

Hydrologic Influences of the Blanco River on the Trinity and Edwards Aquifers, Central Texas, USA

B.A. Smith, B.B. Hunt, A.G. Andrews, J.A. Watson, M.O. Gary,
D.A. Wierman and A.S. Broun

Abstract The Blanco River of central Texas provides an important hydrologic link between surface and groundwater as it traverses two major karst aquifer systems—the Trinity and Edwards Aquifers. The Blanco River is characterized by alternating gaining and losing stretches due to the presence of springs that discharge water into the river and swallets that drain water from the river. The region consists primarily of Lower Cretaceous limestone, dolomite, and marls. One of the more significant springs along the Blanco River is Pleasant Valley Spring. During below-average flow conditions, Pleasant Valley Spring becomes the headwaters of the Blanco River even though the headwaters, under wet conditions, are about 50 km upstream. Water that enters the Edwards Aquifer from the Blanco River can eventually discharge at both San Marcos Springs to the south and Barton Springs to the north. During periods of extreme drought, when other recharging streams are dry, the Blanco River can provide enough water to the Edwards Aquifer that will help maintain flow at Barton Springs where endangered species of salamanders need sufficient flow of high-quality groundwater. In the western part of the study area, increasing rates of pumping from the Trinity Aquifer, combined with impact from drought, are reducing heads in the aquifer and are subsequently reducing springflows (such as from Pleasant Valley Spring) that sustain the Blanco River. Decreasing flow in the Blanco River can lead to less recharge to the Edwards Aquifer and less discharge from San Marcos and Barton Springs. A better understanding of these aquifer systems and how they are influenced by the Blanco River is important for management of groundwater in an area undergoing significant population growth.

B.A. Smith (✉) · B.B. Hunt · A.G. Andrews · J.A. Watson
Barton Springs/Edwards Aquifer Conservation District, 1124 Regal Row,
Austin, TX, USA
e-mail: brians@bseacd.org

M.O. Gary
Edwards Aquifer Authority, San Antonio, TX, USA

D.A. Wierman · A.S. Broun
Independent Consultant, Dripping Springs, TX, USA

1 Introduction

This study was conducted to better understand the relationship between the Blanco River and the underlying Trinity and Edwards Aquifers. The Blanco River extends across about 110 km of Hill Country terrain in central Texas. Only under very wet conditions does the river have continuous flow of water across its entire length. Under extreme drought conditions the Blanco River flows over only about half of its length. Karst features related to faults and fractures, stratigraphy, and lithology determine whether water is entering or leaving the river. This study interprets recently-collected flow and potentiometric data and results of dye trace studies to describe the interaction of the Blanco River with the underlying aquifers. The Trinity Aquifers and the Edwards Aquifer provide water to millions of people in central Texas. There are no other sources of water over much of this area.

2 Geography and Hydrogeology

The study area (Fig. 1) consists of the Edwards Plateau to the west and the Balcones Fault Zone (BFZ) to the east. The boundary between the Edwards Plateau and the BFZ is approximately the line on Fig. 1 between the Edwards Aquifer and the Trinity Aquifer. The climate of the study area is classified as subtropical humid, with mild winters and hot summers, although during some periods it may be more accurately considered semi-arid, especially in the western portions in the Hill Country. Average annual rainfall for this area is about 770 mm (Hunt et al. 2012). The entire area is prone to drought, which may be severe and persist for months to many years. Virtually every decade has had one or more significant drought periods that has lasted for a substantial part of a year or more. The most extreme drought in recorded history in this area was the decadal drought from 1947 to 1956 (BSEACD 2014). During the hottest and driest periods most of the rain will evaporate with very little left to run off the surface or infiltrate the subsurface. Some storm events of up to 200 mm of rain have occurred in the area with no appreciable flow developing in the creeks (Smith et al. 2011).

The geologic units that make up the Edwards Aquifer are mostly limestone and dolomite. The Trinity Aquifers are composed of (from stratigraphically highest to lowest) the Upper Glen Rose Limestone, Lower Glen Rose Limestone, Hensell Sand, Cow Creek Limestone, and the Hammett Shale (Fig. 2). The Upper and Lower Glen Rose Limestones consist mostly of limestone, dolomite, shale, and marl. Some units of the Upper and Lower Glen Rose Limestones contain evaporites.

Studies of structures along the BFZ (Collins and Hovorka 1997) indicate that much of this area consists of southeast dipping, *en echelon*, normal faults with throws of as much as 260 m. Some of these faults are continuous over many kilometers, while others extend only a few kilometers or less. Fault blocks between the points where fault displacement decreases to zero are called relay ramps. The relay ramps transfer

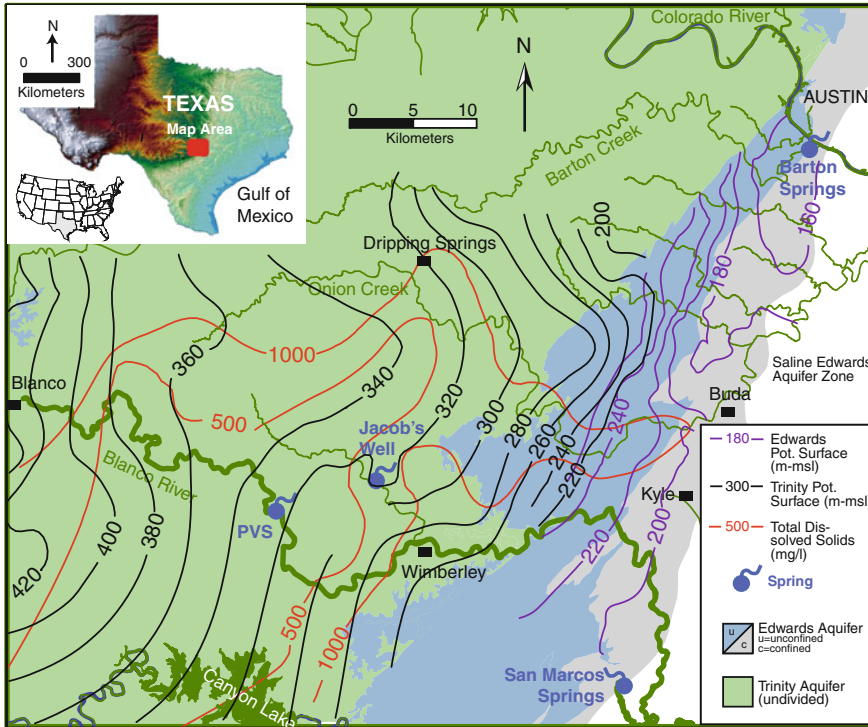


Fig. 1 Location map of the study area

displacement from one fault to an adjacent fault. Faulting and fracturing along the BFZ play a significant role in the development of the Edwards and Trinity Aquifers.

Since the Edwards and Trinity Aquifers consist largely of limestone and dolomite, karst features, such as caves, sinkholes, and solutionally enlarged fractures, direct water into the subsurface. In the upland areas, runoff from rain events might flow into these recharge features for only a few hours. The majority of water recharging the Edwards Aquifer in the study area comes from flow in the creeks and rivers. Slade (2014) estimates that 75 % of the water entering the Edwards Aquifer in the area between Kyle and Barton Springs (Fig. 1) comes from infiltration of water in the stream beds, with the remaining 25 % infiltrating in the uplands between the streams.

3 Blanco River Flow

Under average-to-dry conditions, the Blanco River (Fig. 2) consists of long stretches of a dry streambed and intermittent stagnant pools with no flow. Other stretches of the river maintain flow under all but the most extreme drought

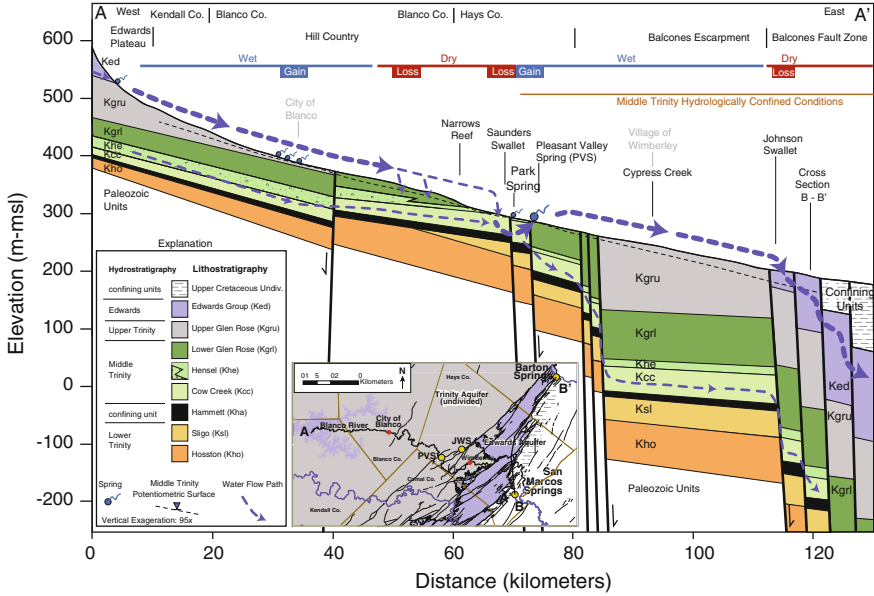


Fig. 2 Generalized hydrogeologic cross section A to A’ along the Blanco River during drought conditions

conditions (Wierman et al. 2010). What controls flow, or the lack of flow, in the river, in addition to periods of rainfall or drought, are karst features that allow water to enter the subsurface or to discharge to the river. West of the City of Blanco (Figs. 1 and 2), rain falls on the semi-arid landscape of the Texas Hill Country. Some of that water penetrates the thin soil and passes through the vadose zone where it recharges the Upper Trinity Aquifer. Some of the water falling on the surface might run off to a normally-dry creek bed, and then flow into the Blanco River. Near the City of Blanco some of the water that recharges the shallow aquifer in the upgradient areas discharges into the Blanco River through a series of small springs. About 20 km downstream of the City of Blanco, the Blanco River becomes a losing stream as water flows into the subsurface through numerous small recharge features. At Saunders Swallet in Hays County (Fig. 2), the river is dry most of the time, other than periods of high rainfall. Less than 1 km downstream of Saunders Swallet, groundwater discharges from several springs (Park Springs) and the Blanco River becomes a flowing river again. Another 2 km downstream is Pleasant Valley Spring (Fig. 3) from which discharge has been measured at up to 0.8 m³/s. Along this stretch of the river, groundwater discharges at multiple locations through gravels on the stream bed. Pleasant Valley Spring occurs where a northeast-trending fault and associated fractures cross the Blanco River. During drought conditions, Pleasant Valley Spring is the headwaters of the Blanco. Even under average conditions, Pleasant Valley Spring provides the majority of water flowing in the river. From this point, the Blanco River continues



Fig. 3 View of Pleasant Valley Spring on the Blanco River. Groundwater discharges from the aquifer through a gravel bar that cuts diagonally across the river bed. Inset photograph is an upstream view of the Blanco River where groundwater discharges from a gravel bar beneath the large, *red tree* to the *left*

as a flowing stream for another 40 km where recharge features, such as Johnson Swallet (Fig. 2), in the Edwards recharge zone divert enough water to cause the river to go dry again under moderate drought conditions. When enough water is flowing in the river, some of that water will continue to flow past the recharge zone of the Edwards Aquifer. From that point on, the geologic units underlying the river have low permeability and the Blanco River continues to where it joins the San Marcos River.

4 Recharge to the Trinity Aquifers

Described earlier is the pathway of water where it either flows in the river or where it is interchanged between the river and the shallow aquifer. However, there are other pathways for the water to flow further away from the river. One of these pathways is where the water enters the Middle Trinity Aquifer and moves deeper into the subsurface (Fig. 2). The geologic units in the study area are encountered at greater depths to the east owing to normal faulting with downthrown blocks to the east of the faults. One area for recharge to the Middle Trinity Aquifer is near

Saunders Swallet (Fig. 2) where the Hensel Sand and Cow Creek Limestone are exposed at the surface. Another area is about 8 km upstream of the Narrows. Some of the water entering the Cow Creek Limestone might discharge into the Blanco River again at Pleasant Valley Spring where it migrates upward about 10–20 m along faults and fractures. In this area, the Hensel consists mostly of dolomite with low permeability and acts as an aquitard. The Hammett Shale acts as an aquitard below the Cow Creek. Any water in the Cow Creek that does not exit the aquifer at this point will follow a deep pathway as faulting takes the Cow Creek to depths of 400 m within the study area and considerably deeper as the water migrates deeper into the subsurface to the east. This pathway is not directly across the faults, but lateral flow is thought to occur along relay ramps where the amount of throw along a fault decreases to zero (Collins and Hovorka 1997). At these depths, evaporite minerals are common in the Upper and Lower Glen Rose formations. These evaporite minerals were initially present in the same sediments to the west, but they have largely been removed by infiltration of meteoric water. Therefore, these units have very low permeability, and faults that cut across these units have low permeability (Smith and Hunt 2010). A multiport monitor well was installed near Onion Creek (Fig. 4) that penetrated the Cow Creek Limestone in the deepest sampling port in the well at a depth of 410 m (Wong et al. 2013). Water samples collected from the Cow Creek are of moderately low total dissolved solids (TDS) values (about 900 mg/L)(Wong et al. 2013). Considering the potentiometric and TDS contours shown in Fig. 1, it is likely that the source of the water encountered in the Onion Creek monitor well comes from the Blanco River or from that general area. Where this Cow Creek groundwater ultimately surfaces is unknown. Some of that water might flow north toward the Colorado River, finding pathways along permeable faults to discharge into the river. Or, the water might continue moving deeper into the basin where other faults could allow it to reach the surface and discharge into rivers on the Texas coastal plain.

5 Recharge to the Edwards Aquifer

Water in the Blanco River that reaches the recharge zone of the Edwards Aquifer will either enter karst features along that stretch to recharge the Edwards, or will flow downstream to join the San Marcos River. Flow data indicate that up to 0.6 m³/s of Blanco River water may enter the Edwards Aquifer along this stretch (USGS 2014, unpublished data). From here, the water can either flow south to discharge at San Marcos Springs, or it may flow north to discharge at Barton Springs, or it may flow in both directions. A dye trace study conducted in 2009 showed that dye injected into Johnson Swallet on the Blanco River (Fig. 2) arrived at both springs (Johnson et al. 2012).

The main factor that determines the direction of flow of groundwater beneath the Blanco River is the amount of water recharging the Edwards from Onion Creek, which is about 4 km north of the Blanco River (Fig. 1). About 5.7 m³/s can

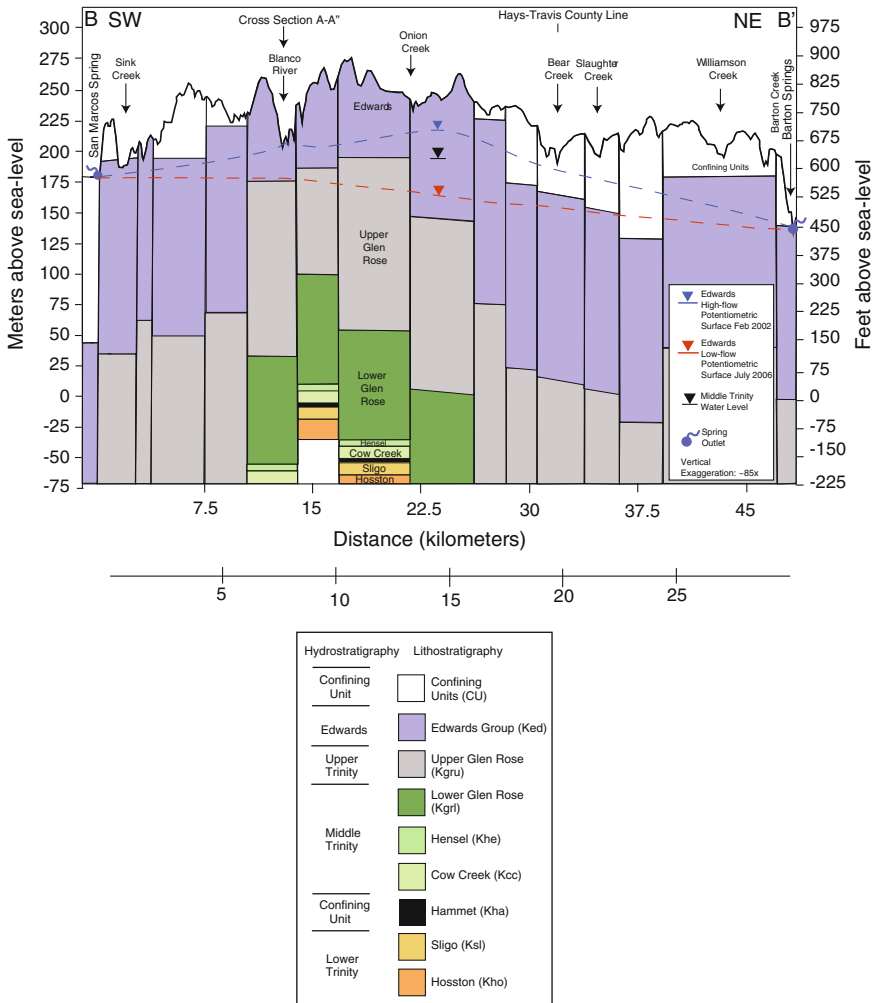


Fig. 4 Generalized hydrogeologic cross section B to B' from San Marcos Springs to Barton Springs

recharge the Edwards Aquifer from Onion Creek (Smith et al. 2011). The Blanco River, with fewer large recharge features and a shorter stretch over the recharge zone can only provide about 0.6 m³/s of recharge. The large amount of recharge from Onion Creek allows a significant groundwater mound to develop beneath Onion Creek during wet conditions (Fig. 4). Groundwater flowing south from the Onion Creek mound dominates the smaller mound beneath the Blanco River allowing water from Onion Creek to flow south and eventually discharge at San Marcos Springs (Figs. 1 and 4) (Smith et al. 2012; Johnson et al. 2012). Under dry conditions, flow ceases in Onion Creek, while the Blanco River continues to flow.

The Onion Creek mound slowly dissipates, eventually allowing water from the Blanco River to flow north to Barton Springs. Figure 4 shows a cross section with the Onion Creek groundwater mound under wet conditions and another potentiometric surface during drought conditions with hydraulic heads as much as 50 m lower.

6 Conclusions

Water flows from the headwaters of the Blanco River to the outlets at San Marcos and Barton Springs or into the deep subsurface along various convoluted pathways. Some of the water flows in the river for much of its journey and some flows mostly in the subsurface. But, some of that water is following pathways that can take it from the river to the subsurface and back to the river again multiple times. A complex combination of geology, structures, lithologies, and karst features determines the actual pathways. A better understanding of the relationships between the Blanco River and the Trinity and Edwards Aquifers is needed to allow for better management of the water resources of central Texas. Considering the implications of water supply for the people and endangered species that live in San Marcos and Barton Springs, further studies need to be made to provide for optimum management of the river and the aquifers.

References

- BSEACD (2014) Regional habitat conservation plan for groundwater use and management of the Barton Springs segment of the Edwards Aquifer. Barton Springs/Edwards Aquifer conservation district, prepared for U.S. fish and wildlife service, Austin, TX, Feb 2014, p 191, plus appendices
- Collins EW, Hovorka SD (1997) Structure map of the San Antonio segment of the Edwards Aquifer and Balcones fault zone, south-central Texas: structural framework of a major limestone aquifer: Kinney, Uvalde, Medina, Bexar, Comal and Hays Counties. The University of Texas at Austin, Bureau of economic geology, miscellaneous Map No. 38, scale 1:250,000, p 14
- Hunt BB, Smith BA, Slade R, Gary RH, Holland WF (2012) Temporal trends in precipitation and hydrologic responses affecting the Barton Springs segment of the Edwards Aquifer, central Texas. In: 62nd annual convention on gulf coast association of geological societies transactions, Austin, TX, 21–24 Oct 2012
- Johnson S, Schindel G, Veni G, Hauwert N, Hunt B, Smith B, Gary M (2012) Tracing groundwater flowpaths in the vicinity of San Marcos Springs, Texas. Edwards Aquifer Authority, Report No. 12-03, p 139, San Antonio, TX
- Slade R (2014) Documentation of a recharge-discharge water budget and main streambed recharge volumes, and fundamental evaluation of groundwater tracer studies for the Barton Springs segment of the Edwards Aquifer. *Tex Water J Tex Water Resour Inst* 5(1):12–23

- Smith BA, Hunt BB (2010) Hydraulic interaction between the Edwards and Trinity Aquifers. In: Wierman D, Broun A, Hunt B (eds) Hydrogeologic atlas of the Hill Country Trinity Aquifer, Barton Springs/Edwards Aquifer, USA, 17 plates, July 2010
- Smith BA, Hunt BB, Johnson SB (2012) Revisiting the hydrologic divide between the San Antonio and Barton Springs segments of the Edwards Aquifer: insights from recent studies. In: 62nd annual convention on gulf coast association of geological societies journal vol 1. Austin, TX, pp 55–68, 21–24 Oct 2012
- Smith BA, Hunt BB, Beery J (2011) Final report for the onion creek recharge project, northern Hays County, Texas. Barton Springs/Edwards aquifer conservation district, Austin, TX, prepared for the Texas Commission on Environmental Quality, Aug 2011, p 47, plus appendices
- USGS (2014) Unpublished data, U.S. Geological Survey. www.waterdata.usgs.gov/nwis/uv?08171000
- Wierman, DA, Hunt BB, Broun AS, Smith BA (2010) Recharge and groundwater flow. In: Wierman D, Broun A, and Hunt B (eds) Hydrogeologic atlas of the Hill Country Trinity Aquifer, Barton Springs/Edwards Aquifer, USA, 17 plates, July 2010
- Wong C, Kromann J, Hunt B, Smith B, Banner J (2013) Investigating groundwater flow between Edwards and Trinity Aquifers in central Texas. Ground Water Journal, National Ground Water Association