HEADWATERS GROUNDWATER CONSERVATION DISTRICT

DISTRICT GROUNDWATER MANAGEMENT PLAN

REVISED DECEMBER 8, 2021

Adopted by the Board of Directors December 8, 2021

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HEADWATERS GROUNDWATER CONSERVATION DISTRICT

Groundwater Management Plan

Kerr County, Texas

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Headwaters Groundwater Conservation District

Groundwater Management Plan – 2022

The Headwaters Groundwater Conservation District (the District) is a governmental agency and a body politic and corporate. The District was created to serve a public use and benefit, and is essential to accomplish the objectives set forth in Section 59, article XVI, of the Texas Constitution[1]. The District's boundaries are coextensive with the boundaries of Kerr County, Texas (the County), and all lands and other property within these boundaries will benefit from the works and projects that will be accomplished by the District.

Basis for and Purpose of Management Plan

The 75th Texas Legislature in 1997 enacted Senate Bill 1[2] (SB 1) to establish a comprehensive statewide water planning process. In particular, SB 1 contained provisions that required groundwater conservation districts to prepare management plans to identify the water supply resources and water demands that will shape the decisions of each district. SB 1 designed the management plans to include management goals for each district to manage and conserve the groundwater resources within their boundaries. SB 1 also renamed previously-designated Critical Areas as Priority Groundwater Management Areas. In 2001, the Texas Legislature Enacted Senate Bill 2[3] (SB 2) to build on the planning requirements of SB 1 and to further clarify the actions necessary for districts to manage and conserve the groundwater resources of the state of Texas. The Texas Legislature enacted significant changes to the management of groundwater resources in Texas with the passage of House Bill 1763[4] (HB 1763) in 2005. HB 1763 created a long-term planning process in which groundwater conservation districts (GCDs) in each groundwater management area (GMA) are required to meet and determine the desired future conditions (DFCs) for

[1] https://texaslegalguide.com/Texas_Constitution:Article_XVI,_Section_59
[2] https://capitol.texas.gov/BillLookup/Text.aspx?LegSess=75R&Bill=SB1
[3] https://capitol.texas.gov/BillLookup/Text.aspx?LegSess=77R&Bill=SB2
[4] https://capitol.texas.gov/BillLookup/Text.aspx?LegSess=79R&Bill=HB1763

the groundwater resources within their boundaries by September 1, 2010. In addition, HB 1763 required GCDs to share management plans with the other GCDs in the GMA for review by the other GCDs. The District's management plan satisfies the requirements of SB 1, SB 2, HB 1763, the statutory requirements of Chapter 36.1071[5] of the Texas Water Code, and the administrative requirements of the Texas Water Development Board's (TWDB) rules in volume 31, Chapter 356[6] of the Texas Administrative Code (TAC).

District Creation and History

Under Article XVI, Section 59, of the Texas Constitution, the District was created by the 72nd Legislature House Bill (HB) 1463[7] and approved by the Governor of Texas on June 16, 1991. The 77th Legislature HB 3543[8] amended the enabling legislation and was approved by the Secretary of State on May 23, 2001. And in accordance with Chapter 36 of the Texas Water Code, by the Act of May 25, 2009, 81st Legislature, Special District Local Laws Code, Title 6. Water and Wastewater, Subtitle H. Districts Governing Groundwater Chapter 8842[9] effective April 1, 2011 this plan is submitted.

District Mission

In accordance with Section 36.0015[10] (b), the mission of the District is to provide for the conservation, preservation, protection, recharging, and prevention of waste of groundwater in the County by developing and implementing rules that protect property rights, balance the conservation and development of groundwater to meet the needs of the County, and use the best available science in the conservation and development of

[5] https://statutes.capitol.texas.gov/Docs/WA/htm/WA.36.htm#36.1071
[6] https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=5&ti=31&pt=10&ch=356&sch=E&rl=Y
[7] https://capitol.texas.gov/BillLookup/History.aspx?LegSess=72R&Bill=HB1463
[8] https://capitol.texas.gov/BillLookup/Text.aspx?LegSess=77R&Bill=HB3543
[9] https://statutes.capitol.texas.gov/Docs/SD/htm/SD.8842.htm
[10] https://statutes.capitol.texas.gov/Docs/WA/htm/WA.36.htm#36.0015

No text available on the Legislature website for HB1463 groundwater. As specified in Section 36.101[11] (a), the District's rules (1) consider all groundwater uses and needs, (2) are fair and impartial, (3) recognize the landowner's ownership of and rights associated with groundwater as described in Section 36.002[12], and (4) consider the public interest in conservation, preservation, and protection of groundwater. To effectuate its purpose, the District is committed to working with citizens, businesses, and other governmental entities to develop, promote, and implement water conservation and management strategies to protect water resources for the benefit of the citizens, economy and environment of the County.

More specifically, the District's Rules supports the availability and accessibility of groundwater for future generations through groundwater production rules and protects the quality of groundwater by adopting rules for water well drilling construction standards and well spacing from potential sources of pollution. The preservation of this most valuable resource will be managed on a local basis in a prudent and cost-effective manner by the District through management, conservation, and public education regarding both. Official action shall be taken by the District only after full consideration and respect has been afforded to the individual property rights of all citizens of the County in groundwater and maintaining groundwater in place.

This management plan is intended as a tool to focus the thoughts and actions of those staff and elected officials who are given the responsibility for the execution of District activities to further the District's management goals, which are described later in this management plan.

Hill Country Priority Groundwater Management Area

Over thirty (30) years ago, the TCEQ's predecessor agency--the Texas Water Commission--designated the "Hill Country Critical Area" that today is known as the Hill Country Priority Groundwater Management Area. A Priority Groundwater Management Area (PGMA) is "an area designated and delineated by the commission under Chapter

[11] https://statutes.capitol.texas.gov/Docs/WA/htm/WA.36.htm#36.101
[12] https://statutes.capitol.texas.gov/Docs/WA/htm/WA.36.htm#36.002

35[13] [of the Water Code] as *an area experiencing or expected to experience critical groundwater problems*." See Section 36.001(14) (emphasis added). Currently, there are eight (8) PGMAs in Texas, covering areas in 35 counties. The Hill Country PGMA includes all of Bandera, Blanco, Gillespie, Kendall, and Kerr counties and portions of Bexar, Comal, Hays, and Travis counties.

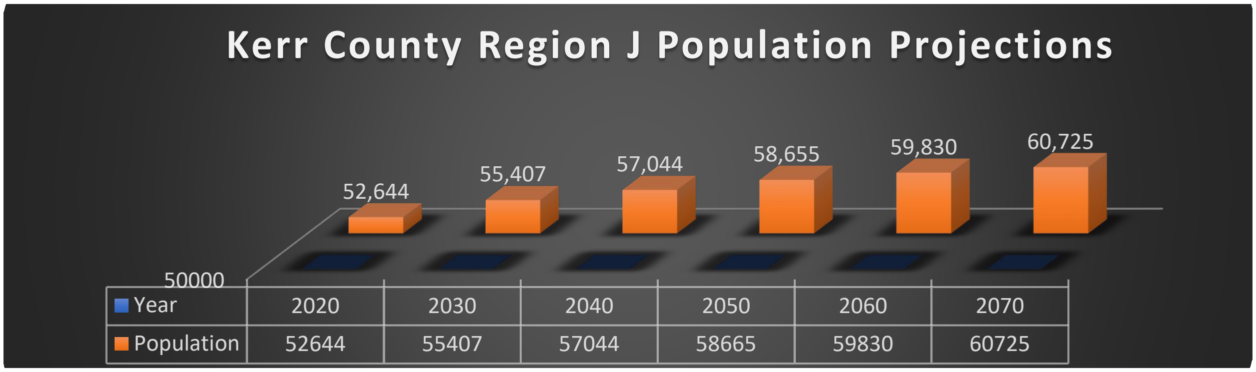
Time period for this plan

This plan will become effective upon adoption by the District's board of directors and approved as administratively complete by the Texas Water Development Board. The plan will remain in effect for five (5) years after the date of approval or until a revised plan is adopted and approved. The District's board of directors will review the status of all performance standards in this plan annually.

Demographics

The District boundaries are contiguous with that of the County. The County encompasses 1,106 square miles and is located in the Hill Country of southwest central Texas. The county is bounded on the north by Kimble and Gillespie counties, on the east by Kendall County, on the west by Edwards and Real counties and on the south by Bandera and Real counties. Kerrville, the largest city in the County, is also the county seat for the County. Retirement living, private camps, resorts, hunting, medical services, and private higher education dominate the economy in the County. Agriculture, light industry, and manufacturing contribute to the economy to a lesser extent. The County is part of the Plateau Regional Water Planning Group (RWPG) known as "Region J." The County population is displayed in the table below according to population estimates prepared by data developed and submitted by Region J. These estimates include Ingram, Kerrville, and County-Other data.

[13] https://statutes.capitol.texas.gov/Docs/WA/htm/WA.35.htm



During the most recent regional planning process, Region J Planning Group members recognized a need for more water than is justified simply from the population-derived water-demand estimates because “the census does not recognize the significant seasonal population increase that occurs in these [Region J] counties as the area draws large numbers of hunters and recreational visitors, as well as absentee landowners who maintain vacation, retirement, and hunting properties.” January 2021 Plateau Region Water Plan[14] at ES-3.

Different growth patterns are evident in different areas of the County. The use of smaller tracts with a greater population density are projected for the eastern portion of the County, while the trend in the western portion of the County is toward the creation of larger acreage tracts with sparse population density.

Topography and Climatic Conditions

The predominantly rough and rolling topography of the County is characteristic of the Edwards Plateau or Hill Country region. In the western part of the County, the land surface is gently rolling, interrupted by steep slopes and narrow valleys caused by the erosion of resistant limestone beds. Extensive dissection of the plateau in the eastern part of the County has formed wide valleys separated by high hills of generally uniform altitude. The altitude of the land surface ranges from about 1,400 ft. above mean sea level (MSL) at the southeastern edge of the County to about 2,400 feet in the western

[14] https://www.twdb.texas.gov/waterplanning/rwp/plans/2021/index.asp#region-j

part (Reeves, 1969). Historically, the vegetative cover was considered to be an oak and juniper savannah. Presently, second and third growth juniper is increasing in density to the point of being dominant. Most of the County is drained by the Upper Guadalupe River (approximately 75%), which rises in the western part of the County and flows eastward for approximately 40 miles before exiting the County. The Llano and Pedernales Rivers to the north and the Medina River to the south drain small peripheral areas of the County amounting to less than 25 percent of the total area (Reeves, 1969). The County has a subhumid to semiarid climate coupled with mild winters and hot summers. Average 30-year annual rainfall recorded by the Knipling-Bushland U.S. Livestock Insects Research Laboratory:[15] Kerrville, TX for the years (1991-2020) is 31.22 inches. Net lake surface evaporation ranges from approximately 45 inches per year in the eastern part of the county to about 55 inches per year in the western part.

Water Resources of Kerr County

"Water Supply Needs" projected in the "Estimated Historical Water Use and 2017 State Water Plan Datasets"[16] demonstrate a need of -3,386-acre feet in 2020 to -3,678-acre feet in 2070. The 2021 Plateau Region Water Plan projects an 8,000 + increase in population over the next 50-year period and an accompanying increase in water supply needs. The County is currently experiencing rapid growth, and numerous large subdivision projects are on the horizon in the County.

As part of the "Water Management Strategies" listed in the TWDB 2017 State Water Plan Data, in preparation for growth and anticipated increased water demand, the District is involved in very detailed mapping and exploration of the Lower Paleozoic aquifers. The District has drilled and completed a well in the Ellenburger Aquifer in the City limits of Kerrville. The Ellenburger Aquifer has traditionally not been a significant source of water in The County. After successful testing, the City of Kerrville refunded the District all drilling and testing costs and placed the well in Kerrville's water supply

[15] https://www.ars.usda.gov/ARSUserFiles/30940500/KRVL_WeatherData/2020_WTHR/Avg_Rain_2020.pdf

[16] Appendix D, this plan

network. The District has plans to drill and test another Ellenburger Aquifer well in 2022 and provide data to the City of Kerrville and The County for more potential water supply wells.

Groundwater Resources of Kerr County

Groundwater availability modeling information in GAM Run 21-003[17] provided by the Executive Administrator of the TWDB is available in this plan (Appendix E). The Trinity Aquifer is the principal source of groundwater in The County. The Trinity Aquifer in the Hill Country is an extension of the lower part of the Edwards-Trinity (Plateau) Aquifer of the Edwards Plateau, with the Edwards group and its equivalents mostly removed, see Strata Geological Services Report Hydrogeology of The County 2008[18]. The Trinity Aquifer yields water from limestone and sandstone of the Cretaceous Trinity Group. The Trinity Aquifer is composed of three permeable zones separated by two relatively impermeable horizontal barriers. The Upper Trinity is made up of the upper member of the Glen Rose Limestone Formation. The Middle Trinity is composed of the Lower Glen Rose Limestone, the Hensel Sand, and the Cow Creek Limestone formations. The Lower Trinity consists of the Hosston and Sligo formations. Relatively impermeable tight sediments within the Glen Rose Limestone separate the Upper and Middle Trinity. The Hammett Shale separates the Middle and Lower Trinity. Recharge of the Trinity Aquifer occurs through lateral flow of water from the Edwards Plateau, infiltration of precipitation on the outcrop area, and surface water leakage from shallow tributary streams in upland areas. Relatively impermeable inner beds in the upper and middle Glen Rose Limestone generally impede the downward percolation of precipitation. A second, less reliable, aquifer in the County is the Fort Terrett Formation of the Edwards Group. Erosion caused by stream flow off the edge of the Edwards Plateau trending eastward across the County has removed most of the Fredericksburg and Washita strata. Unconfined conditions prevail over parts of the County, varying greatly in response to diverse geologic conditions and topographic effects. The production of wells in the Fort Terrett Formation is usually confined to domestic and livestock use, but the Fort Terrett

[17] https://www.twdb.texas.gov/groundwater/docs/GAMruns/GR21-003.pdf
[18] https://hgcd.org/wp-content/uploads/2015/07/2008-Kerr-Hydrogeology-Report-.pdf

is essential in maintaining stream flow of the Guadalupe River. The Lower Paleozoic (Ellenburger) Aquifer is currently being explored for an alternate source of Groundwater. During periods of extended drought (1) well levels in the western part of the County show minimal impact, (2) wells in the Eastern part of the County east of Kerrville, and along the Guadalupe River to the east county line have a larger decline, and (3) some shallow wells throughout the County tend to lose the ability to pump water. Most domestic and livestock wells in the west are completed in the Edwards Trinity (Plateau) Aquifer, which recharges quickly from rain on the Edwards Plateau.

**Surface Water Resources - **Guadalupe River Basin

Within the plateau region, the Guadalupe River Basin occurs almost exclusively within The County. The Basin drains approximately 510 square miles at Kerrville, and approximately 839 square miles at Comfort near the eastern county line. The River originates almost entirely within western The County as three branches (Johnson Creek, North Fork, and South Fork) merge west of Kerrville to form the main river course. A study report titled Spring Flow Contribution to the Headwaters of the Guadalupe River in Western The County (2005) was prepared for the Plateau Water Planning Group (PWPG). The total amount of authorized water rights for the Guadalupe River within the plateau region is 21,020 acre-feet/year. Municipal use accounts for 8,076 acre-feet/year. Holders of these water rights include the City of Kerrville, the Upper Guadalupe River Authority (UGRA), and independent persons. The City of Kerrville and the UGRA own the largest municipal water rights. Certificate of Adjudication 1996, 5394-B, 2026 and Permit 3505 are held by Kerrville. UGRA holds Permit 5394-A. Authorized diversions from the Guadalupe River associated with these water rights are taken from an 840-acre on channel reservoir located in the City of Kerrville and are pumped from the reservoir to Kerrville's water treatment plant. A summary of the pertinent information for their water rights is shown in Table 3-6. Texas Parks and Wildlife Department owns a continuous flow-through water right for 5,780-acre feet/year used for the Heart of the Hills Fisheries Science Center; consumptive use is approximately 400 acre-feet/year. Industrial use permits are authorized for 17 acre-feet/year and irrigation rights for 6,904 acre-feet/year. The remaining water-rights holders use their water for mining, hydroelectric power, and recreation. One individual holds a water right (35,125 acre-feet/year) for hydroelectric use; however, this right has not been exercised. The County holds the rights for three non-consumptive recreation-use reservoirs in and near Kerrville.

Table 3-6: Municipal Surface Water rights for Kerrville and UGRA

Water Rights Permit	Authorized Diversion (acre-ft/yr.)	Permit Holder	Priority Data	Storage (acre-feet)	Restrictions
1996 (amended 4/10/98)	225 (Mun.)	Kerrville	4/4/1914		
3505	3,603	Kerrville	5/23/1977	840	Max diversion rate = 9.7 cfs Divert only when reservoir is above 1,608 ft msl
5394-A and 5394-B (amended 4/10/98)	2,169	Kerrville (Kerrville Municipal use)	1/6/1992	Utilizes the storage authorized for Permit 3505	Max combined diversion rate for water rights #3505 and #5394 = 15.5 cfs. Minimum instream flow requirements vary from 30 to 50 cfs during year
	2,000	UGRA (County Municipal use)			

During winter months when there is surplus surface water supply, a portion of the treated water is injected into the Lower Trinity Aquifer for subsequent use during the typically dry summer months. This aquifer storage and recovery (ASR) program has been in full operation since 1998.

Both the City of Kerrville and the UGRA have within their authorizations (Permits Nos. 5394B and 5394A respectively) a Special Condition addressing the seasonal distribution of allowed diversions. The Special Condition stipulates that during the months of October through May, the permittees may divert only when the flow of the

Guadalupe River exceeds 50 cfs, and during the months of June through September, the permittees are authorized to divert only when the flow of the Guadalupe River exceeds 30 cfs. Another Special Condition common to both permittees are that, when inflows to Canyon Reservoir are less than 50 cfs, each permittee is to restrict diversions to allow a flow of at least 50 cfs to pass through. Yet another Special Condition imposed on both permittees is that diversions may be made only when the level of UGRA Lake is above 1,608 feet above mean sea level. Pursuant to a Memorandum of Understanding (MOU) between the Guadalupe-Blanco River Authority (GBRA) and the Commissioner's Court of The County, the South-Central Texas Water Planning Group (Region L) recognizes a potential commitment of approximately 2,000 acre-feet/year from the firm yield of Canyon Reservoir for the calendar years 2021 through 2050. GBRA's hydrology studies indicate that a commitment of about 2,000 acre-feet/year would be necessary to allow permits for 6,000 acre-feet/year to be issued by TCEQ for diversions in The County. Data from the Corps of Engineers show a computed inflow into Lake Canyon of 132,900 acre-feet/year in 1996. The Guadalupe-San Antonio Water Availability Model (WAM) estimates naturalized flows to be 27,800 acre-feet in 1956. The USGS gage 08167000 on the Guadalupe River at Comfort gives a lowest annual streamflow amount of 14.5 cfs (approximately 10,585 acre-feet/year) occurring in 1956. This gage has been recording since 1939. Interestingly, statistics for the gage include the fact that, for water years 1939 through 1997, the mean annual runoff was 157,800 acre-feet or approximately 216 cfs, and that 90 percent of these flows exceeded 25 cfs. This puts the 1956 occurrence of 14.5 cfs within the 0 to 10 percent non-exceedance category. In calendar year 1996, the annual mean was 151 cfs and the median was 85 cfs. The mean and median for 1997 exceeded the 1996 values. These facts seem to substantiate that the drought-of-record for The County occurred in 1956, not in 1996, as consistent with most other areas of the State.

Technical District Information Required by Texas Administrative Code

Estimate of Modeled Available Groundwater in the District Based on Desired Future Conditions.

Texas Water Code § 36.001[19] defines modeled available groundwater (MAG) as "the amount of water that the Executive Administrator of the TWDB determines may be produced on an average annual basis to achieve a desired future condition established under Section 36.108"[20]. The joint planning process set forth in Texas Water Code § 36.108 must be collectively conducted by all GCDs within the same GMA. The District is a member of GMA 9, which consists of all or portions of nine different GCDs and almost all of the counties within the Hill Country Priority Groundwater Management Area and is currently in the third round of joint planning. An explanatory report is currently in the process of being completed by an outside consulting group selected by the GMA 9 committee.

After the groundwater management plan was adopted following notice and hearing, a copy was provided to local and regional surface water management entities.
Please Refer to Appendix A

Resolution adopting the Desired Future Conditions and Non-Relevant Aquifers for Kerr County in accordance with GMA 9. **Please Refer to Appendix B**

GAM Run 16-023 MAG, Modeled Available Groundwater for the Aquifers in Groundwater Management Area 9. **Please Refer to Appendix C**

Amount of Groundwater Being Used within the District on an Annual Basis. *"TWDB Estimated Historical Water Use."* **Please Refer to Appendix D**

Annual Amount of Recharge from Precipitation to the Groundwater Resources within the District "*GAM Run 21-003*". **Please Refer to Appendix E**

[19] https://statutes.capitol.texas.gov/Docs/WA/htm/WA.36.htm#36.001

[20] https://statutes.capitol.texas.gov/Docs/WA/htm/WA.36.htm#36.108

Annual Volume of Water that discharges from the Aquifer to Springs and Surface Water Bodies. *"GAM Run 21-003."* **Please Refer to Appendix E**

Estimates of the Annual Volume of Flow into the District, out of the District and between Aquifers. "*GAM Run 21-003."* **Please Refer to Appendix E**

Projected Surface Water Supply within the District

"Texas 2017 State Water Plan." **Please Refer to Appendix D**

Projected Total Demand for Water within the District

"Texas 2017 State Water Plan**."** **Please Refer to Appendix D**

Water Supply Needs

"Texas 2017 State Water Plan." **Please Refer To Appendix D**

Final Report: Identification of the Vulnerability of the Major and Minor Aquifers of Texas to Subsidence with Regard to Groundwater Pumping TWDB Contract Number 1648302062"' ***Partial*** "TWDB Contract Number 1648302062". **Please Refer to Appendix F**

HGCD Resolution No. 2021-3 Adopting the December 8, 2021 Management Plan, Public Notice of a Public Hearing and Meeting Agendas. **Please Refer to Appendix G**

GAM for the Hill Country Portion of the Trinity Aquifer System, Texas Updated Model. "Report 377, June 2011

https://www.twdb.texas.gov/publications/reports/numbered_reports/doc/R377_HillCountryGAM.pdf

Methodology to Track District Progress in Achieving Management Goals

An Annual Management Plan Tracking Report will be created by the general manager and staff of the District and provided to the members of the Board of Directors. The annual report will cover the activities of the District including information on the District's performance in regards to achieving the District's management goals and objectives. A copy of the annual report will be kept on file and will be available for public inspection at the District's offices upon adoption.

Action, Procedures, Performance and Avoidance for Plan Implementation and Details on How the District Will Manage Groundwater Supplies.

The District has adopted rules and policies relating to the permitting of wells and the production of groundwater. The rules and policies adopted by the District are pursuant to Texas Water Code Chapter 36 and the provisions of this plan, and are based on the best available science and technical evidence. The District will strive to enforce all rules and policies in a fair and equitable way, treating all similarly-situated citizens with equality. The rules may be viewed at http://hgcd.org/resources/rules-plans. In certain situations, citizens of the County may apply to the District for discretion in enforcement of the rules on grounds of unique local conditions. In granting an exception to any rule the District Board shall consider among other issues the potential for adverse effect on adjacent landowners. The exercise of said discretion in granting an exception, where an applicant or permittee shows that such exception is warranted and consistent with the District's legal responsibilities, shall not be construed as limiting the power of the District Board. The District will utilize the provisions of this management plan to determine the direction or priority for District activities.

Operations of the District, agreements entered into by the District and any additional planning efforts in which the District may participate will be consistent with the provisions of this plan. In the implementation of this plan and the management of groundwater supplies, activities of the District will be undertaken in cooperation and coordination with the appropriate state and regional water plans, and local governmental entities, including the County Commissioners Court.

Management Goals, Chapter 36.1071 (a)

A. Provide the most efficient use of groundwater

Understand and explore the current and potential new groundwater resources in the County. The District has drilled, ran geophysical logs, and tested seventeen monitor wells in the Trinity Aquifer, and two wells in the Lower Paleozoic (Ellenburger) Aquifer. The District has retained a consulting group to evaluate the sustainability of the aquifers in east Kerr county in regard to the District's current well spacing requirements, and production cap.

A-1 Objective – Establish and maintain a monitor well program.

A-1 Performance Standard – The District currently monitors forty (40) + wells, in the Middle and Lower Trinity aquifers distributed across the County, one Ellenburger well and twelve (12) wells in the Edwards Trinity (Plateau) Aquifer. Aquifer levels and hydrographs for each individual monitor well are displayed on the District website www.hgcd.org, and reported in the board of directors' monthly board book. Monitor well data is shared with the TWDB, six wells are part of the TWDB monitor well satellite recorder program, two of those wells are duel Middle and Lower Trinity monitor wells.

A-2 Objective – Regulate and account for groundwater withdrawal in The County.

A-2 Performance Standard - An application and/or registration form is required for all non-exempt and exempt wells drilled in The County. A file has been created for all new wells and old existing wells (as they are discovered) and detailed information regarding each well entered into the District database. District staff performs well site inspections before, during and after the drilling and completion of each new well drilled in an effort to ensure compliance with HGCD district rules and the Texas Department of Licensing and Regulation (TDLR) standards for well completion. The District requires all licensed drillers and pump installers to submit State well logs, Certified Statement of Completion of drilling and pump installation within 30 days of completion. All non- exempt (permit) wells are required to have a meter installed at the wellhead and the annual production of the well reported to the

District in January. The total annual permit production combined with the annual estimated exempt well production number provided by TWDB is documented in the HGCD annual groundwater report and provides the estimated current groundwater demand for the District.

B. Controlling and Preventing Waste of Groundwater

B-1. Objective - Make and enforce rules (Water Code Chapter 36.101) to ensure that groundwater is used solely for beneficial purposes and prohibit activities that contribute to the waste of groundwater.

B-1 Performance Standard – Exempt well registrations are issued in compliance with Water Code Section 36.117 for domestic, livestock or poultry use only, and limited to 25,000 gallons per day, (or 17.36) gallons per minute pump capacity. non-exempt (permit) wells are regulated by the district production cap, the intended use, pumping capacity, spacing from property lines, and beneficial purpose without waste. The District will publish a minimum of one article each year in a local newspaper regarding wasteful and non-essential water uses. The District endeavors to identify, document, and investigate occurrences of waste reported and include any verified occurrences in the annual management plan tracking report to the board of directors.

C. Addressing Conjunctive Surface Water Management Issues

C.-1. Objective – Each year, the district will participate in the regional planning process by attending the Region J regional water planning group meetings to encourage the development of surface water supplies to meet the needs of water user groups in the district. A representative of the district will attend a minimum of 50 percent of the Region J regional water planning group meetings.

C.1. Performance Standard – The district will, in each annual report, document the participation of district representatives in the Region J meetings and the number of meetings attended in the preceding calendar year. Documentation will consist of a table listing all Region J meetings scheduled during the preceding 12 months, and the name(s) of district staff attending.

D. Address Natural Resources Issues.

D-1. Objective – Prohibit contamination/pollution of the aquifers in The County from other natural resources being produced. A representative from the District will attend all GMA 9 meetings, and is a part of any discussions regarding ways to protect the environment.

D-1. Performance Standard – Require all licensed water well drillers to monitor the total dissolved solids (TDS) during the drilling process to be able to seal off and report any Injurious water encountered in compliance with the Texas Department of Licensing and Regulation (TDLR) 76.101. For every well that is drilled water well drillers are monitored to prevent spillage of any fluids, tailings, or cuttings into any body of surface water.

D-2. Objective – Monitor water quality throughout the District.

D-2. Performance Standard – The District requires a water quality analysis from all new wells within sixty days after pump installation. At a minimum, the water quality report shall include data regarding the following; e, coli, total coliforms, chloride conductivity, fluoride, total hardness, iron, nitrate, PH, and total dissolved solids. Well owners are notified by the District when e. coli, total coliforms or injurious water is detected on the lab report.

E. Addressing Drought Conditions

E-1. Objective – Monitor drought conditions

E-1. Performance Standard – In addition to the U.S. Drought Monitor https://www.waterdatafortexas.org/drought/drought-monitor, the District has a network of drought index wells that are monitored monthly. The drought index well levels are used in consideration with the Palmer Drought Severity Index, and the flow rate of the Guadalupe River at Kerrville to initiate various drought stages. Drought information is available on the TWDB website at https://www.waterdatafortexas.org/drought/. When drought stages are triggered, a notice goes out by mail to all permit well owners/operators, and a notice is placed in a local newspaper and on the district website. Drought conditions are reported to the board of directors and documented in the management plan annual tracking report. Non-exempt (permit) well owners are required to sign an affidavit of compliance with the district drought contingency plan. In the plan, exempt well owners are encouraged to conserve and restrict non-essential use of groundwater during times of drought.

F. Addressing Conservation

F-1. Objective – Conservation

F-1. Performance Standard – Each year, publish a minimum of one article in local newspapers encouraging water conservation, and direct the public to water conservation links on the District website (www.hgcd.org). District rules require well spacing, pump capacities and a production cap to limit the amount of water use per acre. The district conservation plan is available on the district website. The District issues authorization to drill exempt and non-exempt water wells to be used for beneficial purpose without waste. Conservation information is also available on the TWDB website at http://www.twdb.texas.gov/conservation/index.asp

G. Addressing Rainwater Harvesting

G-1. Objective – Promote the benefits of and provide access to information regarding Rainwater Harvesting.

G-2. Performance Standard – A link is provided on the District website that discusses rainwater basics, and provides contractors, landowners, and others rainwater harvesting system planning material to be able to capture, store, and use rainwater for landscaping. The use and advantages of rainwater harvesting are mentioned in at least one newspaper article annually.

H. Addressing the Desired Future Conditions of the Groundwater Resources.

H-1. Objective –Achieve the Desired Future Condition for the hill country Trinity aquifers adopted by GMA9, stated in GAM Task-10-005 Scenario 6.

H-2. Performance Standard – The District has drilled a network of thirteen (13) Middle and six (6) Lower Trinity Monitor wells throughout the County. These wells are designated as the District's DFC wells. Each year the Middle and Lower Trinity average levels are compared to the 2008 base line. In the district rules and annual groundwater report the combined annual permitted volume added to the estimated exempt pumping volume provided by TWDB is used to evaluate and compare the District's current demand to the "MAG assigned HGCD" in GAM Run 16-023 MAG. The District is in GMA 9 and participates in joint planning and all requirements of Chapter 36, Sec 36.108.

I. Management Goals Not applicable to the District

I-1 Recharge Enhancement – is not within the District's ability to be cost effective. This goal is not applicable at this time.

I-2 Precipitation Enhancement – is not within the District's ability to be cost effective. This goal is not applicable at this time.

I-3 Brush Control – is not within the District's ability to be cost effective. This goal is not applicable at this time.

I-4 Controlling and Preventing Subsidence - The District will watch for any signs of subsidence in the future and will investigate any reports of potential subsidence. The District has reviewed the Final Report: Identification of the Vulnerability of the Major and Minor Aquifers of Texas to Subsidence with Regard to Groundwater Pumping, TWDB Contract Number 1648302062[21]. Figure 4.18 page 4-32, illustrates the calculated subsidence risk for the Edwards-Trinity) Plateau Aquifer, it shows from west to east a low to medium risk but states the data is likely skewed due to driller log descriptions of clay. On page 4-78, the results of the Trinity Aquifer subsidence risk factor data sources and summary (table 4.18) indicate the downdip (eastern) portions of the aquifer have the greatest risk for future subsidence due to pumping. Figure 4.91 page 142, illustrates the subsidence risk factor for the Ellenburger-San Saba Aquifer has a low to medium- low risk for future subsidence due to pumping. Land surface subsidence has not been observed in the District. This goal is not applicable at this time.

[21] https://www.twdb.texas.gov/groundwater/models/research/subsidence/subsidence.asp

APPENDIX A

Evidence that, following notice and hearing, the District coordinated in the development of its management plan with regional surface water management entities.

From: gene@hgcd.org
To: "Stuart Barron"
Subject: HGCD Revised Management Plan December 8, 2021
Date: Thursday, December 9, 2021 7:35:00 AM
Attachments: HGCD Management Plan Revision December 8, 2021.pdf
image001.png

HEADWATERS GROUNDWATER CONSERVATION DISTRICT

125 Lehmann Dr. Ste 202 Kerrville, Texas 78028 Phone (830) 896-4110
www.hgcd.org e-mail hgcd@hgcd.org

December 9, 2021

Stuart Barron
Executive Director of Public Works
and Engineering
City of Kerrville
701 Main Street
Kerrville, Texas 78028

RE: Revised District Management Plan

Dear Mr. Barron

This groundwater management plan has been prepared in accordance with Texas Water Code Chapter 36, Section 1071 and Texas Water Development Board requirements under Texas Administrative Code, Chapter 356. After notice and hearing the plan was adopted by the Headwaters Groundwater Conservation District Board of Directors in a regular meeting on December 8, 2021. The plan will now be forwarded to the Texas Water Development Board for final approval. This copy of the HGCD 2021 revised Management Plan is provided to the City of Kerrville for review and comment.

Please contact the District with any questions or the need for more information. A printed copy will be provided upon request.

Respectfully,

Gene Williams

General Manager
Headwaters Groundwater Conservation District

From: gene@hgcd.org
To: "mtkcwcid@hctc.net"
Subject: Copy of HGCD Revised Management Plan for Kendall Co. WCID 1
Date: Thursday, December 9, 2021 7:47:00 AM
Attachments: HGCD Management Plan Revision December 8, 2021.pdf
image001.png

HEADWATERS GROUNDWATER CONSERVATION DISTRICT

125 Lehmann Dr. Ste 202 Kerrville, Texas 78028 Phone (830) 896-4110

www.hgcd.org e-mail hgcd@hgcd.org

December 9, 2021

Keith Marquart
General Manager
Kendall County WCID 1
28 US Hwy 87
P.O. Box 745
Comfort, TX 78013

RE: Revised District Management Plan

Dear Mr. Marquart,

The attached groundwater management plan has been prepared in accordance with Texas Water Code Chapter 36, Section 1071 and Texas Water Development Board requirements under Texas Administrative Code, Chapter 356. After notice and hearing the plan was adopted by the Headwaters Groundwater Conservation District Board of Directors in a regular meeting on December 8, 2021. The plan will now be forwarded to the Texas Water Development Board for final approval. This copy of the HGCD 2021 revised Management Plan is provided to the Kendall County WCID 1, for review and comment.

Please contact the District with any questions or the need for more information. A printed copy will be provided upon request.

Respectfully,

Gene Williams

General Manager
Headwaters Groundwater Conservation District

From: gene@hgcd.org
To: jletz@co.kerr.tx.us
Subject: Copy of HGCD Revised Management Plan for Region J
Date: Thursday, December 9, 2021 7:43:00 AM
Attachments: HGCD Management Plan Revision December 8, 2021.pdf
image001.png

HEADWATERS GROUNDWATER CONSERVATION DISTRICT

125 Lehmann Dr. Ste 202 Kerrville, Texas 78028 Phone (830) 896-4110

www.hgcd.org e-mail hgcd@hgcd.org

December 9, 2021

Mr. Jonathan Letz
Chair, Plateau Water Planning Group (Region J)
700 E. Main Street
Kerrville, Texas 78028

RE: Revised District Management Plan

Dear Mr. Letz,

The attached groundwater management plan has been prepared in accordance with Texas Water Code Chapter 36, Section 1071 and Texas Water Development Board requirements under Texas Administrative Code, Chapter 356. After notice and hearing the plan was adopted by the Headwaters Groundwater Conservation District Board of Directors in a regular meeting on December 8, 2021. The plan will now be forwarded to the Texas Water Development Board for final approval. This copy of the HGCD 2021 revised Management Plan is provided to the Plateau Water Planning Group (Region J) for review and comment.

Please contact the District with any questions or the need for more information. A printed copy will be provided upon request.

Respectfully,

Gene Williams

General Manager
Headwaters Groundwater Conservation District

From:	gene@hgcd.org
To:	"Greg.Creacy@tpwd.texas.gov"
Subject:	Copy of HGCD Revised Management Plan for TPWL
Date:	Thursday, December 9, 2021 7:52:00 AM
Attachments:	HGCD Management Plan Revision December 8, 2021.pdf image001.png

HEADWATERS GROUNDWATER CONSERVATION DISTRICT

125 Lehmann Dr. Ste 202 Kerrville, Texas 78028 Phone (830) 896-4110

www.hgcd.org e-mail hgcd@hgcd.org

December 9, 2021

Greg Creacy
Natural Resources
Texas Parks and Wildlife Department
4200 Smith School Road
Austin, TX 78744

RE: Revised District Management Plan

Dear Mr. Creacy,

The attached groundwater management plan has been prepared in accordance with Texas Water Code Chapter 36, Section 1071 and Texas Water Development Board requirements under Texas Administrative Code, Chapter 356. After notice and hearing the plan was adopted by the Headwaters Groundwater Conservation District Board of Directors in a regular meeting on December 8, 2021. The plan will now be forwarded to the Texas Water Development Board for final approval. This copy of the HGCD 2021 revised Management Plan is provided to the Texas Parks and Wildlife Department for review and comment.

Please contact the District with any questions or the need for more information. A printed copy will be provided upon request.

Respectfully,

Gene Williams

General Manager
Headwaters Groundwater Conservation District

From:	gene@hgcd.org
To:	"Raymond Buck, Jr."
Subject:	Copy of HGCD Revised Management Plan for UGRA
Date:	Thursday, December 9, 2021 7:54:00 AM
Attachments:	HGCD Management Plan Revision December 8, 2021.pdf image001.png

HEADWATERS GROUNDWATER CONSERVATION DISTRICT

125 Lehmann Dr Ste 202 Kerrville, Texas 78028 Phone (830) 896-4110

www.hgcd.org e-mail hgcd@hgcd.org

December 9, 2021

Ray Buck
General Manager
Upper Guadalupe River Authority
125 Lehmann Dr. Ste.100
Kerrville, Texas 78028

RE: Revised District Management Plan

Dear Mr. Buck

The attached groundwater management plan has been prepared in accordance with Texas Water Code Chapter 36, Section 1071 and Texas Water Development Board requirements under Texas Administrative Code, Chapter 356. After notice and hearing the plan was adopted by the Headwaters Groundwater Conservation District Board of Directors in a regular meeting on December 8, 2021. The plan will now be forwarded to the Texas Water Development Board for final approval. This copy of the HGCD 2021 revised Management Plan is provided to the Upper Guadalupe River Authority for review and comment.

Please contact the District with any questions or the need for more information. A printed copy will be provided upon request.

Respectfully,

Gene Williams

General Manager
Headwaters Groundwater Conservation District

APPENDIX B

HGCD RESOLUTION ADOPTING THE DESIRED FUTURE CONDITIONS AND NON-RELEVANT AQUIFERS FOR KERR COUNTY IN ACCORDANCE WITH GMA 9 JOINT PLANNING

STATE OF TEXAS § **RESOLUTION 2017-2**
§
COUNTY OF KERR §

HEADWATERS GROUNDWATER CONSERVATION DISTRICT

ADOPTION OF DESIRED FUTURE CONDITIONS AND NON-RELEVANT AQUIFERS FOR KERR COUNTY IN ACCORDANCE WITH GROUNDWATER MANAGEMENT AREA# 9 JOINT PLANNING

WHEREAS, the Headwaters Groundwater Conservation District (HGCD) is a groundwater conservation district created in accordance with and subject to Chapter 36, Texas Water Code and;

WHEREAS, HGCD is required under Chapter 36.108, Texas Water Code; to participate in Groundwater Management Area Joint Planning and;

WHEREAS, the HGCD is located in Groundwater Management Area# 9 and;

WHEREAS, Groundwater Management Area # 9 has completed the joint planning required under Chapter 36.108 and by resolution, has adopted Desired Future Conditions (DFCs) for relevant aquifers and declared portions of certain aquifers as non-relevant for regional planning purposes, and submitted the resolution and an Explanatory Report to the Texas Water Development Board (TWDB) and;

WHEREAS Chapter 36.108 (d-4) and TWDB Rule 356.34 require districts within GMA 9 to adopt the DFCs as soon as possible after being notified that the GMA 9 resolution and Explanatory Report are administratively complete and;

WHEREAS, the TWDB has notified GMA 9 both by email on January 31, 2017 and in person at a GMA 9 meeting held on February 6, 2017 that the DFCs and the Explanatory Report are administratively complete;

NOW THEREFORE BE IT RESOLVED, that the Board of Directors of the Headwaters Groundwater Conservation District does hereby adopt the following DFCs and non-relevant aquifers for Kerr County as described in the GMA 9 resolution and Explanatory Report:

DESIRED FUTURE CONDITIONS

Trinity Aquifer	Allow for an increase in average drawdown of approximately 30 feet through 2060 (throughout GMA-9) consistent with "Scenario 6" in TWDB GAM Task 10-005.
Edwards-Trinity (Plateau) Aquifer	Allow for no net increase in average drawdown in Bandera and Kendall Counties through 2070.
Ellenburger-San Saba Aquifer	Allow for an increase in average drawdown of no more than 2 feet in Kendall County through 2070.
Hickory Aquifer	Allow for an increase in average drawdown of no more than 7 feet in Kendall County through 2070.

NON-RELEVANT AQUIFER CLASSIFICATIONS

Edwards Aquifer (Balcones Fault Zone)	Bexar, Comal, Hays, and Travis Counties
Edwards Trinity (Plateau)	Blanco and Kerr Counties
Ellenburger-San Saba	Blanco and Kerr Counties
Hickory	Blanco, Hays, Kerr, and Travis Counties
Marble Falls	Blanco County

PASSED AND APPROVED THIS 8th DAY OF March, 2017

with 5 ayes, 0 nays, and 0 abstentions.

John R Elliott

John Elliott, Board President

Tom Jones

Tom Jones, Board Secretary

APPENDIX C

GAM Run 16-023 MAG

Modeled Available Groundwater For the Aquifers in Groundwater Management Area 9

GAM RUN 16-023 MAG: MODELED AVAILABLE GROUNDWATER FOR THE AQUIFERS IN GROUNDWATER MANAGEMENT AREA 9

Ian C. Jones, Ph.D., P.G.
Texas Water Development Board
Groundwater Division
Groundwater Availability Modeling Section
(512) 463-6641
February 28, 2017

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GAM RUN 16-023 MAG: MODELED AVAILABLE GROUNDWATER FOR THE AQUIFERS IN GROUNDWATER MANAGEMENT AREA 9

Ian C. Jones, Ph.D., P.G.
Texas Water Development Board
Groundwater Division
Groundwater Availability Modeling Section
(512) 463-6641
February 28, 2017

EXECUTIVE SUMMARY:

We have prepared estimates of the modeled available groundwater for the relevant aquifers of Groundwater Management Area 9—the Trinity, Edwards Group of the Edwards-Trinity (Plateau), Ellenburger-San Saba, and Hickory aquifers. The estimates are based on the desired future conditions for these aquifers adopted by the groundwater conservation districts in Groundwater Management Area 9 on April 28, 2016. The explanatory report and other materials submitted to the Texas Water Development Board (TWDB) were determined to be administratively complete on November 23, 2016.

The modeled available groundwater values are summarized by decade for the groundwater conservation districts (Tables 1, 3, 5, and 7) and for use in the regional water planning process (Tables 2, 4, 6, and 8). The modeled available groundwater estimates are 2,208 acre-feet per year in the Edwards Group of the Edwards-Trinity (Plateau) Aquifer, up to 75 acre-feet per year in the Ellenburger-San Saba Aquifer, 140 acre-feet per year in the Hickory Aquifer, and range from approximately 93,000 acre-feet per year in 2010 to about 90,500 acre-feet per year in 2060 in the Trinity Aquifer. Please note that the Trinity Aquifer includes both the Trinity Aquifer as defined by the TWDB and the Trinity Group of the Edwards-Trinity (Plateau) Aquifer. The modeled available groundwater estimates were extracted from results of model runs using the groundwater availability models for the Hill Country portion of the Trinity Aquifer version 2.01 (Jones and others, 2011), and the minor aquifers of the Llano Uplift Area (Shi and others, 2016).

REQUESTOR:

Mr. Ronald Fieseler, chair of Groundwater Management Area 9 districts.

DESCRIPTION OF REQUEST:

In a letter dated April 25, 2016, Mr. Ronald Fieseler provided the TWDB with the desired future conditions of the Trinity, Edwards Group of the Edwards-Trinity (Plateau), Ellenburger-San Saba, and Hickory aquifers in Groundwater Management Area 9. Mr.

Fieseler provided additional clarifications for baseline years for each desired future condition, areas not covered by the models, assumed climatic conditions, and spatial pumping distributions through emails to the TWDB on June 8, 2016, August 15, 2016 and September 9, 2016. Mr. Fieseler also clarified the water level drawdown for the Ellenburger-San Saba Aquifer in Kendall County in a letter dated October 19, 2016.

The final adopted desired future conditions for the aquifers in Groundwater Management Area 9 are:

- Trinity Aquifer *[Upper, Middle, and Lower undifferentiated]* - Allow for an increase in average drawdown of approximately 30 feet through 2060 (throughout GMA-9) consistent with "Scenario 6" in TWDB GAM Task 10-005.
- Edwards Group of Edwards-Trinity (Plateau) *[Aquifer]* in Kendall and Bandera counties - Allow for no net increase in average drawdown in Bandera and Kendall counties through 2070.
- Ellenburger-San Saba Aquifer in Kendall County - Allow for an increase in average drawdown of no less than 7 feet in Kendall County through 2070.
- Hickory Aquifer in Kendall County - Allow for an increase in average drawdown of no more than 7 Feet in Kendall County through 2070.

The Trinity Aquifer includes both the Trinity Aquifer as defined by the TWDB and the Trinity Group of the Edwards-Trinity (Plateau) Aquifer.

Additionally, districts in Groundwater Management Area 9 voted to declare that the following aquifers or parts of aquifers be classified as non-relevant for the purposes of joint planning:

- Edwards Group of the Edwards-Trinity (Plateau) Aquifer in Kerr and Blanco counties.
- Ellenburger-San Saba Aquifer in Blanco and Kerr counties.
- Hickory Aquifer in Blanco, Hays, Kerr, and Travis counties.
- Marble Falls Aquifer in Blanco County.
- Edwards (Balcones Fault Zone) Aquifer in Bexar, Comal, Hays, and Travis counties.

METHODS:

As defined in Chapter 36 of the Texas Water Code, "modeled available groundwater" is the estimated average amount of water that may be produced annually to achieve a desired future condition. Groundwater conservation districts are required to consider modeled available groundwater, along with several other factors, when issuing permits in order to manage groundwater production to achieve the desired future condition(s). The other factors districts must consider include annual precipitation and production patterns, the estimated amount of pumping exempt from permitting, existing permits, and a reasonable estimate of actual groundwater production under existing permits.

The desired future condition for the Trinity Aquifer is identical to the one adopted in 2010 and the associated modeled available groundwater is based on a specific model run and scenario—Scenario 6 in GAM Task 10-005 (Hutchison, 2010) and GAM Task 10-050 (Hassan, 2012). Trinity Aquifer water-level drawdown is based on 2008 water levels.

For other relevant aquifers—the Edwards Group of the Edwards-Trinity (Plateau), Ellenburger-San Saba, and Hickory aquifers—the groundwater availability models for the Hill Country portion of the Trinity Aquifer version 2.01 (Jones and others, 2011), and the minor aquifers of the Llano Uplift Area (Shi and others, 2016) were used to simulate the desired future conditions outlined in the explanatory report (GMA 9 and others, 2016) and further clarified as noted in the previous section. Water level drawdown calculations were based on the water levels simulated in final years of the historical versions of the respective models. These final years are 1997 in the groundwater availability model for the Hill Country portion of the Trinity Aquifer and 2010 in the groundwater availability model for the minor aquifers of the Llano Uplift Area. The predictive model runs retain pumping rates from the historic period—1980 through 1997—except in the aquifer or area of interest. In those areas, pumping rates are varied such that they produce the desired future average water level drawdown conditions. Pumping rates were reported on 10-year intervals from 2010 through 2060 (for the Trinity Aquifer) and 2010 through 2070 (for all other relevant aquifers). The groundwater availability estimates for 2070 for the Trinity Aquifer will be determined by the regional water planning groups.

Water level drawdown averages were calculated for the relevant portions of each aquifer. Drawdown for model cells which became dry during the simulation (water level dropped below the base of the cell) were excluded from the averaging. Estimates of modeled available groundwater therefore decrease over time as continued simulated pumping predicts the development of dry model cells in areas of Hays, Kerr, and Travis counties. The calculated water-level drawdown averages were compared with the desired future conditions to verify that the pumping scenario achieved the desired future conditions.

Modeled available groundwater values for the Trinity Aquifer and the Edwards Group of the Edwards-Trinity (Plateau) Aquifer were determined by extracting pumping rates by decade from the model results using ZONEBUDGET Version 3.01 (Harbaugh, 2009). For the Ellenburger-San Saba and Hickory aquifers, modeled available groundwater values were determined by extracting pumping rates by decade from the model results using ZONBUDUSG Version 1.01 (Panday and others, 2013).

PARAMETERS AND ASSUMPTIONS:

Trinity and Edwards-Trinity (Plateau) Aquifers

We used the groundwater availability model (version 2.01) for the Hill Country portion of the Trinity Aquifer developed by Jones and others (2009) to determine modeled available groundwater in the Trinity Aquifer and the Edwards Group of the Edwards-Trinity (Plateau) Aquifer. See Jones and others (2009) for details on model construction, recharge, discharge, assumptions, and limitations. The parameters and assumptions for the groundwater availability model for the Hill Country portion of the Trinity Aquifer are described below:

- The model has four layers:
  - Layer 1 represents mostly the Edwards Group of the Edwards-Trinity (Plateau) Aquifer and larger portions of the Edwards Group not classified as an aquifer,
  - Layer 2 represents the Upper Trinity Aquifer,
  - Layer 3 represents the Middle Trinity Aquifer, and
  - Layer 4 represents the Lower Trinity Aquifer.
- The model was run with MODFLOW-96 (Harbaugh and McDonald, 1996).
- Parts of Bandera, Blanco, and Kerr counties are not included in the model and consequently are not included in the modeled available groundwater calculations.
- Drawdown for cells with water levels below the base elevation of the cell ("dry" cells) were excluded from calculation of average drawdown and the modeled available groundwater values.
- In separate model runs, modeled available groundwater was calculated for the Trinity Aquifer and the Edwards Group of the Edwards-Trinity (Plateau) Aquifer. The Trinity Aquifer is defined as the Trinity Group occurring within Groundwater Management Area 9, irrespective of whether it forms part of the Trinity Aquifer or Edwards-Trinity (Plateau) Aquifer.
- The results for the Trinity Aquifer presented in this report are based on Scenario 6 of GAM Task 10-005 (Hutchison, 2010). See Hutchison (2010) for a full description of the methods, assumptions, and results of the model simulations. Each scenario in GAM Task 10-005 consisted of a series of 387 separate 50-year

model simulations, each with a different recharge configuration. Though the pumping input to the model was the same for each of the 387 simulations, the pumping output differed depending on the occurrence of inactive (or dry) cells. Because the analysis was statistical any baseline year may be assumed, therefore average drawdown is based on 2008 conditions as noted in the Groundwater Management Area 9 explanatory report.

- The results for the Edwards Group of the Edwards-Trinity (Plateau) Aquifer are based on a single model run using historic pumping rates in all parts of the model area except the Edwards Group of Kendall and Bandera counties and average recharge from GAM Task 10-005. Recharge used in this model run represents the average recharge taken from the 387 simulations (Run 169) used in Trinity Aquifer model runs. Average drawdown was calculated based on the last historic stress period (1997).

Minor aquifers of the Llano Uplift Area

We used version 1.01 of the groundwater availability model for the minor aquifers in the Llano Uplift Area. See Shi and others (2016) for assumptions and limitations of the model. The parameters and assumptions for the groundwater availability model for the minor aquifers of the Llano Uplift Area are described below:

- The model contains eight layers:
    - Layer 1 (the Trinity Aquifer, Edwards-Trinity (Plateau) Aquifer, and younger alluvium deposits),
    - Layer 2 (confining units),
    - Layer 3 (the Marble Falls Aquifer and equivalent units),
    - Layer 4 (confining units),
    - Layer 5 (Ellenburger-San Saba Aquifer and equivalent units),
    - Layer 6 (confining units),
    - Layer 7 (the Hickory Aquifer and equivalent units), and
    - Layer 8 (Precambrian units).
- The model was run with MODFLOW-USG beta (development) version (Panday and others, 2013).

- Perennial rivers and reservoirs were simulated using the MODFLOW-USG river package. Springs were simulated using the MODFLOW-USG drain package.

- There is no historic pumping information available for the Ellenburger-San Saba and Hickory aquifers of Kendall County. Consequently, we used uniformly distributed pumping to simulate the desired future condition and determine the modeled available groundwater.

RESULTS:

The modeled available groundwater for the Trinity Aquifer that achieves the desired future conditions adopted by districts in Groundwater Management Area 9 decreases from 93,052 to 90,503 acre-feet per year between 2010 and 2060 (Tables 1 and 2). This decline is attributable to the occurrence of increasing numbers of dry model cells over time in parts of Hays, Kerr, and Travis counties. The modeled available groundwater for the Edwards Group of the Edwards-Trinity (Plateau), Ellenburger-San Saba, and Hickory aquifers are 2,208, 75, and 140 acre-feet per year, respectively (Tables 3 through 8). The modeled available groundwater for the respective aquifers has been summarized by aquifer, county, and groundwater conservation district (Tables 1, 3, 5, and 7). The modeled available groundwater is also summarized by county, regional water planning area, river basin, and aquifer for use in the regional water planning process (Tables 2, 4, 6, and 8).

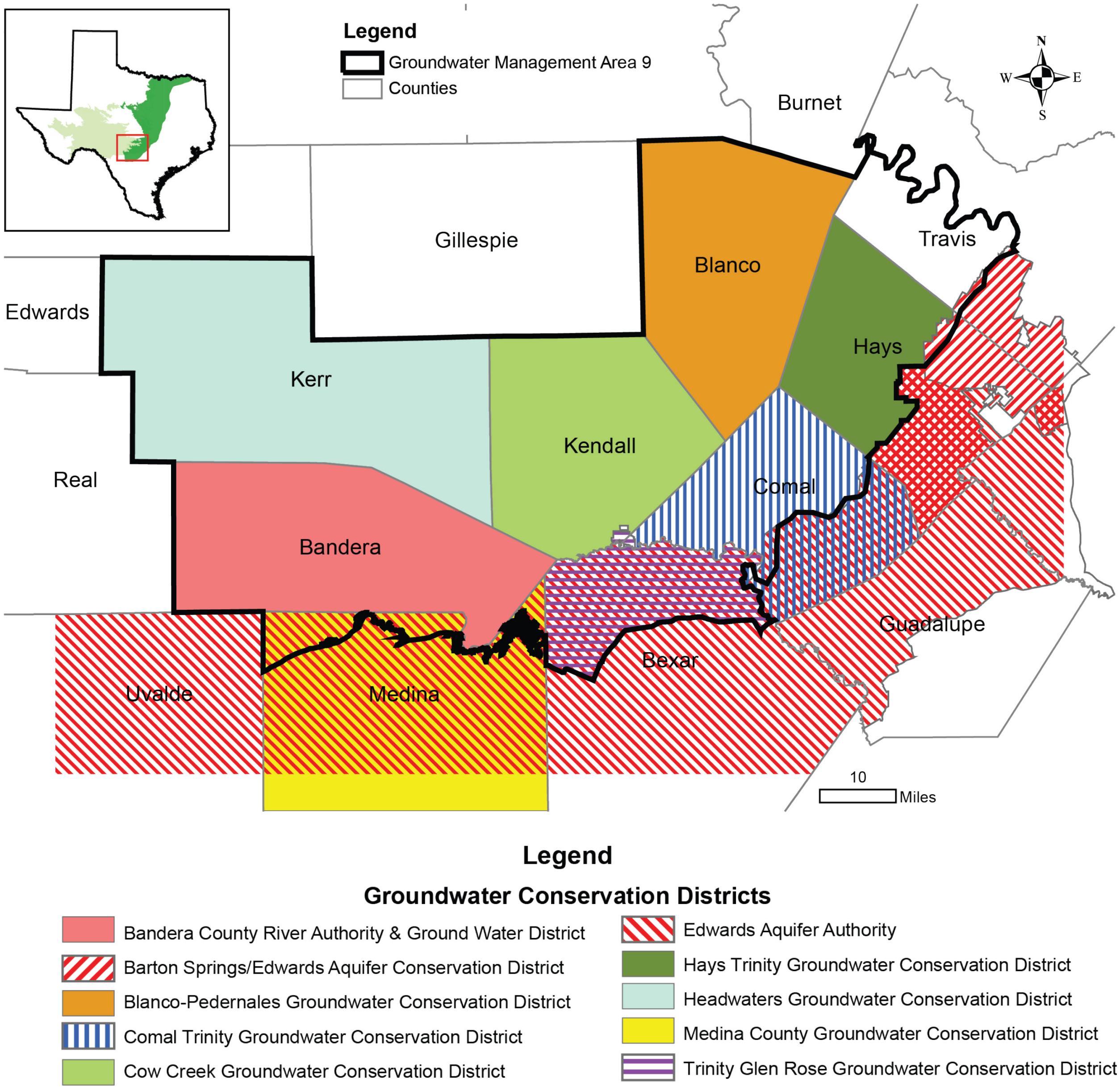

FIGURE 1. MAP SHOWING THE GROUNDWATER CONSERVATION DISTRICTS IN GROUNDWATER MANAGEMENT AREA 9. NOTE: THE BOUNDARIES OF THE EDWARDS AQUIFER AUTHORITY OVERLAP WITH THE MEDINA COUNTY, TRINITY GLEN ROSE, AND COMAL TRINITY GROUNDWATER CONSERVATION DISTRICTS AND THE BARTON SPRINGS/EDWARDS AQUIFER CONSERVATION DISTRICT.

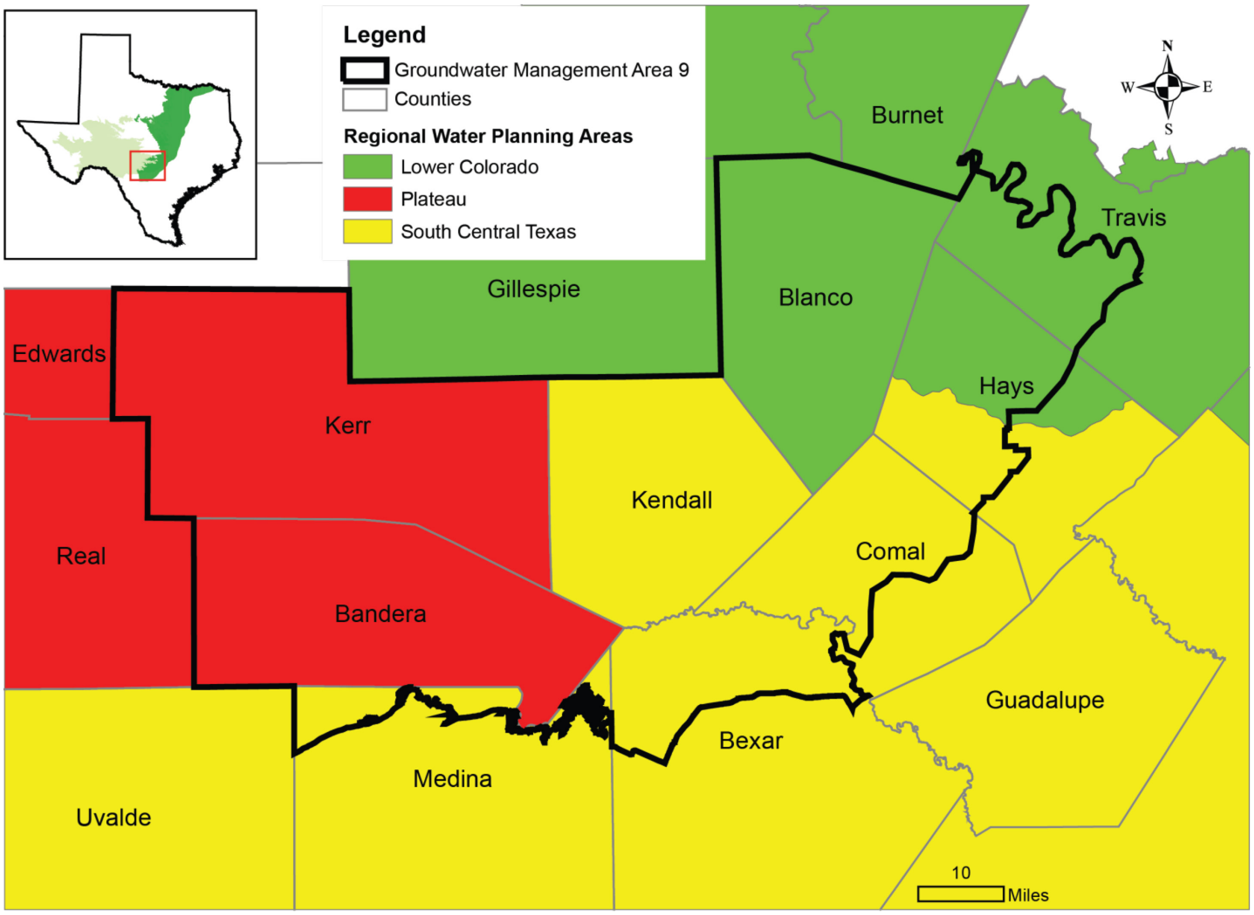

FIGURE 2. MAP SHOWING REGIONAL WATER PLANNING AREAS IN GROUNDWATER MANAGEMENT AREA 9.

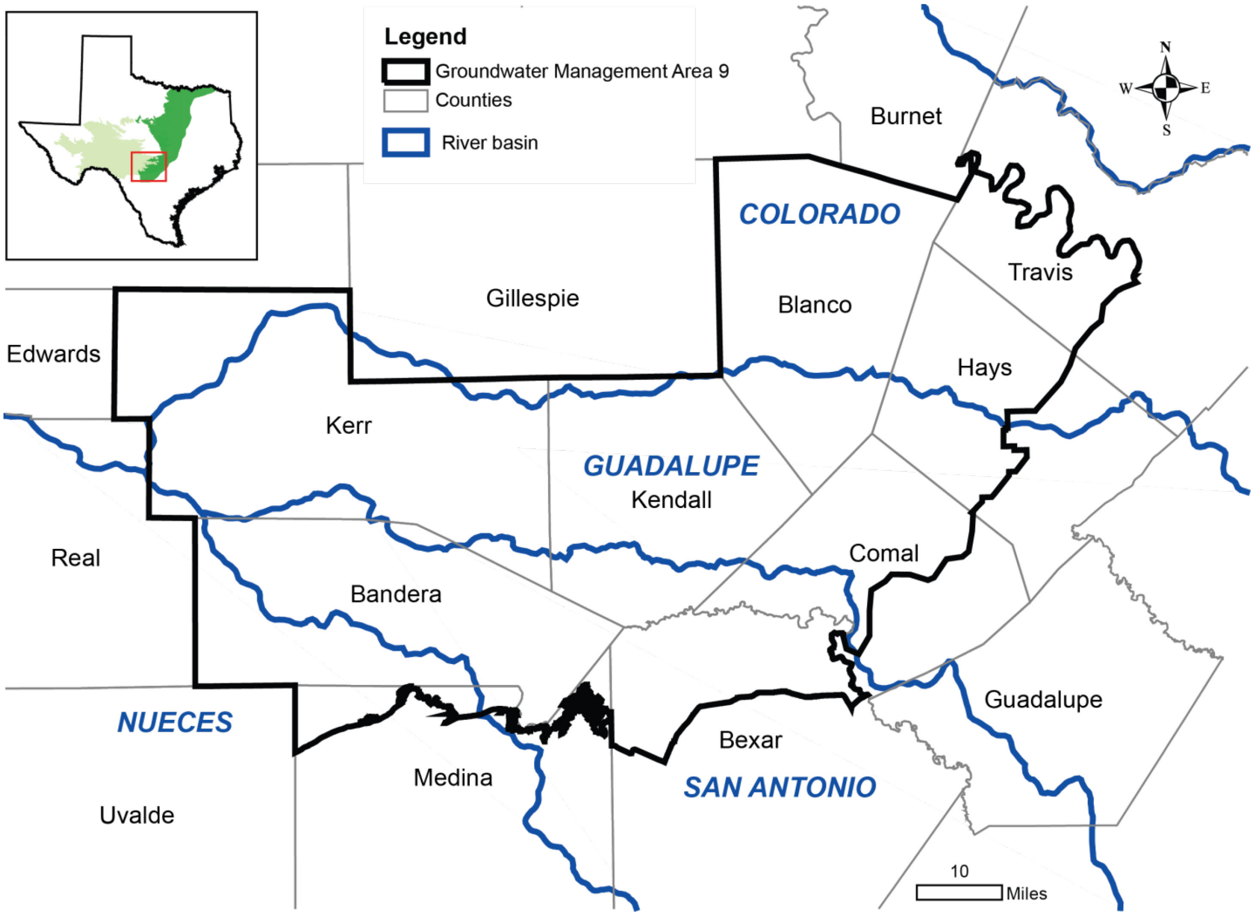

FIGURE 3. MAP SHOWING RIVER BASINS IN GROUNDWATER MANAGEMENT AREA 9. THESE INCLUDE PARTS OF THE COLORADO, GUADALUPE, SAN ANTONIO, AND NUECES RIVER BASINS.

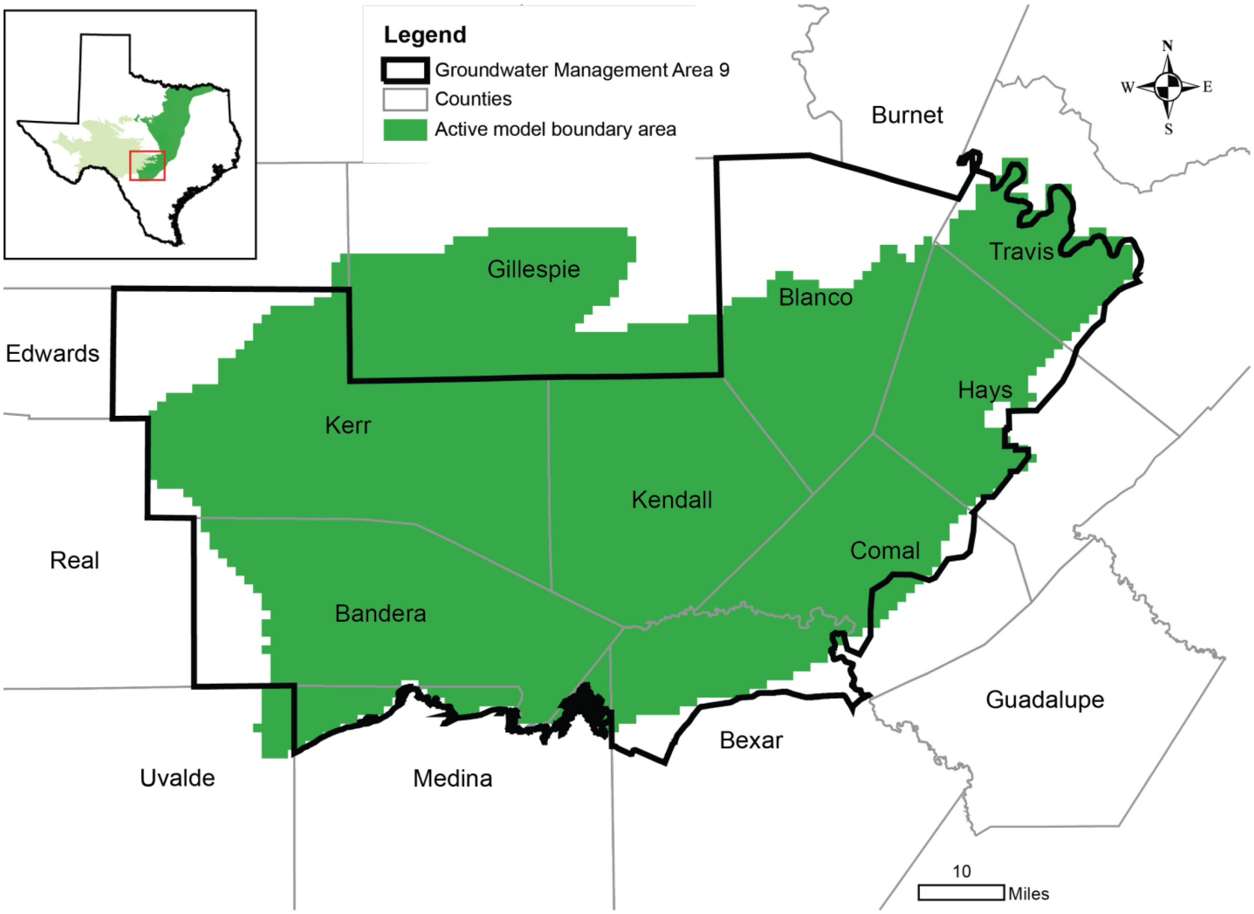

FIGURE 4. MAP SHOWING THE AREAS COVERED BY THE TRINITY AQUIFER IN THE GROUNDWATER AVAILABILITY MODEL FOR THE HILL COUNTRY PORTION OF THE TRINITY AQUIFER IN GROUNDWATER MANAGEMENT AREA 9.

TABLE 1. MODELED AVAILABLE GROUNDWATER FOR THE TRINITY AQUIFER IN GROUNDWATER MANAGEMENT AREA 9 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT AND COUNTY FOR EACH DECADE BETWEEN 2010 AND 2060. RESULTS ARE IN ACRE-FEET PER YEAR.

District	County	Year					
		2010	2020	2030	2040	2050	2060
Bandera County River Authority & Groundwater District Total	Bandera	7,284	7,284	7,284	7,284	7,284	7,284
Barton Springs/Edwards Aquifer Conservation District Total	Hays	22	22	22	22	22	22
Blanco-Pedernales Groundwater Conservation District Total	Blanco	2,573	2,573	2,573	2,573	2,573	2,573
Comal Trinity Groundwater Conservation District Total	Comal	10,076	10,076	10,076	10,076	10,076	10,076
Cow Creek Groundwater Conservation District Total	Kendall	10,622	10,622	10,622	10,622	10,622	10,622
Hays Trinity Groundwater Conservation District Total	Hays	9,109	9,098	9,095	9,094	9,094	9,094
Headwaters Groundwater Conservation District Total	Kerr	16,435	14,918	14,845	14,556	14,239	14,223
Medina County Groundwater Conservation District Total	Medina	2,500	2,500	2,500	2,500	2,500	2,500

TABLE 1. CONTINUED.

District	County	Year					
		2010	**2020**	**2030**	**2040**	**2050**	**2060**
Trinity Glen Rose Groundwater Conservation District	Bexar	24,856	24,856	24,856	24,856	24,856	24,856
Trinity Glen Rose Groundwater Conservation District	Comal	138	138	138	138	138	138
Trinity Glen Rose Groundwater Conservation District	Kendall	517	517	517	517	517	517
Trinity Glen Rose Groundwater Conservation District Total		**25,511**	**25,511**	**25,511**	**25,511**	**25,511**	**25,511**
No district Total	**Travis**	**8,920**	**8,672**	**8,655**	**8,643**	**8,627**	**8,598**
GMA 9	**Total**	**93,052**	**91,276**	**91,183**	**90,881**	**90,548**	**90,503**

TABLE 2. MODELED AVAILABLE GROUNDWATER FOR THE TRINITY AQUIFER IN GROUNDWATER MANAGEMENT AREA 9 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2010 AND 2060. RESULTS ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Year					
			2010	2020	2030	2040	2050	2060
Bandera	J	Guadalupe	76	76	76	76	76	76
		Nueces	903	903	903	903	903	903
		San Antonio	6,305	6,305	6,305	6,305	6,305	6,305
		Total	**7,284**	**7,284**	**7,284**	**7,284**	**7,284**	**7,284**
Bexar	L	San Antonio	24,856	24,856	24,856	24,856	24,856	24,856
		Total	**24,856**	**24,856**	**24,856**	**24,856**	**24,856**	**24,856**
Blanco	K	Colorado	1,322	1,322	1,322	1,322	1,322	1,322
		Guadalupe	1,251	1,251	1,251	1,251	1,251	1,251
		Total	**2,573**	**2,573**	**2,573**	**2,573**	**2,573**	**2,573**
Comal	L	Guadalupe	6,906	6,906	6,906	6,906	6,906	6,906
		San Antonio	3,308	3,308	3,308	3,308	3,308	3,308
		Total	**10,214**	**10,214**	**10,214**	**10,214**	**10,214**	**10,214**

TABLE 2. CONTINUED.

County	RWPA	River Basin	Year					
			2010	2020	2030	2040	2050	2060
Hays	K	Colorado	4,721	4,710	4,707	4,706	4,706	4,706
	L	Guadalupe	4,410	4,410	4,410	4,410	4,410	4,410
		Total	**9,131**	**9,120**	**9,117**	**9,116**	**9,116**	**9,116**
Kendall	L	Colorado	135	135	135	135	135	135
		Guadalupe	6,028	6,028	6,028	6,028	6,028	6,028
		San Antonio	4,976	4,976	4,976	4,976	4,976	4,976
		Total	**11,139**	**11,139**	**11,139**	**11,139**	**11,139**	**11,139**
Kerr	J	Colorado	318	318	318	318	318	318
		Guadalupe	15,646	14,129	14,056	13,767	13,450	13,434
		San Antonio	471	471	471	471	471	471
		Total	**16,435**	**14,918**	**14,845**	**14,556**	**14,239**	**14,223**
Medina	L	Nueces	1,575	1,575	1,575	1,575	1,575	1,575
		San Antonio	925	925	925	925	925	925
		Total	**2,500**	**2,500**	**2,500**	**2,500**	**2,500**	**2,500**

TABLE 2. CONTINUED.

County	RWPA	River Basin	Year					
			2010	**2020**	**2030**	**2040**	**2050**	**2060**
Travis	K	**Colorado (Total)**	**8,920**	**8,672**	**8,655**	**8,643**	**8,627**	**8,598**
GMA 9			**93,052**	**91,276**	**91,183**	**90,881**	**90,548**	**90,503**

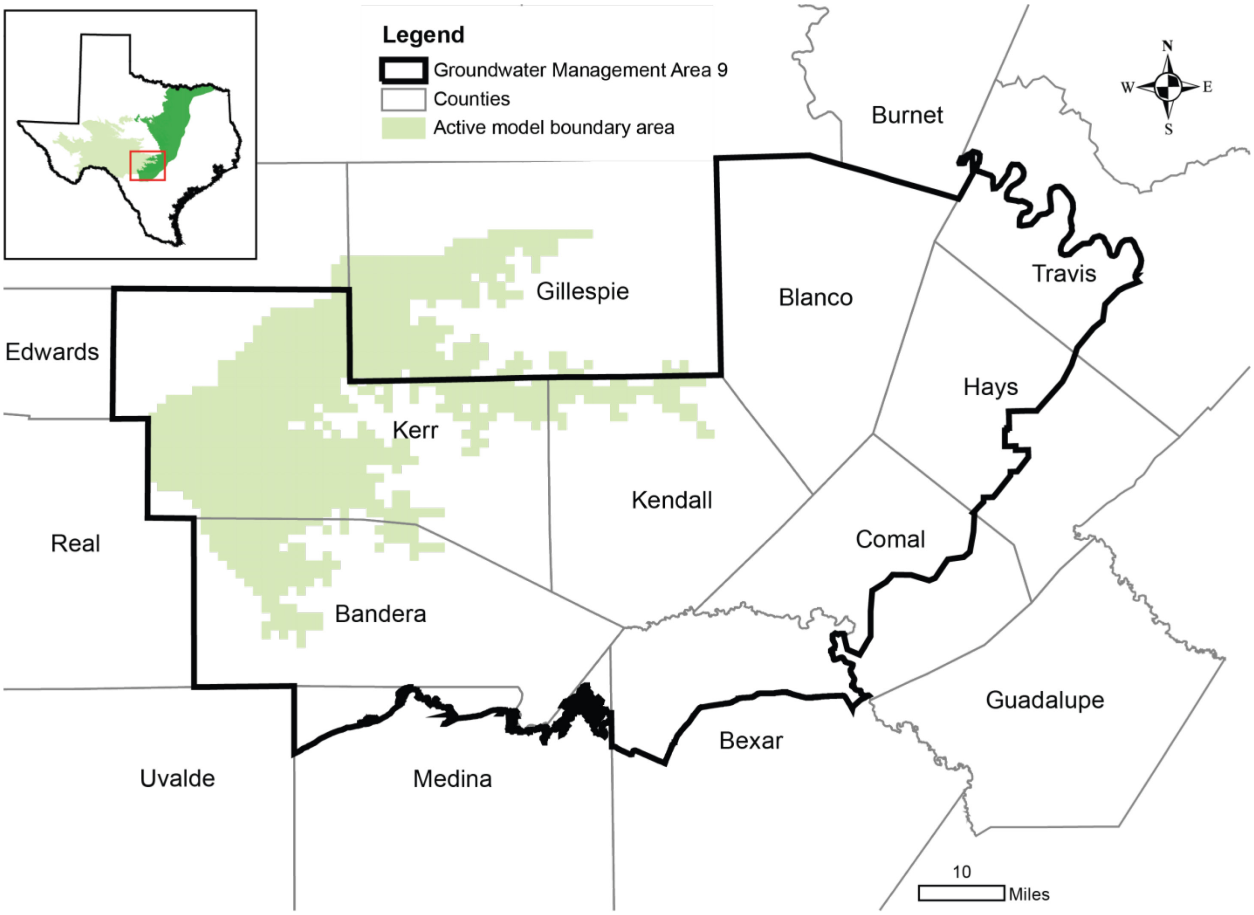

FIGURE 5. MAP SHOWING THE AREAS COVERED BY THE EDWARDS GROUP OF THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN THE GROUNDWATER AVAILABILITY MODEL FOR THE HILL COUNTRY PORTION OF THE TRINITY AQUIFER IN GROUNDWATER MANAGEMENT AREA 9.

TABLE 3. MODELED AVAILABLE GROUNDWATER FOR THE EDWARDS GROUP OF THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN GROUNDWATER MANAGEMENT AREA 9 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT AND COUNTY, FOR EACH DECADE BETWEEN 2010 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

District	County	Year						
		2010	2020	2030	2040	2050	2060	2070
Bandera County River Authority & Groundwater District Total	Bandera	2,009	2,009	2,009	2,009	2,009	2,009	2,009
Cow Creek Groundwater Conservation District Total	Kendall	199	199	199	199	199	199	199
Grand Total		2,208	2,208	2,208	2,208	2,208	2,208	2,208

TABLE 4. MODELED AVAILABLE GROUNDWATER BY DECADE FOR THE EDWARDS GROUP OF THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN GROUNDWATER MANAGEMENT AREA 9 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2010 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Year						
			2010	2020	2030	2040	2050	2060	2070
Bandera	Plateau (J)	Guadalupe	81	81	81	81	81	81	81
		Nueces	38	38	38	38	38	38	38
		San Antonio	1,890	1,890	1,890	1,890	1,890	1,890	1,890
		Total	**2,009**	**2,009**	**2,009**	**2,009**	**2,009**	**2,009**	**2,009**
Kendall	South Central Texas (L)	Colorado	69	69	69	69	69	69	69
		Guadalupe	130	130	130	130	130	130	130
		Total	**199**	**199**	**199**	**199**	**199**	**199**	**199**
Grand Total			**2,208**	**2,208**	**2,208**	**2,208**	**2,208**	**2,208**	**2,208**

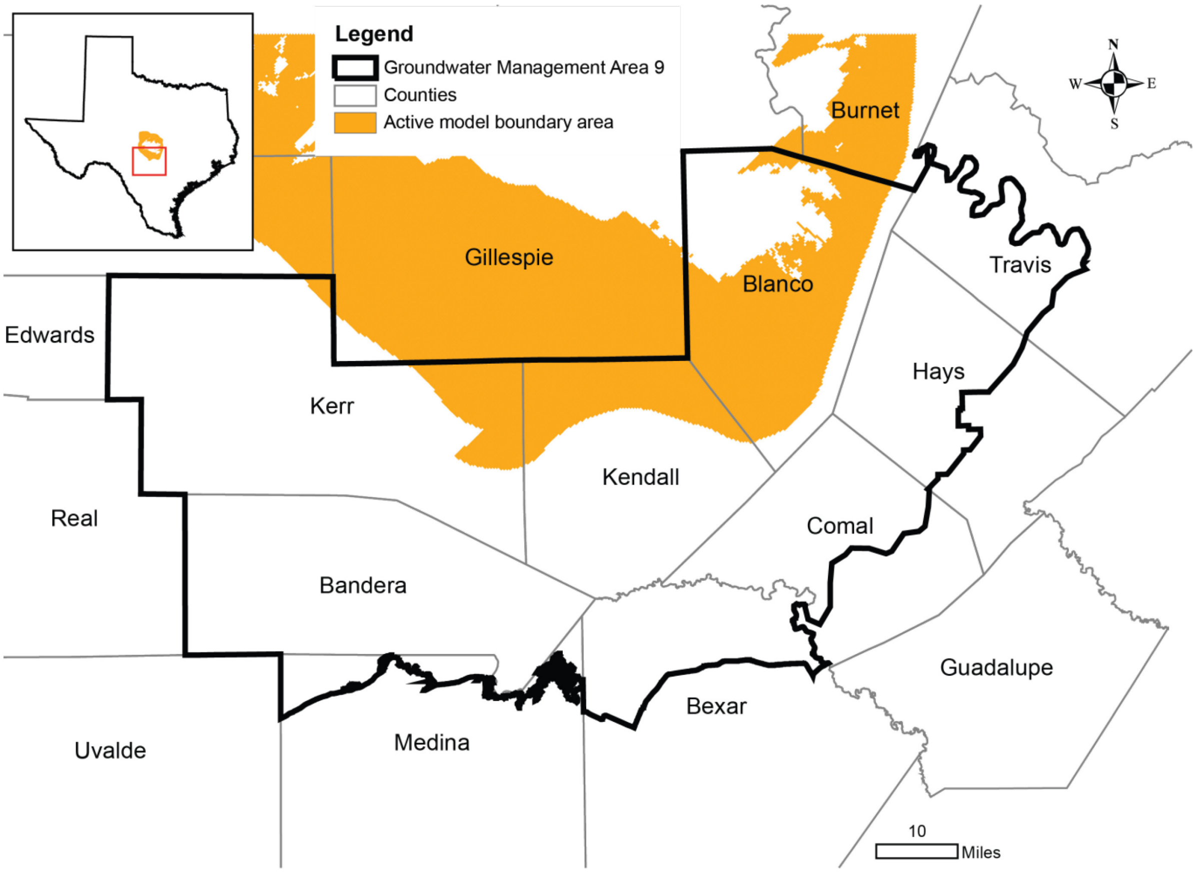

FIGURE 6. MAP SHOWING THE AREAS COVERED BY THE ELLENBURGER-SAN SABA AQUIFER IN THE GROUNDWATER AVAILABILITY MODEL FOR THE MINOR AQUIFERS OF THE LLANO UPLIFT AREA IN GROUNDWATER MANAGEMENT AREA 9.

TABLE 5. MODELED AVAILABLE GROUNDWATER FOR THE ELLENBURGER-SAN SABA AQUIFER IN GROUNDWATER MANAGEMENT AREA 9 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT AND COUNTY FOR EACH DECADE BETWEEN 2010 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

District	County	Year						
		2010	2020	2030	2040	2050	2060	2070
Cow Creek Groundwater Conservation District Total	**Kendall**	**75**	**75**	**75**	**75**	**75**	**75**	**75**

TABLE 6. MODELED AVAILABLE GROUNDWATER FOR THE ELLENBURGER-SAN SABA AQUIFER IN GROUNDWATER MANAGEMENT AREA 9 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2010 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Year						
			2010	2020	2030	2040	2050	2060	2070
Kendall	South Central Texas (L)	Colorado	10	10	10	10	10	10	10
		Guadalupe	64	64	64	64	64	64	64
		Total	**75**	**75**	**75**	**75**	**75**	**75**	**75**

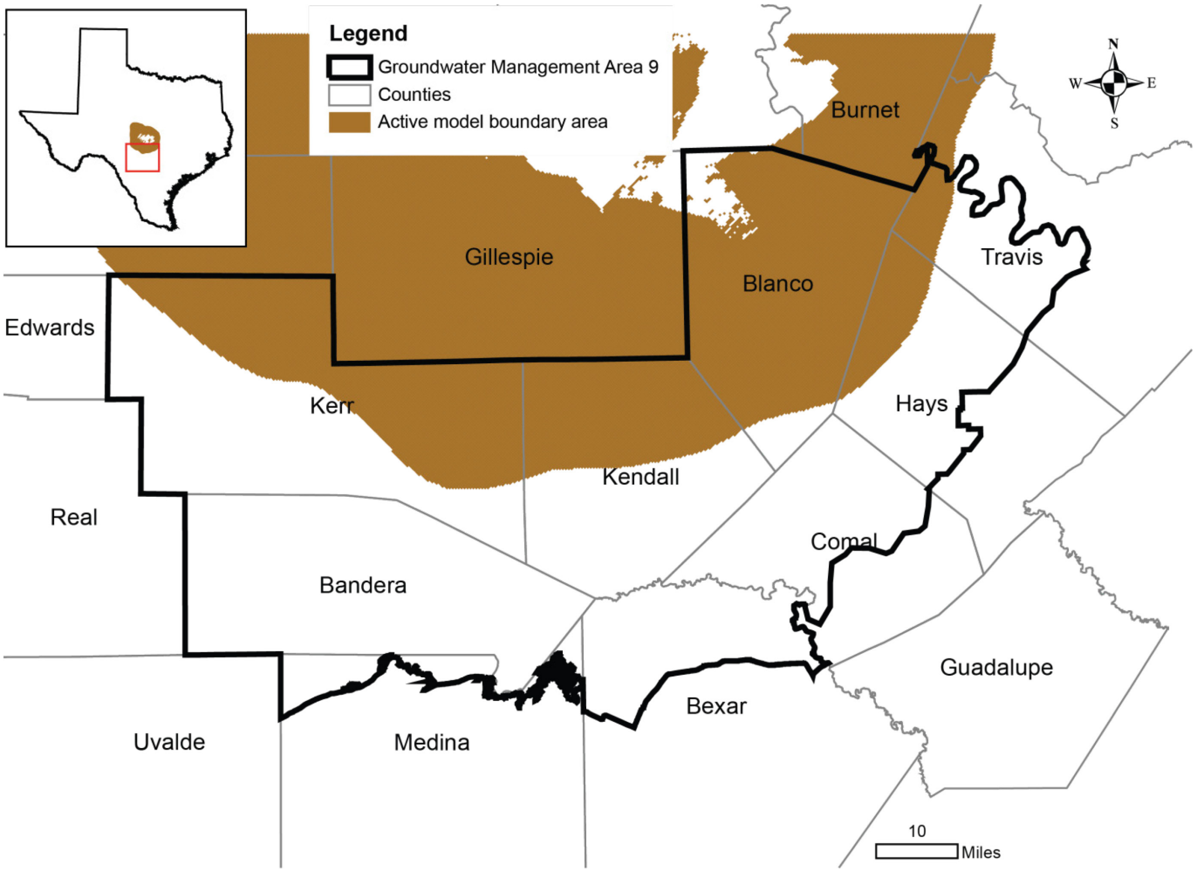

FIGURE 7. MAP SHOWING AREAS COVERED BY THE HICKORY AQUIFER IN THE GROUNDWATER AVAILABILITY MODEL FOR THE MINOR AQUIFERS OF THE LLANO UPLIFT AREA IN GROUNDWATER MANAGEMENT AREA 9.

TABLE 7. MODELED AVAILABLE GROUNDWATER FOR THE HICKORY AQUIFER IN GROUNDWATER MANAGEMENT AREA 9 SUMMARIZED BY DISTRICT AND COUNTY FOR EACH DECADE BETWEEN 2010 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

District	County	Year						
		2010	2020	2030	2040	2050	2060	2070
Cow Creek Groundwater Conservation District Total	**Kendall**	**140**	**140**	**140**	**140**	**140**	**140**	**140**

TABLE 8. MODELED AVAILABLE GROUNDWATER FOR THE HICKORY AQUIFER IN GROUNDWATER MANAGEMENT AREA 9 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2010 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

County	RPWA	River Basin	Year						
			2010	2020	2030	2040	2050	2060	2070
Kendall	South Central Texas (L)	Colorado	12	12	12	12	12	12	12
		Guadalupe	128	128	128	128	128	128	128
		Total	**140**	**140**	**140**	**140**	**140**	**140**	**140**

LIMITATIONS:

The groundwater model used in completing this analysis is the best available scientific tool that can be used to meet the stated objectives. To the extent that this analysis will be used for planning purposes and/or regulatory purposes related to pumping in the past and into the future, it is important to recognize the assumptions and limitations associated with the use of the results. In reviewing the use of models in environmental regulatory decision making, the National Research Council (2007) noted:

> *"Models will always be constrained by computational limitations, assumptions, and knowledge gaps. They can best be viewed as tools to help inform decisions rather than as machines to generate truth or make decisions. Scientific advances will never make it possible to build a perfect model that accounts for every aspect of reality or to prove that a given model is correct in all respects for a particular regulatory application. These characteristics make evaluation of a regulatory model more complex than solely a comparison of measurement data with model results."*

A key aspect of using the groundwater model to evaluate historic groundwater flow conditions includes the assumptions about the location in the aquifer where historic pumping was placed. Understanding the amount and location of historic pumping is as important as evaluating the volume of groundwater flow into and out of the district, between aquifers within the district (as applicable), interactions with surface water (as applicable), recharge to the aquifer system (as applicable), and other metrics that describe the impacts of that pumping. In addition, assumptions regarding precipitation, recharge, and streamflow are specific to a particular historic time period.

Because the application of the groundwater model was designed to address regional scale questions, the results are most effective on a regional scale. The TWDB makes no warranties or representations relating to the actual conditions of any aquifer at a particular location or at a particular time.

It is important for groundwater conservation districts to monitor groundwater pumping and groundwater levels in the aquifer. Because of the limitations of the groundwater model and the assumptions in this analysis, it is important that the groundwater conservation districts work with the TWDB to refine this analysis in the future given the reality of how the aquifer responds to the actual amount and location of pumping now and in the future. Historic precipitation patterns also need to be placed in context as future climatic conditions, such as dry and wet year precipitation patterns, may differ and affect groundwater flow conditions.

Model "Dry" Cells

The predictive model run for this analysis results in water levels in some model cells dropping below the base elevation of the cell during the simulation. In terms of water level, the cells have gone dry. However, as noted in the model assumptions the transmissivity of the cell remains constant and will produce water.

A total of 18 cells out of 23,805 active cells simulating the Trinity Aquifer cells go "dry" during the predictive period through 2060. These dry cells are located in western Travis County, central Hays County and Kerr County. These dry cells are associated either with areas of high pumping or thin parts of the Trinity Aquifer.

REFERENCES:

Groundwater Management Area 9 (GMA 9) Joint Planning Committee, Blanton and Associates, Inc., and LBG-Guyton Associates, 2016, Groundwater Management Area 9 explanatory report for desired future conditions: major and minor aquifers, April 2016, 189 p.

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Hassan, M. M., 2012, GAM Run 10-050 MAG: Texas Water Development Board GAM Run Report 10-050, v. 2, 10 p.

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National Research Council, 2007, Models in Environmental Regulatory Decision Making Committee on Models in the Regulatory Decision Process, National Academies Press, Washington D.C., 287 p., http://www.nap.edu/catalog.php?record_id=11972.

Panday, S., Langevin, C. D., Niswonger, R. G., Ibaraki, M., and Hughes, J. D., 2013, MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: U.S. Geological Survey Techniques and Methods, book 6, chap. A45, 66 p.

Shi, J., Boghici, R., Kohlrenken, W., and Hutchison, W., 2016, Numerical model report: minor aquifers of the Llano Uplift Region of Texas (Marble Falls, Ellenburger-San Saba, and Hickory): Texas Water Development Board published report, 400 p.

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APPENDIX D

Estimated Historical Water Use And
2017 State Water Data Plan Datasets

Headwaters Groundwater Conservation District

Estimated Historical Water Use And 2017 State Water Plan Datasets:

Headwaters Groundwater Conservation District

by Stephen Allen
Texas Water Development Board
Groundwater Division
Groundwater Technical Assistance Section
stephen.allen@twdb.texas.gov
(512) 463-7317
April 20, 2021

GROUNDWATER MANAGEMENT PLAN DATA:

This package of water data reports (part 1 of a 2-part package of information) is being provided to groundwater conservation districts to help them meet the requirements for approval of their five-year groundwater management plan. Each report in the package addresses a specific numbered requirement in the Texas Water Development Board's groundwater management plan checklist. The checklist can be viewed and downloaded from this web address:

http://www.twdb.texas.gov/groundwater/docs/GCD/GMPChecklist0113.pdf

The five reports included in this part are:

1. Estimated Historical Water Use (checklist item 2)

   from the TWDB Historical Water Use Survey (WUS)

2. Projected Surface Water Supplies (checklist item 6)
3. Projected Water Demands (checklist item 7)
4. Projected Water Supply Needs (checklist item 8)
5. Projected Water Management Strategies (checklist item 9)

   from the 2017 Texas State Water Plan (SWP)

Part 2 of the 2-part package is the groundwater availability model (GAM) report for the District (checklist items 3 through 5). The District should have received, or will receive, this report from the Groundwater Availability Modeling Section. Questions about the GAM can be directed to Dr. Shirley Wade, shirley.wade@twdb.texas.gov, (512) 936-0883.

DISCLAIMER:

The data presented in this report represents the most up-to-date WUS and 2017 SWP data available as of 4/20/2021. Although it does not happen frequently, either of these datasets are subject to change pending the availability of more accurate WUS data or an amendment to the 2017 SWP. District personnel must review these datasets and correct any discrepancies in order to ensure approval of their groundwater management plan.

The WUS dataset can be verified at this web address:

http://www.twdb.texas.gov/waterplanning/waterusesurvey/estimates/

The 2017 SWP dataset can be verified by contacting Sabrina Anderson (sabrina.anderson@twdb.texas.gov or 512-936-0886).

For additional questions regarding this data, please contact Stephen Allen (stephen.allen@twdb.texas.gov or 512-463-7317).

Estimated Historical Water Use
TWDB Historical Water Use Survey (WUS) Data

Groundwater and surface water historical use estimates are currently unavailable for calendar year 2019. TWDB staff anticipates the calculation and posting of these estimates at a later date.

KERR COUNTY

All values are in acre-feet

Year	Source	Municipal	Manufacturing	Mining	Steam Electric	Irrigation	Livestock	Total
2018	GW	4,000	3	14	0	1,047	229	5,293
	SW	3,953	20	111	0	223	335	4,642
2017	GW	3,999	1	54	0	1,515	222	5,791
	SW	3,991	7	125	0	455	345	4,923
2016	GW	3,835	1	39	0	397	230	4,502
	SW	4,275	10	146	0	293	293	5,017
2015	GW	4,596	0	27	0	607	228	5,458
	SW	2,928	0	174	0	441	293	3,836
2014	GW	4,656	0	30	0	1,509	279	6,474
	SW	2,880	0	137	0	519	372	3,908
2013	GW	4,915	0	31	0	1,077	253	6,276
	SW	3,245	0	126	0	624	403	4,398
2012	GW	5,607	20	30	0	459	300	6,416
	SW	3,316	0	76	0	855	401	4,648
2011	GW	5,800	8	0	0	293	432	6,533
	SW	3,475	0	0	0	362	457	4,294
2010	GW	4,681	6	17	0	447	428	5,579
	SW	4,635	0	54	0	567	462	5,718
2009	GW	4,092	23	16	0	246	343	4,720
	SW	4,255	0	49	0	807	459	5,570
2008	GW	4,885	24	15	0	73	367	5,364
	SW	3,498	0	44	0	1,015	430	4,987
2007	GW	4,623	23	0	0	133	327	5,106
	SW	3,529	0	0	0	1,035	287	4,851
2006	GW	4,625	7	0	0	120	328	5,080
	SW	3,814	0	0	0	400	291	4,505
2005	GW	3,847	6	0	0	76	314	4,243
	SW	3,981	0	0	0	450	230	4,661
2004	GW	4,475	6	0	0	47	171	4,699
	SW	4,347	0	0	0	478	461	5,286
2003	GW	3,439	8	0	0	77	171	3,695
	SW	4,347	0	0	0	772	515	5,634

Projected Surface Water Supplies
TWDB 2017 State Water Plan Data

KERR COUNTY

All values are in acre-feet

RWPG	WUG	WUG Basin	Source Name	2020	2030	2040	2050	2060	2070
J	COUNTY-OTHER, KERR	GUADALUPE	GUADALUPE RUN-OF-RIVER	15	15	15	15	15	15
J	IRRIGATION, KERR	GUADALUPE	GUADALUPE RUN-OF-RIVER	958	958	958	958	958	958
J	KERRVILLE	GUADALUPE	GUADALUPE RUN-OF-RIVER	150	150	150	150	150	150
J	LIVESTOCK, KERR	COLORADO	COLORADO OTHER LOCAL SUPPLY	46	46	46	46	46	46
J	LIVESTOCK, KERR	GUADALUPE	GUADALUPE OTHER LOCAL SUPPLY	393	393	393	393	393	393
J	LIVESTOCK, KERR	SAN ANTONIO	SAN ANTONIO OTHER LOCAL SUPPLY	23	23	23	23	23	23
J	MANUFACTURING, KERR	GUADALUPE	GUADALUPE RUN-OF-RIVER	9	9	9	9	9	9
J	MINING, KERR	GUADALUPE	GUADALUPE RUN-OF-RIVER	89	89	89	89	89	89
	Sum of Projected Surface Water Supplies (acre-feet)			**1,683**	**1,683**	**1,683**	**1,683**	**1,683**	**1,683**

Projected Water Demands
TWDB 2017 State Water Plan Data

Please note that the demand numbers presented here include the plumbing code savings found in the Regional and State Water Plans.

KERR COUNTY

All values are in acre-feet

RWPG	WUG	WUG Basin	2020	2030	2040	2050	2060	2070
J	COUNTY-OTHER, KERR	COLORADO	53	53	53	53	54	55
J	COUNTY-OTHER, KERR	GUADALUPE	1,946	1,986	1,994	2,029	2,072	2,110
J	COUNTY-OTHER, KERR	NUECES	1	1	1	1	1	1
J	COUNTY-OTHER, KERR	SAN ANTONIO	29	29	28	29	29	30
J	INGRAM	GUADALUPE	165	160	155	153	154	155
J	IRRIGATION, KERR	COLORADO	23	22	21	21	20	19
J	IRRIGATION, KERR	GUADALUPE	804	779	755	730	708	687
J	IRRIGATION, KERR	SAN ANTONIO	15	15	14	14	13	13
J	KERRVILLE	GUADALUPE	4,619	4,688	4,706	4,759	4,821	4,875
J	LIVESTOCK, KERR	COLORADO	195	195	195	195	195	195
J	LIVESTOCK, KERR	GUADALUPE	642	642	642	642	642	642
J	LIVESTOCK, KERR	NUECES	11	11	11	11	11	11
J	LIVESTOCK, KERR	SAN ANTONIO	42	42	42	42	42	42
J	LOMA VISTA WATER SYSTEM	GUADALUPE	417	424	425	431	438	444
J	MANUFACTURING, KERR	GUADALUPE	25	27	29	30	32	34
J	MINING, KERR	COLORADO	14	15	19	19	21	23
J	MINING, KERR	GUADALUPE	62	65	81	83	90	97
		Sum of Projected Water Demands (acre-feet)	**9,063**	**9,154**	**9,171**	**9,242**	**9,343**	**9,433**

Projected Water Supply Needs
TWDB 2017 State Water Plan Data

Negative values (in red) reflect a projected water supply need, positive values a surplus.

KERR COUNTY

All values are in acre-feet

RWPG	WUG	WUG Basin	2020	2030	2040	2050	2060	2070
J	COUNTY-OTHER, KERR	COLORADO	-5	-5	-5	-5	-6	-7
J	COUNTY-OTHER, KERR	GUADALUPE	3,242	3,202	3,194	3,159	3,116	3,078
J	COUNTY-OTHER, KERR	NUECES	-1	-1	-1	-1	-1	-1
J	COUNTY-OTHER, KERR	SAN ANTONIO	84	84	85	84	84	83
J	INGRAM	GUADALUPE	387	392	397	399	398	397
J	IRRIGATION, KERR	COLORADO	21	22	23	23	24	25
J	IRRIGATION, KERR	GUADALUPE	556	581	605	630	652	673
J	IRRIGATION, KERR	SAN ANTONIO	-14	-14	-13	-13	-12	-12
J	KERRVILLE	GUADALUPE	-3,194	-3,263	-3,281	-3,334	-3,396	-3,450
J	LIVESTOCK, KERR	COLORADO	-106	-106	-106	-106	-106	-106
J	LIVESTOCK, KERR	GUADALUPE	131	131	131	131	131	131
J	LIVESTOCK, KERR	NUECES	-6	-6	-6	-6	-6	-6
J	LIVESTOCK, KERR	SAN ANTONIO	-18	-18	-18	-18	-18	-18
J	LOMA VISTA WATER SYSTEM	GUADALUPE	-30	-37	-38	-44	-51	-57
J	MANUFACTURING, KERR	GUADALUPE	9	7	5	4	2	0
J	MINING, KERR	COLORADO	-12	-13	-17	-17	-19	-21
J	MINING, KERR	GUADALUPE	42	39	23	21	14	7
		Sum of Projected Water Supply Needs (acre-feet)	**-3,386**	**-3,463**	**-3,485**	**-3,544**	**-3,615**	**-3,678**

KERR COUNTY

WUG, Basin (RWPG)

All values are in acre-feet

Water Management Strategy	Source Name [Origin]	2020	2030	2040	2050	2060	2070
COUNTY-OTHER, KERR, COLORADO (J)							
MUNICIPAL AND COUNTY OTHER CONSERVATION FOR UGRA	DEMAND REDUCTION [KERR]	5	5	5	5	6	7
		5	**5**	**5**	**5**	**6**	**7**
COUNTY-OTHER, KERR, GUADALUPE (J)							
CCP/UGRA - ELLENBURGER AQUIFER WATER SUPPLY WELL	ELLENBURGER AQUIFER [KERR]	108	108	108	108	108	108
CCP/UGRA - WELL FIELD FOR DENSE, RURAL AREAS	TRINITY AQUIFER [KERR]	994	994	994	994	994	994
CENTER POINT WWW - WATER LOSS AUDIT AND MAIN-LINE REPAIR	DEMAND REDUCTION [KERR]	1	1	1	1	1	1
EKC/UGRA - ACQUISITION OF SURFACE WATER RIGHTS	GUADALUPE RUN-OF-RIVER [KERR]	1,029	1,029	1,029	1,029	1,029	1,029
EKC/UGRA - ASR FACILITY	TRINITY AQUIFER ASR [KERR]	1,124	1,124	1,124	1,124	1,124	1,124
EKC/UGRA - CONSTRUCTION OF AN OFF-CHANNEL SURFACE WATER STORAGE	GUADALUPE RIVER OFF-CHANNEL LAKE/RESERVOIR [RESERVOIR]	1,121	1,121	1,121	1,121	1,121	1,121
EKC/UGRA - CONSTRUCTION OF SURFACE WATER TREATMENT FACILITIES AND DISTRIBUTION LINES	GUADALUPE RUN-OF-RIVER [KERR]	15	15	15	15	15	15
HILLS AND DALES WWW - WATER LOSS AUDIT AND MAIN-LINE REPAIR	DEMAND REDUCTION [KERR]	1	1	1	1	1	1
KERR COUNTY OTHER - VEGETATIVE MANAGEMENT - ASHE JUNIPER	TRINITY AQUIFER [KERR]	0	0	0	0	0	0
MUNICIPAL AND COUNTY OTHER CONSERVATION FOR UGRA	DEMAND REDUCTION [KERR]	9	9	9	10	9	8
RUSTIC HILLS WATER - WATER LOSS AUDIT AND MAIN-LINE REPAIR	DEMAND REDUCTION [KERR]	1	1	1	1	1	1
VERDE PARK ESTATES WWW - WATER LOSS AUDIT AND MAIN-LINE REPAIR	DEMAND REDUCTION [KERR]	1	1	1	1	1	1
		4,404	**4,404**	**4,404**	**4,405**	**4,404**	**4,403**
COUNTY-OTHER, KERR, NUECES (J)							
MUNICIPAL AND COUNTY OTHER CONSERVATION FOR UGRA	DEMAND REDUCTION [KERR]	1	1	1	1	1	1
		1	**1**	**1**	**1**	**1**	**1**
IRRIGATION, KERR, SAN ANTONIO (J)							
KERR COUNTY IRRIGATION - ADDITIONAL GROUNDWATER WELL	TRINITY AQUIFER [KERR]	20	20	20	20	20	20
		20	**20**	**20**	**20**	**20**	**20**
KERRVILLE, GUADALUPE (J)							

CITY OF KERRVILLE - INCREASE WASTEWATER REUSE	GUADALUPE RUN-OF-RIVER [KERR]	5,041	5,041	5,041	5,041	5,041	5,041
CITY OF KERRVILLE - INCREASED WATER TREATMENT AND ASR CAPACITY	TRINITY AQUIFER ASR [KERR]	3,360	3,360	3,360	3,360	3,360	3,360
CITY OF KERRVILLE - PURCHASE WATER FROM UGRA	GUADALUPE RUN-OF-RIVER [KERR]	0	0	0	0	0	0
CITY OF KERRVILLE - WATER LOSS AUDIT AND MAIN-LINE REPAIR	DEMAND REDUCTION [KERR]	147	147	147	147	147	147
		8,548	**8,548**	**8,548**	**8,548**	**8,548**	**8,548**
LIVESTOCK, KERR, COLORADO (J)							
KERR COUNTY LIVESTOCK - ADDITIONAL GROUNDWATER WELLS	EDWARDS-TRINITY-PLATEAU AQUIFER [KERR]	108	108	108	108	108	108
KERR COUNTY LIVESTOCK - ADDITIONAL GROUNDWATER WELLS - GUADALUPE RIVER BASIN	EDWARDS-TRINITY-PLATEAU AQUIFER [KERR]	10	10	10	10	10	10
		118	**118**	**118**	**118**	**118**	**118**
LIVESTOCK, KERR, NUECES (J)							
KERR COUNTY LIVESTOCK - ADDITIONAL GROUNDWATER WELLS - GUADALUPE RIVER BASIN	EDWARDS-TRINITY-PLATEAU AQUIFER [KERR]	10	10	10	10	10	10
		10	**10**	**10**	**10**	**10**	**10**
LIVESTOCK, KERR, SAN ANTONIO (J)							
KERR COUNTY LIVESTOCK - ADDITIONAL GROUNDWATER WELL	TRINITY AQUIFER [KERR]	20	20	20	20	20	20
		20	**20**	**20**	**20**	**20**	**20**
LOMA VISTA WATER SYSTEM, GUADALUPE (J)							
LOMA VISTA WSC - ADDITIONAL GROUNDWATER WELL	TRINITY AQUIFER [KERR]	57	57	57	57	57	57
LOMA VISTA WSC - CONSERVATION PUBLIC INFORMATION	DEMAND REDUCTION [KERR]	4	4	4	4	4	4
		61	**61**	**61**	**61**	**61**	**61**
MINING, KERR, COLORADO (J)							
KERR COUNTY MINING - ADDITIONAL GROUNDWATER WELL	TRINITY AQUIFER [KERR]	30	30	30	30	30	30
		30	**30**	**30**	**30**	**30**	**30**
Sum of Projected Water Management Strategies (acre-feet)		**13,217**	**13,217**	**13,217**	**13,218**	**13,218**	**13,218**

APPENDIX E

GAM Run 21-003: Headwaters Groundwater Conservation District Management Plan

GAM RUN 21-003: HEADWATERS GROUNDWATER CONSERVATION DISTRICT MANAGEMENT PLAN

Jevon Harding, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Availability Modeling Department
(512) 463-7979
April 19, 2021

EXECUTIVE SUMMARY:

Texas State Water Code, Section 36.1071, Subsection (h) (Texas Water Code, 2011), states that, in developing its groundwater management plan, a groundwater conservation district shall use groundwater availability modeling information provided by the Executive Administrator of the Texas Water Development Board (TWDB) in conjunction with any available site-specific information provided by the district for review and comment to the Executive Administrator.

The TWDB provides data and information to the Headwaters Groundwater Conservation District in two parts. Part 1 is the Estimated Historical Water Use/State Water Plan dataset report, which will be provided to you separately by the TWDB Groundwater Technical Assistance Department. Please direct questions about the water data report to Mr. Stephen Allen at 512-463-7317 or stephen.allen@twdb.texas.gov. Part 2 is the required groundwater availability modeling information and this information includes:

1. the annual amount of recharge from precipitation, if any, to the groundwater resources within the district;

2. for each aquifer within the district, the annual volume of water that discharges from the aquifer to springs and any surface-water bodies, including lakes, streams, and rivers; and

3. the annual volume of flow into and out of the district within each aquifer and between aquifers in the district.

The groundwater management plan for the Headwaters Groundwater Conservation District should be adopted by the district on or before November 17, 2021 and submitted to the executive administrator of the TWDB on or before December 17, 2021. The current management plan for the Headwaters Groundwater Conservation District expires on February 15, 2022.

We used two groundwater availability models to estimate the management plan information for the aquifers within the Headwaters Groundwater Conservation District. Information for the Hickory and Ellenburger-San Saba aquifers is from version 1.01 of the groundwater availability model for the minor aquifers of the Llano Uplift area (Shi and others, 2016a and b). Information for the Trinity and Edwards-Trinity (Plateau) aquifers is from version 1.01 of the groundwater availability model for the Edwards-Trinity (Plateau) Aquifer (Anaya and Jones, 2009).

This report replaces the results of GAM Run 16-019 (Jones, 2016), as the approach used for analyzing model results has been since refined to more accurately delineate flows between hydraulically connected units and because of updates to the spatial grid file used to define county, groundwater conservation district, and aquifer boundaries. In addition, this analysis includes results from the final groundwater availability model for the minor aquifers of the Llano Uplift area, whereas only the draft model was available at the time of publication for GAM Run 16-019. Tables 1 through 4 summarize the groundwater availability model data required by statute. Figures 1, 3, and 5 show the area of the models from which the values in the tables were extracted. Figures 2, 4, 6, and 7 provide generalized diagrams of the groundwater flow components provided in Tables 1 through 4. If, after review of the figures, the Headwaters Groundwater Conservation District determines that the district boundaries used in the assessment do not reflect current conditions, please notify the TWDB at your earliest convenience.

METHODS:

In accordance with the provisions of the Texas State Water Code, Section 36.1071, Subsection (h), the groundwater availability models mentioned above were used to estimate information for the Headwaters Groundwater Conservation District management plan. Water budgets were extracted for the historical model period for the Hickory and Ellenburger-San Saba aquifers (1981-2010) using ZONEBUDGET USG Version 1.00 (Panday and others, 2013). Water budgets were extracted for the historical model period for the Trinity and Edwards-Trinity (Plateau) aquifers (1981-2000) using ZONEBUDGET Version 3.01 (Harbaugh, 2009). The average annual water budget values for recharge, surface-water outflow, inflow to the district, outflow from the district, and the flow between aquifers within the district are summarized in this report.

PARAMETERS AND ASSUMPTIONS:

Hickory and Ellenburger-San Saba aquifers

- We used version 1.01 of the groundwater availability model for the minor aquifers in the Llano Uplift Region to analyze the Hickory and Ellenburger-San Saba aquifers. See Shi and others (2016a and b) for assumptions and limitations of the model.
- The groundwater availability model for the minor aquifers in the Llano Uplift Region contains eight layers (from top to bottom):
  - Layer 1 — Cretaceous age and younger water-bearing units
  - Layer 2 — Permian and Pennsylvanian age confining units
  - Layer 3 — the Marble Falls Aquifer and equivalent
  - Layer 4 — Mississippian age confining units
  - Layer 5 — the Ellenburger-San Saba Aquifer and equivalent
  - Layer 6 — Cambrian age confining units
  - Layer 7 — the Hickory Aquifer and equivalent, and
  - Layer 8 — Precambrian age confining units
- Individual water budgets for the district were determined for the Ellenburger-San Saba Aquifer (Layer 5) and the Hickory Aquifer (Layer 7). The Marble Falls Aquifer does not occur within the Headwaters Groundwater Conservation District and therefore no groundwater budget values are included for it in this report.
- Water budget terms were averaged for the period 1981 to 2010 (stress periods 2 through 31)
- The model was run with MODFLOW-USG (Panday and others, 2013).

Trinity and Edwards-Trinity (Plateau) aquifers

- We used version 1.01 of the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers to analyze the Trinity and Edwards-Trinity (Plateau) aquifers. See Anaya and Jones (2009) for assumptions and limitations of the model.

- The groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers contains two layers. Within Headwaters Groundwater Conservation District, these generally represent the Edwards Group and equivalent limestone hydrostratigraphic units of the Edwards-Trinity (Plateau) Aquifer (Layer 1) and the undifferentiated Trinity Group hydrostratigraphic units or equivalent units of the Trinity Aquifer and the Edwards-Trinity (Plateau) Aquifer (Layer 2).

- Individual water budgets for the district were determined for the Edwards-Trinity (Plateau) Aquifer (Layers 1 and 2, combined) and the Trinity Aquifer (Layer 2). The Pecos Valley Aquifer does not occur within the Headwaters Groundwater Conservation District and therefore no groundwater budget values are included for it in this report.

- Water budget terms were averaged for the period 1981 to 2000 (stress periods 2 through 21)

- The model was run with MODFLOW-96 (Harbaugh and McDonald, 1996).

RESULTS:

A groundwater budget summarizes the amount of water entering and leaving the aquifer according to the groundwater availability model. Selected groundwater budget components listed below were extracted from the groundwater availability model results for the Hickory, Ellenburger-San Saba, Trinity, and Edwards-Trinity (Plateau) aquifers located within the Headwaters Groundwater Conservation District and averaged over the historical calibration periods, as shown in Tables 1 through 4.

1. Precipitation recharge—the areally distributed recharge sourced from precipitation falling on the outcrop areas of the aquifers (where the aquifer is exposed at land surface) within the district.

2. Surface-water outflow—the total water discharging from the aquifer (outflow) to surface-water features such as streams, reservoirs, and springs.

3. Flow into and out of district—the lateral flow within the aquifer between the district and adjacent counties.

4. Flow between aquifers—the net vertical flow between the aquifer and adjacent aquifers or confining units. This flow is controlled by the relative water levels in each aquifer and aquifer properties of each aquifer or confining unit that define the amount of leakage that occurs.

The information needed for the district's management plan is summarized in Tables 1 through 4. It is important to note that sub-regional water budgets are not exact. This is due to the size of the model cells and the approach used to extract data from the model. To avoid double accounting, a model cell that straddles a political boundary, such as a district or county boundary, is assigned to one side of the boundary based on the location of the centroid of the model cell. For example, if a cell contains two counties, the cell is assigned to the county where the centroid of the cell is located.

TABLE 1: SUMMARIZED INFORMATION FOR THE HICKORY AQUIFER THAT IS NEEDED FOR THE HEADWATERS GROUNDWATER CONSERVATION DISTRICT'S GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Hickory Aquifer	0
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Hickory Aquifer	0
Estimated annual volume of flow into the district within each aquifer in the district	Hickory Aquifer	4,832
Estimated annual volume of flow out of the district within each aquifer in the district	Hickory Aquifer	2,349
Estimated net annual volume of flow between each aquifer in the district	From the Hickory Aquifer to the Mississippian age confining units	15
	From the Hickory Aquifer to the Ellenburger-San Saba Aquifer	213
	From the Hickory Aquifer to the brackish portion of the Ellenburger-San Saba hydrostratigraphic unit	2,113
	Into the Hickory Aquifer from the Cambrian age confining units	4,217
	From the Hickory Aquifer to the brackish portion of the Hickory hydrostratigraphic unit	3,908
	From the Hickory Aquifer to the Precambrian age confining units	411

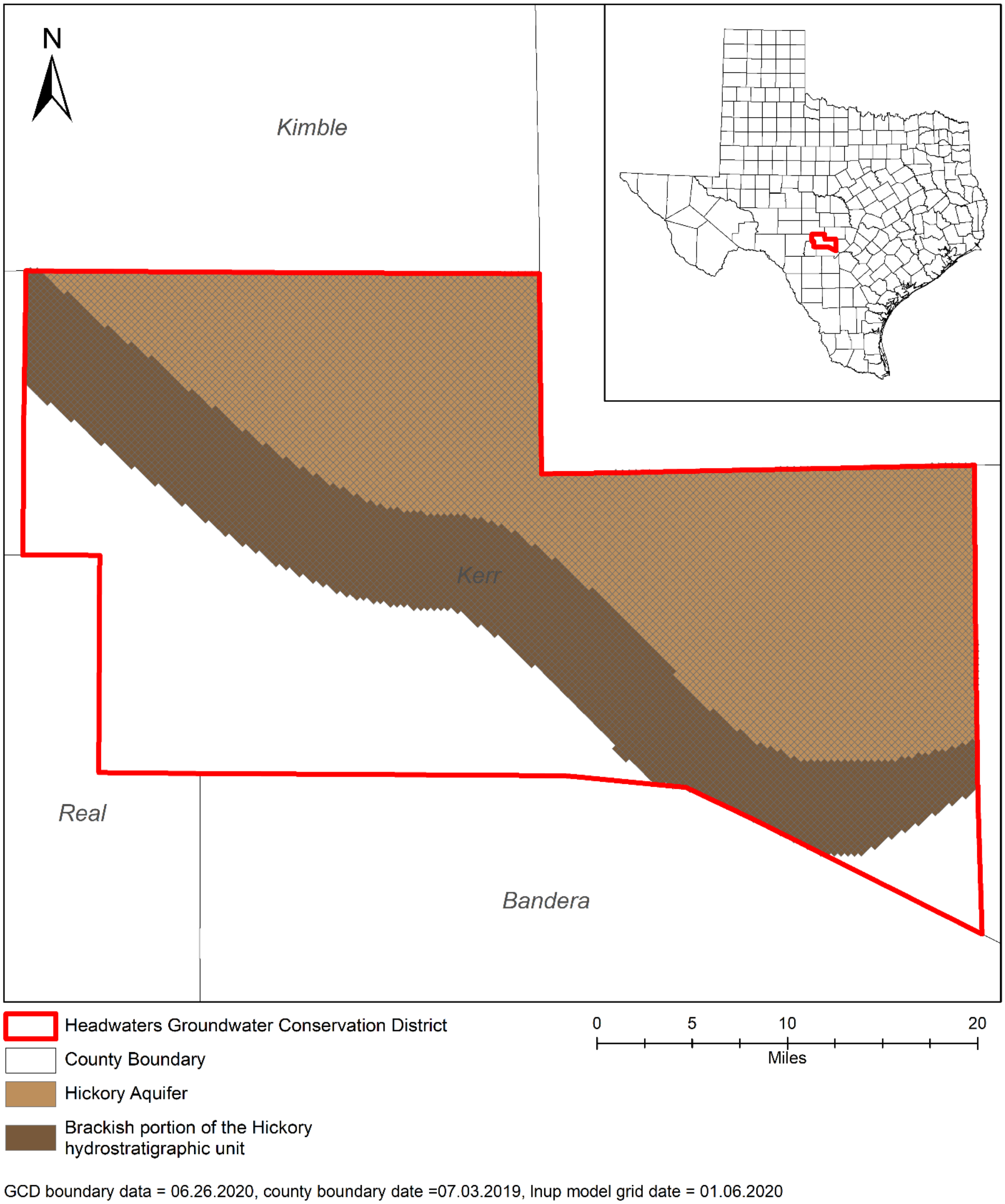
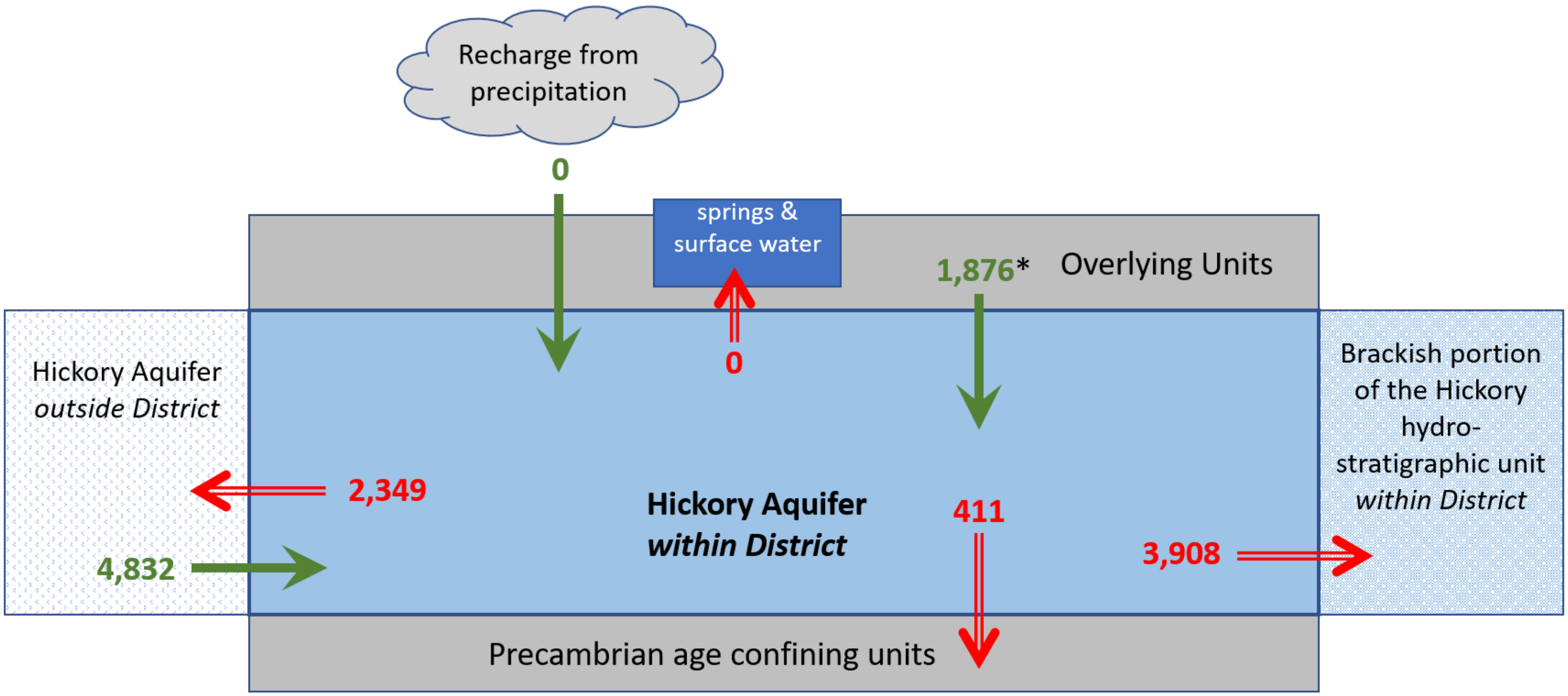


FIGURE 1: AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE MINOR AQUIFERS IN THE LLANO UPLIFT REGION FROM WHICH THE INFORMATION IN TABLE 1 WAS EXTRACTED (THE HICKORY AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).



* Flow from overlying units includes net outflow of 15 AFY to Mississippian age confining units, 213 AFY to the Ellenburger-San Saba Aquifer and 2,113 AFY to the brackish portion of the Ellenburger-San Saba hydrostratigraphic unit and net inflow of 4,217 AFY from the Cambrian age confining units.

Caveat: This diagram only includes the water budget items provided in Table 1. A complete water budget would include additional inflows and outflows. If the District requires values for additional water budget items, please contact TWDB.

FIGURE 2: GENERALIZED DIAGRAM OF THE SUMMARIZED BUDGET INFORMATION FROM TABLE 1, REPRESENTING DIRECTIONS OF FLOW FOR THE HICKORY AQUIFER WITHIN HEADWATERS GROUNDWATER CONSERVATION DISTRICT. FLOW VALUES EXPRESSED IN ACRE-FEET PER YEAR (AFY).

TABLE 2: SUMMARIZED INFORMATION FOR THE ELLENBURGER-SAN SABA AQUIFER THAT IS NEEDED FOR THE HEADWATERS GROUNDWATER CONSERVATION DISTRICT'S GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Ellenburger-San Saba Aquifer	0
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Ellenburger-San Saba Aquifer	0
Estimated annual volume of flow into the district within each aquifer in the district	Ellenburger-San Saba Aquifer	3,967
Estimated annual volume of flow out of the district within each aquifer in the district	Ellenburger-San Saba Aquifer	4,027
Estimated net annual volume of flow between each aquifer in the district	From the Ellenburger-San Saba Aquifer to the Permian & Pennsylvanian age confining units	3
	From the Ellenburger-San Saba Aquifer to the brackish portion of the Marble Falls hydrostratigraphic unit	74
	Into the Ellenburger-San Saba Aquifer from the Mississippian age confining units	551
	From the Ellenburger-San Saba Aquifer to the brackish portion of the Ellenburger-San Saba hydrostratigraphic unit	1,189
	Into the Ellenburger-San Saba Aquifer from the Cambrian age confining units	549
	Into the Ellenburger-San Saba Aquifer from the Hickory Aquifer	213
	Into the Ellenburger-San Saba Aquifer from the Precambrian age confining units	1

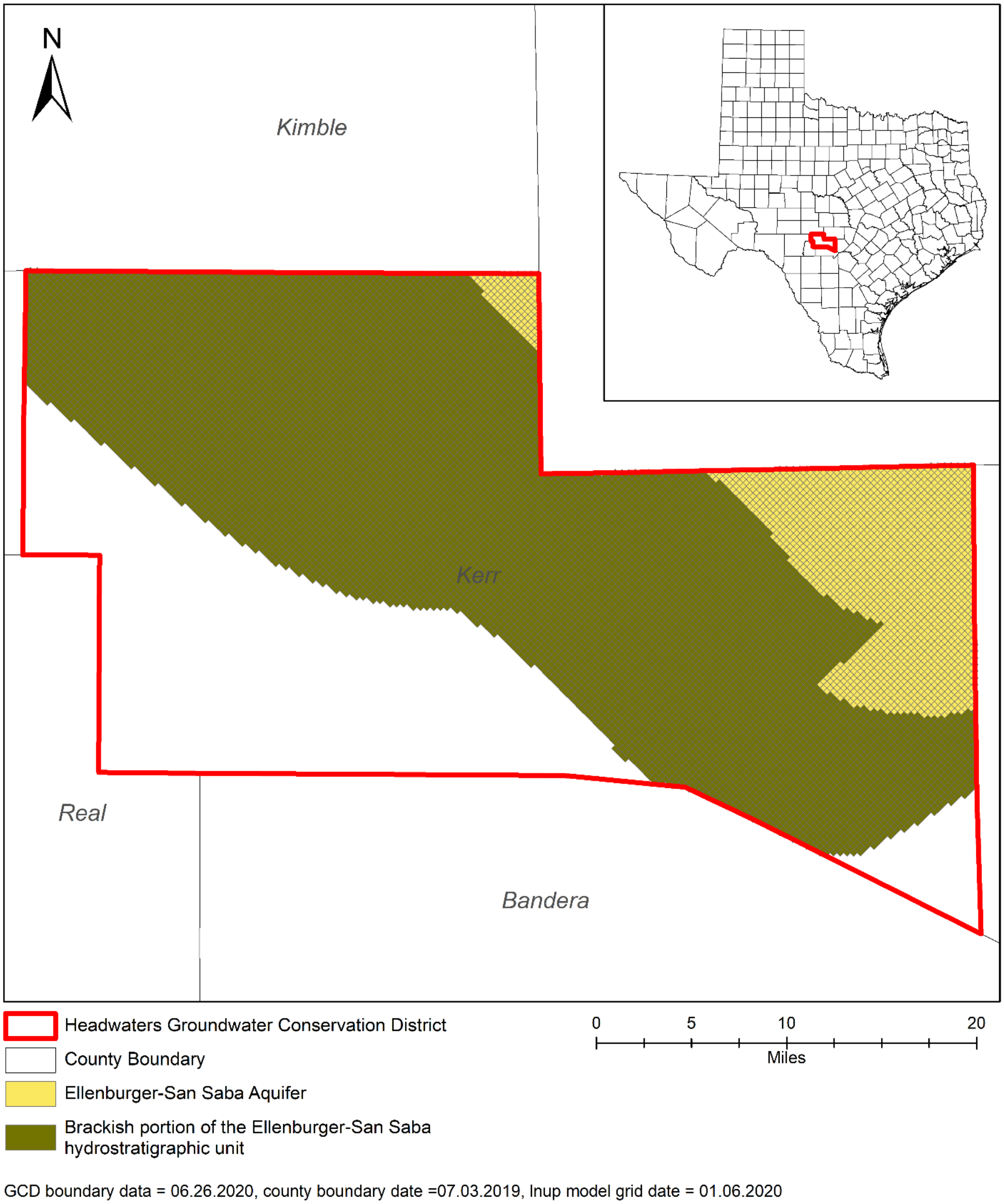
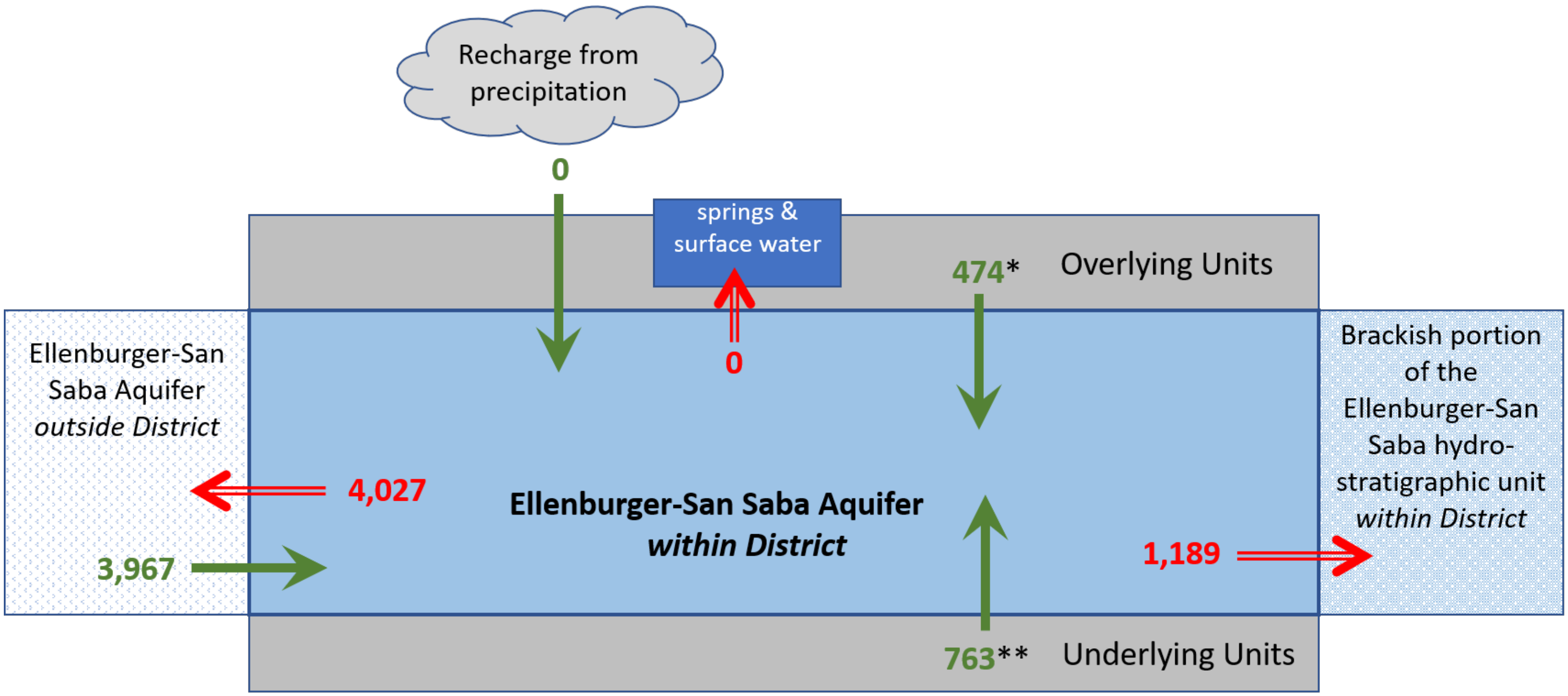


FIGURE 3: AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE MINOR AQUIFERS IN THE LLANO UPLIFT REGION FROM WHICH THE INFORMATION IN TABLE 2 WAS EXTRACTED (THE ELLENBURGER-SAN SABA AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).



* Flow from overlying units includes net outflow of 3 AFY to Permian & Pennsylvanian age confining units and 74 AFY to the Marble Falls Aquifer and net inflow of 551 AFY from the Mississippian age confining units

** Flow from underlying units includes net inflow of 549 AFY from the Cambrian age confining units, 213 AFY from the Hickory Aquifer and 1 AFY from the Precambrian age confining units.

Caveat: This diagram only includes the water budget items provided in Table 2. A complete water budget would include additional inflows and outflows. If the District requires values for additional water budget items, please contact TWDB.

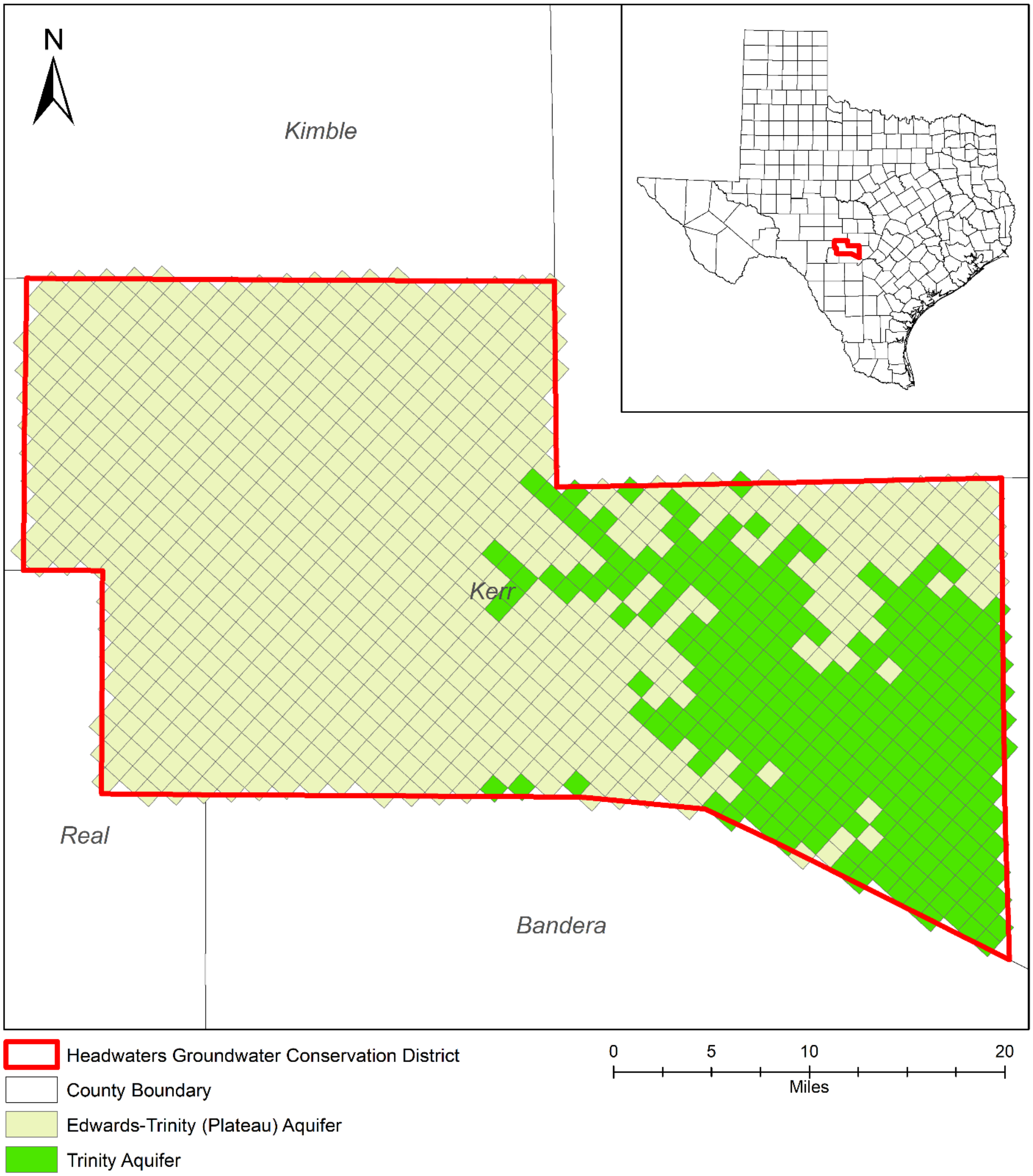
FIGURE 4: GENERALIZED DIAGRAM OF THE SUMMARIZED BUDGET INFORMATION FROM TABLE 2, REPRESENTING DIRECTIONS OF FLOW FOR THE ELLENBURGER-SAN SABA AQUIFER WITHIN HEADWATERS GROUNDWATER CONSERVATION DISTRICT. FLOW VALUES EXPRESSED IN ACRE-FEET PER YEAR (AFY).

TABLE 3: SUMMARIZED INFORMATION FOR THE TRINITY AQUIFER THAT IS NEEDED FOR THE HEADWATERS GROUNDWATER CONSERVATION DISTRICT'S GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Trinity Aquifer	21,331
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers.	Trinity Aquifer	18,473
Estimated annual volume of flow into the district within each aquifer in the district	Trinity Aquifer	2,229
Estimated annual volume of flow out of the district within each aquifer in the district	Trinity Aquifer	7,861
Estimated net annual volume of flow between each aquifer in the district	Into the Trinity Aquifer from the Edwards-Trinity (Plateau) Aquifer	5,438

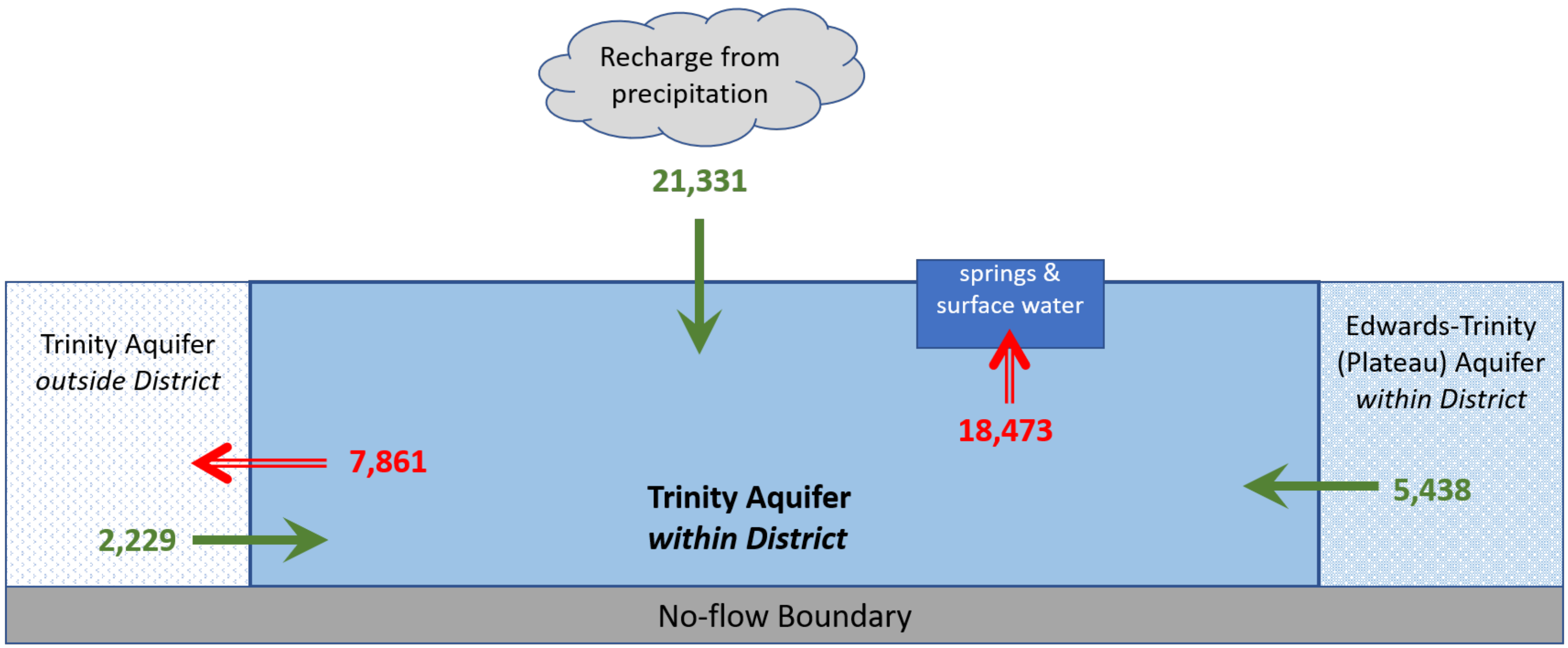
TABLE 4: SUMMARIZED INFORMATION FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER THAT IS NEEDED FOR THE HEADWATERS GROUNDWATER CONSERVATION DISTRICT'S GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Edwards-Trinity (Plateau) Aquifer	26,454
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers.	Edwards-Trinity (Plateau) Aquifer	17,697
Estimated annual volume of flow into the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	8,305
Estimated annual volume of flow out of the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	20,483
Estimated net annual volume of flow between each aquifer in the district	From the Edwards-Trinity (Plateau) Aquifer into the Trinity Aquifer	5,438



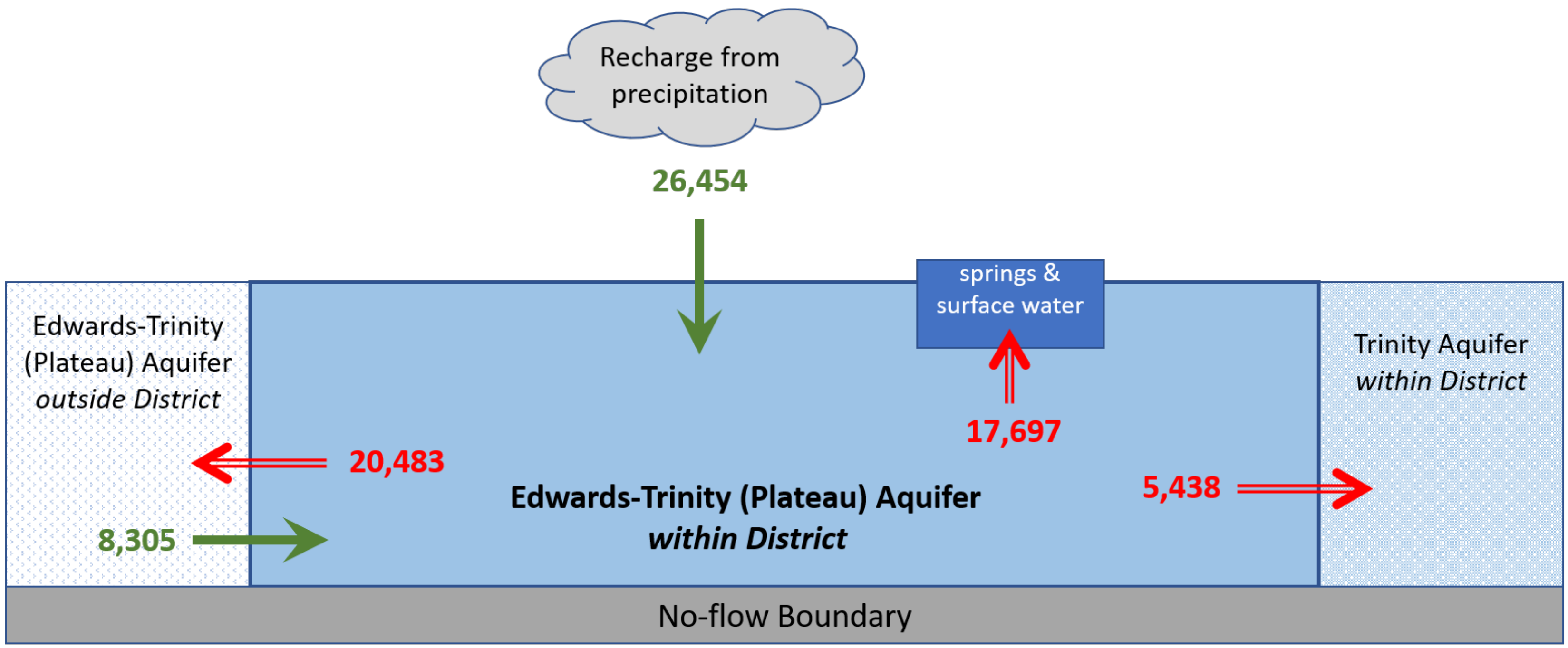
GCD boundary data = 06.26.2020, county boundary date =07.03.2019, eddt_p model grid date = 01.06.2020

FIGURE 5: AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE EDWARDS-TRINITY (PLATEAU) AND PECOS VALLEY AQUIFERS FROM WHICH THE INFORMATION IN TABLES 3 AND 4 WAS EXTRACTED (THE EDWARDS-TRINITY (PLATEAU) AND TRINITY AQUIFER EXTENTS WITHIN THE DISTRICT BOUNDARY).



Caveat: This diagram only includes the water budget items provided in Table 3. A complete water budget would include additional inflows and outflows. If the District requires values for additional water budget items, please contact TWDB.

FIGURE 6: GENERALIZED DIAGRAM OF THE SUMMARIZED BUDGET INFORMATION FROM TABLE 3, REPRESENTING DIRECTIONS OF FLOW FOR THE TRINITY AQUIFER WITHIN HEADWATERS GROUNDWATER CONSERVATION DISTRICT. FLOW VALUES EXPRESSED IN ACRE-FEET PER YEAR (AFY).



Caveat: This diagram only includes the water budget items provided in Table 4. A complete water budget would include additional inflows and outflows. If the District requires values for additional water budget items, please contact TWDB.

FIGURE 7: GENERALIZED DIAGRAM OF THE SUMMARIZED BUDGET INFORMATION FROM TABLE 4, REPRESENTING DIRECTIONS OF FLOW FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER WITHIN HEADWATERS GROUNDWATER CONSERVATION DISTRICT.FLOW VALUES EXPRESSED IN ACRE-FEET PER YEAR (AFY).

LIMITATIONS:

The groundwater models used in completing this analysis are the best available scientific tools that can be used to meet the stated objectives. To the extent that this analysis will be used for planning purposes and/or regulatory purposes related to pumping in the past and into the future, it is important to recognize the assumptions and limitations associated with the use of the results. In reviewing the use of models in environmental regulatory decision making, the National Research Council (2007) noted:

> *"Models will always be constrained by computational limitations, assumptions, and knowledge gaps. They can best be viewed as tools to help inform decisions rather than as machines to generate truth or make decisions. Scientific advances will never make it possible to build a perfect model that accounts for every aspect of reality or to prove that a given model is correct in all respects for a particular regulatory application. These characteristics make evaluation of a regulatory model more complex than solely a comparison of measurement data with model results."*

A key aspect of using the groundwater model to evaluate historic groundwater flow conditions includes the assumptions about the location in the aquifer where historic pumping was placed. Understanding the amount and location of historical pumping is as important as evaluating the volume of groundwater flow into and out of the district, between aquifers within the district (as applicable), interactions with surface water (as applicable), recharge to the aquifer system (as applicable), and other metrics that describe the impacts of that pumping. In addition, assumptions regarding precipitation, recharge, and interaction with streams are specific to particular historic time periods.

Because the application of the groundwater models was designed to address regional scale questions, the results are most effective on a regional scale. The TWDB makes no warranties or representations related to the actual conditions of any aquifer at a particular location or at a particular time.

It is important for groundwater conservation districts to monitor groundwater pumping and overall conditions of the aquifer. Because of the limitations of the groundwater model and the assumptions in this analysis, it is important that the groundwater conservation districts work with the TWDB to refine this analysis in the future given the reality of how the aquifer responds to the actual amount and location of pumping now and in the future. Historic precipitation patterns also need to be placed in context as future climatic conditions, such as dry and wet year precipitation patterns, may differ and affect groundwater flow conditions.

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Texas Water Code, 2011, http://www.statutes.legis.state.tx.us/docs/WA/pdf/WA.36.pdf

APPENDIX F

Final Report: Identification of the Vulnerability of the Major and Minor Aquifers of Texas to Subsidence with Regard to Groundwater Pumping
TWDB Contract Number 1648302062

Final Report: Identification of the Vulnerability of the Major and Minor Aquifers of Texas to Subsidence with Regard to Groundwater Pumping

TWDB Contract Number 1648302062

Prepared By

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March 21, 2017

4.2.3 Edwards–Trinity (Plateau)

The Edwards-Trinity (Plateau) Aquifer is located in central-west Texas and is the primary source of water for development in the Edwards Plateau region. Figure 4.13 provides a map of the aquifer extent. The aquifer is composed of three early Cretaceous sedimentary rock units, from oldest to youngest, the Trinity, Fredericksburg, and Lower Washita. The Fredericksburg and Lower Washita are typically lumped together as the Edwards Aquifer.

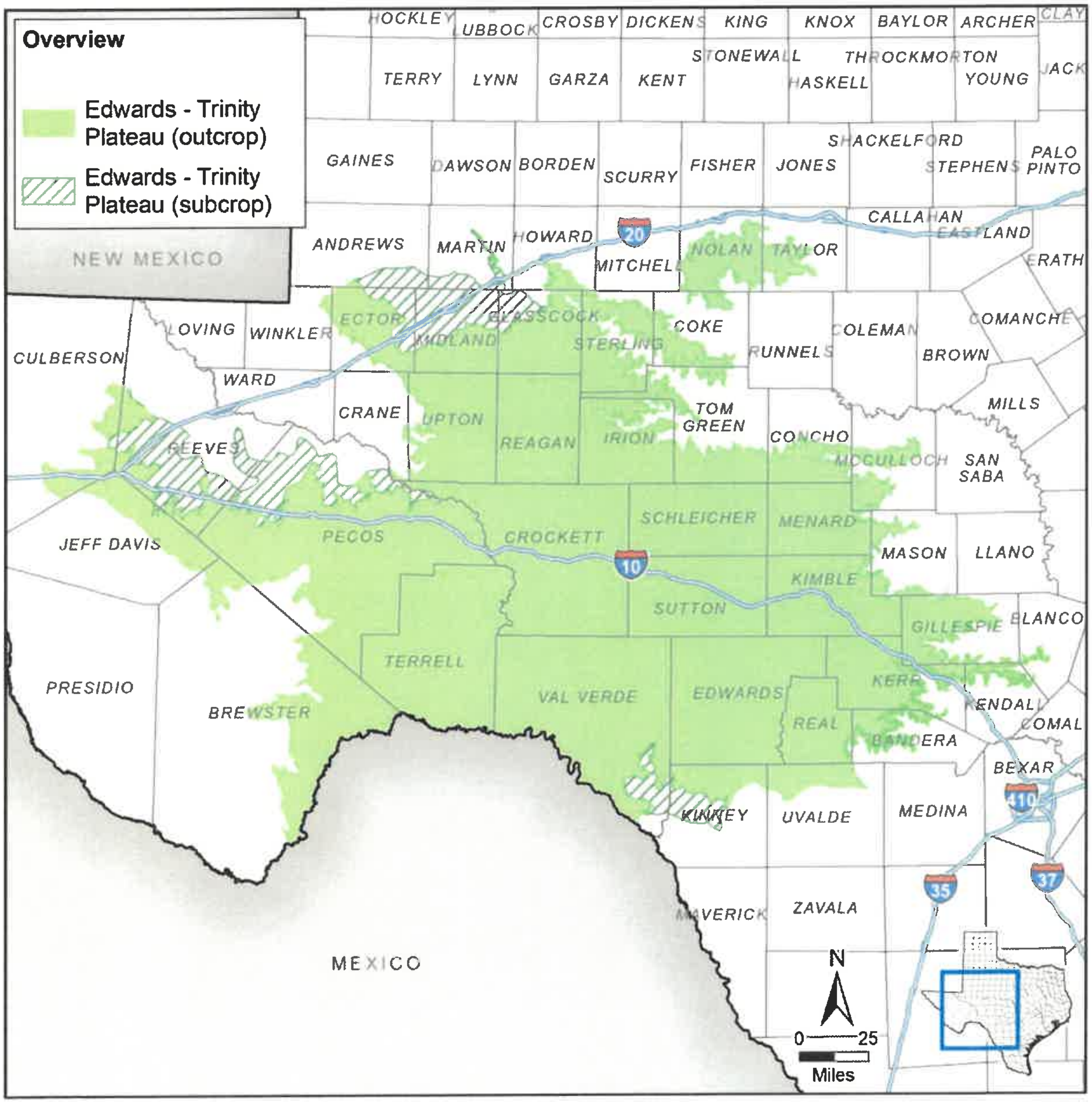

Figure 4.13. **Edwards-Trinity (Plateau) Aquifer extent.**

Hydrostratigraphy

The Edwards-Trinity (Plateau) Aquifer is large in spatial extent and the hydrostratigraphy varies across the extent of the aquifer. In this section, we describe the aquifer based on the six geographic regions shown on Figure 4.14. The Edwards-Trinity (Plateau) Aquifer is subdivided into the Trinity Group and Edwards Group. In general, the Trinity hydrostratigraphic unit of the aquifer is composed of sandstone, siltstone, claystone, and shale. The Edwards hydrostratigraphic unit is composed of limestone and dolomite. Figure 4.15 provides a cross-section of the aquifer from south to north and from northwest to southeast.

The southeastern and northeastern Edwards Plateau is underlain by a relatively impermeable base of Paleozoic rock. In these regions, the Trinity Group is subdivided into three units, from oldest to youngest, up to approximately 880 feet of Hosston Sand underlying up to approximately 240 feet of Sligo formation. The Lower Trinity is hydraulically separated from the Middle Trinity by the Hammett Shale. The Middle Trinity is composed of up to 88 feet of Cow Creek Limestone underlying 210 feet of Hensell Sand and underlying the lower member of the Glen Rose Limestone. The Upper Trinity is composed of the upper member of the Glen Rose Limestone. The Upper and Lower Glen Rose limestone combined is up to 1,530 feet thick. The Edwards Group, from oldest to youngest, is composed of up to approximately 300 feet of Fort Terrett Formation underlying up to approximately 380 feet of the Segovia Formation. In the higher elevation points of the southeastern Plateau, the Edwards Group Aquifer overlays the Trinity Aquifer and is exposed at the surface (Barker and Ardis, 1996). At the lower elevations, the Edwards Group Aquifer is not present and the Trinity Aquifer is exposed at the surface.

The central Edwards Plateau of the aquifer is underlain in areas by a relatively impermeable base of Paleozoic rock and in other areas by the Triassic age Dockum Group. The Dockum Group is generally impermeable except for areas of Santa Rosa sandstone which is hydraulically connected to the Trinity Group. The Trinity Group is composed of, from oldest to youngest, up to approximately 395 feet of basal cretaceous sand, up to approximately 1,530 feet of Glen Rose Limestone and Antlers Sand. The Basal Cretaceous sand is interbedded by and grouped with the Maxon Sand. The Edwards Formation is up to approximately 1,045 feet thick and composed of, from oldest to youngest, the West Nueces Formation, Fort Terrett Formation, McKnight Formation, Fort Lancaster Formations, Devils River Formation, and Salmon Peak Formation. The aquifer is generally confined by up to or greater than approximately 620 feet of Upper Cretaceous sediments (Barker and Ardis, 1996).

The northwestern Edwards-Trinity (Plateau) is underlain by Late Triassic sediments of the Dockum Group. In general, the hydraulic connection between the Edwards-Trinity (Plateau) Aquifer and Dockum group is limited, except in areas where the aquifer contacts the Santa Rosa Sandstone. The Trinity Aquifer is composed of, from oldest to youngest, up to approximately 385 feet of Basal Cretaceous Sand and Antlers Sand. The Edwards Aquifer is composed of, from oldest to youngest, up to approximately 165 feet of Finlay Formation and up to approximately 410 feet of Boracho Formation. Portions of the northwest aquifer is overlain by and hydraulically connected to the Ogallala Aquifer (Barker and Ardis, 1996).

The Southwestern Edwards-Trinity (Plateau) section is underline by a relatively impermeable base of Paleozoic rock. The Trinity Group is composed of, from oldest to youngest, up to approximately 385 feet of Basal Cretaceous Sand and up to approximately 200 feet of Maxon Sand. The Edwards Aquifer is composed of the Telephone Canyon, Del Carmen, Sue Peaks, and Santa Elena Formations. The aquifer is confined by the Upper Cretaceous sediments of the Del Rio Clay, Buda Limestone, and Boquillas Formation (Barker and Ardis, 1996).

The western Edwards Plateau section of the aquifer is underlain by the Dockum Group, Capitan Reef Complex, and Rustler aquifers. The Capitan Reef Complex and Rustler Aquifer are hydraulically connected to the Edwards-Trinity (Plateau) Aquifer and the Dockum is hydraulically connected where there is Santa Rosa Sandstone. The Trinity Aquifer is composed of, from youngest to oldest, up to approximately 395 feet of Basal Cretaceous Sand and up to approximately 220 Feet of Maxon sand. In the farthest northwestern region, the Trinity Aquifer is composed of, from oldest to youngest, up to approximately 180 feet of Yearwood Formation and up to approximately 170 feet of Cox Sandstone (Barker and Ardis, 1996; George and others, 2011). The Edwards Aquifer is composed of, from oldest to youngest, up to approximately 300 feet of Fort Terrett Formation and up to approximately 405 feet of Fort Lancaster Formation or up to approximately 165 feet of Finlay Formation and up to approximately 410 feet of Boracho Formation. The aquifer is confined in portions by Upper Cretaceous sediments of the Del Rio Clay, Buda Limestone, and Boquillas Formation. In other areas the aquifer is hydraulically connected to the Pecos Valley Alluvium Aquifer (Barker and Ardis, 1996).

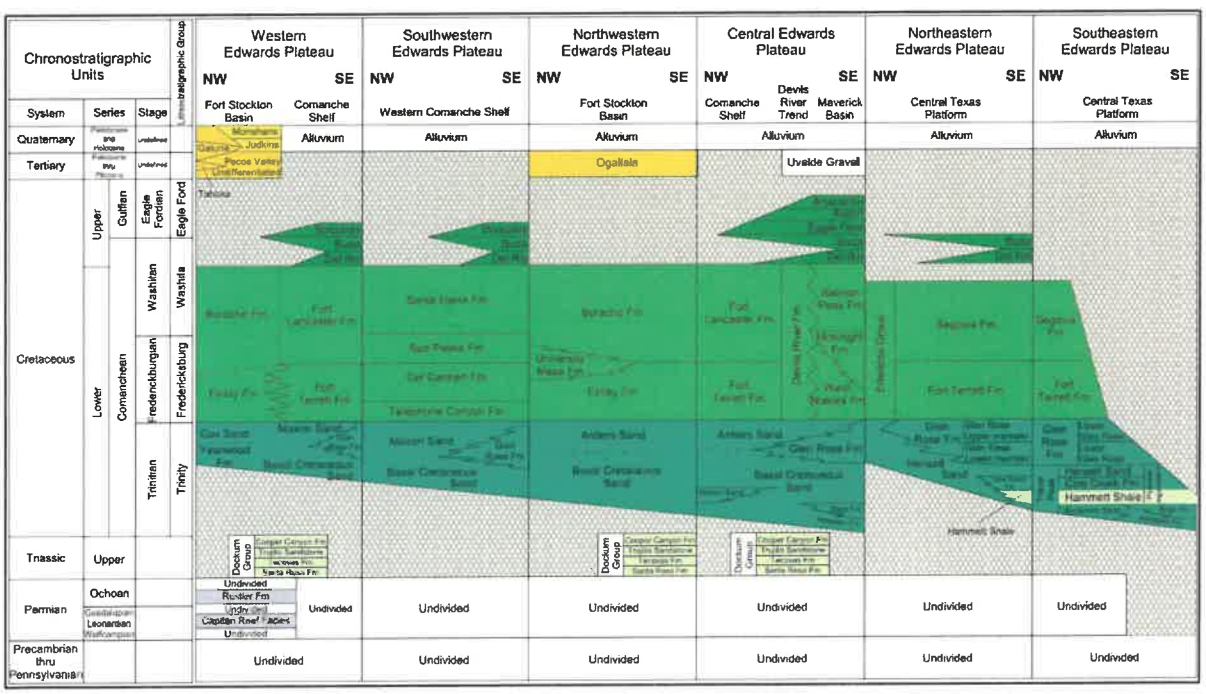

Figure 4.14. **Stratigraphic column and geologic and hydrogeologic units within the Edwards-Trinity (Plateau) Aquifer (Anaya and Jones, 2009).**

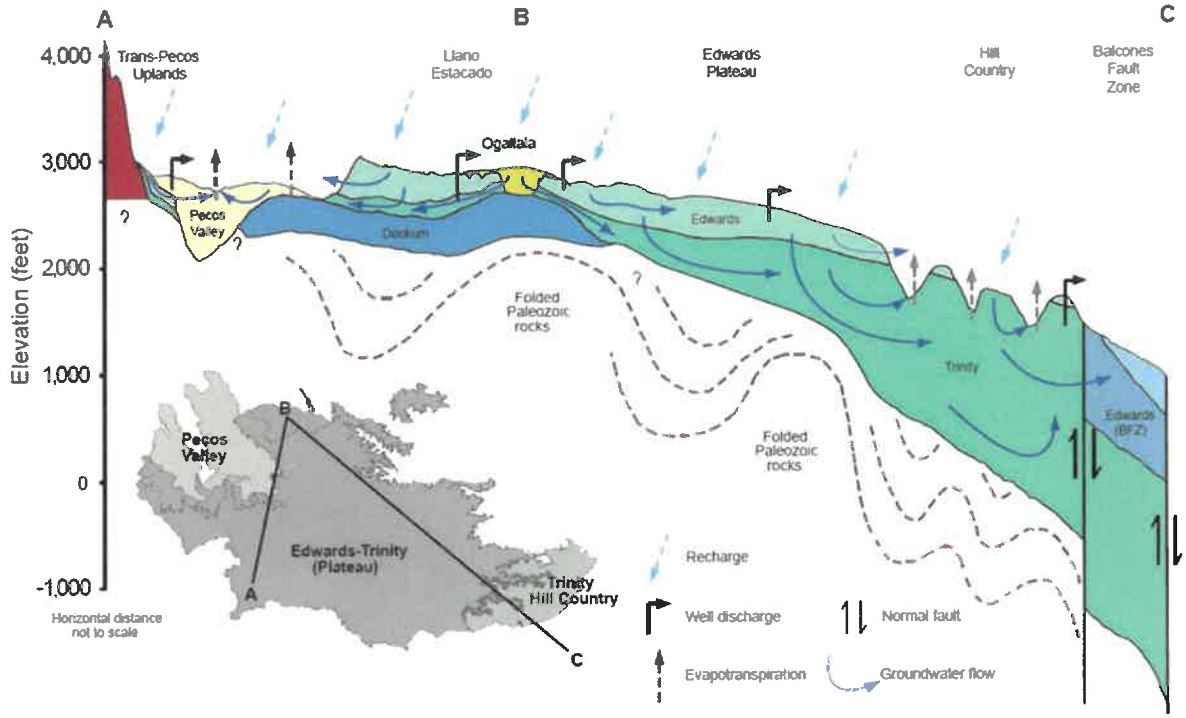

Figure 4.15. Cross Section of the Edwards-Trinity (Plateau) Aquifer (George and others, 2011).

Hydraulic Properties

Within the Edwards-Trinity (Plateau) Aquifer, there have been many studies that documented the hydraulic properties including: hydraulic conductivity, transmissivity, and storativity. Across the extent of the Edwards hydrostratigraphic unit, the aquifer hydraulic properties can vary greatly due to the influence of very high hydraulic conductivity in Karst terrain. The hydraulic properties of the Edwards-Trinity (Plateau) Aquifer documented by Anaya and Jones (2009) are used as the primary source for aquifer hydraulic properties presented in this section.

The geometric mean of the hydraulic conductivity for the Edwards Aquifer outside of karstic areas is 6.7 feet per day. The geometric mean of the hydraulic conductivity of the Trinity Group of the aquifer varies between 4.5 feet per day in the north and 2.5 feet per day in the south. For the Edwards and Trinity aquifers, estimated maximum transmissivity values are 8,000 square feet per day and 7,000 square feet per day, respectively (Anaya and Jones, 2009).

The saturated thickness of the aquifer varies between approximately 0 to more than 2,000 feet. The saturated thickness is generally greater in the southern and southeastern portions of the aquifer and thins to the north and northwest. Correspondingly, the transmissivity of the aquifer is also greater in the southeastern portion of the aquifer and smaller towards the northwest (Anaya and Jones, 2009).

Hydraulic Heads

The Trinity hydrostratigraphic unit acts as confined or semi-confined across most of the aquifer due to the overlying low permeability lower member of the Edwards hydrostratigraphic unit. Gradients are generally directed from the north to the south and southeast. In many areas, the water levels in the aquifer have declined across time primarily due to withdrawals for agricultural use. In the southern portions of the aquifer water levels have declined due to withdrawals for increased municipal use due to population growth (Anaya and Jones, 2009).

The Edwards hydrostratigraphic unit acts as unconfined across much of the aquifer. Gradients are generally directed from the north to the south and southwest towards the Balcones Fault Zone. The water levels in the aquifer have remained fairly consistent across time with minor variations primarily in response to climatic changes (Anaya and Jones, 2009).

Groundwater Pumping

More than two-thirds of the groundwater extraction from the aquifer is used for irrigation with the remaining being used primarily for municipal and livestock supply (TWDB, 2017b). Based on Texas Water Development Board data, recent annual pumping from the Edwards-Trinity (Plateau) Aquifer has ranged from less than 150,000 acre-feet to more than 250,000 acre-feet (see Figure 4.16). Overall, the extraction of groundwater has had a minimal impact on water levels as recharge rate is estimated to be greater than the extraction rate. The average recharge rate estimated through groundwater model calibration is about 1.2 million acre-feet per year (Anaya and Jones, 2009).

Subsidence Vulnerability

Clay thickness in the Edwards-Trinity (Plateau) Aquifer is greatest in the eastern part of the aquifer. Like the Edwards BFZ, many of the marly sections in the eastern portion of the aquifer are described as clay by local drillers which result in large clay thicknesses. While the maximum reported total clay thickness in the aquifer is over 600 feet, the average SRV based on clay thickness and extent is 1.4 with a third quartile of 2. Figure 4.17 illustrates the clay thickness at SDR well locations and regional distribution of the thicknesses. The lithology of the Edwards-Trinity (Plateau) Aquifer is primarily carbonates in the Edwards and detrital sands in the Trinity (George and others, 2011) resulting in an average SRV of 2.

For evaluation purposes we assumed a preconsolidation equal to the water level following peak pumping in 1965 (Hutchison and others, 2011). We set the static water level in the aquifer equivalent to the results for the end of the model calibration period. These values resulted in an average and third quartile preconsolidation SRV of 3.

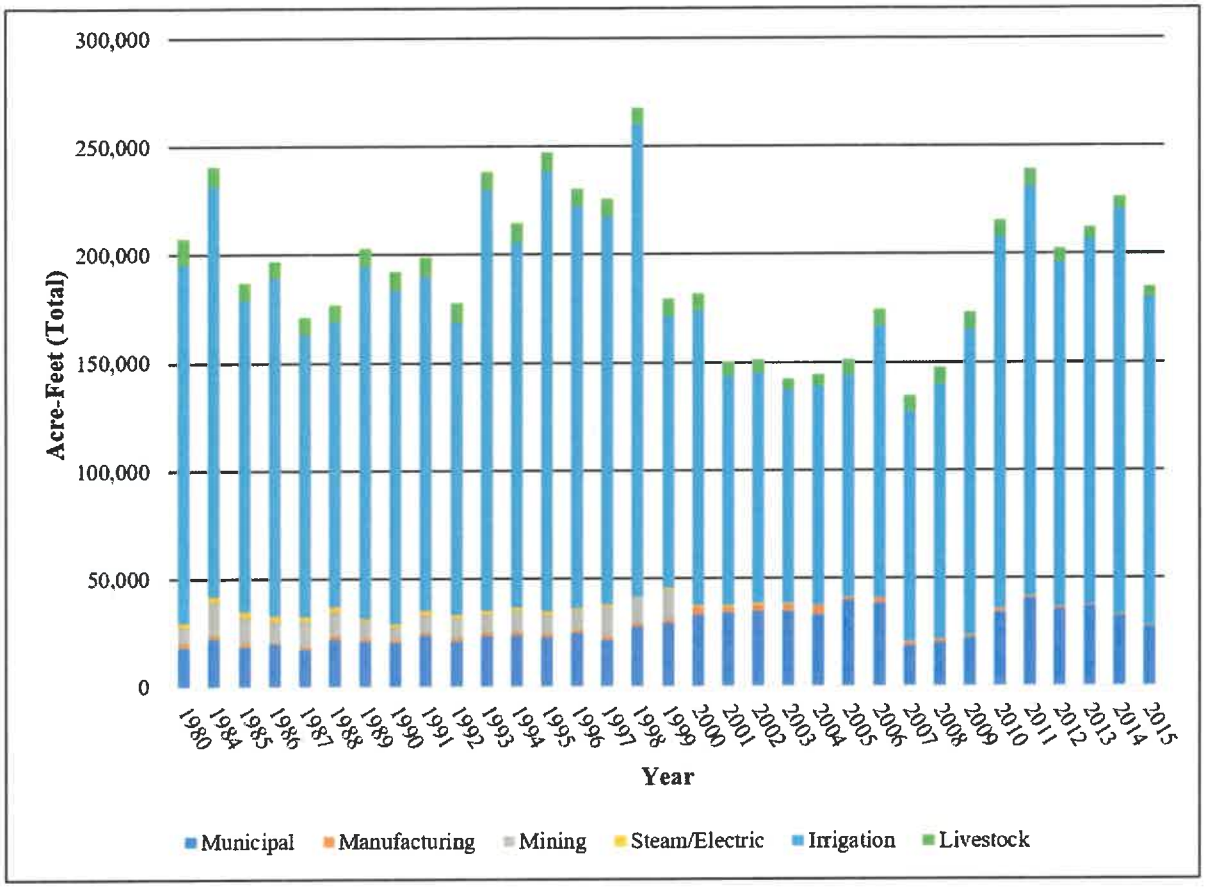

Figure 4.16. **Historic pumping volumes from the Edwards-Trinity (Plateau) Aquifer in the municipal, manufacturing, mining, and steam/electricity production, irrigation, and livestock sectors from 1980 to 2015 (TWDB, 2017b).**

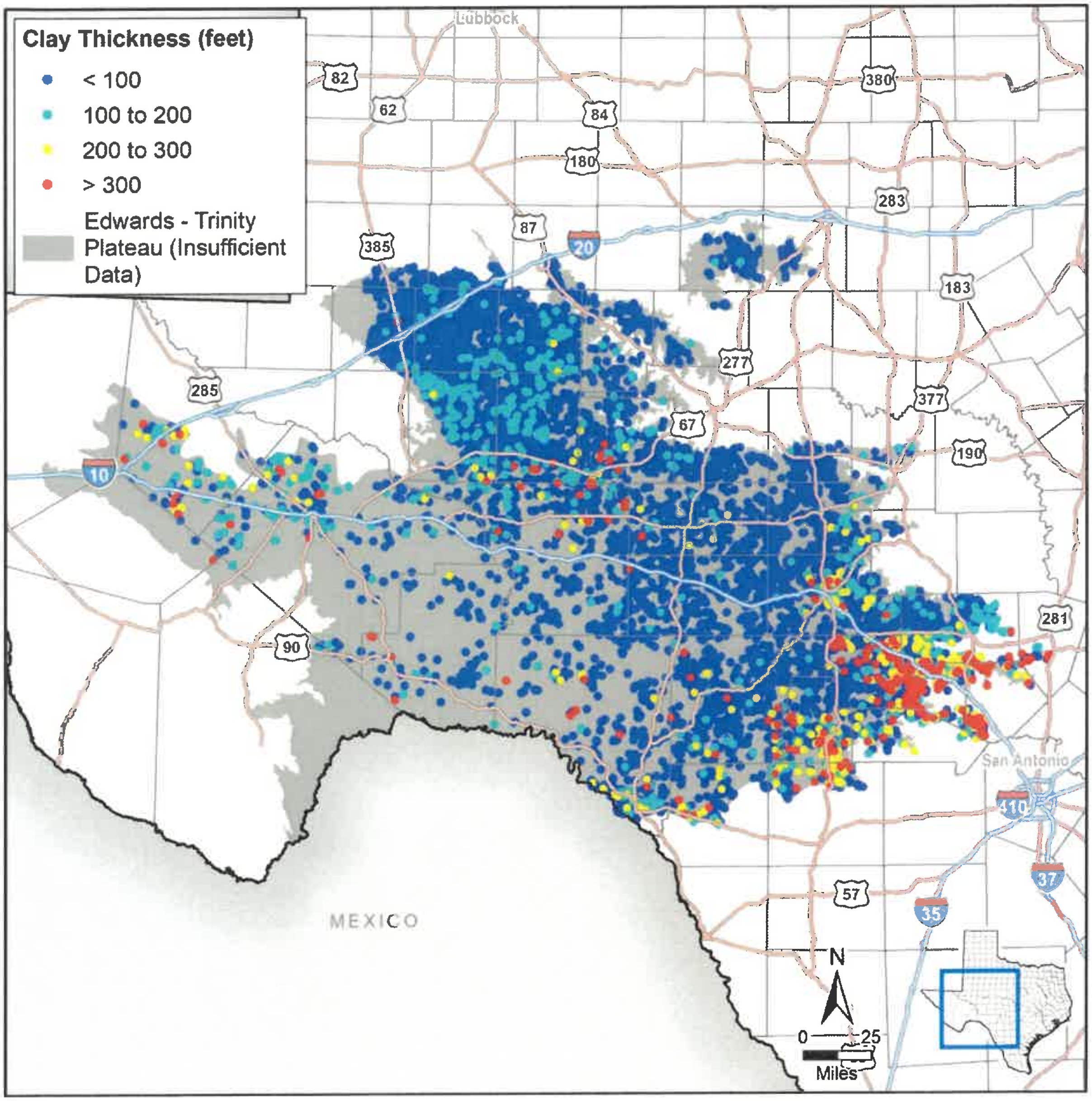

Figure 4.17. Calculated Edwards-Trinity (Plateau) Aquifer clay thickness at well locations.

We determined the water level trend using the simulated water levels from 1980 through 2005 of the transient calibration period for the model (Hutchison and others, 2011) and the predicted DFC water levels from final MAG simulation (Hassan, 2011; Shi, 2012). Predicted water level changes due to the water level trend are highly variable, but average 9 feet of decline. Table 4.7 summarizes the data sources and values for each subsidence risk factor.

Table 4.7. Edwards-Trinity (Plateau) Aquifer subsidence risk factor data sources and summary.

Subsidence Risk Factor Variable	Data Source	Value	3rd Quartile SRV
Clay Layer Thickness and Extent	SDR lithology table	0 to 620 feet	2
Clay Compressibility	Estimated based on lithology	Hard Clay	1
Aquifer Lithology	George and others (2011)	Carbonate and Consolidated Clastic	2
Preconsolidation Characterization	End of 1965 water level from transient model simulations (Hutchison and others, 2011)	903 to 3,856 feet mean sea level	3
Predicted Water Level Decline based on Trend	Trend in simulated water levels from transient model simulations (Hutchison and others, 2011)	Average 9 feet decline	2
Predicted DFC Water Level Decline	Difference in head from final Modeled Available Groundwater simulations (Hassan, 2011; Shi, 2012)	Average 7 feet decline	2

Results of the assessment suggest that the eastern part of the Edwards-Trinity (Plateau) Aquifer has the greatest risk for future subsidence due to pumping. However, the risk is likely skewed due to the drillers logs descriptions of clay. Figure 4.18 illustrates the calculated subsidence risk for the Edwards-Trinity (Plateau) Aquifer.

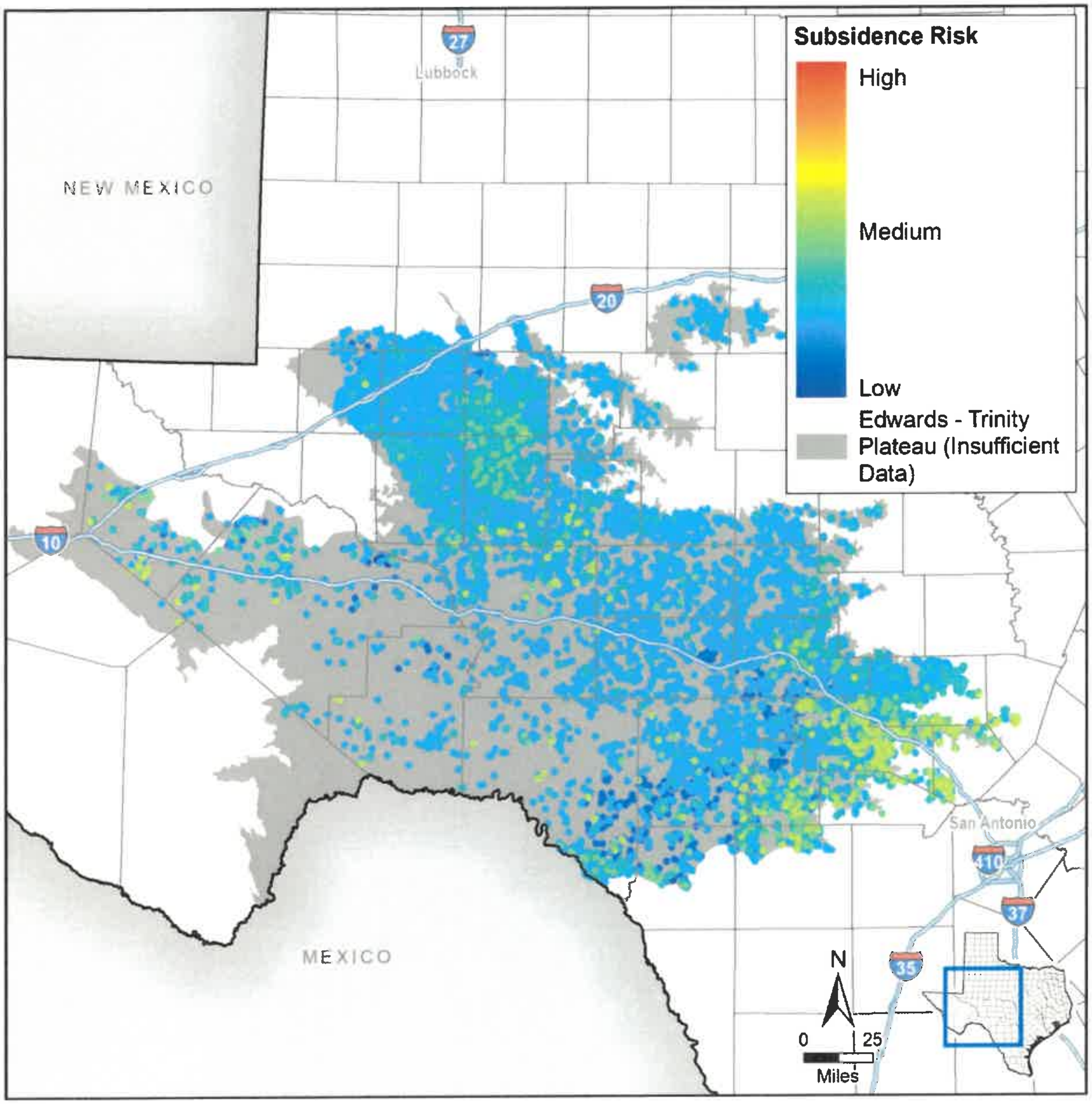

Figure 4.18. **Edwards-Trinity (Plateau) Aquifer subsidence risk vulnerability at well locations.**

4.3.8 Ellenburger-San Saba

The Ellenburger-San Saba Aquifer spans across 16 counties in the Central Texas Hill Country. The aquifer is composed of Paleozoic limestone and dolomite that extends in a circular pattern around the Llano Uplift and dip radially into the subsurface away from the center of the uplift to depths of approximately 3,000 feet. Figure 4.87 provides a location map showing the outcrop and subcrop portions of the aquifer. Regional block faulting has significantly compartmentalized the aquifer.

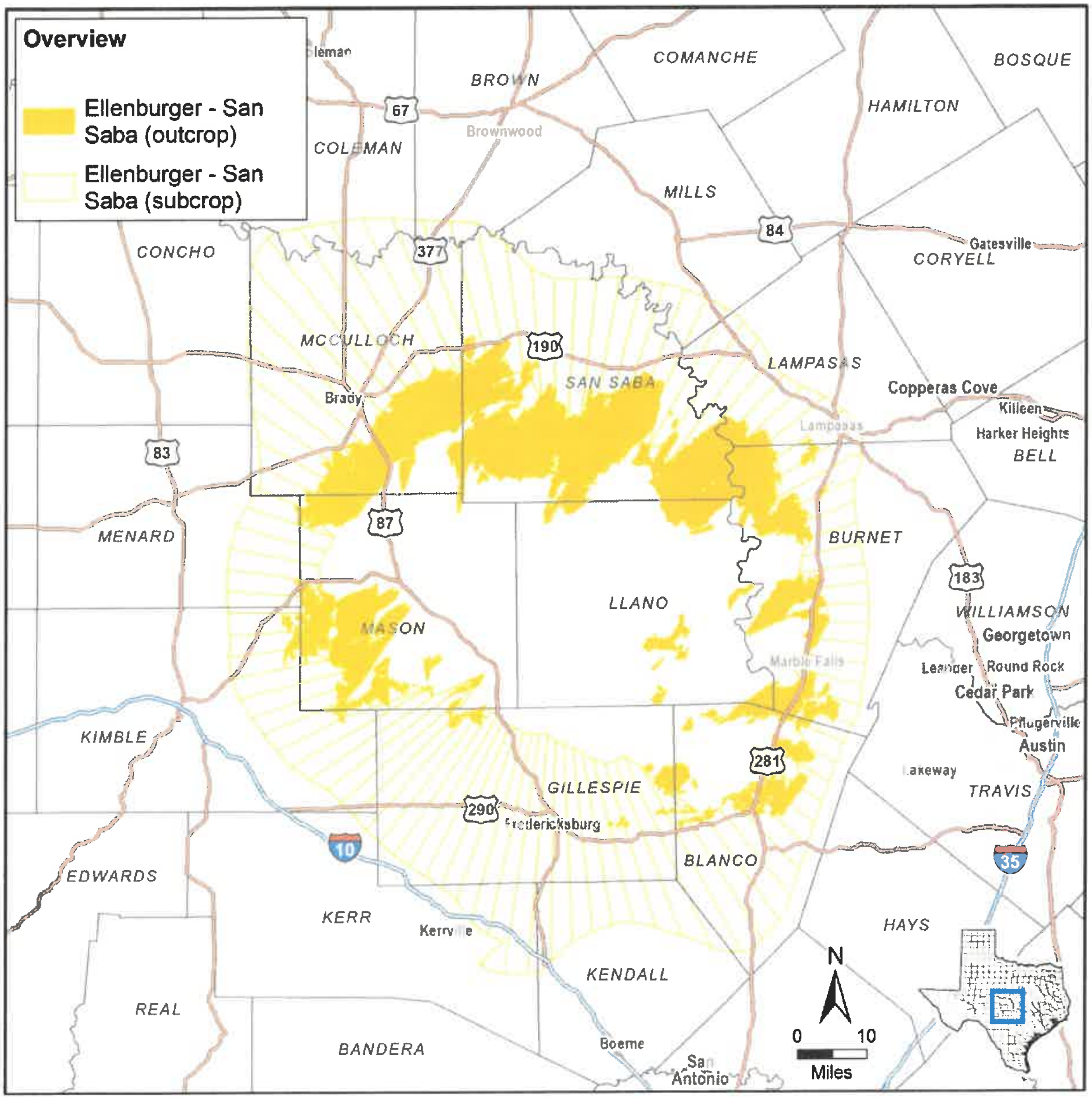

Figure 4.87. **Ellenburger-San Saba Aquifer extent.**

Hydrostratigraphy

The Ellenberger-San Saba Aquifer consists of the Tanyard, Gorman, and Honeycut formations of the Ellenburger Group and the San Saba Limestone Member of the Wilberns Formation. The unconfined portion of the aquifer crops out in a circular pattern around the Llano Uplift. The Llano Uplift is a structural high dome consisting of Precambrian rocks, much of which are igneous granites and other metamorphics aging up to over 1.36 billion years (Reese and others, 2000). Metamorphosis including compression and folding occurred approximately 1.2 billion years ago with multi-directional fracturing (Johnson, 2004).

The complex Precambrian formations which make up the structural base in the area are composed of a sequence of meta-sedimentary and meta-igneous rock, with scattered intrusive igneous rock. Major meta-sedimentary units include the Packsaddle Schist and the Valley Spring Gneiss; meta-igneous units include the Coal Creek Serpentine, the Big Spring Gneiss, and the Red Mountain Gneiss. Igneous rocks include the Llanite Quartz Porphyry, the Sixmile Granite, the Oatman Creek Granite, and the Town Mountain Granite (Preston and others, 1996). In general, these rocks crop out in the center of the uplift and act as confining units to overlying aquifers. Rocks overlying the Precambrian Base dip radially away from the dome structure with high variability in magnitude, ranging from a few feet to over 100 feet per mile (Barnes and Bell, 1977). Table 4.32 provides a stratigraphic column of the geologic units near the Llano Uplift; Figure 4.88 provides a cross-section of a portion of the Ellenburger-San Saba Aquifer with overlying and underlying hydrogeologic units near Gillespie County.

Stratigraphically above the Precambrian base lies the Cambrian aged Moore Hollow Group which consists of the Riley and Wilberns Formations. The oldest member of the Riley Formation is the Hickory Sandstone consisting of cross-bedded terrestrial and marine quartz sandstones, siltstones, and mudstones which make up the Hickory Aquifer. In certain areas the Cap Mountain limestone overlies the Hickory, acting as a confining unit. The youngest member of the Riley Formation, the Lion Mountain Sandstone, is intermittently found overlying the Cap Mountain Limestone. The Welge Sandstone, the oldest member of the Wilberns Group, is hydraulically connected to the Lion Mountain forming the Mid-Cambrian Aquifer. The Morgan Creek Limestone and the Point Peak Shale are found directly above the Welge Sandstone and act as a confining unit between the Mid-Cambrian and the Ellenburger-San Saba aquifers. Completing the Wilberns Group is the San Saba Limestone which is the stratigraphically lowest part of the Ellenburger-San Saba Aquifer (Barnes and Bell, 1977; Preston and others, 1996).

Table 4.32. Stratigraphic column of the Ellenburger-San Saba illustrating the hydrogeologic units (Preston and others, 1996).

Era	System	Group	Formation	Member	Hydrogeologic Unit	
CZ	Quaternary	Pleistocene to Recent floodplain (alluvium and fluviatile terrace deposits)			Localized Alluvium	
Mesozoic	Cretaceous	Edwards	Segovia		Edwards Plateau Aquifer	Edwards-Trinity Aquifer
			Fort Terrett	Kirschberg Evaporite		
				Dolomitic		
				Burrowed		
				Basal Nodular	Confining Unit	
		Trinity	Glen Rose Limestone	Upper	Upper Trinity Aquifer	
				Lower	Middle Trinity Aquifer	
			Travis Peak Equivalent: Hensell Sand / Bexar Shale			
			Travis Peak Equivalent: Cow Creek Limestone			
			Travis Peak Equivalent: Hammett Shale		Confining Unit	
			Travis Peak Equivalent: Sycamore Sand (Sligo, Hosston)		Lower Trinity Aquifer	
Paleozoic	Pennsylvanian	Canyon	Undivided	Undivided	Confining Units	
		Strawn	Undivided			
		Bend	Smithwick			
			Marble Falls Limestone		Marble Falls Aquifer	
	Mississippian and Devonian	Mississippian and Devonian Undivided Rocks			Confining Units	
	Ordovician	Ellenburger	Honeycut	Undivided	Ellenburger-San Saba Aquifer	
			Gorman	Undivided		
			Tanyard	Staendebach		
				Threadgill		
	Cambrian	Moore Hollow	Wilberns	San Saba		
				Point Peak	Confining Units	
				Morgan Ck Ls		
				Welge Ss	Mid-Cambrian Aquifer	
			Riley	Lion Mtn Ss		
				Cap Mtn Ls	Confining Unit	
				Hickory Ss	Hickory Aquifer	
Precambrian	Town Mountain Granite				Confining Units	
	Red Mountain Gneiss					
	Packsaddle Schist					
	Lost Creek Gneiss					
	Valley Springs Gneiss					

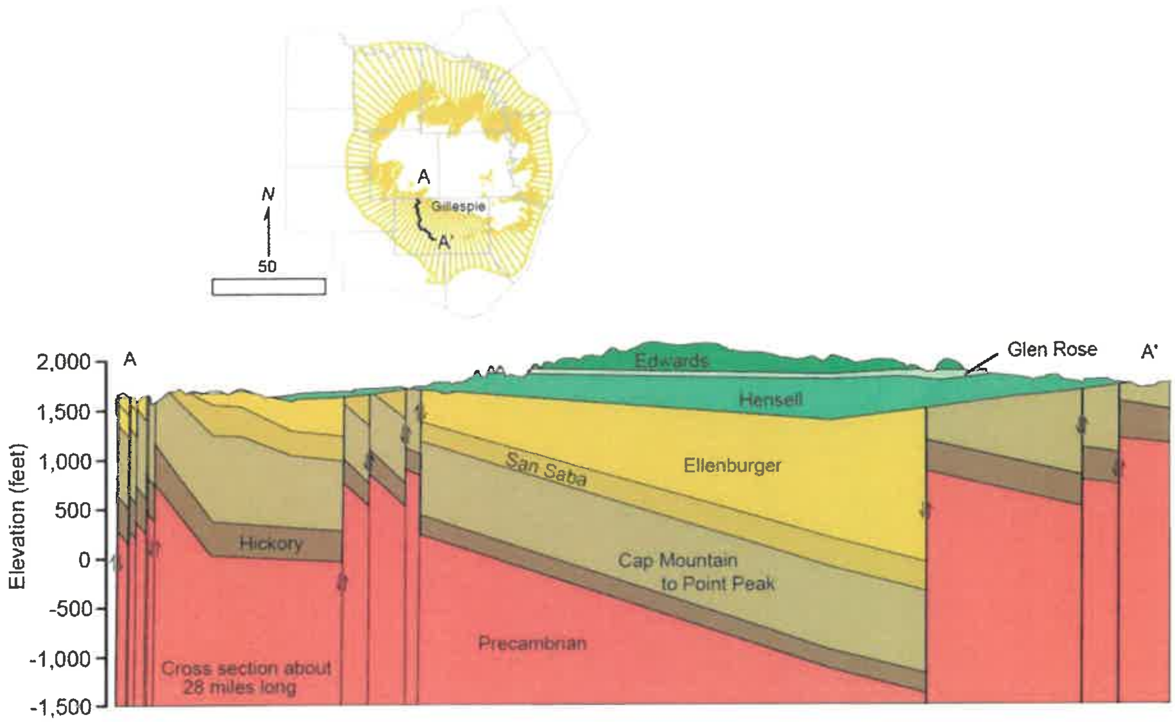

Figure 4.88. **Cross-section of the Ellenburger-San Saba Aquifer along with overlying and underlying hydrogeologic units (George and others, 2011).**

Overlying the Moore Hollow Group is the Ordovician aged Ellenburger Group which consists of the Tanyard, Gorman, and Honeycut Formations and generally encircles the Llano Uplift. The Tanyard Formation is divided into two members: the basal dolostone Threadgill Member and the overlying limestone Staendebach Member. Above the Tanyard Formation, the Gorman and Honeycut Formations are comprised of dolostones and limestones which complete the Ellenburger Group and the Ellenburger-San Saba Aquifer (Preston and others, 1996). The aquifer is highly permeable in places, as indicated by wells that yield as much as 1,000 gallons per minute and springs that issue from the aquifer maintaining the base flow of streams in the area.

Scattered discontinuously throughout the study area, Devonian and Mississippian aged formations consist of thin remnants of dark shales, petroliferous limestones, crinoidal limestone, chert breccias, fractured cherts, and microgranular limestones with bedded chert (Preston and others, 1996; Standen and Ruggiero, 2007). Where present, the formations act as confining layers between the Ellenburger-San Saba Aquifer and the Marble Falls Aquifer (Preston and others, 1996).

Hydraulic Properties

Within the Ellenburger-San Saba Aquifer, hydraulic properties of transmissivity, storativity, and hydraulic conductivity have been examined extensively by Bluntzer (1992). Due to the heterogeneity of the aquifer, the hydraulic properties vary by several orders of magnitude. Table 4.33 provides a summary of the hydraulic properties calculated for the Ellenburger-San Saba Aquifer.

Table 4.33. Hydraulic properties for the Ellenburger-San Saba Aquifer.

Aquifer Properties	Range	References
Hydraulic conductivity (ft/d)	1.0×10^{-2} – 225	1
Transmissivity (ft^2/d)	7 – 32,000	1
Storativity	8.0×10^{-5} – 1.7×10^{-3}	1

References:(1) Bluntzer (1992), Shi and others (2016a)

Hydraulic Heads

The Ellenburger-San Saba Aquifer can be related in groundwater flow and direction to the other Paleozoic aquifers (that is, the overlying Marble Falls and underlying Hickory). The predominant force driving the movement of groundwater flow through this aquifer is gravity. Within outcrop areas, karstic features such as sinkholes and caves exist to allow for recharge and subsequent higher heads. Prior to the 1950s, water levels in the Ellenburger-San Saba were under steady state conditions. Fluctuations were influenced by natural cycles of recharge and discharge events. Water levels were estimated to be at an elevation of 1,600 feet MSL decreasing to 1,200 feet MSL in the eastern counties. Transient water levels have remained steady in this aquifer with the exception of three wells in Gillespie County showing a net decline from the 1980s to early 1990s.

Groundwater Pumping

Figure 4.89 provides a graph of the historic pumping volumes from the Ellenburger-San Saba Aquifer in the municipal, manufacturing, mining, and steam/electricity production, irrigation, and livestock sectors from 1980 to 2015. Withdrawal rates have stayed relatively constant since the 1980s averaging over 6,700 acre-feet per year. Withdrawals for municipal use is the dominant form of pumping in the Ellenburger-San Saba and accounts for approximately 60 percent of the production. Future demands for pumping are unlikely to increase significantly.

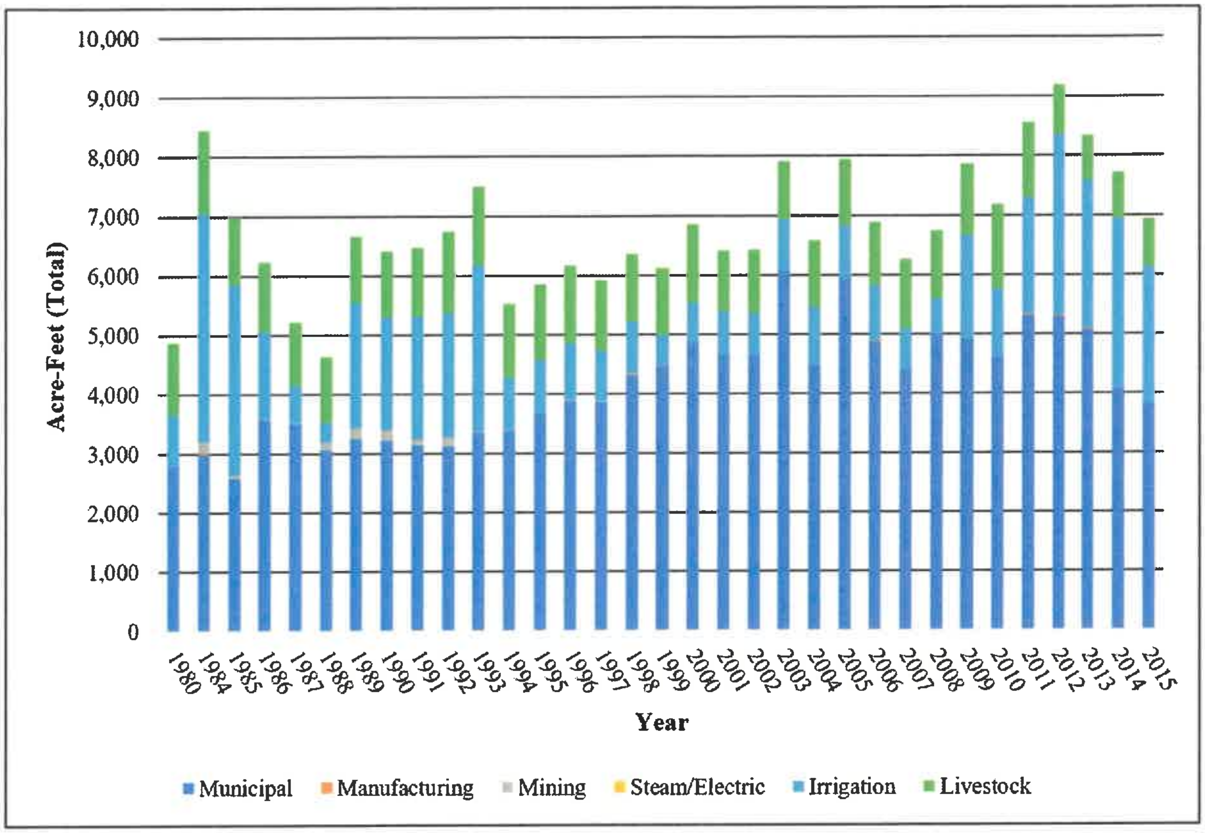

Figure 4.89. **Historic pumping volumes from the Ellenburger-San Saba Aquifer in the municipal, manufacturing, mining, and steam/electricity production, irrigation, and livestock sectors from 1980 to 2015 (TWDB, 2017b).**

Subsidence Vulnerability

Reported clay thickness within the Ellenburger-San Saba Aquifer is generally less than 10 feet. Clay thickness increases radially downdip within the aquifer, with clay thickness ranging from 0 to 882 feet resulting in an average SRV of 1.5 with a third quartile of 2. Figure 4.90 illustrates the clay thicknesses and regional distribution throughout the aquifer. The lithology of the aquifer is predominantly composed of carbonate limestone and dolostone with some consolidated clastic sediments. The clay layers within the aquifer are characterized as hard clay.

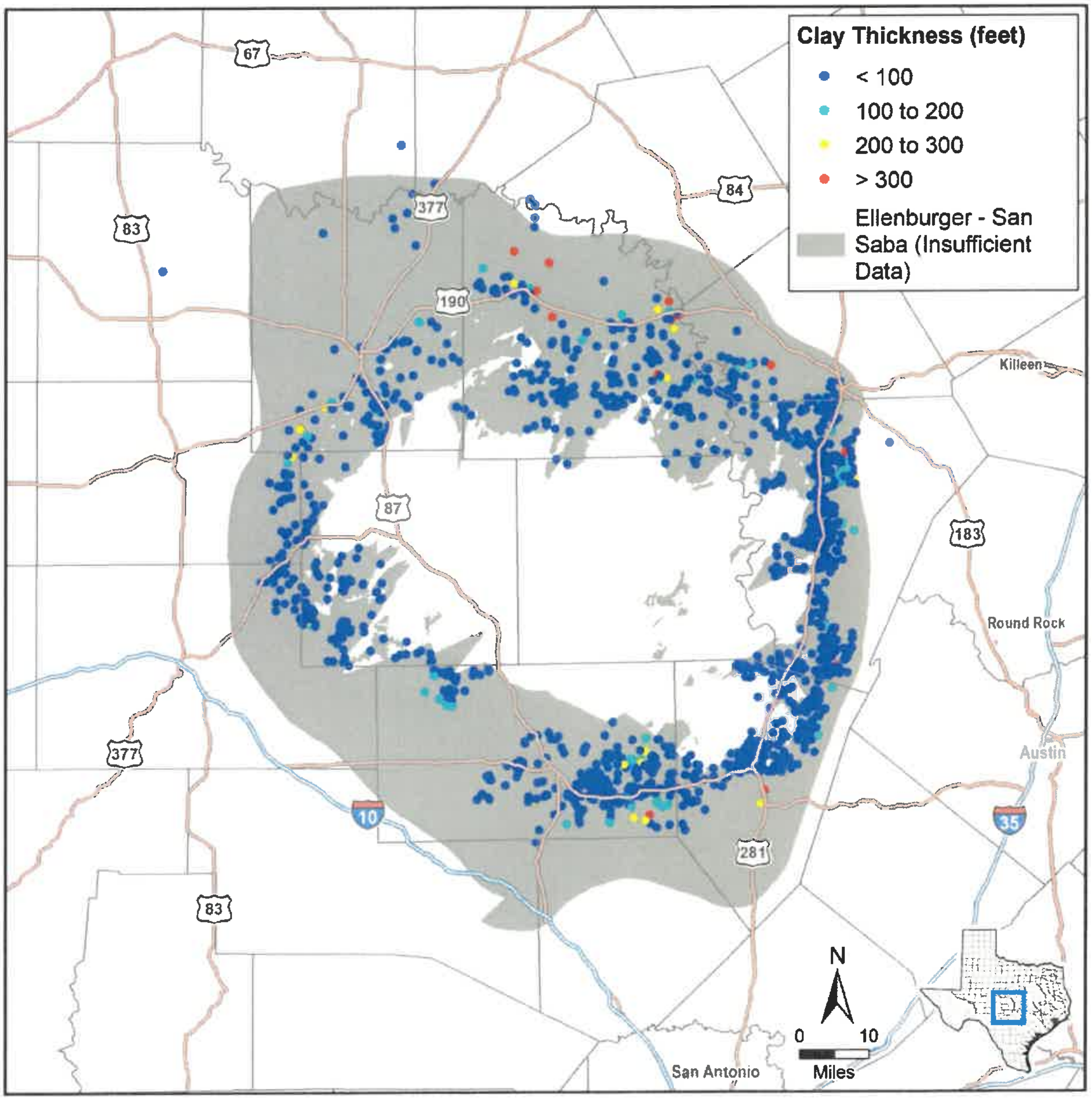

Figure 4.90. Calculated Ellenburger-San Saba Aquifer clay thickness at well locations.

Water levels within the Ellenburger-San Saba Aquifer are generally stable with small fluctuations. Shi and others (2016a) noted that water level declines in the aquifer have been experienced in a small area of Gillespie County. We set the preconsolidation level at the well sites to the minimum water level from the calibrated GAM (Shi and others, 2016b). For the static water level, we used the simulated water level for 2017 from the MAG run for GMA 9 (Jones, 2017). We calculated the water level trend using all of the simulated water levels from the calibrated GAM (Shi and others, 2016b) and the GMA 9 adopted DFCs and MAG run for the DFC water levels. While most of the aquifer is located in GMA 7 with smaller portions in GMA 8 and GMA 9, we used the 2016 joint planning cycle GMA 9 MAG run results (Jones, 2017) for our analyses because, as of the time of our analysis, the 2016 joint planning cycle MAG simulations had not yet been conducted. Table 4.34 summarizes the data sources and values for each subsidence risk factor.

Table 4.34. Ellenburger-San Saba Aquifer subsidence risk factor data sources and summary.

Subsidence Risk Factor Variable	Data Source	Value	3rd Quartile SRV
Clay Layer Thickness and Extent	SDR lithology table	0 to 882 feet	2
Clay Compressibility	Estimated based on lithology	Hard Clay	1
Aquifer Lithology	Shi and others (2016a)	Carbonate/ Consolidated Clastic	2
Preconsolidation Characterization	Minimum water level from transient model simulations (Shi and others, 2016b)	718 to 1,804 feet mean sea level	3
Predicted Water Level Decline based on Trend	Trend in simulated water levels from transient model simulations (Shi and others, 2016b)	Less than 1-foot decline	2
Predicted DFC Water Level Decline	Estimate from adopted DFCs for GMA 9	2 feet decline	2

Results of the assessment suggest that the Ellenburger-San Saba Aquifer has a low to medium-low risk for future subsidence due to pumping. Figure 4.91 illustrates the subsidence risk factor for the Ellenburger-San Saba Aquifer.

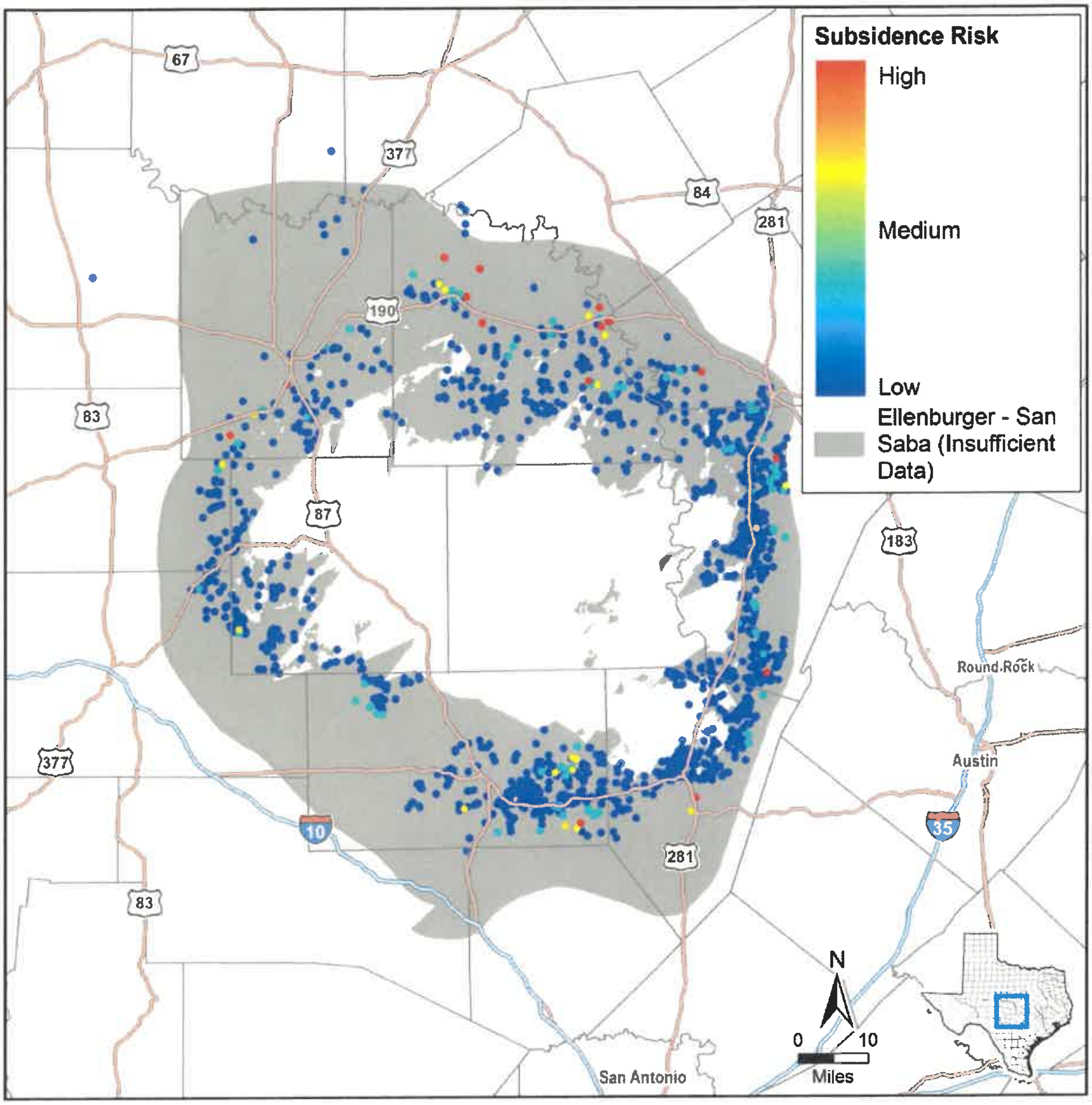

Figure 4.91. **Ellenburger-San Saba Aquifer subsidence risk vulnerability at well locations.**

4.3.9 *Hickory*

The Hickory Aquifer consists of the water-bearing Hickory Sandstone member of the Riley Formation. Figure 4.92 shows the extent of the Hickory Aquifer extending radially from the Llano Uplift in the Central Texas area. The aquifer is considered to be the primary aquifer in the central portion of the Llano Uplift region and reaches a maximum thickness of approximately 480 feet.

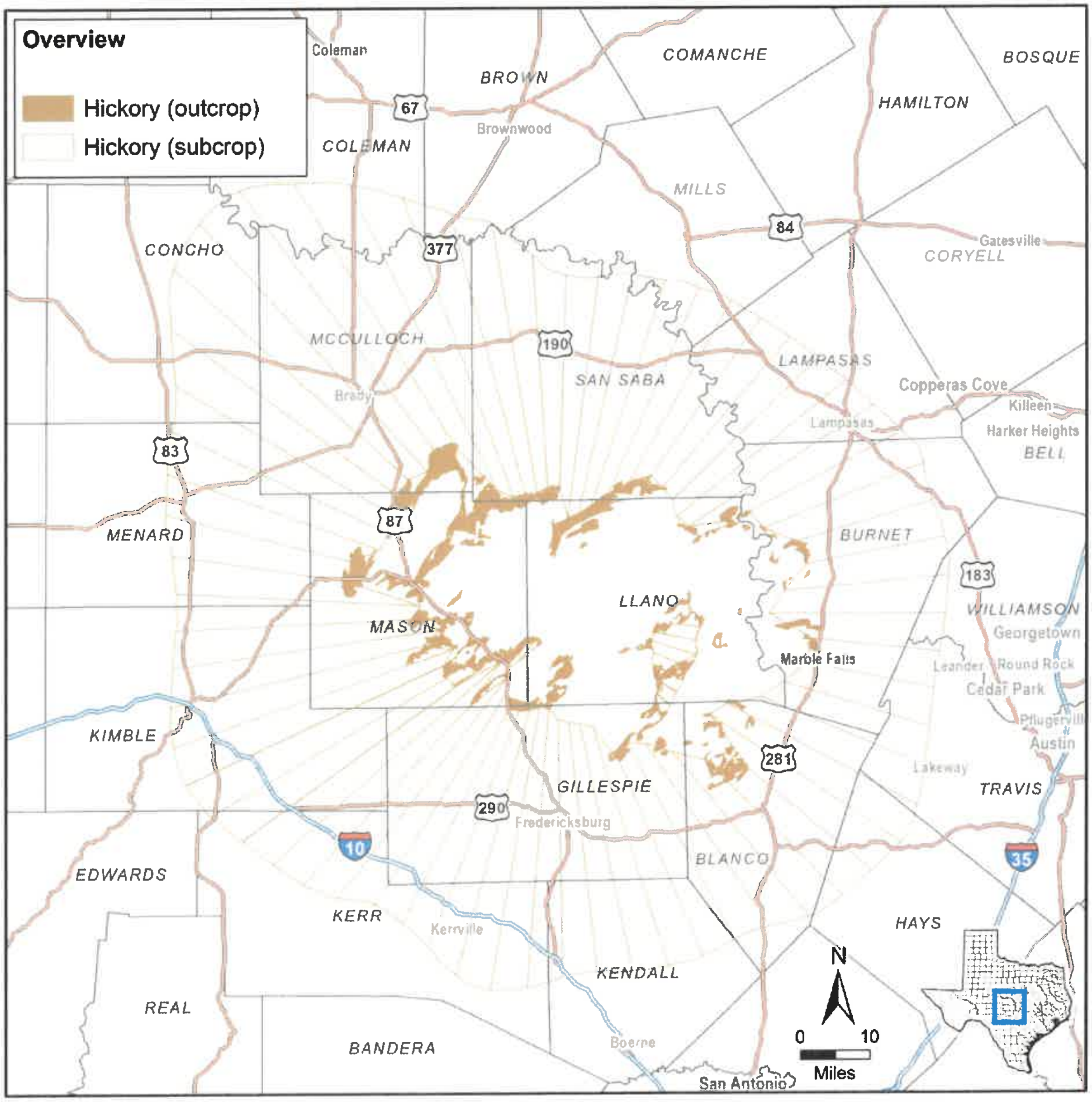

Figure 4.92. Hickory Aquifer extent.

Hydrostratigraphy

The Hickory Aquifer consists of the Hickory Sandstone of the Riley Formation. Like the Ellenburger-San Saba Aquifer, the unconfined portion of the aquifer crops out in a circular pattern around the Llano Uplift. The Llano Uplift is a structural high dome consisting of Precambrian rocks, much of which are igneous granites and other metamorphics aging up to over 1.36 billion years (Reese and others, 2000). Metamorphosis including compression and folding occurred approximately 1.2 billion years ago with multi-directional fracturing (Johnson, 2004).

The complex Precambrian formations which make up the structural base in the area are composed of a sequence of meta-sedimentary and meta-igneous rock, with scattered intrusive igneous rock. Major meta-sedimentary units include the Packsaddle Schist and the Valley Spring Gneiss; meta-igneous units include the Coal Creek Serpentine, the Big Spring Gneiss, and the Red Mountain Gneiss. Igneous rocks include the Llanite Quartz Porphyry, the Sixmile Granite, the Oatman Creek Granite, and the Town Mountain Granite (Preston and others, 1996). In general, these rocks crop out in the center of the uplift and act as confining units to overlying aquifers. Rocks overlying the Precambrian Base dip radially away from the dome structure with high variability in magnitude, ranging from a few feet to over 100 feet per mile (Barnes and Bell, 1977). Table 4.35 provides a stratigraphic column of the geologic units near the Llano Uplift; Figure 4.93 provides a cross-section of a portion of the Hickory Aquifer with overlying and underlying hydrogeologic units near Gillespie County.

Stratigraphically above the Precambrian base lies the Cambrian aged Moore Hollow Group which consists of the Riley and Wilberns Formations. The oldest member of the Riley Formation is the Hickory Sandstone consisting of crossbedded terrestrial and marine quartz sandstones, siltstones, and mudstones which make up the Hickory Aquifer. In some areas, the sandstones are composed of grains from the igneous granitic rocks of the Llano Uplift. The granitic rocks contain minerals which are a source of radium and in certain areas can be detected in groundwater pumped from the Hickory Aquifer. The major faulting associated with the Llano Uplift has influenced the flow of groundwater and the production ability of the Hickory Aquifer in this area. Faults have caused portions of the aquifer to become compartmentalized which restrict groundwater flow in some areas and increase production in other portions of the aquifer.

In certain areas the Cap Mountain limestone overlies the Hickory, acting as a confining unit. The youngest member of the Riley Formation, the Lion Mountain Sandstone, is intermittently found overlying the Cap Mountain Limestone. The Welge Sandstone, the oldest member of the Wilberns Group, is hydraulically connected to the Lion Mountain forming the Mid-Cambrian Aquifer. The Morgan Creek Limestone and the Point Peak Shale are found directly above the Welge Sandstone and act as a confining unit between the Mid-Cambrian and the Ellenburger-San Saba aquifers. Completing the Wilberns Group is the San Saba Limestone which is the stratigraphically lowest part of the Ellenburger-San Saba Aquifer (Barnes and Bell, 1977; Preston and others, 1996).

Table 4.35. Stratigraphic column of the Hickory illustrating the hydrogeologic units (Preston and others, 1996).

Era	System	Group	Formation	Member	Hydrogeologic Unit	
CZ	Quaternary	Pleistocene to Recent floodplain (alluvium and fluviatile terrace deposits)			Localized Alluvium	
Mesozoic	Cretaceous	Edwards	Segovia		Edwards Plateau Aquifer	Edwards-Trinity Aquifer
			Fort Terrett	Kirschberg Evaporite		
				Dolomitic		
				Burrowed		
				Basal Nodular	Confining Unit	
		Trinity	Glen Rose Limestone	Upper	Upper Trinity Aquifer	
				Lower	Middle Trinity Aquifer	
			Travis Peak Equivalent: Hensell Sand / Bexar Shale			
			Travis Peak Equivalent: Cow Creek Limestone			
			Travis Peak Equivalent: Hammett Shale		Confining Unit	
			Travis Peak Equivalent: Sycamore Sand (Sligo, Hosston)		Lower Trinity Aquifer	
Paleozoic	Pennsylvanian	Canyon	Undivided	Undivided	Confining Units	
		Strawn	Undivided			
		Bend	Smithwick			
			Marble Falls Limestone		Marble Falls Aquifer	
	Mississippian and Devonian	Mississippian and Devonian Undivided Rocks			Confining Units	
	Ordovician	Ellenburger	Honeycut	Undivided	Ellenburger-San Saba Aquifer	
			Gorman	Undivided		
			Tanyard	Staendebach		
				Threadgill		
	Cambrian	Moore Hollow	Wilberns	San Saba		
				Point Peak	Confining Units	
				Morgan Ck Ls		
				Welge Ss	Mid-Cambrian Aquifer	
			Riley	Lion Mtn Ss		
				Cap Mtn Ls	Confining Unit	
				Hickory Ss	Hickory Aquifer	
Precambrian	Town Mountain Granite				Confining Units	
	Red Mountain Gneiss					
	Packsaddle Schist					
	Lost Creek Gneiss					
	Valley Springs Gneiss					

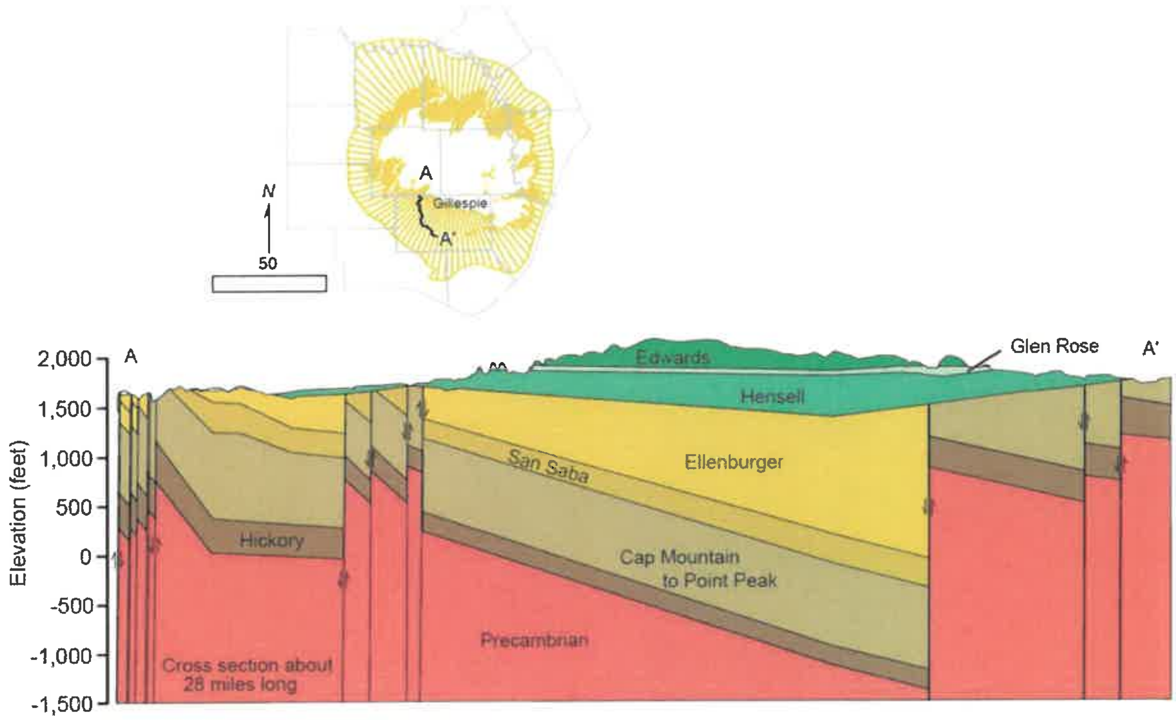

Figure 4.93. **Cross-section of the Hickory Aquifer along with overlying and underlying hydrogeologic units (George and others, 2011).**

Hydraulic Properties

Within the Hickory Aquifer, hydraulic properties of transmissivity, storativity, and hydraulic conductivity have been examined extensively by Shi and others (2016a). Due to the heterogeneity and structural disconformity of the aquifer, the hydraulic properties vary by several orders of magnitude. Table 4.36 provides a summary of the hydraulic properties calculated for the Hickory Aquifer.

Table 4.36. **Hydraulic properties for the Hickory Aquifer.**

Aquifer Properties	Range	References
Hydraulic conductivity (ft/d)	3.0×10^{-2} – 125	1
Transmissivity (ft²/d)	15 – 10,350	1
Storativity	3.7×10^{-5} – 1.0×10^{-4}	1

References:(1) Shi and others (2016a)

Hydraulic Heads

The groundwater trends of the Hickory Aquifer associated with the other Paleozoic aquifers are from areas of high water level elevations to low water level elevations as well as from areas of recharge to discharge. The groundwater movement is controlled by several factors such as: 1) hydraulic gradient, 2) rock permeability distribution, 3) orientation of bedding plane, and 4) faulting and fractures. Withdrawals from wells can induce change to the direction and rate of groundwater movement throughout the aquifer, especially if withdrawal occurs along faults acting as hydraulic barriers between aquifer units (Bluntzer, 1992). Generally, gradients are from the Llano Uplift toward deeper parts of the aquifer.

Groundwater Pumping

Discharge for the Hickory Aquifer occurs through various springs and channel seepage. Seepage is produced from the base flow of effluent streams (Bluntzer, 1992). Other sources of discharge come from well withdrawals for irrigation, municipal, and other practices. In the Hickory Aquifer, the predominant use of water is for agricultural purposes followed by municipal and most recently mining uses. Figure 4.94 provides a graph of the historic pumping volumes from the Hickory Aquifer in the municipal, manufacturing, mining, and steam/electricity production, irrigation, and livestock sectors from 1980 to 2015. Overall, pumping rates generally declined from 1980 through 2000 and have since remained relatively constant typically ranging between 15,000 and 20,000 acre-feet per year.

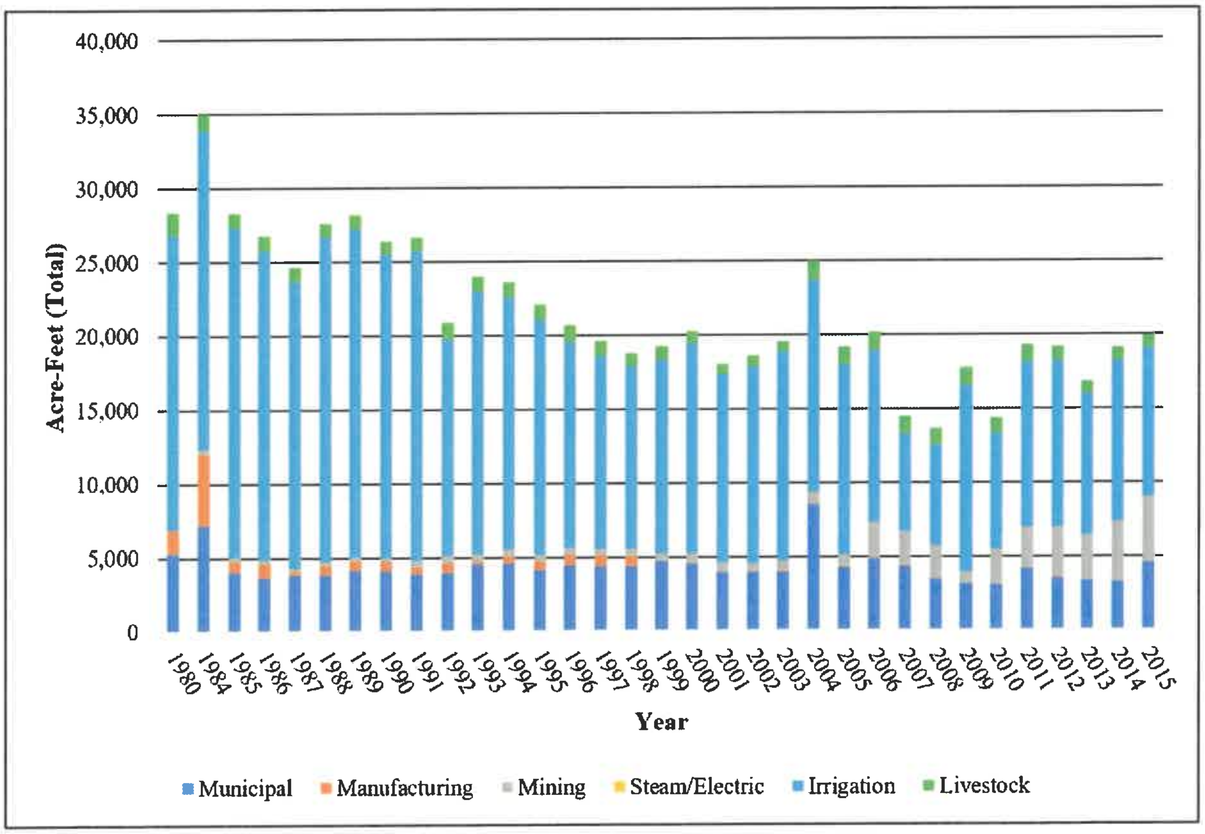

Figure 4.94. **Historic pumping volumes from the Hickory Aquifer in the municipal, manufacturing, mining, and steam/electricity production, irrigation, and livestock sectors from 1980 to 2015 (TWDB, 2017b).**

Subsidence Vulnerability

Reported clay thickness within the Hickory Aquifer is generally less than 5 feet. Most wells are completed within or near the unconfined zone of the aquifer where there is little clay. Within the aquifer, clay thickness increases radially downdip, with clay thickness ranging from 0 to 754 feet resulting in an average SRV of 1.4 with a third quartile of 2. Figure 4.95 illustrates the clay thicknesses and regional distribution throughout the aquifer. The lithology of the aquifer is predominantly composed of sandstone (consolidated clastic) with some carbonates. The clay layers within the aquifer are characterized as hard clay.

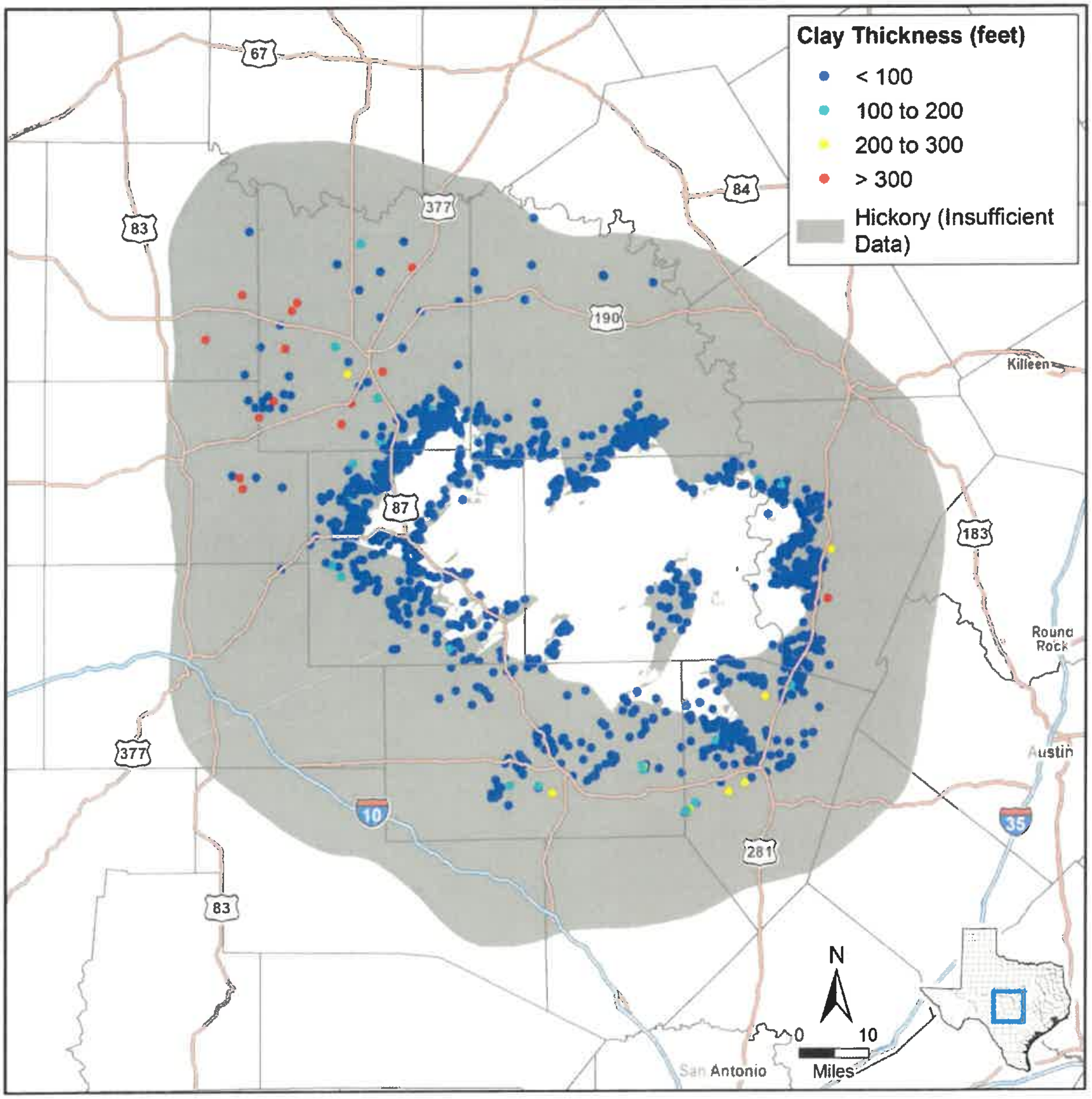

Figure 4.95. Calculated Hickory Aquifer clay thickness at well locations.

Water levels within the Hickory Aquifer are generally stable with small fluctuations. Shi and others (2016a) noted that water level increases have been documented in a well in Gillespie County and water level declines have been experienced in a well within McCulloch County. We set the preconsolidation level at the well sites to the minimum water level from the calibrated GAM (Shi and others, 2016b). For the static water level, we used the simulated water level for 2017 from the MAG run (Jones, 2017). We calculated the water level trend using all of the simulated water levels from the calibrated GAM (Shi and others, 2016b) and the GMA 9 adopted DFCs and MAG run for the DFC water levels. While most of the aquifer is located in GMA 7 with smaller portions in GMA 8 and GMA 9, we used the 2016 joint planning cycle GMA 9 MAG run results (Jones, 2017) for our analyses because, as of the time of our analysis, the 2016 joint planning cycle MAG simulations had not yet been conducted. Table 4.37 summarizes the data sources and values for each subsidence risk factor.

Table 4.37. Hickory Aquifer subsidence risk factor data sources and summary.

Subsidence Risk Factor Variable	Data Source	Value	3rd Quartile SRV
Clay Layer Thickness and Extent	SDR lithology table	0 to 754 feet	2
Clay Compressibility	Estimated based on lithology	Hard Clay	1
Aquifer Lithology	Shi and others (2016a)	Consolidated Clastic	3
Preconsolidation Characterization	Minimum water level from transient model simulations (Shi and others, 2016b)	754 to 1,857 feet mean sea level	3
Predicted Water Level Decline based on Trend	Trend in simulated water levels from transient model simulations (Shi and others, 2016b)	Less than 1-foot decline	2
Predicted DFC Water Level Decline	Estimate from adopted DFCs for GMA 9	Less than 1-foot decline	2

Results of the assessment suggest that the Hickory Aquifer has a low risk for future subsidence due to pumping. Figure 4.96 illustrates the subsidence risk factor for Hickory Aquifer.

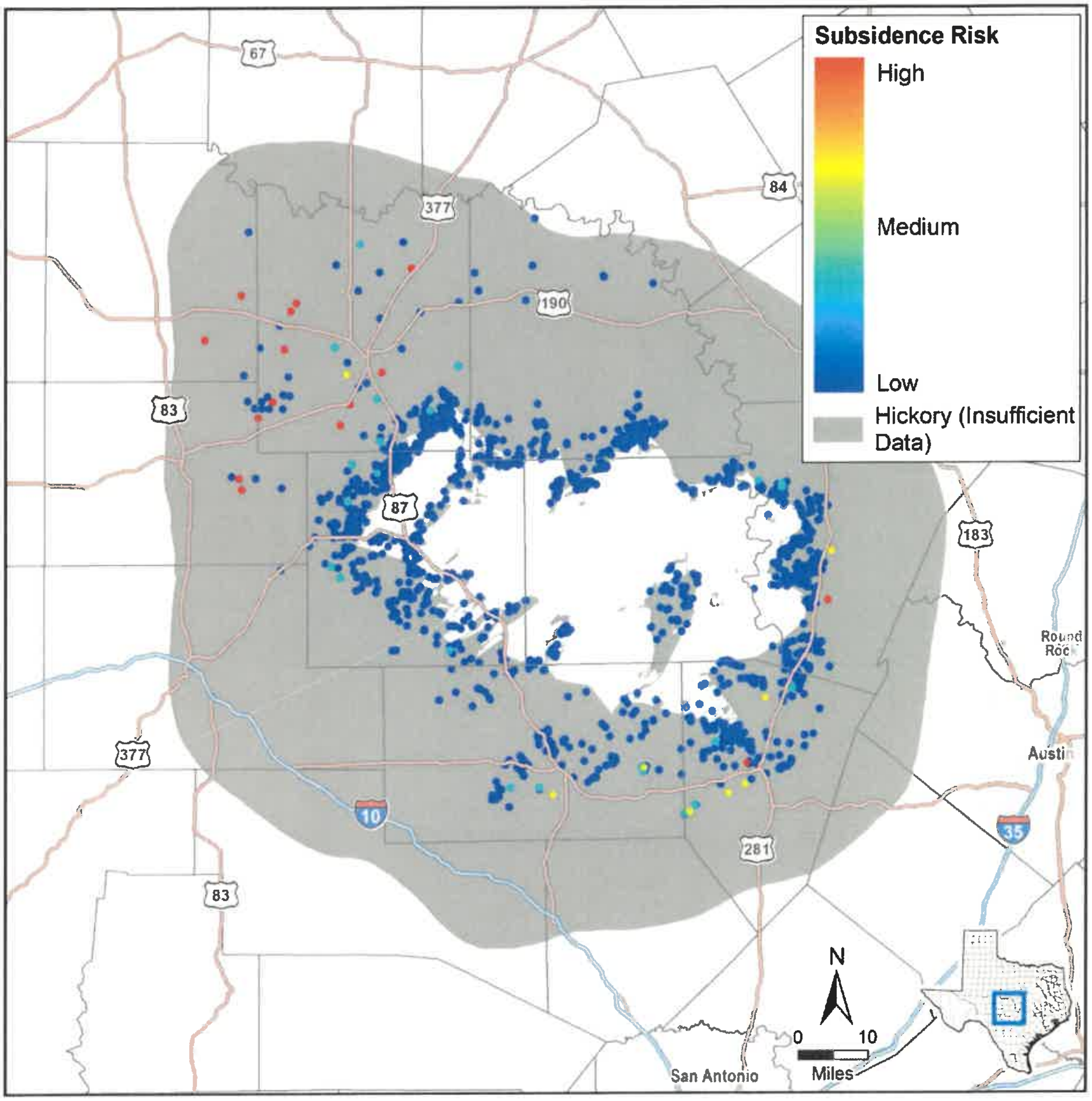

Figure 4.96. **Hickory Aquifer subsidence risk vulnerability at well locations.**

APPENDIX G

HGCD Resolution No. 2021-3 Adopting the December 8, 2021 Management Plan
Public Notice of a Public Hearing
Meeting Agendas.

RESOLUTION NO. 2021-2

RESOLUTION ADOPTING the REVISED DISTRICT MANAGEMENT PLAN FOR HEADWATERS GROUNDWATER CONSERVATION DISTRICT

WHEREAS, the Headwaters Groundwater Conservation District (the District), after Notice and Hearing, conducted a Regular Meeting on December 08, 2021 concerning the Proposed District Management Plan – Revised December 2021; and

WHEREAS, the Board of Directors of the District desires to formally adopt the Headwaters Groundwater Conservation Proposed District Management Plan - Revised December 2021.

NOW, THEREFORE, BE IT RESOLVED that the Board of Directors of the District does hereby adopt the District Management Plan – Revised December 2021 and directs the General Manager of the District to forward a copy of the adopted 2021 Management Plan to the Texas Water Development Board for approval.

NOW, THEREFORE, BE IT FURTHER RESOLVED that this Resolution shall take effect upon final approval by the Texas Water Development Board.

Adopted this 8th day of December, 2021.

John Elliott, President
Board of Directors

Headwaters G.C.D.
THE STATE OF TEXAS
KERR COUNTY
Kerrville, Texas

ATTEST:

Ann Peay, Secretary/Treasurer
Board of Directors

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830.896.4110 hgcd@hgcd.org

HEADWATERS GROUNDWATER CONSERVATION DISTRICT

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Meetings, Agendas, Notices, Tax & Budget Information

The HGCD Board of Directors meetings are held at least once a quarter on the second Wednesday of the Month @ 1:30 PM

Notice of Public Hearing

Agenda Management Plan Hearing 2021-12-08

Proposed Management Plan Revised 120821

Agenda Regular Meeting 2021-12-08

Kerr County Currently in Stage 2 Drought

September 2020 Drought Conditions Article

Minutes - Reg Meeting 2021-10-13

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Public Notice | Public Notice | Public Notice

Public Notice for Public Input Meeting:

The City of Kerrville Parks and Recreation Advisory Board will host a public input meeting on December 15, 2021 at 5:15 p.m. at the Dietert Center, 451 Guadalupe Street, Kerrville, Texas to receive community input for the Parks and Recreation Department's Parks, Recreation, and Open Space Master Plan Update.

For more information, please contact the City of Kerrville Parks and Recreation Department at (830) 257-7300 or recreation@kerrvilletx.gov.

ADVERTISEMENT FOR PROPOSAL

Request for Sealed Proposals for the **City of Kerrville Public Safety Communications** will be received by the office of the City Secretary, City Hall, 701 Main Street, Kerrville, Texas 78028 until **3:00 p.m. on Monday, December 20, 2021**. There will not be a reading aloud of proposers.

The date and time of submittals shall be clearly marked on the outside of the sealed envelope. No proposals will be accepted after 3:00 p.m. on the date of the submission.

The Request for Proposals document and all submission forms can be found on the City's website www.kerrvilletx.gov.

All questions regarding this project shall only be submitted in writing and directed to:
Charvy Tork, Director of Information Technology
charvy.tork@kerrvilletx.gov

Deadline for Submission of Written Inquiries shall be **Wednesday, December 15, 2021**

Public Notice

Notice of Public Hearing HEADWATERS GROUNDWATER CONSERVATION DISTRICT BOARD OF DIRECTORS PUBLIC HEARING ON THE PROPOSED DISTRICT MANAGEMENT PLAN - REVISED DECEMBER 2021 DATE: Wednesday, December 08, 2021 TIME: 1:30 PM PLACE: Boardroom, Guadalupe Basin Natural Resources Center HEARING & DISTRICT OFFICE ADDRESS: 125 Lehmann Dr., Kerrville, TX. A copy of the Proposed District Management Plan – Revised December 2021 may be viewed at the District Office

Notice of Public Hearing

HEADWATERS GROUNDWATER CONSERVATION DISTRICT BOARD OF DIRECTORS PUBLIC HEARING ON THE PROPOSED DISTRICT MANAGEMENT PLAN – REVISED DECEMBER 2021

DATE: WEDNESDAY, DECEMBER 08, 2021
TIME: 1:30 PM
PLACE: GUADALUPE BASIN NATURAL RESOURCES CENTER- BOARDROOM
ONLINE LIVE BROADCAST ACCESS: Click Here for Zoom Meeting Access
Manual Entry: https://zoom.us/join, Meeting ID: 896 5766 9627, Passcode: *772311*

Notice is hereby given that a ***Public Hearing on the Proposed District Management Plan – Revised December 2021*** of the Headwaters Groundwater Conservation District will be held on December 08, 2021 at 1:30 pm, at 125 Lehmann Drive, Kerrville, Kerr County, Texas at which time the following items will be discussed:

---

1. Call to Order and Roll Call, Certification of Quorum in Compliance with Texas Open Meetings Law.

2. Headwaters Groundwater Conservation District Board of Directors will accept public comments on the Proposed District Groundwater Management Plan – Revised December 2021.

   A copy of the Proposed District Management Plan – Revised December 2021 may be viewed at the District Office Monday through Thursday 8:00 AM to 5:00 PM, Friday 8:00 AM to 12:00 PM, or on the District website: www.hgcd.org

3. Adjournment

This notice is published pursuant to the Texas Open Meeting Act, Chapter 551, and the Texas Administrative Code, dated this 3rd day of December 2021.

I hereby certify that the above Notice of Meeting of the Board of Directors for Headwaters Groundwater Conservation District is a true and correct copy of said Notice; that a true and correct copy of said notice was posted on or before December 3, 2021 by 5:00 pm, in accordance with Open Meetings Act Section 551.054 and the Texas Administrative Code Rule 356.53; that said Notice was posted in its administrative office in Kerrville, Kerr County, Texas at a place convenient and readily accessible to the general public at all times; that said Notice was published in a local newspaper; that said Notice was posted on the HGCD Website www.hgcd.org; and that said Notice was furnished to each Director.

Gene Williams, General Manager
Headwaters Groundwater Conservation District

HEADWATERS GROUNDWATER CONSERVATION DISTRICT
BOARD OF DIRECTORS REGULAR MEETING

DATE: WEDNESDAY, DECEMBER 08, 2021
TIME: Immediately Following the 1:30 PM District Management Plan Hearing
PLACE: GUADALUPE BASIN NATURAL RESOURCES CENTER-BOARDROOM
ONLINE LIVE BROADCAST ACCESS: Click Here for Zoom Meeting Access

Manual Entry: https://zoom.us/join, Meeting ID: 896 5766 9627, Passcode: *772311*

Notice is hereby given that a ***Regular Meeting*** of the Headwaters Groundwater Conservation District will be held on December 08, 2021 at 125 Lehmann Drive, Kerrville, Kerr County, Texas at which time the following items will be discussed and possible action taken to wit:

---

1. Call to Order and Roll Call, Certification of Quorum in Compliance with Texas Open Meetings Law.

2. Public Comment - Any person may address the Board at any time on any agenda item of this meeting. Non-agenda items may only be addressed during the Public Comment section of this meeting; no formal action will be taken on the non-agenda items.

3. Consent Agenda
    1. Approval of the District Rules Hearing Minutes (November 10, 2021)
    2. Approval of the Regular Meeting Minutes (November 10, 2021)
    3. Approval of Paying of the Bills
    4. Receiving the Treasurer's Report (November 2021)
    5. Public Funds Investment Policy Reporting (November 2021)
    6. Receiving the Groundwater Report

4. Discussion and Possible Action, after Notice and Hearing, to Approve Resolution 2021-2, Adopting the District Groundwater Management Plan – Revised December 2021 and Submitting the Plan to the Texas Water Development Board for Final Approval.

5. General Managers Report
    - GMA9 Update

6. Directors Request for Agenda Items for Next Meeting.

7. Adjournment

This notice is published pursuant to the Texas Open Meeting Act, Chapter 551, and Texas Government Code, Dated this 3rd day of December 2021.

I hereby certify that the above Notice of Meeting of the Board of Directors for Headwaters Groundwater Conservation District is a true and correct copy of said Notice; that a true and correct copy of said Notice was posted on December 3, 2021 by 5:00 pm, in accordance with Open Meetings Act Section 551.054, and that a copy of said Notice was furnished to each Director.

Gene Williams, General Manager
Headwaters Groundwater Conservation District