Flow Potential Between Stacked Karst Aquifers in Central Texas, USA

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Abstract The Cretaceous-age Middle Trinity Aquifer in central Texas exhibits significant karst features where it is exposed at the surface. Where these units are overlain by the karstic Upper Trinity and Edwards Aquifers, the degree of karstification is not known, but groundwater in certain units of the Middle Trinity Aquifer is chemically similar to shallow groundwater in this area. Geochemical, potentiometric, and hydraulic conductivity data suggest that this deep groundwater is following pathways from the recharge areas that allow for rapid flow compared to other deep units that contain waters of significantly different chemistry. A 340-m deep multiport monitor well was installed in the Edwards (shallowest), and Upper and Middle Trinity Aquifers to better understand the vertical and horizontal relationships of these aquifers. The well was completed with 14 monitor zones allowing for groundwater sampling, hydraulic conductivity testing, and pressure measurements (potentiometric levels) in each zone. Data from this well suggest that karstification processes are active at depths of 300 m below land surface in a confined aquifer at least 25 km from the closest recharge areas.

1 Introduction

The majority of studies of the Edwards and Trinity Aquifers in central Texas are based on data collected from water-supply wells and very few scientifically-designed monitor wells. The purpose of this study was to collect data from discrete intervals of the Edwards and Trinity Aquifers (Fig. 1) that could provide insight to the potential for flow within and between the Edwards and Trinity Aquifers so that groundwater availability and quality issues for these aquifers may be better addressed.

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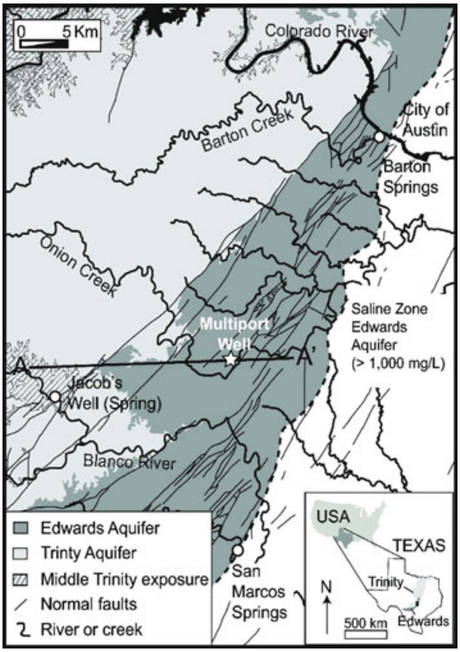

Fig. 1 Location map of study area

2 Geology

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

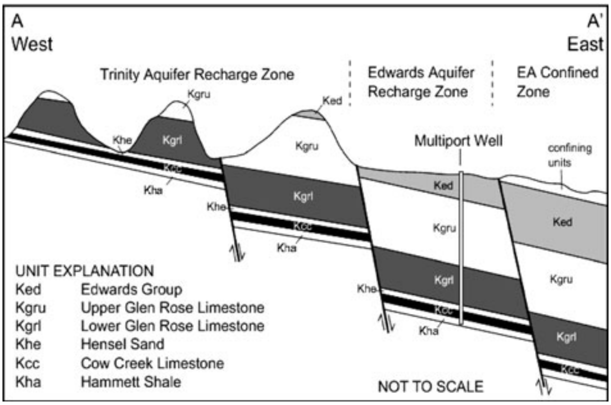

Fig. 2 Schematic cross section showing stratigraphic and structural relationships of geologic units

Glen Rose Limestones consist mostly of limestone, dolomite, shale, and marl. Some units of the Upper Glen Rose Limestone contain evaporates.

Studies of structures along the Balcones Fault Zone (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 displacement from one fault to an adjacent fault (Collins 1995). Faulting along the BFZ plays a significant role in the development of the Edwards and Trinity Aquifers.

3 Methodology

Most aquifer studies rely on data that are obtained from wells that penetrate large sections of an aquifer, or multiple aquifers, or from wells with very limited completion intervals. Monitoring of many discrete intervals is needed to provide data

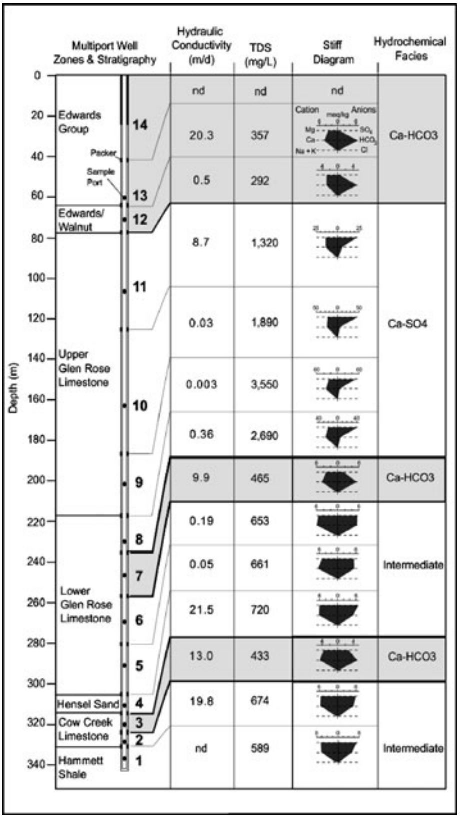

Fig. 3 Construction diagram of multiport monitor well with stratigraphy, hydraulic conductivity data, geochemical data, and hydrochemical facies

that reflect the true complexity of most aquifers. To address these issues, a multiport well, using material manufactured by Westbay Instruments, Inc. (Schlumberger), was installed with 14 discrete monitoring zones in the Edwards, Upper Trinity, and Middle Trinity Aquifers (Figs. 2 and 3). The multiport system used in this study allows potentiometric and hydraulic conductivity measurements and groundwater sample collection from 14 discrete zones within a single borehole. A 12-cm diameter borehole was drilled to a depth of 340 m and equipped with permanent packers to isolate the 14 zones into separate hydrostratigraphic units of the Edwards and Trinity Aquifers. The average thickness of the multiport zones in the well is 22 m with the thickest zone at 60 m and the thinnest zone at 8 m (Fig. 3).

4 Results

Potentiometric data were collected over a 22-month period in all 14 zones in the multiport well (Fig. 4). The region was experiencing severe drought conditions during the first 20 months of data collection. Hydraulic heads in the uppermost five

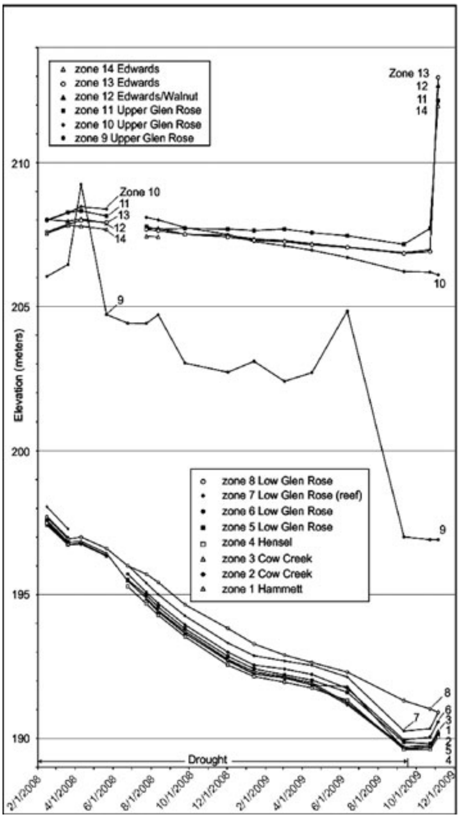

Fig. 4 Potentiometric head data from multiport monitor well

zones were up to 22 m higher than hydraulic heads in the lowermost eight zones. Potentiometric data indicate a potential for flow from the upper zones consisting of Edwards and Upper Trinity units toward the lower zones composed of Middle Trinity units.

Groundwater samples collected from the multiport well in June 2009 were analyzed for total dissolved solids (TDS), major anions and cations, and certain metals. A summary of the results of these analyses are presented in Fig. 3. A review of select cation and anion concentrations shows that the samples can be divided into three distinct groupings (hydrochemical facies): Ca–HCO_3, Ca–SO_4, and an intermediate facies.

5 Interpretation

Differences in hydraulic head values show that there is a potential for flow between the various aquifer units, but pathways are needed for flow to actually take place. Considering that there are many low permeability beds in the upper and lower members of the Glen Rose Limestone (Ashworth 1983), vertical flow would likely occur only through faults and fractures. Declining heads in the Middle Trinity zones throughout most of the study period suggests a hydrologic regime that is well connected to a source area. The most likely recharge areas for the Middle Trinity Aquifer are about 25 km to the west of the multiport well where these units are exposed at the surface.

Significant geochemical differences between monitoring zones provide additional evidence that there is virtually no vertical flow through the formations. Hydraulic head values and geochemistry suggest that any flow along faults in this area is very limited.

Groundwater samples with the highest values of TDS and sulfate are associated with low permeability units of limestone, dolomite, marl, and shale with evaporites. Groundwater samples dominated by calcium and bicarbonate are associated with high permeability units of limestone and dolomite with few evaporites, if any. Samples with intermediate values of calcium and sulfate are associated with units with varied permeabilities that are predominantly limestone, dolomite, sand, silt, and shale.

Where fault displacement is greater than the thickness of high permeability units, flow through the units can be cut off if low permeability units are juxtaposed against high permeability units. However, many of these faults are relay-ramp structures that start at a point with no displacement then increase in displacement over the strike of the fault. Therefore, there is considerable lateral continuity of permeable units, even though some portions of the permeable units may be entirely offset by faults.

6 Conclusions

Significant differences in head and geochemical values suggest that there is little vertical flow between zones in the vicinity of the multiport well. The large differences in geochemical values between zones and the presence of distinct hydrochemical facies suggest that flow along faults in this area is small compared to horizontal flow in each zone. Extensive faulting associated with the BFZ might suggest that lateral flow would be fairly limited due to offsetting of permeable beds, however the presence of relay ramps between faults indicates that there is considerable lateral continuity of permeable beds.

Potentiometric, structural, and geochemical data support the interpretation that groundwater encountered in the permeable zones of the Middle Trinity is influenced more by lateral flow though distinct lithologies rather than flow along faults. Karst processes have affected these deep limestones by solutionally enlarging fractures and bedding planes.

References

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