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Addressing water needs using aquifer storage and recovery

According to state water planners, large volumes of water storage will be needed to achieve cost-effective, sustainable, and reliable water supplies to meet projected future demands for Texas. Water storage traditionally has involved building new surface water reservoirs, often by damming rivers and streams, but policymakers increasingly are looking to another method known as aquifer storage and recovery (ASR). ASR involves collecting drinking water during wet periods and storing it underground in an aquifer through an injection well from which it can be drawn for use during periods of peak demand.

While surface reservoirs continue to feature prominently in the 2017 state water plan, adopted in May by the Texas Water Development Board (TWDB), many consider ASR to be more resistant than reservoirs to loss of water through evaporation, the expense of obtaining land for a reservoir, and destruction of wildlife habitat and private property. At the same time, some say a principal challenge to widespread implementing of ASR is a legal and regulatory framework for water policy that is not well adapted to this technology.

A few Texas municipalities have employed ASR for a number of years. According to the state water plan, by 2070 the volume of water available in Texas through ASR is projected to be 152,000 acre-feet per year, more than triple the amount estimated in the 2012 plan.

This report provides an introduction to ASR in Texas, including a history of ASR projects and a review of the regulatory structure that has evolved around the technology, including enactment of a new state law in 2015. It also examines uses for ASR, questions about the degree to which it could replace traditional, aboveground reservoirs, and some remaining challenges to its widespread implementation.

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Number 84-8

What is ASR?

ASR is defined in the 2017 state water plan as "the practice of injecting water, when available, into an aquifer where it is stored for later use." When selecting a possible site for ASR, two factors typically considered are:

- whether the geology and hydrology of the proposed aquifer are suitable to contain the injected water and prevent its migration from the storage site; and
- whether the location of the site allows the operator to prevent other pumpers from accessing the stored water.

Geology and hydrology. In the planning stages, prospective ASR operators typically investigate sites to ensure that the aquifer formation has geologic and hydrologic properties suitable to receive and contain injected water. ASR is feasible only in certain geologic formations and where the native groundwater is chemically compatible with the injected water. This is to prevent the accumulation of deposits in the well that might restrict the ability later to withdraw the stored water. Most aquifers in Texas are made up of limestone or sandstone. While both can be suitable for ASR, a sandstone aquifer is generally preferred because it is porous and more absorbent, which facilitates injection and water recovery.

Components of an ASR project in a confined aquifer

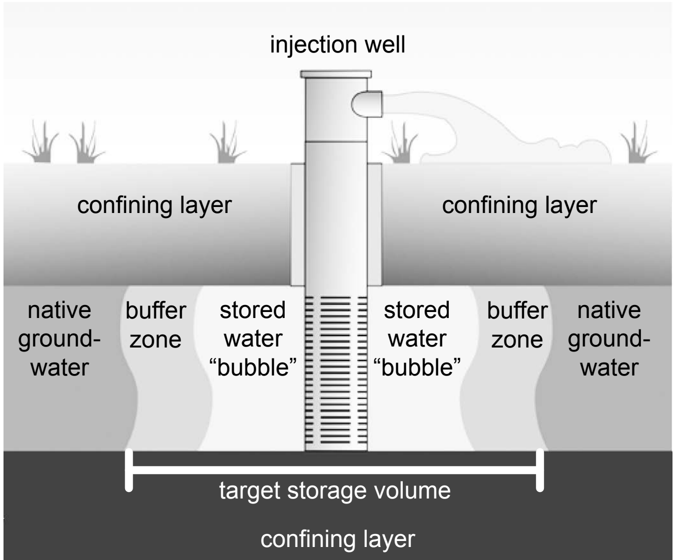

Image courtesy of Texas Water Development Board

Another factor affecting the suitability of an aquifer is whether it is confined or unconfined. In a confined aquifer, layers of rock or clay limit the movement of groundwater into or out of the aquifer, better preventing the migration of injected water. An upper confining layer also protects against surface contamination. The figure below shows a cross-section of an ASR well in which water is stored in an aquifer between two confining layers.

Transferring water underground for ASR storage is accomplished through an injection well regulated by the Texas Commission on Environmental Quality (TCEQ) through its underground injection control program. Whether the injected water is state-owned surface water, privately owned groundwater, or treated wastewater, each ASR project requires a class V injection well permit designed to protect underground sources of drinking water (USDW) from contamination. As defined in federal regulations, a USDW is an aquifer or a part of an aquifer that is currently used, or that may be needed, as a drinking water source. The water in a USDW contains, by definition, less than 10,000 milligrams per liter of total dissolved solids.

Injecting water into a confined aquifer increases the pressure within it. The stored water, which forms a "bubble" around the injection well, is separated from the native groundwater by a buffer zone of mixed water that forms between the two, as illustrated in the figure below. Once formed, the buffer zone allows full recovery of the stored water. However, longer storage times can result in the gradual migration of the injected water from the storage site. A buffer zone is not required when there is no significant difference in water quality between the stored water and the native groundwater. In many instances, however, the native groundwater is of lower quality than the injected water.

Until earlier this year, TCEQ rules required the quality of water stored in an ASR project to meet drinking water standards before being injected. In 2015, the 84th Legislature enacted HB 655 by Larson, which amended this requirement under certain circumstances (*see Water quality protection, page 6*) and introduced other measures designed to create a regulatory environment more conducive to the wider implementation of ASR. The history of ASR projects operating in Texas before enactment of HB 655 reveals how efforts to implement this technology have both shaped and been shaped by state regulations.

Water regulation and early ASR projects in Texas

The current system governing water rights in Texas provides different regulatory schemes for groundwater and surface water, although the two sources of water are part of the same hydrologic cycle. All surface water — including from streams, lakes, and bays — is owned by the state. To lawfully divert, store, or use surface water for any purpose — other than an exempt use such as domestic use, raising livestock or producing oil — a user first must obtain a water right from TCEQ.

Groundwater in Texas is privately owned and subject to the common-law rule of capture, which allows a landowner to withdraw unlimited amounts of water from below his or her land for beneficial use without liability to surrounding landowners. However, groundwater use may be regulated by a local groundwater conservation district with jurisdiction over the affected aquifer. Texas Water Code, ch. 36 establishes groundwater conservation districts as "the state's preferred method of groundwater management" and invests each with rulemaking authority to protect and conserve the resource under its jurisdiction in a manner that recognizes the water rights of landowners. By some estimates, the state's 99 groundwater conservation districts have jurisdiction over roughly 70 percent of the land area in Texas, and more than 90 percent of groundwater produced in the state comes from underground sources within this geographic area.

The separate legal systems for surface water and groundwater have affected many aspects of Texas water policy, including the development of ASR. While the use of ASR in Texas dates back to the 1960s, the Legislature did not develop a statutory framework for this technology until 1995, after a legal challenge to an ASR project operated by the city of Kerrville.

Kerrville project. Kerrville's ASR project, which still operates, was the first one authorized to use state surface water under a TCEQ permit originally granted in 1993 to the Upper Guadalupe River Authority. This permit allows the authority to divert surface water from the river during winter months, or at other times when water use is low, and inject it into the Lower Trinity Aquifer after treating it to drinking water standards for municipal use.

Kerrville's ASR project operates within the jurisdiction of the Headwaters Groundwater Conservation District, which has no specific rules on ASR. Instead, the district issued an operating permit requiring the city to report the net stored surface water to the district. Any water recovered in excess of the injected amount counts against the volume of groundwater the city may produce under its permit.

At the time the permit was granted, TCEQ's predecessor, the Texas Natural Resource Conservation Commission (TNRCC), had no formal statutory guidance or rules to manage or use ASR. This left the permit for the Kerrville project open to legal challenges on the ownership of surface water after it had been injected underground for storage in an ASR project. In *Texas River Protection Authority v. Texas Natural Resource Conservation Commission*, the plaintiff argued that TNRCC could not issue a valid permit allowing the Upper Guadalupe River Authority to inject surface water underground because this had the effect of improperly changing a state resource into privately owned groundwater subject to the rule of capture. In affirming a district court decision upholding the permit, the Third Court of Appeals in Austin ruled in

Current ASR projects in Texas

Three Texas utilities currently use ASR as a water supply and storage strategy — the city of Kerrville, the San Antonio Water System, and the El Paso Water Utilities. Because each project relies on a different source of water for storage — surface water, groundwater, and reclaimed and treated wastewater, respectively — each provides a model for how ASR can be used to store and recover different sources of water under various conditions. The development of each project sheds light on the ongoing legal and regulatory issues surrounding the implementation of this technology in Texas. For more information on each project, *see this page* (Kerrville), *page 4* (San Antonio), and *page 8* (El Paso).

Texas also has one special-purpose ASR district in and around Corpus Christi. While the Corpus Christi Aquifer Storage and Recovery Conservation District does not currently operate any ASR facilities, it has been involved in studies related to the technology and recently received grant funding from TWDB for a demonstration project. TWDB also awarded grant funding for demonstration projects to the Victoria County Groundwater Conservation District and the Edwards Aquifer Authority.

1995 that the permit's legality depended not on the water's legal character but on the fact that Kerrville was putting it to beneficial use, as stipulated in Texas Water Code, ch. 11, which governs state water rights.

In 1995, the 74th Legislature enacted HB 1989 by Ciro Rodriguez, creating the first statutory authorization to store surface water using ASR technology. It also allowed for the temporary permitting of pilot projects in certain areas of Texas, with a process to make the permits permanent for successful projects. The bill required ASR operators to cooperate with affected groundwater districts and comply with their rules. It also authorized use of TWDB funds for ASR feasibility studies of potential aquifers to be completed in partnership with TCEQ. Carrizo-Wilcox Aquifer in Bexar County was evaluated as a potential site, leading to construction of the San Antonio Water System's existing Twin Oaks ASR facility.

San Antonio Water System project. The Twin Oaks ASR facility run by SAWS in southern Bexar County began operating in 2004. It is one of the largest ASR projects in the nation, covering more than 3,200 acres. During periods of heavy rainfall, the Edwards Aquifer produces groundwater at a rate that exceeds SAWS' daily demands. The Twin Oaks facility stores this excess

Comparing ASR with surface reservoirs

About 7.2 million acre-feet (2.3 trillion gallons) of water evaporates from surface water reservoirs in an average year, according to TWDB. This is about 21 percent of the total combined available storage in Texas reservoirs.

Despite the drawback of evaporation, surface water reservoirs are a major part of the 2017 state water plan, with 26 new major reservoirs recommended to meet the needs of several regions. As part of a discussion on how ASR might affect the need for new surface water reservoirs, the House Natural Resources Committee is charged this interim with analyzing how evaporation contributes to freshwater loss and with examining techniques, including ASR, to prevent such losses.

According to TWDB, seven regional water planning groups recommended 17 ASR projects as water management strategies for the 2017 plan. The 2012 plan included only eight. An ASR system must appear in the plan to be eligible for a low-interest loan through the new State Water Infrastructure Fund of Texas (SWIFT). While no ASR facility has received SWIFT funding to date, TWDB is scheduled to consider a funding application from the city of Bryan for final approval on July 21.

Those who favor increased use of ASR as an alternative to surface water reservoirs say ASR can provide a significant part of the future storage needed without losing water to evaporation. They say aquifers also do not experience the accumulation of sediment that can reduce the storage capacity of a surface reservoir, nor do they require flooding large areas of land, which they say degrades private property and the environment.

ASR also can provide cost benefits, proponents say. For example, storing drinking water in an ASR facility may reduce the need to expand water treatment plants if the operator has pretreated it to drinking water standards before injection. In this case, the recovered water likely would require only disinfection when recovered. Also, ASR wells can be added one at a time to meet demand, providing more flexibility for planning and operations, while surface water reservoirs require significant lead time and up-front capital investment.

Those who believe the state should continue relying heavily on surface water reservoirs say that the reservoirs' purpose, geology, and volume of water stored are important considerations when weighing the suitability of widespread ASR. Many surface water reservoirs, besides storing much of the state's water supply, also provide flood control. ASR facilities cannot serve this purpose. ASR also is not geologically feasible in many areas to be served by new surface water reservoirs in the state water plan, and some planned reservoirs are too large to be replaced by ASR.

While ASR has clear benefits, critics say, Texas has a long and successful history of using surface water reservoirs to store large volumes of affordable water. State and regional water plans are statutorily required to identify sites for reservoir development, and the Texas Constitution (Art. 3, sec. 49-d) also expresses the state's interest in reservoir construction and enlargement.

groundwater in a formation within the Carrizo-Wilcox Aquifer for later use.

When SAWS began planning its Twin Oaks ASR facility, no rules were in place for ASR projects using groundwater. While the enactment of HB 1989 led to regulations for ASR projects supplied by *surface water*, such as Kerrville's, until recently Texas law and TCEQ rule provided no specific guidance for projects relying on the injection and later retrieval of *groundwater*. In addition, until recently, an operator considering an ASR project within a groundwater conservation district's territory faced a regulatory scheme that, regardless of the source of water, placed the operator under the jurisdiction of one entity (TCEQ) when injecting the water into the aquifer and another (the water district) when recovering it. Each of the state's 99 groundwater conservation districts has its own rules, and while some address ASR, many do not. According to water suppliers, this resulted in significant variation in the way groundwater districts addressed ASR projects, both for pumping groundwater for storage and receiving injected water for storage and later recovery.

When planning for the Twin Oaks project began in the mid-1990s, SAWS said, it considered the effect that groundwater conservation district rules might have on its ability to retrieve the water it intended to store underground. After evaluating several locations, SAWS selected a site within the Carrizo-Wilcox Aquifer that was not regulated by a groundwater conservation district. While the rule of capture applied in that area, SAWS owned enough of the land overlying the site to ensure that it could protect the stored water from other pumpers (*see Protecting stored water from other pumpers,* page 6).

Some surrounding landowners opposed the project, including those outside Bexar County whose groundwater was regulated by the Evergreen Underground Water Conservation District. This culminated in an effort to annex the proposed site within the Evergreen district, a measure that failed in an election but that prompted SAWS in 2002 to strike a water management agreement with the Evergreen district in an effort to gain regulatory certainty and avoid future annexation.

Many of the challenges faced by SAWS in its attempt to establish its ASR project are echoed in the findings of *An Assessment of Aquifer Storage and Recovery in Texas*, a TWDB study published in 2011 that examined the relatively low rate of ASR installation in Texas. According to the water utilities surveyed for the study, one of the main barriers to the wider implementation of ASR was the regulatory burden stemming from the separate legal systems governing surface water and groundwater. Recommendations to deal with this issue included proposed legal and regulatory changes to incentivize ASR implementation and to clarify the role of groundwater conservation districts in such projects.

Recent legislation

In 2015, the 84th Legislature enacted HB 655 by Larson, which repealed some of the existing requirements for surface water ASR projects, including that a developer conduct a pilot project before filing a permit application for a project and that a surface water right holder obtain TCEQ's permission to store water before seeking to implement a project. The new law establishes the same regulatory framework for all ASR projects, regardless of the source of the stored water, by giving TCEQ exclusive jurisdiction over both the injection and recovery of stored water under its existing ASR underground injection control program.

The law contains provisions governing ASR projects in areas under the jurisdiction of a groundwater conservation district, with certain exceptions. It also prescribes measures designed to protect water quality in the receiving aquifer and modifies certain rules, including the requirement that water meet drinking water standards before being injected.

ASR in groundwater conservation districts. HB 655 specifies how ASR facilities must account for the water they inject and recover. It requires ASR project developers to meter all wells and report total injected and recovered amounts monthly to TCEQ and to any applicable groundwater district, as well as results of annual water quality testing of injected and recovered water.

For ASR projects within the jurisdiction of a groundwater conservation district, the amount of water that a project may recover is limited to the lesser of the total amount injected or the amount the TCEQ determines can be recovered. If the project withdraws more water than the amount authorized by TCEQ, the ASR operator must report the excess volume to the district. A district's spacing, production, and permitting rules and fees apply only to the excess volume. These new requirements do not apply to the regulation of an ASR project in the Edwards Aquifer

Authority, the Harris-Galveston Subsidence District, the Fort Bend Subsidence District, the Barton Springs Edwards Aquifer Conservation District, or the Corpus Christi Aquifer Storage and Recovery Conservation District.

Supporters of HB 655 say the law encourages development of ASR projects by creating an efficient process and increasing regulatory certainty for projects in areas within groundwater conservation districts, which includes most of Texas. Giving TCEQ exclusive jurisdiction over both the injection and recovery of stored water and limiting a district's permitting rules and fees only to withdrawals exceeding the authorized amount will ensure that operators can access the water they injected without regulatory interference, while allowing districts to continue managing and protecting native groundwater.

While concerns remain about a groundwater conservation district's ability to manage the aquifer, supporters of HB 655 say it establishes a clear jurisdictional boundary by requiring an ASR operator to report to TCEQ and the groundwater district the volume of water injected for storage and the volume recovered. Water produced that exceeds the amount TCEQ determines can be recovered is subject to district regulation. Supporters say any need for ASR operators to monitor the migration of injected water could be determined on a case-by-case basis, depending on local aquifer conditions, as part of the permitting process by TCEQ. HB 655 does not affect the authority of a district to issue permits and enforce pumping restrictions when groundwater will be used as the source water to be stored.

Still, in the wake of HB 655, some express concerns about the ability of groundwater conservation districts to properly manage the aquifers under their charge. Many districts believe regular monitoring and modeling by the operator is necessary to detect migration of injected water and to ensure that the water withdrawn from an ASR project is the same as the water that was stored there. For example, some have suggested requiring ASR projects to collect water samples in the buffer zone where native and injected waters are comingling. Analysis of these samples could inform TCEQ, ASR project owners, and adjacent landowners of the rate of migration away from the storage site, and verify the amount of recoverable water. Without such safeguards, some say, there will not be a clear jurisdictional boundary, making it difficult for districts to impose necessary restrictions on groundwater pumping, which is one of their most important duties.

Water quality protection. HB 655 requires TCEQ to assess the impacts of an ASR project on the water in the receiving aquifer. In adopting rules or issuing permits, the commission must consider:

- whether the injection of water will comply with the federal Safe Drinking Water Act;
- the extent to which the water injected for storage can be successfully recovered for beneficial use;

Protecting stored water from other pumpers

The inability of ASR operators to protect stored water from other pumpers who might have access to it has been identified as a significant impediment to ASR implementation. In areas of Texas that are not subject to groundwater conservation district regulations, the common-law rule of capture allows landowners to pump groundwater for beneficial use without liability to their neighbors. The state's three existing ASR operators have taken steps to minimize risk to their stored water by using storage zones deep within the aquifer, making it cost prohibitive for other pumpers to access it. Operators also have employed administrative means, such as land ownership and municipal ordinances, to protect it.

Some experts believe that a legal or regulatory framework to protect the ownership rights of water pumped underground, even under property not owned by the ASR operator, is needed to address concerns. For example, well spacing requirements and production limits on other wells in the vicinity could prevent other users from accessing the stored water in areas under the jurisdiction of a groundwater conservation district.

Another proposal, with application outside of a groundwater conservation district, is expanding use of wellfield protection areas to prohibit pumping around certain ASR well systems. Wellfield protection areas are local ordinances that limit certain land use activities around a well field that serves a public water supply. These areas are used nationwide to protect against pollution, but some say expanding their use to prohibit pumping could infringe on property rights.

- the project's effect on existing water wells; and
- whether the injected water could degrade the quality of the native groundwater so that it might be harmful or require an unreasonably higher level of treatment to be suitable for beneficial use.

The new law also prohibits TCEQ from adopting or enforcing groundwater quality protection standards for injected water that are more stringent than applicable federal standards. During rulemaking, TCEQ amended ASR rules to be consistent with current Environmental Protection Agency (EPA) requirements. Under the new TCEQ rules, which became effective May 19, water no longer must meet drinking water standards before it is injected. Instead, the operator must assure that injection will not endanger any drinking water sources.

Under the new TCEQ rules, a drinking water source is considered endangered if injection results in the presence of any contaminant that may result in the system falling out of compliance with any national primary drinking water regulation or if injection adversely affects human health. In general, this standard requires the injected water to be of equal quality or better than the groundwater within the receiving aquifer. However, on a case-by-case basis, TCEQ may consider the extent to which natural processes, such as sand filtration, are sufficient to remove contaminants that might endanger drinking water sources. Water recovered from an ASR project that feeds a public water supply remains subject to drinking water standards.

Some controversy exists around the idea of expanding the use of ASR beyond the storage and recovery of drinking water. Supporters of recent changes say the new rules will reduce the cost of employing ASR for projects using reclaimed wastewater or for purposes that do not require potable water, such as irrigation or power plant cooling. While critics express concerns that water movement could cause nonpotable injected water to migrate off site into a drinking water well, supporters say the new permitting rules will protect water quality by allowing TCEQ to require controls such as monitoring and testing of the injected water as part of the permitting process. In addition, they say, the rules allow TCEQ to consider the quality of the receiving aquifer and the ultimate purpose of the recovered water when determining whether the injected water must first be treated to drinking water standards.

ASR with treated wastewater

ASR traditionally has been used to store drinking water for public water supply. However, ASR using reclaimed and treated wastewater is the fastest-growing new application of this technology. An El Paso facility was one of the first in the nation to inject reclaimed wastewater treated to drinking water quality into an aquifer for storage and recovery (*see next page*). According to TWDB, reclaimed water ASR programs also are operating in Arizona, California, and Florida (*see ASR in Florida, below*).

What is reuse? The terms "reclaimed water," "reused water," and "recycled water" are used interchangeably in the water industry to describe the reuse of treated wastewater. TCEQ's administrative rules describe reclaimed water as "domestic or municipal wastewater that has been treated to a quality suitable for a beneficial use" (30 Texas Administrative Code, §210.3).

ASR in Florida

About a third of all ASR wells nationwide store drinking water in brackish or saline aquifers, according to the Texas Water Development Board. Florida, which has many projects of this type, has adopted a revised underground injection program with five classifications of groundwater aquifers, depending on the water quality within the receiving aquifer. The water quality standards for each classification are based first on whether the water is potable, then on its content of dissolved solids, and finally on whether the receiving formation is a confined or unconfined aquifer.

Under the Florida approach, water injected into an aquifer for ASR storage need not necessarily be treated to drinking water standards. Instead, water may be injected as long as it meets or exceeds the quality of the native water in the receiving aquifer. Some point out that the enactment of HB 655 in Texas (*see page 5*), which under certain circumstances allows for the storage of water that does not meet drinking water standards, could allow the state to consider a similar aquifer classification scheme to store nonpotable water for irrigation and industrial purposes.

Direct reuse involves piping treated wastewater straight from a wastewater treatment facility to a distribution system. Indirect reuse places the treated wastewater back into a water supply source, such as a lake, river, or aquifer, for later use. Both direct and indirect reuse can be used to produce drinking water and non-potable water for various purposes.

As presented in the 2017 state water plan, reuse is expected to provide about 14 percent of the new water needed to meet statewide demands in 2070, which translates to 1.2 million acre-feet per year. One of the challenges for effectively reusing water, however, is that wastewater discharge is fairly constant throughout the year, while demand for water peaks during the summer. ASR offers the possibility of storing large volumes of treated wastewater throughout the year to address water shortages during peak times.

El Paso Water Utilities project. El Paso's facility is a hybrid ASR/aquifer recharge project that since 1985 has used treated wastewater from the city's water reclamation plant to recharge the Hueco Bolson Aquifer, which provides more than 55 percent of the city's drinking water. In this system, the injection and recovery are not accomplished using the same well, as in a traditional ASR project (*see Figure, page 2*, depicting a traditional project). Instead, wastewater that has been treated to drinking water standards is added to the aquifer using injection wells, as well as recharge basins that allow the water to percolate from the surface into the aquifer. Once there, it takes about five years for the treated wastewater to travel to downgradient production wells for recovery. These production wells recover a mix of treated wastewater and natural groundwater.

Water quality. A major issue in the use of reclaimed wastewater in an ASR project is the level of treatment required before injection and storage to protect the native groundwater. The enactment in 2015 of HB 655 allows TCEQ to determine on a case-by-case basis that the action of natural processes on the injected water would be sufficient to remove contaminants that might endanger the native water.

For example, even after initial treatment, wastewater may contain pathogens or other constituents that adversely affect water quality. In some cases, these constituents can be removed through further treatment before injection, such as by sand filtration. In an aquifer in which sand filtration occurs naturally, further treatment of the water might not be required. Under such circumstances, TCEQ could include permit requirements, such as groundwater monitoring, to ensure the natural processes were effective in removing contaminants from the injected water.

— by Blaire D. Parker