

DISTRICT GROUNDWATER MANAGEMENT PLAN

(PROPOSED TO BE) REVISED & ADOPTED - NOVEMBER 17, 2026

CONTACT PAGE FOR:

HEADWATERS GROUNDWATER CONSERVATION DISTRICT

Groundwater Management Plan

Kerr County, Texas

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Headwaters Groundwater Conservation District

Groundwater Management Plan – 2027

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 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

[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

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 1463[7] (HB 1463) and approved by the Governor of Texas on June 16, 1991. The 77th Legislature House Bill 3543[8] (HB 3543) 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 Texas Water Code (TWC) Section 36.0015(b)[10], the mission of the District is to provide for the conservation, preservation, protection, recharging, and prevention of waste [as defined in TWC Chapter 36.001(8)[11]] 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 groundwater. As specified in TWC Section 36.101(a)[12], 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

[5] https://statutes.capitol.texas.gov/?tab=1&code=WA&chapter=WA.36&artSec=36.1071
[6] https://texas-sos.appianportalsgov.com/rules-and-meetings?chapter=356&interface=VIEW_TAC&part=10&title=31
[7] https://capitol.texas.gov/BillLookup/History.aspx?LegSess=72R&Bill=HB1463 (*No text available on Legislative website.)
[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/?tab=1&code=WA&chapter=WA.36&artSec=36.0015
[11] https://statutes.capitol.texas.gov/?tab=1&code=WA&chapter=WA.36&artSec=36.001
[12] https://statutes.capitol.texas.gov/?tab=1&code=WA&chapter=WA.36&artSec=36.101

with groundwater as described in TWC Section 36.002[13], 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 35[14] [of the Water Code] as *an area experiencing or expected to experience critical groundwater problems*." See also TWC Section 36.001(14) (emphasis added). Currently, there are eight

[13] https://statutes.capitol.texas.gov/?tab=1&code=WA&chapter=WA.36&artSec=36.002
[14] https://statutes.capitol.texas.gov/?tab=1&code=WA&chapter=WA.35&artSec=35.002

(8) PGMAs[15] 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

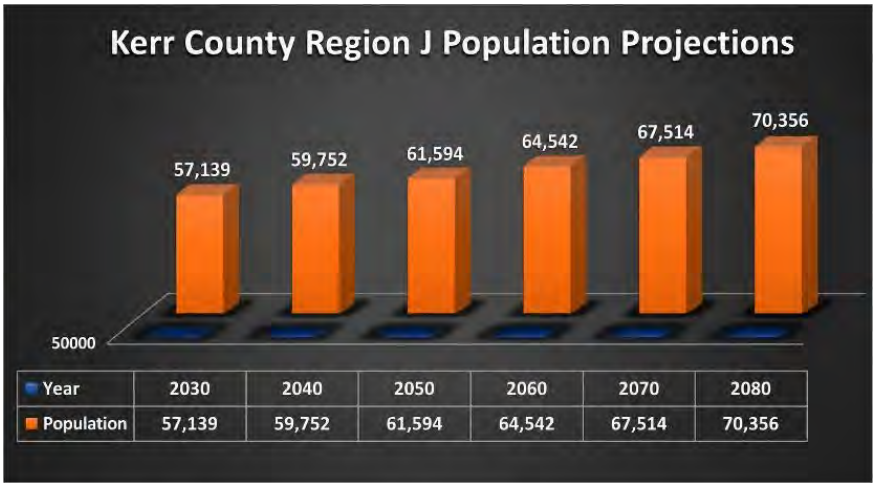
This plan will become effective upon adoption by the District's board of directors and approved as administratively complete by the Texas Water Development Board. The plan will remain in effect for five (5) years after the date of approval or until a revised plan is adopted and approved in accordance with TWC Chapter 36.1072(e)[16]. Any amendments to this plan shall be in accordance with TWC Chapter 36.1073[17]. 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 Water Planning Group (PWPG) known as "Region J." The County population is displayed, in Table 2-1 below, according to population estimates prepared by and submitted by Region J in the 2026 Plateau (Region J) State Water Plan[18]. These estimates, which include Ingram, Kerrville, and County-Other data, project a 13,000+ increase in population over the next 50-year period.

[15] https://www.tceq.texas.gov/downloads/groundwater/maps/pgma-areas.pdf
[16] https://statutes.capitol.texas.gov/?tab=1&code=WA&chapter=WA.36&artSec=36.1072
[17] https://statutes.capitol.texas.gov/?tab=1&code=WA&chapter=WA.36&artSec=36.1073
[18] https://www.twdb.texas.gov/waterplanning/rwp/plans/2026/J/RegionJ_2026_RWP.pdf?d=16094.900000000373, Table 2-1

2026 Plateau Region Water Plan, Table 2-1, Kerr County Totals



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 quantities because “the census does not recognize the significant seasonal population increase that occurs as the [Region J] counties draw large numbers of hunters and recreational visitors, as well as absentee landowners who maintain vacation, retirement, and hunting properties.” 2026 Plateau (Region J) Water Plan, Section 2.1.2[19].

Different growth patterns are evident in different areas of the County. It is recognized that a greater percentage of the rural population is concentrated in the eastern portion of the County[16]. The trend in the western portion of the County is comprised of larger acreage tracts with sparse population density. 2026 Plateau (Region J) Water Plan, Figure 2-3[19].

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 feet above mean sea level (MSL) at

[19] https://www.twdb.texas.gov/waterplanning/rwp/plans/2026/J/RegionJ_2026_RWP.pdf?d=16094.900000000373

the southeastern edge of the County to about 2,400 feet in the western part (Reeves, 1969)[20]. 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)[20]. 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: Kerrville, TX for the years (1995-2025)[21] is 28.25 inches. Net lake surface evaporation ranges from approximately 58 inches per year in the eastern part of the county to about 62 inches per year in the western part (2026 Plateau (Region J) Water Plan, Figure 1-6)[22].

Water Resources of Kerr County

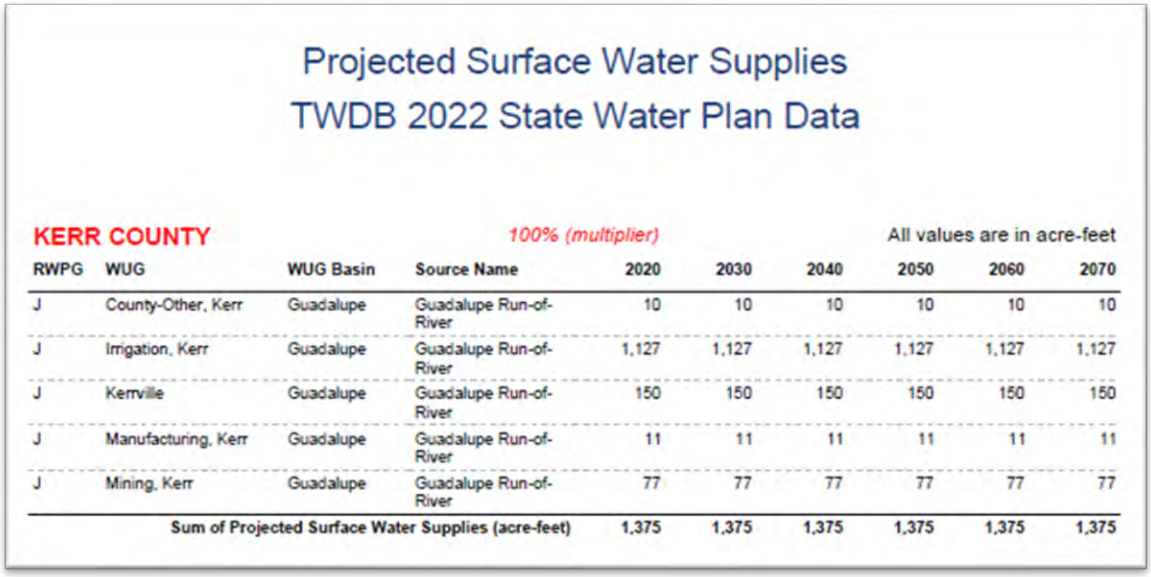
Projected Surface Water Supply

TWC §36.1071(e)(3)(F) and 31 TAC §356.52(a)(6)(F) require an estimate of the projected surface water supply within the District according to the most recently adopted state water plan.

The District encompasses all of Kerr County. Therefore, the Kerr County values provided by the TWDB represent the District values, and no geographic apportionment is necessary.

Based on the *TWDB Estimated Historical Groundwater Use and 2022 State Water Plan Datasets for Headwaters Groundwater Conservation District*, dated July 17, 2026, also attached as Appendix A, the projected surface water supply within the District is:

[20] https://www.twdb.texas.gov/publications/reports/numbered_reports/doc/R102/R102.pdf
[21] https://www.ars.usda.gov/ARSUserFiles/30940500/KRVL_WeatherData/2025_WTHR/WTHR2025.pdf
[22] https://www.twdb.texas.gov/waterplanning/rwp/plans/2026/J/RegionJ_2026_RWP.pdf?d=16094.900000000373



Projected Surface Water Supplies
TWDB 2022 State Water Plan Data

KERR COUNTY *100% (multiplier)* 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	10	10	10	10	10	10
J	Irrigation, Kerr	Guadalupe	Guadalupe Run-of-River	1,127	1,127	1,127	1,127	1,127	1,127
J	Kerrville	Guadalupe	Guadalupe Run-of-River	150	150	150	150	150	150
J	Manufacturing, Kerr	Guadalupe	Guadalupe Run-of-River	11	11	11	11	11	11
J	Mining, Kerr	Guadalupe	Guadalupe Run-of-River	77	77	77	77	77	77
			Sum of Projected Surface Water Supplies (acre-feet)	**1,375**	**1,375**	**1,375**	**1,375**	**1,375**	**1,375**

The projected surface water supply remains constant throughout the planning period. Because surface water availability can affect groundwater demand, the District will continue to consider surface water use and availability when evaluating groundwater conditions and conjunctive-use matters under District Rule 7.

Projected Total Water Demand

TWC §36.1071(e)(3)(G) and 31 TAC §356.52(a)(6)(G) require an estimate of projected total water demand within the District according to the most recently adopted state water plan.

Water Demand, as defined by the 2012 State Water Plan Glossary, is the quantity of water projected to meet the overall necessities of a water user group in a specific future year." Additional explanation: These are water demand volumes as projected for specific Water User Groups in the Regional Water Plans. This is not groundwater pumpage or demand based on any existing water source. This demand is how much water each Water User Group is projected to require in each decade over the planning horizon. Projected water demands include water from all sources and should not be interpreted as projected groundwater use alone.

Based on the *TWDB Estimated Historical Groundwater Use and 2022 State Water Plan Datasets for Headwaters Groundwater Conservation District*, dated July 17, 2026, also attached as Appendix A, the projected water demand within the District is:

Projected Water Demands
TWDB 2022 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 *100% (multiplier)* All values are in acre-feet

RWPG	WUG	WUG Basin	2020	2030	2040	2050	2060	2070
J	County-Other, Kerr	Colorado	43	44	44	44	45	46
J	County-Other, Kerr	Guadalupe	1,974	2,008	2,013	2,046	2,090	2,127
J	County-Other, Kerr	Nueces	1	1	1	1	1	1
J	County-Other, Kerr	San Antonio	23	23	24	24	24	25
J	Irrigation, Kerr	Colorado	61	61	61	61	61	61
J	Irrigation, Kerr	Guadalupe	1,239	1,239	1,239	1,239	1,239	1,239
J	Irrigation, Kerr	San Antonio	42	42	42	42	42	42
J	Kerrville	Guadalupe	5,082	5,158	5,178	5,237	5,305	5,364
J	Kerrville South Water	Guadalupe	341	346	347	352	358	363
J	Livestock, Kerr	Colorado	166	166	166	166	166	166
J	Livestock, Kerr	Guadalupe	546	546	546	546	546	546
J	Livestock, Kerr	Nueces	9	9	9	9	9	9
J	Livestock, Kerr	San Antonio	36	36	36	36	36	36
J	Manufacturing, Kerr	Guadalupe	20	21	21	21	21	21
J	Mining, Kerr	Colorado	14	15	18	19	20	22
J	Mining, Kerr	Guadalupe	62	65	82	83	91	98
		Sum of Projected Water Demands (acre-feet)	**9,659**	**9,780**	**9,827**	**9,926**	**10,054**	**10,166**

Total water demand is projected to increase from 9,659 acre-feet per year in 2020 to 10,166 acre-feet per year in 2070, an increase of approximately 5.2 percent. Most of the projected demand and growth are associated with municipal and County-Other WUGs.

The District recognizes that growth in total demand, changes in surface water availability, and implementation of alternative supplies may affect future groundwater demand.

Consideration of Water Supply Needs within the District

TWC §36.1071(e)(4) and 31 TAC §356.52(a)(7)(A) require details of the District's

consideration of water supply needs, emphasizing needs that impact groundwater supply within the District.

Needs, as defined by the 2012 State Water Plan Glossary, is the projected water demands in excess of existing water supplies for a water user group or a wholesale water provider. (See 2012 State Water Plan Chapter 6 for more detail.) Additional explanation: These are the volumes of water that result from comparing each Water User Group's projected existing water supplies to its projected water demands. If the volume listed is a negative number, then the Water User Group shows a projected need during a drought if they do not implement any water management strategies. If the volume listed is a positive number, then the Water User Group shows a projected surplus. Note that if a Water User Group shows a need in any decade, then they are considered to have a potential need during the planning horizon, even if they show a surplus elsewhere.

The following are the specific datasets and water supply needs that the District considered, based on the TWDB Estimated Historical Groundwater Use and 2022 State Water Plan Datasets for Headwaters Groundwater Conservation District, dated July 17, 2026, also attached as Appendix A:

Projected Water Supply Needs
TWDB 2022 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	21	20	20	20	19	18
J	County-Other, Kerr	Guadalupe	6,564	6,530	6,525	6,492	6,448	6,411
J	County-Other, Kerr	Nueces	-1	-1	-1	-1	-1	-1
J	County-Other, Kerr	San Antonio	238	238	237	237	237	236
J	Irrigation, Kerr	Colorado	31	31	31	31	31	31
J	Irrigation, Kerr	Guadalupe	421	421	421	421	421	421
J	Irrigation, Kerr	San Antonio	21	21	21	21	21	21
J	Kerrville	Guadalupe	1,551	1,475	1,455	1,396	1,328	1,269
J	Kerrville South Water	Guadalupe	46	41	40	35	29	24
J	Livestock, Kerr	Colorado	-119	-119	-119	-119	-119	-119
J	Livestock, Kerr	Guadalupe	-173	-173	-173	-173	-173	-173
J	Livestock, Kerr	Nueces	-6	-6	-6	-6	-6	-6
J	Livestock, Kerr	San Antonio	-27	-27	-27	-27	-27	-27
J	Manufacturing, Kerr	Guadalupe	28	27	27	27	27	27
J	Mining, Kerr	Colorado	-11	-12	-15	-16	-17	-19
J	Mining, Kerr	Guadalupe	60	57	40	39	31	24
	Sum of Projected Water Supply Needs (acre-feet)		-337	-338	-341	-342	-343	-345

- Most of the projected need is associated with livestock use, which may affect groundwater through exempt well production.

- Smaller needs are identified for mining uses, which may be affected by District permitting, Production Caps, well-spacing, metering, reporting, drought-management, and aquifer-specific requirements.
- No projected shortage is identified for the City of Kerrville, Kerrville South Water, irrigation, manufacturing, or the majority of the County-Other WUGs.

The District addresses groundwater demands through its Rules governing exempt and permitted wells, spacing, permit acreage, Production Caps, metering and reporting, drought management, and achievement of DFCs. Projected needs are planning estimates and do not establish groundwater availability or a right to receive a permit for a particular volume.

Consideration of Water Management Strategies

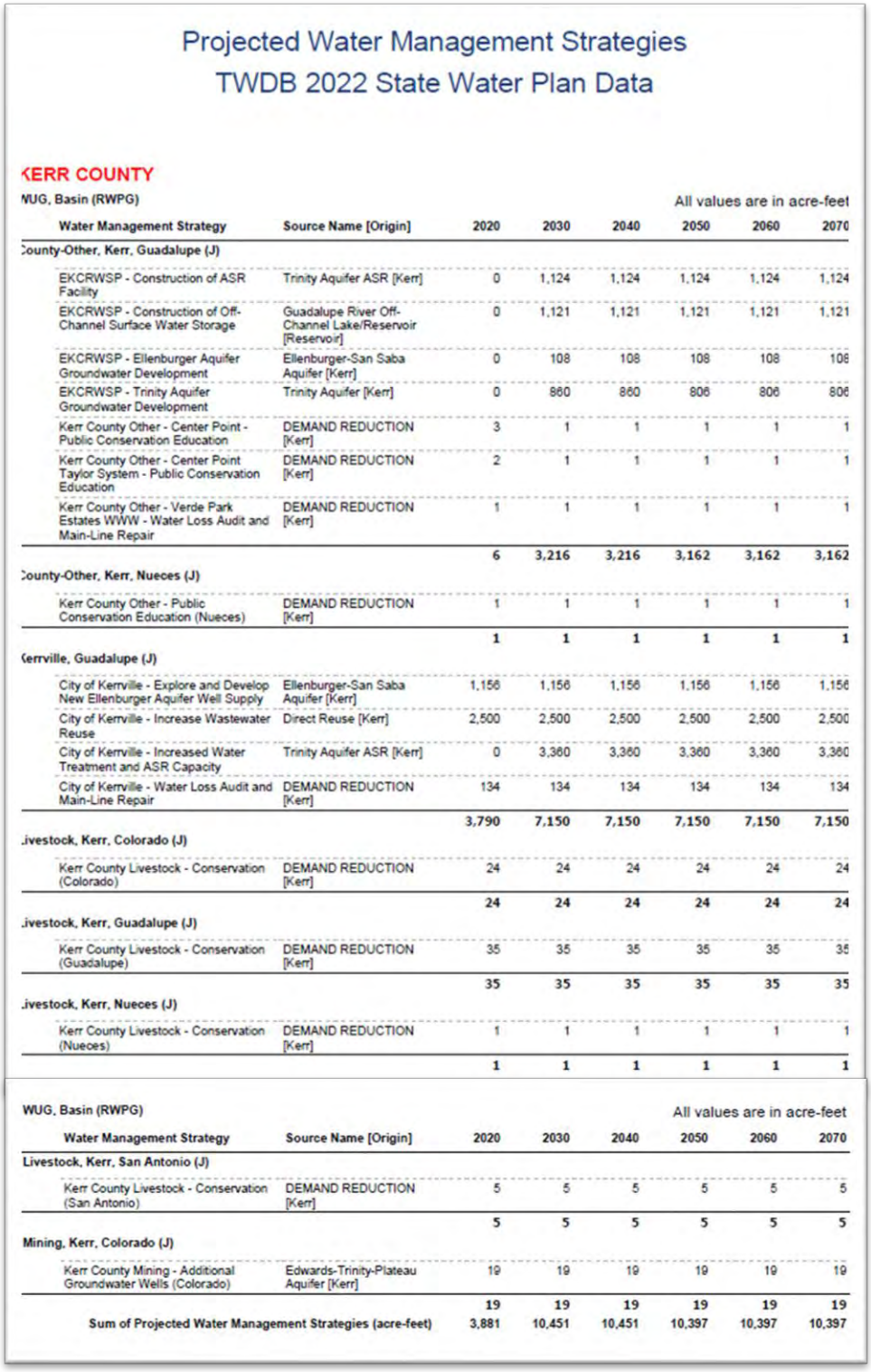
TWC §36.1071(e)(4) and 31 TAC §356.52(a)(7)(B) require details of the District's consideration of water management strategies sourced from within District boundaries, emphasizing strategies that are or will be impacted by District actions.

A Recommended Water Management Strategy, as defined by the 2012 State Water Plan Glossary, is a specific project or action to increase water supply or maximize existing supply to meet a specific need. (See 2012 State Water Plan Chapter 7 for more detail.) Additional explanation: These are the specific water management strategies (with associated water volumes) that are recommended in the currently adopted Regional Water Plans.

Because the District and Kerr County boundaries are coterminous, the strategies identified as originating within Kerr County—including the proposed East Kerr County Regional Water Supply Project (EKCRWSP)—are sourced from within the District.

The following are the specific datasets and water management strategies that the District considered, based on the *TWDB Estimated Historical Groundwater Use and 2022 State*

Water Plan Datasets for Headwaters Groundwater Conservation District, dated July 17, 2026, also attached as Appendix A:



Projected Water Management Strategies
TWDB 2022 State Water Plan Data

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, Guadalupe (J)							
EKCRWSP - Construction of ASR Facility	Trinity Aquifer ASR [Kerr]	0	1,124	1,124	1,124	1,124	1,124
EKCRWSP - Construction of Off-Channel Surface Water Storage	Guadalupe River Off-Channel Lake/Reservoir [Reservoir]	0	1,121	1,121	1,121	1,121	1,121
EKCRWSP - Ellenburger Aquifer Groundwater Development	Ellenburger-San Saba Aquifer [Kerr]	0	108	108	108	108	108
EKCRWSP - Trinity Aquifer Groundwater Development	Trinity Aquifer [Kerr]	0	860	860	806	806	806
Kerr County Other - Center Point - Public Conservation Education	DEMAND REDUCTION [Kerr]	3	1	1	1	1	1
Kerr County Other - Center Point Taylor System - Public Conservation Education	DEMAND REDUCTION [Kerr]	2	1	1	1	1	1
Kerr County Other - Verde Park Estates WWW - Water Loss Audit and Main-Line Repair	DEMAND REDUCTION [Kerr]	1	1	1	1	1	1
		6	**3,216**	**3,216**	**3,162**	**3,162**	**3,162**
County-Other, Kerr, Nueces (J)							
Kerr County Other - Public Conservation Education (Nueces)	DEMAND REDUCTION [Kerr]	1	1	1	1	1	1
		1	**1**	**1**	**1**	**1**	**1**
Kerrville, Guadalupe (J)							
City of Kerrville - Explore and Develop New Ellenburger Aquifer Well Supply	Ellenburger-San Saba Aquifer [Kerr]	1,156	1,156	1,156	1,156	1,156	1,156
City of Kerrville - Increase Wastewater Reuse	Direct Reuse [Kerr]	2,500	2,500	2,500	2,500	2,500	2,500
City of Kerrville - Increased Water Treatment and ASR Capacity	Trinity Aquifer ASR [Kerr]	0	3,360	3,360	3,360	3,360	3,360
City of Kerrville - Water Loss Audit and Main-Line Repair	DEMAND REDUCTION [Kerr]	134	134	134	134	134	134
		3,790	**7,150**	**7,150**	**7,150**	**7,150**	**7,150**
Livestock, Kerr, Colorado (J)							
Kerr County Livestock - Conservation (Colorado)	DEMAND REDUCTION [Kerr]	24	24	24	24	24	24
		24	**24**	**24**	**24**	**24**	**24**
Livestock, Kerr, Guadalupe (J)							
Kerr County Livestock - Conservation (Guadalupe)	DEMAND REDUCTION [Kerr]	35	35	35	35	35	35
		35	**35**	**35**	**35**	**35**	**35**
Livestock, Kerr, Nueces (J)							
Kerr County Livestock - Conservation (Nueces)	DEMAND REDUCTION [Kerr]	1	1	1	1	1	1
		1	**1**	**1**	**1**	**1**	**1**

WUG, Basin (RWPG) — All values are in acre-feet

Water Management Strategy	Source Name [Origin]	2020	2030	2040	2050	2060	2070
Livestock, Kerr, San Antonio (J)							
Kerr County Livestock - Conservation (San Antonio)	DEMAND REDUCTION [Kerr]	5	5	5	5	5	5
		5	**5**	**5**	**5**	**5**	**5**
Mining, Kerr, Colorado (J)							
Kerr County Mining - Additional Groundwater Wells (Colorado)	Edwards-Trinity-Plateau Aquifer [Kerr]	19	19	19	19	19	19
		19	**19**	**19**	**19**	**19**	**19**
Sum of Projected Water Management Strategies (acre-feet)		**3,881**	**10,451**	**10,451**	**10,397**	**10,397**	**10,397**

- **Groundwater development:** Trinity and Ellenburger-San Saba Aquifer development may be affected by District requirements governing permits, Production Caps, permit

acreage, well spacing, metering, reporting, drought management, and DFCs.

- **Aquifer storage and recovery:** ASR projects are addressed by District Rule 18 and Texas Water Code Chapter 36, Subchapter N.
- **Edwards-Trinity (Plateau) wells:** New non-exempt (permit) wells may be affected by District Rule 5, which contains restrictions regarding certain new permitted wells in the Edward-Trinity (Plateau) Aquifer.
- **Conservation:** Conservation strategies are supported by the District's management plan goals which require the District to encourage groundwater conservation and efficient use of groundwater. In addition, groundwater wells permitted by the District are subject to the District's Drought Contingency Plan, as provided by Rule 16. These measures may reduce groundwater demand, particularly during drought.
- **Wastewater reuse and surface-water storage:** Wastewater reuse and off-channel surface-water storage are generally implemented under authorities outside the District's direct regulatory jurisdiction. However, these strategies may supplement existing supplies and reduce or defer reliance on groundwater. If a project includes a groundwater well, aquifer storage and recovery (ASR), or another component within the District's statutory authority, that component will be subject to applicable law and District Rules.

Identification of a strategy in the State Water Plan does not constitute District approval, establish groundwater availability, or create a right to produce a particular quantity of groundwater. Any strategy requiring District authorization will be evaluated under applicable law, District Rules, aquifer conditions, and the information available at the time.

Groundwater Resources of Kerr County

Groundwater availability modeling information in GAM Run 21-003[23] 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 Kerr County 2008"[24]. 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 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

[23] Appendix E of this Management Plan
[24] https://www.hgcd.org/links-to-water-information

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[25]

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 Kerr 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 Kerr County (2005)"[26] 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[27], 5394-B[28], 2026[29] and Permit 3505[30] are held by Kerrville. UGRA holds Permit 5394-A[28]. 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 3-7. 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

[25] https://www.twdb.texas.gov/waterplanning/rwp/plans/2026/J/RegionJ_2026_RWP.pdf?d=16094.900000000373, Section 3.2.7
[26] https://www.ugra.org/assets/pdfs/SpringflowGuadalupe2005.pdf
[27] https://gisweb.tceq.texas.gov/WRRetrieveRights/?ID=ADJ1996
[28] https://gisweb.tceq.texas.gov/WRRetrieveRights/?ID=WRPERM5394
[29] https://gisweb.tceq.texas.gov/WRRetrieveRights/?ID=ADJ2026
[30] https://gisweb.tceq.texas.gov/WRRetrieveRights/?ID=WRPERM3505

in and near Kerrville.

Table 3-7: Municipal Surface Water rights for Kerrville and UGRA

Water Rights Permit	Authorized Diversion (acre-ft/yr.)	Permit Holder	Priority Data	Storage (ac-ft)	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-B & 5394-D (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)			

Note: Permit 2026 (priority 1961) 54 ac/ft 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 cubic feet per second (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 Nimitz Lake (the UGRA Lake renamed in 2011) 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 Kerr 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 Kerr 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[31] 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"[32]. 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 fourth 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 21-014 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**

Projected Surface Water Supply within the District "Texas 2022 State Water Plan." **Please Refer to Appendix D**

[31] https://statutes.capitol.texas.gov/?tab=1&code=WA&chapter=WA.36&artSec=36.001
[32] https://statutes.capitol.texas.gov/?tab=1&code=WA&chapter=WA.36&artSec=36.108

Projected Total Demand for Water within the District "Texas 2022 State Water Plan**."**

Please Refer to Appendix D

Water Supply Needs *"Texas 2022 State Water Plan."*

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

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

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

Resolution No. 2023-3 MAG - Amended Management Plan, September 13, 2023 Public Hearing Notices and Regular Meeting Agenda.

Please Refer to Appendix G

Groundwater Availability Model (GAM) for the
Southern Portion of the Trinity Aquifer System (version 3.01)

https://www.twdb.texas.gov/groundwater/models/gam/trnt_h/trnt_s.asp

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 regard 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 https://www.hgcd.org/rules-plans-reports. 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. Providing the Most Efficient Use of Groundwater[33]

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-one (41) wells, in the Middle and Lower Trinity aquifers distributed across the County, two (2) Ellenburger wells and twelve (12) wells in the Edwards-Trinity (Plateau) Aquifer. Seven (7) wells are part of the TWDB monitor well satellite recorder program, two of those wells are dual Middle and Lower Trinity monitor wells. All monthly monitor well water level information is shared with the TWDB. Monthly aquifer levels and hydrographs for each individual monitor well are collected and published on the District website www.hgcd.org. The most recent reports and graphs are reported to the board of directors as part of their board meeting information packet.

The District will, in each annual management plan tracking report, document the frequency that the aquifer levels and hydrographs were posted on the District's website and reported to the board of directors as part of their board meeting information packet.

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 (permit) and exempt wells drilled in The County. A file has been

[33] Most efficient use of groundwater – Practices, techniques, and technologies that a district determines will provide the least consumption of groundwater for each type of use balanced with the benefits of using groundwater.

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 permitted production combined with the annual estimated exempt well production number, which is provided by TWDB, is documented in the HGCD annual groundwater report and provides the estimated current groundwater demand for the District.

The District will, in each annual management plan tracking report, document the annual number of new exempt and non-exempt (permit) wells completed in compliance with HGCD District Rules and TDLR standards for well completion, and document when the most recent HGCD annual groundwater report was received by the board of directors.

B. Controlling and Preventing Waste of Groundwater

B-1. Objective - Make and enforce rules (TWC 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 TWC 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.

The District will, in each annual management plan tracking report, document the reported occurrences of waste, within the preceding calendar year, and the resulting conclusions, and document the publication(s) regarding wasteful and non-essential water uses that occurred in a local newspaper.

C. 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. 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 4-79, the results of the Trinity Aquifer subsidence risk factor data sources and summary (figure 4.49) 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.

D. Addressing Conjunctive[34] Surface Water Management Issues

D-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

[34] Conjunctive Use – The combined use of groundwater and surface water sources that optimize the beneficial characteristics of each source, such as water banking, aquifer storage and recovery, enhanced recharge, and joint management.

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.

D-1. Performance Standard – The District will, in each annual management plan tracking 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 calendar year, and the name(s) of district staff attending.

E. Address Natural Resources Issues[35] that Impact the Use and Availability of Groundwater and which are Impacted by the Use of Groundwater

E-1. Objective – Prohibit contamination/pollution of the aquifers in The County from other natural resources being produced. Monitor water quality throughout the District.

E-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.

The District requires a water quality analysis from all new wells within sixty (60) 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 TDS. Well owners are notified by the District when e. coli, total coliforms or injurious water is detected on the lab report.

[35] Natural resources issues – Issues relating to environmental and other concerns that may be affected by a district's groundwater management plan and rules, such as impacts on endangered species, soils, oil and gas production, mining, air and water quality degradation, agriculture, and plant and animal life.

The District will, in each annual management plan tracking report, document the number of water quality analyses that were completed on new wells or monitor wells, within the preceding calendar year.

E-2. Objective – A representative from the District will attend a minimum of 75% of the GMA 9 meetings and is a part of any discussions regarding ways to protect the environment.

E-2. Performance Standard – The District will, in each annual management plan tracking report, provide a table that lists all GMA 9 meetings scheduled during the preceding calendar year and the name(s) of the District's designated representative in attendance at each meeting.

F. Addressing Drought Conditions

F-1. Objective – Monitor drought conditions.

F-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.
When drought stages are triggered, a notice goes out by mail to all non-exempt (permit) well owners/operators, and a notice is placed in a local newspaper, on the District website, and at the District office. 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. Statewide and Local drought information is available at https://www.drought.gov/states/texas and https://www.drought.gov/states/texas/county/Kerr. Drought conditions are reported to the board of directors as part of their board meeting information packet.

The District will, in each annual management plan tracking report, document the drought conditions for the preceding calendar year and document the frequency that drought conditions were reported to the board of director as part of their board meeting information packet.

G. Addressing Conservation

G-1. Objective – **Conservation.**

G-1. Performance Standard – District Rules require well spacing, pump capacities and a production cap to limit the amount of water use per acre. The District issues authorization to drill exempt and non-exempt (permit) water wells to be used for beneficial purpose without waste. The District Conservation Plan is posted on the District's website. TWDB's Water Conservation webpage is shared on the District website, under Links to Water Information, along with a variety of other online water education resources. Each year, the District will 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).

The District will, in each annual management plan tracking report, document the details of the local newspaper publication(s) encouraging conservation.

H. Addressing Recharge Enhancement[36]

This goal is not applicable at this time. It is not within the District's ability to be cost effective.

I. Addressing Rainwater Harvesting

I-1. Objective – **Promote the benefits of and provide access to information**

[36] Recharge Enhancement – Increased recharge accomplished by the modification of the land surface, streams, or lakes to increase seepage or infiltration rates or by the direct injection of water into the subsurface through wells.

regarding Rainwater Harvesting.

I-1. Performance Standard – A variety of rainwater harvesting resources are provided on the District website, under Links to Water Information, 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. Each year, the District will publish a minimum of one article in local newspapers encouraging the use and advantages of rainwater harvesting.

The District will, in each annual management plan tracking report, document the details of the local newspaper publication(s) encouraging the use and advantages of rainwater harvesting.

J. Addressing Precipitation Enhancement

This goal is not applicable at this time. It is not within the District's ability to be cost effective.

K. Addressing Brush Control

This goal is not applicable at this time. It is not within the District's ability to be cost effective.

L. Addressing the Desired Future Conditions Established Under TWC §36.108

L-1. Objective –**Achieve the Desired Future Conditions for the hill country Trinity aquifers adopted by GMA 9, stated in GAM Task 10-005 Scenario 6.**

L-1. 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. At the end of each calendar year, the Middle and Lower Trinity average water levels for the District's DFC wells are calculated for each aquifer and compared to their respective 2008 base line to determine the water level difference. The differences are then measured against the most recently adopted DFCs, as stated in GMA 9 Resolution #111521-01 and summarized in Appendix A of GAM Task 10-005[37] Scenario 6 for Kerr County. This information is documented in the annual "HGCD Desired Future Conditions Tracking Report". At the end of each calendar year, an annual groundwater report is produced. This report combines annual permitted volumes and the estimated exempt pumping volume, which is provided by TWDB. The total is used to evaluate and compare the District's current demand to the "MAG assigned HGCD" in GAM Run 21-014 MAG[38]. This information is documented in the annual "HGCD Desired Future Conditions Tracking Report", which is annually reviewed and accepted by the HGCD Board of Directors, and once accepted, it is posted on the District website at https://www.hgcd.org/water-data.

Information on the DFCs, the non-relevant aquifer classifications, the MAG for each decade between 2020 and 2060, and how the MAG is annually evaluated is documented in the District Rules (Rule 21).

The District is in GMA 9 and participates in joint planning and all requirements of Chapter 36, Sec 36.108.

The District will, in each annual management plan tracking report, include the most recent "HGCD Desire Future Conditions Tracking Report".

[37] https://www.twdb.texas.gov/groundwater/docs/GAMruns/Task10-005.pdf
[38] Appendix C, of this Management Plan

District Performance in Achieving the Desired Future Conditions

The District's most recent desired future conditions (DFCs), adopted through GMA 9 Resolution #111521-01 and HGCD Resolution 2023-01, allow for increases in average groundwater-level drawdown consistent with Scenario 6 of TWDB GAM Task 10-005. For GMA 9 as a whole, the adopted DFC allows an average increase in drawdown of approximately 30 feet in the Trinity Aquifer. Because drawdown is not projected to occur uniformly throughout the management area, Scenario 6 projects Kerr County-specific average increases in drawdown of 56.8 feet in the Middle Trinity, 58.2 feet in the Lower Trinity, and 39.2 feet for the Trinity Aquifer overall.

Table L-1: HGCD Desired Future Conditions Tracking Report

HGCD DESIRED FUTURE CONDITIONS TRACKING REPORT 2008 THRU 2025										
DFC WELL LEVELS (DRAWDOWN COMPARED TO 2008) Middle and Lower Trinity Monitor Wells Drilled by HGCD							Current Available MAG			
Year	DFC Wells Middle Trinity Average	MT Drawdown from Baseline 2008	Gam Task 10-005 Scenario 6 DFC for MT	DFC Wells Lower Trinity Average	LT Drawdown from Baseline 2008	Gam Task 10-005 Scenario 6 DFC for LT	Year	Modeled Available Groundwater GAM Run 21-014 MAG*	Total Current Demand**- Permitted plus Exempt	Acre Feet left to Permit
2008	1537	0	-56.8	1396	0	-58.2	2008	15952	-11470	4482
2009	1529	-8	-56.8	1370	-26	-58.2	2009	15952	-11441	4511
2010	1542	5	-56.8	1388	-8	-58.2	2010	16435	-11554	4881
2011	1533	-4	-56.8	1367	-29	-58.2	2011	16435	-10672	5763
2012	1525	-12	-56.8	1361	-35	-58.2	2012	16435	-10730	5705
2013	1540	3	-56.8	1360	-36	-58.2	2013	16435	-11125	5310
2014	1537	0	-56.8	1356	-40	-58.2	2014	16435	-11650	4785
2015	1539	2	-56.8	1357	-39	-58.2	2015	14918	-11458	3460
2016	1542	5	-56.8	1403	7	-58.2	2016	14918	-11553	3365
2017	1541	4	-56.8	1406	10	-58.2	2017	14918	-11737	3181
2018	1541	4	-56.8	1400	4	-58.2	2018	14918	-10937	3981
2019	1547	10	-56.8	1394	-2	-58.2	2019	14918	-11244	3674
2020	1534	-3	-56.8	1382	-14	-58.2	2020	14918	-11669	3249
2021	1540	3	-56.8	1390	-6	-58.2	2021	14918	-11884	3034
2022	1539	2	-56.8	1372	-24	-58.2	2022	14918	-12211	2707
2023	1533	-4	-56.8	1368	-28	-58.2	2023	14918	-12775	2143
2024	1534	-3	-56.8	1371	-25	-58.2	2024	14918	-12615	2303
2025	1532	-5	-56.8	1369	-27	-58.2	2025	14918	-12942	1976
Lower Trinity Levels are influenced by the City of Kerrville ASR Wells.							*GAM Run 21-014 MAG - Updated 12/8/2022 **Totals Provided from the HGCD Annual Groundwater Report			
The District will evaluate annually the volume of water permitted by the District and the Exempt pumping estimates provided by the Texas Water Development Board, and compare the total volume to the MAG, as stated in Report GAM Run 21-014 MAG. - Updated 12/8/2022										

Using 2008 average water levels as the baseline (see Table L-1), the District's 2025

monitoring data indicates an average increase in drawdown of 5 feet in the Middle Trinity, 27 feet in the Lower Trinity, and 16 feet for the Trinity Aquifer overall. These values remain below the corresponding Kerr County projections in Scenario 6. The District's overall Trinity average increase in drawdown of 16 feet also remains below the approximate 30-foot average increase in drawdown adopted for GMA 9 as a whole.

Based on the most recent available monitoring data, the District has continuously achieved the adopted DFCs for the current and preceding five-year joint planning cycles. The District will continue to evaluate groundwater-level trends through implementation of its monitoring program, groundwater management plan, and District Rules.

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APPENDIX A

Evidence that, following notice and hearing, the District coordinated in the development of its management plan with regional surface water management entities[39].

[39] Surface water management entities – Political subdivisions as defined by Texas Water Code Chapter 15 and identified from Texas Commission on Environmental Quality records that area granted authority under Texas Water Code Chapter 11 to store, take, divert, or supply surface water either directly or by contract for use within the boundaries of a District.

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APPENDIX B

GMA 9 RESOLUTION ADOPTING THE GROUNDWATER MANAGEMENT AREA 9 JOINT PLANNING COMMITTEE'S PROPOSED CLASSIFICATION OF LOCALLY MANAGED AQUIFERS AS NON-RELEVANT FOR JOINT PLANNING PURPOSES AND THE DESIRED FUTURE CONDITIONS FOR RELEVANT MAJOR AND MINOR AQUIFERS IN GMA 9

HGCD RESOLUTION ADOPTING THE DESIRED FUTURE CONDITIONS AND NON-RELEVANT AQUIFERS FOR KERR COUNTY IN ACCORDANCE WITH GMA9 JOINT PLANNING

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STATE OF TEXAS	§	
	§	**RESOLUTION # 111521-01**
GROUNDWATER	§	
MANAGEMENT AREA 9	§	

Adopting the Groundwater Management Area 9 Joint Planning Committee's Proposed Classification of Locally Managed Aquifers as Non-Relevant for Joint Planning Purposes and the Desired Future Conditions for Relevant Major and Minor Aquifers in GMA 9, and authorizing the GMA 9 Chairman to formally submit them and all other required information to the TWDB.

WHEREAS. the Groundwater Conservation Districts (GCDs) located within or partially within Groundwater Management Area 9 (GMA 9) are required under Chapter 36.108, Texas Water Code to conduct joint planning and designate the Desired Future Conditions (DFCs) for aquifers within GMA 9; and

WHEREAS, the Board Presidents or their Designated Representatives of the GCD Members of the Groundwater Management Area 9 Joint Planning Committee (GMA 9) have met as a Committee in various meetings and conducted joint planning in accordance with Section 36.108, Texas Water Code since September 2005; and

WHEREAS, GMA 9, having given proper and timely notice, held an open meeting of the GMA 9 Committee on March 22, 2021 in a ZOOM Virtual Meeting format allowed under a variance to the Open Meetings Act issued by the Governor of Texas due to the Covid pandemic; and

WHEREAS, following GMA 9's March 22, 2021 adoption of GMA 9 Proposed DFCs and the Proposed Classification of Non-Relevant Aquifers. and in accordance with Section 36.108, GMA 9 has solicited and considered public comment during a Public Hearing at each GCD located within or partially within GMA 9, through written public comments, and through public comment in person at various GMA 9 Committee meetings; and

WHEREAS, the GMA 9 Committee received and considered technical advice regarding the requirements contained in Chapter 36.108(subsections c-d3), including but not limited to local aquifers, hydrology, geology, recharge characteristics, local groundwater demands and usage, population projections, ground and surface water inter-relationships, and other considerations that affect groundwater conditions from the Texas Water Development Board (TWDB), Regional Water Planning Groups J, K, and L, consultants, hydrologists, geologists, and other groundwater professionals; and

WHEREAS, following public discussion and due consideration of the current and future needs and conditions of the aquifers in question, the current and projected groundwater demand estimates from local GCDs, the TWDB, and Regional Water Planning Groups J, K, and L, the potential effects on springs, surface water, habitat, and water-dependent species for DFCs set through the year 2060 for the Trinity Aquifer or 2080 for the Edwards Group of the Edwards-Trinity (Plateau), the Ellenburger-San Saba, and Hickory aquifers, the following motions were made and acted upon:

Motion #1:

Moved by George Wissmann and seconded by Micah Voulgaris to adopt the following Desired Future Condition through the year 2060 for the Trinity Aquifer located in GMA 9:

- 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.

The vote on the motion was 9 ayes. 0 nays, and 0 abstentions. and the Motion Passed.

Motion #2

Moved by Micah Voulgaris and seconded by Dave Mauk to adopt the following Desired Future Condition through the year 2080 for the Edwards Group of the Edwards-Trinity (Plateau) Aquifer for those portions located in Kendall and Bandera counties:

- Allow For No Net Increase in Average Drawdown in Kendall and Bandera Counties Through 2080.

The vote on the motion was 9 ayes, 0 nays. and 0 abstentions. and the Motion Passed.

Motion #3

Moved by Micah Voulgaris and seconded by Dave Mauk to adopt the following Desired Future Condition through the year 2080 for the portions of the Ellenburger-San Saba Aquifer located in Kendall County:

- Allow for An Increase in Average Drawdown of No More Than 7 Feet in Kendall County Through 2080.

The vote on the motion was 9 ayes, 0 nays, and 0 abstentions. and the Motion Passed.

Motion #4

Moved by Micah Voulgaris and seconded by Dave Mauk to adopt the following Desired Future Condition through the year 2080 for the portions of the Hickory Aquifer located in Kendall County:

- Allow for An Increase in Average Drawdown of No More Than 7 Feet in Kendall County Through 2080.

The vote on the motion was 9 ayes, 0 nays. and 0 abstentions, and the Motion Passed.

Motion #5

Moved by Jimmy Klepac and seconded by Gene Williams to propose the classification of the Edwards Group of the Edwards-Trinity (Plateau) Aquifer located in Blanco County and Kerr County as non-relevant for the purposes of joint planning.

The vote on the motion was 9 ayes. 0 nays. and 0 abstentions, and the Motion Passed

Motion #6

Moved by Jimmy Klepac and seconded by George Wissmann to propose the classification of the Ellenburger-San Saba Aquifer located in Blanco County and Kerr County as non-relevant for the purposes of joint planning.

The vote on the motion was 9 ayes, 0 nays, and 0 abstentions, and the Motion Passed.

Motion #7

Moved by Charlie Flatten and seconded by Jimmy Klepac to propose the classification of the Hickory Aquifer located in Blanco, Hays, Kerr, and Travis counties as non-relevant for the purposes of joint planning.

The vote on the motion was 9 ayes, 0 nays, and 0 abstentions, and the Motion Passed.

Motion #8

Moved by Jimmy Klepac and seconded by George Wissmann to propose the classification of the Marble Falls Aquifer located in Blanco County as non-relevant aquifer for the purposes of joint planning.

The vote on the motion was 9 ayes, 0 nays, and 0 abstentions, and the Motion Passed.

Motion #9

Moved by David Caldwell and seconded by Lane Cockrell to propose the classification of the Edwards Aquifer (Balcones Fault Zone) located in Bexar, Comal, Hays, and Travis counties as non-relevant for the purposes of joint planning.

The vote on the motion was 9 ayes, 0 nays, and 0 abstentions, and the Motion Passed.

Whereas, the above Motions and Votes of each Committee Member have been recorded in the Minutes of the November 15, 2021 GMA 9 Committee Meeting,

NOW THEREFORE BE IT RESOLVED, Groundwater Management Area 9 Joint Planning Committee Members present and voting on November 15, 2021 do hereby document, record, and confirm the above-described Motions and Votes.

Approved by consensus and signed on November 15, 2021 by the following Voting Groundwater Management Area 9 Joint Planning Committee Members:

Jimmy Klepac – Board President of the Blanco-Pedernales GCD

Dave Mauk – General Manager and Designated Representative for the Bandera County River Authority and Groundwater Conservation District

David Caldwell - General Manager and Designated Representative for the Medina County GCD

Charlie Flatten - General Manager and Designated Representative for the Hays Trinity GCD

Micah Voulgaris – General Manager and Designated Representative for the Cow Creek GCD

George Wissmann – General Manager and Designated Representative for the Trinity Glen Rose GCD

Gene Williams - General Manager and Designated Representative for the Headwaters GCD

H.L. Saur - General Manager and Designated Representative of the Comal Trinity GCD

Lane Cockrell - General Manager and Designated Representative for the Southwestern Travis County GCD

RECORDS MGMT.
PERMANENT DOCUMENT

STATE OF TEXAS §
§ **RESOLUTION 2023-1**
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 November 8, 2022 and in person at a GMA 9 meeting held on December 9, 2022 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 Group of Edwards-Trinity (Plateau) Aquifer	Allow for no net increase in average drawdown in Bandera and Kendall Counties through 2080.
Ellenburger-San Saba Aquifer	Allow for an increase in average drawdown of no more than 7 feet in Kendall County through 2080.
Hickory Aquifer	Allow for an increase in average drawdown of no more than 7 feet in Kendall County through 2080.

NON-RELEVANT AQUIFER CLASSIFICATIONS

Edwards Aquifer (Balcones Fault Zone)	Bexar, Comal, Hays, and Travis Counties
Edwards Group of the 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, 2023

with 4 ayes, Ø nays, and 1 abstentions.

Tom Jones, Board President

John Elliott, Board Secretary

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

APPENDIX C

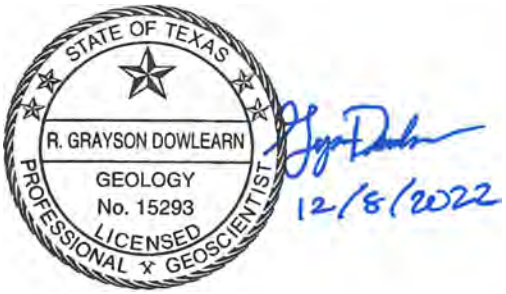
GAM Run 21-014 MAG

Modeled Available Groundwater for the Aquifers in Groundwater Management Area 9

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GAM RUN 21-014 MAG: MODELED AVAILABLE GROUNDWATER FOR THE AQUIFERS IN GROUNDWATER MANAGEMENT AREA 9

Grayson Dowlearn, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Modeling Department
512-475-1552
December 8, 2022



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GAM RUN 21-014 MAG: MODELED AVAILABLE GROUNDWATER FOR THE AQUIFERS IN GROUNDWATER MANAGEMENT AREA 9

Grayson Dowlearn, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Modeling Section
512-475-1552
December 8, 2022

EXECUTIVE SUMMARY:

Groundwater Management Area (GMA) 9 adopted the desired future conditions for the Hickory and Ellenburger-San Saba aquifers, for the combined Trinity Aquifer and Trinity Group of the Edwards-Trinity (Plateau) Aquifer, and for the Edwards Group of the Edwards-Trinity (Plateau) Aquifer on November 15, 2021. Groundwater Management Area 9 submitted a Desired Future Conditions Explanatory Report (GMA 9 and others, 2021) and other supporting documents to the Texas Water Development Board (TWDB) on December 9, 2021. The TWDB determined that the explanatory report and other materials submitted by the district representatives were administratively complete on November 8, 2022.

Modeled available groundwater estimates are approximately 140 acre-feet per year for the Hickory Aquifer and approximately 60 acre-feet per year for the Ellenburger-San Saba Aquifer for the period between 2020 and 2080. Modeled available groundwater estimates range between a maximum of 90,264 acre-feet per year in 2020 and a minimum of 89,491 acre-feet per year in 2060 for the combination of Trinity Aquifer and Trinity group of the Edwards-Trinity (Plateau) Aquifer within Groundwater Management Area 9. Modeled available groundwater estimates are approximately 2,210 acre-feet per year for the Edwards Group of the Edwards-Trinity (Plateau) Aquifer for the period between 2020 and 2080. Modeled available groundwater estimates are provided in Tables 2 through 10.

Figure 1 provides the groundwater conservation district and county boundaries within Groundwater Management Area 9. Figure 2 provides the county, regional water planning area, and river basin boundaries within Groundwater Management Area 9.

REQUESTOR:

Mr. Ronald Fieseler, General Manager of Blanco Pedernales Groundwater Conservation District and Administrator of Groundwater Management Area 9.

DESCRIPTION OF REQUEST:

Mr. Ronald Fieseler provided the TWDB with the desired future conditions of the aquifers within Groundwater Management Area 9 on behalf of Groundwater Management Area (GMA) 9 in a letter dated December 9, 2021. Groundwater conservation district representatives in Groundwater Management Area 9 adopted desired future conditions for the aquifers within Groundwater Management Area 9 on November 15, 2021, as described in Resolution No. 111521-01 (Appendix D in GMA 9 and others, 2021). Desired future conditions are listed in Table 1 and represent average water level drawdowns across the specified area until the specified ending year.

TABLE 1. DESIRED FUTURE CONDITIONS FOR GROUNDWATER MANAGEMENT AREA 9 EXPRESSED AS AVERAGE DRAWDOWN (ADAPTED FROM SUBMITTED RESOLUTION).

Major or minor aquifer	Desired future condition
Trinity Aquifer and Trinity Group of the Edwards-Trinity (Plateau) 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 Group of Edwards-Trinity (Plateau)	Allow for no net increase in average drawdown in Bandera and Kendall counties through 2080
Ellenburger-San Saba	Allow for an increase in average drawdown of no more than 7 feet in Kendall County through 2080
Hickory	Allow for an increase in average drawdown of no more than 7 feet in Kendall County through 2080

Additionally, Groundwater Management Area 9 voted to declare certain aquifers and/or portions of aquifers to be non-relevant for the purposes of joint planning, as shown in Table 2.

TABLE 2. AQUIFERS AND PORTIONS OF AQUIFERS WHICH WERE DECLARED NON-RELEVANT FOR THE PURPOSES OF JOINT PLANNING WITHIN GROUNDWATER MANAGEMENT AREA 9.

Major or minor aquifer	Non-relevant area
Edwards (Balcones Fault Zone) Aquifer	Entire aquifer (Bexar, Comal, Hays, and Travis counties)
Edwards Group of Edwards-Trinity (Plateau) Aquifer	Portion in Blanco and Kerr counties
Ellenburger-San Saba Aquifer	Portion in Blanco and Kerr counties
Hickory Aquifer	Portion in Blanco, Hays, Kerr, and Travis counties
Marble Falls Aquifer	Entire aquifer (Blanco County)

After reviewing the submitted documents, TWDB staff requested clarifications regarding the methodology and assumptions used in the definitions of desired future conditions. Appendix A includes the responses to these clarifications that Groundwater Management Area 9 provided to the TWDB on October 17, 2022.

METHODS:

Hickory and Ellenburger-San Saba Aquifers

The groundwater availability model for the minor aquifers of the Llano Uplift Region of Texas (Version 1.01; Shi and others, 2016a, 2016b) was used to calculate the drawdown and modeled available groundwater for the Hickory and Ellenburger-San Saba aquifers (Llano Uplift aquifers) within Groundwater Management Area 9. The predictive model files used in the evaluation were originally developed by the TWDB in the previous joint planning cycle for GAM Run 16-023 (Jones, 2017). The evaluation in GAM Run 16-023 only went to 2070, so the TWDB extended the model files to 2080 for this evaluation.

Pumping was distributed evenly across the Kendall County portion of the Llano Uplift aquifers and then varied until the desired future condition was achieved within the accepted tolerance defined by Groundwater Management Area 9. Modeled water levels were extracted for December 2010 (initial water levels equivalent to the final stress period of the historically calibrated model) and December 2080 (stress period 70). Drawdown was calculated as the difference in water levels between those two endpoints. Drawdown averages were calculated by aquifer for each area specified in the desired future conditions. The modeled available groundwater values were determined by extracting pumping rates by decade from the model results using ZONEBUDGET USG Version 1.00 (Panday and others, 2013).

Trinity Aquifer and Trinity Group of the Edwards-Trinity (Plateau) Aquifer

The groundwater availability model for the Hill Country Portion of the Trinity Aquifer (Version 2.01; Jones and others, 2011) was used to calculate the drawdown and modeled available groundwater values for the combination of Trinity Aquifer and Trinity Group of the Edwards-Trinity (Plateau) Aquifer within Groundwater Management Area 9. Predictive model files from TWDB GAM Task 10-005 (Hutchison, 2010) were used, as specified by Resolution No. 111521-01 (Appendix D in GMA 9 and others, 2021). GAM Task 10-005 (Hutchison, 2010) ran a predictive pumping scenario (“Scenario 6") under 387 different recharge conditions. For every model run, modeled water levels were extracted for December 2008 (initial water levels) and December 2060 (stress period 50), and drawdown was calculated as the difference in water level between those two endpoints. The drawdown average across Groundwater Management Area 9 was calculated as the average of the 387 scenarios. The TWDB confirmed that the desired future conditions adopted by Groundwater Management Area 9 are achievable using this methodology. The modeled available groundwater values were determined by extracting pumping rates by decade from each model run’s results and then averaging the modeled pumping rates from the 387 scenarios using custom Fortran scripts developed by the TWDB for Task 10-005 (Hutchison, 2010).

Edwards Group of the Edwards-Trinity (Plateau) Aquifer

The groundwater availability model for the Hill Country Portion of the Trinity Aquifer (Version 2.01; Jones and others, 2011) was also used to calculate the drawdown and modeled available

groundwater for the Edwards Group of the Edwards-Trinity (Plateau) Aquifer within Groundwater Management Area 9. The predictive model files used in the evaluation were originally developed by the TWDB in the previous joint planning cycle for GAM Run 16-023 (Jones, 2017). The evaluation in GAM Run 16-023 only went to 2070, so the TWDB extended these model files to 2080 for this evaluation.

The TWDB created a predictive pumping scenario by copying "Scenario 6" from TWDB Task 10-005 and then varying Edwards Group pumping by a constant multiplier across Bandera and Kendall counties until the desired future condition was achieved within the accepted tolerance defined by Groundwater Management Area 9. The TWDB used these predictive model files to extract modeled water levels from December 1997 (initial water levels equivalent to the final stress period of the historically calibrated model) and December 2080 (stress period 83) and drawdown was calculated as the difference in water level between those two endpoints. The modeled available groundwater values were determined by extracting pumping rates by decade from the model results using ZONEBUDGET Version 3.01 (Harbaugh, 2009).

Modeled Available Groundwater and Permitting

As defined in Chapter 36 of the Texas Water Code (2011), "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.

PARAMETERS AND ASSUMPTIONS:

Hickory and Ellenburger-San Saba aquifers

- Version 1.01 of the groundwater availability model for the minor aquifers of the Llano Uplift Region of Texas was the base model for this analysis. See Shi and others (2016a, 2016b) for assumptions and limitations of the historical calibrated model.
- In the previous joint planning cycle, the TWDB created predictive model files to extend the base model to 2070 for planning purposes. For the current analysis, these model files were extended an additional ten years to 2080 using the same assumptions used in the previous cycle. See GAM Run 16-023 (Jones, 2017) for assumptions and limitations of this predictive model simulation.
- The model has eight layers, which represent the Cretaceous age and younger water-bearing units (Layer 1), Permian and Pennsylvanian age confining units (Layer 2), the Marble Falls Aquifer and equivalent (Layer 3), Mississippian age confining units (Layer 4), the Ellenburger-San Saba Aquifer and equivalent (Layer 5), Cambrian age confining units (Layer 6), the Hickory Aquifer and equivalent (Layer 7), and Precambrian age confining units (Layer 8).
- To be consistent with assumptions made by Groundwater Management Area 9 (see GMA 9 and others, 2021), the TWDB assumed a tolerance of five percent of the drawdown when comparing desired future conditions to modeled drawdown results.

- The model was run with MODFLOW-USG (Panday and others, 2013).
- Drawdown averages and modeled available groundwater volumes were calculated based on the extent of the official TWDB aquifer boundary (Figures 3 and 4). The most recent TWDB model grid file dated August 23, 2022 (*lnup_grid_poly082322.csv*) was used to determine model cell entity assignment (county, groundwater management area, groundwater conservation district, river basin, regional water planning area).
- Drawdowns for cells that became dry during the simulation were excluded from the drawdown averages. Pumping in dry cells was excluded from the modeled available groundwater calculations.
- Estimates of modeled available groundwater from the model simulation were rounded to the nearest whole number.

Trinity Aquifer and Edwards-Trinity (Plateau) Aquifer

- Version 2.01 of the groundwater availability model for the Hill Country Portion of the Trinity Aquifer was the base model for this analysis. See Jones and others (2011) for assumptions and limitations of the historical calibrated model.
- The model has four layers which represent the Edwards Group of the Edwards-Trinity (Plateau) Aquifer (Layer 1), the Upper Trinity hydrostratigraphic unit (Layer 2), the Middle Trinity hydrostratigraphic unit (Layer 3), and the Lower Trinity hydrostratigraphic unit (Layer 4).
- The evaluation of the Trinity Aquifer and the Trinity Group of the Edwards-Trinity (Plateau) Aquifer used predictive model files created by the TWDB that extended the base model to 2060 for planning purposes and represented 387 different potential recharge scenarios. See GAM Task 10-005 (Hutchison, 2010) for the assumptions and limitations of these predictive model simulations.
- The evaluation of the Edwards Group of the Edwards-Trinity (Plateau) Aquifer used predictive model files created by the TWDB during the previous joint planning cycle that extended the base model to 2070 for planning purposes. For the current analysis, the TWDB extended these model files an additional ten years to 2080 using the same assumptions used in the previous cycle. See GAM Run 16-023 (Jones, 2017) for assumptions and limitations of this predictive model simulation.
- Although the base model (Jones and others, 2011) was only calibrated to 1997, the TWDB developed a subsequent steady-state version of the model representing observed conditions in the Trinity Aquifer as of 2008 (Chowdhury, 2010). Since that model provided the initial water levels for the GAM Task 10-005 (Hutchison, 2010) predictive model files, the reference year of 2008 can be used for drawdown calculations for the Trinity Aquifer and the Trinity Group of Edwards-Trinity (Plateau) Aquifer. Since this verification did not apply to the Edwards Group of the Edwards-Trinity (Plateau) Aquifer, the original reference year of 1997 from the base model was used for drawdown calculations in that unit.
- Drawdowns for cells that became dry during the simulation were excluded from the drawdown averages. Pumping volumes are reduced to zero if a cell becomes dry during the predictive model run. The modeled available groundwater values do not include dry cells for decades after the cell becomes dry.

- Drawdown averages and modeled available groundwater volumes were calculated based on the extent of active model cells, not the official TWDB aquifer boundary (Figures 5 and 6). The most recent TWDB model grid file dated August 15, 2022 (*trnt_h_grid_poly081522.csv*) was used to determine model cell entity assignment (county, groundwater management area, groundwater conservation district, river basin, regional water planning area).
- To be consistent with Groundwater Management Area 9's assumptions (see GMA 9 and others, 2021), a tolerance of five percent of the desired future condition drawdown was assumed when comparing desired future conditions to modeled drawdown results.
- The model was run with MODFLOW-96 (Harbaugh and McDonald, 1996)
- Estimates of modeled available groundwater from the model simulation were rounded to the nearest whole number.

RESULTS:

The modeled available groundwater estimates that achieve the desired future conditions adopted by Groundwater Management Area 9 are as follows:

- Hickory Aquifer: 140 acre-feet per year (summarized by county and groundwater conservation district in Table 3 and by county, regional water planning area, and river basin in Table 4).
- Ellenburger-San Saba Aquifer: Approximately 60 acre-feet per year for the that (summarized by county and groundwater conservation district in Table 5 and by county, regional water planning area, and river basin in Table 6).
- Combined Trinity Aquifer and Trinity Group of the Edwards-Trinity (Plateau) Aquifer: Ranges from a maximum of 90,264 acre-feet per year in 2020 and a minimum of 89,491 acre-feet per year in 2060 (summarized by county and groundwater conservation district in Table 7 and by county, regional water planning area, and river basin in Table 8).
- Edwards Group of the Edwards-Trinity (Plateau) Aquifer: 2,210 acre-feet per year (summarized by county and groundwater conservation district in Table 9 and by county, regional water planning area, and river basin in Table 10).

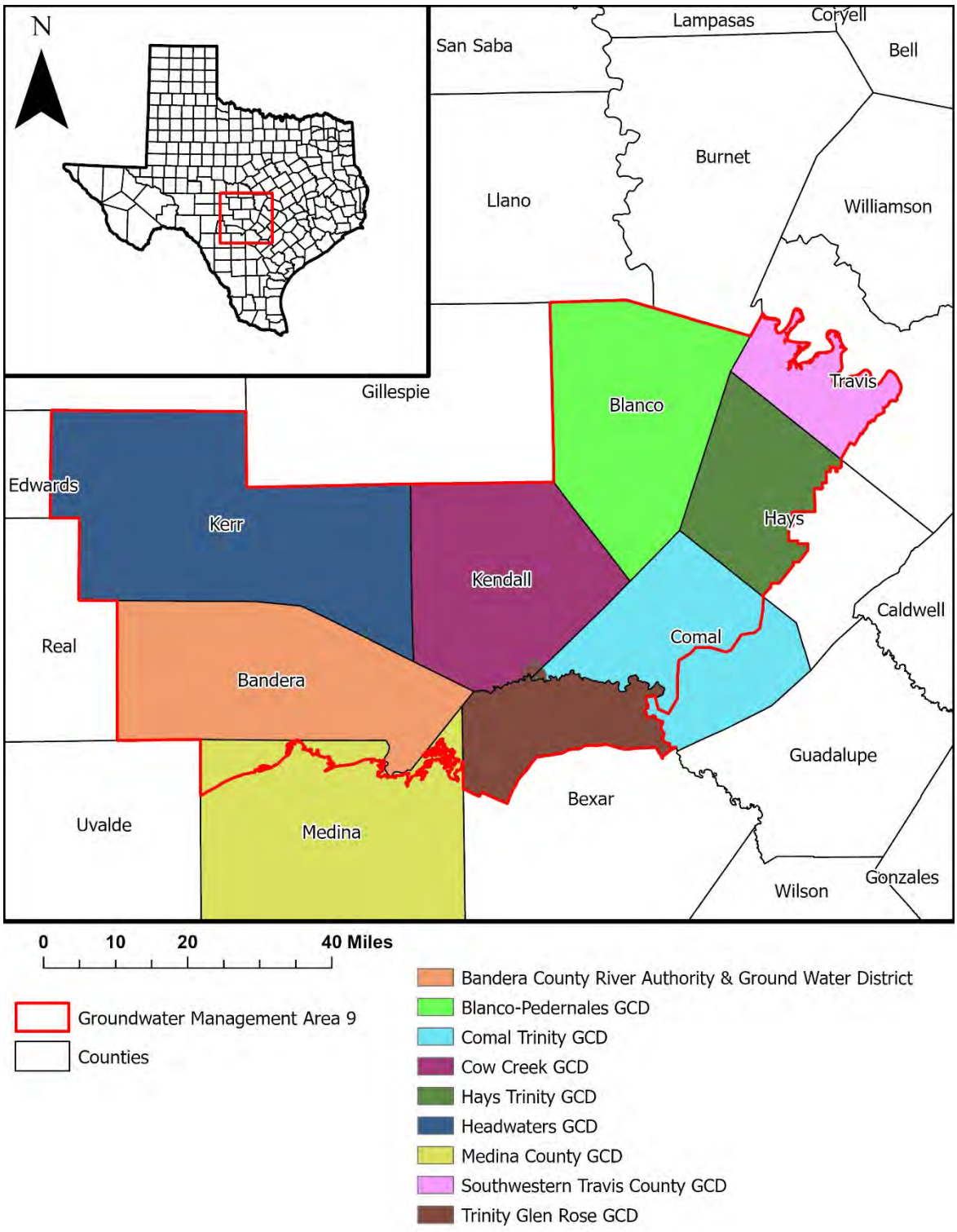


FIGURE 1. MAP SHOWING GROUNDWATER MANAGEMENT AREA 9, GROUNDWATER CONSERVATION DISTRICTS (GCD), AND COUNTY BOUNDARIES.

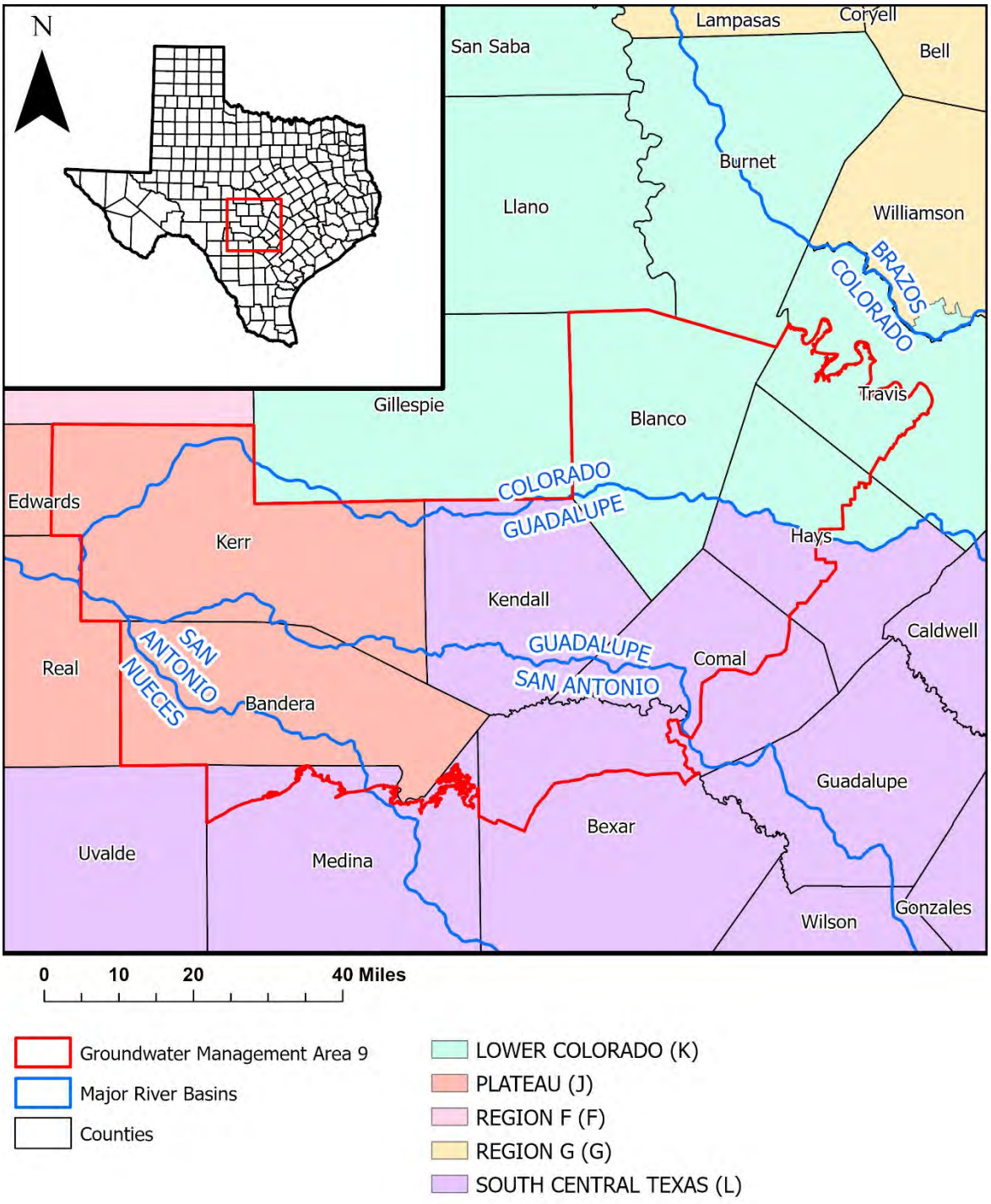


FIGURE 2. MAP SHOWING GROUNDWATER MANAGEMENT AREA 9, REGIONAL WATER PLANNING AREAS, RIVER BASINS, AND COUNTY BOUNDARIES.

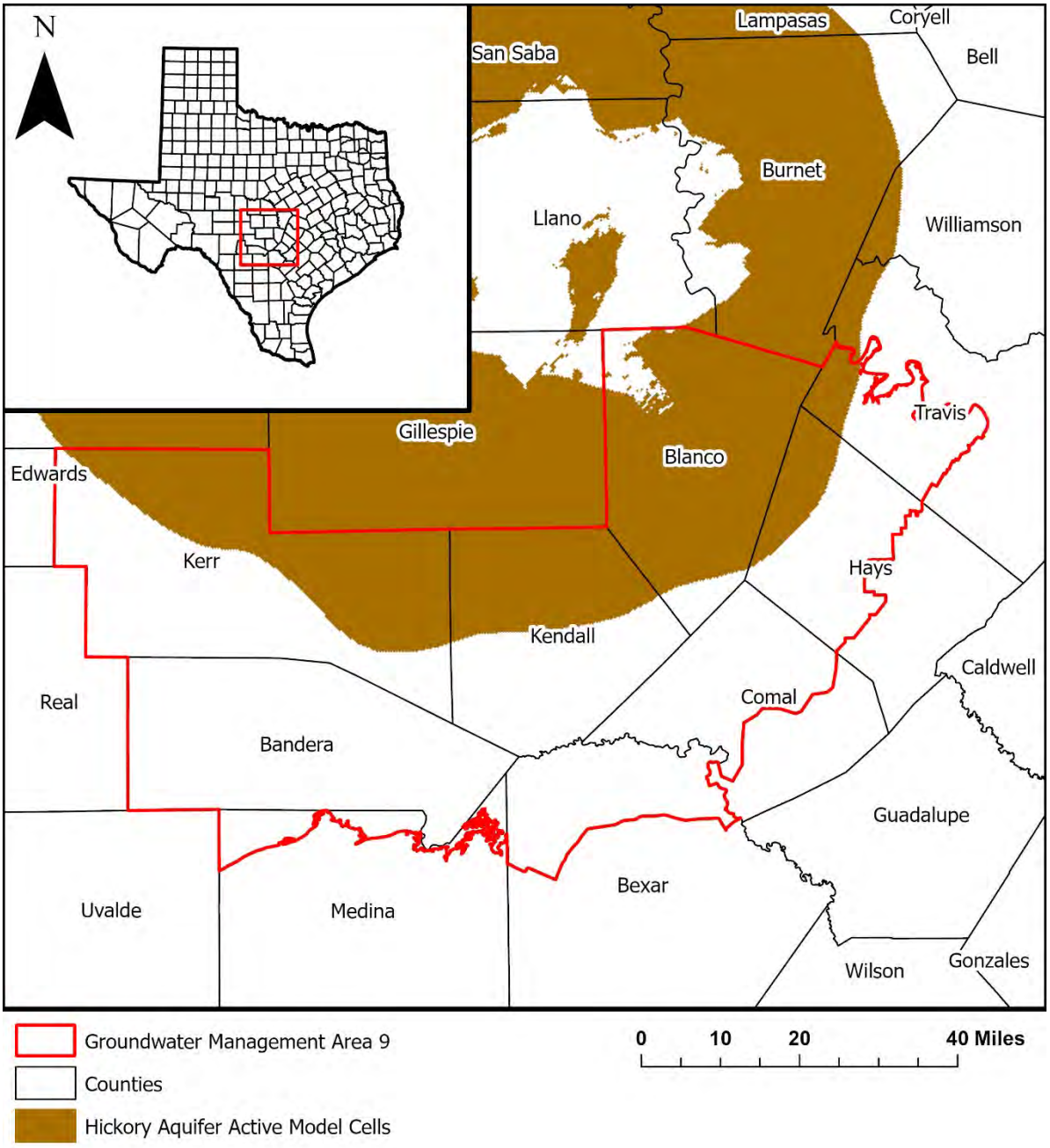


FIGURE 3. MAP SHOWING THE ACTIVE MODEL CELLS REPRESENTING THE HICKORY AQUIFER (LAYER 7) IN THE MINOR AQUIFERS OF THE LLANO UPLIFT REGION OF TEXAS GROUNDWATER AVAILABILITY MODEL IN RELATION TO GROUNDWATER MANAGEMENT AREA 9.

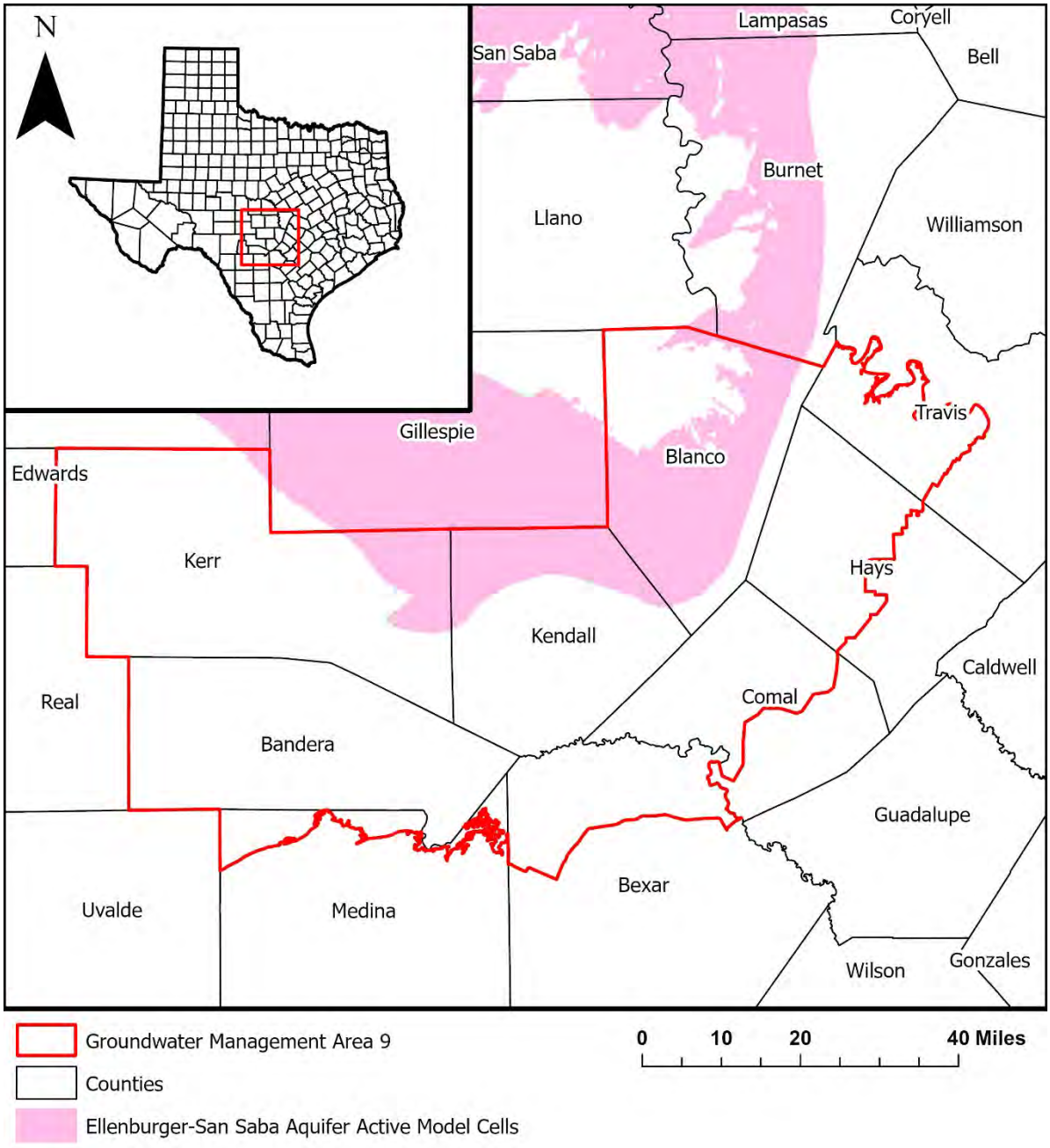


FIGURE 4. MAP SHOWING THE ACTIVE MODEL CELLS REPRESENTING THE ELLENBURGER-SAN SABA AQUIFER (LAYER 5) IN THE MINOR AQUIFERS OF THE LLANO UPLIFT REGION OF TEXAS GROUNDWATER AVAILABILITY MODEL IN RELATION TO GROUNDWATER MANAGEMENT AREA 9.

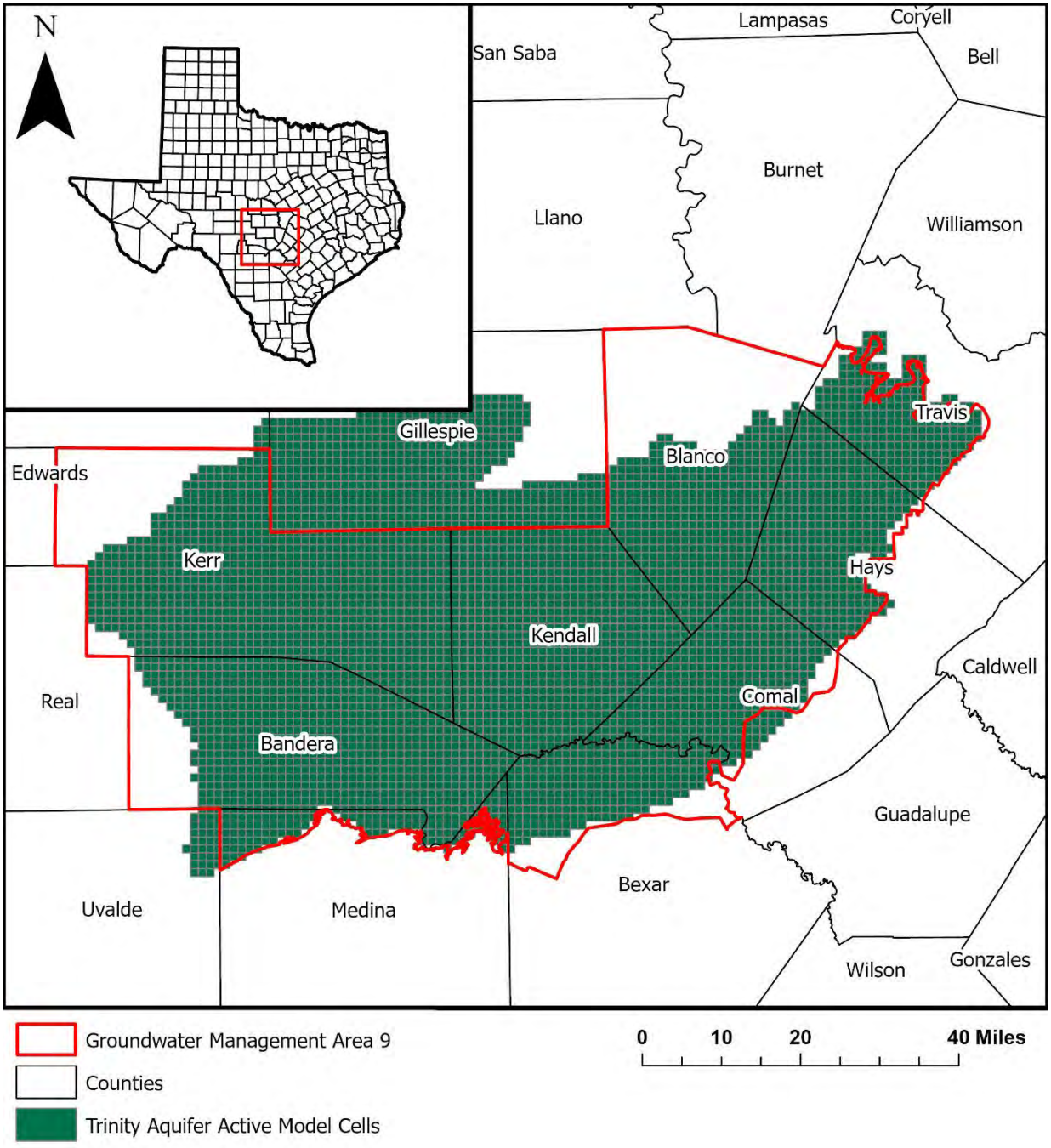


FIGURE 5. MAP SHOWING THE ACTIVE MODEL CELLS REPRESENTING THE TRINITY AQUIFER AND TRINITY GROUP OF THE EDWARDS-TRINITY (PLATEAU) AQUIFER (LAYERS 2, 3, AND 4) IN THE HILL COUNTRY PORTION OF THE TRINITY AQUIFER GROUNDWATER AVAILABILITY MODEL IN RELATION TO GROUNDWATER MANAGEMENT AREA 9.

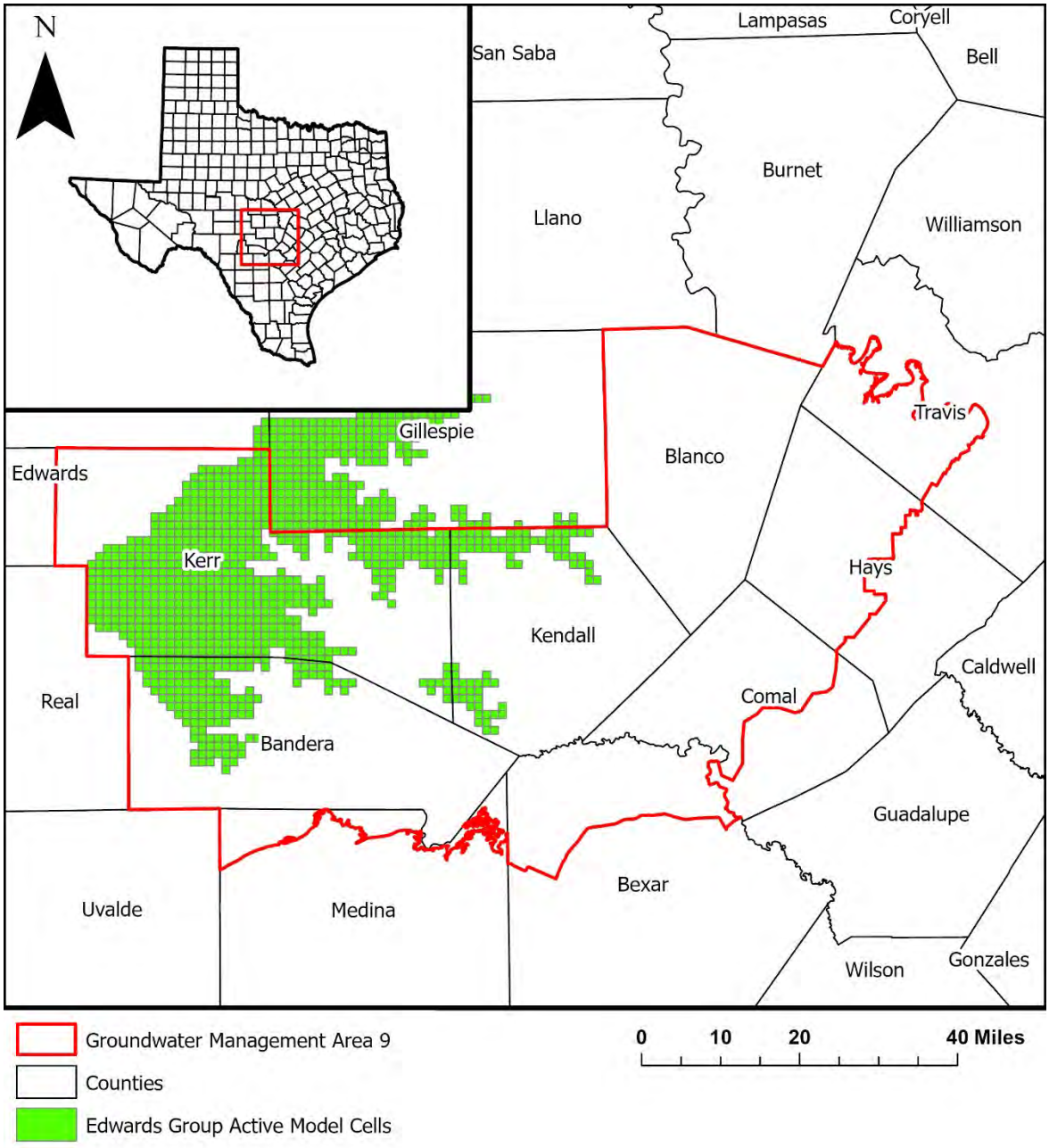


FIGURE 6. MAP SHOWING THE ACTIVE MODEL CELLS REPRESENTING THE EDWARDS GROUP OF THE EDWARDS-TRINITY (PLATEAU) AQUIFER (LAYER 1) IN THE HILL COUNTRY PORTION OF THE TRINITY AQUIFER GROUNDWATER AVAILABILITY MODEL IN RELATION TO GROUNDWATER MANAGEMENT AREA 9.

TABLE 3. MODELED AVAILABLE GROUNDWATER FOR THE HICKORY AQUIFER IN GROUNDWATER MANAGEMENT AREA 9 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT AND COUNTY FOR EACH DECADE BETWEEN 2020 AND 2080. VALUES ARE IN ACRE-FEET PER YEAR.

Groundwater Conservation District (GCD)	County	Aquifer	2020	2030	2040	2050	2060	2070	2080
Cow Creek GCD	Kendall	Hickory	141	140	141	140	141	140	141

TABLE 4. MODELED AVAILABLE GROUNDWATER FOR THE HICKORY AQUIFER IN GROUNDWATER MANAGEMENT AREA 9. RESULTS ARE SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE FROM 2030 TO 2080. VALUES ARE IN ACRE-FEET PER YEAR.

County	RWPA	Basin	Aquifer	2030	2040	2050	2060	2070	2080
Kendall	L	Colorado	Hickory	12	12	12	12	12	12
Kendall	L	Guadalupe	Hickory	128	128	128	128	128	128
Groundwater Management Area 9 Total			**Hickory**	**140**	**140**	**140**	**140**	**140**	**140**

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 2020 AND 2080. VALUES ARE IN ACRE-FEET PER YEAR.

Groundwater Conservation District (GCD)	County	Aquifer	2020	2030	2040	2050	2060	2070	2080
Cow Creek GCD	Kendall	Ellenberger-San Saba	62	62	62	62	62	62	62

TABLE 6. MODELED AVAILABLE GROUNDWATER FOR THE ELLENBURGER-SAN SABA AQUIFER IN GROUNDWATER MANAGEMENT AREA 9. RESULTS ARE SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE FROM 2030 TO 2080. VALUES ARE IN ACRE-FEET PER YEAR.

County	RWPA	Basin	Aquifer	2030	2040	2050	2060	2070	2080
Kendall	L	Colorado	Ellenberger-San Saba	9	9	9	9	9	9
Kendall	L	Guadalupe	Ellenberger-San Saba	53	54	53	54	53	54
Groundwater Management Area 9 Total			**Ellenberger-San Saba**	**62**	**63**	**62**	**63**	**62**	**63**

TABLE 7. MODELED AVAILABLE GROUNDWATER FOR THE TRINITY AQUIFER AND TRINITY GROUP OF THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN GROUNDWATER MANAGEMENT AREA 9 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD) AND COUNTY FOR EACH DECADE BETWEEN 2020 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR.

Groundwater Conservation District	County	Aquifer	2020	2030	2040	2050	2060
Bandera County River Authority & Ground Water District	Bandera	Trinity	7,284	7,284	7,284	7,284	7,284
Blanco-Pedernales GCD	Blanco	Trinity	2,573	2,573	2,573	2,573	2,573
Comal Trinity GCD	Comal	Trinity	9,383	9,383	9,383	9,383	9,383
Cow Creek GCD	Kendall	Trinity	10,622	10,622	10,622	10,622	10,622
Hays Trinity GCD	Hays	Trinity	9,074	9,071	9,070	9,070	9,070
Headwaters GCD	Kerr	Trinity	14,918	14,845	14,556	14,239	14,223
Medina County GCD	Medina	Trinity	2,340	2,340	2,340	2,340	2,340
Southwestern Travis County GCD	Travis	Trinity	8,559	8,542	8,530	8,515	8,485
Trinity Glen Rose GCD	Bexar	Trinity	24,856	24,856	24,856	24,856	24,856
	Comal	Trinity	138	138	138	138	138
	Kendall	Trinity	517	517	517	517	517
Trinity Glen Rose GCD Total		**Trinity**	**25,511**	**25,511**	**25,511**	**25,511**	**25,511**
Groundwater Management Area 9 Total		**Trinity**	**90,264**	**90,171**	**89,869**	**89,537**	**89,491**

TABLE 8 MODELED AVAILABLE GROUNDWATER FOR THE TRINTY AQUIFER AND TRINITY GROUP OF THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN GROUNDWATER MANAGEMENT AREA 9. RESULTS ARE SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE FROM 2030 TO 2060. VALUES ARE IN ACRE-FEET PER YEAR.

County	RWPA	Basin	Aquifer	2030	2040	2050	2060
Bandera	J	Guadalupe	Trinity	76	76	76	76
Bandera	J	Nueces	Trinity	903	903	903	903
Bandera	J	San Antonio	Trinity	6,305	6,305	6,305	6,305
Bexar	L	San Antonio	Trinity	24,856	24,856	24,856	24,856
Blanco	K	Colorado	Trinity	1,322	1,322	1,322	1,322
Blanco	K	Guadalupe	Trinity	1,251	1,251	1,251	1,251
Comal	L	Guadalupe	Trinity	6,252	6,252	6,252	6,252
Comal	L	San Antonio	Trinity	3,269	3,269	3,269	3,269
Hays	K	Colorado	Trinity	4,707	4,706	4,706	4,706
Hays	L	Guadalupe	Trinity	4,364	4,364	4,364	4,364
Kendall	L	Colorado	Trinity	135	135	135	135
Kendall	L	Guadalupe	Trinity	6,028	6,028	6,028	6,028
Kendall	L	San Antonio	Trinity	4,976	4,976	4,976	4,976
Kerr	J	Colorado	Trinity	318	318	318	318
Kerr	J	Guadalupe	Trinity	14,056	13,767	13,450	13,434
Kerr	J	Nueces	Trinity	0	0	0	0
Kerr	J	San Antonio	Trinity	471	471	471	471
Medina	L	Nueces	Trinity	1,575	1,575	1,575	1,575
Medina	L	San Antonio	Trinity	765	765	765	765
Travis	K	Colorado	Trinity	8,542	8,530	8,515	8,485
Groundwater Management Area 9 Total			**Trinity**	**90,171**	**89,869**	**89,537**	**89,491**

TABLE 9 MODELED AVAILABLE GROUNDWATER FOR THE EDWARDS GROUP OF THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN GROUNDWATER MANAGEMENT AREA 9 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD) AND COUNTY FOR EACH DECADE BETWEEN 2020 AND 2080. VALUES ARE IN ACRE-FEET PER YEAR.

GCD	County	Aquifer	2020	2030	2040	2050	2060	2070	2080
Bandera County River Authority & Ground Water District	Bandera	Edwards	2,009	2,009	2,009	2,009	2,009	2,009	2,009
Cow Creek GCD	Kendall	Edwards	200	200	200	200	200	200	200
Groundwater Management Area 9 Total		**Edwards**	**2,209**	**2,209**	**2,209**	**2,209**	**2,209**	**2,209**	**2,209**

TABLE 10 MODELED AVAILABLE GROUNDWATER FOR THE EDWARDS GROUP OF THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN GROUNDWATER MANAGEMENT AREA 9. RESULTS ARE SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE FROM 2030 TO 2080. VALUES ARE IN ACRE-FEET PER YEAR.

County	RWPA	Basin	Aquifer	2030	2040	2050	2060	2070	2080
Bandera	J	Guadalupe	Edwards	81	81	81	81	81	81
Bandera	J	Nueces	Edwards	38	38	38	38	38	38
Bandera	J	San Antonio	Edwards	1,890	1,890	1,890	1,890	1,890	1,890
Kendall	L	Colorado	Edwards	69	69	69	69	69	69
Kendall	L	Guadalupe	Edwards	130	130	130	130	130	130
Groundwater Management Area 9 Total			**Edwards**	**2,208**	**2,208**	**2,208**	**2,208**	**2,208**	**2,208**

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.

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APPENDIX A: CLARIFICATIONS

Groundwater Management Area 9 Joint Planning Committee

Bandera County River Authority and Groundwater District
Blanco-Pedernales Groundwater Conservation District
Comal Trinity Groundwater Conservation District
Cow Creek Groundwater Conservation District
Hays-Trinity Groundwater Conservation District
Headwaters Groundwater Conservation District
Medina County Groundwater Conservation District
Trinity Glen Rose Groundwater Conservation District
Southwestern Travis County Groundwater Conservation District

Mr. Micah Voulgaris, GMA 9 Planning Committee Chairman P.O. Box 1557 Boerne, Texas 78006

October 17, 2022

Stephen Allen, P.G., Geoscientist
Groundwater Technical Assistance Team
Groundwater Resources
Texas Water Development Board
P. O. Box 13231
1700 North Congress Avenue
Austin, Texas 78711-3231

Re: Acknowledgement of clarifications needed for the Texas Water Development Board to declare the Groundwater Management Area 9 Desired Future Conditions submittal administratively complete

Mr. Allen,

This letter is in response to your email sent to me on Tuesday, October the 11th.

It was the intent of the Groundwater Management Area 9 Joint Planning Committee to adopt Desired Future Conditions that produced drawdown values consistent with the previous two planning cycles.

GMA 9 acknowledges and accepts all ten of the "other clarifications" and the two "optional clarifications" as outlined in the attached document sent by the TWDB.

Please let us know if you need additional information or if further action is required.

Thank you,
Groundwater Management Area 9

Micah Voulgaris
GMA 9 Chairman

Enclosure: *GMA09_Clarifications_v1*

FIGURE A1: PAGE 1 OF CORRESPONDENCE BETWEEN GROUNDWATER MANAGEMENT AREA 9 AND THE TWDB RELATED TO CLARIFIACTIONS (LETTER FROM GROUNDWATER MANAGEMENT AREA 9 ACKNOWLEDGING AND ACCEPTING CLARIFICATIONS)

Critical Clarifications *(need additional files or an update to Legal DFC Resolution)*:

- None, unless the GMA disagrees with clarifications and assumptions below.

Other Clarifications (*TWDB will only need acknowledgement for administratively complete*):

Trinity Aquifer:

1. Please confirm that the phrase *"average drawdown of approximately 30 feet through 2060 consistent with Scenario 6 in TWDB GAM Task 10-005"* in the DFC Resolution means "*no more than 30 feet of average water level decline in 2060, as compared to 2008 water levels, averaged over all TWDB GAM Task 10-005 Scenario 6 model iterations.*"[1] This method produces drawdown values consistent with the DFC values provided in the Explanatory Report and is consistent with the methodology used in the previous planning cycle.
2. Please confirm that the GMA accepts the following assumptions for calculating modeled drawdown: 1) exclude all cells that become dry and 2) use all active model cells even if they do not fall within the official TWDB aquifer boundary. This method produces drawdown values consistent with the DFC values provided in the Explanatory Report and is consistent with the methodology used in the previous planning cycle.
3. As in the previous planning cycle, we will only provide MAG values calculated within the extent of the TWDB Trinity (Hill Country) Aquifer GAM. Since this model does not extend across the entire GMA, these MAG values will not include any pumping that might occur outside the model extent. Please confirm that this methodology is acceptable to the GMA. Otherwise, please contact TWDB to request additional MAG value calculations.

Edwards Group of the Edwards-Trinity (Plateau) Aquifer:

4. Please confirm that the phrase *"no net increase in average drawdown through 2080"* in the DFC Resolution means *"no average water level decline in 2080, as compared to 1997 water levels."*[2] This method produces drawdown values consistent with the DFC values provided in the Explanatory Report and is consistent with the methodology used in the previous planning cycle.
5. Since the GMA did not provide predictive model files, TWDB used the predictive model files *[based on Trinity (Hill Country) Aquifer GAM]* developed by TWDB during the previous planning cycle (see GAM Run 16-023) and extended them to 2080 by assuming the same recharge rates and the same percentage increase in pumping rates as was used in the previous planning cycle. Please confirm that this methodology is acceptable to the GMA.
6. Please confirm that the GMA accepts the following assumptions for calculating modeled drawdown: 1) exclude all cells that become dry and 2) include all active model cells even if they do not fall within the official TWDB aquifer boundary. This method produces drawdown values consistent with the DFC values provided in the Explanatory Report and is consistent with the methodology used in the previous planning cycle.
7. As in the previous planning cycle, we will only provide MAG values calculated within the extent of the TWDB Trinity (Hill Country) Aquifer GAM. Since this model does not extend across the entire GMA, these MAG values will not include any pumping that might occur outside the model extent.

---

[1] 2008 is the last calibrated water level available from the TWDB GAM Task 10-005 model

[2] 1997 is the last calibrated water level available from the TWDB Trinity (Hill Country) Aquifer GAM

FIGURE A2: PAGE 2 OF CORRESPONDENCE BETWEEN GROUNDWATER MANAGEMENT AREA 9 AND THE TWDB RELATED TO CLARIFIACTIONS (OTHER CLARIFICATIONS NUMBERS 1 TO 7)

Please confirm that this methodology is acceptable to the GMA. Otherwise, please contact TWDB to request additional MAG value calculations.

Ellenburger-San Saba & Hickory Aquifers:

8. Please confirm that the phrase "*average drawdown of no more than 7 feet in Kendall County through 2080*" in the DFC Resolution means "*average water level decline of no more than 7 feet in 2080, as compared to 2010 water levels*."[3] This method produces drawdown values consistent with the DFC values provided in the Explanatory Report and is consistent with the methodology used in the previous planning cycle.
9. Since the GMA did not provide predictive model files, TWDB used the predictive model files *[based on Llano Uplift GAM]* developed by TWDB during the previous planning cycle (see GAM Run 16-023) and extended them to 2080 by assuming the same recharge rates and the same pumping rates and distribution as was used in the previous planning cycle. Please confirm that this methodology is acceptable to the GMA.
10. Please confirm that the GMA accepts the following assumptions for calculating modeled drawdown: 1) only include active model cells within the official TWDB aquifer boundary. This method produces drawdown values consistent with the DFC values provided in the Explanatory Report and is consistent with the methodology used in the previous planning cycle.

Optional Clarifications *(Clerical corrections to Explanatory Report)*[4]:

Edwards Group of the Edwards-Trinity (Plateau) Aquifer:

– baseline year for DFC incorrectly listed as 2008 rather than 1997 *(see Clarification #4)*

Ellenburger-San Saba & Hickory Aquifers:

– baseline year for DFC incorrectly listed as 2008 rather than 2010 *(see Clarification #8)*

[3] 2010 is the last calibrated water level available from the TWDB Llano Uplift GAM.

[4] Since TWDB considers the legal DFC Resolution documents, rather than the Explanatory Report, as the official definition of DFCs, TWDB does not officially require corrections to the Explanatory Report. However, because the Explanatory Report is often used as a simplified, more-readable summary of the legal DFC Resolution documents, we recommend correcting the Explanatory Report to match the DFC Resolutions to avoid confusion.

FIGURE A3: PAGE 3 OF CORRESPONDENCE BETWEEN GROUNDWATER MANAGEMENT AREA 9 AND THE TWDB RELATED TO CLARIFIACTIONS (OTHER CLARIFICATIONS NUMBERS 8 TO 10 AND OPTIONAL CLARIFICATIONS)

APPENDIX D

Estimated Historical Water Use And 2022 State Water Data Plan Datasets

Headwaters Groundwater Conservation District

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TWDB Estimated Historical Groundwater Use and 2022 State Water Plan Datasets

Headwaters Groundwater Conservation District

Texas Water Development Board
Groundwater Division
Groundwater Technical Assistance Department
stephen.allen@twdb.texas.gov
(512) 463-7317
July 17, 2026

GROUNDWATER MANAGEMENT PLAN DATA

This set of water data tables (part one of a two-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 table addresses a specific numbered requirement in the Texas Water Development Board's groundwater management plan review checklist. The checklist can be found at this web address:

https://www.twdb.texas.gov/groundwater/docs/GCD/GCD_Mgmt_Plan_Checklist_2025.pdf

The five tables included in part one of this data package are:

TWDB Historical Water Use Survey (WUS)

- Estimated Historical Water Use (checklist item 2)

State Water Plan (SWP)

- Projected Surface Water Supplies (checklist item 6),
- Projected Water Demands (checklist item 7),
- Projected Water Supply Needs (checklist item 8),
- Projected Water Management Strategies (checklist item 9)

Part two of the two-part package is the groundwater availability model (GAM) run report for the district (checklist items 3 through 5). The district should have received, or will receive, this report from the TWDB Groundwater Modeling Department. Questions about the GAM can be directed to the Groundwater Modeling Team at GAM@twdb.texas.gov.

DISCLAIMER:

Data presented in these tables are the most up to date WUS and SWP data available as of 7/17/2026. Although it does not happen often, these data are subject to change pending the availability of more accurate WUS data or an amendment to the 2022 SWP. District personnel should review the data table values and correct any discrepancies to ensure approval of their groundwater management plan.

The WUS data can be verified at this web address:

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

The 2022 SWP data can be verified by contacting WRPdatarequests@twdb.texas.gov

The values presented in the data tables are county based. In cases where groundwater conservation districts cover only a portion of one or more counties the data values are modified with an apportioning multiplier to create new values that more accurately represent conditions within district boundaries. The multiplier used in the following formula is a land area ratio: (data value * (land area of district in county / land area of county)). For two of the four SWP tables (Projected Surface Water Supplies and Projected Water Demands) only the county-wide water user group (WUG) data values (county other, manufacturing, steam electric power, irrigation, mining, and livestock) are modified using the multiplier. WUG values for municipalities, water supply corporations, and utility districts are not apportioned; instead, their full values are retained when they are located within the district and eliminated when they are located outside (we offer districts the opportunity to review this determination).

The county values in two of the SWP tables (Projected Water Supply Needs and Projected Water Management Strategies) are not apportioned because district-specific values are not required to be presented in the groundwater management plan. However, a district is required to “consider” the county values in these two tables by drafting a short summary of the needs and strategies values in the groundwater management plan.

In the WUS table every category of water use (including municipal) is apportioned. Staff determined that breaking down the annual municipal values into individual WUGs was too complex.

TWDB recognizes that the apportioning formula used is not ideal but it is the best available process with respect to time and staffing constraints. If a district believes it has data that are more accurate, they can add those data to the plan with an explanation of how the data were derived. Apportioning percentages that the TWDB used are listed above each applicable table.

For additional questions regarding this data, please contact GWMPlans (GWMPlans@twdb.texas.gov)

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

KERR COUNTY *100% (multiplier)* All values are in acre-feet

Year	Source	Municipal	Manufacturing	Mining	Steam Electric	Irrigation	Livestock	Total
2023	GW	3,957	2	68	0	1,332	152	5,511
	SW	3,609	9	32	0	328	275	4,253
2022	GW	4,464	5	62	0	1,777	159	6,467
	SW	3,359	16	133	0	445	356	4,309
2021	GW	3,567	2	14	0	1,049	239	4,871
	SW	4,023	14	110	0	463	307	4,917
2020	GW	4,049	2	24	0	703	245	5,023
	SW	3,285	9	101	0	404	339	4,138
2019	GW	4,299	6	48	0	1,079	245	5,677
	SW	3,017	16	0	0	296	368	3,697
2018	GW	3,807	3	14	0	1,047	244	5,115
	SW	3,953	20	111	0	223	337	4,644
2017	GW	3,799	1	54	0	1,515	237	5,606
	SW	3,991	7	125	0	455	347	4,925
2016	GW	3,568	1	39	0	397	246	4,251
	SW	4,275	10	146	0	293	296	5,020
2015	GW	4,319	0	27	0	607	245	5,198
	SW	2,928	0	174	0	441	295	3,838
2014	GW	4,360	0	30	0	1,509	279	6,178
	SW	2,880	0	137	0	519	372	3,908

Projected Surface Water Supplies
TWDB 2022 State Water Plan Data

KERR COUNTY

100% (multiplier)

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	10	10	10	10	10	10
J	Irrigation, Kerr	Guadalupe	Guadalupe Run-of-River	1,127	1,127	1,127	1,127	1,127	1,127
J	Kerrville	Guadalupe	Guadalupe Run-of-River	150	150	150	150	150	150
J	Manufacturing, Kerr	Guadalupe	Guadalupe Run-of-River	11	11	11	11	11	11
J	Mining, Kerr	Guadalupe	Guadalupe Run-of-River	77	77	77	77	77	77
	Sum of Projected Surface Water Supplies (acre-feet)			**1,375**	**1,375**	**1,375**	**1,375**	**1,375**	**1,375**

Projected Water Demands
TWDB 2022 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

100% (multiplier)

All values are in acre-feet

RWPG	WUG	WUG Basin	2020	2030	2040	2050	2060	2070
J	County-Other, Kerr	Colorado	43	44	44	44	45	46
J	County-Other, Kerr	Guadalupe	1,974	2,008	2,013	2,046	2,090	2,127
J	County-Other, Kerr	Nueces	1	1	1	1	1	1
J	County-Other, Kerr	San Antonio	23	23	24	24	24	25
J	Irrigation, Kerr	Colorado	61	61	61	61	61	61
J	Irrigation, Kerr	Guadalupe	1,239	1,239	1,239	1,239	1,239	1,239
J	Irrigation, Kerr	San Antonio	42	42	42	42	42	42
J	Kerrville	Guadalupe	5,082	5,158	5,178	5,237	5,305	5,364
J	Kerrville South Water	Guadalupe	341	346	347	352	358	363
J	Livestock, Kerr	Colorado	166	166	166	166	166	166
J	Livestock, Kerr	Guadalupe	546	546	546	546	546	546
J	Livestock, Kerr	Nueces	9	9	9	9	9	9
J	Livestock, Kerr	San Antonio	36	36	36	36	36	36
J	Manufacturing, Kerr	Guadalupe	20	21	21	21	21	21
J	Mining, Kerr	Colorado	14	15	18	19	20	22
J	Mining, Kerr	Guadalupe	62	65	82	83	91	98
		Sum of Projected Water Demands (acre-feet)	**9,659**	**9,780**	**9,827**	**9,926**	**10,054**	**10,166**

Projected Water Supply Needs
TWDB 2022 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	21	20	20	20	19	18
J	County-Other, Kerr	Guadalupe	6,564	6,530	6,525	6,492	6,448	6,411
J	County-Other, Kerr	Nueces	-1	-1	-1	-1	-1	-1
J	County-Other, Kerr	San Antonio	238	238	237	237	237	236
J	Irrigation, Kerr	Colorado	31	31	31	31	31	31
J	Irrigation, Kerr	Guadalupe	421	421	421	421	421	421
J	Irrigation, Kerr	San Antonio	21	21	21	21	21	21
J	Kerrville	Guadalupe	1,551	1,475	1,455	1,396	1,328	1,269
J	Kerrville South Water	Guadalupe	46	41	40	35	29	24
J	Livestock, Kerr	Colorado	-119	-119	-119	-119	-119	-119
J	Livestock, Kerr	Guadalupe	-173	-173	-173	-173	-173	-173
J	Livestock, Kerr	Nueces	-6	-6	-6	-6	-6	-6
J	Livestock, Kerr	San Antonio	-27	-27	-27	-27	-27	-27
J	Manufacturing, Kerr	Guadalupe	28	27	27	27	27	27
J	Mining, Kerr	Colorado	-11	-12	-15	-16	-17	-19
J	Mining, Kerr	Guadalupe	60	57	40	39	31	24
	Sum of Projected Water Supply Needs (acre-feet)		**-337**	**-338**	**-341**	**-342**	**-343**	**-345**

Projected Water Management Strategies
TWDB 2022 State Water Plan Data

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, Guadalupe (J)							
EKCRWSP - Construction of ASR Facility	Trinity Aquifer ASR [Kerr]	0	1,124	1,124	1,124	1,124	1,124
EKCRWSP - Construction of Off-Channel Surface Water Storage	Guadalupe River Off-Channel Lake/Reservoir [Reservoir]	0	1,121	1,121	1,121	1,121	1,121
EKCRWSP - Ellenburger Aquifer Groundwater Development	Ellenburger-San Saba Aquifer [Kerr]	0	108	108	108	108	108
EKCRWSP - Trinity Aquifer Groundwater Development	Trinity Aquifer [Kerr]	0	860	860	806	806	806
Kerr County Other - Center Point - Public Conservation Education	DEMAND REDUCTION [Kerr]	3	1	1	1	1	1
Kerr County Other - Center Point Taylor System - Public Conservation Education	DEMAND REDUCTION [Kerr]	2	1	1	1	1	1
Kerr County Other - Verde Park Estates WWW - Water Loss Audit and Main-Line Repair	DEMAND REDUCTION [Kerr]	1	1	1	1	1	1
		6	**3,216**	**3,216**	**3,162**	**3,162**	**3,162**
County-Other, Kerr, Nueces (J)							
Kerr County Other - Public Conservation Education (Nueces)	DEMAND REDUCTION [Kerr]	1	1	1	1	1	1
		1	**1**	**1**	**1**	**1**	**1**
Kerrville, Guadalupe (J)							
City of Kerrville - Explore and Develop New Ellenburger Aquifer Well Supply	Ellenburger-San Saba Aquifer [Kerr]	1,156	1,156	1,156	1,156	1,156	1,156
City of Kerrville - Increase Wastewater Reuse	Direct Reuse [Kerr]	2,500	2,500	2,500	2,500	2,500	2,500
City of Kerrville - Increased Water Treatment and ASR Capacity	Trinity Aquifer ASR [Kerr]	0	3,360	3,360	3,360	3,360	3,360
City of Kerrville - Water Loss Audit and Main-Line Repair	DEMAND REDUCTION [Kerr]	134	134	134	134	134	134
		3,790	**7,150**	**7,150**	**7,150**	**7,150**	**7,150**
Livestock, Kerr, Colorado (J)							
Kerr County Livestock - Conservation (Colorado)	DEMAND REDUCTION [Kerr]	24	24	24	24	24	24
		24	**24**	**24**	**24**	**24**	**24**
Livestock, Kerr, Guadalupe (J)							
Kerr County Livestock - Conservation (Guadalupe)	DEMAND REDUCTION [Kerr]	35	35	35	35	35	35
		35	**35**	**35**	**35**	**35**	**35**
Livestock, Kerr, Nueces (J)							
Kerr County Livestock - Conservation (Nueces)	DEMAND REDUCTION [Kerr]	1	1	1	1	1	1
		1	**1**	**1**	**1**	**1**	**1**

Projected Water Management Strategies
TWDB 2022 State Water Plan Data

WUG, Basin (RWPG)

All values are in acre-feet

Water Management Strategy	Source Name [Origin]	2020	2030	2040	2050	2060	2070
Livestock, Kerr, San Antonio (J)							
Kerr County Livestock - Conservation (San Antonio)	DEMAND REDUCTION [Kerr]	5	5	5	5	5	5
		5	**5**	**5**	**5**	**5**	**5**
Mining, Kerr, Colorado (J)							
Kerr County Mining - Additional Groundwater Wells (Colorado)	Edwards-Trinity-Plateau Aquifer [Kerr]	19	19	19	19	19	19
		19	**19**	**19**	**19**	**19**	**19**
Sum of Projected Water Management Strategies (acre-feet)		**3,881**	**10,451**	**10,451**	**10,397**	**10,397**	**10,397**

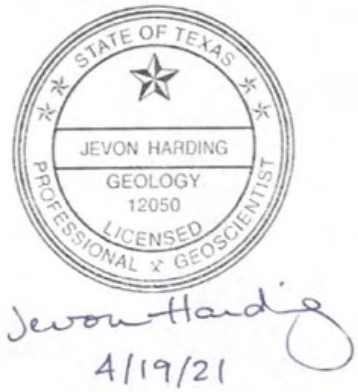
APPENDIX E

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

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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



Jevon Harding
4/19/21

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

Jevon Harding, P.G.
Texas Water Development Board
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(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.

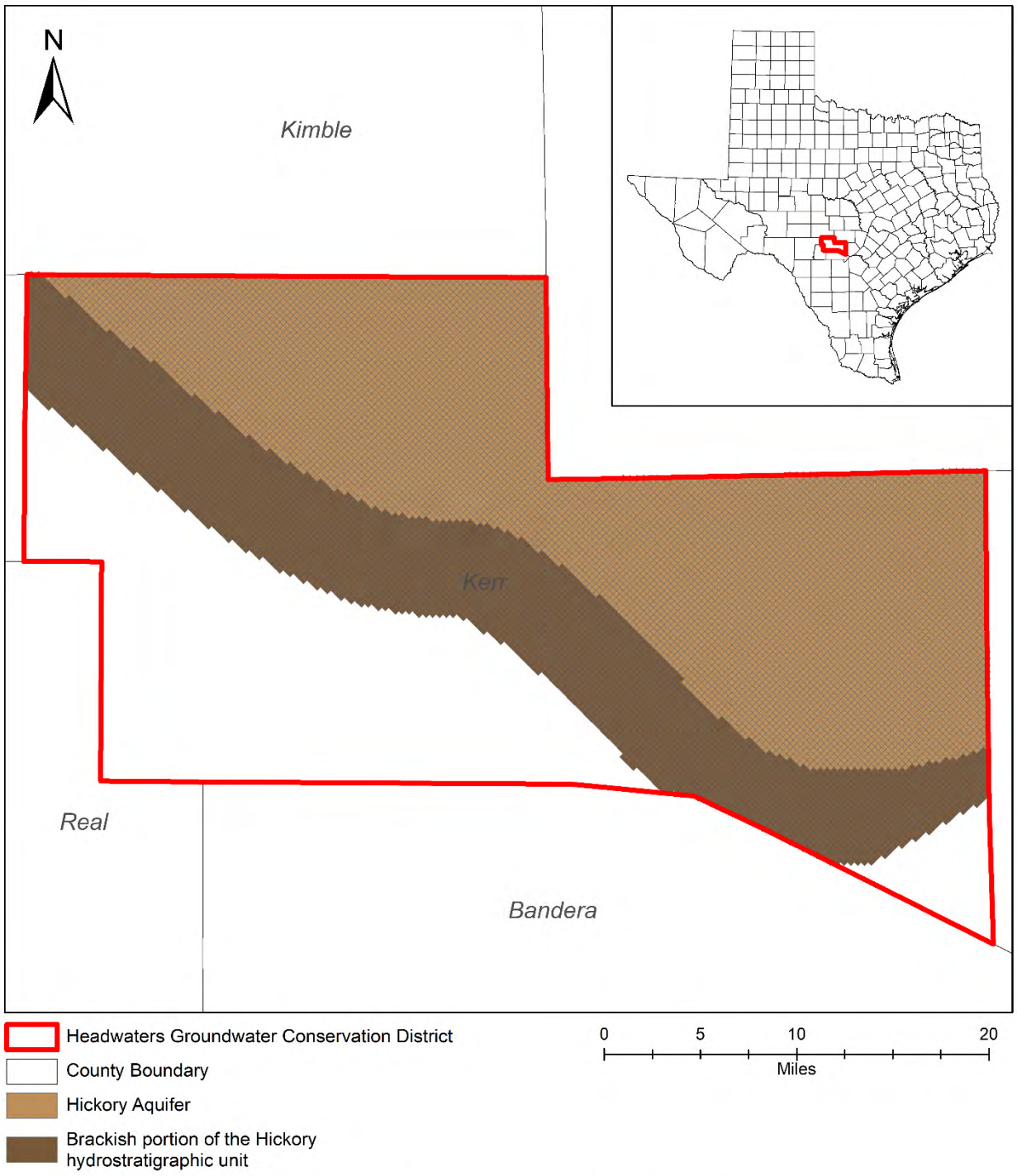
3. Flow into and out of district—the lateral flow within the aquifer between the district and adjacent counties.

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.

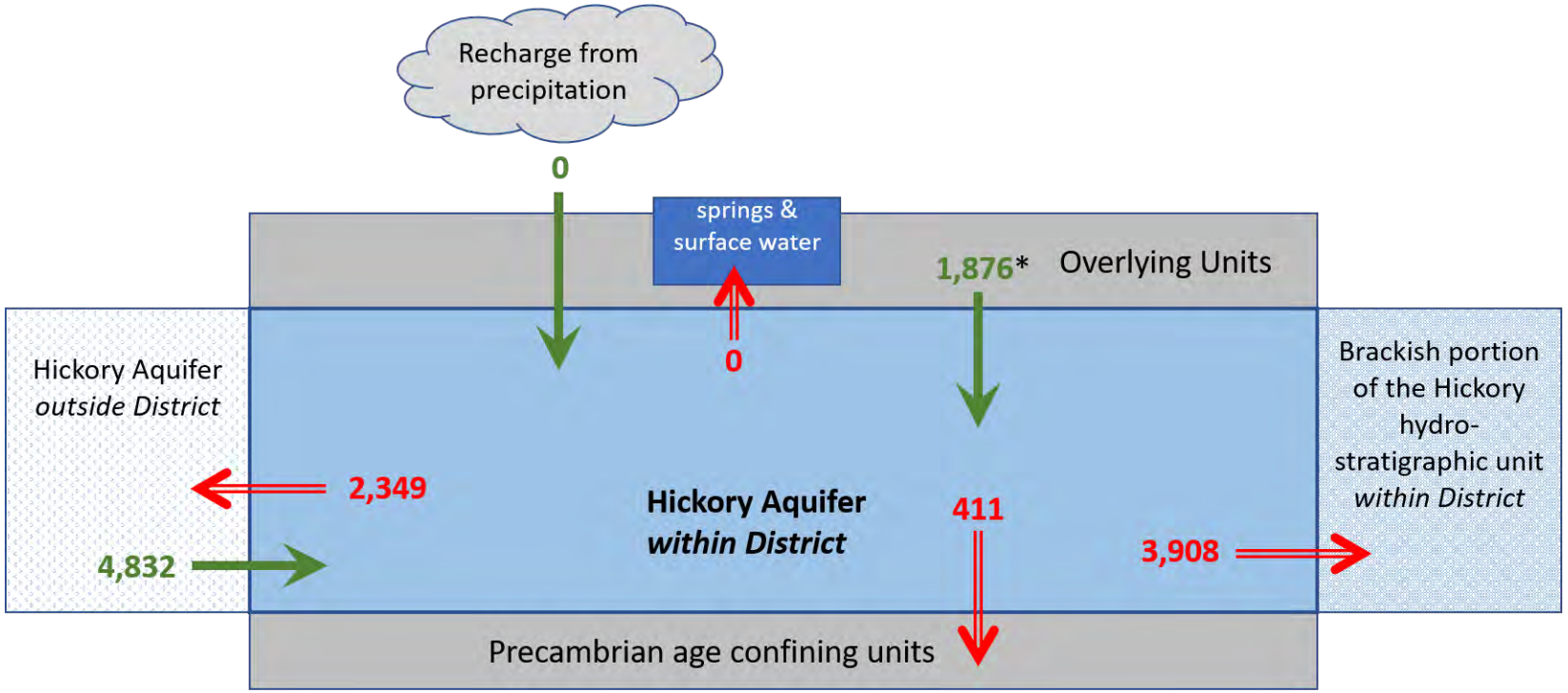
TABLE 1: SUMMARIZED INFORMATION FOR THE HICKORY AQUIFER THAT IS NEEDED FOR THE HEADWATERS GROUNDWATER CONSERVATION DISTRICT'S GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

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



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

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

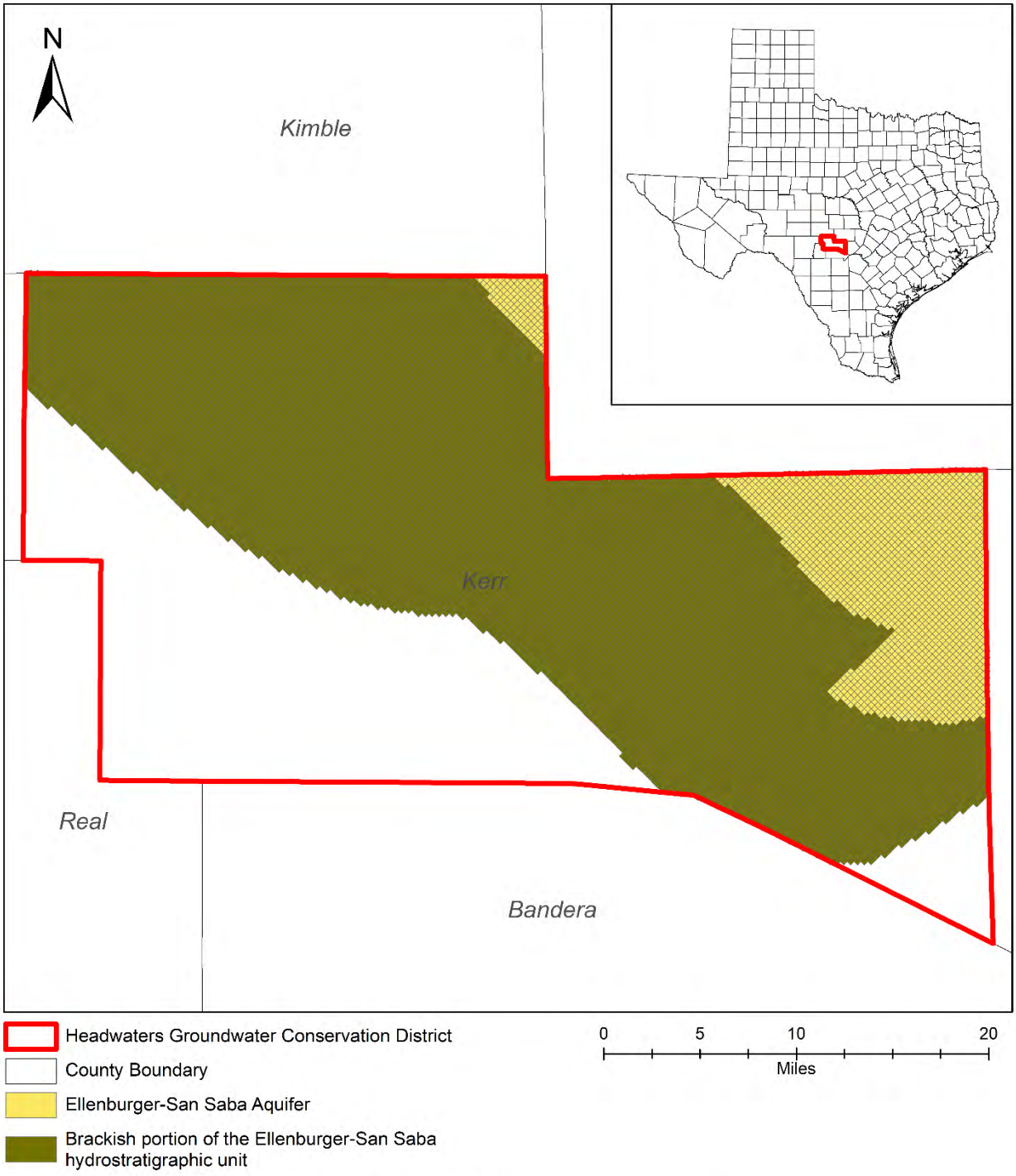
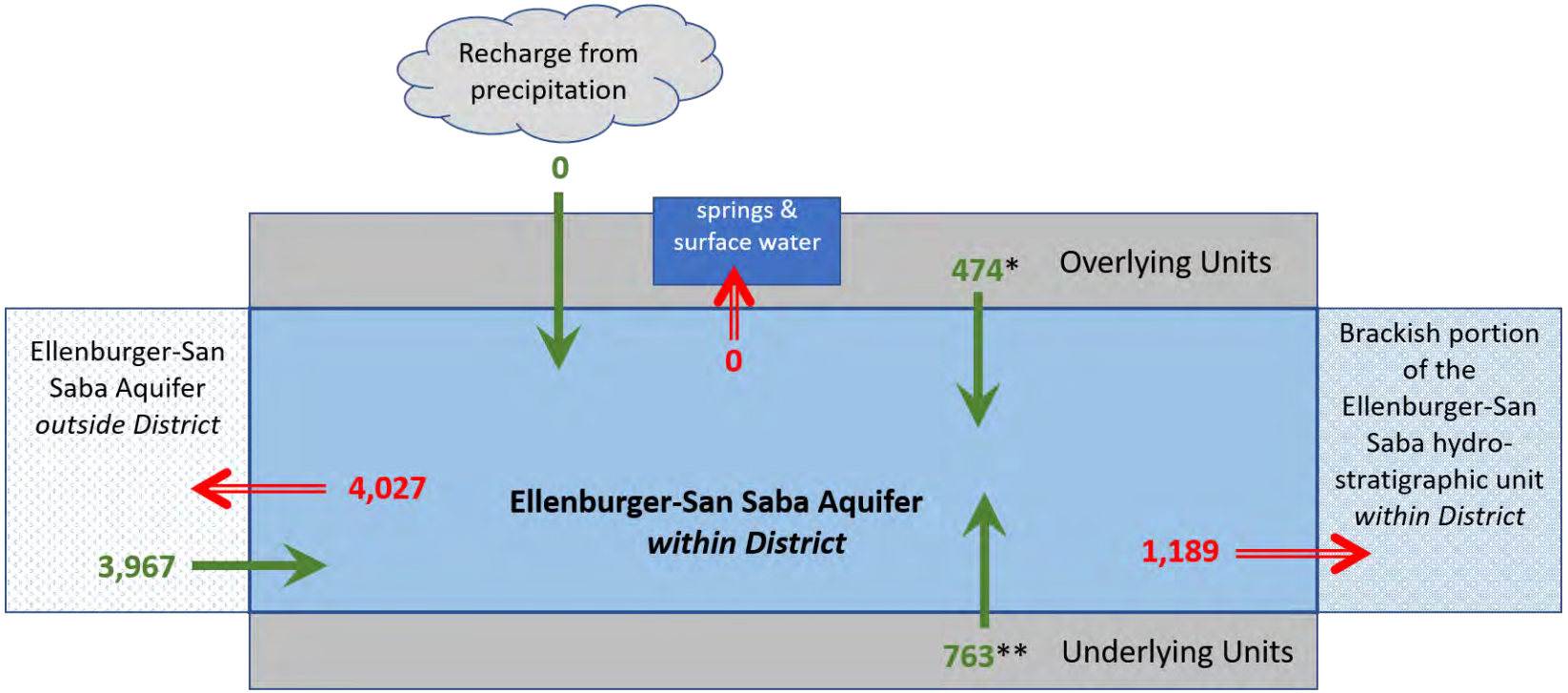


FIGURE 3: AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE MINOR AQUIFERS IN THE LLANO UPLIFT REGION FROM WHICH THE INFORMATION IN TABLE 2 WAS EXTRACTED (THE ELLENBURGER-SAN SABA AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).



* 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.

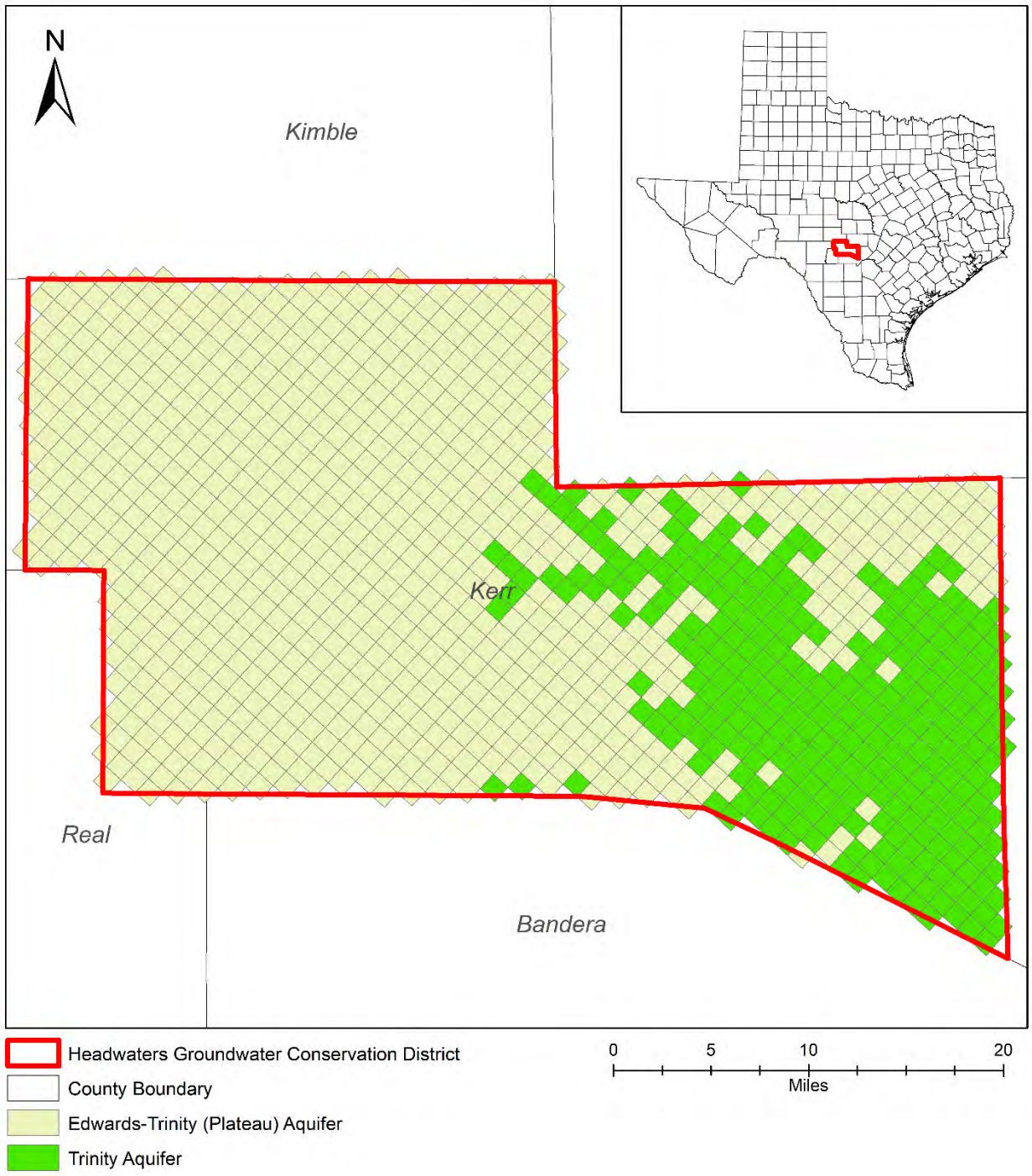
FIGURE 4: GENERALIZED DIAGRAM OF THE SUMMARIZED BUDGET INFORMATION FROM TABLE 2, REPRESENTING DIRECTIONS OF FLOW FOR THE ELLENBURGER-SAN SABA AQUIFER WITHIN HEADWATERS GROUNDWATER CONSERVATION DISTRICT. FLOW VALUES EXPRESSED IN ACRE-FEET PER YEAR (AFY).

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

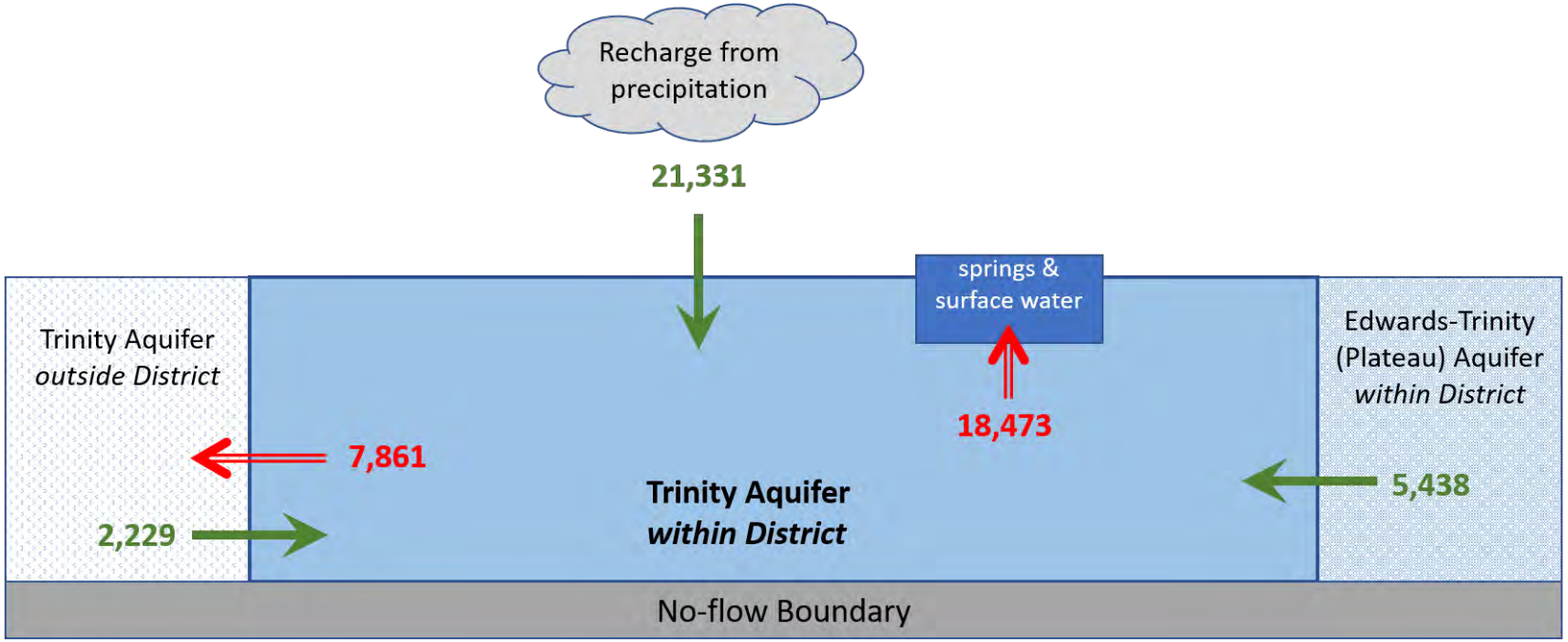
TABLE 4: SUMMARIZED INFORMATION FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER THAT IS NEEDED FOR THE HEADWATERS GROUNDWATER CONSERVATION DISTRICT'S GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

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



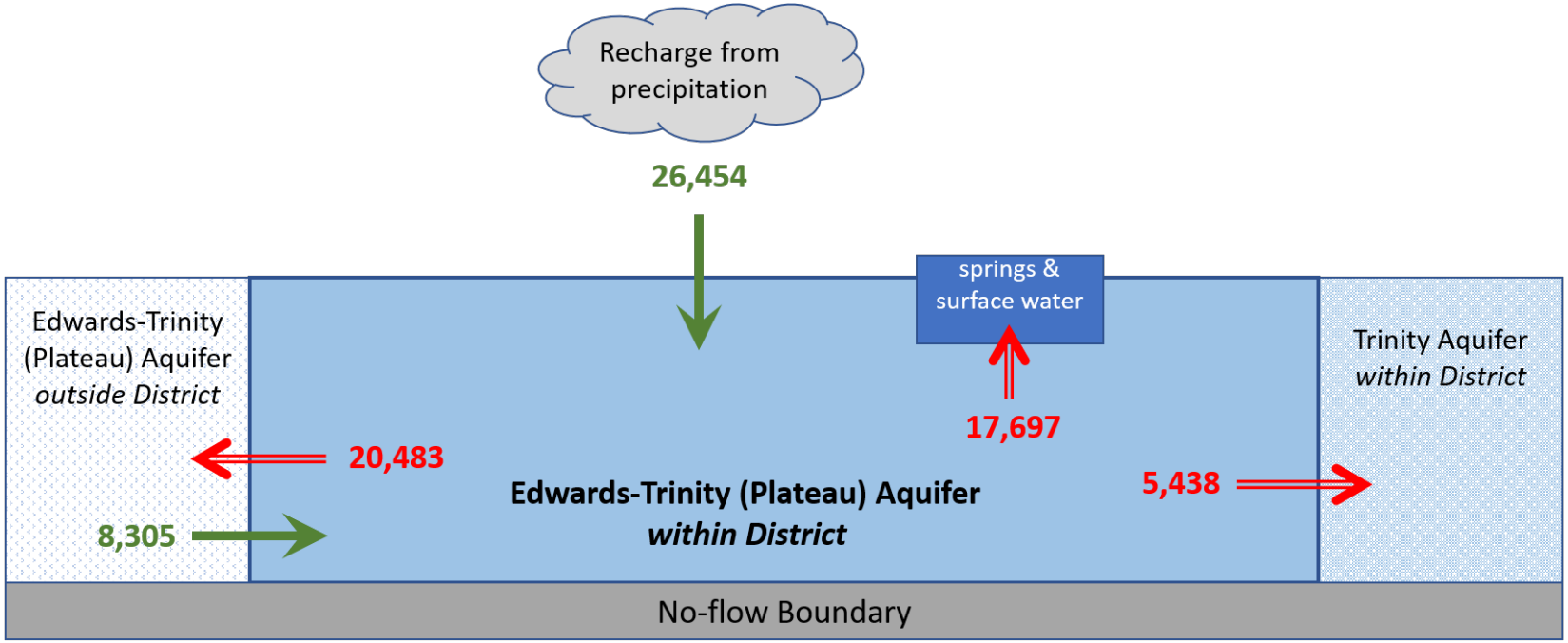
GCD boundary data = 06.26.2020, county boundary date =07.03.2019, eddt_p model grid date = 01.06.2020

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.

REFERENCES:

Anaya, R., and Jones, I. C., 2009, Groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers of Texas: Texas Water Development Board Report 373, 103 p. http://www.twdb.texas.gov/groundwater/models/gam/eddt_p/ET-Plateau_Full.pdf

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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

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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

Jordan Furnans, Ph.D., P.E., P.G.
Michael Keester, P.G.
Dave Colvin, P.G., PMP
Jacob Bauer, P.G. (WY)
Joel Barber, P.E. (CO)
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March 21, 2017

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Geoscientist and Engineer Seals

The Texas Water Development Board contracted with LRE Water, LLC, a licensed professional geoscientist firm (Texas License No. 50516) and licensed professional engineering firm (Texas License No. 14368). This report documents the work of the following licensed professional geoscientists and licensed professional engineers in the State of Texas:

Jordan Furnans, Ph.D., P.E., P.G.

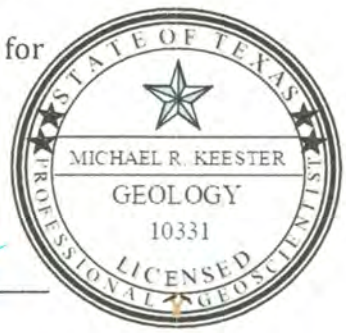
Dr. Furnans was the Project Manager for this work and was responsible for oversight of the project. His work also involved final report review and acceptance.



Signature 3/21/18 Date

Michael Keester, P.G.

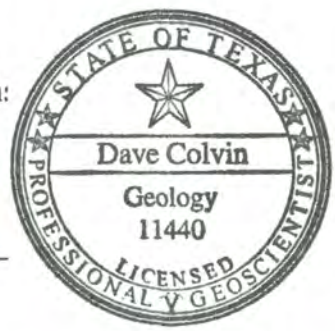
Mr. Keester was responsible for developing the methodology for assessing the aquifer subsidence risk for each of the major and minor aquifers, performing the subsidence risk assessment, developing the subsidence prediction tool, and for reviewing, editing, and compiling contributions from other report authors. He also assisted with subsidence investigations recommendations for high risk aquifers.



Signature 03/21/2018 Date

Dave Colvin, P.G.

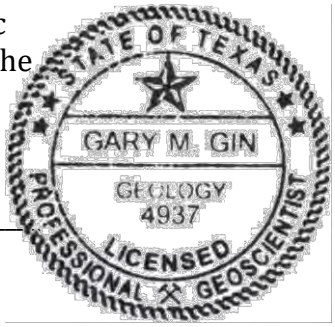
Mr. Colvin was responsible for the summary discussion of subsidence risk, developing the subsidence monitoring and investigation recommendations and assessing the limitations and recommendations for the project results.



Signature 3/21/18 Date

Gary Gin, P.G.

Mr. Gin was responsible for the hydrostratigraphy, hydraulic properties, hydraulic heads, and groundwater pumping for the Bone Spring-Victorio Peak, Trinity, and Woodbine aquifers.

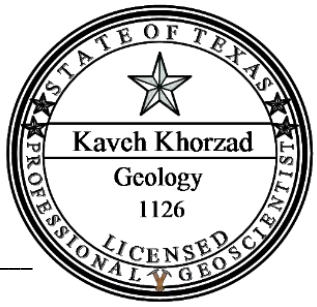


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Kaveh Khorzad, P.G.

Mr. Khorzad was responsible for the hydrostratigraphy, hydraulic properties, hydraulic heads, and groundwater pumping for the Blossom, Brazos River Alluvium, Edward (Balcones Fault Zone), Ellenburger-San Saba, Gulf Coast, Hickory, Lipan, Marathon, Marble Falls, Nacatoch, Seymour, and Yegua-Jackson aquifers.

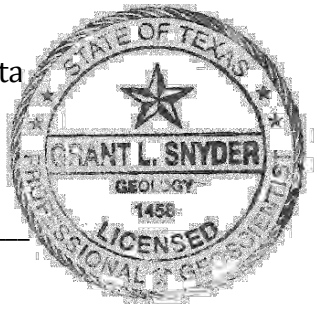


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Date

Grant Snyder, P.G.

Mr. Snyder was responsible for the hydrostratigraphy, hydraulic properties, hydraulic heads, and groundwater pumping for the Blaine, Carrizo-Wilcox, Queen City, and Sparta aquifers.



Signature

3/21/18
Date

Other Contributors

Jacob Bauer, P.G. (WY)

Mr. Bauer assisted with developing the subsidence prediction tool, summary discussion of subsidence risk, and the hydrostratigraphy, hydraulic properties, hydraulic heads, and groundwater pumping for the Igneous Aquifer.

Joel Barber, P.E. (CO)

Mr. Barber assisted with the hydrostratigraphy, hydraulic properties, hydraulic heads, and groundwater pumping for the Capitan Reef Complex, Edwards-Trinity (Plateau), Hueco-Mesilla Bolson, Pecos Valley, Rustler, and West Texas Bolsons aquifers.

Velma Danielson

Ms. Danielson was responsible for stakeholder outreach and stakeholder data compilation.

Lori Erickson

Ms. Erickson was responsible for GIS efforts associated with the project including figure preparation and geodatabase development and organization.

Andrew Worsley

Mr. Worsley assisted with the hydrostratigraphy, hydraulic properties, hydraulic heads, and groundwater pumping for the Blossom, Brazos River Alluvium, Edward (Balcones Fault Zone), Ellenburger-San Saba, Gulf Coast, Hickory, Lipan, Marathon, Marble Falls, Nacatoch, Seymour, and Yegua-Jackson aquifers.

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.

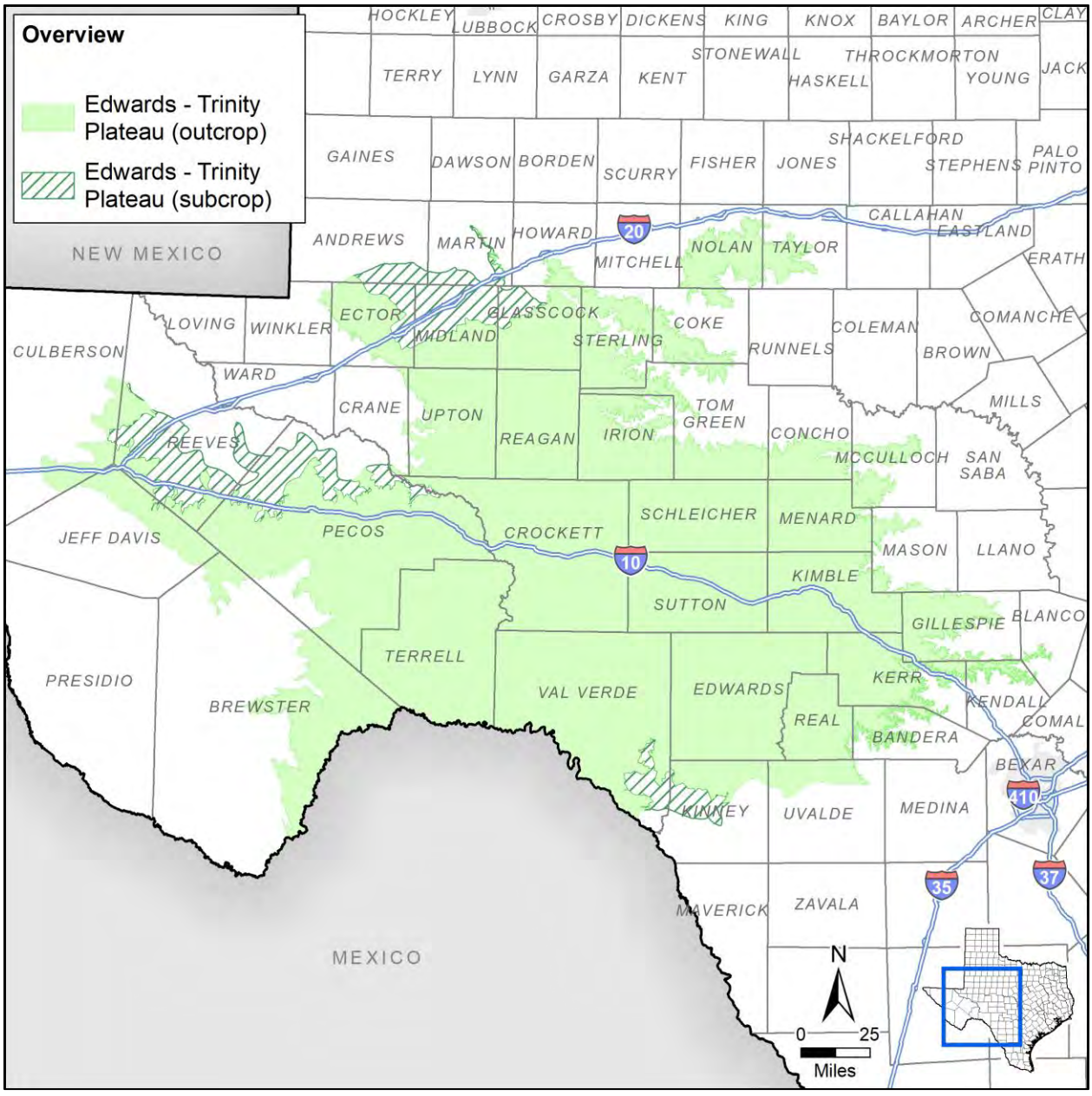


Figure 4.13. Edwards-Trinity (Plateau) Aquifer extent.

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).

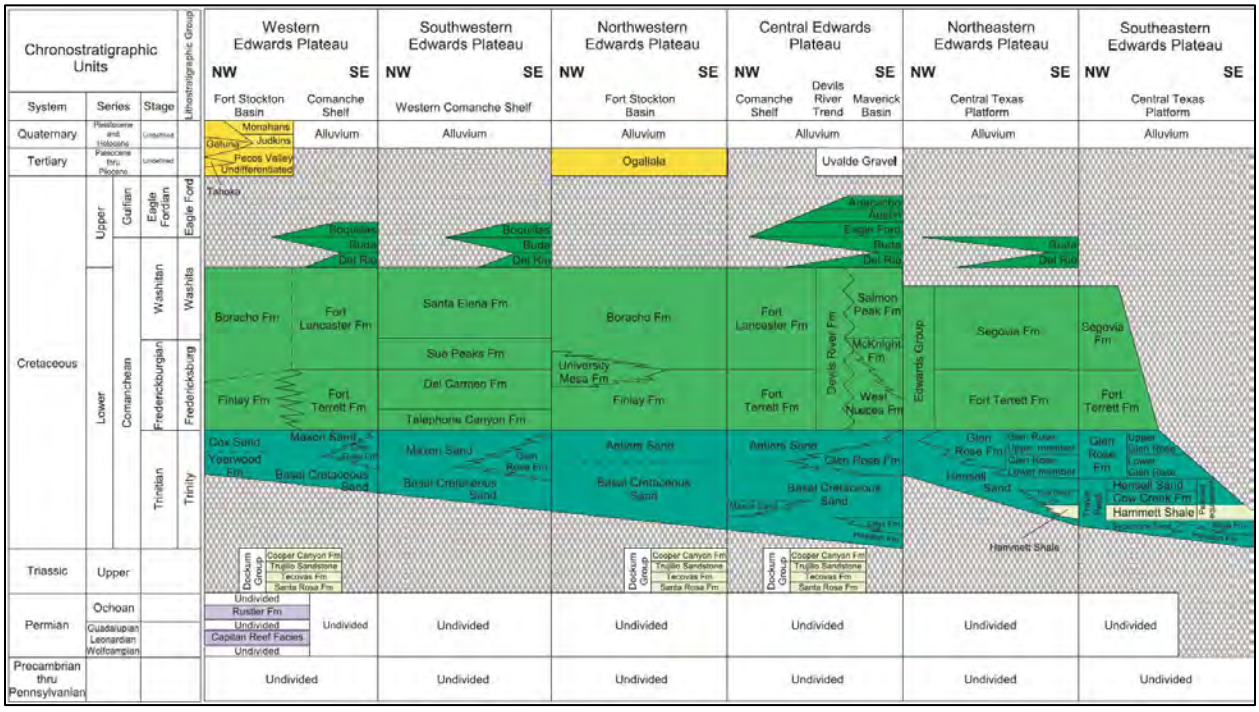


Figure 4.14. Stratigraphic column and geologic and hydrogeologic units within the Edwards-Trinity (Plateau) Aquifer (Anaya and Jones, 2009).

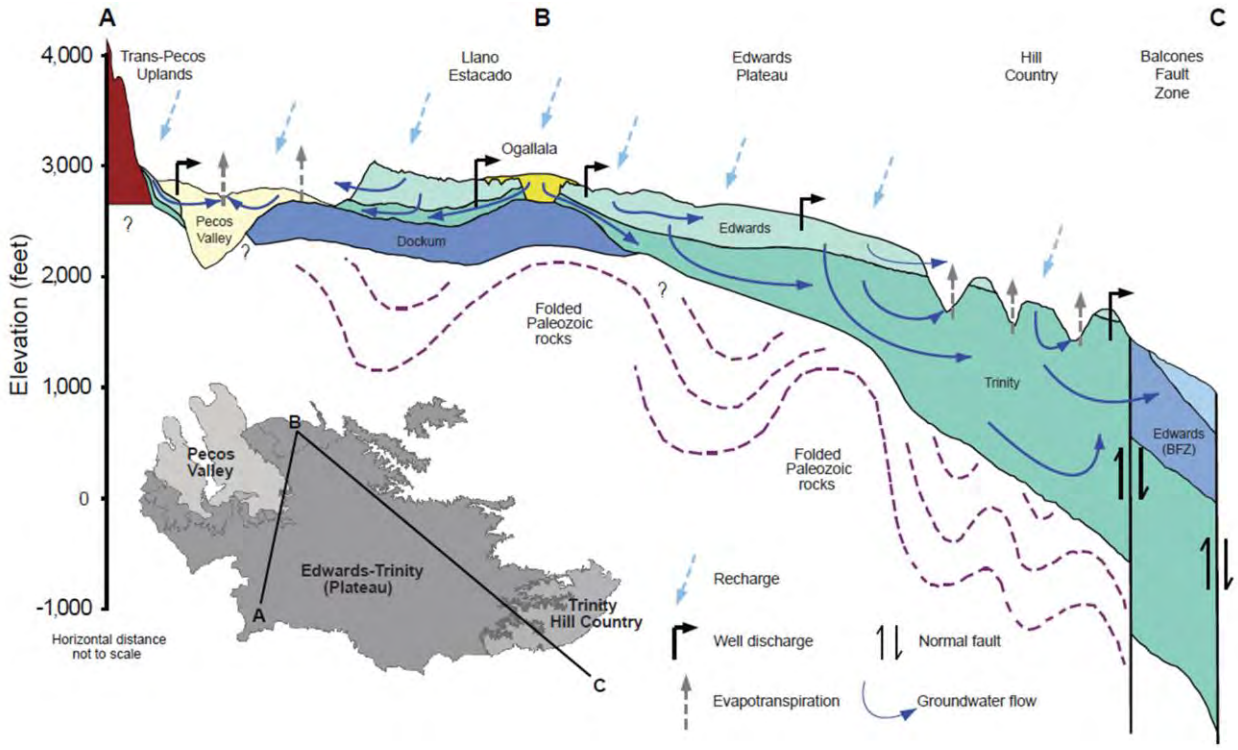


Figure 4.15. Cross Section of the Edwards-Trinity (Plateau) Aquifer (George and others, 2011).

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.

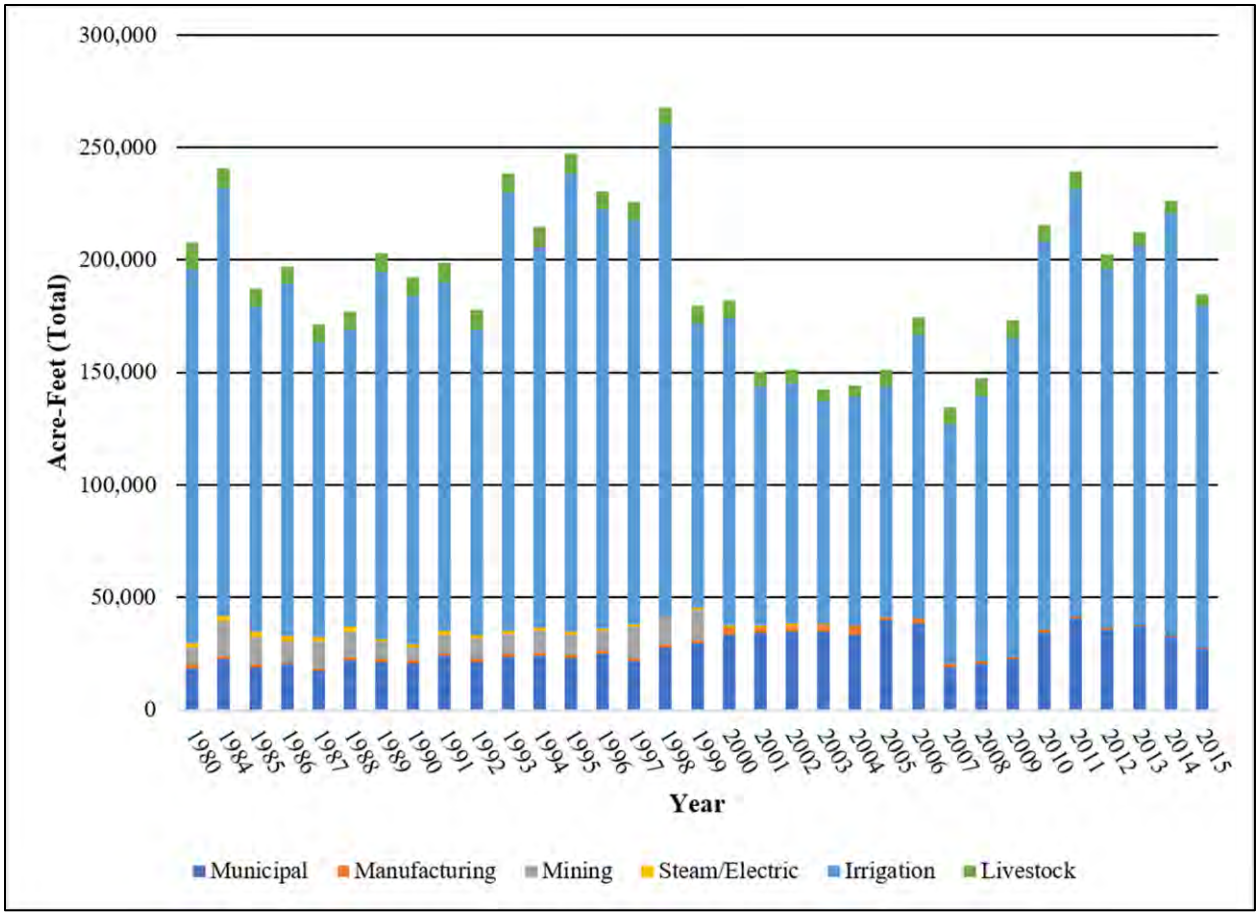


Figure 4.16. Historic pumping volumes from the Edwards-Trinity (Plateau) Aquifer in the municipal, manufacturing, mining, and steam/electricity production, irrigation, and livestock sectors from 1980 to 2015 (TWDB, 2017b).

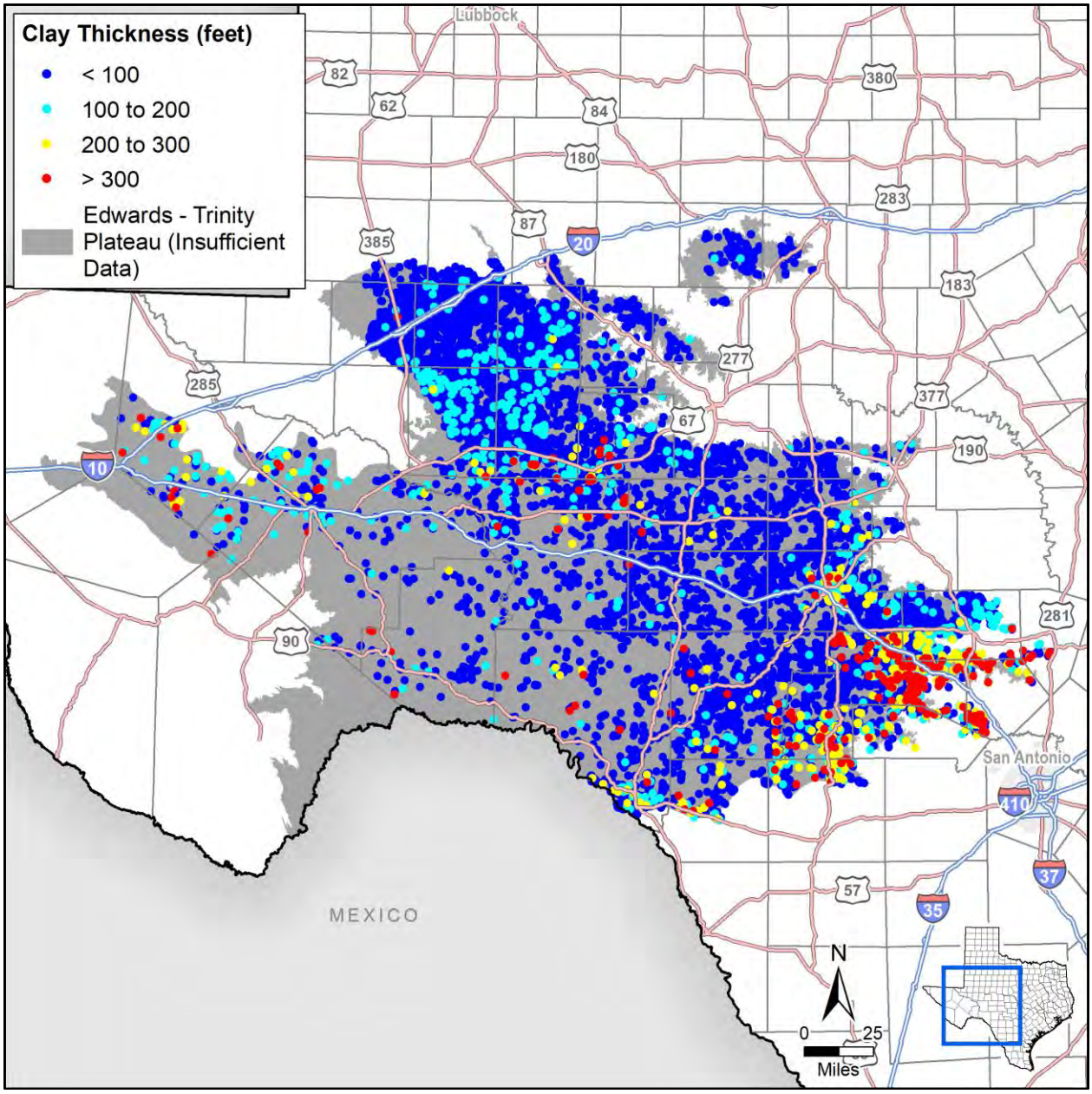


Figure 4.17. Calculated Edwards-Trinity (Plateau) Aquifer clay thickness at well locations.

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.

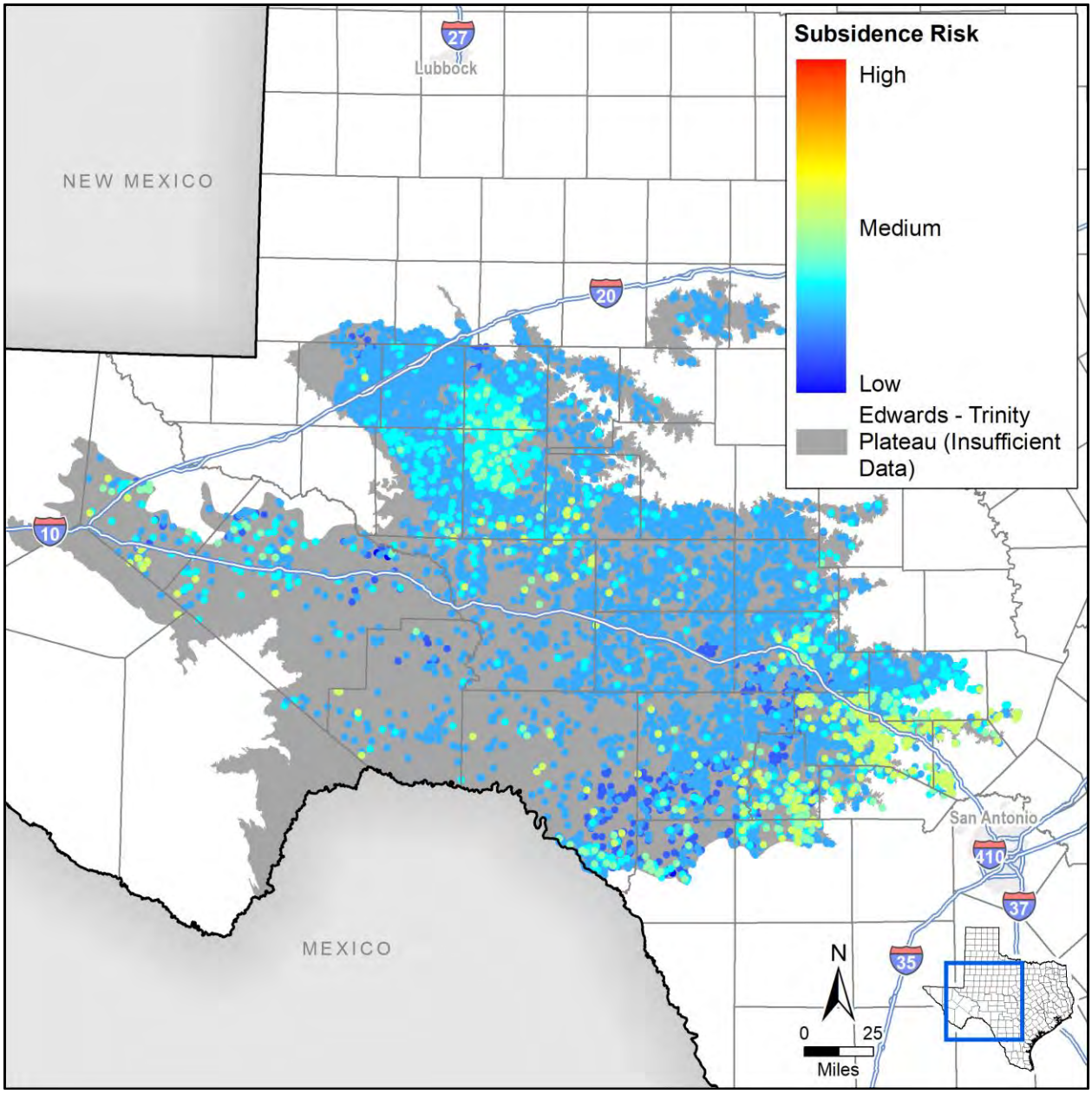


Figure 4.18. Edwards-Trinity (Plateau) Aquifer subsidence risk vulnerability at well locations.

4.2.9 Trinity

The Trinity Aquifer is a major aquifer that extends across central and northeastern Texas. The northern portion of the Trinity Aquifer is a major water resource for a large portion of north-central Texas including the growing population centers along the Interstate 35 corridor from the Dallas-Fort Worth Metroplex to Austin. Figure 4.44 provides a map showing the aquifer extent. This aquifer is one of the most extensive and highly used groundwater resources in Texas. Although its primary use is for municipal purposes, it is also used for livestock, irrigation, and other domestic purposes.

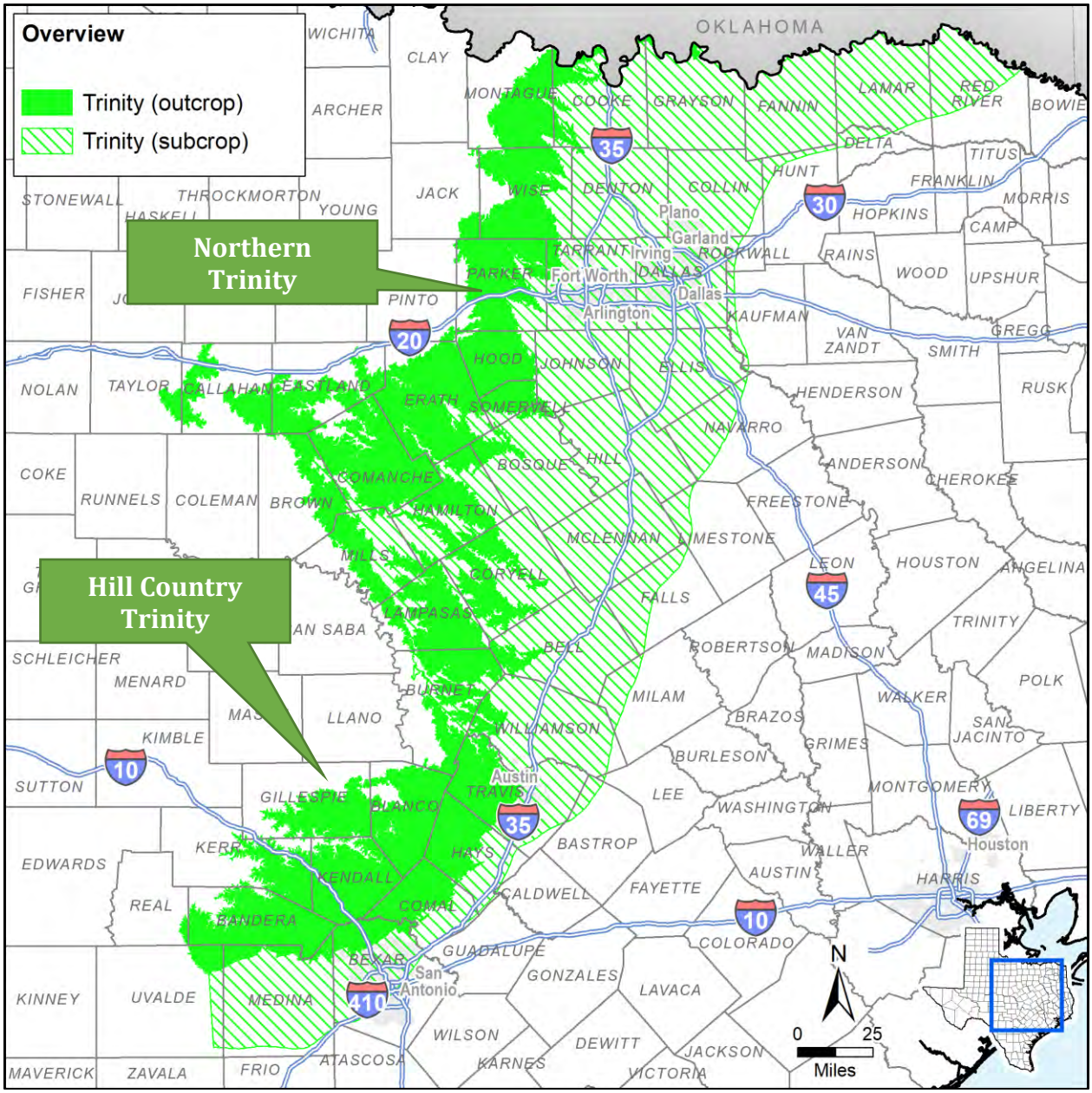


Figure 4.44. Trinity Aquifer extent.

Hydrostratigraphy

The Trinity Aquifer is composed of smaller aquifers that are named differently in different parts of the state. The Trinity Group is composed of the Antlers, Glen Rose, Paluxy, Twin Mountains, Travis Peak, Hensell, and Hosston aquifers. The aquifer consists of limestones, sands, clays, gravels, and conglomerates.

As discussed by Kelley and others (2014), the northern Trinity Aquifer is sandstone-dominated in the northwest, where it is locally referred to as the Antlers Aquifer. Elsewhere, limestones of the Glen Rose Formation separate the lower portion of the northern Trinity Aquifer (namely, sandstones of the Hosston and Hensell aquifers and the Pearsall Formation) from the sandstones in the upper portion of the northern Trinity Aquifer (namely, the Paluxy Aquifer). Sandstones in the Woodbine Aquifer are separated from the underlying northern Trinity Aquifer by limestones and shales in the Washita/and Fredericksburg groups. The Hosston Aquifer, which is the stratigraphically lowest sandstone layer, is the most widespread and best developed aquifer in the system. The Hosston Aquifer includes greater net sandstone and thicker individual sandstones than any other layer. The Hensell Aquifer is well developed in western portions of the study area, but thins and becomes increasingly shale dominated to the east. The Pearsall and Glen Rose formations include sandstones only in the north. The Paluxy Aquifer is dominated by thick sandstones across broad areas, where it rivals the Hosston Aquifer, but thins across the southern one-third of the study area. The Woodbine Aquifer includes thick sandstones in the east-central and northeastern portions of the study area. Figure 4.45 illustrates the geologic units of the northern portion of the Trinity.

As discussed by Jones and others (2011), the Hill Country portion of the Trinity Aquifer system comprises sediments of the Trinity Group and is divided into lower, middle, and upper aquifers on the basis of hydraulic characteristics of the sediments. The Lower Trinity Aquifer consists of the Hosston (and the Sycamore Sand in outcrop) and Sligo formations; the Middle Trinity Aquifer consists of the Cow Creek Limestone, the Hensell Sand, and the lower member of the Glen Rose Limestone; and the Upper Trinity Aquifer consists of the upper member of the Glen Rose Limestone. Low-permeability sediments throughout the upper member of the Glen Rose Limestone separate the Middle and Upper Trinity aquifers. The Lower and Middle Trinity aquifers are separated by the low-permeability Hammett Shale. Figure 4.46 illustrates the geologic units of the Hill Country portion of the Trinity.

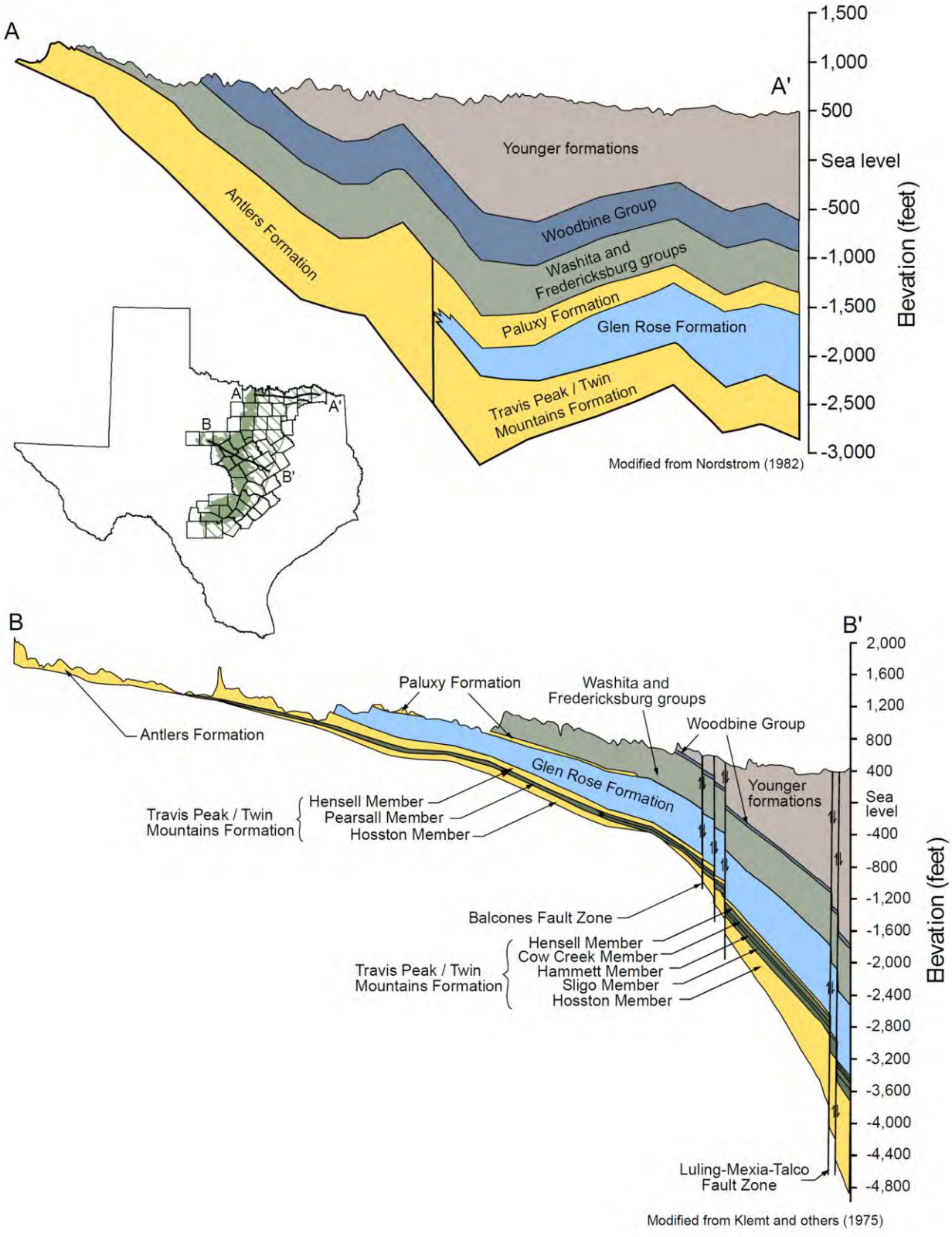


Figure 4.45. Conceptualized cross-section of the geologic sequence of the northern portion of the Trinity Aquifer (Kelley and others, 2014).

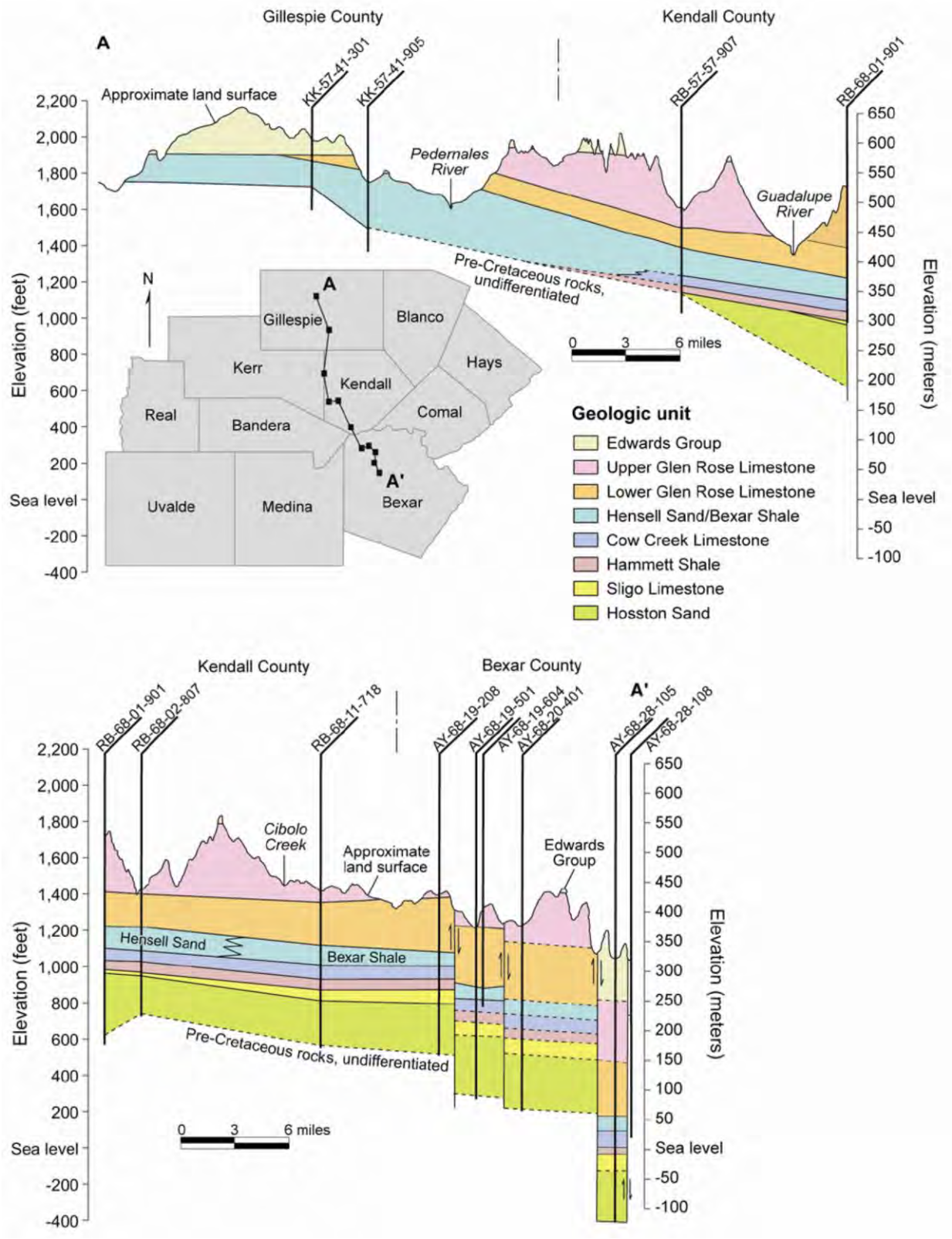


Figure 4.46. Conceptualized cross-section of the geologic sequence of the Hill Country portion of the Trinity Aquifer (Jones and others, 2011).

Hydraulic Properties

Extensive studies have been conducted on the hydraulic properties of the Trinity Aquifer (Jones and others, 2011; Kelley and others, 2014). Across the aquifer, the hydraulic properties can vary greatly. In many parts of the system, the properties may vary over relatively short distances due to fractures and dissolution features. Table 4.17 provides a summary of the hydraulic properties calculated for the Trinity Aquifer.

Table 4.17. Hydraulic properties for the Trinity Aquifer.

Aquifer Properties	Northern Portion*	Hill Country Portion	References
Hydraulic conductivity (ft/d)	0.1 – 12.9	5 – 1.3×10^3	1, 2
Transmissivity (ft^2/d)	< 10 – > 8,000	100 – 5.8×10^4	1, 2
Storativity	1.0×10^{-6} – 3.0×10^{-3}	1.0×10^{-5} – 1.0×10^{-3}	2

* Excludes values for shale

References. (1) Kelley and others (2014); (2) Jones and others (2011)

Hydraulic Heads

Generally, groundwater will flow from the outcrop areas of the aquifer to the west and north where recharge occurs toward the downdip portions of the aquifer. Kelley and others (2014) indicate recharge to the northern portion of the aquifer based on chloride mass balance calculations ranges from 0.03 to 6.4 inches per year. For the Hill Country portion of the Trinity, Jones and others (2011) estimate recharge to be about 72,000 acre-feet per year.

In some parts of the northern Trinity Aquifer, water levels have declined as much as 850 feet (Mace and others, 1994; Kelley and others, 2014). In the Hill Country portion, water levels have generally declined in most areas (Jones and others, 2011). These localized water level declines change the natural downdip flow of groundwater toward the pumping centers.

Groundwater Pumping

Figure 4.47 provides a graph of the historic pumping volumes from the Trinity Aquifer in the municipal, manufacturing, mining, and steam/electricity production, irrigation, and livestock sectors from 1980 to 2015. Overall, the pumping demand has stayed relatively constant since 1980, with average withdrawal volumes of approximately 180,000 acre-feet per year. Municipal production accounts for over half of all production from the Trinity Aquifer. With continued growth in the areas overlying the aquifer, future pumping demands are likely to increase as reflected in the adopted DFC evaluation model run by GMA 8 (Beach and others, 2016).

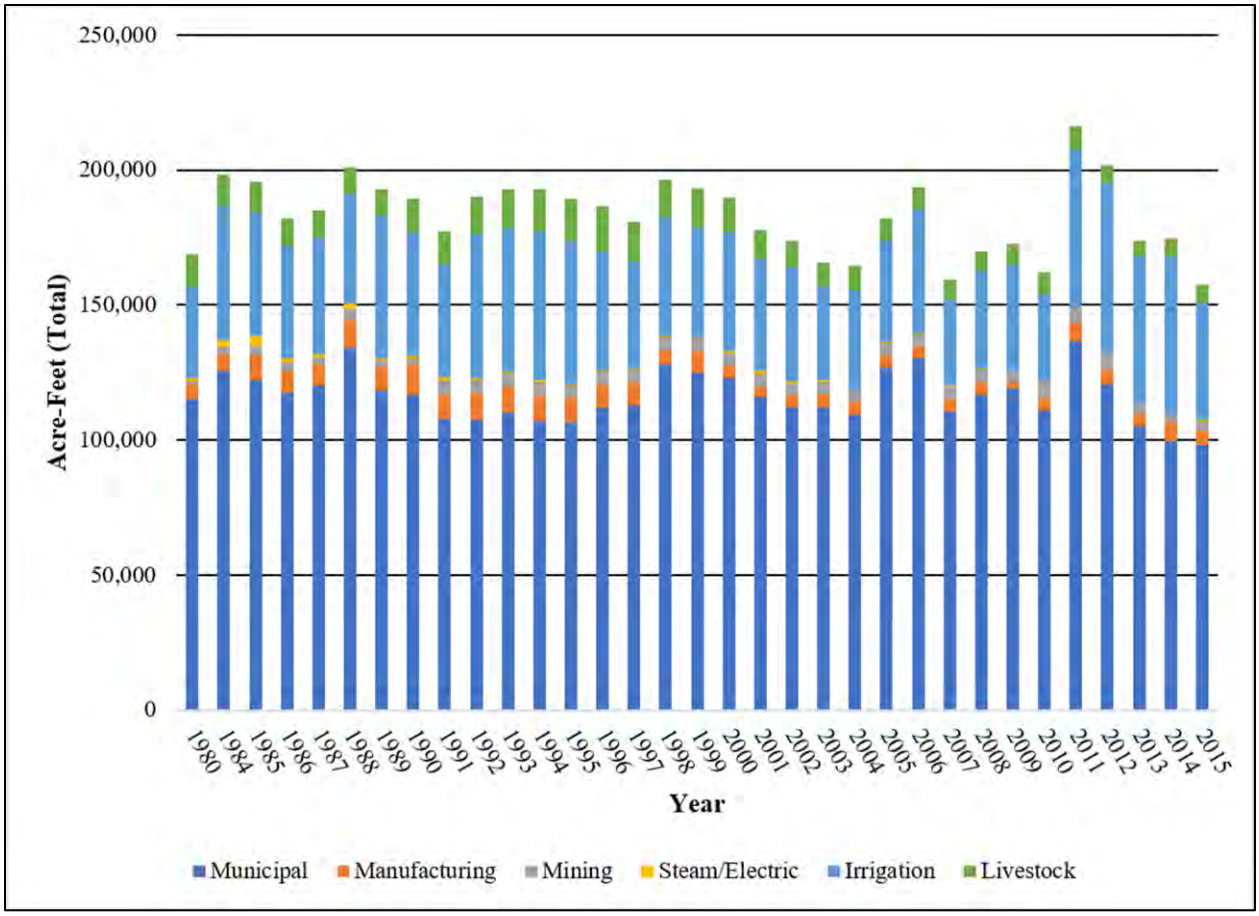


Figure 4.47. Historic pumping volumes from the Trinity Aquifer in the municipal, manufacturing, mining, and steam/electricity production, irrigation, and livestock sectors from 1980 to 2015 (TWDB, 2017b).

Subsidence Vulnerability

Clay thickness in the Trinity is greatest in the downdip areas of the Hill Country portion of the Trinity with values in much of the area exceeding 200 feet. On driller's logs, marly layers in the Cretaceous units of the Trinity are frequently documented as clays leading to larger than otherwise expected clay thicknesses. The maximum reported total clay thickness in the aquifer is more than 800 feet, but the average SRV based on clay thickness and extent is 2.3 with a third quartile of 3. Figure 4.48 illustrates the clay thickness and regional distribution of the thicknesses. The lithology of the Trinity is primarily carbonate and consolidated clastic material.

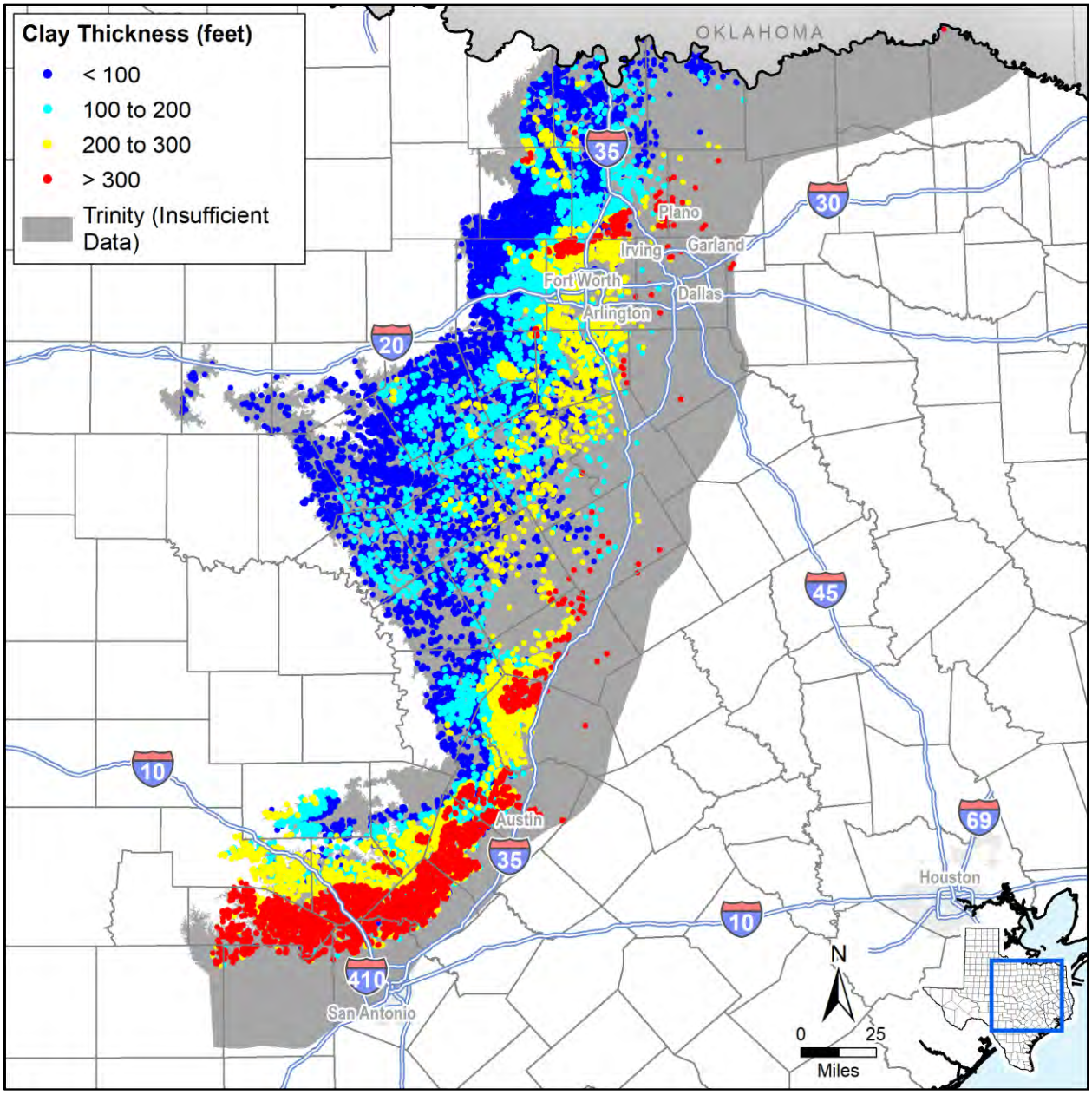


Figure 4.48. Calculated Trinity Aquifer clay thickness at well locations.

Municipal pumping has resulted in water level declines of more than 800 feet in the northern part of the aquifer (Kelley and others, 2014). Though there are some areas with small recovery, we assumed a preconsolidation equal to the water level from the end of the transient calibration period for the GAMs (Jones and others, 2011; Kelley and others, 2014). We also assumed a static water level in the aquifer equivalent to the results for 2017 from the adopted DFC model run for GMA 8 (Beach and others, 2016) and the MAG run for GMA 9 (Jones, 2017). The preconsolidation and static water levels resulted in an average and third quartile SRV of 3 throughout the aquifer.

For the northern portion of the aquifer, we determined the water level trend using the simulated water levels for 1992 through 2012 from the transient calibration period for the GAM (Kelley and others, 2014). For the Hill Country portion, we used the simulated water levels for 1998 through 2017 from the GMA 9 MAG run (Jones, 2017). DFC water levels are from the adopted DFCs for GMA 8 and the GMA 9 MAG run (Beach and others, 2016; Jones, 2017). Table 4.18 summarizes the data sources and values for each subsidence risk factor.

Table 4.18. Trinity 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 862 feet	3
Clay Compressibility	Estimated based on lithology	Hard Clay	1
Aquifer Lithology	Jones and others (2011); Kelley and others (2014)	Carbonate/ Consolidated Clastic	3
Preconsolidation Characterization	Water level from end of transient model simulations (Jones and others, 2011; Kelley and others, 2014)	-621 to 2,003 feet mean sea level	3
Predicted 50-Year Water Level Decline based on Trend	Trend in simulated water levels from transient and MAG model simulations (Kelley and others, 2014; Beach and others, 2016; Jones, 2017)	Average 38 feet decline	3
Predicted DFC Water Level Decline	Difference in head from final DFC and MAG simulations (Beach and others, 2016; Jones, 2017)	Average 50 feet decline	3

Results of the assessment indicate the downdip (that is, eastern) portions of the aquifer have the greatest risk for future subsidence due to pumping. However, as discussed by Mace and others (1994), land surface subsidence has not been observed despite significant water level declines. Figure 4.49 illustrates the subsidence risk factor throughout the aquifer.

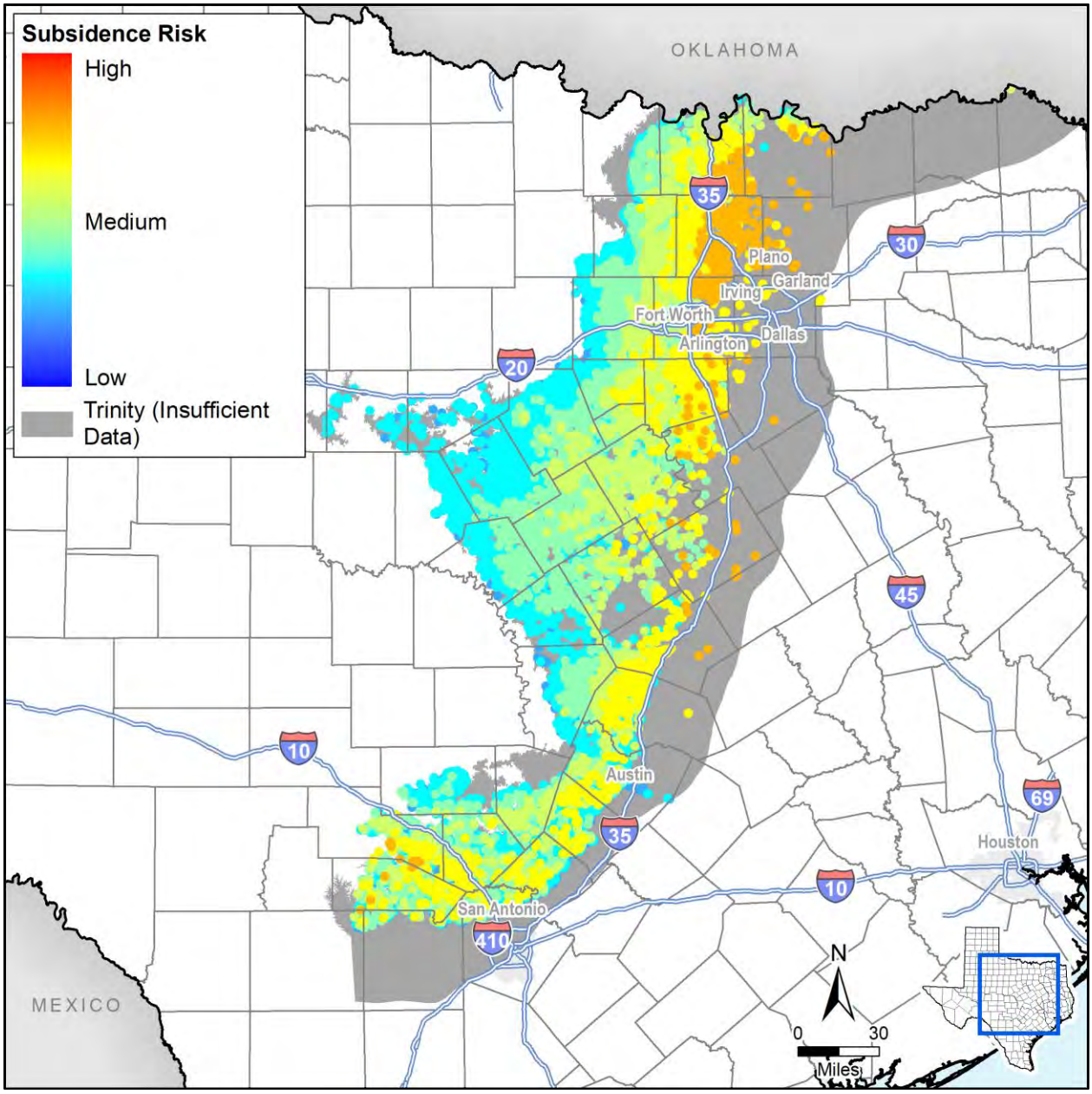


Figure 4.49. Trinity Aquifer subsidence risk vulnerability at well locations.

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.

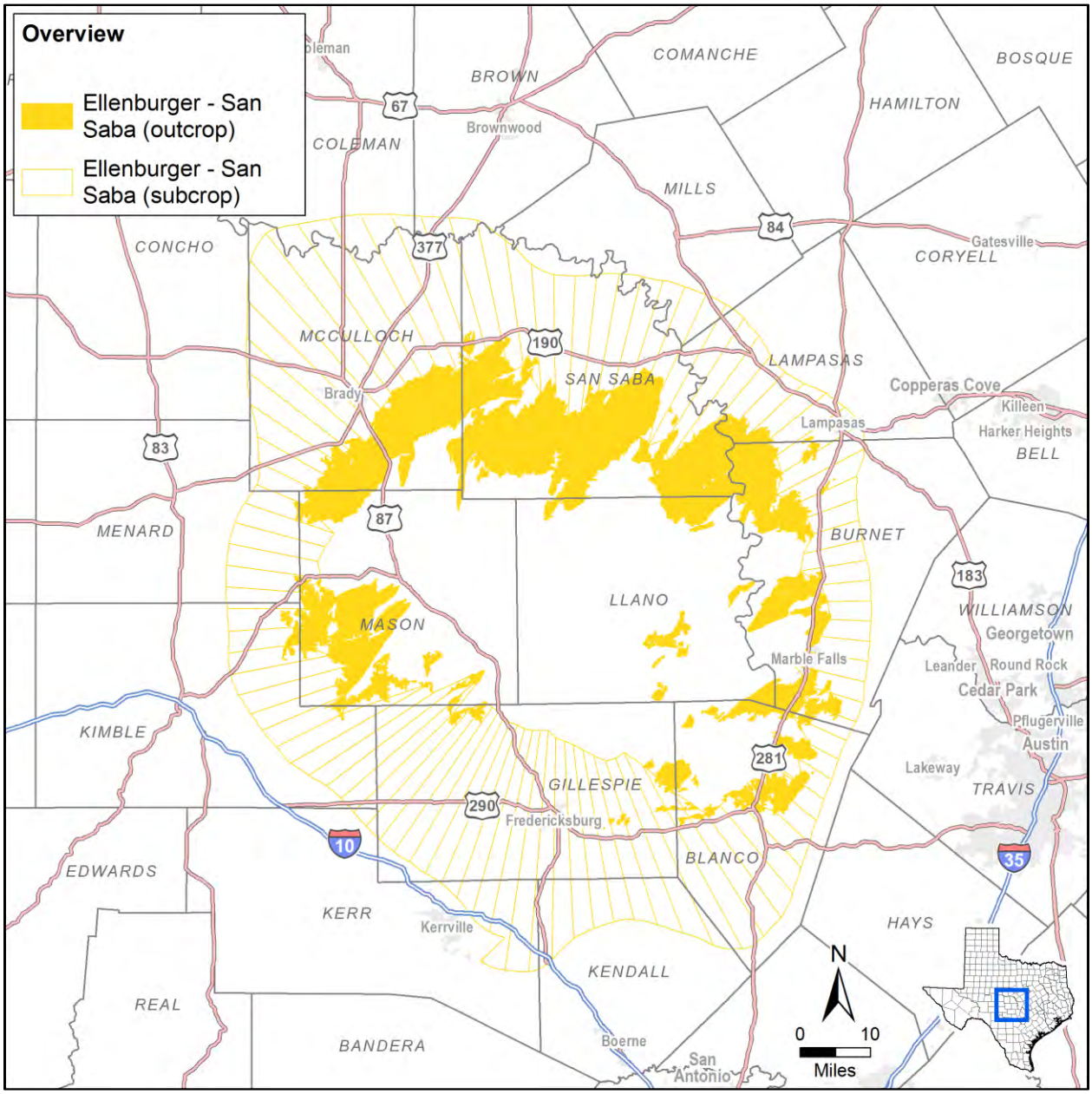


Figure 4.87. Ellenburger-San Saba Aquifer extent.

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					

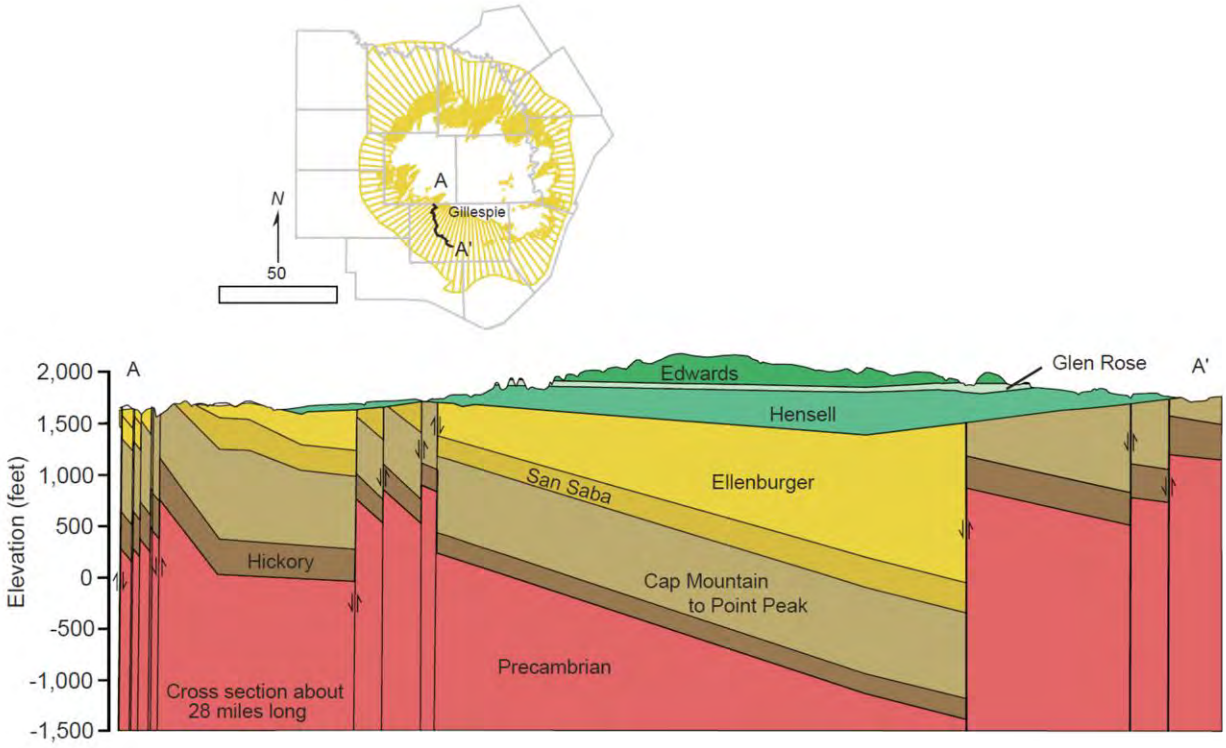


Figure 4.88. Cross-section of the Ellenburger-San Saba Aquifer along with overlying and underlying hydrogeologic units (George and others, 2011).

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.

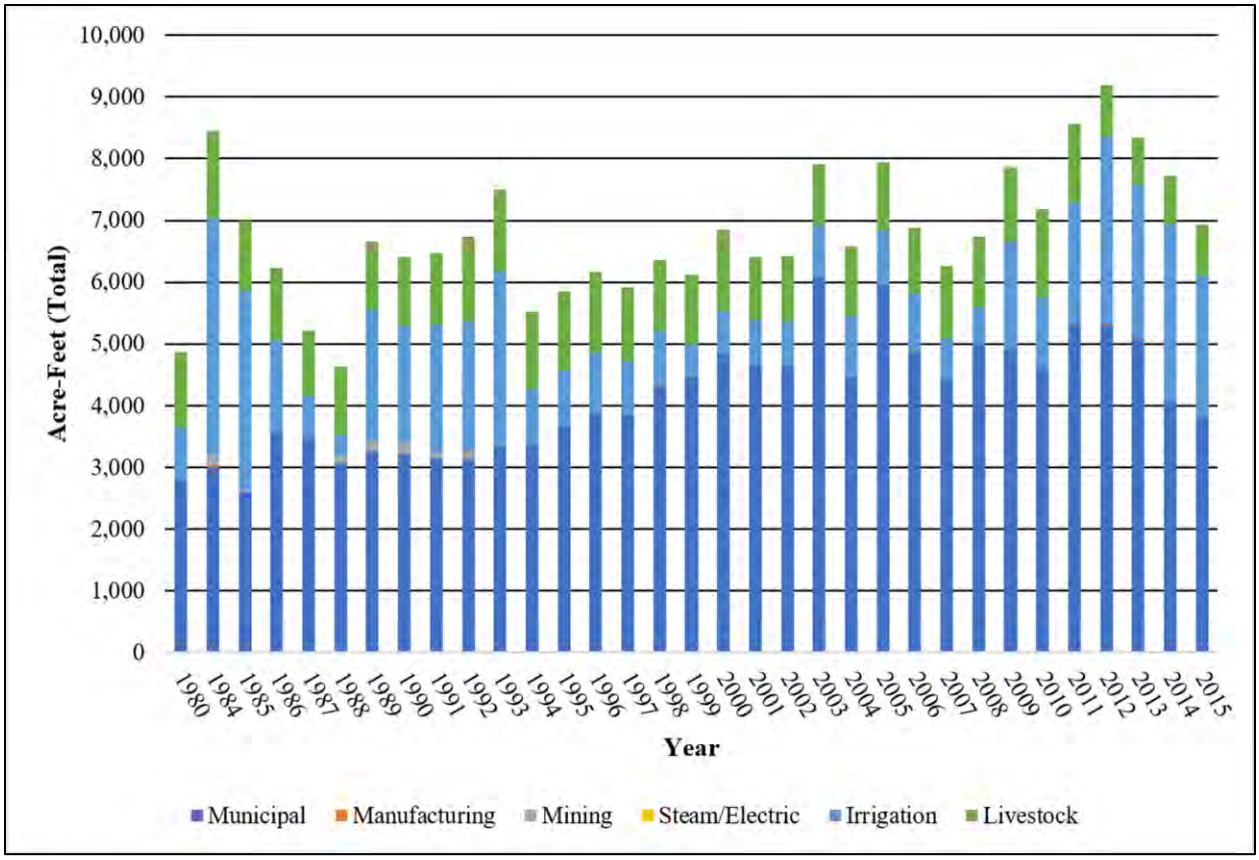


Figure 4.89. Historic pumping volumes from the Ellenburger-San Saba Aquifer in the municipal, manufacturing, mining, and steam/electricity production, irrigation, and livestock sectors from 1980 to 2015 (TWDB, 2017b).

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.

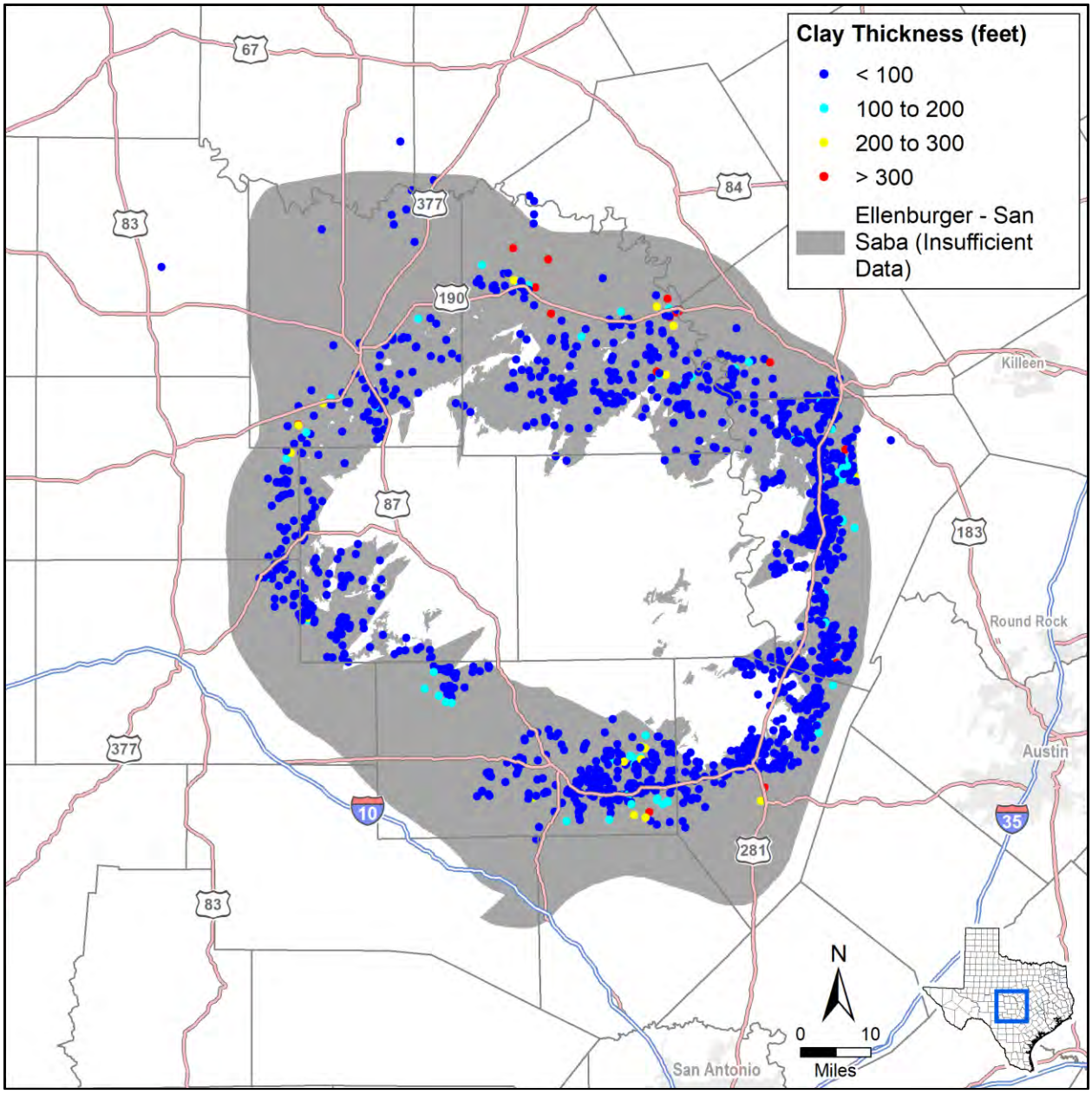


Figure 4.90. Calculated Ellenburger-San Saba Aquifer clay thickness at well locations.

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.

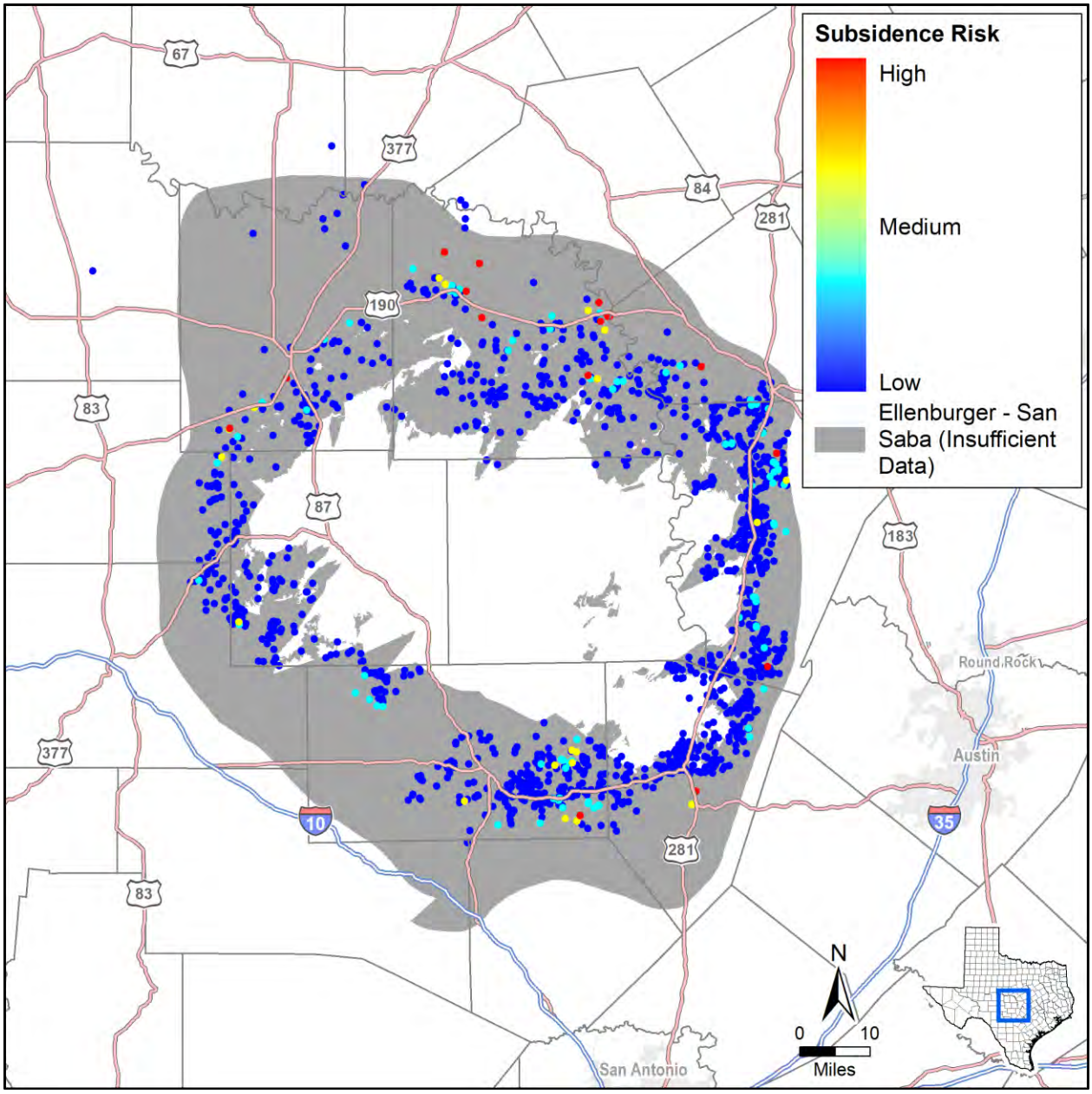


Figure 4.91. Ellenburger-San Saba Aquifer subsidence risk vulnerability at well locations.

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.

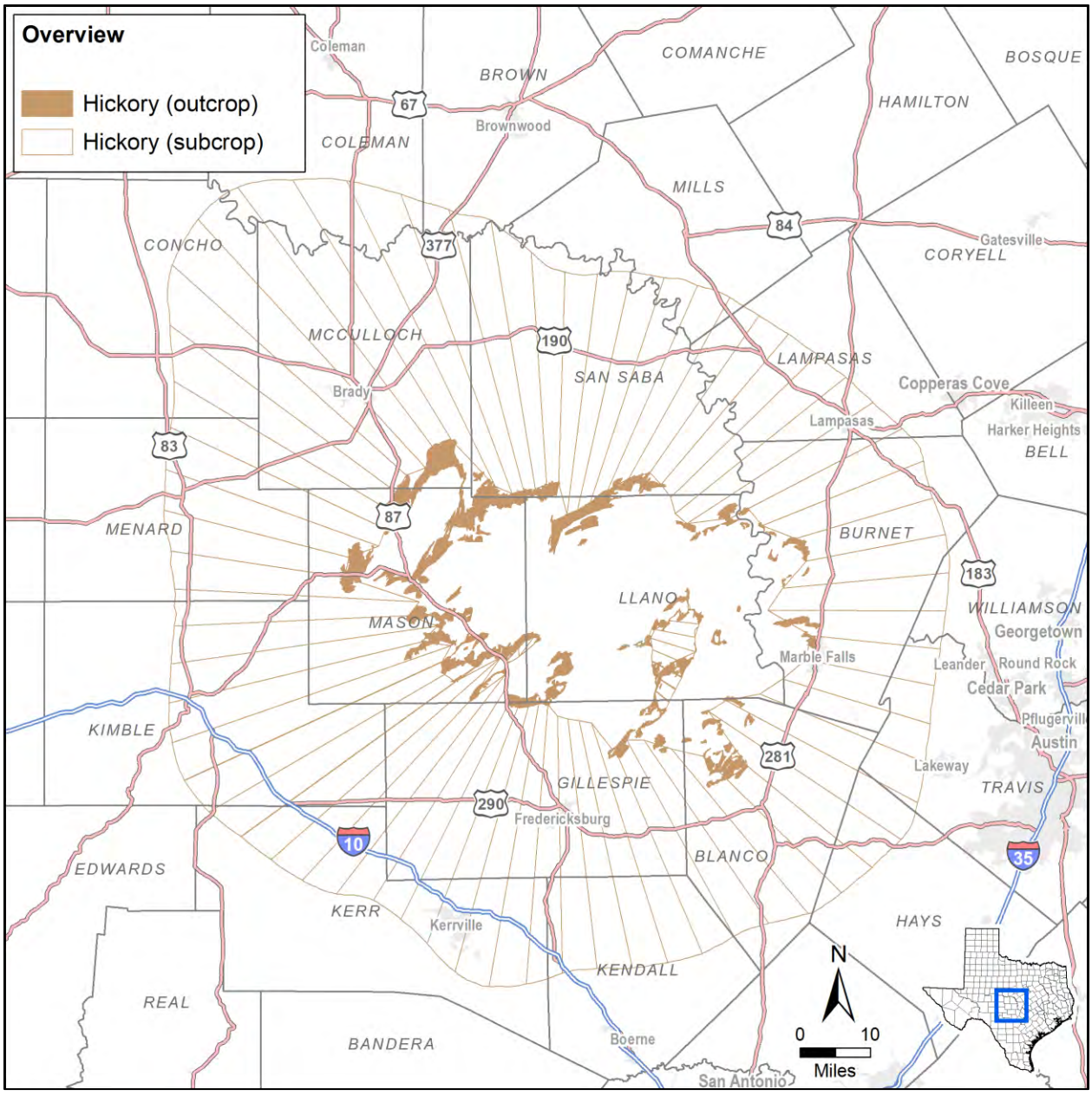


Figure 4.92. Hickory Aquifer extent.

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					

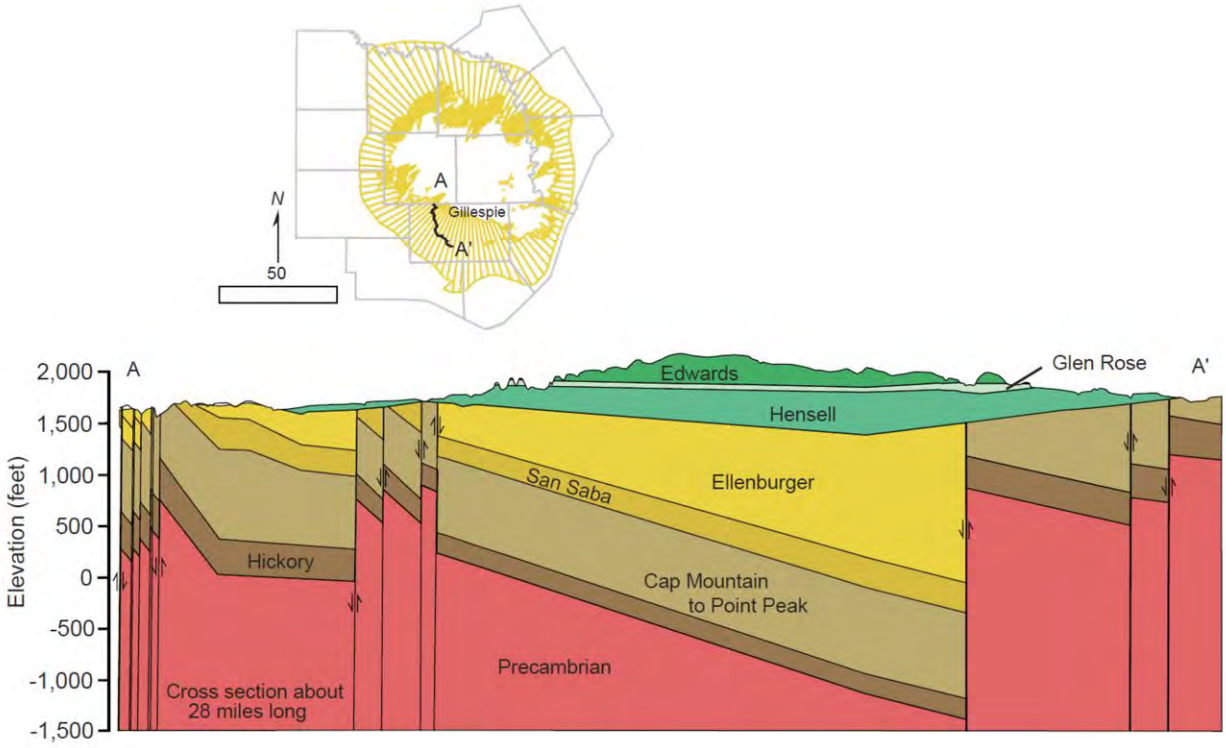


Figure 4.93. Cross-section of the Hickory Aquifer along with overlying and underlying hydrogeologic units (George and others, 2011).

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 (ft^2/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.

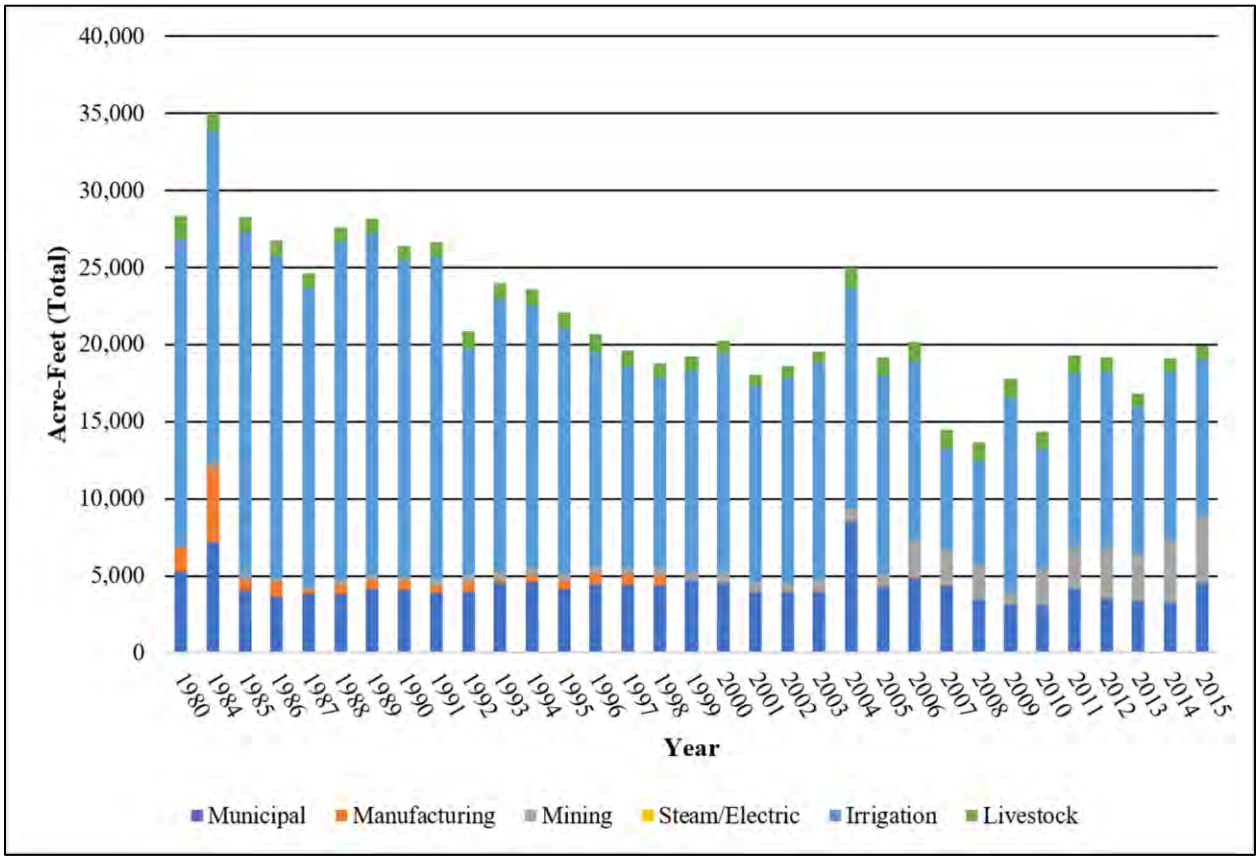


Figure 4.94. Historic pumping volumes from the Hickory Aquifer in the municipal, manufacturing, mining, and steam/electricity production, irrigation, and livestock sectors from 1980 to 2015 (TWDB, 2017b).

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.

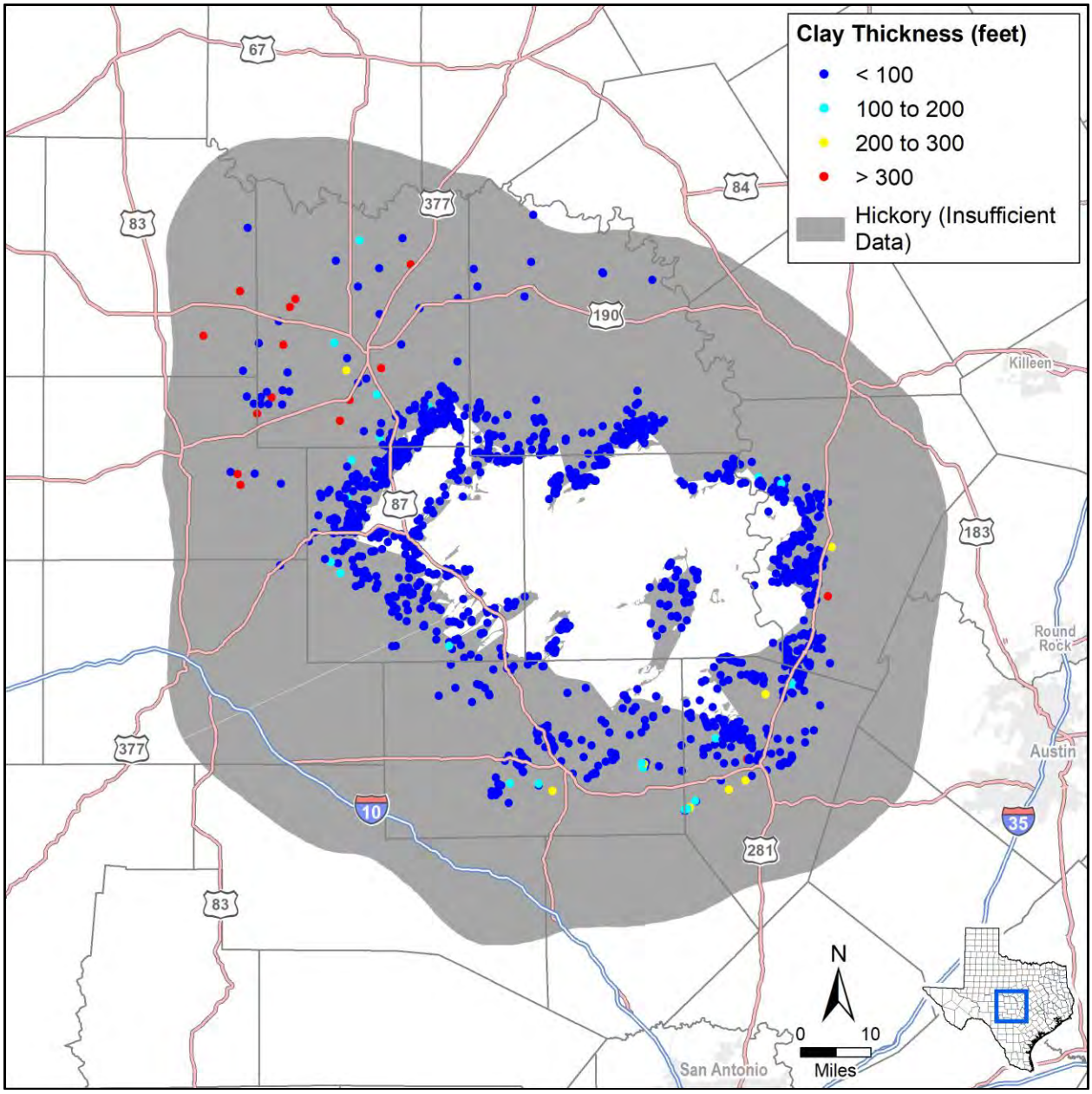


Figure 4.95. Calculated Hickory Aquifer clay thickness at well locations.

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.

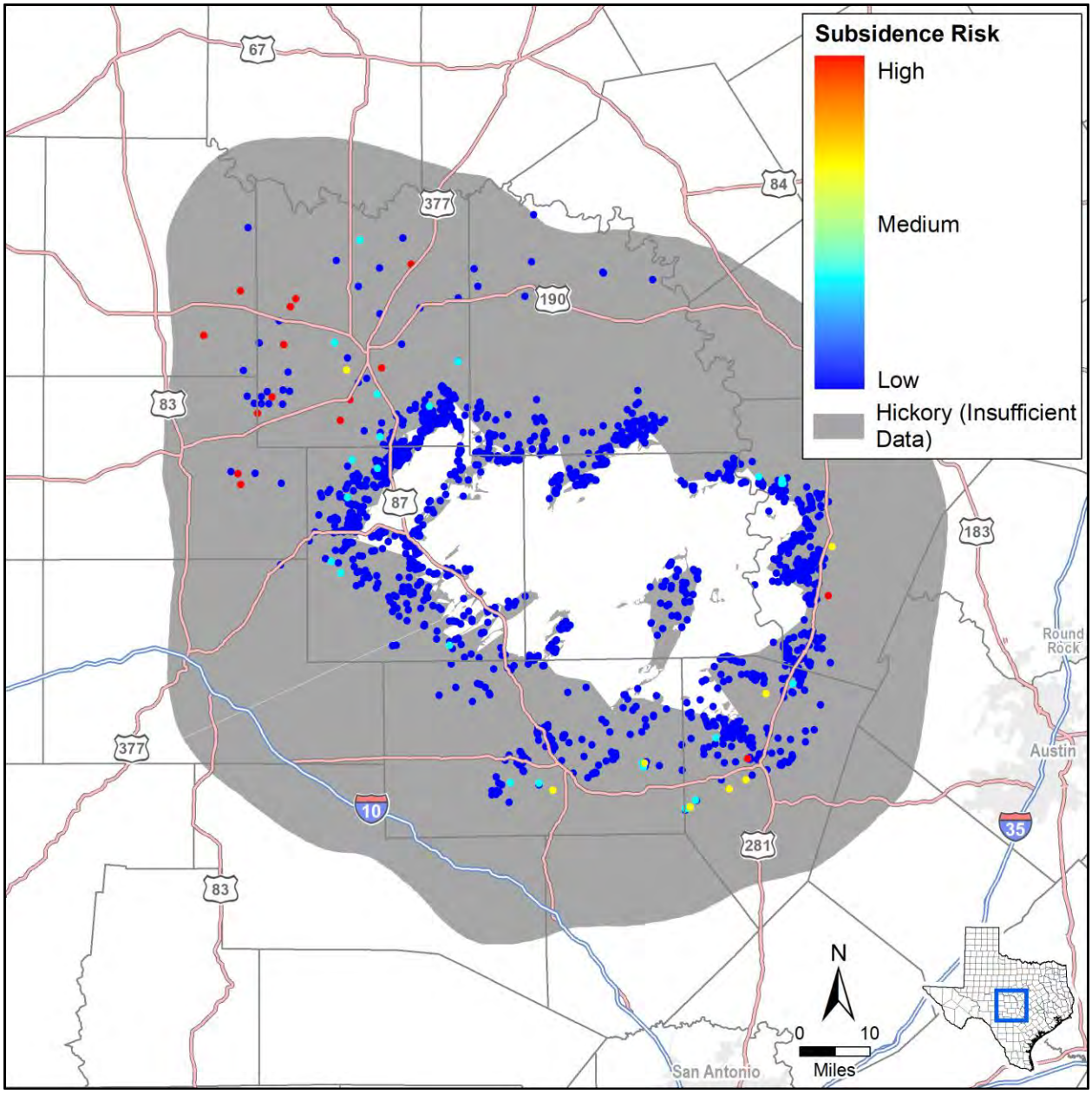


Figure 4.96. Hickory Aquifer subsidence risk vulnerability at well locations.

APPENDIX G

HGCD Resolution No. 2027-1 Adopting the November 17, 2026 Management Plan Revision

Public Hearing Notice Posted at Kerr County Clerk Office and HGCD Office

HGCD Website Posting

Kerrville Daily Times Newspaper Posting & Affidavit of Publication

Special Meeting Agenda Minutes from November 17, 2026 Adopting the Revised Plan

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(DOCUMENT INSERTS - PENDING BOARD ADOPTION)