July 2021 Potentiometric Surfaces of the Lower and Middle Trinity Aquifers in Southwestern Hays County, Texas

Hays Trinity Groundwater Conservation District

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HTGCD Technical Report 2022-0107

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Cover photos: Top: HTGCD and CTGCD staff taking water quality data (Photo by Robin Gary of WVWA); Bottom left: H.L. Saur of CTGCD taking water level measurement; Bottom right: Shane Heath of HTGCD taking water quality data at Red Corral Ranch

July 2021 Potentiometric Surfaces of the Lower and Middle Trinity Aquifers in Southwestern Hays County, Texas

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Introduction

In the western portion of Hays County and northeastern Comal County, residents depend on the Lower and Middle Trinity Aquifers as their water sources. Water from these two aquifers is used for domestic and agricultural purposes for a rapidly expanding population. According to the United States Census Bureau, Hays County ranked second for all counties in the nation in percent growth from 2010 to 2019 (USCB 2020). The development of data into science is critical for the coordinated management of water resources in both aquifers.

The Lower Trinity and Middle Trinity Aquifer potentiometric surface maps presented in this report are indices for aquifer health and characterize Trinity Aquifer flow regimes in-depth. The maps provided are compared to previous studies, such as Davidson (2008), Watson et al. (2014), and Hunt et al. (2019), and will be valuable timestamps for future studies. Additionally, basic water chemistry data were collected for both aquifers during this study and are discussed in this report.

The study area centers on the Hays Trinity Groundwater Conservation District's (HTGCD) Regional Recharge Study Zone (RRSZ), located near the western-southwestern boundary of Hays County within the Blanco River and Cypress Creek watersheds (Gary et al. 2019). HTGCD Rule 16 defined the RRSZ in rule and was made effective on January 1, 2020, and outlines the need for more data to further our understanding of the hydrogeologic system (HTGCD, 2020). Some objectives in the RRSZ include increased monitoring of the Middle and Lower Trinity Aquifers and furthering our knowledge of the water availability of these aquifers. Additional data were collected in the Jacob's Well Groundwater Management Zone (JWGMZ) and the adjacent northern section of Comal County's Comal Trinity Groundwater Conservation District (CTGCD). Well visits were performed from July 12 to August 5, 2021.

Regional Geology and Hydrogeology

The Middle Trinity Aquifer is composed of, from youngest to oldest, the Lower Glen Rose, Hensel, Cow Creek, and Hammett Shale Formations. The study area primarily consists of Lower Glen Rose Limestone surface outcrops due to the regional uplifted by the updip and downdip faults and the Blanco River and Cypress Creek incisions and their tributaries (Figure 1). The Upper Glen Rose Limestone is at the surface at higher surface elevations along the watershed divides. The Hensel and Cow Creek Limestone are only exposed along a small portion of the Blanco River upstream of Pleasant Valley Spring (PVS). The Hammett Shale underlies the Cow Creek and acts as an aquitard separating the Middle Trinity and the older Lower Trinity Aquifers. The Trinity Group rock formations in the area generally have a low slope dip to the southeast and may strongly influence the direction of groundwater flow (Wierman et al., 2010). A stratigraphic column of these units is shown in Figure 2.

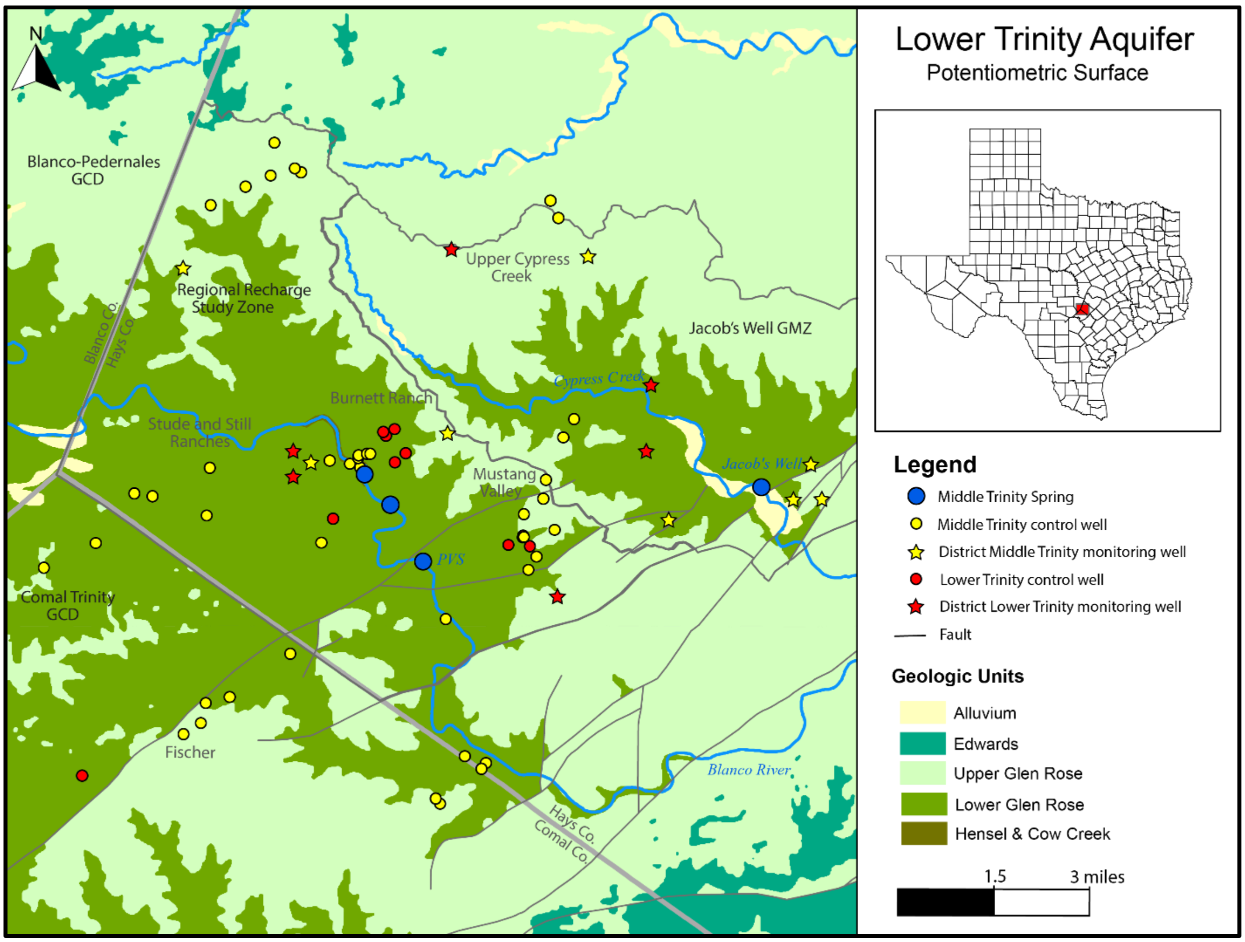

Figure 1. Geologic map of the study area in southwestern Hays County, Texas. Faults and geologic units from BEG (2014).

The Lower Glen Rose Limestone is approximately 250 ft thick and consists of alternating fossiliferous limestone and dolostone facies. It is a karstic formation containing caverns allowing for rapid recharge and groundwater flow. Storage and production are most prominent in the lower and upper rudist patch reef facies. The Hensel is about 35 ft thick and has semi-confining properties due to its shaley dolomitic composition (Wierman et al. 2010).

The Cow Creek limestone, about 75 ft thick, contains three major Middle Trinity springs along a stretch of the Blanco River and Jacob's Well Spring to the east where Cypress Creek baseflow originates (Wierman et al. 2010; Gary et al. 2019). The Cow Creek is considered the most productive water-bearing zone of the Middle Trinity Aquifer (Wierman et al. 2010), evidenced by most wells targeting the Middle Trinity producing from the Cow Creek Formation. Little Park Spring is where the Hensel and Cow Creek limestone crop out and is the most upstream spring of the three. Just downstream is Park Spring is Pleasant Valley Spring. Pleasant Valley Spring (PVS) is the largest Trinity Aquifer spring and marks the boundary between a perennially flowing section of the Blanco River downstream and losing/gaining stretches upstream (Watson et al. 2014).

The Sligo Formation is a carbonate unit that underlies the confining Hammett Shale and is the uppermost unit of the Lower Trinity Aquifer. Below the Sligo is the Hosston Sand. It is a combination of conglomerate, sandstone, and claystone beds composed of erosion of the Llano Uplift (Stricklin et al. 1971). These two units are not as karstified as the Middle Trinity rocks, and the units of the Lower Trinity Aquifer do not crop out within the study area.

Faults and fractures associated with the Balcones Fault Zone (BFZ) are common within the study area. These Miocene-age, predominantly normal faults and associated joints and fractures provide some of the most permeable parts of the Trinity aquifer (Wierman et al. 2010). Groundwater can bypass impermeable units via joints and fractures. Over time groundwater will dissolve the carbonate host rock, enhancing these fractures and joints, promoting increased groundwater flow.

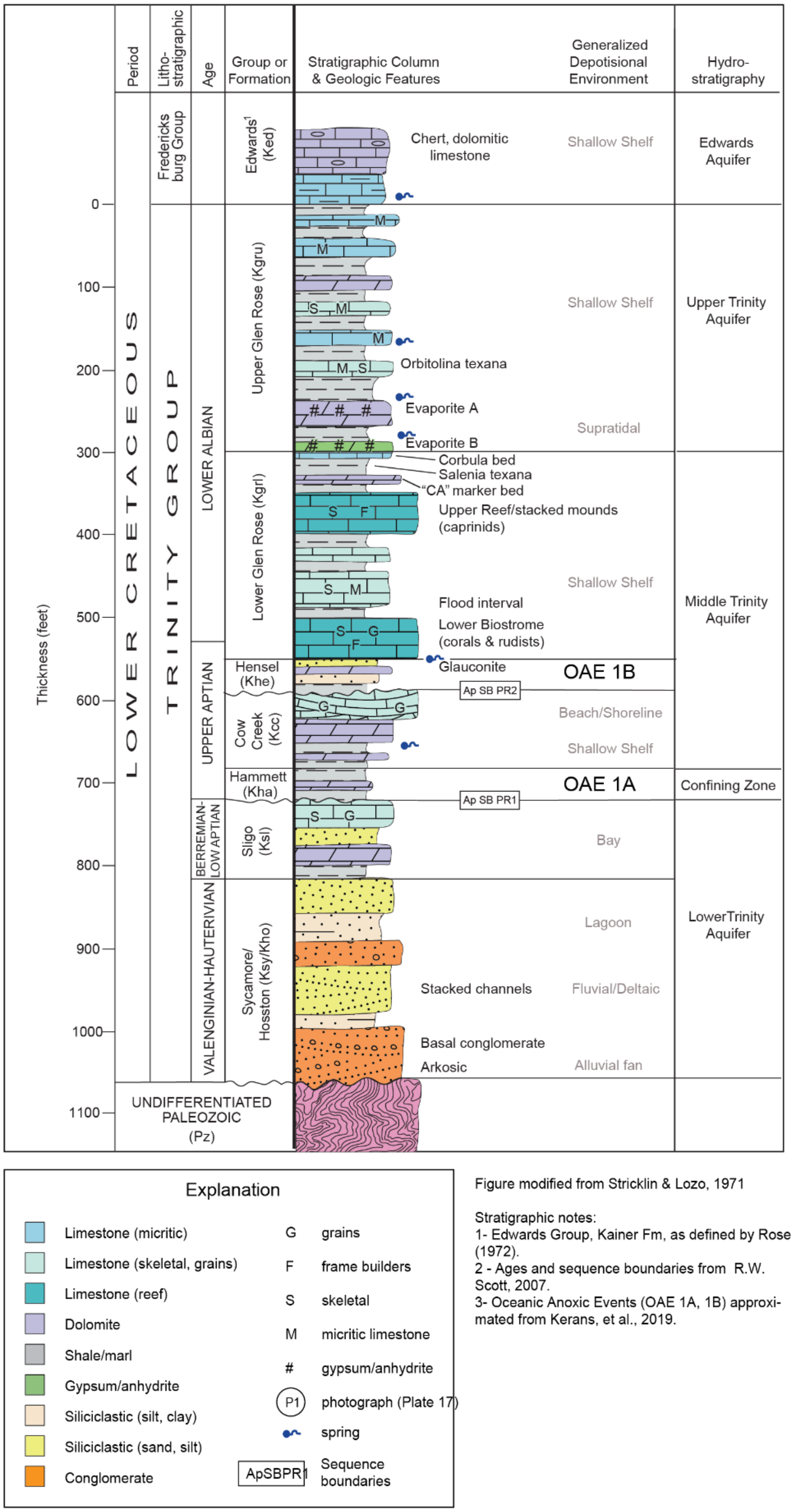

Figure 2. Stratigraphic column containing the Trinity Group. From Hunt et al. (2019).

Hydrologic Conditions

During the data collection period of July 12th – August 5th, the study area received 0.64 inches of rain. The area also received a generous amount of rain on July 9th, with 1.57 inches total at the Wimberley 1 NW, TX US NOAA weather station (NOAA 2021a). According to the Palmer Drought Severity Index, this area was classified as severe drought in January 2021 and shifted to very moist conditions during July 2021.

Multiple wells were measured at the beginning and after well visits to document conditions throughout the synoptic event (Table 1). Overall, these show less than +/- 3 feet of change over the study period, indicating stable conditions despite rain events. Several wells showed more significant swings (McMeans and Lost Springs Ranch in Table 1); these variations were considered when developing the potentiometric surface maps.

Table 1. Water elevation data collected before and after the synoptic event.

Well	Aquifer	7/15/2021	8/19/2021	Change
Byrum Dry Cypress	Lower	892.8	890.9	-1.9
McMeans	Lower	880.7	887.7	7.0
Roberts	Lower	957.3	958.4	1.1
Still Well #1 - WH	Lower	996.0	996.0	0.0
Lost Springs Ranch Telemetry	Lower	249.8	249.3	-0.5
High Gate Ranch Toenail	Middle	1007.0	1004.4	-2.6
Lost Springs Ranch	Middle	952.4	959.5	7.1
Still Well #4 - 1st WM	Middle	1022.0	1020.8	-1.2
ESD	Middle	283.6	283.3	-0.3

Methods

Water level measurements were primarily taken from privately owned domestic wells in the Hill Country Ranches, Burnett Ranch, Mustang Valley, Ledgerock, Fischer in Comal County, and other nearby areas within and surrounding the study area. Additional data was collected from HTGCD permittees and monitoring sites. Measurements were during a four-week period and included wells completed in the Lower Trinity Aquifer and Middle Trinity Aquifer. Overall, 53 measurements were used for the Middle Trinity potentiometric map and 18 for the Lower Trinity potentiometric map. Some water levels from Public Water Supply wells were heavily influenced by pumping and were omitted when constructing contours because they were too dissimilar from nearby wells completed in the same aquifer. Staff members from HTGCD, Wimberley Valley Watershed Association (WVWA), and Comal Trinity Groundwater Conservation District (CTGCD) aided in collecting water levels and water quality data.

A manual electric line (e-line) depth-finder was used for a majority of the water levels as they are typically the most accurate tool for measurements with an error of ± 0.01 feet. When it was not possible to use an e-line for a measurement, a sonic meter was used to detect the water level in the well. Sonic meters have an accuracy of ± 2 feet when well construction allows accurate readings.

Since the measuring point (MP) of each well was usually not at the land surface, the MP height above the land surface was recorded to subtract from the depth to water measured with the e-line or sonic, which allowed us to obtain the depth to water from the surface elevation and then subtract that depth from the surface elevation to get a water level elevation at each well. Coordinates of each well were taken with an iPhone, and USGS NED DEM (United States Geological Survey National Elevation Dataset Digital Elevation model) was used to find the surface elevation at each well site. The USGS NED DEM has a root mean squared error vertical accuracy of 8-feet, with more vertical accuracy the flatter the land (Gesch, 2007). In total, the error for each measurement, depending on the instrument used, is about 8-10 feet.

ArcMap 10.8.1 was used to plot the data and create the contour maps. Water level elevations were used for the Simple Kriging method from the Geostatistical Wizard component of the Geostatistical Analyst extension to make an initial interpolation of the data. The kriging maps were then converted to grids using the GA Layer to Grid tool. Next, contours were created using the Contour Spatial Analyst tool. Contours were adjusted and finalized in Adobe Illustrator. When finalizing the potentiometric surface map, well construction, previous studies, and geologic factors were all considered.

A HANNA Multiparameter Water Quality Meter was used to collect basic water quality data at wells. A water sample was taken from the nearest spigot that produced untreated well water. The HANNA instrument was inserted into the sample, and temperature, pH, conductivity, dissolved oxygen, and total dissolved solids (TDS) levels were recorded for the sample. When sampling, the pump was run until the field parameters stabilized, ensuring a representative sample of the aquifer. TDS measurements were not lab tested. TDS was calculated by taking the conductivity reading from the water quality meter and multiplying it by a correction factor of 0.64. Nitrates and nitrites were also tested using sample testing strips.

Results

Well data, including water level elevations and TDS, for all Middle Trinity wells, are shown in Appendix A and Lower Trinity wells in Appendix B. The producing formation(s) are noted where sufficient data were available.

Figures 3 and 4 are the potentiometric surface contour maps for the Middle Trinity Aquifer and Lower Trinity Aquifer. Some differences in water elevations will be due to wells having different producing formations, which was generally not an issue but was considered when making the final edits to the potentiometric maps. The hydraulic head of the different formations of the Middle and Lower Trinity Aquifers were assumed to be the same where no assessment could be made.

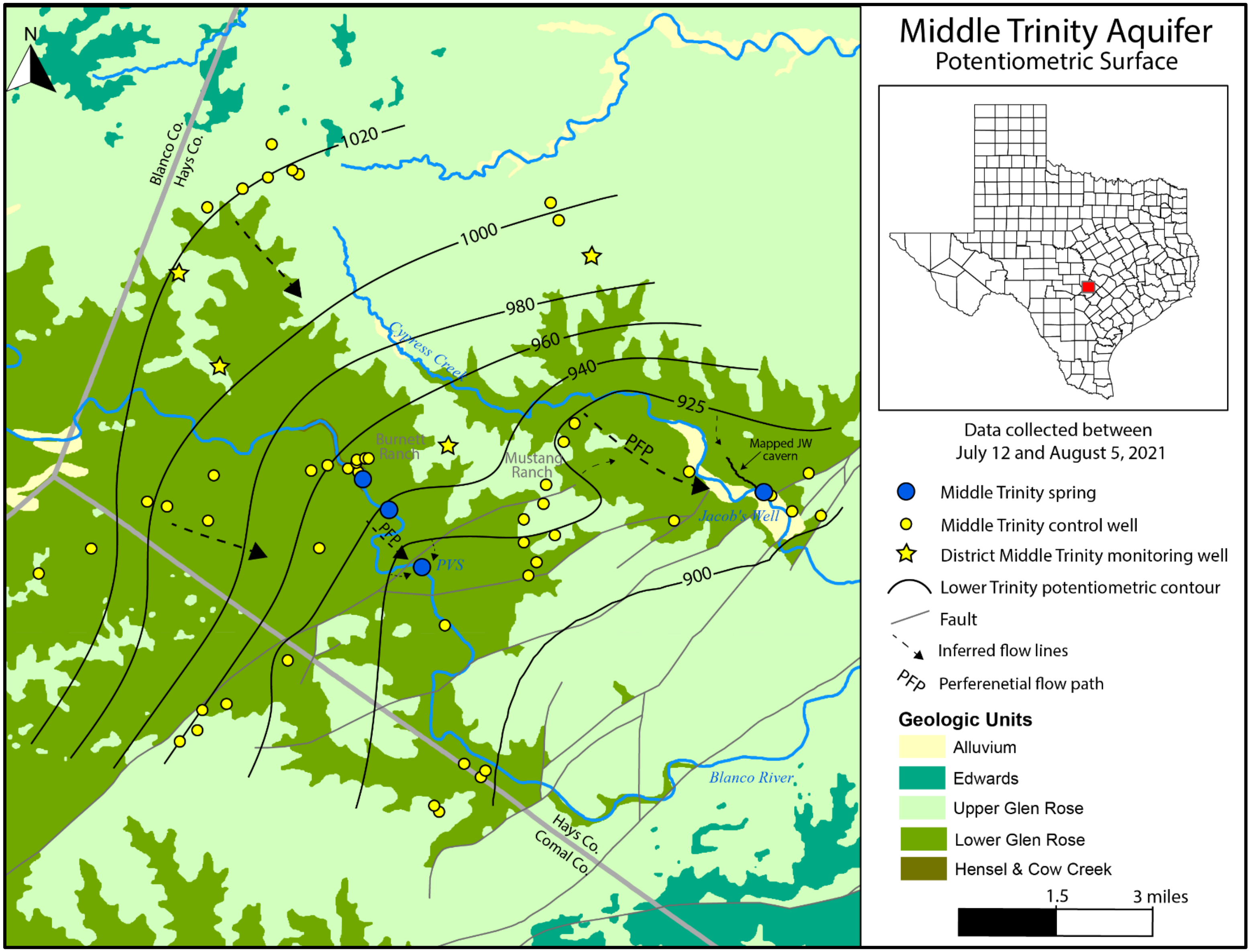

Figure 3. Middle Trinity Aquifer potentiometric surface map. Faults and geologic units from BEG (2014).

Discussion

Middle Trinity Aquifer

The July 2021 Middle Trinity potentiometric map (Figure 3) shows a general trend of groundwater flow from the northwest to the southeast. Groundwater flow generally follows the dip and structure of the Middle Trinity units. The map indicates groundwater entering the RRSZ predominantly from Blanco County. Groundwater contributing to the Cypress Creek watershed flows from the north and continues downdip towards Jacob's Well. Groundwater that does not discharge at Jacob's Well Spring (JWS) or Pleasant Valley Spring (PVS) continues downdip across the faults towards the southeast. As flow approaches the BFZ, contour spacing tightens, and the gradient steepens, as seen in the 2014 and 2018 potentiometric maps. Steeper gradients reveal that BFZ faults act as low-flow boundaries downdip of the study area (Watson et al. 2014; Hunt et al. 2019).

Geologic and hydrologic factors can cause deviations from the generalized flow direction (e.g., facies change, faults, recharge, springs, etc.), some exemplified in the Middle Trinity Aquifer potentiometric surface map. A notable potentiometric trough is observed updip of JWS along the 925-ft contour line and described as a preferential flow path towards JWS. Another smaller trough is likely present upstream of PVS. A higher concentration of water level data around PVS is needed to delineate the extent of the trough. Also, along the 925-ft contour line updip from JWS, a potentiometric ridge separates the two spring troughs. The ridge suggests the presence of a groundwater divide that diverts the water to either flow towards JWS or PVS. The updip extent of the groundwater divide is uncertain; additional water level data in this area are needed.

The hydraulic head above the top of the Cow Creek is mapped to assess spatial influences on the head above Cow Creek thickness (Figure 4A). The map was developed by computing the difference between a raster surface of the Cow Creek Formation and the raster surface of the Middle Trinity water elevations. Water levels below the top of the Cow Creek would be zero or negative values and indicate an unconfined setting. Water levels above the Cow Creek surface are positive values and indicate a confined setting. Since wells are generally completed in both the Cow Creek and Lower Glen Rose, unconfined conditions also indicate the absence of water in the Lower Glen Rose. The Burnett Ranches neighborhood shows unconfined conditions for the Middle Trinity Aquifer surrounding the Blanco River's outcropping Hensel and Cow Creek Formations. The delineated unconfined region's area will recede and expand depending on the hydrologic conditions. Like Little Park Spring (LPS), within the unconfined area, Springs will only flow during wet enough conditions that allow the Cow Creek's water elevation to rise above the ground. The head above the Cow Creek increases at a similar rate as the top of Cow Creek decreases, indicating the stratigraphic dip of the Cow Creek is a more dominant control on flow than geologic structures such as faults and fractures within the study area. The rate of the increasing head above the Cow Creek across the faults increases along strike towards Wimberley as throw increases.

Despite differing hydrologic conditions, general groundwater flow directions and significant features of the potentiometric surface map are similar to previous studies (e.g., Davidson 2008; Watson et al. 2014; Hunt et al. 2019). The similarity to previous studies indicates a consistency of the troughs and ridge and flow regimes across the varying hydrologic conditions. A brief review of water elevations over time is discussed in the "Water Elevations Over Time" section. As more wells target the Middle Trinity Aquifer or during more severe drought conditions, the troughs and groundwater divide may shift, affecting the springshed area and, therefore, the springflow of JWS and PVS and the general groundwater flow regimes. Continued monitoring and additional studies in the future will help track the movement of these features.

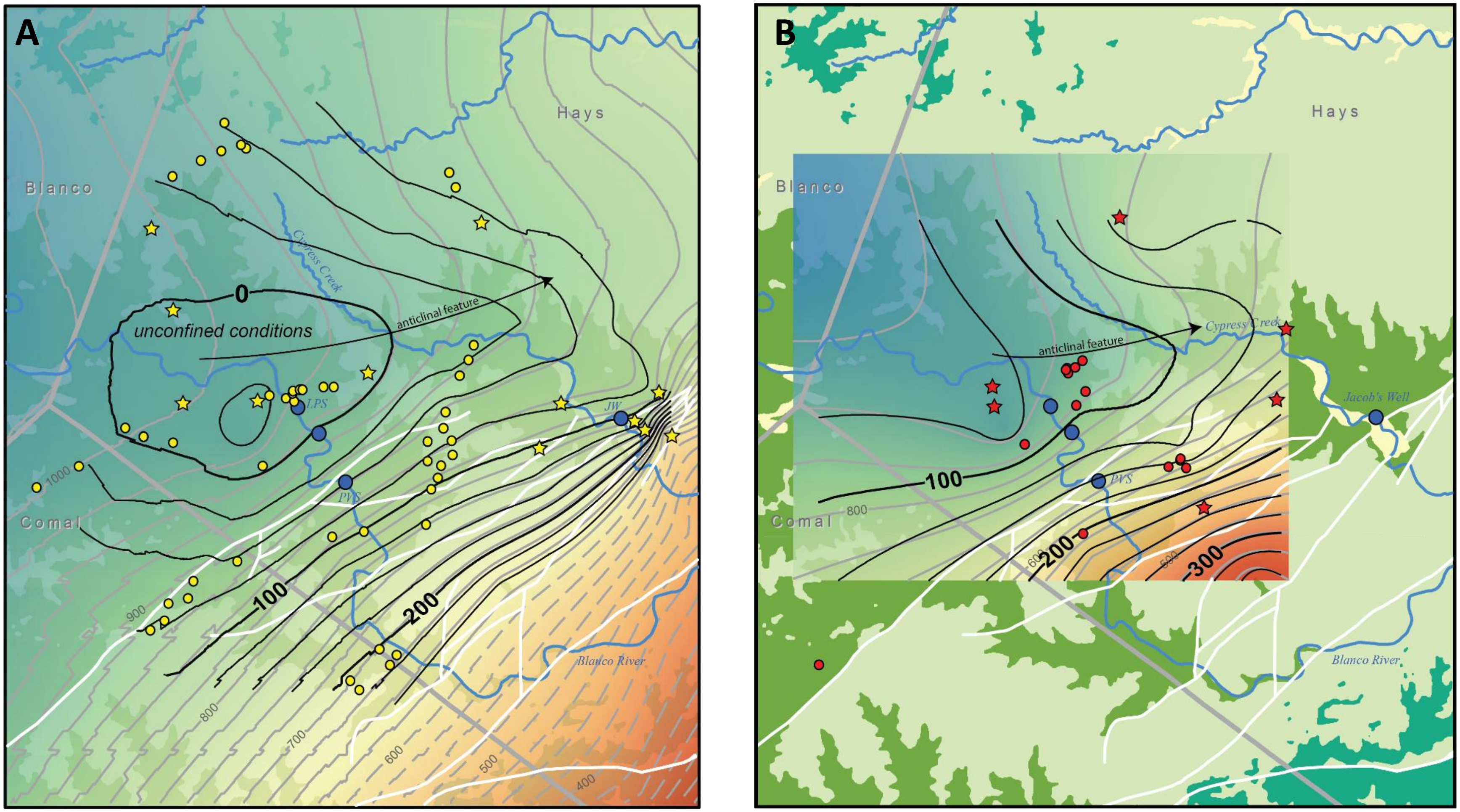

Figure 4. Feet of hydraulic head above the top of the Cow Creek Formation (A) and Sligo Formation (B). Shaded gradient (blue indicating higher, red indicating lower) with grey contours represents top of Cow Creek (A) and top of Sligo (B) and white lines representing faults. Arrow indicates anticlinal structure. All water elevation data collected between July 12 and August 5, 2021. Faults and geologic units from BEG (2014).

Lower Trinity Aquifer

The July 2021 Lower Trinity potentiometric map shows a general trend of groundwater flow from the northwest to the southeast (Figure 5). Like the Middle Trinity, groundwater flow generally follows the dip of the Lower Trinity units.

Water elevation contours near the Burnett Ranch and Mustang Valley neighborhoods show a steeper gradient and tightening of contours relative to Cypress Creek and Blanco watershed regions (Figure 5). The tightening of contours may be due to faults offsetting the aquifer units and a higher concentration of wells in these two neighborhoods, influencing the hydraulic head gradient. Unlike the Middle Trinity, the Lower Trinity has no significant surficial recharge features or springs in the study area. Instead, the Mustang Valley depression and dip of the aquifer units are the predominant factors influencing the flow regimes depicted in the potentiometric map.

There is a high concentration of wells throughout these two neighborhoods. The 860 and 880-ft contours show a depression around the Mustang Valley neighborhood, most likely because of a high concentration of Lower Trinity wells and being just downdip of the faults (Figure 5). More data is needed to delineate the downdip extent of the depression. The depression will likely only increase over time as groundwater use continues and more wells target the Lower Trinity.

The head above the Sligo showed a similar spatial pattern as the Cow Creek Formation (Figure 4). The map was developed by computing the difference between a raster surface of the top of the Sligo Formation and a raster surface of the Lower Trinity water elevations. Due to only a few geophysical logs deep enough to identify the Sligo, logs identifying the Cow Creek and Hammett were used with a general thickness to estimate the Sligo top. Like the Cow Creek, the head above the Sligo increases at a similar rate as the rate at which the top of Sligo decreases, indicating that the faults within the study area do not significantly influence groundwater flow. Since few wells are producing from the Lower Trinity Aquifer downdip of the Wimberley Fault, assessing the influence of the faults further downdip on water elevation is limited. The anticlinal feature plunging into the Cypress Creek watershed may influence saturated thickness, allowing for a local higher head above the aquifer surrounding the anticline's structural axis (Figure 4B).

A more regional Lower Trinty Aquifer syntopic event was done in February 2009, covering parts of Blanco and Travis County and most of HTGCD (Weirman et al., 2011). The previous potentiometric surface map showed a similar generalized flow direction but did not include the depression surrounding the Mustang Ranch neighborhood; the depression most likely formed after 2009 since many wells were drilled after 2009.

It should be noted that the Lower Trinity is much deeper (cost more to drill), often yields a lower production, and has a much higher TDS value (exceeds the EPA standards in the study area) compared to the Middle Trinity. Indicating the Lower Trinity is only targeted when the Middle Trinity is not producing enough water, which may drive future wells to target the Lower Trinity.

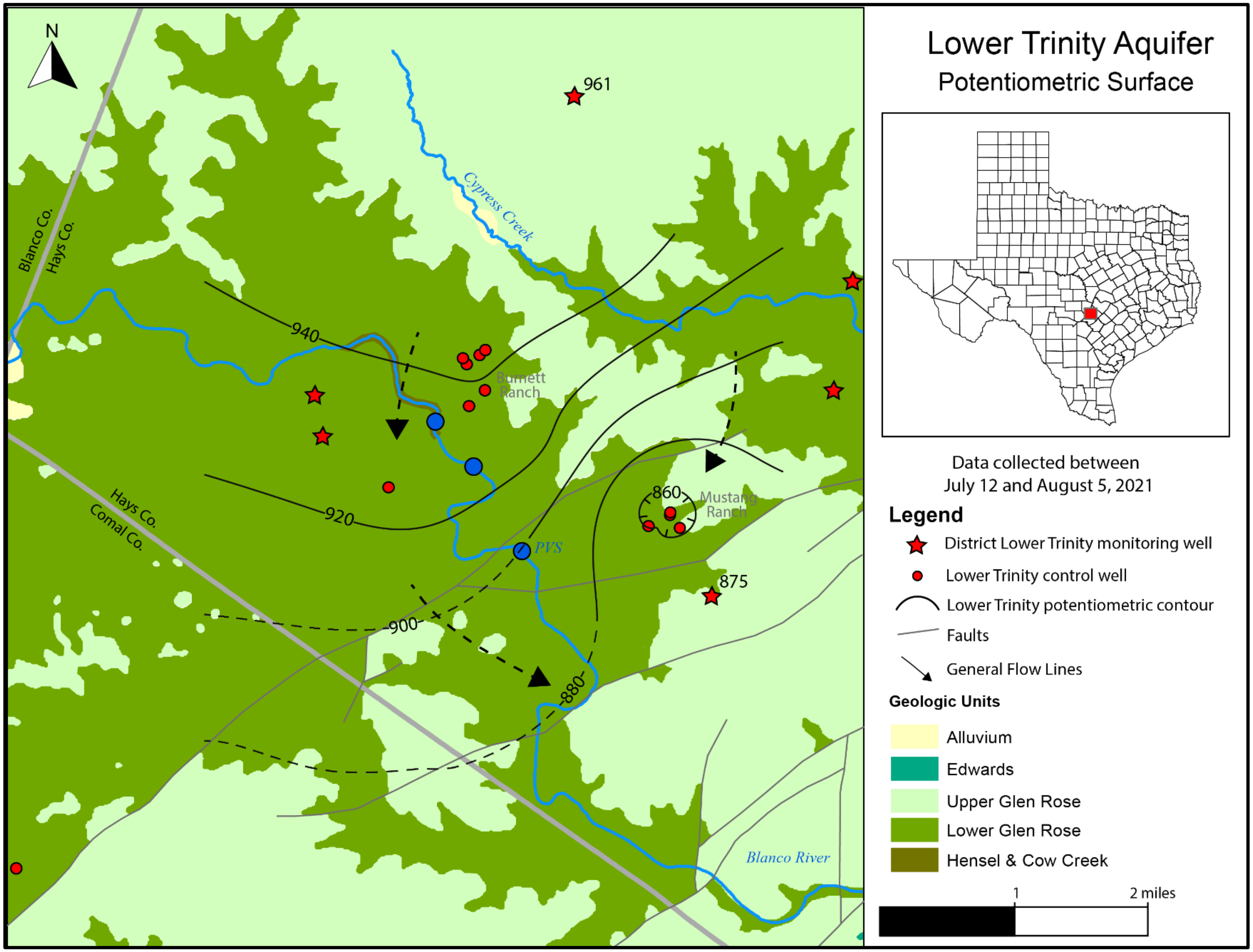

Figure 5. Lower Trinity Aquifer potentiometric surface map. Furthest updip and downdip control points labeled. Faults and geologic units from BEG (2014).

Water Quality

Total dissolved solids (TDS) were calculated from field conductivity measurements using a correction factor of 0.64 (table of results located in Appendix A and Appendix B). Since TDS values were not determined in a lab, a generalized comparison is made between the aquifers, and spatial trends are assessed for both aquifers.

The most prominent trend identified from the water quality data is the difference in TDS measurements between Middle Trinity and Lower Trinity wells. Middle Trinity wells had TDS levels from 230-966 mg/L, and Lower Trinity wells ranged from 1217-3852 mg/L.

The freshwater versus brackish water threshold is commonly defined as a TDS value of 1000 mg/L, water is considered fresh when measurements are below 1000 mg/L, and brackish when they are above 1000 mg/L. TDS values for water samples from Middle Trinity wells indicate freshwater. TDS values for the Lower Trinity wells indicate more brackish or salty water. These results are consistent with previous studies (Wierman et al., 2011) that attribute high TDS values measured in the Lower Trinity Aquifer due to a longer residence time and no direct recharge from surface water and lower TDS values measured in the Middle Trinity Aquifer to direct recharge from the surface through an abundance of Lower Glen Rose and Cow Creek karst features.

Figure 6 shows TDS contour maps of the Middle and Lower Trinity. TDS within the Middle Trinity is highest around the northern boundary of the study area with the lowest values surrounding the Blanco River, signifying recharge along the Blanco River where the Hensel and Cow Creek Formations are exposed to the surface and through losing segment upstream of PVS. TDS values increase downgradient and depth due to the absence of significant recharge features and longer residence time.

The Lower Trinity shows a general trend of increasing TDS from the northeast to the southwest. More data is needed to better represent the spatial distribution of Lower Trinity TDS. Another trend observed is the low TDS areas surrounding the Burnett and Mustang Ranches neighborhoods. The low TDS region may be caused by Middle Trinity water commingling with the Lower Trinity in wells with minimal casing or open completion. Since there is faulting in these areas and the Middle Trinity head is greater than the Lower Trinity head, another possibility is Middle Trinity water leaking into the Lower Trinity via faults or fractures.

Two Lower Trinity wells had TDS values in the 300s and were excluded from the Lower Trinity TDS range given. The well construction reports for these two wells indicate they were completed in the Lower Trinity aquifer, so the cause for low TDS values is uncertain but may be due to commingling with the fresher water in the Middle Trinity. The water levels for these wells were consistent with other nearby Lower Trinity wells, but their TDS values were more similar to Middle Trinity wells.

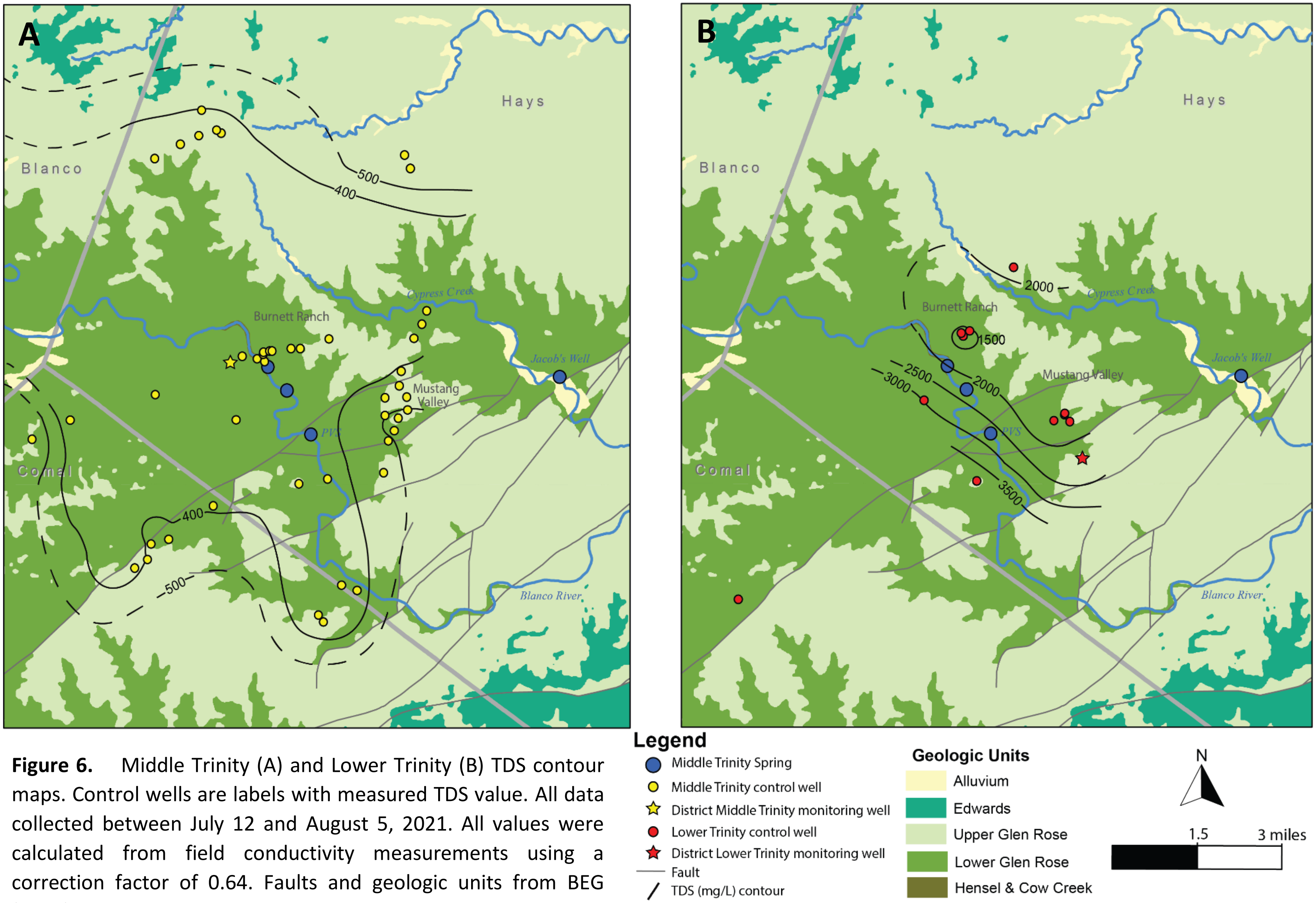

Figure 6. Middle Trinity (A) and Lower Trinity (B) TDS contour maps. Control wells are labels with measured TDS value. All data collected between July 12 and August 5, 2021. All values were calculated from field conductivity measurements using a correction factor of 0.64. Faults and geologic units from BEG (2014).

Communication Between Aquifers

Relationships between the aquifers can be evaluated with water elevations from the Lower and Middle Trinity Aquifers. In all cases, the hydraulic head of the Middle Trinity was higher than the Lower Trinity, and, except where noted, aquifer conditions are confining. Hydraulic head comparisons are limited to the Burnett Ranch and Mustang Valley neighborhoods due to the limited Lower Trinity data. The Middle Trinity heads were about 15-20 feet higher throughout the Burnett Ranch subdivision, while the Mustang Valley subdivision was about 50-60 feet higher. The increased difference is attributable to the overlapping of the Middle Trinity ridge and Lower Trinity depression as seen in the potentiometric maps, faulting between the two regions, and the unconfined conditions in the Burnett Ranch neighborhood.

Regionally, water level elevations suggest that the Middle and Lower Trinity Aquifers act independently throughout the study area. The Hammett Shale, which separates the two aquifer systems, is an effective confining layer. More data needs to be collected to assess if near faulting Middle Trinity groundwater leaks into the Lower Trinity Aquifer.

Water Elevations over Time

Both synoptic water level collection efforts and monitor wells with continuous measurements help track changes in water elevations over time. Water elevations were compared to previous studies and grouped by area (Table 2 and Figure 7). Areas are labeled in Figure 1. Most areas only have 3 data points collected during July 2013, April 2018, and July 2021, so only long-term trends can be considered. In all areas except the Stude/Still Ranches, water levels increased from 2013 – 2018 and declined from 2018 – 2021. The amount and direction of change in the groundwater may be associated with the region's connectivity to surface water, hydraulic head thickness, and relation to faults. Even though the Burnett Ranch wells saw the least change from 2013 to 2021, groundwater in this region is unconfined and has the least available saturated thickness.

Comparing water levels in regions included in previous studies, west of Burnett Ranch does not appear to have significant differences beyond small changes caused by expected hydrological conditions and seasonal effects (Figure 7). The previous two synoptic events occurred during June-2013 and April-2018; the drought stage for the District at those times was Critical and No Drought. For the current study, the District has been in the Alarm stage for 11 months. Two District monitor wells included in previous studies with continuous data are Still #1 and Still #4 (Figure 8). The Still wells are west of the Burnett Ranch subdivision and produce from the Middle Trinity Aquifer. No decreasing trend in either of these wells has been observed since data collection started, likely due to the Middle Trinity’s connectivity with surface water, high transmissivity in the Cow Creek Formation, and is located away from areas with a high concentration of wells as well as being just downgradient of the losing segment of the Blanco River.

Two Lower Trinity District monitor wells within the study area have continuous data from 2008 (Figure 9). The McMeans well is just south of Mustang Ranch, while the LSR Telemetry is on the western end of Burnett Ranch. Both wells show a higher drawdown over time, about 0.5-feet/year than the two Middle Trinity wells. It should be noted that the depth is not known for the McMeans well, only that the water elevation data collected is more similar to surrounding Lower Trinity wells. The LSR Telemetry appears to be open to both the Middle and Lower Trinity Aquifers, but the water elevation is closer to nearby Lower Trinity wells.

Mustang Ranch has about 125-feet of head above the top of the Lower Trinity. Given the Lower Trinity Aquifer's current drawdown rate of 0.5 ft/yr, it would take about 63-years to draw down the aquifer enough to cause unconfined conditions. Also, the rate of decline will only increase as more wells target the Lower Trinity. The Burnett Ranch neighborhood has about 65-feet of head above the Lower Trinity. Assuming the drawdown rate, Burnett Ranch would have unconfined conditions in nearly 33 years. Confining conditions are crucial as when the aquifer transitions from confined to unconfined conditions, the result will be a decrease in production due to the reduction of saturated thickness and, therefore, transmissivity. Additional monitoring wells are needed within the regions with high concentrations of wells to improve our long-term drawdown estimations.

Table 2. Middle Trinity water elevation differences over time by region. Data from Watson et al. (2014), Hunt et al. (2018), and this report.

Region	6/2014	4/2018	7/2021	2018 - 2014	2021 – 2014
Burnett Ranch	957.9	958.9	955.7	1.0	-2.2
Fischer	948.9	954.0	949.2	5.1	0.3
Ledgerock	921.1	924.5	919.0	3.4	-2.1
Mustang Ranch	928.8	935.9	934.9	7.0	6.1
Stude/Still	999.7	995.8	995.4	-3.9	-4.3
Upper Cypress Creek	990.1	1003.2	1004.0	13.1	13.9

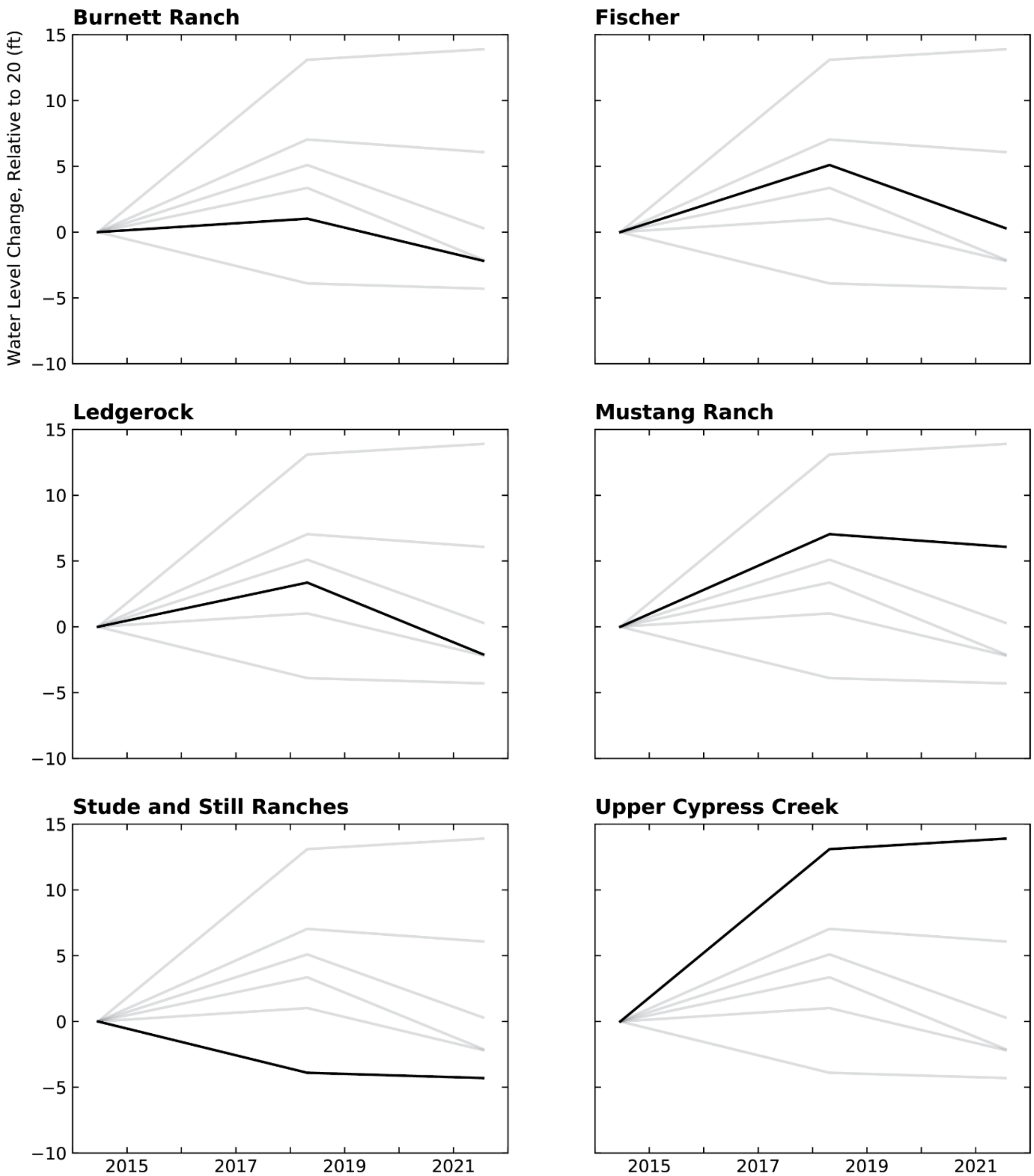

Figure 7. Water elevation changes by region for wells included in previous studies. Black lines represent water average water elevation in titled region in each plot. Middle Trinity Water Elevation changes by area. Data from Watson et al. (2014), Hunt et al. (2018), and this report. Regions are labeled in Figure 1.

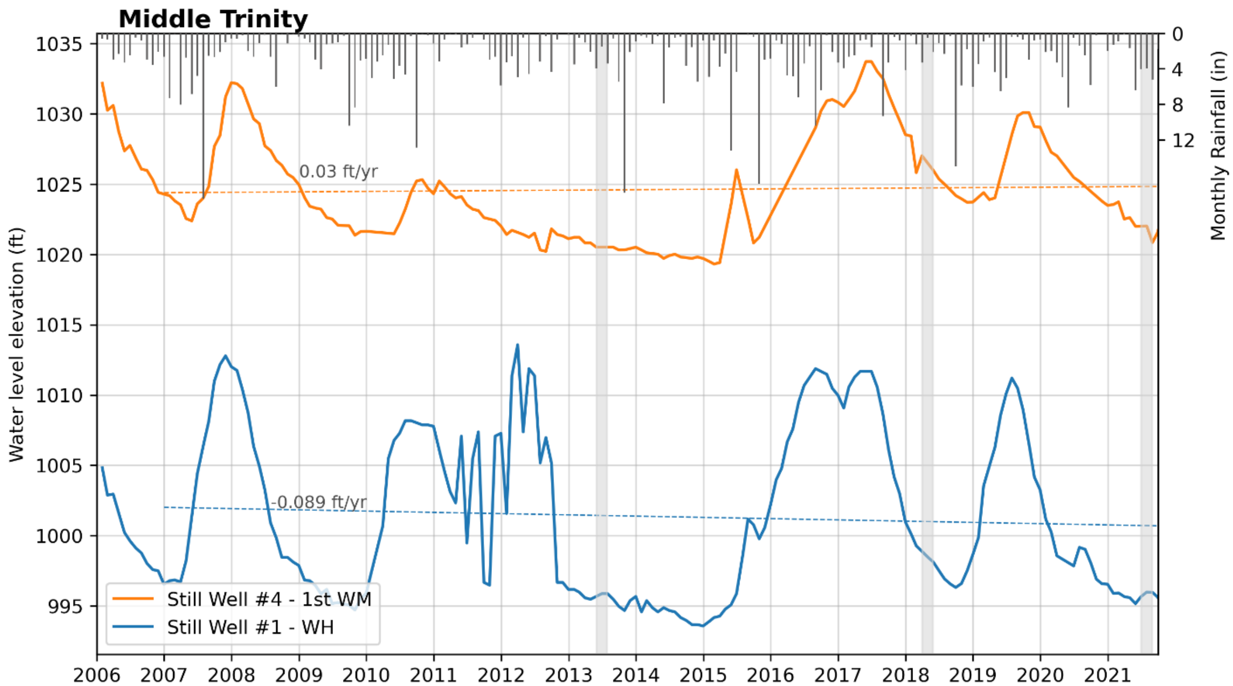

Figure 8. Hydrograph of District Monitor wells Still #1 and #4 with monthly rainfall on the secondary x-axis. Both wells are within the Stude and Still Ranches area. Shaded grey areas represent previous synoptic events (Watson et al., 2013; Hunt at al., 2018) and this report.

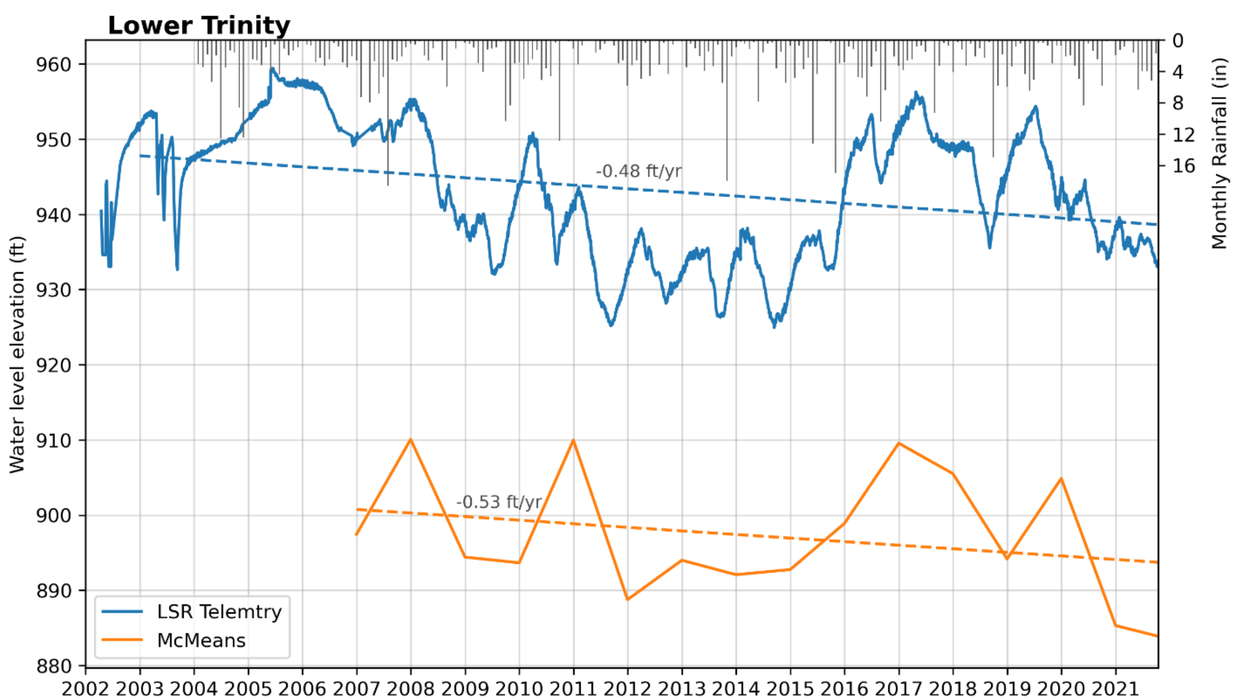

Figure 9. Hydrograph of District monitor wells LSR Telemetry and McMeans with monthly rainfall on the secondary x-axis. The LSR Telemetry is within the Burnett Ranch region and the McMeans well is just south of the Mustang Ranch region.

Conclusion

The July 2021 potentiometric maps for the Middle and Lower Trinity Aquifers provide helpful insights into the current state of groundwater flow paths and water level trends for both aquifers in western Hays County. The Lower Trinity map is the first potentiometric map within the study area at this resolution. Both maps display a general flow towards the Balcones Fault Zone from the northwest to the southeast. Consistent with previous studies, the Middle Trinity potentiometric surface has a significant trough and ridge near Jacob's Well, while the Lower Trinity indicated a depression around the Mustang Ranch development.

Hydraulic head above the Cow Creek top and Sligo top maps were developed to assess spatial trends of the available water column before unconfined conditions. The Cow Creek map showed unconfined conditions surrounding the exposure of Cow Creek within the Blanco River. Both maps indicated the faults within the study area do not have a measurable influence on the groundwater flow. Also, the anticlinal structure plunging into the Cypress Creek watershed coincided with a local effect on the hydraulic head above the Cow Creek.

Conductivity was measured in the field to compare total dissolved solid values across the study area. The Lower Trinity showed a higher (1217-3852 mg/L) TDS than the Middle Trinity (230-966 mg/L) wells. The Middle Trinity showed the lowest TDS values surrounding the Blanco River and the outcropping of the Lower Glen Rose. The Lower Trinity had an increasing trend toward the southwest and the lowest values around the Mustang Ranch and Burnett Ranch neighborhoods.

Water elevations over time indicated a higher drawdown in the Lower Trinity monitoring wells (0.5-ft/yr) compared to the Middle Trinity wells (-0.03-ft/yr). Despite fewer wells, the higher drawdown rate in the Lower Trinity Aquifer is likely due to the aquifer system having a low transmissivity, no known connection with local recharging features, and an increased amount of Lower Trinity wells since the early 2000s.

One of the Regional Recharge Study Zone goals is to increase monitoring and data collection of the Middle and Lower Trinity Aquifers. This study collected 53 Middle Trinity and 18 Lower Trinity water elevations and 46 Middle Trinity and 11 Lower Trinity basic water quality field parameters. The study has also allowed for the assessment of new long-term monitoring wells.

The Lower Trinity will increasingly become a more critical resource as the Middle Trinity continues to be targeted, especially in the Burnett Ranch neighborhood, where the Middle Trinity is already unconfined. Establishing Lower and Middle Trinity water elevation baselines and continuing our monitoring will be vital in understanding and tracking both aquifer's health over time.

Future Research

- The upgradient extent of the Middle Trinity divide between the Blanco River and Cypress Creek watersheds.
- Assess the shifting of the major features of the Middle and Lower Trinity potentiometric map (trough and divides) over changing hydrologic conditions.
- The District needs additional Middle and Lower Trinity monitoring wells in areas with high concentrations of wells to evaluate long-term trends.
- Well construction surveys of existing monitoring wells to ensure accurate determination of producing intervals.
- Additional water elevation and water quality data are needed to characterize the Lower Trinity potentiometric surface map features and geochemical distribution of the aquifer.
- Pumping and drought scenario runs using future BRAAT (Blanco River and Aquifer Assessment Tool) flow model.

Acknowledgments

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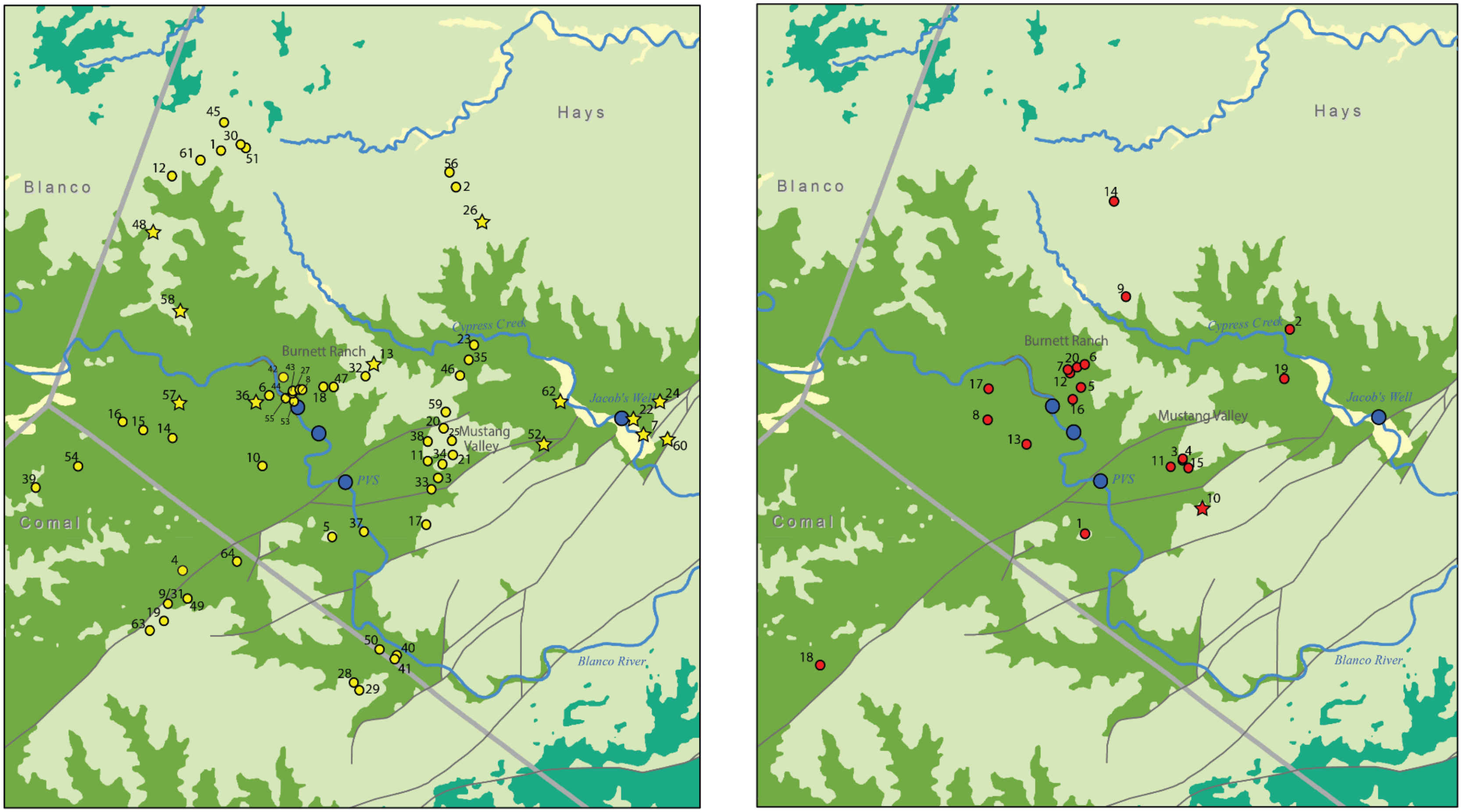
Appendix A. Middle Trinity and Lowe Trinity water elevation and water quality data



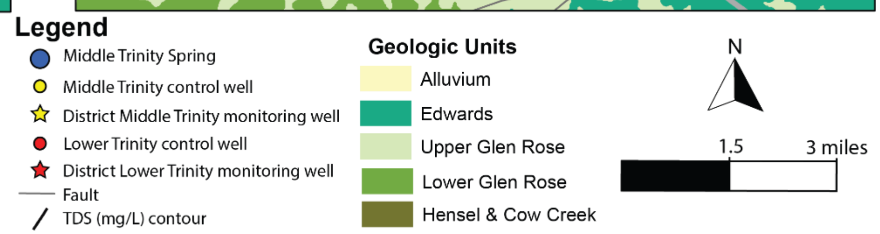


Figure 1. Middle Trinity (A) and Lower Trinity (B) wells visited control points labeled with id that corresponds with Table and 1 and Table 2. Faults and geologic units from BEG (2014).

Table 1. Middle Trinity potentiometric data and TDS for wells used during study (lowest TDS value shown in blue, highest TDS value shown in red – excluding two wells with TDS in 300s).

id	Name	SWN	Well Report Tracking #	Latitude	Longitude	Aquifer	Producing Formation	Surface Elevation (ft-msl)	Measurement Date	Water Level Elevation (ft-msl)	TDS (mg/L)	Notes
1	Archer			30.11039	-98.2456	Middle Trinity		1273	7/27/2021	1020	375	
2	Berry			30.10002	-98.1752	Middle Trinity		1389	7/29/2021	1000	632	
3	Blincow		294563	30.01716	-98.1806	Middle Trinity	LGR, Hensel, Cow Creek	1099	8/3/2021	918	599	
4	Brieger			29.98846	-98.2543	Middle Trinity		1140	7/28/2021		364	
5	Buffington			29.99993	-98.2119	Middle Trinity		1112	8/5/2021		445	
6	Cabler			30.04073	-98.2312	Middle Trinity		1080	7/20/2021	961	282	
7	Camp Young Judaea	5764714		30.02953	-98.1188	Middle Trinity		958	7/15/2021	920		
8	Christian		41640	30.04232	-98.2212	Middle Trinity	LGR, Hensel, Cow Creek	1055	7/22/2021	955	367	
9	Clark			29.98135	-98.2614	Middle Trinity		1139	7/21/2021	958	424	
10	Crow			30.02053	-98.2332	Middle Trinity	LGR, Hensel, Cow Creek	1115	7/20/2021	950	300	
11	Davidson			30.02194	-98.1836	Middle Trinity		1100	8/3/2021	932		
12	Davis			30.10317	-98.2602	Middle Trinity		1274	7/29/2021	1019	484	

id	Name	SWN	Well Report Tracking #	Latitude	Longitude	Aquifer	Producing Formation	Surface Elevation (ft-msl)	Measurement Date	Water Level Elevation (ft-msl)	TDS (mg/L)	Notes
13	Ded. ESD	5763504	488861	30.04613	-98.2023	Middle Trinity	Cow Creek	1237	7/22/2021	954		
14	Dyson - Stude #3			30.02725	-98.2601	Middle Trinity		1120	7/19/2021	993	483	
15	Dyson - Stude Windmill #1			30.03074	-98.27	Middle Trinity		1082	7/19/2021	998		
16	Dyson - Stude Windmill #2			30.03183	-98.2748	Middle Trinity		1092	7/19/2021	1001		
17	Elsey		304162	30.00472	-98.1833	Middle Trinity		1110	8/3/2021		487	
18	Finley		423031	30.04298	-98.2147	Middle Trinity	Cow Creek	1147	8/5/2021		411	
19	Fischer Community Center	6806306	6806306	29.97649	-98.2626	Middle Trinity		1202	7/28/2021	971	402	
20	Fossum		281404	30.03141	-98.179	Middle Trinity		1147	8/5/2021	935	418	
21	Galassini		541827	30.02372	-98.1762	Middle Trinity	Cow Creek	1146	8/3/2021	925		
22	Graham	5764716		30.03333	-98.1239	Middle Trinity		956	7/15/2021	923		
23	Gunnarson			30.05083	-98.1714	Middle Trinity		1117	7/29/2021	919	374	
24	HCP3	5764718		30.03871	-98.1147	Middle Trinity		1040	7/13/2021	922		
25	Hernandez		497461	30.02778	-98.177	Middle Trinity		1158	8/3/2021		454	
26	High Gate Ranch Toenail	5763203		30.09046	-98.1685	Middle Trinity		1293	7/15/2021	1004		
27	Hobbs			30.04239	-98.2221	Middle Trinity		1042	7/20/2021	949	316	
28	Holt			29.95817	-98.2053	Middle Trinity		1046	7/21/2021	912	382	

id	Name	SWN	Well Report Tracking #	Latitude	Longitude	Aquifer	Producing Formation	Surface Elevation (ft-msl)	Measurement Date	Water Level Elevation (ft-msl)	TDS (mg/L)	Notes
29	Holt			29.95671	-98.2042	Middle Trinity		1060	7/21/2021	914		
30	Howard			30.11216	-98.2397	Middle Trinity		1280	7/29/2021	1022	379	
31	Jacob's Well Spring	5763905		30.03449	-98.12614	Middle Trinity	Cow Creek	923		923		Spring
32	Jones		350795	29.9813	-98.2614	Middle Trinity		1138	7/21/2021		966	
33	King			30.04303	-98.2059	Middle Trinity		1215	7/22/2021	1019	364	Sonic reading likely not reliable
34	Klug		234492	30.01395	-98.1825	Middle Trinity	Cow Creek	1060	8/5/2021	917	461	
35	Lendacky		464798	30.02161	-98.1794	Middle Trinity		1132	8/3/2021		523	
36	Little		161520	30.04632	-98.1741	Middle Trinity	Cow creek	1203	7/27/2021	923	373	
37	LSR Water Supply Corp	5763702		30.03936	-98.2352	Middle Trinity		1150	8/4/2021	957	442	
38	Lundgren			30.00195	-98.2028	Middle Trinity		995	8/5/2021	912	363	
39	Menem		506435	30.02762	-98.1836	Middle Trinity	Cow Creek, also LGR/Hensel	1127	8/5/2021	936	574	
40	Nicholson			30.01444	-98.3011	Middle Trinity		1249	7/21/2021	1108	426	
41	Owen			29.96669	-98.193	Middle Trinity		960	7/28/2021	913	369	
42	Owen			29.96506	-98.1941	Middle Trinity		951	7/28/2021	905		

id	Name	SWN	Well Report Tracking #	Latitude	Longitude	Aquifer	Producing Formation	Surface Elevation (ft-msl)	Measurement Date	Water Level Elevation (ft-msl)	TDS (mg/L)	Notes
43	Pixley			30.04363	-98.227	Middle Trinity		1039	7/20/2021		261	
44	Pleasant Valley Spring	5763809		30.01222	-98.20583	Middle Trinity	Cow Creek	923		923		Spring
45	Pope - Cowboy Well	5763402	312566	30.04199	-98.2241	Middle Trinity	LGR, Hensel, Cow Creek	1010	7/20/2021	956	230	
46	Pope - Riverhouse		407575	30.0412	-98.2241	Middle Trinity	Cow Creek	1001	7/20/2021	955	324	
47	Pousson			30.1184	-98.2446	Middle Trinity	LGR, Hensel, Cow Creek	1346	7/29/2021	1017	401	
48	Price			30.04408	-98.1766	Middle Trinity		1196	7/27/2021		365	
49	Ramachandran		222564	30.04245	-98.2123	Middle Trinity		1168	7/22/2021		386	
50	Red Corral Ranch	5762305		30.08686	-98.2663	Middle Trinity		1256	7/15/2021	1016		
51	Roberts			29.98279	-98.2557	Middle Trinity	Cow Creek	1109	8/5/2021	954	755	
52	Rockefeller			29.96832	-98.1981	Middle Trinity		978	7/28/2021	901	378	
53	Sampsel			30.11124	-98.2382	Middle Trinity	LGR, Hensel, Cow Creek	1283	7/27/2021	1015	416	
54	Section 25	5763901		30.0272	-98.1473	Middle Trinity		1039	7/13/2021	922		
55	Smith			30.03907	-98.2237	Middle Trinity		1023	7/22/2021	958	345	
56	Stancliff		551189	30.02049	-98.2884	Middle Trinity	primary LGR, also Hensel and Cow Creek	1165	7/21/2021	1060	389	

id	Name	SWN	Well Report Tracking #	Latitude	Longitude	Aquifer	Producing Formation	Surface Elevation (ft-msl)	Measurement Date	Water Level Elevation (ft-msl)	TDS (mg/L)	Notes
57	Stang			30.0399	-98.2262	Middle Trinity		1026	7/22/2021	951	349	
58	Stewart		511820	30.10429	-98.1772	Middle Trinity	LGR, Hensel, Cow Creek	1367	7/27/2021	995	564	
59	Still #1	5762901		30.03818	-98.2587	Middle Trinity		1075	7/15/2021	992		
60	Still #4	5762602		30.06367	-98.2575	Middle Trinity		1209	7/15/2021	1029		
61	Vallejo			30.03599	-98.1783	Middle Trinity		1179	7/29/2021	932	408	
62	WC Maint 2	5764703		30.02846	-98.1117	Middle Trinity		962	7/13/2021	916		
63	Weinberg			30.10769	-98.2517	Middle Trinity		1305	7/29/2021	1021	363	
64	Woodcreek 23	5763908		30.03908	-98.1437	Middle Trinity		1050	7/13/2021	922		
65	Zlatkovich			29.97375	-98.2669	Middle Trinity		1190	7/28/2021	949	381	
66	Zoboroski			29.99343	-98.2408	Middle Trinity		1140	7/28/2021	936	375	

Table 2. Lower Trinity potentiometric data and TDS for wells used during study (lowest TDS value shown in blue, highest TDS value shown in red – excluding two wells with TDS in 300s).

id	*Name*	*SWN*	*Well Report Tracking #*	*Latitude*	*Longitude*	*Aquifer*	*Producing Formation*	*Surface Elevation (ft-msl)*	*Measurement Date*	*Water Level Elevation (ft-msl)*	*TDS (mg/L)*	*Notes*
1	Buffington		564245	30.00151	-98.2124	Lower Trinity		1112	8/5/2021		3852	
2	Byrum Dry Cypress	5763603	86847	30.05889	-98.1542	Lower Trinity	Hosston	1069	7/15/2021	894		
3	Davidson		556897	30.02229	-98.1838	Lower Trinity	Sligo/Hosston	1100	8/3/2021	844	1799	
4	Davidson			30.02185	-98.1839	Lower Trinity		1100	8/3/2021	859		
5	Finley		92903	30.0425	-98.2144	Lower Trinity	Sligo/Hosston	1155	8/5/2021	938		
6	Livingston - Prima Vista		482381	30.04909	-98.2144	Lower Trinity	Sligo	1136	7/20/2021	942	372	
7	Loschiavo		458031	30.04772	-98.2181	Lower Trinity	Hosston	1096	7/22/2021	937	1435	
8	LSR Telemetry	5763705		30.03486	-98.2411	Lower Trinity		1185	7/22/2021	935		
9	Getaway Austin		523359	30.06882	-98.2003	Lower Trinity	Hosston	1258	7/27/2021	882	2167	Omitted, too much pumping influence
10	McMeans	5763806		30.00804	-98.1767	Lower Trinity		1102	8/10/2021	876		
11	Mozisek		508961	30.02006	-98.1875	Lower Trinity	Hosston	1099	8/3/2021	862	1428	
12	Nesby		474497	30.04671	-98.2174	Lower Trinity	Sligo/Hosston	1068	7/20/2021	940	1217	
13	Regante		421458	30.02644	-98.2304	Lower Trinity	Sligo/Hosston	1078	7/22/2021	911	3000	

id	*Name*	*SWN*	*Well Report Tracking #*	*Latitude*	*Longitude*	*Aquifer*	*Producing Formation*	*Surface Elevation (ft-msl)*	*Measurement Date*	*Water Level Elevation (ft-msl)*	*TDS (mg/L)*	*Notes*
14	Roberts	5763201		30.09064	-98.2014	Lower Trinity		1344	7/15/2021	961		
15	Shadowens		291138	30.01972	-98.1822	Lower Trinity	Sligo/Hosston	1097	8/3/2021	858	1916	
16	Stanovich		575340	30.03985	-98.2171	Lower Trinity	Sligo	1083	7/22/2021	941	323	
17	Still #6	5763706	89794	30.04121	-98.2418	Lower Trinity		1105	8/10/2021	928		
18	Tucker			29.96364	-98.2918	Lower Trinity		1230	7/21/2021	876	2669	
19	WC Arapahoe	5763604	297090	30.04252	-98.1557	Lower Trinity		1090	7/13/2021	887		
20	Wilks		463965	30.04832	-98.2153	Lower Trinity	Hosston	1116	7/20/2021	929	1482	
21	Wimberley Oaks Water Supply Corp			30.00315	-98.1839	Lower Trinity		1095	8/4/2021	745	2312	Omitted, too much pumping influence