ATTACHMENT F

GAM Run 07-37

by Kan Tu, Ph.D., P.G.
Texas Water Development Board
Groundwater Availability Modeling Section
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April 9, 2008

EXECUTIVE SUMMARY:

We ran the groundwater availability model for the Edwards-Trinity (Plateau) Aquifer for a 71-year simulation, which consisted of 20 years (1980-1999) of historic conditions followed by a 51-year (2000-2050) predictive time period. Average recharge conditions were used for the entire 51 years of the predictive portion of the simulation. The pumpage used in this simulation was based on the groundwater availability estimates from the 2007 State Water Plan and baseline pumpage discussed in GAM Run 07-03 (Donnelly, 2007).

Results of this model run indicate that water-level declines after 51 years range from 50 feet to 100 feet for most counties in the model area. This mainly resulted from the increase in pumpage from the baseline pumpage that was approved by the Groundwater Management Area 7 and used in the previous GAM Run 07-03 (Donnelly, 2007). Extreme drawdowns (up to 600 feet) in Pecos, Glasscock, and Reagan counties in the Trinity part of the Edwards-Trinity (Plateau) Aquifer were predicted by the model at the end of 51 years, but research into the model performance during the calibration time period indicates that the model is not appropriately simulating the response of the Trinity Aquifer to pumpage in these areas (Donnelly, 2007). It is recommended that this model not be used to evaluate groundwater conditions in Pecos, Glasscock, and Reagan counties.

REQUESTOR:

Ms. Caroline Runge from the Menard County Underground Water Conservation District (on behalf of Groundwater Management Area 7).

DESCRIPTION OF REQUEST:

Ms. Runge asked for a new model run using the groundwater availability model for the Edwards-Trinity (Plateau) Aquifer. This model run would be a 71-year simulation, with the first 20 years being the historic portion of the simulation followed by a 51-year predictive period. Average recharge conditions were used for the predictive portion of the simulation. Each year of the predictive portion of the simulation would use a specified pumpage based on groundwater availability estimates from the 2007 State Water Plan and pumpage approved by members of Groundwater Management Area 7.

METHODS:

Recharge and initial streamflow were averaged for the 1961 to 1990 time period. These averages were then used in the 51-year predictive portion of the model simulation along with adjustments to the baseline pumpage to reflect availability estimates from the 2007 State Water Plan. Resulting water levels and drawdowns using 1999 water levels as a baseline were then evaluated and are described in the Results section below.

PARAMETERS AND ASSUMPTIONS:

The groundwater availability model for the Edwards-Trinity (Plateau) Aquifer was used for this model run. The parameters and assumptions for this model are described below:

- We used version 1.01 of the groundwater availability model of the Edwards-Trinity (Plateau) Aquifer, which includes the Pecos Valley Aquifer (formerly known as the Cenozoic Pecos Alluvium Aquifer). See Anaya and Jones (2004) for assumptions and limitations of the model.

- The root mean squared error (a measure of the difference between simulated and actual water levels during model calibration) in the entire Edwards-Trinity (Plateau) and Pecos Valley (formerly the Cenozoic Pecos Alluvium) groundwater availability model for the period of 1990 to 2000 is 143 feet, or six percent of the range of measured water levels (Anaya and Jones, 2004).

- The model includes two layers, representing the Edwards and associated limestones (Layer 1) and undifferentiated Trinity units (Layer 2). The Pecos Valley Aquifer is included in Layer 1 of the model.

- The model run was 71 years in length. The first 20 years were the historic calibration-verification portion of the simulation, followed by a 51-year predictive period.

- The groundwater availability model simulates discharge to springs and seeps mostly along the northern and eastern margins of the aquifer. Spring and seep parameters used in the model are from the calibrated model.

- Recharge was distributed in the groundwater availability model based on a percent of annual precipitation and aquifer outcrop (surface geology).

- The groundwater availability model simulates the interaction between the aquifer(s) and major streams and rivers flowing in the region. Flow both from the stream to the aquifer and from the aquifer to the stream is allowed, and the direction of flow is determined by the water levels in the aquifer and the surface water elevation of the stream during each stress period in the simulation. The stream parameters, including streambed conductance and initial flow values, used in the model are from the calibrated model.

- The groundwater availability model uses general head boundary cells to simulate cross-formational groundwater flow between the Edwards-Trinity (Plateau) and adjacent aquifers, including the Ogallala, Dockum, Edwards (Balcones Fault Zone), and Llano Uplift area aquifers. Parameters assigned to the general head boundary cells such as aquifer conductance and water levels were from the calibrated model.

- We used Groundwater Vistas Version 5 as the interface to process model output.

Specified Pumpage

The pumpage for this model run considered the individual county groundwater availability estimates from the 2007 State Water Plan. The baseline pumpage approved by the Groundwater Management Area 7 and used in GAM Run 07-03 (Donnelly, 2007) was used as the basis for generating the new pumpage data set. The following modifications were made to the GAM Run 07-03 (Donnelly, 2007) baseline pumpage to create the specified pumpage used in this simulation.

- The baseline pumpage totals were increased in most counties in the model area. The total amount of pumpage used in each county in this simulation is shown in Tables 1 and 2. For each county, the higher pumpage of either the 2007 State Water Plan or the GAM Run 07-03 (Donnelly, 2007) baseline pumpage was determined for this specified pumpage. In addition, Groundwater Management Area 7 requested that 59,234 acre-feet per year of pumpage be used for Kinney County.

- For all counties listed in Table 1 the specified pumpage maintains the existing model spatial pumping distribution used in the baseline simulation discussed in GAM Run 07-03 (Donnelly, 2007). When the groundwater availability per aquifer and county from the 2007 State Water Plan value exceeded the baseline pumpage from GAM Run 07-03, then this additional amount of pumpage was evenly distributed among all cells that had pumpage in baseline GAM Run 07-03 (Donnelly, 2007) on a county-by-county and aquifer basis. This information is presented under the column 'Added Pumpage to Each Cell' in Table 1

- Pumpage was distributed in a slightly different manner in Crockett, Irion, Kimble, Kinney, Schleicher, Sutton, and Val Verde counties (Table 2). The additional Edwards-Trinity (Plateau) Aquifer pumpage was allocated proportionally to both model layer 1 and 2 based on the existing baseline pumpage distributions. For model layer 1 (the Edwards layer in the area of interest), the additional pumpage was evenly distributed among all cells that had existing pumpage in the GAM Run 07-03 (Donnelly, 2007) baseline run. However, for model layer 2 (the Trinity layer), the additional pumpage was assigned evenly across all active cells per county.

Table 1. The specified pumpage used in this model simulation in comparison with both GAM Run 07-03 (Donnelly, 2007) baseline pumpage and the groundwater availability numbers from the 2007 State Water Plan. All pumpage numbers are reported in acre-feet per year

County	Aquifer	GAM Run 07-03 baseline pumpage	2007 State Water Plan availability	Specified pumpage used in this run	Addition to baseline pumpage	Total number of well cells	Added pumpage to each cell
Andrews	Pecos Valley Aquifer	60	1,189	1,189	1,129	267	4
	Edwards-Trinity (Plateau) Aquifer	8	4,640	4,640	4,632	163	28
	Total	68	5,829	5,829	5,761	430	
Bandera	Edwards-Trinity (Plateau) Aquifer	327	17,310	17,310	16,983	242	70
	Trinity Aquifer	2,004	18,558	18,558	16,554	574	29
	Total	2,331	35,868	35,868	33,537	816	
Bexar	Trinity Aquifer	2,399	1,175	2,399	0	245	0
Blanco	Edwards-Trinity (Plateau) Aquifer	17	157	157	140	17	8
	Trinity Aquifer	727	1,600	1,600	873	535	2
	Total	744	1,757	1,757	1,013	552	
Brewster	Edwards-Trinity (Plateau) Aquifer	673	300	673	0	976	0
Burnet	Trinity Aquifer	114	2,550	2,550	2,436	23	106
Coke	Edwards-Trinity (Plateau) Aquifer	21	3,242	3,242	3,221	244	13
Comal	Trinity Aquifer	3,059	1,800	3,059	0	343	0
Concho	Edwards-Trinity (Plateau) Aquifer	277	12,278	12,278	12,001	348	34
Crane	Pecos Valley Aquifer	549	2,537	2,537	1,988	561	4
	Edwards-Trinity (Plateau) Aquifer	8	115	115	107	21	5
	Total	557	2,652	2,652	2,095	582	
Culberson	Edwards-Trinity (Plateau) Aquifer	37	55	55	18	142	0
Ector	Pecos Valley Aquifer	48	3,143	3,143	3,095	101	31
	Edwards-Trinity (Plateau) Aquifer	5,489	11,324	11,324	5,835	666	9
	Total	5,538	14,467	14,467	8,929	767	
Edwards	Edwards-Trinity (Plateau) Aquifer	7,794	8,699	8,699	905	2,239	0
Gillespie	Edwards-Trinity (Plateau) Aquifer	1,494	1,500	1,500	6	611	0
	Trinity Aquifer	2,476	3,400	3,400	924	366	3
	Total	3,970	4,900	4,900	930	977	

County	Aquifer	GAM Run 07-03 baseline pumpage	2007 State Water Plan availability	Specified pumpage used in this run	Addition to baseline pumpage	Total number of well cells	Added pumpage to each cell
Glasscock	Edwards-Trinity (Plateau) Aquifer	59,280	20,938	59,280	0	942	0
Hays	Trinity Aquifer	2,818	3,713	3,713	895	370	2
Howard	Edwards-Trinity (Plateau) Aquifer	585	1,700	1,700	1,115	72	15
Jeff Davis	Edwards-Trinity (Plateau) Aquifer	141	200	200	59	325	0
Kendall	Edwards-Trinity (Plateau) Aquifer	124	905	905	781	89	9
	Trinity Aquifer	3,391	3,935	3,935	544	576	1
	Total	3,515	4,840	4,840	1,325	665	
Kerr	Edwards-Trinity (Plateau) Aquifer	1,762	16,410	16,410	14,648	1,102	13
	Trinity Aquifer	2,419	17,324	17,324	14,905	278	54
	Total	4,181	33,734	33,734	29,553	1,380	
Loving	Edwards-Trinity (Plateau) Aquifer	32	4,363	4,363	4,331	98	44
Martin	Edwards-Trinity (Plateau) Aquifer	94	3,398	3,398	3,304	62	53
Mason	Edwards-Trinity (Plateau) Aquifer	3	3,828	3,828	3,825	91	42
McCulloch	Edwards-Trinity (Plateau) Aquifer	31	8,249	8,249	8,218	201	41
Medina	Trinity Aquifer	69	860	860	791	113	7
Menard	Edwards-Trinity (Plateau) Aquifer	1,844	19,000	19,000	17,156	962	18
Midland	Edwards-Trinity (Plateau) Aquifer	21,140	19,395	21,140	0	876	0
Nolan	Edwards-Trinity (Plateau) Aquifer	151	1,000	1,000	849	463	2
Pecos	Pecos Valley Aquifer	44,038	58,578	58,578	14,540	1,049	14
	Edwards-Trinity (Plateau) Aquifer	41,471	114,849	114,849	73,378	3,641	20
	Total	85,509	173,427	173,427	87,918	4,690	
Reagan	Edwards-Trinity (Plateau) Aquifer	61,816	31,235	61,816	0	1,769	0
Real	Edwards-Trinity (Plateau) Aquifer	11,375	5,737	11,375	0	734	0
	Trinity Aquifer	150	380	380	230	14	16
	Total	11,525	6,117	11,755	230	748	
Reeves	Pecos Valley	54,401	60,520	60,520	6,119	1,220	5
	Edwards-Trinity (Plateau) Aquifer	53,346	53,845	53,845	499	1,139	0
	Total	107,747	114,365	114,365	6,618	2,359	

County	Aquifer	GAM Run 07-03 baseline pumpage	2007 State Water Plan availability	Specified pumpage used in this run	Addition to baseline pumpage	Total number of well cells	Added pumpage to each cell
Sterling	Edwards-Trinity (Plateau) Aquifer	375	5,168	5,168	4,793	521	9
Taylor	Edwards-Trinity (Plateau) Aquifer	117	500	500	383	166	2
Terrell	Edwards-Trinity (Plateau) Aquifer	1,032	2,100	2,100	1,068	3,419	0
Tom Green	Edwards-Trinity (Plateau) Aquifer	741	15,037	15,037	14,296	601	24
Travis	Trinity Aquifer	1,721	3,900	3,900	2,179	186	12
Upton	Edwards-Trinity (Plateau) Aquifer	20,604	18,929	20,604	0	1,467	0
Uvalde	Edwards-Trinity (Plateau) Aquifer	566	3,185	3,185	2,619	323	8
	Trinity Aquifer	176	580	580	404	84	5
	Total	742	3,765	3,765	3,023	407	
Ward	Pecos Valley Aquifer	5,821	17,288	17,288	11,467	658	17
Winkler	Pecos Valley Aquifer	558	51,994	51,994	51,436	747	69
	Edwards-Trinity (Plateau) Aquifer	1	517	517	516	8	64
	Total	559	52,511	52,511	51,952	755	

Table 2. The specified pumpage used in this model simulation in comparison with GAM Run 07-03 (Donnelly, 2007) baseline pumpage and the groundwater availability numbers from the 2007 State Water Plan. All pumpage numbers are reported in acre-feet per year.

County	GAM Run 07-03 baseline pumpage	2007 State Water Plan availability	Addition to baseline pumpage	Model layer	Total number of active cells	Total number of well cells	Added pumpage
Crockett	5,493	25,460	19,967	Layer 1	2,662	2,560	17,429
				Layer 2	2,744	1,436	2,539
				Total	5,406	3,996	19,968
Irion	432	9,445	9,013	Layer 1	674	625	4,836
				Layer 2	664	387	4,177
				Total	1,338	1,012	9,013
Kimble	843	23,965	23,122	Layer 1	943	858	6,888
				Layer 2	1,197	952	16,235
				Total	2,140	1,810	23,122
Kinney	6,832	59,234	52,402	Layer 1	556	529	31,817
				Layer 2	564	211	20,585
				Total	1,120	740	52,402
Schleicher	3,732	16,164	12,432	Layer 1	1,310	1,310	12,400
				Layer 2	996	4	31
				Total	2,306	1,314	12,431
Sutton	3,445	20,775	17,330	Layer 1	1,454	1,448	17,227
				Layer 2	1,351	69	103
				Total	2,805	1,517	17,330
Val Verde	14,562	49,607	35,045	Layer 1	3,112	3,052	34,668
				Layer 2	3,213	555	377
				Total	6,325	3,607	35,045

RESULTS:

Included in Appendix A are estimates of the water budgets after running the model for 51 years. The components of the water budget are described below.

- Wells—water produced from wells in each aquifer. This component is always shown as “Outflow” from the water budget, because all wells included in the model produce (rather than inject) water. Wells are modeled using the MODFLOW Well package.

- Springs and seeps—water that drains from an aquifer to seeps and springs along the margins of the aquifer. This component is always shown as “Outflow”, or discharge, from the water budget. Springs and seeps are modeled using the MODFLOW Drain package.

- Recharge—simulates areally distributed recharge due to precipitation falling on the outcrop areas of aquifers. Recharge is always shown as “Inflow” into the water budget. Recharge is modeled using the MODFLOW Recharge package.

- Vertical Leakage (Upward or Downward)—describes the vertical flow, or leakage, between two aquifers. This flow is controlled by the water levels in each aquifer and aquifer properties of each aquifer that define the amount of leakage that can occur. “Inflow” to an aquifer from an overlying or underlying aquifer will always equal the “Outflow” from the other aquifer.

- Storage—water stored in the aquifer. The storage component that is included in “Inflow” is water that is removed from storage in the aquifer (that is, water level declines). The storage component that is included in “Outflow” is water that is added back into storage in the aquifer (that is, water level increases). This component of the budget is often seen as water both going into and out of the aquifer because this is a regional budget, and water levels will decline in some areas (water is being removed from storage) and will rise in others (water is being added to storage).

- Lateral flow—describes lateral flow within an aquifer between a county and adjacent counties.

- Rivers and Streams—water that flows between perennial streams and rivers and an aquifer. The direction and amount of flow depends on the water level in the stream or river and the aquifer. In areas where water levels in the stream or river are above the water level in the aquifer, water flows into the aquifer and out of the stream and is shown as “Inflow” in the budget. In areas where water levels in the aquifer are above the water level in the stream or river, water flows out of the aquifer and into the stream and is shown as “Outflow” in the budget. Rivers and streams are modeled using the MODFLOW Stream package.

- Inter-aquifer Flow—The model uses general-head boundaries to simulate the movement of water between the Edwards or Trinity aquifer units and adjacent aquifers, including the Ogallala, Dockum, Edwards (Balcones Fault Zone), and Llano Uplift area aquifers.

The results of the model run are described for the individual aquifers units, the Edwards and associated limestones (Layer 1) and the undifferentiated Trinity unit (Layer 2). The Pecos Valley Aquifer is included in Layer 1.

Water levels from the end of the transient calibration portion of the model run (the end of 1999) for layers 1 and 2 are shown in Figures 1 and 2, respectively. These figures show the starting water levels for the 51-year (2000 to 2050) predictive portion of the model run. Water levels at the end of the 51-year predictive portion of the simulation for layers 1 and 2 are shown in Figures 3 and 4, respectively. Because differences between initial water levels and water levels after 51 years of pumpage are sometimes difficult to discern in these figures, maps of water level changes were made. A water-level change map shows the difference between the water levels at the end of the historic portion of the model run (1999) and the water levels at the end of the 51-year predictive portion of the model run (2050). Water-level changes over the 51-year predictive portion of the model simulation for Layers 1 and 2 are shown in Figures 5 and 6, respectively. Average and maximum water-level changes for each aquifer in each county of the model are provided in Table 3.

Table 3. Average and maximum water level changes by county and aquifer. Negative values indicate an average lowering of water levels between 1999 and 2050 while a positive value indicates an increase in water levels since 1999. A dashed line indicates the aquifer does not exist or was not modeled for a particular county.

	Edwards and Pecos Valley aquifers (Layer 1)			**Trinity Aquifer (Layer 2)**		
County Name	Area (square miles)	Average change (feet)	Maximum change (feet)	Area (square miles)	Average change (feet)	Maximum change (feet)
Andrews	267	-27	-66	163	-78	-172
Bandera	52	-34	-48	798	-68	-177
Bexar	--	--	--	245	37	11
Blanco	--	--	--	552	41	-33
Brewster	774	-25	-126	712	-77	-219
Burnet	--	--	--	26	-49	-152
Coke	--	--	--	244	-19	-41
Comal	--	--	--	362	31	0
Concho	194	-64	-120	189	-323	-487
Crane	573	-9	-39	9	-176	-177
Crockett	2,662	-62	-105	2,744	-65	-134
Culberson	142	-24	-29	--	--	--
Ector	105	-24	-45	667	-157	-207
Edwards	2,015	-26	-75	2,120	-72	-156
Gillespie	313	5	0	889	-7	-75
Glasscock	572	18	2	761	-465	-613

	Edwards and Pecos Valley aquifers (Layer 1)			Trinity Aquifer (Layer 2)		
Hays	--	--	--	370	29	0
Howard	--	--	--	72	-64	-107
Irion	674	-34	-72	664	-105	-307
Jeff Davis	325	-54	-96	--	--	--
Kendall	--	--	--	665	18	-34
Kerr	625	-11	-39	1,106	-90	-166
Kimble	943	-8	-59	1,197	-61	-163
Kinney	556	-78	-140	564	-125	-182
Loving	98	-12	-27	--	--	--
Martin	--	--	--	110	-347	-506
Mason	28	-13	-32	78	-87	-184
Medina	--	--	--	119	-17	-66
Menard	756	-39	-120	472	-107	-170
Midland	158	9	5	862	-242	-505
McCulloch	24	-20	-30	198	-198	-357
Nolan	--	--	--	464	2	-2
Pecos	4,269	-70	-166	1,634	-301	-620
Reagan	1,173	-7	-72	1,141	-316	-603
Real	421	-10	-36	700	-88	-158
Reeves	2,359	-20	-67	--	--	--
Schleicher	1,310	-64	-117	996	-58	-81
Sterling	215	2	-6	360	-111	-441
Sutton	1,454	-48	-85	1,351	-62	-156
Taylor	--	--	--	166	1	0
Terrell	2,343	-24	-64	2,380	-86	-307
Tom Green	346	-45	-116	372	-83	-337
Travis	--	--	--	254	1	-21
Upton	922	8	-33	940	-229	-429
Uvalde	157	-7	-22	394	-23	-68
Val Verde	3,206	-21	-112	3,213	-71	-174
Ward	658	-21	-62	--	--	--
Winkler	749	-52	-83	8	-207	-211

Figure 5 indicates that water levels in Layer 1 (Edwards and associated limestones and the Pecos Valley Aquifer) show mainly decreases in water levels ranging from 0 to 50 feet over the 51-year predictive portion of the run. Several localized areas of higher water level declines of greater than 100 feet can be seen in Figure 5, centering in Pecos, Kinney, Schleicher, and Concho counties.

Figure 6 indicates that water levels in Layer 2 (Trinity Aquifer) decrease throughout most of the region, generally less than 100 feet. Very large cones of depression are centered in Glasscock, Reagan, and Pecos counties, that are present at the end of the historic portion of the model run (Figure 2), continue to deepen with the model predicting up to 600 feet of decline in this area over the 51-year predictive time period. Several other smaller localized areas of higher water level declines can be seen in Figure 6, including in Kinney, Bandera, Menard, and Concho counties.

During previous model runs, the model response for the Trinity Aquifer was evaluated. It was determined that the model did not correctly simulate the response of water levels in Glasscock and Reagan counties appropriately during model calibration, and in fact water level declines during the historic calibration-verification time period were much lower than the model simulated water level declines (Donnelly, 2007). While using the model results without consideration of this could be viewed as taking a conservative approach, the water level declines predicted by the model are so great that we recommend taking another approach to evaluate the desired future conditions in this area, especially if a "managed depletion" approach to aquifer management is being considered.

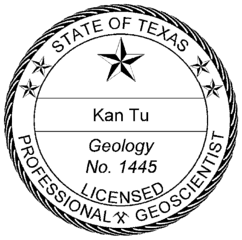
Another change in water levels that can be observed in Figure 6 is an area of increasing water levels centered Blanco, Hays, Kendall, and Comal counties. The reason for this increase is not known at this time and will require further evaluation, but it occurs primarily outside of the Groundwater Management Area 7 boundaries. Blanco, Hays, Kendall, and Comal counties are also included in the groundwater availability model for the Trinity Hill Country Aquifer, which may be a better tool for evaluating aquifer conditions in this area than the groundwater availability model for the Edwards-Trinity (Plateau) Aquifer.

Because some of the desired future conditions for the groundwater management area may be based on discharge to springs or baseflow to rivers and streams, we also evaluated the water budgets for each of these components for each county in the model area. These budgets are provided in Appendix A. The components of the water budget are divided up into "In" and "Out", representing water that is coming into and leaving from the budget. As might be expected, water from wells is only in the "Out" column, representing water that is removed from the aquifer from wells. Likewise, recharge is only found in the "In" column. Streams and rivers, however, have values in both the "In" and "Out" columns. This is because some stream reaches lose water to the aquifer, and some gain water from the aquifer depending on the water levels in the aquifer. Also included in these budgets are values for vertical leakage to overlying and underlying formations as well as lateral inflow from adjacent counties. Future model runs can be compared to these budgets to determine the impact of additional pumpage compared to this baseline run.

REFERENCES:

Anaya, R., and Jones, I., 2004, Groundwater availability model for the Edwards-Trinity (Plateau) and Cenozoic Pecos Alluvium aquifer systems, Texas: Texas Water Development Board, GAM Report, 208 p.

Donnelly, A.C.A., 2007, GAM Run 07-03, Texas Water Development Board GAM Run Report, 49 p.



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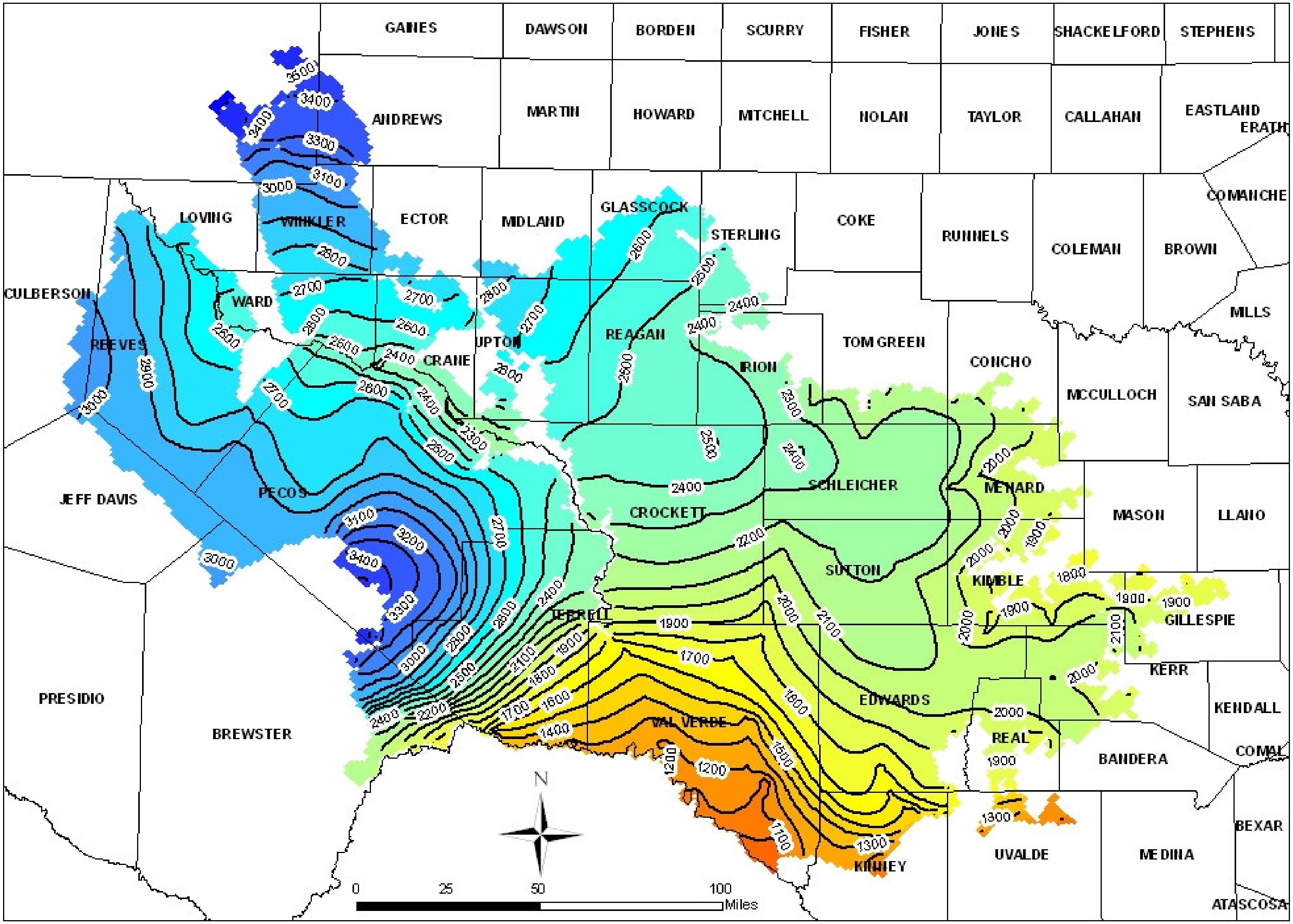

Figure 1. Initial water level elevations for the predictive model run in Layer 1 (Edwards and associated limestones and the Pecos Valley Aquifer) of the groundwater availability model for Edwards-Trinity (Plateau) Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 100 feet.

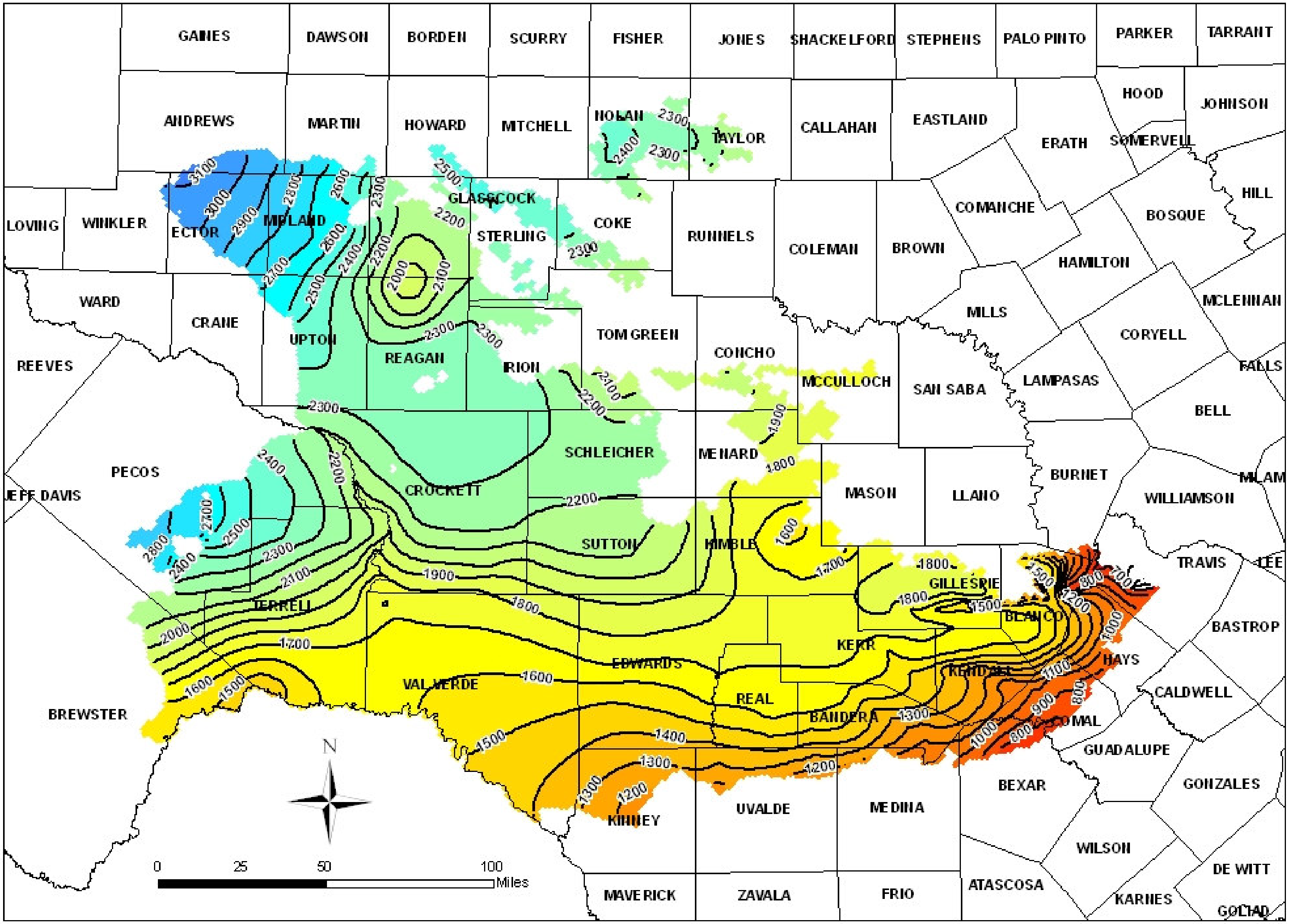

Figure 2. Initial water level elevations for the predictive model run in Layer 2 (Trinity Aquifer) of the groundwater availability model for Edwards- Trinity (Plateau) Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 100 feet.

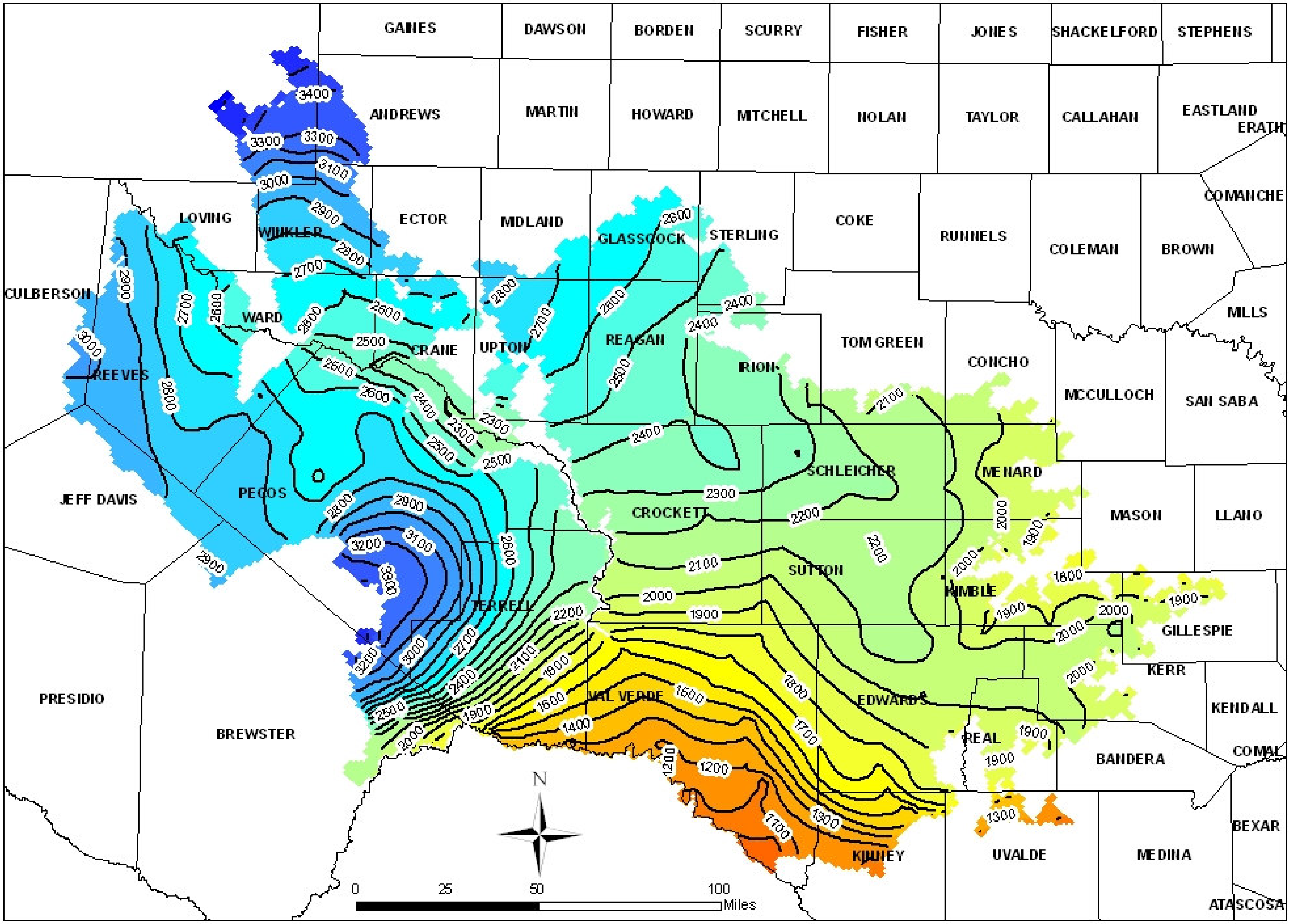

Figure 3. Water level elevations after 51 years using baseline pumpage in Layer 1 (Edwards and associated limestones and the Pecos Valley Aquifer). Water level elevations are in feet above mean sea level. Contour interval is 100 feet.

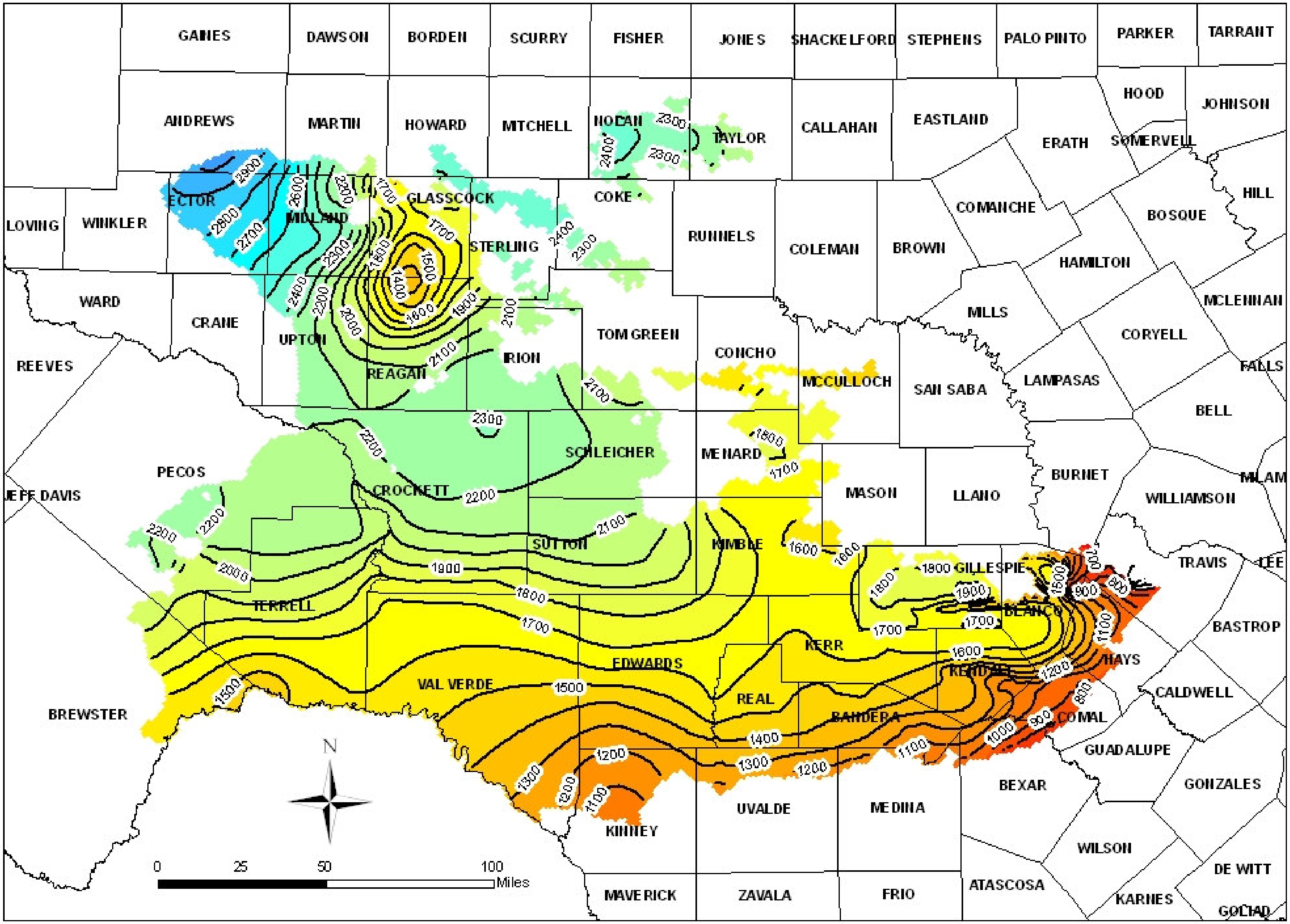

Figure 4. Water level elevations after 51 years using baseline pumpage in Layer 2 (Trinity Aquifer). Water level elevations are in feet above mean sea level. Contour interval is 100 feet.

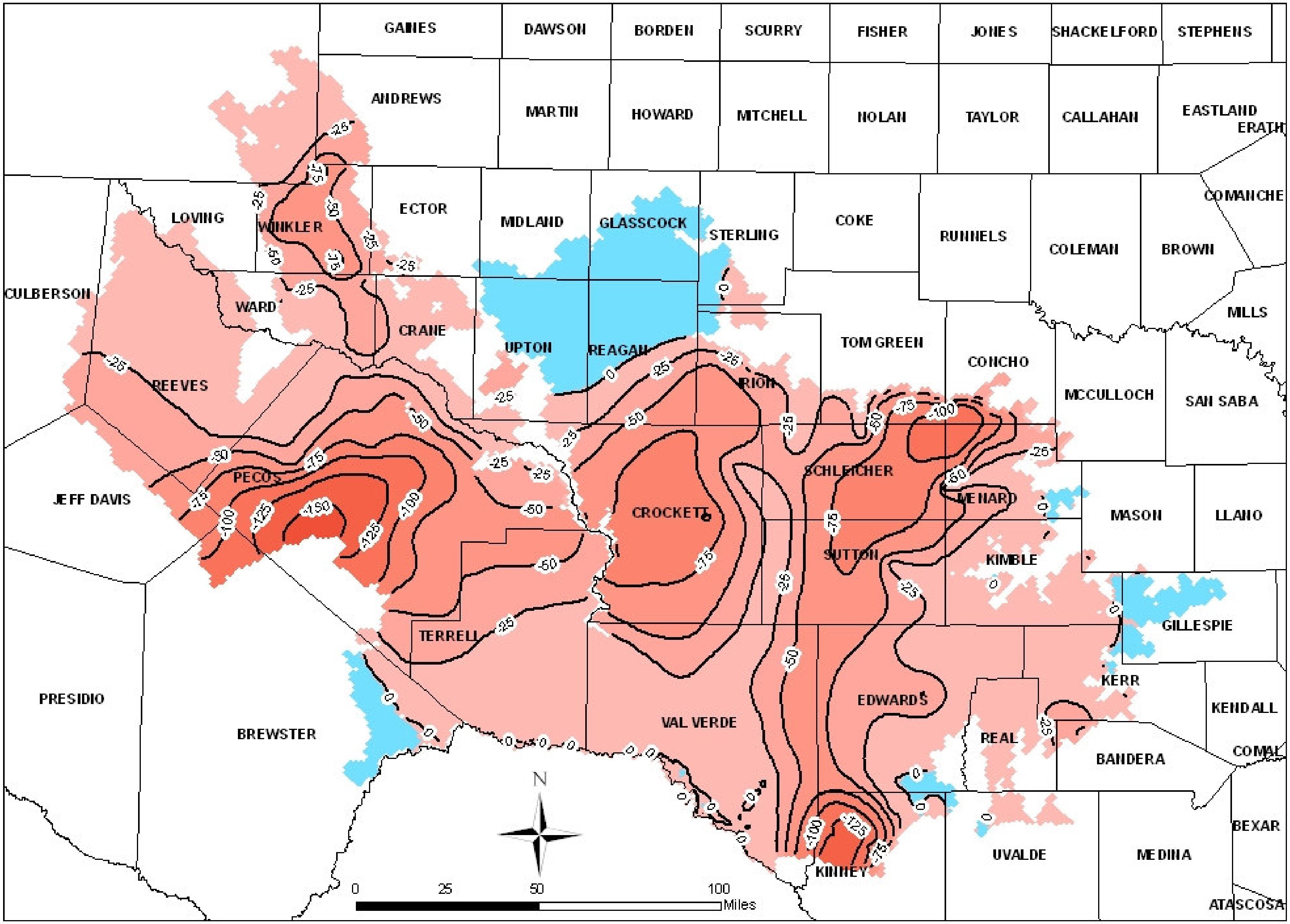

Figure 5. Changes in water levels (in feet) after 51 years using the specified pumpage in Layer 1 (Edwards and associated limestones and the Pecos Valley Aquifer). Decreases in water levels (drawdowns) are shown in red and increases in water levels are shown in blue. Contour interval is 25 feet.

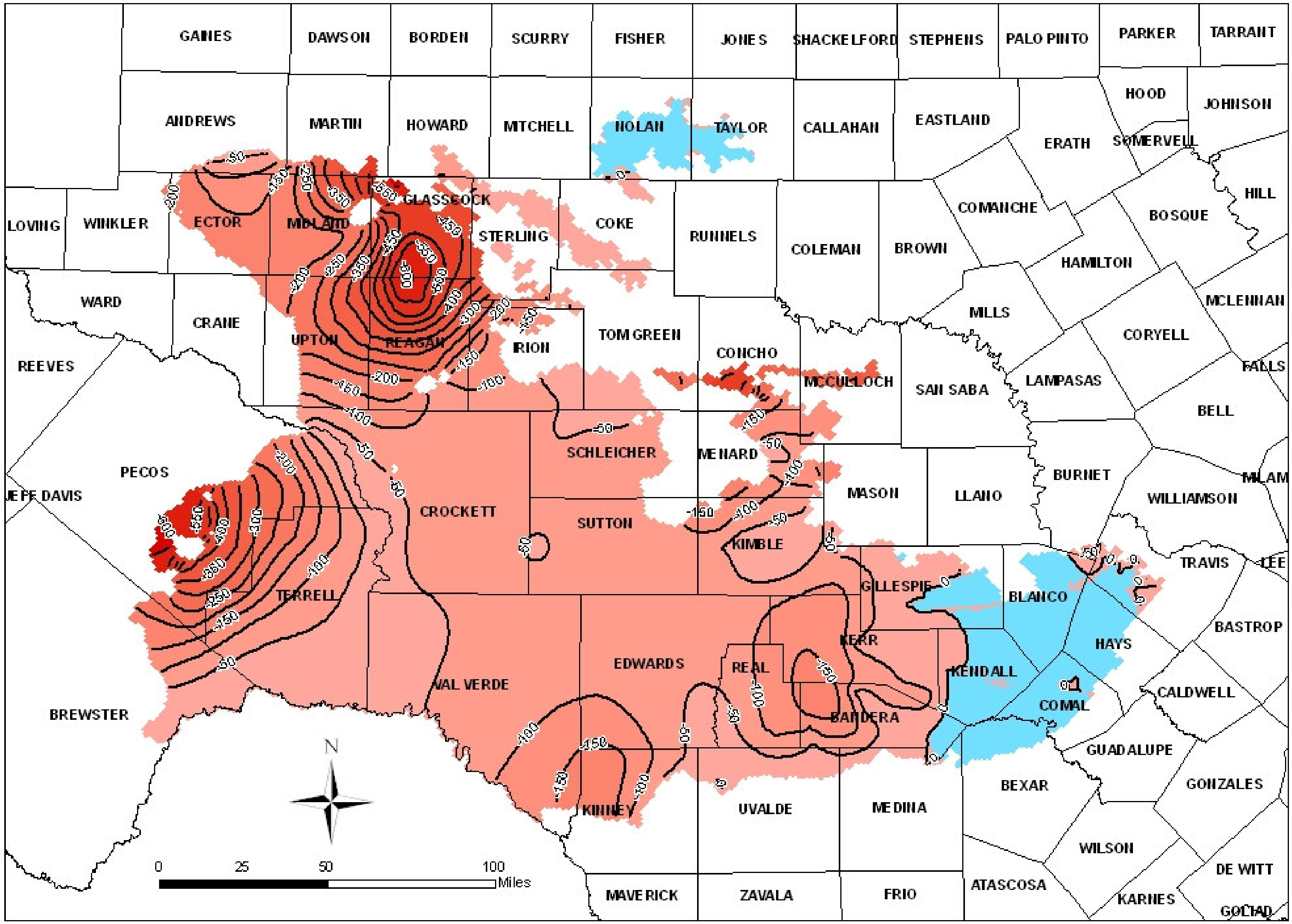

Figure 6. Changes in water levels after 51 years using the specified pumpage in Layer 2 (Trinity Aquifer). Decreases in water levels (drawdowns) are shown in red and increases in water levels are shown in blue. Contour interval is 50 feet.

Table A-1. Annual water budgets for each county at the end of the 51-year predictive portion of the model run using the requested pumpage and normal rainfall condition in the groundwater availability model for the Edwards-Trinity (Plateau) Aquifer (in acre-feet per year). Total pumpage for each county listed in Tables 1 and 2 matches the total value listed for wells in the water budget. The model includes two layers, representing the Edwards and associated limestones (Layer 1) and undifferentiated Trinity units (Layer 2). The Pecos Valley Aquifer is included in Layer 1 of the model

	Andrews		Bandera		Bexar		Blanco		Brewster		Burnet	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Model Layer 1												
Reservoirs (Constant Head Cells)	0	0	0	0	--	--	--	--	0	0	--	--
Storage	1,616	0	0	0	--	--	--	--	945	0	--	--
Springs and Seeps (Drain Package)	0	0	0	816	--	--	--	--	0	22,808	--	--
Inter-aquifer Flow (GHB Package)	0	1,189	0	0	--	--	--	--	0	0	--	--
Wells	0	1,188	0	3,537	--	--	--	--	0	85	--	--
Streams and Rivers (Stream Package)	0	0	3,785	282	--	--	--	--	0	0	--	--
Recharge	2,079	0	1,579	0	--	--	--	--	19,850	0	--	--
Lateral Inflow	1,172	2,490	1,127	1,803	--	--	--	--	7,033	4,932	--	--
Vertical Leakage Downward	--	--	9	63	--	--	--	--	1,161	1,163	--	--
Model Layer 2												
Reservoirs (Constant Head Cells)	0	0	381	2,280	0	0	0	0	0	0	0	226
Storage	214	0	1,022	0	0	0	0	420	1,331	0	0	0
Springs and Seeps (Drain Package)	0	0	0	0	0	0	0	15,533	0	0	0	260
Inter-aquifer Flow (GHB Package)	7,680	521	0	1,972	0	30,505	0	8	0	0	0	0
Wells	0	4,641	0	32,332	0	2,399	0	1,758	0	588	0	2,550
Streams and Rivers (Stream Package)	0	0	6,466	12,992	0	0	0	10,961	1,730	10,454	0	0
Recharge	3,912	0	48,555	0	21,238	0	45,590	0	5,854	0	1,877	0
Vertical Leakage Upward	--	--	63	9	--	--	--	--	1,163	1,161	--	--
Lateral Inflow	228	6,873	16,316	23,217	18,973	7,307	4,742	21,653	2,796	671	1,877	718
Total Pumpage		5,829		35,869		2,399		1,758		673		2,550

Table A-1. (continued)

	Coke		Comal		Concho		Crane		Crockett		Culberson	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Model Layer 1												
Reservoirs (Constant Head Cells)	--	--	--	--	0	0	0	0	0	0	0	0
Storage	--	--	--	--	124	0	3,670	0	4,305	0	1,188	0
Springs and Seeps (Drain Package)	--	--	--	--	0	566	0	0	0	0	0	0
Inter-aquifer Flow (GHB Package)	--	--	--	--	0	0	89	1,749	0	43	65	439
Wells	--	--	--	--	0	6,729	0	2,603	0	22,222	0	55
Streams and Rivers (Stream Package)	--	--	--	--	0	0	100	6,762	11,891	3,693	0	0
Recharge	--	--	--	--	5,205	0	5,465	0	43,957	0	2,183	0
Lateral Inflow	--	--	--	--	2,125	635	3,998	2,208	12,215	28,515	548	3,490
Vertical Leakage Downward	--	--	--	--	519	41	--	--	162	18,056	--	--
Model Layer 2												
Reservoirs (Constant Head Cells)	0	0	6,276	7,129	0	0	0	0	0	0	--	--
Storage	2	0	0	1	1,901	0	48	0	809	0	--	--
Springs and Seeps (Drain Package)	0	3,343	0	0	0	0	0	0	0	0	--	--
Inter-aquifer Flow (GHB Package)	0	50	2,437	12,111	48	0	8	1	10	2,830	--	--
Wells	0	3,243	0	3,059	0	5,548	0	51	0	3,229	--	--
Streams and Rivers (Stream Package)	0	0	471	27,570	0	0	0	0	336	8,018	--	--
Recharge	5,916	0	30,369	0	3,274	0	138	0	2,301	0	--	--
Vertical Leakage Upward	--	--	--	--	41	519	--	--	18,056	162	--	--
Lateral Inflow	1,164	446	20,169	9,854	976	174	658	800	6,782	14,055	--	--
Total Pumpage		3,243		3,059		12,278		2,654		25,451		55

Table A-1. (continued)

	Ector		Edwards		Gillespie		Glasscock		Hays		Howard	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Model Layer 1												
Reservoirs (Constant Head Cells)	0	0	0	0	0	0	0	0	--	--	--	--
Storage	3,848	0	32	0	0	0	0	0	--	--	--	--
Springs and Seeps (Drain Package)	0	0	0	4,149	0	9,298	0	1,615	--	--	--	--
Inter-aquifer Flow (GHB Package)	0	405	0	0	0	0	0	0	--	--	--	--
Wells	0	3,143	0	7,835	0	619	0	54	--	--	--	--
Streams and Rivers (Stream Package)	0	0	13,089	25,346	1,043	1,323	0	0	--	--	--	--
Recharge	788	0	74,639	0	10,113	0	11,144	0	--	--	--	--
Lateral Inflow	103	1,161	6,278	51,894	3,493	2,040	509	2,118	--	--	--	--
Vertical Leakage Downward	0	32	5	4,821	362	1,732	137	8,002	--	--	--	--
Model Layer 2												
Reservoirs (Constant Head Cells)	0	0	0	0	0	0	0	0	0	0	0	0
Storage	2,304	0	1,456	0	105	21	7,655	0	0	454	25	0
Springs and Seeps (Drain Package)	0	0	0	0	0	7,430	0	0	0	0	0	0
Inter-aquifer Flow (GHB Package)	117	1,057	0	0	0	7	16,893	59	0	17,804	1,335	22
Wells	0	11,324	0	860	0	4,280	0	59,226	0	3,715	0	1,700
Streams and Rivers (Stream Package)	0	0	3,417	166	3,485	20,920	0	0	0	3,239	0	0
Recharge	11,774	0	3,185	0	36,773	0	5,156	0	32,522	0	1,517	0
Vertical Leakage Upward	32	0	4,821	5	1,732	362	8,002	137	--	--	--	--
Lateral Inflow	4,596	6,441	12,673	24,522	716	9,790	32,705	10,989	7,255	14,566	311	1,466
Total Pumpage		14,467		8,695		4,899		59,280		3,715		1,700

Table A-1. (continued)

	Irion		Jeff Davis		Kendall		Kerr		Kimble		Kinney	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Model Layer 1												
Reservoirs (Constant Head Cells)	0	0	0	0	--	--	0	0	0	0	0	0
Storage	119	0	1,633	0	--	--	0	0	9	0	1,881	0
Springs and Seeps (Drain Package)	0	4,654	0	0	--	--	0	7,371	0	18,322	0	5,069
Inter-aquifer Flow (GHB Package)	0	0	11	12	--	--	0	0	0	0	1,859	8,195
Wells	0	5,068	0	201	--	--	0	5,208	0	7,135	0	35,963
Streams and Rivers (Stream Package)	1,042	3,352	0	0	--	--	8,297	5,221	1,192	3,726	1,908	11,445
Recharge	14,334	0	5,294	0	--	--	19,184	0	25,672	0	42,401	0
Lateral Inflow	6,244	1,881	1,364	8,088	--	--	3,566	12,008	15,516	6,344	24,616	10,872
Vertical Leakage Downward	106	6,891	--	--	--	--	10	1,248	148	7,009	2	1,127
Model Layer 2												
Reservoirs (Constant Head Cells)	0	0	--	--	0	0	0	0	0	0	0	0
Storage	448	0	--	--	6	346	952	1	659	0	193	0
Springs and Seeps (Drain Package)	0	171	--	--	0	0	0	0	0	2,175	0	0
Inter-aquifer Flow (GHB Package)	969	277	--	--	0	0	0	0	0	0	3,345	2,169
Wells	0	4,375	--	--	0	4,842	0	28,524	0	16,830	0	23,268
Streams and Rivers (Stream Package)	0	0	--	--	246	38,587	6,394	5,260	10,568	11,224	0	0
Recharge	2,287	0	--	--	51,352	0	27,329	0	7,256	0	1,163	0
Vertical Leakage Upward	6,891	106	--	--	--	--	1,248	10	7,009	148	1,127	2
Lateral Inflow	3,120	8,786	--	--	9,152	16,981	10,907	13,035	9,629	4,745	20,291	681
Total Pumpage		9,444		201		4,842		33,732		23,965		59,231

Table A-1. (continued)

	Loving		Martin		Mason		McCulloch		Medina		Menard	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Model Layer 1												
Reservoirs (Constant Head Cells)	0	0	--	--	0	0	0	0	--	--	0	0
Storage	2,421	0	--	--	0	0	0	0	--	--	229	0
Springs and Seeps (Drain Package)	0	0	--	--	0	344	0	9	--	--	0	3,193
Inter-aquifer Flow (GHB Package)	2	161	--	--	0	0	0	0	--	--	0	0
Wells	0	4,363	--	--	0	967	0	942	--	--	0	12,518
Streams and Rivers (Stream Package)	1,799	1,096	--	--	0	0	0	0	--	--	253	5,718
Recharge	604	0	--	--	829	0	677	0	--	--	20,304	0
Lateral Inflow	2,254	1,458	--	--	533	61	230	39	--	--	5,883	3,685
Vertical Leakage Downward	--	--	--	--	80	69	117	34	--	--	256	1,811
Model Layer 2												
Reservoirs (Constant Head Cells)	--	--	0	0	0	0	0	0	541	599	0	0
Storage	--	--	633	0	43	0	1,078	0	265	0	639	0
Springs and Seeps (Drain Package)	--	--	0	0	0	277	0	0	0	0	0	0
Inter-aquifer Flow (GHB Package)	--	--	2,480	41	0	0	171	13	0	24,180	0	0
Wells	--	--	0	3,398	0	2,861	0	7,306	0	860	0	6,482
Streams and Rivers (Stream Package)	--	--	0	0	0	0	0	0	0	0	3,795	99
Recharge	--	--	2,833	0	1,477	0	5,073	0	8,448	0	3,142	0
Vertical Leakage Upward	--	--	--	--	69	80	34	117	--	--	1,811	256
Lateral Inflow	--	--	6,205	8,713	2,126	497	1,089	9	21,445	5,061	750	3,304
Total Pumpage		4,363		3,398		3,828		8,248		860		19,000

Table A-1. (continued)

	Midland		Nolan		Pecos		Reagan		Real		Reeves	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Model Layer 1												
Reservoirs (Constant Head Cells)	0	0	--	--	0	0	0	0	0	0	0	0
Storage	0	0	--	--	49,618	0	61	0	0	0	85,455	0
Springs and Seeps (Drain Package)	0	0	--	--	0	0	0	651	0	7,762	0	0
Inter-aquifer Flow (GHB Package)	0	0	--	--	57	4,871	0	0	0	0	209	4,156
Wells	0	3	--	--	0	138,264	0	1,001	0	2,844	0	114,361
Streams and Rivers (Stream Package)	0	0	--	--	302	14,674	0	0	259	4,604	1,063	33,048
Recharge	2,691	0	--	--	148,323	0	21,100	0	12,474	0	67,867	0
Lateral Inflow	226	789	--	--	20,063	43,519	3,380	5,111	5,857	2,802	11,712	14,741
Vertical Leakage Downward	10	2,135	--	--	1,881	18,918	277	18,056	41	619	--	--
Model Layer 2												
Reservoirs (Constant Head Cells)	0	0	0	0	0	0	0	0	0	0	--	--
Storage	21,775	0	0	0	11,543	0	4,764	0	749	0	--	--
Springs and Seeps (Drain Package)	0	0	0	9,932	0	0	0	0	0	0	--	--
Inter-aquifer Flow (GHB Package)	3,214	423	0	0	0	0	15,009	98	0	0	--	--
Wells	0	21,137	0	1,001	0	35,171	0	60,815	0	8,680	--	--
Streams and Rivers (Stream Package)	0	0	0	0	1,859	5,428	0	0	9,511	112	--	--
Recharge	15,283	0	11,947	0	7,165	0	21	0	8,759	0	--	--
Vertical Leakage Upward	2,135	10	--	--	18,918	1,881	18,056	277	619	41	--	--
Lateral Inflow	16,939	37,775	167	1,180	8,356	5,363	36,585	13,244	5,845	16,649	--	--
Total Pumpage		21,140		1,001		173,435		61,816		11,525		114,361

Table A-1. (continued)

	Schleicher		Sterling		Sutton		Taylor		Terrell		Tom Green	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Model Layer 1												
Reservoirs (Constant Head Cells)	0	0	0	0	0	0	--	--	0	0	0	0
Storage	1,335	0	0	0	782	0	--	--	2,156	0	168	0
Springs and Seeps (Drain Package)	0	0	0	2,061	0	0	--	--	0	4,296	0	3,530
Inter-aquifer Flow (GHB Package)	0	0	0	0	0	0	--	--	0	0	0	0
Wells	0	16,124	0	1,563	0	20,652	--	--	0	698	0	7,390
Streams and Rivers (Stream Package)	12,162	2,484	0	0	6,918	13,582	--	--	170	33,633	198	423
Recharge	24,018	0	4,546	0	29,044	0	--	--	43,448	0	8,029	0
Lateral Inflow	4,135	17,666	1,329	1,289	16,390	12,217	--	--	42,829	34,323	6,462	1,960
Vertical Leakage Downward	1	5,378	172	1,134	272	6,955	--	--	267	15,920	47	1,601
Model Layer 2												
Reservoirs (Constant Head Cells)	0	0	0	0	0	0	0	0	0	0	0	0
Storage	23	0	100	0	274	0	0	0	6,214	0	423	0
Springs and Seeps (Drain Package)	0	0	0	740	0	0	0	4,490	0	0	0	1,013
Inter-aquifer Flow (GHB Package)	0	0	1,064	1,102	0	0	0	0	0	0	273	18
Wells	0	43	0	3,604	0	122	0	500	0	1,395	0	7,647
Streams and Rivers (Stream Package)	0	0	0	0	327	0	0	0	185	15,959	573	1,741
Recharge	0	0	5,992	0	0	0	4,595	0	682	0	3,601	0
Vertical Leakage Upward	5,378	1	1,134	172	6,955	272	--	--	15,920	267	1,601	47
Lateral Inflow	1,879	7,236	2,189	4,861	5,483	12,644	495	100	6,903	12,283	7,114	3,120
Total Pumpage		16,167		5,167		20,774		500		2,093		15,037

Table A-1. (continued)

	Travis		Upton		Uvalde		Val Verde		Ward		Winkler	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Model Layer 1												
Reservoirs (Constant Head Cells)	--	--	0	0	0	0	18,105	47,386	0	0	0	0
Storage	--	--	495	0	0	0	367	0	13,519	0	46,206	0
Springs and Seeps (Drain Package)	--	--	0	0	0	2,592	0	574	0	0	0	0
Inter-aquifer Flow (GHB Package)	--	--	4	902	5	5,857	0	0	2	4,645	0	3,083
Wells	--	--	0	337	0	1,433	0	49,078	0	17,290	0	51,996
Streams and Rivers (Stream Package)	--	--	0	0	0	0	29,574	104,264	739	10,649	0	0
Recharge	--	--	15,277	0	7,422	0	90,068	0	6,575	0	5,300	0
Lateral Inflow	--	--	1,007	5,665	3,116	1,464	72,312	10,465	15,412	3,662	7,936	4,363
Vertical Leakage Downward	--	--	105	9,983	840	37	2,468	1,128	--	--	--	--
Reservoirs (Constant Head Cells)	3,563	31,081	0	0	0	0	0	0	--	--	0	0
Storage	0	81	4,611	0	272	0	1,435	0	--	--	26	0
Springs and Seeps (Drain Package)	0	0	0	0	0	0	0	0	--	--	0	0
Inter-aquifer Flow (GHB Package)	13,129	346	7,831	16	964	19,660	0	0	--	--	0	5
Wells	0	3,900	0	20,266	0	2,332	0	534	--	--	0	517
Streams and Rivers (Stream Package)	19	6,704	0	0	2,566	14,394	93	1,370	--	--	0	0
Recharge	16,098	0	2,632	0	19,757	0	152	0	--	--	119	0
Vertical Leakage Upward	--	--	9,983	105	37	840	1,128	2,468	--	--	--	--
Lateral Inflow	9,364	60	16,320	20,989	18,930	5,301	12,010	10,445	--	--	377	0
Total Pumpage		3,900		20,604		3,765		49,612		17,290		52,513