GAM run 07-19

by Richard Smith, P.G.
Texas Water Development Board
Groundwater Availability Modeling Section
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August 10, 2007

EXECUTIVE SUMMARY:

We ran both the northern part of the Ogallala Aquifer groundwater availability model and the southern part of the Ogallala Aquifer groundwater availability model using various percentages per annum declines depending on the groundwater conservation district desired future condition. For the North Plains Groundwater Conservation District, we used 2 percent; for Hemphill County Groundwater Conservation District, we used 1 percent; and for the Panhandle Groundwater Conservation District and the High Plains Underground Water Conservation District, we used 1.25 percent per annum declines for the period 2001 through 2060. We calculated the pumpage using the specified change in the volume in storage from one year to the next. We then created new MODFLOW well files and ran the models. Finally, we generated drawdown and water-level maps for all counties in Groundwater Management Area 1.

The results indicate a number of cells going dry within ten years of starting the desired pumping and numerous dry cells at the end of the 2001 through 2060 model simulation period. In MODFLOW, when the water level in a model cell falls below the bottom of the cell, the cell goes dry. Because the cell no longer has water in it, MODFLOW turns the cell off. When a cell goes dry, the model is indicating that there is not enough water flowing into the cell (for example, recharge) or there is too much water being removed from the cell (for example, pumping) to keep water in the cell. If pumping is the primary factor, the model is saying that the pumping may be too great for the aquifer in this area. When MODFLOW shuts a cell off, that cell is off for the rest of the simulation unless the rewetting option is used. However, the MODFLOW rewetting option is difficult to use, and it is usually better to identify why the cell went dry and address the causes rather than use the rewetting option. In reality, the aquifer will probably not go dry because pumping will become uneconomical before the aquifer goes dry in any particular area. However, the GAM is suggesting that these areas may experience water supply problems sometime in the next 50 years.

REQUESTOR:

Mr. Daniel Krienke with the North Plains Groundwater Conservation District on behalf of Groundwater Management Area 1.

DESCRIPTION OF REQUEST:

Apply the pumpage estimated in a previous spreadsheet analysis (see GAM run 06-25) to the northern part of the Ogallala Aquifer model and a small portion of the southern part of the Ogallala Aquifer model for counties that are located within the boundaries of Groundwater Management Area 1 to determine the amount of drawdown and projected water levels in 2010, 2020, 2030, 2040, 2050, and 2060 for the:

- North Plains Groundwater Conservation District using a 2 percent per annum decline in storage;
- Panhandle Groundwater Conservation District and the High Plains Underground Water Conservation District using a 1.25 percent per annum decline in storage;
- Hemphill County Groundwater Conservation District using a 1 percent per annum decline in storage.

METHODS:

To address the request, we did the following steps:

- Extracted the annual model-wide recharge rates from the water budgets from the groundwater availability model runs for the northern and southern parts of the Ogallala Aquifer for the counties within Groundwater Management Area 1. Average recharge is based on a percentage of precipitation for the 1950 through 1990 period of record.
- Calculated the groundwater in storage for the baseline year 2000 using unique cell values. To do so, we first calculated saturated thickness by subtracting the bottom of the Ogallala Aquifer, as included in the models, from the simulated and calibrated model water levels in 2000. On a cell-by-cell basis in the models, we multiplied the saturated thickness by the area of the cell and by the model cell's specific yield to get a volume. See GAM Run 06-25 dated November 2, 2006 for the results.
- Computed the 1, 1.25, and 2 percent annual depletion from 2001 through 2060 using a spreadsheet analysis. Annual depletion was calculated based on a depletion of the previous year's total storage with the addition of average recharge
- Annual pumpage was calculated as the percentage change in total storage for each year from 2000 to 2060 in each county of the various groundwater conservation districts. The North Plains Groundwater Conservation District includes Dallam, Hansford, Hartley, the northwestern half of Hutchinson, Lipscomb, Moore, Ochiltree, and Sherman counties. The Panhandle Groundwater Conservation District includes Armstrong, Carson, Donley, Gray, Potter, part of Hutchinson, Randall, Roberts, and Wheeler counties. The High Plains Underground Water Conservation District includes part of Armstrong, Potter, and Randall counties. The Hemphill County Groundwater Conservation District is the entirety of Hemphill County.
- The pumpage was then used to create a MODFLOW well file for the 2001 to 2060 period in both the northern and southern parts of the Ogallala Aquifer

groundwater availability models. We ran the models for that period and generated maps showing drawdown and water levels each decade throughout the models extent. We used water levels in 2000 as the base year to determine differences in water levels.

PARAMETERS AND ASSUMPTIONS:

- Used version 2.01 of the groundwater availability model for the northern part of the Ogallala Aquifer (Dutton, 2004) and version 1.01 of the groundwater availability model for the southern part of the Ogallala Aquifer (Blandford and others, 2003),
- See Dutton and others (2001) and Dutton (2004) for assumptions and limitations of the model for the northern part of the Ogallala Aquifer. Root mean squared error for this model is 53 feet. This error has more of an effect on model results where the aquifer is thin.
- See Blandford and others (2003) for assumptions and limitations of the model for the southern part of the Ogallala Aquifer. Root mean squared error for this model is 47 feet. This error will have more of an effect on model results where the aquifer is thin.
- Recharge was reappraised in the updated model of the northern part of the Ogallala Aquifer (Dutton, 2004).
- Average recharge used in both of the models was based on a percentage of precipitation for the 1950 through 1990 period of record. Since this includes the 1950s drought of record, the average recharge used for this analysis is considered a conservative estimate.
- For Randall, Potter, and Armstrong counties, which are partially included in both the northern and southern parts of the Ogallala Aquifer groundwater availability models, we combined the results of the volume calculation from each model to get full county totals. However, we used the volume calculated from each model for that segment of the county covered as the starting point for the annual percentage decline.
- With regard to Hutchinson County, the volume calculated for 2000 in the northwest section of the county was given a 2 percent per annum decline rate and the southeast remainder of the county was given a 1.25 percent decline rate since this county is managed by both the North Plains Groundwater Conservation District and the Panhandle Groundwater Conservation District .
- We did not change the distribution pattern of the pumping that was used in the calibrated models in 2000 when we allocated the predictive pumpage estimates. As a consequence, drawdowns are concentrated in present pumping locations.

RESULTS:

Table 1 shows the amount of pumping on a yearly basis in acre-feet per year. All counties in the two models within Groundwater Management Area 1 are shown in Figure 1 with their respective per annum declines as requested by the groundwater management area. Figures 2 and 3 show the locations of pumping within the models of the northern and southern part of the Ogallala Aquifer as of 2000. This is the distribution used to locate pumping from 2001 to 2060.

Ten years of the pumping (2001 through 2010) results in a number of areas showing dry cells (Figures 4 and 5). Isolated pumping centers in Hemphill, Lipscomb, Roberts, Ochiltree, Armstrong, Carson, Hansford, and Randall counties show dry cells to a limited degree. In contrast, numerous contiguous cells in Moore, Hartley, and Dallam counties have gone dry in the model. These areas continue to expand through time until their maximum extent is reached in 2060.

In 2020, after twenty years of the desired pumping, dry cells in Hemphill County do not increase. In fact, the model shows that water levels rise (Figures 6 and 7; negative contour values). This may be an artifact of cells going dry, since any pumpage assigned to the cells that went dry is discontinued. Numerous dry cells continue to occur and expand in Roberts, Moore, Carson into Gray, Lipscomb, northeast Hansford, Sherman, Hartley, and Dallam counties. Randall and Armstrong counties show large drawdowns both in the north and southern sections of the counties. It should also be noted that, like Hemphill County, Dallam County shows a water level rise in the northwest corner. Again, this is likely due to cells going dry. Water level rises are indicated on the drawdown maps with negative values.

By 2030, water level rises occur in isolated parts of several counties, including southeast Potter, northeast Randall (northern part of the Ogallala Aquifer model), western Dallam, south central Hartley, and north central Hemphill (Figures 8 and 9). However, the overall trends are steep declines and dry cells. Expanding areas of dry cells include eastern Dallam going into Hartley and connecting with dry cells in Moore County. Further dry cell expansion areas include northwest Lipscomb, northeast Hansford, central Roberts, and northeast Carson into Gray County. Dry cells develop in south central Randall and south west Armstrong (southern part of the Ogallala Aquifer model). Large declines also occur throughout Sherman, most of Roberts, Randall to the south, and northeast Lipscomb counties.

Slight groundwater rises continue in 2040 (Figures 10 and 11) in the same areas as shown for 2030. The expansion of contiguous dry cells in eastern Dallam and eastern Hartley counties coalesces with the dry cells in Moore County. Patches of dry cells form in Sherman, northeastern Moore, western Lipscomb, and northeast Ochiltree counties. Large declines expand in Roberts, Lipscomb, Hansford, Sherman, and Randall Counties to the south.

By 2050, the expansion of areas with dry cells in the model of the northern part of the Ogallala Aquifer is generally limited to those cells contiguous to cells that were dry by 2040 (Figures 12 and 13). However, a number of new dry cells occur in the west central area of Lipscomb County. Areas that expand include Sherman, Moore, Roberts, Gray, Carson, Hansford, Dallam into Hartley, and Randall (in the model for the southern part of the Ogallala Aquifer) counties. Water level rises continue in western Dallam, north central Hartley, and north central Hemphill counties.

In 2060 the number of dry cells reaches a maximum (Figures 14 and 15). New dry cells occur in Sherman, Hansford, Ochiltree, Lipscomb, Moore, Carson, and Randall (in the model for the southern part of the Ogallala Aquifer) counties. Water level rises occur in Dallam, Hartley, Potter, and Hemphill counties. These rises occur when recharge exceeds the amount of pumpage and flow out of the cell.

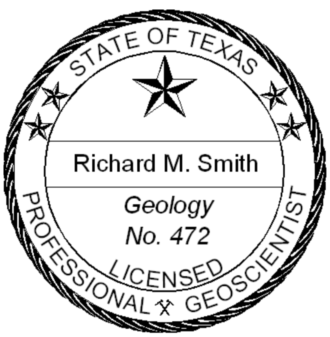
REFERENCES:

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

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.

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.

Smith, R, 2006, GAM Run 06-25, Texas Water Development Board, 28 p.



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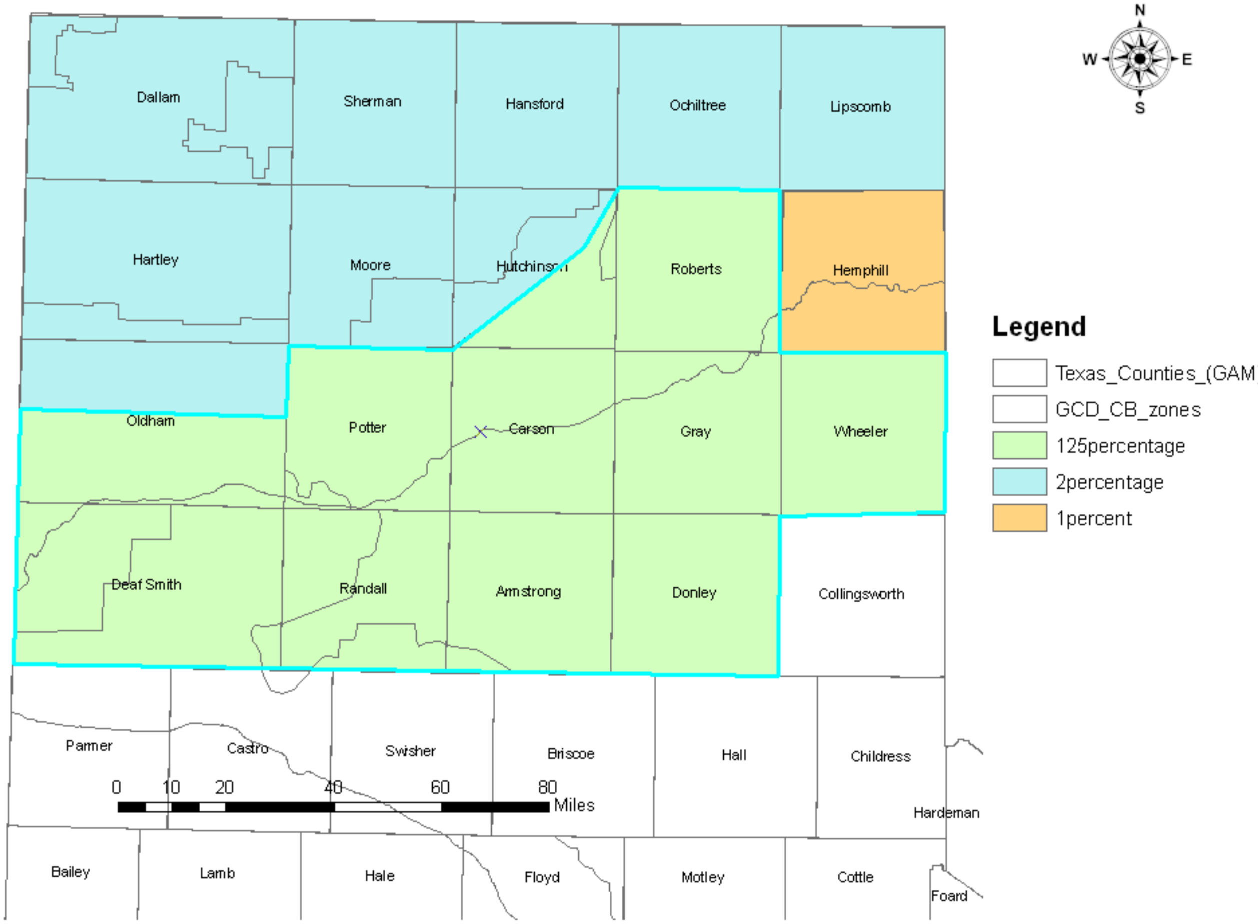

Figure 1: Location of counties with the associated 1, 1.25 and 2 percent of volume declines per annum from 2000 to 2060

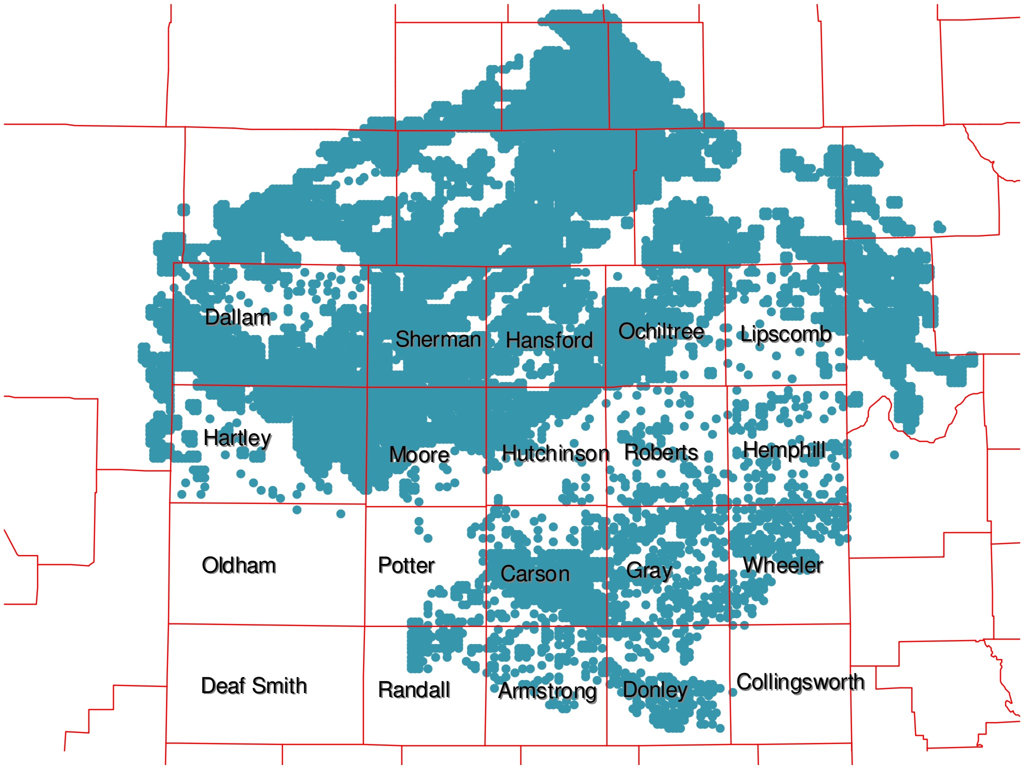

Figure 2: Location of pumping cells in the model of the northern part of the Ogallala Aquifer in 2000. These locations remained the same throughout the projected period 2001 through 2060.

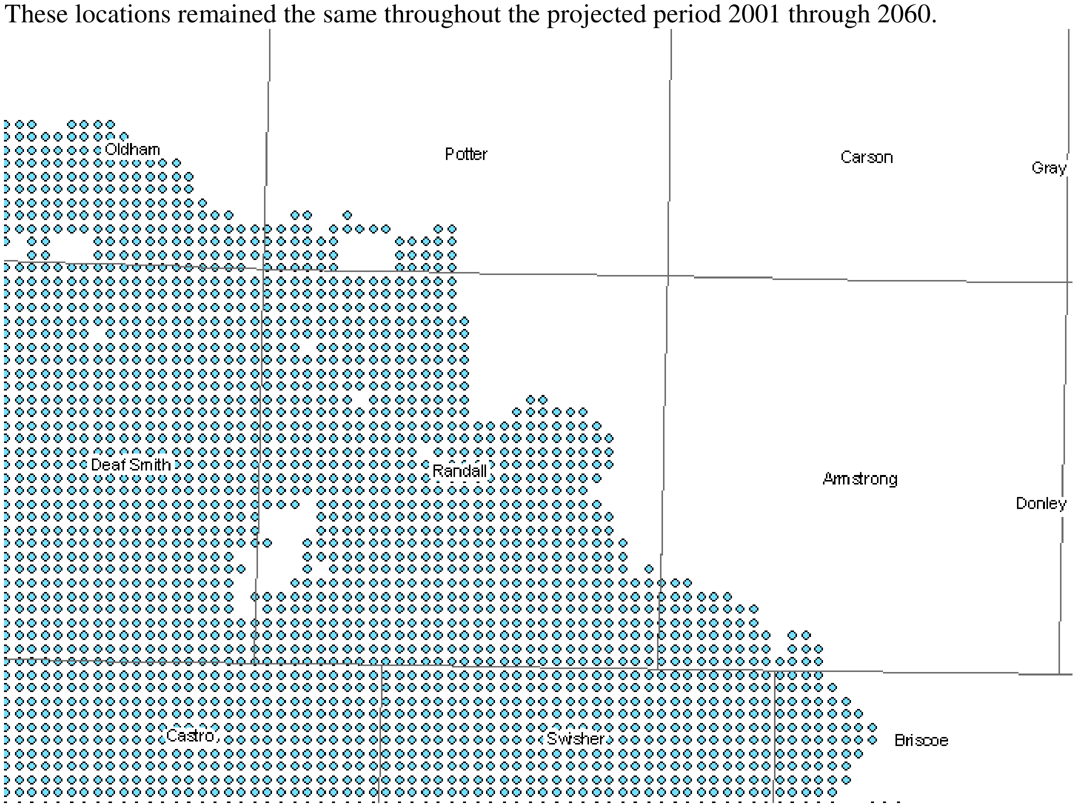

Figure 3: Location of pumping cells in the model of the southern part of the Ogallala Aquifer in 2000. These locations remained the same throughout the projected period 2001 through 2060.

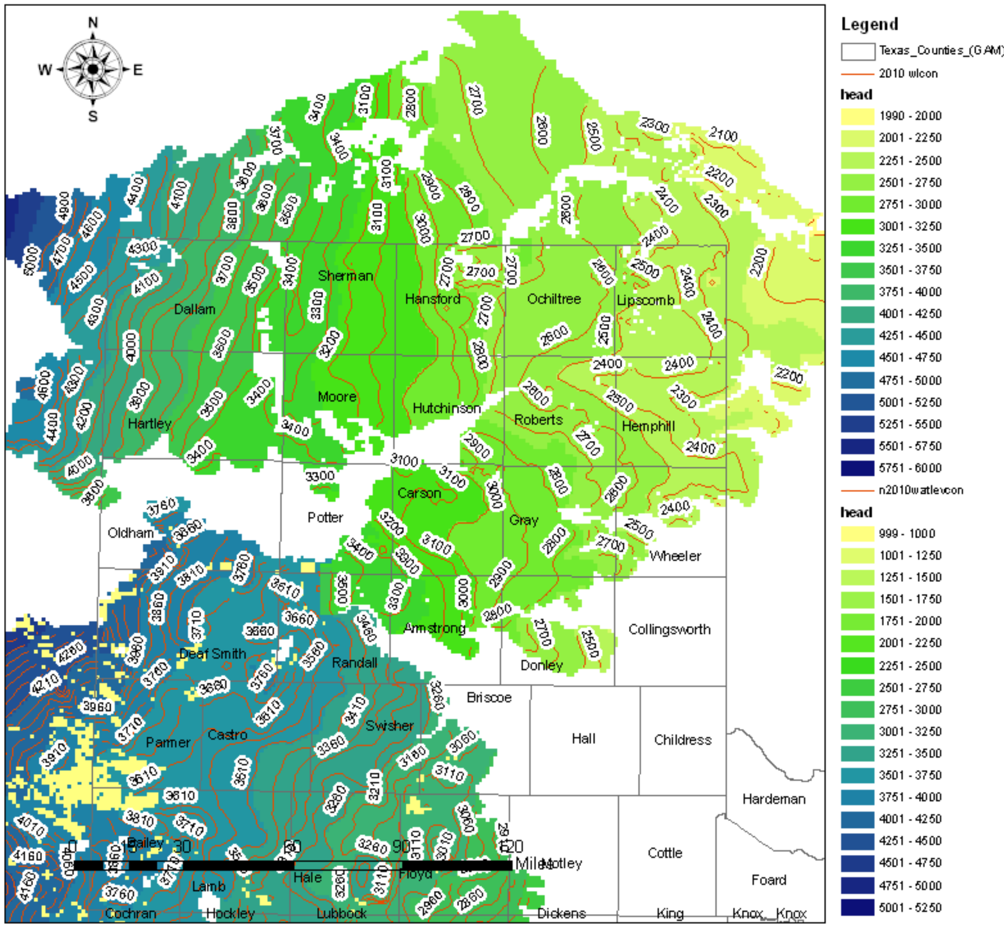

Figure 4: Water levels in 2010 based on 1, 1.25, and 2 percent of volume declines starting in 2001. Yellow cells in the south and white cells in the north represent dry cells generated in the model of the southern part of the Ogallala Aquifer and the model of the northern part of the Ogallala Aquifer, respectively.

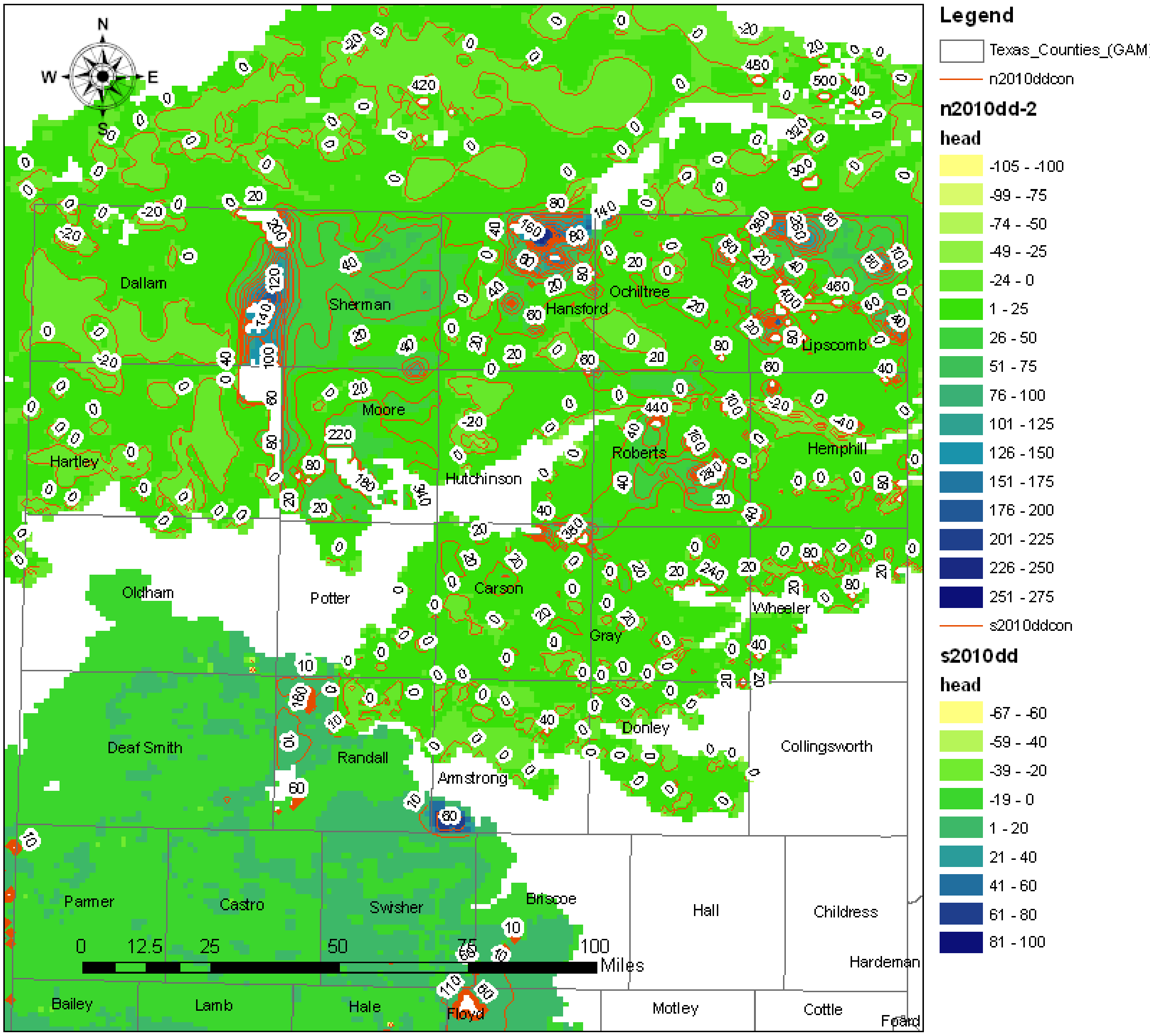

Figure 5: Drawdowns in 2010 based on 1, 1.25, and 2 percent of volume declines starting in 2001. White cells in the south and in the north represent dry cells generated in the model of the southern part of the Ogallala Aquifer and the model of the northern part of the Ogallala Aquifer, respectively.

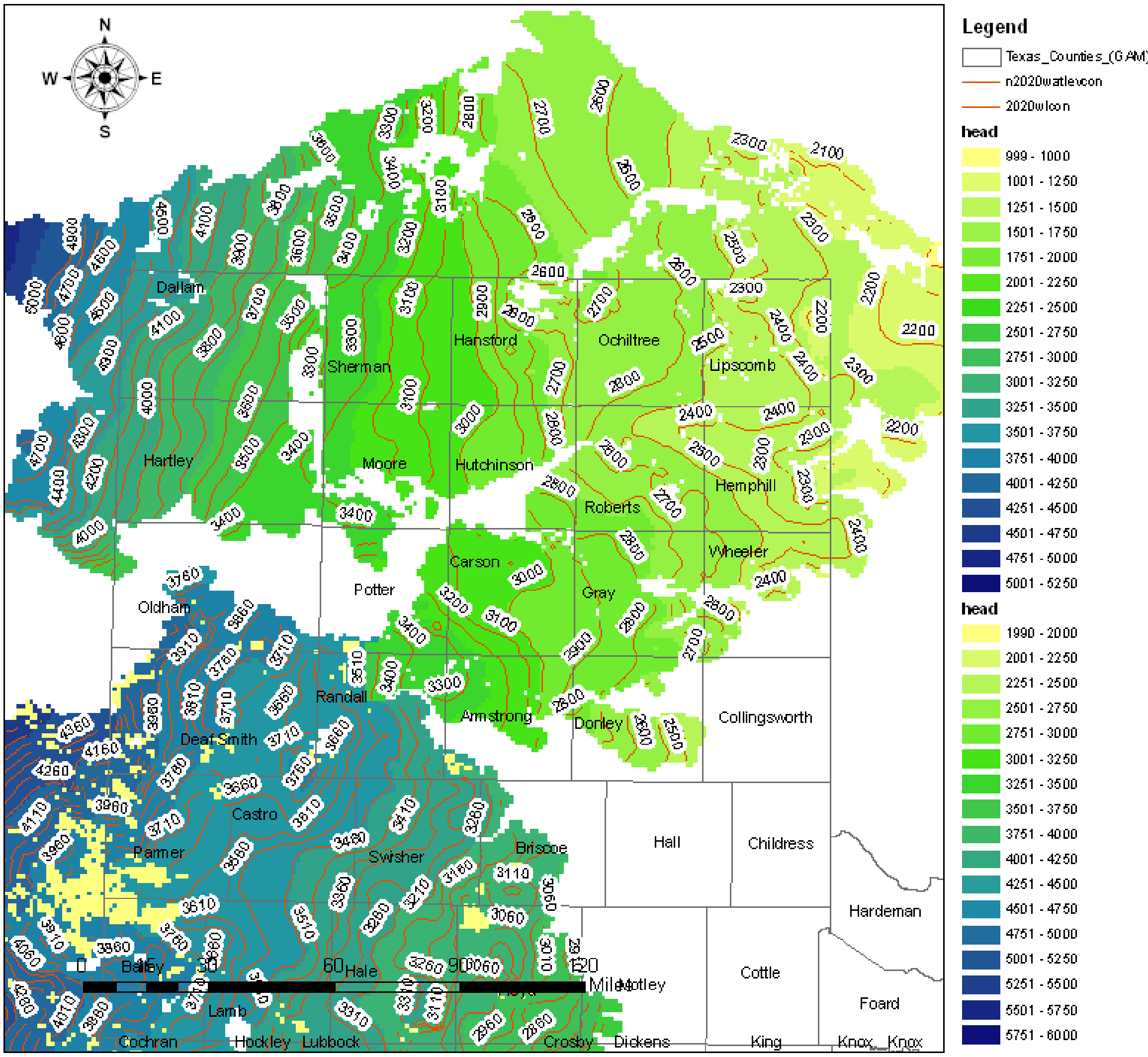

Figure 6: Water levels in 2020 based on 1, 1.25, and 2 percent of volume pumpage starting in 2001. Yellow cells in the south and white cells in the north represent dry cells generated in the Ogallala South and the Ogallala North GAMs respectively.

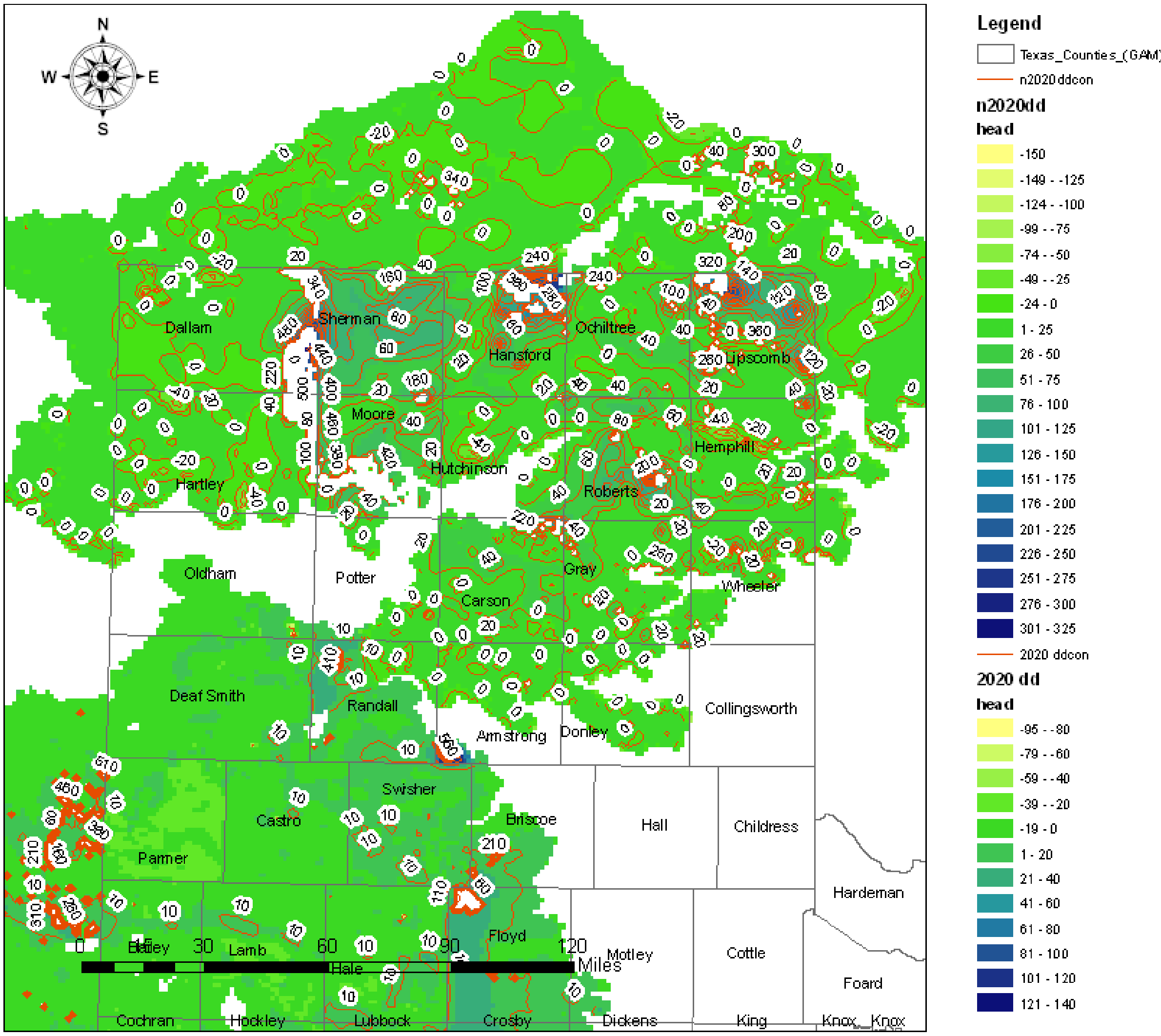

Figure 7: Drawdowns in 2020 based on 1, 1.25, and 2 percent of volume pumpage starting in 2001. White cells in the south and in the north represent dry cells generated in the model of the southern part of the Ogallala Aquifer and the model of the northern part of the Ogallala Aquifer, respectively.

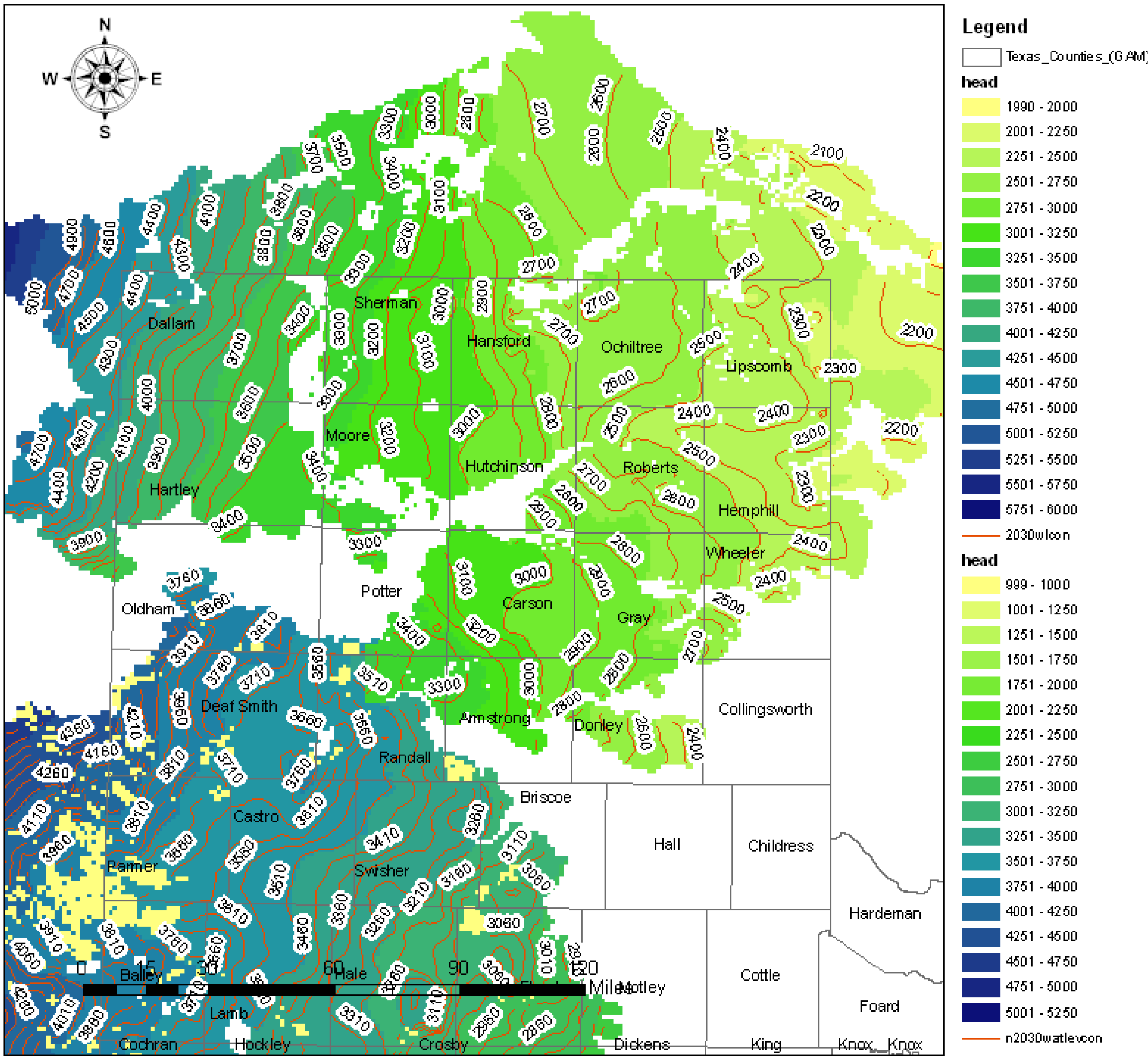

Figure 8: Water levels in 2030 based on 1, 1.25, and 2 percent of volume pumpage starting in 2001. White cells in the south and in the north represent dry cells generated in the model of the southern part of the Ogallala Aquifer and the model of the northern part of the Ogallala Aquifer, respectively.

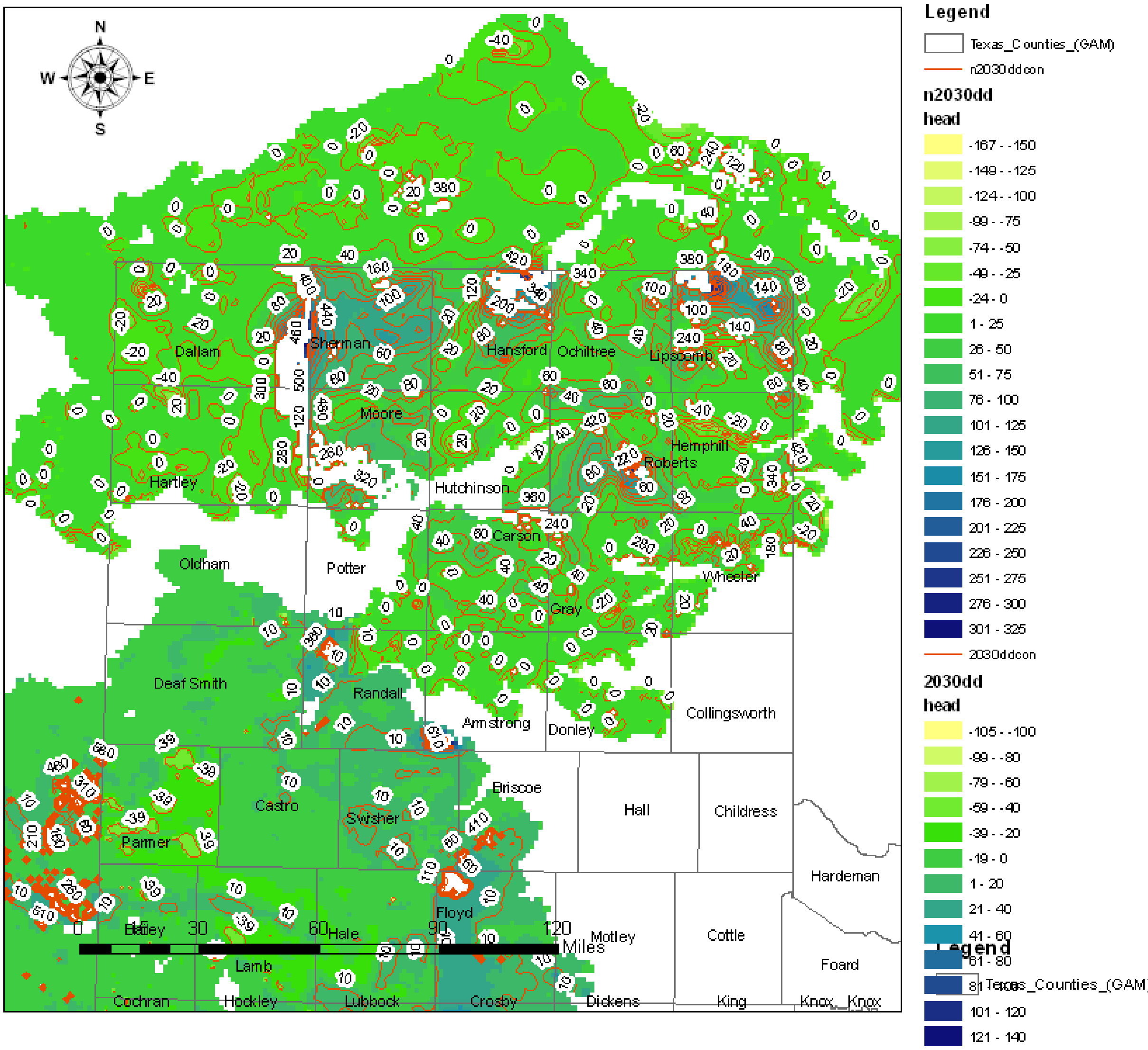

Figure 9: Drawdowns in 2030 based on 1, 1.25, and 2 percent of volume pumpage starting in 2001. White cells in the south and in the north represent dry cells generated in the model of the southern part of the Ogallala Aquifer and the model of the northern part of the Ogallala Aquifer, respectively.

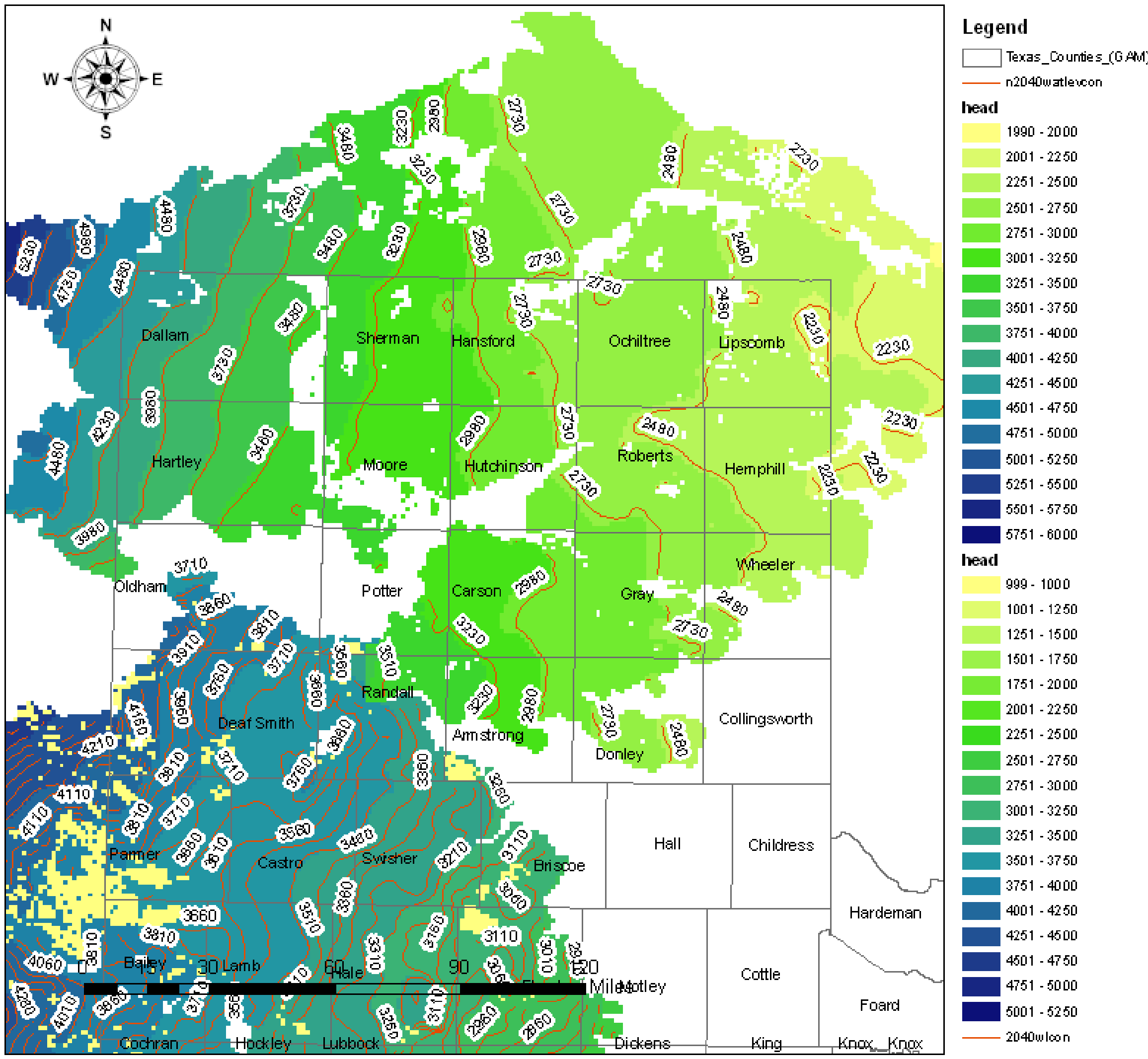

Figure 10: Water levels in 2040 based on 1, 1.25, and 2 percent of volume pumpage starting in 2001. White cells in the south and in the north represent dry cells generated in the model of the southern part of the Ogallala Aquifer and the model of the northern part of the Ogallala Aquifer, respectively..

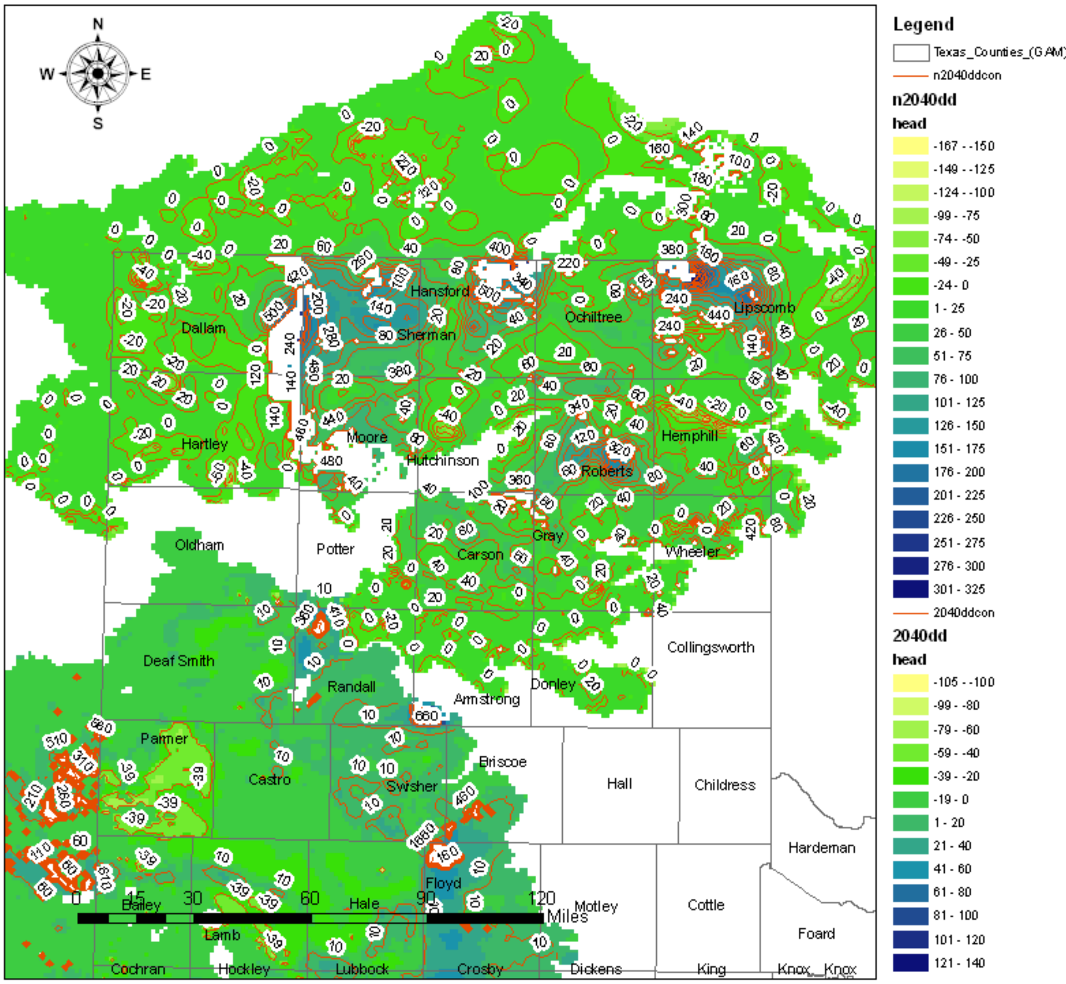

Figure 11: Drawdowns in 2040 based on 1, 1.25, and 2 percent of volume pumpage starting in 2001. White cells in the south and in the north represent dry cells generated in the model of the southern part of the Ogallala Aquifer and the model of the northern part of the Ogallala Aquifer, respectively.

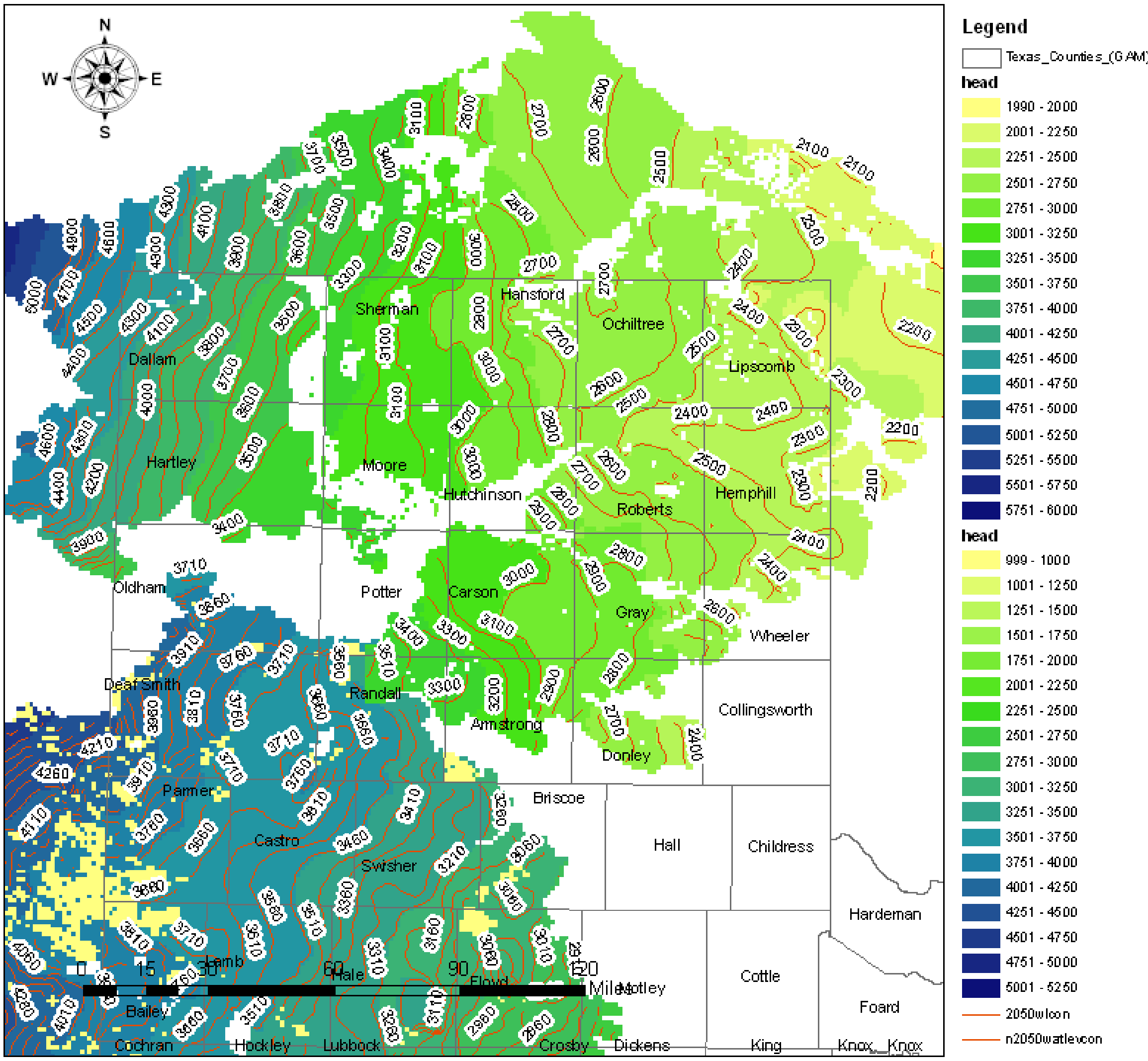

Figure 12: Water levels in 2050 based on 1, 1.25, and 2 percent of volume pumpage starting in 2001. White cells in the south and in the north represent dry cells generated in the model of the southern part of the Ogallala Aquifer and the model of the northern part of the Ogallala Aquifer, respectively.

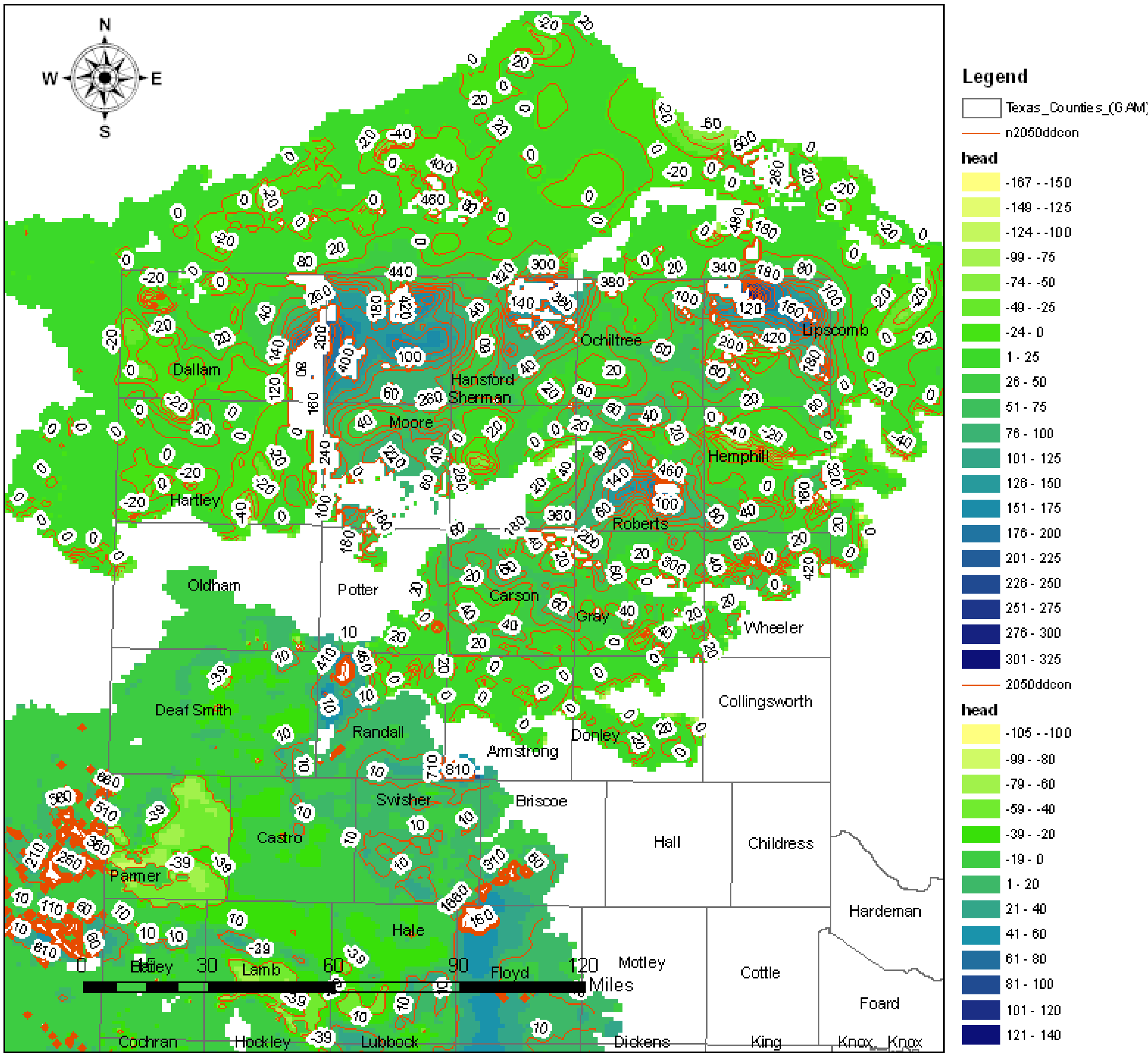

Figure 13: Drawdowns in 2050 based on 1, 1.25, and 2 percent of volume pumpage starting in 2001. White cells in the south and in the north represent dry cells generated in the model of the southern part of the Ogallala Aquifer and the model of the northern part of the Ogallala Aquifer, respectively.

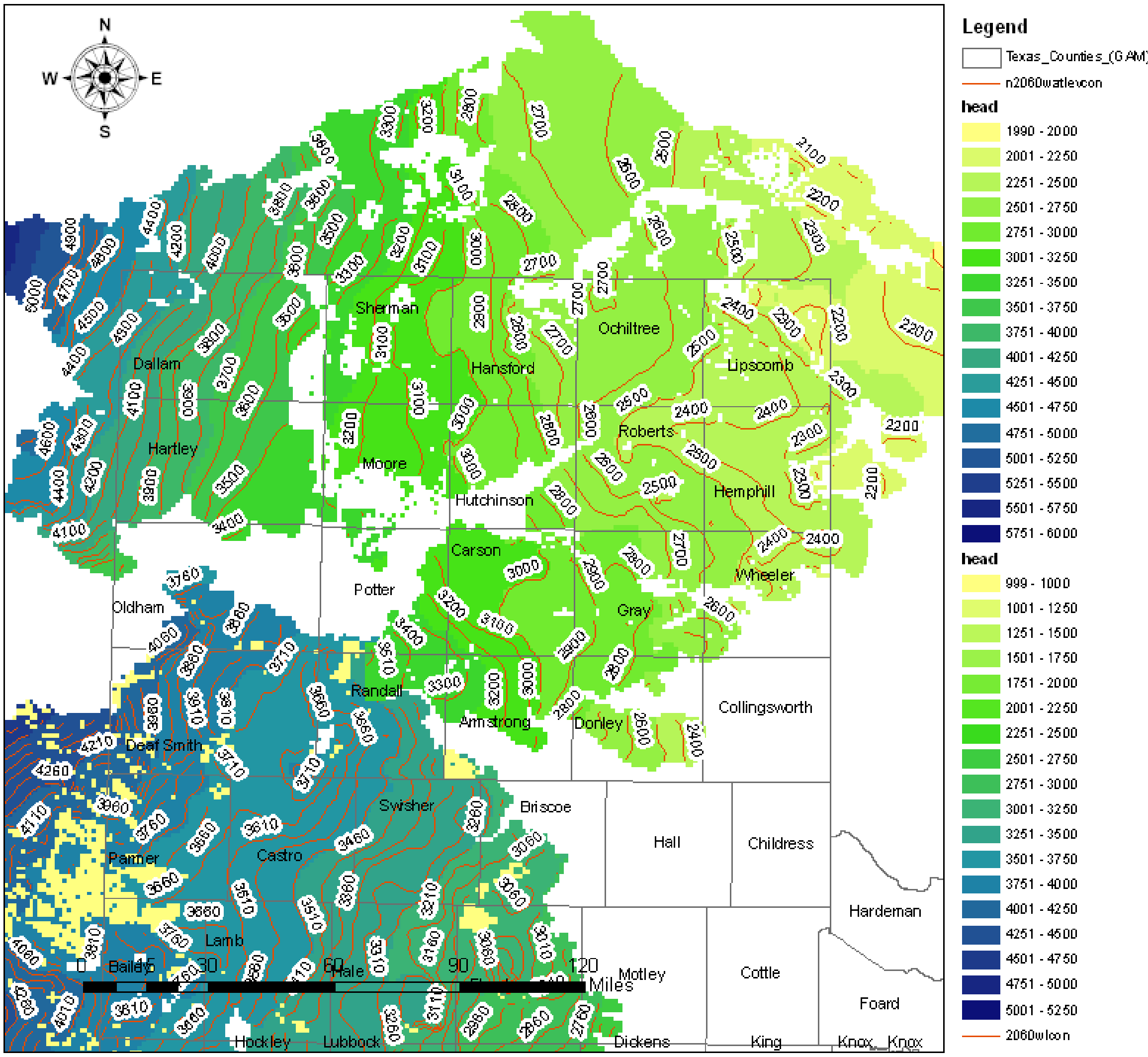

Figure 14: Water levels in 2060 based on 1, 1.25, and 2 percent of volume pumpage starting in 2001. White cells in the south and in the north represent dry cells generated in the model of the southern part of the Ogallala Aquifer and the model of the northern part of the Ogallala Aquifer, respectively.

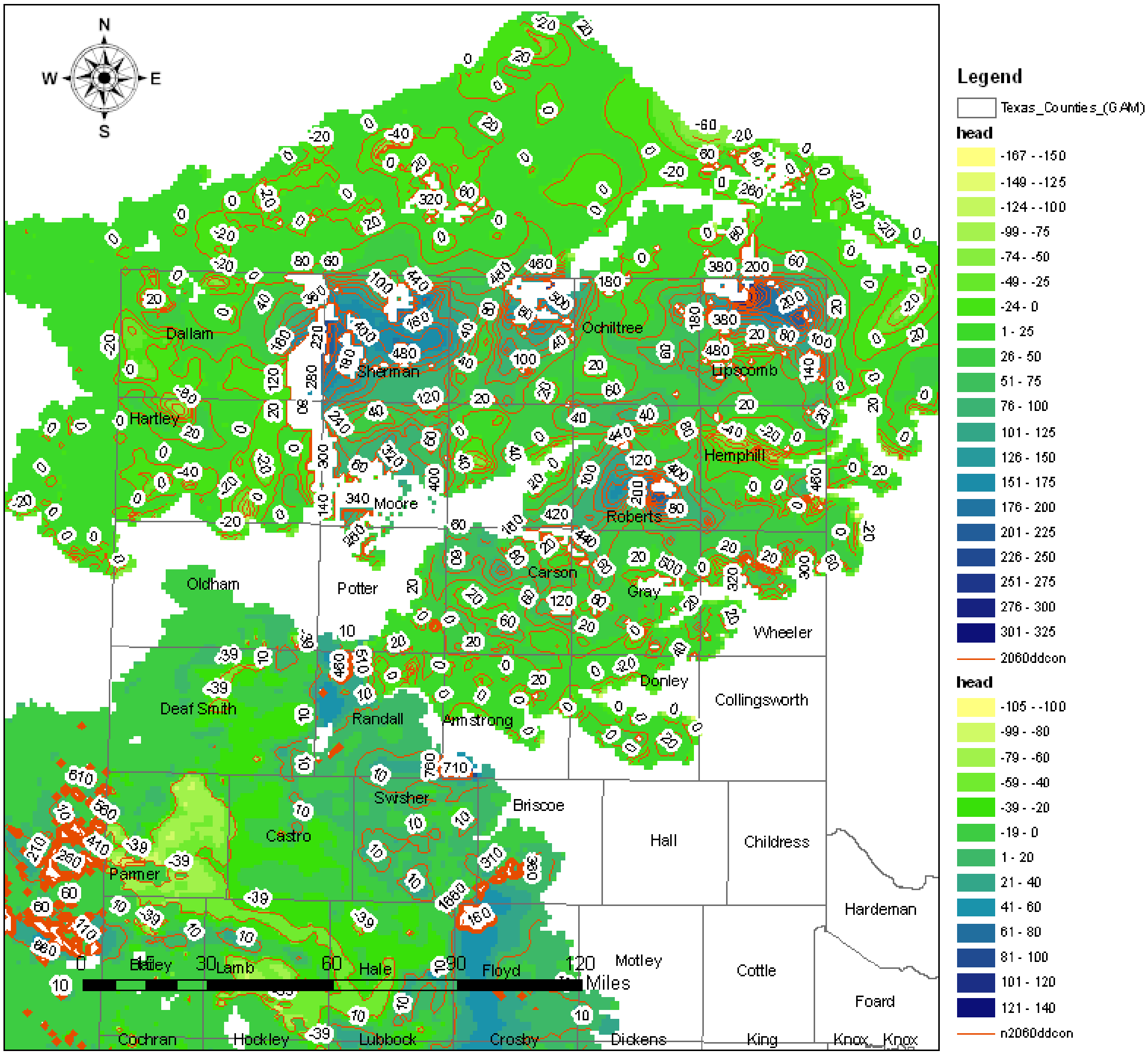

Figure 15: Drawdowns in 2060 based on 1, 1.25, and 2 percent of volume pumpage starting in 2001. White cells in the south and in the north represent dry cells generated in the model of the southern part of the Ogallala Aquifer and the model of the northern part of the Ogallala Aquifer, respectively.

Table 1: Pumpage each year in acre-feet corresponding to the percentage drawdown as requested by the Groundwater Conservation Districts in Groundwater Management Area 1.

County	Percent decline	Volume in 2000	Pumpage 2001	Pumpage 2002	Pumpage 2003	Pumpage 2004	Pumpage 2005	Pumpage 2006	Pumpage 2007	Pumpage 2008	Pumpage 2009	Pumpage 2010
Hemphill	1	15,638,152	156,382	155,132	153,895	152,670	151,457	150,257	149,069	147,892	146,727	145,574
*Armstrong (N GAM)	1.25	3,471,363	17,724	17,523	17,325	17,129	16,936	16,745	16,557	16,370	16,186	16,005
*Armstrong (S GAM)	1.25	579,904	32,917	32,544	32,175	31,812	31,453	31,098	30,748	30,402	30,061	29,723
Carson	1.25	15,280,781	191,010	188,725	186,469	184,240	182,040	179,867	177,722	175,603	173,511	171,444
Donley	1.25	6,249,296	78,116	77,318	76,530	75,752	74,984	74,225	73,476	72,736	72,006	71,284
Gray	1.25	13,648,169	170,602	168,678	166,778	164,902	163,050	161,220	159,414	157,630	155,868	154,128
*Potter (N GAM)	1.25	2,723,265	27,792	27,477	27,165	26,858	26,555	26,255	25,959	25,667	25,378	25,093
*Potter (S GAM)	1.25	322,408	10,279	10,163	10,047	9,934	9,822	9,711	9,601	9,493	9,387	9,281
*Randall (N GAM)	1.25	1,540,382	17,993	17,840	17,688	17,539	17,391	17,246	17,102	16,960	16,819	16,681
*Randall (S GAM)	1.25	4,717,998	60,237	59,724	59,217	58,717	58,223	57,736	57,254	56,778	56,309	55,845
Roberts	1.25	27,494,610	343,683	339,687	335,742	331,846	327,998	324,199	320,447	316,742	313,083	309,470
Wheeler	1.25	7,485,439	93,568	92,700	91,842	90,996	90,160	89,334	88,519	87,714	86,919	86,134
**Hutchinson (South)	1.25	2,507,258	15,520	15,326	15,134	14,945	14,758	14,574	14,392	14,212	14,034	13,859
Dallam	2	17,604,513	352,090	345,479	339,001	332,652	326,430	320,332	314,356	308,500	302,761	297,137
Hansford	2	21,693,703	433,874	425,350	416,996	408,810	400,787	392,925	385,220	377,669	370,269	363,017
Hartley	2	24,925,026	498,501	488,871	479,435	470,187	461,124	452,243	443,539	435,009	426,650	418,457
**Hutchinson (North)	2	8,624,293	156,665	153,532	150,461	147,452	144,503	141,613	138,780	136,005	133,285	130,619
Lipscomb	2	18,640,279	372,806	365,759	358,853	352,085	345,452	338,952	332,583	326,340	320,222	314,227
Moore	2	10,662,411	213,248	209,136	205,106	201,156	197,286	193,493	189,775	186,133	182,563	179,064
Ochiltree	2	19,795,557	395,911	388,169	380,582	373,147	365,860	358,720	351,722	344,864	338,143	331,556
Sherman	2	19,498,315	389,966	382,320	374,827	367,483	360,287	353,234	346,322	339,549	332,911	326,406

*The amount of pumping in Armstrong, Potter and Randall counties was apportioned to the northern or southern part of the Ogallala Aquifer models based on the percentage contribution to the total county volume calculated from the respective model. N GAM denotes portion of the aquifer in the northern part of the Ogallala Aquifer model and S GAM denotes the portion located in the southern part of the Ogallala Aquifer model.

**Hutchinson County was divided between 1.25 percent and 2 percent based on the Groundwater Conservation Districts boundaries (See Figure 1).

Table 1: (Continued)

County	Percent decline	Volume in 2000	Pumpage 2011	Pumpage 2012	Pumpage 2013	Pumpage 2014	Pumpage 2015	Pumpage 2016	Pumpage 2017	Pumpage 2018	Pumpage 2019	Pumpage 2020
Hemphill	1	15,638,152	144,433	143,302	142,184	141,076	139,979	138,894	137,819	136,755	135,701	134,659
*Armstrong (N GAM)	1.25	3,471,363	15,826	15,649	15,474	15,301	15,131	14,962	14,796	14,632	14,470	14,309
*Armstrong (S GAM)	1.25	579,904	29,390	29,062	28,737	28,416	28,100	27,787	27,478	27,173	26,872	26,575
Carson	1.25	15,280,781	169,404	167,389	165,400	163,435	161,495	159,579	157,687	155,818	153,973	152,151
Donley	1.25	6,249,296	70,572	69,868	69,173	68,487	67,810	67,141	66,480	65,828	65,183	64,547
Gray	1.25	13,648,169	152,410	150,714	149,039	147,384	145,751	144,138	142,545	140,971	139,418	137,884
*Potter (N GAM)	1.25	2,723,265	24,812	24,534	24,260	23,989	23,721	23,457	23,196	22,938	22,684	22,433
*Potter (S GAM)	1.25	322,408	9,177	9,074	8,973	8,873	8,774	8,676	8,579	8,484	8,390	8,297
*Randall (N GAM)	1.25	1,540,382	16,544	16,409	16,276	16,144	16,014	15,885	15,758	15,633	15,509	15,387
*Randall (S GAM)	1.25	4,717,998	55,387	54,935	54,488	54,047	53,611	53,181	52,757	52,337	51,923	51,514
Roberts	1.25	27,494,610	305,903	302,379	298,900	295,465	292,072	288,722	285,413	282,146	278,920	275,734
Wheeler	1.25	7,485,439	85,358	84,593	83,837	83,090	82,353	81,625	80,906	80,196	79,495	78,803
**Hutchinson (South)	1.25	2,507,258	13,685	13,514	13,345	13,179	13,014	12,851	12,690	12,532	12,375	12,221
Dallam	2	17,604,513	291,625	286,223	280,930	275,742	270,658	265,676	260,793	256,009	251,319	246,724
Hansford	2	21,693,703	355,910	348,945	342,119	335,430	328,875	322,451	316,156	309,986	303,940	298,014
Hartley	2	24,925,026	410,429	402,562	394,851	387,295	379,890	372,633	365,521	358,552	351,722	345,028
**Hutchinson (North)	2	8,624,293	128,007	125,446	122,938	120,479	118,069	115,708	113,394	111,126	108,903	106,725
Lipscomb	2	18,640,279	308,352	302,594	296,951	291,421	286,002	280,691	275,487	270,386	265,388	260,489
Moore	2	10,662,411	175,635	172,275	168,982	165,755	162,593	159,494	156,456	153,480	150,563	147,704
Ochiltree	2	19,795,557	325,101	318,776	312,577	306,502	300,548	294,713	288,995	283,392	277,900	272,519
Sherman	2	19,498,315	320,031	313,783	307,661	301,661	295,781	290,018	284,371	278,836	273,413	268,098

*The amount of pumping in Armstrong, Potter and Randall counties was apportioned to the northern or southern part of the Ogallala Aquifer models based on the percentage contribution to the total county volume calculated from the respective model. N GAM denotes portion of the aquifer in the northern part of the Ogallala Aquifer model and S GAM denotes the portion located in the southern part of the Ogallala Aquifer model.

**Hutchinson County was divided between 1.25 percent and 2 percent based on the Groundwater Conservation Districts boundaries (See Figure 1).

Table 1:(Continued)

County	Percent decline	Volume in 2000	Pumpage 2021	Pumpage 2022	Pumpage 2023	Pumpage 2024	Pumpage 2025	Pumpage 2026	Pumpage 2027	Pumpage 2028	Pumpage 2029	Pumpage 2030
Hemphill	1	15,638,152	133,626	132,604	131,592	130,590	129,599	128,617	127,645	126,683	125,730	124,787
*Armstrong (N GAM)	1.25	3,471,363	14,151	13,995	13,841	13,689	13,538	13,390	13,243	13,099	12,956	12,814
*Armstrong (S GAM)	1.25	579,904	26,281	25,991	25,705	25,422	25,143	24,867	24,595	24,326	24,060	23,798
Carson	1.25	15,280,781	150,352	148,576	146,821	145,089	143,378	141,688	140,020	138,372	136,745	135,139
Donley	1.25	6,249,296	63,919	63,299	62,686	62,081	61,484	60,894	60,311	59,736	59,168	58,607
Gray	1.25	13,648,169	136,369	134,873	133,396	131,937	130,497	129,074	127,669	126,282	124,912	123,560
*Potter (N GAM)	1.25	2,723,265	22,184	21,939	21,697	21,459	21,223	20,990	20,759	20,532	20,308	20,086
*Potter (S GAM)	1.25	322,408	8,205	8,115	8,025	7,937	7,849	7,763	7,678	7,594	7,511	7,429
*Randall (N GAM)	1.25	1,540,382	15,267	15,148	15,030	14,914	14,799	14,686	14,574	14,463	14,354	14,247
*Randall (S GAM)	1.25	4,717,998	51,110	50,711	50,317	49,929	49,544	49,165	48,791	48,421	48,056	47,695
Roberts	1.25	27,494,610	272,588	269,481	266,413	263,384	260,392	257,438	254,520	251,640	248,795	245,985
Wheeler	1.25	7,485,439	78,119	77,444	76,777	76,119	75,469	74,827	74,193	73,567	72,949	72,338
**Hutchinson (South)	1.25	2,507,258	12,068	11,917	11,768	11,621	11,476	11,332	11,190	11,051	10,912	10,776
Dallam	2	17,604,513	242,220	237,807	233,482	229,243	225,089	221,018	217,029	213,119	209,288	205,533
Hansford	2	21,693,703	292,207	286,516	280,940	275,474	270,118	264,869	259,725	254,684	249,744	244,902
Hartley	2	24,925,026	338,469	332,040	325,740	319,566	313,516	307,586	301,776	296,081	290,500	285,031
**Hutchinson (North)	2	8,624,293	104,591	102,499	100,449	98,440	96,471	94,542	92,651	90,798	88,982	87,202
Lipscomb	2	18,640,279	255,688	250,984	246,373	241,855	237,427	233,088	228,835	224,668	220,583	216,581
Moore	2	10,662,411	144,903	142,157	139,467	136,830	134,246	131,714	129,232	126,800	124,417	122,081
Ochiltree	2	19,795,557	267,245	262,076	257,011	252,047	247,183	242,415	237,744	233,165	228,678	224,281
Sherman	2	19,498,315	262,889	257,784	252,781	247,879	243,074	238,366	233,752	229,230	224,798	220,455

*The amount of pumping in Armstrong, Potter and Randall counties was apportioned to the northern or southern part of the Ogallala Aquifer models based on the percentage contribution to the total county volume calculated from the respective model. N GAM denotes portion of the aquifer in the northern part of the Ogallala Aquifer model and S GAM denotes the portion located in the southern part of the Ogallala Aquifer model.

**Hutchinson County was divided between 1.25 percent and 2 percent based on the Groundwater Conservation Districts boundaries (See Figure 1).

Table 1 (Contimued)

County	Percent decline	Volume in 2000	Pumpage 2031	Pumpage 2032	Pumpage 2033	Pumpage 2034	Pumpage 2035	Pumpage 2036	Pumpage 2037	Pumpage 2038	Pumpage 2039	Pumpage 2040
Hemphill	1	15,638,152	123,853	122,929	122,014	121,108	120,211	119,323	118,444	117,573	116,712	115,859
*Armstrong (N GAM)	1.25	3,471,363	12,675	12,537	12,401	12,267	12,135	12,004	11,874	11,747	11,621	11,496
*Armstrong (S GAM)	1.25	579,904	23,539	23,284	23,031	22,782	22,536	22,292	22,052	21,815	21,581	21,350
Carson	1.25	15,280,781	133,552	131,986	130,438	128,911	127,402	125,912	124,441	122,988	121,554	120,137
Donley	1.25	6,249,296	58,053	57,505	56,965	56,432	55,905	55,385	54,871	54,364	53,863	53,368
Gray	1.25	13,648,169	122,224	120,905	119,602	118,316	117,045	115,791	114,552	113,329	112,121	110,928
*Potter (N GAM)	1.25	2,723,265	19,868	19,651	19,438	19,227	19,019	18,814	18,611	18,411	18,213	18,017
*Potter (S GAM)	1.25	322,408	7,348	7,268	7,189	7,111	7,035	6,959	6,883	6,809	6,736	6,664
*Randall (N GAM)	1.25	1,540,382	14,140	14,035	13,931	13,829	13,728	13,628	13,529	13,432	13,336	13,241
*Randall (S GAM)	1.25	4,717,998	47,339	46,987	46,640	46,297	45,958	45,624	45,294	44,967	44,645	44,327
Roberts	1.25	27,494,610	243,211	240,472	237,766	235,095	232,457	229,852	227,279	224,739	222,230	219,753
Wheeler	1.25	7,485,439	71,735	71,140	70,552	69,972	69,398	68,832	68,273	67,721	67,176	66,638
**Hutchinson (South)	1.25	2,507,258	10,641	10,508	10,377	10,247	10,119	9,993	9,868	9,744	9,623	9,502
Dallam	2	17,604,513	201,853	198,247	194,713	191,250	187,856	184,529	181,270	178,075	174,945	171,877
Hansford	2	21,693,703	240,158	235,508	230,951	226,485	222,109	217,820	213,617	209,498	205,462	201,506
Hartley	2	24,925,026	279,671	274,419	269,271	264,227	259,283	254,438	249,691	245,038	240,478	236,009
**Hutchinson (North)	2	8,624,293	85,458	83,749	82,074	80,433	78,824	77,247	75,703	74,188	72,705	71,251
Lipscomb	2	18,640,279	212,659	208,815	205,047	201,356	197,738	194,192	190,717	187,312	183,975	180,705
Moore	2	10,662,411	119,792	117,549	115,350	113,196	111,085	109,016	106,988	105,001	103,053	101,145
Ochiltree	2	19,795,557	219,972	215,749	211,610	207,554	203,580	199,684	195,867	192,126	188,460	184,867
Sherman	2	19,498,315	216,199	212,028	207,941	203,935	200,010	196,162	192,392	188,698	185,077	181,528

*The amount of pumping in Armstrong, Potter and Randall counties was apportioned to the northern or southern part of the Ogallala Aquifer models based on the percentage contribution to the total county volume calculated from the respective model. N GAM denotes portion of the aquifer in the northern part of the Ogallala Aquifer model and S GAM denotes the portion located in the southern part of the Ogallala Aquifer model.

**Hutchinson County was divided between 1.25 percent and 2 percent based on the Groundwater Conservation Districts boundaries (See Figure 1).

Table 1 (Continued)

County	Percent decline	Volume in 2000	Pumpage 2041	Pumpage 2042	Pumpage 2043	Pumpage 2044	Pumpage 2045	Pumpage 2046	Pumpage 2047	Pumpage 2048	Pumpage 2049	Pumpage 2050
Hemphill	1	15,638,152	115,014	114,178	113,351	112,531	111,720	110,917	110,122	109,335	108,556	107,785
*Armstrong (N GAM)	1.25	3,471,363	11,373	11,252	11,132	11,013	10,897	10,781	10,667	10,555	10,443	10,334
*Armstrong (S GAM)	1.25	579,904	21,122	20,896	20,673	20,454	20,236	20,022	19,810	19,601	19,395	19,191
Carson	1.25	15,280,781	118,738	117,356	115,992	114,645	113,315	112,001	110,704	109,423	108,158	106,908
Donley	1.25	6,249,296	52,880	52,397	51,921	51,450	50,986	50,527	50,074	49,627	49,185	48,749
Gray	1.25	13,648,169	109,750	108,587	107,438	106,304	105,184	104,078	102,986	101,907	100,842	99,790
*Potter (N GAM)	1.25	2,723,265	17,824	17,634	17,446	17,260	17,076	16,895	16,716	16,540	16,365	16,193
*Potter (S GAM)	1.25	322,408	6,593	6,522	6,453	6,384	6,316	6,249	6,183	6,117	6,053	5,989
*Randall (N GAM)	1.25	1,540,382	13,147	13,054	12,963	12,872	12,783	12,695	12,608	12,522	12,437	12,354
*Randall (S GAM)	1.25	4,717,998	44,013	43,703	43,397	43,095	42,796	42,501	42,210	41,922	41,638	41,358
Roberts	1.25	27,494,610	217,307	214,891	212,505	210,150	207,823	205,526	203,258	201,018	198,806	196,621
Wheeler	1.25	7,485,439	66,106	65,581	65,063	64,551	64,046	63,546	63,053	62,567	62,086	61,611
**Hutchinson (South)	1.25	2,507,258	9,384	9,266	9,150	9,036	8,923	8,812	8,701	8,593	8,485	8,379
Dallam	2	17,604,513	168,870	165,924	163,036	160,206	157,433	154,716	152,052	149,442	146,884	144,377
Hansford	2	21,693,703	197,629	193,830	190,107	186,458	182,882	179,378	175,944	172,579	169,280	166,048
Hartley	2	24,925,026	231,630	227,338	223,132	219,011	214,971	211,013	207,133	203,332	199,606	195,955
**Hutchinson (North)	2	8,624,293	69,826	68,429	67,060	65,719	64,405	63,117	61,854	60,617	59,405	58,217
Lipscomb	2	18,640,279	177,500	174,359	171,281	168,265	165,309	162,412	159,573	156,790	154,064	151,392
Moore	2	10,662,411	99,275	97,442	95,646	93,885	92,160	90,470	88,813	87,189	85,598	84,039
Ochiltree	2	19,795,557	181,346	177,896	174,514	171,200	167,953	164,770	161,651	158,594	155,599	152,663
Sherman	2	19,498,315	178,051	174,643	171,303	168,030	164,823	161,679	158,599	155,580	152,621	149,722

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**Hutchinson County was divided between 1.25 percent and 2 percent based on the Groundwater Conservation Districts boundaries (See Figure 1).

Table 1 (Continued)

County	Percent decline	Volume in 2000	Pumpage 2051	Pumpage 2052	Pumpage 2053	Pumpage 2054	Pumpage 2055	Pumpage 2056	Pumpage 2057	Pumpage 2058	Pumpage 2059	Pumpage 2060
Hemphill	1	15,638,152	107,021	106,265	105,516	104,775	104,042	103,316	102,597	101,885	101,180	100,482
*Armstrong (N GAM)	1.25	3,471,363	10,225	10,118	10,012	9,908	9,805	9,703	9,603	9,503	9,405	9,308
*Armstrong (S GAM)	1.25	579,904	18,990	18,791	18,594	18,401	18,209	18,020	17,833	17,649	17,467	17,287
Carson	1.25	15,280,781	105,675	104,457	103,254	102,066	100,893	99,734	98,590	97,460	96,345	95,243
Donley	1.25	6,249,296	48,318	47,893	47,473	47,058	46,648	46,244	45,844	45,450	45,060	44,675
Gray	1.25	13,648,169	98,751	97,725	96,713	95,712	94,725	93,749	92,786	91,835	90,896	89,968
*Potter (N GAM)	1.25	2,723,265	16,023	15,855	15,689	15,525	15,363	15,203	15,046	14,890	14,736	14,584
*Potter (S GAM)	1.25	322,408	5,926	5,864	5,803	5,742	5,682	5,623	5,565	5,507	5,450	5,394
*Randall (N GAM)	1.25	1,540,382	12,271	12,189	12,109	12,029	11,950	11,873	11,796	11,720	11,645	11,571
*Randall (S GAM)	1.25	4,717,998	41,081	40,807	40,537	40,271	40,007	39,747	39,491	39,237	38,987	38,739
Roberts	1.25	27,494,610	194,464	192,334	190,230	188,153	186,102	184,076	182,076	180,100	178,150	176,223
Wheeler	1.25	7,485,439	61,142	60,680	60,222	59,771	59,325	58,885	58,450	58,021	57,597	57,179
**Hutchinson (South)	1.25	2,507,258	8,274	8,171	8,069	7,968	7,868	7,770	7,673	7,577	7,482	7,389
Dallam	2	17,604,513	141,921	139,513	137,154	134,842	132,576	130,355	128,179	126,047	123,957	121,908
Hansford	2	21,693,703	162,881	159,776	156,734	153,753	150,831	147,968	145,162	142,412	139,717	137,076
Hartley	2	24,925,026	192,377	188,870	185,433	182,066	178,765	175,531	172,361	169,255	166,211	163,227
**Hutchinson (North)	2	8,624,293	57,053	55,912	54,793	53,697	52,623	51,571	50,540	49,529	48,538	47,567
Lipscomb	2	18,640,279	148,773	146,207	143,692	141,227	138,812	136,445	134,125	131,852	129,624	127,440
Moore	2	10,662,411	82,511	81,013	79,545	78,107	76,698	75,316	73,962	72,636	71,336	70,062
Ochiltree	2	19,795,557	149,786	146,967	144,204	141,496	138,843	136,242	133,694	131,196	128,749	126,350
Sherman	2	19,498,315	146,881	144,096	141,367	138,693	136,072	133,504	130,987	128,520	126,103	123,734

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