GAM Run 16-033 MAG: Modeled Available Groundwater for the Aquifers in Groundwater Management Area 10

Robert G. Bradley, P.G. and Radu Boghici, P.G.
Texas Water Development Board
Groundwater Division
(512) 463-5808
July 20, 2018

STATE OF TEXAS
Robert G. Bradley
Geology
No. 707
LICENSED
PROFESSIONAL GEOSCIENTIST

STATE OF TEXAS
Radu Boghici
Geology
No. 482
LICENSED
PROFESSIONAL GEOSCIENTIST

This page is intentionally left blank.

GAM RUN 16-033 MAG: MODELED AVAILABLE GROUNDWATER AQUIFERS IN GROUNDWATER MANAGEMENT AREA 10

Robert G. Bradley, P.G. and Radu Boghici, P.G.
Texas Water Development Board
Groundwater Division
(512) 463-5808
July 20, 2018

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 for the groundwater conservation districts (Tables 1, 3, 5, and 8) and by decade 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); 8,564 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 46,481 acre-feet per year in the Trinity Aquifer. Appropriate groundwater availability models were used 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 Texas Water Development Board (TWDB) determined that the explanatory report and other materials were administratively complete on February 12, 2018.

REQUESTOR:

Mr. John Dupnik, Chair of Groundwater Management Area 10.

DESCRIPTION OF REQUEST:

In a letter dated November 3, 2017, Mr. John Dupnik provided the TWDB with the desired future conditions of the relevant aquifers in Groundwater Management Area 10. The desired future conditions, adopted June 26, 2017, by the groundwater conservation districts within Groundwater Management Area 10, are reproduced below:

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.

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 purpose.

In response to a request for clarifications from the TWDB on December 14, 2017, and January 29, 2018 Mr. John Dupnik indicated the following preferences for calculating modeled available groundwater volumes in Groundwater Management Area 10:

Austin Chalk-Buda Limestone aquifers (only in Uvalde County)

The TWDB will use the methods and assumptions from AA 10-26 MAG and AA 10-27 MAG, with a planning period from 2010 to 2060.

Freshwater Edwards, Northern Subdivision

The TWDB will use the methods and assumptions from GAM Run 10-059 MAG Version 2, with a planning period from 2010 to 2060. Groundwater Management Area 10 specified two desired future conditions for this aquifer. We will provide only the drought conditions modeled available groundwater for regional water planning purposes because this corresponds to the methods used in regional water planning (planning for water in times of drought). We will provide both the average recharge conditions and the drought conditions modeled available groundwater in the final report. The modeled available groundwater values will be unchanged from the previous planning cycle.

Saline Edwards, Northern Subdivision

The TWDB will use aquifer parameters from AA 10-35 MAG, with a planning period from 2010 to 2060, but we will recalculate with a simple water budget as outlined in Table 1 of the Saline Edwards explanatory report, instead of the method used in AA 10-35 MAG. On January 29, 2018, we received Technical Memo 2017-1221 from the Barton Springs/ Edwards Aquifer Conservation District, which outlines the technical clarification on the method to use for this aquifer.

Freshwater Edwards, Western Subdivision (only in Kinney County)

The TWDB will use the methods and assumptions from GAM Run 12-002 MAG, with a planning period from 2010 to 2060. The modeled available groundwater values will be unchanged from the previous planning cycle.

Leona Gravel (only in Uvalde County)

The TWDB will use the methods and assumptions from AA 10-28 MAG, with a planning period from 2010 to 2060.

Trinity (downdip of recharge zone)

The TWDB will use the methods and assumptions from AA 10-06 with a planning period from 2010 to 2060. The changes in groundwater district boundaries since AA 10-06 will require reapportionment of the modeled available groundwater.

METHODS:

The desired future conditions for the Austin Chalk-Buda Limestone aquifers (relevant in Uvalde County), Leona Gravel Aquifer (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, Trinity Aquifer, and western portion of the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer in Kinney County 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 to incorporate changes in the Groundwater Management Area 10 and groundwater conservation district boundaries. Additionally, a change in methodology required the recalculation of the Saline Edwards (Balcones Fault Zone) Aquifer modeled available groundwater, however, aquifer parameters from AA 10-35 MAG (Bradley, 2011) were incorporated into this assessment.

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 were a simplified version of one found in Freeze and Cherry (1979, p.365).

This was the best method to calculate a modeled available groundwater estimate at this time; however, this method has limitations and should be replaced with better tools, including groundwater 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

Chapter 36 of the Texas Water Code defines “modeled available groundwater” to be 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). Districts must also 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:

Austin Chalk-Buda Limestone Aquifers

- All parameters and assumptions for the Austin Chalk Aquifer are described in AA 10-26 MAG (Thorkildsen and Backhouse, 2011a) and for the Buda Limestone in AA 10-27 MAG (Thorkildsen and Backhouse, 2011b). Both reports assumed a 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 (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 (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).

Freshwater Edwards (Balcones Fault Zone) Aquifer

NORTHERN SUBDIVISION OF GROUNDWATER MANAGEMENT AREA 10

- 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 clarifications we received from Mr. John Dupnik, we assume 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 (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 for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer. See Hutchison and Hill (2011a) for assumptions and limitations of the numerical flow model.

---

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

- 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, during average recharge conditions, the contributing zone for the flow at Barton Springs does not extend this far south, we deemed the use of the model appropriate for this purpose.
- Similar to 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.

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.
- We used version 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.

Saline Edwards (Balcones Fault Zone) Aquifer

- A detailed description of all parameters is available for the saline portion of the Edwards (Balcones Fault Zone) Aquifer in the northern subdivision of Groundwater Management Area 10 in AA 10-35 MAG (Bradley, 2011). Table 1 from Barton Springs/Edwards Aquifer Conservation District Technical Memo 2017-1221 (Hunt, 2017) outlines the approach used to estimate modeled available groundwater. We used a 50-year planning period from 2010 to 2060.

- Map areas (Figure 5) from AA 10-35 MAG (Bradley, 2011) were used to calculate volumes based on a storage coefficient of 7.0×10^{-4} (Hunt and others, 2010) and a desired future condition of 75 feet of drawdown. Map areas are designated as Plum Creek Conservation District only where their jurisdiction does not overlap with the Barton Springs/Edwards Aquifer Conservation District.
- A water-level decline of 75 feet is uniform across the aquifer for the 50-year planning period.
- The aquifer is homogeneous and isotropic, lateral inflow to the aquifer is equal to lateral outflow from the aquifer, and future pumping will not alter this balance.

Leona Gravel Aquifer

- A detailed description of all parameters and assumptions is available for the Leona Gravel Aquifer in Uvalde County in AA 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 AA 10-06 (Thorkildsen and Backhouse, 2010b). 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 AA 10-06 (Thorkildsen and Backhouse, 2010b). 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. First, changes were made to the Groundwater Management Area 10 boundary to exclude the Guadalupe County, Hays Trinity, and Trinity Glen Rose groundwater conservation districts. There were also changes in to the Barton Springs/Edwards Aquifer Conservation District boundary to include a portion of the Trinity Aquifer in Hays County.

- Bexar County is excluded from the modeled available groundwater calculations because the groundwater management area designated the Trinity Aquifer in Bexar County not relevant for joint planning.
- Outcrop areas are calculated as unconfined areas of the aquifer and subcrop areas are calculated as confined areas of the aquifer. Map areas 1-10 represent outcrop areas, and map areas 11-31 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 Texas Climatic Atlas (Narasimhan and others, 2008), which is the average for years 1971 to 2000; 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 1×10^{-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 5×10^{-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 5×10^{-2} (Ashworth, 1983).
- Water-level drawdowns are 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. For purposes of planning (Tables 2, 4, 6, and 9), the values may have been populated past the dates noted in Parameters and Assumption Section using the trend of results.

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); 8,564 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 46,481 acre-feet per year in the Trinity Aquifer.

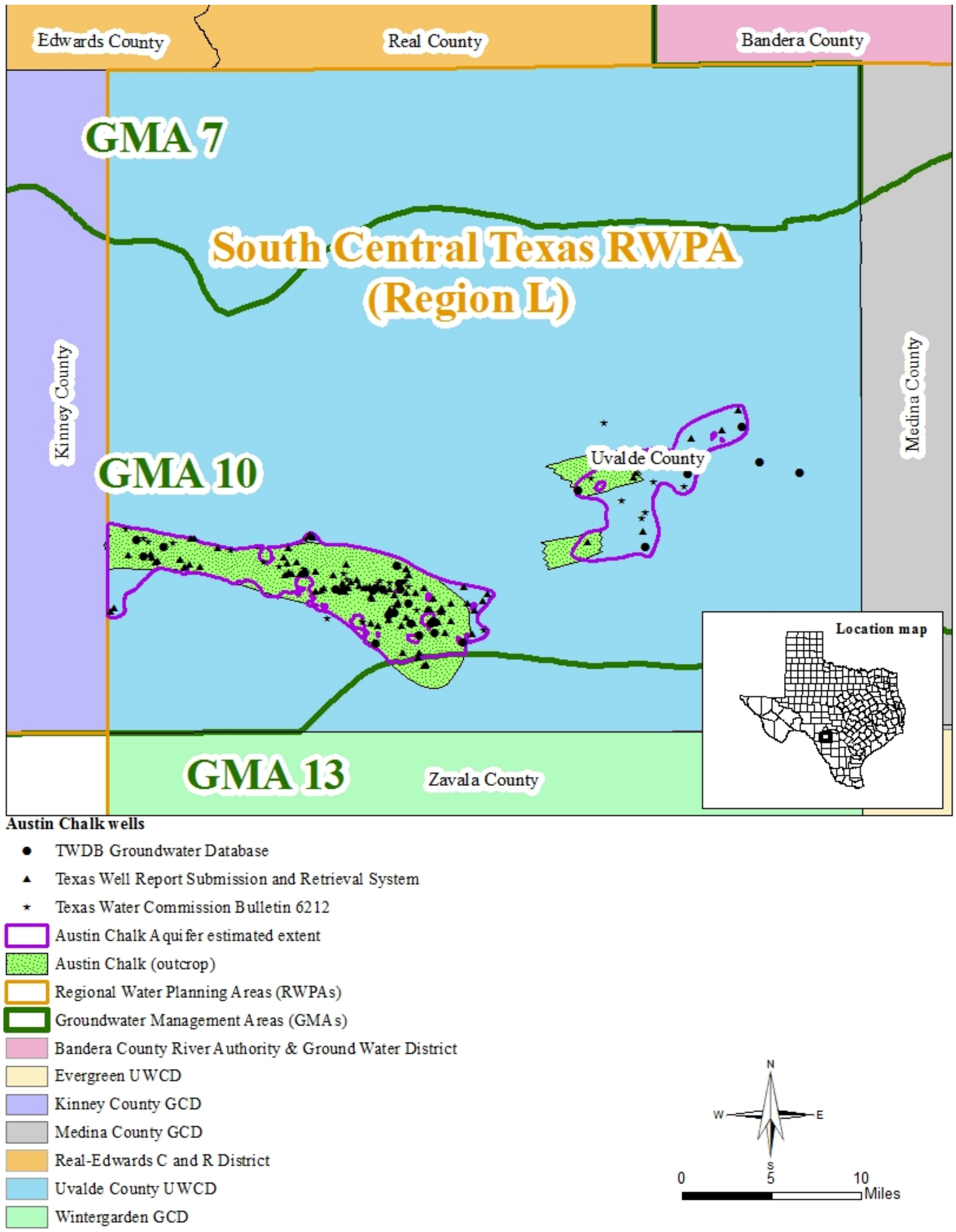

FIGURE 1. MAP SHOWING REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), AND COUNTIES IN THE VICINITY OF THE AUSTIN CHALK AQUIFER IN UVALDE COUNTY.

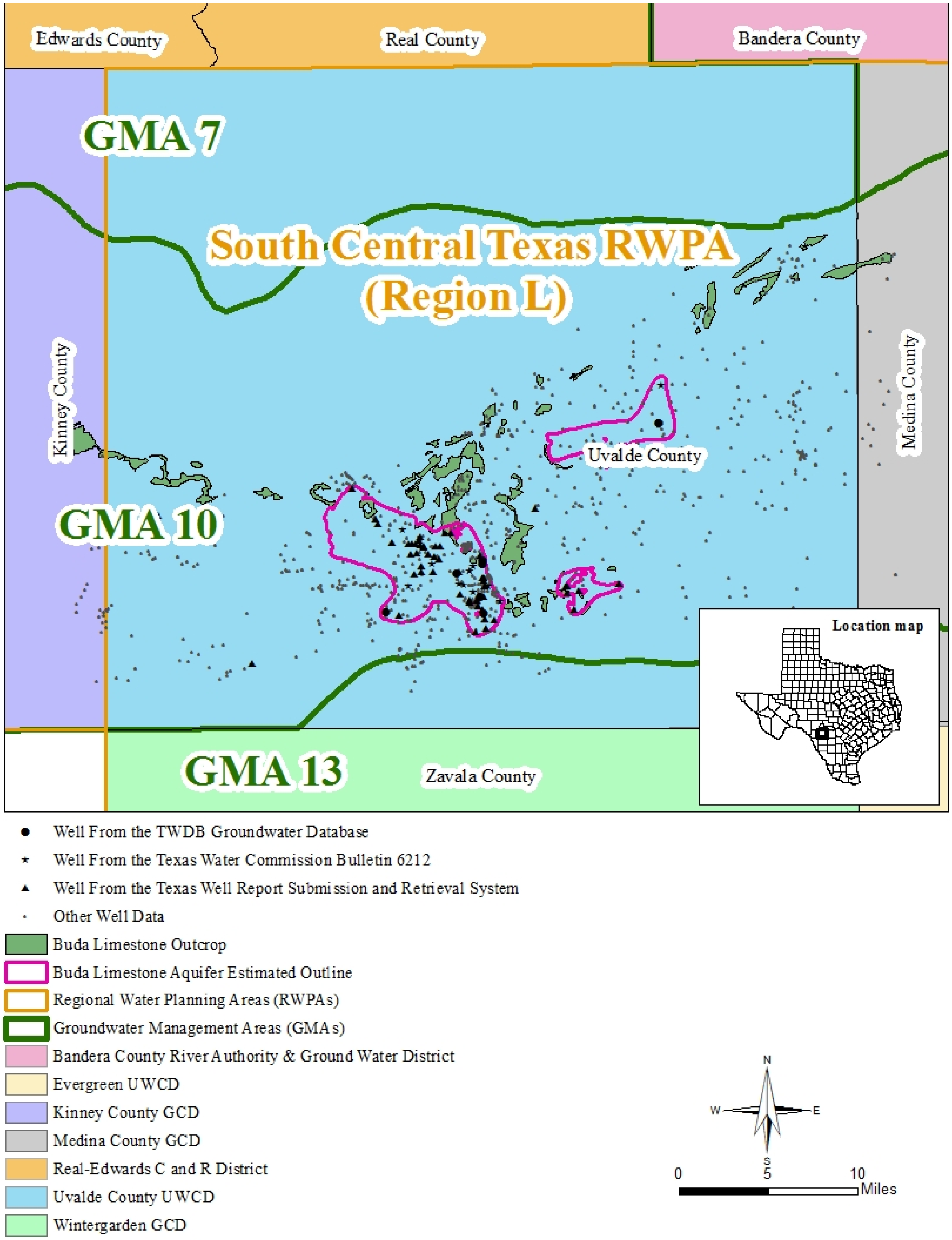

FIGURE 2. MAP SHOWING REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), AND COUNTIES IN THE VICINITY OF THE BUDA LIMESTONE AQUIFER IN UVALDE COUNTY.

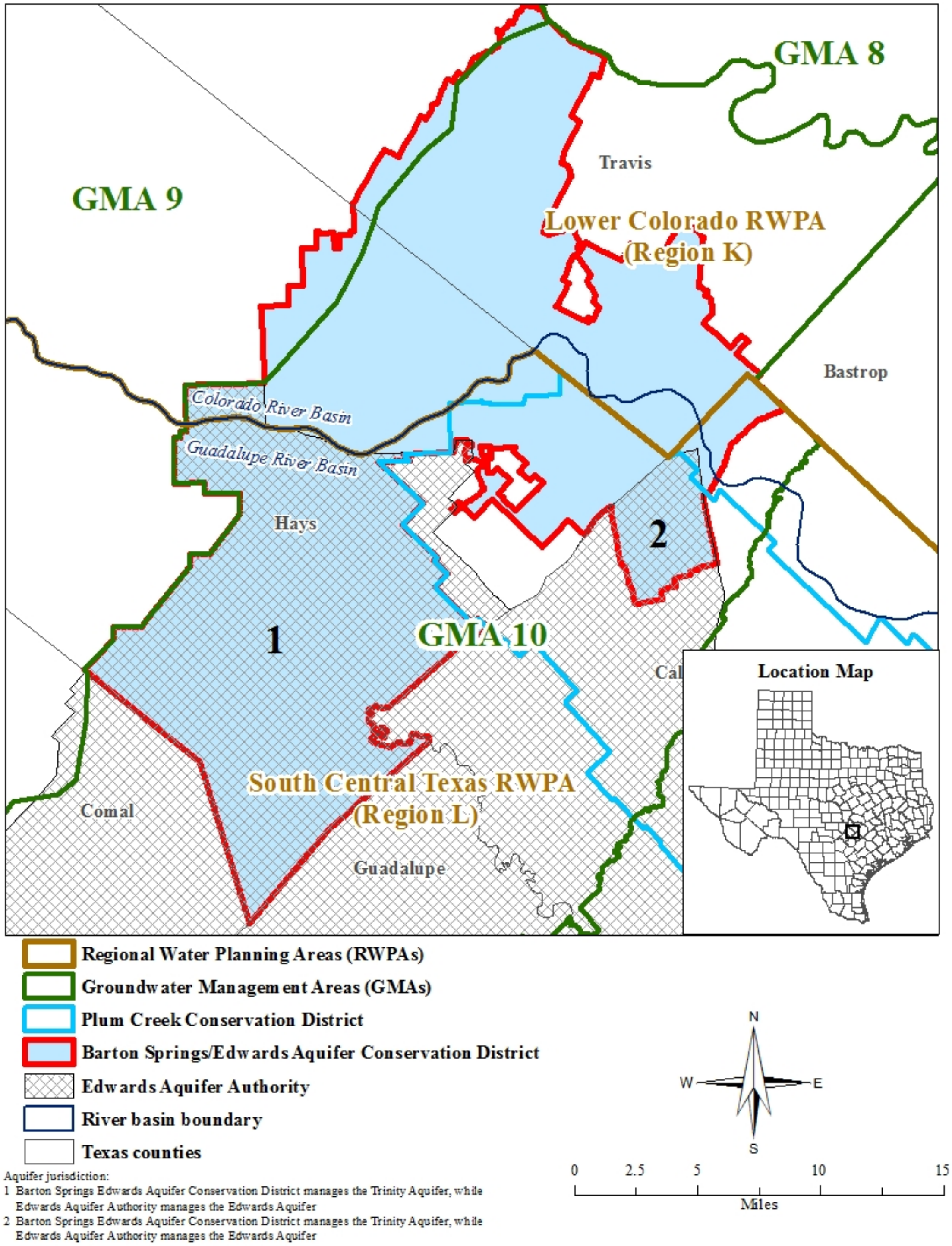

FIGURE 3. **MAP SHOWING REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), AND COUNTIES IN THE VICINITY OF THE FRESHWATER AND SALINE EDWARDS (BALCONES FAULT ZONE) AQUIFER IN THE NORTHERN SUBDIVISION OF GROUNDWATER MANAGEMENT AREA 10.**

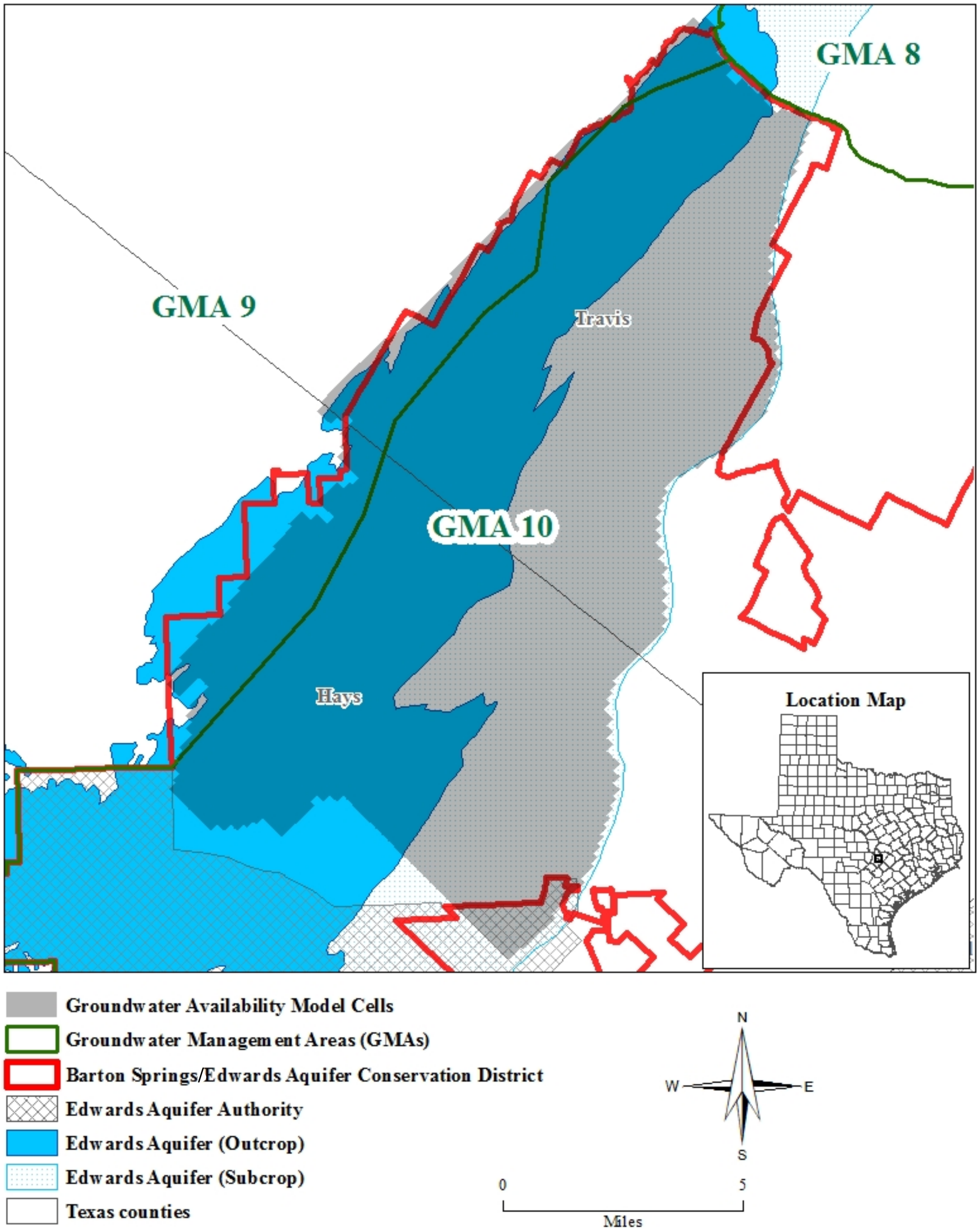

FIGURE 4. **MAP SHOWING GROUNDWATER AVAILABILITY MODEL EXTENT, EDWARDS (BALCONES FAULT ZONE) AQUIFER, AND ADMINISTRATIVE BOUNDARIES IN THE NORTHERN PART OF THE BARTON SPRINGS/EDWARDS AQUIFER CONSERVATION DISTRICT IN THE NORTHERN SUBDIVISION OF GROUNDWATER MANAGEMENT AREA 10.**

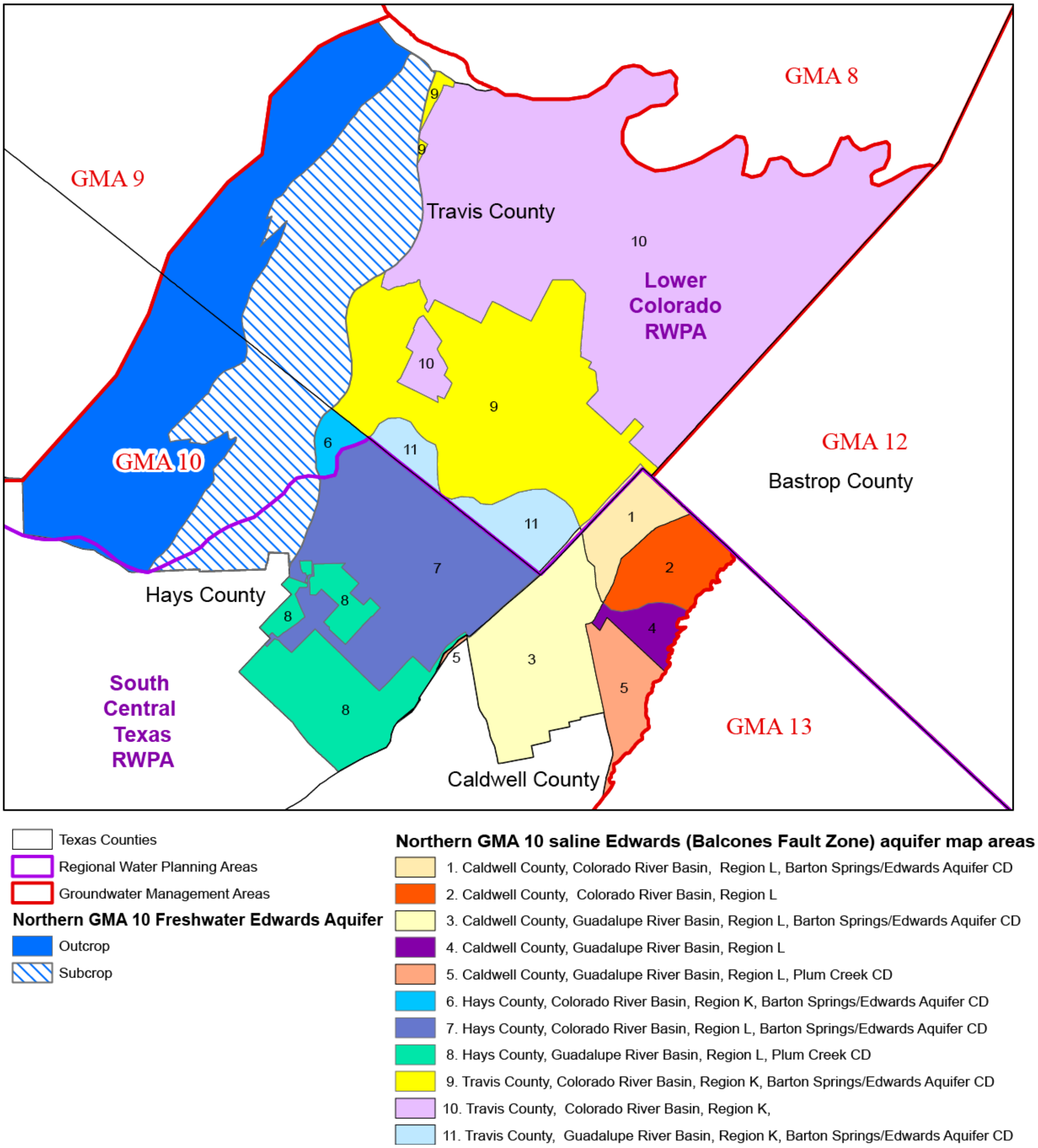

FIGURE 5. MAP SHOWING AREAS USED FOR ESTIMATING THE SALINE, EDWARDS (BALCONES FAULT ZONE) AQUIFER, MODELED AVAILABLE GROUNDWATER IN THE NORTHERN SUBDIVISION OF GROUNDWATER MANAGEMENT AREA 10, (MODIFIED FROM BRADLEY,2011) .

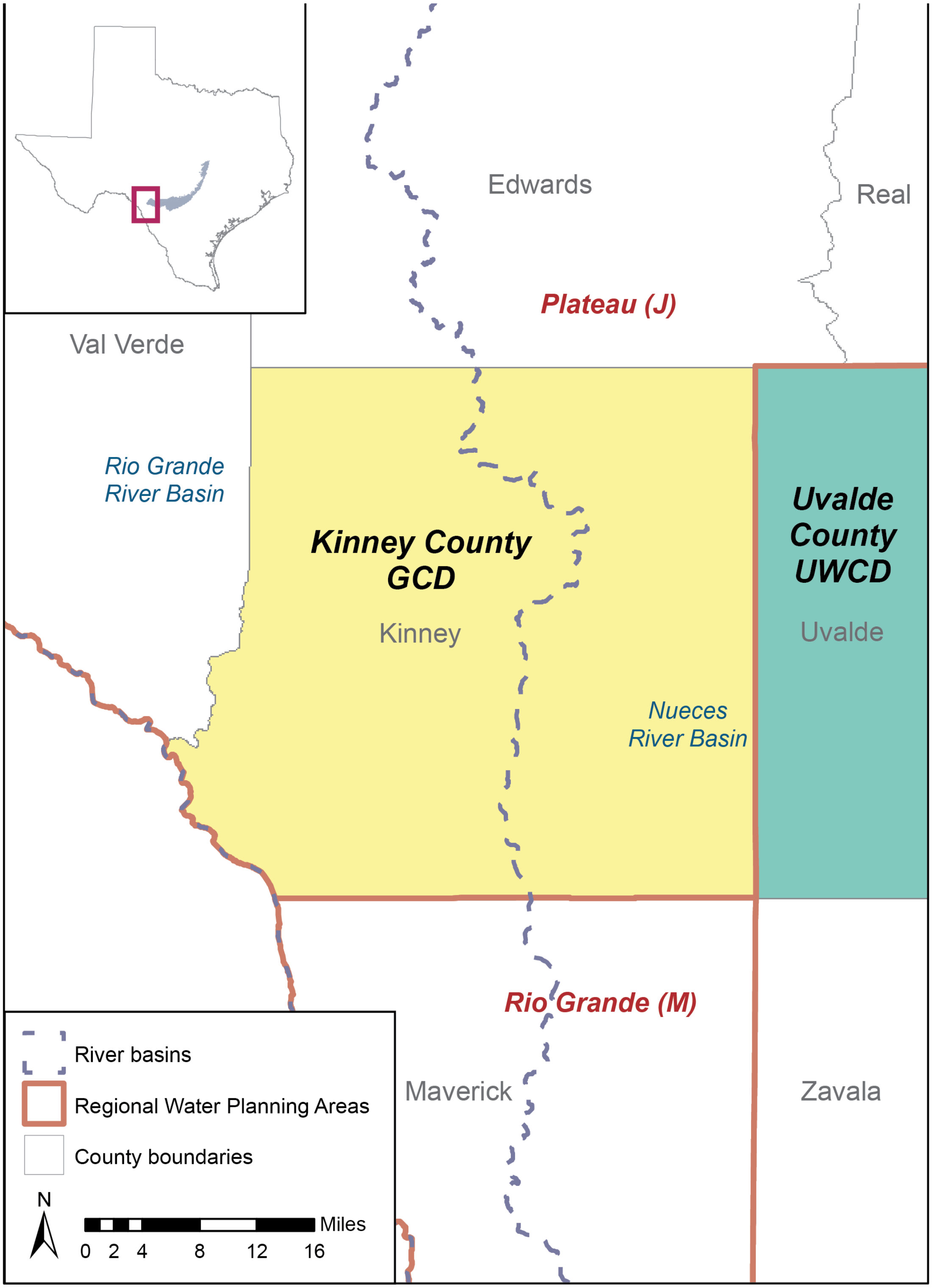

FIGURE 6. MAP SHOWING REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), AND COUNTIES IN THE VICINITY OF THE FRESHWATER EDWARDS (BALCONES FAULT ZONE) AQUIFER IN THE WESTERN SUBDIVISION OF GROUNDWATER MANAGEMENT AREA 10 (KINNEY COUNTY).

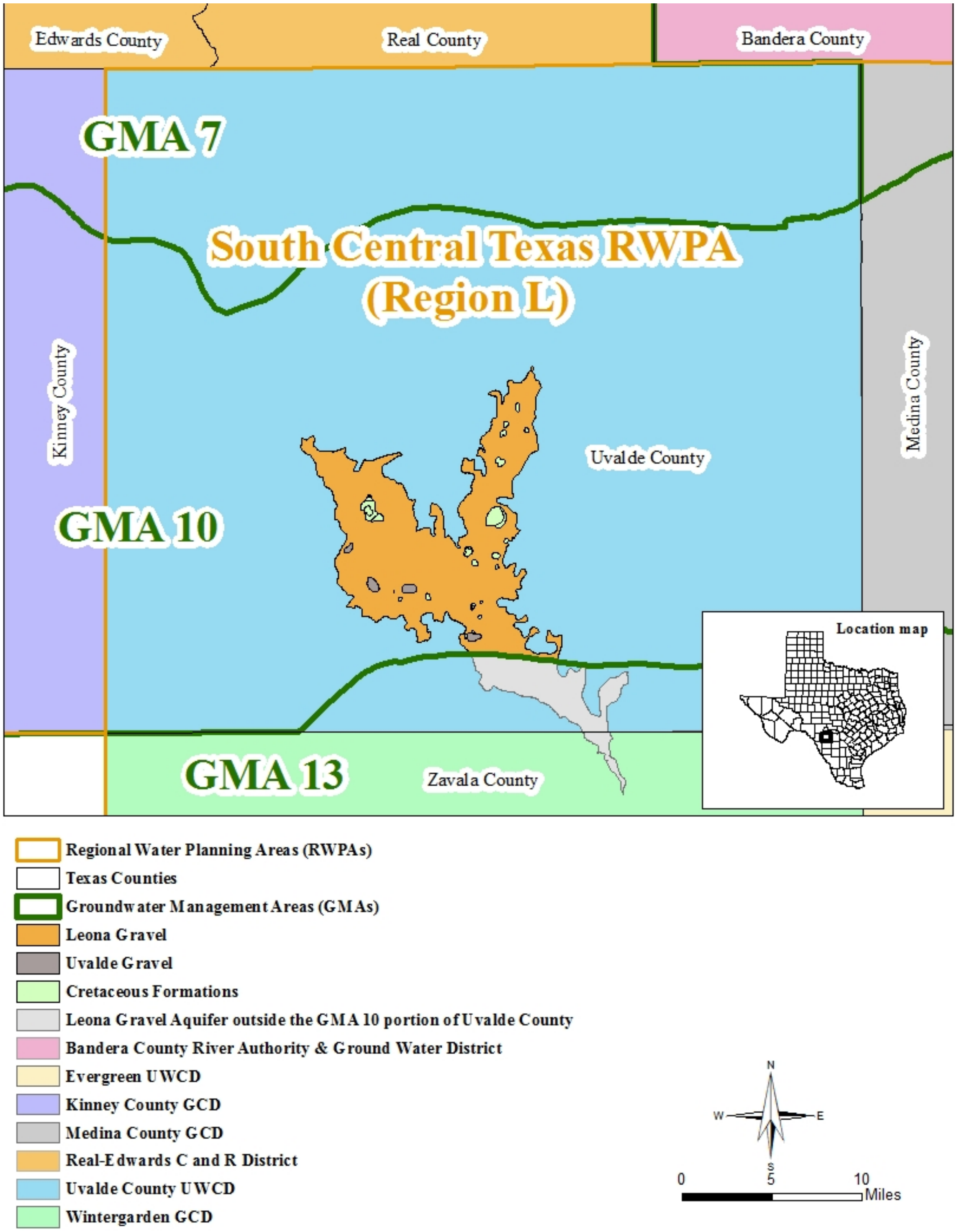

FIGURE 7. **MAP SHOWING REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS, UWCDS), AND COUNTIES IN THE VICINITY OF THE LEONA GRAVEL AQUIFER IN GROUNDWATER MANAGEMENT AREA 10 (UVALDE COUNTY).**

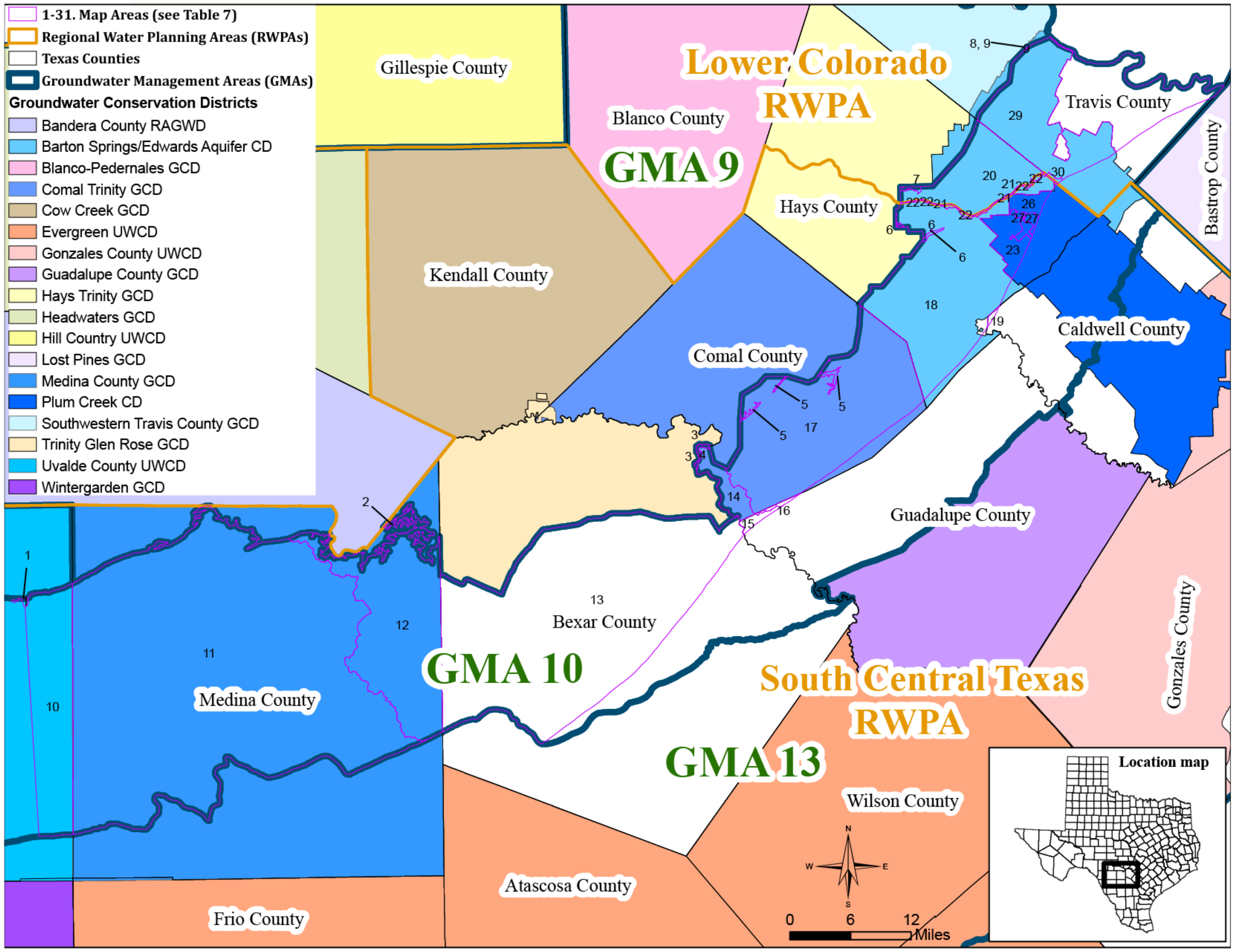

FIGURE 8 MAP SHOWING REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), AND COUNTIES IN THE VICINITY OF THE TRINITY AQUIFER IN GROUNDWATER MANAGEMENT AREA 10.

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 2010 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR.

Groundwater Conservation District	County	Aquifer	2010	2020	2030	2040	2050	2060
Uvalde County Underground Water Conservation District	Uvalde	Austin Chalk	2,935	2,935	2,935	2,935	2,935	2,935
		Buda Limestone	758	758	758	758	758	758
		Leona Gravel	9,385	9,385	9,385	9,385	9,385	9,385
Total			**16,013**	**16,013**	**16,013**	**16,013**	**16,013**	**16,013**

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 2020 AND 2070. VALUES ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Aquifer	2020	2030	2040	2050	2060	2070
Uvalde	L	Nueces	Austin Chalk	2,935	2,935	2,935	2,935	2,935	2,935
			Buda Limestone	758	758	758	758	758	758
			Leona Gravel	9,385	9,385	9,385	9,385	9,385	9,385
Total				**16,013**	**16,013**	**16,013**	**16,013**	**16,013**	**16,013**

TABLE 3. MODELED AVAILABLE GROUNDWATER FOR THE FRESHWATER PORTION OF THE EDWARDS (BALCONES FAULT ZONE) AQUIFER IN GROUNDWATER MANAGEMENT AREA 10 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD) AND COUNTY FOR EACH DECADE BETWEEN 2010 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR.

Recharge Condition	Groundwater Conservation District	County	2010	2020	2030	2040	2050	2060
Average	Barton Springs/Edwards Aquifer Conservation District	Hays	7,950	7,950	7,950	7,950	7,950	7,950
		Travis	3,578	3,578	3,578	3,578	3,578	3,578
	Non-District Areas	Hays	29	29	29	29	29	29
Total for average recharge conditions			**11,557**	**11,557**	**11,557**	**11,557**	**11,557**	**11,557**
Drought	Barton Springs/Edwards Aquifer Conservation District	Hays	2,590	2,590	2,590	2,590	2,590	2,590
		Travis	1,166	1,166	1,166	1,166	1,166	1,166
	Non-District Areas	Hays	9	9	9	9	9	9
Total for drought recharge conditions			**3,765**	**3,765**	**3,765**	**3,765**	**3,765**	**3,765**
Kinney County Groundwater Conservation District		Kinney	6,321	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) AQUIFER IN GROUNDWATER MANAGEMENT AREA 10 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2020 AND 2070. VALUES ARE IN ACRE-FEET PER YEAR.

Recharge Condition	County	RWPA	River Basin	2020	2030	2040	2050	2060	2070
Average	Hays	K	Colorado	7,037	7,037	7,037	7,037	7,037	7,037
	Hays	L	Guadalupe	942	942	942	942	942	942
	Travis	K	Colorado	3,578	3,578	3,578	3,578	3,578	3,578
	Total for average recharge conditions			**11,557**	**11,557**	**11,557**	**11,557**	**11,557**	**11,557**
Drought	Hays	K	Colorado	2,292	2,292	2,292	2,292	2,292	2,292
	Hays	L	Guadalupe	307	307	307	307	307	307
	Travis	K	Colorado	1,166	1,166	1,166	1,166	1,166	1,166
	Total for drought recharge conditions			**3,765**	**3,765**	**3,765**	**3,765**	**3,765**	**3,765**
Not applicable	Kinney	J	Nueces	6,319	6,319	6,319	6,319	6,319	6,319
			Rio Grande	2	2	2	2	2	2

TABLE 5. MODELED AVAILABLE GROUNDWATER FOR THE SALINE PORTION OF THE EDWARDS (BALCONES FAULT ZONE) AQUIFER IN GROUNDWATER MANAGEMENT AREA 10 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD) AND COUNTY FOR EACH DECADE BETWEEN 2010 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR.

Groundwater Conservation District	County	2010	2020	2030	2040	2050	2060
Barton Springs/Edwards Aquifer Conservation	Caldwell	858	858	858	858	858	858
	Hays	1,171	1,171	1,171	1,171	1,171	1,171
	Travis	1,770	1,770	1,770	1,770	1,770	1,770
Non-District Areas	Caldwell	369	369	369	369	369	369
	Travis	3,583	3,583	3,583	3,583	3,583	3,583
Plum Creek Conservation District	Caldwell	210	210	210	210	210	210
	Hays	602	602	602	602	602	602
Total		**8,563**	**8,563**	**8,563**	**8,563**	**8,563**	**8,563**

TABLE 6. MODELED AVAILABLE GROUNDWATER FOR THE SALINE PORTION OF THE EDWARDS (BALCONES FAULT ZONE) AQUIFER IN GROUNDWATER MANAGEMENT AREA 10 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2020 AND 2070. VALUES ARE IN ACRE-FEET PER YEAR

County	RWPA	River Basin	2020	2030	2040	2050	2060	2070
Caldwell	L	Colorado	469	469	469	469	469	469
		Guadalupe	968	968	968	968	968	968
Hays	K	Colorado	66	66	66	66	66	66
	L	Guadalupe	1,707	1,707	1,707	1,707	1,707	1,707
Travis	K	Colorado	5,073	5,073	5,073	5,073	5,073	5,073
		Guadalupe	280	280	280	280	280	280
Total			**8,563**	**8,563**	**8,563**	**8,563**	**8,563**	**8,563**

TABLE 7. INPUTS TO CALULATE 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[1,2,3]	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	4	0	40
2	Medina GCD	Medina	San Antonio	L	1	0	0	0	0
3	No GCD	Bexar	San Antonio	L	N/A	N/A	N/A	N/A	N/A
4	Comal Trinity GCD	Comal	San Antonio	L	594	67	147	15	229
5	Comal Trinity GCD	Comal	Guadalupe	L	1,282	149	318	32	499
6	Barton Springs/ Edwards Aquifer Conservation District	Hays	Guadalupe	L	505	61	13	13	87
7	Barton Springs/ Edwards Aquifer Conservation District	Hays	Colorado	K	494	57	12	12	81
8	Barton Springs/ Edwards Aquifer Conservation District	Travis	Colorado	K	3	0	0	0	0
9	Southwestern Travis County GCD	Travis	Colorado	K	11	1	0	0	1
10	Uvalde County UWCD	Uvalde	Nueces	L	63,464	N/A	755	0	755
11	Medina GCD	Medina	Nueces	L	459,975	N/A	5,470	12	5,482
12	Medina GCD	Medina	San Antonio	L	98,983	N/A	1,177	2	1,179

1. Map areas 1-10 represent outcrop areas and were assumed to be under unconfined aquifer conditions.

2. Map areas 11-31 represent subcrop areas and were assumed to be under confined aquifer conditions.

3. Map areas 24-26 cover the Barton Springs/Edwards Aquifer Conservation District and Plum Creek Conservation District where the two districts overlap. These values are assigned to the Barton Springs/Edwards Aquifer Conservation District.

Table 7 (Continued)

Map area[1,2,3]	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
13	No GCD	Bexar	San Antonio	L	N/A	N/A	N/A	N/A	N/A
14	Comal Trinity GCD	Comal	San Antonio	L	9,243	N/A	2,290	0	2,290
15	No GCD	Guadalupe	San Antonio	L	1,907	N/A	472	0	472
16	No GCD	Guadalupe	Guadalupe	L	757	N/A	188	0	188
17	Comal Trinity GCD	Comal	Guadalupe	L	123,232	N/A	30,533	3	30,536
18	Barton Springs/ Edwards Aquifer Conservation District	Hays	Guadalupe	L	104,045	N/A	2,597	3	2,600
19	No GCD	Caldwell	Guadalupe	L	420	N/A	10	0	10
20	Barton Springs/ Edwards Aquifer Conservation District	Hays	Colorado	K	36,033	N/A	899	0	899
21	Barton Springs/ Edwards Aquifer Conservation District	Hays	Guadalupe	K	354	N/A	9	0	9
22	Barton Springs/ Edwards Aquifer Conservation District	Hays	Colorado	L	1,286	N/A	32	0	32
23	Plum Creek CD	Hays	Guadalupe	L	9,934	N/A	248	0	248

1. Map areas 1-10 represent outcrop areas and were assumed to be under unconfined aquifer conditions.

2. Map areas 11-31 represent subcrop areas and were assumed to be under confined aquifer conditions.

3. Map areas 24-26 cover the Barton Springs/Edwards Aquifer Conservation District and Plum Creek Conservation District where the two districts overlap. These values are assigned to the Barton Springs/Edwards Aquifer Conservation District.

Table 7 (Continued)

Map area[1,2,3]	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
24	Barton Springs/ Edwards Aquifer Conservation District[3]	Hays	Guadalupe	K	17	N/A	0	0	0
25	Barton Springs/ Edwards Aquifer Conservation District[3]	Hays	Colorado	K	1	N/A	0	0	0
26	Barton Springs/ Edwards Aquifer Conservation District[3]	Hays	Guadalupe	L	5,864	N/A	146	0	146
27	Plum Creek CD	Hays	Guadalupe	L	1,108	N/A	28	0	28
28	Southwestern Travis County GCD	Travis	Colorado	K	18	N/A	0	0	0
29	Barton Springs/ Edwards Aquifer Conservation District	Travis	Colorado	K	55,223	N/A	339	0	339
30	Barton Springs/ Edwards Aquifer Conservation District	Travis	Guadalupe	K	396	N/A	2	0	2
31	No GCD	Travis	Colorado	K	53,547	N/A	329	0	329

1. Map areas 1-10 represent outcrop areas and were assumed to be under unconfined aquifer conditions.

2. Map areas 11-31 represent subcrop areas and were assumed to be under confined aquifer conditions.

3. Map areas 24-26 cover the Barton Springs/Edwards Aquifer Conservation District and Plum Creek Conservation District where the two districts overlap. These values are assigned to the Barton Springs/Edwards Aquifer Conservation District.

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 2010 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR.

Groundwater Conservation District	County	2010	2020	2030	2040	2050	2060
Barton Springs/ Edwards Aquifer Conservation District	Hays	3,854	3,854	3,854	3,854	3,854	3,854
	Travis	341	341	341	341	341	341
Comal Trinity GCD	Comal	33,554	33,554	33,554	33,554	33,554	33,554
Medina County GCD	Medina	6,661	6,661	6,661	6,661	6,661	6,661
Non-District Areas	Caldwell	10	10	10	10	10	10
	Guadalupe	660	660	660	660	660	660
	Travis	329	329	329	329	329	329
Plum Creek Conservation District	Hays	276	276	276	276	276	276
Southwestern Travis County GCD	Travis	1	1	1	1	1	1
Uvalde County UWCD	Uvalde	795	795	795	795	795	795
Total		**46,481**	**46,481**	**46,481**	**46,481**	**46,481**	**46,481**

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 2020 AND 2070. VALUES ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	2020	2030	2040	2050	2060	2070
Caldwell	L	Guadalupe	10	10	10	10	10	10
Comal	L	Guadalupe	31,035	31,035	31,035	31,035	31,035	31,035
		San Antonio	2,519	2,519	2,519	2,519	2,519	2,519
Guadalupe	L	Guadalupe	188	188	188	188	188	188
		San Antonio	472	472	472	472	472	472
Hays	K	Colorado	980	980	980	980	980	980
		Guadalupe	9	9	9	9	9	9
	L	Colorado	32	32	32	32	32	32
		Guadalupe	3,109	3,109	3,109	3,109	3,109	3,109
Medina	L	Nueces	5,482	5,482	5,482	5,482	5,482	5,482
		San Antonio	1,179	1,179	1,179	1,179	1,179	1,179
Travis	K	Colorado	669	669	669	669	669	669
		Guadalupe	2	2	2	2	2	2
Uvalde	L	Nueces	795	795	795	795	795	795

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 historical groundwater flow conditions includes the assumptions about the location in the aquifer where historical 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 streamflow are specific to a particular historical 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. Historical 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:

Ashworth, J. B., 1983, Ground-water availability of the Lower Cretaceous formations in the Hill Country of south-central Texas: Texas Department of Water Resources Report 273, 173 p.

Bradley, R. G., 2011, GTA Aquifer Assessment 10-35 MAG, Northern saline Edwards Aquifer Modeled Available Groundwater Estimates, Texas Water Development Board, 13 p. http://www.twdb.texas.gov/groundwater/docs/AA/AA10-35_MAG.pdf

Bradley, R. G., 2013, Aquifer Assessment 10-28 MAG: Aquifer Assessment for the Leona Gravel Aquifer Within Uvalde County in Groundwater Management Area 10, Texas Water Development Board, 13 p. http://www.twdb.texas.gov/groundwater/docs/AA/AA10-28_MAG.pdf

Cleaveland, M.K., 2006, Extended chronology of drought in the San Antonio area, revised report: University of Arkansas, 29 p. http://www.gbra.org/Documents/Reports/TreeRingStudy.pdf

Freeze, A.R. and Cherry, J.A., 1979, Groundwater, Prentice-Hall, 604 p.

George, P., 2010, GTA Aquifer Assessment 09-01: Texas Water Development Board, 14 p. http://www.twdb.texas.gov/groundwater/docs/AA/AA09-01.pdf

Green, R.T, Winterle, J.R., and Prikryl, J.D., 2008, Discharge from the Edwards Aquifer through the Leona River floodplain, Uvalde, Texas: Journal of the American Water Resources Association, v. 44, No. 4, pp. 887-901.

Green, R.T., Bertetti, F.P., and McGinnis, R., 2009, Analysis of the Water Resources of the Area Centered Within and Near Uvalde and Zavala Counties and Review of a Report on a Potential Well Field and Pipeline in Uvalde County, Texas: SwRI Project No. 20-14842, 53 p.

Harbaugh, A. W., 2009, Zonebudget Version 3.01, A computer program for computing subregional water budgets for MODFLOW ground-water flow models, U.S. Geological Survey Groundwater Software.

Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G., 2000, MODFLOW-2000, The U.S. Geological Survey modular ground-water model-User guide to modularization concepts and the ground-water flow process: U.S. Geological Survey, Open-File Report 00-92.

Hunt, B.B, 2017, Refining the northern Saline Edwards Aquifer desired future condition, northern subdivision of GMA-10, Hays and Travis counties, Texas, Barton Springs Edwards Aquifer Conservation District, Technical Memo 2017-1221, 2p.

Hunt, B.B., Smith, B.A., Kromann, J.,Wierman, D.A., and Mikels, J.K., 2010, Compilation of pumping tests in Travis and Hays counties, central Texas: Barton Springs/Edwards Aquifer Conservation District Data Series Report 2010-0701, 12p.

Hunt, B.B., Smith, B.A., Holland, W.F., 2011, Technical Note 2011-0707: Information in Support of the Drought DFC and Drought MAG, Barton Springs Segment of the Edwards Aquifer, Barton Springs/Edwards Aquifer Conservation District, 5 p.

Hutchison, W. R., 2011, Draft GAM Task 10-027 (revised): Texas Water Development Board, 8 p. http://www.twdb.texas.gov/groundwater/docs/GAMruns/Task10-027revised_draft.pdf

Hutchison, W.R., 2010, GAM Task 10-005, Texas Water Development Board, 27p. http://www.twdb.texas.gov/groundwater/docs/GAMruns/Task10-005.pdf

Hutchison, W.R. and Hill, M., 2011a, Report: Recalibration of the Edwards (Balcones Fault Zone) Aquifer—Barton Springs Segment—Groundwater Flow Model, Texas Water Development Board, 115.p. http://www.twdb.texas.gov/groundwater/models/alt/ebfz_b/EBFZ_B_Model_Recalibration_Report.pdf

Hutchison, W.R. and Hill, M.E., 2011b, GAM Run 09-019: Groundwater Model Runs to Estimate Monthly Average Discharge from Barton Springs under Alternative Pumping Scenarios and Alternative Initial Conditions, June 1, 2011, 29 p.

Hutchison, W.R. and Oliver, W., 2011, GAM Run 10-058 MAG Version 2: Groundwater Management Area 10 Model Runs to Estimate Springflow Under Assumed Future Pumping and Recharge Conditions for the Northern Subdivision of the Edwards (Balcones Fault Zone) Aquifer, Texas Water Development Board, 17.p. http://www.twdb.texas.gov/groundwater/docs/GAMruns/GR10-059_MAG_v2.pdf

Hutchison, W.R., Shi, J, and Jigmond, M, 2011, Groundwater Flow Model of The Kinney County Area, Texas Water Development Board, 219 p. http://www.twdb.texas.gov/groundwater/models/alt/knny/Kinney_County_Model_Report.pdf

Jones, I. C., Anaya, R., and Wade, S., 2009, Groundwater availability model for the Hill Country portion of the Trinity Aquifer system, Texas, Texas Water Development Board updated Trinity Hill Country GAM, 194 p.

Narasimhan, B., Srinvasan, R., Quiring, S., and Nielsen-Gammon, J.W., 2008, Digital Climatic Atlas of Texas: Texas A&M University, Texas Water Development Board contract, Report 2005-483-5591, 108 p.

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

Shi, J, 2012, GAM Run 12-002 MAG: Modeled Available Groundwater for the Edwards (Balcones Fault Zone) Aquifer in Groundwater Management Area 10 for Kinney County, Texas Water Development Board, 9 p. http://www.twdb.texas.gov/groundwater/docs/GAMruns/GR12-002_MAG.pdf

Texas Water Code, 2017, http://www.statutes.legis.state.tx.us/docs/WA/pdf/WA.36.pdf.

Thorkildsen, D. and Backhouse, S., 2010, GTA Aquifer Assessment 10-06: Groundwater Management Area 10 Trinity Aquifer Draft Managed Available Groundwater estimates, Texas Water Development Board, 20 p. http://www.twdb.texas.gov/groundwater/docs/AA/AA10-06.pdf

Thorkildsen, D. and Backhouse, S., 2011a, GTA Aquifer Assessment 10-26, Austin Chalk Aquifer Managed Available Groundwater Estimates, Texas Water Development Board 11 p. http://www.twdb.texas.gov/groundwater/docs/AA/AA10-26_MAG.pdf

Thorkildsen, D. and Backhouse, S., 2011b, GTA Aquifer Assessment 10-27, Buda Limestone Aquifer Managed Available Groundwater Estimates, Texas Water Development Board 10 p. http://www.twdb.texas.gov/groundwater/docs/AA/AA10-27_MAG.pdf