30 Years of Aquifer Science

BSEACD Fact Sheet 0817

Barton Springs Edwards Aquifer CONSERVATION DISTRICT

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Introduction

The Barton Springs/Edwards Aquifer Conservation District (District) was established in 1987 with a strong foundation in science, and has continued that emphasis on science for the past 30 years. In 1987, scientific knowledge about the Edwards Aquifer was used as the basis for the need for a groundwater district and to delineate the boundaries of the District (Slade et al., 1985; Slagle et al., 1986). To achieve the statutory mandate of aquifer protection, the District establishes policies from which regulations are promulgated. The District's Board of Directors, which is responsible for setting these policies, has relied on the scientific staff of the District to advise them about aquifer science so that appropriate and defensible policies can be established.

Over a period of more than 120 years, numerous studies have been made about the geology and hydrogeology of central Texas. Some of the studies that helped lay a foundation of scientific knowledge can be traced back to the late 1800s when R. T. Hill and others (1902) studied the geology of central Texas and produced a geologic map of the Austin area. Since then, many organizations such as the U. S. Geological Survey (USGS), Texas Water Development Board (TWDB), Edwards Aquifer Authority (EAA), University of Texas at Austin (UT), Bureau of Economic Geology (BEG), Texas State University (TSU), University of Texas at San Antonio (UTSA), and the City of Austin (COA) have conducted studies of the Edwards Aquifer and other aquifers in central Texas. Some of these studies have focused on the Barton Springs segment of the Edwards Aquifer (Barton Springs aquifer), and other have focused on the southern, or San Antonio, segment.

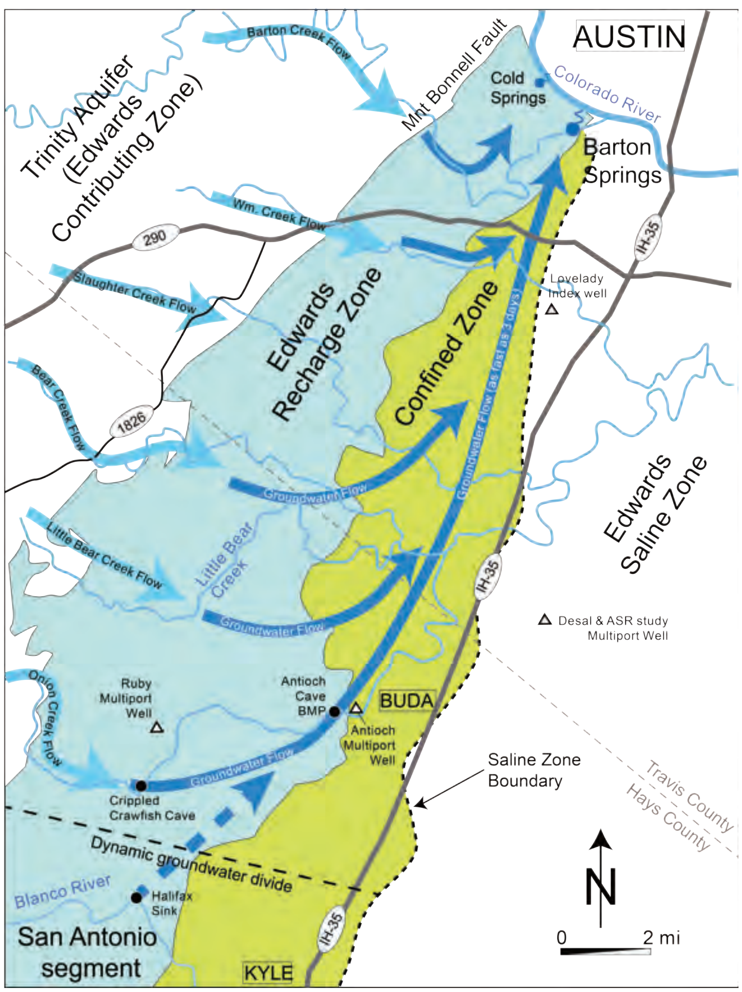


Figure 1. Conceptual flow diagram of the Barton Springs segment of the Edwards Aquifer with locaitons of select study sites indicated.

As demand for water in the region has increased in recent years, the number of studies of the underlying Trinity Aquifers, saline Edwards, and aquifer storage and recovery (ASR) has increased.

Policies for Aquifer Management

Since the District's authority is mainly in permitting groundwater production, the District has been concerned about how much groundwater can be produced without causing undesired effects such as significantly diminished springflow and water levels in wells, and degradation of water quality. Therefore, the District has conducted studies to address these concerns. Some studies that have been conducted over the past 30 years to address specific policy issues are:

- Sustainble Yield: Determining the impact of pumping from the Edwards Aquifer and how it would affect springflow, water levels in wells, and water quality. The main tools for these studies are numerical groundwater models, which brought about the District's sustainable yield policy that set pumping limits for the Edwards Aquifer.

- Drought Triggers: To minimize impacts to wells and springs during drought, studies were conducted to determine which rates of springflow and water levels correspond to drought conditions. Based on these studies, drought triggers were established and reductions in pumping were set for different stages of drought.

- Recharge Enhancement: Recognizing the importance of high rates of recharge to the aquifer, studies have been made to evaluate how more water could be recharged and how that could improve springflow, water levels, and water quality.

- Edwards-Trinity Aquifer Connection: Studies have been conducted to determine if pumping from the Trinity Aquifers could induce flow from the Edwards Aquifer. Data collected from multiport monitor wells have indicated that there is no significant vertical connection between these aquifers and can be managed independently.

- Additional Water Supplies: Significant increases in demand for Trinity groundwater have indicated a need to better understand the Trinity Aquifers and how increased pumping could impact water levels in supply wells and springflow inside and outside the District. Studies were conducted to determine the feasibility of alternative water supplies such as desalinization and aquifer storage and recovery (ASR) in both the Edwards and Trinity units.

Aquifer and District Boundaries

The original political boundaries of the District generally reflect the Barton Springs aquifer boundaries as it was known in 1987. The western boundary of the District was set roughly following the contact between the Edwards units to the east with the Trinity units to the west. The Mount Bonnell Fault also approximates this boundary. Years of geologic mapping by various geologists have determined these contacts. The eastern boundary had been proposed to follow the loosely delineated boundary between the fresh and saline portions of the Edwards Aquifer. However, because of water providers situated largely east of the interface, but using fresh Edwards water, the boundary was extended eastward to include their territories.

A groundwater divide along the southern boundary was first studied when the Edwards Underground Water District was formed in 1959. The USGS conducted extensive studies of the Barton Spring segment of the Edwards aquifer in the early 1980s (Slade et al., 1985 and 1986). In July and August 1985, a study was done to determine the location of this groundwater divide and how it might change under different hydrologic conditions. This study indicated that while the groundwater divide did move over time, it was generally situated near Highway 150 west of Kyle. Therefore, the boundary was set along the east-west section of Highway 150 within the unconfined portion of the aquifer, and then a line was drawn from that point on Highway 150 southeast to the freshwater/saline water interface over the confined portion of the aquifer (Figures 1 and 2). Recent studies by the District, EAA, and others (Smith et al., 2012) indicate that the southern groundwater divide moves south under drought conditions to the Blanco River, which provides water to both San Marcos and Barton Springs.

In 2016 the Texas Legislature passed HB 3405 which extended the District boundaries to cover the unregulated Trinity Aquifer in Hays County (Figure 2).

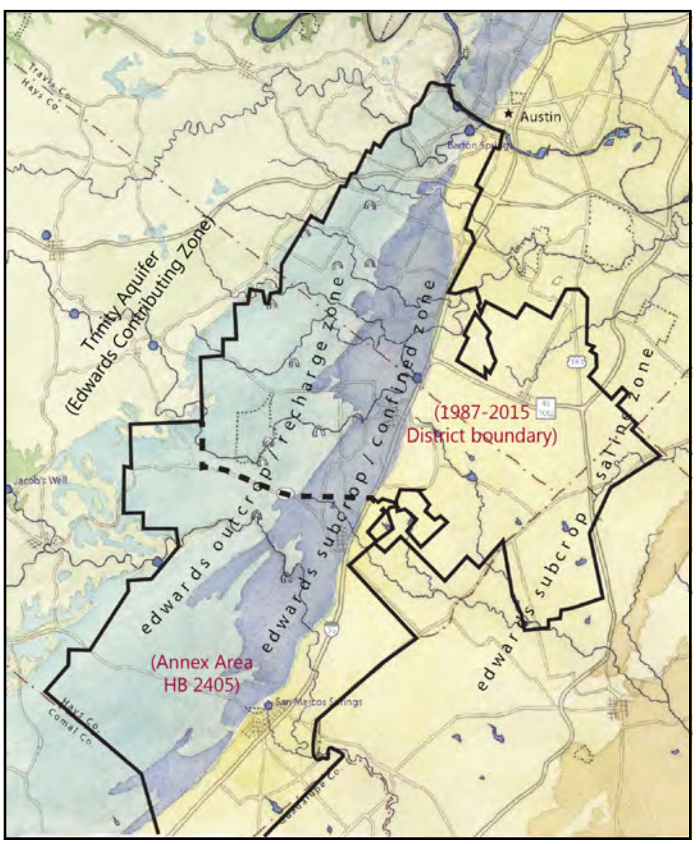


Figure 2. Map of central Texas water resources and District boundaries. Basemap by Molly O'Halloran.

Figure 3. District staff sample a water well.

Water-Quality Studies

The Edwards Aquifer continues to be a clean water resource. However, due to its karstic nature it is highly susceptible to contamination. Accordingly, many agencies monitor and study the aquifer. In the early 1990s, the TWDB funded a study of water quality of 37 Edwards wells and springs. One round of sampling was conducted during low flow conditions in 1990, and another was during high flow conditions in 1993. The report (Hauwert and Vickers, 1994) states that high levels of arsenic, bacteria, aluminum, and petroleum hydrocarbons were detected in some of these wells and springs.

In 1997, the District received a grant from Environmental Protection Agency (EPA) and Texas Commission on Environmental Quality (TCEQ) to evaluate water quality in wells and springs in the District. Results of the study (BSEACD, 2001) indicated that water quality in the wells that were sampled were all within federal and state standards for drinking water, except for one well located in a highly urbanized area. Bacteria levels were at times elevated above drinking water standards in Barton and Cold Springs.

District staff routinely sample groundwater for general chemistry on behalf of the TWDB, and has sampled over 800 sites since 2000 (Figure 3). The data are available online at the TWDB groundwater database. In addition the District annually monitors Barton Springs and select wells for hydrocarbon contamination.

Water-Level Studies

Groundwater levels are one of most fundamental data sets collected about an aquifer. The District maintains about 35 monitor wells in the Edwards and Trinity Aquifers with continuous data recorders. The Lovelady monitor well is a drought index well and has data available online at the USGS website (https://waterdata.usgs.gov). Hydrographs of Lovelady and Barton Springs are shown in Figure 4.

The District also periodically maps the elevation of water levels in the Edwards and Trinity Aquifers by measuring hundreds of wells over a short period of time. Those maps are called potentiometric maps and help characterize the quantity of water and direction of flow in an aquifer (Hunt and Gary, 2014).

Drought Trigger Studies

A "Regional Water Plan", published in 1990 (BSEACD, 1990), included a drought contingency plan that spelled out three stages of drought: Alert, Alarm, and Critical. These stages were based on water levels in five monitor wells, one of which is near Barton Springs and closely approximates the amount of flow from the springs. Statistical analysis of water-level data from these wells, plus a long period of record of Barton Springs flow, was used to set each trigger level. The reasons for setting drought trigger levels are so that pumpage from the aquifer can be reduced during drought to protect water quality and to protect the amount of water in wells and springs. Reductions in permitted pumping of 10%, 20%, and 30% were required for each stage of drought. One of the stated intents of the study was to assure that flows at Barton Springs do not fall appreciably below historic low levels. A further evaluation of drought stages was conducted by the District in 2000 with minor revisions to the previous policy.

To better manage the Edwards Aquifer under new permitting rules promulgated in 2005 for sustainable yield, the District reevaluated the existing drought trigger methodology. It was determined that the Lovelady monitor well, which is in the transition zone between fresh and saline Edwards groundwater, is more representative of drought and non-drought conditions than Barton Springs and other monitor wells. A drought trigger policy and subsequent regulations were promulgated in 2006 in which drought declarations were triggered by rates of flow from Barton Springs and water levels in the Lovelady well. This policy established four stages of drought: Alarm, Critical, Exceptional, and Emergency Response Period, each with prescribed reduction in pumping by the District's permittees (Figure 4). Under the most extreme drought scenario, permitted pumping could be reduced by as much as 50% (Smith et al., 2008; Smith et al., 2013).

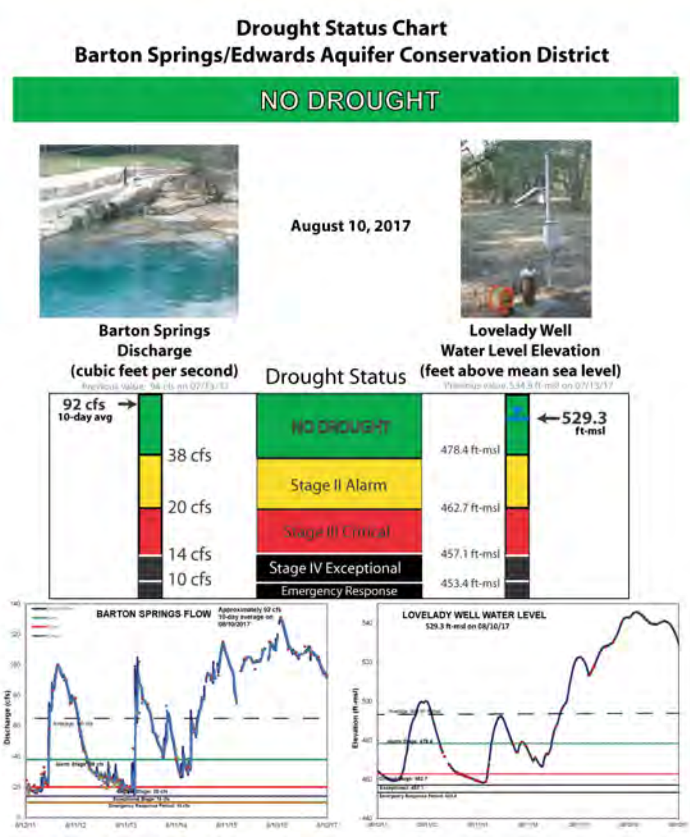


Figure 4. Drought status chart showing indices and thresholds for drought declarations made by the Board of Directors of the District.

Recharge Enhancement Studies

An undestanding of recharge is critical to the managment of aquifers. Numerous studies of recharge to the Edwards Aquifer have been conducted (Slade et al., 2016; BSEACD, 2001). Recent studies have focused on recharge to the Trinity Aquifers along the Blanco River (Smith et al., 2015) and upper Onion Creek (Hunt et al., 2016).

In 1995, a grant from EPA and TCEQ was obtained by the District to address non-point source pollution in Onion Creek. As recommended in the 1990 Regional Water Plan, a Best Management Practice (BMP) structure was designed for the entrance to Antioch Cave that would control the flow of water from Onion Creek into the cave. Construction of the BMP was done from August to December 1997. A concrete vault with dimensions of 10 ft wide, by 14 ft long, and 8 ft high was constructed over the cave entrance, which was situated near the middle of the creek. A 3-ft diameter butterfly valve was installed in one side of the vault. The concept was that prior to a significant storm, District staff would close the valve so that stormwater carrying significant amounts of storm-related pollution could be prevented from entering the vault and therefore prevented from entering the Edwards Aquifer. A few days later the valve would be opened to allow the better quality, post-storm water to enter the cave. In addition to preventing pollution from entering the cave, the vault would prevent buildup of sediment and other debris that could clog the cave. If the cave were to be clogged for any extended amount of time, the reduction in recharge to the aquifer could be significant (Fieseler, 1998).

In 2007 another grant was awarded to the District by EPA and the TCEQ. The goal was to complete the recommendations of the previous study by installing a second valve on the vault at Antioch and to automate the system (Figure 5). Analyses of water samples that were collected during five storm events provided levels of total suspended solids, nitrate nitrogen, and phosphorous over the period of each storm event. Combined with estimates of the amount of stormwater that was prevented from entering the cave, calculations were made of how much of each of these three contaminants was prevented from entering the cave, and subsequently the aquifer. A report published in 2011 estimated that 190,480 pounds of sediment related to storm events were prevented from entering the aquifer (Smith et al., 2010 and 2011). That is equivalent to 98 tons of sediment, or about 8 truckloads of sediment. In addition, 2,436 pounds of nitrate nitrogen and 295 pounds of phosphorous were prevented from entering the aquifer.

Figure 5. Antioch Cave recharge enhancement structure. Photo taken September 2010.

Trinity Aquifer Studies

As the District placed restrictions on pumping from the Edwards Aquifer, staff recognized that current and potential future permittees would be looking for other sources of water. One obvious source of groundwater would be the Trinity Aquifers. Some studies had suggested that there were some connections between the Edwards and Trinity Aquifers within and near the District. To address this and other questions about the Trinity Aquifers, staff established three sets of well pairs that consisted of one Edwards well adjacent to a Middle Trinity well. Results of water-quality sampling and water-level measurements over time showed that there was a difference in both water quality and water levels between the Edwards and Middle Trinity Aquifers. However, the results still indicated that there was a potential for flow between these aquifers.

To address the Edwards-Trinity connections, two multiport monitor wells were installed- one at Ruby Ranch and one near Antioch Cave on Onion Creek (Figure 6). This type of well is designed to isolate numerous hydrogeologic units in a single well from which unique groundwater samples can be collected, water pressures can be measured, and hydraulic conductivity tests can be made. Results of sampling and testing of these two wells gave more detailed evidence that there was significant hydraulic separation between the Middle Trinity Aquifer and the Edwards (Smith and Hunt, 2010; Wong et al., 2014). Based on these studies, the District set policies that would manage the aquifers as separate entities and that drought curtailments for Trinity permittees would not be as strict as those for Edwards permittees.

The Trinity Aquifers within and near the District have not been studied as extensively as the Edwards Aquifer and data sets are not available going back many years. But recent studies (Wierman et al., 2010) have focused on the Trinity Aquifers of the Hill Country. With high rates of growth in the Hill Country, where the primary sources of water are the Trinity Aquifers, demand for groundwater from the Trinity Aquifers is increasing rapidly. There is potential for existing wells to go dry and for springs to have diminished flow due to pumping large amounts of water from newly permitted wells, but there were only limited data to conduct such evaluations until recently. The District is currently conducting a study to determine the potential for unreasonable impacts to wells, springs, and other water resources in the Trinity Aquifers. In February and March 2017, the District installed two multiport wells in areas with the highest demand for Trinity water. One of these wells was installed in central Hays County and the other was installed in southwest Travis County (Figure 7). Testing is currently being done in each well and the results will be used to help evaluate the impacts of pumping. The District is currently writing procedures for how to determine the potential for unreasonable impacts, similar in some ways to aquifer testing that has been a required part of the permitting process for Edwards wells since the District was formed in 1987.


Figure 7. C&C Groundwater drilling a borehole for a multiport monitor well in Travis County. February, 2017.

Desalination and ASR Studies

In 2016, with the award of a Regional Facility Planning grant from TWDB, the District installed a multiport monitor well in the saline Edwards. A team of engineers, scientists, and financial specialists was assembled by Carollo Engineers, Inc. to do a feasibility study of desalination and ASR in the saline Edwards and ASR in the freshwater Trinity Aquifer (Figure 8). Results from the multiport well are being incorporated into the grant report at the time of publication of this report- 30 Years of Aquifer Science (August 2017). Sampling of all zones in the saline Edwards units shows very high amounts of total dissolved solids (TDS), with values between 13,000 and 18,000 milligrams per liter of sample (mg/L). The main constituents of the saline water are sodium and chloride with high amount of sulfur. Costs for various scenarios of desalination and ASR will be included in the feasibility report for the project.

A test of ASR in the freshwater Middle Trinity Aquifer was conducted in the spring and summer of 2017. District staff worked with the Ruby Ranch Water Supply Corporation and the Ruby Ranch Homeowners Association. In March 2017, TCEQ issued a permit for the ASR testing. The ASR test involved two phases of injection of water from an Edwards supply well that is adjacent to a Middle Trinity well, both operated by the Ruby Ranch Water Supply Corporation. Water-quality sampling was conducted throughout in periods of injection and extraction. Laboratory analyses showed that arsenic levels went from below the detection level to about 2 micrograms per liter (ug/L), still well within the drinking water standard of 10 ug/L. The two phases of testing showed that the Middle Trinity Aquifer can receive and store water, and that based on the two phases of injection and extraction, water quality has stayed well within the range of drinking water standards.

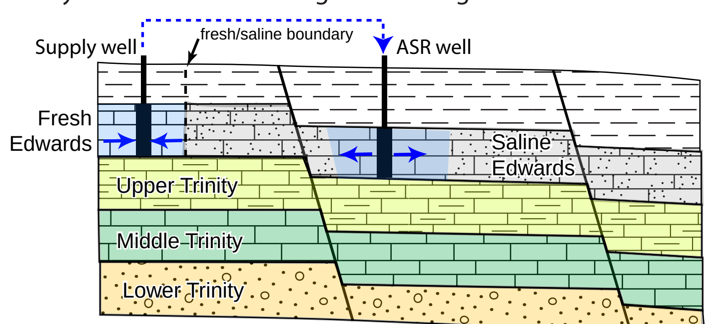
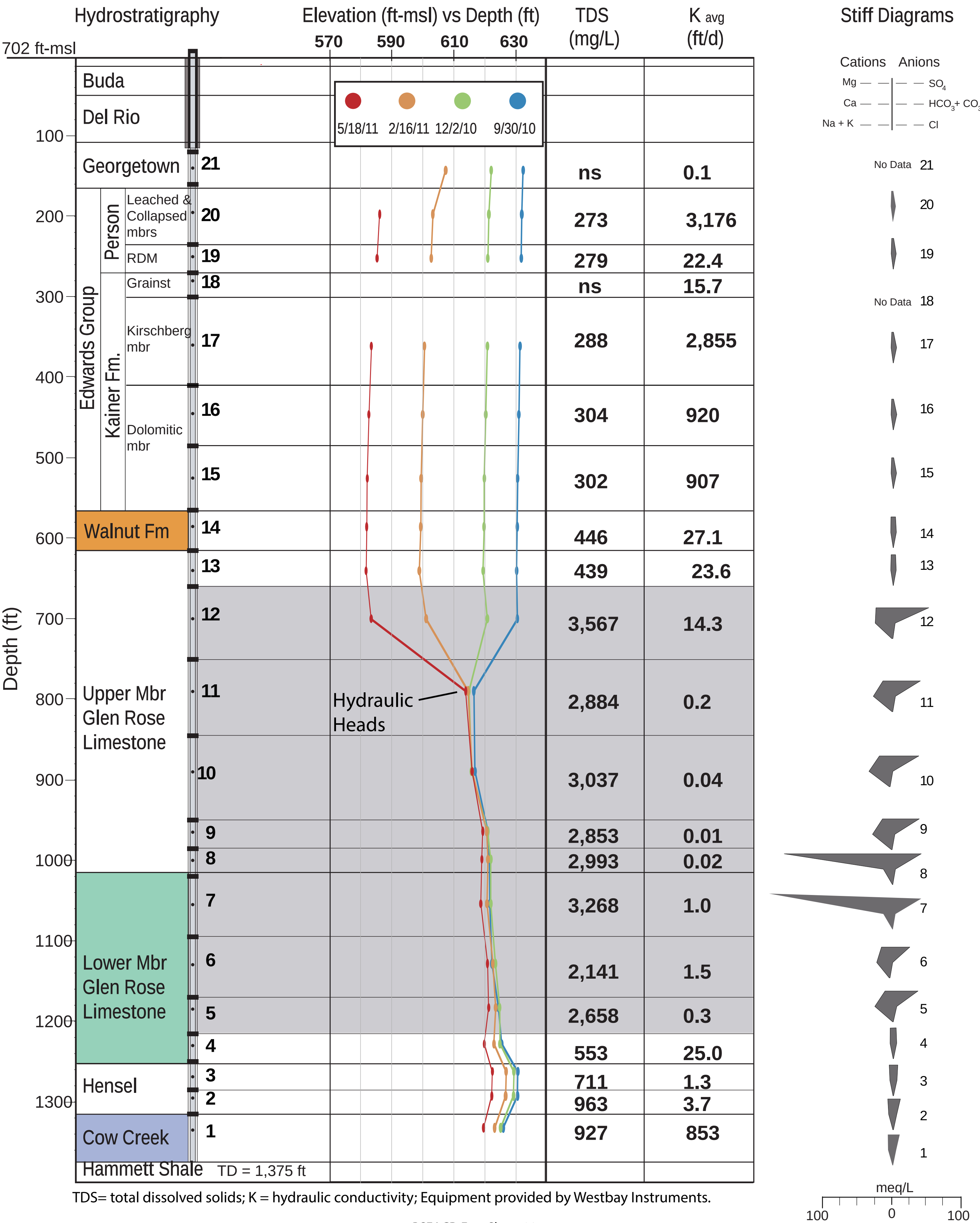


Figure 8. Schematic ASR diagram.

Figure 6. Antioch Multiport Well



TDS= total dissolved solids; K = hydraulic conductivity; Equipment provided by Westbay Instruments.

Modeling & Sustainable Yield

Numerical groundwater modeling of the Barton Springs aquifer has been conducted since the early 1980s with a publication by USGS staff in 1985 (Slade et al., 1985). This model was based on the widely used MODFLOW computer code. Other models were run by Wanakule of Texas State University in 1989, and in 1996, Barrett and Charbeneau ran a lumped parameter model. In 2000, the Bureau of Economic Geology (BEG) and TWDB ran a MODFLOW model using similar parameters to the Slade et al. (1985) model, but with more recent data. All of these models indicated the potential for flow from Barton Springs to diminish significantly, or to cease flowing altogether under severe drought conditions and high rates of pumping. In 2001, the District, BEG, Lower Colorado River Authority (LCRA), and TWDB updated the 2000 model to meet groundwater availability model (GAM) standards set by TWDB (Scanlon et al., 2001). The results again indicated that Barton Springs could cease flowing under drought-of-record conditions with high rates of pumping (Figure 9). There was also a significant potential for a number of wells to go dry. Under a pumping increase of 50%, the model estimated that not only would Barton Springs stop flowing, but the general direction of groundwater flow would be to the major pumping centers in the southeast rather than north to the springs.

The 2001 GAM model was calibrated to conditions from 1989 to 1998 during which time there were periods of drought and high-flow aquifer conditions. However, more severe drought conditions, such as the drought of record of the 1950s, were not adequately simulated with this model. District staff revised the model using data from the drought of record, and in 2004 published a report titled "Sustainable Yield Evaluation of the Barton Springs Segment of the Edwards Aquifer, Travis and Hays Counties, Central Texas". This study indicated that under drought-of-record conditions and with doubling of the amount of water being pumped from the aquifer, about 20% of the wells in the District would go dry and Barton Springs would cease flowing (Smith and Hunt, 2004).

The results of the "sustainable yield model" and other evaluations of aquifer data led to the development of a conditional permitting process for the District. This policy stated that no more permits would be issued for Edwards groundwater other than permits that would allow for pumping during non-drought periods. This meant that no more "historical" permits would be issued, but conditional permits would be issued if the permittees agreed to all the permit conditions. This effectively set a maximum historic pumpage of 0.5 cubic feet per second (cfs; 7,600 acre-ft/year). According to the sustainable yield model and springflow data from the drought-of-record, this amount of pumping would allow for a minimum springflow of 6.5 cfs (4,705 acre-ft/yr).

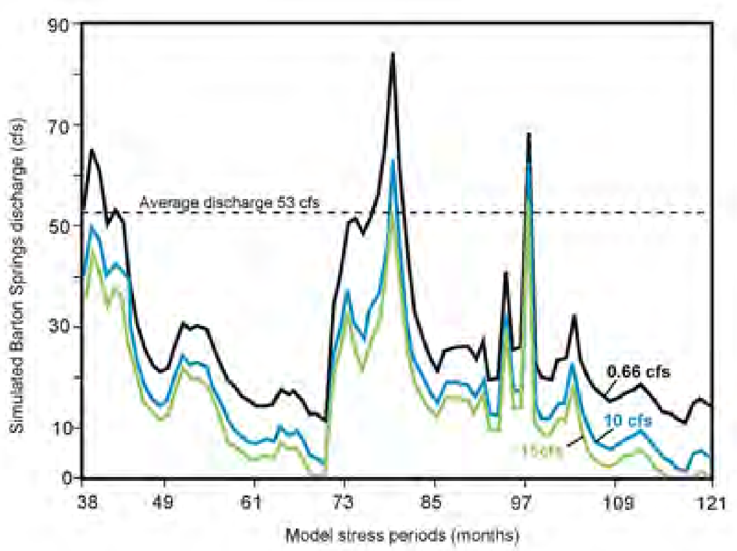


Figure 9. Hydrograph of simulated springflow at Barton Springs under 1950s drought conditions and pumping rates of 0.66, 10, and 15 cfs.

Figure 10. Photo of the endangered Barton Springs Salamander. Photo by Jean Krejca of Zara Environmental LLC.

As a member of Groundwater Management Area 10, the District expressed a minimum springflow of 6.5 cfs as its Desired Future Conditions (DFC) for the Barton Springs aquifer under drought of record conditions. In order to maintain that springflow the Modeled Available Groundwater (MAG) computed by the TWDB is 5.2 cfs (3,765 acre-ft/yr) of pumping.

Habitat Conservation Plan

As early as 2003, the District had considered applying for an incidental take permit (ITP) through the U. S. Fish and Wildlife agency (USFW) to provide further protection to the two species of endangered salamanders at Barton Springs and to decrease liability to the District and its permittees from any harm that might come to the salamanders (Figure 10). In 2006, USFW awarded a grant to the District to begin preparing a habitat conservation plan (HCP). Consultants were hired to help prepare the various documents that are needed for an ITP. A biological study was done to better quantify the sensitivity of the salamanders to levels of dissolved oxygen in the springs. A study to determine the amount of dissolved oxygen in wells, in groundwater discharging at Barton Springs, and in the Barton Springs pool was also conducted. As of July 2017, USFW announced a public review period for the environmental impact statement. This, plus a response to the public comments, are the last steps in the process before being awarded and ITP.

Dye Trace Studies

Figure 12. Dye trace of a sinkhole in the Arbor Trails shopping center stormwater pond. Dye was traced to wells on its path to Barton Springs in less than 4 days.

Starting in 1996, District staff have conducted numerous dye trace studies with the City of Austin to understand flow paths within the Edwards Aquifer between the recharge zone and Barton Springs (Hauwert et al., 2004). To do these studies, an inorganic dye is injected into a recharge feature such as a cave or sinkhole. Unless water is naturally flowing into the feature, water is piped into the sinkhole to help flush the dye into the aquifer. Figure 11 is a schematic diagram showing how water travels from recharge features to the springs. Downgradient of the feature, water samples are collected from wells and springs to determine if the dye has reached that location, and if so, how much dye is in the water and what time the dye reached that location. In most cases, the dye will not be visible in the samples, but laboratory instruments can detect extremely minute traces of the dye. Rates of groundwater flow, as determined by these traces, vary from 0.6 miles per day to about 1 mile per day under low flow, or drought conditions. Under moderate to high flow conditions, flow rates were estimated to vary from 1 mile per day to about 7 miles per day. These studies help provide an understanding of the dynamics of the aquifer system along with a better understanding of the sensitivity of the aquifer to contamination. The ease of entry of water and contaminants into the aquifer, and the speed at which groundwater travels, indicates how sensitive wells and springs are to such threats. If a chemical spill should occur over the recharge zone and enter the aquifer, the results of the dye trace studies will help determine the path that the chemicals might take and the time it might take for the chemicals to reach downgradient wells and springs.

Dye trace studies that started in 1996, with joint projects between the District and COA, have continued with various objectives in mind. One trace was conducted in 2002 in which dye was injected into Crippled Crawfish Cave on COA watershed protection lands. This cave is located within the bed of Onion Creek and is about 18 miles straight-line distance from Barton Springs. Dye injected into this cave reached Barton Springs in about 2.5 days. This gives a flow rate of about 38,000 ft per day, or about 7.2 miles per day. Dye from this trace was also detected in San Marcos Springs, although the amount of dye detected at the springs was small and the time of travel was estimated to have been about 3 weeks. To further evaluate direction of groundwater flow in the vicinity of the Blanco River and Onion Creek, the District teamed with COA and EAA in 2008 and 2009 to inject dye into two recharge features in the bed of the Blanco River and into an upland sinkhole one mile north of the Blanco River. Dye injected into the upland sinkhole was detected in Barton Springs, but not at San Marcos Springs. Dyes injected into the two recharge features in the Blanco River were detected at both Barton and San Marcos Springs (Smith et al., 2012). These dye trace studies show the complexity of groundwater flow in an area that is considered a groundwater divide under certain circumstances.

Another groundwater dye trace was conducted on February 3, 2012 following the opening of a sinkhole beneath a stormwater retention pond on January 24, 2012 (Figure 12). Dye injected into this sinkhole arrived at Barton Springs in less than 4 days, giving a minimum flow rate of 1.3 miles per day (Hunt et al., 2013). Each of these traces shows the sensitivity of the aquifer and the springs to contaminants entering the aquifer. The fast rates of travel through the aquifer show that wells and springs can be quickly impacted by releases of contaminants, and also that once contaminants get into the aquifer, they can be trapped in less permeable portions of the aquifer for long periods of time (Hunt and Smith, 2014).

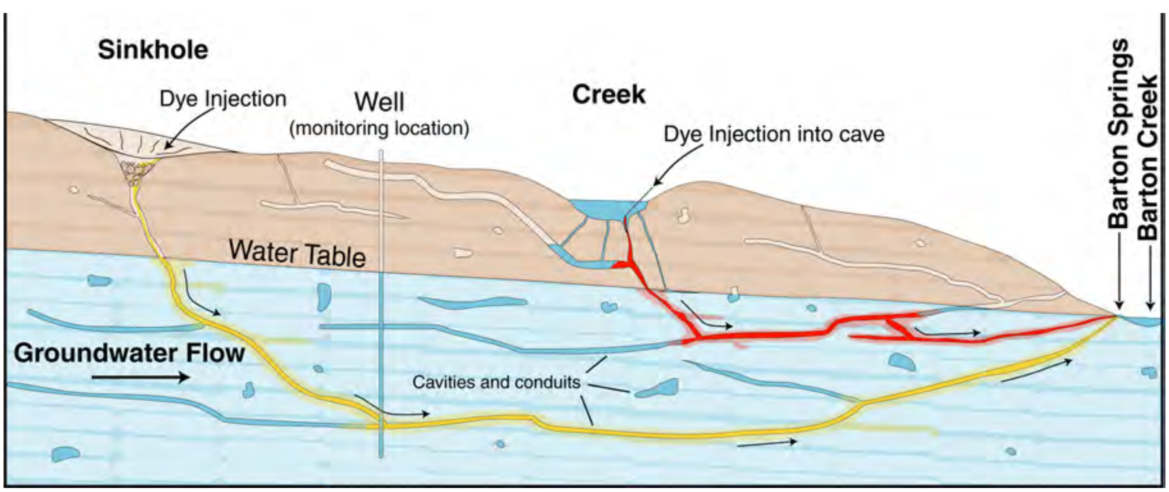


Figure 11. Schematic diagram showing how water (and dye) travels from recharge features to wells and springs.

Future Studies

Many of the methods mentioned in this document will be used in future studies as the District continues to manage the various aquifers within the District boundaries. Dye trace studies will focus more on surface/groundwater interactions in the contributing zone. Surface water in this area both recharges the Trinity Aquifers and contributes surface flow to the Edwards Aquifer recharge zone. A revised numerical groundwater model of the Trinity Aquifers will be initiated by TWDB in the next few years with considerable input of data recently collected by the District. One phase of studies of desalination and ASR will be completed in the fall of 2017, but other such studies will continue. More studies will be conducted in and around Antioch Cave such as additional dye traces and aquifer testing associated with injection of large amounts of water in Onion Creek into the cave. As the District begins implementing the HCP in 2018 or 2019, studies will focus on the Edwards Aquifer in the vicinity of Barton Springs. We are looking forward to another 30 years, and more, of conducting good science to guide aquifer management policy.

Acknowledgments

Over the past 30 years, the District has built upon the work of many scientists going back 120 years. The District's Board of Directors has been very supportive of the scientific studies conducted by the aquifer Science staff since the inception of the District. The District is fortunate to have a public that supports its mission. Staff at the District also create a supportive environment allowing the science to occur. We acknowledge the District's current and former staff, managers, and Directors in their efforts and support. We acknowledge the support of many agencies and individuals. Some enduring scientific partnerships over the past 17 years deserve mention and include: Alex S. Broun (HTGCD), Marcus Gary (UT, EAA), Ron Fieseler (BPGCD), Nico Hauwert (COA), David Johns (COA), Geary Schindel (EAA, Jack Sharp (UT), and Douglas Wierman (TSU-Meadows). Finally, we wish to acknowledge Dr. Kent Butler, a visionary who helped create the District.

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A full report and list of references of "30 Years of Aquifer Science" can be found at: http://bseacd.org/scientific-reports/

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