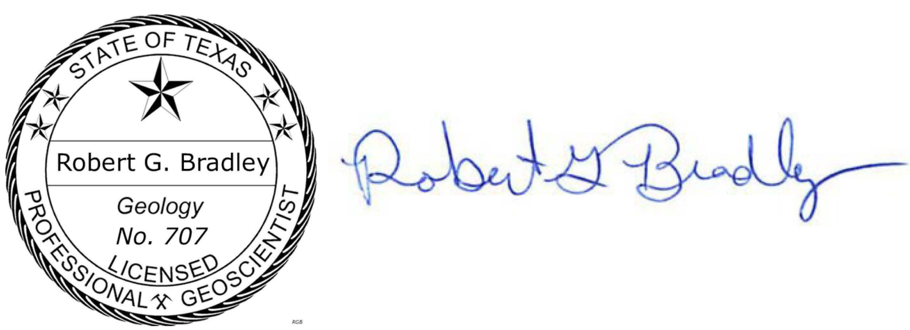
GAM Run 21-015 MAG: Modeled Available Groundwater for the Aquifers in Groundwater Management Area 10

Robert G. Bradley, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Technical Assistance Department
512-936-0870

April 12, 2023



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EXECUTIVE SUMMARY:

The modeled available groundwater for the relevant aquifers of Groundwater Management Area 10—the Austin Chalk-Buda Limestone (relevant in Uvalde County), Barton Springs segment of the Edwards (Balcones Fault Zone), saline portion of the Barton Springs segment of the Edwards (Balcones Fault Zone), western portion of the San Antonio segment of the Edwards (Balcones Fault Zone) in Kinney County, Leona Gravel (relevant in Uvalde County), and Trinity—are summarized by decade for groundwater conservation districts (Tables 1, 3, 5, and 8) and for use in the regional water planning process (Tables 2, 4, 6, and 9).

The modeled available groundwater estimates are 2,935 acre-feet per year in the Austin Chalk Aquifer (Uvalde County); 758 acre-feet per year in the Buda Limestone Aquifer (Uvalde County); 11,557 acre-feet per year in the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer during average recharge conditions (3,765 acre-feet per year during drought conditions); 8,672 acre-feet per year in the saline portion of the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer; 6,321 acre-feet per year in the freshwater portion of the western part of the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer; 9,385 acre-feet per year in the Leona Gravel Aquifer (Uvalde County); and 46,403 acre-feet per year in the Trinity Aquifer.

No new model runs were performed for this round of joint planning. However, referenced reports used appropriate groundwater availability models to determine the modeled available groundwater for the Kinney County area of the Edwards (Balcones Fault Zone) Aquifer and to determine average recharge conditions for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer.

Water budget methods were used to calculate the modeled available groundwater for the rest of the relevant aquifers in Groundwater Management Area 10.

The values for the saline Edwards (Balcones Fault Zone) and Trinity aquifers were recalculated to reflect changes in the groundwater management area boundaries.

The Texas Water Development Board (TWDB) determined that the desired future conditions explanatory report and other materials submitted by Groundwater Management Area 10 were administratively complete on October 20, 2022.

REQUESTOR:

Mr. Michael Redman, chair and technical coordinator of Groundwater Management Area 10 at the time of the desired future condition submittal to the TWDB.

DESCRIPTION OF REQUEST:

Mr. Michael Redman provided the TWDB with the desired future conditions of Groundwater Management Area (GMA) 10. These desired future conditions were adopted by the groundwater conservation district representatives in Groundwater Management Area 10 on October 26, 2021. The desired future conditions, as described in Resolution GMA 10 2021-10-26 (GMA 10, 2021) are:

Austin [Chalk]-Buda Limestone Aquifer(s), relevant in Uvalde County only:

- Buda Limestone: no drawdown (including exempt and non-exempt use); and
- Austin Chalk: no drawdown (including exempt and non-exempt use).

Freshwater Edwards Aquifer in the Northern [Groundwater Management Area 10] Subdivision

- Springflow at Barton Springs during average recharge conditions shall be no less than 49.7 [cubic feet per second] averaged over an 84-month (7-year) period; and,
- Springflow of Barton Springs during extreme drought conditions, including those as severe as a recurrence of the 1950s drought of record, shall be no less than 6.5 [cubic feet per second] average on a monthly basis.

Saline Edwards Aquifer in the Northern [Groundwater Management Area 10] Subdivision

- No more than 75 feet of regional average potentiometric surface drawdown due to pumping when compared to pre-development conditions.

Freshwater Edwards Aquifer in the Western [Groundwater Management Area 10] Subdivision

- The water level in well 70-38-902 shall not fall below 1,184 [feet above] mean sea level.

Leona Gravel Aquifer, relevant in Uvalde County only:

No drawdown (including exempt and non-exempt use).

Trinity Aquifer, in hydrologically confined zone downdip of the Trinity outcrop:

Outside of Uvalde and Bexar counties: average regional well drawdown not exceeding 25 feet during average recharge conditions (including exempt and non-exempt use);

In Uvalde County: no (zero) regional well drawdown (including exempt and non-exempt use); [and]

In Bexar County: non-relevant for joint planning purposes.

In Plum Creek GCD: non-relevant for joint planning purposes.

On December 21, 2021, Mr. Michael Redman, technical coordinator of Groundwater Management Area 10, submitted the desired future conditions packet for Groundwater Management Area 10. TWDB staff reviewed the submitted packet with the desired future conditions and received clarifications on assumptions from the Groundwater Management Area 10 interim technical coordinator Daniel Meyer on June 8, 2022. Confirmation from Mr. Meyer states that the planning horizon for all aquifers is 2010 to 2060, that the desired future condition under extreme drought conditions is based on Hunt and others (2011), as in the last round of planning (2016), and the desired future condition under average recharge conditions are based on assumptions and limitations for the recalibrated model for the Edwards (Balcones Fault Zone) Aquifer-Barton Springs Segment (Hutchison and Hill, 2011a), as in the last round of planning (2016).

METHODS:

The desired future conditions for the Austin Chalk-Buda Limestone aquifers (relevant in Uvalde County), Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer, saline portion of the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer, western portion of the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer in Kinney County, Leona Gravel Aquifer (relevant in Uvalde County), and Trinity Aquifer, are identical to the ones adopted in 2010. The applicable water budget methodologies to calculate modeled available groundwater are unchanged except for the saline Edwards (Balcones Fault Zone) and Trinity aquifers.

Therefore, the modeled available groundwater volumes presented for most of the aquifers are the same as those shown in the previous water budget assessments and model runs.

These reports are AA 10-26 MAG (Thorkildsen and Backhouse, 2011a), AA 10-27 MAG (Thorkildsen and Backhouse, 2011b), GAM Run 10-059 MAG Version 2 (Hutchison and Oliver, 2011), GAM Run 12-002 MAG (Shi, 2012), and AA 10-28 MAG (Bradley, 2013). The modeled available groundwater numbers were recalculated for the Trinity Aquifer and saline Edwards (Balcones Fault Zone) Aquifer to incorporate changes in the Groundwater Management Area 10 boundary.

For the water budget approaches, modeled available groundwater volumes were determined by summing estimates of effective recharge and the change in aquifer storage. The water budget for these analyses is a simplified version of one found in Freeze and Cherry (1979, p.365).

This is currently the best method to calculate a modeled available groundwater estimate in the absence of updated groundwater availability models and additional data. The methods used here have limitations and should be replaced with better tools, including groundwater availability models and additional data as they become available. These analyses assume homogeneous and isotropic aquifers. However, real aquifer conditions do not satisfy these assumptions. These analyses further assume that precipitation is the only source of aquifer recharge, that lateral inflow to the aquifer is equal to lateral outflow from the aquifer, and that future pumping will not alter this balance. In addition, certain assumptions have been made regarding future precipitation, recharge, and streamflow in developing these estimates. Those assumptions also need to be considered and compared to actual future data when evaluating achievement of the desired future condition.

Estimates of modeled available groundwater volumes from the numerical flow models were determined by extracting pumping rates by decade from the model results using ZONEBUDGET Version 3.01 (Harbaugh, 2009). Annual pumping rates were divided by county, river basin, regional water planning area, and groundwater conservation district within Groundwater Management Area 10 (Figures 1 through 7 and Tables 1 through 9).

Modeled Available Groundwater and Permitting

As defined in Chapter 36 of the Texas Water Code (2022), "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 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:

The parameters and assumptions for the modeled available groundwater estimates are described below:

Austin Chalk-Buda Limestone Aquifers

- All parameters and assumptions for the Austin Chalk Aquifer are described in Aquifer Assessment 10-26 MAG (Thorkildsen and Backhouse, 2011a) and for the Buda Limestone in Aquifer Assessment 10-27 MAG (Thorkildsen and Backhouse, 2011b). Both reports assumed a 50-year planning period from 2010 to 2060.
- The Austin Chalk Aquifer in Uvalde County is in a state of dynamic equilibrium and the 2008 estimated pumpage of 2,935 acre-feet per year (Green and others, 2009) achieves the adopted desired future condition.
- The Buda Limestone Aquifer in Uvalde County is in a state of dynamic equilibrium and the 2008 estimated pumpage of 758 acre-feet per year (Green and others, 2009) achieves the adopted desired future condition.
- Conditions are physically possible across the management area and a water-level decline of 0 feet is uniform across the aquifer(s).

Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer

- All parameters and assumptions for the freshwater portion of the Edwards (Balcones Fault Zone) Aquifer in the northern subdivision of Groundwater Management Area 10 are described in GAM Run 10-059 MAG Version 2 (Hutchison and Oliver, 2011). Both approaches discussed below assumed a 50-year planning period from 2010 to 2060.
- A water balance approach was used to estimate modeled available groundwater during extreme drought conditions[1] based on information provided by Barton Springs/Edwards Aquifer Conservation District. See Hunt and others (2011) for additional details on the methods and assumptions for this approach.
- The total amount of water available for discharge by both springs and pumping during extreme drought conditions (11.7 cubic feet per second or 8,470 acre-feet per year) was estimated using information from the 1950's drought of record as described in Hunt and others (2011).
- The water balance approach does not contain information about the spatial distribution of pumping. For the purposes of regional water planning, the estimated total pumping available during extreme drought conditions was divided by county, regional water planning area, river basin, and groundwater conservation district based on the distribution of pumping in the modeled approach under average recharge conditions (Hutchison and Oliver, 2011).
- For average recharge conditions, we used the numerical groundwater flow model that was recalibrated to include the 1950s drought of record for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer. See Hutchison and Hill

[1] The desired future conditions statement adopted by the district representatives in Groundwater Management Area 10 uses the term "extreme drought conditions" to include the drought of record.

(2011a) for assumptions and limitations of the numerical flow model. The model does not cover the Edwards Aquifer (Balcones Fault Zone) in the southernmost Barton Springs/Edwards Aquifer Conservation District jurisdiction (see Figure 4). However, given that the contributing zone for the flow at Barton Springs during average recharge conditions does not extend this far south, the model is appropriate for this purpose.

- As in GAM Run 09-019 (Hutchison and Hill, 2011b), the simulations consisted of 342 7-year simulations extending from 1648 through 1995 based on a tree-ring dataset from Cleaveland (2006). Each 7-year simulation consisted of 84 monthly stress periods.
- Model simulations indicated that, during average recharge conditions, an average springflow of 49.7 cubic feet per second could be maintained by allowing 11,557 acre-feet per year pumping.

Saline portion of the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer

- A detailed description of all parameters is available in Aquifer Assessment 10-35 MAG (Bradley, 2011) for the saline portion of the Edwards (Balcones Fault Zone) Aquifer in the northern subdivision of Groundwater Management Area 10. Table 1 from Barton Springs/Edwards Aquifer Conservation District Technical Memo 2017-1221 (Hunt, 2017) outlines the approach used to estimate modeled available groundwater.

Western portion of the San Antonio segment of the Edwards (Balcones Fault Zone) in Kinney County

- All parameters and assumptions for the freshwater portion of the Edwards (Balcones Fault Zone) Aquifer in the western subdivision of Groundwater Management Area 10 (Kinney County) are described in GAM Run 12-002 MAG (Shi, 2012). We used A 50-year planning period from 2010 to 2060.
- Shi (2012) used 1.01 of the numerical groundwater flow model of the Kinney County Area. See Hutchison and others (2011) for assumptions and limitations of the numerical groundwater flow model. The model was run with MODFLOW-2000 (Harbaugh and others, 2000).
- The model has four layers: Layer 1 represents the Carrizo-Wilcox and associated aquifers, Layer 2 represents the upper Cretaceous formations that yield groundwater, Layer 3 represents the Edwards (Balcones Fault Zone) Aquifer and the Edwards Group of the Edward-Trinity (Plateau) Aquifer, and Layer 4 represents the Trinity Aquifer.

Leona Gravel Aquifer

- A detailed description of all parameters and assumptions is available for the Leona Gravel Aquifer in Uvalde County in Aquifer Assessment 10-28 MAG (Bradley, 2013). We used a 50-year planning period from 2010 to 2060.
- See George (2010) for assumptions and parameters used to estimate effective recharge. Recharge is received mainly from inflow from the Edwards Aquifer (Green and others, 2008) with additional recharge from direct precipitation. The period 1996 to 2011 was selected for analysis of J-27 water levels due to the start of mandated management of the Edwards Aquifer in 1996.

Trinity Aquifer

- A detailed description of all parameters and assumptions is available in Aquifer Assessment 10-06 (Thorkildsen and Backhouse, 2010). We used a 50-year planning period from 2010 to 2060.
- The methods and assumptions used to estimate modeled available groundwater for the Trinity Aquifer remain unchanged from Aquifer Assessment 10-06 (Thorkildsen and Backhouse, 2010). Because the Groundwater Management Area 10 boundary was adjusted since the last round of joint planning, this required a reapportionment of the modeled available groundwater as estimated in the original aquifer assessment.
- Bexar County and Plum Creek Conservation District are excluded from the modeled available groundwater calculations because the groundwater management area designated the Trinity Aquifer as not relevant for the purposes of joint planning in these areas.
- Outcrop areas are calculated as unconfined areas of the aquifer and subcrop areas are calculated as confined areas of the aquifer. Map areas 1-7 represent outcrop areas, and map areas 8-22 are subcrop areas (see Figure 8 and Table 7).
- Recharge is assigned only to the outcrop areas. The average annual precipitation for outcrop map areas was determined from the PRISM Average Annual Total Precipitation, 1991-2020 (PRISM, 2021), which is the average for years 1991 to 2022; the values range from 29 to 36 inches per year. The effective recharge rate is estimated to be 4 percent.
- The effective recharge calculation is the map area, in acres, multiplied by the estimated average annual precipitation, in feet, and the effective recharge rate, in percent.
- Lateral inflow to the Trinity Aquifer in Groundwater Management Area 10 is estimated to be 46,018 acre-feet per year based on the average outflow across the Balcones Fault Zone results (Scenario 6) from GAM Task 10-005 (Hutchison, 2010). This volume was apportioned across each county by aquifer map areas.

GAM Task 10-005 does not include inflows to Uvalde County, so a proportional amount based on inflow to Medina County was used to estimate the inflow to Uvalde County.

- The storage coefficient for the Trinity Aquifer subcrop is assumed to be 1 X 10^{-5} derived from aquifer tests of the Trinity Aquifer subcrop in Travis and Hays counties (Hunt and others, 2010). The storage coefficient for the Trinity Aquifer subcrop in the remaining counties is assumed to be 5 X 10^{-5} as derived from the calibrated groundwater availability model for the Hill Country portion of the Trinity Aquifer system in Texas (Jones and others, 2009). The average specific yield of the Trinity Aquifer outcrop is estimated to be 5 X 10^{-2} (Ashworth, 1983).
- Water-level drawdowns are assumed to be uniform across the aquifer. Annual volumes from drawdowns are calculated by dividing the total volume by 50 years.
- Modeled available groundwater estimates are the sum of the effective recharge, lateral inflow, and volume from water-level decline.

RESULTS:

Tables 1 through 6 and 8 through 9 show the combination of modeled available groundwater summarized (1) by groundwater conservation district and county and (2) by county, river basin, and regional water planning area for use in the regional water planning process. The modeled available groundwater results for the groundwater conservation districts (Tables 1, 3, 5, and 8), reflect the ending year discussed in the Parameters and Assumption Section of this report. Values for planning purposes the in Tables 2, 4, 6, and 9 are not extended past the end of the desired future conditions period (2010-2060).

The modeled available groundwater estimates are 2,935 acre-feet per year in the Austin Chalk Aquifer (Uvalde County); 758 acre-feet per year in the Buda Limestone Aquifer (Uvalde County); 11,557 acre-feet per year in the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer during average recharge conditions (3,765 acre-feet per year during drought conditions); 8,672 acre-feet per year in the saline portion of the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer; 6,321 acre-feet per year in the freshwater portion of the western part of the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer; 9,385 acre-feet per year in the Leona Gravel Aquifer (Uvalde County); and 46,403 acre-feet per year in the Trinity Aquifer.

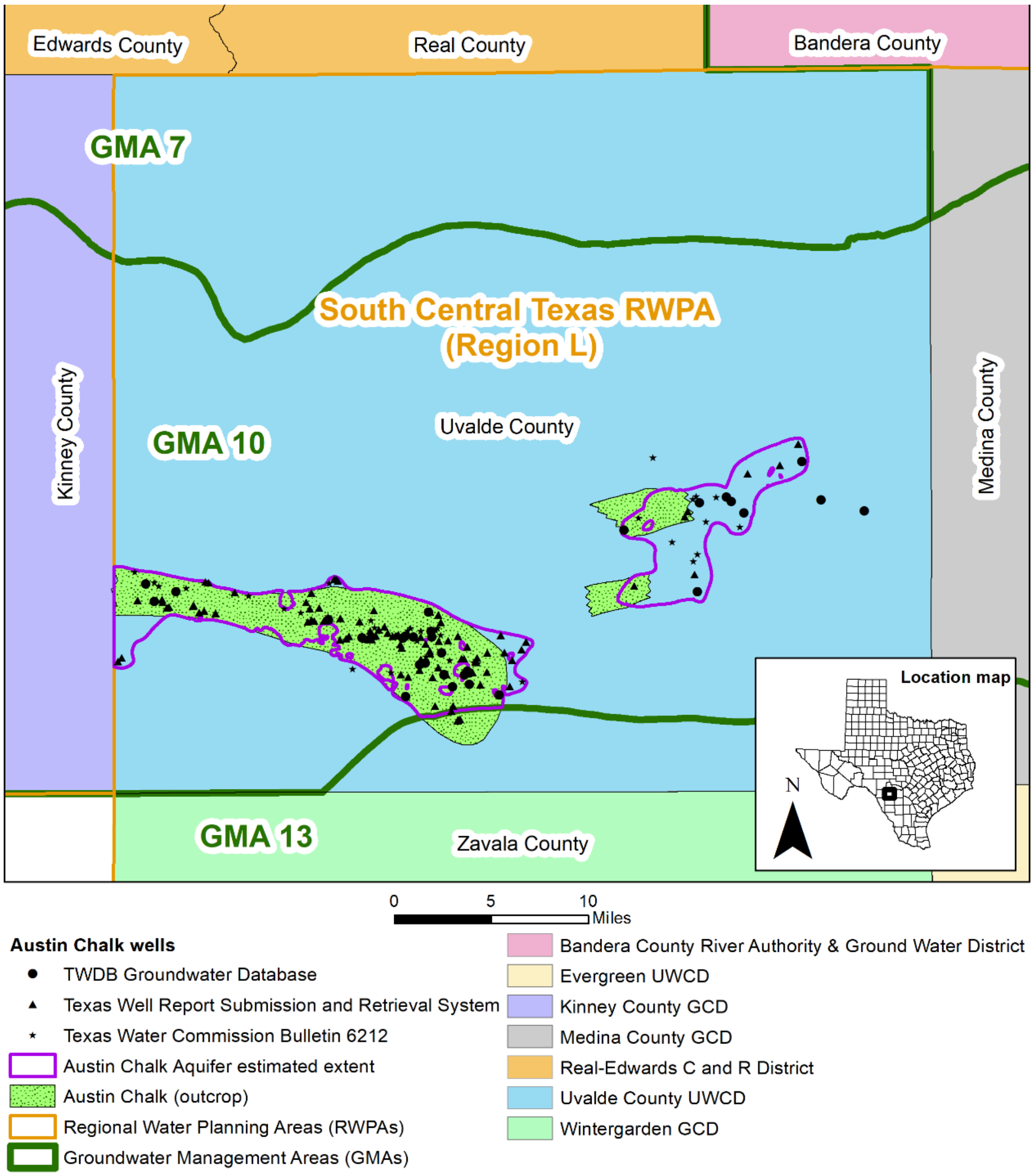


FIGURE 1. **REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER MANAGMEENT AREAS (GMAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS, UWCD), AND COUNTIES IN THE VICINITY OF THE AUSTIN CHALK AQUIFER IN UVALDE COUNTY (MODIFIED FROM BRADLEY AND BOGHICHI, 2018).**

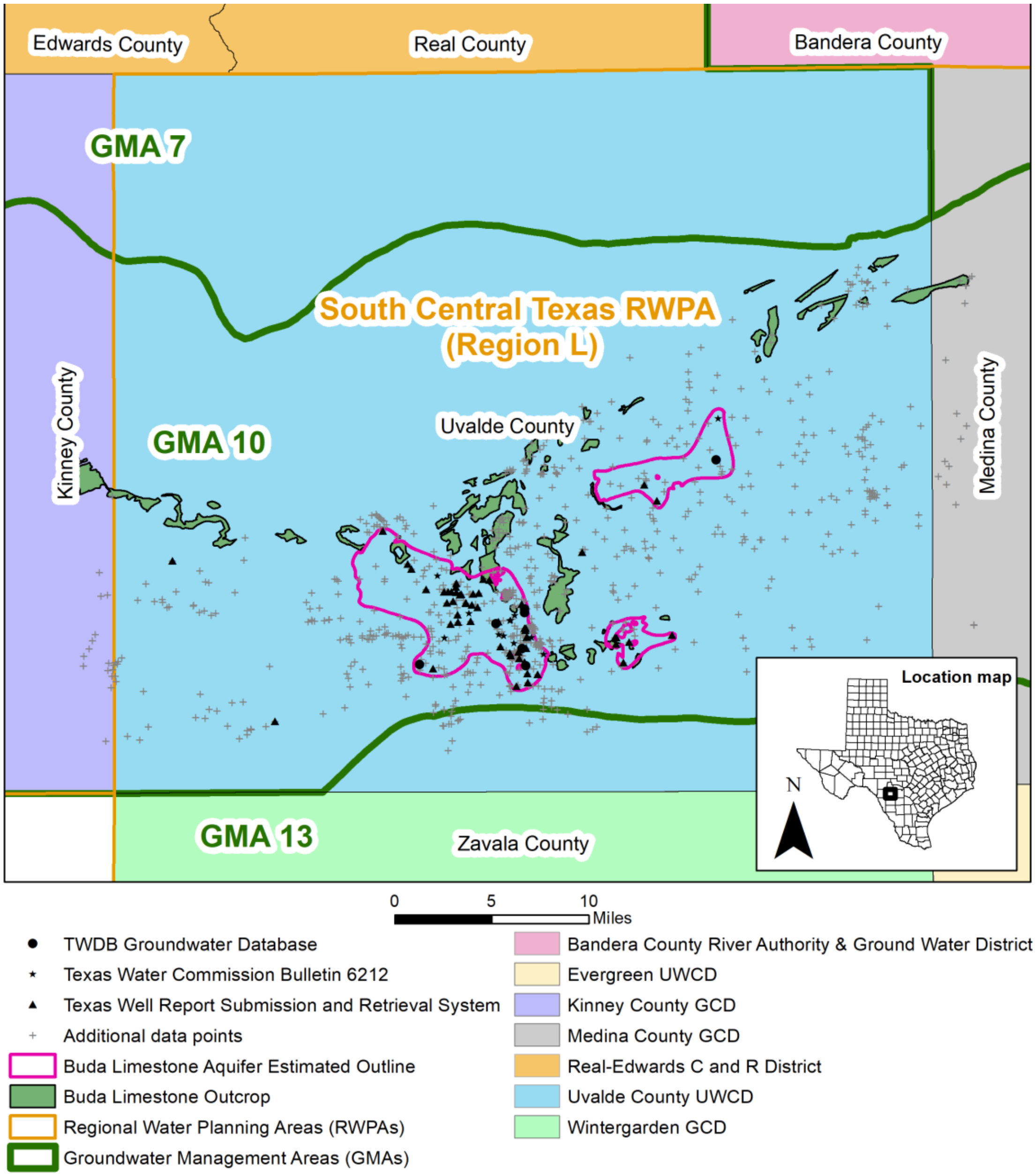


FIGURE 2. REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER MANAGEMENT AREAS (GMAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS, UWCDS), AND COUNTIES IN THE VICINITY OF THE BUDA LIMESTONE AQUIFER IN UVALDE COUNTY (MODIFIED FROM BRADLEY AND BOGHICHI, 2018).

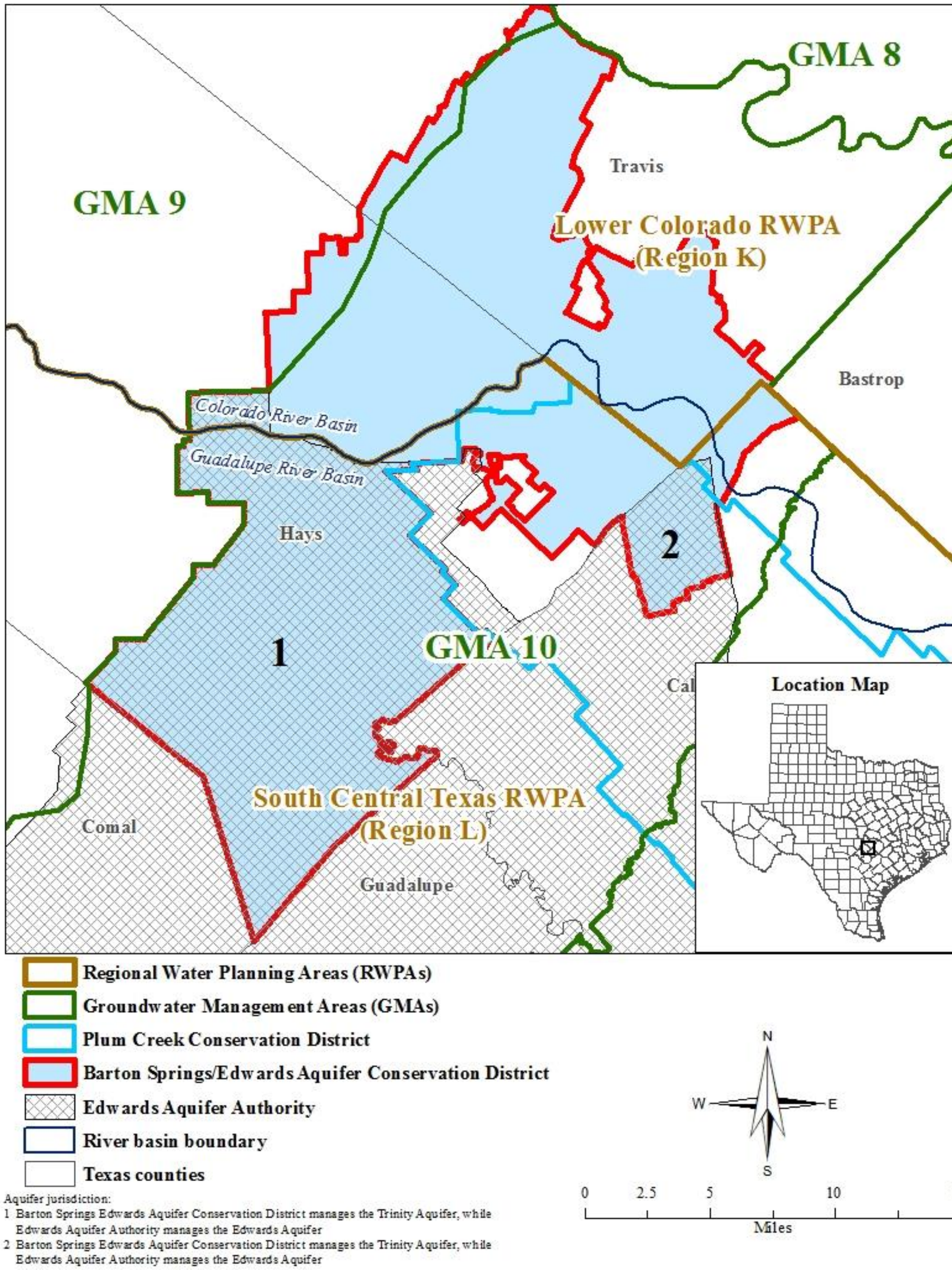


FIGURE 3. REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER MMANAGEMENT AREAS (GMAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), AND COUNTIES IN THE VICINITY OF THE FRESHWATER AND SALINE EDWARDS (BALCONES FAULT ZONE) AQUIFER IN THE NORTHERN SUBDIVISION OF GROUNDWATER MANAGEMENT AREA 10 (FROM BRADLEY AND BOGHICHI, 2018).

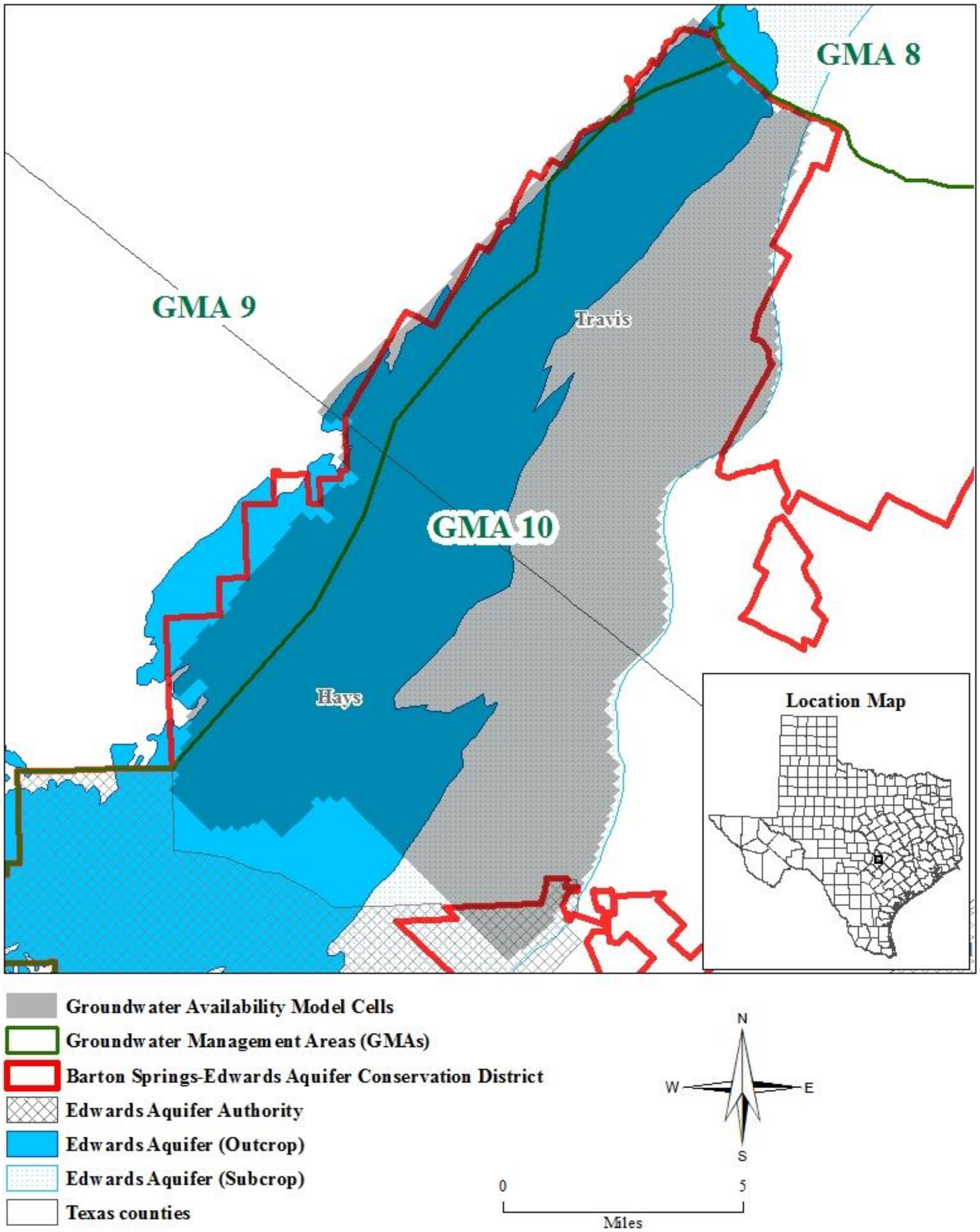
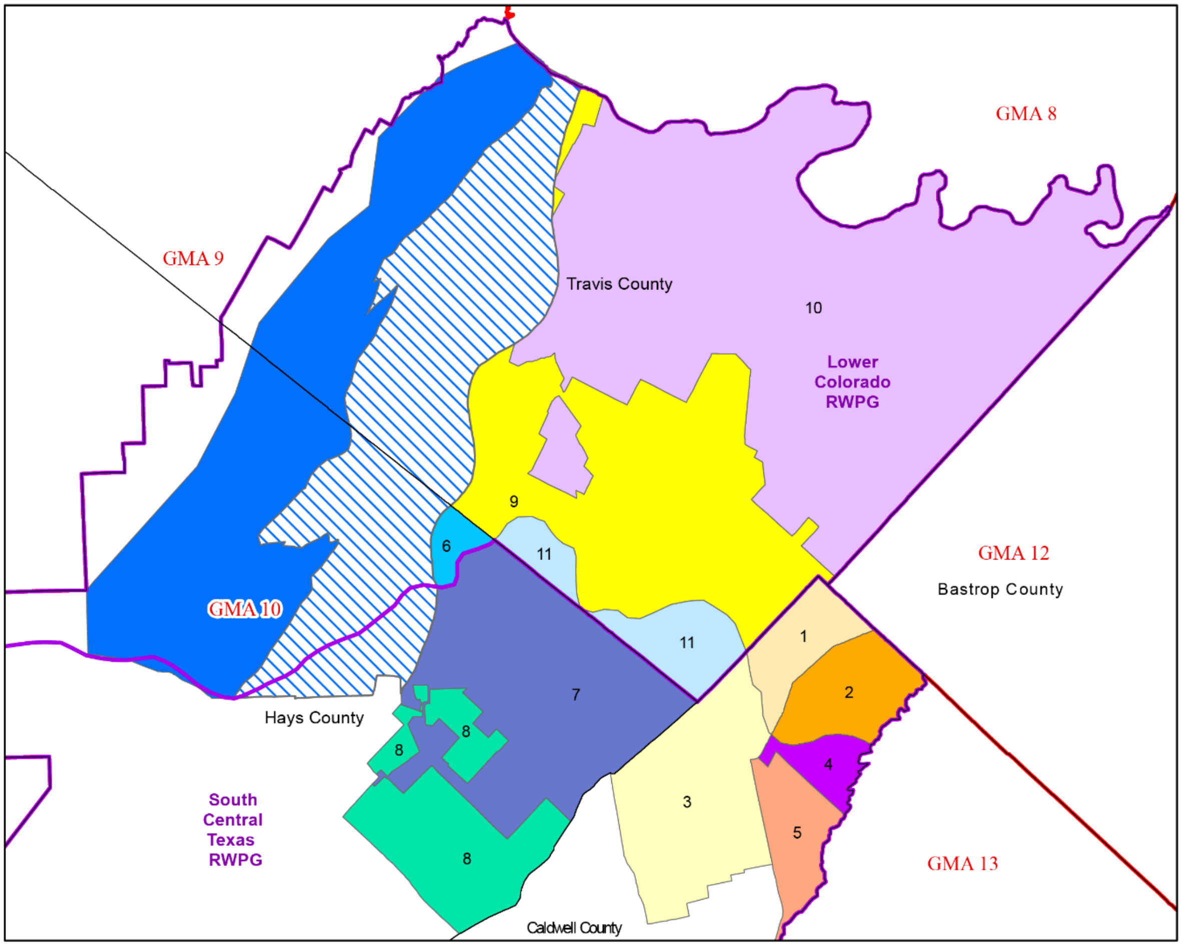


FIGURE 4. GROUNDWATER AVAILABILITY MODEL EXTENT, EDWARDS (BALCONES FAULT ZONE) AQUIFER, AND ADMINISTRATIVE BOUNDARIES IN THE NORTHERN PART OF THE BARTON SPRINGS/EDWARDS AQUIFER CONSERVATION DISTRICT IN THE NORTHERN SUBDIVISION OF GROUNDWATER MANAGEMENT AREA 10 (FROM BRADLEY AND BOGHICHI, 2018).



Texas Counties
Regional Water Planning Areas
Groundwater Management Areas

Northern GMA 10 Freshwater Edwards Aquifer

Outcrop
Subcrop

Northern GMA 10 saline Edwards (Balcones Fault Zone) aquifer map areas

1. Caldwell County, Colorado River Basin, Region L, Barton Springs/Edwards Aquifer CD
2. Caldwell County, Colorado River Basin, Region L, No District
3. Caldwell County, Guadalupe River Basin, Region L, Barton Springs/Edwards Aquifer CD
4. Caldwell County, Guadalupe River Basin, Region L, No District
5. Caldwell County, Guadalupe River Basin, Region L, Plum Creek CD
6. Hays County, Colorado River Basin, Region K, Barton Springs/Edwards Aquifer CD
7. Hays County, Guadalupe River Basin, Region L, Barton Springs/Edwards Aquifer CD
8. Hays County, Guadalupe River Basin, Region L, Plum Creek CD
9. Travis County, Colorado River Basin, Region K, Barton Springs/Edwards Aquifer CD
10. Travis County, Colorado River Basin, Region K, No District
11. Travis County, Guadalupe River Basin, Region K, Barton Springs/Edwards Aquifer CD

FIGURE 5. UPDATED AREAS USED FOR ESTIMATING THE SALINE EDWARDS (BALCONES FAULT ZONE) AQUIFER MODELED AVAILABLE GROUNDWATER IN THE NORTHERN SUBDIVISION OF GROUNDWATER MANAGEMENT AREA 10 (MODIFIED FROM BRADLEY AND BOGHICHI, 2018).

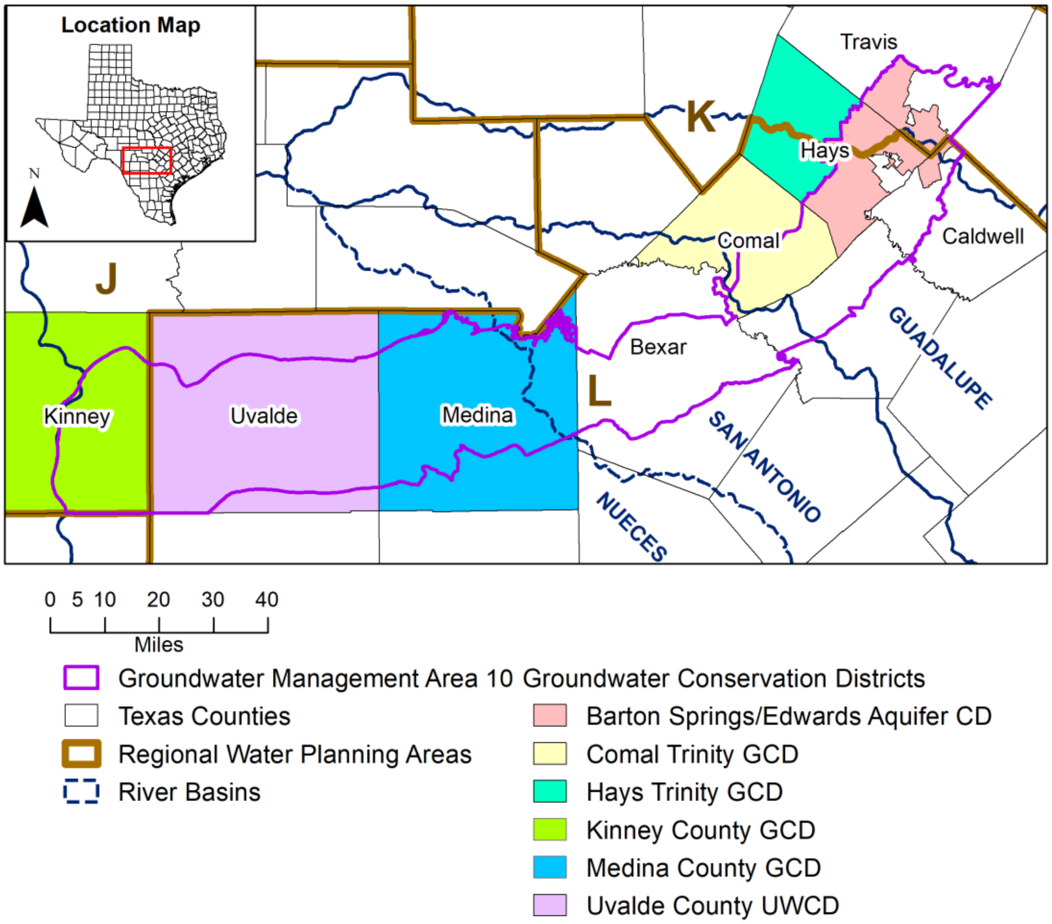


FIGURE 6. REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS, UWCDS), RIVER BASINS, AND COUNTIES IN THE VICINITY OF THE FRESHWATER EDWARDS (BALCONES FAULT ZONE) AQUIFER IN THE WESTERN SUBDIVISION OF GROUNDWATER MANAGEMENT AREA 10 (KINNEY COUNTY) (FROM BRADLEY AND BOGHICHI, 2018).

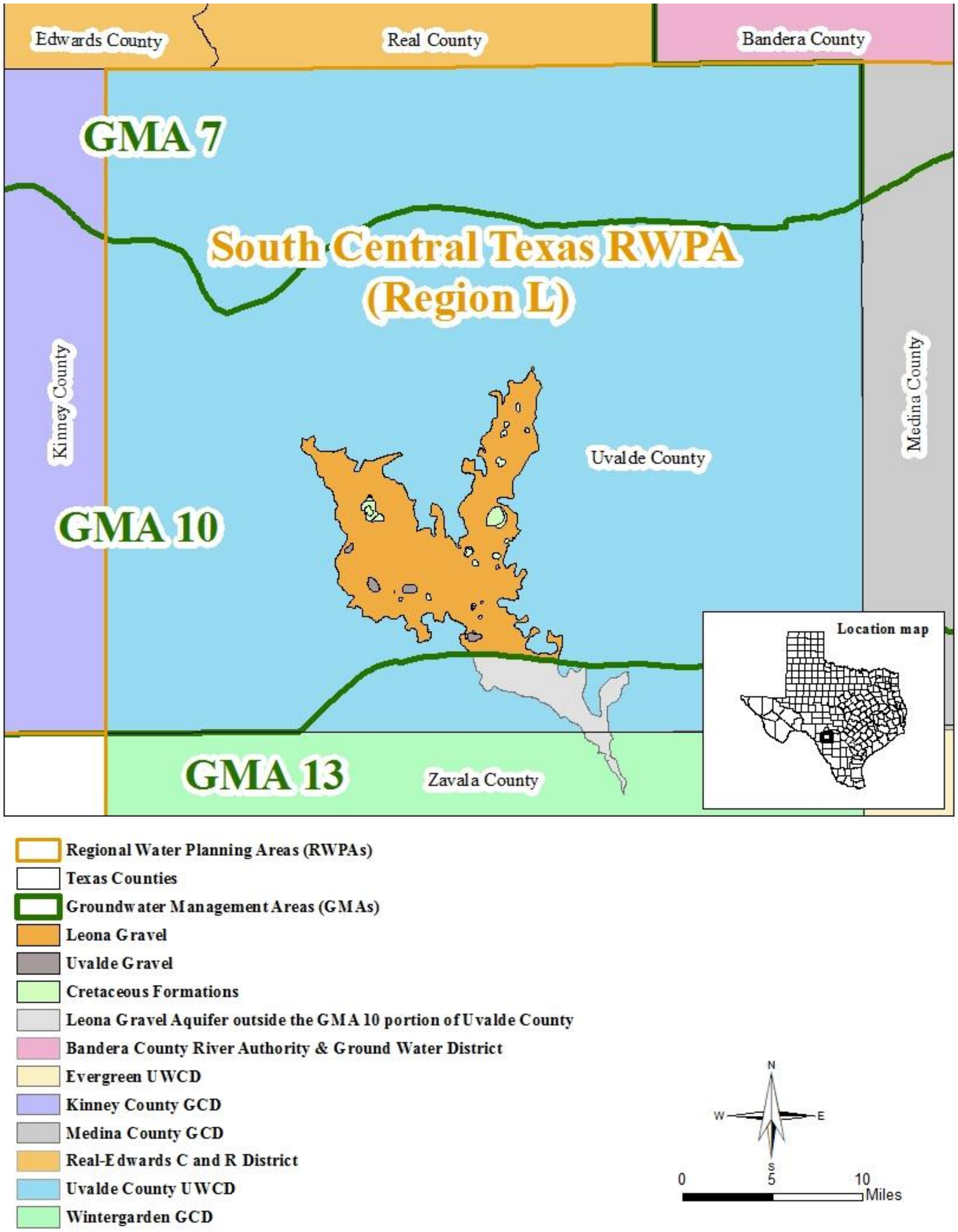


FIGURE 7. REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS, UWCDS), AND COUNTIES IN THE VICINITY OF THE LEONA GRAVEL AQUIFER IN GROUNDWATER MANAGEMENT AREA 10 (UVALDE COUNTY) (FROM BRADLEY AND BOGHICHI, 2018).

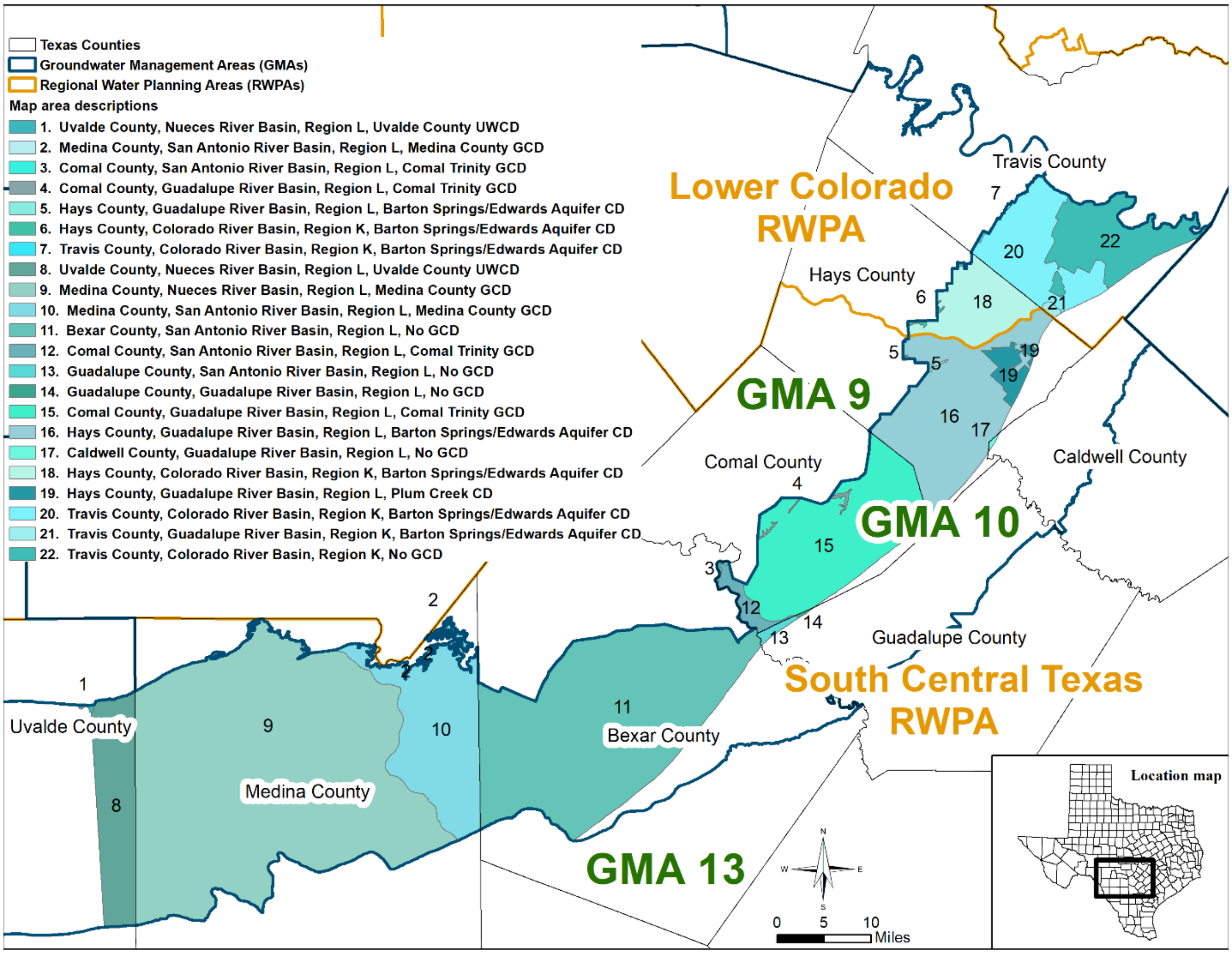


FIGURE 8 REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), AND COUNTIES IN THE VICINITY OF THE TRINITY AQUIFER IN GROUNDWATER MANAGEMENT AREA 10. MAP AREAS INDICATE COUNTY, RIVER BASIN, REGIONAL WATER PLANNING AREA, AND GROUNDWATER CONSERVATION DISTRICT SPLITS.

TABLE 1. MODELED AVAILABLE GROUNDWATER FOR THE AUSTIN CHALK, BUDA LIMESTONE, AND LEONA GRAVEL AQUIFERS IN UVALDE COUNTY IN GROUNDWATER MANAGEMENT AREA 10 FOR EACH DECADE BETWEEN 2020 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR (FROM BRADLEY AND BOGHICHI, 2018).

Groundwater Conservation District	County	Aquifer	2020	2030	2040	2050	2060
Uvalde County Underground Water Conservation District	Uvalde	Austin Chalk	2,935	2,935	2,935	2,935	2,935
		Buda Limestone	758	758	758	758	758
		Leona Gravel	9,385	9,385	9,385	9,385	9,385
Total			**13,078**	**13,078**	**13,078**	**13,078**	**13,078**

TABLE 2. MODELED AVAILABLE GROUNDWATER FOR THE AUSTIN CHALK, BUDA LIMESTONE, AND LEONA GRAVEL AQUIFERS IN UVALDE COUNTY IN GROUNDWATER MANAGEMENT AREA 10 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2030 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR (FROM BRADLEY AND BOGHICHI, 2018).

County	RWPA	River Basin	Aquifer	2030	2040	2050	2060
Uvalde	L	Nueces	Austin Chalk	2,935	2,935	2,935	2,935
			Buda Limestone	758	758	758	758
			Leona Gravel	9,385	9,385	9,385	9,385
Total				**13,078**	**13,078**	**13,078**	**13,078**

TABLE 3. MODELED AVAILABLE GROUNDWATER FOR THE FRESHWATER PORTION OF THE EDWARDS (BALCONES FAULT ZONE [BFZ]) AQUIFER IN GROUNDWATER MANAGEMENT AREA 10 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD) AND COUNTY FOR EACH DECADE BETWEEN 2020 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR (FROM BRADLEY AND BOGHICHI, 2018).

Recharge Condition	Groundwater Conservation District	County	Aquifer	2020	2030	2040	2050	2060
Average	Barton Springs/Edwards Aquifer Conservation District	Hays	Edwards (BFZ)	7,950	7,950	7,950	7,950	7,950
		Travis	Edwards (BFZ)	3,578	3,578	3,578	3,578	3,578
	Non-District Areas	Hays	Edwards (BFZ)	29	29	29	29	29
Total for average recharge conditions			**Edwards (BFZ)**	**11,557**	**11,557**	**11,557**	**11,557**	**11,557**
Drought	Barton Springs/Edwards Aquifer Conservation District	Hays	Edwards (BFZ)	2,590	2,590	2,590	2,590	2,590
		Travis	Edwards (BFZ)	1,166	1,166	1,166	1,166	1,166
	Non-District Areas	Hays	Edwards (BFZ)	9	9	9	9	9
Total for drought recharge conditions			**Edwards (BFZ)**	**3,765**	**3,765**	**3,765**	**3,765**	**3,765**
Kinney County Groundwater Conservation District		Kinney	Edwards (BFZ)	6,321	6,321	6,321	6,321	6,321

TABLE 4. MODELED AVAILABLE GROUNDWATER FOR THE FRESHWATER PORTION OF THE EDWARDS (BALCONES FAULT ZONE [BFZ]) AQUIFER IN GROUNDWATER MANAGEMENT AREA 10 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2030 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR (FROM BRADLEY AND BOGHICHI, 2018).

Recharge Condition	County	RWPA	River Basin	Aquifer	2030	2040	2050	2060
Average	Hays	K	Colorado	Edwards (BFZ)	7,037	7,037	7,037	7,037
	Hays	L	Guadalupe	Edwards (BFZ)	942	942	942	942
	Travis	K	Colorado	Edwards (BFZ)	3,578	3,578	3,578	3,578
	Total for average recharge conditions			**Edwards (BFZ)**	**11,557**	**11,557**	**11,557**	**11,557**
Drought	Hays	K	Colorado	Edwards (BFZ)	2,292	2,292	2,292	2,292
	Hays	L	Guadalupe	Edwards (BFZ)	307	307	307	307
	Travis	K	Colorado	Edwards (BFZ)	1,166	1,166	1,166	1,166
	Total for drought recharge conditions			**Edwards (BFZ)**	**3,765**	**3,765**	**3,765**	**3,765**
Not applicable	Kinney	J	Nueces	Edwards (BFZ)	6,319	6,319	6,319	6,319
			Rio Grande	Edwards (BFZ)	2	2	2	2

TABLE 5. MODELED AVAILABLE GROUNDWATER FOR THE SALINE PORTION OF THE EDWARDS (BALCONES FAULT ZONE [BFZ]) AQUIFER IN GROUNDWATER MANAGEMENT AREA 10 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
Barton Springs/Edwards Aquifer Conservation District	Caldwell	Edwards (BFZ)	834	834	834	834	834
	Hays	Edwards (BFZ)	1,179	1,179	1,179	1,179	1,179
	Travis	Edwards (BFZ)	1,769	1,769	1,769	1,769	1,769
Non-District Areas	Caldwell	Edwards (BFZ)	368	368	368	368	368
	Travis	Edwards (BFZ)	3,720	3,720	3,720	3,720	3,720
Plum Creek Conservation District	Caldwell	Edwards (BFZ)	208	208	208	208	208
	Hays	Edwards (BFZ)	594	594	594	594	594
Total		**Edwards (BFZ)**	**8,672**	**8,672**	**8,672**	**8,672**	**8,672**

TABLE 6. MODELED AVAILABLE GROUNDWATER FOR THE SALINE PORTION OF THE EDWARDS (BALCONES FAULT ZONE [BFZ]) AQUIFER IN GROUNDWATER MANAGEMENT AREA 10 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2030 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Aquifer	2030	2040	2050	2060
Caldwell	L	Colorado	Edwards (BFZ)	455	455	455	455
		Guadalupe	Edwards (BFZ)	955	955	955	955
Hays	K	Colorado	Edwards (BFZ)	66	66	66	66
	L	Guadalupe	Edwards (BFZ)	1,707	1,707	1,707	1,707
Travis	K	Colorado	Edwards (BFZ)	5,199	5,199	5,199	5,199
		Guadalupe	Edwards (BFZ)	290	290	290	290
Total			**Edwards (BFZ)**	**8,672**	**8,672**	**8,672**	**8,672**

TABLE 7. INPUTS TO CALCULATE MODELED AVAILABLE GROUNDWATER FOR THE TRINITY AQUIFER IN GROUNDWATER MANAGEMENT AREA 10, SUMMARIZED BY MAP AREA REPRESENTING EACH GROUNDWATER CONSERVATION DISTRICT (GCD), COUNTY, RIVER BASIN, AND REGIONAL WATER PLANNING AREA (RWPA) COMBINATIONS. AREA VALUES ARE IN ACRES, AND OTHER VALUES ARE IN ACRE-FEET PER YEAR.

Map area[1,2]	GCD	County	River Basin	RWPG	Areal extent	Estimated annual effective recharge	Estimated annual lateral inflow	Estimated annual volume from water-level decline	Modeled available groundwater
1	Uvalde County UWCD	Uvalde	Nueces	L	372	36	0	0	36
2	Medina County GCD	Medina	San Antonio	L	9	1	0	0	1
3	Comal Trinity GCD	Comal	San Antonio	L	596	69	148	15	232
4	Comal Trinity GCD	Comal	Guadalupe	L	1,282	159	318	32	509
5	Barton Springs/Edwards Aquifer CD	Hays	Guadalupe	L	505	63	12	13	88
6	Barton Springs/Edwards Aquifer CD	Hays	Colorado	K	879	105	21	22	148
7	Barton Springs/Edwards Aquifer CD	Travis	Colorado	K	757	94	4	19	117

1. Map areas 1-7 represent outcrop areas and were assumed to be under unconfined aquifer conditions.
2. Map areas 8-22 represent subcrop areas and were assumed to be under confined aquifer conditions.

TABLE 7 (CONTINUED)

Map area[1,2]	GCD	County	River Basin	RWPG	Areal extent	Estimated annual effective recharge	Estimated annual lateral inflow	Estimated annual volume from water-level decline	Modeled available groundwater
8	Uvalde County UWCD	Uvalde	Nueces	L	63,455	0	755	0	755
9	Medina County GCD	Medina	Nueces	L	455,940	0	5,422	11	5,433
10	Medina County GCD	Medina	San Antonio	L	103,050	0	1,225	3	1,228
11	No GCD	Bexar	San Antonio	L	N/A	N/A	N/A	N/A	N/A
12	Comal Trinity GCD	Comal	San Antonio	L	8,707	0	2,157	0	2,157
13	No GCD	Guadalupe	San Antonio	L	2,360	0	585	0	585
14	No GCD	Guadalupe	Guadalupe	L	303	0	75	0	75
15	Comal Trinity GCD	Comal	Guadalupe	L	123,770	0	30,666	3	30,669

1. Map areas 1-7 represent outcrop areas and were assumed to be under unconfined aquifer conditions.
2. Map areas 8-22 represent subcrop areas and were assumed to be under confined aquifer conditions.

TABLE 7 (CONTINUED)

Map area[1,2]	GCD	County	River Basin	RWPG	Areal extent	Estimated annual effective recharge	Estimated annual lateral inflow	Estimated annual volume from water-level decline	Modeled available groundwater
16	Barton Springs/Edwards Aquifer CD	Hays	Guadalupe	K	111,163	0	2,656	3	2,659
17	No GCD	Caldwell	Guadalupe	L	424	0	10	0	10
18	Barton Springs/Edwards Aquifer CD	Hays	Colorado	K	43,190	0	1,032	1	1,033
19	Plum Creek CD	Hays	Guadalupe	L	N/A	N/A	N/A	N/A	N/A
20	Barton Springs/Edwards Aquifer CD	Travis	Colorado	K	58,524	0	337	1	338
21	Barton Springs/Edwards Aquifer CD	Travis	Guadalupe	K	1,340	0	8	0	8
22	No GCD	Travis	Colorado	K	55,760	0	321	1	322

1. Map areas 1-7 represent outcrop areas and were assumed to be under unconfined aquifer conditions.
2. Map areas 8-22 represent subcrop areas and were assumed to be under confined aquifer conditions.

TABLE 8. MODELED AVAILABLE GROUNDWATER FOR THE TRINITY AQUIFER IN GROUNDWATER MANAGEMENT AREA 10 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
Barton Springs/ Edwards Aquifer CD	Hays	Trinity	3,928	3,928	3,928	3,928	3,928
	Travis	Trinity	463	463	463	463	463
Comal Trinity GCD	Comal	Trinity	33,567	33,567	33,567	33,567	33,567
Medina County GCD	Medina	Trinity	6,662	6,662	6,662	6,662	6,662
Non District Areas	Caldwell	Trinity	10	10	10	10	10
	Guadalupe	Trinity	660	660	660	660	660
	Travis	Trinity	322	322	322	322	322
Uvalde County UWCD	Uvalde	Trinity	791	791	791	791	791
Total		**Trinity**	**46,403**	**46,403**	**46,403**	**46,403**	**46,403**

TABLE 9. MODELED AVAILABLE GROUNDWATER FOR THE TRINITY AQUIFER IN GROUNDWATER MANAGEMENT AREA 10 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2030 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Aquifer	2030	2040	2050	2060
Caldwell	L	Guadalupe	Trinity	10	10	10	10
Comal	L	Guadalupe	Trinity	31,178	31,178	31,178	31,178
		San Antonio	Trinity	2,389	2,389	2,389	2,389
Guadalupe	L	Guadalupe	Trinity	75	75	75	75
		San Antonio	Trinity	585	585	585	585
Hays	K	Colorado	Trinity	1,181	1,181	1,181	1,181
	L	Guadalupe	Trinity	2,747	2,747	2,747	2,747
Medina	L	Nueces	Trinity	5,433	5,433	5,433	5,433
		San Antonio	Trinity	1,229	1,229	1,229	1,229
Travis	K	Colorado	Trinity	777	777	777	777
		Guadalupe	Trinity	8	8	8	8
Uvalde	L	Nueces	Trinity	791	791	791	791
Total			**Trinity**	**46,403**	**46,403**	**46,403**	**46,403**

LIMITATIONS:

Groundwater availability models

The groundwater models 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 a 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 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.

Water budget methods

The water budget analyses were determined to be the best methods to develop a modeled available groundwater estimate for those aquifers without a groundwater availability model. However, these methods have limitations and should be replaced with better tools including groundwater availability models and additional data that are not currently available. The methods used here assume that the aquifer is in a state of dynamic equilibrium. This assumption needs to be considered and compared to actual water levels and pumping data when evaluating the desired future condition of no drawdown.

Given these limitations, users of this information are cautioned that the modeled available groundwater estimates should not be considered a definitive, permanent description of the amount of groundwater that can be pumped to meet the adopted desired future condition. 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 future groundwater pumping and water levels to know if they are achieving their desired future conditions. Because of the limitations and assumptions in this analysis, it is important that the groundwater conservation districts work with the TWDB to refine these modeled available groundwater numbers given the reality of how the aquifer responds to the actual amount and location of pumping now and in the future.

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