

Fieldtrip Guidebook

Recharge and Discharge Features of the Edwards and Trinity Aquifers, Central Texas



**Karst Horizons
15th International Congress of
Speleology
Kerrville, Texas USA**

July 22, 2009



**Barton Springs
Edwards Aquifer**
CONSERVATION DISTRICT

Fieldtrip conducted by the
Barton Springs/Edwards Aquifer Conservation District
Austin, Texas



Front Cover (top left, clockwise)

High-angle photo of Barton Springs Pool; Whirlpool formed over Antioch Cave (before BMP); Jacob's Well (photo courtesy of the Wimberley Valley Watershed Association), Glass-bottom boats on Spring Lake, Aquarena Springs.



**Barton Springs
Edwards Aquifer**
CONSERVATION DISTRICT

“Committed to conserving, protecting, recharging, and preventing waste of groundwater and to preserving all the aquifers in the District”

Fieldtrip leaders and guidebook prepared by:

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Barton Springs/Edwards Aquifer Conservation District

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Wimberley Valley Watershed Association

Special thanks to:

Joe Beery for his logistical support at Antioch, Al Broun for use of his geologic figures on the Trinity, Marcus Gary for his poster on Jacob’s Well, Jenna Kromann for figure and guidebook preparation, US Geological Survey for copies of literature, TCEQ and EPA 319h project coordinators, and Kirk Holland and the BSEACD Board of Directors for their support of Aquifer Science.

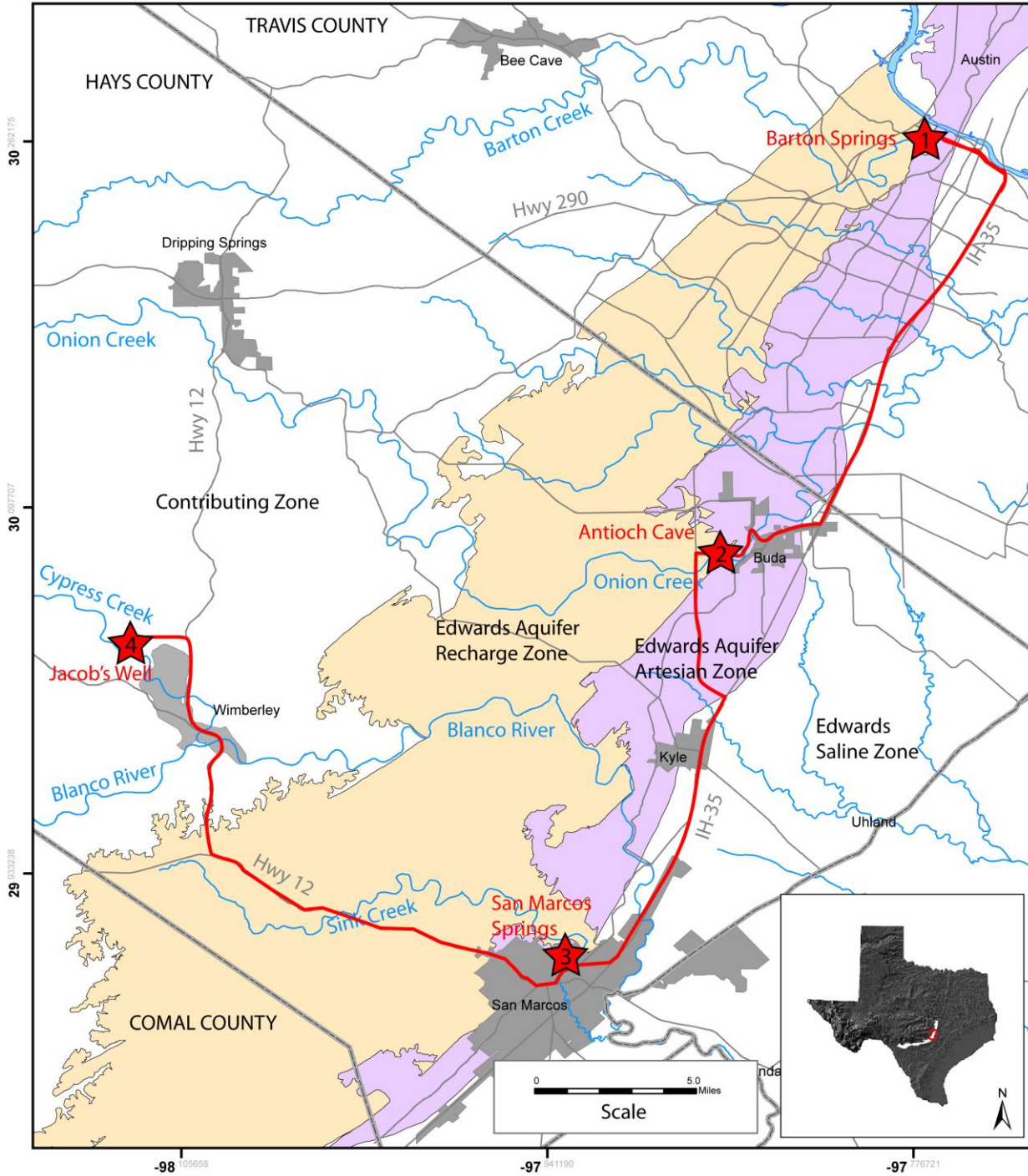
Itinerary

Recharge and Discharge Features of the Edwards and Trinity Aquifers, Central Texas

July 22, 2009

- 8:00 am Depart Kerrville
- 10:00 am **STOP #1: Barton Springs** for brief overview of Barton Springs and the Edwards Aquifer.
- 11:00 am Depart for Buda and Antioch Cave.
- 11:30 am **STOP #2: Antioch Cave** on Onion Creek. View cave entrance and BMP that is used to enhance recharge to the Edwards Aquifer.
- 12:30 pm Depart for San Marcos and Aquarena Springs.
- 1:00 pm **STOP #3: Aquarena Springs.** Tour of Aquarena Springs and ride on glass bottom boats.
*Lunch at River Systems Institute/Aquarena Springs.
- 2:30 pm Depart for Wimberley and Jacob's Well .
- 3:00 pm **STOP #4: Jacob's Well.** Presentation on Jacob's Well with visit to the springs.
- 4:00 pm Depart Kerrville with arrival at about 6:00.

Fieldtrip Map



Regional Setting

The Edwards Aquifer of Central Texas is a karst aquifer developed in faulted and fractured Cretaceous-age limestones and dolomites. The aquifer system lies within the Miocene-age Balcones Fault Zone (BFZ), or Balcones Escarpment, of Central Texas. The aquifer contains hydrologic divides that separate the aquifer into three major segments: San Antonio, Barton Springs, and Northern segments. The entire aquifer system is about 270 miles long covering an area of about 4,350 square miles with about 1,700 square miles of recharge zone and 2,650 square miles of confined, or artesian, zone. The aquifer ranges in width from 2 to almost 40 miles and from 400 to more than 600 feet in thickness.

Discharge from the aquifer occurs at some of the largest springs and water-supply wells in the southwestern United States. The aquifer system is the sole-source of water for 2 million people with pumping totaling about 474,400 acre-ft/yr (155 billion gallons, 655 cfs) (Smith et al., 2005).

The Edwards aquifer is regulated by groundwater conservation districts. The principal management district for the San Antonio segment is the Edwards Aquifer Authority, the Barton Springs segment is managed by the Barton Springs/Edwards Aquifer Conservation District, and a portion of the northern segment is managed by the Clearwater Underground Water Conservation District (Bell County only).

The largest springs in Texas issue from the Edwards Aquifer and include Comal, San Marcos, and Barton Springs. These springs have a mean annual historical flow of 200,900 (277 cfs) and 114,300 (199 cfs), and 38,400 (53 cfs) acre-ft/yr, respectively. Each of these springs provide habitat for federally-listed endangered aquatic species.

Barton Springs Segment of the Edwards Aquifer

The Barton Springs segment of the Edwards Aquifer is bounded to the north by the Colorado River, by a groundwater divide to the south, by the interface between the fresh- and saline-water zones to the east, and by the outcrop and saturated thickness of the Edwards Group to the west. The Barton Springs segment is 155 square miles in area, with about 80% of the area under unconfined conditions, and a maximum thickness of about 450 feet.

The Barton Springs segment provides water for about 60,000 people and currently has about 7,800 acre-ft/yr (2.5 billion gallons; 11 cfs) of authorized pumping from 94 permit holders. Groundwater use is characterized as 80% public-supply, 13% industrial (quarry operations), and 7% irrigation (golf courses). The District contains about 1,230 operational wells, with the majority producing water from the Edwards (Hunt et al., 2006).

The largest natural discharge point of the Barton Springs segment of the Edwards Aquifer is Barton Springs, located in Barton Creek about ¼ mi upstream of its confluence with the Colorado River. Barton Springs consists of four major outlets, the largest discharging directly into Barton Springs pool, a major recreational attraction of the City of Austin. Each of the spring outlets provides habitat for the federally-listed Barton Springs Salamander.

The formation of the aquifer was influenced significantly by fracturing and faulting associated with the Miocene-age BFZ and dissolution of limestone and dolomite units by infiltrating meteoric water (Sharp, 1990; Barker et al., 1994). Faults trend predominantly to the northeast and are downthrown to the southeast, with total offset of about 1,100 ft across the study area (see figures). Dissolution along fractures, faults, and bedding plane partings and within certain lithologic units has created numerous sinkholes, sinking streams, springs, conduits, and caves.

It is estimated that 85% of recharge to the aquifer occurs along its six major (ephemeral) losing streams that cross the recharge zone, and the remaining recharge occurring in the upland areas of the recharge zone (Slade et al., 1986). The amount of cross-formational flow (sub-surface recharge) occurring through adjacent aquifers is unknown, although it is thought to be relatively small on the basis of water-budget analysis for surface recharge and discharge (Slade et al., 1985). Current investigations are underway to estimate the potential for cross-formational flow to the aquifer from the Trinity and the saline zone of the Edwards units.

The Edwards Aquifer is geologically and hydraulically heterogeneous and anisotropic, both of which strongly influence groundwater flow and storage (Slade et al., 1985; Maclay and Small, 1986; Hovorka et al., 1996; Hovorka et al., 1998; Hunt et al., 2005). Karst aquifers such as the Edwards Aquifer are commonly described as triple porosity (and permeability) systems consisting of matrix, fracture, and conduit porosity (Ford and Williams, 1992; Quinlan et al., 1996; Palmer et al., 1999). Hovorka and others (1998) have described the Edwards Aquifer as having permeability ranging over eight orders of magnitude. Most storage of water in the Edwards Aquifer is within the matrix porosity (Hovorka et al., 1998); therefore, volumetrically, flow through the aquifer is dominantly diffuse. However, groundwater dye-tracing studies demonstrate that significant components of groundwater flow occur in a well integrated network of conduits, caves, and smaller dissolution features (BSEACD/COA, 2001; Hauwert et al., 2002). Groundwater generally flows west to east across the recharge zone, converging with preferential groundwater flow paths subparallel to major faulting, and then flowing north toward Barton Springs. Rates of groundwater flow along preferential flow paths, determined from dye tracing, can be as fast as 4 to 7 mi/day under high-flow conditions or about 1 mi/day under low-flow conditions (Hauwert et al., 2002).

Water Quality

Water quality of the Barton Springs segment is very good (BSEACD/COA, 2001). However, the study area is located in one of the most rapidly urbanizing regions of the State; therefore there is an increasing potential for a variety of anthropogenic sources of contamination. Impacts to water quality from anthropogenic sources are currently observed at Barton Springs (City of Austin, 1997; Barbara Mahler, USGS, personal communication).

Aqueous chemistry of ground water discharging from Barton Springs varies with aquifer conditions, with the most substantial decrease in water quality occurring under low-flow conditions. Increases in chloride, sodium, sulfate, and strontium concentrations are reported for low-flow conditions that result from an influx from the Edwards saline-water zone and the underlying Trinity Aquifer (Senger and Kreitler, 1984). Increasing pumping under drought conditions may increase the potential for subsurface recharge from these undesirable groundwater sources. Such degradation of water quality could affect potable water supplies and the habitat for federally-listed endangered species at Barton Springs.

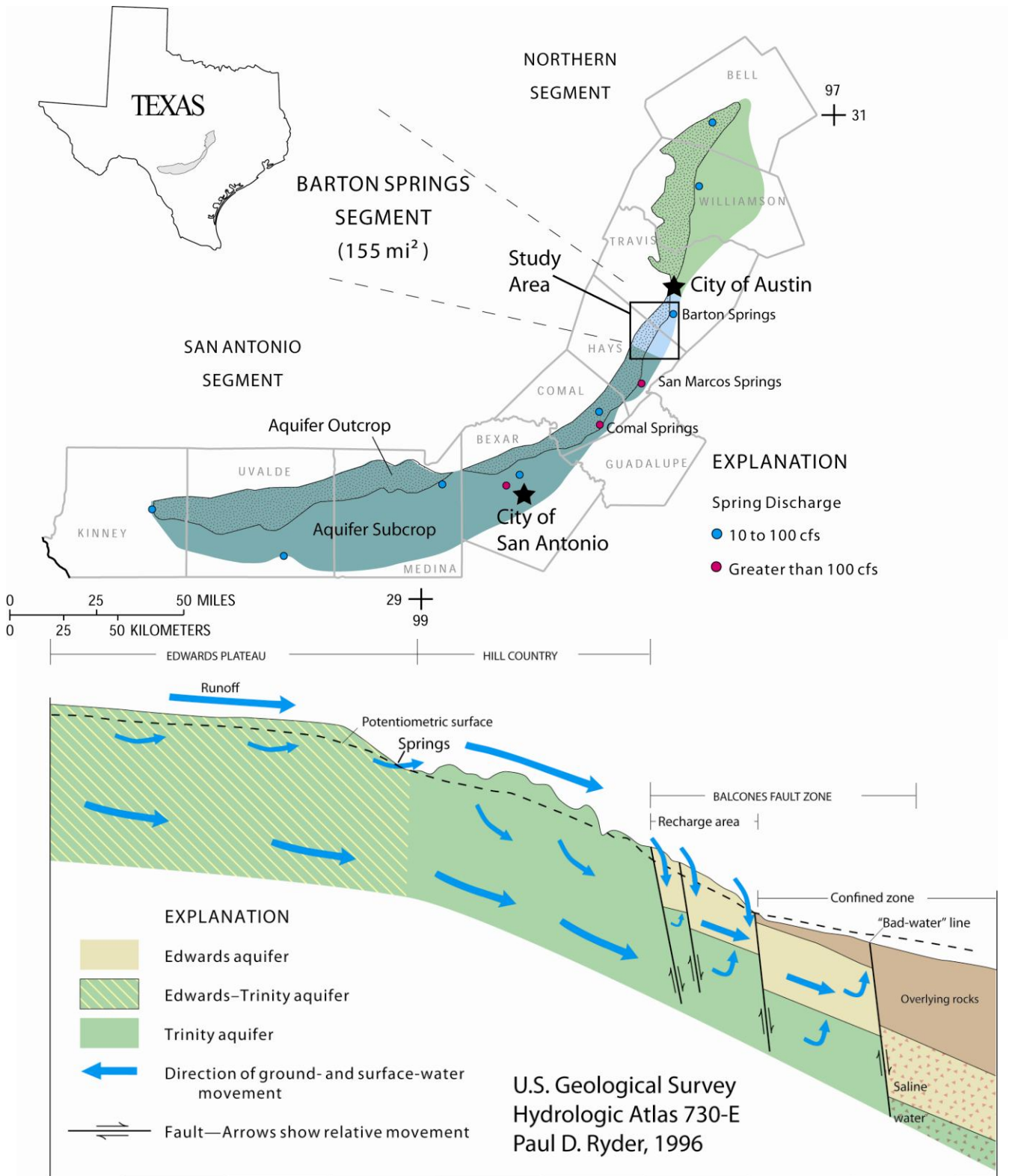
Aquifer Conditions

The climate of the study area is characterized as humid subtropical with an annual rainfall amount of 33.5 inches. Precipitation is fairly evenly distributed throughout the year with peaks occurring in May and September (Brune and Duffin, 1983). However, the region often receives a large portion of its annual rainfall in a very short period of time, resulting in flash flooding and periods of short, but intense recharge events. As a result of the climate, karstic nature, and pumping, the Edwards Aquifer is a very dynamic resource with rapid fluctuations in spring flow, water levels, and storage.

Central Texas' worst drought on record was a 7-year period from 1950 through 1956 (see hydrograph). The lowest total annual rainfall for Austin's Camp Mabry in 1954 was 11.42 inches. During this drought, water levels reached historic low levels and many springs stopped flowing completely, including Comal Springs. The annual mean discharge for Barton Springs was 13 cubic feet per second (cfs) in 1956, with the lowest monthly mean discharge of 11 cfs occurring in July and August of 1956. The lowest measured spring discharge value was 9.6 cfs on March 26, 1956. Long-term average spring-flow values for Barton Springs are about 53 cfs (Scanlon et al., 2001).

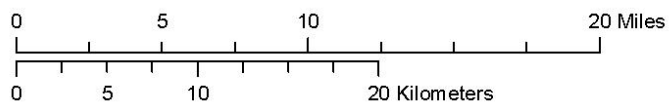
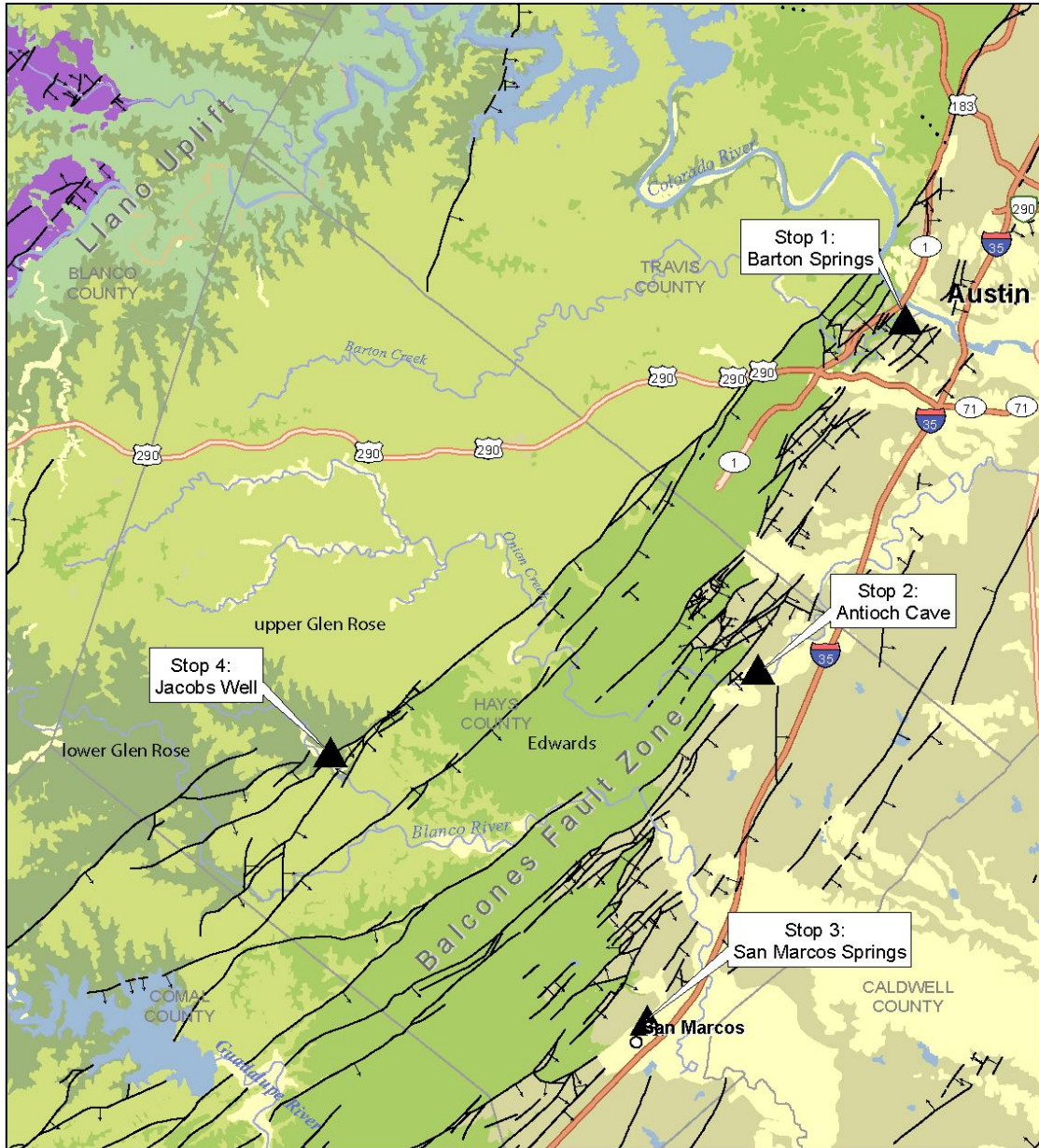


Whirlpool forming above Cripple Crawfish Cave, a major recharge feature of the Edwards Aquifer. Photo by David Johns



Modified from Maclay, R.W., and Small, T.A., 1986, Carbonate geology and hydrology of the Edwards aquifer in the San Antonio area, Texas: Texas Water Development Board Report 296, 90 p.

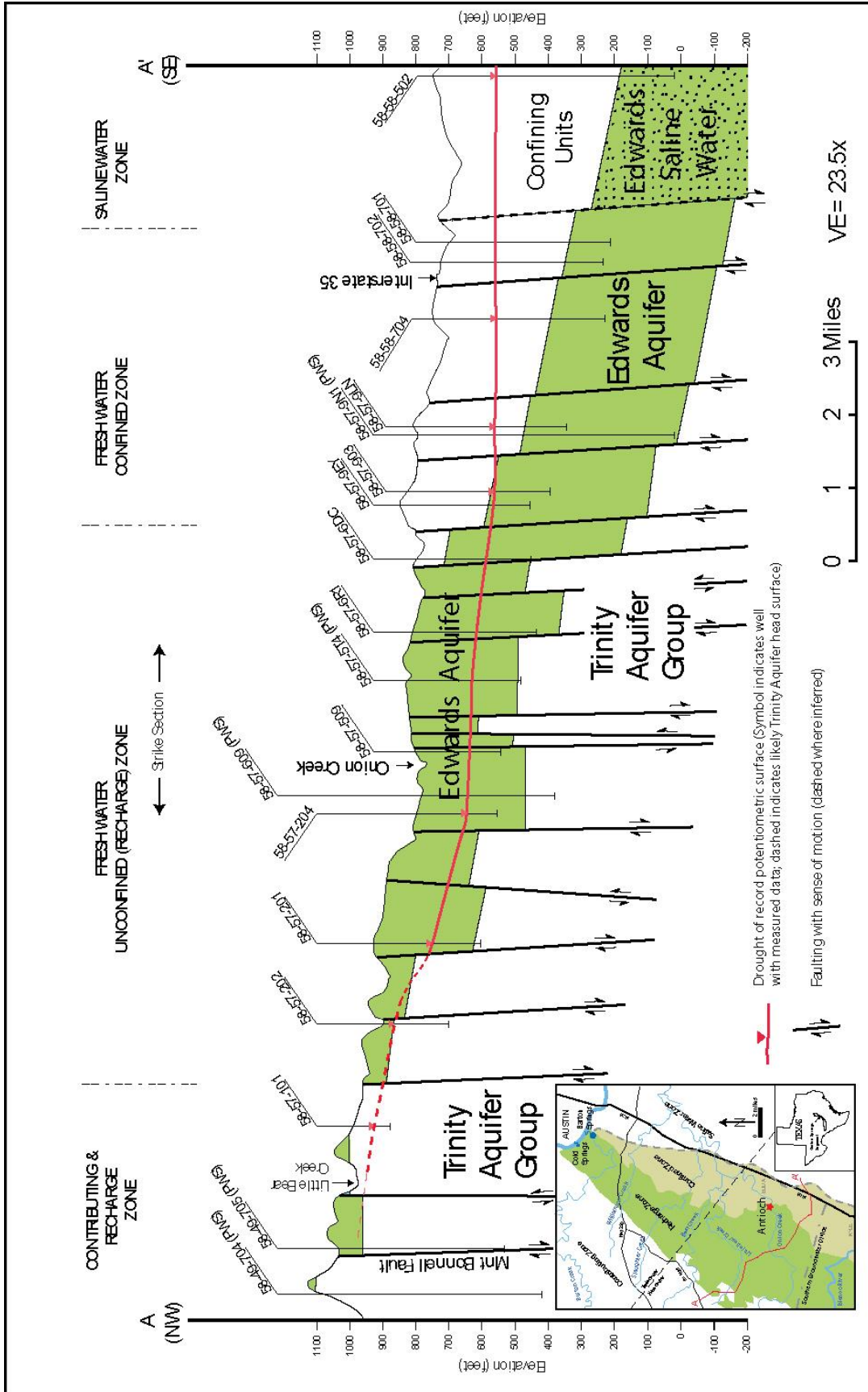
Fieldtrip Geologic Map

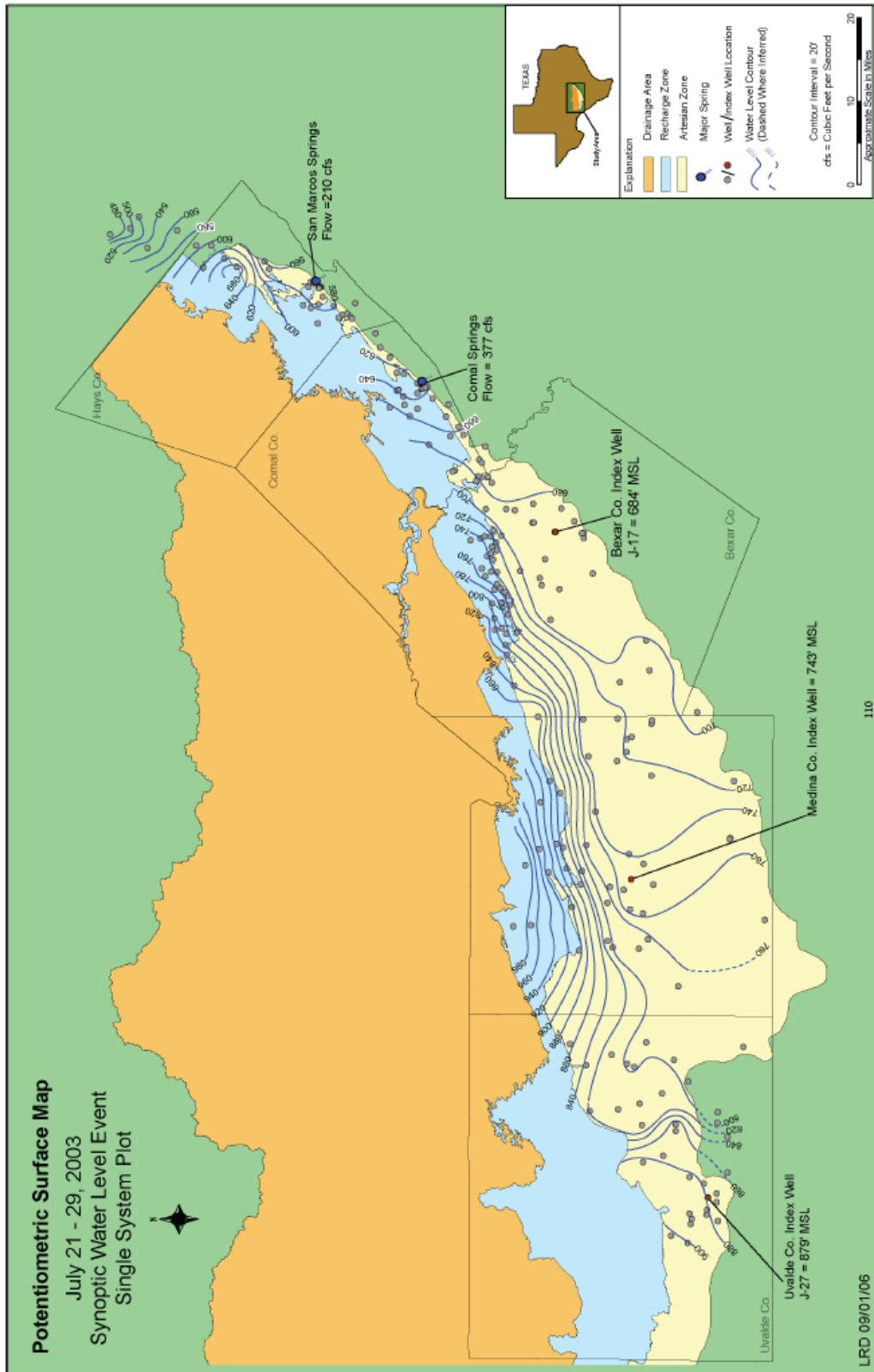


Stratigraphic Column

Era	Period	Provincial Series	Provincial Stage	Stratigraphic unit	Hydrostratigraphy			
Mesozoic	Cretaceous	upper	Gulfian	Navorroan	Navarro Group		Confining Units	
				Tayloran	Taylor Group			
				Austinian	Austin Group			
				Eaglefordian	Eagle Ford			
		lower	Comanchean	Washitan		Buda Limestone		Edwards Aquifer
						Del Rio Clay		
						Georgetown Formation		
				Edwards Group		Person Formation		
					Kainer Formation			
	Fredericksburgian							
	Trinitian			upper Glen Rose		upper		
		lower Glen Rose		middle				
		Pearsall Fm.	Hensel Sand Mbr (Bexar Shale Mbr)		middle			
			Cow Creek Mbr					
			Hammett Shale Mbr (Pine Island Shale Mbr)				confining unit	
Sligo Fm		lower						
Sycamore (Hosston) Fm								
Paleozoic				Undifferentiated Paleozoic Rocks	Paleozoic aquifers			

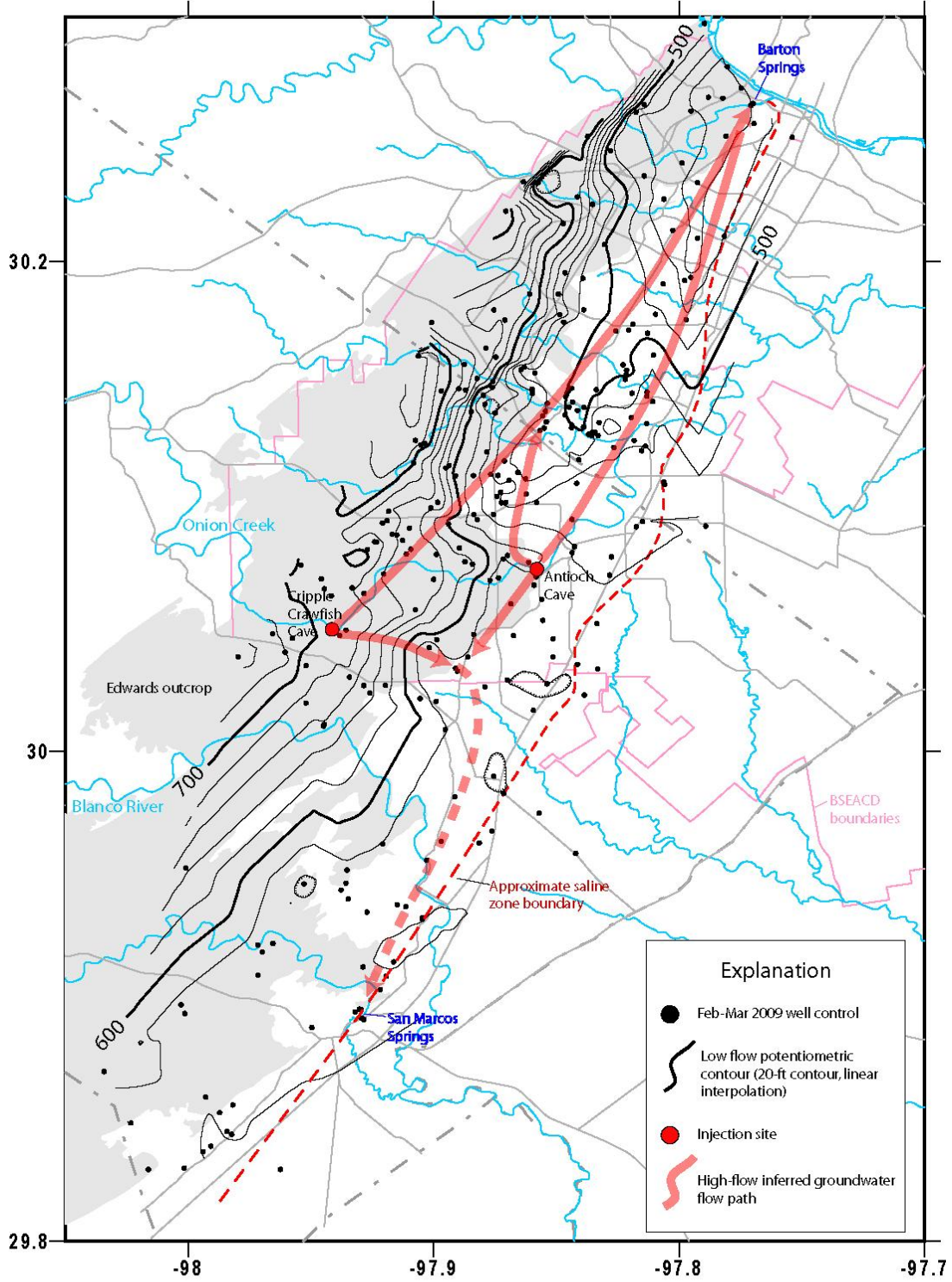
Modified from Barker and Ardis (1996).





Source: Edwards Aquifer Authority Report 06-02

Edwards Aquifer Drought Synoptic Map (March 2009) with dye tracing results

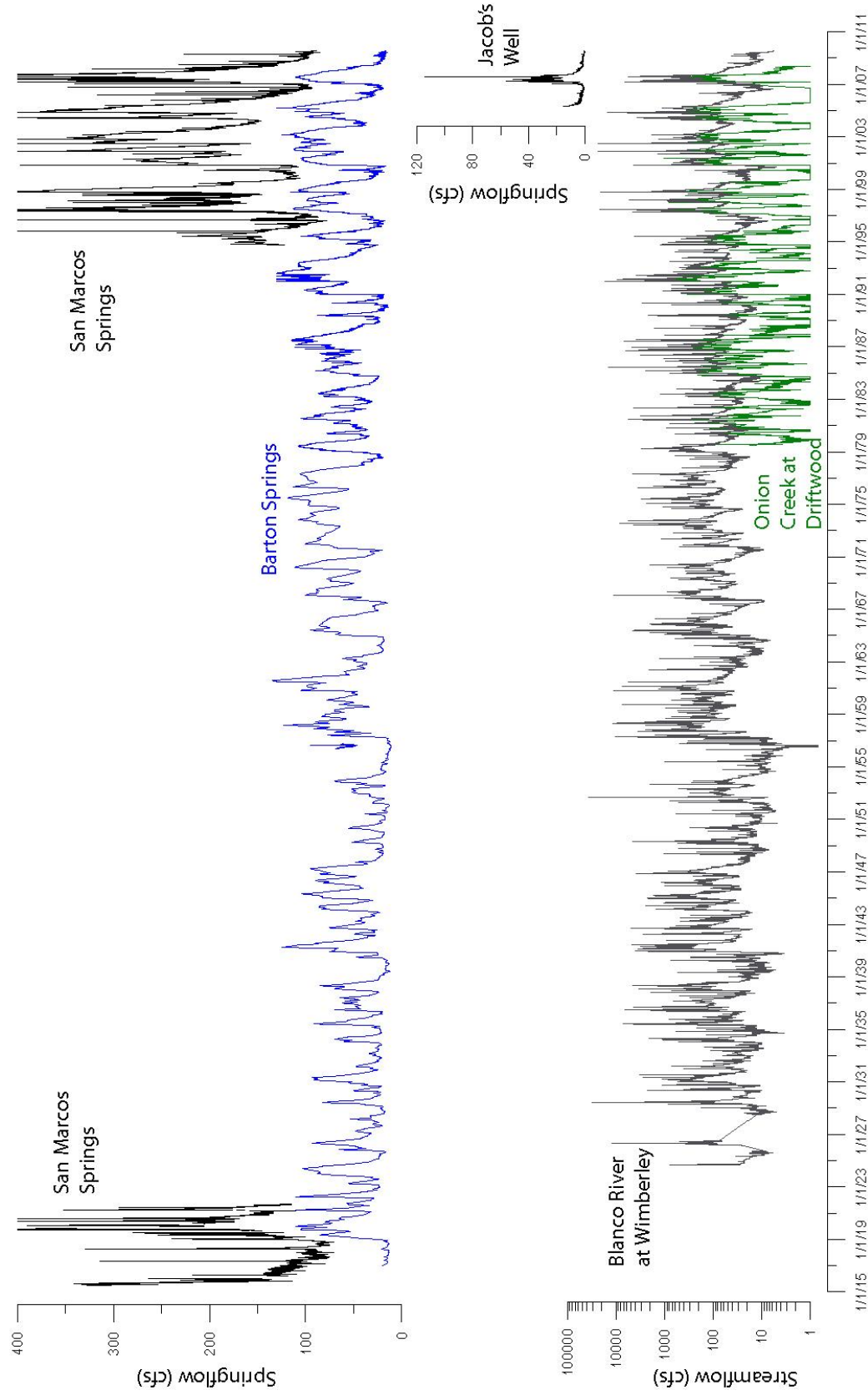


Explanation	
●	Feb-Mar 2009 well control
—	Low flow potentiometric contour (20-ft contour, linear interpolation)
●	Injection site
→	High-flow inferred groundwater flow path

Data provided by the BSEACD, EAA, SAWS, and the COA.
Contours generated by Surfer using linear triangulation.

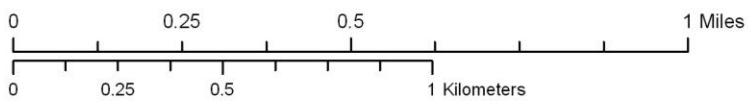
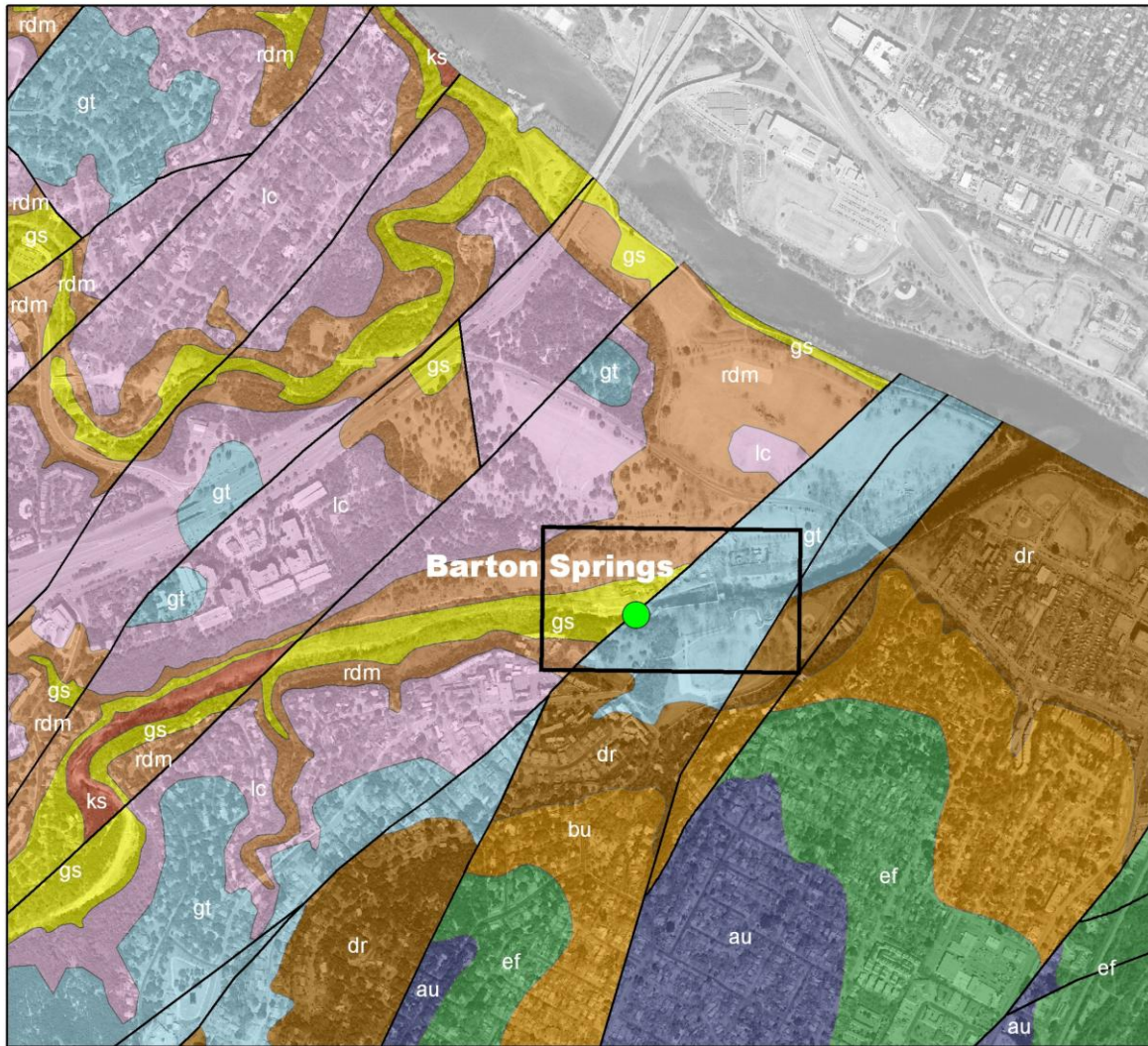
5.27.2009
BSEACD

PERIOD OF RECORD HYDROGRAPHS FOR FIELDTRIP LOCATIONS



Data from the USGS

Barton Springs



Legend

- Barton Springs
- BSEACD Faults
- BSEACD Geology**
- au - Austin Chalk
- ef - Eagle Ford
- bu - Buda Limestone
- dr - Del Rio Clay
- gt - Georgetown
- lc - Edwards Leached/Collapsed mbr
- rd - Edwards Regional Dense mbr
- gs - Edwards Grainstone mbr
- ks - Edwards Kirschberg mbr

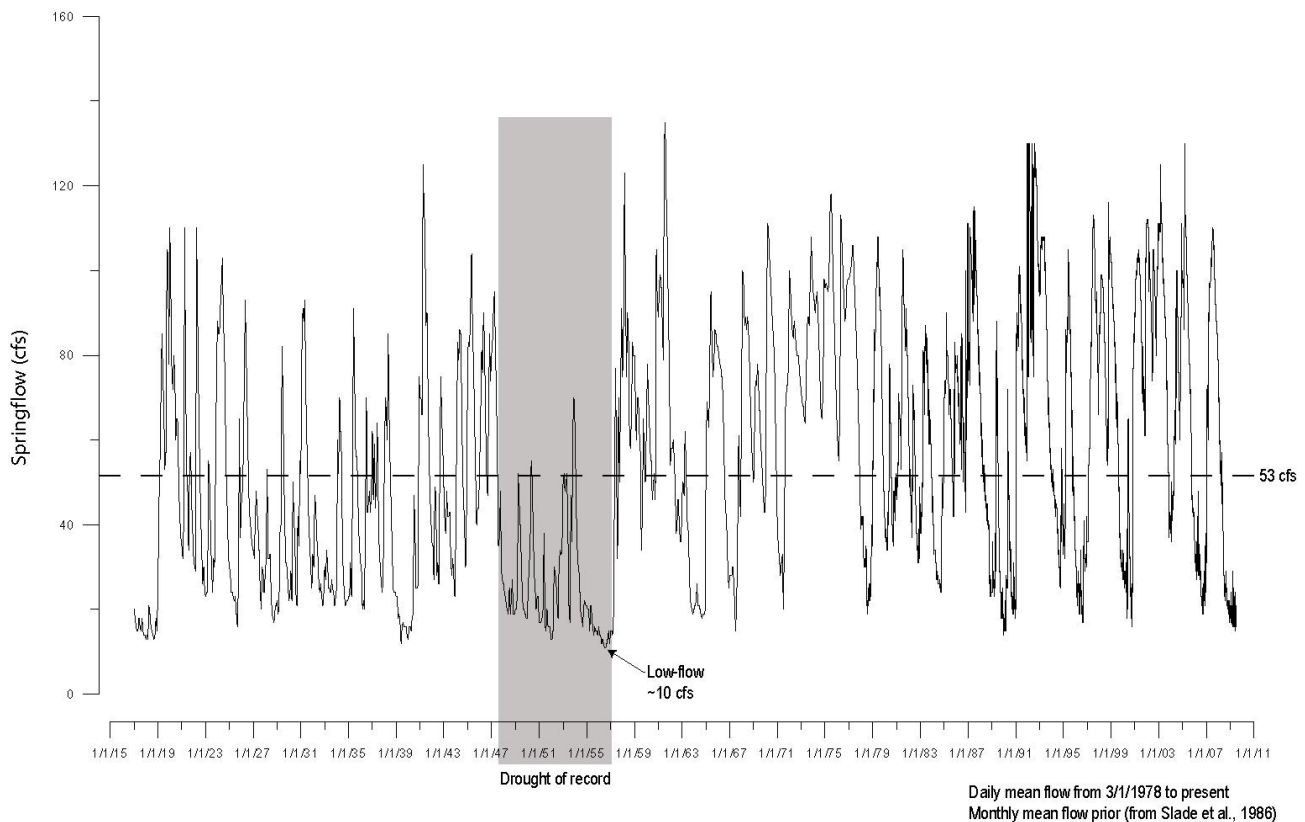


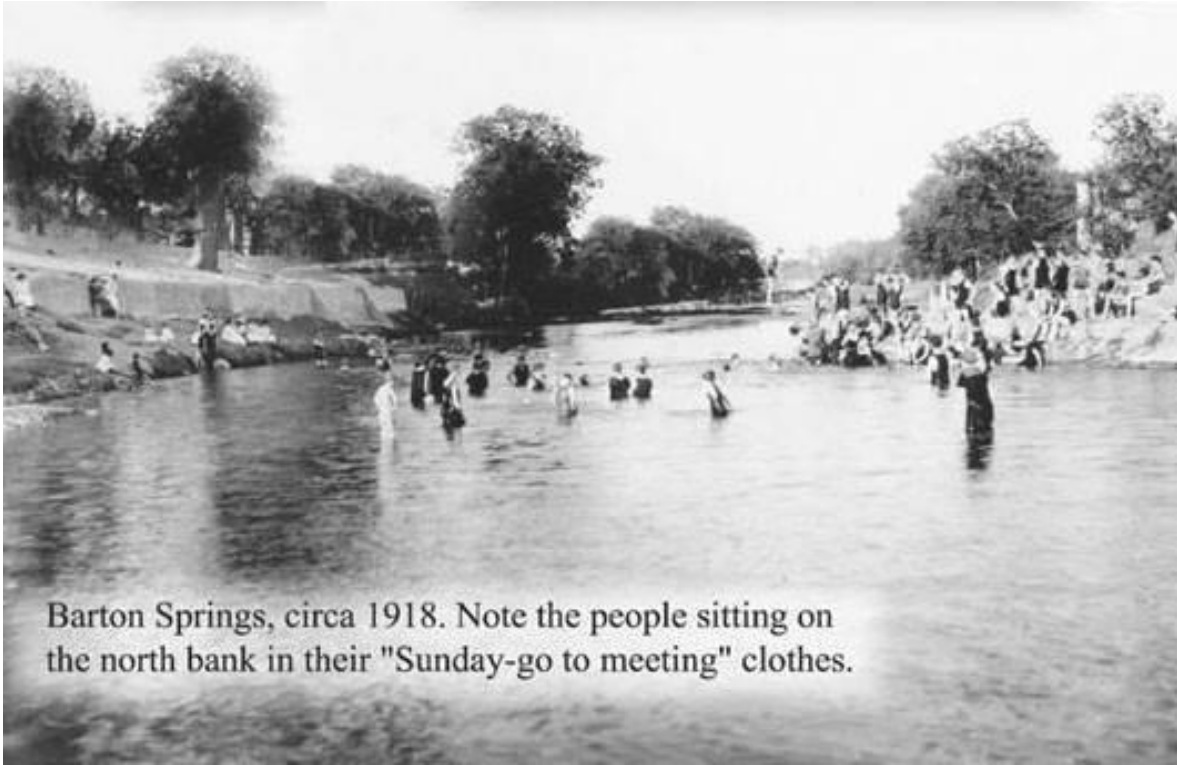
Stop 1: Barton Springs

Quick Facts:

- 4th largest spring system in Texas
- Water temperature: 68°F (22°C)
- Mean discharge: 53 cfs (1,500 lps)
- Lowest recorded discharge: 9.8 cfs (278 lps) on March 29, 1956
- Elevation: 462 feet above sea level
- Known habitat of the federally listed Barton Springs salamander (*Eurycea sosorum*).
- Dye trace studies indicate that Barton Springs is hydraulically linked to water recharging from creeks as far south as Onion Creek (17 mi away).
 - Flow rates vary from 0.6 to 7 mi/day depending on flow conditions

Barton Springs Discharge 1917-2009





Barton Springs, circa 1918. Note the people sitting on the north bank in their "Sunday-go to meeting" clothes.

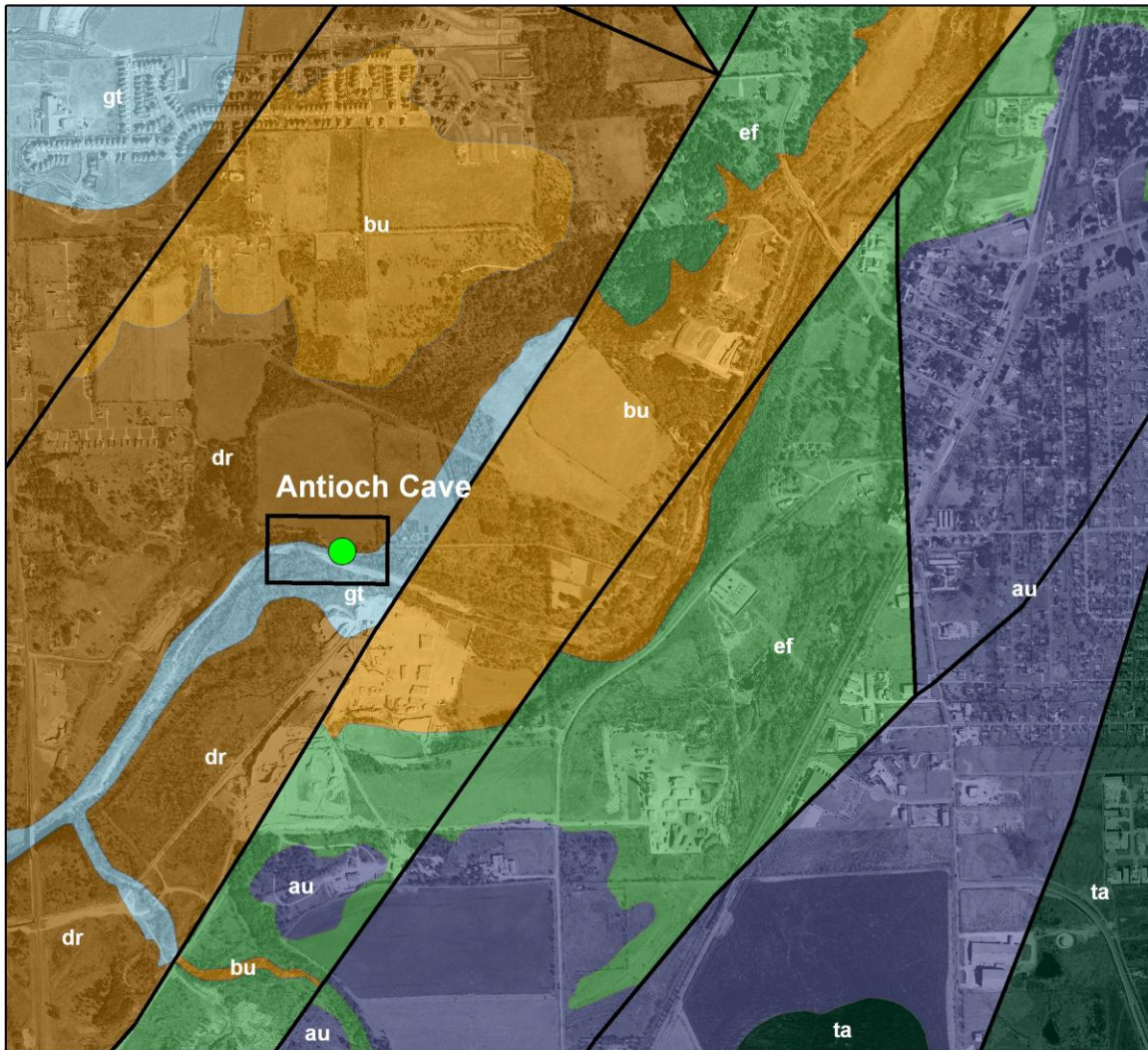


Aerial view of Barton Springs Pool.



View of pool during cleaning. Barton Springs fault is clearly visible in this photo (see line marking trend)

Antioch Cave



0 0.25 0.5 1 Miles

0 0.25 0.5 1 Kilometers

Legend

● Antioch Cave

— BSEACD Faults

BSEACD Geology

■ ta - Taylor Clay

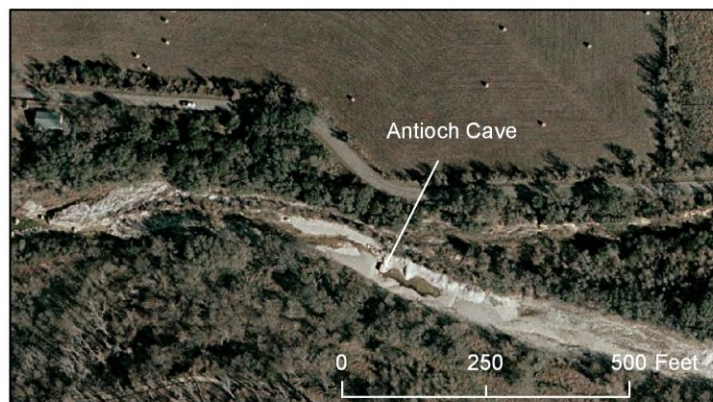
■ au - Austin Chalk

■ ef - Eagle Ford

■ bu - Buda Limestone

■ dr - Del Rio Clay

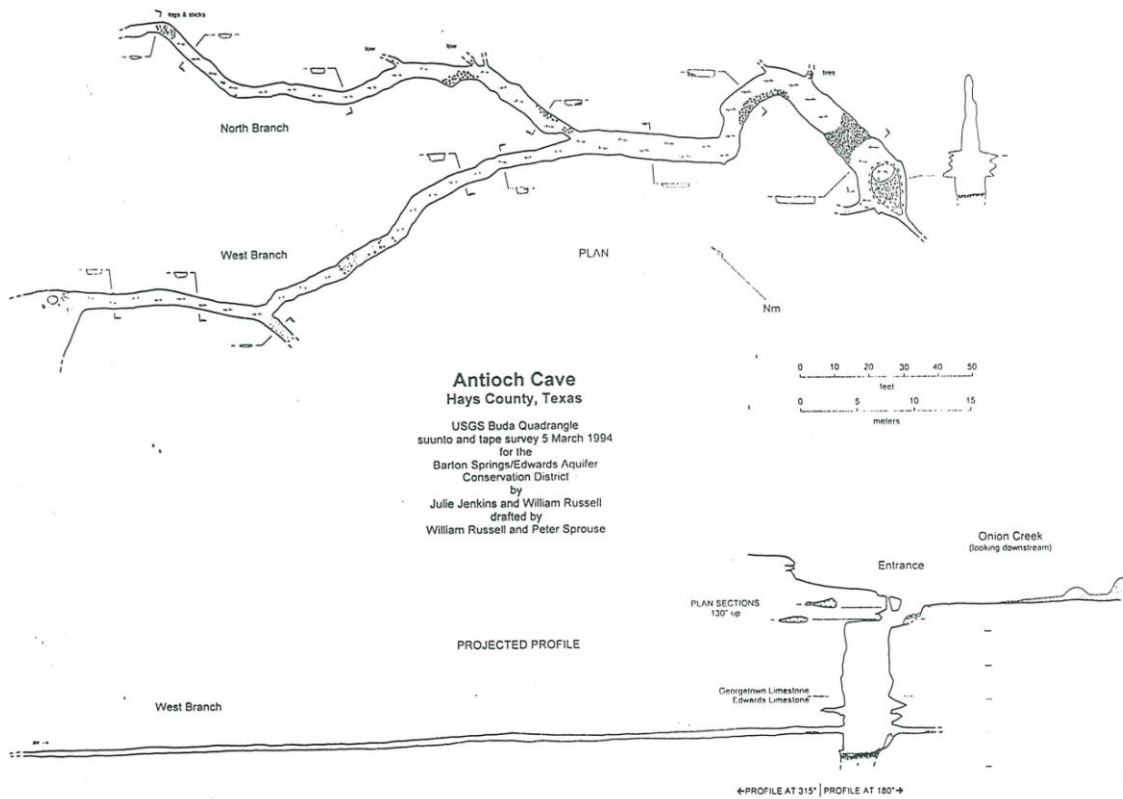
■ gt - Georgetown



Stop 2: Antioch Cave on Onion Creek

Quick Facts:

- Average recharge into cave in 1998 was 46 cfs (1,300 lps); largest capacity recharge feature in the Barton Springs segment
- Surface water catchment area: ~175 square miles
- Elevation: ~690 feet above sea level
- Site of the BSEACD's EPA and TCEQ-funded recharge enhancement project.
- Dye traced to Barton Springs in 7-8 days (17 miles away)



RECHARGE ENHANCEMENT AND AUTOMATED MONITORING OF RECHARGE TO THE EDWARDS AQUIFER IN CENTRAL TEXAS

By: Brian A. Smith, Ph.D., PG, Joseph Beery, and Brian Hunt, PG

ABSTRACT

The majority of recharge to the Barton Springs segment of the Edwards Aquifer is through recharge features such as caves, sinkholes, and solutionally enlarged fractures that are located in the beds of creeks that cross the recharge zone. Approximately 45% of the creek recharge in the Barton Springs segment is from Onion Creek. Because this is a karst aquifer with conduits carrying large volumes of recharged water to various parts of the aquifer and to the springs, only a limited amount of filtration and settling occurs. Since this water comes from rainfall runoff and creek flow, it contains varying amount of sediment, bacteria, and other contaminants.

To improve the quality and increase the quantity of water entering the aquifer, a Best Management Practices (BMP) structure was constructed over the entrance to Antioch Cave in Onion Creek that directs a considerable amount of water into the aquifer. This structure was built with an air-pressure activated valve so that the valve could be maintained in the closed position during periods of storm-water flow and which could then be opened when the quality of water improves as the storm pulse recedes. Because of the remote location of the cave, it is not possible to have the valve in the appropriate position at all times. A system for automated monitoring of water quality in the creek has been installed on the BMP at Antioch Cave. Under predetermined conditions, the system will activate the valve to either close to prevent sediment and contaminant laden storm water from entering the aquifer or to open to allow better quality water to enter the aquifer. A similar system is being designed for another cave further upstream on Onion Creek (Site B).

This project was made possible with two 319(h) (non-point source pollution) grants from the Texas Commission on Environmental Quality and the U.S. Environmental Protection Agency. This abstract and figures were presented at the Austin Geological Society meeting April 2008.

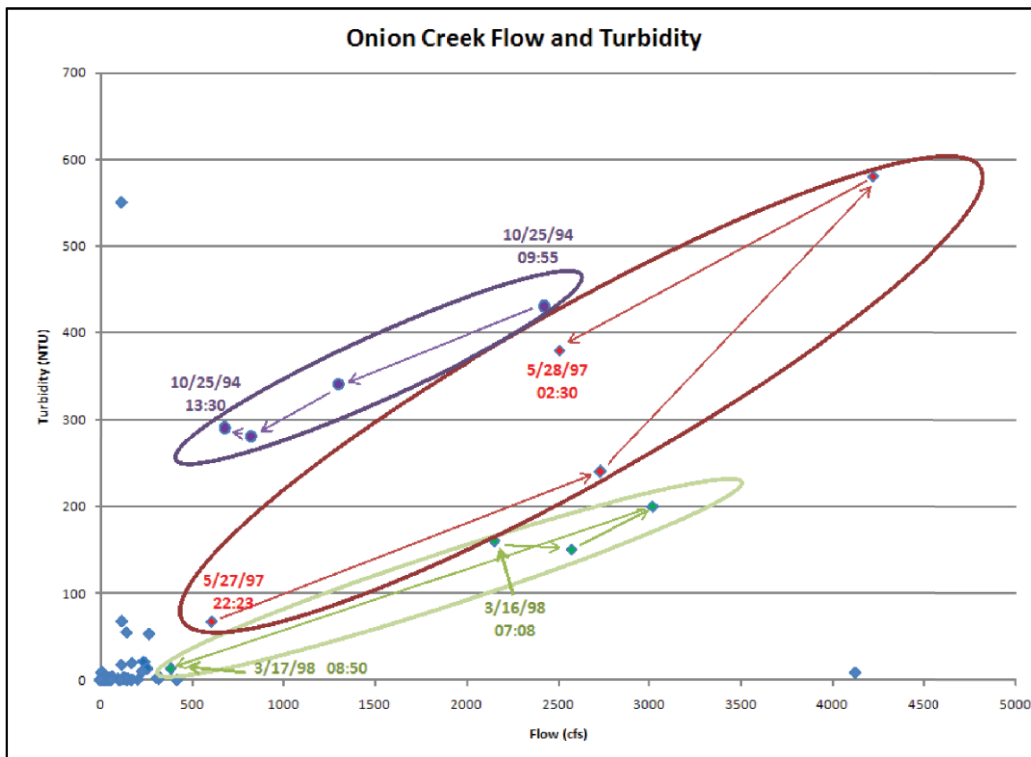
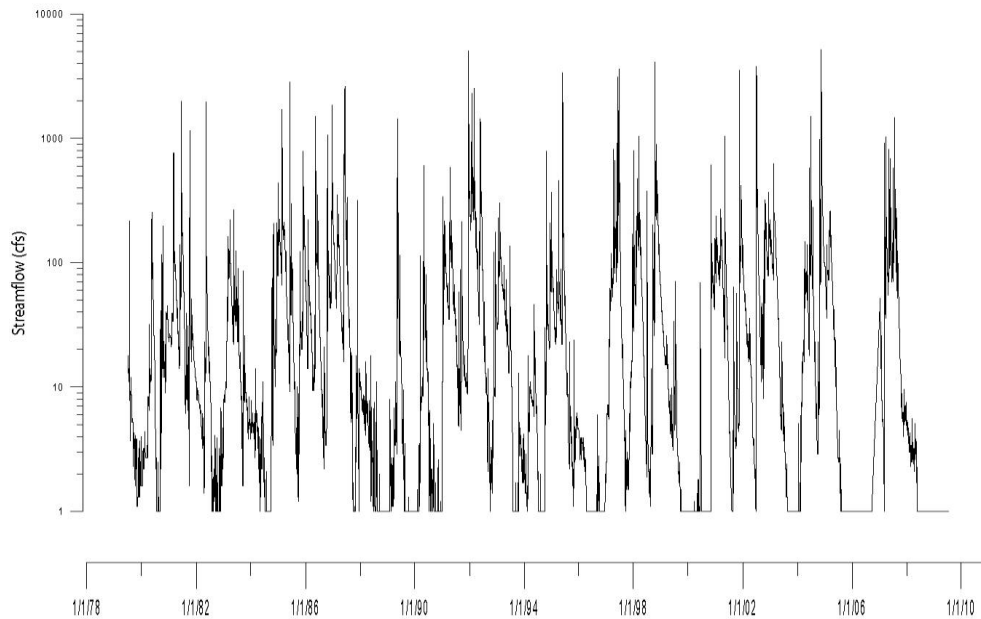


Chart showing flow and turbidity in Onion Creek for three storm events as monitored by the USGS. Contaminant levels for these storm events are presented in the table below.



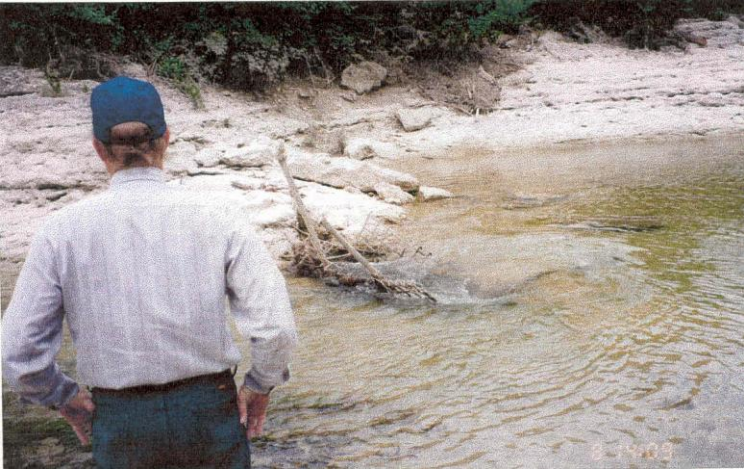
Antioch Cave vault with newly installed intake screen (Sept. 2008).

Onion Creek Flow 1978-2009





A series of pictures of Antioch Cave from left to right: Recharge into a pristine Antioch Cave entrance in Onion Creek; concrete vault and valve system build upon Antioch Cave which controls recharge; inside the vault.

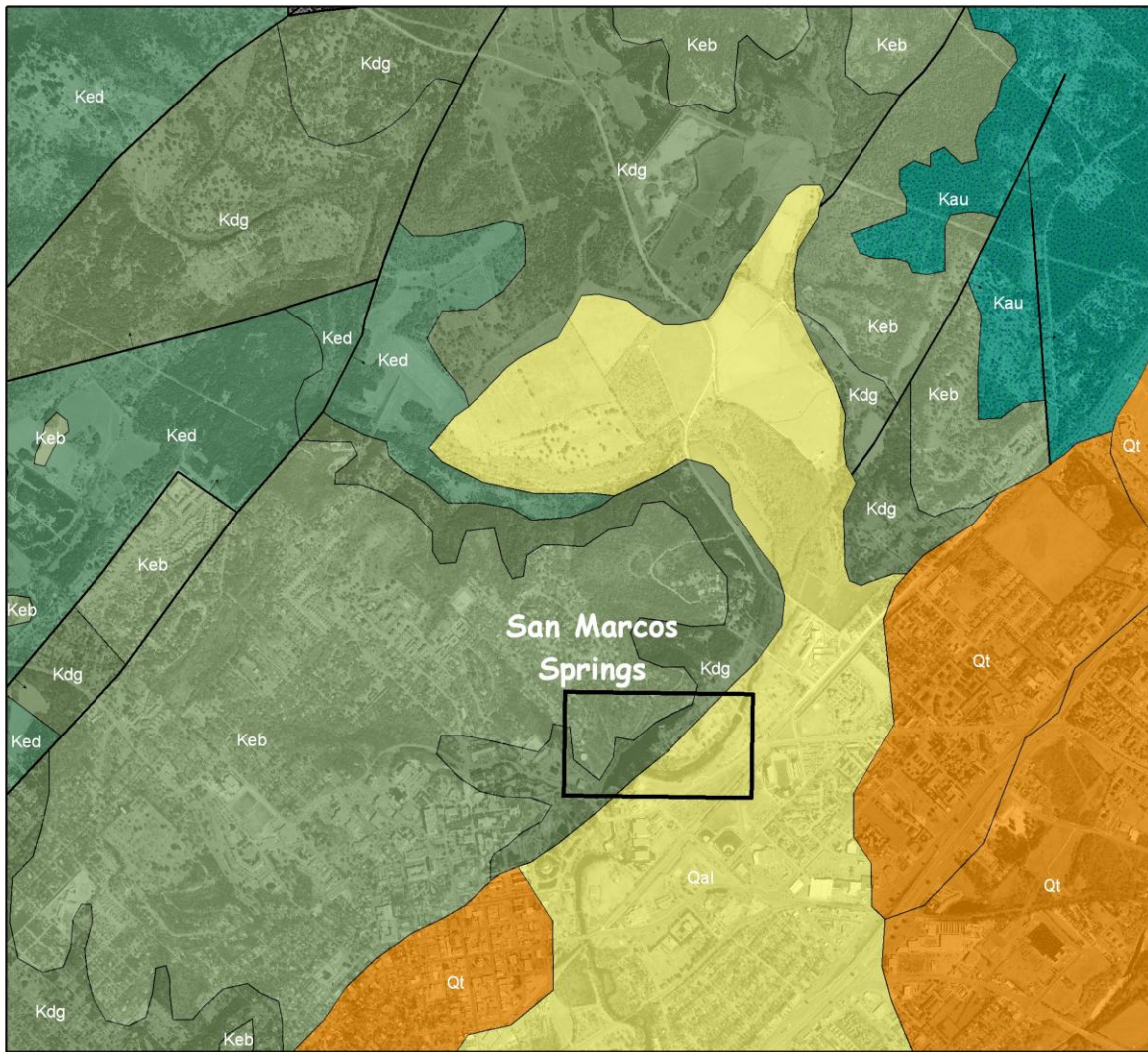


Ron Fieseler entering Antioch Cave and observing recharge ca. 1994.



Caver rappelling into entrance pit of Antioch Cave. Vault and air vent are visible. Photo by Peter Sprouse

San Marcos Springs



Legend

— GAT Faults

GAT Geology

- Qal - Alluvium
- Qt - Terrace Deposits
- Kau - Austin Chalk
- Keb - Eagle Ford Group
- Kdg - Del Rio Clay
- Ked - Fredericksburg Group

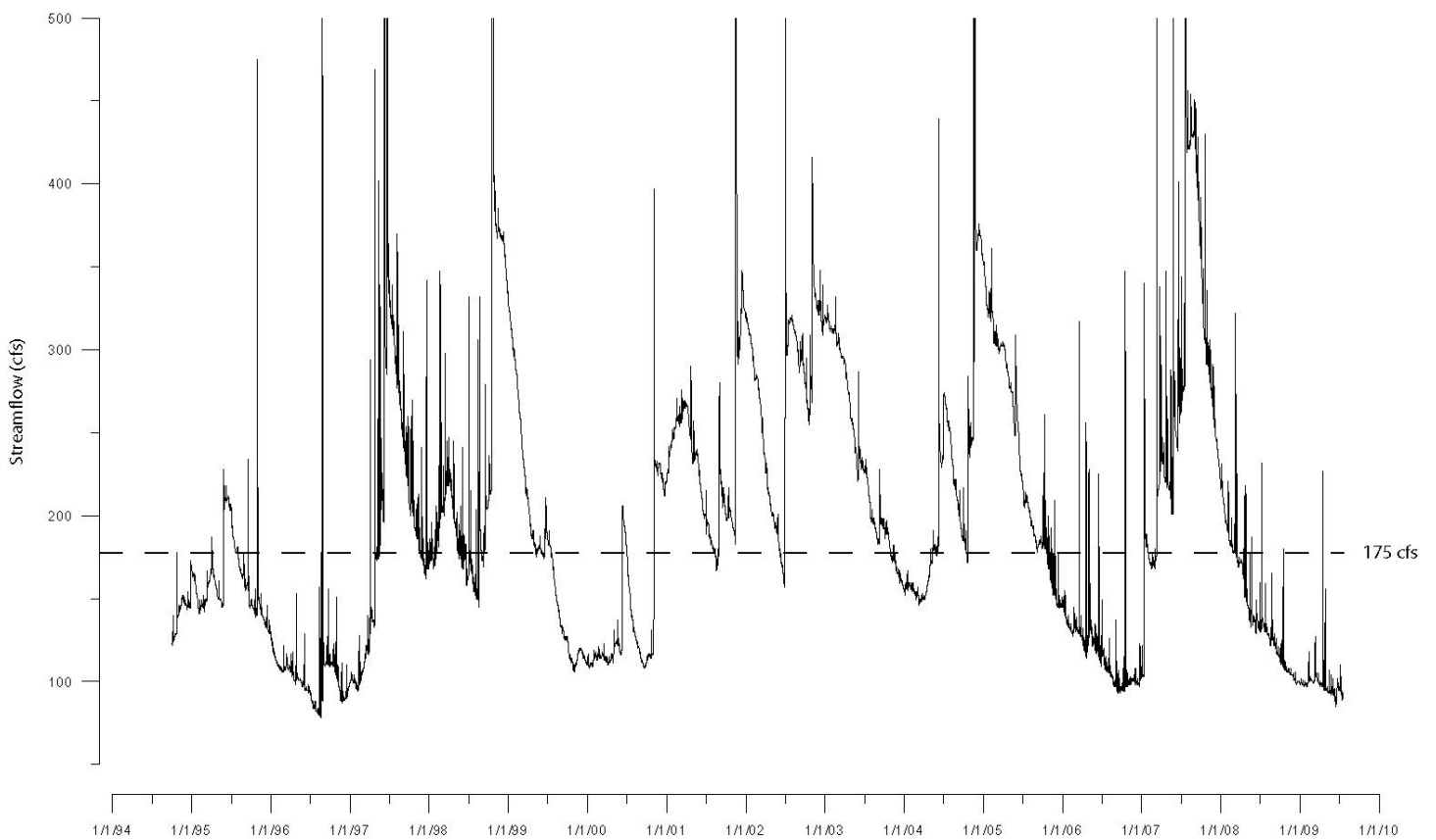


Stop 3: San Marcos Springs

Quick Facts:

- 2nd largest spring system in Texas
- Mean discharge: 175 cfs (4,950 lps)
- Lowest recorded discharge: 46 cfs (1,300 lps) on 8/16/1956
- Elevation: ~557 feet above sea level
- San Marcos Springs is a system of over 200 individual springs.
- Home to numerous endemic species

San Marcos River Discharge 1995-2009



Data from USGS

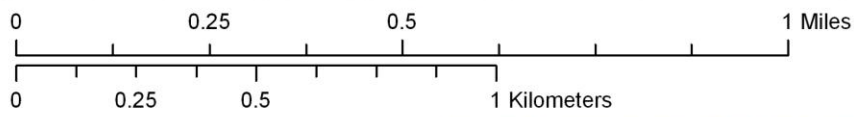
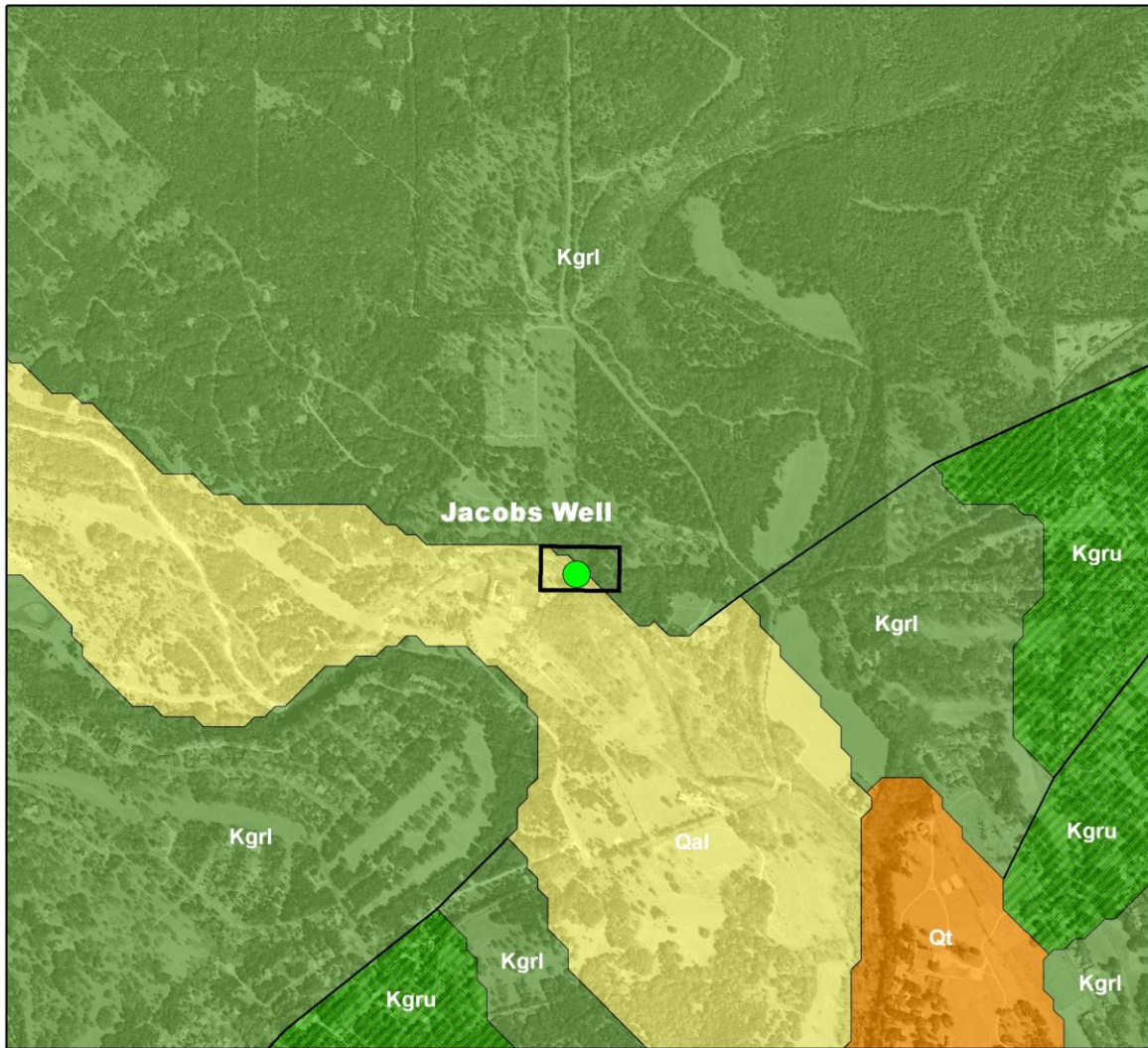


View of Spring Lake looking south. Photo by Brian B. Hunt.



Dye receptor being changed at Diversion Spring within Spring Lake. Photo by Brian A. Smith.

Jacobs Well



Legend

● Jacobs Well

— GAT Faults

GAT Geology

■ Qal - Alluvium

■ Qt - Terrace Deposits

■ Kgru - Upper Glen Rose

■ Kgrl - Lower Glen Rose



Stop 4: Jacob's Well

Quick Facts:

- One of the largest springs from the Trinity Aquifer in the Hill Country
- Discharge: varies from 0 to 114 cfs (3,200 lps)
- Elevation: ~922 feet above sea level

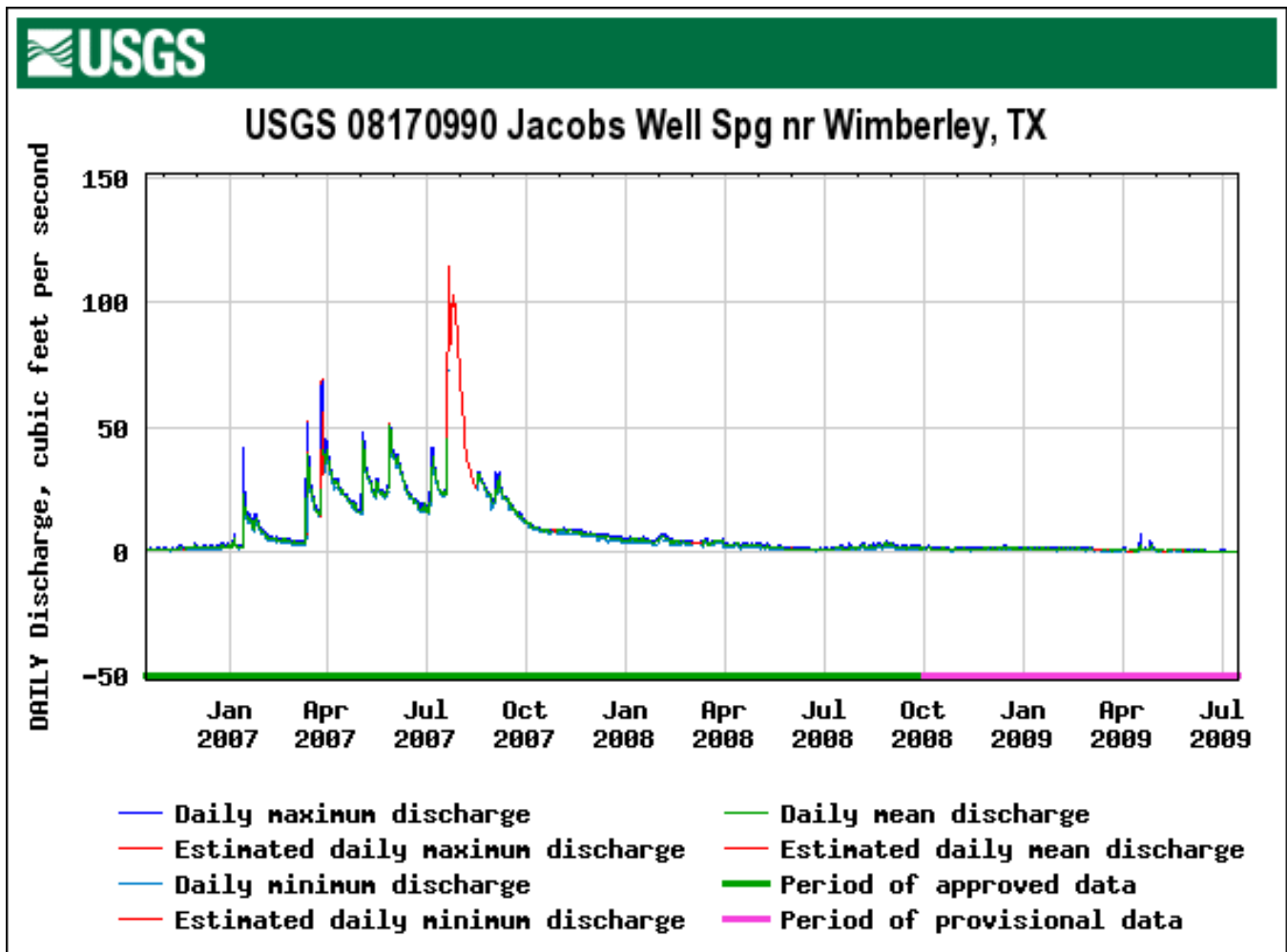
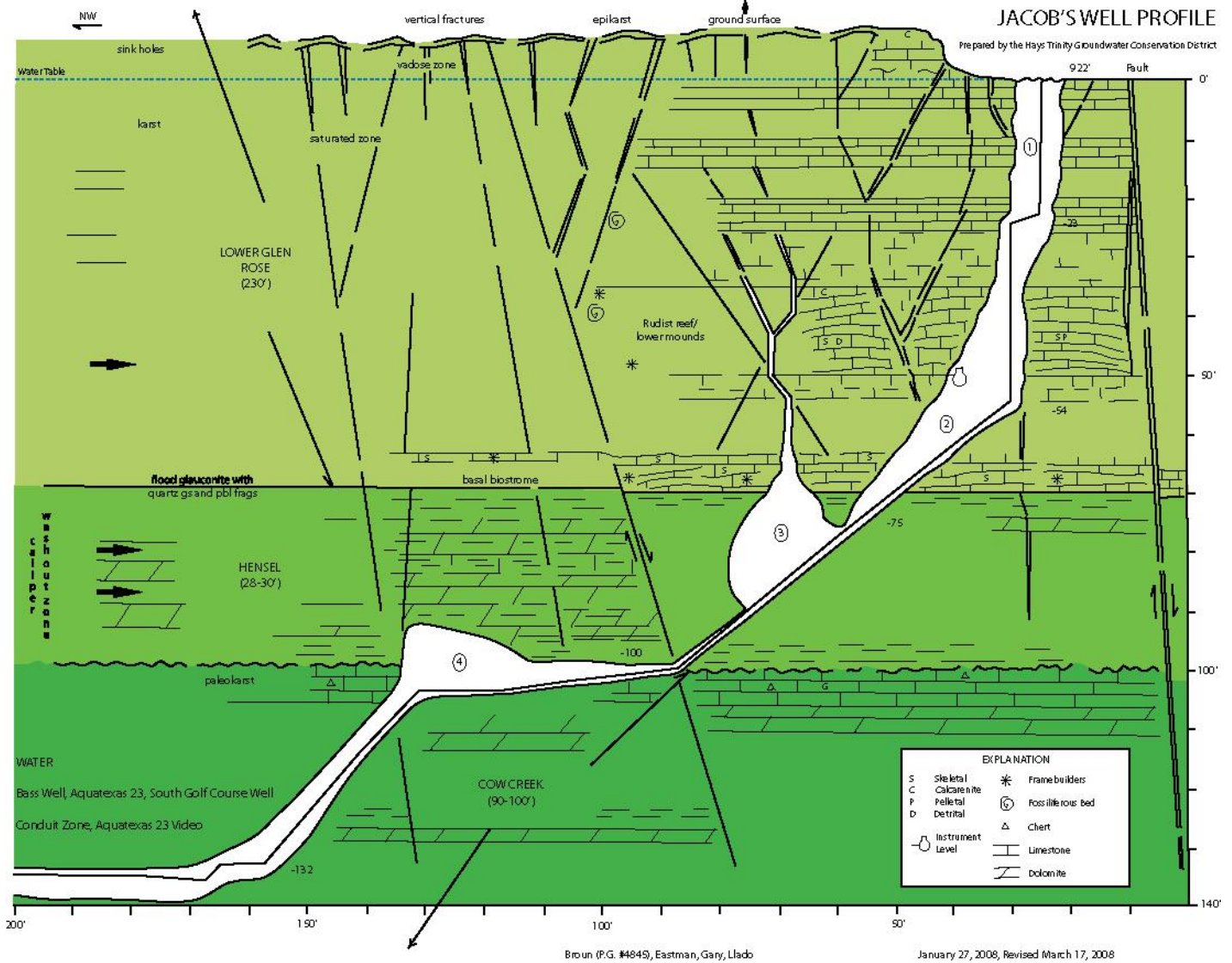




Photo courtesy of the Wimberley Valley Watershed Association



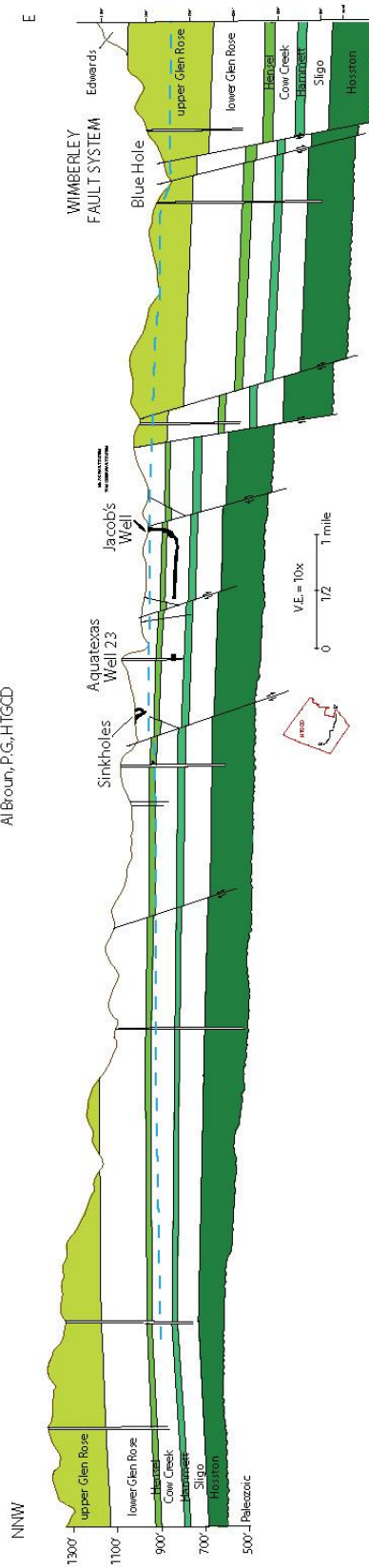
Cave divers within Jacob's well



This figure illustrates the geologic profile of Jacob's Well (figure from Broun et al., 2008). The spring issues from the lower Glen Rose Fm. At 100 feet depth is the contact between the Hensel and Glen Rose with chambers developed at the upper and lower contact of the Hensel. The dominant lateral conduit development is within the Cow Creek Fm.

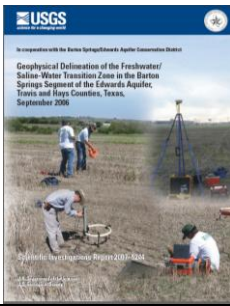
STRUCTURAL CROSS SECTION-CYPRESS CREEK DRAINAGE
 Lower Cretaceous Trinity Group, Hays County, Texas

Al Broun, P.G., HTGCD

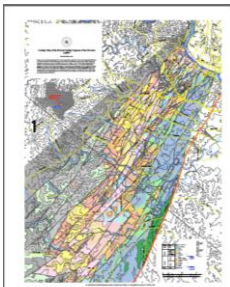


Cross section from Broun et al., 2008

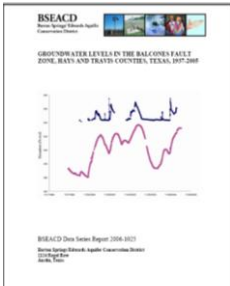
Overview



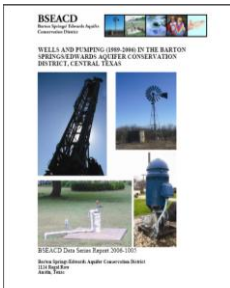
Payne, J.D., Kress, W.H., Shah, S.D., Stefanov, J.E., Smith, B.A., and Hunt, B.B., 2007, Geophysical delineation of the freshwater/saline-water transition zone in the Barton Springs segment of the Edwards aquifer, Travis and Hays Counties, Texas, September 2006: U.S. Geological Survey Scientific Investigations Report 2007-5244, 21 p., 6 app.
<http://pubs.usgs.gov/sir/2007/5244/>



Hauwert, N., Beery, J., Hunt, B.B., and Banda, N., 2006, Geologic Map of the Barton Springs segment of the Edwards Aquifer: BSEACD Map Series, 1 plate.
http://www.bseacd.org/graphics/BSEACD_Geology_Map_1_4_07.pdf



Hunt, B.B. and Smith, B.A., 2006, Groundwater levels in the Balcones Fault Zone, Hays and Travis Counties, Texas, 1937-2005: BSEACD Data Series Report 2006-1025, 19p.
http://www.bseacd.org/graphics/BSEACD_Water_Level-Database_2006_1025.pdf

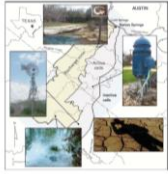


Hunt, B.B., Smith, B.A., Holland, W.F., and Beery, J., 2006, Wells and Pumping (1989-2006) in the Barton Springs/Edwards Aquifer Conservation District, Central Texas: BSEACD Data Series Report 2006-1005, 51p.
http://www.bseacd.org/graphics/BSEACD_Wells_and_Pumping_Data_Report_2006-1005.pdf



Hunt, B.B., Smith, B.A., Beery, J., Johns, D., and Hauwert, N., 2005, Summary of 2005 groundwater dye tracing, Barton Springs segment of the Edwards Aquifer, Hays and Travis Counties, Central Texas: BSEACD Report of Investigations 2006-0530, 23p.
http://www.bseacd.org/graphics/Summary_2005_Dye_Tracing.pdf

EVALUATION OF SUSTAINABLE YIELD OF THE
BARTON SPRINGS SEGMENT OF THE EDWARDS AQUIFER,
HAYS AND TRAVIS COUNTIES, CENTRAL TEXAS



Smith, B.A. and Hunt, B.B., 2004, Evaluation of sustainable yield of the Barton Springs segment of the Edwards Aquifer, Hays and Travis Counties, Central Texas: BSEACD Report, 71p.

http://www.bseacd.org/graphics/SYM_Final_Report.pdf

GEOLOGIC FRAMEWORK AND HYDROGEOLOGIC CHARACTERISTICS
OF THE EDWARDS AQUIFER OUTCROP (BARTON SPRINGS
SEGMENT), NORTHEASTERN HAYS AND SOUTHWESTERN
TRAVIS COUNTIES, TEXAS



Small, T.A., Hanson, J.A., and Hauwert, N.M., 1996, Geologic framework and hydrogeologic characteristics of the Edwards aquifer outcrop (Barton Springs segment), northeastern Hays and southwestern Travis Counties, Texas: U.S. Geological Survey Water-Resources Investigations Report 96-4306, 15 p., 1 pl.

<http://pubs.water.usgs.gov/wri96-4306/>

Barton Springs



In cooperation with the City of Austin

Relation of Specific Conductance in Ground
Water to Intersection of Flow Paths by
Wells, and Associated Major Ion and
Nitrate Geochemistry, Barton Springs
Segment of the Edwards Aquifer,
Austin, Texas, 1978–2003



Scientific Investigations Report 2007-5002

U.S. Department of the Interior
U.S. Geological Survey

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In cooperation with the Texas Commission on Environmental Quality

Recent (2003–05) Water Quality of
Barton Springs, Austin, Texas, With
Emphasis on Factors Affecting Variability



Scientific Investigations Report 2006-5299

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Enhancing the Accuracy of Springflow Data



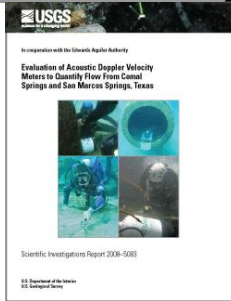
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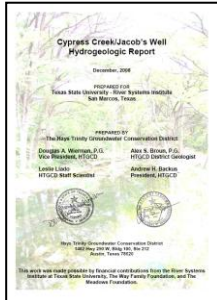
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Selected internet resources:

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<http://www.bseacd.org/>

The Edwards Aquifer Website, by Gregg Eckardt
<http://www.edwardsaquifer.net/>

Edwards Aquifer Authority
<http://www.edwardsaquifer.org/>

Hays-Trinity Groundwater Conservation District
<http://haysgroundwater.org/>