberg, McCarthy & Wilson, LLP

In Cooperation with

El Paso Water Utilities Board
City of Kerrville, Texas
San Antonio Water System

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Texas Water Development Board
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Texas Water Development Board

Report # 0904830940

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Acronyms Used in the Report

ASR	Aquifer Storage and Recovery
ASTR	Aquifer Storage Transfer Recovery
AwwaRF	American Water Works Association Research Foundation
EPWU	El Paso Water Utilities Board
HB	House Bill
mgd	million gallons per day
PVC	polyvinyl chloride
SAWS	San Antonio Water System
TCEQ	Texas Commission on Environmental Quality
TSV	Target Storage Volume
U.S.	United States
USGS	U. S. Geological Survey
WRF	Water Research Foundation (formerly AwwaRF)
WRP	Water Reclamation Plant

1 Executive summary

Introduction and background

Much of Texas is semi-arid to arid, susceptible to drought, and characterized by declining groundwater levels and intermittent river flows. The current Texas water plan (*Water for Texas 2007*) projects a need for almost 9 million acre-feet per year of new water by 2060. It will be difficult for conservation and other traditional strategies, especially expensive, controversial surface reservoirs, to meet all of that demand. The capture and storage of water when it is available is critical to sustainable water management.

The escalating costs and environmental challenges associated with surface water reservoirs have encouraged water professionals to explore Aquifer Storage and Recovery (ASR). ASR has proven to be an efficient and cost-effective method of storing water when it is available; however Texas is lagging behind other states in the implementation of ASR, and there is very little current interest in new projects. At the present time less than 4 percent of the nation's operational ASR wellfields are located in Texas, although other fast-growing states are actively implementing this technology. The number of operational ASR wellfields in the United States has quadrupled during the last ten years.

In November 2008, the Texas Water Development Board (TWDB) issued a Request for Qualifications for a Priority Research Project related to an assessment of ASR in Texas. In response to that Request, this research went through a series of logical steps to: (i) determine why ASR has been successful for at least three Texas utilities; (ii) determine why ASR is not being implemented to a greater extent in Texas and what unique features have made it more attractive in other areas within the U.S. and overseas; and (iii) recommend public policy, technical and legal changes to facilitate implementation of ASR in Texas.

The specific scope of the study included: preparing a legal white paper on ASR; conducting interviews with the three major Texas utilities currently using ASR as a water supply and storage strategy; conducting a survey of water utilities that have considered ASR but have not implemented a project; and making presentations related to the research effort.

The definition of ASR used in this study is "the storage of water in a suitable aquifer through a well during times when water is available, and recovery of the water from the same aquifer during times when it is needed using the same well or a different well."

ASR systems in Texas

Section 3 describes in detail the three ASR systems in Texas currently being operated by El Paso Water Utilities (EPWU), the City of Kerrville and the San Antonio Water System (SAWS). These ASR projects provide excellent examples of variations on successful application of ASR technology. Each utility elected to use a different source of supply (reclaimed water, surface water and groundwater, respectively), as well as different aquifers. These ASR projects provide valuable information on the diverse objectives, opportunities and challenges of this technology.

Going into the planning stages, each Texas organization had slightly different objectives, but in all three case studies it is evident that ASR provided additional benefits and exceeded the utilities' expectations. It is also evident from the case studies that public acceptance and support for ASR has been excellent.

The challenges faced by the three Texas utilities mirrored national issues that have been resolved in other states. Legal and regulatory matters were more challenging, and took more time and effort than the resolution of technical issues. It was also evident that the actual capital costs, and operations and maintenance expenses are often not well understood.

Survey of other Texas water purveyors

An online survey was sent to a total of 22 Texas utilities that had either studied and not implemented ASR or had considered it in the past. The survey consisted of 11 questions to solicit utility response on storage needs and whether ASR could be a useful supply strategy to meet those needs, the understanding of ASR, whether the utility had previously considered ASR, and to identify any concerns that may have limited evaluation and/or implementation of ASR. The online survey was followed with a telephone interview in selected cases to gather additional information.

A significant majority of the surveyed utilities (89 percent) indicated a need for additional water storage. Approximately half of the survey respondents indicated a need for additional water supplies that might be provided through ASR. The majority of the surveyed utilities (76 percent) indicated that its staff is familiar with ASR, and 10 of the 17 surveyed utilities have considered ASR as an alternative storage or water supply option. However, only three of those 10 utilities have conducted ASR-related studies.

Utilities that had considered ASR were asked why an ASR project had not been implemented. The primary concerns that have prevented these utilities from further studying or implementing ASR projects included:

- Ability to recover stored water;
- Quality of the recovered water;
- Cost-effectiveness of an ASR system; and
- Potential for other pumpers to capture the utility's stored water

Protecting and enhancing the utility's ability to recover its stored water is a bigger issue than the perceived technical and cost concerns. An improved legal/public policy framework that protects the ASR owner's right to its stored water, even under properties not owned by the ASR system operator, could alleviate the principal concerns expressed by the surveyed utilities regarding their ability to recover stored water.

Legal perspective

In 1995, the Texas Legislature enacted HB 1989 creating the first express statutory authorization to store surface water using ASR technology for subsequent recovery and beneficial use. Although ASR has a solid regulatory and legal foundation in Texas, there is substantial room for improvement and enhancement of the rules and statutes both at the state and local levels.

Texas' current regulations and statutes, both statewide and local, do not readily facilitate the maximum beneficial use of either groundwater or surface water for ASR. The shortfalls are not just reflective of the regulations and statutes governing the water supply source, but the ability to protect the water once it has been injected for storage. This inability to protect the stored water with certainty reduces or compromises many of the benefits and, as a result, the economics of ASR utilization. Ironically, the "threats" to the stored water are from other persons with access to the stored waters and also from the entities with regulatory jurisdiction over it.

Section 7of the report includes a list of specific recommendations for legal and/or regulatory changes that could enhance the implementation of ASR in Texas.

Conclusions and recommendations

The principal challenges for ASR in the United States have been the legal and regulatory frameworks which, in many states, have not yet caught up with the technical application of this technology. The same is true in Texas where the lack, or perceived lack of ability to protect the stored water is one of the greatest identifiable impediments to ASR implementation.

In order to achieve cost-effective, sustainable and reliable water supplies sufficient to meet projected future demands for Texas, large volumes of water storage will be required. Storage above ground in surface water reservoirs is often problematic due to adverse environmental impacts; land requirements; high costs; and water losses due to evaporation, transpiration and siltation. ASR can provide a significant portion of the storage needed to meet that future demand. The existing ASR systems in Texas have shown that the technology is feasible using different water supply sources as well as in different types of aquifers, and that the technical aspects of ASR are not the major factors inhibiting its implementation.

Additional work is needed to encourage the development of more ASR projects. The following specific recommendations are offered as means to enhance the development of ASR in Texas:

ASR demonstration program

We recommend that TWDB and TCEQ collaborate on the establishment of an ASR demonstration program with the goal of increasing the number of ASR projects in operation while at the same time strengthening the legal, political, legislative, regulatory and educational framework in support of ASR.

Proposed legal and regulatory modifications

Modification of the current provisions of Chapter 11, and/or Chapters 295 and 297 of the TCEQ rules is warranted to provide flexibility in water rights permitting that allows ASR implementation and/or expedited permitting consideration to add ASR as a storage component to water rights permits. Two examples for consideration include seasonal and scalping permit authorizations that could be used as sources of ASR supply.

Groundwater districts need legislative guidance on how to deal with ASR projects. Chapter 11, and TCEQ rules provide limited guidance, but it relates to ASR projects which use surface water as their supply source. Chapter 36 provides even less specific guidance with respect to ASR projects. Local groundwater districts are very inconsistent in how they address ASR projects, assuming they even address ASR in their rules and/or management plans.

Specific recommendations are discussed in Section 7.

More accurate actual cost data

TWDB should develop incentives for utilities operating ASR facilities to keep more detailed and specific cost data related to ASR implementation and the associated operating and maintenance expenses. These incentives could include a requirement for segregated accurate cost data as a requirement for State funding through TWDB, including funding through the demonstration program. In addition, short duration, highly-focused research could develop cost information at Texas' three operational ASR systems.

Interagency coordination

In addition to the demonstration program described above, there should be a dedicated effort to foster inter-agency cooperation on ASR between TWDB and the TCEQ. A regular ASR work group should be established by the two agencies for the purpose of coordinating administrative and regulatory strategies that can enhance the implementation of ASR.

Funding for statewide data gathering

Using the recommendations in this report, TWDB should establish an ongoing program to fund data gathering and implementation activities related to ASR. In addition, when TWDB processes applications for funding assistance with treatment, reservoir storage and water transmission or distribution system improvements, it could require that ASR wells be evaluated as an alternative to larger pipelines, treatment plants or reservoirs for meeting peak demands, or more likely as a combination of ASR with these other options so that needs can be met at reduced cost.

Research

The report discusses additional data gathering to support a better understanding of the storage potential of the state's aquifers. However, more focused ongoing research is also needed. Some of the studies should be focused on the technical issues identified in this report, such as concerns about water quality degradation with long-term storage. In addition, other research should be focused on the cost of ASR implementation.

Additional focused education

More outreach is needed with the water utilities, and with State agencies, legislators, groundwater conservation districts, hydrogeologists and well drillers. We recommend that periodic presentations be made specifically to the Texas Alliance of Groundwater Districts, the Texas Ground Water Association, Texas Water Conservation Association, Texas Section of the American Water Works Association, Texas Municipal League, Texas Association of Counties, Texas Rural Water Association and the Western States Water Council.

Evaluation of water exchange opportunities

As discussed in more detail in Section 5, Chapter 36 of the Texas Water Code should be amended to facilitate the development of ASR projects capable of utilizing aquifers to move water from the source and/or point of injection to the point of need. In other words, similar to the use of state water courses to transport water utilizing a “bed and banks permit” issued by the TCEQ, groundwater districts should be authorized to issue permits allowing water to be injected at one point in the aquifer and withdrawn at a different point.

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2 Introduction and background

Much of Texas is semi-arid to arid, susceptible to drought, and characterized by declining groundwater levels and intermittent river flows. The current Texas water plan (*Water for Texas 2007*) projects a need for almost 9 million acre-feet per year of new water by 2060. It will be difficult for conservation and other traditional strategies, especially expensive, controversial surface reservoirs, to meet all of that demand. At the same time, many conservation districts are establishing rules, management plans and "desired future conditions" that limit the potential use of groundwater.

The capture and storage of water when it is available is critical to sustainable water management. The escalating costs and environmental challenges associated with surface reservoirs have encouraged water professionals to explore Aquifer Storage and Recovery (ASR). ASR has proven to be an efficient and cost-effective method of storing water when it is available; however Texas is lagging behind other states in the implementation of ASR, and there is very little current interest in new projects. At the present time less than 4 percent of the nation's operational ASR wellfields are located in Texas, although other fast-growing states such as Florida and California are actively pursuing this technology. In *Water for Texas 2007* only one planning region (the Plateau Region) recommended an ASR project as a major strategy, and that is an expansion of an existing project in Kerr County. **Figure 2-1** shows the 95 wellfields in the United States (2009) in which water is injected and recovered from the same wells.

2.1 Project scope

In November 2008, the Texas Water Development Board (TWDB) issued a Request for Qualifications for a Priority Research Project related to an assessment of ASR in Texas. This study was conducted to fulfill the requirements of that research effort under TWDB Contract No. 0904830940. This research study goes through a series of logical steps to: (i) determine why ASR has been successful for at least three Texas utilities; (ii) determine why ASR is not being implemented to a greater extent in Texas and what unique features have made it more attractive in other areas (within the United States and overseas); and (iii) recommend public policy, technical and legal changes to facilitate implementation of ASR where it can be used to meet water demands in Texas.

The specific scope of the study included: preparing a legal white paper on ASR from a public policy and institutional perspective; conducting interviews with the three major Texas utilities currently using ASR as a water supply and storage strategy; conducting a survey of water utilities that have considered ASR but not implemented a project (or operated an ASR system and subsequently abandoned the operation); and attending meetings with TWDB and making presentations related to the research effort. A national perspective is also provided based on the research team's experience working on ASR studies throughout the United States.

2.2 Background information on ASR

Beginning in Turkmenistan and western India several hundred years ago, aquifer storage and recovery has since been extensively applied for water resources management and conservation in water-short regions around the world. In concept, ASR can include the storage of drinking water, treated surface water, reclaimed wastewater or groundwater from other aquifers. In its basic concept, water is stored underground in a suitable aquifer through wells and is recovered when needed from the same wells. Water may also be recovered from other wells, using a slight variation of ASR technology called "Aquifer Storage Transfer Recovery" or ASTR. ASR is particularly applicable in areas, including most parts of Texas, where surface recharge of aquifers through spreading basins and infiltration galleries is not viable.

Within the United States, ASR has proven itself to be efficient and cost effective, and it has much less environmental impact than traditional surface reservoir storage. At the present time there are approximately 95 wellfields operating in the United States in which ASR is accomplished by using the same well for injection and recovery **(See Figure 2-1)**. There are currently at least 13 operating projects in Florida and approximately 30 additional Florida projects in various stages of permitting, construction or testing. At least twelve (12) ASR projects are operating in New Jersey and the northeast, and at least eleven (11) projects are operational in California.

Although limited in number, the three Texas projects exemplify a well-documented cross-section of ASR technology. The projects are described in detail in Section 3. Each of these projects consists of the four traditional ASR subsystems: source water; storage aquifer; recharge wells; and recovery facilities. However, the ASR projects in El Paso, Kerrville and San Antonio utilize three different sources of water supply—reclaimed water, surface water and groundwater, respectively.

Since 1988, TWDB has funded the following ASR projects:

- **1988:** Aquifer Storage Recovery Feasibility Investigation, Phase I Preliminary Assessment, Upper Guadalupe River Authority (UGRA), Kerrville, Texas.
- **1989:** Aquifer Storage Recovery Feasibility Investigation, Phase IIA, Volume I, UGRA, Kerrville, Texas.
- **1992:** Aquifer Storage Recovery Feasibility Investigation, Phase IIB - Full-Scale Testing and Evaluation, UGRA, Kerrville, Texas.
- **1998:** Preliminary Investigation and Feasibility Analysis, Step 1, San Antonio Water System (SAWS) and Bexar Metropolitan Water District, San Antonio, Texas.
- **1999:** Aquifer Storage Recovery Feasibility Investigation, Step 2, City of Laredo, Texas.

All of these documents are available on the TWDB website at: http://www.twdb.state.tx.us/RWPG/rpfgm_rpts.asp.

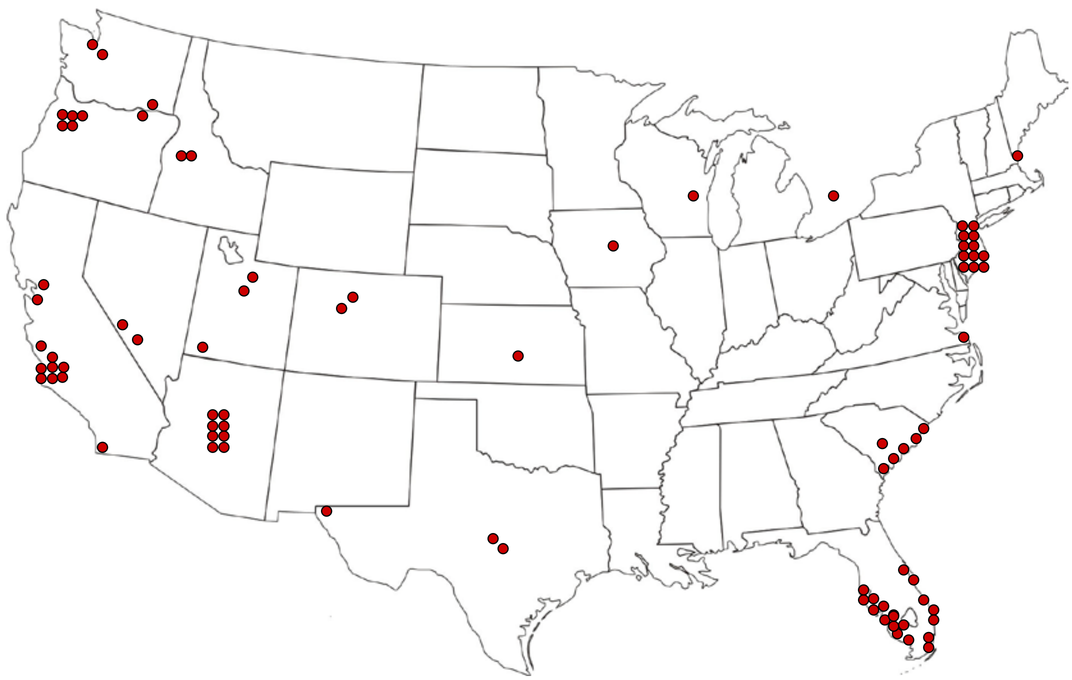

Figure 2-1: Geographic distribution of operational ASR wellfields (2009)

2.3 ASR terminology

Figure 2-2 illustrates the cross-section of an ASR well used for both injection and recovery, and some of the terminology used in this research report. In this illustration water is stored underground in an aquifer between two confining layers. The stored water is separated from the native groundwater by water in the buffer zone. The Target Storage Volume (TSV) is the sum of the stored water volume and the buffer water volume. No buffer zone is required when there is no significant difference in the water quality between the stored recharge water and the native or ambient groundwater. However, in most projects, a buffer zone is required. In fact, about one-third of all ASR wells are used to store drinking water in brackish or saline aquifers, and many projects store water in an aquifer that has at least one constituent that makes it unsuitable for potable purposes without treatment.

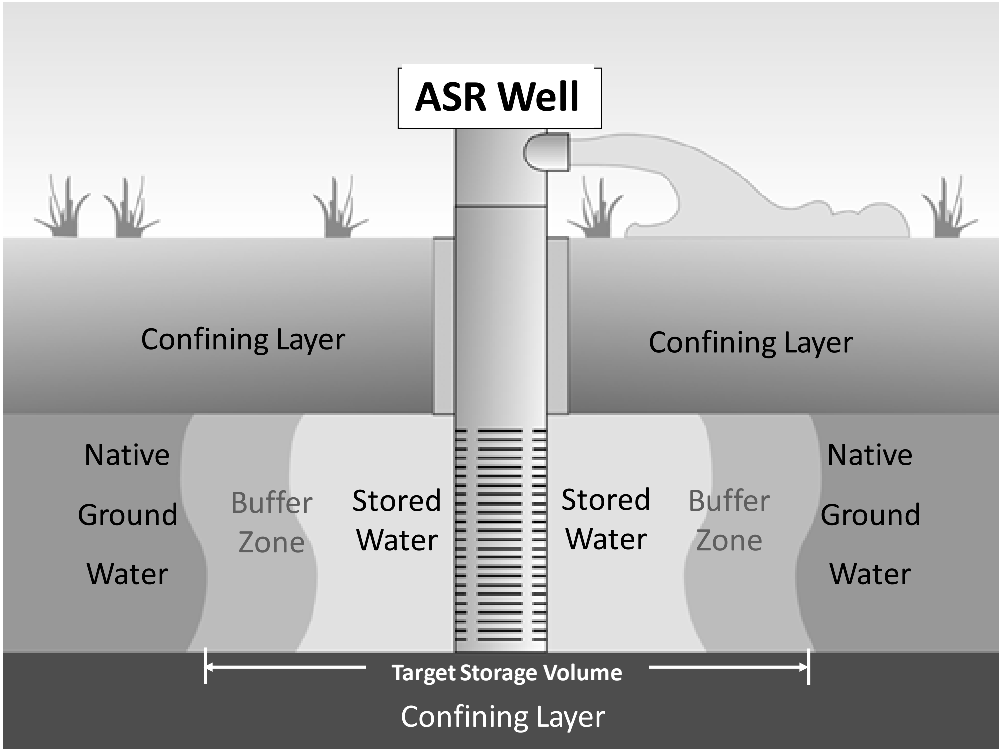

Figure 2-2: Typical ASR well used for both injection and recovery

The ambient groundwater quality in many Texas aquifers is variable, with many areas containing elevated concentrations of iron, manganese and hydrogen sulfide. The normal approach for ASR wellfields in which the same well is used for injection and recovery is to form and maintain the buffer zone separating the stored drinking water from the surrounding ambient groundwater. Initially the buffer zone would be formed around each well, however after reaching a sufficient cumulative storage volume, multiple individual storage bubbles around each well coalesce. The buffer zone then surrounds the entire wellfield. In essence, the buffer zone is like the walls of a ground storage tank. As a general operating criterion, it is acceptable to empty the reservoir but not acceptable to take down the walls of the tank.

The buffer zone is normally formed only one time, usually near the beginning of ASR operations, while the recovered water volume is recharged and recovered as needed. The TSV depends upon many variables and, based upon operating experience at several other locations, typically ranges from about 50 days to 350 days of recovery at the design production capacity of the wellfield. For karst, brackish, limestone aquifers the buffer zone volume is typically about half of the TSV; however, for a fresh, confined, sandstone aquifer such as the Carrizo-Wilcox aquifer in Texas, the buffer zone would most likely be considerably less than half of the TSV. With that buffer zone created, recovery of the stored water volume would not normally require retreatment other than disinfection. Continued pumping would be possible beyond this point however an increasing blend of stored drinking water with surrounding ambient groundwater will occur, steadily depleting the buffer zone and eventually requiring full retreatment of the recovered water to meet drinking water standards. The key issue, therefore, is to estimate the buffer zone volume and subtract that from the volume already recharged. The difference is an estimate of the volume that can be recovered without requiring retreatment. Operational testing and aquifer simulation modeling are two tools that can help with the estimation of the buffer zone volume.

The marginal cost of water stored in the buffer zone is usually quite low since it is normally produced during off-peak times, and reflects the incremental cost for chemicals, electricity and residuals disposal at such times. There is usually not a significant risk or economic penalty for overestimating the volume of water required for the buffer zone. It is important to point out that, once the buffer zone has been formed, subsequent ASR operations would be expected to achieve full recovery of the stored water, achieving 100 percent recovery efficiency. A wellfield operations plan is needed for each project. With such a plan, it is normally possible to achieve 100 percent recovery efficiency under design conditions with the least dependence upon operation of any groundwater treatment facilities, thereby minimizing operating expenses.

Figure 2-3 shows an illustration of an entire ASR process, from various sources of supply to injection and recovery.

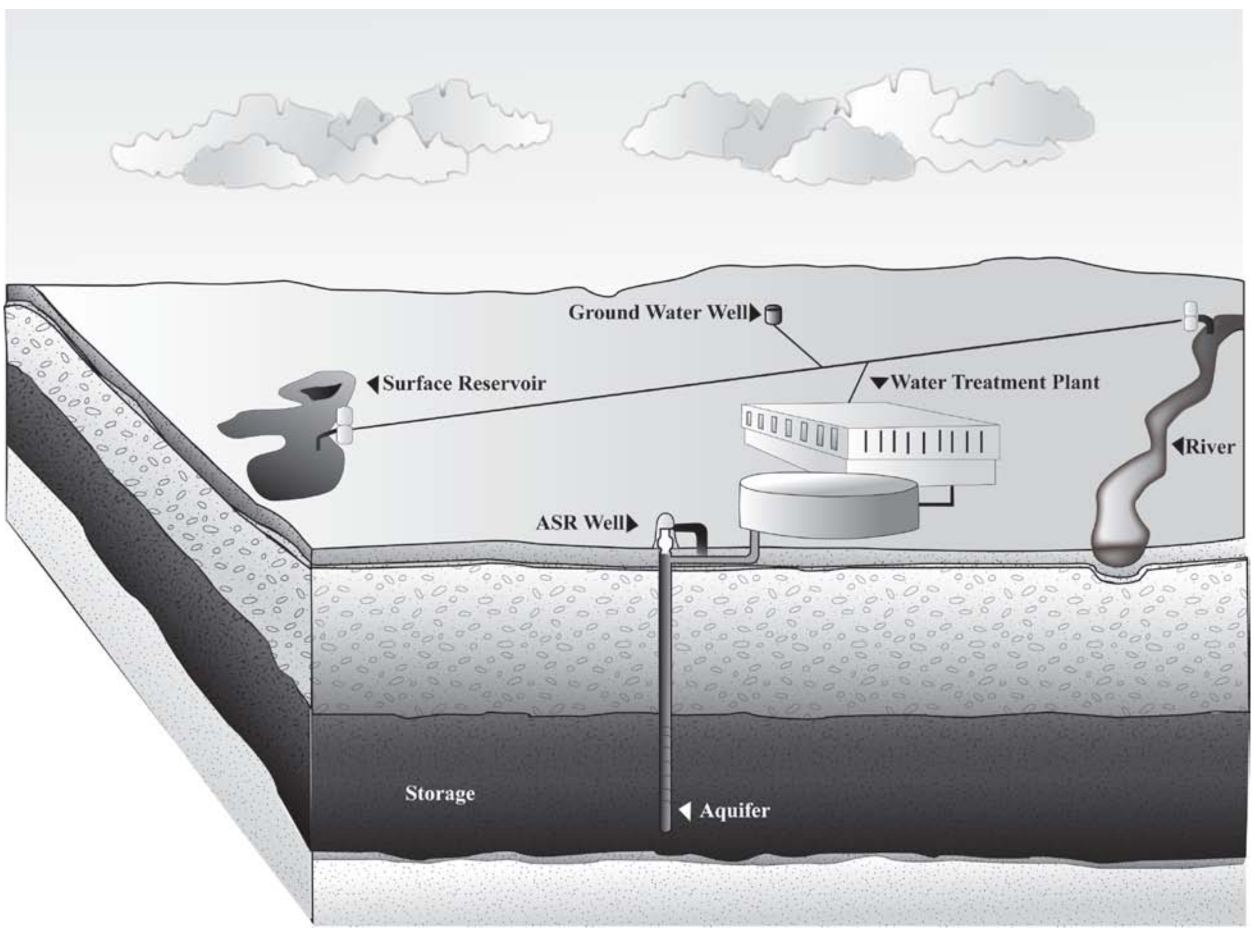

Figure 2-3: Illustration of generic ASR process

2.4 Reclaimed water as a source of supply

In recent years, there has been a substantial amount of nationwide interest and activity relating to storing highly treated wastewater ("reclaimed water") underground. In areas where surface recharge of reclaimed water is not a viable option, well recharge is the only way to achieve this goal. However, reclaimed water injection wells traditionally tend to clog, requiring periodic backflushing to maintain their performance. Redesigning injection wells as ASR wells, equipping them with pumps and with the proper materials of construction and the other unique features associated with ASR well design has been shown to be an acceptable design and operational approach. As a result, reclaimed water ASR programs are under development in southern California and in several other states, wherever there is a need for sustainable and reliable water supplies in water-short areas where surface recharge is not viable.

2.5 Definition of ASR

The concept of recharge and injection of water into the ground has been in existence for centuries. However, only in recent years has the concept been broadened to include the later recovery of that water for beneficial use. The strict definition of ASR coined by David Pyne in his textbook *Aquifer Storage Recovery* is the storage of water in a suitable aquifer through a well during times when water is available, and recovery of the water from the same well during times when it is needed. This definition has been adopted by the U.S. Environmental Protection Agency and other organizations.

The basis for ASR is a dual purpose well. The ASR well is an injection well that has a pump which allows the well to be backflushed, and that same pump can also be used for recovery of stored water. In many instances where ASR wellfields have been developed, water is not always recovered using the same well that injected it. [In Australia and other areas, recovery of the stored water using different wells is typically called "aquifer storage transfer recovery", or ASTR.] All three of the ASR systems operating in Texas have wellfields with the capability to inject and recover water using the same well, but they also have the ability to recover the stored water from other wells in the same aquifer.

Therefore, the definition of ASR used in this study is "the storage of water in a suitable aquifer through a well during times when water is available, and recovery of the water from the same aquifer during times when it is needed using the same well or a different well."

In Section 3, the three current Texas ASR operations are described in detail. Two of those utilities, the San Antonio Water System (SAWS) and the City of Kerrville, exclusively use wells for injection, and those wells can also be used to recover stored water. The third agency, El Paso Water Utilities (EPWU), currently operates both injection wells and spreading basins as the means for storing water. For purposes of this study, the EPWU water management system is considered an ASR operation because: (i) EPWU initially began its ASR project exclusively with injection wells, and injection wells are still used; (ii) the agency's injection wells are equipped with pumps which can be used for recovering stored water; (iii) EPWU's stated purposes for operating its ASR system include recovering stored water to meet peak demands for potable or industrial purposes; and (iv) non-ASR production wells used to recover stored water are located in the same aquifer as the injection wells, and they are operated as part of the same municipal system.

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3 ASR systems in Texas

The following three ASR systems are currently operating in Texas: San Antonio Water System (SAWS), the City of Kerrville, and El Paso Water Utilities (EPWU). Table 1 lists the capacities and other characteristics of these three ASR systems. As the information indicates, the three Texas ASR systems represent a broad range of capacities (2.65 to 60 mgd), source waters, and reasons for implementation. The SAWS system represents one of the largest ASR facilities in the US, and the EPWU ASR facility is one of less than a dozen reclaimed water ASR systems nationwide.

The SAWS, City of Kerrville, and EPWU ASR programs are success stories. Other communities in Texas can learn from their experience and can thereby gain confidence in ASR technology and its applicability to meet a variety of needs. Meetings and site visits were held with all three utilities to achieve an understanding of the issues that motivated initial development of these three ASR programs, the opportunities and constraints encountered along the way, public involvement and communications activities, capital and operating costs, operating performance, current issues and future plans for ASR expansion.

Table 3-1. Capacity and details of SAWS, City of Kerrville, and EPWU ASR facilities.

Component	SAWS (60 mgd)	Kerrville (2.65 mgd)	EPWU (10 mgd)
Date	2004	1995	1985
Source Water	Groundwater	Treated River Water	Treated Wastewater
Storage	400-600 feet Carrizo	495-613 feet Lower Trinity	300-835 feet Hueco Bolson
Issues	• Single pipeline • Distribution system limitations	• Litigation during permitting • Lack of source water	• Original well design • Customers for reclaimed water
Expansion Plans	Part of 50-year Management Plan Evaluating TSV	Adding 3rd ASR well WTP; expansion in Regional Plan	Expanding FHWRP; Constructing 4th spreading basin

3.1 San Antonio Water System

Four meetings with SAWS were conducted (June 29, 2009, meeting with Charles Ahrens and Gary Guy; August 26, 2009, meeting with Roberto Macias, Jeff Haby and Phillip Cook; and February 4, 2010 and January 19, 2011 meetings with Jeff Haby), plus several additional communications and exchanges relating to supplemental data and information that has been generously provided by SAWS staff.

Prior to these meetings a summary of SAWS ASR wellfield development and initial operations had been developed by ASR Systems as part of a case study prepared for the American Water Works Association Research Foundation (AWWARF, now Water Research Foundation, WRF) That report, entitled *Design, Operation and Maintenance Considerations for Sustainable*

Underground Storage Facilities (Project 3034), was published in 2008. David Pyne was the Principal Investigator for the report while Tom Morris/ASR Systems prepared the case study. Subsequently, in early 2009, a second, updated and more detailed report on the SAWS Twin Oaks ASR Facility was prepared on the same subject by David Pyne and Tom Morris, as part of an American Society of Civil Engineers case study for a book to be published on sustainable water supply alternatives. The book has yet to be published however the chapter on the SAWS ASR wellfield program is included as **Appendix "C"** to this Report. **Figure 3-1** shows the Twin Oaks ASR Wellfield Facilities and their location in Bexar County. **Figure 3-2 and Figure 3-3** show photographs of selected wellfield facilities. A very brief summary of the wellfield history and facilities follows.

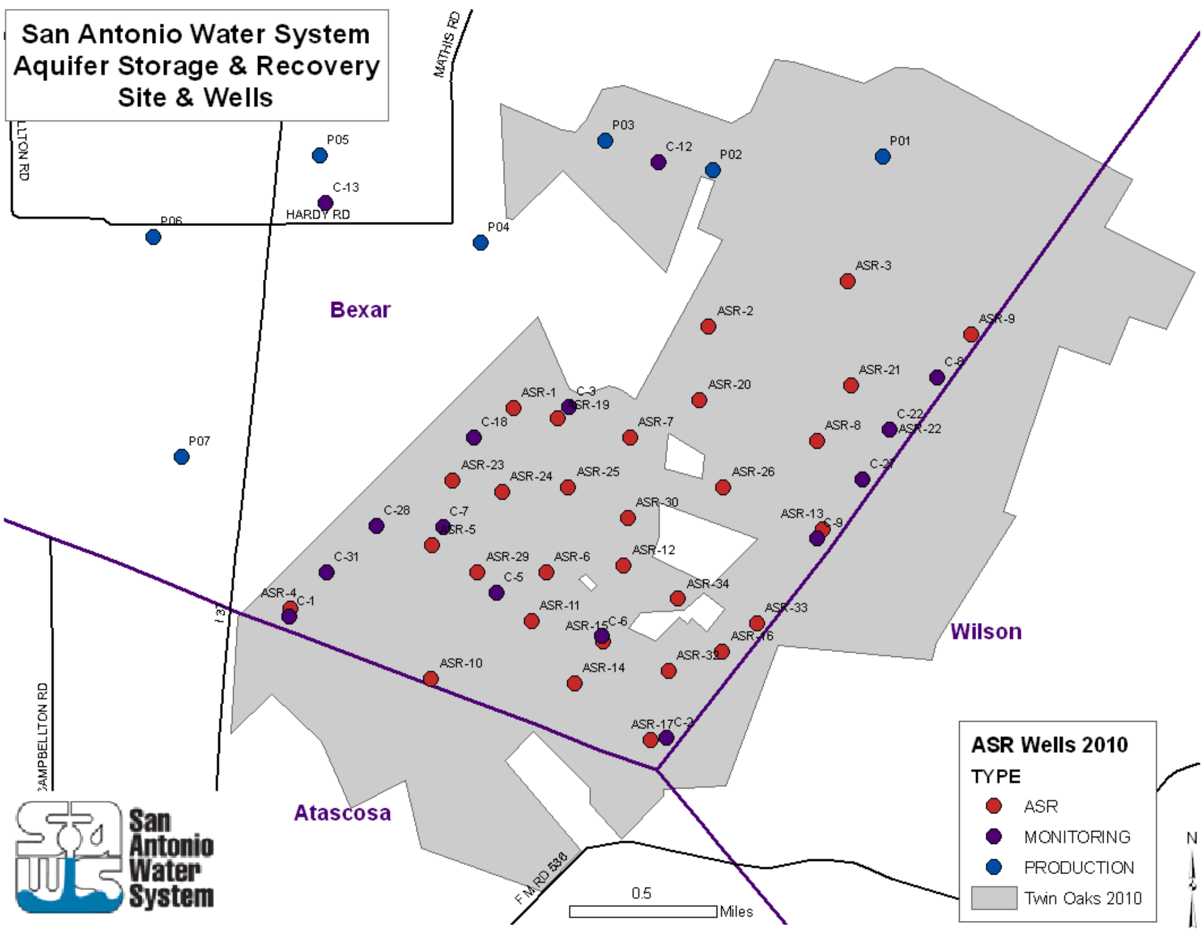

Figure 3-1: ASR wellfield layout (SAWS, 2010)

Figure 3-2: Flow control facilities and ground storage tank at Twin Oaks WTP

Figure 3-3: Water treatment plant (Morris, 2006)

Six locations and five separate aquifer systems for ASR were evaluated by SAWS before selecting the Carrizo-Wilcox Aquifer option in 2004. This location was selected since it provided the lowest costs for transmission, site development and operation. The Twin Oaks

ASR Facility, located 30 miles south of San Antonio, was then developed by SAWS to capture surplus water during wet months and store it underground for drought management and emergency relief. Water is injected into a semi-confined sand aquifer, forming a large water bubble. During times when groundwater levels are high, water from the Edwards Aquifer is disinfected to meet drinking water standards and is then pumped to the Carrizo-Wilcox Aquifer for storage. A total of 29 high capacity ASR wells and three native Carrizo-Wilcox Aquifer pumping wells were installed using flooded reverse circulation and mud rotary techniques. Well tests were conducted between 500 to 3,500 gallons per minute (gpm). Individual well pumping yields were ultimately designed around a range of 1,800 to 2,500 gpm. Recharge capacities range from 1,200 to 2,000 gpm.

The Carrizo-Wilcox Aquifer has a natural pH of 5.5 and has slightly elevated concentrations of iron, manganese and hydrogen sulfide, so a storage, treatment, and pumping system was built to treat the recovered water (if needed) and deliver up to 60 million gallons per day back to San Antonio. To date, recovered ASR water and native Carrizo water have been passed through the treatment plant because of the inability to by-pass the plant with water from the ASR wells. However, the recently-completed Phase 2 construction included the facilities necessary to by-pass water recovered from the ASR wells. The ASR facilities have been mostly used for banking the recharged water, achieving a cumulative storage volume of over 87,000 acre feet as of December 2010. Recovery pumping augmented local water supplies during the recent drought. The recovered water from the ASR wells has not required retreatment, other than disinfection. The wells are backwash-pumped as needed to maintain recharge efficiency. As stated above, water pumped from the three Carrizo production wells requires full treatment, including disinfection.

The SAWS Twin Oaks ASR Facility is the third largest ASR wellfield in the United States, behind Las Vegas Valley Water District, which has 157 mgd of recovery capacity, and also Calleguas Metropolitan Water District, California, which has 68 mgd of recovery capacity. Following is a discussion of the ASR operations at this site, addressing issues of interest to TWDB and Texas water utilities.

3.1.1 Issues that motivated initial wellfield development

The fundamental issue is the need for additional water storage to provide a reliable, sustainable water supply during normal drought cycles. SAWS has about 250,000 acre feet of water rights leased or owned from the Edwards Aquifer. Typically only a portion of this water is utilized for municipal water supply purposes. SAWS has invested a significant amount of money on alternative supplies, including surface water from Canyon Reservoir and water from other groundwater sources. However during dry periods SAWS typically spends a considerable sum of money each year purchasing supplemental water to meet peak demands. During 2008 supplemental water purchases cost about $60 million, even though SAWS used only 208,000 acre feet out of its 250,000 acre-feet for which it has Edwards Aquifer water rights. Investing $250 million in ASR wellfield, transmission and treatment facilities was relatively easy to justify based upon economic considerations.

Additional factors that motivated ASR development included the various stages of drought restrictions imposed by the Edwards Aquifer Authority upon SAWS pumping, reflecting the need to maintain springflow and to address downstream environmental and other concerns. The decreasing availability of water during droughts combined with the growing need for additional water to support growth in the San Antonio area created a situation where a range of water supply and water storage options were considered. ASR storage was one of the least expensive, most viable options.

3.1.2 Opportunities and constraints that were encountered

The initial plan was to pump out available fresh water from the 3,200 acre wellfield and then to start ASR operations, utilizing the depression created in the water levels in the Carrizo aquifer to effectively contain the stored water. The Carrizo-Wilcox Aquifer is not regulated in Bexar County by a local groundwater conservation district. While consistent with Texas's "Rule of Capture" groundwater law as applied within southern Bexar County, such a wellfield development approach turned out to be politically non-viable due to opposition from surrounding landowners, including those outside Bexar County whose groundwater is regulated under the jurisdiction of the Evergreen Underground Water Conservation District ("Evergreen"). A 2002 agreement was subsequently reached between SAWS and Evergreen by which ASR recharge operations would begin initially, not after several years of groundwater pumping. SAWS would also be entitled to pump 2 acre feet per year from the aquifer for each acre of land contained within the wellfield, or a total of 6,400 AFY, in addition to water recovered as needed from the ASR wellfield, up to the volume previously stored. The 2002 Agreement also prevents SAWS from recharging from any source other than the Edwards Aquifer or the Carrizo-Wilcox aquifer, intending thereby to prevent recharge with reclaimed wastewater.

This was a fundamental change in the overall ASR program. Raising the range of groundwater elevations occurring during ASR recharge and recovery has made it easier for stored water to move offsite in response to changes in the local gradient of groundwater levels. Groundwater elevations on average are higher than originally planned. The regional gradient of water levels in the Carrizo aquifer has been increased as a result of heavy irrigation pumping, primarily to the west of the ASR wellfield. It has been reported that adjacent offsite production wells owned by Bexar Metropolitan Water District ("Bexar Met") have improved in water quality during recent years, suggesting some offsite movement of stored Edwards Aquifer water. SAWS is not currently aware of any improvement in the Bexar Met wells. However, SAWS recognizes that had this change in operating plan been anticipated initially, it would have considered the acquisition of additional land in order to maintain control over the area where the ASR water is stored. (In fact, the SAWS staff indicated that the only two things they would do to enhance the ASR project were to purchase additional land for the wellfield, and to construct a dual pipeline delivery system.) Redistribution of pumping within the wellfield, including the three Carrizo wells and the offsite adjacent Bexar Met wells, helps to flatten the local hydraulic gradient, helping to keep the stored water available for recovery when needed.

With the existing wellfield area, uncertainty regarding the upper limits to the volume of water that can be stored is currently a significant operational issue. Under Texas water law and the 2002 Evergreen Agreement, SAWS is entitled to recover up to the same volume of Edwards Aquifer water that it has previously stored, plus 6,400 AFY attributed to natural recharge of the native Carrizo Aquifer. The principal constraints upon the volume of water that may be stored and recovered are therefore not volumetric but economic, as measured by the cost for treatment of recovered water and mitigation of offsite impacts. Under normal ASR operations the only treatment required is for re-disinfection of the recovered water. If recovery continues sufficiently long so that poorer quality ambient groundwater from the Carrizo aquifer is pulled back to the ASR wells, the recovered water would have to be fully treated prior to distribution.

Another significant economic consideration is the cost for the wellfield mitigation program under which SAWS pays to mitigate any adverse hydraulic effects caused, or potentially caused, by ASR wellfield operations. The purpose of the mitigation program is to mitigate the effects of drawdown during an extended recovery period. This has been an expensive program, reflecting a proactive commitment by SAWS to maintain harmonious relationships with surrounding landowners. Cost to date has exceeded $5 million. Most of this money has been on perceived issues related to water quantity, not quality. Under the program, new wells have been drilled and pumps have been lowered.

The initial ASR wellfield operation concept was to store water and recover it annually. This has subsequently evolved into a long-term water banking operation, storing more water in wet years and recovering water in dry years. At the beginning of summer 2009 about 54,000 AF was in storage. Approximately 7,500 acre-feet of stored ASR water and native Carrizo water was then recovered to help meet peak demands during a very dry summer, supplementing SAWS water supplies by 20 mgd for several months. That volume has since been replaced and supplemented. As of December 2010 over 87,000 acre feet of water was in storage.

Refining ASR wellfield operations and other water utility operations has been complicated by periodic changes in Edwards Aquifer Critical Period Management rules governing withdrawals by Edwards pumpers so as to protect springflows and endangered species. Changing the operating rules after major capital investments have been made is a significant concern for SAWS. Providing a greater volume of water storage has proven to be a helpful strategy for dealing with such uncertainties.

3.1.3 Public involvement and communications activities

Planning and budgeting for development of this wellfield extended over a period of approximately 10 years prior to start of construction in 2002. During this period there were numerous meetings, public meetings, reports and other activities intended to help move the program forward.

As part of its planning, public information and community outreach programs, SAWS interacted with groundwater districts in the areas that were being evaluated as potential ASR storage sites, including the Evergreen Underground Water Conservation District (“Evergreen”). In planning its ASR project, SAWS’ considerations related to the location of the storage site included: (i) minimizing the distance that the Edwards Aquifer water would be pumped for storage; and (ii) demonstrating its willingness to store the water in Bexar County (its “own backyard”). SAWS relations with Evergreen were extensive because the Evergreen district includes Atascosa and Wilson Counties, which are directly adjacent to southern Bexar County.

In 2001 as SAWS began the development of its ASR project, landowners in southern Bexar County filed an annexation petition with Evergreen. An annexation election was held on

February 2, 2002, but the voters rejected annexation. In spite of the result of that election, SAWS and Evergreen agreed that it was best for the two agencies to work together and enter into a water management agreement. As part of its collaboration with Evergreen, SAWS opened a satellite office within the district, and it began holding public meetings within the local area. When a second landowner petition was filed in May 2002, the Evergreen board of directors determined that it was not necessary to call an annexation election because the two agencies were working on a management plan. On December 2, 2002, the two organizations executed a Water Resource Protection and Management Agreement (the "Agreement").

The Agreement includes provisions that ensure management of the ASR project so as to protect landowners within the adjacent Evergreen district and those outside the district in southern Bexar County. At the same time, the Agreement provides SAWS with a reliable management and operations structure in lieu of a regulatory environment in which permits are of short duration, and management plans and rules can change over the life of a project. The Agreement includes among other provisions: (i) requirements that would have to be met in Evergreen's rules if the SAWS property were ever annexed by Evergreen; (ii) provisions that allow SAWS to recover up to the full amount of Edwards Aquifer water that it stores (with certain limitations during the first full year of operation); and (iii) authorization to withdraw from the Carrizo-Wilcox Aquifer up to 2 ac-ft/yr per acre of land owned by SAWS, with additional amounts authorized in 2004 through 2007 while SAWS was starting up its ASR project. The Agreement also describes a well monitoring program and the mitigation program that SAWS has implemented as part of its ASR operations. The Agreement also requires that the mitigation program will be managed in not only Bexar County, but also in Wilson and Atascosa Counties.

Over the course of the last ten years, Evergreen and SAWS have developed a good working relationship that provides benefits to both entities and the constituents they serve. SAWS continues to meet monthly with Evergreen staff, and the agencies exchange monitoring data.

As discussed above, SAWS has committed to a major program to mitigate any offsite impacts caused, or that may potentially be caused by ASR wellfield operations. This has included extensive monitoring of water levels and water quality, replacement of wells, setting pumps deeper in existing wells, and other mitigation activities. This program employs two SAWS staff full time. Most of the ASR wellfield activity since operations began in 2004 has been associated with recharge, building up the storage volume underground to its current level. Some recovery of the stored water has occurred to help meet peak demands, however recovery rates have generally been about 20 mgd or less, well below the initial 30 mgd design recovery rate for the wellfield.

Water purveyors in the area of the ASR wellfield initially had concerns about chlorine residuals in the stored water. Operation of the project has demonstrated that no water containing chlorine reaches offsite production wells. [Experience with other ASR projects in the U.S. has shown that under conditions similar to those occurring during storage in the Carrizo-Wilcox Aquifer, chlorine in drinking water typically dissipates within a period of a few days. Travel times from ASR wells to offsite production wells are probably on the order of several years.]

SAWS has been very willing to share its experience with ASR. Many groups visit the site annually to learn from the SAWS ASR experience.

3.1.4 Capital costs and operating expenses

SAWS has indicated that, as of March 2008, it has invested approximately $238 million to construct the ASR facility, thereby avoiding the need to spend about $600 million to buy Edwards Aquifer water rights. The major capital cost items are distributed approximately as follows:

Transmission pipelines	$ 92.1 million
Water treatment plant	$ 56.2 million
ASR wellfield facilities	$ 46.8 million
Wellfield mitigation program	$ 5.3 million
Land acquisition	$ 8.4 million
Engineering, legal, permitting project management, etc.	$ 29.2 million
Total	$238.2 million

There are about 42 miles of 60-inch and 42-inch transmission pipelines capable of conveying 60 mgd of Edwards Aquifer water from San Antonio to the wellfield, a straight line distance of about 30 miles, plus additional piping within the wellfield. The same transmission pipeline is used to recover the ASR water and deliver into the SAWS water distribution system. Water treatment plant facilities include ground storage reservoirs, 30 mgd treatment facilities for groundwater produced from the Carrizo-Wilcox aquifer, 60 mgd chlorination facilities, and a 60 mgd pumping station. The wellfield includes 29 ASR wells, thirteen (13) monitoring wells and three (3) Carrizo-Wilcox aquifer production wells. Facilities were constructed in two phases, the first of which was completed in 2004 providing 30 mgd recovery capacity, and the second was conducted in 2006, expanding capacity to 60 mgd.

As shown in the table above, the ASR wellfield facilities cost about $52.1 million, including the mitigation program (which could be considered an operating expense). With 60 mgd design recovery capacity, this equates to a unit cost of $0.87 per gallon per day of recovery capacity. By comparison, ASR unit capital costs nationwide average about $1.14 per gallon per day of recovery capacity, within a range of $0.50 to $2.00. The principal determinant of the unit cost is well yield. High yield wells tend to be associated with low unit costs, and vice versa. However there are several other factors that contribute to the unit capital cost for ASR storage. It is pertinent that the ASR wellfield cost is a relatively small component of the total capital cost, reflecting the considerable distance from San Antonio to the ASR wellfield, and the associated piping and pumping costs. Furthermore, experience to date suggests that operation of the water treatment plant will generally prove to be unnecessary if ASR operations can be conducted in such a manner as to minimize or avoid recovery of Carrizo aquifer water.

For the entire Twin Oaks ASR Facility, operating and maintenance expenses for 2009, after about five years of operation, totaled $2.6 million. (Separate information for just the ASR wellfield is not available.) This works out to approximately $43,000 per mgd of recovery capacity, which is above the previous upper end of the range of experience nationwide based on limited available data. This range has varied from $5,000 to $40,000 per mgd of recovery capacity. However, it is important to remember that these expenses include the operation and maintenance of the native groundwater production wells and the associated water treatment plant. Since the Phase 2 wellfield equipment is still within its warranty period, future operating expenses may be slightly higher than this. For planning purposes it would be appropriate to budget comparable operations at about $45,000 per year per mgd of recovery capacity. As stated above, the elevated operating cost most likely reflects not only operation and maintenance of the ASR and Carrizo-Wilcox production wells but also the water treatment plant, pump station, ground storage and transmission facilities associated with the ASR wellfield, plus the wellfield mitigation program.

3.1.5 Operating performance

The SAWS ASR wellfield has performed well, recharging a substantial volume of water and recovering water to help meet needs during the recent drought. Extended operation under design conditions (60 mgd) has not been demonstrated because of the inability to distribute this volume of water in non-peak periods. When distribution system improvements have been made, it will be possible to recover water at higher rates.

Most significantly, recovery of stored water to date has not required retreatment other than disinfection to meet target drinking water standards.

3.1.6 Current issues and considerations

An important current issue is to better define the storage volume available at the Twin Oaks ASR wellfield location, including the legal, regulatory, economic, water quality and other factors that define the volume of water available for recovery. Specifically, there will likely be an optimal range of target storage volumes, and also a maximum storage volume for this site.

A second key issue is to define the optimal operating criteria for the wellfield, including improved definition of when to start and stop recharge, and when to start and stop recovery. For example, during a drought, better definition is needed as to when to start and stop leasing Edwards Aquifer water for aquifer recharge. Water stored underground is not subject to drought restrictions that may be imposed by regulatory agencies so this stored water is particularly valuable for recovery during severe droughts.

Another potential issue is the proximity of the Twin Oaks ASR Facility to planned SAWS brackish water supply (from the Wilcox aquifer) and reverse osmosis water treatment facilities, located about 2.5 miles to the northeast. The brackish water supply and deep injection disposal of concentrate produced as a result of the desalination process will not utilize the Carrizo Aquifer, and preliminary testing has indicated that there are no adverse impacts. Because SAWS currently plans to drill some of the brackish Wilcox wells at the Twin Oaks Facility, it will establish through aquifer testing, simulation modeling and initial operations that leakage of water through overlying and underlying confining layers does not significantly impact ASR operations, or vice versa.

There may be an opportunity that would improve operations at the Twin Oaks ASR Facility. This option would include the integration of the three existing Carrizo production wells (and the four additional wells currently being completed) into the ASR wellfield operations. This would perhaps require an amendment to the existing agreement with Evergreen clarifying that the current 6,400 acre-feet per year that can be produced by SAWS from the 3,200 acres can be either produced for immediate use, or added to ASR storage and recovered when needed. That amendment should also clarify that the treated Carrizo water can be recovered from any well within the wellfield. Such an amended agreement would facilitate improved wellfield operations by enabling redistribution of recharge and recovery, and perhaps more importantly, eventually reducing the need for operation of the groundwater treatment plant. The 2002 agreement does not specifically address the ability to implement this proposed operational change. It is noteworthy that the same agreement already addresses the need for a buffer zone to separate the Edwards Aquifer water from the Carrizo-Wilcox aquifer water. As discussed above, the volume of water required in the buffer zone needs to be evaluated more carefully in light of operations during the past six years.

3.1.7 Future plans for ASR expansion

SAWS has no specific plans for another ASR expansion at this time. Pending resolution of the current issues discussed above, and construction of additional ASR storage at this or other locations may be useful and cost-effective.

Depending upon a number of factors and assumptions, the projected water shortfall for SAWS ranges from 37,000 acre-feet to 141,000 acre-feet between now and 2060 if the “drought of record” is superimposed on existing and projected water supplies and demands. As part of a diversified portfolio of water supply options to achieve water supply reliability, ASR is likely to play a major role. Investigations are planned to consider the optimal and maximum amount of ASR storage at the Twin Oaks Facility and the possible location of one or more additional ASR wellfields. Among the possible locations for an additional ASR wellfield, SAWS should consider the brackish portion of the Edwards aquifer. Approximately one-third of all ASR wellfields nationwide are in brackish aquifers.

ASR provides the opportunity to smooth out water supply operations, meeting peak and emergency demands from storage rather than from construction of new water supply facilities. This can significantly reduce capital costs.

Prior to expansion of ASR facilities it will most likely be useful to complete the SAWS distribution system and other hydraulic improvements that will enable SAWS to recover water from the Twin Oaks ASR wellfield during non-peak periods at rates up to its design recovery capacity of 60 mgd.

3.2 City of Kerrville

A meeting was held with water utility representatives of the City of Kerrville (Charles Hastings and Grant Terry) on August 26, 2009. Subsequently, additional information was graciously provided by Mr. Stuart Baron, Water/Wastewater Manager.

The first surface water ASR project in Texas was permitted by the former Texas Natural Resource Conservation Commission (“TNRCC”) on August 25, 1993.[1] The permit, issued to the Upper Guadalupe River Authority ("UGRA"), authorized the diversion of surface water from the Guadalupe River for municipal use. Incident to that diversion of State water, the permit authorized UGRA to store the diverted water by injecting the same down a well into the Lower Trinity Aquifer beneath the City of Kerrville after treatment to drinking water standards.

Water diverted and treated by UGRA was sold to the City of Kerrville for its retail water supply system. Historically, the City of Kerrville had relied upon the Hosston-Sligo Sand of the Edwards-Trinity Group of Aquifers as the sole source for its municipal water supply system. This was true despite the fact that the City sits on the banks of the Guadalupe River.

According to Kerrville's water use records dating back to the mid-1940s, the City was able to pump sufficient quantities of groundwater to meet 100% of its water supply needs. Over years, however, the City's total dependence upon the available groundwater supplies caused a dramatic drop in the level of the aquifer. By the late 1970s, Kerrville's continued reliance upon groundwater threatened to "mine" the aquifer.

Since 1981, water has been diverted from the Guadalupe River and treated to meet the City's daily demands. Reliance upon groundwater reserves since 1981 has been limited primarily to the hotter summer months when demands peak on the City's system.

The City of Kerrville's municipal demands continued to be met through the 1980s with the combination of the available groundwater and the newly permitted surface water supplies. Population growth within the City of Kerrville and the entirety of Kerr County, however, increased significantly during the 1980s. The growth phenomena caused the City of Kerrville and UGRA to evaluate future water demands of the City, and County-wide, and the adequacy of UGRA's existing conjunctive use operations to meet those demands. Based upon a determination that additional water supplies would be needed, UGRA spearheaded an initiative to conduct a regional TWDB-sponsored study to evaluate all available groundwater and surface water supplies within Kerr County. [2]

Upon completion of the Kerr County water supply study, UGRA filed a water rights application with the former Texas Water Commission in July of 1990. As initially filed, that application contemplated the alternative possibilities of (i) using a traditional/conventional large off-channel surface reservoir, or (ii) implementation of the then "innovative technology," at least for purposes of its development in Texas, of ASR to firm-up the municipal yield desired in the permit.

Based upon additional testing of the hydrogeologic characteristics of the aquifer beneath Kerrville, UGRA concluded that the development of the underlying aquifer as a "storage facility" for surface water diverted from the Guadalupe River would be the most economically efficient, and environmentally sensitive, feasible means to firm-up the yield sought by UGRA for its municipal use. The results of engineering and other technical analysis commissioned by UGRA allowed UGRA to confirm its ability to utilize ASR technology as a substitute for the construction of a traditional large off-channel reservoir.[3] In addition to avoiding the need to inundate hundreds of acres of hill country habitat by constructing a conventional surface reservoir, reliance upon ASR for the "storage component" to firm up the yield associated with its surface water appropriation saved UGRA an estimated $26 to $30 million dollars [1990 dollars] in capital expenditures.

In 1997, UGRA sold its water treatment system, including the ASR project, to the City of Kerrville.

Kerrville currently obtains its surface water supply from a small, instream reservoir on the Guadalupe River. The City has two water rights, the second of which provides for ASR operations. Water is treated at a 6.0 mgd surface water treatment plant (5 mgd conventional and 1 mgd membrane). The City has plans to expand the plant capacity to 10.0 mgd with addition of Xenon membrane filters. For the ASR operations, water is stored underground during winter months in the Hosston-Sligo Formation of the Lower Trinity Aquifer. Wells typically are cased to about 485 feet deep and are open hole to about 620 feet. Ambient water quality in the Hosston-Sligo Formation is excellent, almost the identical quality as the drinking water that is utilized as the source of water for recharge. **Figures 3-4 and 3-5** show photographs of the Kerrville ASR wells.

Figure 3-4: ASR Well R-1 at Kerrville Water Treatment Plant

Kerrville has two existing ASR wells and is in the process of adding a third ASR well. The first ASR well began operations in 1998 following successful conclusion of three years of litigation. The issuance of a final unappealable State permit to divert water from the Guadalupe River was delayed by opposition from whitewater kayaking and canoeing interests who objected to any efforts to take water out of the Guadalupe River, even during high flow events. The City subsequently took over ASR well operations from the Upper Guadalupe River Authority (UGRA), the agency that had originally developed the ASR facility at the water treatment plant site. Recovery capacity of Well R-1 is 1.65 mgd. Well R-2 was placed on line after 1998 at a separate location in downtown Kerrville and has a recovery capacity of 1.0 mgd. Well R-3 is expected to also have about a 1 mgd recovery capacity. The largest volume of drinking water stored to date has been approximately 700 million gallons (MG) or approximately 2,100 acre-feet. As of August 2009 the cumulative storage volume was at 515 MG. The target storage volume is 1.5 billion gallons however several years will be required to achieve this goal since recharge opportunities are limited by water rights regulatory constraints in the City's surface water permit. The City can only recharge approximately 140 MG per year. The increase in water treatment plant capacity is being sized to treat available water supplies during winter months to meet system demands while also recharging the ASR wells to the maximum extent possible.

Kerrville's average system water demand in the winter is about 3.5 mgd, while summer demands typically vary from 5.5 to 6.5 mgd. The highest peak day demand to date has been about 8.8 mgd. On the day of the August 26, 2009 meeting, the water demand was 4.1 mgd. Of this amount, 1 mgd was being diverted from the river for treatment and delivery, as limited by the State permit and the City's Stage 3 drought restrictions. On that same day, 2 mgd was being delivered from ASR recovery, and 1 mgd was being obtained from production of native Trinity Aquifer groundwater from City production wells.

Figure 3-5: ASR Well R-2.

3.2.1 Issues that motivated initial wellfield development

In the early 1980's, UGRA was faced with the need to develop a reliable surface water supply to augment Kerrville's use of the Trinity Aquifer. UGRA evaluated a surface water treatment plant, but additional storage was needed to meet demands when the river authority could not divert from the river. UGRA evaluated an offstream storage reservoir on tributaries of the Guadalupe River, at an estimated cost of about $30 million. In the early 1990's an ASR test program was undertaken, demonstrating the viability of this technology for underground storage of drinking water and resulting in completion of Well R-1. At that time it appeared that the total capital investment to address UGRA's supplemental water storage needs would be about $3 million, or 10 percent of the cost for building an offstream storage reservoir.

3.2.2 Opportunities and constraints that were encountered

Upon well completion in 1993, ASR operations were tied up for three years due to litigation brought by a whitewater group, styled *Texas River Protection Association v. TNRCC*, 910 S.W.2d 147 (Tex. App. – Austin 1995, writ denied), as discussed above. The cost of associated litigation doubled UGRA's investment in the ASR program. Despite two appeals by the plaintiffs, the outcome of this litigation was found in UGRA's favor. Although the ASR wells were exercised periodically during the litigation, actual ASR operations did not begin until after the City of Kerrville took over UGRA's ASR and treatment facilities in 1998.

The location of the two existing and one planned ASR wells within the City of Kerrville jurisdictional limits facilitates management of the stored water. The City has the authority to implement a local ordinance prohibiting the drilling of private wells, thereby protecting storage of public water supplies in the Hosston-Sligo formation. This effectively creates "groundwater zoning" within the City limits. For Kerrville this is not a significant challenge since recharge water quality and groundwater quality are similar so there is no real incentive for neighboring landowners to try to pump out the City's stored water. A benefit for neighboring landowners is that groundwater levels are generally elevated in the vicinity of the ASR wells. For Well R-1, the site is at a large water treatment plant property abutting the Guadalupe River, the floodplain for which is quite wide at this location next to the City's dam. There are limited opportunities for neighboring landowners to try to pump out the stored ASR drinking water.

3.2.3 Public involvement and communications activities

The public in the Kerrville area is very aware of the ASR wellfield and has been very interested and supportive of ASR activities. The City Council is briefed on a regular basis and understands that without the ASR recovered water, the City would be under more severe drought restrictions. Approximately four groups tour the facility each year.

3.2.4 Capital costs and operating expenses

No capital cost or operating expense information was obtained for the current ASR wellfield facilities. The City does not keep separate accounting and financial records for the ASR facilities. As indicated above, the original projected capital cost in 1993 was $3 million, compared to the $30 million projected cost for an offstream reservoir. The City's most recent report on the third ASR well included a total capital cost estimate of approximately $1.25 million for a 1.0 mgd well.

The City previously had separate electric meters on each of the ASR wells, but that is no longer the case. The City staff estimated that the operations and maintenance expenses for the ASR facilities are very small.

3.2.5 Operating performance

The ASR wellfield performs well and has provided a reliable and significant portion of the City's water supply for the past 12 years. In a "normal" year without drought conditions, the City obtains about 85 percent of its water directly from the surface water plant (not including treated surface water that is put into ASR storage) and about 10 percent of its water from the native Trinity Aquifer groundwater. The remainder of the water comes from ASR wells. The ASR wells have helped to maintain higher groundwater levels locally. City staff expressed surprise that no one else in Texas is currently planning to construct or expand ASR wellfield facilities.

3.2.6 Current issues and considerations

A key constraint on ASR operations is the City's limited ability to divert additional water for treatment and storage during winter months, primarily due to the special condition restrictions in the City's surface water rights permits. Legal and regulatory measures that would facilitate access to additional Guadalupe River water in winter would enable the City to more rapidly achieve its target storage volume, thereby enhancing reliable and sustainable water supplies for its customers. In the winter months river flows are typically higher, water demands are lowest, and excess water treatment capacity is available. Current restrictions limit the City to adding about 140 MG per year of supplemental storage.

3.2.7 Future plans for ASR expansion

The City is in the process of constructing Well R-3, thereby increasing its ASR recovery capacity from 2.6 mgd to about 3.6 mgd. This will also enable the City to get drinking water into storage at a higher rate during the periods of time when water is actually available for diversion from the river, for treatment and recharge.

3.3 El Paso Water Utilities

A meeting with the El Paso Water Utilities Board staff (EPWU or "El Paso") was held on October 27, 2009. Those EPWU staff members in attendance were: John Balliew (VP—Operations & Technical Services); Scott Reinert (Water Resources Manager); Eric Bangs (Assoc Hydrogeologist); Vick Pedregon (Fred Hervey WRP Superintendent); and Alfredo Ruiz (Assoc Hydrogeologist).

EPWU currently uses the following sources of water supply:

- Rio Grande surface water (approximately 52 percent)—60,000 ac-ft/yr from 2 water treatment plants;
- Hueco-Bolson Aquifer (approximately 26 percent)—30,000 ac-ft/yr (including about 5,000 ac-ft/yr from a 27.5-mgd brackish groundwater treatment plant located east of the El Paso airport; and
- Mesilla Bolson Aquifer (approximately 22 percent)—25,000 ac-ft/yr.

At the present time, EPWU is using about 60,000 acre-feet per year of its 65,000 acre-feet per year surface water authorization. The Rio Grande water is only "available" as a source of supply from February through October (which coincides with the irrigation season). Water for EPWU is released from Elephant Butte Reservoir which is about 120 miles upstream of El Paso. If

EPWU were to request water during the winter months, it would have to absorb all of the stream losses from the Reservoir to El Paso.

In its presentation, EPWU listed the following stated purposes for implementing ASR:

- Store excess reclaimed water not needed for irrigation and industrial uses;
- Partially restore groundwater levels;
- Improve water quality by diluting nitrates and reducing brackish water intrusion; and
- Meet peak demand for potable or industrial purposes.

Unlike SAWS and Kerrville, the El Paso ASR system stores highly-treated reclaimed wastewater that meets drinking water standards. This is the only reclaimed water ASR program in Texas and is one of fewer than ten reclaimed water ASR programs operational nationwide. The others are in Arizona, California and Florida. However, there is a substantial amount of nationwide interest and activity relating to storing reclaimed water underground.

A TWDB study in 1979 found that El Paso would have limitations on its water supplies in the future. Based on that study, and the results of the Bureau of Reclamation's High Plains recharge study, EPWU started an aggressive conservation program (which has resulted in a decrease from about 220 to 130 gallons/capita/day) and a process for diversifying its water supplies. In addition to its demand management, El Paso started using more surface water from the Rio Grande, developed a tiered water rate system, and implemented a water recycling program. The development history of the El Paso ASR program is also linked with growth on the northeast side of the city, leading to construction of a state-of-the art wastewater treatment plant. At a distance of 20 miles from the Rio Grande, effluent discharge to the river was not economical since the piping would have had to pass through the city. A decision was made to build a 10 mgd advanced wastewater treatment plant (the Fred Hervey Water Reclamation Plant) near an existing groundwater production wellfield where the rate of groundwater level decline in the Hueco Bolson aquifer was about three (3) feet per year. Treated effluent that is not utilized for golf course irrigation or industrial cooling purposes near the advanced wastewater treatment plant could also be utilized for aquifer recharge to control the rate of groundwater level decline and to serve as a source of water supply. The rate of water level decline has since slowed to about one foot per year.

Water levels in the EPWU production wells near the injection facilities have stabilized over the past twenty years. This is a result of increased use of surface water and reduced pumpage of groundwater. In 1988, 88,000 acre-feet of groundwater was pumped by EPWU from the Hueco Bolson Aquifer. In 2009, 24,000 acre-feet of groundwater was pumped from the aquifer. Since 1985 over 70,000 acre-feet of reclaimed water has been recharged to the aquifer.

In cooperation with the U.S. Bureau of Reclamation and the U.S. Environmental Protection Agency, construction of the Fred Hervey Plant began in 1982, and it was completed in 1985 at a cost of about $33 million. The plant produces effluent of drinking water quality with a chlorine residual of about 1.0 mg/L. The treated water is pumped from the plant into a 16-inch pipeline that delivers water to the injection wells, spreading basins, and recycled water customers. The residual is about 0.7 mg/L at a storage reservoir about 4 miles from the plant. As shown on the following figure, the treatment plant processes at the Hervey Plant include filtration, ozonation and granular activated carbon, achieving drinking water standards for reuse of the water. The Plant is currently being expanded to a capacity of 12 mgd.

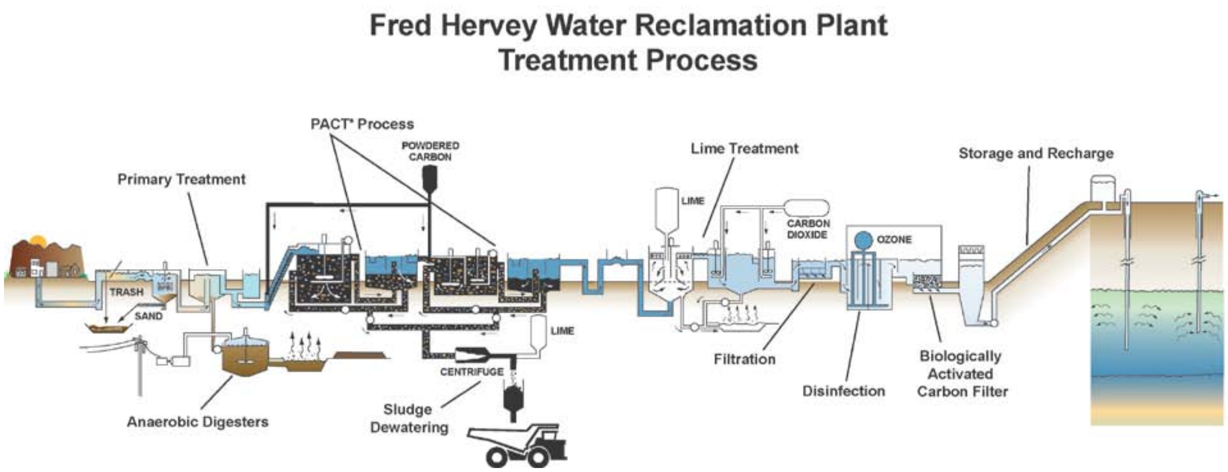

Figure 3-6: Schematic and description of the Fred Hervey Water Reclamation Plant

The recharge water also has a chlorine residual of approximately 1 mg/L. No disinfection byproduct issues are evident in the recharge water. No sulfate, metal or salt mobilization issues are evident in the recovered water. All but one of the recharge wells is equipped with a pump so that the wells can be periodically backflushed to purge any accumulated particulates and to restore the wells' recharge capacities. Back flushing frequency is approximately once every six months and is triggered when the individual well recharge rate declines to 10 to 20 percent of typical local well production rates, or about 150 to 300 gallons per minute.

Injection of reclaimed water began in 1985 with a total of ten (10) wells, all of which were constructed with galvanized casing and screens. Nine of the 16-inch diameter wells were constructed with uncoated mild steel casing and 16-inch diameter galvanized, continuous wire-wrap screen. A combination of 16-inch and 18-inch diameter galvanized mill-slotted screen was used in a tenth well. The original wells were completed with multiple screen intervals to a total depth of between 632 and 881 feet below land surface. The average recharge rate after construction was 498 gpm with a design back flush rate of 700 gpm. By 1992 all of these original wells had collapsed due to corrosion. Currently there are four (4) injection wells in service. These replacement wells were all completed with PVC casing and screens. Well depths are about 900 feet with screened intervals from 200 to 850 feet. The water table is at a depth of about 350 to 400 feet.

Within the past 10 years, field investigations were conducted to determine the viability of vadose zone wells and infiltration basins to achieve EPWU's aquifer recharge goals. The vadose zone test well program was deemed a failure. However, the infiltration basin program was successful. Based on a 2003 AwwaRF study entitled *Comparison of Alternative Methods for Recharge of a*

Deep Aquifer" Tailored collaboration, copyright 2003, EPWU began implementing spreading basins in place of drilling additional ASR wells. Two pairs of one-acre basins were originally installed, achieving infiltration rates of about 9 feet/day. Evaporation loss from the basins is about 8 feet/year. The third pair of one-acre basins is now being installed, and EPWU has permits for up to five pairs of basins. Travel time from the basin floor to the water table is about thirteen (13) days. EPWU has experienced no salt loading or air entrainment issues with the basins. Infiltration basins are now the preferred method for aquifer recharge at El Paso. They have proven to be cost-effective relative to ASR injection wells.

3.3.1 Issues that motivated initial wellfield development

As stated above, the original motivations for this ASR program were to recharge the Hueco Bolson aquifer and thereby reduce the historic rate of groundwater level decline, while augmenting local water supplies and avoiding the need for long-distance conveyance of the wastewater treatment plant effluent to the Rio Grande. Over time the project purposes were expanded to include water quality and water supply. Those goals have been achieved and the program has been in successful operation for 25 years.

3.3.2 Opportunities and constraints that were encountered

The original 10 wells were permitted for operation by TCEQ in the 1980's when the Fred Hervey Plant was constructed. The four replacement wells have been covered under the same permit. The permit has no specific aquifer testing or monitoring requirements other than normal routine TCEQ monitoring.

TCEQ requires an aquifer residence time of two (2) years to ensure inactivation of viruses in the recovered water. The two-year residence time has been interpreted at a downgradient spacing of 1,210 feet based on the estimated groundwater flow velocity. El Paso has four (4) groundwater production wells located approximately 2,560 feet downgradient with additional production wells located approximately 3,300 feet downgradient from the injection wells. The travel time from the injection locations to these production wells is more than five (5) years which exceeds the minimum time required by TCEQ.

There is currently no groundwater conservation district for the Hueco Bolson Aquifer in the area of El Paso's operations.

3.3.3 Public involvement and communications activities

Existing advanced waste treatment, infiltration basin and ASR well operations have substantial public support with no significant public opposition. EPWU has placed as much emphasis on conservation as it has on use of reclaimed water. Overall, there has been little public concern with the project, other than bird enthusiasts who want to protect wetland habitat at the Fred Hervey Plant. More information on public education programs is described below.

EPWU has a number of public education programs related to the operation of the Fred Hervey Plant and the ASR facilities. These include:

- Open houses and plant tours in which the staff readily drinks the finished product;
- Observation of National Water Week;
- Use of plant brochures; and
- Public acknowledgement of the “residence time” between the time water is recharged and when it is recovered in the production wells.

3.3.4 Capital costs and operating expenses

Only limited information was obtained regarding costs. Like SAWS and Kerrville, EPWU does not keep separate accounting or cost information on its ASR system.

In general, EPWU’s ASR wells cost about $425,000 for well construction and equipping. These ASR well costs are very low compared to normal experience for ASR wells to depths of 900 feet. EPWU did have problems finding drilling contractors who were capable of properly using PVC as the pipe material. One of the ASR well sites is shown below in **Figure 4-7**.

The infiltration basins cost about $70,000 each. The relative cost-effectiveness of infiltration basins compared to ASR wells is not a surprise since this is well-documented. Where the goal is just to get water into the ground, infiltration basins, where viable, will almost always be more cost-effective than ASR wells or injection wells. Where the goal is to get water into the ground and to recover it locally for drinking water supply purposes, recharge through ASR wells is usually more cost-effective than infiltration basins since the water is only treated one time, prior to recharge instead of following recovery.

Infiltration basins are also simpler to operate, easier to rehabilitate and have fewer mechanical components than ASR injection wells. However, in many areas of the United States, infiltration basins are not feasible or viable due to high land costs, inappropriate geology such as thick, deep confining layers, or shallow water tables. In these areas well recharge is the only option, and ASR wells provide better, more cost-effective performance than infiltration basins. El Paso is fortunate to have suitable conditions for infiltration basin recharge even though the depth to localized groundwater is over 350 feet.

At the present time the operating and maintenance expenses for the Fred Hervey Plant are approximately $3.5 million/year which results in a unit cost of about $2.13 per 1,000 gallons. EPWU staff estimated that about 2 percent of that cost is attributable to the ASR facilities, exclusive of electrical power expenses. Revenues from the reclaimed water sales are based on a rate structure that is about 90 percent of the Utility’s potable water rate. Therefore, the reclaimed water revenues are based on a rate of about $2.40 per 1,000 gallons.

3.3.5 Operating performance

El Paso’s ASR system performance has been mixed, primarily reflecting the corrosion issues associated with the use of galvanized casing and screens in the initial injection wells. The construction of new injection wells with PVC casing and screens has been important to the overall success of the ASR program. Recharge occurs intermittently, whenever the availability of reclaimed water exceeds demands for local irrigation and industrial uses. EPWU currently supplies about 5,000-6,000 acre-feet per year of reclaimed water to its customers.

The Fred Hervey injection wells are important to the overall management of the Hueco Bolson Aquifer. As stated above, water levels in the production wells near the injection facilities have stabilized over the past twenty years. Since 1985 over 70,000 acre-feet of reclaimed water has been recharged to the aquifer by the injection wells and spreading basins. However, other factors should also be credited with stabilizing the water levels. The increased use of surface water and the reduced groundwater pumping have contributed significantly. The combination of reduced groundwater pumpage and continued long-term recharge of reclaimed water has been beneficial to the management of the Hueco Bolson water resource.

Substantial additional ASR recharge capacity is available, potentially about 5 to 7 times the current typical recharge rates. However if expansion of the ASR wellfield were to entail additional reclaimed water ASR permitting, EPWU believes that the effort and cost may not be worth the benefit.

3.3.6 Current issues and considerations

In addition to the relative cost-effectiveness of the infiltration basins, a significant factor affecting the selection of recharge options has been the regulatory framework for infiltration basins and for ASR wells, which has become quite challenging. EPWU believes that getting additional wells permitted for recharge with reclaimed water could be difficult, extremely expensive, time-consuming, and with an uncertain outcome. Permitting recharge basins is also complicated and costly, but far less costly and with a higher probability of success than permitting reclaimed water ASR wells.

The ultimate fate of the current recharge program is uncertain. Direct use of the reclaimed water for irrigation and other purposes is expected to utilize a steadily increasing percentage of the available reclaimed water, reducing the availability of this water. Future water supply sources for El Paso are not likely to provide surplus water. Reflecting the mixed experience in El Paso with ASR well recharge and the relative success of the infiltration basins, there is low confidence by EPWU that ASR wells are a sustainable tool for expanded recharge operations. Improved design and different operation and management practices may have led to greater success with the ASR wells, although this would have required greater investment of time and funds. There do not appear to be current plans for trying to integrate ASR storage with any of the other water supply options.

3.3.7 Future plans for ASR expansion

As part of the EPWU land use master planning process, additional property has been reserved for the purpose of building ASR facilities. Additional ASR capacity will be built as needed. However, the EPWU staff stated that as existing ASR wells eventually fail or need major work, they will probably be replaced with infiltration basins, not ASR wells.

The staff of EPWU identified the following issues related to development of additional ASR:

- Other demands for reclaimed water limit the amount that can be recharged;
- TCEQ seemed to have an adverse perception of ASR;
- Permitting of injection wells is more complicated than it needs to be;
- Groundwater regulations are being developed without sufficient flexibility for different aquifers or local conditions;
- Micro-constituent issues may complicate the injection of reclaimed water in the future.

The current regional water plan calls for increased use of reclaimed water throughout the city of El Paso. Reclaimed water reuse in the city is currently at about 6,000 acre-feet per year. That quantity is expected to increase to about 12,000 acre-feet per year by the year 2060.

Since El Paso initiated its ASR operations a variety of aquifer recharge applications have been developed around the nation. Some of them may be useful in the El Paso area as a part of an array of water supply sources and underground storage options to achieve sustainable and reliable water supplies.

As stated above, EPWU has 65,000 acre-feet per year of water rights on the Rio Grande and currently uses about 60,000 acre-feet per year. EPWU has conducted a preliminary evaluation to assess the feasibility of injecting excess treated surface water into the Fred Hervey injection wells. The schedule for the injection of this surface water is still under evaluation. This water would typically be available in the early months of the irrigation season (March and April). This is the time when surface water is available, and the peak water demands associated with hot weather are not yet occurring. This excess surface water would be treated and pumped into the city distribution system. A short section of pipe and associated valves would be needed to deliver this water to the recharge basins. This additional water would supplement the ongoing ASR program and would be beneficial to the sustainability of the Hueco Bolson Aquifer.

EPWU is continuing to increase its water supply from a variety of sources. These sources include: surface water from the Rio Grande; local groundwater; desalination of brackish groundwater; conservation; and reuse of reclaimed water.

Figure 3-7: EPWU ASR well site

4 Survey of other Texas water purveyors

A survey was distributed to water utilities throughout Texas, some of which have considered but not implemented ASR projects, to assess reasons for the relatively low rate of ASR installation in Texas. Follow-up telephone interviews were conducted with seven of the survey respondents and two additional utilities that had previously considered implementation of ASR.

This section presents the approach and key findings from the survey and telephone interviews. Also included is a discussion of two utilities that previously operated ASR systems and an Aquifer Storage and Recovery Conservation District that is managing groundwater resources, including those injected for storage and later use.

4.1 Survey methodology

An online survey was developed through Cvent (www.cvent.com) and was sent to a total of 22 utilities. The survey consisted of 11 questions to solicit utility response on their storage needs and whether ASR could be a useful supply strategy to meet those needs, their understanding of ASR, whether the utility had previously considered ASR to meet storage or water supply needs, and to identify any concerns that may have limited evaluation/implementation of ASR. The survey was developed by the Malcolm Pirnie Team and reviewed by staff members of TWDB. A copy of the survey is shown below.

Texas Water Development Board
Aquifer Storage and Recovery Research Project
Task No. 4 – Utility Survey—Web-Based Screening Survey

Introduction and Background

The Texas Water Development Board (TWDB) is funding research on Aquifer Storage and Recovery (ASR) under its 2009 Priority Water Research Topics program. The study is being conducted by a Malcolm Pirnie team and focuses on the state of ASR in Texas. The scope of the project includes: providing a legal white paper on ASR from a public policy perspective; conducting interviews with utilities currently using ASR; and conducting a survey of water utilities which might have considered ASR.

The purposes of this screening survey are to: gather background information on your utility's current (or past) interest in ASR; and to determine if a more in-depth interview would be beneficial to our research. Your time participating in this important study is greatly appreciated!

Description of ASR
Aquifer Storage and Recovery (ASR) is a water storage alternative in which water is pumped into a confined or unconfined aquifer and stored until it is required, at which time it is pumped back out of the aquifer. ASR can provide a cost effective alternative to the construction of above-ground storage reservoirs. ASR systems have been installed throughout the U.S. to serve

a variety of applications, including seasonal or long-term storage; extending the life of existing treatment facilities; and meeting peak demands.

Survey Questions

1. Is the need for additional water storage a key issue for your utility? (Mark all that apply)
   - Seasonal storage?
   - Long term supply storage?
   - Storage for peaking purposes?
   - Other purposes?
2. Do you have a need for additional water supplies that might be served by ASR?
3. Are you or your staff familiar with the technical aspects of ASR?
4. In the past, have you considered ASR as an alternative storage or water supply option?
5. Have you conducted technical studies of ASR as a storage or water supply option?
6. If studies have been conducted, would you be willing to share your previous ASR studies for our use in this research project for the TWDB?
7. If you have considered or studied ASR in the past, why was an ASR project not implemented? (Mark all that apply)
   - Lack of a suitable source of water (of adequate volume?) for storage;
   - Technical problems associated with the treatment or availability of the source of supply;
   - Technical problems with the aquifer proposed for storage;
   - Concerns about apparent regulatory burdens;
   - Lack of available data on the proposed aquifer;
   - Higher cost than other alternatives;
   - Lack of funding for an ASR project;
   - Concerns about your physical ability to recover the stored water;
   - Concerns about the quality of the recovered water;
   - Concerns about other pumpers getting access to your stored water;
   - Other technical problems or concerns;
   - Other legal or public policy concerns;
   - Other general concerns or problems;
   - Lack of public support; or
   - Strategy not included in regional water plan (hence no funding available from TWDB).
8. Would you like to know more about ASR and/or this study?
9. May the Pirnie study team contact you for additional information?

9.1 If so, please provide your name and contact information below.

10. If you have additional comments or questions, please enter them in the space provided below.

Concerns related to the ability to recover the stored water were broken out into: technical issues associated with the hydrogeology of the aquifer (c); perceived concerns about the physical ability to recover the water and water quality (h, i); and, policy-related concerns regarding the potential for other pumpers to access the stored water (j). The survey was delineated in this way to gain insight into whether utilities' concerns about the ability to recover stored water were based on physical limitations with the storage aquifer or more non-technical concerns such as socio-economic factors (including cost) and legal issues.

The survey was conducted in January 2010 and was initiated by sending out an email with a link to the online survey to the 22 utilities listed below. Email reminders were sent out each week for four weeks. This approach led to a 77 percent response rate, with 17 of the 22 utilities responding. The Upper Trinity Regional Water District provided two separate responses (from two different staff members), leading to a total of eighteen individual responses.

Surveyed Utilities (responding utilities shown in bold)	Phone Interview?
Brazos River Authority	Yes
Brownsville Public Utilities	
Canyon Lake Water Service Company	
City of Austin	Yes
City of College Station	Yes
City of Corpus Christi	
City of Highland Park	
City of Houston	
City of Laredo	
City of McAllen	
City of the Colony	Yes
Guadalupe-Blanco River Authority	
Gulf Coast Water Authority	
Lavaca-Navidad River Authority	
Mustang Special Utility District	
New Braunfels Utilities	
Sabine River Authority	
San Jacinto River Authority	Yes
San Patricio Municipal Water District	Yes
Tarrant Regional Water District	
Trinity River Authority	Yes
Upper Trinity Regional Water District (2 responses)	

Follow-up phone interviews were conducted with seven of the surveyed utilities to obtain additional information. The interviews focused on clarifying and documenting any concerns the utilities had expressed regarding ASR (e.g., water quality, legal/regulatory issues, cost concerns, etc.) in their online responses.

During the project, two Texas utilities were identified that had previously operated ASR systems, but those systems are no longer in service. These utilities are: the City of Midland and the Colorado River Municipal Water District. Both utilities were interviewed to obtain information on the ASR systems and reasons why they were abandoned.

4.2 Results

4.2.1 Online survey

The majority of the surveyed utilities (89 percent) indicated a need for additional water storage **(Figure 4-1)**. Survey respondents were asked to indicate which of the following types of additional water storage were needed (marking all that applied): seasonal storage, long term supply, storage for peaking, and storage for other purposes. Ten (10) of 15 utilities expressing a need for additional storage listed storage for peaking purposes as one of the needs. Ten (10) utilities indicated a need for storage for long term supply, and six utilities indicated a need for seasonal storage. Based on these responses, ASR could be a useful tool for the surveyed utilities to meet their storage needs, depending on other utility characteristics (such as hydrogeological conditions of potential storage zone, local politics, etc.). ASR has been successfully applied in a number of locations to provide storage for long term supply, storage for peaking purposes, and seasonal storage.

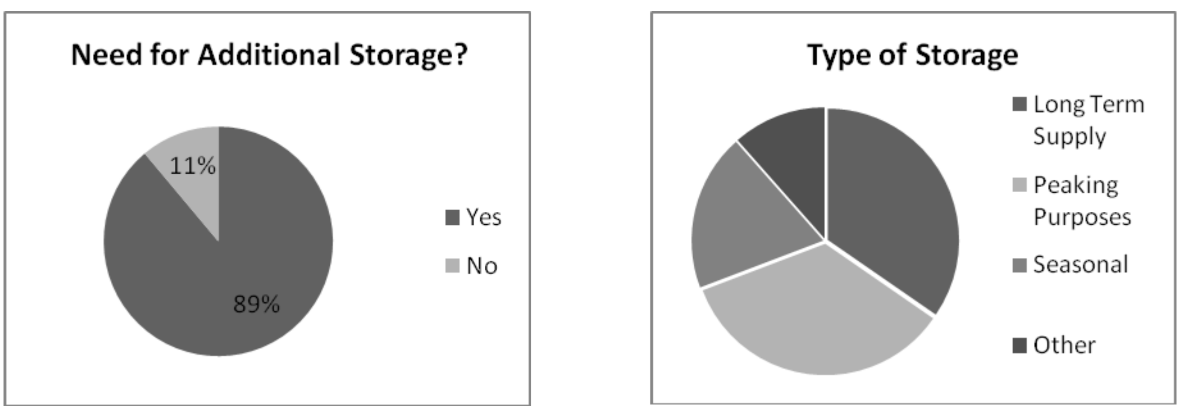

Figure 4-1: Survey responses regarding storage needs and type

Approximately half (53 percent) of the survey respondents indicated a need for additional water supplies that might be provided through ASR. One utility expressed a need for additional information on ASR to determine if it could be used to meet its water supply needs. Two utilities that responded that their additional water supplies could not be provided by ASR indicated that their staff are not familiar with the technical aspects of ASR and that no technical studies of ASR had been conducted. For those two utilities (and perhaps others in Texas), a lack of readily-available information or familiarity with ASR may be a deterrent to the consideration of ASR.

The majority of the surveyed utilities (76 percent) did indicate that its staff is familiar with the technical aspects of ASR and 10 of the 17 surveyed utilities (approximately 60 percent) have considered ASR as an alternative storage or water supply option. However, only a small percentage of the utilities have conducted studies on the feasibility of ASR. Specifically, only three of the 10 utilities (33 percent) which have considered ASR responded that technical studies of ASR had been conducted. A fourth utility that indicated technical studies had not been conducted did provide a feasibility report that could be considered a technical evaluation of ASR to meet water supply/storage needs.

Utilities that had considered ASR as a water supply or storage option were asked why an ASR project had not been implemented. The utilities were asked to mark all of the reasons that applied, as listed in the survey instrument.

Figure 4-2 shows the responses from ten surveyed utilities that have considered ASR. The four most common reasons why the surveyed utilities had not implemented an ASR project were: (i) concerns about the physical ability to recover stored water (60 percent); (ii) concerns about the quality of the recovered water (50 percent); (iii) a higher cost than other alternatives (50 percent); and (iv) concern about other pumpers getting access to the utility's stored water (40 percent). Several utilities also expressed concerns about regulatory burdens, lack of funding, and lack of available data on the proposed aquifer.

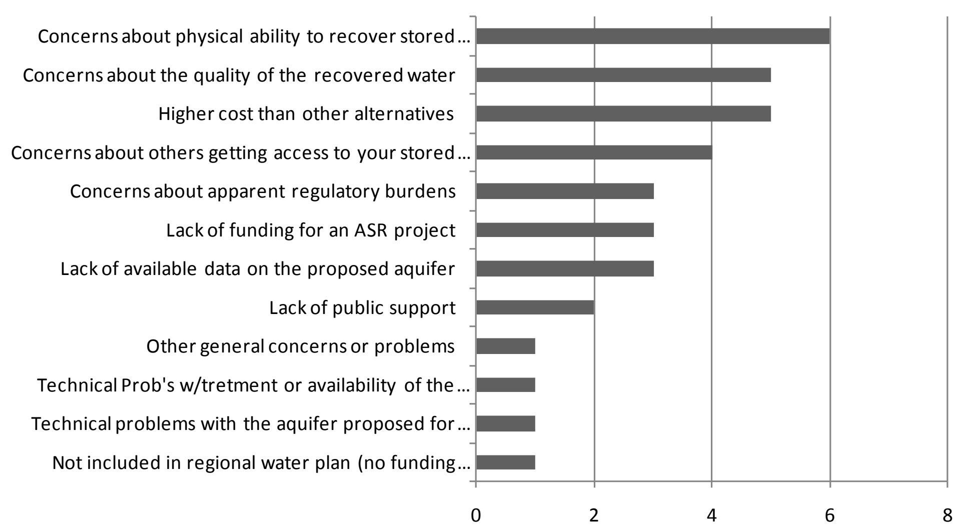

Figure 4-2: Reasons why an ASR project has not been implemented

Figure 4-3 shows the responses of the surveyed utilities that have considered ASR and have conducted technical studies. These four utilities expressed many of the same concerns as those which had not conducted technical studies. Specifically, ASR projects had not been implemented due to concerns about the physical ability to recover stored water, concerns about the quality of the recovered water, and a higher cost than other alternatives. Although the data set is small, the results suggest that the technical studies either confirmed or did not resolve the utilities' concerns.

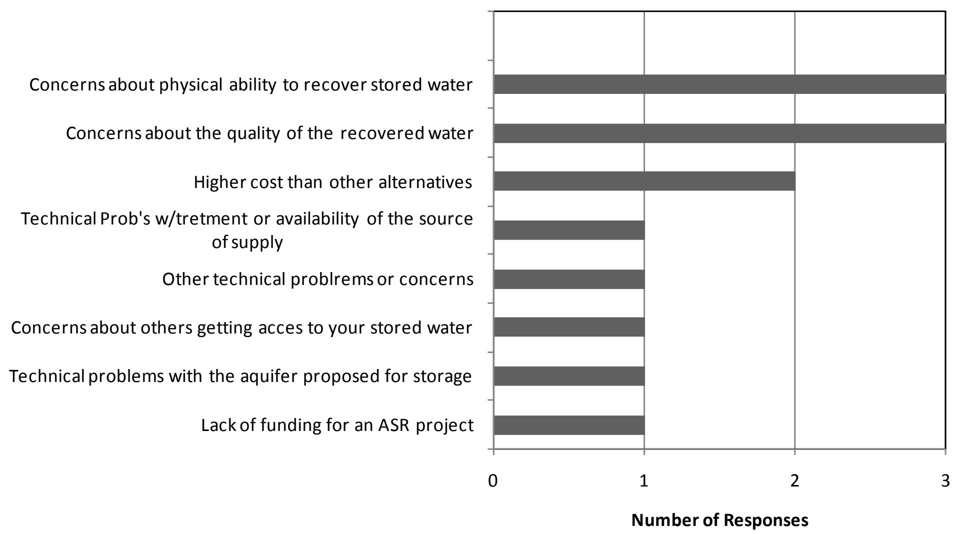

Figure 4-3: Reasons why an ASR project has not been implemented (responses from utilities that have conducted studies)

The majority (72 percent) of utilities that participated in this survey indicated a desire to know more about ASR and/or this study. Publication of the report for this TWDB priority research project will provide a good initial step toward increasing public access to information on key opportunities, considerations, and constraints associated with the use of ASR. Detailed responses from the online survey are provided in Attachment 2.

4.2.2 Follow-up interviews

Follow-up telephone interviews focused primarily on clarifying and documenting the concerns about ASR that the utilities expressed in the survey responses. Interviewees were also asked questions regarding the basis for their concerns (e.g., site-specific studies, general reports, word of mouth information, etc.).

Detailed logs of all seven interviews are provided in Attachment 3. The interview responses are summarized below. The discussion with San Jacinto River Authority (SJRA) is not included because the interview was very brief, and SJRA officials indicated no current need for an ASR project.

Of the interviewed utilities, three indicated that the cost of ASR relative to other alternatives was preventing them from pursuing the technology. Two of those utilities had conducted feasibility studies and the perceived costs were based on the cost estimates in those studies. The third utility had no substantial cost data to substantiate the economic concerns regarding ASR. One of the utilities that had developed a cost estimate for ASR (AACE Level 5) conducted a side by side comparison with both direct reuse and brackish groundwater desalination. Based on the cost estimate, ASR appeared to be significantly more expensive. The utility has not implemented any of the alternatives to date.

Two utilities indicated concerns regarding the suitability of the receiving/storage aquifer. One utility's concern was based on the unconfined nature of the aquifer and perceived issues regarding the ability to recover all of the stored water. This utility stated that the unconfined nature of the aquifer would make it very difficult to convince customers that ASR is a cost-effective and technologically-feasible option, even if it could be successfully implemented on a technical basis. The other utility's concern related to the brackish quality of the receiving aquifer. These responses further confirm that more widespread information on ASR, addressing issues such as the ability to use ASR in all types of aquifers, could be an important step toward increasing the consideration and utilization of ASR as a water resources tool in Texas.

Three other interviewed utilities discussed regulatory/political considerations as deterrents to implementing ASR. The first utility cited political concerns related to the local groundwater district and agricultural interests. The second utility stated that the lack of regulatory protection for stored water was a significant deterrent to pursuing ASR.

The third utility currently uses only surface water and indicated that implementation of ASR would require them to comply not only with the Surface Water Treatment Rules (SWTRs), but also the Groundwater Rule. Compliance with both sets of rules would require additional monitoring systems, groundwater operations training, and new groundwater protection measures. Two sources of supply could also add complexity to the operation of the utility's distribution system.

One utility discussed issues related to injected and recovered water quality as the principal reasons why ASR had not been further considered. Specifically, the City of Austin previously conducted a feasibility study on ASR (1996) and prepared a research paper evaluating the stability of pipeline scale with the introduction of stored water from an ASR wellfield. The pH of finished surface water supplied by the City of Austin is currently between pH 9.6 and 9.8. The finished water could be re-carbonated to lower the pH prior to injection into the ground, minimizing potential issues related to aquifer clogging, etc. However, the City expressed concerns regarding the future cost of pH adjustment (Austin saw an estimated chemical cost increase of 10.5 percent in 2008). Additionally, the City would need to adjust the pH of recovered water to prevent dissolution/dislodging of pipeline scale, and it had other concerns related to clogged meters and pipeline replacements.

4.2.3 Information on utilities that previously operated ASR systems

The results of telephone interviews conducted with the City of Midland and Colorado River Municipal Water District, two Texas utilities that previously operated ASR systems are summarized below.

City of Midland

The City of Midland ("Midland" or the "City") is located in Midland County, in the Permian Basin area of west Texas. Midland operated an ASR system for several years, but the system has not been in operation since at least 2002. Data on the operation of the system are not readily available at this time.

The system used untreated groundwater from the Ogallala Aquifer as the source of supply. The water was chlorinated and then injected into a local regional aquifer near the City. Water was recovered to meet peak water demands in the summer months.

During the ASR operation, Midland pumped groundwater from its Paul Davis Well Field which is located north of the City in Martin and Andrews Counties. Depending on which production well(s) were being used, the water was pumped between 30 to 50 miles to the McMillan Well Field for storage. The local aquifer used for storage is a depleted portion of the Ogallala Aquifer.

According to the current City staff, Midland stopped the ASR operation for two primary reasons:

- There is no groundwater district in the area, and the City did not feel that it had sufficient legal control of the water it had stored in the local aquifer. Midland did not own the surface estate in the area of its local well field. In fact, the City had a non-exclusive right to produce water from the well field. Therefore, Midland feared that adjacent irrigators could pump water that the City had stored; and
- Perchlorate was found in the local well field, and the City decided to stop producing water from the aquifer even though the EPA had not made a final regulatory determination on the chemical.

Colorado River Municipal Water District

The Colorado River Municipal Water District (CRMWD or the "District"), headquartered in Big Spring, operated an ASR system for seven years, from 1963 to 1970. The system used untreated surface water from J. B. Thomas Reservoir as the source of supply. The water was injected into the southern end of the Ogallala Aquifer at the District's Martin County Well Field.

In the 1950's, J.B. Thomas Reservoir and the Martin County Well Field were developed as the District's first major projects, using funds from a 1951 bond issue. The well field is located approximately 8 ½ miles northwest of Stanton, Texas. The District constructed a second pipeline from the Martin County Pump Station to the City of Odessa in the late 1950's to enable the delivery of greater quantities of water during the peak summer months. The second pipeline gave the District excess delivery capacity in some months. The District began an ASR program to take surplus water from J.B. Thomas Reservoir during the winter months, inject it into the Ogallala Aquifer using its production wells, and recover the water during the summer months using this increased pipeline capacity to meet peak demands of the City of Odessa.

According to CRMWD documents, the District began "experimenting with artificial re-charge" by injecting water in December 1963 at an average daily rate of about 1.8 mgd. During that first winter (through March 1964) approximately 160 million gallons (about 500 acre-feet) was stored. In the District's annual operating report, Assistant Manager O.H. Ivie estimated that "…at least 95 percent of the injected water was recovered…."

The injection of raw surface water resumed on November 1, 1964. During the winter of 1964-1965, approximately 175 million gallons was stored underground. During the first three months of 1965, the District used three wells for injection, and during November and December of 1965, the District used seven wells. The operating report included a table that showed that in calendar year 1965, a total of 251,471,000 gallons was stored, and 165,483,000 gallons were recovered, leaving a balance in storage of 156,837,000 gallons.

At the end of the third period of operation (ending in March 1966) the District had about 347 million gallons (approximately 1,000 acre-feet) of water in storage. The cover letter for the annual operating report stated that "This method of storage of surface water in the underground de-watered aquifer has proved to be both economical and a satisfactory method of operation." At the end of calendar year 1966, the District had 414.3 million gallons (about 1,300 acre-feet) in storage.

During the winter of 1966-67, raw water was stored at a rate of about 2.25 mgd. At the end of calendar year 1967, the District had 349 million gallons (about 1,200 acre-feet) in storage.

In 1968, the District drilled three additional wells in the Martin County Well Field "…to increase the rate of injection during the winter months and recovery of the water during peak periods." The water was capable of being injected at a maximum rate of 3.2 mgd. At the end of calendar year 1968, the District had about 379.1 million gallons in storage.

At the end of calendar year 1969, the District had 233.2 million gallons in storage.

In the spring of 1969 the District completed construction of the E.V. Spence Reservoir. That project included a new pipeline that balanced the flow capacity into and out of the Martin County Pump Station. With the construction of the Spence Project, there was no excess capacity in the pump station or the pipeline to Odessa, and thus the ASR project was abandoned. All of the injected water had been recovered by the end of August 1970.

The District is currently considering new opportunities for ASR, including the use of treated brackish groundwater as a source of supply. Like many agencies, the District's staff has concerns about its ability to recapture the water it injects due to losses in the aquifer, water pumping from adjacent lands, or migration of the water into different aquifers. However, the District's staff feels that their previous experience has shown that ASR can be a part of the District's water supply programs in the future.

4.2.4 Information on the Corpus Christi Aquifer Storage and Recovery Conservation District

The first special purpose district created to promote the use of ASR is the Corpus Christi Aquifer Storage and Recovery Conservation District (the "ASR District"). It was created in 2005 by SB 1831 of the 79th Texas Legislature pursuant to Article XVI, Section 59, Texas Constitution. The ASR District is "… committed to manage and protect the groundwater resources of the District, including those injected into the ground for storage and later use. The District is committed to maintaining a sustainable, adequate, reliable, cost effective and high quality source of groundwater to promote the vitality, economy and environment of the District." It has all of the rights, responsibilities and authorities of a groundwater conservation district created under

Chapter 36 of the Texas Water Code, however it is not a groundwater district. The legislation provides that the creation of the ASR District does not preclude the creation of a separate groundwater district in San Patricio County. In addition to allowing for the creation of a groundwater district that would have "joint and coextensive powers" with the ASR District in San Patricio County, the ASR District's enabling legislation prescribes that "the district may not allow more water to be recovered from a municipal aquifer storage area in San Patricio County than the amount of water stored by the district at the municipal aquifer storage area." The ASR District does not currently operate any ASR facilities, however it has been involved in studies related to the technology. Implementing ASR is an express power of the ASR District.

The ASR District includes portions of Aransas, Kleberg, Nueces and San Patricio Counties. The boundaries of the ASR District include the city of Corpus Christi and the area immediately surrounding Corpus Christi Bay. The ASR District has a five-member board of directors appointed by the Corpus Christi City Council.

In its June 5, 2008 Management Plan the ASR District states that its primary goal is to facilitate the operation of ASR operations by the city of Corpus Christi in order to enhance water supply, treatment and distribution operations. The ASR District is located in the area of the Gulf Coast Aquifer. The major objective is to protect its future ASR wellfields in that aquifer by ensuring that other pumpers do not tap into the stored water that will be injected by the city in the future. The city requires new developments within one mile of the city's distribution system to obtain all their potable water from either the city or one of the two water control and improvement districts (WCIDs) which provide water in the area. The city also does not allow the use of groundwater for irrigation purposes within the ASR District.

More specifically, the ASR District is investigating the use of ASR to meet several specific objectives, including: seasonal and long-term storage; peaking augmentation; improving distribution system water quality by maintaining flows during low demand periods; deferring facility expansions by using ASR to meet peak demands; instream flow mitigation; and salinity management.

The objective of streamflow mitigation is of interest because other Texas utilities have not mentioned this application of ASR technology, even though it is used in other parts of the nation and the world. The city owns and operates a reservoir system upstream of Corpus Christi on the Nueces River (the Choke Canyon-Lake Corpus Christi System). In its State permits, the city is required to meet minimum flow requirements into Nueces Bay. The ASR District is considering the use of stored ASR water to fulfill those flow requirements, thereby reducing releases from the reservoir system. The end result may be an increase in the firm yield of the reservoir system.

The ASR District's Management Plan requires a five-year action plan for the implementation of ASR. In previous studies, the city has investigated the construction of ASR wells on North Padre and Mustang Islands as part of a proposed desalination project. According to the Management Plan, the current plan includes the development of two wellfields with a total target storage volume of approximately 3,700 acre-feet and a total recovery capacity of approximately 7.5 mgd.

4.3 Key findings

The survey results provide valuable information on where effort should be placed to increase the consideration and implementation of ASR as a potential water supply or storage option in Texas. Based on the responses, publicly-available data demonstrating the ability to recover stored water from ASR wells, and at high quality, are needed. Since it is not absolutely clear from the survey responses whether the concerns regarding ability to recover stored water are based on perceived legal or technical limitations or both, information on both the legal framework in Texas for recovery of stored water and the physical limitations should be addressed.

The responses regarding perceived higher costs than other alternatives are not supported by the full scale capital, and operation and maintenance (O&M) information, and historical perspectives provided by SAWS and the City of Kerrville. For those two systems, ASR was a more cost effective option than other alternatives considered during the planning phase, and the ASR systems continue to provide cost savings relative to other options, despite some unexpected expenses such as mitigation. The cost effectiveness of ASR will vary from site-to-site. However, the survey response indicates that publication of robust cost data illustrating the potential cost-competitiveness of ASR could facilitate more wide-spread consideration of ASR as a water supply or storage alternative.

The survey responses indicate that the majority of the utilities have a need for additional storage (89 percent response) or water supplies (53 percent response) that could potentially be met through ASR. Primary concerns that have prevented these utilities from further studying or implementing ASR projects to meet their storage and supply requirements include:

- Ability to recover stored water;
- Quality of the recovered water;
- Cost-effectiveness of an ASR system; and
- Potential for other pumpers to capture the utility's stored water

Because ASR has been a technically-feasible and affordable water storage and supply alternative in other fast-growing states, it is likely that more education can increase its implementation in Texas. More publicly-available information on ASR is needed to help alleviate some of the concerns that may be based on misconceptions. Presentations and publications provided as part of this study provide an important initial contribution to making available more data on ASR.

In the survey of Texas water utilities described in Section 4, several entities identified as a concern the physical ability to recover the stored water. Some of the respondents may have interpreted this question in the survey to include the ability to recover the stored water before other pumpers got access to it. However, other respondents undoubtedly were concerned about the physical ability to produce the stored water before it migrated or "drained" away due to the gradient of the aquifer. Flat gradients are not typical in Texas, especially in more shallow aquifers, and if a significant gradient exists, the stored water can migrate, making the bubble and buffer zone more difficult to manage. The issue is related to both the gradient of the aquifer and related movement of water, and the timing of the recovery of water.

This migration of the stored water is a real issue, and it is one that must be addressed in the planning and study phases of an ASR project. Solute transport modeling to establish the direction and rate of water movement, to establish constituent concentrations during recovery, and to estimate the percentage of recovery is one of the site selection tasks normally performed at the end of the second phase of an ASR project. From past experience, it appears that deeper aquifers have fewer problems with water movement. For example, SAWS has seen little movement of its injected water over the past six years. For utilities that intend to use ASR for seasonal storage and/or peaking, migration is not a significant issue because the water is recovered before it can move away from the well. Likewise, when aquifers with good quality water are used for storage, the issue is less significant so long as the water quality objectives of the utility can be met. In general this issue has not been a significant problem, but the hydraulic gradient and water movement must definitely be considered.

With regard to the cost-effectiveness of ASR, this research effort has shown that some utilities do not keep capital cost and O&M expense information in sufficient detail to adequately evaluate the true cost. Many water utilities aggregate O&M expenses into broad categories, and it is difficult to pull out the costs directly attributable to ASR system construction and operations. For example, ASR wells may not be separately metered making it difficult to determine the actual cost for power. In most cases, ASR operating expenses are actually marginal or incremental costs of the larger water utility operation, making ASR a very viable option, but one that is difficult to document. For example, the Kerrville ASR operation uses treated surface water from a plant that operates every day, whether or not water is being injected into the aquifer. The marginal cost of treating and injecting the ASR water is actually just a function of chemicals and electricity.

Protecting and enhancing the utility's ability to recover its stored water is in reality a bigger issue than the perceived technical and socio-economic concerns. An improved legal/public policy framework that protects the ASR owner's right to its stored water, even under properties not owned by the ASR system operator, could alleviate the principal concern expressed by the surveyed utilities regarding their ability to recover stored water.

5 Legal perspective for Texas

Aquifer Storage and Recovery Projects in Texas – What Have We Accomplished and How Can We Accomplish More – A Legal Perspective of the Historical Development of Aquifer Storage and Recovery Technology and Projects in Texas and Recommendations to Facilitate Greater Utilization

Edmond R. McCarthy, Jr. [1]

5.1 Setting the Framework for Aquifer Storage & Recovery Projects in Texas

A. Background on ASR

This paper provides a legal framework for the historic, existing and potential use of ASR technology as a water development and management technique to extend Texas' limited water resources and meet the state's growing demand. [Footnotes are found in Appendix G.] As a "technology," Aquifer Storage and Recovery ("ASR") is typically characterized by the injection of water into a receiving aquifer for purposes of temporary storage with plans for recovering it in the future for beneficial use using the same well(s).[3] Recovery of the stored water, however, actually can be accomplished using the same or different well(s) depending upon a variety of factors, including (i) the hydrogeologic characteristics of the affected aquifer, (ii) the physical facilities associated with the project, including the location of the project, "potential threats" from third-party offsite groundwater development activities, and alternative "injection" methodologies, and (iii) the needs of the project owner.

Due to the mechanical (artificial) means used to inject the water into the aquifer for storage, and the associated recovery facilities, ASR is to be distinguished from typical "recharge projects" where water is captured on the surface in basins and reservoirs and allowed to percolate into the receiving aquifer with the intent to increase, maintain and/or supplement the volume of water within the aquifer. An additional factor critical to the distinction between an aquifer storage project and an ASR project is the operator's "intent." Specifically, is the project being operated strictly for the purpose of increasing the volume of the aquifer, or is the purpose to "store" the water in the aquifer on a temporary (albeit long term) basis so that it will be available for recovery at a later date for application to the operator's beneficial purposes. The latter intent has as a "ripple effect" or supplemental benefit the increase in the amount of the storage in the affected or receiving aquifer.

In this respect, an ASR project is no different than using a conventional surface water reservoir or tank to store water for future needs. Similar to the secondary benefits associated with storage of water in a surface reservoir, *e.g.*, recreational use and groundwater recharge, storage in the aquifer can have secondary benefits such as positive changes in the piezometric pressure within the aquifer and increases in the level of the groundwater table.

B. Need for ASR in Texas

Water is an irreplaceable necessity for all living things — our most precious resource. Unlike many other natural resources, water is a "renewable resource." The supply, however, is finite. The story of water in Texas is a story of our continuous state of drought broken up periodically by tumultuous rainfall events and resultant floods.[4]

In May 1961, then Chief Engineer of the Texas Board of Water Engineers, John J. Vandertulip, wrote as part of his introduction to a Report to the Texas Legislature entitled "A Plan for Meeting the 1980 Water Requirements of Texas" the following words:

> Nature within the past decade has inscribed upon the wide-spreading Texas landscape grim warnings of greater disasters to come if development in the State's water resources is neglected.
>
> Texans have seen drought alternate with flood in a disheartening pattern of extremes. In many cases, the same areas suffering from acute water shortages are later ravaged by floods, and the water so urgently needed for the economy of the State wastes to the Gulf, leaving grief and destruction in its wake . . . .
>
> The legendary vagaries of Texas weather, more amusing in folklore than actual experience, discourage any hope of relief through improvement to its natural behavior. If Texans cannot change the weather, they can at least, through sound, farsighted planning, conserve and develop water resources to supply their needs . . . . .[5]

The Report was prepared for submission to the 57th Texas Legislature as Texas was recovering from the infamous "drought of the 1950s." Though written a half century ago, Mr. Vandertulip's prophetic admonition to the Legislature rings eerily true for Texans today as we continue (i) to plan for addressing Texas' growing population and increasing water demands which exceed currently available supplies as documented in the 2007 State Water Plan,[6] and (ii) experience repetitive droughts across the state.[7] When viewed in the context of Texas' projected population explosion, doubling between now and 2060, Mr. Vandertulip's words resonate with the following conclusions from the 2007 Plan:

- Population in Texas is expected to more than double between the years 2000 and 2060, growing from about 21 million to about 46 million.
- The demand for water in Texas is expected to increase by 27 percent, from almost 17 million acre-feet of water in 2000 to 21.6 million acre-feet in 2060.
- Existing water supplies—the amount of water that can be produced with current permits, current contracts, and existing infrastructure during drought—are projected to decrease about 18 percent, from about 17.9 million acre-feet in 2010 to about 14.6 million acre-feet in 2060. This decrease is primarily due to the accumulation of sediments in reservoirs and the depletion of aquifers.
- Texas is going to need an additional 8.8 million acre-feet of water by 2060 if new water supplies are not developed.

- The planning groups identified about 4,500 water management strategies and projects to generate an additional 9.0 million acre-feet per year of water supplies for Texas.
- The planning groups also estimated that the capital costs to design, construct, or implement the 4,500 water management strategies and projects would cost about $30.7 billion.
- If Texas does not implement the state water plan, water shortages during drought could cost businesses and workers in the state about $9.1 billion per year by 2010 and $98.4 billion per year by 2060.
- If Texas does not implement the state water plan, about 85 percent of the state's projected population will not have enough water by 2060 in drought conditions.[8]

Once formally adopted by the TWDB, the State Water Plan is mandated by the Texas Legislature to "be a guide to state water policy."[9] Implementation of ASR technology in Texas offers water resource planners an opportunity to write a new chapter in Texas' "drought/flood story" and achieve the goals of maximizing the availability of this finite resource and developing a sustainable water supply to meet the needs of future generations of Texans. The successful implementation of the technological advancements in ASR, however, may be impeded if the current legal and regulatory landscape is not updated.

The scarcity of available locations for the development of new sources of traditional water supplies, *i.e.*, construction of large surface water reservoirs, combined with the continually growing body of stricter environmental regulatory schemes, increased resistance from property rights groups and environmental interests, as well as simple economic issues, provide an impetus for the exploration and implementation of "non-traditional" approaches to the development of water supplies coupled with strategies that contemplate the joint or conjunctive use and management of available surface water and groundwater.[10] Among these "non-traditional" approaches is ASR.

Surface water and groundwater are subparts of a single hydrologic cycle.[11] Implementation of the conjunctive use concept to maximize their beneficial use, and minimize the adverse impact to or waste of, these valuable resources requires integrated management strategies. In simpler terms, conjunctive management dictates a balancing of the supply and the demand of the available water resources to avoid either depleting the available quantities or degrading the quality of the resources.

Where feasible, available water resources, particularly surface water, should be used to meet current demands and provide storage for future demands. This is particularly true during "wetter" periods of the year. The state's groundwater resources, particularly those in stable aquifers and/or with fewer spring outlets, can be held in reserve or transferred to less productive aquifers, to meet demands during "dry" periods of the year, or during periods of low flows when the available surface water may have to be left flowing in watercourses to provide for the protection of instream uses, downstream water rights holders, and/or fresh water inflows to receiving bays and estuaries.

While part of the same hydrologic cycle, surface water and groundwater are governed and regulated by two very distinct legal systems in Texas. Those separate legal systems impact the ability to develop ASR projects in Texas. In addition to state law requirements, ASR projects must also comply with applicable federal regulatory programs.

5.2 Legal Framework for Water Sources Used to Develop an ASR Project in Texas

Water in Texas generally falls into one of two categories: (i) ”groundwater” and (ii) ”surface water.”[12] Both the ownership of, and regulatory scheme governing water in Texas is dependent upon its classification. A basic understanding of the laws related to these two water sources is essential in the development of an ASR Project.

Groundwater is privately owned and subject to the “Rule of Capture;”[13] however, its use may be modified through the lawful regulation by a groundwater conservation district, if any, with jurisdiction over the affected aquifer(s).[14] Surface water is owned by the state, and held in trust for the benefit of all of the people of the state.[15] State water must be “appropriated” for use.[16]

5.2.1 Texas Groundwater Law - An Overview

Unless the groundwater estate has been severed from the surface estate,[17] groundwater in Texas is a “vested” real property right that belongs to the owner of the surface estate.[18] The groundwater estate, *i.e.*, the groundwater in place or “*in situ*,” may be sold, leased, assigned, or otherwise encumbered like any other real property right.[19] The use and enjoyment of both the groundwater rights and the groundwater produced, which once could be enjoyed by the surface owner unfettered, has over time become subject to lawful regulation by groundwater districts.[20]

Texas has followed the “Rule of Capture” and the “Rule of Absolute Ownership” with respect to groundwater since 1904 when the Texas Supreme Court in *Houston and Texas Central Railroad Company v. East,*[21] adopted the “Rule of Absolute Ownership” from the English case of *Acton v. Blundell.*[22] In *East* the Court concluded that the owner of the surface had the right to dig, and to capture the water from beneath his property, even if it adversely affected his neighbor.[23] The Court’s ruling in *East* involved <u>both</u> property rights and tort law concepts associated with the production of groundwater. Specifically the Court’s decision was based upon the principle that a surface owner owns the groundwater beneath his property, and can produce that water even if it adversely impacts his neighbor.[24] Following *East*, when exercising the property rights associated with the production of groundwater, subject to certain express limitations involving waste, negligence and subsidence,[25] a landowner was <u>not</u> subject to any “tort liability” for damages incurred by neighboring landowners that flow directly or indirectly from the exercise of those property rights.[26]

In 1917, the Texas Constitution was amended to add Section 59 to Article XVI, which is commonly known as the “Conservation Amendment” to the Texas Constitution.[27] The Amendment declares that conservation of the State’s natural resources, including water, to be a public right and duty, and imposed the obligation upon the State Legislature for the implementation of that policy. Pursuant to the Conservation Amendment, the Texas Legislature is empowered to pass “all laws” necessary to protect, enhance and preserve natural resources of the State, including its groundwater.[28]

In 1927, the Texas Supreme Court clarified that the property rights in groundwater are associated with the ownership of the surface of the land. In *Texas Company v. Burkett*,[29] the Supreme Court recognized that the ordinary percolating waters are the "exclusive property of the owner of the surface."[30] The Court also concluded that there was no restriction against the sale of percolating waters for industrial use off of the land from which the groundwater was produced. The Court held that there was a "presumption" that the source of the water produced was groundwater.[31]

In 1949, the Legislature took its first actions to enact groundwater legislation and create "districts" pursuant to the Conservation Amendment.[32] In the "early years" groundwater districts were created to address specific known problems related to the production of groundwater. For example, in the Texas Panhandle region, several districts were created to address the identified "mining" of the Ogallala Aquifer which was significantly depleted due to historic pumping for irrigation and the Aquifer's severely limited recharge characteristics. In the 1970s, "subsidence" within the state's gulf coast region around the City of Houston resulted in the creation of what is now the Harris-Galveston Subsidence District.[33] During the interim between the adoption of the Conservation Amendment and the creation of the first groundwater district, Texas Courts continued to follow both the Rule of Absolute Ownership and Rule of Capture adopted by the Texas Supreme Court in the *East* case.

Almost a quarter of a century after *Burkett*, in *City of Corpus Christi v. City of Pleasanton,*[34] the Supreme Court again considered the question of a landowner's rights in the groundwater produced from wells on the landowner's property. The Court focused on whether the transport of groundwater down the bed and banks of a state owned watercourse constituted "waste" within the meaning of Texas law.[35] Although in this situation more than seventy percent of the groundwater discharged into the river for transport to its point of use was lost due to evaporation and seepage,[36] the Court concluded that the "losses" were a necessary incident to achieve the intended beneficial use of the water at its end point.[37]

In the course of its opinion, the Court reaffirmed the "Rule of the Capture" it had established in the *East* case,[38] and the attendant ownership interests of the landowner in the groundwater articulated in *Burkett*.[39] The Court went further and concluded that, at common law, there was no "limitation of the means of transporting the [ground]water to the place of use."[40]

Landowner's rights related to the ownership of the groundwater were further refined by what is commonly known as the "*Comanche Springs*" case.[41] In the *Comanche Springs* case, *Pecos County WCID No. 1 v. Williams*,[42] the El Paso Court of Appeals considered the complaint by downstream surface water rights holders that the high volumes of groundwater being pumped by landowners for irrigation in the vicinity of Fort Stockton were causing the springs to stop flowing and depriving them of the ability to exercise their surface water rights.[43] The Court upheld the landowner's right to pump the groundwater for beneficial use notwithstanding the detriment to adjacent or downstream landowners.[44] Relying upon the Supreme Court's rulings in *East*, *Burkett*, and several Court of Appeals decisions, that the surface landowner had the absolute ownership of the water beneath his land,[45] the El Paso Court held that there were no "correlative rights" in the groundwater for the benefit of downstream landowners.[46]

In 1978, the Supreme Court limited the unbridled rights of a landowner to produce groundwater from beneath his property pursuant to the Rule of Capture in *Friendswood Development Co. v. Smith-Southwest Indus., Inc.*[47] The Court affirmed the landowner's ownership of the groundwater beneath the surface of the property,[48] but held that a landowner was prohibited from <u>negligently</u> pumping groundwater in a manner that would cause subsidence.[49] In criticizing the analysis performed by the Court of Appeals in *Friendswood*, the Texas Supreme Court noted that the cases cited by the Court of Appeals involved unreasonable use of correlative property rights or the balancing of legal and equitable rights between property owners. The Supreme Court then noted that this "… [correlative rights] concept … was deliberately rejected with respect to withdrawals of underground water when this Court adopted the common law rule that such rights are not correlative, but are absolute, and thus are not subject to the conflicting 'reasonable use' rule."[50]

Approximately ten years after the *Friendswood* decision, the Austin Court of Appeals relied upon the "Rule of Capture" and the "Rule of Absolute Ownership" developed in the lineage of the Supreme Court's rulings in the *East, Burkett, City of Corpus Christi, Friendswood* and *City of Sherman* cases in *Denis v. Kickapoo Land Co.*[51] to uphold a landowner's right to capture groundwater before it reached the surface at a spring opening and, thereafter, to produce and flow the same downstream to a place of beneficial use.[52] The Austin Court observed that "[w]hen squarely faced with the issue, the Supreme Court has consistently adhered to the English rule of [absolute ownership]."[53]

In 1996, the Texas Supreme Court declined to re-address the specific question of the landowner's vested rights in the groundwater beneath the surface of their property when it was attempted to be raised in the *Barshop* decision,[54] concluding that the question "was <u>not</u> presented to the Court."[55] The Court limited its ruling to upholding the constitutionality of the legislation creating the Edwards Aquifer Authority ("EAA").[56] The Court reserved the question, at least in the context of the EAA, for a case in which the "application" of the EAA Act resulted in a claimed "taking" of a landowner's groundwater.[57]

The Supreme Court was confronted in 1999 with a direct challenge to the continued reliance upon the Rule of Capture in Texas in *Sipriano v. Great Spring Waters of America.*[58] *Siprianos* and others filed suit for damages alleging that Ozarka, which had installed wells to support a bottling plant that produced approximately 90,000 gallons of water a day "24/7," had negligently drained their groundwater.[59] The trial court granted summary judgment for Ozarka on the basis of the Rule of Capture.[60] In a split decision, the Supreme Court upheld the Rule of Capture adopted by the *East* Court in 1904 reiterating the proposition that "By constitutional amendment, Texas voters made groundwater regulation a duty of the Legislature."[61] The Court also acknowledged the Legislature's position that "[g]roundwater conservation districts . . . are the state's preferred method of groundwater management."[62]

The Supreme Court "dodged the bullet" presented by an allegation that a *landowner's* property rights in his groundwater had been taken when in 2002, it found that a claimed "taking" of groundwater by the EAA was not yet "ripe" for adjudication.[63]

When the Texas Legislature has addressed groundwater ownership in Texas, mainly in the context of regulatory programs associated with groundwater conservation districts, *lawmakers* have affirmed that groundwater is owned by a surface landowner. The best, strongest and most recent expression of that statement is found in the provisions of Section 36.002[64] which reads in part as follows:

> The ownership and rights of the owners of the land and their lessees and assigns in *groundwater* are hereby recognized, and nothing in this [Water] Code shall be construed as depriving or divesting the owners or their lessees and assigns of the ownership or rights, except as those rights may be limited or altered by rules promulgated by a district.[65]

The plain meaning of the language is that a landowner owns the groundwater under their *individual* properties.[66] The nature of the right of ownership of groundwater beneath individually owned tracts has only recently been questioned.

The question is not whether there is common ownership of groundwater in an aquifer but, rather, whether there is any ownership of groundwater in place. There have been two *recent* Court of Appeals decisions on that question.[67] Both cases came out of the San Antonio Court of Appeals in 2008 and reached the same answer to the question: groundwater in place is owned by the surface owner.[68] Petitions for Review were filed with the Supreme Court in both cases. The Court denied the Petition in *City of Del Rio v. Clayton Sam Colt Hamilton Trust* and granted the Petition in *Edwards Aquifer Authority v. Day*. Oral arguments were heard in the *Day* case in February 2010, and a decision is pending before the Court.

5.2.2 State Surface Water Overview:

“State water” is defined very broadly by statute as follows:[69]

> Water of the ordinary flow, under flow and tides of every flowing river, natural stream, and lake, and of every bay or arm of the Gulf of Mexico, and the storm water, flood water, and rain water of every river, natural stream, canyon, ravine, depression and water shed in the state is “State water.”[70]

All water flowing in a “watercourse” is presumptively owned by the state.[71] The Texas Commission on Environmental Quality (“TCEQ”) has been designated as the state’s current “agent” for water rights matters.[72]

To lawfully divert, store or use State water for any purpose, unless authorized as an “exempt use,” [73] you must first obtain a water right from the state.[74] It is illegal to “take, divert, or appropriate” surface water without prior authorization.[75] Civil penalties in the amount of up to $5,000/day for each day the unlawful use continues can be imposed.[76] It is also unlawful to sell a water right unless the right has been perfected, or the Commission, by permit, has authorized such a sale.[77]

Another historic means to use surface water without obtaining a water right is the exercise of a “riparian right.” This right allows the owner of property adjacent to a stream to divert a “reasonable” amount of water for domestic and livestock purposes. Because that right is considered a “correlative right,” the riparian landowner must allow sufficient water to flow past his property to satisfy the rights of other downstream riparian land owners both as to the quantity and quality of the water.[78] These riparian rights are still recognized today, but are commonly known as “domestic and livestock” or “D&L” uses.[79] The limited quantity of water available to a riparian water right, coupled with the restrictions upon the purposes and places of use of the water developed as a “riparian right,” makes those rights unsuitable for use in an ASR project.

The general rule regarding the ability to store and divert or otherwise use surface water is that you must hold a valid water right[80] in one of the following forms: “permits,” “certificates of adjudication,” or “certified filings.” Certificates of adjudication[81] and, in particular, “certified filings”[82] are historic evidences of the right to appropriate State water. The most common form of evidence of the ability to appropriate State water today is a water rights permit.[83]

The right to divert and use surface water for beneficial purposes is considered a usufructury right or a “right of use.”[84] The holder of a water rights permit does not hold title to the corpus of the water, which title remains in the state.[85] In Texas, the surface water right is treated as a property right and, as against all other persons, the permit holder possesses a superior property right that can be bought and sold.[86]

An individual who wishes to obtain a water right may either acquire an existing right or file an application for a new permit with the TCEQ. As many watersheds in the state are already considered fully appropriated,[87] acquiring an existing water right is often the most efficient means of securing a water right.[88] Depending on (i) the type of water right or amendment sought, *e.g.*, whether for municipal, industrial, agriculture, or other use, (ii) the quantity and/or diversion rate, (iii) the location of the proposed diversion point and/or place of use and whether the water has or proposes to have “storage” (on-channel or off-channel) associated with it, (iv) the surrounding and downstream environment, and (v) the number of existing downstream water rights, limitations may be imposed on a water right that affects its value and/or usefulness to the permittee.[89]

Surface water rights may be obtained for varying periods of time, *e.g.*, in perpetuity,[90] for “a term”, *i.e.*, a set number of years,[91] or as a “temporary permit.”[92] A permit obtained in perpetuity becomes a permanent property right unless it is canceled. A term permit is issued generally in watersheds which are already fully appropriated. These permits are issued for a finite period to allow subsequent evaluation of whether water either remains available, or water has become available that would allow conversion of the term permit to a perpetual permit. Use of “term permits” also provides the Commission with an “opportunity” to terminate a water right due to a lack of available water in a river basin.[93]

Term permits are usually issued for a period of ten to twenty years. They may be extended upon application by the permittee, however, renewal is not guaranteed.[94] Term permits are sometimes issued when existing permits are amended in order to implement a “lease” or similar contractual agreement. Such term permits usually will contain a provision automatically terminating the amendment upon expiration of the lease or contractual relationship.

“Temporary permits” are usually issued for a quantity not to exceed 10 acre-feet to be used over a period of time not to exceed three (3) years. These types of permits are frequently used for construction, particularly road construction projects. Temporary permits may be issued for longer terms or larger volumes, but only after the issuance of notice and holding a public hearing.[95]

Water rights permits, and amendments thereto, may only be issued by the Commission after a determination that the purpose for which the water will be used is a "beneficial purpose."[96] By statute, multiple categories of use have been articulated by the Legislature as beneficial uses.[97] These include domestic and municipal use, agricultural and industrial uses, mining, hydroelectric power generation, navigation, recreation, stock raising, public parks and game preserves. State water may also be used for any other "beneficial use."[98] ASR is not considered "use," but rather a means of storage incident to one or more of the authorized beneficial uses recognized in Chapter 11, Texas Water Code.[99] Most significantly, the same molecule of water injected into the aquifer need not be the molecule of water subsequently recovered for beneficial use.[100]

The three major components involved in the permitting/amendment process are the application itself, and the required "accounting plan" and "water conservation/drought management plan." These components are summarized below.

A. The Application and Amendment Process:[101] To obtain a water right, or an amendment to an existing right, an individual must file an application with the TCEQ. The application must be on a form developed by the Commission, and must comply with the Commission's rules and regulations.[102] Although a different form, an application for an amendment must generally comply with the requirements for an application for a new water right. Some amendments can be issued "administratively", *i.e.*, without any requirement for issuing notice or providing an opportunity for a public hearing on the application.[103]

An important issue for applicants seeking a Section 11.122(b) Amendment to an existing water right is whether the application will require the issuance of "Notice" and an opportunity for a public hearing on the application. In *City of Marshall v. City of Uncertain*,[104] the Supreme Court addressed the issue of whether the TCEQ was required to approve, without notice or an opportunity for a contested case hearing, an amendment of the City of Marshall's water rights permit filed under Section 11.122(b), Texas Water Code. In 2001, the City filed a permit amendment application seeking authorization to change the purpose of use to include industrial purposes. Although TCEQ received multiple requests for a contested case hearing on the amendment, the Commission concluded Section 11.122(b) required the amendment to be granted without publication of any notice or granting an opportunity for a contested case hearing because the requested amendment was within the authorization of the existing permit if the same were fully utilized.[105] On appeal, the Travis County District Court held that TCEQ erred in its determination that Section 11.122(b) required approval of the amendment without a contested case hearing and remanded the application to TCEQ.[106] The Austin Court of Appeals affirmed, in part, concluding that Section 11.122(b) allowed a hearing where the amendment sought a change in the purpose of use.[107]

The Supreme Court concluded that Section 11.122(b) requires an amendment application to meet "all other applicable requirements of this chapter [11, Texas Water Code] for the approval of an application."[108] All "other" requirements, the Court concluded, included assessment of matters outside of Section 11.122, including the potential adverse impact of the amendment on other water rights' holders and/or the environment.[109]

> [W]e interpret Section 11.122(b) to require the Commission to assess specified criteria other than impacts on other water-rights holders and the on-stream environment when considering a proposed water-rights amendment.[110]

The Court did confirm that TCEQ must make the "full use assumption" in considering impacts on water rights or the riverine and riparian environment.[111] However, the Court held that the Commission must consider the potential, for the need to conduct a limited hearing on other issues addressed by Chapter 11 unless the record before the TCEQ was sufficient to allow a determination on the issues to be made without a hearing.[112]

In the *Marshall* case the Supreme Court noted that the protestants had raised substantive issues outside of full use assumption, including the proposed amendment's impact on public welfare, groundwater and the adequacy of Marshall's conservation plan. In the Court's opinion, these issues were not considered by the Commission based upon the Commission's "record" reviewed by the Court.[113] As a result, the Court concluded that the TCEQ erred when it determined not to grant the protestants' hearing requests, and affirmed the Court of Appeals decision, albeit for different reasons.[114]

On September 7, 2007, the Commission conducted a workshop on rules and policy issues related to the notice requirements of Section 11.122, Texas Water Code, in light of the Supreme Court's decision in the *Marshall* case. Further information related to the issues considered by the Commission, including the TCEQ Staff's analysis of the issues is available on the TCEQ website.[115]

Since the 2007 workshop, the TCEQ Executive Director's Staff has requested applicants provide additional information in response to Section 11.122(b) amendment applications. Those requests include the option for the applicant to either agree to allow (and pay for) basin-wide notice to be published or, alternatively, respond to the following seven "*Marshall* Questions":

***Marshall* Questions:**[116]

1. Confirm whether this application meets the administrative requirements for an amendment to a water use permit pursuant to TWC Chapter 11 and Title 30 Texas Administrative Code (TAC) §§ 281, 295, and 297. An amendment application should include, but is not limited to, a sworn application, maps, completed conservation plan, fees, etc.
2. Discuss how the proposed amendment is a beneficial use of the water right as defined in TWC §11.002 and listed in TWC §11.023. Identify the specific proposed use of the water (*e.g.*, road construction, hydrostatic testing, etc.) for which the amendment is requested.
3. Explain how the proposed amendment is not detrimental to the public welfare. Consider any public welfare matters the applicant thinks might be relevant to a decision on the application. Examples could include concerns related to the well-being of humans and the environment.
4. Discuss the effects, if any, of the proposed amendment on groundwater or groundwater recharge.

5. Describe how the proposed amendment addresses a water supply need in a manner that is consistent with the state water plan or the applicable approved regional water plan for any area in which the proposed appropriation is located or, in the alternative, describe conditions that warrant a waiver of this requirement.[117]
6. Provide evidence that reasonable diligence will be used to avoid waste and achieve water conservation as defined in TWC §11.002. Examples of evidence could include, but are not limited to, a water conservation plan or, if required, a drought contingency plan, meeting the requirements of 30 TAC §288.
7. Explain how the proposed amendment will or will not impact water right holders or the environment beyond and irrespective of the fact that the water right can be used to its full authorized amount.

The information provided by an applicant in response to these questions, in addition to any analysis by TCEQ staff, forms the basis of a memorandum from the Executive Director to the Commissioners with a recommendation for Commission action on whether publication of notice of the amendment is required. Upon filing of this memorandum, the Executive Director currently schedules the matter for consideration by the Commission during a regularly scheduled agenda conference, unless the type of amendment and attendant facts establish that prior Commission rulings on similar amendment applications provide the Executive Director with sufficient guidance to make the determination on whether notice and/or an opportunity for hearing is required.

B. Accounting Plans: Another recent development in the TCEQ water rights permitting process is a heightened requirement for applicants to demonstrate the ability to prove that they are only diverting the water authorized by their water right(s). This is accomplished through the development during the permitting process of a TCEQ-approved “accounting plan.” A thorough discussion of the specifications for developing an “accounting plan” is beyond the scope of this paper, but the accounting plan is essentially an operational program description that explains exactly when and how the water will be diverted and used. Any water project of any consequence that involves State water should expect the need to develop/negotiate an accounting plan with the TCEQ. While the TCEQ has not had an opportunity to consider the merits of requiring an “accounting plan” in a water right authorizing ASR storage, it is difficult to imagine that such a plan would not be required with an additional element to account for the surface water injected in and recovered from the ASR project.

An Accounting Plan for an ASR project would most likely address, but not be limited to, such issues as (i) the volumes of water injected and recovered; (ii) the reduction in evaporation losses associated with storing water underground instead of above ground in surface reservoirs; (iii) the ability to recover the same volume of stored water regardless of the potential lateral movement of the stored water underground around an ASR well or wellfield; (iv) planned pre-treatment or post-treatment of the injected water and any potential losses of stored water due to possible changes in water quality during storage that renders the recovered water unsuitable in quality for its intended purpose.

C. Water Conservation & Drought Contingency Plans: Water conservation and drought management requirements for surface water rights holders have increased since 1997.[118]

Specifically, as part of the Senate Bill 1 process, the Legislature prescribed that all applications for new and/or amended water rights include a water conservation plan.[119] Additionally, existing water rights holders authorized to appropriate (i) 1,000 acre-feet or more per annum for municipal, industrial or other uses, or (ii) 10,000 acre-feet or more per annum for irrigation use were required to submit water conservation plans by September 1, 1999.[120] Wholesale and retail water suppliers, including irrigation districts are required to develop drought contingency plans, and to coordinate the same with the regional water planning groups.[121] These plans are to be updated at least every five years.

5.3 Current "Permitting" Framework for Developing an ASR Project in Texas

A. <u>Framework for UIC Permits</u>

Aquifer storage in the ASR process is accomplished using an injection well, regulated by the Underground Injection Control ("UIC") Program administered by the TCEQ.[122] The wells used to inject water for storage in an ASR project are classified as Class V Injection Wells. Accordingly, all ASR injection wells must be permitted pursuant to Chapter 27, Texas Water Code, and Chapter 331, Title 30 of the Texas Administrative Code. ASR wells, used for injection and recovery purposes, may be subject to other permitting requirements based upon the source of water to be injected and/or the aquifer in which the water is proposed to be stored.[123]

The UIC regulatory framework was set up originally pursuant to the 1974 Safe Drinking Water Act. Rules were promulgated by EPA in 1981 pursuant to that Congressional legislation. Texas is one of 39 states that have been granted "primacy" by EPA, with responsibility for implementation of the UIC program. For other states the UIC program is implemented directly by EPA. The primary focus of the UIC program is to protect underground sources of drinking water (defined as aquifers with total dissolved solids concentrations less than 10,000 mg/L) from contamination. Injected fluids are therefore assumed to be wastewaters or other potential sources of contamination.

In recent years extension of the UIC program to the regulation and management of ASR programs storing drinking water (instead of disposing of wastewater) has, in some cases, encountered significant regulatory challenges. Progress has been achieved at the federal level, and in many states, to adapt the UIC program in such a way as to encourage, and not hinder, the ability to achieve sustainable and reliable water supplies through underground storage of drinking water and water from other sources with suitable quality. Most importantly, compliance is typically determined relative to drinking water standards in the storage aquifer, not relative to different standards developed for contaminant remediation. Also, allowance is typically made for natural physical, microbial and geochemical processes that occur underground around an ASR well that tend to improve water quality, including allowance for the time required for such natural processes to occur.

The respective regulatory frameworks related to Class V Injection Wells in general, as well as specific requirements for permitting, constructing, operating and plugging and abandonment of

Class V Wells used in an ASR project mandated by the Texas UIC program,[124] are outlined in **Appendices "A**" and **"B"** in Sections 10.1 and 10.2 of this report, *supra*.

B. Framework for ASR Projects Relying Upon Surface Water Permits

Using State owned surface water as the supply source for an ASR project triggers additional statutory requirements under Chapter 11 of the Water Code,[125] as well as applicable Commission rules.[126]

In addition to the information required in support of an application for a water right, an individual wishing to store appropriated water in an ASR project must submit to the TCEQ the information required for a Class V injection well,[127] and a map or plat showing the location of the injection facility and the aquifer in which the water will be stored.[128] If the location of the project will involve storage of water in a groundwater reservoir within the jurisdiction of a groundwater conservation district, the applicant is also required to do the following:

(1) Provide a copy of the application to each groundwater district that is affected;

(2) Cooperate with each underground water district to ensure compliance with its rules;

(3) Cooperate with each district to develop rules regarding injection, storage and withdrawal; and

(4) Comply with any rules adopted by the district governing injection, storage or withdrawal of appropriated water stored in an underground reservoir.[129]

In the event that an applicant enters into some contractual agreement with an underground water district, that agreement must be provided to the Commission for incorporation as a condition in the permit.[130] In addition to the factors set forth in Chapter 11[131] that must be considered by the Commission prior to issuing a permit to appropriate state water pursuant to Section 11.121,[132] in the case of an application to store State owned surface water in an ASR project, the Commission must consider the following:

(1) Whether the introduction of the water into the aquifer will alter the physical, chemical or biological quality of the native groundwater to a degree that would:

    (a) render the groundwater produced from the aquifer harmful or detrimental;

    (b) require treatment of groundwater pumped from the aquifer to a greater extent than the native groundwater requires in order for that water to be applied to a beneficial use;

(2) Whether water stored in the receiving aquifer can be successfully stored and subsequently retrieved for beneficial use; and

(3) Whether reasonable diligence will be used to protect the stored water from unauthorized withdrawals to the extent necessary to maximize the Permittee's ability to retrieve and beneficially use the stored water without experiencing unreasonable losses.[133]

In its evaluation of the three criteria outlined above, the Commission may consider other relevant facts, associated with the project, including the following:

(1) The location and depth of the aquifer in which the water will be stored;

(2) The nature and extent of surface development and activity above the stored water;

(3) The Permittee's ability to prevent unauthorized withdrawals by contract or the exercise of the power of eminent domain;

(4) The existence of an underground water conservation district with jurisdiction over the aquifer in which the water is to be stored and that district's ability to adopt rules to protect the stored water;

(5) The existence of any political subdivision or state agency with authority to regulate the drilling of wells.[134]

Any permit issued for the storage of water in a groundwater reservoir within the jurisdiction of a groundwater conservation district must contain a condition that requires the permittee to register its injection and recovery wells. The permit must also contain a condition that requires that the permittee provide a monthly written report to the groundwater conservation district on the amount of water injected for storage and the amount of water recaptured for use.[135]

The general requirements for obtaining a surface water permit, as well as specific additional requirements to be satisfied as a precondition to obtaining the necessary TCEQ authorizations to use surface water as a source of supply for an ASR project are outlined in summary fashion in **Appendix "B"**.[136]

C. Framework for Permits to Develop ASR Projects in an Aquifer(s) Regulated by a Groundwater District

Irrespective of whether the source of the water to be utilized in the development of the ASR project is (i) appropriated "state water" subject to the requirements of Chapter 11, Texas Water Code, and Chapters 285 and 297, Title 30 of the Texas Administrative Code, (ii) privately owned groundwater, or (iii) treated wastewater effluent, the development of an ASR project within the jurisdiction of a groundwater conservation district must comply with the rules of the affected district.[137] Other than the limited guidance found in Sections 11.153-11.154[138] regarding the storage of appropriated state surface water in an aquifer within the jurisdiction of a groundwater conservation district, Texas law provides limited express statutory guidance regarding the regulation of ASR projects by these districts.[139]

Not all groundwater conservation districts in Texas have adopted rules related to aquifer storage and recovery projects and/or even recharge projects using injection wells. Based upon available information provided by the TWDB, there are twenty-two active groundwater conservation districts in Texas with some form of rules relating to aquifer storage and/or recharge, including ASR project specific rules.[140] The lists below identify those twenty-two groundwater conservation districts broken down by the general types of rules they have adopted to address aquifer storage and recharge and, as applicable, ASR Projects specifically:

a. Districts requiring permits for ASR projects:
   1. Corpus Christi Aquifer Storage and Recovery Conservation District
   2. Edwards Aquifer Authority
   3. Evergreen Underground Water Conservation District

4. Irion County Water Conservation District
5. Jeff Davis County Underground Water Conservation District
6. Lipan-Kickapoo Water Conservation District
7. Medina County Groundwater Conservation District
8. Plum Creek Conservation District
9. Presidio County Underground Water Conservation District
10. Rolling Plains Groundwater Conservation District
11. Sterling County Underground Water Conservation District
12. Sutton County Underground Water Conservation District

b. Districts requiring permits for recharge facilities:
1. Gonzales County Underground Water Conservation District
2. Guadalupe County Groundwater Conservation District
3. Uvalde County Underground Water Conservation District

c. Districts requiring permits for both ASR projects and recharge facilities:
1. Real-Edwards Conservation and Reclamation District
2. Districts requiring permits or approval to drill recharge wells
3. Hemphill County Underground Water Conservation District
4. Panhandle Groundwater Conservation District
5. Permian Basin Underground Water Conservation District

d. Districts prohibiting ASR projects:
1. Live Oak Underground Water Conservation District
2. McMullen County Groundwater Conservation District
3. Wintergarden Groundwater Conservation District.

As groundwater conservation districts are authorized to amend their rules as necessary to perform their statutory functions, the reader should utilize the information provided herein as a starting point for due diligence with respect to investigating the requirements, if any, of any groundwater district in which they desire to explore development of an ASR Project.

Five examples of Districts around the state that have adopted rules related to these issues were selected for discussion in this Report in order to touch on various permitting issues, and the ways groundwater districts of varying size and geographic locations currently address ASR Projects. The districts are: the Edwards Aquifer Authority, the Evergreen Underground Water Conservation District, the Gonzales County Underground Water Conservation District, the Medina County Groundwater Conservation District, and the Permian Basin Underground Water Conservation District. The Gonzales County, Evergreen, Medina County and Permian Basin Groundwater Districts are Chapter 36, Texas Water Code based groundwater conservation districts. While they have underlying enabling legislation for their creation, they look primarily to the provisions of Chapter 36 for their powers and guidance in their operations, including adoption of rules. The Edwards Aquifer Authority has certain powers enumerated in Chapter 36 but looks primarily to its enabling legislation for its authority.[141] Each of these five districts is discussed separately below.

1. **Edwards Aquifer Authority**. Section 1.44 of the Edwards Aquifer enabling legislation, entitled "Cooperative Contracts for Artificial Recharge"[142] appears to limit the EAA's authority with respect to artificial recharge projects within the Edwards Aquifer, and is much more specific than any other provision found related to ASR projects in areas within the jurisdiction of a groundwater conservation district.[143] Pursuant to Chapter 791, Texas Gov't Code, the EAA may enter into contracts with other political subdivisions to provide for artificial recharge of the aquifer using injection wells and surface water subject to the control of the other political subdivision. The water injected would be stored for retrieval[144] by the political subdivision or its authorized assignee for beneficial use within the boundaries of the Edwards Aquifer Authority.[145] The statute prohibits the EAA from "unreasonably" denying a request by another political subdivision for such a cooperative contract if the entity agrees to file injection/artificial recharge records with the EAA and provide for the protection of the quality of the aquifer and the rights of other Edwards Aquifer users when designating the location of their injection wells, the method of injection or recharge, and the location and type of the retrieval wells.[146] According to the EAA's enabling legislation, the storage of water artificially recharged into the aquifer is for a limited duration of less than 12 months. Specifically, water injected into the Edwards Aquifer by the political subdivision using artificial recharge must be withdrawn during the 12-month period following the recharge,[147] and the amount withdrawn is limited to the amount of water actually injected as demonstrated and established by expert testimony less the following amounts:

(1) An amount determined by the EAA to account for part of the artificially recharged water discharged through spring outlets in the Edwards Aquifer, *e.g.*, Comal Springs, San Marcos Springs;[148] and

(2) An amount determined by the EAA to "compensate" the EAA in lieu of the payment of "user's fees."[149]

In addition to the limitations associated with entering into cooperative contracts for the artificial recharge and subsequent recovery of water from the Edwards Aquifer, the EAA is required to provide for the protection and maintenance of water quality in the Aquifer pursuant to the water injected under contract.[150] Unless the water used to recharge the Aquifer is recharged through a "natural recharge feature," the water used for artificial recharge must be "groundwater withdrawn from the aquifer."[151] The restrictions of Section 144 are elaborated upon in the District's rules and include the following:[152] In addition to information generally required for all permit applications the applicant must provide a complete name of the aquifer recharge, storage and recovery project[153]; the name of the source of the water to be used for recharge[154]; a map showing the location of the points of recharge, location of all known existing wells within the recharge project area and/or within a mile thereof and identifying the depth of all existing wells and proposed injection facilities, recovery wells, monitor wells as well as the part of the aquifer that the water will be stored in.[155] The application must also identify any known "possible sources of contamination" within a mile of the project, e.g., existing/proposed livestock or poultry yards, septic systems, and underground/above ground storage tanks.[156] A detailed description of the recharge and storage methodology including the method, size of facilities, well type, number, size and capacity of wells, impoundments, drainage area, height and length of dams, outlet structures and controls, stage-outflow ratings, elevation to area capacity, and state recharge ratings and water treatment facilities, as applicable.[157]

The application must outline the procedure to be used to measure/calculate the artificial and natural recharge occurring while the project is operational.[158] The application must provide detailed source water quality and aquifer water quality monitoring procedures. It must describe how monitoring reports will be provided to the EAA regarding source water and aquifer water quality within the perimeter of the project area and within one-quarter (1/4) mile of the project area perimeter.[159] The application must also describe the following:

(1) The purpose for which the stored water will subsequently be withdrawn and used.[160] If the recharge will be conducted for purposes of increasing spring flow then the application must identify the spring and the anticipated augmentation or maintenance of the spring flow that will be directly attributable to the project, including all of the applicant's supporting calculations[161];

(2) Projected rate of recharge and cubic feet per second (cfs), including supporting calculations[162];

(3) Total amount of additional groundwater to be recharged monthly and annually in acre-feet, including supporting calculations[163];

(4) Proposed date of project construction and estimated completion date.[164]

The application must also demonstrate the applicant's financial capability to design, construct, operate and maintain the project for the term of the permit (707.418(16)). The EAA's rules also contain a "catch all" authorizing the EAA's General Manager to require the applicant to provide additional information deemed by the General Manager to "determine the feasibility of the project and to properly evaluate the application."[165]

Wells intended to recover recharged amounts of water must include the following additional information:

(1) Proposed term of the permit[166];

(2) Purpose of use of the stored water including, if for increasing spring flow, identification of the springs and the anticipated augmentation or maintenance of the spring flow directly attributed to the recharge recovery permit[167];

(3) The proposed maximum rate of withdrawal in gallons per minute (gpm)[168]; and

(4) The proposed formula for calculating the volume of withdrawals on a monthly and annual basis.[169]

The application must describe the location of the proposed point(s) of withdrawal and recharge recovery point(s),[170] as well as the proposed place of use of the water recovered pursuant to the recharged recovery permit.[171] Finally, the application must describe the proposed source for the water to be used for the recharge,[172] the proposed metering or alternative measuring method to be used by the applicant,[173] documentary evidence demonstrating the applicant's financial ability to design, construct, operate and maintain the project for the term of the permit.[174] Finally, the applicant may be required to provide additional information deemed necessary by the general manager to determine the feasibility of the project and evaluate the application.[175]

The groundwater authorized by recharge recovery permits are not subject to the caps or other limitations established by the Edwards Aquifer Rules for initial regular permits.[176] Detailed rules for aquifer recharge, storage and recovery projects are found in Subchapter J of the EAA Rules.[177]

In addition to having the most extensive rules of any district with jurisdiction over groundwater in Texas, the EAA also has the most definitive policy statement with respect to ASR. The EAA's rules provide that their purposes are to "promote the augmentation and management of waters recharged in the aquifers in order to:

> (1) Augment the amount of groundwater that may be available for subsequent withdrawal for beneficial uses from the aquifer; or
>
> (2) Maintain or augment the amount of spring flows at San Marcos and Comal Springs.[178]

The EAA's rules, however, are also some of the most restrictive, both with respect to the sources available for recharge and storage in the aquifer, as well as the length of time that the water may be stored, and the areas where the recovered water may be used.[179] The EAA rules provide that ASR projects constructed on or after September 1, 1993, must have an ASR permit from the EAA.[180] The rules also provide that ASR permits will not be issued for projects constructed prior to September 1, 1993,[181] however, modification of any structure, facility or works constructed prior to September 1, 1993, which will result in "additional artificial recharge in excess of the amount of recharge that the structure, facility, or works may have provided prior to the modification," is eligible for an ASR permit.[182] Similarly, the EAA does not issue permits authorizing the production of water that has been "historically recharged" into the aquifer prior to securing an ASR permit from the EAA.[183] In addition to the policy statement articulated in Section 711.241, the EAA rules specifically prescribe the purposes for which artificial recharge of the aquifer may be accomplished:

> Artificial recharge of the aquifer must have as its primary purpose:
>
> (1) The augmentation of the amount of groundwater available for withdrawal from the aquifer through the storage of source water in the aquifer that is incidental to, and in furtherance of, the subsequent withdrawal of the stored water for beneficial use for irrigation, industrial, or municipal purposes;
>
> (2) Augmentation of the amount of groundwater available to maintain or increase spring flows at Comal or San Marcos Springs; or
>
> (3) Any other beneficial use of the water recognized by law.[184]

ASR permits are transferable.[185] ASR permits, unlike other EAA permits, however, are not subject to proportional adjustment under the district's rules,[186] may not be retired pursuant to the EAA's equal percentage reduction rules or the regular permit retirement rules,[187] are not subject to being suspended pursuant to the EAA's demand management and critical period management rules or the groundwater trust,[188] and may not be "interrupted" pursuant to the demand management and critical period management rules of the EAA.[189] While ASR permits may not be "canceled,"[190] they are subject to being abandoned.[191] With respect to the sources of water that are eligible or ineligible for use in an ASR project permitted by the Authority, the EAA has multiple criteria. For example, if the EAA is a participant in the ASR project,[192] then the following sources of water may not be used to recharge the aquifer:

(1) Surface water that is the "historic yield of the flood water to the Nueces River Basin as determined by the [TCEQ];"

(2) Surface water from a watercourse located within the recharge zone of the aquifer the diversion of which for recharge into the aquifer would impair senior water rights or vested riparian rights; or

(3) Surface water that is not recharged through a natural recharge feature.[193]

Usually, the following groundwater sources may not be used in an ASR project in which the EAA is a participant:

(1) Groundwater withdrawn in Uvalde County and transported to a point of recharge outside of Uvalde County;

(2) Groundwater withdrawn in Medina County and transported to a point of recharge outside of Medina County;

(3) Groundwater withdrawn from an aquifer other than the Edwards Aquifer which has been designated by the TCEQ as a "priority groundwater management area" pursuant to Section 35.012, Texas Water Code; or

(4) Groundwater withdrawn from an aquifer other than the Edwards Aquifer and recharged through an injection well.[194]

Additionally, the EAA may not use "reclaimed water," as that term is defined in Section 210.3 (30 TAC) of the TCEQ's rules in an EAA participation ASR project.[195]

In the case of an ASR project conducted by a political subdivision pursuant to Section 1.44 of the EAA Act and Section 711.269 of the EAA's rules,[196] the following water sources may not be used to recharge the aquifer:

(1) Any surface water unless it is recharged through a "natural recharge feature;"[197]

(2) Groundwater withdrawn from an aquifer other than the Edwards Aquifer unless it is recharged through a "natural recharge feature;"[198]

(3) Withdrawn from a point in Uvalde County and transported to a recharge point outside of Uvalde County;[199]

(4) Withdrawn from a point in Medina County and transported to a recharge point outside of Medina County;[200]

(5) Withdrawn from an aquifer other than the Edwards Aquifer which has been designated by the TCEQ as a "priority groundwater management area" pursuant to Section 35.012, Texas Water Code.[201]

Additionally, reclaimed water, as the term is defined in Section 210.3 (30 TAC) may not be used to recharge the aquifer.[202]

Finally, the EAA rules contain a "catch all" provision limiting the sources of water available for recharge to the aquifer in Section 711.251(d) which provides that "for all other aquifer recharge, storage and recovery projects, the following source water may not be recharged into the aquifer":

(1) Surface water that is (i) not recharged through a natural recharge feature,[203] (ii) the normal or ordinary flows of watercourses located within Bexar, Comal, Hays, Kinney, Medina, or Uvalde Counties,[204] or (iii) storm and flood waters of those same watercourses if the waters proposed to be recharged are already appropriated by a person other than the applicant, will result in an "unreasonable loss of state water" if recharged, or the stored water cannot be withdrawn at a later time for application to a beneficial use.[205]

Groundwater may not be used as the source water for recharge in those same ASR projects if it is withdrawn from an aquifer other than the Edward's, unless recharged through a natural recharge feature."[206] Similarly, groundwater withdrawn from a point of withdrawal in Uvalde County that is transported to a point of recharge outside of Uvalde County, or withdrawn at a point of withdrawal within Medina County and transported to a point of recharge outside of Medina County may not be used.[207] Finally, reclaimed water, as the term is defined in Section 210.3 (30 TAC) of the Commission's rules may not be used as source water for recharge in an ASR project.[208]

In addition to the limitations on source water described above, the EAA's rules also prohibit the approval of an aquifer storage and recovery permit unless the application demonstrates the applicant's ability to protect the water quality of the aquifer once the permit is issued.[209] The EAA's rules make clear that it is the Authority's intent to insure the highest water quality and safety of the native groundwater within the Edwards Aquifer with respect to "microbiological, chemical and radiological quality for use as water for public water supplies in the [Edwards] Aquifer region.[210] For groundwater to be recharged using artificial injection, the EAA's rules prescribe that the quality of source water at the point of entry of recharge into the aquifer must meet or exceed water quality standards prescribed by Chapter 290 of the TCEQ's rules (30 TAC) related to maximum contaminant levels for inorganic contaminants, organic contaminants, radiological contaminants, microbial contaminants, maximum residual disinfectant concentrations, turbidity levels, total trihalomethanes, and haloacetic acids (five), treatment standards for total organic carbon and regulation of lead and copper.[211] To the extent that the source water does not meet the water quality criteria described above, the water is "required to be treated to meet or exceed the criteria prior to recharge into the aquifer."[212] For ASR projects in which the source water will be groundwater, the EAA rules also require that if the groundwater is from an aquifer within the jurisdiction of a groundwater conservation district that the applicant provide a copy of the application to the groundwater district(s), cooperate with the district and comply with its rules, including any other out of district transport requirements.[213] If a groundwater district with jurisdiction over the source water requires that the applicant reach an agreement with the district regarding withdrawal and transport of the groundwater for recharge of the Edwards, evidence of that compliance must be provided by the applicant and included as a condition in the ASR permit issued by the Edwards.[214]

Before the EAA will issue an ASR permit, the applicant must establish to the Board's satisfaction 22 separate criteria including the following:

(1) That the proposed recharge is artificial recharge to the aquifer and not historic recharge;

(2) That the recharge can be accurately measured;

(3) The project will result in the augmentation of the amount of groundwater available for withdrawal from the aquifer through storage of source water that can be subsequently withdrawn and beneficially used or available to maintain or increase spring flows at Comal or San Marcos Springs;

(4) The applicant has legal access to an authority to transport and recharge the source water;

(5) The source water is legally eligible to be recharged and meets the applicable water quality standards;

(6) The project will not degrade the physical, chemical or biological quality of the native groundwater in the Edwards Aquifer;

(7) The application was not filed for the purpose of "speculation," but instead the applicant has present intentions directly and promptly to pursue the completion of the project as set out in the application, which may be evidenced by a contract with an end user;

(8) Approval of the application is consistent with the Edwards Aquifer Act and the EAA's rules; and

(9) The applicant has the financial ability to design, construct, operate and maintain the project for the term of the permit period.[215]

In addition to securing the permit authorizing the recharge and storage in the aquifer, a separate permit must be obtained in order to recover the recharged water.[216] The recharge recovery permit shall specify the total amount of water available for recovery on a monthly basis based upon a calculation of the artificial recharge attributable to the ASR project less (i) the amount of additional water discharged through the springs due to the stored water, (ii) the amount of artificial recharge attributable to other permitted aquifer storage and recovery projects, (iii) the amount of any stored water lost, and, finally, (iv) an amount of groundwater not to be recovered [by the permittee] to compensate the [EAA] in lieu of aquifer management fees as may be determined by the Board.[217] Unless otherwise expressly provided for in the recharge recovery permit, the permittee is entitled to withdraw and recover the measured amount of water recharged into the Edwards Aquifer during any 12-month calendar period during the following 12-month calendar period.[218] The EAA's rules prescribe 18 criteria for approval of a recharge recovery permit. Among the key criteria are that the recovery well and place of use of the water will be within the Edwards Aquifer Authority's boundaries, and that "continuous minimum spring flows of the Comal Springs and San Marcos Springs, necessary to protect endangered and threatened species to the extent required by Federal law, will not be negatively impacted when compared to spring flow conditions if the project did not exist.[219]

As evidenced by the discussion above, the EAA appears to have the most developed regulatory structure of any special purpose district with authority over one or more aquifers in the State; however, its ASR regulations are also the most restrictive if not prohibitive. Additionally, the one million-plus Texans residing within the EAA's jurisdiction have a continuing need to develop additional water supplies to meet growing demands. Applications for ASR permits and/or recharge recovery permits, however, cannot be filed with the EAA unless the Board issues an order authorizing such applications to be filed.[220] To date, the EAA Board has not issued any order authorizing the filing of either type of application.[221]

The Edwards Aquifer is recognized as one of the nation's most unique groundwater systems. The hydrology and hydrogeology of the artesian zone create regulatory and operational complexities. However, the EAA's regulations impose numerous restrictions on ASR implementation. One of the most critical restrictions is the twelve-month storage period limitation, thereby eliminating the opportunity to store more water in wet years for recovery during dry years and droughts. This is called "water banking" and is one of the most common applications and benefits of ASR.

The twelve-month storage limitation may preclude the opportunity to store water in brackish or saline portions of the Edwards Aquifer. The U.S. Geological Survey (USGS) is currently in the second year of a three-year study of the hydrologic conductivity and hydraulics of the saline zone of the Edwards Aquifer. This study and additional research could evaluate the viability of storing water in the saline zone.

Storing drinking water in brackish aquifers is quite common for ASR wells in several other states. Consequently the opportunity may exist to store a substantial volume of drinking water close to San Antonio, supplementing storage at the Twin Oaks ASR wellfield located 30 miles south of San Antonio.

Given the "political sensitivity" of this concept, significant scientific investigation such as the USGS study and public education will be required before implementation would be practicable. The effort, however, is merited given the fact that the implementation of this strategy would potentially help to achieve sustainable and reliable water supplies for the San Antonio area while also protecting spring flows. Several ASR projects nationwide are now being implemented for the primary purpose of achieving environmental goals, such as augmenting river flows during dry weather periods.

2. Evergreen Underground Water Conservation District. The Evergreen Underground Water Conservation District ("EUWCD") defines "ASR" as an "Aquifer Storage and Retrieval Project, which is a project with two phases that anticipates the use of a Class V aquifer storage well for injection into a geologic formation, group of formations, or part of a formation that is capable of underground storage of appropriated surface water or groundwater for subsequent retrieval and beneficial use."[222] The term "Aquifer Storage Well" is defined to be a "Class V injection well designed and used expressly for the injection of water into a geologic formation, group of formations, or part of a formation that is capable of underground storage of water for later retrieval and beneficial use."[223]

Rule 6.6 of the EUWCD's Rules addresses ASR Projects under the District's jurisdiction in Atascosa, Frio, Karnes and Wilson Counties.[224] EUWCD requires all ASR projects be "permitted" by the district.[225] The rules require both an "injection permit" and a "recovery permit."[226] Additionally, the rules require an application(s) for an "ASR permit"[227] be accompanied by applications for production permits "for each well to be used for injection or retrieval of water."[228] Information peculiar to ASR Projects that must be included in the ASR Permit Application include the following:

(i) the proposed injection rates and volumes;[229]

(ii) the proposed frequency of injection periods;[230]

(iii) the proposed retrieval rates and volumes;[231]

(iv) the proposed frequency of retrieval periods;[232]

(v) the estimated radial distances of travel (of the injected water) from the injection wells on an annual basis;[233]

(vi) the estimated maximum extent of travel for the life of the project;[234]

(vii) the location of all injection, retrieval and monitoring wells;[235]

(viii) the actual or anticipated location of the well(s) from which water will be injected and/or retrieved, including pump size, and the production and injection capacity;[236]

(ix) the source of the water to be injected, and its quality (including a "chemical analysis" of the water;[237]

(x) the "presently anticipated duration required for the proposed use of the project";[238]

(xi) provide information "showing" the anticipated effect of the ASR project on the groundwater quality;[239]

(xii) a "report" identifying any potential impacts to artificial penetrations within one-half mile of the perimeter of the "buffer zone";[240]

(xiii) identify well(s) producing from the same formation as the ASR project within one-half mile of the well[241] and the owners of said wells,[242] and

(xiv) the "catchall"; *i.e.*, other information as determined by EUWCD to be necessary for the production of underground sources of "drinking water."[243]

Subsection c. of Rule 6.6, entitled "Map Requirements," provides that the applicant for ASR Permit must include an "overall plan of the project area."[244] The rule is ambiguous with respect to whether the "map" and "overall plan" are the same or different.[245] Given the detailed information required by Subsection (c),[246] the applicant would be wise to either include multiple maps so that the required information is legible and discernable, or in addition to the required map(s) the applicant provide a narrative that appropriately referenced the map(s). Whichever way the Applicant chooses to format its ASR Permit application, the following information is required:

(i) the project area;[247]

(ii) the locations and extent of proposed "works" and "all pertinent features;"[248]

(iii) the location "by latitude and longitude" of all proposed or existing injection and retrieval wells associated with the ASR project;[249]

(iv) names and locations of underground formation(s) in which water will be stored for subsequent retrieval and indicating the "general direction of flow;"[250]

(v) cross sections and profiles of underground formations (1) into which water will be "injected and stored", (2) which confines the injection interval, (3) located between the storage area and land surface and the actual and/or proposed operating depths of all planned injection and retrieval facilities;[251]

(vi) the location of a "buffer zone" surrounding the land surface area overlying the location of (1) the stored water and (2) "beyond which pumpage by other wells will not interfere or significantly affect the movement or storage of the water;"[252]

(vii) the location and ownership of "all existing domestic, public water supply, irrigation, or commercial wells "within one-half mile of the perimeter of "the buffer zone described in this subsection;[253] and

(viii) the "catchall" – "Any other information the District may require to determine the feasibility of the [ASR] project."[254]

The EUWCD's rules require that the ASR wells be constructed in compliance with TCEQ's UIC standards.[255] The rules also enumerate post-completion reporting requirements for ASR wells, including the following:

(i) as-built drilling and completion data;[256]

(ii) all logging and testing data;[257]

(iii) formation fluid and injection fluid analysis;[258]

(iv) injectivity and pumping tests determining well capacity and reservoir characteristics;[259]

(v) hydrogeologic modeling predicting mixing zone characteristics and injection fluid movement and quality;[260]

(vi) the "catchall" – "other information as determined by the District as necessary for the protection of underground sources of drinking water.[261]

Operating and reporting requirements peculiar to ASR Projects with the EUWCD include the following:

(i) ASR wells must be operated in a manner that does not present a hazard to or cause pollution of "an underground source of drinking water";[262]

(ii) the "injection pressure at the wellhead shall not exceed a maximum which shall be calculated so as to assure the pressure in the "injection zone" does not cause movement of "fluid" out of the injection zone;[263]

(iii) the injected water is required to meet "drinking water standards";[264]

(iv) monthly reports must be filed with the EUWCD on the following:

a. average injection rates;

b. injection and retrieval volumes;

c. average injection pressures;

d. water quality analyses of injected water;

e. "other information".[265]

(v) In the event an ASR operator "ceased operations" for more than two years, before "resuming operation of the well," the ASR operator must provide EUWCD 30 days prior notice.[266]

EUWCD's operating requirement prescribed in subparagraph (ii) above is potentially problematic if applied more generally at other ASR wellfield locations in Texas. This UIC program requirement is aimed at projects designed for disposal of wastewater into confined aquifers, rather than an ASR project. If the operating requirement is applied to ASR wells, this requirement could substantially limit recharge rates and volumes while not gaining any significant public benefit. Injection pressure for ASR wells should be limited, but not for this reason. Instead injection pressure should not exceed the drawdown achievable by pumping an ASR well. This will facilitate periodic back flushing of the well to waste for a few minutes to hours, thereby controlling particulate clogging.

Once an ASR permit is issued, EUWCD "employees" have access to the ASR facility for "inspection and data collection" at any time "during regular District business hours."[267] According to EUWCD Rules, any of the following may trigger the need for filing an amendment application for the ASR Permit prior to implementation of the change:

(i) changes or additions to the ASR injection and/or retrieval sites;[268]

(ii) changes in either the "source water" or the "chemical constituents" of the source water;[269]

(iii) changes in the "annual injection and retrieval rate."[270]

Although the same information is required to be included in the ASR Permit Application, and any amendment application,[271] EUWCD Rules also require that the Permittee prepare and submit to the District a "plan"[272] to address the following:

(i) monitor the quality of the water injected and retrieved;[273]

(ii) water levels of the receiving body of groundwater within one-half mile of the perimeter of the buffer zone;[274] and

(iii) describe how the water injected and retrieved will be measured and reported.[275]

In the event that "water quality is being affected outside of the ASR buffer zone, the Rules contemplate that the EUWCD Board will issue notice to the ASR Permittee and conduct a hearing.[276] Following the hearing, the Rules provide that the Board "may order the [ASR] permittee to suspend operations or revoke the permits.[277]

Finally, the EUWCD Rules provide that the "[r]etrieval of stored water may not exceed 90% of the total amount of water actually injected [into the ASR Project]."[278] The Rule is silent with respect to the EUWCD's authority to require a permittee to "contribute" 10% of the water injected into the aquifer for storage by limiting the ASR Permittee's subsequent recovery of stored water to 90% of the amount injected.[279] While Section 11.154(b)(2)[280] contemplates the possibility that an ASR permit applicant and a groundwater district could "negotiate" an "agreement" regarding the terms for injection, storage and recovery of State water, which could include terms limiting the amount of injected water recoverable,[281] this provision (i) applies only to ASR projects where the "source water" is State- owned surface water subject to a Section 11.121[282] water rights permit, and (ii) does not expressly authorize a groundwater district to limit the amount of injected water to be recovered.[283] The provision does not apply to privately owned groundwater use as the "source water." This is a distinction from the express statutory power granted to the Edwards Aquifer Authority in Section 1.44 of the Act to require an ASR permittee to contribute some agreed amount of the injected water in the Aquifer irrespective of whether the source is surface water or groundwater.[284]

3. Gonzales County Underground Water Conservation District. The Gonzales County Underground Water Conservation District has adopted rules which address "recharge" of the aquifer. The specific rule applicable to aquifer recharge projects within the district is Rule 14 entitled "Recharge Facilities." The other district rule is Rule 1 which provides definitions of terms used in the Rule including the term "Recharge Well." The District's rules do not, however, include a definition of the term "Recharge Facility" or "Recharge Facilities." The District's rules define the term "Recharge Well" to mean "a well used to allow or cause water to flow out of the well into the aquifer either under a gravity head or a head maintained by an injection pump in order to replenish the groundwater."[285]

Rule 14 requires that an application be made and permit issued by the District prior to the installation and/or operation of a recharge facility.[286]

In addition to typical information required as part of an application, *e.g.*, the applicant's name, names and addresses of the owners of the land in which the recharge facility would be located, a legal description for the location of the facility and a schedule for time of construction and/or operation of the facility and the names and addresses of property owners within ½ mile of the proposed recharge facility and any wells on those properties, the application must include a "Complete Construction and Operations Plan" which includes at a minimum the following:

a. A technical description of the facility to be used for recharge.

b. The source of the water to be recharged.

c. The quality of the water to be recharged.

d. The volume of water to be recharged.

e. The rate at which the water will be recharged.

f. The formation into which waters will be recharged.

Additionally, the Applicant must provide "scientific evidence demonstrating that the proposed operation will not (i) endanger the structural characteristics of the formation receiving the discharged water, or (ii) cause waste.[287] The District's rules also authorize the general manager to require "any additional information."[288]

In considering the application for construction and operation of a recharge facility, the District's Board is required to consider whether the recharge facility will result in any of the following:

a. Waste
b. Pollution
c. Significant subsidence.
d. Endanger the structural characteristics of the formation.[289]

The operator of a permitted recharge facility is required to keep records and provide reports of its operation to the District on a monthly basis. Those reports are required to include the following:

1. Volume of water recharged.
2. Source of the water recharged.
3. Quality of the water recharged.
4. Any additional information prescribed by the permit.[290]

Permits for recharge facilities are authorized for a five year period[291] and may be reissued for additional five-year periods upon approval by the Board in accordance with the rules then in effect.[292] Recharge wells are required to be completed and equipped in a manner necessary "to protect human life and prevent pollution."[293]

The owner of the recharge facility and the owner of the wells, if different, are charged with liability for the prevention of pollution and waste and any resulting damage from the operation of the recharge facility to the formation.[294] The owner of the wells is also required to prevent "personal injury, property damage or pollution" from the wells or their activities.[295]

4. Medina County Groundwater Conservation District. The Medina County District Rules address permits for both aquifer storage and recovery projects[296] and recharge facilities.[297] The following defined terms in the District's rules are important, too, in understanding of the provisions in Chapter 9 (ASR project) and Chapter 10 (recharge projects) of the District's rules.

(1) "Aquifer Storage and Recovery ("ASR Project") is defined to mean a "process of storing water through injection wells or other means into a suitable aquifer for later recovery or retrieval."[298]

(2) "Injection Well" is defined to include "a recharge well used to replenish the water in an aquifer."[299]

(3) "Recharge" is defined to mean the "amount of water that infiltrates to the water table of an aquifer."[300]

(4) "Recharge Facility" is defined to mean "any system for recharge, injection, storage, pressure, maintenance, cycling or recycling, of water, which includes one or more wells, spreading dams, or percolation basins, or any other surface or

> subsurface system engineered and designed for the purpose of recharging water into a groundwater reservoir."[301]

ASR Projects must be permitted by the District and may be renewed at the end of the term prescribed in the initial permit.[302] The application for an ASR injection well must include (i) information required for a classified injection well at the TCEQ;[303] (ii) a map or plat showing the location of the injection facility in the aquifer in which the water will be stored;[304] and (iii) a map or plat showing the location of all water wells within a 5-mile radius of the proposed injection site that are completed in the same aquifer.[305] In determining whether or not to issue an ASR Permit, the District's Board must consider the following:

(1) Whether the introduction of water into the aquifer will alter the physical, chemical or biological quality of the native groundwater to a degree that would render the groundwater produced from the aquifer harmful or detrimental to people, animals, vegetation, or property, or require treatment prior to beneficial use; and

(2) Whether the water stored can be successfully withdrawn without causing undue hardship to the aquifer or any other user of the aquifer.[306]

The Board may also consider "all relevant facts" related to the ASR Application including the following:

(1) The location and depth of the aquifer in which the water will be stored;

(2) The nature and extent of the surface development and activity above the stored water; and

(3) The Permittee's ability to determine the compatibility of the stored water with the resident water and monitor the impact to the receiving aquifer.[307]

ASR permits may include conditions believed to be necessary to "ensure the safety, quality, and quantity of groundwater available for withdrawal by other well owners."[308] A permittee is subject to cancellation of the permit and/or civil penalties for violation of any permit condition.[309]

Recharge facilities must also be permitted.[310] In addition to the name and address of the applicant, and the fee owner of the land on which the recharge facility will be located if that person is different from the applicant, the permit application must include the following:

(1) A legal description of the location of the recharge facility;[311]

(2) A time schedule for construction and/or operation of the facility;[312]

(3) The names and addresses of property owners within ½ mile of the proposed recharge facility and any wells located on those properties;[313]

(4) A complete construction and operation plan for the recharge facility which includes at a minimum the following:

   (a) A technical description of the facility to be used for recharge;

   (b) The source of the water to be recharged;

   (c) The quality of the water to be recharged;

(d) The volume of the water to be recharged;

(e) The rate at which the water will be recharged;

(f) The information [*sic*] into which water will be recharged[314]; and

(g) Scientific information showing that the proposed operation of the recharge facility will not (i) endanger the structural characteristics of the formation receiving the recharged water, (ii) cause pollution, or (iii) cause any waste.[315]

The Board may also require the applicant for a recharge facility to provide additional information.[316] Permits for a recharge facility cannot be issued without the District first conducting a hearing on the application.[317] Notice of the hearing must be published at least 30 days prior to the date on which the District will consider the application by mailing notice, first class mail, postage prepaid, to the following: the applicant and property owners within ½ mile of the proposed recharge facility.[318] The notice must also be published by the District in a newspaper of general circulation in Medina County "[b] because of the potential to impact areas outside of a one half (1/2) mile radius.[319] The notice must include the name and address of the applicant, the date the application was filed, the time and place of the hearing, the location of the proposed recharge facility, and a brief summary of the information included in the application.[320] A recharge facility permittee must keep records and make monthly reports to the District which include, at a minimum, the volume, source and quality of the water recharged through the recharge facility. The reports must also include any additional information specified in the recharge facility permit.[321] The owner of a recharge facility assumes, and is charged with strict liability for, the prevention of pollution and waste from the facility. They are also responsible and liable for any damage to the recharged formation resulting from the operation of the recharge facility.[322] Except for recharge facilities existing on or before the effective date of the District's rules, recharge facilities must be permitted.[323]

5. Permian Basin Underground Water Conservation District. The Permian Basin Underground Water Conservation District also has a rule related to recharge wells.[324] The District's single paragraph rule requires that an application be filed and a permit issued for purposes of drilling and completing "recharge wells." The District's rules do not define the term "recharge well" but merely prescribe that the application state that it is for a "recharge well." The application for a recharge well must include the same information required for "new wells" but only "insofar as is applicable." Recharge wells must be equipped in such a manner "as to protect human life." The owner of a recharge well must assume, and is charge with, "full responsibility for the prevention of pollution" from the recharge well. Once the recharge well has been drilled, the owner is required to "promptly" provide the District with a well completion report.[325]

5.4 Framework of Legal Issues Impeding Development of ASR in Texas[326]

Passed in 1995, House Bill 1989 addressed the absence of express authorization to implement ASR in Chapter 11, Texas Water Code, by authorizing the storage and recovery of appropriated surface water within or above an underground source of drinking water ("USDW") in ASR "Pilot Projects" within 10 identified counties and eight specific aquifers.[327] Amendments passed in 1997 removed the location restrictions in the original legislation which initially restricted ASR implementation to 10 named counties and eight specific aquifers. No substantive amendments to Texas' statutes regulating surface water have been enacted since 1997.[328]

Pursuant to Section 11.154, when evaluating a surface water permit that incorporates ASR, the Commission is required to consider whether the introduction of water into the aquifer would alter the geophysical, chemical, or biological quality of native groundwater to a degree that it would (1) render the groundwater produced from the aquifer harmful or detrimental to people, animals, vegetation or property, or (2) require treatment of the groundwater to a greater extent than the native groundwater requires before being applied to the same beneficial use. The Commission must also conclude that a reasonable recovery of the appropriated surface water will occur and that reasonable diligence will be used to protect the water stored in the receiving aquifer from unauthorized withdrawals to the extent necessary to maximize the permit holder's ability to retrieve and beneficially use the stored water without experiencing unreasonable loss of appropriated water.

To implement the ASR legislation, the Commission amended Chapters 295, 297 and 331 of its rules (30 TAC). Chapters 295[329] and 297[330] address the procedural and substantive requirements for obtaining a surface water rights permit for use in an ASR project. ASR wells are considered Class V injection wells for purposes of the State's Underground Injection Control ("UIC") Program.[331] The amendments to Chapter 331[332] addressed the technical and procedural requirements for obtaining an injection well permit for the project. Section 331.184(3) (30 TAC) authorizes construction and operation of Class V injection wells "by rule" for systems storing potable water.

While <u>not</u> controlled by the provisions of Chapter 11, Texas Water Code, utilization of groundwater as the source supply for purposes of ASR is still subject to Commission regulations.[333] Specifically, ASR projects, regardless of the water source, require Class V injection well permits.[334]

The specific permitting requirements for an ASR project are dependent upon the source of water for the project. If surface water is involved, a permit pursuant to Section 11.121, Texas Water Code, or an amendment to an existing water right authorizing ASR will be required.[335] In addition to the traditional requirements for a water right permit,[336] an ASR project involving surface water has special permitting requirements.[337]

Permitting of surface water for an ASR project is done in two phases. The first phase of an ASR project ("Phase I") contemplates the temporary use of state water to prove the viability of the ASR project.[338]

As part of Phase I, Commission rules require the following information:

(1) information necessary to demonstrate compliance with Chapter 331 (including subchapters A, H and K) of the Commission's rules;[339]

(2) a map/plat reflecting the proposed depth and location of the injection and recovery wells, and the aquifer proposed for storage of the water;[340] and

(3) if the aquifer is subject to the jurisdiction of a groundwater district(s), then the application must also include:[341]

a. proof that notice (*e.g.*, a copy of the ASR application) was provided to the district(s) by certified mail;[342] and

b. a copy of any agreement with the district(s) regarding the ASR project.[343]

Upon completion of Phase I, the applicant must prepare a "final report" compliant with Commission requirements,[344] and submit it to the Commission as part of the ASR surface water application.[345]

The final report is the first step in Phase II of the ASR application.[346] The next step is the submission of an operational plan outlining the projected (i) injection rates and volumes,[347] (ii) frequency of injection periods,[348](iii) retrieval rates and volumes,[349] (iv) frequency of retrieval periods,[350] (v) projected annual radial distances of travel from injection well(s),[351] (vi) maximum projected travel distance from injection well(s) over projected life,[352] and (vii) the location of injection, retrieval and monitoring wells.[353]

Additionally, the applicant must prepare (i) a report identifying all existing domestic, public water supply, irrigation and commercial wells located within one-quarter mile of the project's "buffer zone,"[354] and (ii) a monitoring plan that describes how water injected and retrieved will be measured and reported.[355] The rules also require the applicant to provide any other information necessary for the Executive Director to protect groundwater sources of drinking water.[356] Unless the applicant has eminent domain powers (*i.e.*, condemnation authority), the application must include written easements, or other evidence of authority, to store the water beneath or construct and maintain ASR facilities on the properties of third parties.[357] Finally, in addition to the "mapping" requirements for a standard water rights application, an ASR application requires maps reflecting the following information not previously discussed:

(1) overall project description, including all pertinent facilities;[358]

(2) names and locations of all groundwater formations State water will be stored in and retrieved from and the general flow direction;[359]

(3) cross sections/profiles of groundwater formations associated with the project;[360] and

(4) if applicable, identify any Chapter 294 critical area in which storage is anticipated.[361]

If the water supply source for the ASR project is groundwater to be produced from an aquifer within the jurisdiction of a groundwater conservation district, the ASR operator must comply with the applicable district rules, as well as secure all required permits.[362] If the source groundwater supply will need to be transported outside the affected groundwater conservation district for injection in the ASR project, then the ASR operator will also be required to obtain a permit authorizing out-of-district transport.[363] Additionally, if the aquifer(s) to be utilized for storage by the ASR project is located within the jurisdiction of a groundwater conservation district, the ASR operator must comply with the applicable district rules, as well as secure all required permits. [364]

Regardless of the source of water (surface water or groundwater), a new ASR project must comply with the State's Underground Injection Control ("UIC") Program.[365] Specifically, the project's well(s) must have a Class V injection well permit(s).[366]

As part of the permit criteria, the applicant is required to demonstrate the mechanical integrity of the well system,[367] and that injection will not result in pollution of an underground source of drinking water.[368] Additionally, the permit must include terms and conditions that will protect fresh water from pollution.[369]

Construction standards for Class V wells are prescribed by Commission rule.[370] Wells must be installed by a licensed water well driller.[371] The rules require both pre-construction and post-completion reporting to the Commission.[372] Criteria for sealing of well casing, surface completion and other protective measures, including sampling, are also outlined in the rules.[373]

If use of a Class V well is to be discontinued or abandoned, Commission rules prescribe alternative means for closure.[374] As a general rule, closure required the removal of all casing, and filling of the well bore with cement from the bottom to the land surface.[375] The cement must be injected under pressure via a tremie pipe.[376] Alternatively, closure may be accomplished by filling the well with "fine sand, clay, or heavy mud followed by a cement plug" at least ten feet below land surface.[377] This alternative, less costly closure, is only available if the well was *not* completed through zones containing "undesirable groundwater, water that is injurious to human health and the environment or water that can cause pollution to land or other water."[378] Zones containing undesirable groundwater, etc. must be plugged by isolating them with cement plugs and the remainder of the well bore filled with bentonite and then plugged with cement from land surface to a depth of at least ten feet.[379]

The development of ASR in Texas has encountered several issues that are not clearly and/or expressly addressed under Texas law related to the storage in, protection of, and right to recover water injected into an aquifer as part of an ASR project. The continued debate in the halls of the Texas Capitol and multiple courthouses around the state regarding (i) the ownership of groundwater beneath the surface of the property, (ii) the landowner's rights to develop and control that groundwater *in situ*, including the right to sell and/or lease the groundwater estate, (iii) the "Rule of Capture," and (iv) the regulatory authority of groundwater districts add an extra layer of uncertainty to the process.

Water utilities in Texas that include groundwater resources in their water supply inventories historically have relied frequently upon the Rule of Capture to facilitate the development and production of those groundwater resources. Specifically, rather than acquire either large surface land holdings and the rights to the groundwater beneath the same, or the rights to large portions of the groundwater estate, water utilities have acquired the rights, whether by fee title or leasehold, to smaller tracts of land of sufficient size to facilitate the drilling and operation (as well as maintenance) of a groundwater production well(s) and the requisite 150 foot radius sanitary control easement.[380] Where necessary, the size of the tract(s) acquired for the groundwater well(s) has been large enough to accommodate other utility facilities, *e.g.*, storage tanks, treatment and purification systems, pump stations and pipeline right of way and related access.

From these small tracts, customarily less than ten (10) surface acres in size, the utilities have relied upon the Rule of Capture to pump vast quantities of groundwater being drained potentially from their ten (10) acre tract and the hundreds, if not thousands, of surrounding acres. Again, as a cost savings benefit to the affected utilities and their respective customers, the water produced from beneath neighboring landowners' tracts by the utility's well(s) has been at zero additional cost to the utility above and beyond the utility's production and treatment costs.

Accordingly, the concept of acquiring large tracts of land for purposes of acquiring, or at least giving some control over the groundwater beneath the surface of that property is a foreign concept. The need for control of larger tracts, and the development of a legal and regulatory framework will aid in the development of ASR in Texas to the benefit of (i) the entity developing the project, (ii) the neighboring landowner(s), and (iii) any groundwater district(s) with regulatory jurisdiction over the aquifer(s) impacted by the project.

Under current law, particularly in areas without a groundwater district in place and, possibly where one is in place but does not regulate ASR projects and/or the water stored in them, ASR projects are "at risk." Specifically, an ASR project is "at risk" to the extent that the water the utility injects into the aquifer(s) for storage may be accessed and produced by a third party that has either a well drilled directly into some portion of the aquifer where the water is stored or a well that is drilled into the aquifer that is capable of draining the stored water. In the absence of a regulatory process implemented by a groundwater district to regulate groundwater production to protect the "stored" water in the ASR project, that stored water is subject to being lawfully produced by a third party exercising its right to use the water produced from a well on his property for beneficial purposes in a non-wasteful, non-negligent or non-malevolent manner pursuant to the Rule of Capture.[381]

All three of Texas' currently operational ASR projects[382] are operating "at risk" with respect to one or more of these issues. Each of the ASR projects has taken steps to minimize those risks, however, in a manner in which their respective management has concluded is reasonably prudent to minimize the threat of significant loss of stored water due to third-party production. To date the three ASR projects have been able to recover their ASR water when they need it without any identified loss due to third party interference.

The El Paso FHWRP Project is protected by the depth to which water is injected for storage and subsequently recovered through production. The substantial costs associated with drilling a large production well into the portions of the Hueco Bolson Aquifer utilized in the FHWRP Project serve as a strong detriment to any third-party production of the project's injected water.

Similarly, the Kerrville ASR Project relies upon the deeper Hosston-Sligo formation for the storage of its ASR Project water. Most of the groundwater production in the Kerrville area is for agricultural, and domestic and livestock use. Those wells are in the shallower Glen-Rose and Trinity formations where the drilling and production costs are more commercially practicable for the associated use. Additionally, as the calculated transmissivities within the aquifer the stored water is injected into result in movement of water away from the injection well at a rate of less than 120 feet per year, UGRA, which developed the ASR project, felt secure due to the location of its primary injection and recovery facilities. These facilities are centrally located within the corporate limits of the City of Kerrville, a home-rule city, that has ordinances prohibiting the drilling and/or production of wells within the City limits.

The SAWS' ASR Project is somewhat differently situated. The SAWS ASR Project was developed in a rural setting in southern Bexar County, Texas, approximately 30 miles south of San Antonio. The Carrizo-Wilcox Aquifers and related groundwater formations developed for the ASR project are not regulated in Bexar County. However, those same aquifers in Atascosa County, directly to the south of Bexar County and the SAWS ASR Project, are within the regulatory jurisdiction of the Evergreen Underground Water Conservation District (the "EUWCD" or "Evergreen District"). The SAWS' ASR Project area is not within the corporate limits or extra-territorial jurisdiction of any municipal corporation. There are no regulatory constraints on the development of wells or production of groundwater in the area other than those provided by the Evergreen District.

As its first precautionary measure to protect the water it planned to inject and store beneath the surface, SAWS acquired approximately 3,200 acres of land on which to site its ASR project. This acreage provides SAWS with a buffer area in which it controls the drilling of any wells that could "tap" into the water reserves it has injected for storage and future recovery for beneficial use in the SAWS municipal water system. This feature of the SAWS' ASR Project avoided contests with the landowners regarding ownership, storage rights and/or trespass issues associated with the development and operation of the ASR Project.

Proximate to the SAWS' ASR Project site, the Bexar Metropolitan Water District ("BexarMet"), including customers in Bexar and surrounding counties, announced plans to develop a major well field within a mile of the SAWS ASR Project. BexarMet is the second largest municipal retail water utility operation in the San Antonio metropolitan area. As announced, the BexarMet well field would have had the potential capability to pump water stored in the SAWS' ASR Project.[383]

Among the specific legal questions frequently raised by entities interested in potential ASR development are the following:

1) Assuming the surface owner owns the native groundwater beneath his property, who owns water (irrespective of its source as groundwater or surface water) once it is injected for storage in an ASR project?
2) What is the "legal character" of water injected for storage in an ASR project (irrespective of its source as groundwater or surface water)?
3) Does the movement of water injected for storage in an ASR project beyond the boundaries of the surface of the property owned and/or controlled by the ASR project operation constitute an actionable "trespass?"
4) Can groundwater districts lawfully charge or assess some form of a "toll" in the form of a cap on the percentage amount of the water stored in the ASR project as a condition to grant an ASR and/or Recovery Permit to the ASR operator?
5) What obligations, if any, does a groundwater district have to protect the water injected for storage in an ASR project from being produced by a third party?

Current Texas law does not necessarily address any of these issues expressly. There is, however, some limited appellate case law from which answers can be extrapolated and recommendations formulated. Similarly, statutory, regulatory and/or judicial decisions related to analogous substances, *e.g.*, oil and gas, provide a basis for analyzing the issues, and providing answers and/or recommendations. Unfortunately, the interrelationships between the multiple issues make it difficult to provide direct, separate and discrete answers to the questions posed. Responses to each issue, however, are interwoven in the following analysis.

The issues of ownership of surface water after it had been injected for storage in an ASR project, and its legal character as surface water or groundwater subject to the "Rule of Capture" were addressed by the Austin Court of Appeals in a challenge to the water rights permit issued to the Upper Guadalupe River Authority ("UGRA"). That Permit authorized the diversion of water for municipal use including the right to store the diverted water using ASR technology (the "UGRA case").[384] In the UGRA case, the TCEQ's predecessor agency, the Texas Natural Resource Conservation Commission, had granted UGRA a Section 11.121[385] water rights permit that included an ASR "storage component" in the absence of any express statutory language regarding ASR.[386] The Austin Court agreed with UGRA and TNRCC's position that (i) the "beneficial purpose" for which the water right had been granted was "municipal use," rather than ASR storage, and (ii) the storage in the ASR project for subsequent recovery and beneficial use for municipal purposes as authorized by Texas law.[387]

Alternatively, the Court could have relied upon the "other beneficial purposes" language in Section 11.023(b),[388] to uphold the permit. The Texas Legislature subsequently amended the Water Code to allow the surface water to be stored in an ASR project.[389] That legislation provides limited guidance with respect to the handling of the injected surface water if the ASR project is located within the jurisdiction of a groundwater district by imposing certain obligations on the ASR permit applicant to work with the affected groundwater district.[390]

According to co-author David Pyne, ASR experience in other states has generally been consistent on this issue. If a water utility or other owner has perfected the right to store water underground, it also has gained the right to recover the water that has been stored.

Claims for damages to groundwater resulting from operations affecting groundwater can generally be put into one of two categories: (1) too much pumping of groundwater on one tract which impairs a neighbor's ability to pump groundwater from beneath an adjacent or nearby tract; and/or (2) there is some activity occurring on an adjoining or nearby tract that causes groundwater-related harm of some type to a neighboring property. In the absence of some violation of an applicable lawful rule or regulation of a groundwater district with jurisdiction over the pumping in question (*e.g.*, pumping with a permit, pumping in violation of permit condition or limitation, violation of a spacing or allowable rule), the first claim of damages is covered by the "Rule of Capture" limiting if not shielding the pumping landowner from liability.[391] The second category of complaints generally have something to do with damages based upon alleged changes in water quality or, as in the case of the *Friendswood Development Company* case, *supra,*[392] subsidence of properties in the vicinity of where the water had been pumped.

Historically, Texas Courts have held that for there to be a "trespass" resulting from a contaminant present in groundwater, there must be physical entry upon the adjoining land by some "thing."[393] Not all "things" crossing property lines in the subsurface constitute a trespass or give rise to damages claims. For example, Texas courts have created exceptions from liability for waterflood operations authorized by the Texas Railroad Commission,[394] subsurface fracturing of a natural gas well even if the fractures migrate to an adjoining property,[395] and disposal of waste authorized by TCEQ.[396]

In *Taco Cabana, Inc. v. Exxon Corporation,*[397] the San Antonio Court of Appeals noted that "Exxon is not required to remove and dispose of soil or water which *may exceed* state action limits."[398] The Court reasoned that to "… the extent that any common law duties regarding removal of contamination existed, such duties have been displaced by the Water Code and implementing administrative regulations because the Legislature has delegated to the TWC [a predecessor to TCEQ] the task of determining appropriate cleanup standards."[399]

Taco Cabana had sued Exxon for remediation of a gasoline station site when Taco Cabana noted a strong odor of hydrocarbons during construction of its restaurant.[400] The site had been owned by Exxon and used as a gasoline station. Following closure of the station Exxon had caused the gasoline tanks to be removed and addressed some noted subsurface contamination at the site through appropriate procedures of the agency delegated jurisdiction by the Legislature, *i.e.*, the former Texas Natural Resource Conservation Commission - predecessor to Texas Commission on Environmental Quality ("TCEQ").[401]

The San Antonio Court expanded on its rationale in *Taco Cabana, supra*, six years later in *Ronald Holland's A-Plus Transmission & Automotive, Inc. v. E-Z Mart Stores, Inc.*[402] The Court's ruling in the *E-Z Mart* case was, in effect, that unless the regulatory action levels applicable to the contaminants detected were exceeded, there was no cause of action.[403] The San Antonio Court emphasized that only "unreasonable" contamination on land, meaning "levels which exceed state action levels" would establish a trespass cause of action.[404]

These opinions are consistent with other decisions stating that when actions, such as subsurface disposal or injection, are authorized by Railroad Commission or TCEQ permits, even if substances move across property lines there is no harm to the adjoining property owner and, hence, no liability. Given that the substance or thing that might migrate on to a neighboring property as a result of injection in an ASR project is water which must be of quality that will not degrade the quality of the native groundwater and reduce the beneficial uses of the native groundwater and will be injected pursuant to authorization by the TCEQ and possibly a groundwater district, there should be no basis for a cause of action for damages for trespass based upon injury or harm to the water quality.

In October 2009, the Beaumont Court of Appeals affirmed the trial court's decision denying injunctive relief to a landowner asserting causes of action, including one for trespass resulting from subsurface injection pursuant to an underground injection well permit issued by the Texas Commission on Environmental Quality authorizing deep well subsurface disposal of nonhazardous wastewater on neighboring tracts of land.[405] The lawsuit arose as a result of alleged migration of the injected wastewater plume underneath the plaintiff FPL Framing, Ltd.'s property. Relying heavily upon the Supreme Court's decisions in *Manziel, supra,* and *Garza,* *supra,* the Beaumont Court upheld the judgment from the district court concluding that "under the common law, when a state agency has authorized deep subsurface injections, no trespass occurs when fluids that were injected at deep levels are then alleged to have later migrated at those deep levels into the deep subsurface of nearby tracts."[406]

The Texas Supreme Court has granted the Petition for Review in the case and scheduled oral arguments.[407] Although the case involves a Class I injection well, rather than a Class V injection well as is involved in an ASR Project, the issues upon which the Supreme Court granted the petition for review enumerated below merit attention:

> (1) whether a permit-holder with authority to inject wastewater underground can be immune from liability when the wastewater intrudes beneath neighboring property and, if so,
>
> (2) whether that trespass sanctioned by a state regulatory agency constitutes an unconstitutional taking.

According to the notice published by the Supreme Court regarding the decision to grant the Petition for Review, a "turning-point issue [in the case] is whether subsurface [waste]water migration can be actionable as a trespass."[408]

In terms of a nuisance claims, Texas courts have recognized three possible types of actions that would result in a nuisance:[409] a physical harm to property based upon an encroachment of a damaging substance (*e.g.*, damaging quantities of damaging substances), physical harm to a person or his or her property (*e.g.*, an assault on senses or by other personal injury), and emotional harm from deprivation of enjoyment of property.[410]

In Texas, long-standing decisions hold that the mere fact that something is present on another property, without more, cannot create a claim for nuisance.[411] The last of those three, emotional harm alone as a basis for nuisance claims, has been disallowed in recent cases.[412]

The issue of the "character" of water, *i.e.*, whether it is surface water or groundwater as discussed, *supra*, affects both the ownership of the water, as well as what set of laws govern or regulate it.[413] For example, groundwater emerging from an aquifer at a spring outlet that enters into a water course becomes surface water.[414] Rainfall that percolates through the surface strata infiltrating an aquifer becomes groundwater.

ASR technology adds another layer of complexity to the issue. For example, does surface water diverted pursuant to a Section 11.121 permit[415] and injected into an aquifer for storage lose its character as State-owned water and become groundwater owned by the owner of the overlying land and subject to the Rule of Capture? The Austin Court of Appeals addressed this issue in *Texas River Protection Association v. Texas Natural Resource Conservation Commission, supra*.[416] The Court rejected the protestants' argument that the permit was invalid because the injected surface water lost its character and became privately owned groundwater subject to the Rule of Capture.[417] In reaching its conclusion the Court provided the following rationale:

> The gravamen of appellants' argument is that water cannot be put to beneficial municipal use, as a matter of law, if it has become groundwater subject to the rule

> of capture. As a general rule, the Code gives the state the right to exclude others from using surface water, while groundwater is subject to capture by private landowners. See Code §§ 11.021, 52.002. However, the right to exclude other users is not the legal touchstone of a diversion permit. The Code provides that a permit is properly granted if "the proposed appropriation contemplates the application of water to any beneficial use...." Code § 11.134(b)(3)(A); see also Code § 11.023(b) (providing that state water may be appropriated, diverted, or stored for any beneficial use). Thus, beneficial use is the yardstick by which to measure the legality of a permit. Even if the state stores water in a manner that negates its right to exclude private takers, a permit will stand if the water is actually put to a beneficial use. The characterization of stored water as groundwater subject to the rule of capture does not invalidate a permit as a matter of law. Appellants have failed to show, as a factual matter from the record, that the aquifer storage plan authorized by permit 5394 will prevent beneficial use of the water. Therefore, we hold that the ASR plan does not invalidate this permit. We overrule appellants' second point of error.[418]

The Court went on to reject protestants' other arguments regarding the fact that UGRA and TCEQ could not insure that UGRA would be recovering exactly the same water it had injected.[419] In dismissing the argument, the Court held that water is a "fungible commodity."[420] Accordingly, UGRA was not required to extract from the aquifer the very same water molecules that it injected into the aquifer.[421] The relevant legal requirement in the Court's opinion was that the water be put to a beneficial use.[422] That conclusion dictated that the ASR project allow for the quantity of water put into the aquifer be recoverable and capable of being put to beneficial use.[423]

Although not expressly articulated, part of the Austin Court's rationale in upholding the validity of UGRA's permit was UGRA's ability to control the water it injected for storage in the ASR project and its ability thereafter to recover the same.[424] The theme of controlling the water at issue was again a pivotal concern to the Court in the *San Marcos v TCEQ, supra*, decision.[425] In that case the City of San Marcos sought to convey its privately owned groundwater from its wastewater treatment plant to a downstream diversion point where the City proposed to recover the effluent and treat it as part of its municipal water supply.[426] Distinguishing its earlier decisions in *Texas River Protection Association v. Texas Natural Resource Conservation Commission*, *supra*,[427] and *Dennis v. Kickapoo Land Co., supra*,[428] the Austin Court held (i) that the City's treated effluent when discharged into the river for transport was "foreign" to, and "not fungible" with, the ordinary flows of the river,[429] and (ii) that the City's act of discharging the effluent into the river despite its expression of intent to recover an equal amount downstream was tantamount to voluntarily abandonment of its control over the effluent thereby causing the City to lose its claim to any rights in the same.[430]

Groundwater, once severed and produced at the well head, and reduced to possession becomes "personal property."[431] In *City of Altus, Okla. v. Carr*,[432] the Federal District Court for the Western District of Texas recognized that a landowner's right to appropriate the groundwater beneath his property was an interest in real property.[433] As "personalty" once produced, the question comes up as to what the character of the groundwater will be if it is re-injected into the ground for storage in an aquifer using ASR. Relying upon the rationale of the Austin Court of

Appeals in the UGRA ASR permit case,[434] that "beneficial use is the yardstick by which to measure the legality of a permit," it should not matter with respect to an ASR operator's ability to recovery the groundwater stored in the ASR project.[435] The issues are (i) how much water the ASR operator should be allowed to recover as a percentage of the injected groundwater or, inversely, how much groundwater the ASR operator should be required to leave in the aquifer, and (ii) whether and how a groundwater district with jurisdiction over an aquifer with an ASR project in it should be required to protect the injected water stored in the ASR project. Current Texas law does not address either issue. According to co-author David Pyne, other states have enacted a variety of approaches to this issue, ranging from full recovery of the stored water allowed in most states, to 10% left in the aquifer in at least one state. Restrictions upon full recovery are typically associated with areas having a long history of groundwater level declines, causing excessive drawdowns, subsidence and/or water quality deterioration. Another separate issue, which is partially addressed vis-à-vis the use of surface water as a source supply for the ASR project, is what "self-help" steps the ASR operator should be required to take to protect his ASR project.[436]

By analogy, we can look at how Texas law treats the storage of another natural resource in underground reservoirs – natural gas. In 1962, the Dallas Court of Appeals considered the issue of whether title to natural gas, once having been reduced to possession, is lost by the injection of such gas into a natural underground reservoir for storage purposes."[437]

In *Lone Star Gas Co. v. Murchison,*[438] the court began its analysis with the proposition that "there can be no doubt that gas which has been produced is personal property."[439] The court also expressed the position that an owner of personalty "does not lose title thereto by not having the property on his person or on his land unless there is abandonment, and abandonment requires an intent to abandon".[440] Based upon the facts presented, the Court concluded that "[l]ogic and reason dictates . . . that in Texas, the owner of gas does not lose title thereof by storing the same in a well-defined underground reservoir."[441]

A decade later in *Humble Oil & Refining Co. v. West*,[442] the Texas Supreme Court considered the character of title and ownership of natural gas which had been produced and then re-injected into an underground formation for storage purposes and to maintain the integrity of a depleted reservoir from water intrusion.[443] The Wests had conveyed fee title to the surface of the property and the minerals to Humble Oil, subject to a retained royalty.[444] Following Humble's decision to preserve the underground reservoir and store gas in it, West's claimed an entitlement to a royalty on the injected gas when it was subsequently recovered.[445]

The Supreme Court held, as the Dallas Court had in the *Lone Star Gas Co., supra,* case,[446] that the injected gas did not lose is character as "personal property" because of its re-injection to a formation for storage.[447] In concluding that Humble Oil's ownership of the injected gas was not transformed either as a result of its injection for storage or its subsequent recovery,[448] the Court also affirmed the Dallas Court of Appeal's earlier decision in *Lone Star Gas, supra,*[449] rejecting adoption in Texas of the doctrine of *mineral ferae naturae*.[450]

The decision in *Humble Oil, supra,* is also useful and illustrative on another issue in the ASR project arena – "commingling."[451] A theory of recovery urged by West was that Humble Oil's commingling of the produced gas with the native gas has resulted in a "confusion of goods" which required Humble Oil forfeit its interest in its property that it could not clearly identify has having been injected.[452] The Court rejected West's argument holding that while Humble Oil's commingling of the homogeneous gases with different ownership interests placed the burden on Humble Oil, since the mixture was homogeneous, if Humble Oil could establish the "aliquot share" of the mixture of each party, that given the similar nature and value of the commingled goods Humble would not forfeit its interest.[453] According to the Court, "[t]he threshold question for determination is whether the requisite computation of reserves is capable of establishment with reasonable certainty, … ."[454] The case was remanded to the trial court to determine, *inter alia*, whether Humble Oil could satisfy its burden with respect to establishing the parties respective "aliquot shares."[455]

In 1977, the Texas Legislature addressed the issue of subsurface storage of natural gas through the enactment of the Underground Natural Gas Storage and Conservation Act.[456] The Act was adopted in recognition of the fact that the "underground storage of natural gas promotes the conservation of natural gas, permits the building of reserves for orderly withdrawal in periods of peak demand, makes more readily available natural gas resources to residential, commercial, and industrial customers of this state, provides a better year-round market to the various gas fields, and promotes the public interest and welfare of this state."[457]

Pursuant to the Act gas producers can obtain an order from the Texas Railroad Commission authorizing them to pursue eminent domain proceedings to condemn subsurface storage facilities.[458] The Act prescribes procedures and requirements for the condemnation of subsurface formations for natural gas storage.[459]

Accordingly, in the event the gas producer is unable to negotiate a lease to store the natural gas post-production at the wellhead, the Act provides an option for storage of the gas that retains the ownership in the producer consistent with the Supreme Court's holding in *Humble Oil*. The Act provides as follows: "All natural gas in the stratum condemned which is not native gas, and which is subsequently injected into storage facilities is personal property and is the property of the injector or its assigns, and in no event is the gas subject to the right of the owner of the surface of the land or of any mineral or royalty owner's interest under which the storage facilities lie, or of any person other than the injector to produce, take, reduce to possession, either by means of the law of capture or otherwise, waste, or otherwise interfere with or exercise any control over a storage facility."[460]

To the extent that ASR Project owners seek to cause or allow injected groundwater to be stored beneath the property of third-parties and maintain it in storage to the exclusion of all others, including the surface owner, the issue of protecting the stored water from appropriation by third parties is present. ASR operators can negotiate leases for the storage rights from the surface owner and restrict protection of groundwater from the surface of the property. The local groundwater conservation district(s) with jurisdiction over the ASR Project may be able to provide some protection through district rules and permitting practices. ASR Project operators, however, may or may not have the power of eminent domain. Unlike the Underground Natural Gas Storage and Conservation Act, there is no comparable statutory program to allow an ASR Operator to protect the stored water by condemning property for the subsurface storage of water, unless the Operator has some other source of eminent domain power based upon its status as governmental entity or quasi-governmental entity, *e.g.*, municipalities, water districts and river authorities, and/or non-profit water supply corporations.

5.5 "Reuse" - Taking ASR to the Next Level in Water Resource Development in Texas

A. <u>Background</u>

As the population of Texas continues to mushroom, water managers must develop and implement strategies to increase, enhance and, whenever possible, renew and/or extend the "usability" of Texas' limited surface and groundwater resources.[461] The "reuse" of the available water resources is one of several non-traditional strategies available to meet both existing and growing water demands.[462] If ASR represents an example of an innovative water development strategy, then coupling "reuse" and ASR is a very viable innovative tool for the "re-development" of our finite water resources. Of the 14 prescribed strategies considered by regional planning groups in the SB 1 State Water Planning process, the development and increased reliance on "reuse" of treated wastewater was included as a key management strategy in 10 of the 16 regional plans.[463]

Nationwide "reclaimed ASR" is the fastest growing new application of ASR technology. with several operational reclaimed ASR wellfields in Arizona and Florida storing reclaimed water and additional reclaimed ASR wellfields are in the planning or development stages in California and South Carolina. These projects are in addition to the long-established project at El Paso, Texas.

In Texas, wet weather reuse supplies greatly surpass demands where irrigation is the primary reuse water demand. Accordingly, seasonal declines in irrigation demands result in significant releases of this valuable resource. In less temperate parts of the United States, the potential loss of the resource is magnified by the shorter growing season. ASR can provide an environmentally sound, and economically viable means of large-volume storage of reuse water during periods of excess supply for recovery to meet both normal and peak demands during drier periods. Development of treated effluent based ASR projects can achieve full reuse of the treated effluent, regardless of seasonal demand fluctuations.

B. <u>Texas Regulatory Framework for Storage of Reclaimed Water</u>

(1) <u>Introduction.</u>

No specific regulatory provisions or criteria currently exist for the storage of water not meeting drinking water standards within or above an underground source of drinking water ("USDW").[464] The Commission's rule on "operating requirements" for ASR wells, however, has a specific water quality requirement:

The quality of water to be injected must meet the quality criteria prescribed by the commission's drinking water standards as provided in Chapter 290 of this title (relating to Water Hygiene).[465]

The standard adopted by the Commission for ASR projects is <u>not</u> specifically mandated by the provisions related to ASR in Chapter 11 of the Water Code.[466] Specifically, Chapter 11 only prescribes that the Commission consider whether the injection of the water will affect the native groundwater in a way that will cause its subsequent use to be harmful or detrimental, or require it to be treated to a higher degree than would be required for use of the native groundwater.[467]

(2) Chapter 210 (30 TAC).

Unless authorized by an individual wastewater discharge permit issued pursuant to Chapter 26, Texas Water Code, and Chapters 285 and 305 of the Commission's regulations (30 TAC), use of "reclaimed" or "reuse" water in Texas is governed by Chapter 210 of the Commission's regulations (30 TAC). Chapter 210 prescribes the general requirements for the use of reuse water, as well as quality criteria, and design and operational requirements for the beneficial use of reclaimed water.[468] Authorization to use reclaimed or reuse water pursuant to Chapter 210, however, does not provide a substitute for a discharge permit issued under Chapter 305 if a discharge into the waters of the State is contemplated.[469]

Prior to providing the reclaimed water to a third party, the producer must provide written notice to the Commission's Executive Director and receive written approval.[470] The Commission has not developed a standardized form or application form for the "notice." Instead, an applicant should provide the information prescribed in Section 210.4 entitled "Notification." The "notice" must include the following:

(1) description of the intended use, including quantity, quality, origin, end-use location;

(2) documentation of compliance with Chapter 210 requirements by both the producer and user, *e.g.*, copy of the contract/agreement apprising the user of its responsibilities;

(3) documentation of producer's authority to terminate delivery to user for non-compliance; and

(4) documentation of an operation and maintenance plan that, at a minimum, requires:

- a. pipeline labeling and separation plan to prevent "cross-connection" between potable/non-potable water lines;
- b. measures to prevent unauthorized access to reclaimed water facilities;
- c. procedures to monitor transfer and use of reclaimed water;
- d. steps for user to minimize risk of "inadvertent" human exposure;
- e. routine maintenance schedule;
- f. employee training and safety by provider; and
- g. a "contingency plan" for system failures, unauthorized discharges or upsets.[471]

If the "provider" of the reclaimed water is not the "producer," however, the notice must include a copy of an agreement with the producer authorizing the transfer and identifying the origin.[472] If the producer intends to use the reclaimed water within the boundaries of a wastewater facility permitted by the Commission, no notice is required.[473] However, the producer must otherwise comply with the Chapter 210 requirements.

A new notice must be filed and approval obtained if there are any "major changes" in the use of the reclaimed water after the required notice and approval have been completed.[474] Major changes include such things as the location of use, the type of use, and the addition of new producers. Prior to using reclaimed water within the Edwards Aquifer recharge zone, the project must be approved pursuant to Chapter 213, in addition to Chapter 210, of the Commission's rules.[475]

The "producer," "provider" and "user" of the reuse water all have specific minimum "responsibilities" specified in Chapter 210:[476]

1. **Producer**:
   (a) treatment to minimum quality standards;[477]
   (b) sample and analyze water and file reports;[478] and
   (c) notify Executive Director (in writing within 5 days) of unauthorized use of reclaimed water.[479]
2. **Provider**:
   (a) assure proper construction of distribution lines;[480]
   (b) transfer water of "at least" minimum quality at delivery point;[481] and
   (c) notify Executive Director of unauthorized use.[482]
3. **User**:
   (a) comply with Chapter 210;[483] and
   (b) maintain records and file reports.[484]

To insure its "beneficial use," and avoid potential and/or actual unlawful and/or harmful discharges into "waters of the state," reclaimed water can only be supplied on a "demand basis."[485] Accordingly, the user has the right to refuse delivery at any time.[486] As a result, any plan for using reclaimed water should have an adequate "storage" component. Notwithstanding the "demand" condition prescribed by Section 210.7, however, the user must comply with the terms of an otherwise lawful agreement related to the reclaimed water, *e.g.*, the user may be subject to contractual obligations that protect the producer, such as take or pay provisions, providing adequate user facility storage.[487]

Treated wastewater eligible for use as "reclaimed water" is categorized in Chapter 210 as "Type I" and "Type II" reclaimed water.[488] Type I reclaimed water can be used for the following purposes:

(1) residential irrigation;

(2) irrigation of public parks, golf course, school yards and athletic fields;

(3) fire protection (hydrants and building sprinkler systems);

(4) irrigation of food crops, including contact with edible part of the crop, unless the crop will undergo a pasteurization process;

(5) pasture irrigation for "milking animals;"

(6) maintaining water levels in ponds, reservoirs, etc.; and

(7) toilet flushing.[489]

Type II reclaimed water use is more restrictive, requiring that public access and the likelihood of human exposure be limited. Type II reclaimed water use is authorized for the following purposes:

(1) irrigation of "remote" sites;

(2) irrigation of sites bordered by walls/fences and access is controlled by the site owner/operator;

(3) irrigation of public access areas if public access restricted/limited during irrigation, *e.g.*, golf course at night, cemeteries;

(4) irrigation of crops <u>if</u> reclaimed water not likely to have direct contact with edible part of crop;

(5) irrigation of animal feed crops – other than pastures for milking animals;

(6) water impoundments where direct human contact unlikely;

(7) soil compaction or dust control at construction sites;

(8) cooling tower makeup water; and

(9) irrigation and other non-potable uses at a wastewater facility.[490]

Adequately treated reclaimed water can be made available for groundwater recharge, as well as aquifer storage and recovery projects, with the recharged reclaimed water becoming available for both potable and non-potable water purposes. The current major issue to be addressed in Texas is the level of treatment that will be required prior to injection and storage. As discussed herein, the practice of supplementing municipal water supplies with reclaimed water is already utilized by the City of El Paso, Texas.[491]

ASR is a proven water resource technology in Texas. Expansion of the technology as part of potable water supply systems throughout the State is feasible, and a logical next step to maximizing the benefits of the technology is to incorporate ASR into the development of "reuse" water as a significant water supply for the future.

The use of reclaimed water as a source for injection into an ASR well can provide an important element of reliability as the source stream is available year round irrespective of seasonal dry spells or low flow conditions. Moreover, as water demands on the system continue to increase and new users are added, incorporation of a reuse supplied ASR system will continue to provide an important function, allowing the affected utility to know that sufficient dry season supply will be available to meet future demands.

Reuse ASR has proven itself to be a valuable water resource tool. Texas should explore creation of a pilot program for implementation of reuse ASR and amend, as necessary, Chapters 210 and 331 of the Commission's regulations to facilitate the program. In particular, consideration should be given to the relaxation of treatment standards for injection and storage into lesser quality aquifers. Florida has adopted a revised UIC program with a "graduated" criteria that could provide a workable model for Texas to follow. Texas should consider regulations that facilitate the use of basins where conditions are favorable.

Florida adopted revisions to its regulation of reusing treated effluent in 1999. ASR regulations were developed during that process authorizing the storage and recovery of reclaimed water.[492] These regulations provided a regulatory framework for Florida utilities to follow in implementing the incorporation of treated effluent as a supply source for ASR programs. While most of the regulations are already covered under the federal and state Underground Injection Control (UIC) programs, one of the key elements that separated Florida's guidelines pertains to the level of treatment of the effluent required prior to injection and storage using ASR.

Florida's regulations prescribe different water quality standards for injection into aquifers depending on the quality criteria of the receiving zone.[493] In general, the following water quality parameters must be met in these different receiving zones:

Classification	**Designated Uses**
CLASS F-I	Potable water use, groundwater in a single source aquifer described in Rule 62-520.460, F.A.C. which has a total dissolved solids content of less than 3,000 mg/l and was specifically reclassified as Class F-I by the Commission.
CLASS G-I	Potable water use, groundwater in single source aquifers which has a total dissolved solids content of less than 3,000 mg/l.
CLASS G-II	Potable water use, groundwater in aquifers which has a total dissolved solids content of less than 10,000 mg/l, unless otherwise classified by the Commission.
CLASS G-III	Non-potable water use, groundwater in unconfined aquifers which has a total dissolved solids content of 10,000 mg/l or greater; or which has total dissolved solids of 3,000-10,000 mg/l and either has been reclassified by the Commission as having no reasonable potential as a future source of drinking water, or has been designated by the Department as an exempted aquifer pursuant to Rule 62-528.300(3), F.A.C.
CLASS G-IV	Non-potable water use, groundwater in confined aquifers which has a total dissolved solids content of 10,000 mg/l or greater.[494]

According to the Florida Administrative Code, "groundwater quality classifications are arranged in order of the degree of protection required. Class G-I groundwater generally has the most stringent water quality criteria and Class G-IV the least."[495] Florida's rules also specify the water quality criteria corresponding to each groundwater classification.[496]

Classification	General Water Quality Criteria
CLASS F-I	The water quality standards in Rules 62-520.400 and 62-520.420, applicable to Class G-I and Class G-II groundwater apply to Class F-I.[497] The permitting and monitoring requirements of Rules 62-522.200, 62-522.300, 62-522.500, 62-522.600, and 62-522.700, and the zones of discharge prohibitions and dimensions in Rule 62-520.461, F.A.C., are applicable to Class F-I groundwater.[498]
CLASS G-I	In addition to the minimum criteria provided in Rule 62-520.400, F.A.C., groundwater shall meet the primary and secondary drinking water quality standards for public water systems.[499]
CLASS G-II	Same as G-I.[500]
CLASS G-III	The minimum criteria provided in Rule 62-520.400, F.A.C.[501]
CLASS G-IV	No minimum criteria is specified. Applicable standards are determined on a case-by-case basis.[502]

Successful storage of both potable and reclaimed water during wet weather periods for use during peak dry weather conditions could extend significantly Texas' finite water resources.

Florida's example of groundwater use classification in various aquifers and associated criteria restrictions is consistent with the principle of "nondegradation" of native groundwater quality. Such restrictions prevent the impairment of the customary uses of the native groundwater.[503] The above quoted Florida regulations provide a quantitative example Texas may want to consider for incorporation into its comparable ASR regulatory schemes.[504]

5.6 Summary & Recommendations

In 1995, when it enacted HB 1989[505] creating the first express statutory authorization to store appropriated State-owned surface water using ASR technology for subsequent recovery and beneficial use, the Legislature made the following "Findings":

The legislature finds that:

> (1) the underground storage of appropriated water, incidental to a beneficial use, is a beneficial use of water;
>
> (2) the use of aquifers for storage of appropriated water:
>
> (A) enhances the conservation and protection of appropriated water by minimizing seepage and evaporation losses;
>
> (B) reduces the incidental environmental impacts associated with the construction of conventional water storage facilities such as aboveground reservoirs; and

> (C) enhances and protects groundwater resources;
>
> (3) the underground storage of appropriated water maximizes the conservation and beneficial use of water resources;
>
> (4) the storage of appropriated water in aquifers recognizes existing property rights, including the rights of a landowner in groundwater;
>
> (5) the storage of appropriated water in aquifers recognizes the authority and jurisdiction of an underground water conservation district;
>
> (6) the use of aquifers for storage of appropriated water may reduce a portion of the economic burden on taxpayers and utility ratepayers associated with the construction of conventional water storage facilities;
>
> (7) the successful storage of appropriated water underground has been demonstrated in Kerr County by the Upper Guadalupe River Authority in the Hosston-Sligo Aquifer; and
>
> (8) the Texas Natural Resource Conservation Commission and the Texas Water Development Board are encouraged to evaluate additional aquifers within the state to identify the potential for storage of appropriated water underground to maximize and enhance the future availability and beneficial use of the water resources of the state.[506]

ASR has a solid regulatory and legal foundation in Texas. There is, however, substantial room for improvement/enhancement of the rules and statutes both at the state and local levels.

As evidenced by the discussion above, *supra*, Texas' regulatory program for Class V ASR Wells is well developed.[507] As the Class V injection well program is part of the State's federally delegated underground injection control (UIC) program, there is little room for modification of the applicable rules if Texas is to retain its delegated authority. Technological advances and/or Texas-centric hydrogeologic characteristics, however, may warrant state regulators to seek to initiate changes that facilitate the development of new advances in our Class V Well program to encourage ASR implementation. This is particularly true with respect to possible enhanced use of non-potable water as the supply source for ASR storage. Even without modification, however, Texas ASR Class V Well regulations are both workable and reasonably user-friendly to ASR development.

Texas' current regulations and statutes, both statewide and local, however, do not readily facilitate the maximum beneficial use of either groundwater or surface water for ASR. The shortfalls are not just reflective of the regulations/statutes governing the water supply source, but the ability to protect the water once it has been injected for storage. This inability to protect the stored water with certainty reduces/compromises many of the benefits and, as a result, the economics of ASR utilization. Ironically, the "threats" to the stored water that require protection are from both other persons with access to the stored waters, as well as the entities with regulatory jurisdiction over it.

Even before the Legislature adopted statutory provisions expressly authorizing the use of State-owned surface water for ASR projects,[508] Texas Courts recognized the validity of authorizing the storage of water permitted for beneficial use using ASR technology.[509] Amendments to Texas Water Code Chapter 11, and Chapters 295 and 297 of the TCEQ's regulations (30 TAC) have reinforced and clarified the ability to utilize ASR technology for the "storage component" of a surface water permit. Further guidance from the Legislature is necessary, both to encourage the TCEQ to expand the recognized ability to utilize ASR to store surface water and to minimize, if not eliminate, the threat of litigation over any permitting innovations relying upon state owned surface water.

Current Texas law facilitates the use of ASR as a storage alternative in connection with perpetual and/or long-term term permits, *e.g.*, permits with terms of at least twenty (20) years.[510] Modifications to Texas law related to surface water permits could enhance the utilization of ASR technology as a cost effective, as well as environmentally sensitive, alternative for storing appropriated state water. Because ASR storage is possible whenever water is available, there are opportunities for successful projects, even in portions of the State where rivers and streams are now fully appropriated.

Given the time and cost associated with securing a water right permit and the cost to construct an ASR project (including treatment facilities and the injection well(s)), and the ability to store substantial quantities of water in relatively short periods of time and maintain the same in storage without the potential losses associated with storage in conventional reservoirs, *e.g.*, losses of substantial volume due to seepage, evaporation and/or evapotranspiration of the stored water, modification of current provisions of Chapter 11,[511] and/or Chapters 295 and 297 of the TCEQ rules[512] is warranted to provide flexibility in water rights permitting that allows ASR implementation and/or expedited permitting consideration to add ASR as a storage component to water rights permits. Two examples for consideration include seasonal and scalping permit authorizations.

Groundwater Districts need legislative guidance on how to deal with ASR projects. Chapter 11,[513] and TCEQ rules provide limited guidance, but it relates to ASR projects which use surface water as their supply source.[514] Chapter 36 provides even less specific guidance with respect to ASR projects.[515] Local groundwater districts, which the Legislature has indicated are the State's preferred form of groundwater management,[516] are very inconsistent in how they address ASR projects, assuming they even address ASR in their rules and/or management plans.[517] In many instances the reluctance stems from a fear that an ASR project may attempt to bank water to the point where the ASR operator attempts to assert that all of the water in the aquifer belongs to the ASR operator and cannot be produced by or from any other wells drilled into the affected aquifer(s).

A detailed description of some of the potential legal and regulatory options for the State to enhance ASR development are found in Section 7, *infra*.

6 Presentations

One of the requirements for this priority research is to conduct presentations, workshops and/or seminars on the study, and its findings and recommendations. The study team has been actively involved in conducting the Texas Water Development Board's *Texas Innovative Water 2010* (Advancing the Development of New Water Supplies in Texas) Seminar to be held in San Antonio on October 11-12, 2010. That seminar will include a half-day session specifically dedicated to ASR.

In addition, members of the study team have made presentations at the conferences and workshops listed below. Examples of the presentations are shown in **Appendix "D"**.

1. **Bell County Water Symposium.**

   Fred Blumberg made a presentation on ASR technology and the TWDB research project in Belton, Texas on November 12, 2009. The symposium was sponsored by the Clearwater Underground Water Conservation District.

2. **Texas Water Conservation Association.**

   Jorge Arroyo (TWDB) and Fred Blumberg made a presentation on ASR technology and the TWDB research project at the 66th Annual Convention of the TWCA. The presentation was made in San Antonio, Texas on March 4, 2010.

3. **WateReuse Symposium.**

   Dr. Caroline Russell, P.E., made a presentation on ASR technology, the TWDB research and the preliminary findings at the 25th Annual WateReuse Symposium in Washington, D.C. on September 13, 2010.

4. **Regional Water Alliance.**

   On September 15, 2010, Fred Blumberg made a presentation on regional water planning to the Regional Water Alliance administered by the San Antonio River Authority. The Regional Water Alliance is made up of 19 water utilities and cities in Bexar, Comal, Guadalupe, Hays and Wilson Counties. The presentation included a discussion of ASR and its potential as a new water supply.

5. **CLE International *Texas Water Law* Seminar.**

   This seminar was conducted in Austin, Texas on September 16-17, 2010. Fred Blumberg made a presentation entitled "Alternatives to Traditional Water Sources: Aquifer Storage and Recovery."

6. **Texas Innovative Water 2010**

   On October 11, 2010, Fred Blumberg, Ed McCarthy and Tom Morris made presentations on ASR technology, the TWDB research project and its findings and recommendations. The presentations were made as part of the TWDB's Texas Innovative Water 2010 program in San Antonio, Texas.

7. University of Texas School of Law.

On December 2-3, 2010, Fred Blumberg made a presentation on ASR technology, the TWDB research project, and the findings of the project. The presentation was made at the 2010 Texas Water Law Institute.

7 Conclusions and recommendations

7.1 Conclusions

7.1.1 National and international perspectives.

In the U.S. several hydrogeologic investigations related to aquifer storage potential were conducted by the USGS prior to 1969. In these studies drinking water was stored underground in wells and then recovered. The earliest such effort was in 1948 at Camp Peary, North Carolina. However none of those field investigations were placed into operation. The earliest known aquifer storage (and) recovery (ASR) activity in the United States was at Wilmington, Delaware, where a Dupont Corporation industrial ASR wellfield operated for many years prior to 1948. That system is no longer in service and the site has since been converted to a different land use.

The first currently-active ASR well in the United States, located at Wildwood, New Jersey, began storing drinking water underground during winter months of 1969 in order to meet summer peak demands. Since then ASR has progressed from a concept to a proven reality. As of 2009 about 95 ASR wellfields were operating in 21 of the United States. Many more ASR wellfields are in development in these and other states, aggregating more than 500 ASR wells. The largest ASR wellfield is at Las Vegas, Nevada, with 67 wells and a combined recovery capacity of 157 million gallons per day (mgd). The SAWS wellfield in San Antonio, Texas, is the third largest ASR project in the country with a well recovery capacity of 60 mgd and a current volume in storage exceeding 83,000 acre-feet.

The principal drivers for ASR have been economics, proven performance, environmental benefit and operational flexibility. ASR solutions to a wide variety of water management challenges typically can be constructed for less than half the capital cost of other alternatives and, in some cases, the cost savings have been up to about 90%. With so many wellfields in operation around the world it is increasingly clear that the technology is sound and proven.

There are many environmental benefits of ASR. The footprint of an ASR project is significantly smaller than a surface reservoir project of comparable capacity. This is because the size of the well pad is quite small and all of the storage occurs underground. Very little habitat needs to be disturbed to facilitate an ASR project. With ASR water available during periods of drought, surface water diversions during low flow periods can be reduced or eliminated and, if desired, low streamflows can be augmented.

ASR wells can be added one at a time to a water system as needed to meet steadily increasing system demands. As a result, implementation provides considerable planning and operational flexibility as compared to many other options that require significant lead time for planning, permitting, design and construction, as well as up-front capital investment (e.g. construction of dams, water treatment plants and long transmission pipelines). One of the most-recognized benefits of ASR projects over traditional surface reservoir projects, is the substantial saved water with the absence of evaporative losses in ASR well fields. Increasingly ASR is recognized as a viable means for achieving water supply reliability, sustainability and security in light of growing concerns regarding climate change, lack of new water supply sources, vulnerability to emergencies and other water management challenges.

ASR wells are storing drinking water underground in fresh, brackish and saline aquifers at depths as shallow as about 100 feet and as deep as about 2,700 feet. About one-fourth of the successful projects are storing fresh water in brackish aquifers. One international ASR wellfield is successfully storing drinking water in a seawater aquifer. Almost all of the remainder are storing water in fresh aquifers containing one or more constituents that render the ambient groundwater unsuitable for potable use without treatment. Typically such constituents might include iron, manganese, hydrogen sulfide, fluoride, radium, nitrate and/or several other elements often found in groundwater. A few ASR wellfields are storing drinking water in aquifers for which no significant difference exists between the quality of the recharge water and the quality of the ambient groundwater. For these wellfields the principal benefits of ASR are seasonal, long-term, diurnal or emergency storage, and conservation achieved by elimination of evaporative losses associated with traditional reservoir storage. For the other wellfields, the benefits include not only water storage but also the opportunity to recover drinking water instead of ambient groundwater from ASR wells. For all of these ASR projects the recharge water is treated to meet drinking water standards prior to storage. Other than simple redisinfection, the recovered water is typically not required to be treated prior to being distributed to end-users.

There are other water sources for ASR storage besides treated drinking water. In some applications untreated, or partially-treated, groundwater is transferred from one aquifer that is fresh, highly productive and/or unregulated into a different (overlying or underlying) aquifer that is brackish or contains poor quality ambient groundwater, is less productive in its recharge characteristics, and/or is regulated. Alternatively, the groundwater may be transferred intra-aquifer, i.e., from a location where an aquifer is fresh to another location where the water quality in the same aquifer is brackish. Several locations outside of Texas are taking partially-treated surface water from a river, canal or mining pit and storing it without prior treatment at the same location in a deep, brackish aquifer.

The aquifers used for ASR storage include a wide variety of lithologic settings including sand, sandstone, limestone, dolomite, glacial deposits, basalt, fractured bedrock and conglomerates. Most storage aquifers are confined or semi-confined, however several successful ASR operations utilize unconfined aquifers. Confined or semi-confined aquifers tend to be deeper and usually have relatively low groundwater velocity, favoring water storage. By comparison, unconfined aquifers tend to be shallower and have higher groundwater velocities, often allowing greater movement of the stored water away from the ASR well. This either reduces the volume of water that may be recovered, shortens the available time period between recharge and recovery, or necessitates special measures in the wellfield design and operation so that all of the stored water can be recovered.

To date approximately 26 different purposes for ASR have been identified around the world. Gaining an awareness of the variety of possible ASR applications at a particular site and then sorting out which applications are pertinent is a logical first step for any proposed ASR program. Most ASR wellfields are constructed to address a principal function plus one or more secondary objectives. For example, the principal reason might be the operator’s need to meet seasonal peaking demands, however secondary objectives might include water banking, disinfection and/or byproduct reduction, maintaining distribution system pressures during peak demand periods, thermal storage, or possibly other reasons. Careful consideration and ranking of ASR objectives provides a firm foundation for siting of an ASR project, location of ASR wells within the project, and selection of one or more storage aquifers.

In general, ASR projects have fewer adverse environmental impacts than surface storage reservoirs. The footprint of an ASR well is small, there is little or no evaporative loss of the stored water, and the injected water must be of a quality that is better than the native groundwater in the receiving storage aquifer. However, there can be potential adverse impacts that must be considered in the planning phases of an ASR project. For example, diverting, treating and storing surface water could have an impact on the flow regime of a river or stream. If that diversion is being made under the terms of an existing TCEQ permit, that authorization will normally include terms and conditions to protect the environment and downstream senior appropriators. If a new permit must be obtained, the applicant and TCEQ will conduct technical evaluations to determine the environmental impacts. Those evaluations should be performed even if the ASR project is designed to capture flood waters. While the ASR project diversion rate during a flood will normally be an insignificant percentage of the total flow, studies should confirm that the project does not change the flow regime, and affect the aquatic life and geomorphology of the stream over the long term.

There have been a few ASR failures. However, the failures can still be counted as “successes” because they provide valuable lessons that can be applied in future ASR projects to ensure that the problems are not repeated. In most cases, adequate solutions were developed to successfully resolve the challenges. Problems sometimes result from inadequate upper or lower confinement within the storage aquifer. This issue has sometimes undermined ASR success particularly for storage in brackish aquifers. Another example is the mobilization of metals, particularly arsenic, which has occurred at several ASR wellfields in Florida. However, a simple and cost-effective operational solution was developed to successfully control arsenic mobilization within the aquifer at many of these wellfields. The solution involves building up the buffer zone prior to beginning the cycle testing. Pretreatment options to control arsenic mobilization are also available, however, they tend to be more expensive.

These types of challenges have triggered substantial geochemical and microbial research and hydrogeologic modeling in connection with ASR development. These efforts are steadily improving our understanding of underground physical, geochemical and microbial processes that affect water quality and well performance, and aquifer hydraulic response to the recharge, storage and recovery operations in an ASR project. Extensive technical and scientific literature, case studies, books and other information sources are available to guide those endeavoring to develop ASR wellfields.

The principal challenges for ASR in the United States are primarily the legal and regulatory frameworks which, in many states, have not yet caught up with the application of this technology. Conservative approaches to ASR technology have aided the industry and associated research and development activity to demonstrate the safe application of ASR as a solution to water development challenges. Steady improvement is apparent. Increasingly, regulatory agencies at both the federal and state level are accepting a regulatory framework that evaluates compliance with drinking water standards in connection with ASR implementation at three locations: the wellhead prior to storage; at one or more suitably-located monitor wells during ASR storage; and at the point where the recovered water enters the distribution system during recovery.

Monitor wells associated with ASR projects are typically located where they provide the opportunity to measure the natural physical, microbial and geochemical treatment processes that are known to occur close to an ASR well (usually within a radius of a few hundred feet). Wellfield operations are conducted to achieve the best combination of water quality and quantity for the recovered water that is delivered to the end users. Increasingly the potential benefits of ASR are being seen to outweigh any potential risks to public health, native groundwater quality and/or the environment. For most states the ASR legal and regulatory framework is steadily evolving to match the state's needs, overcome the constraints and enhance opportunities.

7.1.2 Texas technical and socio-economic perspectives.

Section 3 describes in detail the three currently-operational ASR systems in Texas. The El Paso, Kerrville and San Antonio ASR projects with their diverse operational characteristics provide excellent examples of variations on successful application of ASR technology. Because each utility has elected to use a different source of supply (reclaimed water, surface water and groundwater, respectively), as well as different geologic settings, these ASR projects provide valuable information on the diverse objectives, opportunities and challenges of this technology. Going into the planning stages, each Texas organization had slightly different objectives (and challenges), but in all three case studies it was evident that ASR provided additional benefits and exceeded the utilities' expectations. It is also evident from the case studies that public acceptance and support for ASR has been excellent. This positive public perception of ASR and its benefits is a notable advantage when compared with more controversial water development project options such as construction of new surface reservoirs and/or interbasin transfers.

The challenges faced by the three ASR utilities mirror the national issues discussed briefly above. Legal and regulatory matters were more challenging, and took more time and effort than the resolution of the technical issues. It is also evident that the actual capital costs, and operations and maintenance (O&M) expenses for ASR projects are often not well understood. In some cases the ASR wellfields were developed as part of a larger project (such as treatment plant construction), and the direct ASR development and implementation related costs are inflated. For example, SAWS includes the cost of the Twin Oaks Water Treatment Facility as part of its ASR project cost, even though that treatment plant may never be needed to treat the recovered Edwards Aquifer water. Also, the actual development, financing, permitting and public involvement expenses related to the ASR portion of a project are often not separately documented. In most cases the O&M expenses are also not well documented because ASR is treated as part of the overall water utility operation. This aggregation of expenses makes it difficult to accurately portray the cost benefits of ASR, especially the advantages derived because ASR operations are primarily a marginal or incremental expense of the overall utility operations. For example, in Kerrville, the city's excess water treatment plant capacity is used to treat surface water for recharge when the city's water supply demands are low. Accordingly, the incremental costs of energy and chemicals (for treatment and recovery) are the city's only direct ASR expense. The stored water is recovered by the ASR wells when demands are high and/or water cannot be diverted for treatment under the city's surface water permits at little or no additional cost.

The utility surveys described in Section 4 document the reasons why other utilities in Texas have not developed ASR systems. The four most common reasons why the surveyed utilities had not implemented an ASR project were: (i) concerns about the physical ability to recover stored water; (ii) concerns about the quality of the recovered water; (iii) a higher cost than other alternatives; and (iv) concern about other pumpers getting access to the utility's stored water. Several utilities also expressed concerns about regulatory burdens, lack of funding, and lack of available data on the proposed storage aquifer.

The survey results provide valuable information on where efforts should be focused to increase the consideration and implementation of ASR as a potential water supply or storage option in Texas. Based on the responses, publically-available data demonstrating the ability to store and recover water within the state's aquifers are needed. Since it is not clear from the survey responses whether the concerns regarding ability to recover stored water are based on perceived legal or technical limitations, or both, information on both the legal framework in Texas for recovery of stored water and the physical limitations should be addressed.

The response regarding perceived higher costs than other alternatives is not supported by the full scale capital costs data, and O&M information, and historical perspectives provided by the SAWS and the City of Kerrville ASR projects. For those two systems, ASR was a more cost effective option than other alternatives considered during the planning and permitting phases, and the ASR systems continue to provide cost savings relative to other options, despite some unexpected expenses such as mitigation. ASR operations in Texas have the added benefit of being located close to the place of use, thereby reducing the cost of lengthy pipelines and the high cost of pumping. For example, SAWS estimates that cost of developing recharge enhancements is about half the cost of its proposed Carrizo groundwater project. The cost effectiveness of ASR will vary from site-to-site. However, the survey response indicates that publication of robust cost data illustrating the potential cost-competitiveness of ASR implementation could facilitate wide-spread consideration of ASR as a water supply or storage alternative.

A brief review of two of the 2010 *Initially Prepared Regional Water Plans* (IPPs) provides some specific basis for the cost-effectiveness of ASR compared to other water storage and supply options. In the IPPs, water supply strategies are compared using protocols and procedures established by the TWDB, and an economic analysis includes the development of a unit cost for each project. In the Region J (Plateau Region) IPP, cost estimates for five strategies were presented. The ASR strategy for the City of Kerrville which included a water treatment plant and ASR well expansion was the cheapest of the five projects. The unit cost for ASR ranged from $146 per ac-ft/yr in 2020 to $60 per ac-ft/yr in 2060. In the Region L (South Central Region) IPP, cost estimates were presented for two ASR projects, and each of those projects included surface storage alternatives. For the "Storage Above Canyon Reservoir" project, ASR at a cost of $3,140 per ac-ft/yr was cheaper than the four off-channel storage reservoirs options that were evaluated. The four storage reservoirs ranged in cost from $4,255 to $13,500 per ac-ft/yr. For the "Medina Lake Firm-Up" project, two ASR scenarios and three off-channel reservoir scenarios were evaluated. The ASR scenario costs at $6,943 and $9,933 per ac-ft/yr, were slightly higher than off-channel reservoir scenarios that ranged from $5,378 to $9,078 per ac-ft/yr. However, it must be pointed out that the off-channel reservoir cost estimates did not include the cost of treating the stored surface water, whereas the ASR options both included a water treatment plant so that drinking water could be injected. When the cost of treatment is added to the off-channel reservoir options, those costs will likely be higher than ASR.

As of June 2010, the nationwide average unit capital costs for providing supplemental capacity to meet peak and emergency demands with ASR wells averages $1.14 per gallon per day of recovery capacity. When compared to most alternative water supply sources this is quite cost-competitive.

The majority of utilities that participated in the survey indicated a desire to know more about ASR and/or this study. This report will provide a good initial step toward increasing public access to information on key opportunities, considerations, and constraints associated with the use of ASR.

Two utilities indicated concerns regarding the suitability of the receiving/storage aquifer. In the survey only one utility discussed water quality as the principal reason why ASR had not been further considered. One utility's concern was based on the unconfined nature of the aquifer and perceived issues regarding the ability to recover all of the stored water. This utility stated that the unconfined nature of the aquifer would make it very difficult to convince customers that ASR is a cost-effective and technologically-feasible option, even if it could be successfully implemented on a technical basis. The other utility's concern related to the brackish quality of the receiving aquifer. These responses further confirm that more widespread information on ASR, addressing issues such as the ability to use ASR in all types of aquifers, could be an important step toward increasing the consideration and utilization of ASR as a water resources tool in Texas.

7.1.3 Texas legal perspectives

ASR has a solid regulatory and legal foundation in Texas. There is, however, substantial room for improvement/enhancement of the rules and statutes both at the state and local levels.

The State's regulatory program for Class V ASR Wells is well developed. As the Class V injection well program is part of the State's federally delegated underground injection control (UIC) program, there is little room for modification of the applicable rules if Texas is to retain its delegated authority. Technological advances and/or Texas-centric hydrogeologic characteristics, however, may warrant regulators to seek to initiate changes that facilitate the development of new advances in our Class V Well program to encourage ASR implementation. This is particularly true with respect to possible enhanced use of other supply sources for ASR storage such as reclaimed water, stormwater or groundwater from other aquifers. Even without modification, however, Texas ASR Class V Well regulations are both workable and reasonably user-friendly to ASR development.

Texas' current regulations and statutes, both statewide and local, do not readily facilitate the maximum beneficial use of either groundwater or surface water for ASR. The shortfalls are not just reflective of the regulations and statutes governing the water supply source, but the ability to protect the water once it has been injected for storage. The inability to protect the stored water with certainty reduces or compromises many of the benefits and, as a result, the economics of ASR utilization. Ironically, the “threats” to the stored water that require protection are from other persons with access to the stored waters, as well as the entities with regulatory jurisdiction over it. The lack, or perceived lack of ability to protect the stored water is the greatest identifiable impediment to ASR implementation in Texas.

Even before the Legislature adopted statutory provisions expressly authorizing the use of State-owned surface water for ASR projects, Texas Courts recognized the validity of authorizing the storage of water permitted for beneficial use using ASR technology. Amendments to TEXAS WATER CODE Chapter 11, and Chapters 295, 297 and 331of the TCEQ’s regulations (30 TAC) have reinforced and clarified the ability to utilize ASR technology for the “storage component” of a surface water permit. Further guidance from the Legislature is necessary, both to encourage the TCEQ to expand the recognized ability to utilize ASR to store surface water and to minimize, if not eliminate, the threat of litigation over any permitting innovations relying upon State-owned surface water.

Current Texas law facilitates the use of ASR as a storage alternative in connection with perpetual and/or long-term term surface water permits. There is significant time and cost associated with securing a permit and constructing an ASR project. These projects have the ability to store substantial quantities of water in relatively short periods of time and maintain that water in storage without the potential losses associated with storage in conventional reservoirs. Therefore, modification of the current provisions of Chapter 11, and/or Chapters 295, 297 and 331of the TCEQ rules (30 TAC) is warranted to streamline and provide flexibility in water rights permitting that allows ASR implementation and/or expedited permitting consideration to add ASR as a storage component to water rights permits. These changes could enhance the utilization of ASR technology as a cost effective, as well as environmentally sensitive, alternative for storing appropriated state water. Two examples of such modifications would include seasonal and scalping permit authorizations.

With regard to groundwater, special purpose districts, particularly groundwater conservation districts which are recognized by both the Texas Legislature and courts as the state’s preferred method of groundwater management, need legislative guidance on how to deal with ASR projects. Current provisions of Chapter 11, Texas Water Code, and TCEQ rules provide limited guidance, but it relates to ASR projects which use surface water as their supply source. Chapter 36 provides even less specific guidance with respect to ASR projects. Local groundwater districts are very inconsistent in how they address ASR projects, assuming they even address ASR in their rules and/or management plans. In many instances the reluctance of groundwater districts to embrace ASR technology stems from a fear that an ASR project may attempt to “bank water” to the point where the ASR operator attempts to assert that all of the water in the storage aquifer belongs to the ASR operator and, therefore, cannot be produced by or from any other wells drilled into the affected aquifer(s).

Current Texas law facilitates the use of ASR as a storage alternative in connection with perpetual and/or long-term term permits, *e.g.*, permits with terms of at least twenty (20) years. Modifications to Texas law related to surface water permits could enhance the utilization of ASR technology as a cost effective, as well as environmentally sensitive, alternative for storing appropriated state water. Because ASR storage is possible whenever water is available, there are opportunities for successful projects, even in portions of the State where rivers and streams are now fully appropriated.

7.2 Recommendations

In order to achieve cost-effective, sustainable and reliable water supplies sufficient to meet projected future demands for Texas, large volumes of water storage will be required. Storage above ground in surface water reservoirs is problematic due to adverse environmental impacts; land requirements; high costs; and water losses due to evaporation, transpiration and siltation. ASR can provide a significant portion of the storage needed to meet that future demand. The existing ASR systems in Texas have shown that the technology is feasible using different water supply sources as well as in different types of aquifers, and that the technical aspects of ASR are not the major factors inhibiting its implementation.

Additional work is needed to encourage the development of more ASR projects.

The following specific recommendations are offered as means to enhance the development of ASR in Texas:

7.2.1 ASR demonstration program

We recommend that the TWDB and TCEQ collaborate on the establishment of an ASR demonstration program with the goal of increasing the number of ASR projects in operation while at the same time strengthening the legal, political, legislative, regulatory and educational framework in support of ASR.

Considering the substantial economic, environmental and water supply benefits associated with increased ASR storage, the TWDB and TCEQ should jointly develop a broad-based program that includes financial incentives for implementation of additional ASR projects. Experience in other states suggests that 50% State funding of an ASR program stimulates substantial interest so long as local project control is maintained. Funding for several projects could be budgeted, subject to a competitive process among water agencies and water utility systems. Project applications would be ranked according to appropriate selection criteria and the top-ranked projects would receive partial funding for implementation.

A separate portion of the ASR demonstration program funding would provide for measures that would increase the data gathering needed to improve the technical, legal, political, legislative and educational framework in support of ASR. More information is needed on which aquifers and formations are best suited for ASR, and where there are actual hydrogeologic limitations to the implementation of ASR. In addition to the studies and research being conducted by the TWDB, it is possible to gather a great deal of additional data on the viability of ASR whenever a demonstration project is implemented.

7.2.2 Proposed legal and regulatory modifications

Modification of current provisions of Chapter 11, and/or Chapters 295 and 297 of the TCEQ rules is warranted to provide flexibility in water rights permitting that allows ASR implementation and/or expedited permitting consideration to add ASR as a storage component to water rights permits. Two examples for consideration include seasonal and scalping permit authorizations:

a) Seasonal Permits – Seasonal fluctuations in weather patterns provide opportunities for utilization of ASR technology. Current regulatory programs for surface water rights permitting, however, are not necessarily conducive to granting permits, particularly municipal use permits, in reliance upon seasonal potential for increased water availability. Specifically, in order for a permit to be issued for municipal purposes, the applicant must demonstrate that the water source itself, or in combination with some other water source, will be available to the permittee on a "firm yield basis". Assuming, however, that a municipal water purveyor is willing to make an investment in an ASR project, it would make sense to permit water diversions above the volume of water calculated to be "available" from the affected river basin on a "run-of-the-river" basis coupled with higher stream flow restrictions calculated to be met during seasonal peak periods, *i.e.*, rainy seasons. Under these circumstances the permittee could divert water in excess of its then current demand. Water could be treated using the Permittee's excess treatment plant capacity and injected into an ASR well for storage until needed. This practice could not only enhance the reliability of the affected municipal water purveyor's water supply inventory, but would provide an opportunity to maximize the beneficial use of the state's limited supply of surface water resources during periods when the potential effects on the environment, including freshwater inflows to our bay and estuary systems, could be minimized due to the higher than average flows.

b) Scalping Permits: Similar to the concept of "overdrafting" from conventional surface reservoirs or "free pumping" in the Rio Grande River Basin under certain specified conditions, permits authorizing the diversion of water for ASR storage could be granted for "scalping operations." These permits would allow diversions, or additional diversions, of water from a watercourse at any time of the year assuming sufficiently high stream flow conditions existed in the river to trigger operation of the "scalping" project. Water would be diverted either for direct treatment and injection into an ASR project or, under limited circumstances, diverted with a short term storage in an off-channel reservoir pending treatment and injection into the ASR project. Granting authorization for an ASR scalping operation would require (i) the permittee demonstrate the availability of sufficient excess treatment capacity and injection and storage capability, and (ii) that the diversions be tied to specific stream flow conditions. Again, the potential benefits both short and long term to "bank" water and firm-up water supply inventories are significantly enhanced by the minimization of potential effects to the environment.

Groundwater Districts need legislative guidance on how to deal with ASR projects. Chapter 11, and TCEQ rules provide limited guidance, but it relates to ASR projects which use surface water as their supply source. Chapter 36 provides even less specific guidance with respect to ASR projects. Local groundwater districts, which the Legislature has indicated are the State's preferred form of groundwater management, are very inconsistent in how they address ASR projects, assuming they even address ASR in their rules and/or management plans.

Among the potential options for the State to enhance ASR development are the following:

1) Define ASR in a context to allow and encourage the ability to inject water of suitable quality for purposes of storage and subsequent recovery for beneficial use:

    a) this assumes compliance with the anti-degradation requirements related to the protection of the quality of native groundwater to maintain current uses;

    b) Amend Chapter 26, Texas Water Code to facilitate such projects. Program would be similar to Chapter 210 (30 TAC) reuse projects;

    c) Amend Chapter 210 (30 TAC) to authorize use of ASR for storage of treated effluent.

    d) measure compliance with applicable water quality standards at a reasonable distance away from an ASR well so that natural physical, biological and geochemical treatment processes have an opportunity to occur, and

    e) measure compliance with applicable water quality standards after an adequate time for natural processes to occur.

2) Amend Chapter 11, Texas Water Code, and associated TCEQ Regulations (*e.g.*, 30 TAC Chapters 295, 297, 331) to enhance the opportunities to store appropriated surface water in ASR projects:

    a) Amend current provisions in Chapter 11, in particular Sections 11.153-11.154, to allow appropriated State surface water to be authorized to be stored using ASR. Amendments would include removing the two-tiered permitting structure requiring permitting of a "pilot project" and then a separate application for either a permit or a permit amendment. ASR projects should be able to seek a consolidated permit. Special conditions can be included in a permit to insure aquifer protection is maintained and projects are implemented in a reasonable time.

       Alternatively, the current statutory provisions should be modified to (i) allow granting a temporary permit for ASR Phase I testing on an expedited basis with limited opportunity for notice and/or hearing, and (ii) allow issuing of a temporary permit authorizing diversions during the permit term of sufficient volume to complete Phase I.

    b) Amend Section 11.138 authorizing issuance of "temporary permits" to facilitate ASR "pilot projects" as described above, and look at similar amendments to authorize scalping operations during seasonal periods of higher than normal flows, including flood level events, during which water could be diverted with little or no impairment to either senior downstream water rights and/or the environment and stored in an ASR project.

c) Amend Section 11.137 regarding "seasonal permits" to facilitate utilization of available water on a seasonal basis for diversion and storage in an ASR project. This could include authorizing seasonal diversions which, when combined with amounts authorized for diversion under a regular permit, could exceed the annual demand and would be available for storage in an ASR project to be "banked" for future low flow or drought periods when stream conditions might otherwise preclude diverted diversions from the water course.

d) Amend Chapter 11 to authorize expressly the use of State water to be stored in an ASR project.

e) Amend the language of Sections 11.153 and 11.154 requiring permit applicants to cooperate with groundwater districts and comply with their rules that the groundwater district cannot impose any more restrictive conditions and/or requirements on the ASR permittee than they impose upon any other permit issued by the groundwater district.

f) Amend Chapter 11 to provide expressly that surface water authorized by a Chapter 11 permit retains its character as surface water so long as it remains under the control of the permittee and that the same is not subject to spacing requirements and/or pumping restrictions imposed on groundwater district production permittees.

g) Amend Chapter 11 to provide expressly for what percent of surface water injected into an ASR project within the jurisdiction of a groundwater district, if any, may be required to be left in the aquifer by the groundwater district, and consideration of the technical justification for any water to be withheld.

3) Amend Chapter 36 to address the following:

a) expressly establish what percentage of the water injected into an aquifer for storage, if any, can be required to be left in the aquifer;

b) require groundwater districts to accept the issuance of Class V injection well permits issued by the TCEQ, or any successor agency, and not require permittees to secure additional permits from the groundwater district for ASR projects;

c) prohibit groundwater districts from assessing production fees or other similar assessments for the production of water stored in an ASR project;

d) prohibit groundwater districts from requiring a production permit for the production of water stored in an ASR project;

e) prohibit groundwater districts from (i) requiring a transport or other similar permit to transport water produced from storage in an ASR project in order to transport the water outside of the district for beneficial use, and/or (ii) from charging or collecting any fee or other assessment from a permittee transporting water produced from storage in an ASR project outside of the district for beneficial use;

f) expressly prescribe the obligation of an ASR project owner or operator to register each ASR well with the groundwater conservation district, and to meter and report to the district on a monthly basis the amount of water injected and recovered from the ASR project on a well by well basis;

g) require groundwater districts to identify aquifers within their jurisdiction that have minimal utilization and could provide suitable storage formations to facilitate ASR projects, and communicate this information as part of the State Water Plan regional planning process and the joint planning within groundwater management areas to identify aquifers available for regional water transfers;

h) amend Sections 36.1071-36.1073, Texas Water Code, to require groundwater districts to include an ASR component in the Management Plans, and any amendments thereto. The ASR component should include identification of formations suitable for ASR and district initiatives to enhance ASR development within the district.

4) EAA should accept and process applications for ASR and Recharge permits, and develop methods to enhance the Aquifer, as well as utilize it to develop water supplies for beneficial use to benefit consumptive uses, *e.g.*, municipal, industrial, agricultural and/or mining uses, non-consumptive uses, *e.g.*, increased recharge to the aquifer itself, and environmental, riparian and in-stream uses.

5) Adopt legislation providing immunity from liability for trespass resulting from injection of water which migrates beyond the boundaries of the property owned or controlled by the ASR operator provided (i) that the ASR operator has no right to protect the stored water from being produced by a third party, *i.e.*, the Rule of Capture would apply, and (ii) authorize limited liability for degradation directly attributable to an ASR project that contaminates the native groundwater and precludes the ordinary and customary uses of the native groundwater, requiring treatment that would otherwise not have been required for the intended use.

6) Adopt legislation recognizing hybrid ASR projects similar to El Paso's FHWRP Hueco Bolson aquifer.

7) Adopt legislation to clarify the distinctions between aquifer recharge projects and ASR projects.

8) Adopt legislation amending Chapters 11, 26, 17 and 36, Texas Water Code to enhance opportunities to store reclaimed water using ASR.

9) The definition of "Aquifer Storage Recovery" in Texas law, coupled with the inconsistent terminology associated with ASR should be rectified. Specifically, Chapters 11, 27 and 36 of the Texas Water Code, and Chapters 295, 297 and 331 of the TCEQ's Rules in 30 Texas Administrative Code should be amended by the Legislature and TCEQ, respectively to adopt the following slightly modified industry recognized definition of "ASR":

Aquifer Storage Recovery may be defined as the storage of water in a suitable aquifer through a well during times when water is available, and recovery of the water from the same well or different wells in the same aquifer during times when the water is needed

Additionally, the terminology used in the various statutory and regulatory programs should be amended to provide consistency. For example, the term "retrieval" should not be used in the place of the term "recovery."

Similarly, at the "local level" the various special purpose districts operating across the state, in particular groundwater conservation districts, adopting rules related to ASR should utilize the same definitions and terminology adopted at the state level. Developing and utilizing a consistent and uniform terminology will avoid confusion in the implementation and enhance the statewide understanding of the technology.

10) Regulatory control over ASR, like the UIC program, should reside in a single statewide agency, *i.e.*, TCEQ. Chapters 27 and 36, Texas Water Code, should be amended to provide for the statewide regulation of ASR projects within the UIC programs. Local groundwater district's role should focus on monitoring and enforcement at the local level of proper implementation of ASR project authorization granted at the state level. To the extent that local hydrologic issues affecting a groundwater conservation district are raised or impacted by a proposed ASR project, such issues and/or concerns can be addressed during the ASR permitting process at TCEQ. To insure that proper notice and opportunity to be heard is provided to the local groundwater district, an ASR project applicant can be required (i) to identify any affected groundwater district in its application, and (ii) to provide proof to TCEQ that a copy of the ASR application was timely delivered to the groundwater district.

11) Chapter 36, Texas Water Code, should be amended to facilitate the development of ASR projects that can significantly enhance the State's ability to meet its future water demands. For example, State regulations should make it possible to utilize aquifers to move water from the source and/or point of injection to the point of water demand. In other words, similar to the use of state water courses to transport water utilizing a "bed and banks permit" issued by the TCEQ, groundwater districts should be authorized to issue permits allowing water to be injected at one point in the aquifer and withdrawn at a different point. Such a permit would be issued upon demonstration that: (i) the injected water will travel from the point of injection to the point of withdrawal; and/or (ii) there are characteristics of the aquifer that establish the existence of a "connection" between the two points such that withdrawal from a point different from the point of injection will not adversely impact the aquifer or its users. Implementation of this recommendation could have substantial economic, environmental and/or water development benefits. Such an innovation could eliminate the cost and physical impact of having to construct substantial cross-district pipelines – some as long as 100(+) miles.

Texas' current preferred form of groundwater management utilizes dozens of separate groundwater districts which, in some instances, regulate the same aquifer. This management is often done without uniform regulations or an overall systematic approach based upon the hydrologic characteristics of the aquifer. The fact that many groundwater districts do not authorize ASR projects is a major impediment to the ability to implement this potentially beneficial concept. Accordingly, at least with respect to the development and utilization of ASR, Chapter 36 should require cooperation between neighboring groundwater districts with regulatory authority over an aquifer(s) capable of ASR development. Such cooperation would maximize the potential beneficial use of the resource to meet the long term water supply demands of Texas documented in the State Water Plan.

7.2.3 More accurate actual cost data

At the present time, there is limited reliable information on both the costs to develop and construct ASR facilities, and the operations and maintenance (O&M) expenses related to those facilities. In many instances, the costs related to ASR facilities are aggregated with other water utility expense categories. Reliable information and data are available only with more detailed cost accounting and recording keeping. Therefore, the TWDB should develop incentives for utilities operating ASR facilities to keep more detailed and specific cost data related to ASR implementation and its associated O&M. These incentives could include a requirement for segregated accurate cost data as a requirement for State funding through the TWDB, including funding through the demonstration program. In addition, short duration, highly-focused research could develop cost information at Texas' three operational ASR systems. At the present time SAWS has contracted with a local university to perform such research, and similar programs could be implemented at other utilities.

7.2.4 Interagency coordination

In addition to the demonstration program described above, there should be a dedicated effort to foster inter-agency cooperation on ASR between the TWDB and the TCEQ. A regular ASR work group should be established by the two agencies for the purpose of coordinating administrative and regulatory strategies that can enhance the implementation of ASR. A great deal could be accomplished in a few years if such a group were to meet regularly with a focused set of objectives based on this report.

7.2.5 Funding for statewide data gathering

Using the recommendations in this report, the TWDB should establish an ongoing program to fund data gathering and implementation activities related to ASR. For example, the expenses related to gathering additional ASR-related water quality data could be a reimbursable expense for public entities drilling new production and monitoring wells. In addition, when the TWDB processes applications for funding assistance with treatment, reservoir storage and water transmission or distribution system improvements, it could require that ASR wells be evaluated as an alternative to larger pipelines, treatment plants or reservoirs for meeting peak demands, or more likely as a combination of ASR with these other options so that needs can be met at reduced cost.

7.2.6 Research

This report discusses additional data gathering to support a better understanding of the storage potential of the state's aquifers. However, more focused ongoing research is also needed. Some of the studies should be focused on the technical issues identified in this report, such as concerns about water quality degradation with long-term storage. In addition, other research should be focused on the cost of ASR implementation. This study has identified a number of utilities that studied but did not implement ASR projects. In some cases, these evaluations may have been based on approaches that did not document the true costs and benefits of ASR, especially the incremental or marginal cost of ASR. We recommend a research project to re-evaluate one or more of these previous studies to see if an updated cost estimate might enhance the viability of ASR.

7.2.7 Additional focused education

This priority research project has included a significant amount of effort related to seminars and presentations to discuss the potential, as well as the inhibiting factors related to enhanced implementation of ASR technology in Texas. However, more outreach is needed with the water utilities, and with State agencies, legislators, groundwater conservation districts, hydrogeologists and well drillers. As someone said, we should "…surround the water community with ASR." Some of that outreach can be accomplished by TWDB publication of this report, information posted on the TWDB website and a summary brochure developed from this report. However, we recommend that periodic presentations be made specifically to the Texas Alliance of Groundwater Districts, the Texas Ground Water Association, Texas Water Conservation Association, Texas Section of the American Water Works Association, Texas Municipal League, Texas Association of Counties, Texas Rural Water Association and the Western States Water Council. Of particular interest should be a better understanding of ASR technology and the data on specific aquifers developed by the TWDB, as described above. As better cost data are obtained, that information should also be disseminated.

7.2.8 Evaluation of water exchange opportunities

As discussed in more detail in Section 5, Chapter 36, Texas Water Code, should be amended to facilitate the development of ASR projects capable of utilizing aquifers to move water from the source and/or point of injection to the point of need. In other words, similar to the use of state water courses to transport water utilizing a "bed and banks permit" issued by the TCEQ, groundwater districts should be authorized to issue permits allowing water to be injected at one point in the aquifer and withdrawn at a different point. Implementation of this recommendation could have substantial economic, environmental and/or water development benefits. Such an innovation could eliminate the costs and physical impact of having to construct substantial cross-district pipelines.

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10 Appendices

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10.1 Appendix "A": Summary Outline of ASR Class V Injection Well Requirements

Chapter 331 in its entirety can be found at (i) the Texas Secretary of State's website: http://info.sos.state.tx.us/pls/pub/readtac$ext.ViewTAC?tac_view=4&ti=30&pt=1&ch=331, and (ii) the TCEQ website: http://www.tceq.texas.gov/rules/index.html

Class V Injection Wells Authorized under Chapter 331 (Underground Injection Control) of the Commission's Rules (30 TAC) must comply with the following:

a. Must obtain an injection well permit, or be authorized by order or rule of the Commission (TCEQ);[1]

b. Mechanical integrity required and the TCEQ Executive Director ("ED") may require demonstration of mechanical integrity;[2]

c. Injection not allowed if it would result in pollution of underground drinking water;[3]

d. Permit/Authorization must include terms necessary to protect fresh water from pollution;[4]

e. Must address unauthorized discharges of chemicals for the associated tankage and equipment;[5]

f. Wastewater Pre-injection Units:[6]

   (i) Pre-injection units must not cause: discharge of waste into waters of the state, [7] a nuisance, [8] or endangerment of the public health and welfare;[9]

   (ii) Pre-injection units must be authorized by permit or registered;[10]

      (1) Owner/Operator submits an application to the ED[11] for any proposed pre-injection unit to obtain approval before operating the pre-injection unit[12] or for any existing unauthorized pre-injection unit, the owner/operator must submit an application before the date the injection well permit renewal application is submitted,[13]

      (2) Owner/Operator must cease operation of pre-injection unit[14] if the pre-injection unit has not been submitted before approval of the injection well permit renewal[15] or if registration is denied,[16]

   (iii) Pre-injection unit registration will be denied or revoked if:[17]

      (1) The unit causes a release of fluid that would pollute underground drinking water, fresh water, or surface water;[18]

      (2) The unit poses an immediate threat to public health/safety;[19]

(iv). Pre-injection units must be designed to protect underground sources of drinking water;[20] to meet all applicable rules and law;[21] to meet the design standards set out in Chapter 317 (30 TAC);[22] and all ponds should be lined according to the requirements of Chapter 331.47 (30 TAC);[23]

g. Closure Standards: (plugging and abandoning) for a well authorized by rule must comply with Section 331.133 (Closure Standards for Injection Wells):

(i) Remove all "removable" casing and then pressure fill well via a tremie pipe with cement from the bottom to the land surface; or[24]

(ii) if the well is **not** completed through zones of undesirable/polluted/groundwater or water that presents a danger to human health or the environment, the well can be filled with fine sand, clay or heavy mud followed by a cement plug extending from land surface to a depth of not less than ten feet below the land surface; or[25]

(iii) if the well is completed through zones of undesirable/polluted/groundwater or water that presents a danger to human health or the environment, these undesirable zones must be isolated with cement plugs and the remainder of the wellbore filled with bentonite grout followed by a cement plug extending from the land surface to a depth of not less than ten feet below the land surface.[26]

(iv) owner/operator must ensure that temporary injection points are pressure grouted from the bottom of the well to the land surface and the injection point is sealed to prevent the migration of fluids into underground sources of drinking water.[27]

(v) owner/operator must close improved sinkholes in a manner that prohibits the movement of contaminated fluids into underground sources of drinking water.[28]

h. Injection into Class V wells is authorized by Section §331.9.[29] Injection used for disposal of more than 5,000 gallons/day of sewage or sewage effluent must be authorized by a wastewater discharge permit;[30]

i. Well authorization by rule expires upon the effective date of a permit issued;[31]

j. Owner/Operator prohibited from injecting into a well[32]

(i) when permit denied,[33]

(ii) when permit application is not timely filed,[34]

(iii) when inventory information is not timely filed,[35]

(iv) when information requested by the Executive Director is not filed in a timely manner,[36]

- (v) failure to comply with the rules with Chapter 331 relating to "Standards of Class V Wells" and "Additional Requirements for Class V Aquifer Storage Wells";[37]

k. Unless the well is closed loop and air-conditioning return flow injection well, owners/operators must submit the following inventory information to the ED prior to construction:[38]
   - (i) name of facility,[39]
   - (ii) name and address of legal contact,[40]
   - (iii) ownership of the facility,[41]
   - (iv) nature, type and operating status of the injection wells; and[42]
   - (v) the location, depth and construction of each well;[43]

l. owner/operator must submit the required inventory for review and modification by the ED, and must obtain approval prior to construction, conversion, or operation of the well;[44]

m. owner/operator must submit the inventory information to ED prior to construction;[45]

n. Commission may require a permit for injection into an exempted aquifer;[46]

o. Requirements for registration of Pre-injection units:
   - (i) complete application form: signed and notarized,[47]
   - (ii) verified legal status of applicant,[48]
   - (iii) signature of applicant,[49]
   - (iv) notarized affidavit from the applicant(s) verifying land ownership or landowner agreement to the proposed activity,[50]
   - (v) Pre-injection unit registration information on file with the Commission shall be confirmed or updated, in writing, no later than 30 days after:
     1. Change of mailing address and/or telephone number of owner/operator;[51] or
     2. Requested by Commission or ED[52]
   - (vi) Maps showing name and address of persons who own the property on which the existing or proposed pre-injection unit is or will be located;[53] the names and addresses of landowners adjacent to the property on which the pre-injection unit is located,[54]
   - (vii) Plans and specs for the pre-injection units sealed by a Texas-licensed PE,[55]
   - (viii) Technical Reports and supporting data required for the application,[56]

p. Public notice requirements apply to applications for a new registration, and a major amendment, or renewal of a registration for a pre-injection unit.[57]

q. Public comment is allowed for new, major amendment, or renewal applications.[58]

r. The Executive Director has the authority to approve pre-injection unit registrations;[59]

s. An applicant or a person affected may file a Motion to Overturn the Executive Director's final approval of an application;[60]

t. All geoscientific information submitted must be prepared by or under the supervision of a licensed professional geoscientist or licensed PE[61]

6. Additional requirements for injection into or through the Edwards Aquifer include the following:[62]

a. Applications submitted after September 1, 2001 for injection wells that transect or terminate in the Edwards Aquifer, may be authorized by rule or by permit only as follows:[63]

i. the groundwater is unaltered, physically, chemically, or biologically; or[64]

ii. the groundwater is treated in connection with remediation that is approved by state or federal order, authorization, or agreement and does not exceed the maximum contaminant levels for drinking water[65]

b. Wells that inject non-toxic tracer dyes may be authorized[66]

c. Improved sinkholes or caves located in karst topographic areas that inject storm, flood, or groundwater may be authorized.[67]

TCEQ's rules provided following specific Standards for Class V Wells:[68]

1. Construction Standards[69]

a. Wells must be installed by a driller licensed by the Texas Department of Licensing and Regulation ("TDLR")[70]

b. Reporting to the Commission[71]

(i) the inventory mentioned in Section 331.10, shall be submitted to the ED for approval prior to construction.[72]

(ii) Within 30 days of completion of well construction, a TDLR state well report form must be submitted to the Executive Director,[73]

(iii) For closed loop and air conditioning return flow wells, no reporting prior to construction is necessary,[74]

c. Temporary injection points must prevent movement of surface water or undesirable groundwater into underground sources of drinking water. [75]

d. Requirements for Sealing of Casing[76]

(i) Except for closed loop injection wells, the annular space between the borehole and the casing shall be filled with cement slurry from ground level to a depth of not less than 10 feet below the land surface or wellhead.[77]

(ii) Closed loop injection wells must be filled with impervious bentonite.[78]

e. Requirements for Surface Completion[79]

(i) All wells except for temporary injection points, subsurface fluid distribution systems, improved sink holes, and large capacity septic systems, must have a concrete slab or sealing block placed above the cement slurry around the well at the ground surface,[80]

(ii) The slab should be at least 2 feet from well and a thickness of 4 inches and must be separated from the well casing by a plastic or mastic coating,[81]

(iii) Slab must be sloped to facilitate drainage,[82]

(iv) For wells that use casing, the top of the casing shall extend a minimum of 12 inches above the original ground surface, and the casing must be capped or completed to prevent pollutants from entering the well,[83]

(v) Closed loop injection wells which are completed below grade are exempt from the surface completion standards,[84]

(vi) Optional use of a steel or PVC sleeve is necessary to prevent possible damage to the casing; the steel sleeve shall be a minimum of 3/16 inches in thickness or the PVC sleeve shall be a minimum of Schedule 80 sun-resistant and 24 inches in length and shall extend 12 inches into cement,[85]

(vi) Wells should not be located in areas subject to flooding.; A well required to be located in a flood-prone area must be completed with a watertight sanitary well seal to maintain a junction between the casing and injection tubing, and a steel sleeve extending at least 36 inches above ground level and 24 inches below the ground surface must be inserted in the well,[86]

Additional protective measures that may be required include the following:

(i) Commingling of waters where the chemical quality differs is prohibited.[87]

(ii) When undesirable groundwater is found in a Class V well, the well must be constructed so that the undesirable water is isolated from any underground source of drinking water[88]

(iii) Class V sampling must be done at the point of injection or as otherwise specified in a permit issued by the ED[89]

C. Additional Requirements for Class V Aquifer Storage wells[90]

1. Area of Review[91]

a. For a Phase I Class V Aquifer Storage Well the area is determined by a radius of 1/4 mile from the proposed or existing wellbore.[92]

b. For a Phase II Class V Aquifer Well the area is determined by a radius of 1/4 mile from the perimeter of a “buffer zone” as described by Section 295.22 (30 TAC)[93]

c. The application must provide information on the activities within the area of review, including the following factors and the potential adverse impacts, if any:[94]
   (i) location of all artificial penetrations that penetrate the interval to be used for aquifer storage including water wells, abandoned water wells, oil & gas wells, saltwater injection wells and waste disposal wells;[95]
   (ii) completion and construction information for the identified artificial penetrations where available;[96]
   (iii) site specific, significant geologic features such as faults and fractures.[97]

2. Construction and Closure Standards[98]
   a. Wells should be designed, constructed, completed and closed to prevent
      (i) commingling through the well bore and casing of injection waters with "other fluids" outside of the authorized injection zone;
      (ii) mixing through the well bore and casing of fluids from aquifers of substantially different water quality; and
      (iii) infiltration through the well bore and casing of water from the surface into groundwater zones.[99]
   b. Plans and specifications, and drilling, completion and closure, must be done in accordance with Sections 331.132 and §331.133 (30 TAC).[100]
   c. If the Operator proposes to change the injection interval to one not reviewed during the authorization process, the operator must notify the ED and may not inject into any unauthorized zone.[101]
   d. The ED must be notified immediately of other changes including the completion of the well, setting of screens, and the injection intervals within the authorized injection zone.[102]
   e. Casing materials for Class V wells should be constructed of materials resistant to corrosion.[103]
   f. All phases of well construction, workover and/or closure must be supervised by qualified, knowledgeable and experienced individuals.[104]

3. Operating Requirements[105]
   a. Class V Aquifer Storage wells must not present a hazard or cause pollution to underground drinking water sources,[106]
   b. The injection pressure at the wellhead must not cause movement of fluid out of the injection zone[107]
   c. If an ASR has not been in operation for more than 2 years, the operator must notify the ED 30 days prior to resuming operation of the well.[108]
   d. Owner/operator must maintain mechanical integrity of all wells operated pursuant to these rules,[109]

e. The quality of water injected must meet the drinking water standards as provided in Chapter 290 (30 TAC)[110]

4. Monitoring and Reporting Requirements[111]
   a. The following must be monitored monthly and reported to the ED on a quarterly basis:[112]
      (i) average injection rates[113]
      (ii) injection and retrieval volumes[114]
      (iii) average injection pressures[115]
      (iv) water quality analyses of injection water;[116] and
   b. Anything else the Executive Director determines must be monitored for the protection of underground sources of drinking water must be monitored and reported as directed by the Executive Director.[117]
   c. A final report for a Phase I ASR project or a feasibility study of any other aquifer storage project must be submitted to the Executive Director within 45 days of the completion of projects. The report must address the requirements presented in Section 331.186 (30 TAC).[118]
5. Additional Requirements for Final Project Authorization:[119] Post-completion of the aquifer storage well, the following information must be obtained and included with the application
   a. as-built drilling and completion data on the well[120]
   b. all logging and testing data on the well[121]
   c. formation fluid analyses[122]
   d. injection and fluid analyses[123]
   e. injectivity and pumping test determining well capacity and reservoir characteristics[124]
   f. hydrogeologic modeling, with supporting data, predicting mixing zone characteristics and injection fluid movement and quality;[125] and

g. any other information determined by the Executive Director to be necessary for the protection of underground sources of drinking water.[126]

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10.2 Appendix "B": Summary Outline of the Permitting Requirements Related to the Use of State Surface Water as the Source of Supply for an ASR Project

<u>Chapters 295 and 297 in their entirety can be found at:</u>
<u>(i) the Texas Secretary of State's websites:</u>
http://info.sos.state.tx.us/pls/pub/readtac$ext.ViewTAC?tac_view=4&ti=30&pt=1&ch=295, and
http://info.sos.state.tx.us/pls/pub/readtac$ext.ViewTAC?tac_view=4&ti=30&pt=1&ch=297; and
(ii) the TCEQ website: http://www.tceq.texas.gov/rules/index.html

I. GENERAL REQUIREMENTS FOR ALL SURFACE WATER PERMITS[1]

A. Fill out a TCEQ Application[2]

1. Written in ink[3]
2. Non-substantive changes allowed after application submission[4]
3. Substantive changes must be notarized [5]
4. Must have name, address, phone number, SS#, firm name, or partnership name of Applicant[6]
5. Source of water diversion (if any)[7]
6. Amount and purpose of diversion and use[8]
7. Rate and method of Diversion[9]
8. Mapped location of diversion point and storage reservoirs; giving course and distance and nearest town[10]
9. State location where, if any, surplus water will be returned[11]
10. Include water conservation and drought contingency plan[12]
    a. techniques used to reduce the consumption of water[13]
    b. techniques to prevent loss/waste of water[14]
    c. techniques to maintain efficiency in use of water[15]
    d. techniques to increase recycling and reuse[16]
11. Name, address, lease, easement from landowners where the water will be stored[17]
12. If applying for a permit to appropriate state water for storage in another's reservoir and/or to divert and use water, need a document giving consent[18]
13. State how use of water complies with state and regional water plans[19]
14. Signature of Applicant[20]
15. Application must be sworn[21]

II. ADDITIONAL REQUIREMENTS FOR THE STORAGE OF SURFACE WATER IN AQUIFERS[22]

A. Obtain a Temporary or Term Permit pursuant to Chapter 297,[23] or a Permit under §297.11[24] unless a water right permit is not required for Phase I of an "aquifer storage and retrieval project[25] that proposes the temporary storage of appropriated surface water in an aquifer for testing and subsequent recovery and beneficial use if the diversion and purpose of use of the surface water is covered by an existing water right.[26] Obtain Necessary Authorization:[27]

1. Temporary Permit[28]
    a. Authorized by a commissioner for beneficial purposes[29]
    b. May not be granted for more than 3 years[30]
    c. Permit is junior to all affected prior appropriations and vested rights on stream[31]
    d. Permit does not vest in the holder any permanent right[32]
    e. If granted for less than 3 years, the permit may be extended by the commission upon written request by the permittee however, the entire period including the initial period shall not exceed 3 years[33]
    f. If permit for use of 10 Ac/Ft or less, for a period of 1 year or less, may be authorized without notice and hearing after a registration and fee has been filed[34]
    g. An application for a temporary permit must have a vicinity map at least 8 1/2 x 11 inches with sufficient information to enable the Executive Director to locate the diversion site and the return water discharge points[35]
2. Term Permit[36]
    a. Commission may issue a permit for a term of years for the use of unused appropriated water when there is insufficient unappropriated water in the source of supply to satisfy the application[37]
    b. Term Permit will be denied if:
        (i) issuance of permit will jeopardize financial commitment made for water projects which would develop the water resources of the area[38]
        (ii) issuance would affect a holder of the unused appropriation[39]
        (iii) the proposed permit is not intended for beneficial use[40]
        (iv) the proposed permit is detrimental to public welfare[41]
    c. Term permit is subordinate to any vested or senior appropriated right[42]
    d. The commission may grant a term permit for an ASR project.[43]
3. Obtain a Permit under §297.11 and the necessary authorization under Chapter 331[44]
4. §297.11 – General Authorization to Divert, Store, or Use State Water[45]

a. Must obtain Water Right[46] which the Commission will only grant if[47]:
    (i) Present Commission with an application that conforms to requirements prescribed by Chapter 295.[48]

(ii) Unappropriated water is available in the source of supply[49]

(iii) The proposed appropriation is intended for beneficial use[50]; does not impair existing water rights or vested riparian rights[51]; is not detrimental to the public welfare[52]; considers the assessments of Texas Water Code §§11.147(d) and (e) and 11.150-11.152[53]; addresses a water supply need consistent with the state water plan[54]

(iv) The applicant provides reasonable diligence to avoid waste[55] and completed all TWDB surveys of ground and surface water[56]

b. Authorization may be with or without term, on annual or seasonal basis, or on a temporary or emergency basis.[57]

c. Permit under §297.11 will not be accepted for processing until the applicant has obtained the necessary authorizations to complete a Phase I project.[58]

d. The Commission will only issue a final order granting a water right or an amendment to an existing water right authorizing that storage of state water in an aquifer for subsequent recovery and beneficial use where completed pilot projects or historically demonstrated projects have been shown to be feasible.[59]

e. A water right permit is not required for Phase I of an ASR project that proposes temporary storage of appropriated surface water in an aquifer for testing, subsequent recovery and beneficial use if the diversion and purpose is covered by an existing water right.[60]

f. If the applicant does not have the power of condemnation and proposes to store state water, the names and addresses of the landowners where the water will be stored shall be given.[61]

g. Map Formatting Requirements[62]:

(i) Maps shall be prepared and under the direction and supervision of a registered professional engineer.[63]

(ii) The plans shall be on tracing linen with waterproof ink, however photographic reproductions are acceptable if on a stable mat film.[64]

(iii) The scale shall not be less than one inch equals 2,000 feet.[65]

(iv) The dimensions of each sheet of plans on tracing linen or approved equivalent shall be 22-24 inches by 36 inches with a 2 inch binding margin at the left-hand edge, and the other three edges shall have margins of not less than ½ inch.[66]

(v) There shall be a title block on the lower right hand corner of all sheets of tracing linen.[67] The title block shall include the name of the project,[68] the name and address of the owner,[69] the county in which the project is located,[70] and the sheet or photograph number and the total number of sheets. For example, "sheet 1 of 1, sheet 4 of 6."[71]

(vi) If applicable, match lines must be shown on appropriate sheets of plans.[72]

(vii) Drawing and aerial photographs shall not be folded.[73]

(viii) If mailed they must be protected by a tube.[74]

(ix) The maps or plats shall be drawn to scale, not less than 1 inch equals 2,000 feet and shall show the following: [75]

- (1) the location and extent of the proposed works accompanied by a vicinity map;[76]
- (2) the location of each point of diversion, by course and distance from a corner of an original land survey and/or other survey point of record[77]
- (3) the location at which return water or surplus water will be discharged into a stream by course and distance from a corner of an original land survey and/or other survey point of record[78]
- (4) the name of the river, stream, or other source of supply with the direction of flow indicated[79]
- (5) the position and area of all lakes, reservoirs, or basins intended to be used, and the water line thereof; [80]
- (6) the location and ownership of all existing canals, laterals, ditches, conduits, reservoirs or other works of like character indicated by appropriate symbols[81]
- (7) the overall plan of the project area showing the locations of the proposed works and all pertinent features including structures, pipelines, roads, natural springs, artesian wells, and property lines, injection and retrieval facilities, by course and distance from a corner of an original land survey associated with the ASR project[82]
- (8) names and locations of underground formations where state water will be stored for later retrieval and the general direction of flow indicated.[83]
- (9) cross sections and profiles of the underground formations into which state water will be injected and stored, any underground formation which confines the injection interval, and any underground formation(s) located between the storage area and the land surface and the actual and/or proposed operating depths of all planned injection and retrieval facilities.[84]
- (10) the location of any area or areas proposed for underground storage which would be within any part or portion of a critical area designated by the Commission as an underground water management area.[85]

(11) For Phase II projects, the location of the buffer zone surrounding the land surface area under which the underground storage of state water will occur and beyond which pumpage by other wells will not interfere[86]

(12) For Phase II projects, the location and ownership of all existing domestic, public water supply, irrigation, or commercial wells within one quarter mile of the perimeter of the buffer zone[87]

h. All elevations shall be referred to mean sea level datum[88]

i. An applicant for a Texas Water Code §11.143 permit (relating to domestic and livestock reservoir use) who wishes to use the reservoir for other purposes must provide an aerial photograph of the site[89]

j. Phase I ASR projects must also include:

(i) information to demonstrate compliance with chapter 331[90]

(ii) a map showing the proposed depth and location of all injection facilities, retrieval wells, and the aquifer where the water will be stored.[91]

(iii) the application for storage of surface water in a groundwater reservoir under the jurisdiction of a groundwater district must include:[92]

(1) evidence of service by certified mail, of a copy of the application or notification submitted to groundwater conservation districts having jurisdiction over the aquifer[93]

(2) a copy of an agreement reached by the applicant with the groundwater conservation district reflecting the applicant's consent to cooperate with the rules governing the injection, storage, or retrieval of appropriated surface water in the underground water reservoir.[94]

k. Phase II ASR projects must include everything required for the Phase I ASR projects as well as[95]:

(i) a copy of the final report of the Phase I ASR project[96]

(ii) an operations plan for the life of the project[97] including the injection[98] and retrieval[99] rates and volumes; frequency of injection[100] and retrieval[101] periods; radial distances of travel from the injection wells on an annual basis;[102] maximum extent of travel for the life of the project;[103] and location of all injection, retrieval and monitoring wells.[104]

(iii) a report identifying potential impacts to artificial penetrations within 1/4 mile of the perimeter of the buffer zone[105]

(iv) a proposed monitoring plan that addresses the quality of the water injected and retrieved as well as the water levels of the receiving body within the perimeter and within 1/4 mile of the perimeter of the buffer zone[106]

III. FEES

A. Statutory fees must accompany an application[107]

B. Filing, Recording and Notice fees are established depending on the type of permit and the number of acre-feet requested to be appropriated[108]

C. Some uses require a "one-time use" fee[109]

D. A maximum fee scale for various types of permits is provided in Section 295.134.[110]

IV. ANNUAL REPORTS MUST BE FILED WITH THE COMMISSION[111]

A. Reports for those who take water from a stream or reservoir during the preceding calendar year.[112]

B. Reports by temporary permit holders[113]

C. Report on time limitations for construction[114]

D. Report of Contractual Sales (purchaser or supplier of state water)[115]

E. Report for ASR projects[116]

1. On the 5-year anniversary date of the issuance of the permit, permit amendment and every 10 years, the operator must supply the ED with an operations report describing what efforts the permittee has made to:[117]
   a. protect state water stored in the receiving aquifer from unauthorized withdrawals; and[118]
   b. maximize the retrieval and beneficial use[119]
2. The Operations report must identify and provide:[120]
   a. potential and real impacts from the operation of the project[121]
   b. summary of all data associated with the monitoring[122]
   c. a comparison of actual movement of injected state water with the monitoring during the operation of the project.[123]
   d. assessment of the project in terms of the groundwater quality[124]

10.3 Appendix "C": SAWS Chapter from David Pyne's ASCE Case Study

CHAPTER 2

Design, Installation, and Operation Challenges of Large-Scale Aquifer Storage and Recovery Wells in San Antonio, South Texas

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ABSTRACT: Six locations and five separate aquifer systems for Aquifer Storage Recovery (ASR) were evaluated before selecting the Carrizo Aquifer option in San Antonio, Texas in 2004. This site was selected since it provided the lowest costs for transmission, site development and operation. The Twin Oaks ASR facility, located at forty-eight kilometers (30 miles) south of San Antonio, Texas, was then developed by the San Antonio Water System to capture surplus water during wet months and store it underground for drought management and emergency relief. Water is injected into a semi-confined sand aquifer, forming a large water bubble. During times when groundwater levels are high, water from the Edwards Aquifer is treated to meet drinking water standards and is then pumped to the Carrizo Aquifer for storage. A total of 29 high capacity ASR wells and three native Carrizo Aquifer pumping wells were installed using flooded reverse circulation and mud rotary techniques. Well tests were conducted between 2,725 to 19,075 cubic meters per day, m^3/d (500 to 3,500 gpm) with design pumping yields around 9,810 to 13,625 m^3/d (1,800 to 2,500 gpm). Recharge capacities range from 6,540 to 10,900 m^3/d (1,200 to 2,000 gpm). The receiving Carrizo Aquifer has a natural pH of 5.5 and is high in iron and manganese, so a storage, treatment, and pumping system was built to treat the recovered water and deliver up to 2.3 million cubic meters per day, MCMD (60 million gallons per day) back to San Antonio. To date, the facility has been mostly used for banking the recharged water, achieving a cumulative storage volume of up to 75 million cubic meters, MCM (61,000 acre feet). Recovery pumping is currently underway, augmenting local water supplies during the

current drought. The recovered water from the ASR wells has not required retreatment, other than disinfection. The wells are backwash pumped monthly to maintain recharge efficiency.

2.1 Introduction

The need to store water underground is increasingly recognized as a key component of any plan to achieve water supply reliability and sustainability, whether to meet urban needs or to meet industrial, agricultural, environmental and other water requirements. Small ASR projects to meet local needs are increasingly being expanded to meet regional water management objectives. One big advantage of storing water in an underground sand aquifer instead of a reservoir is that no water evaporates. The primary driver for rapid development and implementation of ASR technology during the past 40 years has been favorable economics. ASR typically has a unit capital cost of about \$0.33 per liter (\$1.25 per gallon) per day of recovery capacity, within a typical range of \$0.13 to \$0.53 per liter (\$0.50 to \$2.00 per gallon), depending primarily upon individual well yield. Higher capacity wells tend to correlate with low unit capital costs. When compared with other options for water storage, ASR wells are typically less than half the capital cost. When compared with other options for augmenting peak water supplies, ASR technology is usually economically favorable. Other drivers for ASR implementation include the demonstrated viability of this technology in a broad range of applications and geographic settings; the insignificant adverse impacts upon the environment and groundwater quality; and the ability to add wells in small increments of capacity, as needed to keep pace with increasing water demands.

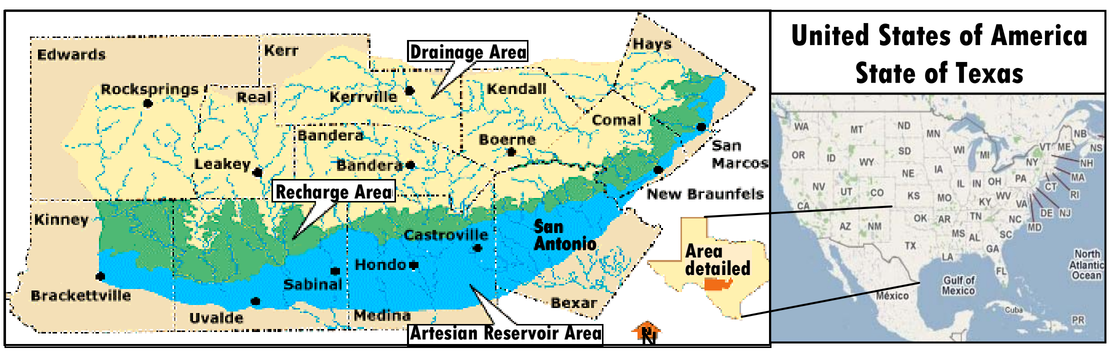


Figure 1 Edwards Aquifer, San Antonio, Texas (Plummer, 2000)

For this reason, the San Antonio Water System (SAWS) has developed a unique aquifer storage recovery (ASR) program, banking groundwater from a karst limestone aquifer with high transmissivity into a distant sand aquifer with relatively low transmissivity. In the rural farmland of south central Texas, 48.3 kilometers (30 miles) south of San Antonio, the Twin Oaks ASR facility was built to bank potable water for seasonal recovery during peak demand periods. The system is designed to recharge excess Edwards Aquifer groundwater during times of plenty into the Carrizo Aquifer through several ASR wells (see Figure 1). Before water can be injected it has to meet drinking water quality standards so that there is no chance that water already in the ground could be contaminated. To ensure that no adverse water quality impacts occur from recovery of the recharged water and blending with any native Carrizo Aquifer water, all recovered water is treated back to the normal system quality before it is used by the city of San Antonio.

The Balcones Fault Zone Edwards Aquifer (Edwards Aquifer) in south central Texas is one of the most permeable and productive aquifers in the United States. The aquifer is the primary source of water for approximately 1.7 million people in the region and provides most of the water for agriculture and industry. The San Antonio segment of the aquifer extends a distance of approximately 290 kilometers (180 miles). The flow from two notable aquifer discharge points, Comal Springs and San Marcos Springs, was greatly reduced, or ceased, during drought periods in 1956, 1966, 1971, 1984, 1989, 1990, and 1996 (Schindel, 2005). In response, the Texas legislature passed Senate Bill 1477 in 1993 mandating a reduction in pumping from the Edwards Aquifer. The Edwards Aquifer Authority was formed to protect the aquifer and set staged limits for withdrawals. In order to maintain adequate spring flow that protects aquatic habitat for a number of threatened and endangered species, the elevation of the aquifer at selected control point wells dictates the pumping limitations. Spring flow also provides a significant portion of water for downstream interests in the Guadalupe River basin (Todd Engineers, 2005). If the water level is above the 70-year mean, then normal allotment pumping is allowed. As the aquifer level drops into concerned and critical levels, allowable pumping volumes are reduced.

The Twin Oaks ASR facility is designed to bank water from the Edwards Aquifer during high water level conditions for delivery back to the community during restricted aquifer pumping periods. The $250 million facility began operation in 2004 and consisted of 48.3 kilometers (30 miles) of transmission pipeline, ASR wells capable of storing up to 65 million cubic meters (53,000 acre feet, AF) per year; a water treatment plant to remove iron and manganese that occurs in the Carrizo Aquifer; an on-site storage tank; and a bank of 1000+ horsepower pumps to reverse the flow in the sole supply line and return the treated water back into the San Antonio community water system. The system was further upgraded in 2006 to include additional ASR and native Carrizo pumping wells, storage capacity, and delivery pumping capacity.

The ASR technology allows underground storage of seasonally available water supplies in the San Antonio area. It provides an additional source of water in the SAWS portfolio that can be called upon during drought periods or emergencies. The sustainability of the storage facility is excellent for short term and moderate term storage. Its viability for long term storage will depend upon the rate of movement of the stored water towards adjacent pumping centers outside the property boundary. Since the aquifer historically has been in equilibrium between natural recharge and current local pumping demand, a “storage pocket” does not exist at this site to retain the recharged water. Instead the stored water bubble displaces ambient groundwater around the individual wells. Eventually the stored water bubbles will tend to coalesce, forming a single large bubble around the wellfield when the stored water volume reaches the large storage capacity of this 1,295 hectares (3,200 acre) site. The recharged water will likely tend to move slowly towards any pumping center at a velocity dependent upon the gradient of water levels in the aquifer near the property line. Careful management will be required to ensure that, during long term storage, migration of the recharge water bubble away from the ASR wells does not occur.

At present, SAWS operates the third largest ASR wellfield in the United States, following behind Las Vegas Valley Water District in Nevada with 594,245 m^3/d (157 MGD) recovery capacity, and Calleguas Municipal Water District in California with 257,380 m^3/d (68 MGD) recovery capacity. It is currently estimated that more than 95 ASR wellfields are operational in at least 20 states, with a total of about 500 ASR wells in operation. Many more ASR wells nationwide are in design, permitting, construction or testing, but have not yet received operational permits. States with the greatest amount of ASR activity include New Jersey, South Carolina, Florida, Arizona, California and Oregon. Storage aquifers include confined and unconfined aquifers; fresh, brackish and saline aquifers with ambient groundwater total dissolved solids concentrations up to 37,000 mg/l. A broad range of geologic settings includes karst limestone and dolomite, sand, sandstone, alluvial deposits, basalt, conglomerates, glacial and fractured hardrock aquifers. ASR well depths are as deep as 823 meters (2,700 feet) and individual well yields are as great as 30,208 m^3/d (8 MGD) (Pyne, 2005).

2.2 Geologic Formation

A unique set of strata, the Carrizo-Wilcox Formation, was selected for its marginal water quality and low demand, depth and confinement, and the lack of hydraulic connection to the Edwards Aquifer or regional rivers. The Carrizo Aquifer that is used locally for farmland irrigation is a sandstone aquifer with a pH of 5.5, containing elevated iron and manganese. Up to 75.3 MCM (61,000 AF) of water have been stored during the first five years of operation. The ASR wellfield is located in the Texas Coastal Plain on the downthrown side of the Balcones Escarpment. Formation dip is approximately 28.4 meters per kilometer (150 feet per mile) in the south south-east direction. Several mapped and un-mapped extensional faults trend in the north-northeast direction. The target formation, the Carrizo Sand, is a medium to very coarse grained, noncalcareous sandstone. It is friable to indurate with thick beds and local iron-oxide banding. The Carrizo Sand ranges from 213 to 244 meters (700 to 800 feet) thick in the area and yields moderate to large supplies of fresh water. The wells are typically screened between 122 and 213 meters (400 and 700 feet) below surface in the formation. The Reklaw Formation comprises the confining layer over the Carrizo Sand. The 61 meter (200 foot) thick unit is a fine to medium grained sandstone and silty clay with abundant hematite, glauconite and muscovite. The Wilcox Group underlies the Carrizo Sand and is composed of mudstone and varying amounts of sandstone and lignite.

The local farmers and Bexar Metropolitan Water District had concerns that the ASR facility would adversely impact the local aquifer. This resulted in an agreement with SAWS to take steps to implement mitigation measures to minimize impacts to area residents. Under rules of the local groundwater district and the agreement, property owners are permitted 2,467 cubic meters (2 acre feet) per year groundwater production for each 0.405 hectare (1-acre) of land. The facility includes 1,295 hectares (3,200 acres) of farmland netting 7.8 MCM (6,400 AF) potential water production rights from the native Carrizo Aquifer. During the recovery of the banked water some mixing is anticipated toward the end of the recovery periods, resulting in recovery of Carrizo aquifer water blended with stored drinking water. Ultimately the banked water, as well as the permitted Carrizo water, adds to the total water sources for SAWS.

2.3 Site Characterization

The Twin Oaks Recharge facility design incorporates recent technology advancements for a large scale ASR program. SAWS interviewed many other agencies performing aquifer recharge through wells. The agency then conducted a site characterization and feasibility program; designed an isolated recharge and recovery facility and developed the program into a full scale operation in 2004.

In 1996, SAWS and Bexar Metropolitan Water District began investigating the feasibility of banking water underground. Site selection and source water compatibility were thoroughly evaluated, considering potential pre and post treatment costs, in ranking the potential ASR application scenarios. Site selection included the evaluation of five different aquifer types at six unique locations. This included the Middle Trinity Aquifer; the Lower Trinity Aquifer; the brackish Edwards Aquifer; the Wilcox Group; and the Carrizo Aquifer. Source water considerations included raw surface water to treated groundwater. Potential sources included raw water from Lake Medina; raw water from the Medina River; raw water from Canyon Lake; treated water from Canyon Regional Water Authority; or treated Edwards Aquifer water. Qualitative geochemical analysis suggested that although adverse reactions are possible, each of the six storage sites was technically suitable for ASR development. Further considerations for each area were made as to the historical and projected water use; general distribution of groundwater users; and delivery requirements.

Finally, the capital, operation and maintenance cost estimates were developed for a typical ASR installation within each zone assuming large-scale ASR implementation. Analysis indicated operation and maintenance costs would range from a low of $.03 per cubic meter ($0.11 per 1,000 gallons) for the Carrizo Aquifer option to a high of $0.09 per cubic meter ($0.34 per 1,000 gallons) for the Lower Trinity Aquifer option. The marginal cost of water produced from an ASR facility including capital costs was estimated to range from $0.66 per cubic meter ($82 per acre-foot) for the Carrizo Aquifer option to $3.21 per cubic meter ($398 per acre-foot) for the Lower Trinity Aquifer option.

By the spring of 2000, the Carrizo Aquifer option was further evaluated in the second phase of the feasibility evaluation. This evaluation included the installation of test and monitoring wells. The five test borings were installed at depths of 213 meters to 579 meters (700 feet to 1,900 feet) to evaluate the aquifer strata. The ASR wells were subsequently completed with screens extending down 183 to 213 meters (600 to 700 feet). Geophysical logging, lithologic descriptions, and core samples were obtained along with water chemistry data from the completed monitoring wells. Water samples were collected and analyzed to determine the chemical constituents in the native groundwater sections encountered. Chemical and geochemical analysis on the water and the core samples concluded that there were no significant concerns regarding implementation of an ASR project in the Carrizo Aquifer using treated Edwards Aquifer water as the source water.

The aquifer capacity evaluation suggested that up to 227,100 m^3/d (60 MGD) of ASR capacity could be developed. Assuming an average seasonal recovery cycle of four months, the ASR wellfield would supply 27.6 MCM (22,400 acre-feet) of supply to help meet peak demands. The analysis indicated that continuous two year recovery at 227,100 m^3/d (60 MGD) was possible with no adverse impacts to the aquifer. Under more demanding conditions, the analysis also indicated that 113,550 m^3/d (30 MGD) of native Carrizo Aquifer water could be recovered for a 50-year yield with no adverse impacts. The conceptual design for the ASR wellfield recommended approximately 30 wells and 21 kilometers (13 miles) of piping connecting to surface storage and pumping facilities. By October 2000, a preliminary design was completed for the wells, treatment plant, on-site piping, and supply line. A total of 11 options for the supply line connection to the San Antonio source water were considered. The 48.3 kilometer (30 mile) pipeline route was selected based upon project schedule, property acquisition, ease of constructability, costs and integration of the returned water at points of greatest need to support growth.

The wellfield geochemical compatibility was tested through three cycle tests. The first test consisted of three days continuous recharge at two test wells for a total volume of approximately 22,710 cubic meters (6-million gallons) each. This test utilized a mixture of water that was in storage in the 48.3 kilometer (30-mile) pipeline and allowed the pipeline to be filled entirely with the projected Edwards Aquifer source water. No stand time was allowed and the wells were immediately pumped, recovering nearly 30,280 cubic meters (8-million gallons) each. The second test increased the radial impact with a recharge volume of 68,130 to 75,700 cubic meters (18 to 20 million gallons - MG) each over 10 days. The water was allowed a 7-day stand time, and then approximately 80 to 90 percent of the recharge volume was recovered. The third cycle included over 22 days recharge with volumes of approximately 166,540 cubic meters (44 million gallons) per well. A 19-day stand time was provided before recovering 75 to 80 percent of the recharge volume.

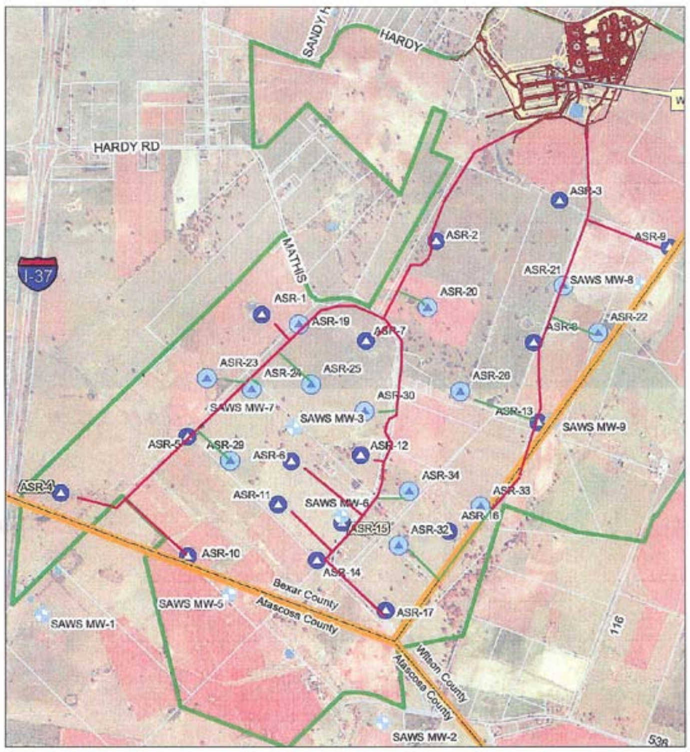


Figure 2: ASR Wellfield Layout (SAWS, 2005)

Testing indicated that mixing of the native Carrizo aquifer water became apparent around 80 percent recovery, so the “mixed” volume of water from the last two cycle tests was left in the ground to create a buffer zone around the wells. The recovered water was injected into other portions of the wellfield to prevent a resource loss. The cycle test volumes were too small to activate the 48.3 kilometer (30-mile) pipeline system and pumps for recovery of the water to the city of San Antonio.

The cycle tests indicated that the recharge water bubble did not mobilize constituents such as arsenic, and the recovered water met drinking water standards. Water levels did not exceed land surface during any of the testing periods. There were minor changes in well efficiency during injection with most losses being fully restored following recovery pumping. During 2006 the ASR wellfield was expanded to include 12 new ASR wells, raising the total to 29 ASR wells and recharge/recovery capacity to 227,100 m^3/d (60 MGD). Figure 2 shows the wellfield layout. Three Carrizo Aquifer wells (production only) were added in order to develop the 7.9 million cubic meters (6,400 AF) water right on the wellfield property. A 75,700 m^3/d (20 MGD) high service pump was added, plus three 52,990 m^3/d (14 MGD) transfer pumps, five booster pumps, a pressure reducing station and a 28,387 cubic meter (7.5 MG) clear well.

2.4 Aquifer Recharge

Many ASR programs are developed in previously stressed aquifers that have experienced significant lowering of water levels, affording a “pocket” for storing water. Many others store water in aquifers that are in an approximate equilibrium between natural recharge and discharge. For these ASR wellfields the stored water laterally displaces the ambient groundwater, forming a bubble around individual ASR wells or around the entire wellfield. The SAWS program utilizes an aquifer that is confined and near equilibrium with small scale use for agriculture, domestic and minor municipal supply. Therefore, no pocket exists into which to place the recharged water. This may create a challenge to retain the stored water bubble that is being banked from season to season. If the water is not recovered in a timely manner, the water may tend to disperse rather than remain in the area of proposed recovery. The potential water banking duration will depend upon the rate of lateral groundwater movement of the stored water bubble underground. This, in turn, will depend upon the gradient of the water levels in the aquifer at the wellfield property line, imposed by pumping from nearby wells.

During cycle testing, the managed recharge into the aquifer was generally at a rate of 7,630 m^3/d (1,400 gpm). This produced a net water level rise of about 7.6 meters (25 feet) at 60-minutes for an average injection specific capacity of 1001 cubic meters per day per meter (56 gpm/ft). This is similar to the production specific capacity observed during the recovery pumping cycles. The source water availability for recharge can be highly variable, depending on seasonal weather conditions. Cyclic droughts will result in seasons with little to no recharge water available. During seasons with rainfall above the mean, water will be placed into storage. Banked water not taken by the summer demand will then be available as a resource during drought years.

To boost the water available from the Edwards Aquifer, the regional aquifer authority at the time installed infiltration basins on the exposed sections, or natural recharge sections, of the Edwards Formation in the mid 1970’s and early 1980’s. The pilot basins recharged over 185 million cubic meters (150,000 AF) in the 30 years of operation. This was only a fraction of the nearly 34,542 million cubic meters (28-million AF) of surplus storm water that flowed through the creeks during the same period. Currently, the ability is being evaluated to install more infiltration basins in the Edwards Aquifer recharge zone. Computer modeling is being used to evaluate the hydraulic impact on the aquifer as a result of more recharge. In the karst setting, the recharged water could move quickly through the system. Spring discharges will increase as a result of the added system head. These losses could add up if the water is allowed to sit there too long. This is where the Twin Oaks Recharge Facility allows this managed recharge to the Edwards Aquifer to be wheeled some distance through the aquifer, removed through pumping, and then piped south to be placed back underground in the Carrizo Aquifer for extended storage. Development of this program will increase the sustainability of the Twin Oaks operation.

2.5 Aquifer Discharge

The Carrizo Aquifer is a confined unit with recharge/discharge occurring through communication with surrounding stratigraphic layers. Physical exits within the aquifer where stored water could be lost were not identified in the feasibility study. The confined nature of the aquifer will prevent the loss of the stored water into adjacent stratigraphic layers, helping protect from losses to undeveloped aquifer sections. The ASR well construction also helps prevent upward fluid migration through placement of annular seals from surface to the top of the target aquifer sections.

Through installation and testing of the 41 cm and 51 cm (16-inch and 20-inch) ASR wells, it was determined that the aquifer could pump 13,625 to 19,075 m^3/d (2,500 to 3,500 gpm) maximum with recovery designs averaging 9,810 to 13,625 m^3/d (1,800 to 2,500 gpm). Recovery specific capacities ranged from 411 to 1,556 m^3/d per meter (23 to 87 gpm/ft) at design rates, with most wells around 805 to 1,073 m^3/d per meter (45 to 60 gpm/ft). Differences in specific capacity are attributed primarily to well construction deficiencies. Different well drilling procedures caused significantly different formation clogging, and poor construction resulted in cement in the screen for several wells.

Water produced from the Twin Oaks ASR facility must match the typical distribution system water quality in San Antonio. The properties of the water delivered to the city must not create any adverse conditions such as corrosion, color, odor, or taste. So the water recovered from the ASR wells and any portion of native Carrizo Aquifer water that is blended with the ASR recovered water, is processed at the on-site treatment facility as needed to remove the iron and manganese, stabilize the pH and restore a disinfection residual. If no blending occurs with native Carrizo Aquifer water, and if the only water being treated is the water recovered from the ASR wells, only disinfection treatment is needed.

Figure 3: Water Treatment Plant (Morris, 2006)

2.6 Water Quality

Typically there is concern whether the source water will plug the receiving aquifer and what level of pretreatment is necessary to prevent this. In this case, native groundwater pumped from one aquifer is piped and stored in another aquifer of lesser quality. The storage aquifer has much slower groundwater movement, allowing retention of the water for later recovery. The source water for recharge is taken from the potable distribution system and has already been treated with chlorine for disinfection. The water has very low turbidity, total suspended solids, salts and metals. Figure 3 shows the outlook of the water treatment plant.

The Twin Oaks Recharge facility must be maintained in some sort of recharge or production operation most of the time. During non-operational periods, there is a chance that slow or non-moving water in the large diameter transmission main between the facility and San Antonio will stagnate. The volume of water stored in the pipeline is significant, on the order of 68,130 to 75,700 cubic meters (18 to 20 million gallons). Therefore, purging this water to waste on any routine basis is a large loss. During the first two years of operation (2004 to 2006) regional precipitation was above normal, allowing the facility to be operated in the recharge mode to develop a water bank in the Carrizo Aquifer. Since then, some water has been recovered to help meet peak demands during drought months.

The water quality issues for the recharge program are tied to the marginal quality of the receiving aquifer and the impact this has on the recovered water. The native Carrizo Aquifer water has a pH of approximately 5.5 due to the extremely high levels of carbon dioxide, Iron at 50 times the drinking water standards, Odor at 67 times the recommended limit, Hydrogen Sulfide at 40 times the limit, and Manganese at 6 times the recommended maximum concentration level for drinking water. In order to recover all of the recharged water, some portion of the native Carrizo Aquifer water would need to be removed from the transition zone of the two water types, degrading the resulting water quality.

Table 1: Receiving Aquifer Water Quality Requirements (SAWS, 2005)

CONTAMINANT	UNITS	RAW WATER DESIGN	MCL	FINISHED WATER GOAL
Primary Drinking Water Contaminant Levels				
Radium- 226&228, Total	pCi/l	4.50	5.00	<3.0
Arsenic	mg/L	<0.01	0.01	<0.01
Secondary Drinking Water Contaminant Levels				
Color, True	Color units	20	15	<3.00
Hydrogen Sulfide	mg/l	2	0.05	<0.03
Iron	mg/l	15	0.3	<0.2
Manganese	mg/l	0.30	0.05	<0.03
pH		5.50	>7.0	>7.8
Odor	T.O.N.	200	3	<2.5
Other Parameters				
Alkalinity, Total	mg/l as $CaCO_3$	30	NA	>100
Calcium	mg/l	23	NA	>40
Dissolved Oxygen	mg/l	0.10	NA	>2.0
Hardness, Total	mg/l as $CaCO_3$	35	NA	>100
Radon	pCi/l	160	300[1]	<100
Turbidity	NTU	0.20	<0.5	<0.1
Corrosion Indices				
Langelier Index		-2.0	NA	>0.20
Ryznar Index		10.1	NA	<7.1
Disinfection By-Products				
Bromate	mg/l	NA	0.010	<0.005
Total Trihalomethanes (TTHM)	mg/l	0.007	0.080	<0.040
Haloacetic Acids (HAA5)	mg/l	0.004	0.060	<0.030

[1] Radon is not currently regulated, MCL shown is proposed.

The 7.8 million cubic meters (6,400 AF) of water rights that SAWS has on the Carrizo Aquifer supports the volume of native water removed for mixing, though the primary intent for this right is to serve as an additional water supply for the City of San Antonio. For this reason, a full scale water treatment plant was constructed at the Twin Oaks Facility to treat the native Carrizo Aquifer water and recharge water blends to normal distribution system standards. Table 1 lists the receiving aquifer water quality requirements.

Experience at other ASR wellfields nationwide has demonstrated the wisdom of maintaining a buffer zone that separates the stored drinking water from the surrounding ambient groundwater. Where such a buffer zone is formed and maintained, recovered water quality usually remains relatively stable. For SAWS, maintaining a buffer zone has resulted in the recovered water not requiring retreatment other than disinfection. The buffer zone volume is usually a fixed volume, estimated initially and then adjusted through operating experience. It is not water that is stored and lost each year.

The water treatment plant processes include alkalinity adjustment, aeration, chemical addition, solids content clarification, filtration, and then disinfection. Back-flush fluids are routed to lagoons for evaporation and solids separation. The plant output meets or exceeds all Texas Commission of Environmental Quality (TCEQ) regulatory requirements including all national primary and secondary drinking water quality standards. This ensures that the water provided by the Twin Oaks Facility does not impact or corrode the distribution system and is aesthetically pleasing.

2.7 Well Design

A total of 29 ASR wells have been installed during construction phases in 2000 and 2006. The wells were installed using direct and reverse drilling programs with variable fluid control programs. The first 17 wells were designed with 41 cm (16-inch) casing and the 12 newer wells with 51 cm (20-inch) casing. All wells are constructed with 304-stainless steel rod-based wire-wrapped well screen. Slot openings ranged from 0.076 to 0.114 cm (0.030 to 0.045 inches). The blank well casing was mild steel with an internal 9-mill epoxy coating machined with threaded end sections. A dielectric coupling with Teflon was installed between the stainless steel well screen and the mild steel casing to limit potential galvanic corrosion. Each well is equipped with a water level sounding tube and gravel feed tube. The screen was enveloped in a minimum 10.2 cm (4-inch) gravel pack composed of well rounded silica sand. The annular space of each well was sealed with cement grout from the top of the target formation to land surface.

The well design included ample room for drawdown under pumping conditions without exposing the well screen. Increasing the well casing size from 41 cm to 51 cm (16-inch to 20-inch) enabled the installation of larger pumps and the increase in individual well yield by nearly 5,450 m^3/d (1,000 gpm). Much of this efficiency improvement is attributed to installation of the wells using a high quality, low formation invasion, fluid control program during drilling. In one well design, ASR-17, a pre-gravel packed screen was used in place of an installed envelope. No adverse performance issues are noted for this well and unique design.

2.8 Well Drilling and Casing Installation

In the first well construction phase, 17 wells were installed by two different contractors using different drilling methods. Nearly half of the ASR wells were drilled mud rotary with bentonite and synthetic polymers. The other half were drilled with flooded reverse circulation utilizing a light-weight water, polymer, and bentonite fluid. Each well site included a small diameter pilot boring drilled mud rotary to depths of 183 to 236 meters (600 to 775 feet) for lithologic control and geophysical logging. Each ASR well drilling method resulted in substantial formation invasion by the drilling fluids. The direct mud rotary wells produced higher efficiencies after chemical cleaning and development than the reverse circulation wells did. This was attributed to the high invasion of solids into the formation during reverse circulation drilling using a high solids, water-based fluid program. The formation invasion and well losses were confirmed by the geophysical logs and subsequent well yields. In the second well construction phase in 2006, 12 wells were drilled flooded reverse circulation utilizing a high quality bentonite polymer water-based drilling fluid program resulting in much less formation invasion (CH2M HILL, 2006).

Numerous problems were encountered with borehole stability. In several cases, the 41 cm (16-inch) casing was not able to be installed in the specified 61 cm (24-inch) boreholes, resulting in casing removal and re-reaming to 66 cm (26-inches) or larger due to washouts. In some cases, exceedingly low well yields were partly attributed to having too large a gravel envelope and not being able to effectively clean the borehole wall. The 51 cm (20-inch) cased wells were reamed to 86 cm (34-inches) at a minimum with very few problems during installation (CH2M HILL, 2003). In two wells, gravel feed tube failures resulted in cement grout flowing into the tubing breaks and down into the screen zone. Numerous attempts to brush, jet, sonic blast, acidize, and ream out the cement were unsuccessful until another contractor came in and filled the well casing with sand to the affected area and applied a concentrated dose of acid. This opened the screens to the aquifer in one well. The sand was subsequently removed from the well casing. The other well was damaged beyond repair, leaving 16 wells available for service during the first phase of well construction.

2.9 Geophysical Tests

Borehole geophysics study was completed in nearly every boring including lithologic test borings, monitoring wells, and all of the ASR wells. Geophysical data from the test wells to 579 meters (1,900 feet) below the facility helped with design of the target formation depth. Monitoring well geophysical logs were used to define formation diversity and enabled arrangement of the wells within the wellfield. The individual ASR well geophysical logs enabled selection of screen locations and aided in slot sizing.

The geophysical log suite included Caliper, Spontaneous Potential, Natural Gamma, Natural Gamma Ray Spectroscopy, Density, Induction, Magnetic Resonance, and Elemental Capture Spectroscopy. The gamma, density and induction logs aided in identifying coarse grained sections of the aquifer, aquifer porosity, and determined the degree and depth of fine grained material in each stratigraphic layer. This very sophisticated log suite was also used to evaluate the degree of drilling fluid invasion and estimate the formation hydraulic yield (transmissivity) through the use of the Magnetic Resonance log and the Elemental Capture Spectroscopy log.

During the first phase of the drilling program, the wells drilled with flooded reverse circulation with a 41 to 46 cm (16 to 18-inch) minimum bit size, required an eight inch diameter mud rotary exploratory well drilled within 6 meters (20-feet) of the final ASR well. These wells were used for geophysical logging and lithologic control at these sites to ensure accuracy of the logs and correlation to other sites. Many of these geophysical logging holes were completed as monitoring wells while others were abandoned with grout.

2.10 Acidization and Chemical Treatments

In the first phase of well installation bentonite clays were used extensively in the drilling fluid control programs, resulting in significant formation invasion. In the mud rotary applications, numerous rounds of mud dispersant chemicals were added to the wells and developed out early in the development program to dislodge and remove the drilling mud. In all cases, the process worked well and produced wells of acceptable quality and efficiency. For the flooded reverse circulation drilled wells, numerous applications of mud dispersants and acids were attempted in the wells to remove invaded material and restore performance. Chemical treatments were repeated during development on low performing wells. The approach resulted in numerous low efficiency wells and a few unacceptable wells. If the formation invasion is not stopped at the borehole wall, then re-circulated solids will be allowed to penetrate deep into the formation to distances that are not reachable with conventional mechanical or chemical development techniques.

During the installation of the second phase wells, a high quality drilling fluid program was maintained, minimizing formation invasion. During gravel pack installation, chlorine and clay dispersants were added. Additional clay dispersant chemicals were added in the first few days of development. This approach produced very clean results. The wells easily met the contact efficiency requirements.

2.11 Well Development

The wells were drilled on all accounts with bentonite and water, requiring some combination of chemical and mechanical development techniques to bring the wells into service. By contract, the driller was to deliver a well of 75% or better efficiency. The drilling method and development approach was left to the drilling contractor. In all cases, the wells were developed by swab and air lifting to remove the heavy materials. Mud dispersant chemicals were used to aid in drill fluid removal. This was followed by high capacity surge pumping. The wells were developed until pre-test specific capacity checks met the specification. In several cases, repeated development and chemical treatments were applied to improve performance.

The wells were pumped nearly 5,450 m^3/d (1,000 gpm) over the reasonable design pumping rate during development. During testing, the wells produced only trace amounts of sand, even at the high rates. This indicates good formation stability and the correct selection of the well screen slot and gravel pack size for the hydrogeologic setting. In a few cases, the wells sat for a few months before well development was even started. This stand time with drill fluids resulted in lower than normal efficiency wells.

It should be noted that the wells were developed for production service, leaving the potential for grain reversal during the recharge operations. The development programs did not use recharge simulations to develop the wells for recharge action. This is apparent during the three cycle recharge events. On each recharge cycle, the injection hydraulics improved (less rise required for the rate). The recovery pumping is clearing the recharge clogging material, resulting in increased performance on the next startup. The forces of these tests are providing development for recharge operations. With time, the recharge and backwash operation will complete the development for injection.

2.12 Pump Tests

During the feasibility study period, many assumptions were made concerning the yield of the Carrizo Aquifer, though no full scale test wells were installed to validate the proposed ASR well design. This resulted in the installation of seventeen undersized ASR wells during the first phase. During phase two construction in 2006, a dozen 51 cm (20-inch) wells were installed between the existing 41 cm (16-inch) wells. The 51 cm (20-inch) wells netted an average 5,450 m^3/d (1,000 gpm) greater yield than the smaller wells.

Tests on the wells included high speed gyroscopic plumbness and alignment tests, step drawdown pumping tests, continuous rate pumping tests, and three unique recharge and recovery tests. The tests provided the specific capacity, average transmissivity, storage coefficient, and well efficiency for each pumping well. The cycle tests provided evaluation of the recharge hydraulic response (specific capacity) and the average mounding slope before clogging sets in. The recovery pumping cleared almost all notable recharge clogging. The subsequent recharge test showed that the clogging was removed and the recharge specific capacity improved.

Pump test results for the first 17 wells had mixed results due to poor drilling and construction practices. Pumping ranged from 2,725 to 13,625 m^3/d (500 to 2,500 gpm). Pumping specific capacities ranged from 411 to 1,573 m^3/d per meter (23 to 88 gpm/ft). The average range is about 858 to 1,109 m^3/d per meter (48 to 62 gpm/ft) with an average of 1,001 m^3/d per meter (56 gpm/ft) (CH2M HILL, 2003). Test results vary due to high formation invasion, incomplete development, enlarged gravel envelopes, and cement in screen. Pumping tests for the final 51 cm (20-inch) wells ranged from 2,725 to 19,075 m^3/d (500 to 3,500 gpm). These step drawdown tests represent the baseline performance for each well under pumping conditions.

Three cycle tests were conducted in two of the 41 cm (16-inch) wells primarily to evaluate whether the process of recharge and recovery of the Edwards Aquifer source water might impact potable water quality. Each cycle contained increasingly larger volumes ranging from approximately 22,710 cubic meters (6 million gallons) to over 83,270 cubic meters (22 million gallons). The mixing stand times increased from immediate turn-around, to 7 days, and then to 19 days (CH2M HILL, 2005). Figure 4 illustrates the injection cycle trend for ASR-15 over cycle test 3. Note the nice straight mounding slope between minute 300 and 2,000. Following the 2,000 minute mark, minor clogging starts to accumulate, causing detectible changes in the water level trend, forcing an upward climb.

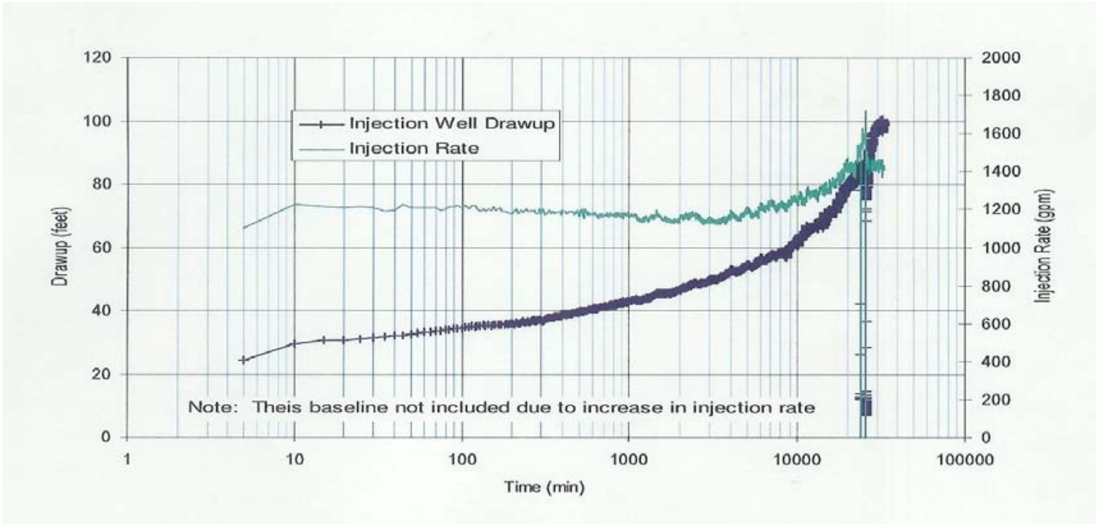


Figure 4: Cycle 3 Injection Test ASR-15 (CH2M HILL, 2005)

ASR wells are typically backflushed regularly to remove particulates that cause clogging. Typical backflushing frequencies are in the range of every few days to every few weeks. Duration of backflushing is typically from ten minutes to about two hours, depending at least in part upon materials of well construction. The Twin Oak ASR wells typically backflush on a monthly basis to maintain water level rise and efficiency.

2.13 Pump and Equipment Design

The wells were equipped with vertical line shaft turbine pumps fitted with reverse rotation ratchets to allow recharge through the pump bowls. Five wells are equipped with downhole flow control valves to allow recharge at greater rates than that achieved through the pump bowls. The wellheads are equipped with pressure gauges, vents, and water level transducers to support a fully automated operation. The above ground piping layout is one of the best observed. The distribution system water line enters the site to an above ground piping manifold with four ports controlled by pressure operated globe valves and butterfly valves. The ports are for recovery pumping from well, recharge supply to well, pipeline pre-startup purging to waste, and pressure blow-off to waste. The well collector line also contains a waste discharge line and control valve. The wellhead and associated conduits are fully sealed to allow full well bore pressure recharge. In support of this operation, an additional by-pass pipe and isolation valve has been placed on the flow line enabling the recharge water to be re-directed to the well casing annular space rather than down the pump column. This would avoid the head losses of injection through the pump string, allowing higher rates. Recharge may occur down the pump column and also down the casing annulus, thereby maximizing recharge rates.

Figure 5: Well Equipping (Morris, 2006)

Unlike a typical potable water system where the tanks and reservoirs provide pressure stabilization, the Twin Oaks wellfield is a closed system. Pressure spikes from the startup and stopping of recharge are relieved to waste at the well site relief valve. If the distribution line contains undesirable water quality, the system operator at the command center has the ability to purge the distribution system water to waste until it is acceptable for recharge. The well is then automatically placed into the injection mode. Recharge startup forces the column air into the formation, contributing to well clogging. A positive back-pressure is soon achieved and maintained on the column throughout the recharge operation. If a downhole control valve is used to increase the base recharge rate during startup of recharge and to prevent air entry into the well, the valve is manually opened in the field to the desired position and locked into place. The start and stop control is by the surface globe valve at the manifold's recharge port. Recharge is stopped once a month to back-flush the wells and to check the operation of the pumping equipment. With the routine pumping activity, the wells are maintained in a high efficiency state. Very little to no declines in recharge performance have been observed (SAWS, 2005).

Conversion between recharge and production is an automated routine. The system control calls for a stop of recharge by closing the supply globe valve. After a stabilization period, the waste valve is opened and the pump is called to start. After discharging to waste for a predetermined time, the logic control switches the flow to the distribution system line, or stops the pump and returns the site back to recharge. To date, most but not all of the recovery pumping has been limited to monthly preventive maintenance events and original facility testing. In the first two years of operation, recharge water was available to sustain the plant in the recharge mode, banking over 24.7 million cubic meters (20,000 AF). This was subsequently increased to as much as 75.3 million cubic meters (61,000 AF). More recent recovery during a drought has reduced this to 62.9 million cubic meters (51,000 AF) as of June 2009. Other than disinfection, the recovered water has not required retreatment.

The facility is in the early stages of developing long-term operational practices, purge durations, equipment calibration procedures, and field monitoring programs aimed at wellbore performance (see Figure 5). Unlike typical utility-based systems that add a few wells at a time, allowing fine tuning of the operations, this facility is a stand-alone 227,100 m^3/d (60 MGD) recharge, recovery, and treatment facility that is essentially completely new.

2.14 Installation Challenges and Critical Decisions

2.14.1 Groundwater Recharge Feasibility

The location selected for aquifer storage does not need to be in the local community, or even within the local municipal supply aquifer. The location could be in some other basin, valley, or hydrologic system connected via pump stations and pipes. In this case, the selected aquifer was located 48.3 kilometers (30-miles) south of the urban center in a completely separate hydrologic system. As for the water quality concern, the existing water quality of the storage aquifer does not need to be pristine for potable water storage. The selected aquifer has a pH of 5.5 with high iron and manganese content. Thus, an aquifer with non-compatible water quality is quite acceptable for ASR. However, treatment may be required if an adequate buffer zone is not formed and maintained at each ASR well.

Stakeholders' involvement is important. An agreement was reached with local water agencies representing domestic and agricultural interests to implement mitigation measures to minimize adverse impacts to residents during the operation of the ASR facility. Such an agreement should also account for water ownership and benefits of the ASR program to the aquifer. Texas law and groundwater regulations do not provide any protection of the stored water. They do not prevent the local groundwater producers on adjacent lands from drawing from the fresh water bubble. So facility design must account, through modeling and operational monitoring, for the maximum concentrated pumping effort that may occur on the facility border by others before the fresh water bubble may be drawn into their production. Groundwater barriers using several ASR wells on their critical border can be formed with the intent of injecting native water. This will feed the local over-pumping with native water, and force the fresh water bubble back to the recovery wellfield.

In this project, preliminary planning and designs included property and pipelines sized for the full scale operation. SAWS purchased enough land upfront to provide them 7.8 million cubic meters (6,400 AF) per year water rights from the native aquifer, and space for 29 ASR wells and three Carrizo extraction wells. The delivery, treatment, and pumping equipment were sized for the maximum 227,100 m^3/d (60 MGD) operation. A treatment plant was built to ensure water developed from the wells meets the normal water quality of the distribution system.

2.14.2 Well Installation

Most wells were drilled with flooded reverse circulation rotary methods. Eight out of twenty of these wells resulted in low efficiency due to poor fluid control programs during drilling. The remainder of the reverse drilled wells were drilled with a bentonite-polymer drilling fluid resulting in very high efficiency wells. Eight of the wells were drilled direct mud rotary. Following the use of mud dispersant chemicals, the mud rotary wells met the required efficiency requirements.

All 29 wells were constructed with blank casing that is composed of mild steel with epoxy coating. No issues have been noted to date, though the wells are only a few years old. The well screens are 304 stainless steel wire-wrap surrounded by a silica gravel envelope. Pump columns are mild steel with no special protection for the well casing epoxy coating during installation.

2.14.3 Well Equipping

The wells are equipped with several manual and electronic devices. Gauges and transducers monitor the wellhead and system pressure. Bi-directional electro-magnetic flow meters are used. The boreholes are equipped with water level transducers but with no automated air release valves. Most of the valves have position indicators. All of this data, along with motor performance data, is being transmitted back to the command center and alarmed for operation.

Borehole flow control valves are equipped in five of the wells. They are used to provide recharge flow at rates higher than that going through the pump bowls and to prevent air entry into the well screens. The valves are operated manually to a set orifice size when used. The wellhead and associated conduits are fully sealed to allow full well bore pressure recharge. In support of this operation, an additional by-pass pipe and isolation valve has been placed on the flow line, enabling the recharge water to be directed to the well casing annular space rather than, or in addition to, down the pump column. This would minimize the effect of head losses of injection through the pump string, allowing higher recharge rates.

The well site piping configuration is among the best for larger ASR wellfields. The system line enters the site to an above ground manifold with four ports controlled by pressure operated globe valves and butterfly valves. The ports are for recovery pumping, recharge supply, pipeline pre-startup purging, and pressure blow-off. The well collector line also contains a waste discharge line and control valve. Large "Y" strainers have been placed on the well recharge lines to prevent the introduction of anything larger than 1/8-inch into the pump bowls.

2.14.4 ASR Operations

The wells are designed to recharge at a rate lower than the production rate to allow pumping purge forces to be greater than injection forces. This facilitates back-flush development of the well with the existing equipment as opposed to rehabilitating the well with a higher capacity development pump. The system is fully monitored and controlled by SCADA. The system operates by a "scheduler program" placing the most efficient unit or well in a specific location, brought online first and least needed unit last. All wells are equipped with recovery pumps. The pumps are operated once a month for preventive maintenance, vibration, and performance checks to ensure operation when needed. This purge cycle helps back-flush the wells and maintain efficiency. A heavy reliance on instrumentation and automated operation must be supported by real-time data collection of the parameters. Common operation parameters such as discharge-to-waste durations change with operation of ASR wells. Waste discharge quality (sand and turbidity) and duration must be frequently checked to ensure proper flush times to remove the harmful debris. Premature shut-down during wasting could cause well or pump damage.

2.15 Conclusions

The San Antonio urban area needed to make better use of the water available within the local Edwards Aquifer system, diverting water during spring runoff and storing it for use during peak summer days and periodic droughts. Over 10 years of feasibility studies, tests, and construction were required to develop the current Twin Oaks ASR facility. This started with evaluation of six potential sites in five unique geologic settings. Considering pre- and post- water treatment costs, delivery options, and infrastructure development costs, the option to utilize the Carrizo Aquifer 48.3 kilometers (30 miles) south of San Antonio was selected for further study. Test wells and soil borings indicated the site was suitable for a large scale recharge and recovery program with minimal risk of geochemical reactions and water loss. The recovered water quality may at times include mixtures of Carrizo Aquifer water with the recovered drinking water from the Edwards Aquifer, requiring that the blend be treated to remove iron and manganese. Yet the recovered water from the ASR wells does not require retreatment, other than disinfection to restore the chlorine residual.

Without a test well program, SAWS moved immediately into installing seventeen wells cased at 41 cm (16-inches). These wells yielded production flows of 8,175 to 13,625 m^3/d (1,500 to 2,500 gpm) with recharge abilities averaging 6,540 to 7,630 m^3/d (1,200 to 1,400 gpm). The well yields are limited by the casing size. In the second phase of construction in 2006, the new wells were installed with 20-inch casing. The well yields increased nearly 5,450 m^3/d (1,000 gpm) per well. A total of 29 wells were installed at the facility up to depths of 213 meters (700 feet). The wells were constructed with stainless steel wire wrapped well screen with a 0.076 to 0.114 cm (0.030 to 0.045-inch) slot opening. The blank casing sections utilized mild steel with a 9-mil epoxy coating on the inside. Threaded casing was used to prevent epoxy damage from casing welds. To date, the epoxy casing has not posed any issues with well operation or maintenance.

Poor fluid control during drilling contributed to several of the wells being low in efficiency. High quality, bentonite and polymer fluid programs proved best to minimize formation invasion. Extensive development of the wells with chemical mud dispersants, acids, and surge pumping prepared the wells for operational service. The wells were tested with step drawdown pumping tests, continuous rate pumping tests, and three multi-day injection cycle tests. The testing indicated a wide variance in well efficiencies attributed to well installation methods. The cycle testing indicated that 80% of the water could be recovered before mixing of the native Carrizo Aquifer water became a concern. With development and maintenance of a buffer zone around each well, higher recovery efficiencies approaching 100% should be attainable in subsequent cycles, depending upon the rate of groundwater movement to offsite wells. No adverse chemical reactions or exceedences in water quality standards were detected throughout the testing.

The operation is currently focused on water banking with little recovery to date. This has focused concerns on equipment maintenance programs to ensure the readiness of the facility and keeping track of where the banked water is going during storage. In the lifespan of the facility, the program is in the early stages of exploring the limits of operation and storage. Until several complete cycles of recharge and recovery have been completed, the operation will be in a learning mode with potential operation and design adjustments to enhance performance and ensure sustainability.

2.18 References

CH2M HILL (2003). South Bexar County Aquifer Storage and Recovery Well Construction and Testing, Prepared for SAWS, 51 p.

CH2M HILL (2005). SAWS Initial ASR Cycling Testing, Technical Memorandum prepared for SAWS, 24 p.

CH2M HILL (2006). Preliminary Investigation and Feasibility Analysis Step 2 Report, Aquifer Storage and Recovery Project, 37 p.

Plummer, J. (2000). The Waters of the Edwards Aquifer, South Central Texas: Perception and Policy, 108 p.

Pyne, R.D.G. (2005). Aquifer Storage Recovery: A Guide To Groundwater Recharge Through Wells, 2nd edition, ASR Press, USA, 608 p.

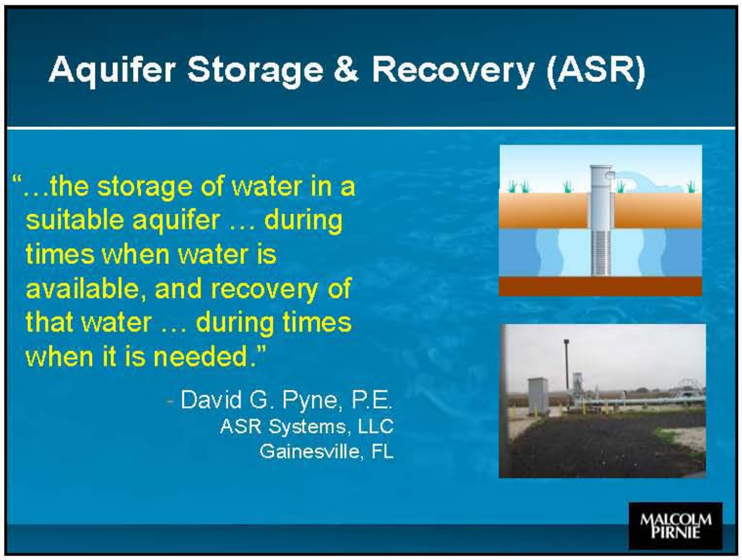
SAWS, 2005. Twin Oaks Operation Plan Technical Memorandum, prepared by the Production and Treatment Operations Department, 34 p.

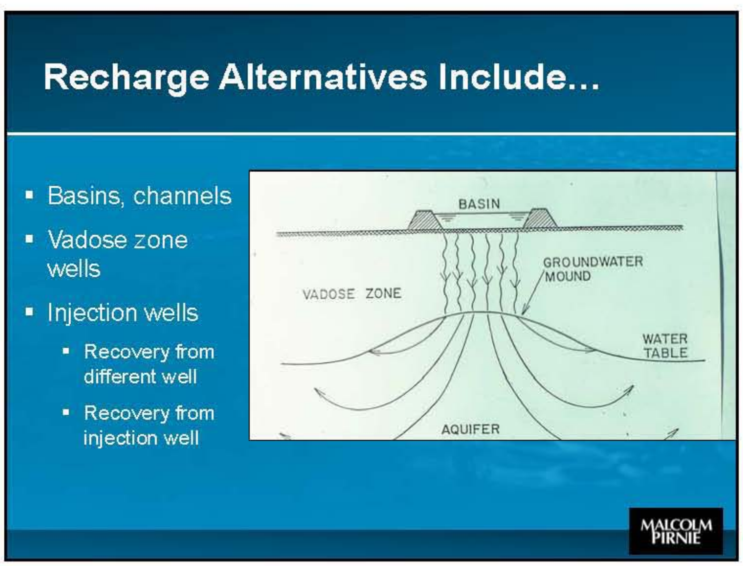
Schindel, G.M. et.al, (2005). Edwards Aquifer Authority Hydrologic Data Report for 2004, Prepared for the EAA, San Antonio, Texas, 199 p.

Todd Engineers (2005). Analysis of Recharge and Recirculation Edwards Aquifer Phase 2, Prepared for the EAA, San Antonio, Texas, 208 p.

10.4 Appendix "D": Presentation Example

12/3/2010





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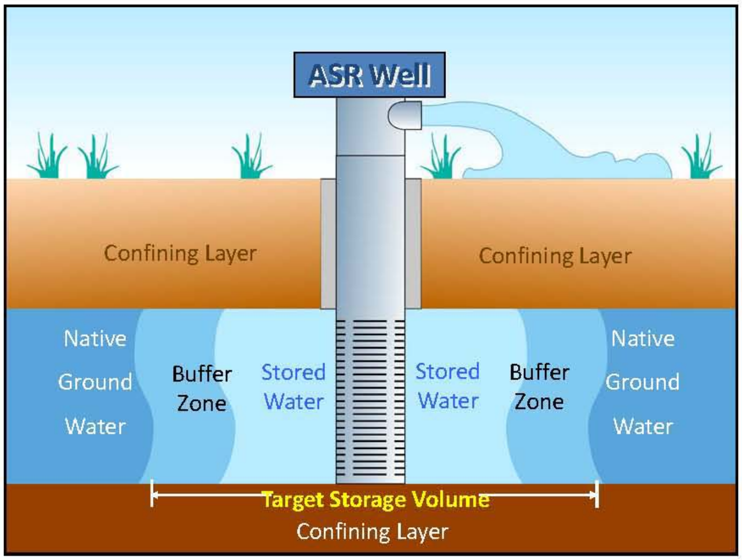
ASR Well
Confining Layer
Confining Layer
Native
Ground
Water
Buffer
Zone
Stored
Water
Stored
Water
Buffer
Zone
Native
Ground
Water
Target Storage Volume
Confining Layer


Operational ASR Wellfields (~ 95 in 2009)
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Sources and Storage Zones

- Water sources:
  - Potable water
  - Reclaimed water--treated
  - Seasonally-available stormwater--treated
  - Groundwater from overlying, underlying or nearby aquifers
- Storage zones
  - Fresh, brackish and saline aquifers
  - Confined, semi-confined and unconfined aquifers
  - Sand, clayey sand, gravel, sandstone, limestone, dolomite, basalt, conglomerates, glacial deposits
  - Vertically “stacked” storage zones

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ASR Operating Ranges

- Well depths
  - 30 to 2700 feet
- Aquifer storage interval thickness
  - 20 to 400 feet
- Storage zone TDS
  - 30 mg/l to 39,000 mg/l
- Storage Volumes
  - 100 AF to >270,000 AF
- Individual wells up to 8 MGD
- Wellfield capacity up to 157 MGD

Calleguas MWD,
Thousand Oaks, California
ASR Well

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Texas ASR Operations

- Currently 3 active ASR operations
  - San Antonio Water System (SAWS)
  - El Paso Water Utilities– Public Service Board (EPWU)
  - City of Kerrville
- Only 1 proposed project in current Water Plan
  - Expansion of Kerrville WTP and ASR
- Few studies underway
  - UGRA Water Supply Study in Kerr County
  - SAWS Capacity and Capability RFP

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San Antonio Water System

San Antonio Water System

Twin Oaks ASR Facility

OBJECTIVES: Began as seasonal storage reserve; transitioned to long-term storage

- 3rd largest ASR project in U.S.
- 29 ASR wells
- Capacity: 60 mgd
- Source: Groundwater from the Edwards Aquifer
- Storage zone: Carrizo Aquifer

Operation began in 2004

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Twin Oaks ASR Facility

San Antonio Water System

Carrizo Aquifer

- Confined aquifer
- pH 5.5
- Elevated Fe/Mn and hydrogen sulfide
- Project includes 7 local Carrizo wells

To date, only disinfection has been needed for recovered ASR water

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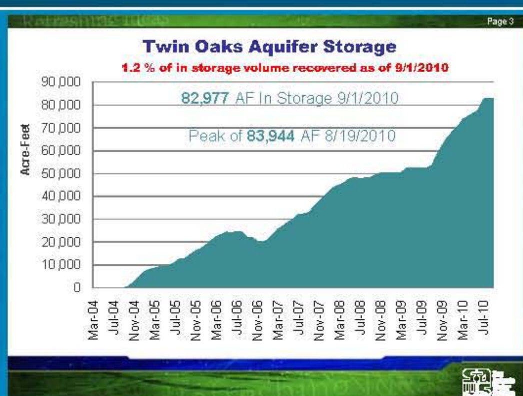
SAWS ASR Storage Volume



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El Paso Water Utilities

OBJECTIVES: Restore GW levels; store reclaimed water; improve WQ; supply peaking water

- 1st ASR project in Texas
- 4 ASR wells and 4 basins
- Capacity: ~10 mgd
- Source: Treated wastewater from Fred Hervey WRP
- Storage zone: Hueco Bolson Aquifer

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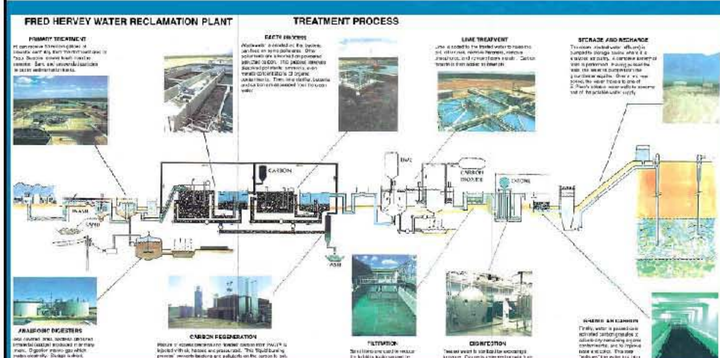
EPWU—Fred Hervey WRP



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CITY OF Kerrville

OBJECTIVES: Storage for drought management and peaking

- 2nd ASR project in Texas (1995)
- 2 ASR wells (3rd in development)
- Current capacity: 2.65 mgd
- Source: Treated surface water from Guadalupe River
- Storage zone: Lower Trinity Aquifer
- Max stored volume to date: 2,100 AF

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Summary

Component	EPWU (10 mgd)	Kerrville (2.65 mgd)	SAWS (60 mgd)
Date	1985	1995	2004
Source Water	Treated Wastewater	Treated River Water	Groundwater
Storage	300-835 feet Hueco Bolson	495-613 feet Lower Trinity	400-600 feet Carrizo
Issues	• Original well design • Customers for reclaimed water	• Litigation during permitting • Lack of source water	• Single pipeline • Distribution system limitations
Expansion Plans	Expanding FHWRP Constructing 4th spreading basin	Adding 3rd ASR well WTP expansion in Regional Plan	Part of 50-year Management Plan Evaluating TSV

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TWDB ASR Research Project

HB 1989 (1995) recognized ASR as a beneficial use

Why is ASR not being implemented?

What policy changes or technical studies are needed?

Scope of Work:

- Legal white paper
- Interviews /site visits with 3 participating utilities
- Survey of other TX utilities
- Review of literature and US/global practices
- Presentations and guidance for implementation

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Study Team

- Malcolm Pirnie, Inc.
- ASR Systems, LLC (Gainesville, FL)
- Edmond McCarthy, Jr., JD
- Existing ASR Utilities in Texas
  - ✓SAWS
  - ✓EPWU
  - ✓Kerrville

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ASR Considerations

- Recharge water quality and treatment requirements
- Water quality in receiving aquifer
- Land availability and cost
- Recovery efficiency
- Project costs and public perception
- Legal / regulatory framework/permits
  - Rule of capture
  - Source water permit(s)
  - TCEQ Class V injection well permit

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ASR Advantages

- Minimal evaporation/loss
- Fewer environmental impacts
- Competitive cost
- Flexibility--incremental well addition
- Broad public acceptance
- Ability to readily supplement other water supply strategies
- Broad range of applications and geographic settings

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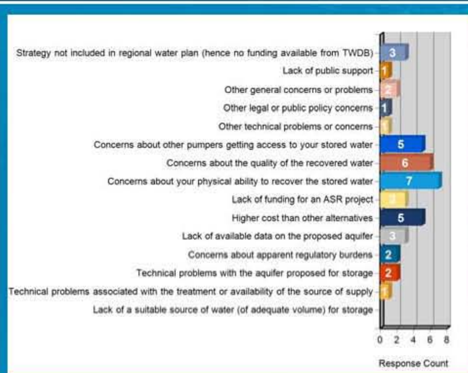
Initial Utility Survey—Why ASR Has Not Been Pursued



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Conclusions

- Technical issues are not the major inhibiting factors
- Regulatory and legal issues impose the major obstacles
- Capital costs and O&M expenses—seldom accurately documented
- Good public perception and acceptance
- Significant opportunities for the future
  - ❑Treated water stored in brackish aquifers
  - ❑Use of reclaimed water as source of supply
  - ❑Use of excess WTP capacity in winter months
  - ❑Peaking water to meet summer demands
  - ❑Temporary and scalping permits

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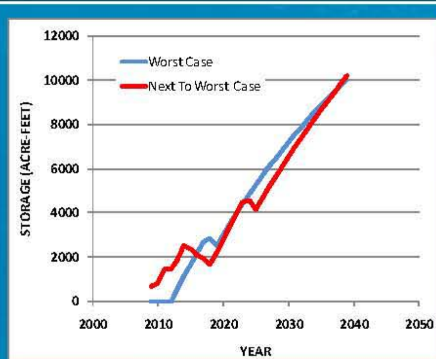
Case Study Storage Volume



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Recommendations

- Demonstration program by TWDB and TCEQ
- Legal and regulatory modifications
- Incentives for more accurate cost data
- Interagency coordination
- Funding for statewide data gathering
- Additional research
- Additional focused education
- Evaluation of water exchange within aquifers

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Questions

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Senior Associate

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10.5 Appendix "E": Utility Reports Reviewed for the TWDB ASR Study

Utility	Report Title	Report Date	Report Author	Type of Study (e.g., ASR evaluation, design, review of full-scale system)	ASR Source Water Type	Date of initial ASR installation (if applicable)	Supply/ storage objectives	Issues
City of Pasadena	Pasadena Groundwater Storage Program: Final Conceptual Design Report	10/2007	RMC Water and Environment	ASR Evaluation, Conceptual Design, Cost Estimate	Imported (surface water?)	N/A	Water Supply Flexibility	None identified with ASR.
City of Austin	Aquifer Storage and Recovery Phase I - Feasibility	10/1996	CH2MHill	Phase 1 Feasibility Study	Colorado River via City of Austin WTP	N/A	Ability to meet future peak day demands without expanding SWTPs	All identified as minimal, impact on: groundwater levels, streamflows, water quality, local ecosystems, potential for contamination of groundwater.
Colorado River Municipal Water District (CRMWD)	Water Conservation and Drought Contingency Plan	05/2009	Freese & Nichols	Drought contingency plan	N/A	N/A	None	None.
El Paso Water Utilities	Permit to Dispose of Wastes - Renewal	5/27/1980	Texas Commission on Environmental Quality (TCEQ, formerly TNRCC)	Permit Renewal	Fred Hervey Water Reclamation Plant	Unknown	Groundwater Recharge	None identified.
City of Kerrville	Amendment of Class V Aquifer Storage and Retrieval Well		TCEQ	Addition of 1 well to initial permit.				
San Antonio Water Systems	Authorization and Registration of a Class V Aquifer Recharge Injection Well		TCEQ					
Brownsville Public Utilities Board (BPUB)	Aquifer Storage and Recovery System - Step 1 Report Feasibility Investigation	01/1996	CH2MHill	ASR Evaluation	Rio Grande River treated at WTP	N/A	Store treated water obtained when River flows are high and BPUB is able to withdraw additional water (over permit) from the River.	Recommends proceeding with drilling test wells in conjunction with TWDB.
Brownsville Public Utilities Board	Aquifer Storage and Recovery System - Step 2 Report Feasibility Investigation	09/1997	CH2MHill	ASR Evaluation - Field Investigati	Rio Grande River treated at SWTP	Test wells drilled. Work began in 10/1995.	Store treated water obtained when River flows are high and BPUB is able to withdraw additional water (over permit) from the River.	Recommends installation of ASR wells in certain geological zones, and continued field research by drilling additional test wells in conjunction with TWDB.
High Plains States	Groundwater Recharge Demonstration Program		US Bureau of Reclamation, http://www.usbr.gov/projects/Project.jsp?proj_Name=High+Plains+States+Groundwater+Recharge+Demonstration+Program+Project					
Los Angeles and San Gabriel Rivers	Water Augmentation Project		http://www.lasgrwc2.org/programsandprojects/was.aspx#					
San Antonio Water Systems	Aquifer Storage and Recovery - Preliminary Investigation and Feasibility Analysis - Step 1 Report	04/1998	CH2MHill	ASR Evaluation	Treated surface water from an undetermined source.	N/A	Long-term storage of treated surface water.	None Identified.
San Antonio Water Systems	Aquifer Storage and Recovery Report - Step 2 Report	04/2000	CH2MHill	Test well drilling, aquifer capacity, water quality compatiblity assessment, conceptual design	Treated surface water from an undetermined source.	May 1999 - March 2000	Long-term storage of treated surface water.	None identified - recommended proceeding with ASR project.
San Antonio Water Systems	Concept Development Report - Carrizo Aquifer Storage and Recovery Project - South Bexar County	10/2000	CH2MHill	Concept development for ASR.	Treated surface water from an undetermined source.	N/A	Long-term storage of treated surface water.	
San Antonio Water Systems	Quality of Groundwater at and near an Aquifer Storage and Recovery Site, Bexar, Atascosa, and Wilson Counties, Texas, June 2004 - August 2008		USGS	Water quality study of native groundwater, and pre- and post-injection ASR water.	Edwards Aquifer groundwater	August 2002 Operational in June 2004	Storage of Edwards Aquifer water	Conclusion of the study was that the injection of Edwards Aquifer water had no appreciable impact on the water quality of the Carrizo Aquifer near the injection point.
City of Wichita	Equus Beds Aquifer Storage and Recovery Project	6/17/2010	www.wichita.gov	Website Publication	Little Arkansas River		Additional water source	Public information document, general overview o
City of Laredo	Step 2 Report - Feasibility Investigation - Aquifer Storage and Recovery System	01/1999	CH2MHill					
Upper Guadalupe River Authority	Aquifer Storage Recovery Feasibility Investigation - Phase 1 - Preliminary Assessment	04/1988	CH2MHill	Preliminary Assessment	Guadalupe River	N/A	Increase water supply capacity and avoid groundwater drawdown.	None identified.
Upper Guadalupe River Authority	Aquifer Storage Recovery Feasibility Investigation - Phase IIA - Monitoring Well PZ-1 - Volume I - Report	12/1989	CH2MHill	Construction of a production zone monitoring well.	Guadalupe River	Monitoring well completed in September 1989.	Increase water supply capacity and avoid groundwater drawdown.	None identified.
Upper Guadalupe River Authority	Aquifer Storage Recovery Feasibility Investigation - Phase IIB - Full-Scale Testing and Evaluation	04/1992	CH2MHill	Construction and testing of a full-scale ASR system.	Guadalupe River	First well installation completed 12/1990.	Increase water supply capacity and avoid groundwater drawdown.	None identified. Report recommended proceeding with ASR as an alternative to WTP expansion.

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10.6 Appendix "F": Responses to TWDB Comments

Study Team Responses To
Consolidated List of Comments on *An Assessment of Aquifer Storage and Recovery in Texas*
TWDB Contract No. 0904830940

General Comments

1. Overall, the report does a good job of addressing many technical, economical, environmental, legal, regulatory, and institutional factors that have impacted ASR implementation in Texas, and, in general, represents an important first step in advancing ASR in Texas. However, it is lengthy and contains a lot of detailed information, some of which is redundant across multiple sections and some of which may be too superfluous to serve as a guidance document. Please consider reducing the report's volume by avoiding repetition, replacing text with tables and figures where appropriate (this would also increase aesthetics), and making sections more deliberate/concise with regard to purpose and intent.

   The report has been made more concise and redundancies have been eliminated. However, some new information was added in response to other comments, as shown below.

2. To allow for a more logical flow to the report, please consider rearranging the sections. One suggestion is below.

   - Executive Summary
   - Introduction and Background
   - Successful ASR Systems in Texas
   - Why is ASR Not Being Used More in Texas?
     - Survey and Results – Technical Issues
     - Legal Issues
   - Conclusions and Recommendations
   - References
   - Appendices

   The report has been reordered.

3. The term ASR is used inconsistently throughout the report. Its definition ranges from injection wells (pages 10 and 31) to spreading basins (page 16) and recovery from the same well (page 10) to recovery from the same aquifer (page 10). Because of the moving definition, it is difficult to assess what is being addressed. Please consider clearly defining ASR at the beginning of the report and discussing issues within the context of that definition. Also, please define hybrid ASR, ASTR, and spreading basins because they are used in various parts of the report.

   The following definition is now shown in the report: ASR is "the storage of water in a suitable aquifer through a well during times when water is available, and recovery of

the water from the same aquifer during times when it is needed using the same well or a different well."

Spreading basins are not included in the definition for purposes of this report.

ASTR is defined in the report.

4. From information presented in the report, it does not appear that the El Paso facility is an ASR system. If it is important to consider the "operator's intent" as stated on page 16, El Paso is not an ASR system. El Paso's motivation was to recharge the Hueco Bolson Aquifer (page 108), not to serve as a storage and recovery facility. Furthermore, the injection wells being used at the facility are not production wells; recovered water is not being produced from the same location in which it was injected; and spreading basins are also being used to place the water into the subsurface. All these suggest that El Paso is not an ASR system, but can be better categorized as a recharge system. Perhaps, once a firmer definition of ASR is established, El Paso's status will become clearer.

   For purposes of this study, the El Paso Water Utilities (EPWU) water management system is considered an ASR operation because: (i) EPWU initially began its ASR project exclusively with injection wells, and injection wells are still used; (ii) the agency's injection wells are equipped with pumps which can be used for recovering stored water; (iii) EPWU's stated purposes for operating its ASR system include recovering stored water to meet peak demands for potable or industrial purposes; and (iv) the non-ASR production wells used to recover stored water are located in the same aquifer as the injection wells, and they are operated as part of the same municipal system.

   In addition, EPWU was shown as an existing ASR operation and participating agency in the Study Team's proposal to the TWDB.

5. For completeness of information and to provide a better perspective on the development of ASR in Texas, mention should be made in the report (Introduction section) of projects that were funded by TWDB in the 1990's. These projects resulted from ASR legislation in 1995 that laid the foundation for ASR studies in several areas of Texas. The references for these studies should be included in the References section.

   The TWDB projects list provided by the TWDB staff has been added.

6. Section 3; Legal Perspective for Texas: To make this section more readable, please consider placing certain information such as detailed background information on law formulations in an appendix. Also, please explore any other strategies to reduce lengthiness and facilitate a more simplistic discussion of concepts.

   The Study Team has deleted and reordered portions of the legal section to reduce the length. Some background information has been retained so that the entire section can be used for reference.

7. Section 3; Legal Perspective for Texas: Although potentially appropriate for legal manuscripts, the current structure of including footnotes within the body text at the bottom of each page is distracting to the general public. Please consider moving the footnotes from the body text to the end of the section or to an appendix.

   Footnotes have been converted to endnotes and are included in Section 10.7 Appendix G.

8. Section 3.1: This section distinguishes between the definition of ASR as a "technology" (i.e., wells only/same location) versus ASR as a "legal/public policy concept" (i.e., wells and spreading basins/recovery from different location). For the sake of clarification towards the general reader, consider whether that distinction is necessary for the purposes of defining ASR and, if so, provide justification.

   See No. 3 above regarding the definition of ASR.

9. The report does a good job of describing the numerous benefits of ASR, including environmental impacts. However, it should also mention the potential for adverse environmental impacts as an important factor to be considered when determining the suitability of ASR at a particular location. For instance, similar to building a surface water reservoir, capturing and injecting flood flows into an aquifer can affect the timing, frequency, duration, and magnitude of a river's flow regime, which in-turn, can have adverse impacts on the flora and fauna that depend on the river. Please address this issue in the report.

   The Study Team has added a discussion of some of the potential adverse impacts.

10. Numerous comments are made in the report suggesting that ASR has benefits surpassing alternative management storage options. Please consider making direct comparisons of storage options using quantifiable information as supporting justification. Beyond environmental, societal, and economic benefits, specific logistical information could be assessed such as comparable volume capacities in storage systems, operation lifetimes, chemical composition sustainability, impacts to downstream users, or the physical ability to accommodate high flows (such as flooding) for storage.

    The Study Team added information on direct comparisons of storage and water supply options from two 2010 IPP regional water plans located in the area of the San Antonio and Kerrville ASR projects.

11. The survey results (Section 7) do not appear to substantiate the report's conclusion that legal/regulatory issues are the principal concern or barrier to ASR. The survey results collected focused equally if not more on the technical (i.e., physical) challenges (60 percent) and economic challenges (50 percent). Therefore, please consider discussing the technical, legal and economic challenges in a more balanced approach. Regarding economics, while we recognize that cost information is lacking for ASR projects, cost and operational information for other alternatives (i.e., surface reservoirs) can be discussed. Regarding technical issues,

while lack of education on ASR may be the driving factor, the report could provide an overview of the wide array of technical issues to consider as a step in this direction. Please consider addressing these issues.

The Study Team considered socio-economic issues such as cost to be a non-technical concern, unlike those related to the physical properties of the storage aquifer or the design of the facilities. In the survey concerns related to the ability to recover the stored water were broken out into: technical issues associated with the hydrogeology of the aquifer (c); perceived concerns about the physical ability to recover the water and water quality (h, i); and, policy-related concerns regarding the potential for other pumpers to access the stored water (j). The survey was delineated in this way to gain insight into whether utilities' concerns about the ability to recover stored water were based on physical limitations with the storage aquifer or more non-technical concerns such as socio-economic factors (including cost) and legal issues. With regard to the utility surveys, some respondents may have interpreted the "concern about physical ability to recover the stored water (c)" as either a hydrogeological issue or a non-technical issue such as other pumpers gaining access to the stored water. From the in-depth interviews with the utilities operating successful ASR projects in Texas, it was obvious that non-technical issues were potentially more of an impediment than those related to the physical properties of the storage aquifer or other technical issues.

12. Please spell "ground water" as "groundwater" throughout the report.

    Done

13. Please uppercase "a" in "aquifer" if it is one of the 30 major and minor aquifers identified by the TWDB and when used in the singular.

    Done.

Page-Specific Comments

Page iii: Please consider adding descriptive titles to the appendices listed in the table of contents.

Added.

Page 3, second bullet: Please replace “Qualify” with “Quality”.

Replaced.

Page 4, list number 1: Please explain the need to redefine ASR in a broader context. ASR, as we understand it, is focused on injecting and recovering the “same” water from the “same” well.

See No. 3 above.

Page 7: This entire section is repeated in the “Conclusions and Recommendations” section of the report. Please consider summarizing the conclusions in the Executive Summary and detailing the actual proposals at the conclusion of the report.

Done.

Page 9; last sentence: Please remove “and” between “studies” and “throughout”.

Removed.

Page 10, second paragraph: ASR is defined here as recovery from the same aquifer as opposed to the same well. Is this within the definition of an ASR? Please clarify.

See No. 3 above.

Page 10, third paragraph: This statement is correct in that the focus of ASR is one of storage and recovery and correctly compares it surface reservoirs. However, by expanding the definition, potentially additional benefits can go beyond storage and recovery. Please consider the implication of this possibility in the discussion.

See No. 3 above.

Page 10, third paragraph, line 4: Please remove “See Figure 2-1” and add it in parenthesis to the end of the previous sentence.

Done.

Page 11, description of Figure 2-2: Note that the terminology is focused on defining the storage of the water that implicitly assumes capture by the same well (strict ASR definition). Please note that expansion of the definition to include El Paso would necessitate expansion of examples shown on the map.

See No. 3 above.

Page 12, Figure 2-2: The figure is based on the strict definition of ASR which is inconsistent with the definition stated on page 10. Please take this comment into consideration.

See No. 3 above. The figure title has been clarified.

Page 12, both paragraphs and page 13 through first full paragraph: This discussion is based on a strict definition as opposed to the "broader" definition of ASR. Please base the discussion on the definition of ASR.

See No. 3 above.

Page 13, last paragraph: This is confusing. The transition from a discussion on the buffer zone in an ASR system to the use of reclaimed water is abrupt and arbitrary. Please consider revising this paragraph. Furthermore, the reference to salinity barriers in California appears to be out of place in the context of the discussion. Please remove this sentence.

Removed.

Pages 10-13: The illustration of the ASR well cross section is useful, but it would be even more useful to show a general illustration of the entire ASR process: from source water to well injection to storage to recovery. Please consider modifying Figure 2-2 or adding another illustration.

A general illustration has been added as Figure 2-3.

Page 13, third paragraph: Please consider defining "reclaimed water".

Defined.

Page 13, paragraph 3, lines 7 and 8: The sentence "However, decades of experience with …." appears to be an incomplete sentence. Please correct.

The partial sentence has been deleted.

Page 15, first paragraph and page 16, first paragraph: These definitions are inconsistent with the definition on page 10. Please refer to the comment in the General Comments section on the need to clearly define ASR.

See No. 3 above.

Page 16, first full paragraph: This statement is specifically why the El Paso project is not an ASR project. Please consider the comment in light of how ASR is defined for the project.

See No. 3 and No. 4 above.

Page 16, third full paragraph: Because of the fuzzy and changing definitions of ASR in the report, it is unclear whether these policy and/or regulatory changes are needed for ASR projects or also for other "artificial recharge" projects. Please clarify and address.

See No. 3 above. Hopefully the clarified definition is less "fuzzy."

Page 16, last paragraph and extending to the first part of page 17: Using injection wells allows for "control" of the stored water (i.e. bubble) that is not possible with recharge from infiltration. This is the essence of ASR. Expanding the definition to include recharge from spreading basins and recovery from "other" wells is inconsistent with policy and regulatory initiatives that rely on the concept of having an identifiable "bubble" and "buffer zone". Please address.

See No. 3 above. Recovery from "other" wells within an ASR wellfield is consistent with the clarified definition of ASR.

Page 17: Please add a period to the first sentence.

Added.

Page 17, first full paragraph: The transition from a discussion of ASR in previous paragraphs to water supply problems in Texas is abrupt. Please consider adding a subsection header at the beginning of the first full paragraph on this page.

Added.

Page 18, first full paragraph, last sentence: Please remove “Texas” from the sentence.

Removed.

Page 18, last paragraph: Please define conjunctive use. ASR can have a role in conjunctive use, but so can other artificial recharge strategies. Legal and regulatory issues for conjunctive use are a superset of the legal and regulatory issues for ASR, and need to be discussed under the reports definition of ASR.

Conjunctive use is defined.

Page 18, last paragraph, last sentence: Please consider moving this sentence which describes the purpose of the paper to the beginning of the section.

Moved.

Page 19, section 3.2: Since surface water is listed first, please consider discussing it first in section 3.2.1 (page 20).

Reordered.

Page 29, second full paragraph, line 3: Please remove one period at the end of the sentence.

One period has been removed.

Page 31, first full paragraph, last line: Please remove the end quote at the end of the sentence.

End quote removed.

Page 32: If the definition of ASR is determined to include spreading basins, please consider including a list of permitting requirements for the use of spreading basins.

See No. 3 above. Spreading basins are not included in the definition.

Page 34, section C: Please explain the basis for selecting the five groundwater conservation districts discussed in the report. There are also other districts that have rules related to ASR.

Five districts were selected to be representative of the various issues related to regulation of ASR, and at the same time to avoid duplication.

Page 34, last paragraph: Please include the Evergreen UWCD in the list of GCDs mentioned because it is discussed later in the report. It should be noted that issues related to the development of ASR rules in EAA, Evergreen UWCD, and Gonzales and Medina GCDs were in response to SAWS planned ASR project that they ultimately sited in an area that did not have a

GCD. An analysis of how SAWS dealt with these entities and their decision making process would be consistent with the scope of this study. Please consider adding this information. Also, please change "For" (sic) at the beginning of the second sentence to "Five".

The Evergreen UWCD has been added. A discussion of the SAWS activities and decision-making processes has been added. The typo has been corrected.

Pages 36 through 38: Please superscript footnote numbers 154 through 176 (except number 168).

Done.

Page 42, list item number 9: Please superscript footnote number 214.

Done.

Page 53, subsection B: Please see earlier comments in the General Comments section on the El Paso project. Also, most of the information here is duplicated in other parts of this report.

See No. 4 above.

Page 56, first three lines: This is data from 2003. Please consider providing more recent data, if available, for the volume of reuse water being recharged to the Hueco Bolson Aquifer.

This outdated information has been deleted in the interest of responding to an earlier comment about redundancy and reducing the volume of the report.

Page 58, subsection E: This is a good description. Please consider adding a substantive discussion of this effort in the "technical" portions of the report.

A discussion on the Corpus Christi ASR District is included in Section 4.

Page 60, first paragraph, last sentence: Please consider including some examples of the irrelevant issues that were encountered by UGRA during the permitting process. It will help us better understand the issues.

The discussion of existing ASR operations in Texas was moved to Section 3. The detailed references to the water rights permitting aspects of the Kerrville project were deleted to avoid redundancy.

Page 64, first full paragraph: Please replace "Capital" with "Capitol".

Done.

Page 64, last paragraph, last line: Please change "aide" to "aid".

Done.

Page 65, first full paragraph: ASR is defined here as "recovery from the same wells". However, the analysis fails to evaluate how this changes if recovery is from different wells, as mentioned elsewhere in the report. Please consider adding this information to the analysis.

See No. 3 above.

Page 66, first full paragraph: The issue of "drainage" is a technical issue that highlights a limitation of the traditional ASR project. Essentially, the illustration on page 12 assumes that the gradient is nearly flat and that the "bubble" and "buffer zone" are manageable. Flat gradients are not typical in Texas. If a significant gradient exists, stored water will migrate and the "bubble" and "buffer zone" will be more difficult to manage and control. The amount of "drainage" is dependent on the regional gradient, and the timing of recovery relative to the injection or spreading (i.e. the storage time). A discussion of this limitation would be helpful since this is at the heart of one of the usual concerns about ASR – capturing the stored water when it might migrate away from the wells. Please consider including a discussion on this issue in the report.

The Study Team added a discussion on this issue.

Page 66, third full paragraph: The subject matter of this paragraph and the paragraphs that follow (legal questions on ASR) is different from the immediately preceding paragraphs (discussion of SAWS and other ASR projects). Please consider adding a subsection header at the start of the paragraph.

Subsection added.

Pages 74 and 75: Please remove one of the two blocks of text starting with "The Commission's rule" and ending with "relating to Water Hygiene". They are duplicates.

Removed.

Page 78, list number 9: Please superscript footnote number 511.

Done.

Page 78, footnote 512: The footnote seems lengthy relative to the fact being presented. Please consider shortening it. Also, the Webpage link (*http://www.cagesun.nmsu.edu/AGRICULTURE/wcc/epconser/index.html*) appears to be incorrect. Please verify and change if incorrect.

Deleted.

Page 79, first full paragraph, lines 6 and 7: Please consider removing the sentence. The reference to El Paso's recharge basins appears to be inappropriate. It again raises the question alluded to earlier about the definition of ASR.

Removed.

Page 87, list number 5(i): Please add the word "operator" after "ASR".

Done.

Page 91, first two paragraphs: Please consider moving this information to and integrating with text in the "Introduction and Background" section of the report.

Done.

Page 91, first paragraph, line 3: Please revise "man" to "many".

Done.

Page 91, third paragraph: Please consider previous comments about including El Paso in this analysis.

See No. 4 above.

Page 92, Table 4-1: Please consider discussing the three ASR projects in Sections 4.1 through 4.3 in the order that they are presented - from left to right - in Table 4-1.

Table 4-1 has been reordered.

Page 93, figure 4-1: As presented, the map provides little information. Please consider including a larger map with a legend of all the features shown on the map.

A new map has been inserted.

Page 94, first paragraph: While the technical details about the SAWS project are interesting, an equally interesting story would be the regulatory issues. The previous chapter detailed ASR rules in groundwater conservation districts where SAWS contemplated ASR projects, but chose instead an area with no district. That story would be consistent with the objectives of understanding the barriers to developing and implementing an ASR project. Please consider including such a discussion.

A discussion on this issue has been added to Section 3.1.3.

Page 95, section 4.1.1, last paragraph: The sentence appears to be incomplete. Please correct.

Corrected.

Page 96, 2nd and 3rd paragraphs: Please delete one of the paragraphs because they are duplicates.

Done.

Pages 99 to 101, section 4.1.6: The general information on ASR in this section is redundant. Please consider removing it.

Done.

Page 98, first full paragraph: This is an editorial remark. Please consider deleting it.

Done.

Page 100, first full paragraph: Please explain how this buffer zone is defined given the regional gradient.

This paragraph has been deleted because most of the information had previously been provided. Given the number of wells in the SAWS wellfield, the buffer zone is related to field, not necessarily to individual wells.

Page 105, section 4.3: Please consider earlier comments on the El Paso project.

See No. 4 above.

Page 106, last paragraph, first line: Please change the date of the TWDB study from “1978” to “1979”.

Done.

Page 106, last paragraph, line 6 and page 108, section 4.3.1, line 4: Please remove “River” from “Rio Grande River” wherever used in the report. It is redundant.

Done.

Page 107, figure 4-6: As presented, the schematic is illegible. Please consider enlarging it and presenting it on a separate page.

EPWU provided a new version of this graphic which was inserted in the report.

Page 107, last paragraph, line 4: Please delete “to waste” from the sentence.

Done.

Page 108, section 4.3.1: The discussion emphasizing the original motivation for the El Paso program to recharge the Hueco Bolson Aquifer is at odds with the legal analysis in Section 3. Please explain why the El Paso program should be considered an ASR project.

See No. 4 above.

Page 110, section 4.3.5: Please note that the performance of the injection wells in the El Paso project has not been mixed. It was unacceptable. This is the reason the utility converted to spreading basins. The project is heading towards a system where spreading basins are used and wells located some distance away (to meet residence time requirements) to “recover” the spread water. This is a more traditional “artificial recharge” project as opposed to an ASR project.

The word “mixed” was used in describing the EPWU injection wells because the wells were performing their function of injecting water into the aquifer, but there were corrosion issues due to the materials initially used. The current injection wells with other materials (PVC) are performing in an acceptable manner.

See No. 4 above.

Page 110, section 4.3.6: As noted, the legal analysis does not mention the permitting process for spreading basins, and it is only mentioned here without details. Please consider expanding the discussion if the definition of an ASR is determined to include spreading basins.

See No. 3 above.

Page 111, section 4.3.7: The previous paragraph notes that injection wells are not going to be replaced with wells, but with spreading basins. This section starts with some of the details of reserving land for spreading basins, but refers to them as “ASR facilities”. Please refer to them as spreading basins, not ASR facilities.

The wording has been changed.

Page 113, first paragraph: Please consider deleting this paragraph. The information is redundant, having already been presented in several earlier sections of the report.

Deleted.

Page 113, second paragraph: Please consider removing the statement, "the lag in ASR implementation in TX relative to other portions of the country is surprising". Not only is this a subjective statement, it is made in the context of climatic conditions rather than within a legal framework which is the focus of the report's conclusion on the dearth of ASR projects in Texas.

Removed.

Page 113, section 5.1: Please include in the main body of the report the list of survey questions that were sent out to the utilities.

The list of survey questions has been inserted.

Page 114, summary table: The scope of work specifically mentioned Laredo and McLaren (sic). Yet these entities did not return the surveys. Were attempts made to follow-up and find out more from them? Please elaborate.

Yes, the Study Team made attempts to have Laredo and McAllen return the surveys.

Page 114, summary table: Corpus Christi responded to the survey, but there was no follow-up interview, even though they have a GCD devoted to this issue as discussed in the legal section. Please explain why there was no follow-up and coordination with the entity? The summary discussion on pages 121 and 122 appears to be a review of the district's management plan only.

The Study Team made unsuccessful attempts to get additional information on the Corpus Christi ASR District.

Page 114, section 5.2: Please consider deleting this paragraph. The information is redundant, having already been presented in several earlier sections of the report.

Deleted.

Page 115, section 5.2.1: Please consider referencing, as appropriate, figure 5-1 in the discussion.

Done.

Page 117, second and third paragraphs: These paragraphs provide discussions and conclusions about the survey results. Please consider placing this information either in a standalone section separate from "results" or removing them altogether and discussing them only within the "Conclusions and Recommendations" section.

These paragraphs were moved.

Page 119, section 5.2.3, City of Midland, paragraph 3, last sentence: Please consider providing more information about the local aquifer into which the water was injected and if the well was located within a groundwater conservation district.

More information was obtained by the Study Team and added to the report. The local aquifer is a depleted portion of the Ogallala Aquifer. There is no groundwater district in the area.

Page 119, section 5.2.3, City of Midland, first list item, line 2: Please consider replacing "surface" with "land".

The Study Team clarified that the discussion referred to the "surface estate" not the land surface.

Page 120, paragraph 2, line 6: Please replace "begin" with "began".

Done.

Page 122, last paragraph, first line: Please replace "recovery" with "recover".

Done.

Page 127, first paragraph: This information appears to be new information not covered previously in the report. In this section, please include only information that was previously covered in the report.

Deleted.

Page 128, third full paragraph, last sentence: The sentence states that ASR using reclaimed water is a "rapidly-expanding application", but the report does not provide justification for the statement. Please consider elaborating on, revising, or removing this statement.

The sentence was deleted. However, one of the Study Team's tasks was to discuss its understanding of the application of ASR within the rest of the United States and the world. The use of reclaimed water in ASR applications is rapidly expanding in other parts of the nation and the world.

Page 129, second full paragraph: Please consider revising this paragraph to provide a more elaborate and informative picture of ASR failures and lessons learned. Further, the first two sentences should be reworded and combined to correct the second sentence beginning with the word, "Like".

Revised.

Pages 130 and 132: For consistency with the sequence in which the information was reported previously, please consider switching the order in which these two sections are presented.

Done.

Page 131, third full paragraph, line 12: Please replace "wider-spread" with "widespread".

Done.

Pages 133 (first full paragraph, lines 8 to 12) and 135 (second full paragraph, lines 6 to 10): The statement, "…reluctance stems from a fear that an ASR project may attempt to bank water…" is duplicative. Please remove one.

Done.

Page 136, list number 2a: Please remove one of the periods at the end of the last sentence.

Done.

Page 141: Please consider adding a more comprehensive reference list.

Done.

Page 141, section 9.2: Please organize the additional references alphabetically.

Done.

Page 145, Appendix A: Please consider attaching properly formatted Chapter 331 in its entirety. As presented, it is confusing.

30 TAC Chapter 331 is a long document with some sections that may not be of interest to the readers of this report. Therefore we have elected to retain the summarized version in the Appendix with an internet link to the chapter in its entirety.

Page 155, Appendix B: Please consider attaching properly formatted Chapter 295 in its entirety. As presented, it is confusing.

30 TAC Chapter 295 is a long document with some sections that may not be of interest to the readers of this report. Therefore we have elected to retain the summarized version in the Appendix with an internet link to the chapter in its entirety.

10.7 Appendix "G": Endnotes

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[1] During the 2001 77th Legislative Session the Texas Legislature renamed the TNRCC the TCEQ (Texas Commission on Environmental Quality) effective January 1, 2004. *See* Act of April 20, 2001, 77th Leg., R.S., ch. 965, 2001 Tex. Gen. Laws 1985.
[2] The findings and conclusions of UGRA's water supply analysis are documented in a report prepared for the TWDB entitled *Kerr County Regional Water Plan Phase IA* (CH2M-Hill, May 1992).
[3] *See Aquifer-Storage Recovery Feasibility Investigation Phase IA – Preliminary Assessment* (CH2M-Hill, April 1988); *Aquifer-Storage Recovery Feasibility Investigation Phase IIA – Monitoring Well PZ1* (CH2M-Hill, December 1989); *Aquifer-Storage Recovery Feasibility Investigation Phase IIB – Full Scale Testing and Evaluation* (CH2M-Hill, April 1992).

[1] Ed McCarthy is a Partner in the Law Firm of Jackson, Sjoberg, McCarthy & Wilson L.L.P. practicing primarily in water and water related matters. Mr. McCarthy has significant experience in representing private, commercial and public entities. He was the lead counsel for the Upper Guadalupe River Authority in the prosecution of its application for a the first surface water right in Texas authorizing the use of Aquifer Storage and Recovery technology to store appropriated surface water. He was also active in the development of HB 1989 codifying the use of ASR in state water permitting, as well as the development of TCEQ regulatory programs implementing ASR legislation.
[2] The Copy Rights to this work are held jointly by the author, Edmond R. McCarthy, Jr. and the Texas Water Development Board ("TWDB") pursuant to TWDB Contract No. 0904830940.
[3] *See* PYNE, AQUIFER STORAGE RECOVERY: A GUIDE TO GROUNDWATER RECHARGE THROUGH WELLS (2d Ed. 2005); PYNE, GROUNDWATER RECHARGE AND WELLS – A GUIDE TO AQUIFER STORAGE RECOVERY, 6 (1995); McCarthy, 1997 *Update on Innovative Water Supply Solutions for Texas: Developments affecting Aquifer Storage & Recovery and Wastewater Reuse Alternatives in Texas*, TEXAS WATER LAW CONFERENCE (CLE INTERNATIONAL, Austin, Texas, November 1997); McCarthy, *Going To The Well: Aquifer Storage and Recovery technology gaining ground in Texas*, TexasH2O (Texas Section of the American Water Works Association, April 1996); McCarthy, *Aquifer Storage & Recovery Technology in Texas: Legislative & Regulatory Developments* (San Antonio Bar Association – Environmental, Oil & Gas Section, April 1996); McCarthy, *Innovative Water Supply Solutions for Texas: 1995 Legislative/Regulatory Developments & A Texas' Appellate Court Decision Bring Aquifer Storage & Recovery Technology to the Forefront of viable Alternative Strategies for Meeting Future Water Demands in Texas*, TEXAS WATER LAW CONFERENCE (CLE INTERNATIONAL, Austin Texas, November 1995); McCarthy, *Aquifer Storage & Recovery Technology in Texas: Legislative & Regulatory Developments Affecting This Alternative Strategy for meeting Future Water Demands*, TEXAS WATER RIGHTS – KEY ISSUES & FUTURE CHALLENGES (Cambridge Institute, Austin Texas, October 1995); McCarthy, *Aquifer Storage – A Viable, Cost Effective & Environmentally Sensitive Conjunctive Use/Management Alternative Strategy For Meeting Future Water Demands*, TEXAS WATER CONSERVATION ASSOCIATION

(TWCA's Summer Technical Conference, Kerrville, Texas, June 1995); McCarthy, *Conjunctive Use/Management - "New" Alternatives for Meeting Future Water Demands*, TEXAS WATER LAW CONFERENCE (CLE INTERNATIONAL, Austin Texas, October 1993). In his books, Mr. Pyne provides a very thorough treatment of the history and success of ASR as a global water management tool. *See generally* McCarthy, *Legal and Institutional Issues Affecting Aquifer Storage Recovery In Texas*, Texas Innovative Water 2010 (TWDB, San Antonio, Texas, October 11-12, 2010) (available on-line at http://www.twdb.state.tx.us/events/tiw2010/docs/Legal_and_Institutional_Issues_ Affecting_Aquifer.ppt); Rochelle, Castleberry & Smith, Ch.2, *Meeting Water Supply Needs: Planning, Permitting, and Implementation*, Essentials of Texas Water Resources, 44 (State Bar of Texas, Sahs Ed., 2009), Thornhill, "Aquifer Storage and Recovery (ASR) and H.B. 1989, An Act Relating To The Underground Storage of Appropriated Water Incidental To A Beneficial Use", TEXAS WATER RIGHTS -- KEY ISSUES AND FUTURE CHALLENGES (Cambridge Institute, October 30, 1995); Thornhill, Adams & McLeod, "Aquifer Storage and Recovery (ASR) As A Replacement For Future Surface Reservoirs" (TWCA 6th Annual Mid-Year Technical Conference June 10, 1993).

[4] *See In re Adjudication of the Water Rights of the Upper Guadalupe Segment of the Guadalupe River Basin*, 642 S.W. 2d 438, 441 (Tex. 1982) ("The story of water law in Texas is also the story of its droughts."); *see generally* Drummond, Sherman & McCarthy, "The Rule of Capture in Texas — Still So Misunderstood After All These Years," 37 TEX. TECH. L. REV. 1 (2005).

[5] TEXAS BOARD OF WATER ENGINEERS, A PLAN FOR MEETING THE 1980 WATER REQUIREMENTS OF TEXAS, at 5 (1961).

[6] *See* Water For Texas 2007 (TWDB 2007) (Texas most current Water Plan as adopted by the Texas Water Development Board pursuant to Section 16.051, Texas Water Code).

[7] *See generally* Texas Water Development Board website for on-line information and data related to Texas drought conditions: www.twdb.state.tx.us/DATA/DROUGHT/index.asp.; House Committee on Natural Resources, Interim Report to the 82nd Texas Legislature 43-44 (December 2010).

[8] *See* 1 Water For Texas 2007 at 2 (TWDB 2007) ; *see generally* House Committee on Natural Resources, Interim Report to the 82nd Texas Legislature 47, 49 (December 2010).

[9] TEXAS WATER CODE §16.051(b).

[10] *See* TWDB, Water for Texas - Today and Tomorrow, p. 19 (1992).

[11] *See* 3 Waters and Water Rights, §19.03, p. 27 (1991); TARLOCK, LAW OF WATER RIGHTS AND RESOURCES, §2.02, p. 2.2 (1993).

[12] Technically there is a "third" category of water known as "diffused" or "occasional" water. These are the terms used to describe the "sheet flow" water that crosses the surface of land during a rainfall event prior to entering a water course at which time it becomes "surface water" owned by the State or percolates beneath the surface and becomes "groundwater" owned by the overlying surface landowner. *Turner v. Big Lake Oil Co.*, 96 S.W.2d 221, 228 (Tex. 1936); *Domel v. Georgetown*, *supra*, 6 S.W.3d at 353; W. HUTCHINS, THE TEXAS LAW OF WATER RIGHTS, 515-516, 557 (1961).

[13] *See Houston & Tex. Cent. Ry. Co. v. East*, 81 S.W.2d 279, 281 (Tex. 1904); *City of Sherman v. Pub. Util. Comm'n*, 642 S.W.2d 681, 686 (Tex. 1983); *Friendswood Dev. Co. v. Smith-Southwest Indus., Inc.*, 576 S.W.2d 21, 25-27 (Tex. 1978); *Sun Oil Co. v. Whitaker*, 483 S.W.2d 808, 811 (Tex. 1972); *Texas Co. v. Burkett*, 296 S.W. 273, 278 (1927); *see generally* Drummond, Sherman & McCarthy, "The Rule of Capture in Texas – Still Misunderstood After All These Years," 37 TEX. TECH L. REV. 1 (2004); *see generally* TEXAS WATER CODE Ch. 36.

[14] *See* TEXAS WATER CODE §36.015.

[15] *See generally* TEXAS WATER CODE §11.021, 11.121.

[16] *Domel v. Georgetown*, 6 S.W.3d 349, 353 (Tex. App.-Austin 1999, pet. denied); *South Texas Water Co. v. Bieri*, 247 S.W.2d 268, 272 (Tex. Civ. App.-Galveston 1952, writ ref'd n.r.e.); *see* TEXAS WATER CODE §§ 11.021, 11.121.

[17] *Sun Oil Co. v. Whitaker*, 438 S.W.2d 808, 811 (Tex. 1972); *see City of Del Rio v. Clayton Sam Colt Hamilton Trust*, 269 S.W.3d 613, 617 (Tex. App.-San Antonio 2008, pet. denied.); *cf., Guffey v.* Stroud, 16 S.W.2d 527, 528 (Tex. Comm'n App. 1929, judm't adopted) (absent an express reservation to surface estate owner, mineral estate owner may use groundwater to develop mineral estate); *see generally Evans v. Ropte*, 96 S.W.2d 973 (Tex. 1936) (right to enter land and take the waters of a spring or well amounts to an interest in land); *Texas Co. v. Burkett*, *supra* 296 S.W.2d at 278 (groundwater is the exclusive property of the surface owner "subject to barter and sale as any other species of property"); *Pfluger v. Clack*, 879 S.W.2d 956, 959 (Tex. Civ. App.-Eastland 1995, writ denied).

[18] *See Rosenthal v. Tex. RR Comm'n*, 2009 Tex. App. LEXIS 6522, *25 n.10 (Tex. App. – Austin, August 20, 2009, pet. denied); *Pfluger v. Clack*, 879 S.W.2d 956, 959 (Tex. App.—Eastland 1995, writ denied) (water, surface or subsurface, is part of surface estate, unless it has been expressly severed by conveyance or reservation).
[19] *See Sun Oil Co., supra*, 438 S.W.2d at 811; *City of Del Rio, supra*, 269 S.W.3d at 617-618; *see generally Houston & Tex. Cent. Ry. Co. v. East*, *supra*, 81 S.W.2d at 281; *City of Sherman v. Pub. Util. Comm'n*, *supra*, 642 S.W.2d at 686; *Friendswood Dev. Co. v. Smith-Southwest Indus., Inc., supra*, 576 S.W.2d at 25-27; *Sun Oil Co. v. Whitaker*, *supra*, 483 S.W.2d at 811; *Texas Co. v. Burkett*, *supra*, 296 S.W. at 278; Drummond, Sherman & McCarthy, "The Rule of Capture in Texas – Still Misunderstood After All These Years," 37 TEX. TECH L. REV. 1 (2004).
[20] *See generally* TEXAS WATER CODE CH. 36.
[21] 81 S.W. 279 (Tex. 1904) (hereinafter referred to as the "*East*" case) ; *see generally* Drummond, Sherman & McCarthy, *The Rule of Capture in Texas – Still Misunderstood After All These Years*, 37 Tex. Tech L. Rev. 1 (2004).
[22] 12 Mees & W (1843).
[23] *East*, *supra*, 81 S.W. at 280.
[24] *Id*.
[25] *See Friendswood Dev. Co. v. Smith-Southwest Indus., Inc.*, 576 S.W.2d 21, 25-27 (Tex. 1978); *City of Del Rio, supra*, 269 S.W.3d at 617-618.
[26] *See City of Sherman v. PUC*, 643 S.W.2d 681, 686 (Tex. 1983); *City of Del Rio, supra*, 269 S.W.3d at 618.
[27] TEX. CONST. ART. XVI, §59.
[28] *Id*.; *see City of Corpus Christi*, *supra*, 276 S.W.2d at 803.
[29] 296 S.W. 273 (Tex. 1927).
[30] *Id*. at 278.
[31] *Id*.; *see Dennis v. Kickapoo Land Co.*, 771 S.W.2d 235, 237 (Tex. Civ. App.-Austin 1989, writ denied).
[32] *See generally* W. HUTCHINS, *supra*, 588 & n. 62 (*citing* Tex. Gen. Laws 1949, Ch. 306).
[33] *See* TEX. SPECIAL DIST. LOCAL LAWS CODE Chapter 8801; *see generally Friendswood Dev. Co., supra*, 576 S.W.2d at 21.
[34] 276 S.W.2d 798 (Tex. 1955); *see* TEX. CONST. ART. XVI, §59; *City of Corpus Christi, supra,* at 803.
[35] *City of Corpus Christi*, *supra,* 276 S.W.2d at 800.
[36] *Id.*
[37] *See id.* at 802-803.
[38] *See id.* at 802.
[39] *See id.*
[40] *Id*.
[41] *See Pecos County WCID No. 1 v. Williams*, 271 S.W.2d 503 (Tex. Civ. App.—El Paso 1954, writ ref'd n.r.e.).
[42] *Pecos County WCID No. 1*, *supra*, 271 S.W.2d, at 503.
[43] *Id.* at 504-505.
[44] *Id.* at 505.
[45] *Id* at 505-506*; see generally* W. HUTCHINS, *supra*, at 560-563.
[46] *Pecos County WCID No. 1*, *supra*, 271 S.W.2d at 505-506.
[47] 576 S.W.2d 21 (Tex. 1978).
[48] *Id*. at 25-27, 30 ("ownership of underground water comes with ownership of the surface; it is part of the soil").
[49] *Id*. at 30. The Court's ruling prohibiting the negligent, willfully wasteful, or "for the purpose of malicious injury" pumping of groundwater which proximately causes subsidence of the land of others was limited to prospective application. *Id*. at 30
[50] *Id*. at 24 (*citing East*).
[51] 771 S.W.2d 235 (Tex. Civ. App.–Austin 1989, writ denied).
[52] *Id.* at 239.
[53] *Id.* at 238.
[54] *Barshop v. Medina County Underground Conservation District*, 925 S.W.2d 618, 630-631 (Tex. 1996).
[55] *Id.* at 626-627.
[56] *Id.*, *see* Act of May 30, 1993, 73rd Leg. R.S., Ch. 626, 1993 Tex. Gen. Laws 2350.
[57] *Barshop*, *supra*, 925 S.W.2d at 625-626 ("[I]t is not necessary to the disposition of this case to definitively resolve the clash between property rights in water and regulation of water.").

[58] 1 S.W.3d 75 (Tex. 1999). This case is commonly referred to as the "*Ozarka*" case.
[59] *Id.*
[60] *Id.*
[61] *Id.* at 80; *see* TEX. CONST. Art. XVI, §59; *see generally City of Corpus Christi*, *supra*, 276 S.W.2d at 803.
[62] *Ozarka*, *supra*, 1 S.W.3d at 79 (*citing* TEXAS WATER CODE §36.0015). In addition Section 36.002, TEXAS WATER CODE provides as follows: The ownership and rights of the owners of the land . . . in groundwater are hereby recognized, and nothing in this Code shall be construed as depriving or divesting the owners . . . of the ownership or rights, except as those rights may be limited or altered by rules promulgated by a [groundwater] district.
[63] *Bragg v. Edwards Aquifer Authority*, 71 S.W.3d 729 (Tex. 2002) (Court concluded that the *Bragg's* "taking" claim resulting from the application of the EAA Act was not yet "ripe").
[64] TEXAS WATER CODE.
[65] *Id.* § 36.002.
[66] *Id.*; *see generally Houston & Tex. Cent. Ry. Co. v. East*, *supra*, 81 S.W.2d at 281; *City of Sherman v. Pub. Util. Comm'n*, *supra*, 642 S.W.2d at 686; *Friendswood Dev. Co. v. Smith-Southwest Indus., Inc.*, *supra*, 576 S.W.2d at 25-27; *Sun Oil Co. v. Whitaker*, *supra*, 483 S.W.2d at 811; *Texas Co. v. Burkett*, *supra*, 296 S.W. at 278; Drummond, Sherman & McCarthy, "The Rule of Capture in Texas – Still Misunderstood After All These Years," 37 TEX. TECH L. REV. 1 (2004)
[67] *See Edwards Aquifer Authority v. Day*, 274 S.W.3d 742 (Tex. App. – San Antonio 2008, pet. granted); *City of Del Rio v. Clayton Sam Colt Hamilton Trust*, 269 S.W.3d 613 (Tex. App.-San Antonio 2008, pet. denied).
[68] *Edwards Aquifer Authority v. Day, supra*, 274 S.W.3d at 756; *City of Del Rio v. Clayton Sam Colt Hamilton Trust*, *supra*, 269 S.W.3d at 617.
[69] *See* TEXAS WATER CODE §11.021.
[70] *Id*.
[71] *Id.*
[72] *See* TEXAS WATER CODE §§5.012-5.013.
[73] *See id.* §§11.142, 11.142.1, 11.142.2; 11.303; *see generally* Acts of 2001, 77th Leg. R.S., Ch. 966, §2.09 2001 Tex. Gen. Laws 1880, 1886-1887 (SB 2 amending Section 11.142 to authorize the impoundment of up to 200 ac-ft of water for fish and wildlife use-similar to the existing domestic and livestock exemption); 30 TAC §§297.21-297.30. The "exemptions," or exceptions to the permit requirement include the right to construct a dam or reservoir that will impound less than 200 acre-feet of water to be used for domestic and livestock (including wildlife) purposes. These reservoirs and dams are generally "off-channel," as TCEQ regulations prohibit the construction of an exempt dam across a "navigable stream" without a permit. Additionally, water may be diverted from the Gulf of Mexico at a rate not to exceed one acre-foot of water during a 24 hour period for purposes of facilitating the drilling and produce from oil and gas or conducting operations associated with such development and production. Reservoirs may be constructed without a permit under the Texas Surface Coal Mining & Reclamation Act if their sole purpose is sediment control as part of a surface coal mining operation. Brackish or marine water may also be used without a permit for mariculture activities. Finally, a tax-exempt, non-profit corporation may divert up to 200 acre-feet of water a year from a river to irrigate the grounds of a 100 year old cemetery that borders the river. *See generally* RG-141, A REGULATORY GUIDANCE DOCUMENT FOR APPLICATIONS TO DIVERT, STORE OR USE STATE WATER, 10-11 (JUNE 1995) (hereinafter cited as "RG-141, *supra*, at ___").
[74] TEXAS WATER CODE §11.121; *see Turner v. Big Lake Oil Co.*, *supra*, 96 S.W.2d at 228; *Motl v. Boyd*, 286 S.W. 458, 473 (Tex. 1926); *Domel v. Georgetown*, *supra,* 6 S.W.3dat 353; HUTCHINS, THE TEXAS LAW OF WATER RIGHTS, 518-519 (1961); Caroom & Sherman, 45 TEXAS PRACTICE, WATER DEVELOPMENT AND WATER RIGHTS, §13.3(a), at 491-492 (1997).
[75] *See* TEXAS WATER CODE §11.081; 11.082, 11.084, *cf., id.* §11.121 (requiring a permit be obtained to use State Water).
[76] *See id.* §11.082 (each day of continued unlawful use is a new violation subject to a separate penalty).
[77] *See id.* §11.084 (the sale of the water right is to be distinguished from the sale of water diverted pursuant to the water right).
[78] *See generally Motl v. Boyd*, *supra, 286 S.W. at* 458; HUTCHINS, *supra*, at 356-369; SKILLERN, TEXAS WATER LAW, 26-30, 34-36, 66 (1988); Caroom & Sherman, *supra*, at 493-494.
[79] *See* 30 TAC §297.21(a).
[80] *See* TEXAS WATER CODE §§11.081, 11.082, 11.084, 11.121.

[81] *See id.* §11.323.
[82] *See id.* §11.307.
[83] During the water rights adjudication process water rights evidenced by certified filing and historically issued permits were adjudicated and, upon the issuance of a district court final order validating the adjudication process, the Commissioner's predecessor agency, *i.e.*, the Texas Water Rights Commission, issued Certificates of Adjudication. *See* TEXAS WATER CODE §11.301 *et seq*. Today, the Commission issues "permits."
[84] *See* Booth, *Ownership of Developed Water Rights in Texas: A Property Right Threatened*, 17 ST. MARY'S L.J. 1185, 1187-1188 (1986).
[85] *See South Texas Water Co. v. Bieri*, *supra*, 247 S.W.2d at 272.
[86] *Id.*
[87] *See* RG-141, *supra*, at 26 (Table 8 – "Fully Appropriated Stream Segments").
[88] *Cf.*, TEXAS WATER CODE §11.084 (prohibiting the sale of an unperfected/unpermitted water right).
[89] *See* 30 TAC §§297.41-297.59 ("Issuance and Conditions of Water Rights").
[90] *See* TEXAS WATER CODE §11.121.
[91] *See id.* §11.138.
[92] *See id.* §11.1381.
[93] *See generally* Caroom & Sherman, *supra*, at 505-506.
[94] TEXAS WATER CODE §§11.124(e), 11.1381.
[95] TEXAS WATER CODE §11.138(a).
[96] *See* TEXAS WATER CODE §11.134(b)(3)(A); *see generally* Caroom & Sherman, *supra*, at 501-502.
[97] *See* TEXAS WATER CODE §11.023(a); *cf.*, 30 TAC §297.43(a) (identifying the beneficial uses contained in §11.023(a), and adding, *without legislative basis*, "in-stream uses, water quality, aquatic and wildlife habitat or freshwater inflows to bays and estuaries").
[98] *See* TEXAS WATER CODE §11.023; 30 TAC §297.43(b).
[99] *See TRPA v. TNRCC*, 910 S.W.2d 147, 150-151 (Tex. App. – Austin 1995, writ denied).
[100] *Id.* at 154-155.
[101] The specific requirements in the application process are outlined in greater detail *infra*. *See* Text, *infra*.
[102] *See* TEXAS WATER CODE Ch. 11; 30 TAC Chs. 281, 288, 295, 297; *see generally* RG-141, *supra*, at 13-15. A copy of the Commission's application forms for a new water right, as well as, an amendment to an existing right may be obtained by contacting the Commission or on-line at *www.tceq.state.tx.us/subject_water.html*.
[103] *See* TEXAS WATER CODE § 11.122(b).
[104] 206 S.W.3d 97 (Tex. 2006).
[105] As the Supreme Court noted, The "full use assumption," also known as the "four corners doctrine," requires the Commission to assess a requested amendment's impact on other water rights and on the in-stream environment based upon the full amount of water authorized by the existing permit irrespective of the amount that the permit holder has actually used.
[106] *City of Marshall*, *supra*, 206 S.W. 3d at 101.
[107] *Id.*
[108] *Id.* at 108.
[109] *Id.*
[110] *Id.* at 110-111.
[111] *Id.*
[112] *Id.* at 111.
[113] *Id.* at 112-113.
[114] *Id.* at 113.
[115] The Commission's September 7, 2007, Workshop Agenda and back-up materials are available on-line at: *http://www.tceq.state.tx.us/assets/public/comm_exec/agendas/worksess/current/2007/070907.pdf*.
[116] *See generally City of Marshall*, *supra*, 206 S.W.3d at 97.
[117] The state and regional water plans are available for download at this website: http://www.twdb.state.tx.us/RWPG/planning_page.asp.
[118] *See* TEXAS WATER CODE §§11.1272, 11.1272.
[119] *See id.* §§11.1271; *see generally* 30 TAC Ch. 288.
[120] *See* TEXAS WATER CODE §11.1271; 30 TAC §288.30(1)-(2).

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[121] *See* TEXAS WATER CODE §11.1272; *see generally* 30 TAC Chapter 288; *Handbook for Drought Contingency Planning for Retail Public Water Suppliers* (TNRCC 2000); *Handbook for Drought Contingency Planning for Wholesale Water Suppliers* (TNRCC 1999).

[122] Texas received delegation for "primacy" in the administration of the UIC Program for Class I, III, IV and V wells from EPA in January 1982. *See* Fed. Reg. 47 FR 618. In April 1982, Texas received delegation of primacy for Class II wells. *See* Fed. Reg. 47 FR 17488. *See* 40 FR §145.32(b) (Memorandum of Agreement between the State of Texas and EPA); *see generally* TEXAS WATER CODE Ch. 27; 45 TEXAS PRACTICE §9.4 Texas UIC Program Authorization (2d Ed. 2005). TCEQ has general regulatory authority over UIC wells other than those associated with all Class V wells except those subject to the jurisdiction of the Railroad Commission of Texas. *Id.*; *see* TEXAS WATER CODE §§27.051-27.056. The City of El Paso's aquifer storage and recovery program discussed *infra* reflects a hybridization of an ASR project through its utilization of both recharge basins and injection wells. *See* Text, *infra*.

[123] *See* TEXAS WATER CODE CHAPTERS 11, 27, 36; 30 TAC CHAPTERS 281, 288, 295, 297 & 331. Rules adopted by groundwater districts and other special purpose political subdivisions, *e.g.* the Edwards Aquifer Authority, may affect the ability to inject and/or recover water from an aquifer within their jurisdiction. *See generally* Text, *infra*.

[124] *See generally* TEXAS WATER CODE CHAPTER 27; 30 TAC CHAPTER 331.

[125] *See* TEXAS WATER CODE §§11.153-11.155.

[126] *See* 30 TAC §§ 295.21-295.221, 297.1.

[127] *See* Text, *supra*.

[128] *See id*. §11.154(a); 30 TAC §§295.21-295.22; 297.1; 331.131-331.133; 331.181-331.186.

[129] *See* TEXAS WATER CODE §11.154(b)(1).

[130] *See id.* §11.154(b)(2).

[131] TEXAS WATER CODE.

[132] *Id.*

[133] *See* TEXAS WATER CODE §11.154(c).

[134] *See id*. §11.154(e).

[135] *See id*. §11.154(d).

[136] *See generally* TEXAS WATER CODE CHAPTER 11; 30 TAC CHAPTERS 281, 288, 295, 297 & 331.

[137] *See* TEXAS WATER CODE §§11.154 (b)(1)(D); 36.101(a)-(b), 36.102. An ASR project constructed outside of a groundwater district would only require a Class V Well UIC Permit, unless surface water was being used as the supply source. In the latter case, an appropriate Section 11.121 TEXAS WATER CODE permit authorizing ASR storage would also be required.

[138] TEXAS WATER CODE.

[139] *See* TEXAS WATER CODE Ch. 36. Operators of ASR projects should analyze the enabling legislation, if any, of any groundwater district with jurisdiction over a proposed project to determine what, if any, specific legislative authority a particular district may have.

[140] E-mail correspondence with Mr. Sanjee Kalaswad, TWDB, dated January 5, 2011.

[141] *See* EAA Act, Act of May 30, 1993, 73rd Leg., R.S., ch. 626, 1993 Tex. Gen. Laws 2350. With respect to aquifer storage and recovery projects and/or recharge projects within the Edwards Aquifer, the EAA looks primarily to the authority created in Section 1.44 of its enabling legislation. *Id*. §1.44.

[142] *See* EAA Act §1.44 (Act of May 30, 1993, 73rd Leg., R.S., ch. 626, §1.44, 1993 Tex. Gen. Laws 2350, 2369, as amended by Act of May 28, 2001, 77th Leg,, R.S., ch. 966, §2.62, 2001 Tex. Gen. Laws 1991, 2022); *See generally* Frownfelter, Ch. 14, *Edwards Aquifer Authority*, Essentials of Texas Water Resources, 377 (State Bar of Texas, Sahs Ed., 2009).

[143] *Id*.

[144] Section 1.44(a) of the EAA Act uses the term "retrieval" rather than "recovery" when discussing water that has been injected through wells for storage. *See* EAA Act § 1.44(a).

[145] *See* EAA Act §144(a).

[146] *Id.* §144(b).

[147] *Id.* §144(c).

[148] *See id.* §144(c)(1).

[149] *See id.* §144(c)(2).

[150] *Id.* §144(e).

[151] *See id.* §144(e)(1)-(2).

[152] *See* EAA Rules Subchapter (D) §§707.418-707.4181.
[153] *See id.* §707.418(1).
[154] *See id.* §707.418(6).
[155] *See id.* §707.418(7).
[156] *See id.* §707.418(7).
[157] *See id.* §707.418(9).
[158] *See id.* §707.418(10).
[159] *See id.* §707.418(11).
[160] *See id.* §707.418(12).
[161] *See id.* §707.418(12).
[162] *See id.* §707.418(13).
[163] *See id.* §707.418(14).
[164] *See id.* §707.418(15).
[165] *See id.* §707.418(17).
[166] *See id.* §707.4181(3).
[167] *See id.* §707.4181(4).
[168] *See id.* §707.4181(5).
[169] *See id.* §707.4181(6).
[170] *See id.* §707.4181(7).
[171] *See id.* §707.4181(8).
[172] *See id.* §707.4181(9).
[173] *See id.* §707.4181(10).
[174] *See id.* §707.4181(11).
[175] *See id.* §707.4181(12).
[176] *Compare id.* §711.164 (limiting groundwater available for initial regular permits to 572,000 acre-feet per calendar year) *with id.* §711.171 (groundwater withdrawals under a recharge recovery permit not subject to total permit withdrawals prescribed by Section 711.164).
[177] *See id.* §§711.240-711.272.
[178] *See id.* §711.241.
[179] *See id.* §§711.249 (Authorized Purposes for ASR), 711.251 (Permissible Source Water for ASR), 711.252 (Water Rights in Source Water), 711.253 (Protection of Water Quality of the Aquifer), 711.254 (Water Quality of Source Water).
[180] *See id.* §711.243.
[181] *See id.* §711.245(a).
[182] *See id.* §711.245(b).
[183] *See id.* §711.247.
[184] *See id.* §711.249.
[185] *See id.* §711.255(c).
[186] *See id.* §711.255(d).
[187] *See id.* §711.255(e).
[188] *See id.* §711.255(f).
[189] *See id.* §711.255(g).
[190] *See id.* §711.255(i).
[191] *See id.* §711.255(h).
[192] *See id.* §711.266
[193] *See id.* §711.251(b).
[194] *See id.* §711.251(b)(2).
[195] *See id.* §711.252(b)(3).
[196] *See id.* §711.269(Aquifer Recharge Storage and Recovery Interlocal Contracts With Political Subdivisions).
[197] *See id.* §711.251(c)(1).
[198] *See id.* §711.251(c)(2)(A).
[199] *See id.* §711.251(c)(2)(B).
[200] *See id.* §711.251(c)(2)(C).

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[201] *See id.* §711.251(c)(2)(D).
[202] *See id.* §711.251(c)(3).
[203] *See id.* §711.251(d)(1)(A).
[204] *See id.* §711.251(d)(1)(B).
[205] *See id.* §711.251(d)(1)(C).
[206] *See id.* §711.251(d)(2)(A).
[207] *See id.* §711.251(d)(2)(C).
[208] *See id.* §711.251(d)(3).
[209] *See id.* §711.253.
[210] *See id.* §711.254(a).
[211] *See id.* §711.254(b)(1).
[212] *See id.* §711.254(c).
[213] *See id.* §711.256(a).
[214] *See id.* §711.256(b); *cf.*, TEXAS WATER CODE §11.154(b)(requiring the terms of agreements between permittees and groundwater districts related to the storage of surface water in a ASR project within the affected district to be incorporated into the surface water permit issued by TCEQ).
[215] *See id.* §711.258.
[216] *See id.* §711.260.
[217] *See id.* §711.261(a)(1).
[218] *See id.* §711.261(b).
[219] *See id.* §711.264.
[220] *See id.* §§711.255(a), 711.260(a).
[221] E-mail Correspondence with Ms. Luana Buckner, President, EAA Board of Directors and General Manager, Medina County GCD, dated August 18, 2010.
[222] EUWCD Rule 1.1b. (Definition of Terms).
[223] EUWCD Rule 1.1c.
[224] *Id*. Rule 6.6 (Aquifer Storage and Recovery (ASR)); *see* District Act defined in Rule 1.1k. Interestingly, the "R" in the definition of "ASR" stands for "Retrieval," while the District's Rule 6.6 uses the term "Recovery" for the "R" in "ASR." *Compare* EUWCD Rule 1.1a. *with Id*. Rule 6.6.
[225] EUWCD Rule 6.6a.
[226] *Id*. Rule 6.6 a.1. Unlike the terms "drilling permit" and "Production Permit," neither "injection permit" nor "recovery permit" are defined in the EUWCD's Rules. *See Id*. Rule 1.1 r.-v.
[227] EUWCD does *not* define the term "ASR Permit." *See id.* Rule 1.1.
[228] *Id*. Rule 6.6 a.3.
[229] EUWCD Rule 6.6 b.2.(c).
[230] *Id.* Rule 6.6 b.2.(d).
[231] *Id.* Rule 6.6 b.2.(e).
[232] *Id.* Rule 6.6 b.2.(f).
[233] *Id.* Rule 6.6 b.2.(g).
[234] *Id.* Rule 6.6 b.2.(h).
[235] *Id.* Rule 6.6 b.2.(i).
[236] *Id.* Rule 6.6 b.2.(j).
[237] *Id.* Rule 6.6 b.2.(l). The rule does *not* elaborate on the required "chemical analysis." *Id*.
[238] *Id.* Rule 6.6 b.2.(n).
[239] *Id.* Rule 6.6 b.2.(o).
[240] *Id.* Rule 6.6 b.2.(p). The rule does not provide any guidance on the required context or detail of the "report." *Id*.
[241] *Id*. Rule does not specify whether the "well" is the injection or recovery well(s), or both. The applicant should likely assume both in the absence of clarification from the EUWCD.
[242] EUWCD Rule 6.6 2.b.(p).
[243] *Id*. Rule 6.6 2.b.(q).
[244] EUWCD Rule 6.6c.
[245] *Id*.
[246] *Id*. Rule 6.6 c.1.-7.

[247] *Id*. Rule 6.6 c.1.
[248] *Id*. The rule enumerates "structures, pipelines, roads, natural springs, artesian wells, and property lines" among the "pertinent features." *Id*.
[249] *Id.* Rule 6.6 c.2.
[250] *Id*. Rule 6.6 c.2.
[251] *Id*. Rule 6.6 c.3.
[252] *Id*. Rule 6.6 c.4. The rules do *not* define the term "Buffer Zone," nor do they provide any criteria with respect to how one could determine whether or to what extent other wells "interfere or significantly affect" the movement of stored water. *Id*.
[253] EUWCD Rule 6.6. c.5.
[254] *Id*. Rule 6.6. c.7.
[255] Rule 6.6 d. prescribes compliance with construction standards in Title 30, Part 1, Chapter 331 Subchapter H Rule § 331.132, and Subchapter K, Rule § 331.183 TAC. *See* EUWCD Rule 6.6 d.4.
[256] EUWCD Rule 6.6. d.2. (a).
[257] *Id*. Rule 6.6. d.2. (b).
[258] *Id*. Rule 6.6. d.2. (c)-(d).
[259] *Id*. Rule 6.6. d.2. (e).
[260] *Id*. Rule 6.6. d.2. (f).
[261] *Id*. Rule 6.6. d.2. (g).
[262] *Id*. Rule 6.6. e.1. The rule is ambiguous in that it does not define the meaning of "an underground source of drinking water", or of "drinking water", nor is it clear whether it applies to an aquifer the natural quality of which does not allow it to be used for "drinking water" without some level of treatment, including simply "disinfection." *Id*. The rules also require the owner/operator of the ASR Well to maintain the "mechanical integrity" of the well(s). *Id*. Rule 6.6.e.4.
[263] *Id*. Rule 6.6. e.2. The EUWCD Rules do *not* define the term "injection zone" or "fluid." *Id*. Accordingly, it is unclear how the area/extent of the "injection zone" is calculated or delineated.
[264] EUWCD Rule 6.6 e.5.
[265] *Id.* Rule 6.6 e.5 (a)-(b).
[266] *Id*. Rule 6.6 e.3. The rule does define the term "ceased operations," nor does it elaborate on what, if any thing the EUWCD can/will do upon receipt of notice of resumed operations. *Id.*
[267] EUWCD Rule 6.6.f.1.
[268] *Id*. Rule 6.6.f.2. (a).
[269] *Id*. Rule 6.6.f.2. (b).
[270] *Id*. Rule 6.6.f.2. (c).
[271] *See generally Id*. Rule 6.6.b.
[272] *Id*. Rule 6.6.f.2. (c).
[273] *Id*. The Rule provides no guidance on the level of detail to be included in the Plan. *Id*.
[274] *Id*. Rule 6.6.f.2. (c). As noted previously, the term "buffer zone" is *not* defined by the EUWCD Rules. *Id.*
[275] *Id*. Rule 6.6.f.2. (c).
[276] *Id*. Rule 6.6.f.2. (c). As noted previously, EUWCD's rules do not define the "buffer zone."
[277] *Id*. Rule 6.6.f.2. (c).
[278] *Id*. Rule 6.6.f.3.
[279] *Id.*
[280] TEXAS WATER CODE
[281] Section 11.154(b)(2)provides as follows: "the Commission shall require that any agreement the applicant reaches with a district … regarding the terms for injection, storage, and withdrawal of appropriated water be included as a condition of the [Section 11.121] permit or permit amendment." *Id.*
[282] TEXAS WATER CODE
[283] *see* TEXAS WATER CODE §11.154(b)(2).
[284] *See* Text Discussion, *supra*.
[285] *See* Gonzales County UWCD Rule 1.
[286] *Id.* Rule 14.A.1.
[287] *See id.* Rule 14.B.7.

[288] *See id.* Rule 14.B.8.
[289]*Id.* Rule 14.C.
[290] *See id.* Rule 14.D.
[291] *Id.* Rule 14.F.
[292] *Id.* Rule 14.G.
[293] *Id.* Rule 14.H.
[294] *Id.* Rule 14.E.
[295] *Id.* Rule 14.H.
[296] *See* Medina County GCD Rules, Chapter 9.
[297] *See id.* Chapter 10.
[298] *See id.* §1.1 (5).
[299] *Id.* §1.1 (24)(D).
[300] *Id*. §1.1 (43).
[301] *Id.* §1.1(44).
[302] *See id.* §9.1.
[303] *Id.* §9.3(a)(1).
[304] *Id.* §9.3(a)(2).
[305] *Id.* §9.3(a)(3).
[306] *Id.* §9.5(a).
[307] *Id.* §9.5(b).
[308] *See id.* §9.7(a).
[309] *Id.* §9.7(b).
[310] *Id.* §10.1.
[311] *Id.* § 10.5(c).
[312] *Id.* § 10.5(d).
[313] *Id.* § 10.5(e).
[314] *Id.* §10.5. The author believes that subsection (f)(6) of the Rule is intended to read as follows: "The formation into which water will be recharged." *See id.* §10.5(f)(6).
[315] *Id.* §10.5(g).
[316] *Id.* §10.5(h).
[317] *Id*. §10.7.
[318] *Id.* §10.7(a).
[319] *Id.* §10.7(b).
[320] *Id.* §10.7(c).
[321] *Id.* §10.11.
[322] *See id.* §10.13.
[323] *Id.* §§10.1, 10.15.
[324] Permian Basin Underground Water Conservation District Rule 9.
[325] *Id.* Rule 9.
[326] The framework of technological issues related to enhanced implementation of ASR technology are discussed in Section 3.
[327] *See* Acts of 1995, 74th Leg. R.S. Ch. 309, 1995 Tex. Gen. Laws 2963-2696 (codified at Texas Water Code §§11.153-11.155). An "Underground source of drinking water" or "USDW**"** is a non-exempt aquifer, or a portion of an aquifer, which supplies drinking water for human consumption or contains fewer than l0,000 milligrams per liter total dissolved solids. See 30 TAC §331.2(107).
[328] *See* TEXAS WATER CODE §§11.153 – 11.155. In 2003 Section 11.155 was amended to delete Subsection (c), which required the TWDB to prepare and file a report with the Legislature in the odd numbered year of each biennium. *See* Acts of 2003, 78th Leg. R.S. Ch. 1057 §9. 2003 Tex. Gen. Laws 3044, 3050.
[329] *See* 30 TAC §§295.21, 295.22, 295.202.
[330] *See id*. §§297.1, 297.21-297.30.
[331] *See id*. §§331.131-331.333, 331.335-331.337, 331.181-331.186.
[332] *See id*. §§331.1-331.21, 331.131-331.333, 331.181-331.186.
[333] *See generally* 30 TAC Chapter 331.

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[334] *See generally id*.; Texas Water Code Ch. 27.
[335] *See* TEXAS WATER CODE §§11.121, 11.122, 11.153-11.155; 30 TAC Chs. 295, 297.
[336] For a detailed discussion of surface water permitting requirements see McCarthy, *Permitting Surface Water Rights in Texas Post-Senate Bill 2*, TEXAS WATER LAW CONFERENCE (CLE INTERNATIONAL, Austin, Texas, October 28-29, 2002); McCarthy, *Buying and Selling of Groundwater and Surface Water Rights*, TEXAS WATER LAW CONFERENCE (CLE INTERNATIONAL, Houston, Texas, May 24-25, 2004); *see generally* Rochelle, Castleberry & Smith, Ch.2, *Meeting Water Supply Needs: Planning, Permitting, and Implementation*, Essentials of Texas Water Resources, 44 (State Bar of Texas, Sahs Ed., 2009).
[337] *See generally* 30 TAC Ch. 331 (regulating Texas' injection well program).
[338] *See* 30 TAC §§295.21-295.22.
[339] *See id.* §295.21(a)(1); *see generally id.* 30 TAC §§331.1-331.21, 331.131-331.137, 331.181-331.186.
[340] *See id.* §295.21 (a)(2); *see generally id.* §331.186.
[341] *See id.* §295.21 (a)(3).
[342] *See id.* §295.21 (a)(3)(A).
[343] *See id.* §295.21 (a)(3)(B).
[344] *See id.* §331.185(b); *see generally id.* §331.186.
[345] *See id.* §295.22(b)(1).
[346] *See generally id.* §295.22(b).
[347] *See id.* §295.22(b)(2)(A); *see generally id*. §331.185(a).
[348] *See id.* §295.22(b)(2)(B); *see generally id.* §331.185(a).
[349] *See id*. §295.22(b)(2)(C); *see generally id.* §331.185(a).
[350] *See id*. §295.22(b)(2)(D); *see generally id.* §331.185(a).
[351] *See id*. §295.22(b)(2)(E); *see generally id.* §331.186.
[352] *See id*. §295.22(b)(2)(F); *see generally id.* §331.186.
[353] *See id*. §295.22(b)(2)(G); *see generally id.* §331.186.
[354] *See id*. §295.22(b)(3); (e)(5)-(6); *see generally id.* §331.182.
[355] *See id*. §295.22(b)(4); *see generally id.* §§331.185-331.186.
[356] *See id*. §295.22(b)(5); *see generally id.* §§331.185-331.186.
[357] *See id*. §295.22(c).
[358] *See id*. §295.22(e)(1); *see generally id.* §331.182.
[359] *See id*. §295.22(e)(2); *see generally id.* §§331.182-331.183.
[360] *See id*. §295.22(e)(3); *see generally id.* §§331.182-331.183.
[361] *See id*. §295.22(e)(4); *see generally id.* 30 TAC Ch. 294.
[362] *E.g.*, TEXAS WATER CODE §§ 36.101, 36.1011, 36.102, 36.113. 36.114, 36.115, 36.119.
[363] *Id.* §36.122.
[364] *E.g.*, *Id.* §§ 36.101, 36.1011, 36.102, 36.113. 36.114, 36.115, 36.119.
[365] *See* 30 TAC Ch. 331 (subchapters A, H and K)
[366] *Id.* §§331.1-331.21, 331.131-331.137, 331.181-331.186.
[367] *Id.* §§331.4, 331.183.
[368] *Id.* §§331.5(a), 331.183.
[369] *Id.* §§331.5(a), 331.183.
[370] *Id.* §§331.132, 331.183.
[371] *Id.* §331.132(a); *cf.*, 16 TAC Ch. 76.
[372] *Id*. 30 TAC §331.132(b).
[373] *Id*. §331.132(c), (d), (g), (h); *see generally id*. §331.183.
[374] *Id*. §331.133; *see generally id*. §331.183.
[375] *Id*. §331.133(b).
[376] *Id*.
[377] *Id*. §331.133(c); *see id*. 30 TAC §331.183.
[378] *Id*. §331.133(c), (d); *see id*. 30 TAC §331.183.
[379] *Id*. §331.133(d); *see id*. 30 TAC §331.183.
[380] *See* 30TAC §§ 290.38(70), 290.47(c) (Appendix C – Sanitary Control Easement for Public Water Supply Well).

[381] E.g., *Houston & Tex. Cent. Ry. Co. v. East*, 81 S.W.2d 279, 281 (Tex. 1904); *City of Sherman v. Pub. Util. Comm'n*, 642 S.W.2d 681, 686 (Tex. 1983); *Friendswood Dev. Co. v. Smith-Southwest Indus., Inc.*, 576 S.W.2d 21, 25-27, 30 (Tex. 1978); *Sun Oil Co. v. Whitaker*, 483 S.W.2d 808, 811 (Tex. 1972); *Texas Co. v. Burkett*, 296 S.W. 273, 278 (1927); *see generally* Drummond, Sherman & McCarthy, "The Rule of Capture in Texas – Still Misunderstood After All These Years," 37 TEX. TECH L. REV. 1 (2004).
[382] El Paso, Kerrville and SAWS. *See* Text Discussion, *infra*.
[383] As reported by SAWS (see Section 3 of this Report), to date SAWS has not experienced any significant loss of ASR water from production at the BexarMet Well Field.
[384] *Texas River Protection Ass'n v. TNRCC*, 910 S.W.2d 147, 153 (Tex. App. – Austin 1995, pet. denied).
[385] TEXAS WATER CODE.
[386] *Texas River Protection Ass'n, supra*, 910 S.W.2d at 152-153.
[387] *Id*. at 152.
[388] TEXAS WATER CODE
[389] TEXAS WATER CODE §§ 11.153-11.154. While the current statutory provisions contemplate a two-step approach to the permitting of surface water for supply of an ASR Project, *e.g.*, a pilot project to demonstrate feasibility followed by additional permitting steps, permanent ASR storage permitting is authorized. *Id*. § 11.154.
[390] *Id*. §§ 11.153-11.154.
[391] *Houston & Tex. Cent. Ry. Co. v. East*, *supra*, *81* S.W.2d at 281.
[392] *Friendswood Dev. Co. v. Smith-Southwest Indus., Inc.*, *supra*, 576 S.W.2d at 21.
[393] *See Gregg v. Delhi-Taylor Oil Corp*., 344 S.W. 2d 411 (Tex. 1961).
[394] *See Railroad Commission of Texas v. Manziel*, 361 SW 2d 560 (Tex. 1962).
[395] *See Coastal Oil & Gas Corp. v. Garza Energy Trust*, 268 S.W. 3d 1 (Tex. 2008).
[396] *See FPL Farming, Ltd. v. TNRCC*, NO. 03-02-00477-CV**,** 2003 LEXIS 1074 (Tex. App. – Austin, 2003, pet. denied)(memorandum opinion); *FLP Farming, Ltd. v. Envt'l Processing Sys., L.C.*, No. 09-08-00083CV, 2009 Tex. App. LEXIS 8268 (Tex. App. – Beaumont Oct. 20, 2009, pet. granted; *see generally* TEXAS WATER CODE Ch. 27; *but see Berkley v. Railroad Commission of Texas*, 282 S.W.3d 240, 243-244 (Tex. App. – Amarillo 2009, no pet.).
[397] 5 S.W.3d 773 (Tex. App. – San Antonio 1999, pet. denied).
[398] *Id.* at 779.
[399] *Id.* at 780.
[400] *Id.* at 777.
[401] *Id.* at 780.
[402] 184 S.W.3d 749 (Tex. App. – San Antonio, 2005, no pet. hist.).
[403] *Id.* at 756.
[404] *Id.*
[405] *FLP Farming, Ltd. v. Envt'l Processing Sys., L.C.*, 2009 Tex. App. LEXIS 8268 (Tex. App. – Beaumont Oct. 29, 2009, pet. granted).
[406] *Id.*
[407] Orders of the Texas Supreme Court issued February 8, 2011.
[408] *Id.*
[409].*Ehler v. LVDVD, L.C.*, 319 S.W.3d 817 (Tex. App. – El Paso 2010, no pet); *see Holubec v. Brandenberger*, 111 S.W.3d 32, 36 (Tex. 2003); *Burditt v. Swenson*, 17 Tex. 489, 502 (1856).
[410] *See, e.g., Mathis v. Barnes*, 316 S.W.3d 795, 801 (Tex. App. – Tyler, 2010, pet. filed); *Texas Pac. Res. Co. v. Cooper*, 109 S.W.3d 557, 560 (Tex. App. – Tyler 2003, pet. denied); *Nugent v. Pride Corp*. 30 S.W.3d 562, 574-575 (Tex. App. – Texarkana 2000, pet. denied); *Maranatha Temple v. Enterprise Prods Co.*, 893 S.W.2d 92, 99 (Tex. App. – Houston [1st Dist] 1994, writ denied).
[411] *See Sanders v. Miller*, 113 S.W. 996 (Tex. Ct. App. - 1908)("no harmful consequences from the pool had then developed, but were in expectancy" - depreciation in premises value alone not sufficient to give a cause of action for damages).
[412] *See Texas Union Pacific Resources Co. v. Cooper,* 199 S.W.3d 557 (Tex. App. – Tyler, 2003, no pet.) (suit involved nuisance claims based on fear that an injury might occur - Tyler Court noted fear of the unknown is not a nuisance); *Maranatha Temple, Inc. v. Enterprise Prod. Co.*, 893 S.W.2d 92 (Tex. App. 1st Dist., 1994, pet denied) ("…there is no case or authority that specifically gives a nuisance in fact cause of action based on fear, apprehension, or other emotional reaction that results from the lawful operations of industries in Texas.").

[413] *Compare* TEXAS WATER CODE § 11.1021 (surface water is owned by the State) *and City of San Marcos v. TCEQ*, 128 S.W.3d 264, 272 (Tex. App. – Austin 2004, pet. denied) *and Domel v Georgetown*, *supra*, 6 S.W.3d at 353 *and South Tex. Water Co. v. Bieri*, *supra*, 247 S.W.2d at 272 *with Id.* § 36.002 *and Texas Co. v. Burkett*, *supra*, 296 S.W. at 278.
[414] *See Texas Co. v. Burkett*, *supra*, 296 S.W. at 278; Denis v. Kickapoo Land Co., , *supra*, 771 S.W.2d at 238-39.
[415] TEXAS WATER CODE.
[416] 910 S.W. 2d 147 (Tex. App. - Austin 1995, writ denied).
[417] *Id*. at 153.
[418] *Id*.
[419] *Id*. at 155.
[420] *Id*.
[421] *Id*.
[422] *Id*.
[423] *Id*. (Commission found that injected water would be recoverable, based on its finding that the injected water would move no more than 120 feet per year).
[424] *Id*.
[425] 128 S.W.3d 264 (Tex. App. – Austin 2004, pet. denied); *cf.*, *Harrell v. Vahlsing*, 248 S.W.2d 762 (Tex. Civ. App.—San Antonio 1952, writ ref'd n.r.e.) (court expressed concern over undue emphasis on mere physical possession of water).
[426] *City of San Marcos v. TCEQ, supra*, 128 S.W.3d at 274.
[427] 910 S.W. 2d 147 (Tex. App. - Austin 1995, writ denied).
[428] 771 S.W.2d 235 (Tex. Civ. App.-Austin 1989, writ denied).
[429] *City of San Marcos v. TCEQ, supra*, 128 S.W.3d at 274-275.
[430] *Id*. at 275-277. Injection into a recover aquifer for purposes of storage and subsequent planned recovery for beneficial use (as recognized in the UGRA ASR litigation – *see* footnotes 682-695 and accompanying text, *supra*) is to be distinguished from the discharge of treated effluent into a state-owned watercourse.
[431] *See Sporhase v. Nebraska*, 458 U.S. 941, 949 (1982); City of Altus, Okla. v. Carr, 255 F.Supp. 828, 840 (W.D. Tex. 1966), *aff'd*, 385 U.S. 35 (1966).
[432] 255 F.Supp. 828, 840 (W.D. Tex. 1966), *aff'd*, 385 U.S. 35 (1966).
[433] *Id.* at 840; *see Sporhase v. Nebraska, supra*, 458 U.S. at 949.
[434] *Texas River Protection Association v. Texas Natural Resource Conservation Commission*, 910 S.W. 2d 147 (Tex. App. - Austin 1995, writ denied).
[435] *Id*. at 153 ("Even if the state stores water in a manner that negates its right to exclude private takers, a permit will stand if the water is actually put to a beneficial use. The characterization of stored water as groundwater subject to the rule of capture does not invalidate a permit as a matter of law.").
[436] 30 TAC §295.22(c). Subsection (c) provides as follows:

> Control of Stored State Water. If the applicant does not have the power of condemnation and proposes to store state water in [an ASR project] and withdraw it from underneath or to place any installation upon the land of another, the name(s) and address(es) of such landowner(s) shall be given. A copy of a duly acknowledged written easement, consent, or license from the landowner(s) or of a written lease or other evidence of agreement between the landowner(s) and the applicant shall be filed with the application.

[437.] *Lone Star Gas Co. v. Murchison*, 353 S.W.2d 870, 877 (Tex. Civ. App.—Dallas 1962, writ ref'd n.r.e.)(*quoting White v. N.Y. State Natural Gas Corp.*, 190 F.Supp. 342, 345, 347 (W.D. Pa. 1960)("[o]nce severed from the realty . . . gas and oil, like other minerals, become personal property.")).
[438.] 353 S.W.2d 870 (Tex. Civ. App.—Dallas 1962, writ ref'd n.r.e.).
[439]. *Lone Star Gas*, *supra*, 353 S.W.2d at 879.
[440]. *Id*.
[441]. *Id*.
[442] 508 S.W.2d 812 (Tex. 1974).
[443] *Id.* at 813 (the affected gas field was in a water-drive field).

[444] *Id.* at 815.
[445] *Id.* at 813-814.
[446] *Lone Star Gas Co. v. Murchison*, 353 S.W.2d 870 (Tex. Civ. App.—Dallas 1962, writ ref'd n.r.e.).
[447] *Humble Oil & Refining v. West, supra,* 353 S.W.2d at 817.
[448] *Id.* at 816-817.
[449] 353 S.W.2d 870 (Tex. Civ. App.—Dallas 1962, writ ref'd n.r.e.).
[450] *Humble Oil & Refining v. West, supra,* 353 S.W.2d at 817.
[451] *Id.* at 818.
[452] *Id.*
[453] *Id.*
[454] *Id.* at 819.
[455] *Id.*
[456] Tex. Nat. Res. Code §§ 91.171 *et seq*.
[457] *Id.* § 91.172.
[458] *Id.* §§ 91.174, 91.179-91.181.
[459] *Id.* §§ 91.171-91.184.
[460] *Id.* § 91.182.
[461] *See generally* Kaiser, Lesikar, Shafer & Gerston, *Water Management Strategies and Ranking the Options*, Texas Water Resource Institute (The Texas A&M University System) (available on-line at www.tx-water-ed.tamu.edu/strategies.html); *see* also Hoffman, *Texas Water Reuse Update*; Postel, *Water and World Population Growth*; Natural Research Council, *Issues in Potable Reuse – The Viability of Augmenting Drinking Water Supplies with Reclaimed Water* (National Academy Press, Washington, D.C., 1998) (available on-line at *search.nap.edu/readingroom/books/potable*).
[462] *See* Golberg, *Reuse Water to Prevent a Water Crisis*, Academy of Natural Sciences (February, 1994) ("scientists worldwide see that already-used water is a key to preventing a water-supply crisis.") (available on-line at www.acnatsci.org/erd/ea/reuse_water.html).
[463] TWDB, 2002. The Dallas and Ft. Worth regional planning group projected that 34 percent of its year 2050 demands would be met with reuse. *Id.*
[464] *See* 30 TAC §§331.184(a)(" All Class V aquifer storage wells shall be operated in such a manner that they do not present a hazard to or cause pollution of an underground source of drinking water.").
[465] *See* 30 TAC §§331.184(e).
[466] *See* TEXAS WATER CODE §§11.153-11.155.
[467] *Id*. §11.154(c)(1).
[468] *See* 30 TAC §210.2.
[469] *See id*. §210.5; *see generally id*. 30 TAC Ch. 305.
[470] *See* 30 TAC §210.4.
[471] *See id*. §210.4(a).
[472] *See id*. §210.4(b).
[473] *See id*. §210.4(c).
[474] *See id*. §210.4(e).
[475] *See id*. §210.4(d).
[476] *See id*. §210.6.
[477] *See id*. §210.33.
[478] *See id*. §§210.34, 210.36.
[479] *See id*. §210.6(1)(E).
[480] *See id*. §210.25.
[481] *See id*. §210.34.
[482] *See id*. §210.6(2)(C).
[483] *See id*. §210.6(3)(A).
[484] *See id*. §210.36(a).
[485] *See id*. §210.7.
[486] *Id*.
[487] *Id*.

[488] *See* 30 TAC §210.32.
[489] *See id*. §210.32(1).
[490] *See id.* §210.32(2).
[491] *See* Roebuck, *City of El Paso Water Conservation & Reuse of Wastewater Program*, 1997 Water Conservation Conference Presentations; *cf., Florida Water Plan Nears Approval – State Seeking EPA's Permission to Store Tainted Liquid in Ground,* Houston Chronicle page 4A (April 13, 2001) (to "head-off dividing water shortages," Florida proposes injection of up to 1.7 billion gallons per day of "untreated, partly contaminated" water into the ground).
[492] *See generally* York & Wadsworth, *Reuse in Florida: Moving Toward the 21st Century*, Florida Water Resources Journal (November 1998) (discussing proposed amendments to Chapter 62-610, Florida Administrative Code).
[493] *See generally* Chapters 62-610, -Florida Administrative Code.
[494] *See* § 62-520.410(1) (Classification of Ground Water, Usage, Reclassification).
[495] *See* § 62-520.410(4).
[496] *See* § 62-520.410(3); *see generally* §§62-520.420 to 62-520.460.
[497] *See* § 62-520.460(2).
[498] *See* § 62-520.460(3). Class F-1 groundwater is limited a certain geographic area in Florida described in the Rule. *See* § 62-520.460(1).
[499] *See* § 62-520.420(1) (*citing* §§ 62-550.310, 62-550.320).
[500] *See* § 62-520.420(1).
[501] *Id*. The criteria do not apply to a UIC facility that has received and "aquifer exemption" pursuant to § 62-528.300(3), unless there is a threat to the environment, public health, safety or the environment. *See* § 62-520.420(2).
[502] *See* § 62-520.440. The minimum criteria of § 62-520.400 do not apply unless there is a threat to the environment, public health, safety or the environment. *See* § 62-520.440.
[503] *See generally* TEXAS WATER CODE §11.154(c)(1)(A)-(B)(Injected water should not alter the physical, chemical, or biological quality of native groundwater to a degree that the introduction would (i) render groundwater produced from the aquifer harmful or detrimental to people, animals, vegetation, or property; or (ii) require treatment of the groundwater to a greater extent than the native groundwater requires before being applied to that beneficial use); 30 TAC §331.184(a)("All Class V aquifer storage wells shall be operated in such a manner that they do not present a hazard to or cause pollution of an underground source of drinking water").
[504] *Compare* TEXAS WATER CODE §11.154(c)(1) *and* 30 TAC §331.184 *with* Florida Administrative Code Chapters 62-510 *and* 62-620,
[505] *See* Act of May 18, 1995, 74th Leg., R.S., ch. 309, 1995 Tex. Gen. Laws 2693 (HB 1989, codified as amended at TEX. WATER CODE ANN. §§ 11.153-.155).
[506] *See id.* Act of May 18, 1995, 74th Leg., R.S., ch. 309, §1.
[507] *See generally* TEXAS WATER CODE Ch. 27, 30 TAC Ch. 331.
[508] *See generally* TEXAS WATER CODE § 11.153 - 11.155; 30 TAC §§ 295.21--295.2, 331.181 - 331.186.
[509] *Texas River Protection Assoc. v. TNRCC*, 910 S.W.2d 147, 152-154 (Tex. App. – Austin 1995, writ denied).
[510] *See generally* TEXAS WATER CODE § 11.121; *compare id*. § 11.121 *with id.* § 11.137 *and id.* § 11.138.
[511] TEXAS WATER CODE
[512] 30 TAC .
[513] TEXAS WATER CODE.
[514] TEXAS WATER CODE §§ 11.153-11.154; 30 TAC §§ 295.21-295.22.
[515] *See generally* TEXAS WATER CODE Chapter 36.
[516] *See id.* § 36.015; *see generally Sipriano v Great Spring Waters of America*, 1 S.W.3d 75, 79 (Tex. 1999).
[517] *See* Text Discussion, *supra*.

[1] 30 TAC §§331.3(a), 331.7(a).
[2] 30 TAC §331.4.
[3] 30 TAC §331.5(a).
[4] 30 TAC §331.5(a).

[5] 30 TAC §331.5(b).
[6] A "pre-injection unit" I defined as "The on-site above-ground appurtenances, structures, equipment, and other fixtures including the injection pumps, filters, tanks, surface impoundments, and piping for wastewater transmission between any such facilities and the well that are or will be used for storage or processing of waste to be injected, or in conjunction with an injection operation." 30TAC §331.2(80).
[7] 30 TAC §331.5(c)(1).
[8] 30 TAC §331.5(c)(2).
[9] 30 TAC §311.5(c)(3).
[10] 30 TAC §§331.7(a), §331.7(d).
[11] 30 TAC §331.17(c)(1).
[12] 30 TAC §331.17(c)(1)(A).
[13] 30 TAC §331.17(c)(1)(B).
[14] 30 TAC §331.17(c)(2).
[15] 30 TAC §331.17(c)(2)(A).
[16] 30 TAC §331.17(c)(2)(B).
[17] 30 TAC §331.17(b).
[18] 30 TAC §331.17(b)(1).
[19] 30 TAC §331.17(b)(2).
[20] 30 TAC §331.17(d)(1).
[21] 30 TAC §331.17(d)(2).
[22] 30 TAC §331.17(d)(3).
[23] 30 TAC §331.17(d)(4).
[24] 30 TAC §331.133(b).
[25] 30 TAC §331.133(c).
[26] 30 TAC §331.133(d).
[27] 30 TAC §331.133(e).
[28] 30 TAC §331.133(f).
[29] 30 TAC §331.9(b).
[30] 30 TAC §331.9(b).
[31] 30 TAC §331.9(b)(1).
[32] 30 TAC §331.9(b)(2).
[33] 30 TAC §331.9(b)(2)(A).
[34] 30 TAC §331.9(b)(2)(B).
[35] 30 TAC §331.9(b)(2)(C).
[36] 30 TAC §331.9(b)(2)(D).
[37] 30 TAC §331.9(b)(2)(E).
[38] 30 TAC §331.10(a).
[39] 30 TAC §331.10(a)(1).
[40] 30 TAC §331.10(a)(2).
[41] 30 TAC §331.10(a)(3).
[42] 30 TAC §331.10(a)(4).
[43] 30 TAC §331.10(a)(5).
[44] 30 TAC §331.10(d).
[45] 30 TAC §331.10(a).
[46] 30 TAC §331.13(b).
[47] 30 TAC §331.18(b)(1).
[48] 30 TAC §331.18(b)(2).
[49] 30 TAC §331.18(b)(3).
[50] 30 TAC §331.18(b)(4).
[51] 30 TAC §331.18(b)(4)(A).
[52] 30 TAC §331.18(b)(4)(B).
[53] 30 TAC §331.18(b)(5)(A).
[54] 30 TAC §331.18(b)(5)(B).

[55] 30 TAC §331.18(b)(6).
[56] 30 TAC §331.18(b)(7).
[57] 30 TAC §331.18(e)(1).
[58] 30 TAC §331.18(i).
[59] 30 TAC §331.18(j)
[60] 30 TAC §331.18(k)
[61] 30 TAC §331.21
[62] 30 TAC §331.19. Injection into any portion of the Edwards Aquifer under the jurisdiction of the Edwards Aquifer Authority also requires compliance with the Authority's enabling legislation and rules. For a more in depth discussion of the Authority's requirements, please see Text, *supra*.
[63] 30 TAC §331.19(a).
[64] 30 TAC §331.19(a)(1)(A).
[65] 30 TAC §331.19(a)(1)(B).
[66] 30 TAC §331.19(a)(2).
[67] 30 TAC §331.19(a)(3).
[68] 30 TAC, Chapter 331, Subchapter H.
[69] 30 TAC §331.132.
[70] 30 TAC §331.132(a).
[71] 30 TAC §331.132(b).
[72] 30 TAC §331.132(b)(1).
[73] 30 TAC §331.132(b)(2).
[74] 30 TAC §331.132(b)(3).
[75] 30 TAC §331.132(b)(4).
[76] 30 TAC §331.132(c).
[77] 30 TAC §331.132(c)(1).
[78] 30 TAC §331.132(c)(2).
[79] 30 TAC §331.132(d).
[80] 30 TAC §331.132(d)(1).
[81] 30 TAC §331.132(d)(1)(A).
[82] 30 TAC §331.132(d)(1)(B).
[83] 30 TAC §331.132(d)(2).
[84] 30 TAC §331.132(d)(3).
[85] 30 TAC §331.132(e).
[86] 30 TAC §331.132(f). "Flood-prone area" is defined as the area within the 100 year flood plain determined by Flood Hazard Maps adopted by the Federal Emergency Management Agency ("FEMA").
[87] 30 TAC §331.132(g)(1).
[88] 30 TAC §331.132(g)(2).
[89] 30 TAC §331.132(h).
[90] CHAPTER 331 SUB-CHAPTER K.
[91] 30 TAC §331.182.
[92] 30 TAC §331.182.
[93] 30 TAC §331.182.
[94] 30 TAC §331.182.
[95] 30 TAC §331.182(1).
[96] 30 TAC §331.182(2).
[97] 30 TAC §331.182(3).
[98] 30 TAC §331.183.
[99] *Id.*
[100] 30 TAC §331.183(1).
[101] 30 TAC §331.183(1)(A).
[102] 30 TAC §331.183(1)(B).
[103] 30 TAC §331.183(2).
[104] 30 TAC §331.183(3).

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[105] 30 TAC §331.184.
[106] 30 TAC §331.184(a).
[107] 30 TAC §331.184(b).
[108] 30 TAC §331.184(c).
[109] 30 TAC §331.184(d).
[110] 30 TAC §331.184(e).
[111] 30 TAC §331.185.
[112] 30 TAC §331.185(a).
[113] 30 TAC §331.185(a)(1).
[114] 30 TAC §331.185(a)(2).
[115] 30 TAC §331.185(a)(3).
[116] 30 TAC §331.185(a)(4).
[117] 30 TAC §331.185(a)(5).
[118] 30 TAC §331.185(6).
[119] 30 TAC §331.186.
[120] 30 TAC §331.186(1).
[121] 30 TAC §331.186(2).
[122] 30 TAC §331.186(3).
[123] 30 TAC §331.186(4).
[124] 30 TAC §331.186(5).
[125] 30 TAC §331.186(6).
[126] 30 TAC §331.186(7).

[1] 30 TAC Chapter 295, Division 1.
[2] 30 TAC §295.1.
[3] 30 TAC §295.2.
[4] *Id.*
[5] *Id.*
[6] 30 TAC §295.3.
[7] 30 TAC §295.4.
[8] 30 TAC §295.5.
[9] 30 TAC §295.6.
[10] 30 TAC §295.7.
[11] 30 TAC §295.8.
[12] 30 TAC §295.9.
[13] *Id.*
[14] *Id.*
[15] *Id.*
[16] *Id.*
[17] 30 TAC §295.10.
[18] 30 TAC §295.12.
[19] 30 TAC §295.16.
[20] 30 TAC §295.14.
[21] 30 TAC §295.15.
[22] 30 TAC Chapter 295, Division 2.
[23] 30 TAC Chapter 297.
[24] 30 TAC §295.21(a)(1).
[25] The TCEQ uses the term "retrieval" rather than "recovery" in connection with its regulations related to "aquifer storage." *See* 30 TAC §§ 295.21-295.22, 297.1(5), 297.19.
[26] 30 TAC §295.21(b).
[27] 30 TAC §295.21(a)(2).

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[28] 30 TAC §297.13.
[29] 30 TAC §297.13(a).
[30] 30 TAC §297.13(b).
[31] *Id.*
[32] *Id.*
[33] 30 TAC §297.13(c).
[34] 30 TAC §297.13(d).
[35] 30 TAC §295.125.
[36] 30 TAC §297.19.
[37] 30 TAC §297.19(a).
[38] 30 TAC §297.19(b)(1).
[39] 30 TAC §297.19(b)(2).
[40] 30 TAC §297.19(b)(3).
[41] 30 TAC §297.19(b)(4).
[42] 30 TAC §297.19(c).
[43] 30 TAC §297.19(d).
[44] 30 TAC §295.21(a)(2).
[45] 30 TAC §297.11.
[46] *Id.*
[47] 30 TAC §297.41(a).
[48] 30 TAC §297.41(a)(1).
[49] 30 TAC §297.41(a)(2).
[50] 30 TAC §297.41(a)(3)(A).
[51] 30 TAC §297.41(a)(3)(B).
[52] 30 TAC §297.41(a)(3)(C).
[53] 30 TAC §297.41(a)(3)(D).
[54] 30 TAC §297.41(a)(3)(E).
[55] 30 TAC §297.41(a)(4).
[56] 30 TAC §297.41(a)(5).
[57] 30 TAC §297.11.
[58] 30 TAC §295.21(a)(2)(A).
[59] 30 TAC §295.21(a)(2)(B).
[60] 30 TAC §295.21(b).
[61] 30 TAC §295.22(c).
[62] 30 TAC §§295.22(d), 295.22(e), 295.121, 295.122, 295.123.
[63] 30 TAC §§295.121(1); 295.41.
[64] 30 TAC §295.121(2).
[65] 30 TAC §295.121(3).
[66] 30 TAC §295.121(4).
[67] 30 TAC §295.121(5).
[68] 30 TAC §295.121(5)(A).
[69] 30 TAC §295.121(5)(B).
[70] 30 TAC §295.121(5)(C).
[71] 30 TAC §295.121(5)(D).
[72] 30 TAC §295.121(6).
[73] 30 TAC §295.122.
[74] *Id.*
[75] 30 TAC §295.123.
[76] 30 TAC §295.123(1).
[77] 30 TAC §295.123(2).
[78] 30 TAC §295.123(3).
[79] 30 TAC §295.123(4).
[80] 30 TAC §295.123(5).

[81] 30 TAC §295.123(6).
[82] 30 TAC §295.22(e)(1).
[83] 30 TAC §295.22(e)(2).
[84] 30 TAC §295.22(e)(3).
[85] 30 TAC §295.22(e)(4).
[86] 30 TAC §295.22(e)(5).
[87] 30 TAC §295.22(e)(6).
[88] 30 TAC §295.22(e)(7).
[89] 30 TAC §295.126.
[90] 30 TAC §295.22(a)(1).
[91] 30 TAC §295.22(a)(2).
[92] 30 TAC §295.22(a)(3).
[93] 30 TAC §295.22(a)(3)(A).
[94] 30 TAC §295.22(a)(3)(B).
[95] 30 TAC §295.22(b).
[96] 30 TAC §295.22(b)(1).
[97] 30 TAC §295.22(b)(2).
[98] 30 TAC §295.22(b)(2)(A).
[99] 30 TAC §295.22(b)(2)(C).
[100] 30 TAC §295.22(b)(2)(B).
[101] 30 TAC §295.22(b)(2)(D).
[102] 30 TAC §295.22(b)(2)(E).
[103] 30 TAC §295.22(b)(2)(F).
[104] 30 TAC §295.22(b)(2)(G).
[105] 30 TAC §295.22(b)(3).
[106] 30 TAC §295.22(b)(4).
[107] 30 TAC §295.131.
[108] 30 TAC §295.132.
[109] 30 TAC §295.133.
[110] 30 TAC §295.134.
[111] 30 TAC §295.202.
[112] 30 TAC §295.202(a).
[113] 30 TAC §295.202(b).
[114] 30 TAC §295.202(c).
[115] 30 TAC §295.202(d).
[116] 30 TAC §295.202(e).
[117] 30 TAC §295.202(e)(1).
[118] 30 TAC §295.202(e)(1)(A).
[119] 30 TAC §295.202(e)(1)(B).
[120] 30 TAC §295.202(e)(2).
[121] 30 TAC §295.202(e)(2)(A).
[122] 30 TAC §295.202(e)(2)(B).
[123] 30 TAC §295.202(e)(2)(C).
[124] 30 TAC §295.202(e)(2)(D).