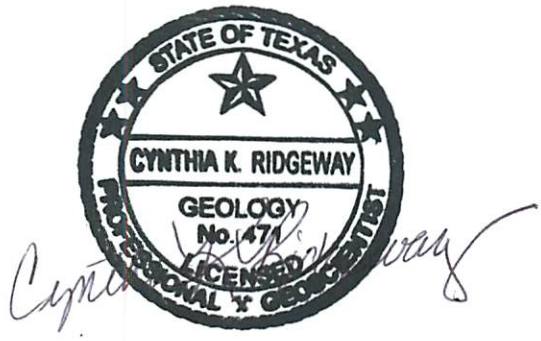
GAM Run 09-026 MAG

by Mr. Wade Oliver

Texas Water Development Board
Groundwater Availability Modeling Section
(512) 463-3132
June 22, 2011



Cynthia K. Ridgeway is the Manager of the Groundwater Availability Modeling Section and is responsible for oversight of work performed by employees under her direct supervision. The seal appearing on this document was authorized by Cynthia K. Ridgeway, P.G. 471 on June 22, 2011.

This page is intentionally blank.

EXECUTIVE SUMMARY:

We ran the groundwater availability models for the northern and southern portions of the Ogallala Aquifer to estimate the managed available groundwater based on desired future conditions adopted by members of Groundwater Management Area 1. The model run for the northern portion of the Ogallala Aquifer is based on Groundwater Availability Model Run 09-001. For the southern portion of the Ogallala Aquifer, the most updated version of the groundwater availability model was run, which is documented in this report. This run included the most recent estimates of pumping in areas outside of Groundwater Management Area 1.

The estimated total pumping from the Ogallala Aquifer in Groundwater Management Area 1 necessary to achieve the requested desired future condition declines from 3,364,389 acre-feet per year in 2010 to 2,027,465 acre-feet per year in 2060. Of this, the estimated exempt use of the aquifer increases from 53,533 to 58,132 acre-feet per year over the same time period. Therefore, the total managed available groundwater within Groundwater Management Area 1 - the amount of water that may be permitted - declines from 3,310,856 acre-feet per year in 2010 to 1,969,333 acre-feet per year in 2060. Estimates for total pumping, exempt use, and managed available groundwater are presented and are divided by county, groundwater conservation district, geographic area, and river basin for each decade between 2010 and 2060.

REQUESTOR:

Mr. Kyle Ingham of the Panhandle Regional Planning Commission acting on behalf of Groundwater Management Area 1

DESCRIPTION OF REQUEST:

In a letter received July 30th, 2009, Mr. Kyle Ingham provided the Texas Water Development Board (TWDB) with the desired future conditions (DFCs) of the Ogallala and Rita Blanca aquifers within Groundwater Management Area 1 and requested that TWDB estimate managed available groundwater values. As described in the request, these aquifers are simulated as a single layer in the groundwater availability model and are referred to collectively as the "Ogallala Aquifer" in the desired future conditions statement (and throughout this report). The desired future conditions for the Ogallala Aquifer, as described in Resolution 2009-01 and adopted July 7, 2009 by the groundwater conservation districts (GCDs) within Groundwater Management Area 1, are described below:

- **"40 [percent] volume in storage remaining in 50 years in the following:**
  - **North Plains [Groundwater Conservation District] consisting of all or parts of the following counties: Dallam, Hartley, Moore and Sherman; and**
  - **Parts of the following counties that are not in a Groundwater Conservation District will also fall under the 40/50 [desired future condition], those counties being Dallam, Hartley and Moore**

- **50 [percent] volume in storage remaining in 50 years in the following:**

- **High Plains Underground Water Conservation District consisting of parts of the following counties: Armstrong, Potter and Randall;**
- **North Plains [Groundwater Conservation District] consisting of all or parts of the following counties: Hansford, Hutchinson, Lipscomb and Ochiltree;**
- **Panhandle Groundwater Conservation District consisting of all or part of the following counties: Armstrong, Carson, Donley, Gray, Hutchinson, Potter, Roberts and Wheeler; and**
- **All or parts of the following counties that are not in a Groundwater Conservation District will also fall under the 50/50 [desired future condition], those counties being Hutchinson, Oldham and Randall**

- **80 [percent] volume in storage remaining in 50 years in Hemphill County; provided that, in the event it is legally determined that the roughly 390-acre tract of land located in southwest Hemphill County and described more particularly in Attachment A (the "390-acre tract") lies within the jurisdiction of the Hemphill County Underground Water Conservation District, then the Desired Future Condition for the 390-acre tract shall be 50 [percent] volume in storage remaining in 50 years and the Desired Future Condition for the remainder of Hemphill County shall be 80 [percent] volume in storage remaining in 50 years"**

The three geographic areas defined in the above desired future conditions statement are shown in Figure 1.

METHODS:

The Ogallala Aquifer within Groundwater Management Area 1 is covered by two groundwater availability models. The groundwater availability model for the northern portion of the Ogallala Aquifer, documented in Dutton and others (2001) and Dutton (2004), covers the majority of Groundwater Management Area 1 and includes the Rita Blanca Aquifer. The groundwater availability model for the southern portion of the Ogallala Aquifer, documented in Blandford and others (2003) and Blandford and others (2008), covers the remaining areas of the Ogallala Aquifer within Groundwater Management Area 1. The area covered by each of the groundwater availability models is shown in Figure 2. Notice that there is an area in Potter and Randall counties where the two models overlap. Since the model for the northern portion of the Ogallala Aquifer is the primary model for Groundwater Management Area 1, results from the northern model were used over the results from the southern model in the overlap area.

The previously completed Groundwater Availability Model Run 09-001 (Smith, 2009) documents the model results reviewed by members of Groundwater Management Area 1 when developing the above desired future conditions. The model run for the northern portion of the Ogallala Aquifer presented in this report is based on the above referenced groundwater availability model run and are divided by county, groundwater conservation district, geographic area, and river basin within Groundwater Management Area 1. Note that Groundwater Management Area 1 is entirely contained within the Panhandle Regional Water Planning Area (Region A). The locations of these areas are shown in Figure 3.

It is important to note that a change was made to the year assigned to each stress period in the current model run compared with Groundwater Availability Model Run 09-001. In Smith (2009), the stress period in the model representing 2006 was used as the base year for the

model run. The first subsequent stress period was assumed to represent 2010 and the volume decline was calculated between 2010 and the end of 2059 (50 years). However, due to the nature of the Ogallala Aquifer with declining water levels through time, it was determined that it would be more appropriate to explicitly simulate the interim time-period from 2007 to 2009. The model run for the northern portion of the Ogallala Aquifer documented here uses 2006 as the base year as in Smith (2009). The first subsequent stress period, however, now represents 2007. The period over which the volume declines that match the desired future conditions were calculated is now from 2007 to 2056 (although the percent volume decline for each geographic area during the 50-year period from 2010 to 2059 is essentially the same). The consequence of this change is that the results presented in the tables below are offset by three years compared to Groundwater Availability Model Run 09-001. For example, the pumping for 2020 in the results section below corresponds to the results presented for 2023 in Smith (2009).

For the southern portion of the Ogallala Aquifer, which covers portions of Oldham, Potter, Randall, and Armstrong counties, the Groundwater Availability Model Run 08-016 Supplement (Smith, 2008) was previously completed and meets the above request. Since completion of the model run, however, the groundwater availability model for the southern portion of the Ogallala Aquifer has been updated (Blandford and others, 2008). For this reason, the updated groundwater availability model was used to reassess these areas. This report documents the methods used in the updated groundwater availability model run for the southern portion of the Ogallala Aquifer in addition to reporting managed available groundwater for Groundwater Management Area 1.

PARAMETERS AND ASSUMPTIONS:

Northern Portion of the Ogallala Aquifer

The parameters and assumptions for the groundwater availability model run for the northern portion of the Ogallala Aquifer are described below:

- We used version 2.01 of the groundwater availability model for the northern portion of the Ogallala Aquifer. This model is an update to the original version documented in Dutton and others (2001). See Dutton (2004) and Dutton and others (2001) for assumptions and limitations of the groundwater availability model

- The groundwater availability model for the northern portion of the Ogallala Aquifer has only one layer which collectively represents the Ogallala and Rita Blanca aquifers. As described in the Resolution 2009-01 adopted by the members of Groundwater Management Area 1, the adopted desired future conditions apply to both the Ogallala and Rita Blanca aquifers. In both the desired future conditions statement and this report as a whole the Ogallala and Rita Blanca aquifers are referred to collectively as the “Ogallala Aquifer.”

- The root mean squared error (a measure of the difference between simulated and measured water levels during model calibration) for the model for the northern

portion of the Ogallala Aquifer is 53 feet. This represents 2.2 percent of the range of measured water levels across the model area.

- Cells were assigned to individual counties, groundwater conservation districts, and river basins as shown in the September 14, 2009 version of the file that associates the model grid to political and natural boundaries for the northern portion of the Ogallala. Note that some minor corrections were made to county and groundwater conservation district grid cell assignments compared to the original Groundwater Availability Model Run 09-001 (Smith, 2009).

- See the Pumping section below and Groundwater Availability Model Run 09-001 (Smith, 2009) for additional details about the pumping in the model run for the northern portion of the Ogallala Aquifer that meets the above desired future conditions.

Southern Portion of the Ogallala Aquifer

The parameters and assumptions for the groundwater availability model run for the southern portion of the Ogallala Aquifer are described below:

- We used version 2.01 of the groundwater availability model for the southern portion of the Ogallala Aquifer, which also includes the Edwards-Trinity (High Plains) Aquifer. This model is an expansion on and update to the previously developed groundwater availability model for the southern portion of the Ogallala Aquifer described in Blandford and others (2003). See Blandford and others (2008) and Blandford and others (2003) for assumptions and limitations of the groundwater availability model.

- The model includes four layers representing the southern portion of the Ogallala Aquifer and the Edwards-Trinity (High Plains) Aquifer. However, only Layer 1 of the model, representing the Ogallala Aquifer, is active within Groundwater Management Area 1. For this reason, results are only presented for the Ogallala Aquifer from the groundwater availability model.

- The mean absolute error (a measure of the difference between simulated and measured water levels during model calibration) for the Ogallala Aquifer in 2000 is 33 feet. This represents 1.8 percent of the range of measured water levels across the model area.

- Cells were assigned to individual counties, groundwater conservation districts, and river basins as shown in the September 14, 2009 version of the file that associates the model grid to political and natural boundaries for the southern portion of the Ogallala Aquifer and Edwards-Trinity (High Plains) Aquifer.

- The pumping for areas outside of Groundwater Management Area 1 is the same as described for the “base” scenario in Groundwater Availability Model Run 09-023

(Oliver, 2010). Details on the pumping within Groundwater Management Area 1 are given below.

Pumping

Pumping within Groundwater Management Area 1 in the groundwater availability model for the northern portion of the Ogallala Aquifer is the same as described in Groundwater Availability Model Run 09-001 (Smith, 2009). For areas of the model outside of Texas, pumping during the predictive period (2007 through 2060) was held constant at the level estimated for 2007 in Dutton and others (2001).

For the southern portion of the Ogallala Aquifer, which covers parts of Oldham, Potter, Randall, and Armstrong counties (Figure 1), the updated version of the groundwater availability model for this area was run to match the above-specified desired future conditions. As described above, a previous model run that matched the above desired future conditions is documented in the supplement to Groundwater Availability Model Run 08-16 (Smith, 2008). This run, however, was performed prior to completion of the updated groundwater availability model for the southern portion of the Ogallala Aquifer and did not contain the most recent levels of pumping for areas outside of Groundwater Management Area 1.

The pumping in the groundwater availability model for the southern portion of the Ogallala Aquifer that matched the desired future conditions was determined using an iterative process. The pumping in the model for the year 2000 (the last year of the historical-calibration period) was held constant between 2001 and 2008. Beginning in 2009, this pumping distribution was increased and then held constant for each year through 2060. The amount of the increase over the pumping in the year 2000 was uniformly spread over all model cells that contained pumping in 2000. After running the model, the decline in the volume of the aquifer between 2009 and 2058 (50 years inclusive) was calculated and the level of pumping for the predictive period was adjusted accordingly. This process was repeated until the decline in aquifer volume in the southern portion of the Ogallala Aquifer in Groundwater Management Area 1 matched the requested decline (50 percent of the original volume after 50 years). It should be noted that the volume decline was also 50 percent for the inclusive 50-year periods 2010 to 2059 and 2011 to 2060. For areas outside of Groundwater Management Area 1, pumping was set to the same level as the “base” scenario documented in Groundwater Availability Model Run 09-023 (Oliver, 2010).

As described in Groundwater Availability Model Run 09-023 (Oliver, 2010), the initial volume of water in the Groundwater Management Area 2 portion of the Ogallala Aquifer, which constitutes the majority of the southern portion of the aquifer, was compared to the volume calculated from water level measurements. From this analysis it was found that the volume of water calculated from water level measurements was approximately 8.7 percent less than the volume calculated for the base year (2008) in the model. For this reason the model output pumping presented in this report for the southern portion of the Ogallala Aquifer has been reduced by 8.7 percent to correct for the initial volume difference. Note that Groundwater Management Area 2 was used for the volume comparison (as opposed to

Groundwater Management Area 1) because it covers the majority of the southern portion of the Ogallala Aquifer and contained a sufficient distribution of water level measurements to create a water level surface for 2008. This is the same process employed in Groundwater Availability Model Run 09-023 and is described in further detail in that report (Oliver, 2010).

Determining Managed Available Groundwater

As defined in Chapter 36 of the Texas Water Code, "managed available groundwater" is the amount of water that may be permitted. The pumping output from groundwater availability models, however, represents the total amount of pumping from the aquifer. The total pumping includes uses of water both subject to permitting and exempt from permitting. Examples of exempt uses include domestic, livestock, and oil and gas exploration. Each district may also exempt additional uses as defined by its rules or enabling legislation.

Since exempt uses are not available for permitting, it is necessary to account for them when determining managed available groundwater. To do this the Texas Water Development Board developed a standardized method for estimating exempt use for domestic and livestock purposes based on projected changes in population and the distribution of domestic and livestock wells in the area. Because other exempt uses can vary significantly from district to district, and there is much higher uncertainty associated with estimating use due to oil and gas exploration, estimates of exempt pumping outside domestic and livestock uses were not included. Districts were encouraged to evaluated the estimates of exempt pumping and, if desired, provide updated estimates. Once established, the estimates of exempt pumping are subtracted from the total pumping output from the groundwater availability models to yield the estimated managed available groundwater for permitting purposes.

RESULTS:

Table 1 contains the total pumping estimates for the Ogallala Aquifer within Groundwater Management Area 1. It contains pumping totals from the groundwater availability models for the northern and southern portions of the Ogallala Aquifer subdivided by county, groundwater conservation district, geographic area, and river basin. These areas are shown in figures 1 and 3. Note that all of Groundwater Management Area 1 is within the Panhandle Regional Water Planning Area (Region A). For this reason results have not been divided by Regional Water Planning Area.

Table 2 shows the total pumping estimates summarized by county within Groundwater Management Area 1 and the total for the area as a whole. The geographic area within which each county is located is also shown. The total pumping for Groundwater Management Area 1 in 2010 is 3,364,389 acre-feet per year. This declines to 2,027,465 acre-feet of pumping per year by 2060 due to cells becoming inactive. A model cell becomes inactive when the water level in the cell drops below the base of the aquifer. In this situation, pumping cannot occur for the remainder of the model simulation.

Table 3 shows the total pumping estimates summarized by groundwater conservation district and geographic area. Between 2010 and 2060, total pumping declines from 54,998 to 54,938 acre-feet per year in Hemphill County Underground Water Conservation District, 72,832 to

48,934 acre-feet per year in High Plains Underground Water Conservation District No. 1 (limited to Groundwater Management Area 1), 1,905,700 to 1,067,874 acre-feet per year in North Plains Groundwater Conservation District, and 1,016,722 to 714,861 acre-feet per year in Panhandle Groundwater Conservation District. The total pumping for areas not covered by a groundwater conservation district within Groundwater Management Area 1 declines from 314,137 to 140,858 acre-feet per year between 2010 and 2060.

Table 4 shows the total pumping summarized by geographic area. The decline in the volume of water stored in the Ogallala Aquifer over 50 years for each of these areas matches the desired future condition adopted by the members of Groundwater Management Area 1. For Area 1, which consists of Dallam, Sherman, Hartley, and Moore counties, total pumping declines from 1,280,345 acre-feet per year to 511,161 acre-feet per year between 2010 and 2060. For Area 2, consisting of Hemphill County, pumping declines from 54,998 to 54,938 acre-feet per year. For Area 3, which encompasses the remaining counties in Groundwater Management Area 1, total pumping declines from 2,029,045 to 1,421,366 acre-feet per year for the same time period.

Table 5 shows the results summarized by river basin. Between 2010 and 2060, the estimated total pumping declines from 2,740,309 to 1,584,138 acre-feet per year for the Canadian River basin. In the Red River basin for the same time period, total pumping estimates decline from 624,080 to 443,327 acre-feet per year.

Tables 6 through 9 show the estimated exempt pumping for the same areas in tables 2 through 5, respectively. Note that the exempt pumping estimates for all areas within a groundwater conservation district were provided by the districts. Hemphill County Underground Water Conservation District provided estimates of additional exempt use above the estimates for domestic and livestock uses provided by the Texas Water Development Board. Each of the other districts provided alternative estimates of exempt use to replace the Texas Water Development Board estimates. Between 2010 and 2060, the estimated exempt pumping increases from 53,533 to 58,132 acre-feet per year.

Tables 10 through 13 contain the estimates of managed available groundwater for the Ogallala Aquifer. As described above, these reflect the difference between the total pumping (tables 2 through 5) and the estimated exempt use (tables 6 through 9). The managed available groundwater for the Ogallala Aquifer in Groundwater Management Area 1 declines from 3,310,856 acre-feet per year in 2010 to 1,969,333 acre-feet per year in 2060. The managed available groundwater estimates are reported by county (Table 10), groundwater conservation district (Table 11), geographic area (Table 12), and river basin (Table 13).

It is important to acknowledge the limitations of the precision of the sub-regional water budgets 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 (for example, a county) 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.

LIMITATIONS:

Managed available groundwater numbers included in this report are the result of subtracting the estimated future exempt use from the estimated total pumping that would achieve the desired future condition adopted by the groundwater conservation districts in the groundwater management area. These numbers, therefore, are the result of (1) running the groundwater model to estimate the total pumping required to achieve the desired future condition and (2) estimating the future exempt use in the area.

The groundwater model used in developing estimates of total pumping is the best available scientific tool that can be used to estimate the pumping that will achieve the desired future condition. Although the groundwater model used in this analysis is the best available scientific tool for this purpose, it, like all models, has limitations. 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 develop estimates of total pumping is the need to make assumptions about the location in the aquifer where future pumping will occur. As actual pumping changes in the future, it will be necessary to evaluate the amount of that pumping as well as its location in the context of the assumptions associated with this analysis. Evaluating the amount and location of future pumping is as important as evaluating the changes in groundwater levels, spring flows, and other metrics that describe the condition of the groundwater resources in the area that relate to the adopted desired future condition.

In addition, certain assumptions have been made regarding future precipitation, recharge, and streamflow in developing these total pumping estimates. Those assumptions also need to be considered and compared to actual future data when evaluating compliance with the desired future condition.

In the case of TWDB's estimates of future exempt use, key assumptions were made as to the pattern of population growth relative to the need for domestic wells or supplied water, per capita use from domestic wells, and livestock uses of water. In the case of district estimates of future exempt use, including exempt use associated with the exploration of oil and gas, the assumptions are specific to that district. In either case, these assumptions need to be considered when reviewing future data related to exempt use.

Given these limitations, users of this information are cautioned that the total pumping numbers should not be considered a definitive, permanent description of the amount of groundwater that can be pumped to meet the adopted desired future condition. 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 future groundwater pumping as well as whether or not they are achieving their desired future conditions. 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 these managed available groundwater numbers given the reality of how the aquifer responds to the actual amount and location of pumping now and in the future.

REFERENCES AND ASSOCIATED MODEL RUNS:

Blandford, T.N., Blazer, D.J., Calhoun, K.C., Dutton, A.R., Naing, T., Reedy, R.C., and Scanlon, B.R., 2003, Groundwater availability of the southern Ogallala aquifer in Texas and New Mexico—Numerical simulations through 2050: Final report prepared for the Texas Water Development Board by Daniel B. Stephens & Associates, Inc., 158 p.

Blandford, T.N., Kuchanur, M., Standen, A., Ruggiero, R., Calhoun, K.C., Kirby, P., and Shah, G., 2008, Groundwater availability model of the Edwards-Trinity (High Plains) Aquifer in Texas and New Mexico: Final report prepared for the Texas Water Development Board by Daniel B. Stephens & Associates, Inc., 176 p.

Dutton, A., 2004, Adjustments of parameters to improve the calibration of the Og-N model of the Ogallala Aquifer, Panhandle Water Planning Area: Bureau of Economic Geology, The University of Texas at Austin, 9 p.

Dutton, A., Reedy, R., and Mace, R., 2001, Saturated thickness of the Ogallala aquifer in the Panhandle Water Planning Area—Simulation of 2000 through 2050 Withdrawal Projections: prepared for the Panhandle Water Planning Group by the Bureau of Economic Geology, The University of Texas at Austin, 54 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.

Oliver, W., 2010, GAM Run 09-023: Texas Water Development Board, GAM Run 09-023 Draft Report, 30 p.

Smith, R., 2008, Supplement to GAM Run 08-16: Texas Water Development Board, GAM Run 08-16 Supplement Report, 24 p.

Smith, R., 2009, GAM Run 09-001: Texas Water Development Board, GAM Run 09-001 Draft Report, 28 p.

Table 1. Estimates of total pumping by year for the Ogallala and Rita Blanca aquifers in Groundwater Management Area 1. Results are in acre-feet per year and are divided by county, groundwater conservation district (GCD), and river basin. UWCD refers to Underground Water Conservation District.

County	District	Basin	Year					
			2010	2020	2030	2040	2050	2060
Armstrong	High Plains UWCD No. 1	Red	8,301	8,301	8,301	8,301	8,241	8,186
	Panhandle GCD	Red	46,315	42,978	39,881	37,008	34,342	32,447
Carson	Panhandle GCD	Canadian	90,494	83,974	77,924	72,309	67,099	63,677
		Red	95,516	88,634	82,248	76,322	70,823	67,211
Dallam	North Plains GCD	Canadian	319,738	258,174	201,321	141,484	92,522	67,739
	No District	Canadian	99,053	83,833	75,332	64,746	52,982	40,965
Donley	Panhandle GCD	Red	86,072	79,870	74,115	68,775	63,820	60,565
Gray	Panhandle GCD	Canadian	39,303	36,471	33,843	31,405	29,142	27,604
		Red	137,295	127,403	118,223	109,705	101,674	96,442
Hansford	North Plains GCD	Canadian	264,397	245,347	227,670	211,237	195,789	184,430
Hartley	North Plains GCD	Canadian	343,255	297,682	272,145	258,245	245,612	231,917
	No District	Canadian	51,590	36,312	23,749	15,449	10,239	6,328
Hemphill	Hemphill County UWCD	Canadian	31,660	31,660	31,660	31,660	31,660	31,660
		Red	23,338	23,338	23,338	23,338	23,278	23,278
Hutchinson	North Plains GCD	Canadian	52,972	49,156	45,614	42,286	39,047	36,316
	Panhandle GCD	Canadian	13,411	12,445	11,548	10,716	9,944	9,437
	No District	Canadian	80,679	74,866	69,472	64,466	59,821	56,770
Lipscomb	North Plains GCD	Canadian	244,981	227,330	210,951	195,751	181,647	172,319
Moore	North Plains GCD	Canadian	186,990	134,601	103,224	87,973	76,074	67,724
	No District	Canadian	32,933	22,357	11,776	6,140	3,137	2,184
Ochiltree	North Plains GCD	Canadian	246,579	228,813	212,326	197,028	182,726	173,125
Oldham	No District	Canadian	20,418	18,094	17,208	16,271	15,096	14,062
		Red	3,952	3,122	2,885	2,772	2,306	2,269
Potter	High Plains UWCD No. 1	Canadian	1,659	1,299	1,219	1,207	1,195	885
		Red	3,491	2,772	1,248	419	412	408
	Panhandle GCD	Canadian	27,992	25,975	24,104	22,367	20,755	19,634
		Red	7,161	6,645	6,166	5,722	5,310	4,996
Randall	High Plains UWCD No. 1	Red	59,381	57,141	55,995	51,410	47,357	39,455
	No District	Red	25,514	24,146	22,979	21,836	19,913	18,280
Roberts	Panhandle GCD	Canadian	345,418	320,530	297,436	276,005	256,118	243,057
		Red	13,528	12,554	11,649	10,810	10,031	9,519
Sherman	North Plains GCD	Canadian	246,787	193,748	164,250	148,183	139,062	134,304
Wheeler	Panhandle GCD	Red	114,217	105,987	98,351	91,264	84,585	80,272

Table 2. Estimates of total pumping for the Ogallala and Rita Blanca aquifers by county for each decade between 2010 and 2060. Results are in acre-feet per year.

County	Geographic Area	Year					
		2010	2020	2030	2040	2050	2060
Armstrong	3	54,616	51,279	48,182	45,308	42,582	40,633
Carson	3	186,010	172,608	160,171	148,631	137,922	130,888
Dallam	1	418,791	342,007	276,653	206,230	145,504	108,704
Donley	3	86,072	79,870	74,115	68,775	63,820	60,565
Gray	3	176,598	163,874	152,066	141,110	130,816	124,046
Hansford	3	264,397	245,347	227,670	211,237	195,789	184,430
Hartley	1	394,845	333,993	295,895	273,694	255,851	238,246
Hemphill	2	54,998	54,998	54,998	54,998	54,938	54,938
Hutchinson	3	147,062	136,466	126,633	117,468	108,812	102,523
Lipscomb	3	244,981	227,330	210,951	195,751	181,647	172,319
Moore	1	219,923	156,958	115,001	94,113	79,212	69,908
Ochiltree	3	246,579	228,813	212,326	197,028	182,726	173,125
Oldham	3	24,370	21,215	20,093	19,043	17,402	16,330
Potter	3	40,303	36,691	32,737	29,714	27,672	25,924
Randall	3	84,895	81,287	78,974	73,246	67,269	57,735
Roberts	3	358,946	333,084	309,085	286,815	266,149	252,576
Sherman	1	246,787	193,748	164,250	148,183	139,062	134,304
Wheeler	3	114,217	105,987	98,351	91,264	84,585	80,272
Total		**3,364,389**	**2,965,556**	**2,658,150**	**2,402,610**	**2,181,758**	**2,027,465**

Table 3. Estimates of total pumping for the Ogallala and Rita Blanca aquifers by groundwater conservation district (GCD) for each decade between 2010 and 2060. Results are in acre-feet per year. UWCD refers to Underground Water Conservation District.

District	Geographic Area	Year					
		2010	2020	2030	2040	2050	2060
Hemphill County UWCD	2	54,998	54,998	54,998	54,998	54,938	54,938
High Plains UWCD No. 1	3	72,832	69,513	66,763	61,336	57,204	48,934
North Plains GCD	1	1,096,770	884,205	740,940	635,885	553,270	501,684
	3	808,930	750,645	696,560	646,303	599,209	566,190
Panhandle GCD	3	1,016,722	943,466	875,487	812,407	753,642	714,861
No District	1	183,575	142,502	110,858	86,335	66,358	49,478
	3	130,562	120,227	112,544	105,345	97,136	91,381
Total		**3,364,389**	**2,965,556**	**2,658,150**	**2,402,610**	**2,181,758**	**2,027,465**

Table 4. Estimates of total pumping for the Ogallala and Rita Blanca aquifers by geographic area for each decade between 2010 and 2060. Results are in acre-feet per year.

Geographic Area	Year					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
1	1,280,345	1,026,707	851,798	722,220	619,628	551,161
2	54,998	54,998	54,998	54,998	54,938	54,938
3	2,029,045	1,883,851	1,751,354	1,625,392	1,507,192	1,421,366
Total	**3,364,389**	**2,965,556**	**2,658,150**	**2,402,610**	**2,181,758**	**2,027,465**

Table 5. Estimates of total pumping for the Ogallala and Rita Blanca aquifers by river basin for each decade between 2010 and 2060. Results are in acre-feet per year.

Basin	Year					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Canadian	2,740,309	2,382,665	2,112,772	1,894,928	1,709,667	1,584,138
Red	624,080	582,891	545,379	507,682	472,090	443,327
Total	**3,364,389**	**2,965,556**	**2,658,150**	**2,402,610**	**2,181,758**	**2,027,465**

Table 6. Estimates of exempt use for the Ogallala and Rita Blanca aquifers by county for each decade between 2010 and 2060. Results are in acre-feet per year.

County	Geographic Area	Year					
		2010	**2020**	**2030**	**2040**	**2050**	**2060**
Armstrong	3	399	375	381	367	360	347
Carson	3	568	426	440	425	396	369
Dallam	1	5,481	5,609	5,689	5,708	5,670	5,585
Donley	3	582	558	516	483	453	414
Gray	3	1,074	877	865	835	797	760
Hansford	3	4,531	4,531	4,531	4,531	4,531	4,531
Hartley	1	6,269	6,315	6,340	6,349	6,331	6,256
Hemphill	2	9,121	9,132	8,371	7,063	6,050	5,174
Hutchinson	3	2,204	2,264	2,206	2,187	2,168	2,149
Lipscomb	3	2,867	2,867	2,867	2,867	2,867	2,867
Moore	1	3,903	4,192	4,530	4,799	4,963	5,061
Ochiltree	3	3,261	3,261	3,261	3,261	3,261	3,261
Oldham	3	391	399	371	327	284	230
Potter	3	1,952	2,560	3,139	3,804	4,529	5,123
Randall	3	5,581	6,763	7,896	9,190	10,601	11,768
Roberts	3	403	598	181	129	121	114
Sherman	1	3,476	3,476	3,476	3,476	3,476	3,476
Wheeler	3	1,470	1,070	734	687	669	647
Total		**53,533**	**55,273**	**55,794**	**56,488**	**57,527**	**58,132**

Table 7. Estimates exempt use for the Ogallala and Rita Blanca aquifers by groundwater conservation district (GCD) for each decade between 2010 and 2060. Results are in acre-feet per year.

District	Geographic Area	Year					
		2010	2020	2030	2040	2050	2060
Hemphill County UWCD	2	9,121	9,132	8,371	7,063	6,050	5,174
High Plains UWCD No. 1	3	3,286	3,917	4,528	5,228	5,995	6,625
North Plains GCD	1	15,343	15,343	15,343	15,343	15,343	15,343
	3	12,482	12,482	12,482	12,482	12,482	12,482
Panhandle GCD	3	6,300	6,332	6,042	6,475	7,027	7,444
No District	1	3,786	4,249	4,692	4,989	5,097	5,035
	3	3,215	3,818	4,336	4,908	5,533	6,029
Total		**53,533**	**55,273**	**55,794**	**56,488**	**57,527**	**58,132**

Table 8. Estimates of exempt use for the Ogallala and Rita Blanca aquifers by geographic area for each decade between 2010 and 2060. Results are in acre-feet per year.

Geographic Area	Year					
	2010	2020	2030	2040	2050	2060
1	19,129	19,592	20,035	20,332	20,440	20,378
2	9,121	9,132	8,371	7,063	6,050	5,174
3	25,283	26,549	27,388	29,093	31,037	32,580
Total	**53,533**	**55,273**	**55,794**	**56,488**	**57,527**	**58,132**

Table 9. Estimates of exempt use for the Ogallala and Rita Blanca aquifers by river basin for each decade between 2010 and 2060. Results are in acre-feet per year.

Basin	Year					
	2010	2020	2030	2040	2050	2060
Canadian	39,919	41,124	41,175	41,222	41,336	41,230
Red	13,614	14,149	14,619	15,266	16,191	16,902
Total	**53,533**	**55,273**	**55,794**	**56,488**	**57,527**	**58,132**

Table 10. Estimates of managed available groundwater for the Ogallala and Rita Blanca aquifers by county for each decade between 2010 and 2060. Results are in acre-feet per year.

County	Geographic Area	Year					
		2010	2020	2030	2040	2050	2060
Armstrong	3	54,217	50,904	47,801	44,941	42,222	40,286
Carson	3	185,442	172,182	159,731	148,206	137,526	130,519
Dallam	1	413,310	336,398	270,964	200,522	139,834	103,119
Donley	3	85,490	79,312	73,599	68,292	63,367	60,151
Gray	3	175,524	162,997	151,201	140,275	130,019	123,286
Hansford	3	259,866	240,816	223,139	206,706	191,258	179,899
Hartley	1	388,576	327,678	289,555	267,345	249,520	231,990
Hemphill	2	45,877	45,866	46,627	47,935	48,888	49,764
Hutchinson	3	144,858	134,202	124,427	115,281	106,644	100,374
Lipscomb	3	242,114	224,463	208,084	192,884	178,780	169,452
Moore	1	216,020	152,766	110,471	89,314	74,249	64,847
Ochiltree	3	243,318	225,552	209,065	193,767	179,465	169,864
Oldham	3	23,979	20,816	19,722	18,716	17,118	16,100
Potter	3	38,351	34,131	29,598	25,910	23,143	20,801
Randall	3	79,314	74,524	71,078	64,056	56,668	45,967
Roberts	3	358,543	332,486	308,904	286,686	266,028	252,462
Sherman	1	243,311	190,272	160,774	144,707	135,586	130,828
Wheeler	3	112,747	104,917	97,617	90,577	83,916	79,625
Total		**3,310,856**	**2,910,283**	**2,602,356**	**2,346,122**	**2,124,231**	**1,969,333**

Table 11. Estimates of managed available groundwater for the Ogallala and Rita Blanca aquifers by groundwater conservation district (GCD) for each decade between 2010 and 2060. Results are in acre-feet per year. UWCD refers to Underground Water Conservation District.

District	Geographic Area	Year					
		2010	2020	2030	2040	2050	2060
Hemphill County UWCD	2	45,877	45,866	46,627	47,935	48,888	49,764
High Plains UWCD No. 1	3	69,546	65,596	62,235	56,108	51,209	42,309
North Plains GCD	1	1,081,427	868,862	725,597	620,542	537,927	486,341
	3	796,448	738,163	684,078	633,821	586,727	553,708
Panhandle GCD	3	1,010,422	937,134	869,445	805,932	746,615	707,417
No District	1	179,789	138,253	106,166	81,346	61,261	44,443
	3	127,347	116,409	108,208	100,437	91,603	85,352
Total		**3,310,856**	**2,910,283**	**2,602,356**	**2,346,122**	**2,124,231**	**1,969,333**

Table 12. Estimates of managed available groundwater for the Ogallala and Rita Blanca aquifers by geographic area for each decade between 2010 and 2060. Results are in acre-feet per year.

Geographic Area	Year					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
1	1,261,216	1,007,115	831,763	701,888	599,188	530,783
2	45,877	45,866	46,627	47,935	48,888	49,764
3	2,003,762	1,857,302	1,723,966	1,596,299	1,476,155	1,388,786
Total	**3,310,856**	**2,910,283**	**2,602,356**	**2,346,122**	**2,124,231**	**1,969,333**

Table 13. Estimates of managed available groundwater for the Ogallala and Rita Blanca aquifers by river basin for each decade between 2010 and 2060. Results are in acre-feet per year.

Basin	Year					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Canadian	2,700,390	2,341,541	2,071,597	1,853,706	1,668,331	1,542,908
Red	610,466	568,742	530,760	492,416	455,899	426,425
Total	**3,310,856**	**2,910,283**	**2,602,356**	**2,346,122**	**2,124,231**	**1,969,333**

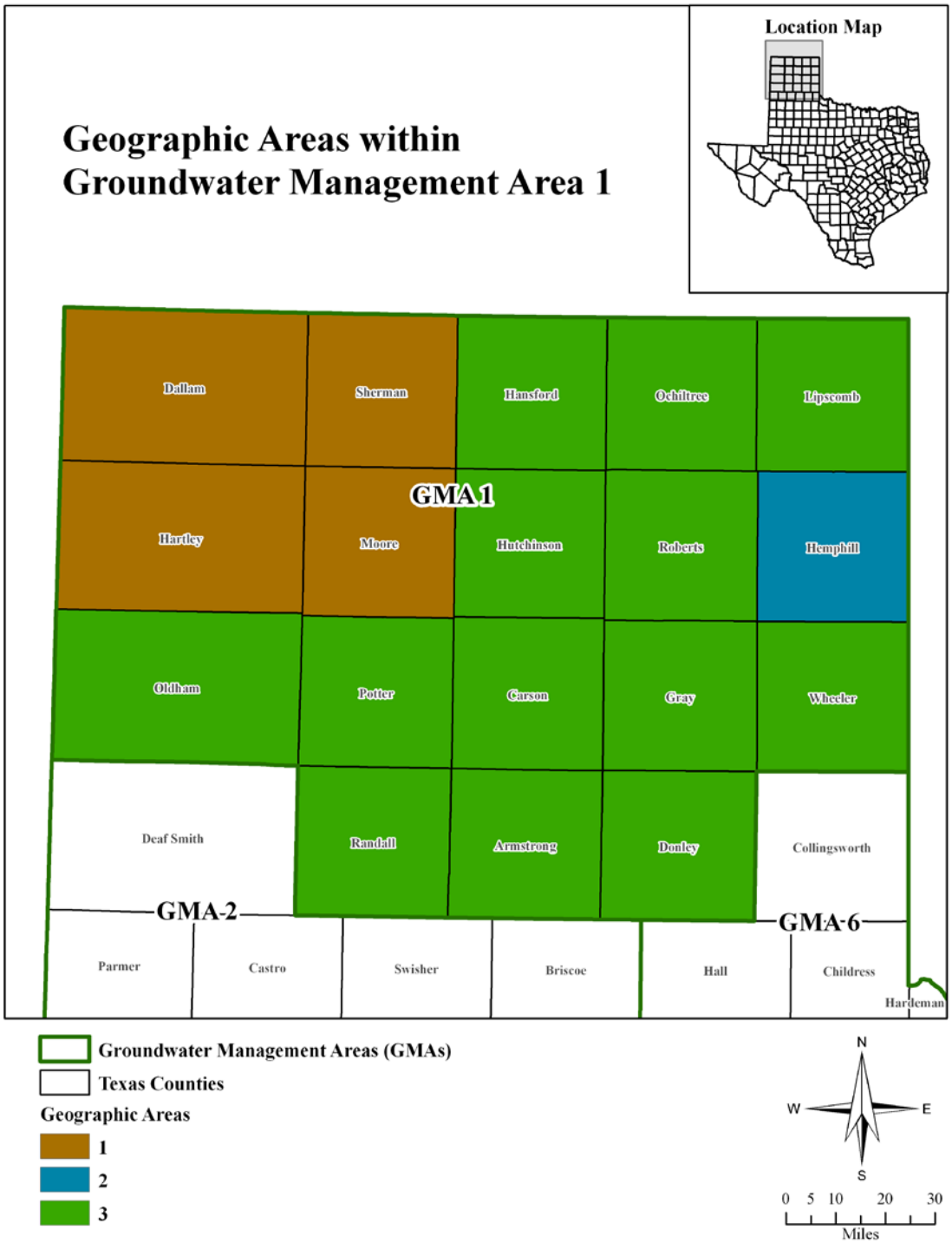


Figure 1. Map showing the geographic areas defined by Groundwater Management Area 1 for defining desired future conditions for the Ogallala Aquifer.

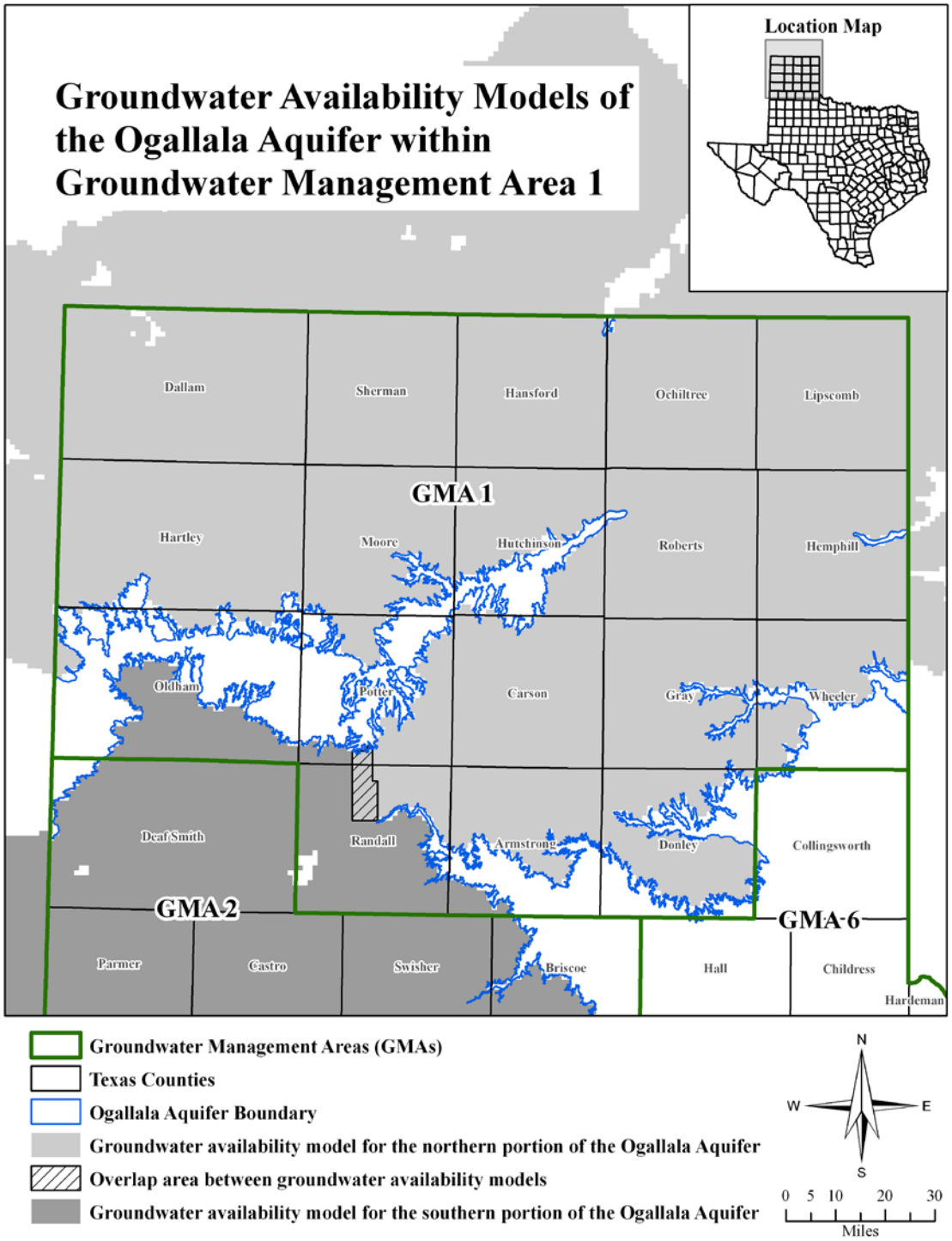


Figure 2. Map showing the areas covered by the groundwater availability models for the northern and southern portions of the Ogallala Aquifer.

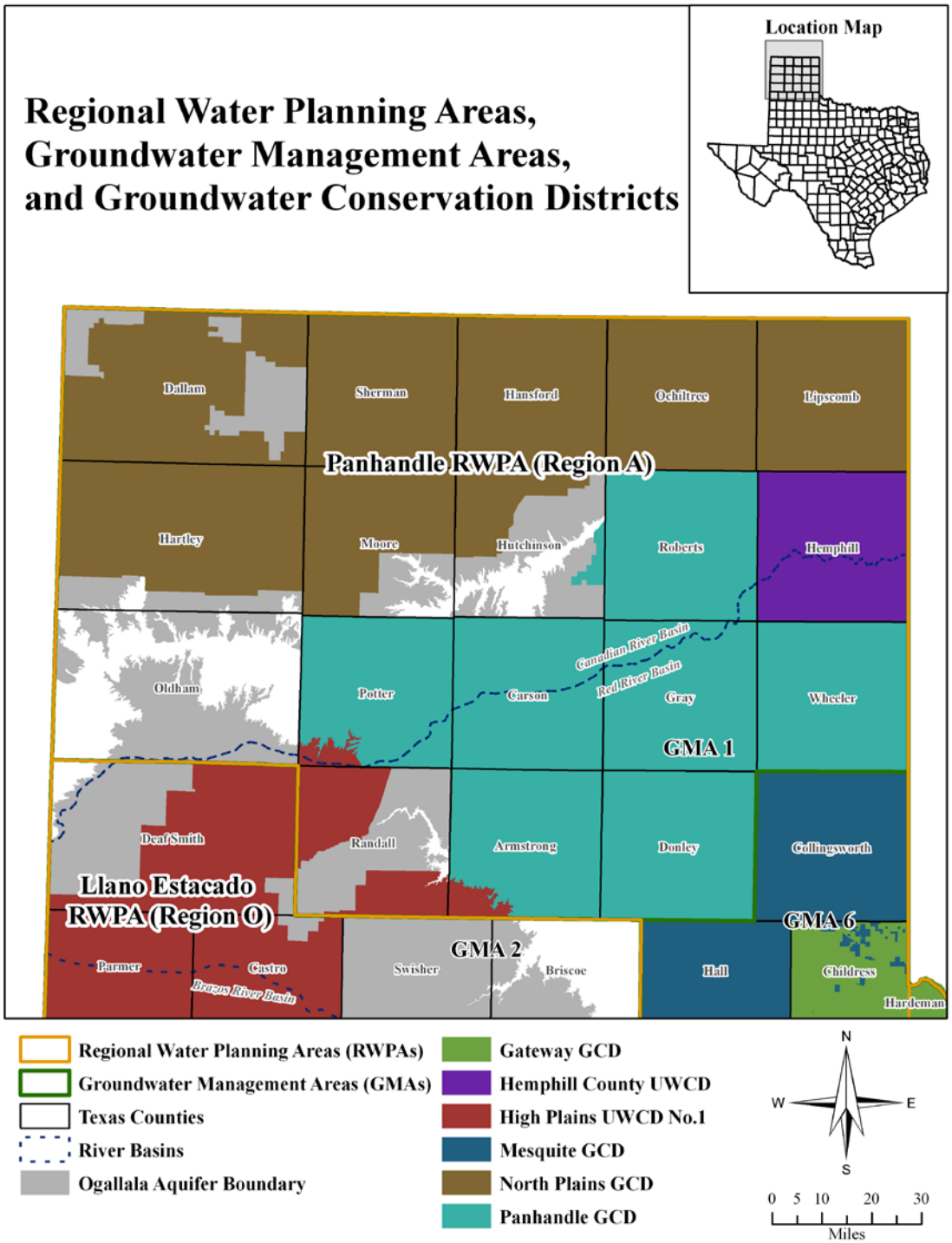


Figure 3. Map showing regional water planning areas, groundwater management areas, groundwater conservation districts, counties, and river basins in and neighboring Groundwater Management Area 1.