GAM Task 13-042: Total Estimated Recoverable Storage by County for Aquifers in High Plains Underground Water Conservation District No. 1

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November 1, 2013

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EXECUTIVE SUMMARY:

Texas Water Code, § 36.108 (d) (Texas Water Code, 2011) states that, before voting on the proposed desired future conditions for a relevant aquifer within a groundwater management area, the groundwater conservation districts shall consider the total estimated recoverable storage as provided by the executive administrator of the Texas Water Development Board (TWDB) along with other factors listed in §36.108 (d). Texas Administrative Code Rule §356.10 (Texas Administrative Code, 2011) defines the total estimated recoverable storage as the estimated amount of groundwater within an aquifer that accounts for recovery scenarios that range between 25 percent and 75 percent of the porosity-adjusted aquifer volume.

This report discusses the methods, assumptions, and results of analyses to estimate the total recoverable storage for the Dockum, Edwards-Trinity (High Plains), and Ogallala aquifers within High Plains Underground Water Conservation District No. 1 that lies within parts of Groundwater Management Area 1 and Groundwater Management Area 2. Tables 1 through 3 summarize the total estimated recoverable storage by county within the district. Figures 2 through 4 indicate the extent of the groundwater availability models used to estimate the total recoverable storage. These analyses supplement GAM Task 13-026 containing total estimated recoverable storage per county and groundwater conservation district for Groundwater Management Area 2, dated September 19, 2013, and GAM Task 13-025 containing total estimated recoverable storage per county and groundwater conservation district for Groundwater Management Area 1, dated August 20, 2013. These analyses were requested on

October 28, 2013 by Mr. Bill Mullican on behalf of the High Plains Underground Water Conservation District No. 1.

DEFINITION OF TOTAL ESTIMATED RECOVERABLE STORAGE:

The total estimated recoverable storage is defined as the estimated amount of groundwater within an aquifer that accounts for recovery scenarios that range between 25 percent and 75 percent of the porosity-adjusted aquifer volume. In other words, we assume that between 25 and 75 percent of groundwater held within an aquifer can be removed by pumping.

The total recoverable storage was estimated for the portion of each aquifer within High Plains Underground Water Conservation District No. 1 that lies within the official lateral aquifer boundaries as delineated by George and others (2011). Total estimated recoverable storage values may include a mixture of water quality types, including fresh, brackish, and saline groundwater, because the available data and the existing groundwater availability models do not permit the differentiation of different water quality types. These values do not take into account the effects of land surface subsidence, degradation of water quality, or any changes to surface water-groundwater interaction that may result from extracting groundwater from the aquifer.

METHODS:

To estimate the total recoverable storage of an aquifer, we first calculated the total storage in an aquifer within the official aquifer boundary in the groundwater conservation district. The total storage is the volume of groundwater that can be removed by completely draining the aquifer.

Aquifers can be either unconfined or confined (Figure 1). A well screened in an unconfined aquifer will have a water level equal to the water level in the aquifer outside the well. Thus, an unconfined aquifer has water levels within the aquifer. A confined aquifer is bounded by low permeable geologic units at the top and bottom, and the aquifer is under hydraulic pressure above the ambient atmospheric pressure. The water level in a well screened in a confined aquifer will be above the top of the aquifer. As a result, calculation of total storage is different between unconfined and confined aquifers. For an unconfined aquifer, the total storage is equal to the volume of groundwater that makes the water level fall to the aquifer bottom. For a confined aquifer, the total storage contains two parts. The first part is the groundwater released from the aquifer when the water level falls from above the top of the aquifer to the top of the aquifer. The reduction of hydraulic pressure in the aquifer by pumping causes expansion of groundwater and deformation of aquifer solids. The aquifer is still fully saturated to this point. The second part, just like unconfined aquifer, is the groundwater released from the aquifer when the water level falls from the top to the bottom of the aquifer. Given the same aquifer area and water level drop, the amount of water released in the second part is much greater than the first part. The difference is quantified by two parameters: storativity related to confined aquifer and specific yield related to unconfined aquifer. For example, storativity values range from 10^{-5} to 10^{-3} for most confined aquifers, while the specific yield values can be 0.01 to 0.3 for most unconfined aquifers. The equations for calculating the total storage are presented below:

- for unconfined aquifers

$$Total\ Storage\ = V_{drained} = Area \times S_y \times (Water\ Level - Bottom)$$

- for confined aquifers

$$Total\ Storage\ = V_{confined} + V_{drained}$$

  - confined part

$$V_{confined} = \ Area \times [\ S \times (Water\ Level - Top)]$$

or

$$V_{confined} = \ Area \times [\ S_s\ \times (\mathrm{Top} - \mathrm{Bottom}) \times (Water\ Level - Top)]$$

  - unconfined part

$$V_{drained} = \ Area \times \left[S_y \times (Top - Bottom)\right]$$

where:

- $V_{drained}$ = storage volume due to water draining from the formation (acre-feet)
- $V_{confined}$ = storage volume due to elastic properties of the aquifer and water(acre-feet)
- *Area* = area of aquifer (acre)
- *Water Level* = groundwater elevation (feet above mean sea level)
- *Top* = elevation of aquifer top (feet above mean sea level)
- *Bottom* = elevation of aquifer bottom (feet above mean sea level)
- S_y = specific yield (no units)

- S_s = specific storage (1/feet)
- S = storativity or storage coefficient (no units)

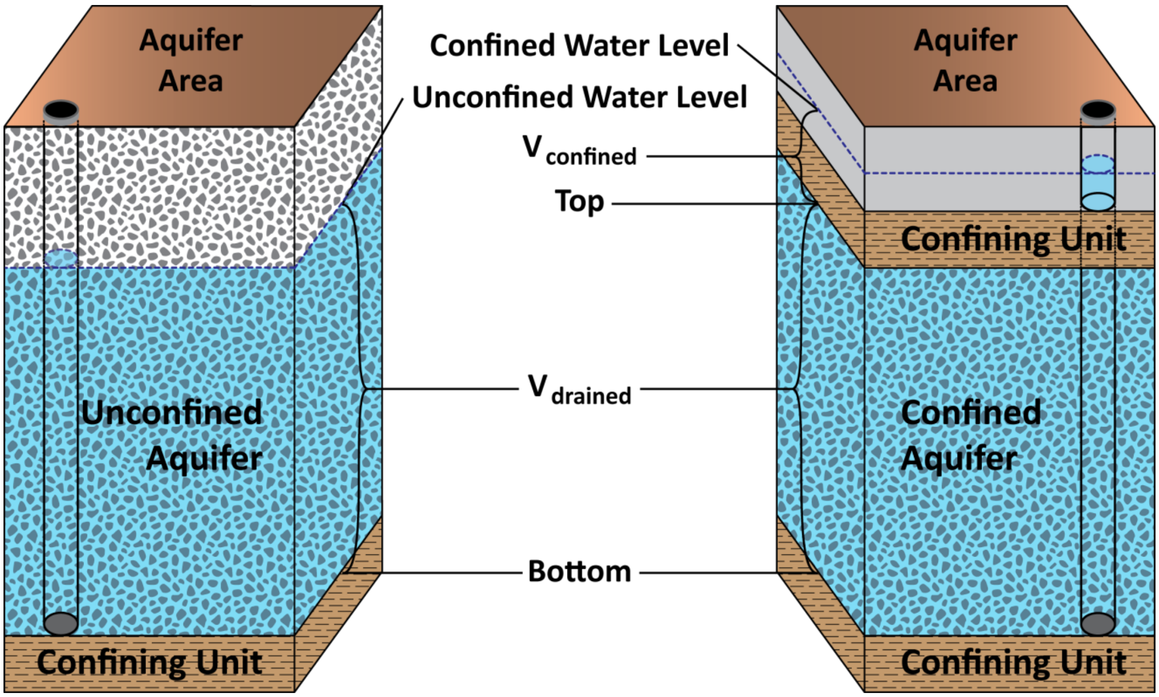

FIGURE 1. SCHEMATIC GRAPH SHOWING THE DIFFERENCE BETWEEN UNCONFINED AND CONFINED AQUIFERS.

As presented in the equations, calculation of the total storage requires data, such as aquifer top, aquifer bottom, aquifer storage properties, and water level. For the Dockum, Edwards-Trinity (High Plains), and Ogallala aquifers in High Plains Underground Water Conservation District No. 1, we extracted this information from existing groundwater availability model input and output files on a cell-by-cell basis. This information was contained in model input and output files on a cell-by-cell basis.

Python scripts and a FORTRAN-90 program were developed and used to expedite the storage calculation. The total recoverable storage was calculated as the product of the total storage and an estimated factor ranging from 25 percent to 75 percent.

PARAMETERS AND ASSUMPTIONS:

Dockum Aquifer

- We used version 1.01 of the groundwater availability model for the Dockum Aquifer to estimate the total recoverable storage. See Ewing and others (2008) for assumptions and limitations of the groundwater availability model.
- This groundwater availability model includes three layers which generally represent the younger geologic units overlying the Dockum Aquifer (Layer 1), the upper portion of the Dockum Aquifer (Layer 2), and the lower portion of the Dockum Aquifer (Layer 3).
- Of the three layers, total estimated recoverable storage was determined and combined for layers representing the Dockum Aquifer (layers 2 and 3).
- The down-dip boundary of the Dockum Aquifer in this model was set to approximately coincide with the extent of the available geologic data, well beyond any active portion—in terms of groundwater use—of the aquifer (Ewing and others, 2008). Consequently, the model extends into zones of brackish and saline groundwater. The official extent of the Dockum Aquifer was used to exclude this area (George and others, 2011).

Southern portion of the Ogallala Aquifer and Edwards-Trinity (High Plains) Aquifer

- We used version 2.01 of the groundwater availability model to estimate the total recoverable storages of the southern portion of the Ogallala and Edwards-Trinity (High Plains) aquifers. 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.
- This groundwater availability model includes 4 layers which represent the southern portion of the Ogallala Aquifer (Layer 1) and the Edwards-Trinity (High Plains) Aquifer—primarily Edwards, Comanche Peak, and Antlers Sand formations— (layers 2-4).

- Of the four layers, total estimated recoverable storage was determined for the Ogallala Aquifer (Layer 1) and Edwards-Trinity (High Plains) Aquifer (layers 2-4) in High Plains Underground Water Conservation District No. 1.

Northern portion of the Ogallala Aquifer

- We used version 3.01 of the groundwater availability model to estimate the total recoverable storage for the northern portion of the Ogallala Aquifer which includes the Rita Blanca Aquifer. This model is an update to the previously developed groundwater availability model for the northern portion of the Ogallala Aquifer described in Dutton and others (2001) and Dutton (2004). See Kelley and others (2010), Dutton (2004), and Dutton and others (2001) for assumptions and limitations of the model.
- Total estimated recoverable storage was determined for the Ogallala Aquifer (layer 1) in High Plains Underground Water Conservation District No. 1.

RESULTS:

Tables 1 through 3 summarize the total estimated recoverable storage by county within the High Plains Underground Water Conservation District No. 1. The total estimates are rounded to two significant figures. Figures 2 through 4 indicate the extent of the groundwater availability models within High Plains Underground Water Conservation District No. 1 for the Dockum, Edwards-Trinity (High Plains), and Ogallala aquifers from which the storage information was extracted.

TABLE 1. TOTAL ESTIMATED RECOVERABLE STORAGE FOR THE DOCKUM AQUIFER BY COUNTY WITHIN THE HIGH PLAINS UNDERGROUND WATER CONSERVATION DISTRICT NO. 1. ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

High Plains UWCD[1] No. 1 by County	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Armstrong	3,400,000	850,000	2,550,000
Castro	5,500,000	1,375,000	4,125,000
Crosby	21,000,000	5,250,000	15,750,000
Deaf Smith	77,000,000	19,250,000	57,750,000
Floyd	39,000,000	9,750,000	29,250,000
Hale	16,000,000	4,000,000	12,000,000
Parmer	30,000,000	7,500,000	22,500,000
Potter	2,700,000	675,000	2,025,000
Randall	25,000,000	6,250,000	18,750,000
Swisher	66,000,000	16,500,000	49,500,000
Total[2]	**285,600,000**	**71,400,000**	**214,200,000**

[1] UWCD is the abbreviation for Underground Water Conservation District.
[2] The total estimated recoverable storages from this report may not exactly match results from GAM Tasks 13-025 or 13-026 because the numbers have been rounded to two significant figures.

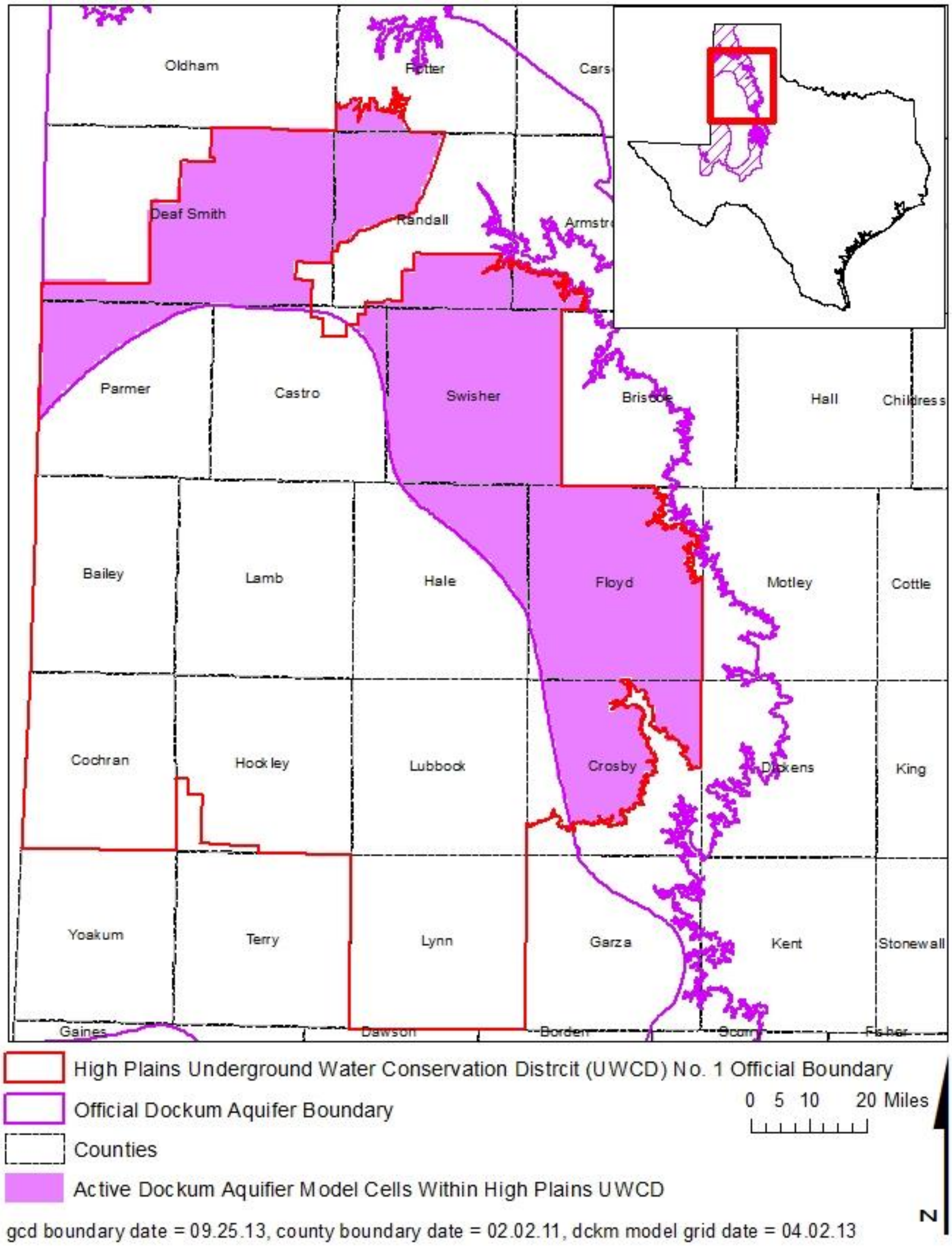

FIGURE 2. EXTENT OF THE GROUNDWATER AVAILABILITY MODEL OF THE DOCKUM AQUIFER USED TO ESTIMATE TOTAL RECOVERABLE STORAGE (TABLE 1) WITHIN HIGH PLAINS UNDERGROUND WATER CONSERVATION DISTRICT NO. 1.

TABLE 2. TOTAL ESTIMATED RECOVERABLE STORAGE FOR THE EDWARDS-TRINITY (HIGH PLAINS) AQUIFER BY COUNTY WITHIN THE HIGH PLAINS UNDERGROUND WATER CONSERVATION DISTRICT NO. 1. ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

High Plains UWCD[3] No. 1 by County	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Bailey	690,000	172,500	517,500
Cochran	1,700,000	425,000	1,275,000
Floyd	730,000	182,500	547,500
Hale	870,000	217,500	652,500
Hockley	2,100,000	525,000	1,575,000
Lamb	500,000	125,000	375,000
Lubbock	2,000,000	500,000	1,500,000
Lynn	3,400,000	850,000	2,550,000
Total[4]	**11,990,000**	**2,997,500**	**8,992,500**

[3] UWCD is the abbreviation for Underground Water Conservation District.
[4] The total estimated recoverable storages from this report may not exactly match results from GAM Tasks 13-025 or 13-026 because the numbers have been rounded to two significant figures.

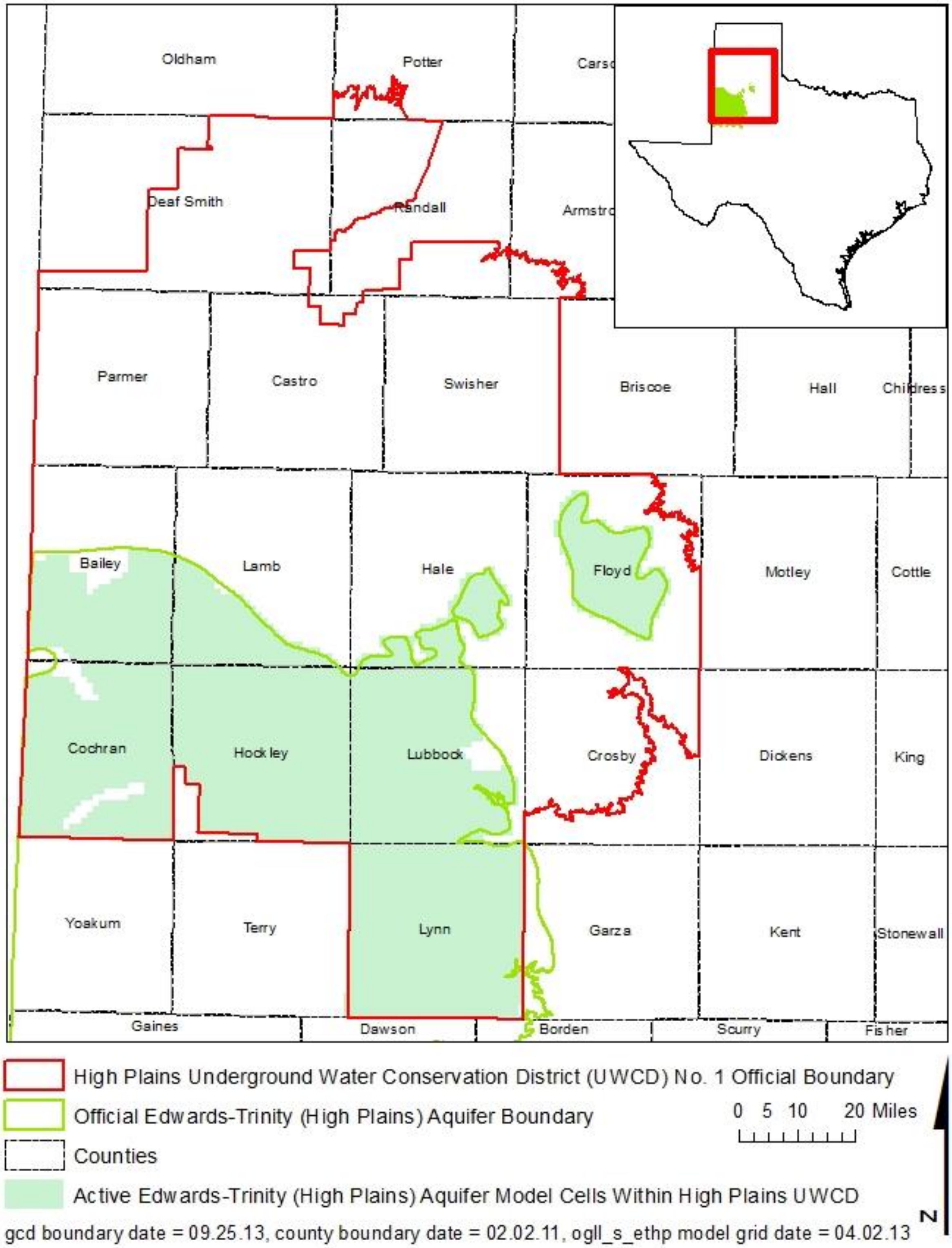

FIGURE 3. EXTENT OF THE GROUNDWATER AVAILABILITY MODEL OF THE EDWARDS-TRINITY (HIGH PLAINS) AQUIFER USED TO ESTIMATE TOTAL RECOVERABLE STORAGE (TABLE 2) WITHIN HIGH PLAINS UNDERGROUND WATER CONSERVATION DISTRICT NO. 1.

TABLE 3. TOTAL ESTIMATED RECOVERABLE STORAGE FOR THE OGALLALA AQUIFER BY COUNTY WITHIN THE HIGH PLAINS UNDERGROUND WATER CONSERVATION DISTRICT NO. 1. ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

High Plains UWCD[5] No. 1 by County	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Armstrong	580,000	145,000	435,000
Bailey	2,900,000	725,000	2,175,000
Castro	9,400,000	2,350,000	7,050,000
Cochran	2,900,000	725,000	2,175,000
Crosby	9,600,000	2,400,000	7,200,000
Deaf Smith	6,400,000	1,600,000	4,800,000
Floyd	12,000,000	3,000,000	9,000,000
Hale	9,500,000	2,375,000	7,125,000
Hockley	5,400,000	1,350,000	4,050,000
Lamb	8,600,000	2,150,000	6,450,000
Lubbock	7,000,000	1,750,000	5,250,000
Lynn	5,000,000	1,250,000	3,750,000
Parmer	3,900,000	975,000	2,925,000
Potter	260,000	65,000	195,000
Randall	3,800,000	950,000	2,850,000
Swisher	7,600,000	1,900,000	5,700,000
Total[6]	**94,840,000**	**23,710,000**	**71,130,000**

[5] UWCD is the abbreviation for Underground Water Conservation District.
[6] The total estimated recoverable storages from this report may not exactly match results from GAM Tasks 13-025 or 13-026 because the numbers have been rounded to two significant figures.

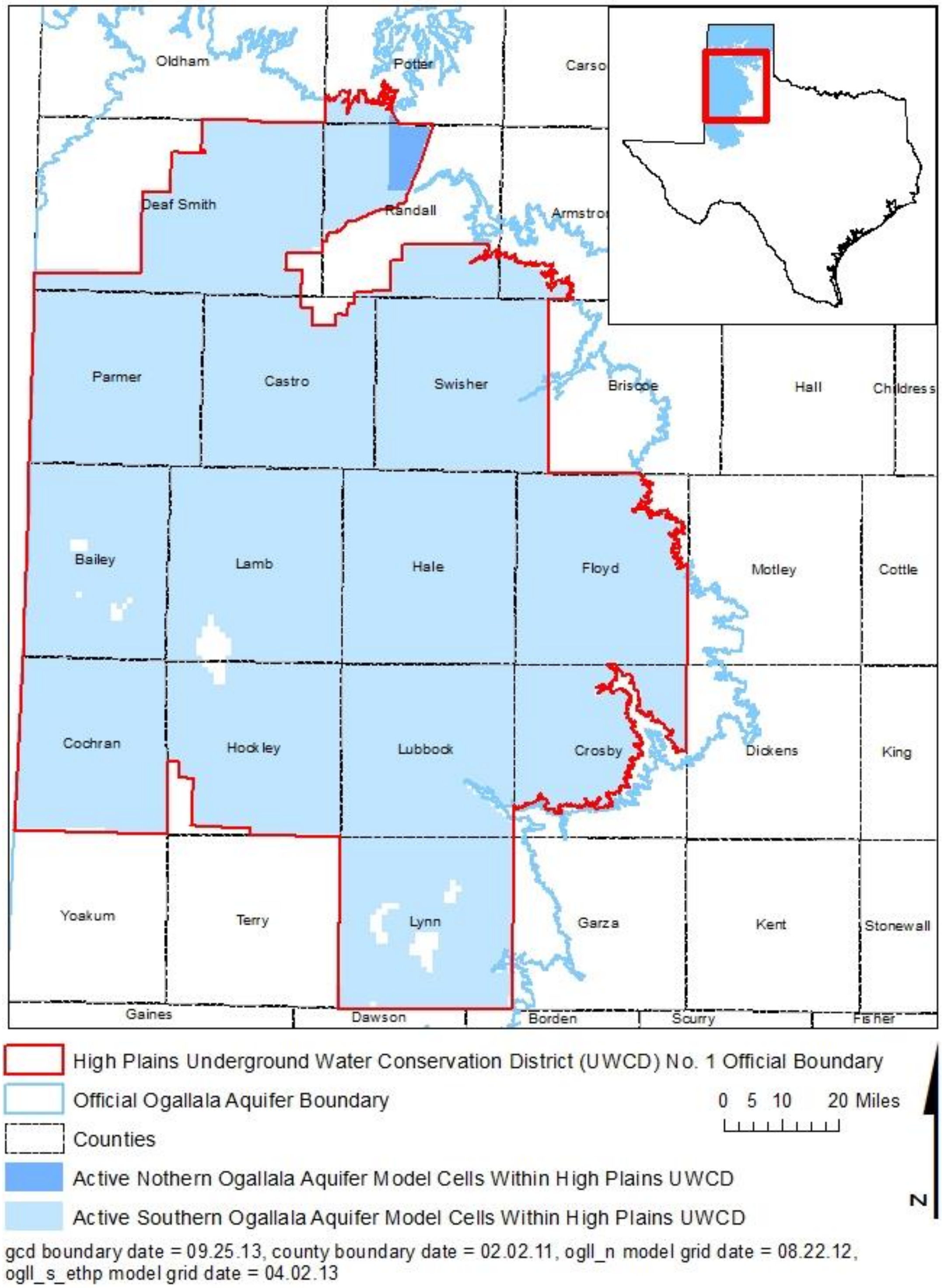

FIGURE 4. EXTENT OF THE GROUNDWATER AVAILABILITY MODEL OF THE OGALLALA AQUIFER USED TO ESTIMATE TOTAL RECOVERABLE STORAGE (TABLE 3) WITHIN HIGH PLAINS UNDERGROUND WATER CONSERVATION DISTRICT NO. 1.

LIMITATIONS

The groundwater models used in completing this analysis are the best available scientific tools that can be used to meet the stated objective(s). 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."*

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.

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