GAM Run 06-29

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EXECUTIVE SUMMARY:

We ran the groundwater availability model (GAM) for the southern part of the Queen City and Sparta aquifers, which includes the Carrizo-Wilcox Aquifer, using 1999 estimated pumpage annually for a 60-year predictive simulation along with average recharge, evapotranspiration rates, and initial streamflows. These model runs indicate that maintaining 1999 pumpage in the GAM results in the following:

- maximum water level declines of less than 40 feet in the Sparta and Queen City aquifers, with some areas of recovery (increase in water levels);
- maximum water level declines of 130 feet in the Carrizo Aquifer, centering around northern Frio County; and
- water level declines of more than 80 feet in all three zones of the Wilcox Aquifer, also centering on northern Frio County and apparently caused by pumpage in the overlying Carrizo Aquifer.

REQUESTOR:

Mr. Mike Mahoney from the Evergreen Underground Water Conservation District (on behalf of Groundwater Management Area 13).

DESCRIPTION OF REQUEST:

Mr. Mahoney asked us to a run baseline model run using the GAM for the southern part of the Queen City, Sparta, and Carrizo-Wilcox aquifers. This baseline model run would be 60-year simulations using initial water levels from the end of the historic calibration simulation and average recharge conditions. Each year of the model run would use the 1999 estimated historic pumpage.

METHODS:

The GAM run was set up using average recharge and evapotranspiration rates and initial streamflows based on the historic calibration-verification runs, representing 1981 to 1999. These averages were then used for each year of the 60-year predictive simulations along with the 1999 estimated historic pumpage. Resulting water levels and water level declines were then evaluated and are described in the Results section below.

PARAMETERS AND ASSUMPTIONS:

The parameters and assumptions for the GAM for the southern part of the Queen City, Sparta, and Carrizo-Wilcox aquifers are described individually below:

- We used Version 1.01 of the GAM for the southern part of the Queen City, Sparta, and Carrizo-Wilcox aquifers.

- See Deeds and others (2003) and Kelley and others (2004) for assumptions and limitations of the GAM for the southern part of the Queen City, Sparta, and Carrizo-Wilcox aquifers.

- The model includes eight layers representing: the Sparta Aquifer (Layer 1), the Weches Formation (Layer 2), the Queen City Aquifer (Layer 3), the Reklaw Formation (Layer 4), the Carrizo Aquifer (Layer 5), the upper Wilcox Aquifer (Layer 6), the middle Wilcox Aquifer (Layer 7), and the lower Wilcox Aquifer (Layer 8).

- The root mean square error (a measure of the difference between simulated and actual water levels during model calibration) in the entire GAM for 1999 is 23 feet for the Sparta Aquifer, 18 feet for the Queen City aquifer, and 33 feet for the Carrizo aquifer (Kelley and others, 2004).

- Pumpage used for each year of the 60-year predictive simulation was the 1999 estimated historic pumpage from the transient calibration-verification run. Historic pumpage included in the transient calibration-verification model run, which includes the 1999 pumpage used for this predictive run, is shown in Appendix A. The locations of cells in each layer of the GAM that include pumpage in 1999 are also shown in Appendix A.

- Recharge rates, evapotranspiration rates, and initial streamflows are averages of historic estimates from 1981 to 1999.

RESULTS:

Included in the results for the GAM are estimates of the water budgets after running the GAM for 60 years. The components of the water budget are described below.

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

- Springs—water that drains from an aquifer if water levels are above the elevation of the spring. This component is always shown as "Outflow", or discharge, from the water budget. Springs are modeled in the GAM using the MODFLOW Drain package.

- Recharge—simulates areally distributed recharge due to precipitation falling on the outcrop (where the aquifer is exposed at land surface) areas of aquifers. Recharge is always shown as "Inflow" into the water budget.

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

- 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 levels decline). The storage component that is included in "Outflow" is water that is added back into storage in the aquifer (that is, water levels increase). 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.

- Evapotranspiration—water that flows out of an aquifer due to direct evaporation and plant transpiration. This component of the budget will always be shown as "Outflow". Evapotranspiration is modeled in the GAM using the MODFLOW Evapotranspiration (EVT) package.

- Rivers and Streams—water that flows between 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 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 in the GAM using the MODFLOW Stream package.

- General-Head Boundary (GHB)—The GAM uses GHBs to simulate the lateral aquifer boundaries. In addition, the downdip portions (areas where the layer is confined or covered by other aquifers or geologic formations) of the top layer in the GAM are modeled with GHBs to simulate the vertical movement of groundwater between the Sparta Aquifer (layer 1) and younger sediments that overlie the Sparta.

The results are described for the four aquifers in the model area; the Sparta Aquifer (layer 1 in the model), the Queen City Aquifer (layer 3), the Carrizo Aquifer (layer 5), and the Wilcox Aquifer (layers 6, 7, and 8). Results for the other units included in the GAM are

not discussed because they are not considered to be aquifers in the region. Although the GAM for the southern part of the Queen City, Sparta, and Carrizo-Wilcox aquifers extends to Fayette and Bastrop counties, only those portions in Groundwater Management Area (GMA) 13 will be included in this report.

Initial water levels (which are from the end of the transient calibration run- the end of 1999) for the Sparta, Queen City, Carrizo, Upper Wilcox, Middle Wilcox, and Lower Wilcox aquifers are shown in Figures 1 to 6. These figures show the starting water levels for this 60-year predictive GAM run. These figures all show that water levels are the highest in the outcrop portions of the aquifers located furthest to the north and/or east, and that water levels decrease as groundwater flows downdip, generally to the south and/or west. Initial heads or water levels in the Carrizo and Wilcox aquifers show a large cone of depression that has formed in Frio, LaSalle, Dimmit, and Zavala counties.

Water levels at the end of the 60-year predictive simulation for the Sparta, Queen City, Carrizo, Upper Wilcox, Middle Wilcox, and Lower Wilcox aquifers are shown in Figures 7 to 12. Water levels at the end of the 60-year runs are very similar to initial water levels (Figures 1 to 6). Because differences between initial water levels and water levels after 60 years of pumpage are difficult to discern in these figures, water level change maps were made. A water level change map shows the difference between the initial water levels and the water levels at the end of the 60-year run.

Water level changes over the 60-year predictive simulation for the Sparta, Queen City, Carrizo, Upper Wilcox, Middle Wilcox, and Lower Wilcox aquifers are shown in Figures 13 to 18. These figures indicate the following:

- Water level declines throughout most of GMA 13 in the Sparta Aquifer (Figure 13) are zero to 30 feet, although a small (less than ten feet) amount of water level recovery is seen in the southern and northern portions of the model area.

- Water level declines in the Queen City Aquifer (Figure 14) are between zero and 40 feet in most of the model area. As with the Sparta Aquifer, the southern and northern portions of the model area show some water level recovery. In northwestern Webb and central Zavala counties water level recoveries of more than 50 feet are shown.

- Water level declines in the Carrizo Aquifer (Figure 15) are predicted to be very large over the next 60 years in some areas, primarily around an area in northern Frio County. Water level declines of over 130 feet are predicted in this area. Large parts of the southern and northern portions of the model area are predicted to show water level recovery over the next 60 years if 1999 pumpage is used.

- Water level declines in the Upper and Middle Wilcox aquifers (Figures 16 and 17) show similar patterns as the Carrizo, with large water level declines focused around northern Frio County and water level recovery in the southern and northern portions of the model area if 1999 pumpage is used for 60 years. Much

of this is due to water level changes in the Carrizo Aquifer (layer 5) because there is very little pumpage in Frio County in the Wilcox in 1999 (Appendix A).

- Water level declines in the Lower Wilcox Aquifer (Figure 18) are up to 80 feet in the area in northern Frio County. As with the Upper and Middle Wilcox, much of this is due to water level changes in the Carrizo Aquifer (layer 5) because there is very little pumpage in Frio County in the Wilcox in 1999 (Appendix A). Most of the rest of this aquifer is predicted to show water level recovery over the next 60 years if 1999 pumpage is used.

In general, areas of recovery are found where no pumpage is included in the GAM in 1999.

Because some of the desired future conditions (DFCs) for the GMA may be based on discharge to springs or baseflow to rivers and streams, we also pulled the water budgets for each of these components for each county in the model area. These budgets are provided in Table 1. 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 pulled out of the budget or aquifer system 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 streams 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 GAM runs can be compared to these budgets to determine the impact of additional pumpage compared to this baseline run.

REFERENCES:

Deeds, N., Kelley, V., Fryar, D., Jones, T., Whallon, A. J., and Dean, K. E., 2003, Groundwater Availability Model for the Southern Carrizo-Wilcox Aquifer: contract report to the Texas Water Development Board, 452 p.

Kelley, V. A., Deeds, N. E., Fryar, D. G., and Nicot, J. P., 2004, Groundwater availability models for the Queen City and Sparta aquifers: contract report to the Texas Water Development Board, 867 p.

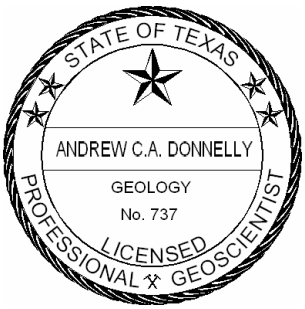

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Table 1. Annual water budgets for each county in GMA 13 at the end of the 60-year predictive model run using 1999 pumpage in the GAM for the southern part of the Queen City, Sparta, and Carrizo-Wilcox aquifers. Values are reported in acre-feet per year.

	Atascosa		Bee		Bexar		Caldwell		De Witt		Dimmit		Frio	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Sparta														
Storage	337	141	11	0	NA	NA	NA	NA	8	5	562	399	1,103	256
River	0	0	0	0	NA	NA	NA	NA	0	0	0	0	0	0
Drain	0	0	0	0	NA	NA	NA	NA	0	0	0	0	0	0
GHB	4,301	3,940	56	20	NA	NA	NA	NA	99	771	259	14	6,329	820
Well	0	516	0	0	NA	NA	NA	NA	0	0	0	0	0	77
Stream	219	489	0	0	NA	NA	NA	NA	0	0	487	908	368	215
Recharge	2,306	0	0	0	NA	NA	NA	NA	0	0	3,302	0	4,277	0
ET	0	0	0	0	NA	NA	NA	NA	0	0	0	154	0	74
Lateral Inflow	719	220	2	1	NA	NA	NA	NA	11	21	331	569	326	2,214
Vertical Leakage Downward	2,176	4,751	13	60	NA	NA	NA	NA	756	76	2	2,899	0	8,747
Queen City														
Storage	811	543	24	0	NA	NA	1	43	24	5	2,264	8,844	797	5,696
River	0	0	0	0	NA	NA	0	0	0	0	0	0	0	0
Drain	0	0	0	0	NA	NA	0	0	0	0	0	0	0	0
GHB	0	0	0	0	NA	NA	0	0	0	0	0	0	0	0
Well	0	964	0	0	NA	NA	0	132	0	0	0	0	0	66
Stream	3,275	2,192	0	0	NA	NA	93	343	0	0	8,794	6,294	7,458	11
Recharge	5,166	0	0	0	NA	NA	1,144	0	0	0	11,146	0	13,821	0
ET	0	44	0	0	NA	NA	0	0	0	0	0	0	0	0
Vertical Leakage Upward	4,949	2,059	17	4	NA	NA	NA	NA	5	751	3,329	14	9,665	0
Lateral Inflow	2,185	620	2	3	NA	NA	53	691	4	12	1,628	2,912	652	3,941
Vertical Leakage Downward	33	9,994	0	36	NA	NA	0	82	737	2	111	9,208	0	22,679

Table 1. (continued)

	Atascosa		Bee		Bexar		Caldwell		De Witt		Dimmit		Frio	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Carrizo														
Storage	12,240	227	20	0	3,250	153	29	19	22	4	130	950	17,932	17
River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GHB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Well	0	52,419	0	19	0	2,804	0	279	0	1	0	2,917	0	99,802
Stream	1,446	10	0	0	1,836	0	75	0	0	0	841	0	536	0
Recharge	8,119	0	0	0	4,423	0	5,531	0	0	0	5,490	0	1,811	0
ET	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vertical Leakage Upward	12,451	0	52	0	127	0	1,165	0	0	721	8,992	3	26,999	0
Lateral Inflow	28,372	14,557	251	350	1,459	8,458	483	6,872	60	2	690	5,841	51,789	4,554
Vertical Leakage Downward	5,101	517	47	0	528	207	105	219	165	54	2,360	5,173	9,575	4,270
Upper Wilcox														
Storage	135	0	27	0	13	18	0	19	27	24	517	245	131	0
River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GHB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Well	0	36	0	19	0	0	0	0	0	0	0	1,321	0	6,049
Stream	0	0	0	0	0	0	0	0	0	0	94	118	0	0
Recharge	0	0	0	0	361	0	0	0	0	0	345	0	0	0
ET	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vertical Leakage Upward	517	5,101	0	47	207	528	219	105	54	165	5,173	2,360	4,270	9,575
Lateral Inflow	491	171	12	19	7	97	1	26	67	17	1,304	3,142	2,398	91
Vertical Leakage Downward	4,462	296	47	0	225	171	0	69	58	0	1,279	1,525	9,002	86

Table 1. (continued)

	Atascosa		Bee		Bexar		Caldwell		De Witt		Dimmit		Frio	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Middle Wilcox														
Storage	2,091	58	17	0	1,485	5	37	18	0	316	1,188	3	721	0
River	0	0	0	0	1,603	0	0	0	0	0	0	0	0	0
Drain	0	0	0	0	0	128	0	19	0	0	0	0	0	0
GHB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Well	0	598	0	19	0	5,543	0	1,169	0	0	0	189	0	4,089
Stream	642	0	0	0	2,455	764	671	8,002	0	0	271	2	0	0
Recharge	622	0	0	0	2,840	0	4,423	0	0	0	724	0	0	0
ET	0	0	0	0	0	13	0	36	0	0	0	0	0	0
Vertical Leakage Upward	296	4,462	0	47	171	225	69	0	0	58	1,525	1,279	86	9,002
Lateral Inflow	885	780	22	9	350	978	3,633	644	167	1	701	1,983	4,014	243
Vertical Leakage Downward	2,842	1,480	35	0	363	1,610	1,515	460	208	0	1,046	1,999	8,515	2
Lower Wilcox														
Storage	705	0	0	29	745	37	6	285	0	208	804	9	644	0
River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drain	0	0	0	0	0	48	0	208	0	0	0	0	0	0
GHB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Well	0	1,527	0	19	0	5,774	0	2,181	0	0	0	50	0	64
Stream	0	0	0	0	3,347	478	562	1,806	0	0	193	0	0	0
Recharge	0	0	0	0	5,306	0	4,665	0	0	0	268	0	0	0
ET	0	0	0	0	0	166	0	411	0	0	0	0	0	0
Vertical Leakage Upward	1,480	2,842	0	35	1,610	363	460	1,515	0	208	1,999	1,046	2	8,515
Lateral Inflow	3,948	1,764	218	135	546	4,688	1,145	431	479	63	2,295	4,454	8,573	640

Table 1. (continued)

	Gonzales		Guadalupe		Karnes		La Salle		Lavaca		Live Oak		Maverick	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Sparta														
Storage	9	272	NA	NA	62	0	2,800	26	0	5	85	0	NA	NA
River	0	0	NA	NA	0	0	0	0	0	0	0	0	NA	NA
Drain	0	27	NA	NA	0	0	0	0	0	0	0	0	NA	NA
GHB	351	6,509	NA	NA	609	1,069	9,225	6,244	140	745	12	570	NA	NA
Well	0	552	NA	NA	0	0	0	1,316	0	0	0	0	NA	NA
Stream	0	1,512	NA	NA	0	0	0	1,841	0	0	0	0	NA	NA
Recharge	3,081	0	NA	NA	0	0	1,923	0	0	0	0	0	NA	NA
ET	0	20	NA	NA	0	0	0	435	0	0	0	0	NA	NA
Lateral Inflow	363	32	NA	NA	93	194	3,084	963	15	60	33	5	NA	NA
Vertical Leakage Downward	5,543	425	NA	NA	894	395	1,571	7,778	702	47	456	10	NA	NA
Queen City														
Storage	22	1,252	0	19	147	0	668	6	0	6	220	0	NA	NA
River	0	0	0	0	0	0	0	0	0	0	0	0	NA	NA
Drain	0	68	0	0	0	0	0	0	0	0	0	0	NA	NA
GHB	0	0	0	0	0	0	0	0	0	3	0	0	NA	NA
Well	0	240	0	0	0	0	0	2	0	0	0	0	NA	NA
Stream	366	4,311	0	0	0	0	0	0	0	0	0	0	NA	NA
Recharge	6,094	0	39	0	0	0	0	0	0	0	0	0	NA	NA
ET	0	176	0	0	0	0	0	0	0	0	0	0	NA	NA
Vertical Leakage Upward	635	5,296	NA	NA	229	741	7,773	1,319	2	700	13	331	NA	NA
Lateral Inflow	1,931	37	2	6	577	141	5,123	837	7	28	28	15	NA	NA
Vertical Leakage Downward	2,599	267	0	16	208	280	9	11,410	728	0	114	29	NA	NA

Table 1. (continued)

	Gonzales		Guadalupe		Karnes		La Salle		Lavaca		Live Oak		Maverick	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Carrizo														
Storage	174	0	668	763	144	0	375	0	0	3	127	0	0	715
River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GHB	0	0	0	0	0	0	0	0	0	393	0	0	0	0
Well	0	2,538	0	1,224	0	471	0	5,684	0	1	0	85	0	144
Stream	0	6,153	83	233	0	0	0	0	0	0	0	0	444	95
Recharge	1,406	0	7,210	0	0	0	0	0	0	0	0	0	2,108	0
ET	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vertical Leakage Upward	1,014	2,410	553	22	284	152	12,410	0	0	766	113	18	46	0
Lateral Inflow	10,902	2,663	17	6,038	4,191	4,600	7,575	16,066	1,466	417	1,150	1,603	4	805
Vertical Leakage Downward	366	98	113	364	637	33	2,511	1,121	213	99	316	0	33	877
Upper Wilcox														
Storage	4	23	0	0	95	0	499	0	0	36	173	0	0	111
River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GHB	0	0	0	0	0	0	0	0	170	0	0	0	0	0
Well	0	1	0	0	0	0	0	2,602	0	0	0	0	0	136
Stream	0	0	0	0	0	0	0	0	0	0	0	0	52	34
Recharge	0	0	0	0	0	0	0	0	0	0	0	0	85	0
ET	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vertical Leakage Upward	98	366	364	113	33	637	1,121	2,511	99	213	0	316	877	33
Lateral Inflow	35	32	1	63	20	52	4,000	2,021	12	45	52	185	21	113
Vertical Leakage Downward	296	10	26	215	542	0	1,514	0	12	0	276	0	41	649

Table 1. (continued)

	Gonzales		Guadalupe		Karnes		La Salle		Lavaca		Live Oak		Maverick	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Middle Wilcox														
Storage	6	143	430	0	78	6	436	0	0	270	88	0	3	78
River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GHB	0	0	0	0	0	0	0	0	59	0	0	0	0	0
Well	0	66	0	3,047	0	0	0	0	0	0	0	0	0	259
Stream	652	0	2,603	3,158	0	0	0	0	0	0	0	0	903	19
Recharge	125	0	5,639	0	0	0	0	0	0	0	0	0	591	0
ET	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vertical Leakage Upward	10	296	215	26	0	542	0	1,514	0	12	0	276	649	41
Lateral Inflow	1,149	2,106	995	3,893	72	90	492	654	116	17	35	25	466	859
Vertical Leakage Downward	669	0	708	467	488	0	1,241	0	124	0	179	0	25	1,380
Lower Wilcox														
Storage	0	192	120	457	5	118	376	24	0	62	0	96	185	275
River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drain	0	0	0	42	0	0	0	0	0	0	0	0	0	0
GHB	0	0	0	0	0	0	0	0	98	53	0	0	0	0
Well	0	0	0	1,550	0	0	0	0	0	0	0	0	0	992
Stream	0	0	891	575	0	0	0	0	0	0	0	0	375	49
Recharge	0	0	4,513	0	0	0	0	0	0	0	0	0	1,353	0
ET	0	0	0	66	0	0	0	0	0	0	0	0	0	195
Vertical Leakage Upward	0	669	467	708	0	488	0	1,241	0	124	0	179	1,380	25
Lateral Inflow	1,750	889	746	3,339	1,397	796	2,445	1,556	210	69	557	282	14	1,770

Table 1. (continued)

	McMullen		Medina		Uvalde		Webb		Wilson		Zavala	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Sparta												
Storage	172	0	NA	NA	NA	NA	21	3,878	836	12	2	1,183
River	0	0	NA	NA	NA	NA	0	0	0	0	0	0
Drain	0	0	NA	NA	NA	NA	0	0	0	137	0	0
GHB	927	1,564	NA	NA	NA	NA	5,154	793	1,125	3,545	0	0
Well	0	0	NA	NA	NA	NA	0	0	0	504	0	0
Stream	0	0	NA	NA	NA	NA	3,938	2,156	83	425	247	62
Recharge	0	0	NA	NA	NA	NA	3,201	0	2,403	0	4,362	0
ET	0	0	NA	NA	NA	NA	0	2,202	0	6	0	0
Lateral Inflow	491	160	NA	NA	NA	NA	240	776	133	401	34	146
Vertical Leakage Downward	904	768	NA	NA	NA	NA	769	3,520	1,249	798	0	3,253
Queen City												
Storage	692	0	NA	NA	NA	NA	103	19,834	722	1,040	329	15,576
River	0	0	NA	NA	NA	NA	0	0	0	0	0	0
Drain	0	0	NA	NA	NA	NA	0	0	0	0	0	0
GHB	0	0	NA	NA	NA	NA	0	0	0	0	0	0
Well	0	0	NA	NA	NA	NA	0	0	0	170	0	0
Stream	0	0	NA	NA	NA	NA	20,882	7,173	1,367	3,592	16,857	0
Recharge	0	0	NA	NA	NA	NA	10,787	0	7,482	0	10,722	0
ET	0	0	NA	NA	NA	NA	0	1,523	0	0	0	0
Vertical Leakage Upward	731	764	NA	NA	NA	NA	4,101	622	1,517	1,117	2,636	0
Lateral Inflow	1,039	119	NA	NA	NA	NA	732	2,566	59	1,825	1,177	979
Vertical Leakage Downward	67	1,645	NA	NA	NA	NA	167	5,056	34	3,437	0	15,165

Table 1. (continued)

	McMullen		Medina		Uvalde		Webb		Wilson		Zavala	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Carrizo												
Storage	253	0	4,575	227	2	1	30	129	2,917	438	8,735	534
River	0	0	0	0	0	0	0	0	0	0	0	0
Drain	0	0	0	0	0	0	0	0	0	0	0	0
GHB	0	0	0	0	0	0	0	0	0	0	0	0
Well	0	120	0	1,477	0	0	0	896	0	15,986	0	31,762
Stream	0	0	1,440	44	658	0	54	0	9,760	118	2,643	0
Recharge	0	0	8,726	0	1,223	0	529	0	8,696	0	6,602	0
ET	0	0	0	0	0	0	0	124	0	0	0	0
Vertical Leakage Upward	1,843	21	8	0	NA	NA	4,756	1	4,838	3	17,176	34
Lateral Inflow	1,705	4,523	956	13,508	6	1,566	97	1,673	6,397	17,498	8,536	11,567
Vertical Leakage Downward	886	23	866	1,313	0	322	410	3,055	1,832	396	7,740	7,535
Upper Wilcox												
Storage	516	0	84	26	8	22	112	101	16	0	216	65
River	0	0	0	0	0	0	0	0	0	0	0	0
Drain	0	0	0	0	0	0	0	0	0	0	0	0
GHB	0	0	0	0	0	0	0	0	0	0	0	0
Well	0	0	0	31	0	0	0	13	0	40	0	8,294
Stream	0	0	0	0	0	0	15	201	0	0	0	0
Recharge	0	0	0	0	100	0	82	0	0	0	304	0
ET	0	0	0	0	0	0	0	69	0	0	0	0
Vertical Leakage Upward	23	886	1,313	866	322	0	3,055	410	396	1,832	7,535	7,740
Lateral Inflow	765	1,004	46	477	1	145	677	2,654	82	14	972	591
Vertical Leakage Downward	587	0	690	733	0	263	48	542	1,530	139	9,109	1,445

Table 1. (continued)

	McMullen		Medina		Uvalde		Webb		Wilson		Zavala	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Middle Wilcox												
Storage	264	0	3,291	24	899	3	81	32	260	0	1,654	361
River	0	0	0	0	0	0	0	0	0	0	0	0
Drain	0	0	0	0	0	0	0	0	0	0	0	0
GHB	0	0	0	0	0	0	0	0	0	0	0	0
Well	0	0	0	980	0	120	0	6	0	772	0	4,901
Stream	0	0	932	32	311	10	3,000	2,812	973	1,489	1,417	4
Recharge	0	0	2,619	0	1,091	0	82	0	968	0	1,006	0
ET	0	0	0	0	0	0	0	150	0	0	0	0
Vertical Leakage Upward	0	587	733	690	263	0	542	48	139	1,530	1,445	9,109
Lateral Inflow	83	100	329	2,560	29	1,001	466	531	1,701	925	2,517	862
Vertical Leakage Downward	340	0	239	3,858	0	1,460	19	612	1,022	345	9,360	2,164
Lower Wilcox												
Storage	92	121	2,284	271	1,935	76	33	47	104	12	670	523
River	0	0	0	0	0	0	0	0	0	0	0	0
Drain	0	0	0	0	0	0	0	0	0	0	0	0
GHB	0	0	0	0	0	0	0	0	0	0	0	0
Well	0	0	0	1,533	0	105	0	1	0	578	0	440
Stream	0	0	113	225	347	15	0	133	117	0	790	84
Recharge	0	0	1,975	0	1,205	0	15	0	69	0	537	0
ET	0	0	0	327	0	4	0	42	0	0	0	0
Vertical Leakage Upward	0	340	3,858	239	1,460	0	612	19	345	1,022	2,164	9,360
Lateral Inflow	683	313	575	6,209	348	5,094	1,670	2,089	4,455	3,478	7,579	1,333

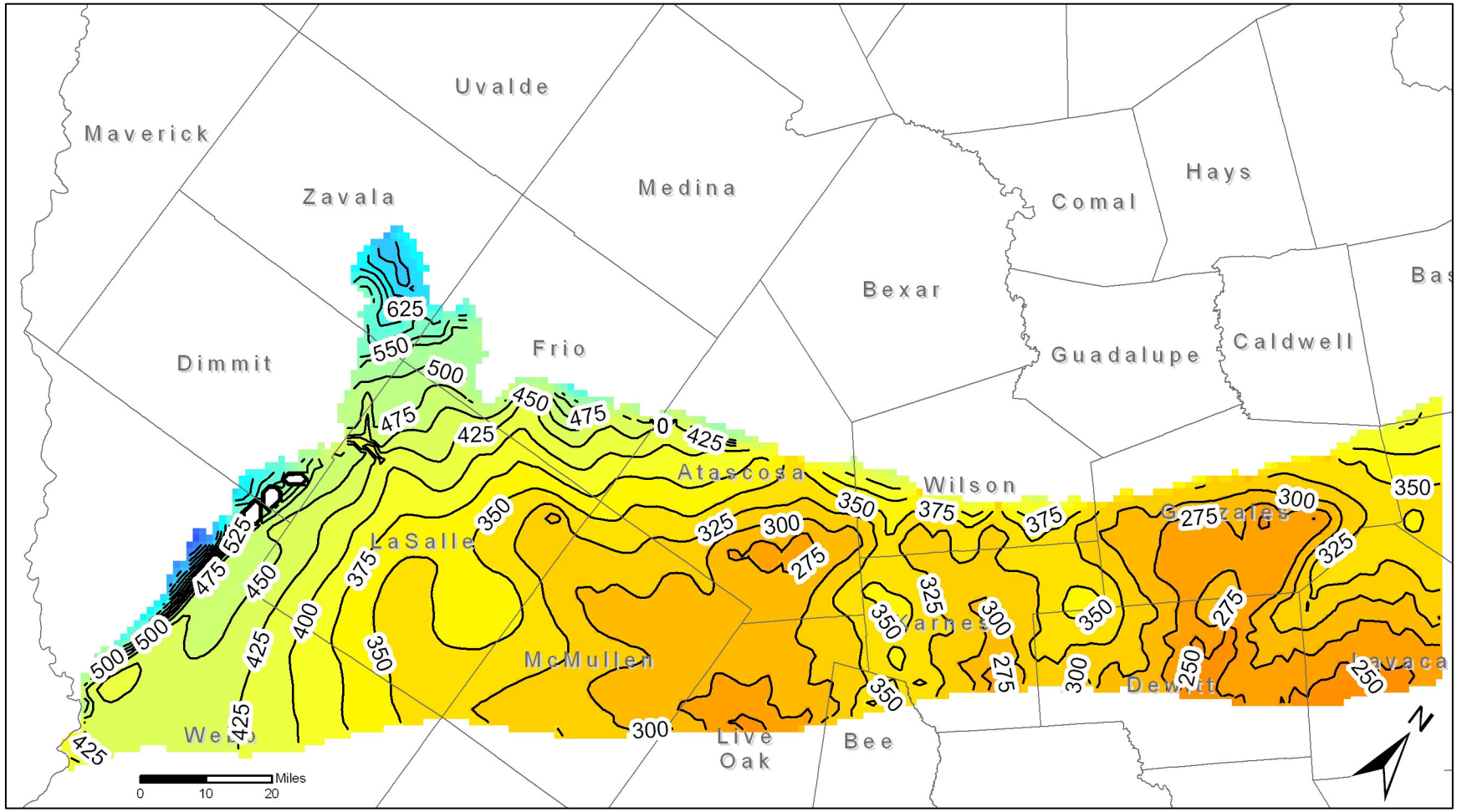

Figure 1. Initial water level elevations for the predictive model run in the Sparta Aquifer from the southern part of the Queen City, Sparta, and Carrizo-Wilcox aquifers GAM. Water level elevations are in feet above mean sea level. Contour interval is 25 feet.

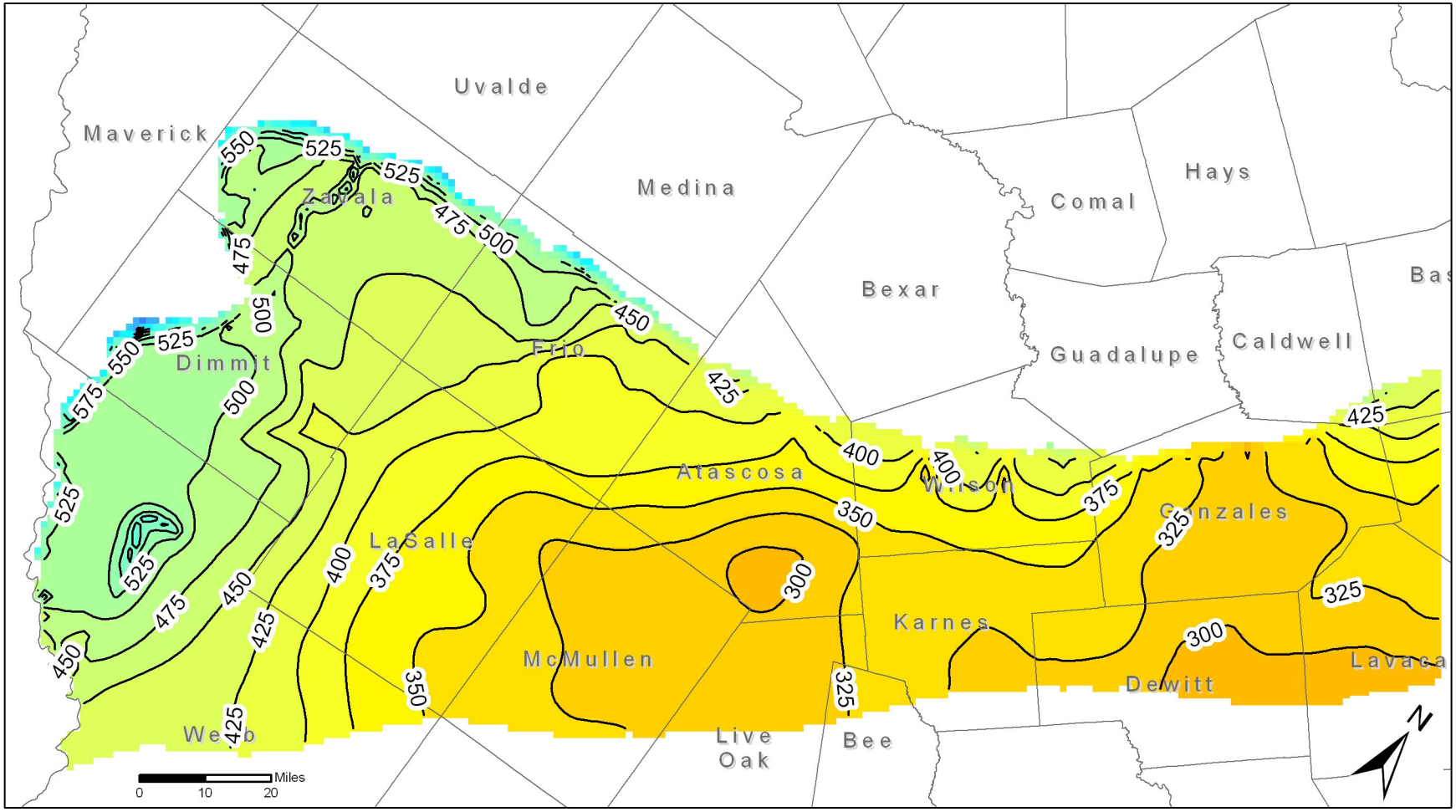

Figure 2. Initial water level elevations for the predictive model run in the Queen City Aquifer from the southern part of the Queen City, Sparta, and Carrizo-Wilcox aquifers GAM. Water level elevations are in feet above mean sea level. Contour interval is 25 feet.

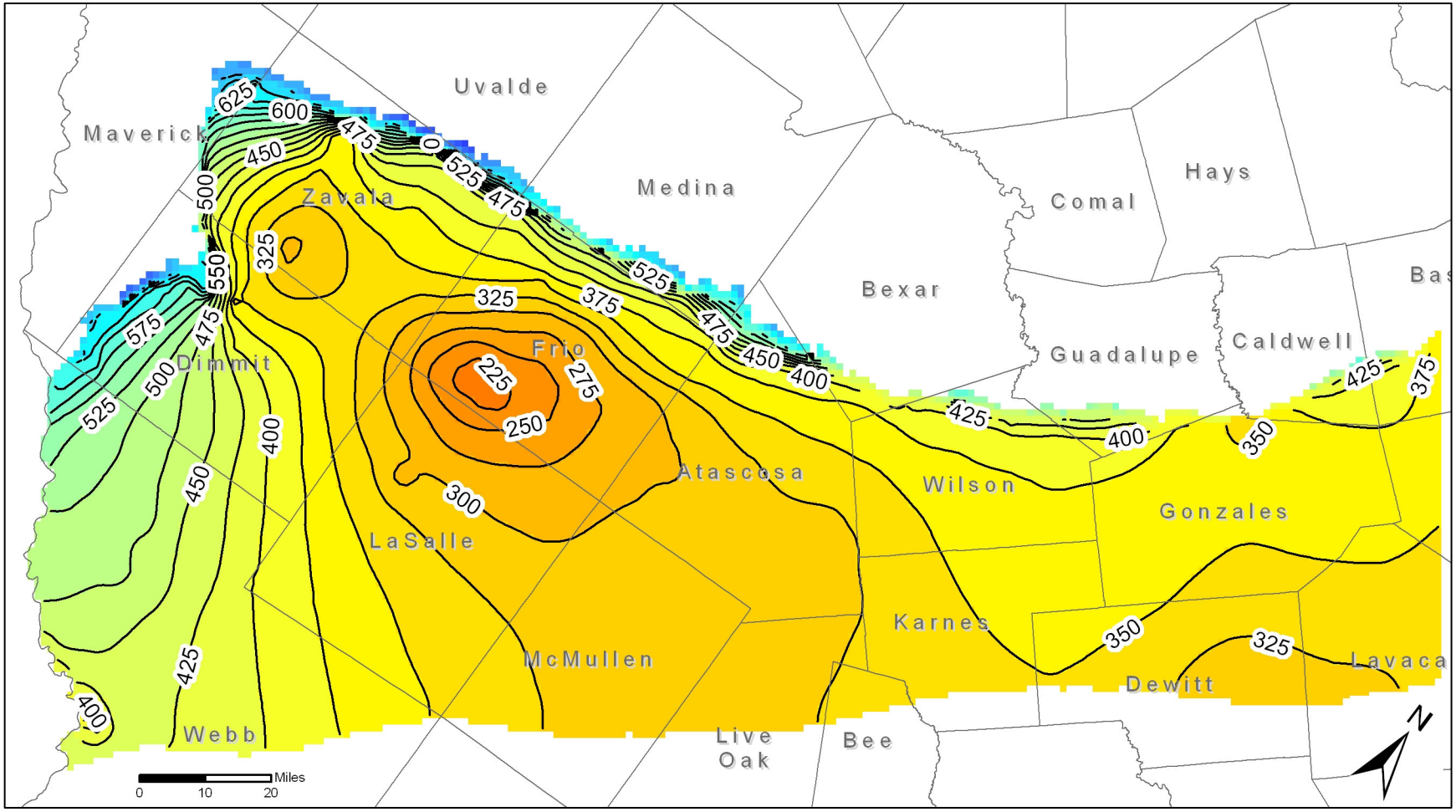

Figure 3. Initial water level elevations for the predictive model run in the Carrizo Aquifer from the southern part of the Queen City, Sparta, and Carrizo-Wilcox aquifers GAM. Water level elevations are in feet above mean sea level. Contour interval is 25 feet.

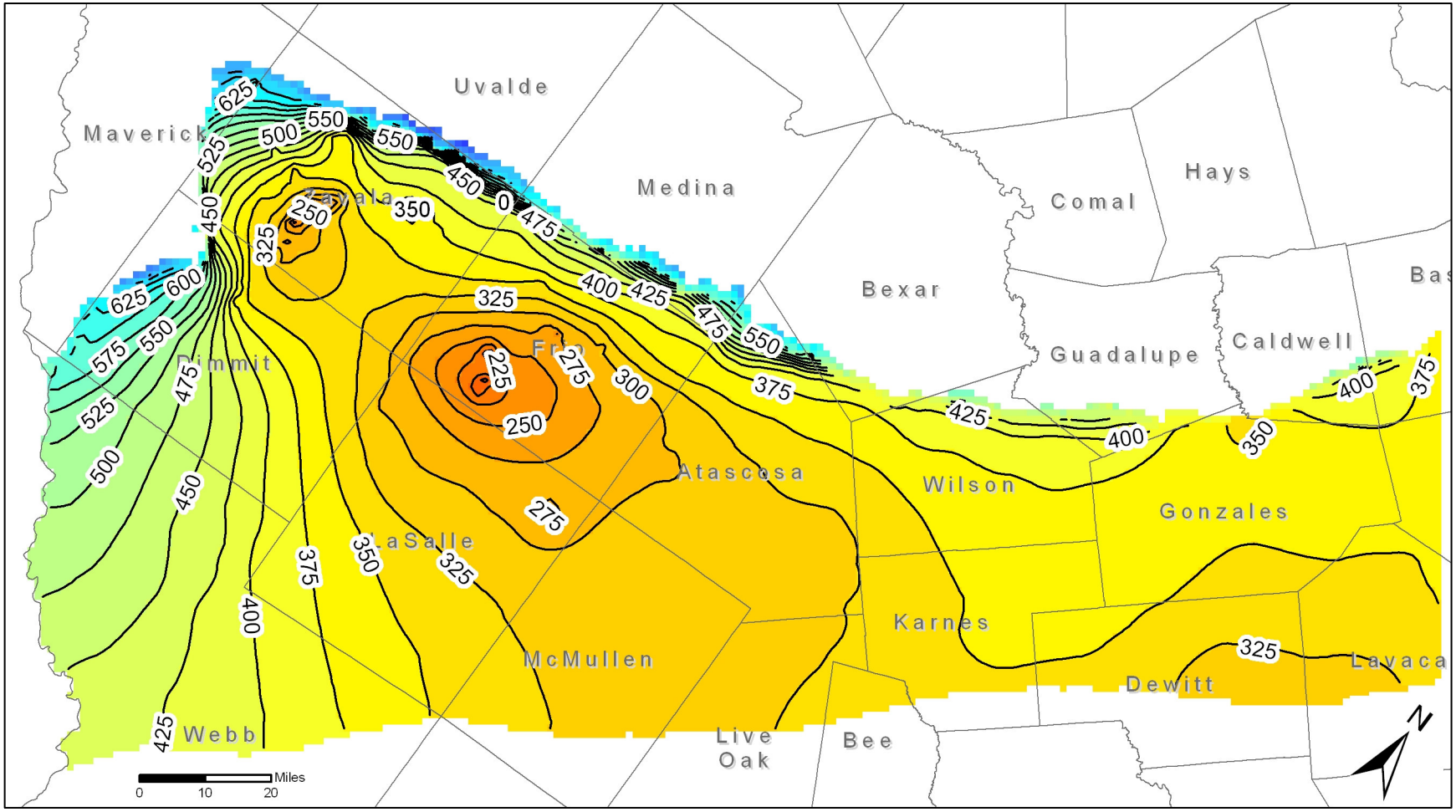

Figure 4. Initial water level elevations for the predictive model run in the Upper Wilcox Aquifer from the southern part of the Queen City, Sparta, and Carrizo-Wilcox aquifers GAM. Water level elevations are in feet above mean sea level. Contour interval is 25 feet.

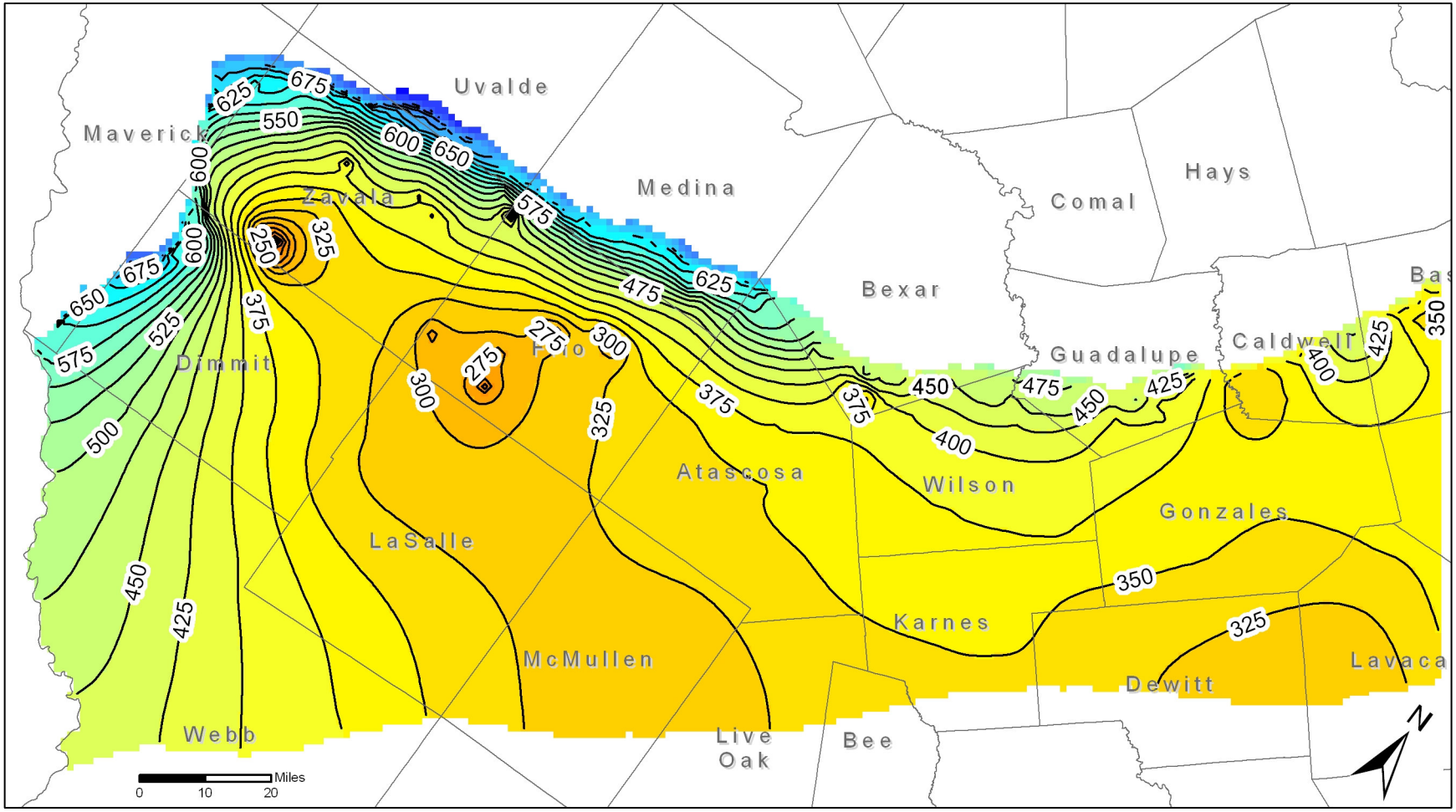

Figure 5. Initial water level elevations for the predictive model run in the Middle Wilcox Aquifer from the southern part of the Queen City, Sparta, and Carrizo-Wilcox aquifers GAM. Water level elevations are in feet above mean sea level. Contour interval is 25 feet.

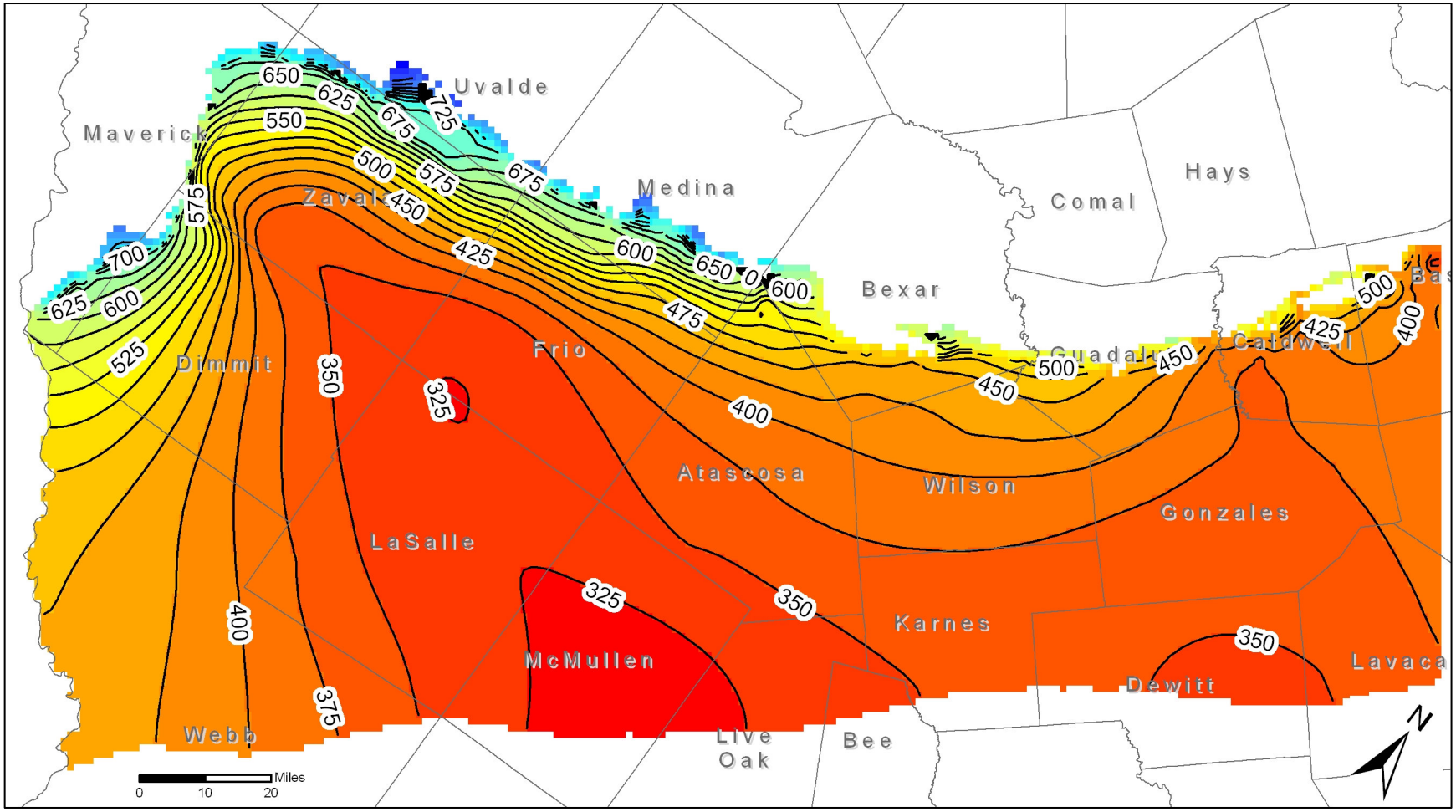

Figure 6. Initial water level elevations for the predictive model run in the Lower Wilcox Aquifer from the southern part of the Queen City, Sparta, and Carrizo-Wilcox aquifers GAM. Water level elevations are in feet above mean sea level. Contour interval is 25 feet.

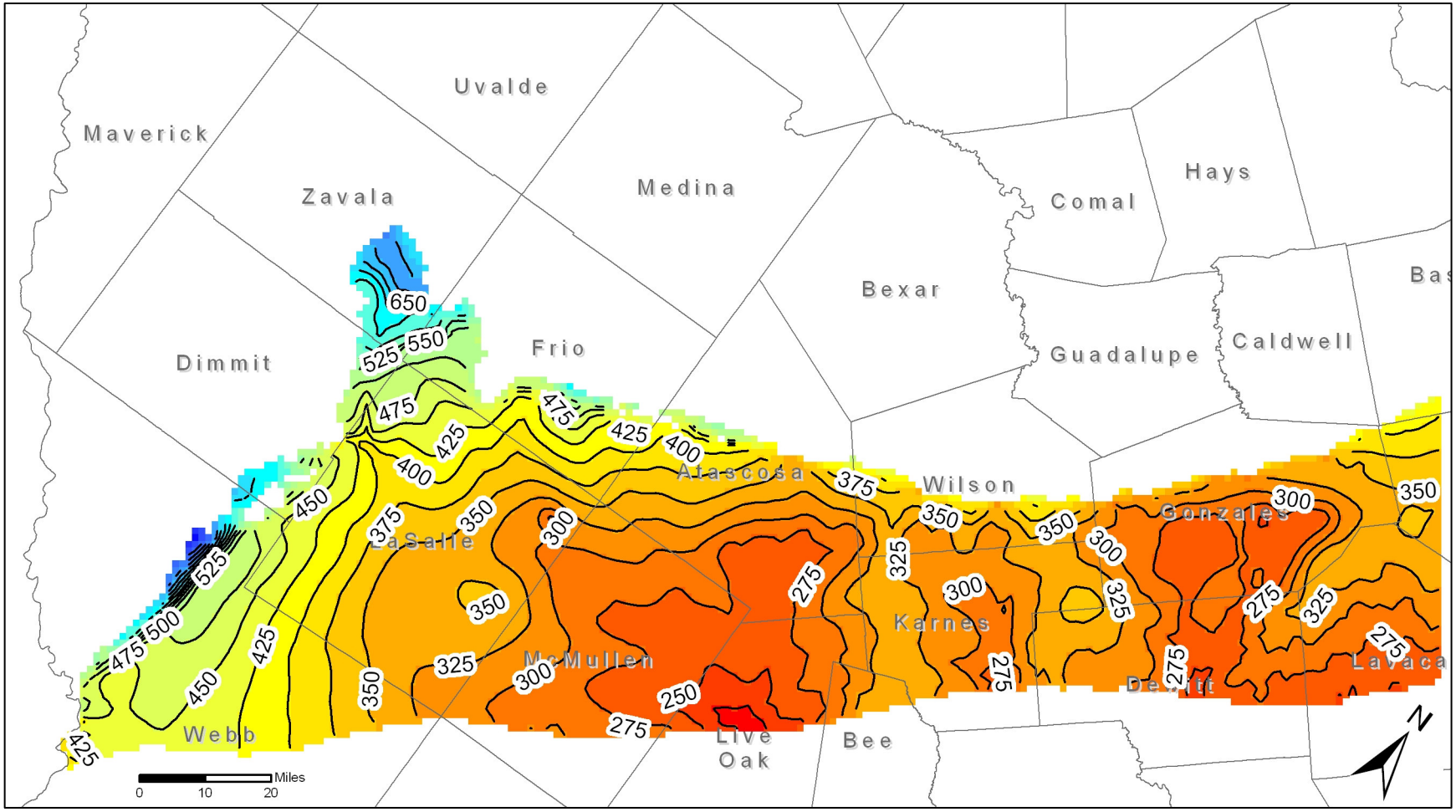

Figure 7. Water level elevations after 60 years using 1999 pumpage in the Sparta Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 25 feet.

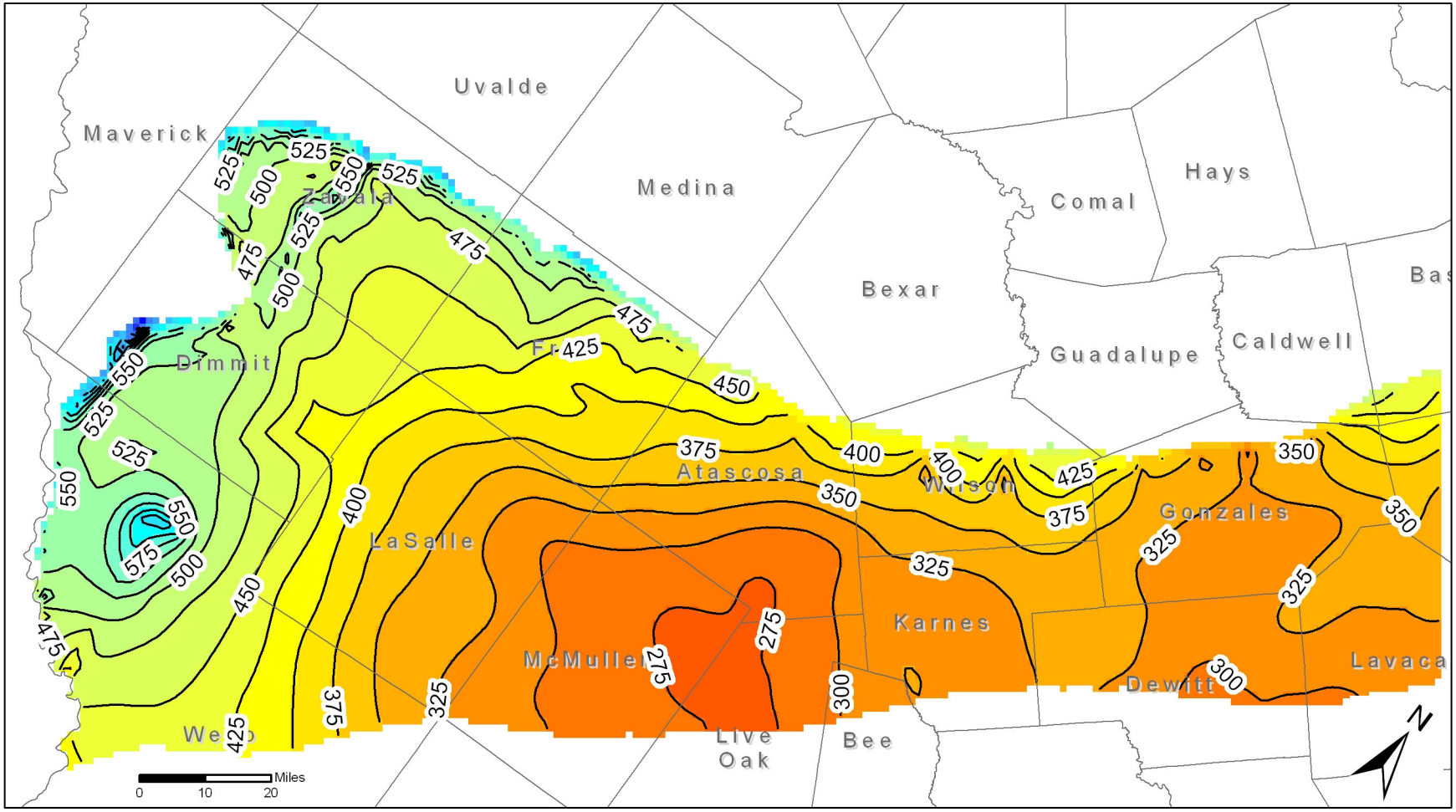

Figure 8. Water level elevations after 60 years using 1999 pumpage in the Queen City Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 25 feet.

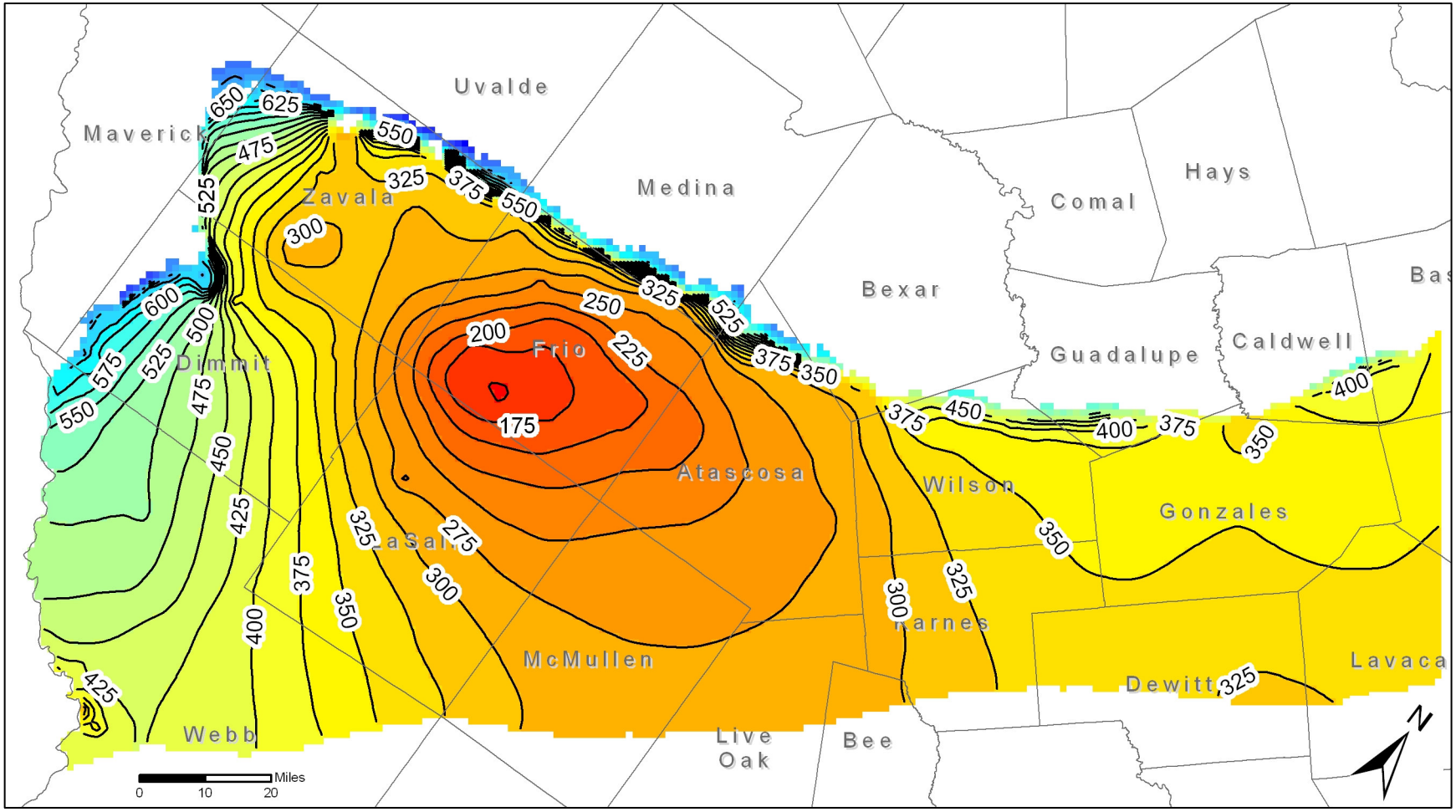

Figure 9. Water level elevations after 60 years using 1999 pumpage in the Carrizo Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 25 feet.

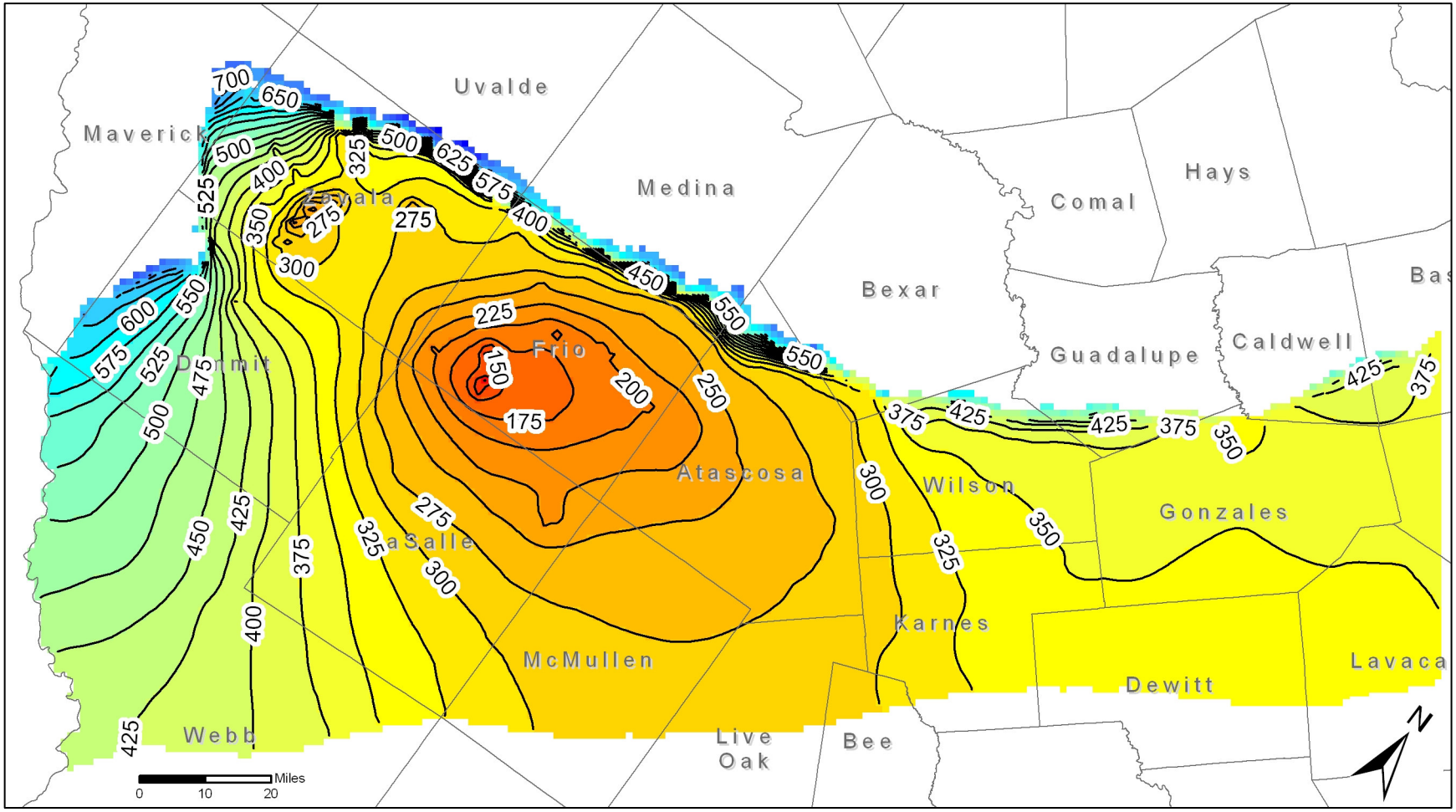

Figure 10. Water level elevations after 60 years using 1999 pumpage in the Upper Wilcox Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 25 feet.

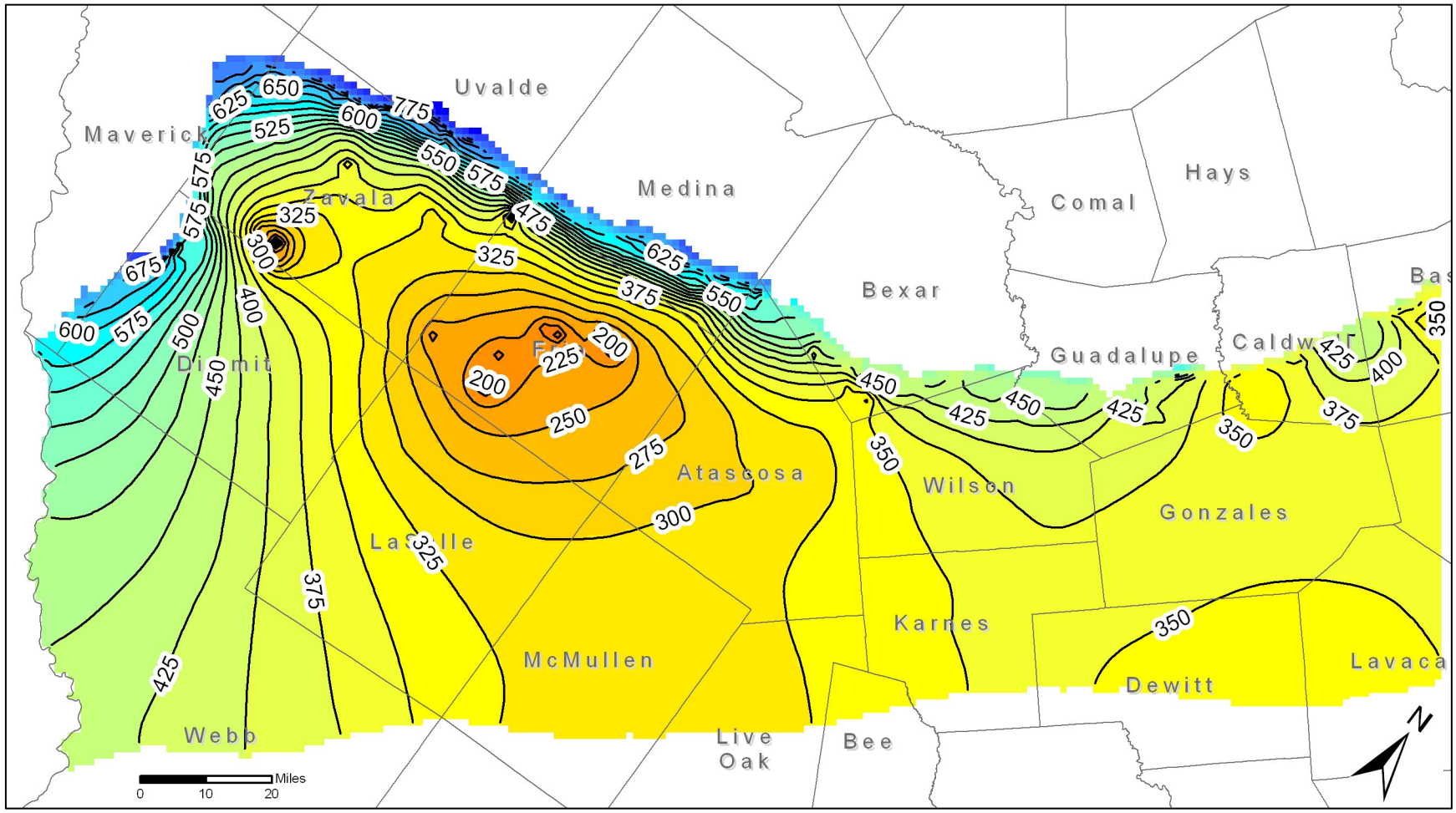

Figure 11. Water level elevations after 60 years using 1999 pumpage in the Middle Wilcox Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 25 feet.

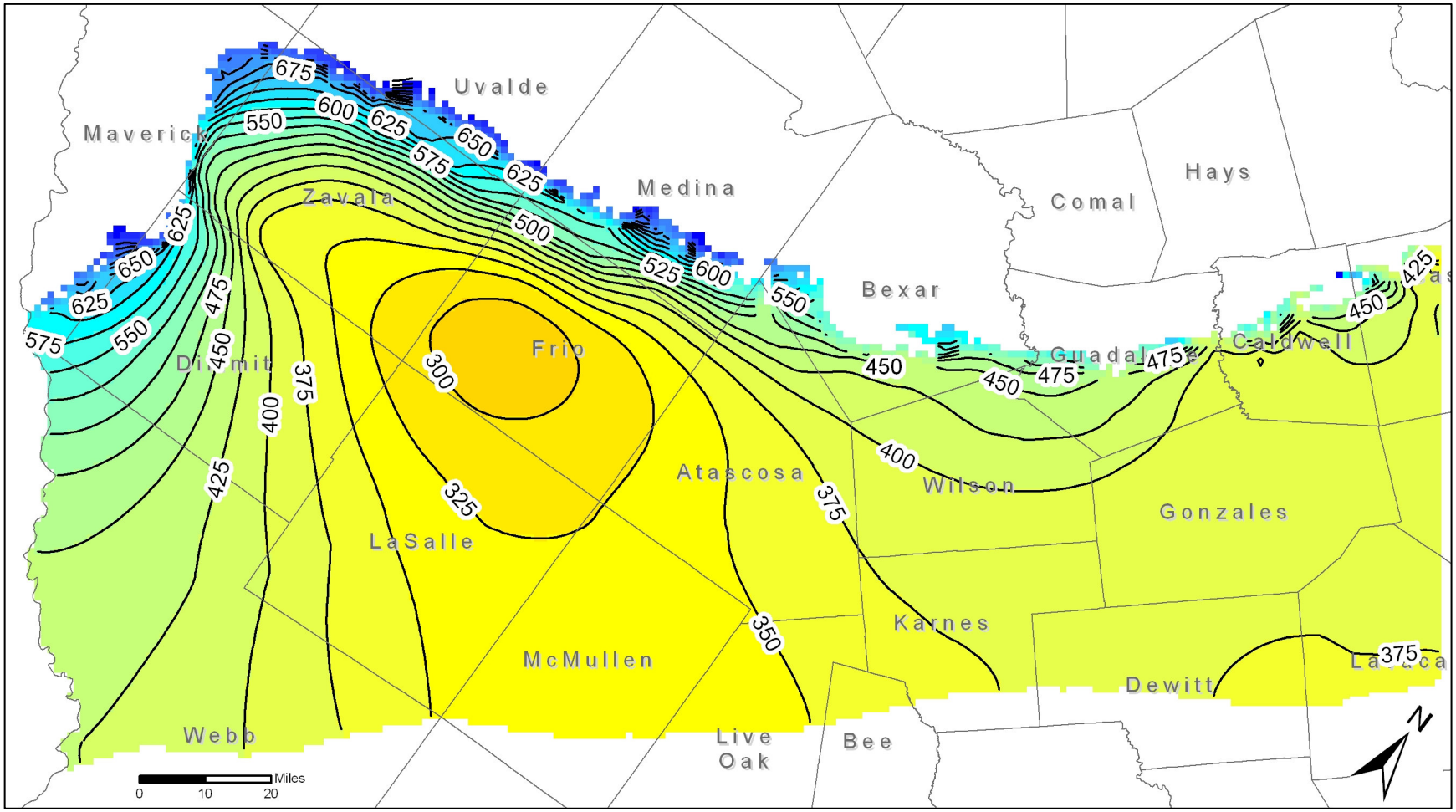

Figure 12. Water level elevations after 60 years using 1999 pumpage in the Lower Wilcox Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 25 feet.

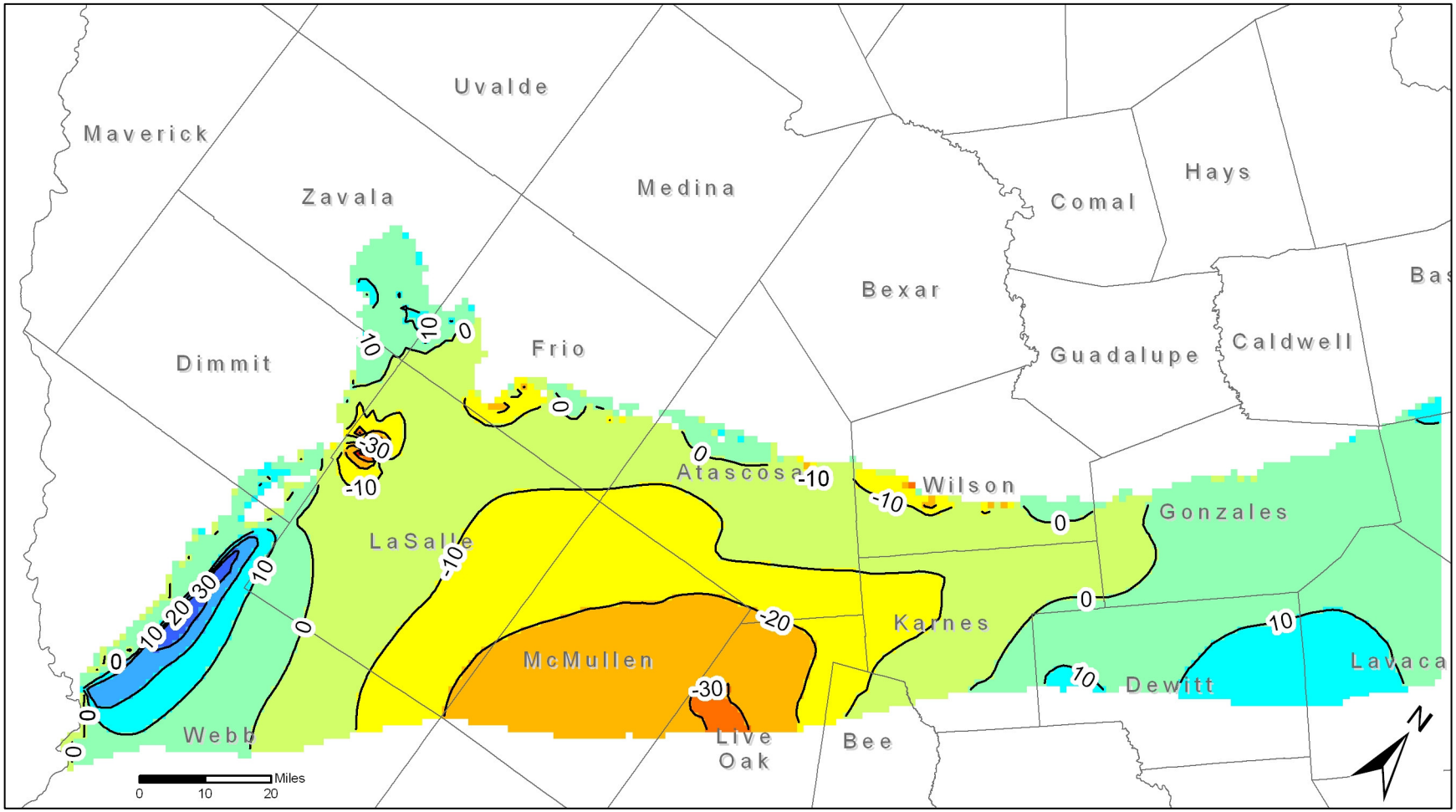

Figure 13. Water level changes after 60 years using 1999 pumpage in the Sparta Aquifer. Water level changes are in feet. Contour interval is 10 feet.

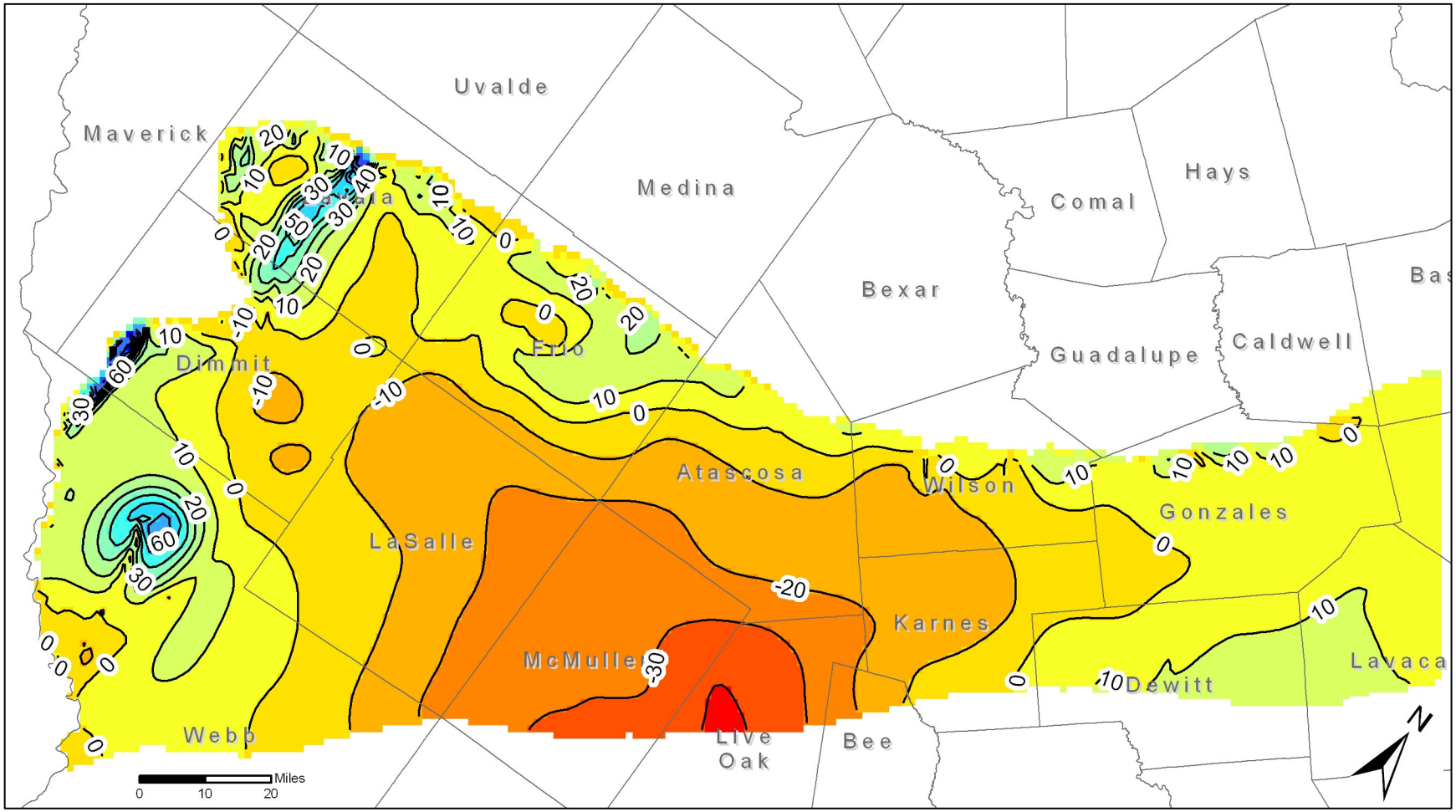

Figure 14. Water level changes after 60 years using 1999 pumpage in the Queen City Aquifer. Water level changes are in feet. Contour interval is 10 feet.

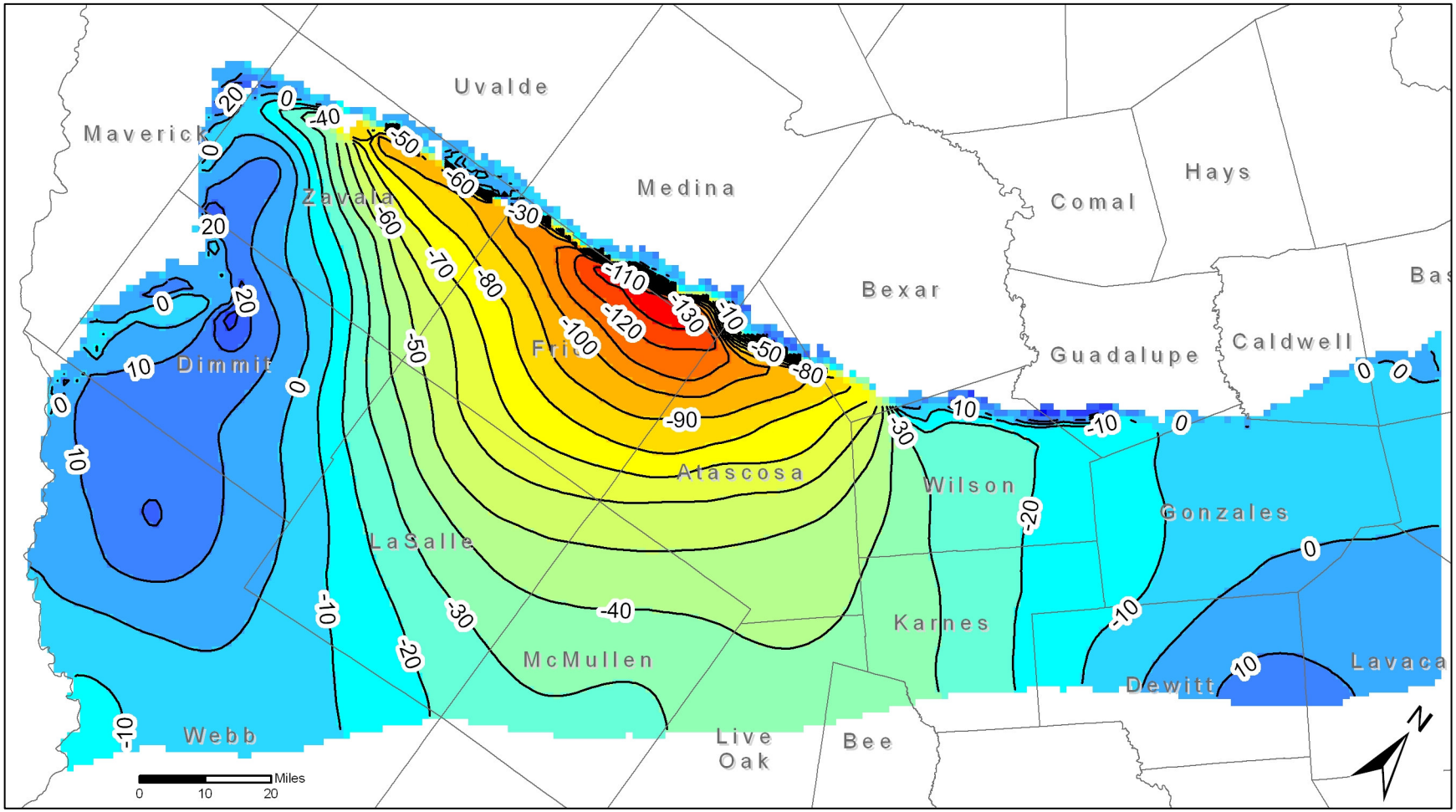

Figure 15. Water level changes after 60 years using 1999 pumpage in the Carrizo Aquifer. Water level changes are in feet. Contour interval is 10 feet.

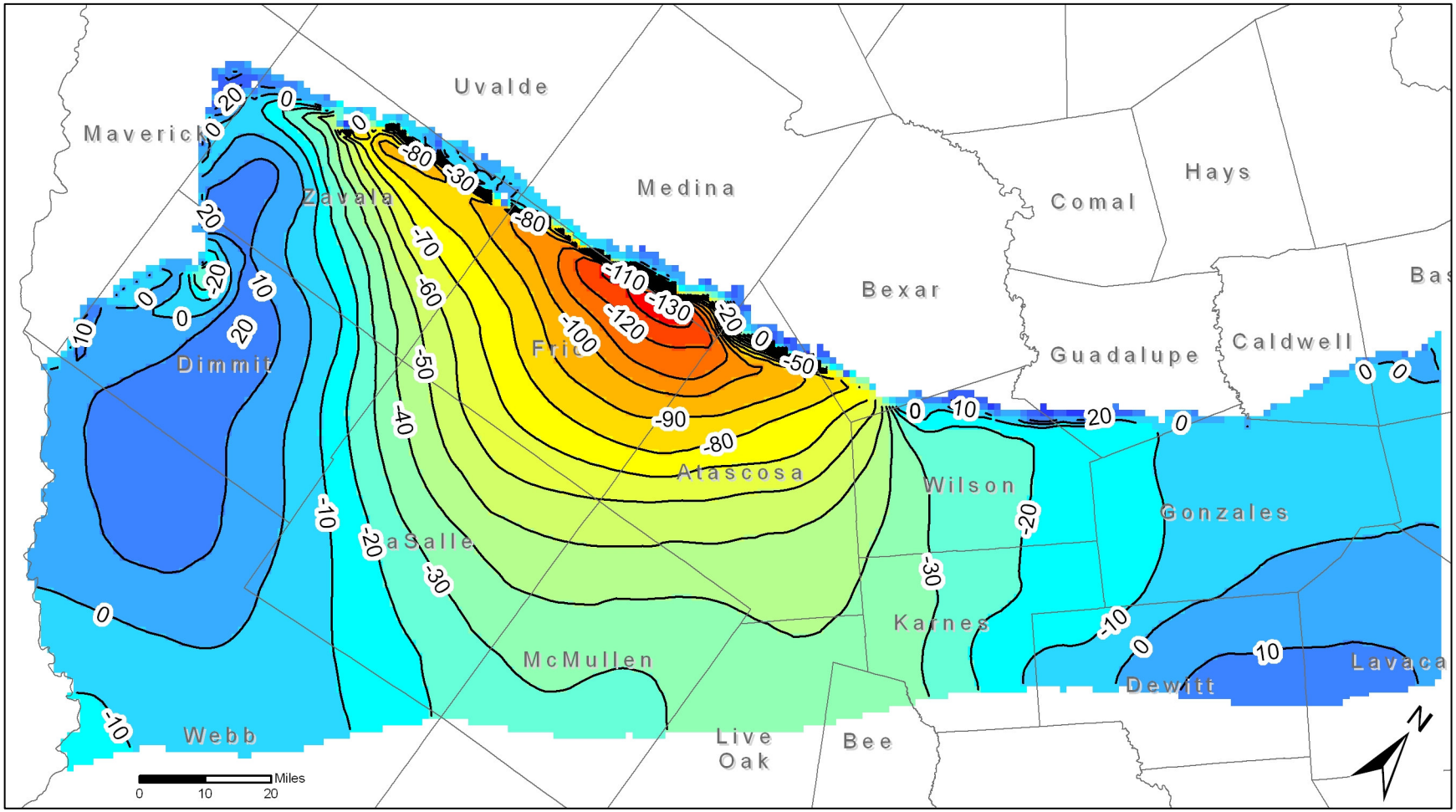

Figure 16. Water level changes after 60 years using 1999 pumpage in the Upper Wilcox Aquifer. Water level changes re in feet. Contour interval is 10 feet.

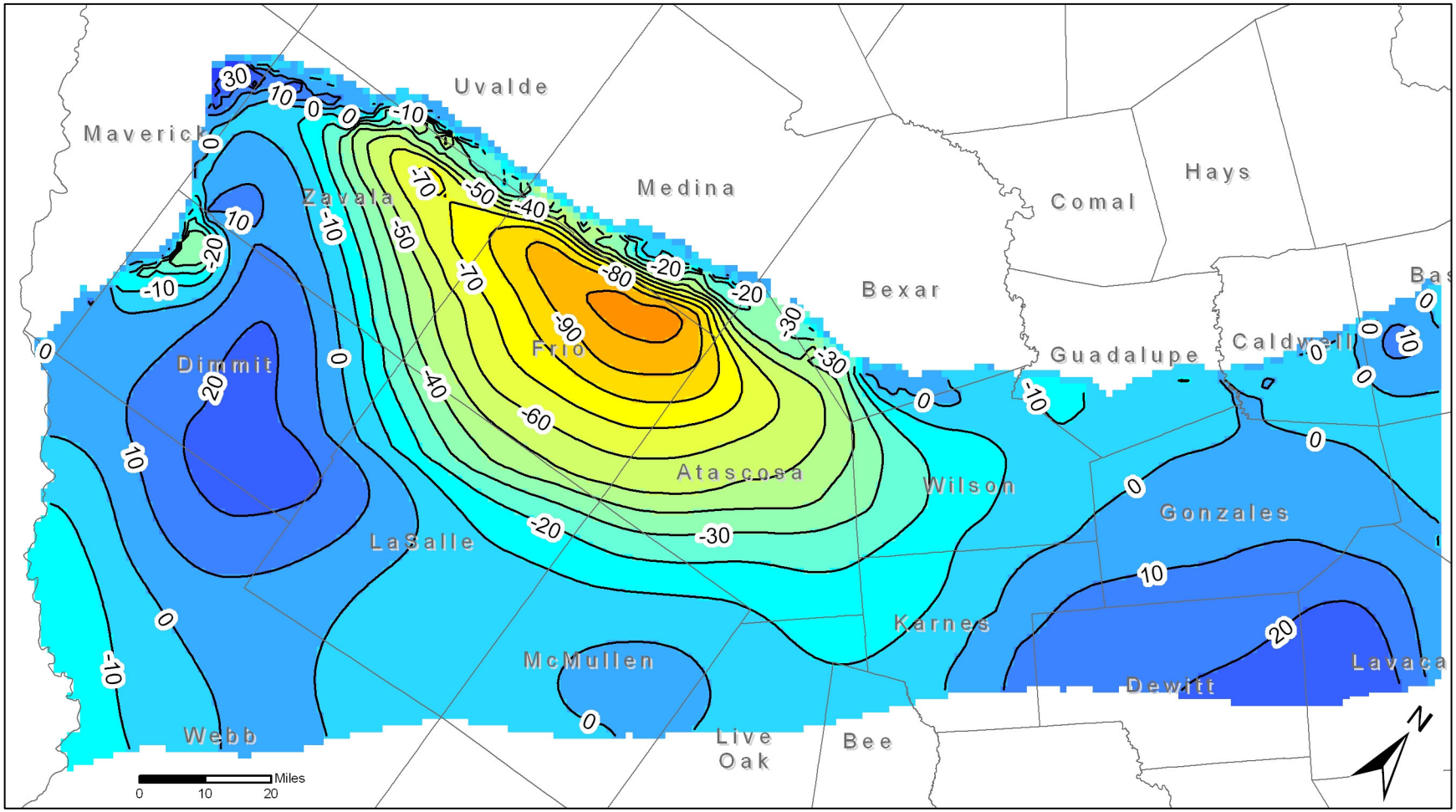

Figure 17. Water level changes after 60 years using 1999 pumpage in the Middle Wilcox Aquifer. Water level changes are in feet. Contour interval is 10 feet.

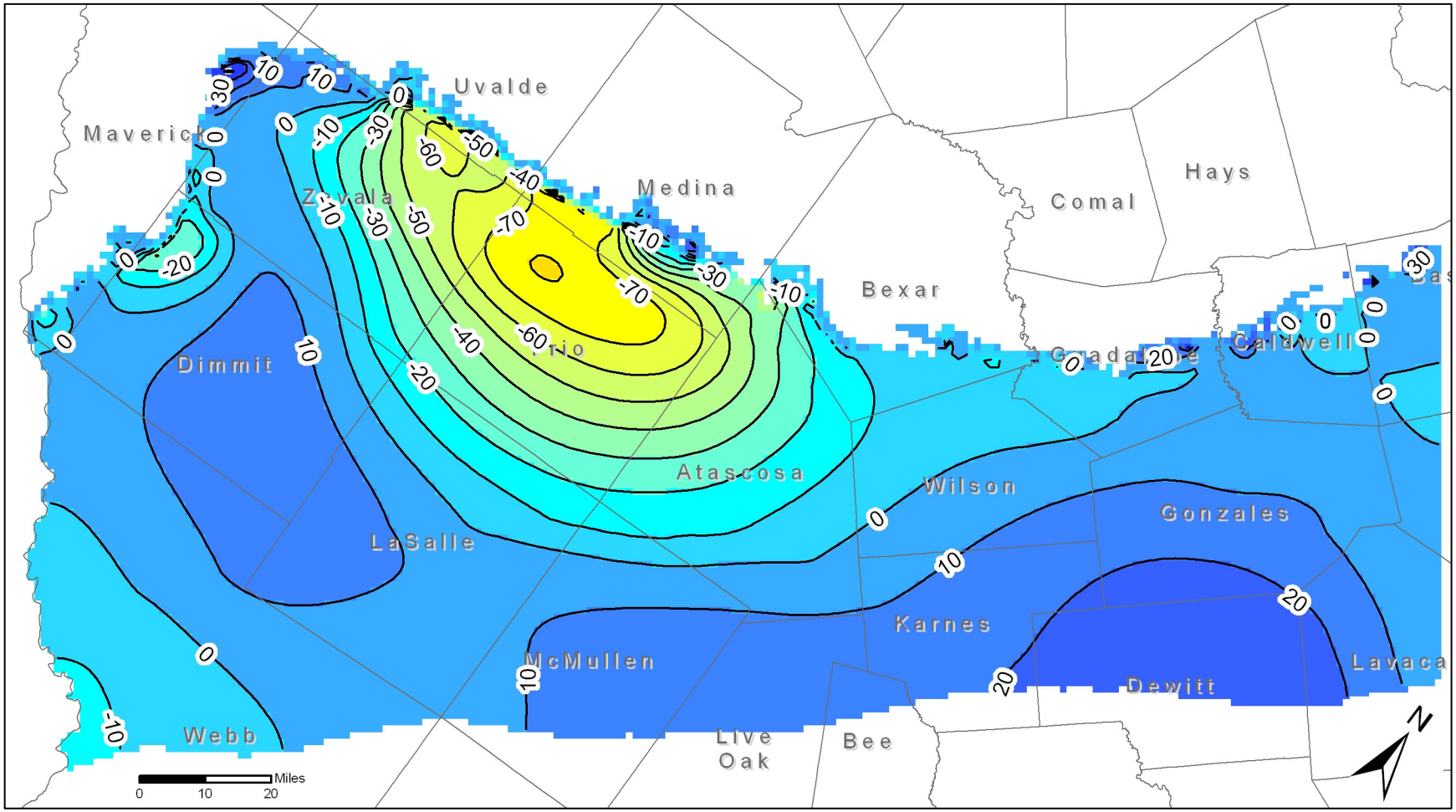

Figure 18. Water level changes after 60 years using 1999 pumpage in the Lower Wilcox Aquifer. Water level changes are in feet. Contour interval is 10 feet.

Appendix A

Summary of Historic Pumpage in the GAM for the Southern Part of the Queen City-Sparta Aquifer

Table A-1. Summary of total estimated historic pumpage included in the GAM for the southern part of the Queen City-Sparta Aquifer (in acre-feet per year).

Year	Total	Atascosa	Bastrop	Bee	Bexar	Caldwell	De Witt	Dimmit	Fayette	Frio	Gonzales	Guadalupe
1975	32,126	1,035	52	0	17	251	0	17,118	0	1,560	142	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	37,104	1,035	52	0	17	251	0	17,118	0	6,421	142	0
1979	327,407	77,597	468	60	12,234	2,865	6	22,243	81	78,047	4,526	3,861
1980	327,555	77,597	468	60	12,234	2,913	6	22,243	79	78,047	4,629	3,861
1981	281,163	52,340	498	64	12,673	2,686	5	17,409	75	78,621	4,703	4,963
1982	289,084	53,126	511	65	13,160	3,201	5	17,831	71	78,736	4,534	4,950
1983	262,702	44,371	531	68	14,065	3,235	5	16,335	65	63,486	4,039	5,037
1984	329,323	43,909	561	72	16,658	3,485	4	20,518	59	92,170	3,558	7,351
1985	259,736	40,682	561	67	14,175	3,155	3	23,385	61	51,274	3,411	4,736
1986	226,305	52,637	575	62	14,621	3,430	3	14,350	61	69,454	3,247	4,631
1987	199,251	36,222	595	63	15,103	3,338	3	9,248	64	68,002	3,615	4,476
1988	282,247	46,432	625	64	15,646	3,360	4	13,877	62	89,101	4,372	4,317
1989	325,006	61,538	687	66	14,904	3,272	4	11,041	64	98,942	4,229	5,786
1990	295,985	57,249	719	67	15,780	3,962	5	9,318	60	84,115	5,003	5,829
1991	297,715	59,575	697	66	16,012	3,094	4	6,931	60	91,869	3,935	5,677
1992	270,569	46,517	700	65	14,925	3,884	4	6,766	63	88,314	3,972	6,175
1993	274,952	54,020	714	80	16,236	3,468	2	9,152	79	100,028	3,001	5,090
1994	290,076	53,643	751	69	15,186	3,618	1	7,835	109	109,070	2,986	5,064
1995	293,281	56,239	766	73	17,250	3,613	2	9,018	102	103,886	3,268	5,320
1996	294,472	57,944	819	74	17,664	4,047	1	8,750	98	95,128	3,528	5,583
1997	228,731	46,922	782	74	16,597	3,527	1	4,977	100	61,260	3,521	5,573
1998	298,448	63,088	761	76	16,016	3,658	1	5,326	77	109,472	3,947	5,700
1999	289,087	56,491	786	77	16,871	3,766	1	4,477	81	110,157	3,397	6,073

Table A-1. (continued)

Year	Karnes	La Salle	Lavaca	Live Oak	Maverick	McMullen	Medina	Uvalde	Webb	Wilson	Zavala
1975	0	5,224	0	0	0	45	394	0	9	55	6,225
1976	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0
1978	0	5,265	0	0	0	45	394	0	9	55	6,301
1979	1,557	12,165	1	114	2,001	416	8,442	4,924	351	10,010	85,439
1980	1,557	12,165	1	114	2,001	416	8,442	4,924	351	10,010	85,439
1981	1,524	9,571	1	73	2,337	383	4,406	1,971	662	9,076	77,123
1982	1,913	9,251	1	71	2,384	1,150	4,417	1,856	677	9,492	81,683
1983	1,169	6,106	1	57	2,416	1,477	4,391	1,744	691	9,887	83,527
1984	1,020	10,886	1	56	2,070	1,544	18,690	608	427	11,062	94,616
1985	745	4,453	1	51	2,522	1,155	1,256	585	283	9,646	97,530
1986	724	4,087	1	70	1,127	1,475	1,602	445	250	9,826	43,628
1987	766	3,738	1	43	1,167	1,597	1,707	467	187	10,215	38,632
1988	832	3,928	1	57	4,697	1,779	1,667	506	235	12,149	78,535
1989	723	7,627	1	83	1,790	1,514	1,883	590	600	13,470	96,193
1990	715	7,646	1	77	5,011	1,550	1,707	587	587	15,853	80,144
1991	673	7,830	1	81	5,116	1,687	1,892	563	2,514	14,781	74,660
1992	586	9,443	1	61	5,212	1,542	1,853	558	1,077	16,835	62,015
1993	568	8,473	1	73	1,488	1,633	1,779	560	775	12,830	54,903
1994	569	7,312	1	73	1,894	1,570	6,875	568	575	14,645	57,662
1995	519	6,734	1	78	2,559	1,524	7,538	582	812	13,899	59,498
1996	481	8,945	1	80	2,658	1,517	7,604	602	910	18,343	59,694
1997	472	6,243	1	61	1,796	1,716	4,913	588	703	16,374	52,531
1998	464	10,801	1	86	3,223	1,808	4,957	591	872	17,480	50,042
1999	471	9,603	1	85	3,298	120	5,008	596	915	18,050	48,763

Table A-2. Summary of estimated historic pumpage in the Sparta Aquifer (Layer 1) included in the GAM for the southern part of the Queen City-Sparta Aquifer (in acre-feet per year).

Year	Total	Atascosa	Bastrop	Fayette	Frio	Gonzales	La Salle	Wilson
1	173	4	0	0	0	136	0	33
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	173	4	0	0	0	136	0	33
5	4,624	835	63	37	39	440	3,134	76
6	5,214	1,034	47	71	66	633	3,140	224
7	4,515	859	45	68	68	590	2,646	240
8	3,859	681	43	63	69	559	2,197	246
9	3,160	506	41	58	70	501	1,728	257
10	2,520	337	39	52	71	470	1,277	273
11	1,461	339	30	55	66	467	230	275
12	1,417	337	26	55	65	434	220	279
13	1,434	340	28	58	66	444	210	287
14	1,498	360	30	56	67	454	228	302
15	1,745	403	36	58	71	468	355	354
16	1,778	418	36	53	72	468	360	372
17	1,750	426	37	54	75	431	357	370
18	1,795	419	38	56	76	429	405	372
19	1,806	427	35	66	76	427	379	395
20	2,552	440	31	95	84	435	1,054	412
21	2,524	464	29	88	82	463	961	436
22	2,932	479	34	84	81	500	1,301	453
23	2,630	489	25	86	85	586	892	467
24	2,894	502	7	64	87	549	1,202	483
25	3,050	517	7	66	87	552	1,316	504

Table A-3. Summary of estimated historic pumpage in the Queen City Aquifer (Layer 3) included in the GAM for the southern part of the Queen City-Sparta Aquifer (in acre-feet per year).

Year	Total	Atascosa	Bastrop	Caldwell	Fayette	Frio	Gonzales	La Salle	Wilson
1975	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0
1979	6,710	4,714	92	0	39	842	794	7	222
1980	6,269	4,515	109	47	3	815	704	1	74
1981	5,266	3,594	106	51	3	850	581	1	80
1982	4,253	2,673	102	52	3	883	456	1	82
1983	3,243	1,752	98	55	3	917	330	1	86
1984	2,239	832	95	60	3	950	206	2	91
1985	1,753	764	91	59	3	538	204	1	92
1986	2,179	997	88	65	3	723	209	1	93
1987	1,844	660	93	67	3	712	211	1	96
1988	2,236	839	98	67	3	914	212	1	101
1989	2,687	1,171	101	60	3	1,018	213	2	119
1990	2,494	1,090	101	61	3	872	240	2	125
1991	2,521	1,142	104	61	4	861	223	2	124
1992	2,277	894	107	59	4	835	252	2	125
1993	2,540	1,047	108	61	8	939	242	2	133
1994	1,656	984	114	100	13	70	235	2	139
1995	1,752	1,038	113	116	10	69	257	2	147
1996	1,766	1,065	126	120	10	61	229	2	152
1997	1,516	850	106	110	11	63	218	2	157
1998	1,627	951	83	103	11	68	246	2	163
1999	1,675	964	88	132	12	66	240	2	170

Table A-4. Summary of estimated historic pumpage in the Carrizo Aquifer (Layer 5) included in the GAM for the southern part of the Queen City-Sparta Aquifer (in acre-feet per year).

Year	Total	Atascosa	Bastrop	Bee	Bexar	Caldwell	De Witt	Dimmit	Fayette	Frio	Gonzales	Guadalupe
1975	13,166	1,029	0	0	0	0	0	5,884	0	1,499	6	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	18,143	1,029	0	0	0	0	0	5,884	0	6,360	6	0
1979	238,519	68,925	54	15	3,169	208	6	10,326	5	70,119	3,225	334
1980	238,519	68,925	54	15	3,169	208	6	10,326	5	70,119	3,225	334
1981	204,121	45,017	58	16	3,117	223	5	8,139	4	70,539	3,458	378
1982	211,382	46,942	61	16	3,212	230	5	8,347	4	70,681	3,443	392
1983	189,231	40,066	64	17	3,430	242	5	7,743	4	56,799	3,131	418
1984	233,292	40,542	70	18	3,688	263	4	9,513	3	82,735	2,807	462
1985	186,661	37,601	70	17	3,321	252	3	10,702	3	46,101	2,668	451
1986	170,373	48,676	73	16	3,406	273	3	6,846	3	62,339	2,534	469
1987	148,914	33,573	75	16	3,482	282	3	4,698	3	61,014	2,887	479
1988	213,320	43,081	79	16	3,647	285	4	6,763	3	80,021	3,627	499
1989	250,207	57,439	85	17	3,521	253	4	5,589	3	88,781	3,471	572
1990	224,326	52,837	90	17	3,805	279	5	4,940	3	75,523	4,209	563
1991	228,782	54,973	83	16	3,748	254	4	3,958	3	82,547	3,204	563
1992	205,312	42,909	83	16	3,505	285	4	3,840	3	79,313	3,214	836
1993	213,040	50,501	86	20	3,963	264	2	4,978	5	89,861	2,265	1,080
1994	224,147	50,504	91	17	3,037	273	1	4,373	1	98,819	2,250	939
1995	224,201	52,927	93	18	3,577	269	2	4,992	3	94,089	2,482	958
1996	223,750	54,534	99	18	3,636	276	1	4,877	3	86,228	2,733	1,001
1997	170,915	44,138	95	19	3,471	257	1	3,117	3	55,531	2,651	990
1998	232,550	58,736	98	19	3,355	253	1	3,284	2	99,140	3,084	1,065
1999	223,218	52,419	100	19	3,513	279	1	2,917	2	99,802	2,538	1,224

Table A-4. (continued)

Year	Karnes	La Salle	Lavaca	Live Oak	Maverick	McMullen	Medina	Uvalde	Webb	Wilson	Zavala
1975	0	4,136	0	0	0	45	394	0	9	0	165
1976	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0
1978	0	4,176	0	0	0	45	394	0	9	0	241
1979	1,557	6,180	1	114	491	415	2,258	268	331	8,962	61,556
1980	1,557	6,180	1	114	491	415	2,258	268	331	8,962	61,556
1981	1,524	4,794	1	73	591	381	1,252	284	641	8,039	55,588
1982	1,913	4,893	1	71	591	1,149	1,254	290	655	8,402	58,832
1983	1,169	3,111	1	57	591	1,474	1,221	302	670	8,767	59,949
1984	1,020	6,620	0	56	418	1,543	4,870	321	407	9,757	68,175
1985	745	2,946	0	51	616	1,154	413	302	266	8,508	70,470
1986	724	2,763	0	70	15	1,475	534	262	234	8,669	30,988
1987	766	2,550	0	43	14	1,593	559	282	170	9,017	27,406
1988	832	2,675	0	57	1,515	1,774	585	272	217	10,783	56,585
1989	723	5,103	0	83	186	1,514	661	313	578	11,984	69,328
1990	715	4,933	0	77	1,518	1,549	590	324	566	14,124	57,659
1991	673	5,084	1	81	1,562	1,686	651	311	2,488	13,129	53,763
1992	586	6,076	1	61	1,617	1,542	635	315	1,062	15,017	44,392
1993	568	5,503	1	73	17	1,632	636	324	760	11,296	39,207
1994	569	4,344	1	73	119	1,570	1,938	328	560	12,876	41,465
1995	519	4,034	1	78	394	1,524	2,097	335	794	12,161	42,854
1996	481	5,224	1	80	416	1,516	2,098	342	888	16,305	42,994
1997	472	3,714	1	61	17	1,716	1,362	347	686	14,425	37,841
1998	464	6,508	1	86	596	1,808	1,462	353	853	15,450	35,932
1999	471	5,684	1	85	596	120	1,477	358	896	15,986	34,731

Table A-5. Summary of estimated historic pumpage in the Upper Wilcox Aquifer (Layer 6) included in the GAM for the southern part of the Queen City-Sparta Aquifer (in acre-feet per year).

Year	Total	Atascosa	Bastrop	Bee	Bexar	Dimmit	Frio	Gonzales
1975	13,040	0	0	0	1	9,643	61	0
1976	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0
1978	13,040	0	0	0	1	9,643	61	0
1979	32,636	143	28	15	1	9,979	4,171	3
1980	32,636	143	28	15	1	9,979	4,171	3
1981	28,284	125	31	16	1	7,729	4,240	4
1982	29,286	124	32	16	1	7,913	4,203	4
1983	27,152	118	34	17	1	7,168	3,372	4
1984	34,478	117	37	18	1	9,177	4,981	3
1985	32,305	81	38	17	0	10,573	2,703	3
1986	19,090	51	40	16	0	6,311	3,743	2
1987	15,503	32	41	16	0	3,831	3,673	3
1988	26,546	34	43	16	0	5,967	4,793	4
1989	29,392	36	47	17	0	4,577	5,370	3
1990	25,604	33	50	17	1	3,631	4,535	4
1991	23,910	35	49	16	0	2,465	4,972	3
1992	22,064	26	49	16	0	2,440	4,798	3
1993	21,385	31	50	20	1	3,482	5,427	1
1994	21,222	31	53	17	0	2,878	5,985	1
1995	21,700	33	55	18	0	3,346	5,718	1
1996	21,803	34	58	18	0	3,231	5,193	1
1997	15,937	26	57	19	0	1,557	3,306	1
1998	20,145	36	58	19	0	1,710	6,034	1
1999	19,078	36	60	19	0	1,321	6,049	1

Table A-5. (continued)

Year	Guadalupe	La Salle	Maverick	McMullen	Medina	Webb	Wilson	Zavala
1975	0	1,089	0	0	0	0	13	2,234
1976	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0
1978	0	1,089	0	0	0	0	13	2,234
1979	0	2,844	253	1	64	16	20	15,098
1980	0	2,844	253	1	64	16	20	15,098
1981	1	2,130	302	1	31	17	18	13,640
1982	1	2,160	304	0	31	17	20	14,461
1983	1	1,266	305	2	30	17	21	14,797
1984	1	2,987	226	0	145	14	23	16,747
1985	0	1,277	317	0	5	13	20	17,257
1986	0	1,102	40	0	7	13	20	7,743
1987	0	977	42	4	8	14	22	6,841
1988	0	1,025	738	5	7	15	26	13,873
1989	0	2,168	129	0	8	17	26	16,993
1990	1	2,352	770	0	7	17	37	14,150
1991	0	2,386	740	0	8	20	34	13,181
1992	1	2,960	766	0	8	10	41	10,945
1993	0	2,590	1	0	7	10	27	9,737
1994	0	1,912	49	0	48	11	32	10,203
1995	0	1,737	181	0	53	13	29	10,516
1996	0	2,418	191	0	54	16	42	10,545
1997	0	1,635	1	0	32	11	36	9,255
1998	0	3,088	276	0	31	13	39	8,837
1999	0	2,602	276	0	31	13	40	8,629

Table A-6. Summary of estimated historic pumpage in the Middle Wilcox Aquifer (Layer 7) included in the GAM for the southern part of the Queen City-Sparta Aquifer (in acre-feet per year).

Year	Total	Atascosa	Bastrop	Bee	Bexar	Caldwell	Dimmit	Frio
1975	5,721	0	52	0	0	251	1,592	0
1976	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0
1978	5,721	0	52	0	0	251	1,592	0
1979	22,275	668	141	15	4,280	908	1,736	2,829
1980	22,275	668	141	15	4,280	908	1,736	2,829
1981	21,852	539	157	16	5,134	902	1,373	2,877
1982	22,751	531	166	16	5,377	1,017	1,401	2,852
1983	22,976	411	178	17	5,868	1,045	1,268	2,290
1984	28,009	432	195	18	6,558	1,129	1,634	3,378
1985	24,015	397	202	17	6,122	1,040	1,894	1,835
1986	19,939	521	212	16	6,306	1,123	1,060	2,542
1987	19,247	347	218	16	6,660	1,122	621	2,495
1988	24,393	442	229	16	6,843	1,132	1,013	3,253
1989	26,217	558	254	17	6,444	1,070	768	3,642
1990	25,008	592	270	17	6,592	1,240	650	3,064
1991	24,599	620	248	16	6,894	1,030	432	3,360
1992	23,255	484	247	16	6,442	1,233	419	3,242
1993	22,951	484	254	20	6,871	1,116	606	3,668
1994	22,532	454	270	17	5,415	1,149	500	4,048
1995	24,097	481	279	18	6,626	1,128	588	3,867
1996	24,299	496	293	18	6,720	1,269	557	3,511
1997	21,119	401	292	19	6,380	1,103	250	2,239
1998	23,230	633	300	19	6,232	1,116	273	4,079
1999	23,947	598	309	19	6,633	1,169	189	4,089

Table A-6. (continued)

Year	Gonzales	Guadalupe	Maverick	Medina	Uvalde	Webb	Wilson	Zavala
1975	0	0	0	0	0	0	0	3,826
1976	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	3,826
1979	64	1,754	407	1,085	238	4	380	7,766
1980	64	1,754	407	1,085	238	4	380	7,766
1981	70	2,092	463	696	159	4	369	6,999
1982	72	2,135	481	703	160	4	389	7,445
1983	73	2,238	493	707	161	4	404	7,820
1984	71	2,778	475	2,129	142	4	456	8,609
1985	70	2,293	514	400	140	3	410	8,678
1986	68	2,334	389	444	92	3	417	4,412
1987	70	2,339	409	460	94	2	435	3,959
1988	74	2,381	741	456	119	3	501	7,189
1989	74	2,868	533	534	141	4	533	8,778
1990	82	2,843	865	534	134	4	644	7,478
1991	73	2,820	895	546	127	5	614	6,918
1992	74	2,833	895	544	119	4	684	6,020
1993	65	2,678	548	579	116	5	563	5,377
1994	64	2,742	633	1,089	119	4	649	5,378
1995	64	2,911	706	1,177	122	5	631	5,492
1996	65	3,024	733	1,199	124	5	765	5,520
1997	64	3,044	672	936	120	5	721	4,872
1998	66	3,097	827	955	120	5	754	4,754
1999	66	3,240	856	980	120	6	772	4,901

Table A-7. Summary of estimated historic pumpage in the Lower Wilcox Aquifer (Layer 8) included in the GAM for the southern part of the Queen City-Sparta Aquifer (in acre-feet per year).

Year	Total	Atascosa	Bastrop	Bee	Bexar	Caldwell	Dimmit	Frio	Guadalupe	Maverick	Medina	Uvalde	Webb	Wilson	Zavala
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	22,643	2,311	90	15	4,784	1,749	202	47	1,772	850	5,035	4,418	1	350	1,020
1980	22,643	2,311	90	15	4,784	1,749	202	47	1,772	850	5,035	4,418	1	350	1,020
1981	17,125	2,207	101	16	4,421	1,510	168	47	2,492	981	2,428	1,528	1	329	896
1982	17,553	2,174	107	16	4,570	1,902	170	47	2,423	1,008	2,430	1,405	1	354	945
1983	16,940	1,519	114	17	4,767	1,893	157	38	2,380	1,026	2,433	1,281	1	354	961
1984	28,785	1,648	125	18	6,411	2,034	195	55	4,110	952	11,546	145	1	461	1,085
1985	13,540	1,501	129	17	4,732	1,804	216	30	1,992	1,075	437	142	1	341	1,124
1986	13,308	2,056	136	16	4,909	1,968	133	42	1,828	682	616	90	0	347	485
1987	12,309	1,269	140	16	4,961	1,867	99	41	1,658	702	681	91	0	359	426
1988	14,254	1,676	146	16	5,156	1,875	134	53	1,436	1,702	619	116	0	436	887
1989	14,758	1,931	163	17	4,938	1,888	107	60	2,346	942	681	135	1	454	1,095
1990	16,773	2,279	172	17	5,382	2,380	97	48	2,423	1,857	577	130	1	552	858
1991	16,154	2,380	177	16	5,369	1,750	76	53	2,293	1,919	687	125	1	509	798
1992	15,866	1,786	176	16	4,977	2,306	68	51	2,506	1,934	666	124	1	595	659
1993	13,230	1,530	181	20	5,401	2,026	86	57	1,331	922	557	119	1	416	582
1994	17,967	1,229	192	17	6,732	2,097	84	63	1,383	1,094	3,800	121	0	536	616
1995	19,007	1,296	199	18	7,047	2,099	92	61	1,451	1,278	4,211	124	1	495	636
1996	19,921	1,336	209	18	7,307	2,382	85	55	1,558	1,318	4,253	136	1	627	636
1997	16,614	1,018	208	19	6,746	2,056	53	35	1,540	1,106	2,584	121	1	567	562
1998	18,002	2,229	215	19	6,428	2,186	59	64	1,538	1,524	2,509	118	1	592	520
1999	18,119	1,956	221	19	6,725	2,186	50	64	1,608	1,570	2,520	118	1	578	502

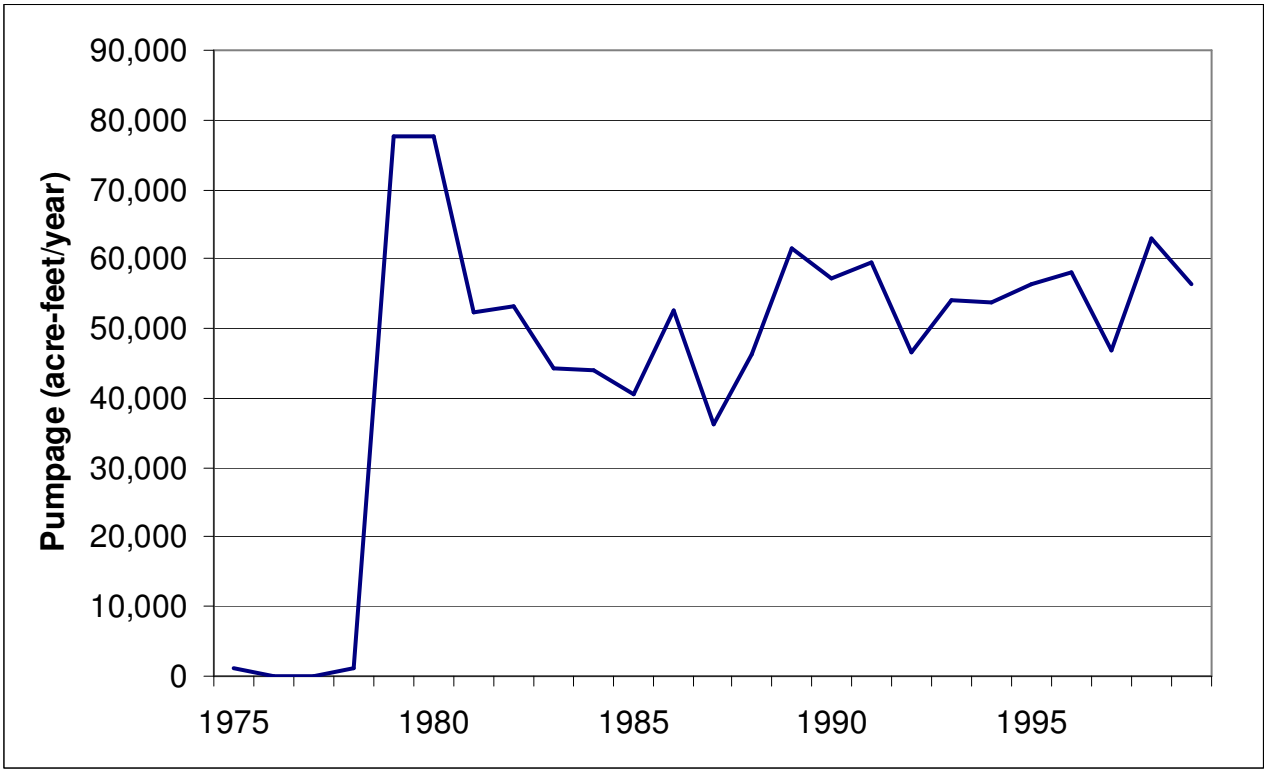

Figure A-1- Total pumpage in Atascosa County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

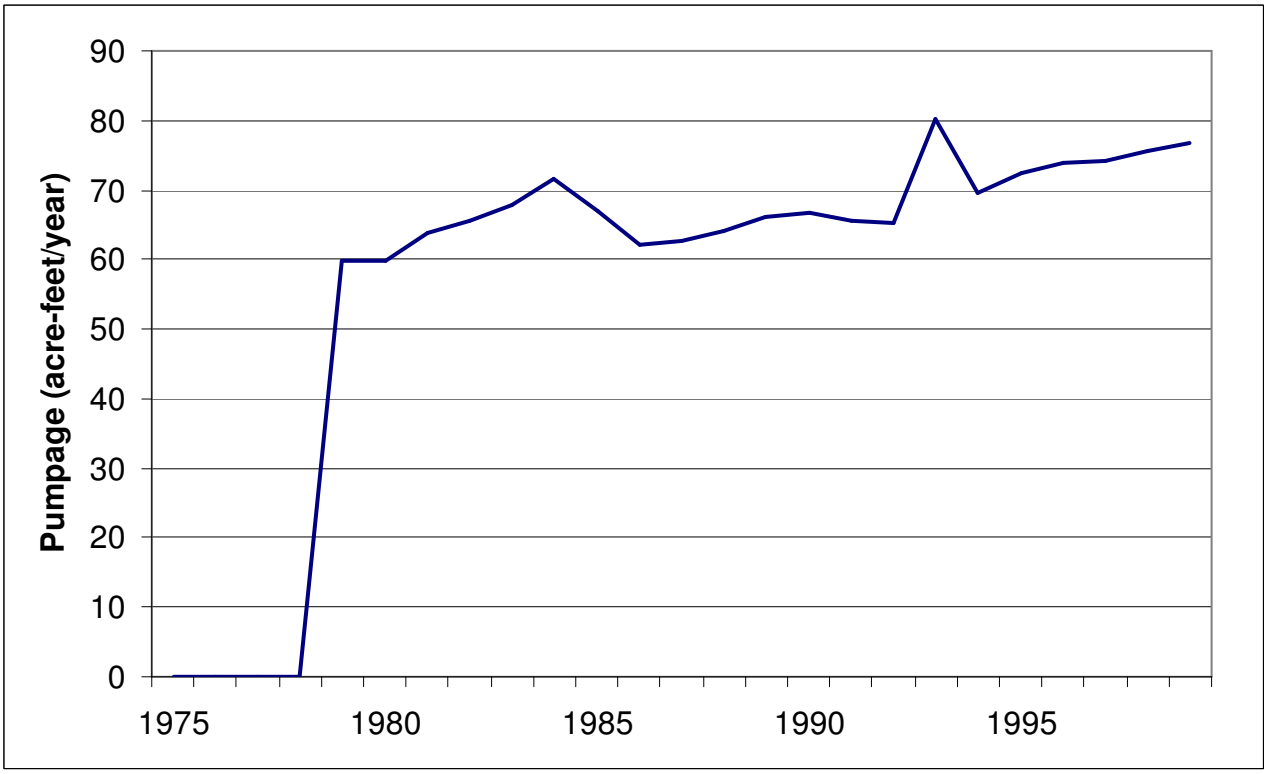

Figure A-2- Total pumpage in Bee County included in GAM for the southern part of the Queen City-Sparta Aquifer.

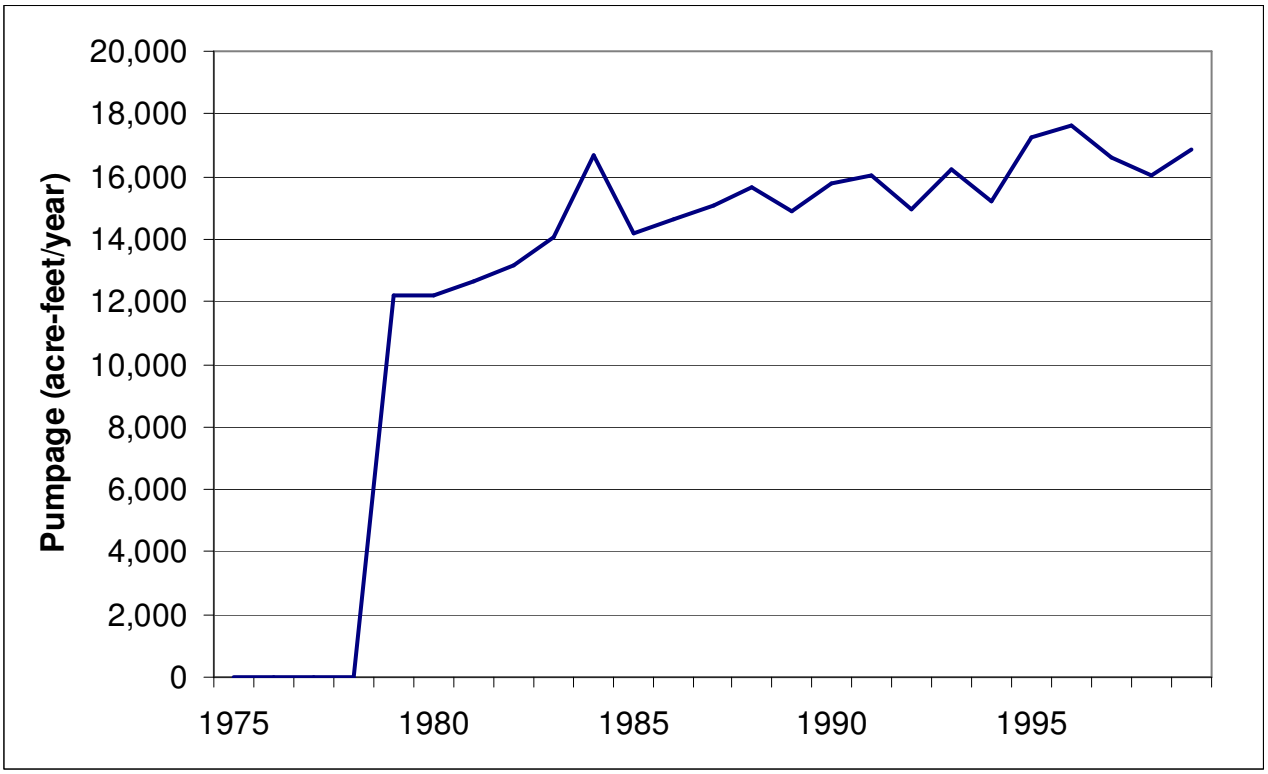

Figure A-3- Total pumpage in Bexar County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

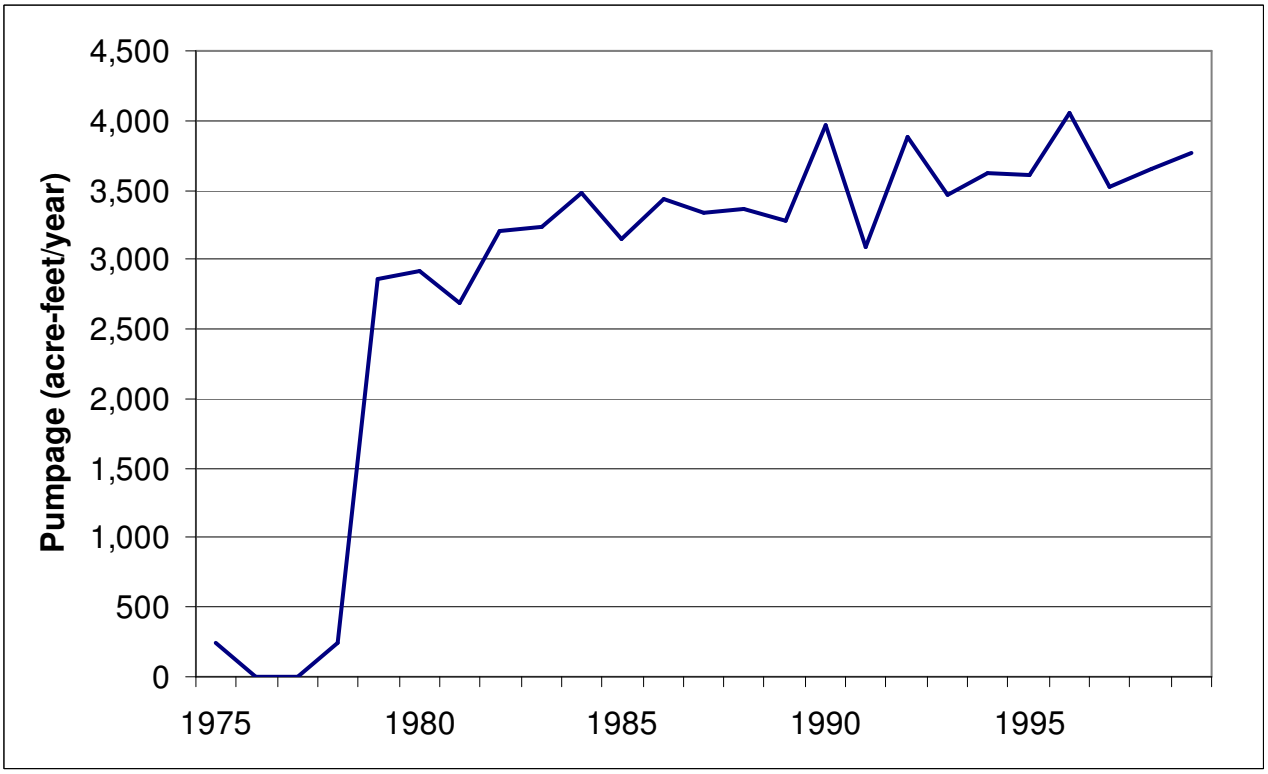

Figure A-4- Total pumpage in Caldwell County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

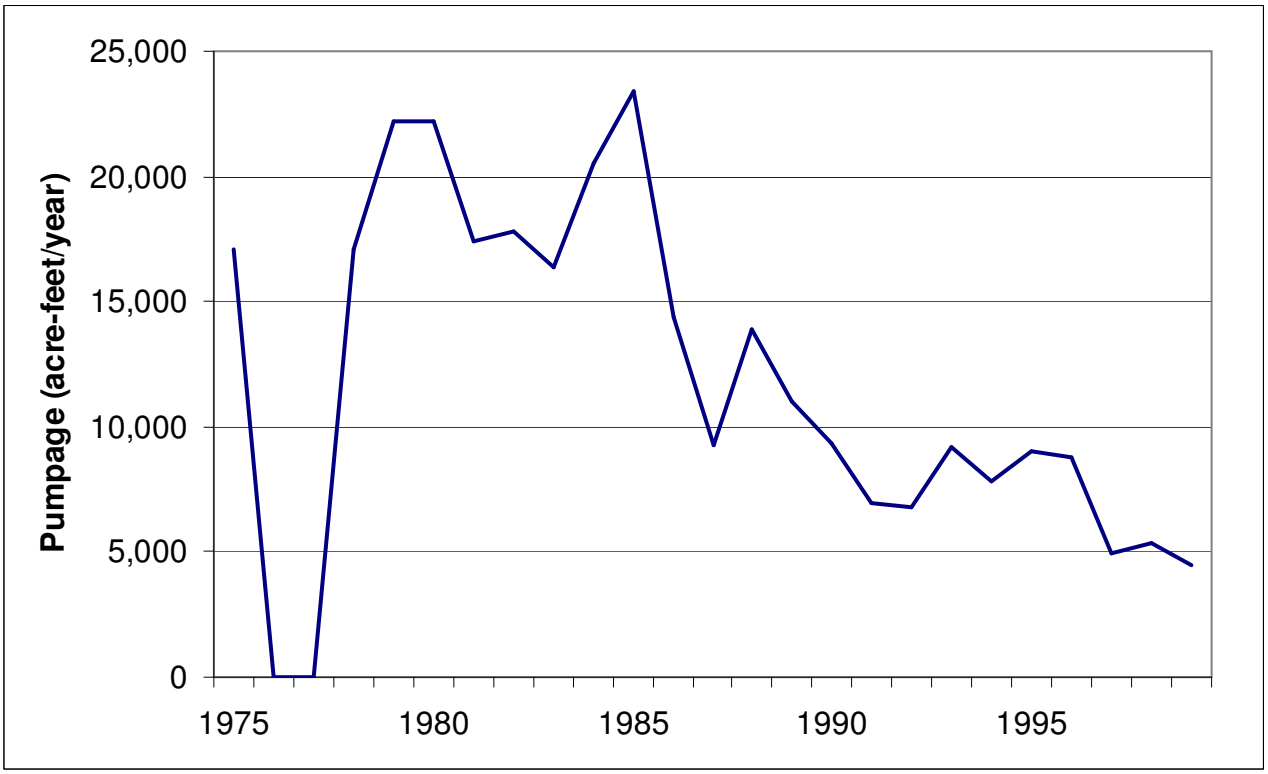

Figure A-5- Total pumpage in Dimmit County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

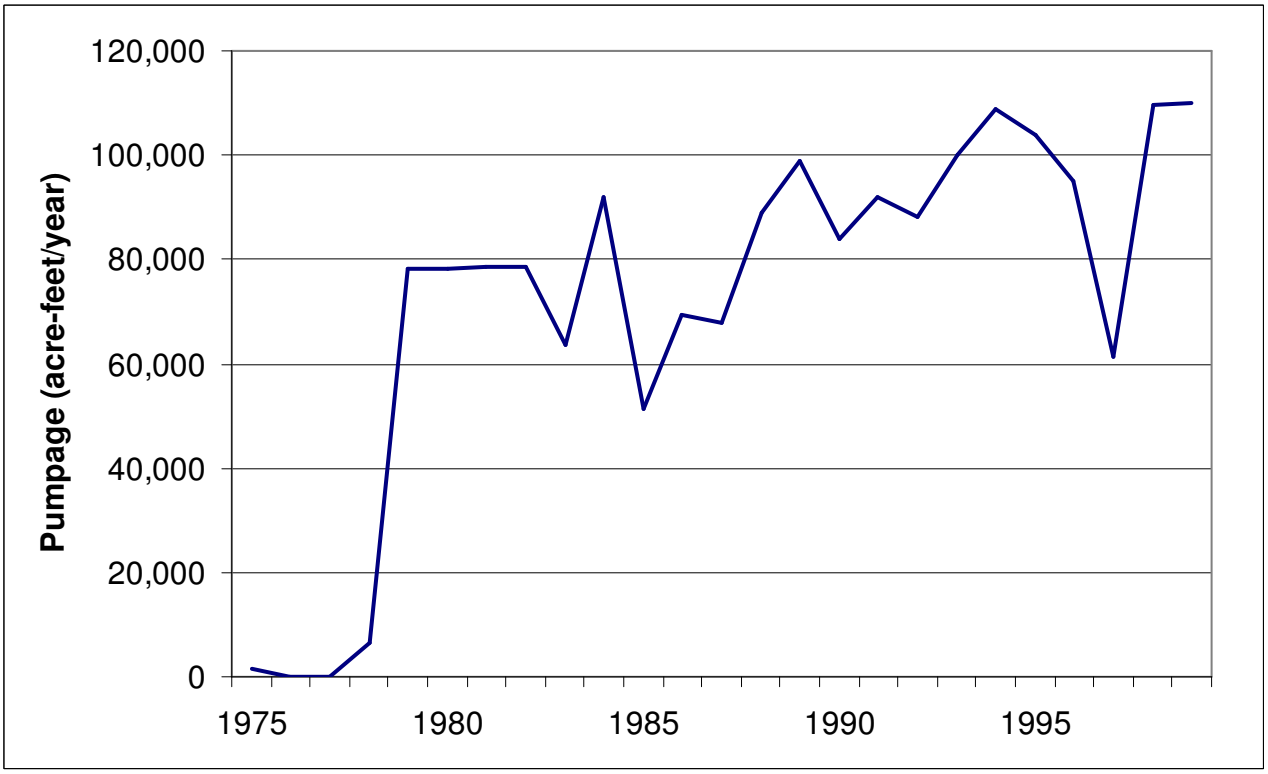

Figure A-6- Total pumpage in Frio County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

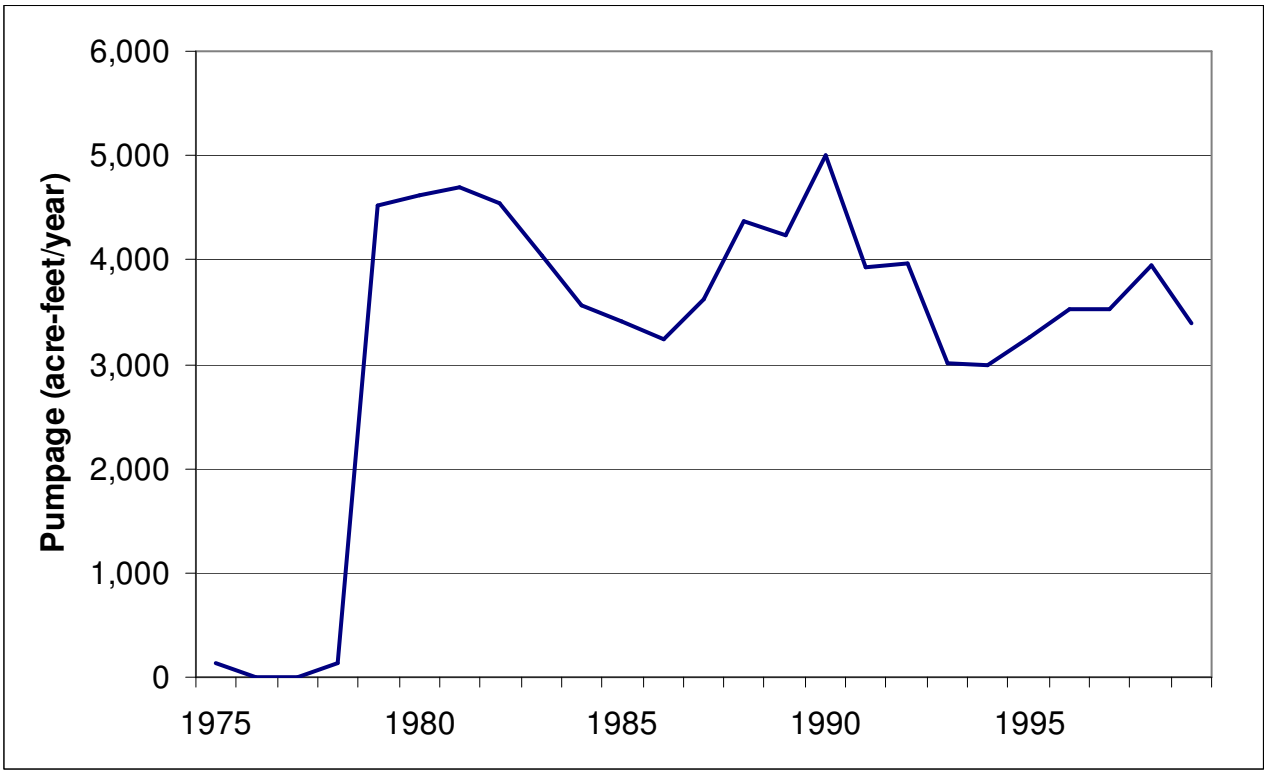

Figure A-7- Total pumpage in Gonzales County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

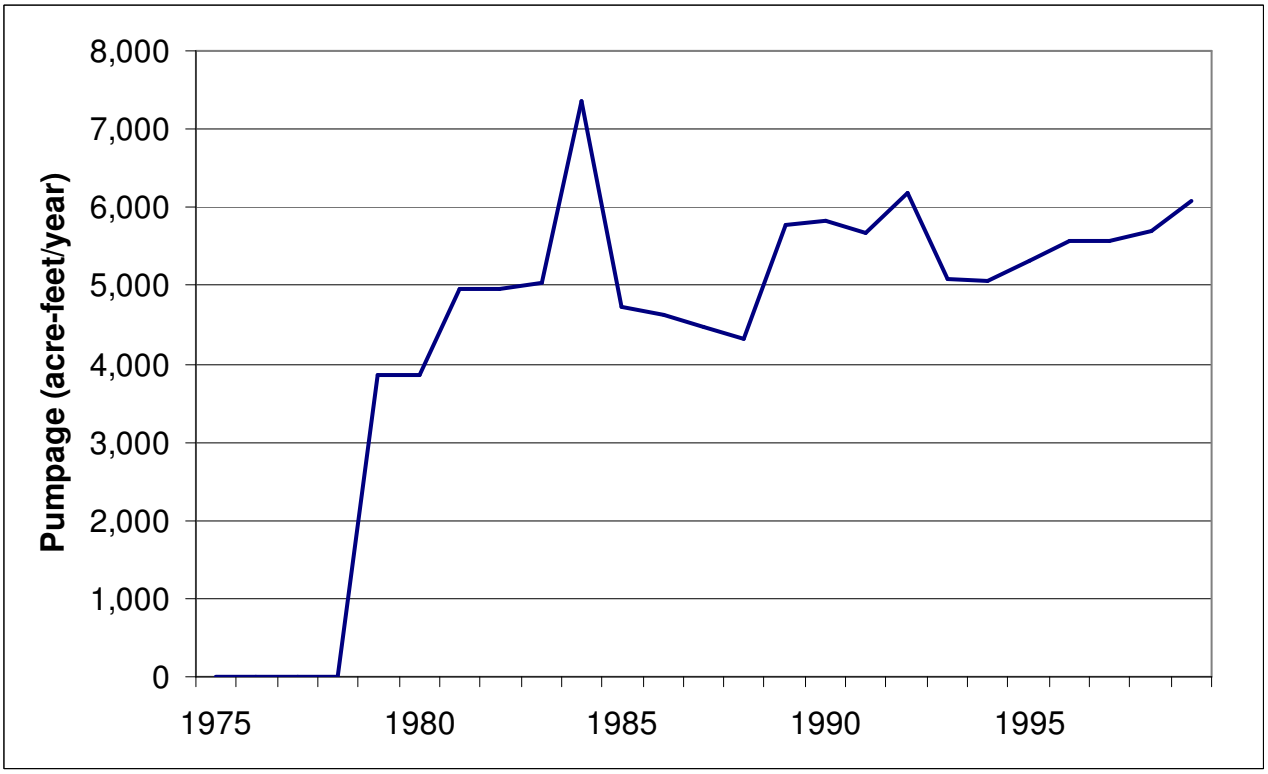

Figure A-8- Total pumpage in Guadalupe County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

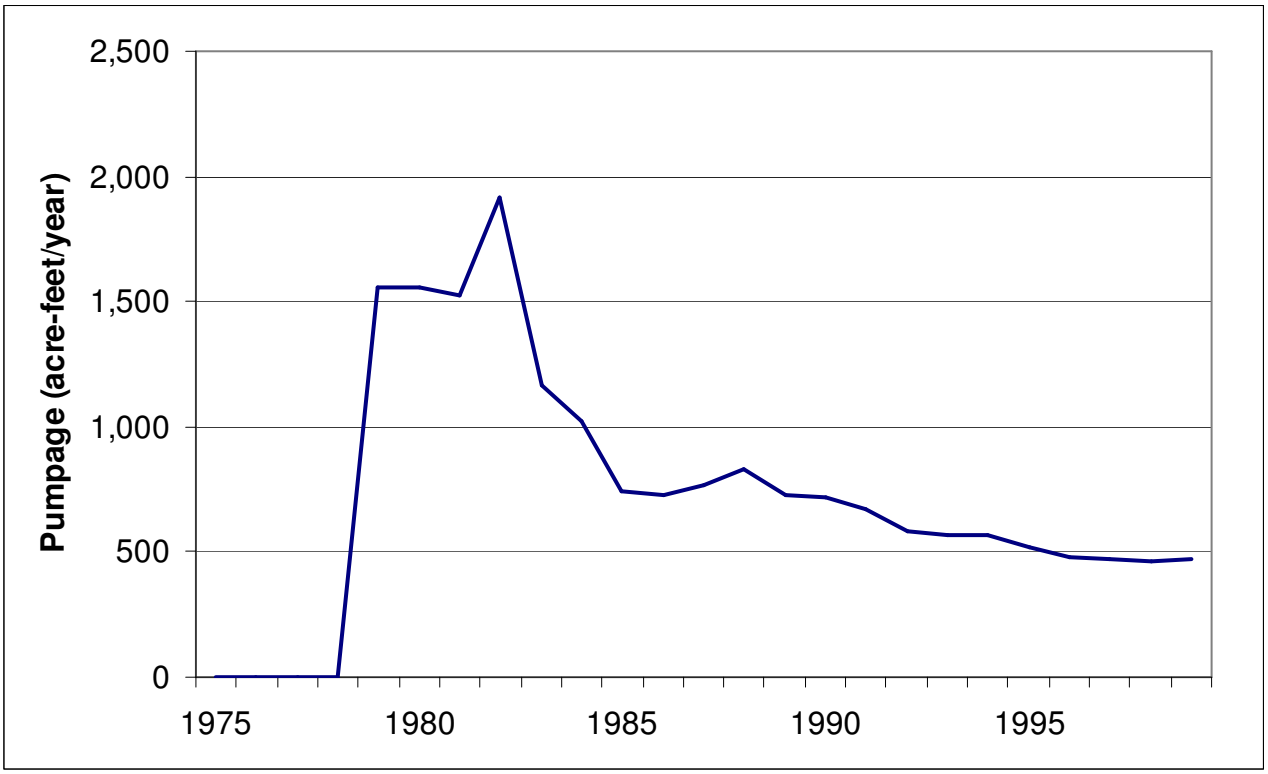

Figure A-9- Total pumpage in Karnes County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

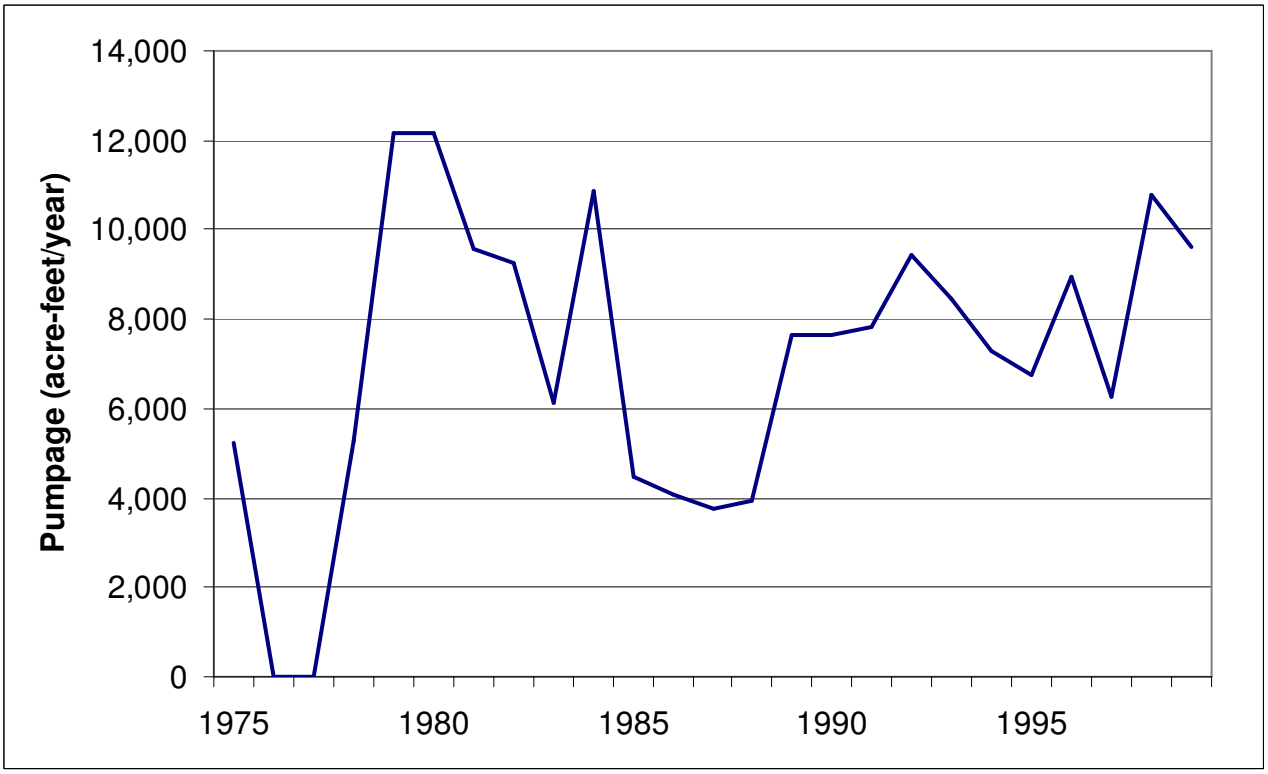

Figure A-10- Total pumpage in LaSalle County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

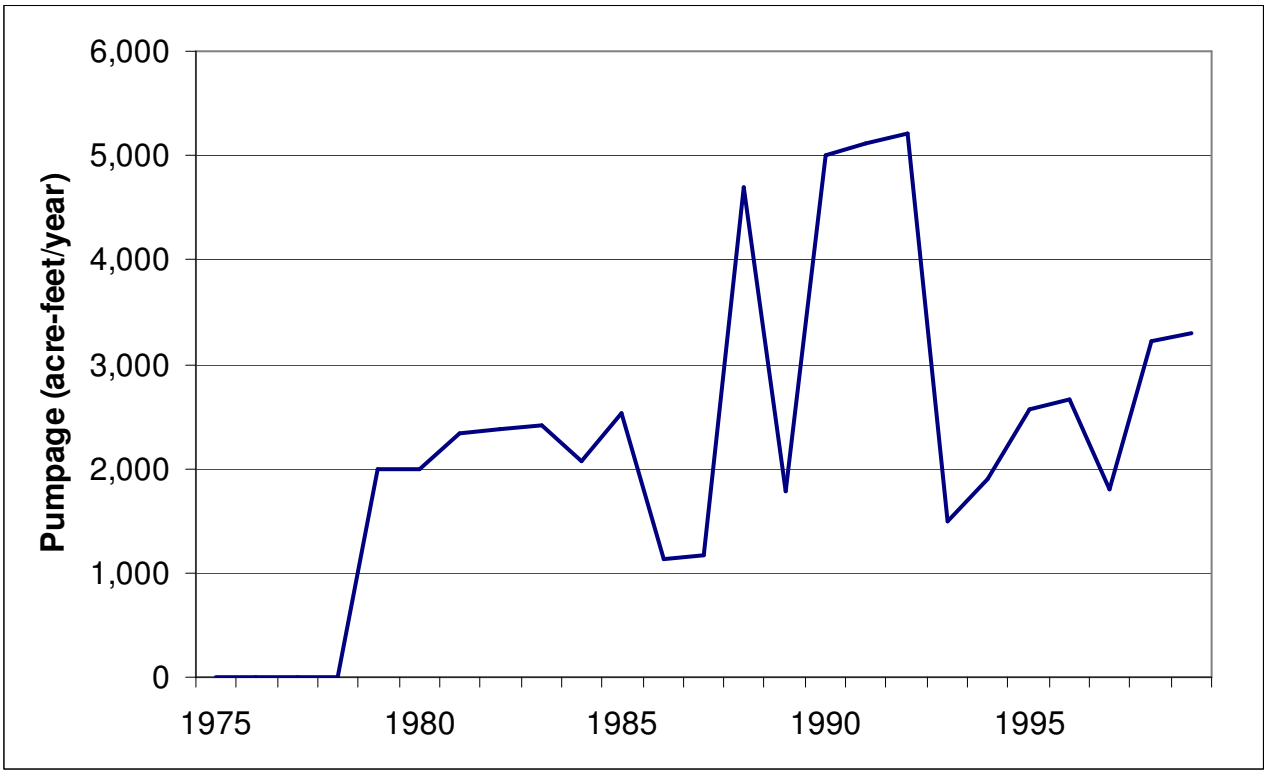

Figure A-11- Total pumpage in Maverick County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

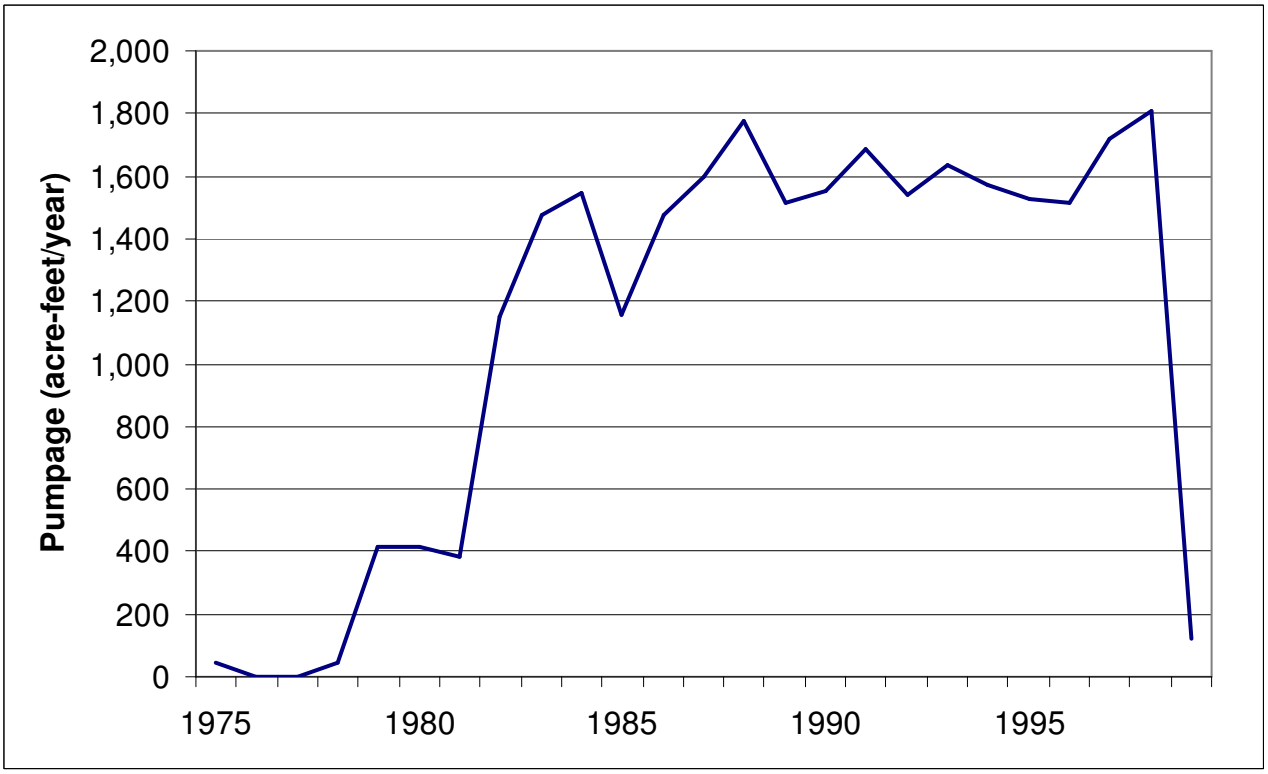

Figure A-12- Total pumpage in McMullen County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

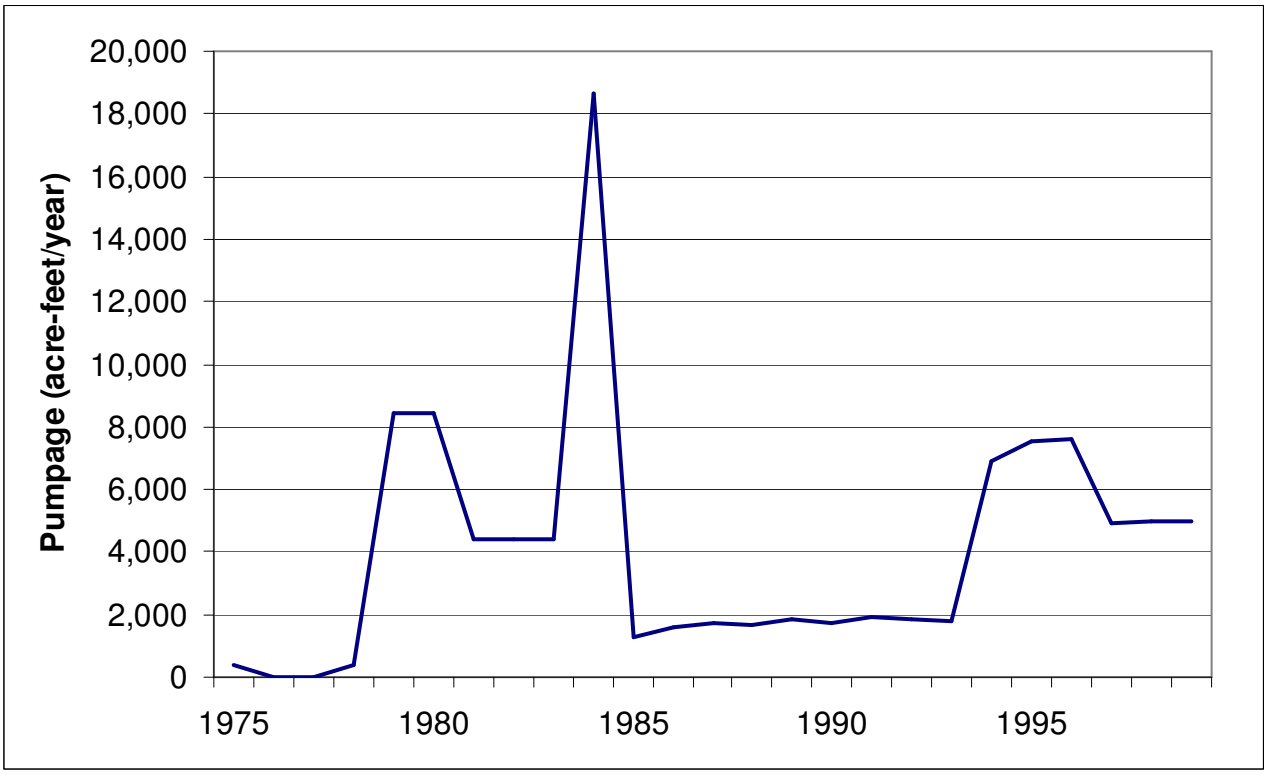

Figure A-13- Total pumpage in Medina County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

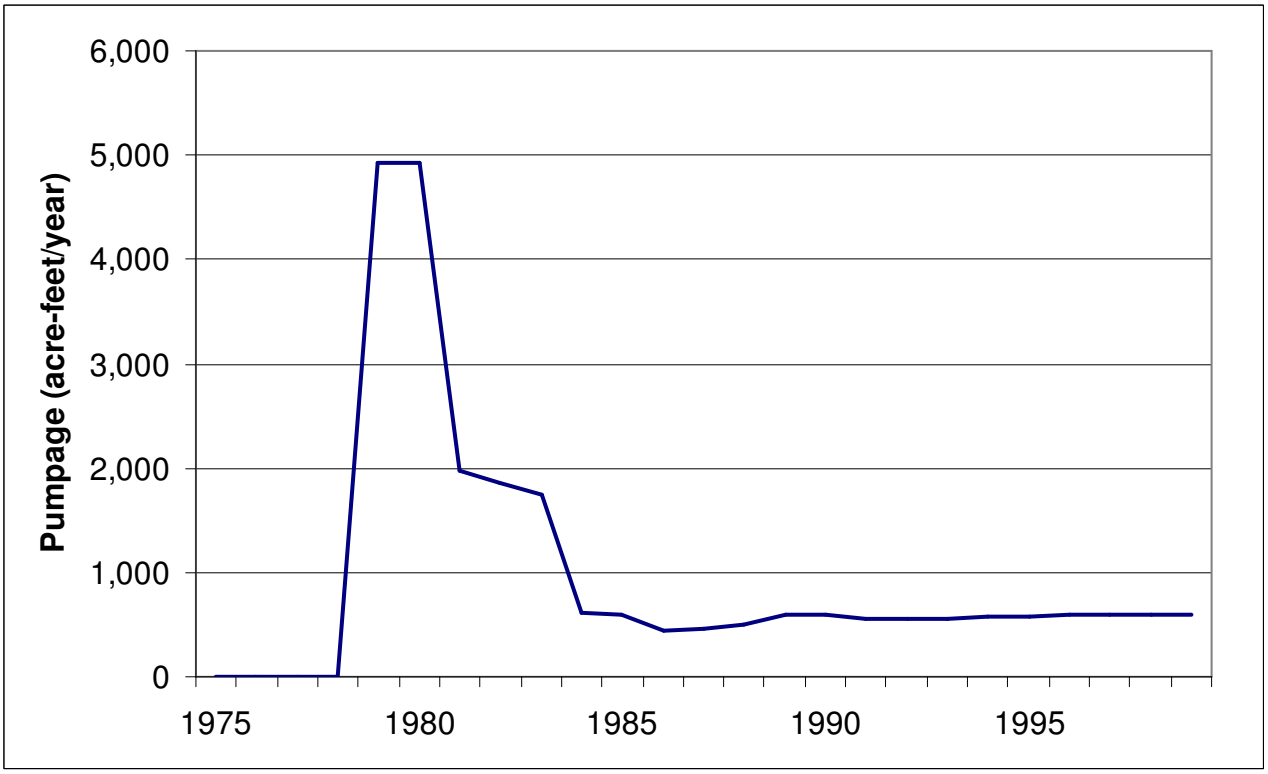

Figure A-14- Total pumpage in Uvalde County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

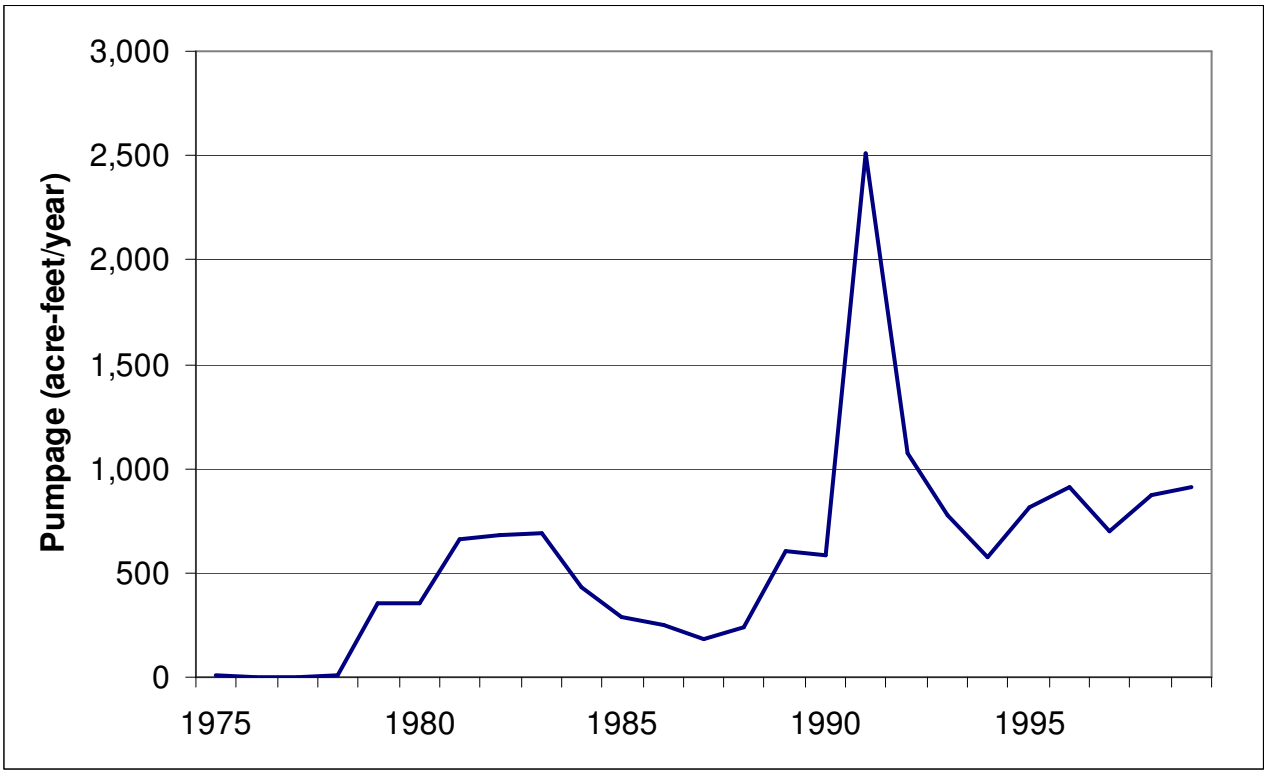

Figure A-15- Total pumpage in Webb County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

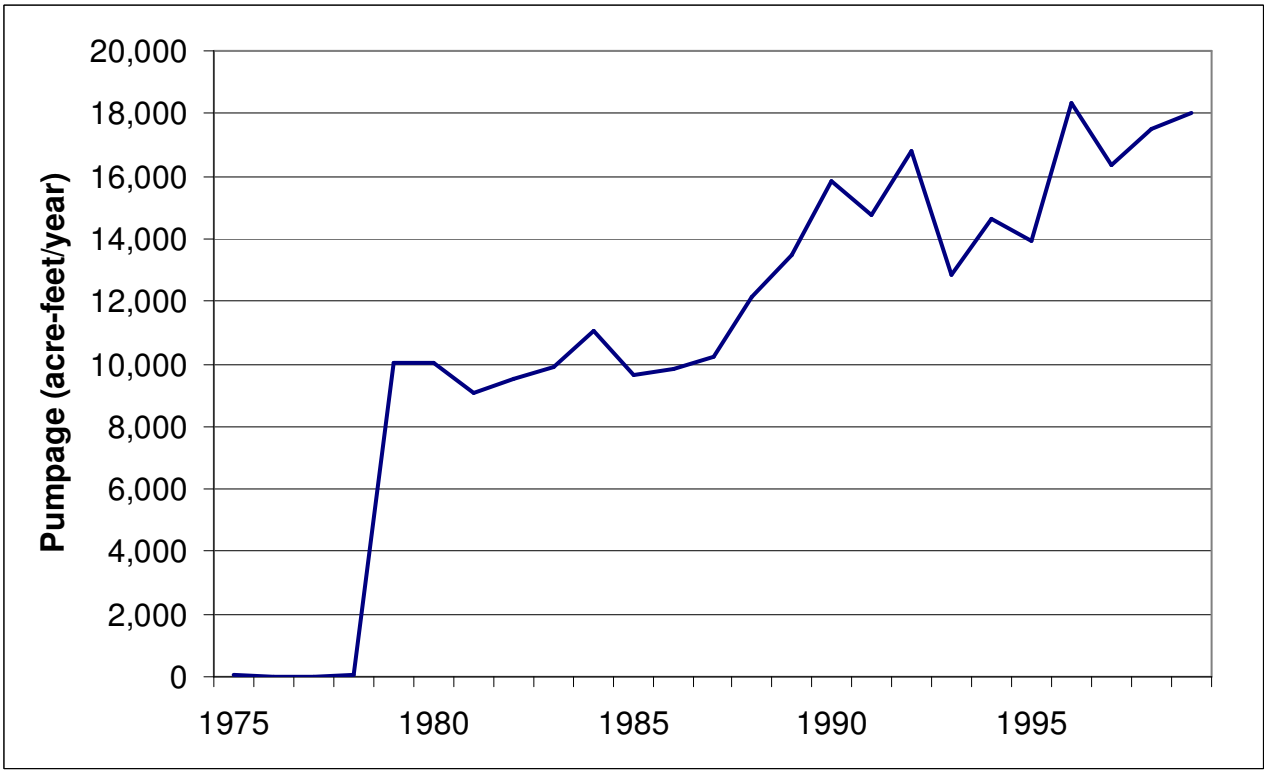

Figure A-16- Total pumpage in Wilson County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

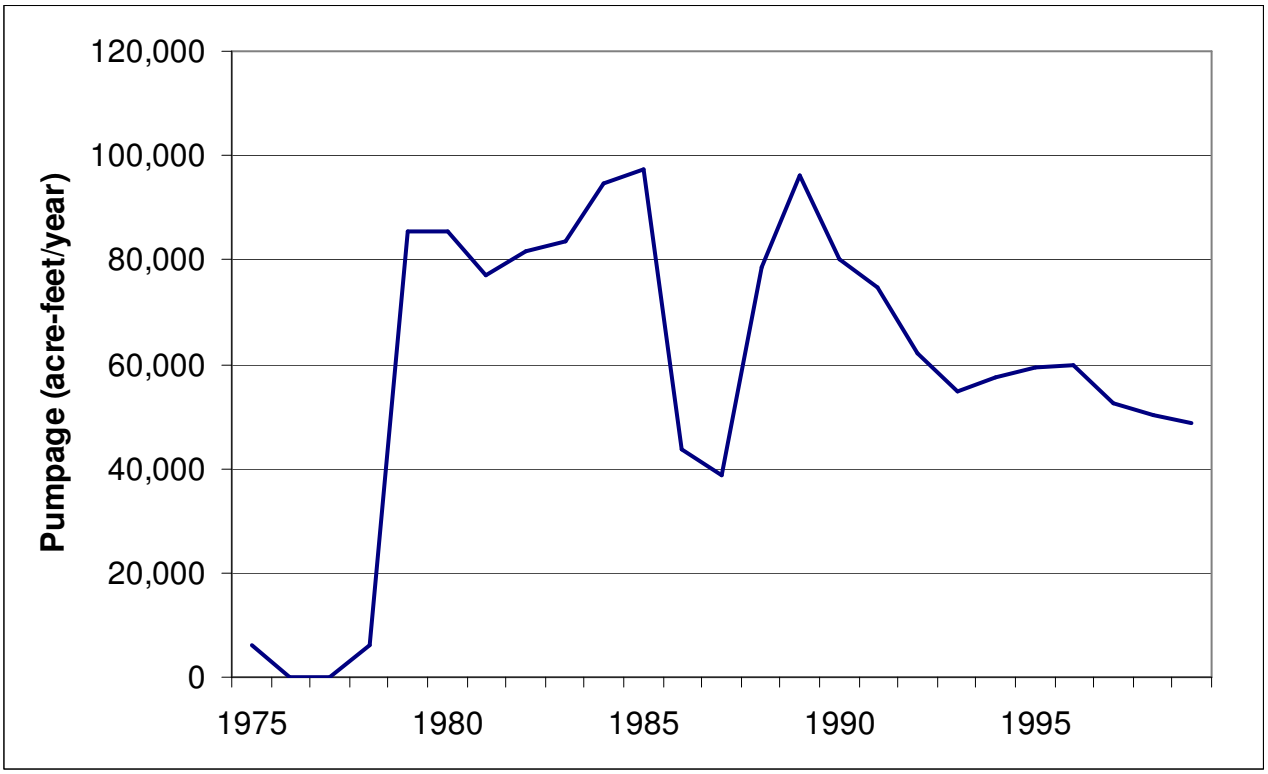

Figure A-17- Total pumpage in Zavala County included in the GAM for the southern part of the Queen City-Sparta Aquifer.

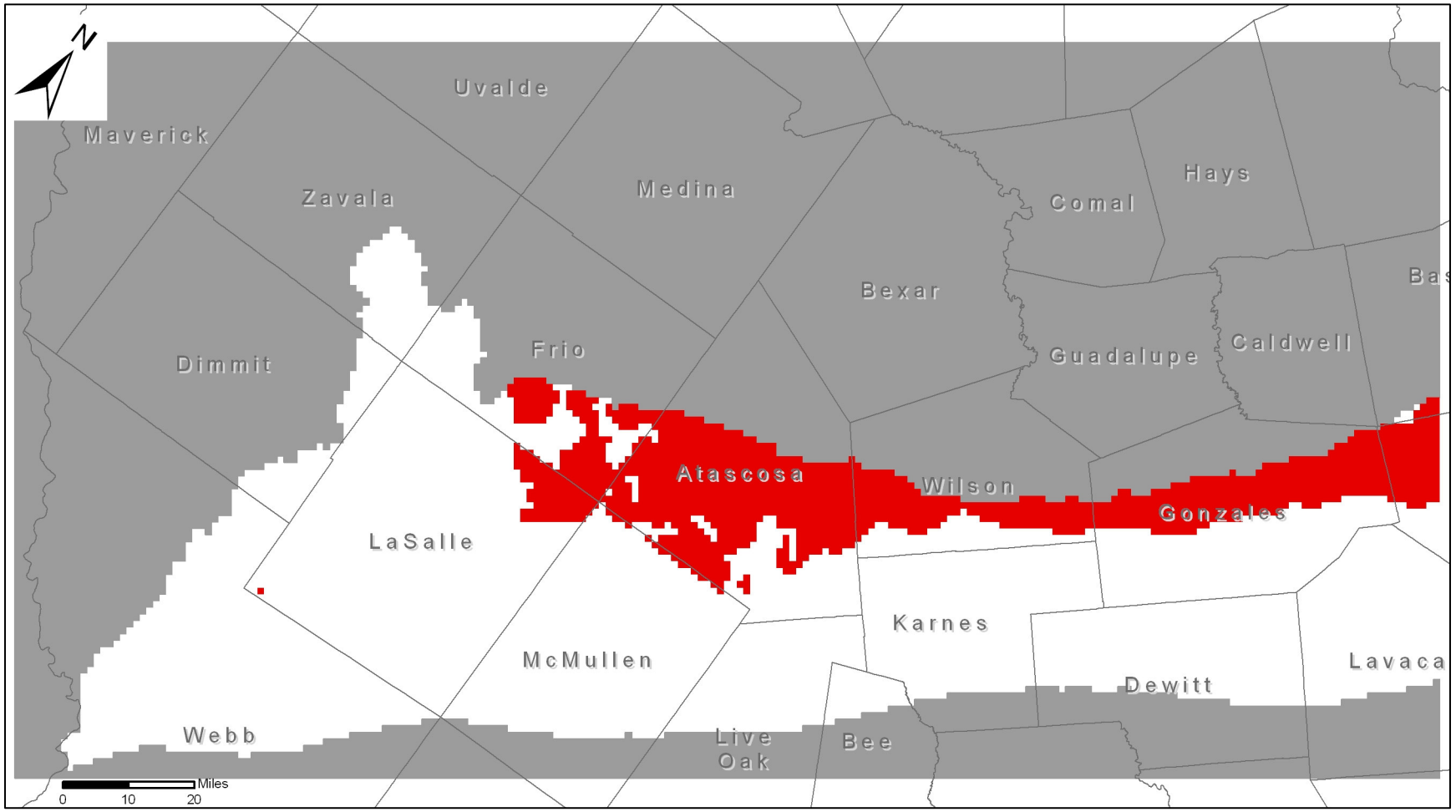

Figure A-18- Location of pumpage included in the GAM in the Sparta Aquifer (layer 1). Pumpage cells are in red. Active cells in this layer are in white.

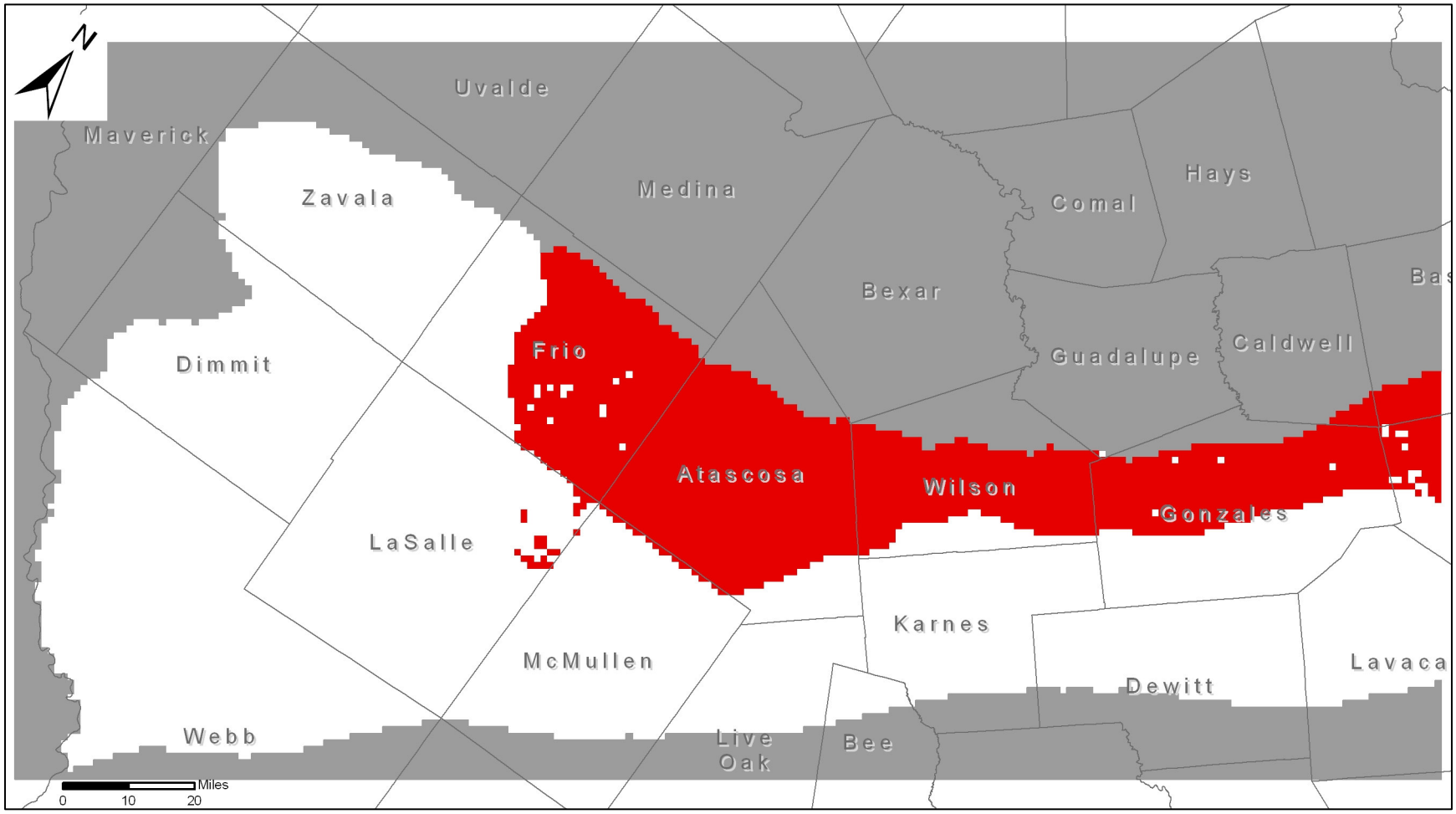

Figure A-19- Location of pumpage included in the GAM in the Queen City Aquifer (layer 3). Pumpage cells are in red. Active cells in this layer are in white.

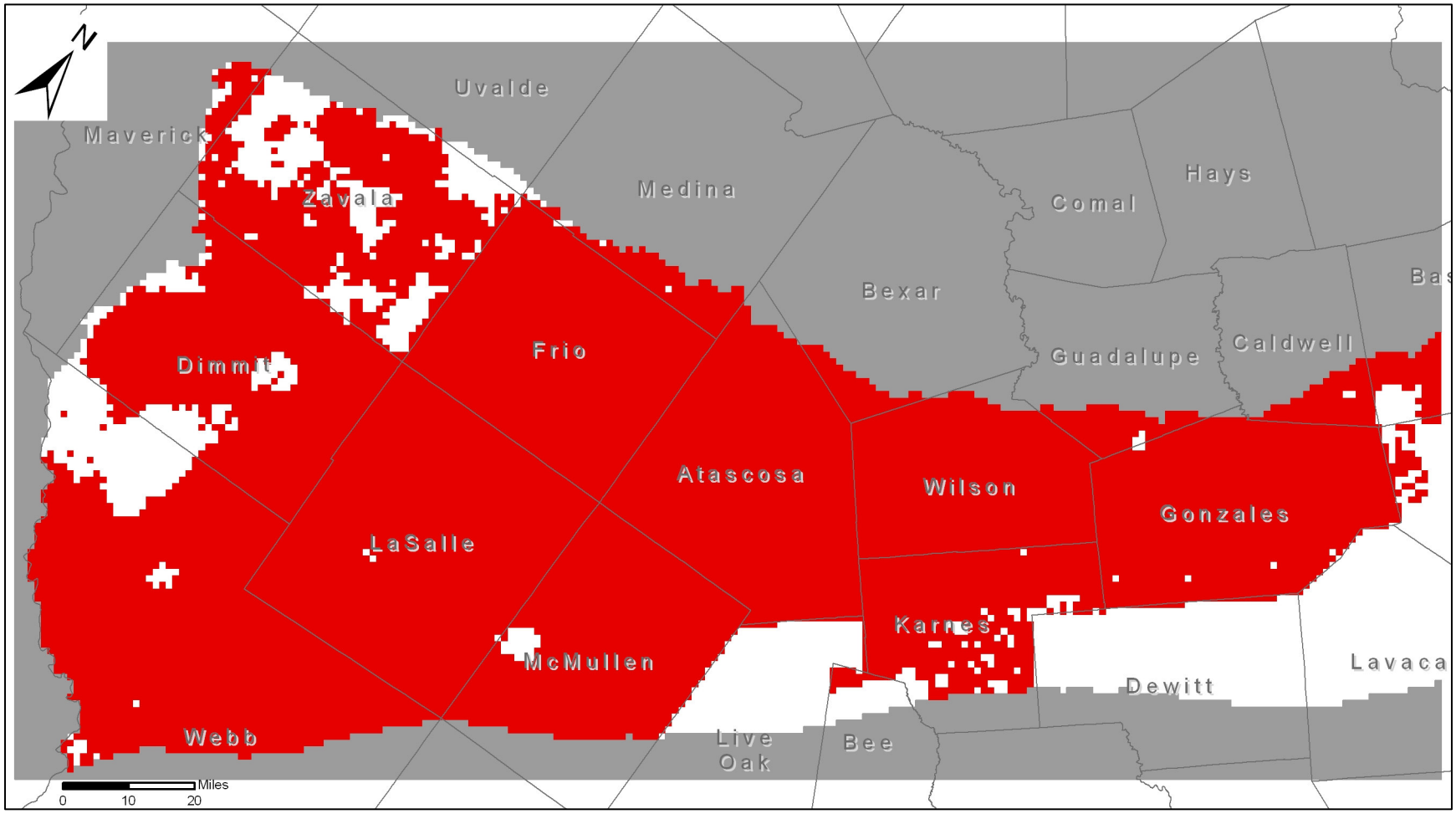

Figure A-20- Location of pumpage included in the GAM in the Carrizo Aquifer (layer 5). Pumpage cells are in red. Active cells in this layer are in white.

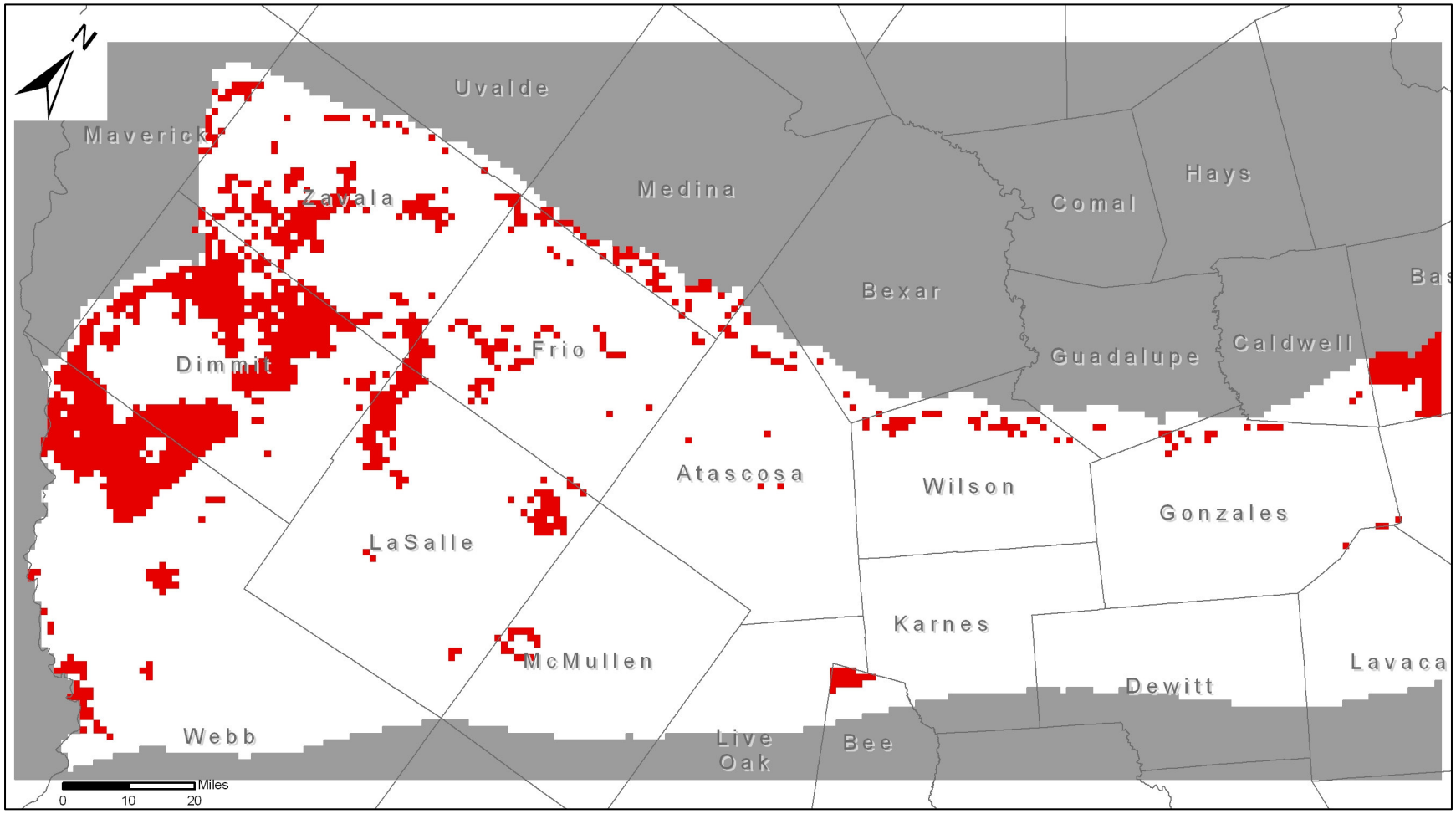

Figure A-21- Location of pumpage included in the GAM in the Upper Wilcox Aquifer (layer 6). Pumpage cells are in red. Active cells in this layer are in white.

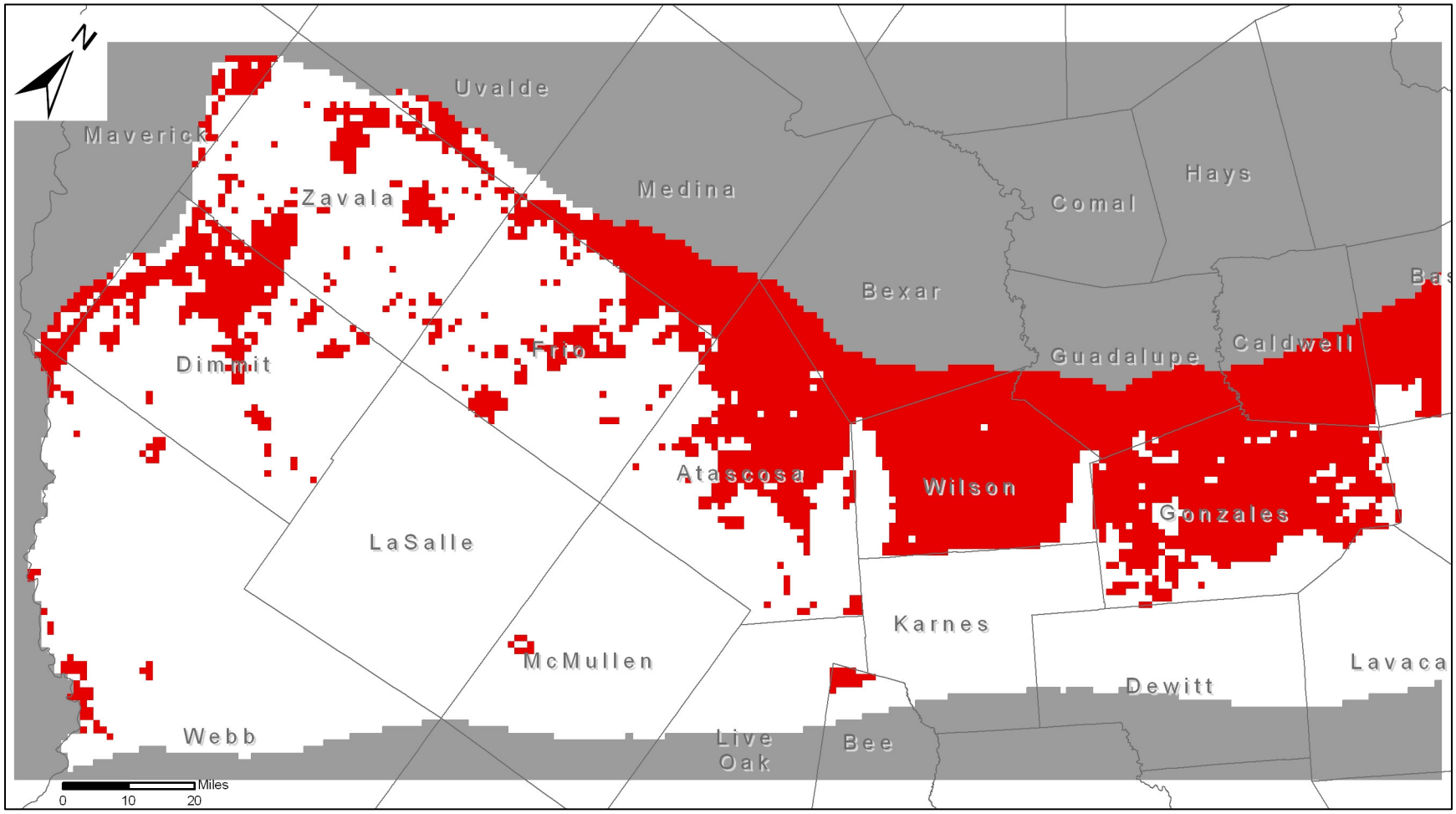

Figure A-22- Location of pumpage included in the GAM in the Middle Wilcox Aquifer (layer 7). Pumpage cells are in red. Active cells in this layer are in white.

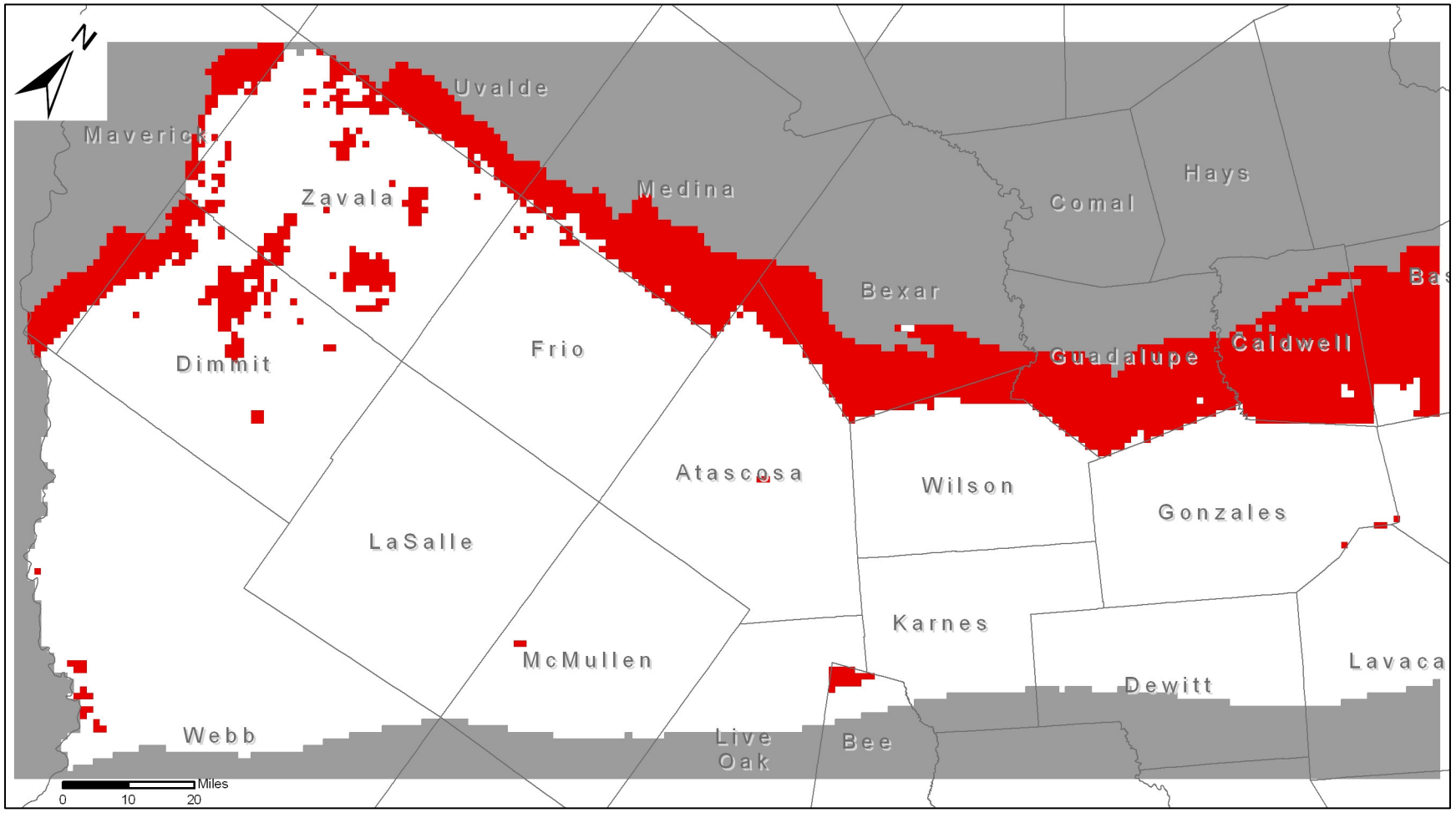

Figure A-23- Location of pumpage included in the GAM in the Lower Wilcox Aquifer (layer 8). Pumpage cells are in red. Active cells in this layer are in white.