GAM Run 07-03

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EXECUTIVE SUMMARY:

We ran the groundwater availability model for the Edwards-Trinity (Plateau) Aquifer for a 71-year simulation, which consisted of 21 years of historic conditions followed by a 50-year predictive time period. Average recharge conditions were used in the predictive portion of the simulation, along with a baseline pumpage approved by the members of Groundwater Management Area 7.

Results of this model run indicated that water levels after 50 years of baseline pumpage stayed within 25 feet of water levels at the end of 2000 with one exception. An area of extreme drawdown (up to 500 feet) centered in Glasscock and Reagan counties in the Trinity Aquifer was predicted by the model at the end of fifty years. Research into the model performance during the calibration time period indicates that the model is not simulating the response of the aquifer to pumpage in this area appropriately. Because properties for this layer are consistent across the entire model area, it is recommended that the use of this model to evaluate desired future conditions in this layer be done with care.

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 baseline model run using the groundwater availability model for the Edwards-Trinity (Plateau) Aquifer. This baseline model run would be a 71-year simulation, with the first 21 years being the historic portion of the simulation followed by a 50-year predictive time 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 baseline pumpage approved by members of Groundwater Management Area 7.

METHODS:

Recharge and initial streamflows were averaged for the 1961 to 1990 time period. These averages were then used for each year of the 50-year predictive portion of the model simulation along with the baseline pumpage. Resulting water levels and drawdowns 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 are using version 1.0 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 21 years were the historic calibration-verification portion of the simulation, followed by a 50-year predictive period.

- Pumpage for each year of the predictive portion of the model run was based the baseline pumpage requested by members of Groundwater Management Area 7 (described below). Pumpage in the historic portion of the model run was the estimated historic pumpage that was developed during the construction of the groundwater availability model. Historic pumpage is included in Appendix A.

- 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 Pecos Valley aquifers 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.

Baseline Pumpage

The year selected by Groundwater Management Area 7 as representative of baseline pumpage for most of the study area was 1995. However, the total pumpage for twelve counties was increased from the calibrated 1995 values based on input from the members of Groundwater Management Area 7. Table 1 shows the adjustments made to the 1995 pumpage data set to create the baseline pumpage totals.

Table 1. 1995 estimated pumpage from the calibration-verification run of the groundwater availability model and the requested baseline pumpage used in this model simulation. All pumpage totals are in acre-feet per year.

County	1995 Pumpage	Requested Baseline Pumpage	Difference	County	1995 Pumpage	Requested Baseline Pumpage	Difference
Coke	21	21	0	Nolan	120	151	31
Concho	277	277	0	Pecos	85,511	85,511	0
Crockett	2,618	5,493	2,875	Reagan	41,659	61,816	20,157
Ector	5,538	5,538	0	Real	596	11,525	10,929
Edwards	1,007	7,793	6,786	Reeves	107,749	107,749	0
Gillespie	3,481	3,970	489	Schleicher	2,353	3,732	1,379
Glasscock	59,280	59,280	0	Sterling	375	375	0
Irion	432	432	0	Sutton	2,933	3,445	512
Kimble	843	843	0	Taylor	117	117	0
Kinney	5,098	6,832	1,734	Terrell	1,015	1,029	14
Mason	3	3	0	Tom Green	741	741	0
McCulloch	31	31	0	Upton	16,245	20,603	4,358
Menard	917	1,844	927	Uvalde	569	742	173
Midland	21,140	21,140	0	Val Verde	6,362	14,562	8,200

RESULTS:

Included in the results are estimates of the water budgets after running the model for 50 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

GAM 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 2000) for Layers 1 and 2 are shown in Figures 1 and 2, respectively. These figures show the starting water levels for the 50-year predictive portion of the model run.

Water levels at the end of the 50-year predictive portion of the simulation for Layers 1 and 2 are shown in Figures 3 and 4, respectively. Water levels at the end of the 50-year runs are similar to initial water levels (Figures 1 and 2), except that water levels in Layer 2 for Glasscock and Reagan counties are obviously lower at the end of the 50-year predictive portion of the run (Figure 4). Because differences between initial water levels and water levels after 50 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 (2000) and the water levels at the end of the 50-year predictive portion of the model run.

Water level changes over the 50-year predictive portion of the model simulation for Layers 1 and 2 are shown in Figures 5 and 6, respectively. Figure 5 indicates that water levels in Layer 1 (Edwards and associated limestones and the Pecos Valley Aquifer) show both increases and decreases in water levels over the 50-year predictive portion of the run. These changes are generally less than 25 feet throughout the layer.

Figure 6 indicates that water levels in Layer 2 (Trinity) decrease throughout most of the region, mostly less than 25 feet. However a very large cone of depression centered in Glasscock and Reagan counties that is present at the end of the historic portion of the model run (Figure 2) continues to deepen, with the model predicting up to an additional 500 feet of decline in this area over the 50-year predictive time period. Because this appeared to be a very large drawdown for a baseline run that used a constant pumpage based on historic estimated pumpage totals, the model response in this area was evaluated. It was determined that the model did not simulate the response of water levels in this area 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. 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 in Blanco and Kendall 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. This area is 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 Table 2. 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.

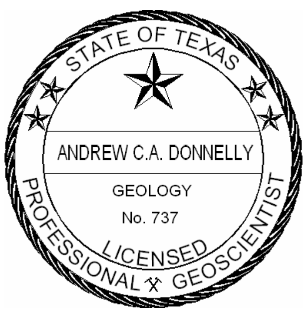

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Table 2. Annual water budgets for each county at the end of the 50-year predictive portion of the model run using the requested baseline pumpage in the groundwater availability model for the Edwards-Trinity (Plateau) Aquifer (in acre-feet per year).

	Andrews		Bandera		Bexar		Blanco		Brewster		Burnet	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Edwards and Pecos Valley Aquifer (Layer 1)												
Reservoirs (Constant Head Cells)	0	0	0	0	--	--	--	--	0	0	--	--
Storage	486	0	0	0	--	--	--	--	284	65	--	--
Springs and Seeps (Drain Package)	0	0	0	2,059	--	--	--	--	0	23,062	--	--
Inter-aquifer Flow (GHB Package)	0	1,273	0	0	--	--	--	--	0	0	--	--
Wells	0	60	0	28	--	--	--	--	0	85	--	--
Streams and Rivers (Stream Package)	0	0	3,549	1,048	--	--	--	--	0	0	--	--
Recharge	2,079	0	1,579	0	--	--	--	--	19,850	0	--	--
Lateral Inflow	856	2,117	865	2,766	--	--	--	--	7,054	3,889	--	--
Vertical Leakage Downward	--	--	4	95	--	--	--	--	1,128	1,233	--	--
Trinity (Layer 2)												
Reservoirs (Constant Head Cells)	0	0	246	2,965	0	0	0	0	0	0	0	684
Storage	120	0	83	0	0	0	0	566	108	0	0	0
Springs and Seeps (Drain Package)	0	0	0	0	0	0	0	16,046	0	0	0	1,183
Inter-aquifer Flow (GHB Package)	2,320	1,102	0	2,564	0	31,060	0	8	0	0	0	0
Wells	0	8	0	2,303	0	2,399	0	744	0	588	0	114
Streams and Rivers (Stream Package)	0	0	3,854	29,141	0	0	0	11,260	1,503	12,846	0	0
Recharge	3,912	0	48,555	0	21,238	0	45,590	0	5,854	0	1,877	0
Vertical Leakage Upward	--	--	95	4	--	--	--	--	1,233	1,128	--	--
Lateral Inflow	424	5,675	16,555	32,418	19,712	7,491	4,965	21,896	5,855	0	1,522	1,418

Table 2. (continued)

	Coke		Comal		Concho		Crane		Crockett		Culberson	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Edwards and Pecos Valley Aquifer (Layer 1)												
Reservoirs (Constant Head Cells)	--	--	--	--	0	0	0	0	0	0	0	0
Storage	--	--	--	--	0	1	1,451	0	843	0	1,085	0
Springs and Seeps (Drain Package)	--	--	--	--	0	5,263	0	0	0	0	0	0
Inter-aquifer Flow (GHB Package)	--	--	--	--	0	0	89	1,818	0	45	64	440
Wells	--	--	--	--	0	108	0	552	0	4,794	0	37
Streams and Rivers (Stream Package)	--	--	--	--	0	0	42	8,041	9,076	5,956	0	0
Recharge	--	--	--	--	5,205	0	5,465	0	43,957	0	2,183	0
Lateral Inflow	--	--	--	--	2,677	1,641	5,272	1,991	10,232	32,470	521	3,443
Vertical Leakage Downward	--	--	--	--	0	868	--	--	279	21,178	--	--
Trinity (Layer 2)												
Reservoirs (Constant Head Cells)	0	0	6,263	7,263	0	0	0	0	0	0	--	--
Storage	0	0	0	1	0	0	36	0	362	0	--	--
Springs and Seeps (Drain Package)	0	6,548	0	0	0	3,436	0	0	0	0	--	--
Inter-aquifer Flow (GHB Package)	0	56	2,434	12,170	0	21	1	4	0	3,642	--	--
Wells	0	21	0	3,059	0	169	0	5	0	698	--	--
Streams and Rivers (Stream Package)	0	0	464	27,718	0	0	0	0	170	12,564	--	--
Recharge	5,916	0	30,369	0	3,274	0	138	0	2,301	0	--	--
Vertical Leakage Upward	--	--	--	--	868	0	--	--	21,178	279	--	--
Lateral Inflow	1,248	540	20,547	9,866	824	1,341	894	1,063	8,485	15,350	--	--

Table 2. (continued)

	Ector		Edwards		Gillespie		Glasscock		Hays		Howard	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Edwards and Pecos Valley Aquifer (Layer 1)												
Reservoirs (Constant Head Cells)	0	0	0	0	0	0	0	0	--	--	--	--
Storage	444	0	0	0	0	0	0	9	--	--	--	--
Springs and Seeps (Drain Package)	0	0	0	4,774	0	9,481	0	1,646	--	--	--	--
Inter-aquifer Flow (GHB Package)	0	433	0	0	0	0	0	0	--	--	--	--
Wells	0	48	0	7,049	0	616	0	54	--	--	--	--
Streams and Rivers (Stream Package)	0	0	11,362	34,470	973	1,400	0	0	--	--	--	--
Recharge	788	0	74,639	0	10,113	0	11,144	0	--	--	--	--
Lateral Inflow	321	1,065	9,284	44,424	3,664	1,876	490	1,925	--	--	--	--
Vertical Leakage Downward	0	29	1	4,569	361	1,739	140	7,964	--	--	--	--
Trinity (Layer 2)												
Reservoirs (Constant Head Cells)	0	0	0	0	0	0	0	0	0	0	0	0
Storage	1,263	0	90	0	4	25	6,754	0	0	630	21	0
Springs and Seeps (Drain Package)	0	0	0	0	0	7,950	0	0	0	0	0	0
Inter-aquifer Flow (GHB Package)	4	2,879	0	0	0	7	15,942	73	0	18,392	473	71
Wells	0	5,489	0	745	0	3,354	0	59,226	0	2,818	0	585
Streams and Rivers (Stream Package)	0	0	2,855	610	3,278	23,424	0	0	0	3,350	0	0
Recharge	11,774	0	3,185	0	36,773	0	5,156	0	32,522	0	1,517	0
Vertical Leakage Upward	29	0	4,569	1	1,739	361	7,964	140	--	--	--	--
Lateral Inflow	3,275	8,077	12,043	21,392	1,248	7,919	33,925	10,939	7,346	14,638	244	1,601

Table 2. (continued)

	Irion		Jeff Davis		Kendall		Kerr		Kimble		Kinney	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Edwards and Pecos Valley Aquifer (Layer 1)												
Reservoirs (Constant Head Cells)	0	0	0	0	--	--	0	0	0	0	0	0
Storage	42	0	1,073	0	--	--	0	0	0	0	0	138
Springs and Seeps (Drain Package)	0	7,675	0	0	--	--	0	9,063	0	22,871	0	7,910
Inter-aquifer Flow (GHB Package)	0	0	11	12	--	--	0	0	0	0	0	13,423
Wells	0	232	0	141	--	--	0	559	0	251	0	4,148
Streams and Rivers (Stream Package)	487	5,036	0	0	--	--	7,843	7,167	997	4,609	1,046	18,554
Recharge	14,334	0	5,294	0	--	--	19,184	0	25,672	0	42,401	0
Lateral Inflow	6,572	2,421	1,991	8,299	--	--	3,838	12,674	16,988	6,832	17,229	15,455
Vertical Leakage Downward	256	6,324	--	--	--	--	6	1,408	11	9,104	4	1,040
Trinity (Layer 2)												
Reservoirs (Constant Head Cells)	0	0	--	--	0	0	0	0	0	0	0	0
Storage	197	0	--	--	0	523	65	5	15	1	5	0
Springs and Seeps (Drain Package)	0	2,211	--	--	0	0	0	0	0	4,698	0	0
Inter-aquifer Flow (GHB Package)	505	680	--	--	0	0	0	0	0	0	24	13,258
Wells	0	200	--	--	0	3,515	0	3,622	0	592	0	2,684
Streams and Rivers (Stream Package)	0	0	--	--	229	41,015	3,378	18,907	6,828	26,519	0	0
Recharge	2,287	0	--	--	51,352	0	27,329	0	7,256	0	1,163	0
Vertical Leakage Upward	6,324	256	--	--	--	--	1,408	6	9,104	11	1,040	4
Lateral Inflow	3,248	9,248	--	--	9,951	16,446	6,725	16,370	12,125	3,510	15,396	1,683

Table 2. (continued)

	Loving		Martin		Mason		McCulloch		Medina		Menard	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Edwards and Pecos Valley Aquifer (Layer 1)												
Reservoirs (Constant Head Cells)	0	0	--	--	0	0	0	0	--	--	0	0
Storage	425	89	--	--	0	0	0	0	--	--	0	2
Springs and Seeps (Drain Package)	0	0	--	--	0	884	0	769	--	--	0	5,210
Inter-aquifer Flow (GHB Package)	2	163	--	--	0	0	0	0	--	--	0	0
Wells	0	32	--	--	0	0	0	2	--	--	0	927
Streams and Rivers (Stream Package)	940	1,860	--	--	0	0	0	0	--	--	0	13,267
Recharge	604	0	--	--	829	0	677	0	--	--	20,304	0
Lateral Inflow	1,882	1,728	--	--	386	221	330	83	--	--	7,882	4,897
Vertical Leakage Downward	--	--	--	--	10	119	11	164	--	--	0	3,884
Trinity (Layer 2)												
Reservoirs (Constant Head Cells)	--	--	0	0	0	0	0	0	430	819	0	0
Storage	--	--	490	0	0	0	0	0	29	0	0	1
Springs and Seeps (Drain Package)	--	--	0	0	0	2,568	0	6,013	0	0	0	1,550
Inter-aquifer Flow (GHB Package)	--	--	1,549	103	0	0	0	327	0	28,100	0	0
Wells	--	--	0	94	0	3	0	29	0	69	0	918
Streams and Rivers (Stream Package)	--	--	0	0	0	0	0	0	0	0	488	1,710
Recharge	--	--	2,833	0	1,477	0	5,073	0	8,448	0	3,142	0
Vertical Leakage Upward	--	--	--	--	119	10	164	11	--	--	3,884	0
Lateral Inflow	--	--	4,802	9,511	1,848	863	1,430	288	26,031	5,952	1,529	4,867

Table 2. (continued)

	Midland		Nolan		Pecos		Reagan		Real		Reeves	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Edwards and Pecos Valley Aquifer (Layer 1)												
Reservoirs (Constant Head Cells)	0	0	--	--	0	0	0	0	0	0	0	0
Storage	0	6	--	--	15,136	15	29	1	0	0	70,658	0
Springs and Seeps (Drain Package)	0	0	--	--	0	0	0	710	0	8,530	0	0
Inter-aquifer Flow (GHB Package)	0	0	--	--	32	5,107	0	0	0	0	206	4,173
Wells	0	3	--	--	0	83,272	0	1,001	0	2,844	0	107,747
Streams and Rivers (Stream Package)	0	0	--	--	107	19,857	0	0	259	5,191	957	36,181
Recharge	2,691	0	--	--	148,323	0	21,100	0	12,474	0	67,867	0
Lateral Inflow	226	787	--	--	15,180	49,297	3,638	3,555	6,911	2,452	15,912	11,709
Vertical Leakage Downward	13	2,054	--	--	1,627	23,768	147	19,548	33	660	--	--
Trinity (Layer 2)												
Reservoirs (Constant Head Cells)	0	0	0	0	0	0	0	0	0	0	--	--
Storage	18,220	0	0	0	1,007	0	3,702	0	61	0	--	--
Springs and Seeps (Drain Package)	0	0	0	10,807	0	0	0	0	0	0	--	--
Inter-aquifer Flow (GHB Package)	2,577	947	0	0	0	0	13,770	298	0	0	--	--
Wells	0	21,137	0	151	0	2,236	0	60,815	0	8,680	--	--
Streams and Rivers (Stream Package)	0	0	0	0	0	18,131	0	0	8,227	727	--	--
Recharge	15,283	0	11,947	0	7,165	0	21	0	8,759	0	--	--
Vertical Leakage Upward	2,054	13	--	--	23,768	1,627	19,548	147	660	33	--	--
Lateral Inflow	19,300	36,528	194	1,183	10,922	20,959	37,252	13,419	9,564	17,835	--	--

Table 2. (continued)

	Schleicher		Sterling		Sutton		Taylor		Terrell		Tom Green	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Edwards and Pecos Valley Aquifer (Layer 1)												
Reservoirs (Constant Head Cells)	0	0	0	0	0	0	--	--	0	0	0	0
Storage	20	5	0	0	6	2	--	--	74	33	0	1
Springs and Seeps (Drain Package)	0	0	0	2,924	0	0	--	--	0	4,385	0	8,769
Inter-aquifer Flow (GHB Package)	0	0	0	0	0	0	--	--	0	0	0	0
Wells	0	3,723	0	82	0	3,425	--	--	0	308	0	159
Streams and Rivers (Stream Package)	8,078	7,913	0	0	3,805	27,575	--	--	167	34,653	0	1,285
Recharge	24,018	0	4,546	0	29,044	0	--	--	43,448	0	8,029	0
Lateral Inflow	4,747	19,861	1,121	1,379	18,588	14,008	--	--	45,524	34,242	7,196	2,964
Vertical Leakage Downward	17	5,381	126	1,390	741	7,179	--	--	308	15,903	11	2,055
Trinity (Layer 2)												
Reservoirs (Constant Head Cells)	0	0	0	0	0	0	0	0	0	0	0	0
Storage	2	0	71	0	6	0	0	0	457	0	8	0
Springs and Seeps (Drain Package)	0	0	0	2,988	0	0	0	4,895	0	0	0	5,007
Inter-aquifer Flow (GHB Package)	0	0	894	1,302	0	0	0	0	0	0	156	39
Wells	0	9	0	293	0	20	0	117	0	724	0	582
Streams and Rivers (Stream Package)	0	0	0	0	397	0	0	0	124	19,640	123	3,382
Recharge	0	0	5,992	0	0	0	4,595	0	682	0	3,601	0
Vertical Leakage Upward	5,381	17	1,390	126	7,179	741	--	--	15,903	308	2,055	11
Lateral Inflow	2,210	7,567	2,412	6,072	5,516	12,337	529	112	20,179	16,712	7,558	4,487

Table 2. (continued)

	Travis		Upton		Uvalde		Val Verde		Ward		Winkler	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Edwards and Pecos Valley Aquifer (Layer 1)												
Reservoirs (Constant Head Cells)	--	--	0	0	0	0	16,636	57,301	0	0	0	0
Storage	--	--	425	4	0	0	22	2	3,001	0	2,485	1,020
Springs and Seeps (Drain Package)	--	--	0	0	0	3,049	0	847	0	0	0	0
Inter-aquifer Flow (GHB Package)	--	--	3	915	0	6,889	0	0	2	4,808	0	3,690
Wells	--	--	0	337	0	241	0	14,405	0	5,821	0	558
Streams and Rivers (Stream Package)	--	--	0	0	0	0	24,990	128,548	404	13,043	0	0
Recharge	--	--	15,277	0	7,422	0	90,068	0	6,575	0	5,300	0
Lateral Inflow	--	--	935	5,008	3,274	1,274	76,509	9,542	17,947	4,439	5,084	7,689
Vertical Leakage Downward	--	--	110	10,416	799	43	3,307	903	--	--	--	--
Trinity (Layer 2)												
Reservoirs (Constant Head Cells)	3,484	32,078	0	0	0	0	0	0	--	--	0	0
Storage	0	130	3,723	0	16	0	51	0	--	--	9	0
Springs and Seeps (Drain Package)	0	0	0	0	0	0	0	0	--	--	0	0
Inter-aquifer Flow (GHB Package)	12,802	475	7,184	75	924	22,709	0	0	--	--	0	25
Wells	0	1,721	0	20,266	0	501	0	157	--	--	0	1
Streams and Rivers (Stream Package)	0	8,030	0	0	2,794	18,945	5	1,926	--	--	0	0
Recharge	16,098	0	2,632	0	19,757	0	152	0	--	--	119	0
Vertical Leakage Upward	--	--	10,416	110	43	799	903	3,307	--	--	--	--
Lateral Inflow	10,104	46	17,298	21,199	25,342	5,926	11,877	7,604	--	--	48	151

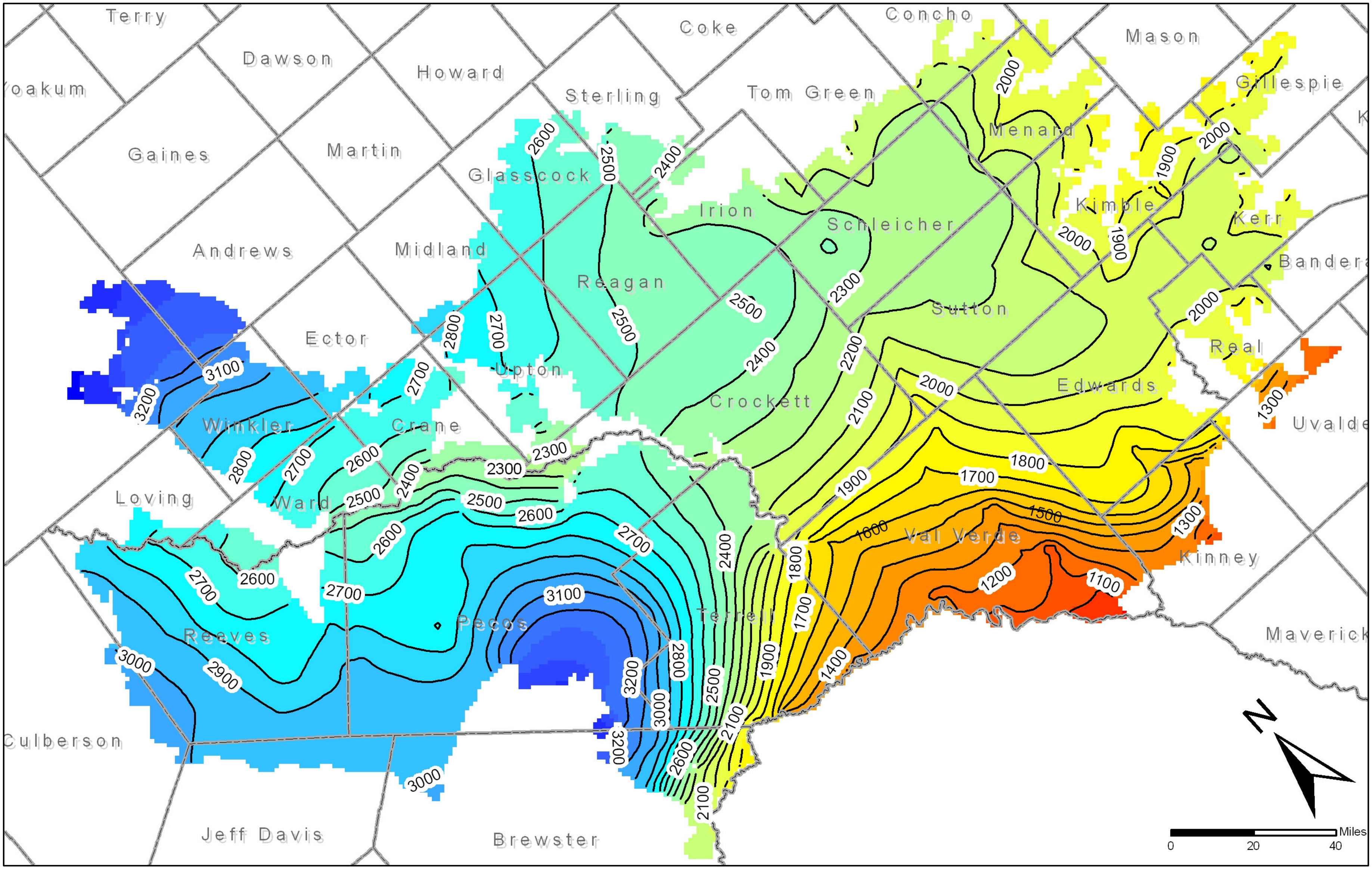

Figure 1. Initial water level elevations for the predictive model run in Layer 1 (Edwards and associated limestones and the Pecos Valley Aquifer) of the groundwater availability model for Edwards- Trinity (Plateau) Aquifer. Water level elevations are in feet above mean sea level. Contour interval is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

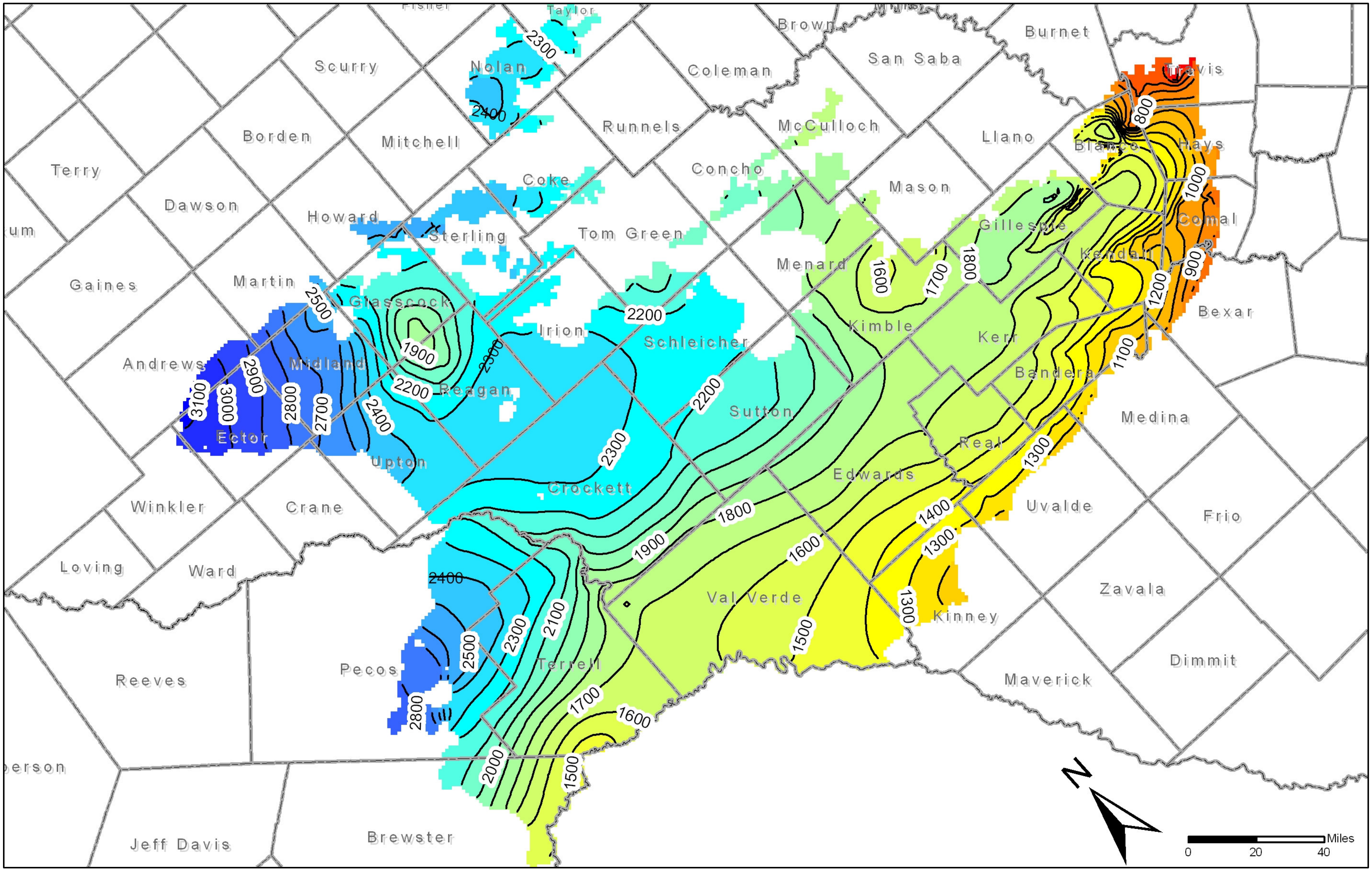

Figure 2. Initial water level elevations for the predictive model run in Layer 1 (Trinity Aquifer) of the groundwater availability model for Edwards- Trinity (Plateau) Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 100 feet.

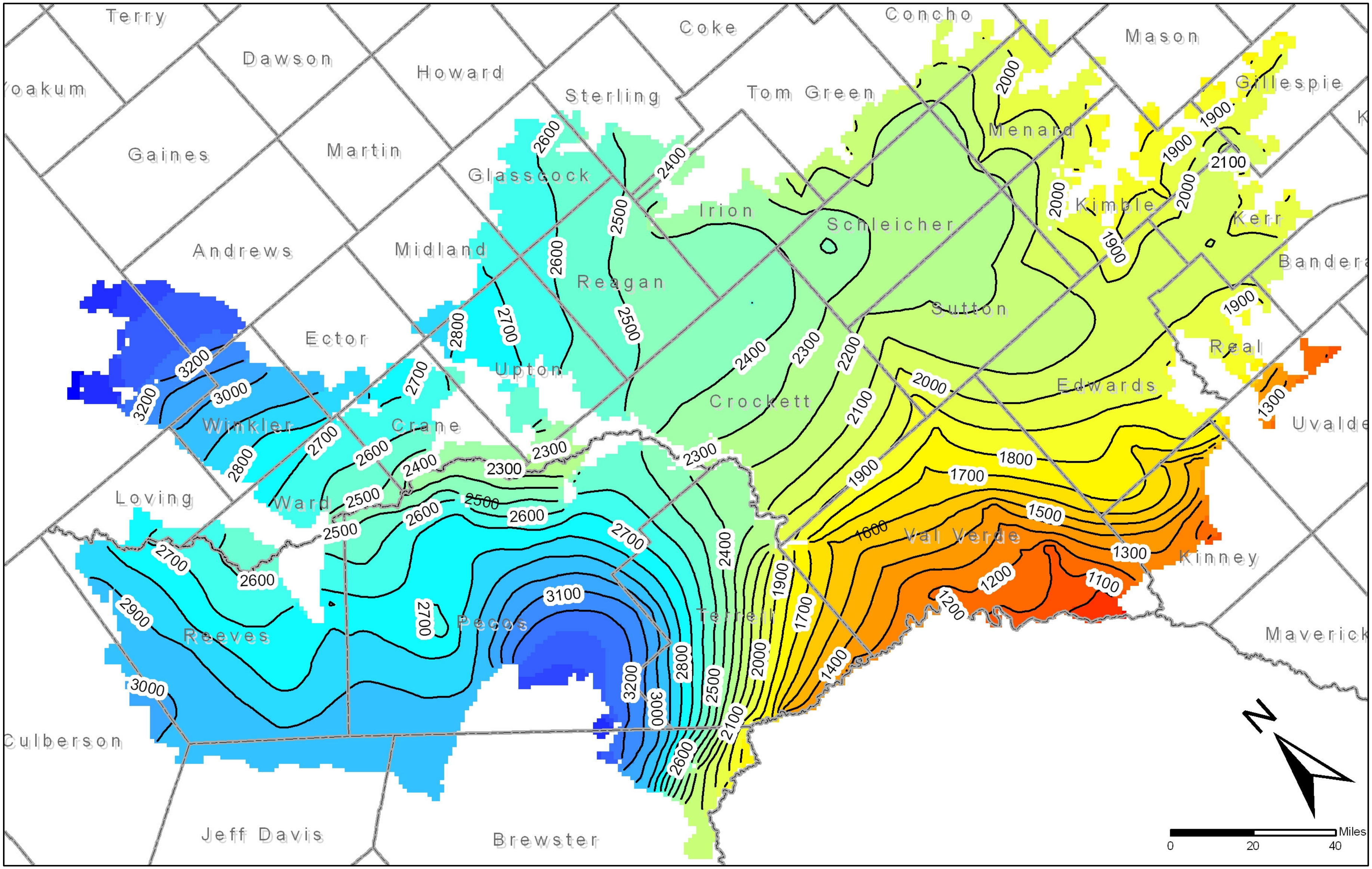

Figure 3. Water level elevations after 50 years using baseline pumpage in Layer 1 (Edwards and associated limestones and the Pecos Valley Aquifer). Water level elevations are in feet above mean sea level. Contour interval is 100 feet.

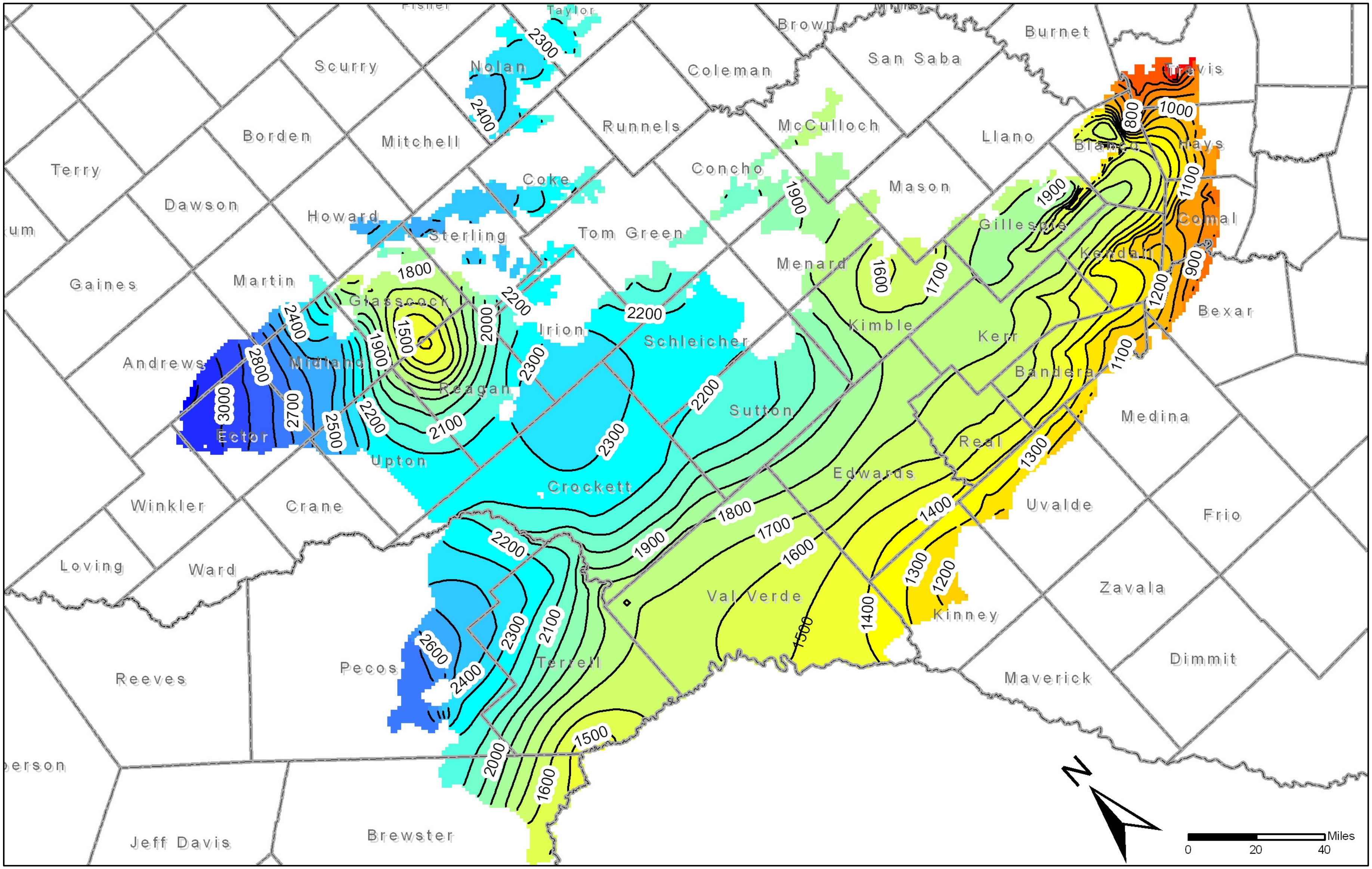

Figure 4. Water level elevations after 50 years using baseline pumpage in Layer 2 (Trinity Aquifer). Water level elevations are in feet above mean sea level. Contour interval is 100 feet.

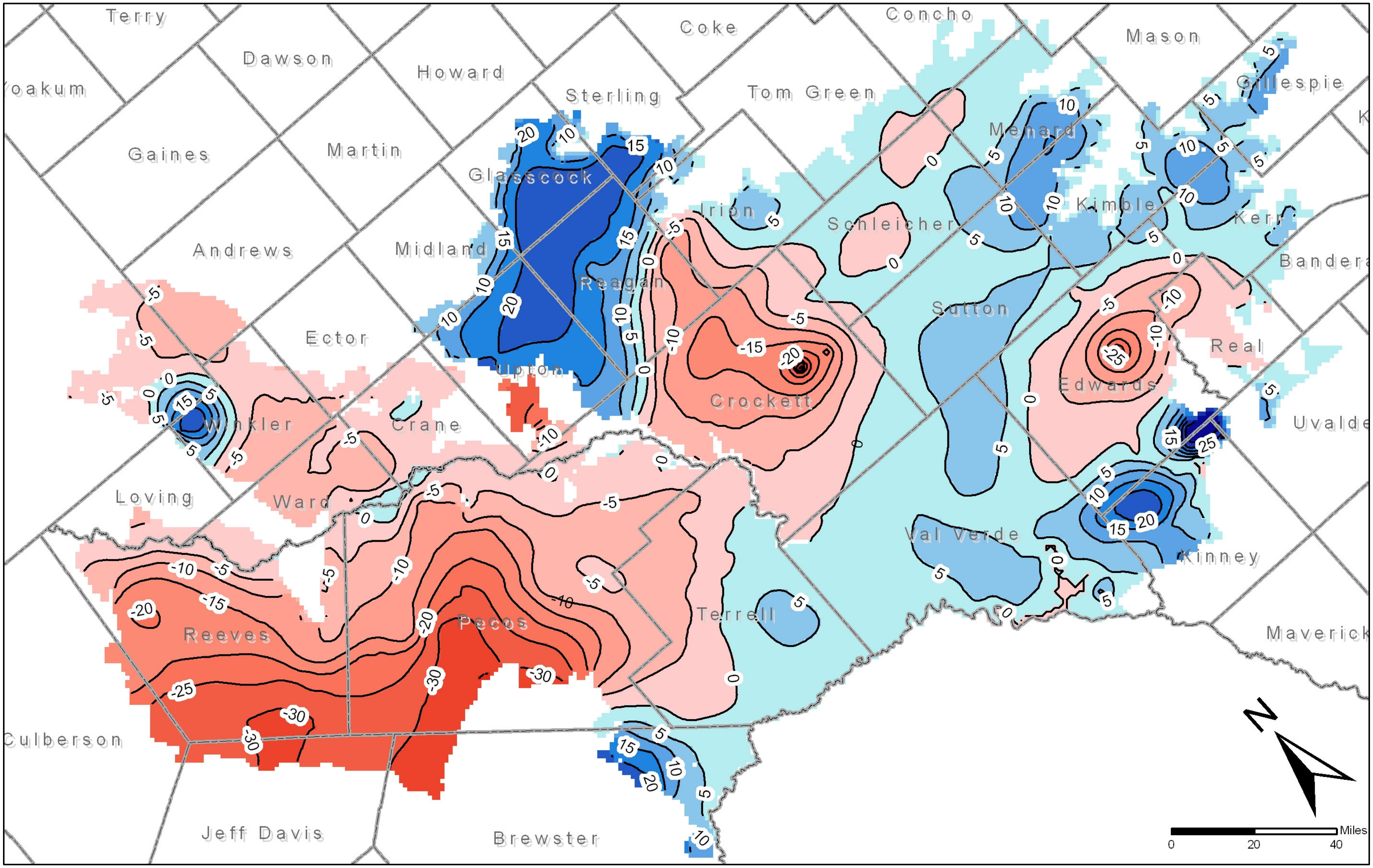

Figure 5. Changes in water levels after 50 years using baseline pumpage in Layer 1 (Edwards and associated limestones and the Pecos Valley Aquifer). Drawdowns are in feet. Contour interval is 5 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue.

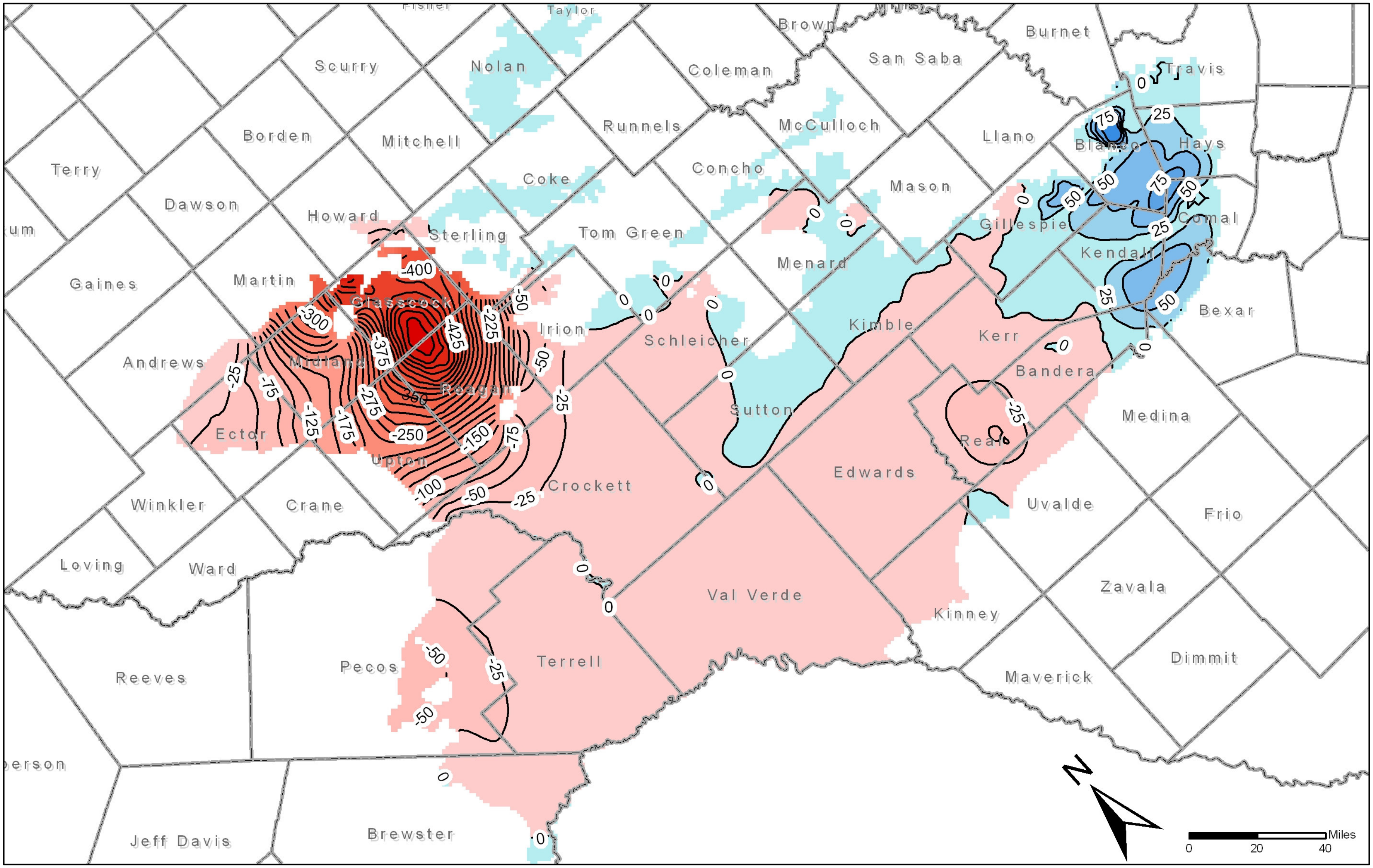

Figure 6. Changes in water levels after 50 years using baseline pumpage in Layer 2 (Trinity Aquifer). Drawdowns are in feet. Contour interval is 25 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue.

Appendix A

Summary of Historic Pumpage in the GAM for the Edwards-Trinity (Plateau) Aquifer

Table A-1. Summary of estimated historic pumpage included in the GAM for the Edwards-Trinity (Plateau) Aquifer (in acre-feet per year).

Year	Total	Andrews	Bandera	Bexar	Blanco	Brewster	Burnet	Coke	Comal	Concho	Crane	Crockett
1980	379,121	120	1,279	1,378	496	422	114	45	1,542	310	1,806	4,261
1981	364,994	141	1,278	1,596	497	441	151	38	1,545	302	1,781	3,611
1982	356,716	151	1,321	1,794	495	459	187	30	1,520	292	1,884	3,251
1983	347,054	149	1,332	1,938	501	477	225	23	1,539	282	1,795	3,145
1984	340,116	151	1,389	2,269	506	496	262	16	1,563	272	1,738	2,647
1985	271,602	121	1,400	1,312	503	783	445	17	1,619	218	1,154	2,597
1986	278,298	92	1,408	1,603	572	847	273	14	1,719	215	1,179	2,489
1987	232,727	45	1,553	1,690	579	905	271	14	1,858	238	1,027	2,267
1988	245,783	25	1,645	1,811	608	940	273	16	1,829	203	1,298	2,678
1989	293,971	85	1,742	1,859	616	500	155	15	1,946	202	1,266	2,809
1990	253,341	55	1,777	1,893	646	530	161	15	2,123	242	1,182	2,569
1991	252,105	62	1,842	1,871	657	537	164	16	2,231	250	1,029	2,529
1992	232,077	85	1,778	1,922	697	443	162	21	2,306	314	626	2,279
1993	615,941	85	2,030	1,962	713	459	135	19	2,452	328	686	2,642
1994	355,640	85	1,993	2,046	699	719	102	19	2,586	266	812	2,846
1995	395,983	94	2,021	2,175	748	679	109	21	2,702	277	793	2,618
1996	371,986	91	2,108	2,055	712	623	106	19	2,768	254	759	2,552
1997	363,611	95	2,143	2,056	736	631	103	18	2,871	271	665	2,571
1998	405,601	86	2,256	2,298	724	631	110	16	2,915	265	768	3,264
1999	312,456	67	2,331	2,399	744	671	114	16	3,059	265	558	3,070

Table A-1. continued

Year	Culberson	Ector	Edwards	Gillespie	Glasscock	Hays	Howard	Irion	Jeff Davis	Kendall	Kerr	Kimble
1980	43	10,583	1,302	1,519	37,954	1,419	177	1,203	162	1,819	6,051	1,071
1981	40	10,596	1,101	1,517	38,818	1,467	168	1,043	151	1,864	3,599	981
1982	37	9,478	1,023	1,519	39,681	1,540	193	895	140	1,906	3,314	917
1983	34	9,577	916	1,539	40,541	1,656	204	755	130	2,008	3,172	909
1984	31	9,184	816	1,561	41,402	1,895	210	622	120	2,241	3,726	828
1985	34	9,199	775	1,547	24,167	1,792	204	512	128	1,988	3,784	814
1986	28	8,139	683	1,608	47,195	1,889	223	586	95	1,942	3,311	923
1987	45	8,341	712	1,455	39,381	2,038	191	646	75	1,906	2,991	888
1988	48	8,421	773	1,437	29,695	2,026	183	627	85	2,417	3,279	901
1989	47	8,726	846	1,844	30,967	2,123	249	703	131	2,422	3,790	750
1990	46	8,689	852	1,907	26,988	1,981	266	1,008	129	2,310	3,420	748
1991	47	9,096	851	1,973	35,426	2,007	258	1,015	132	2,147	3,416	783
1992	31	8,841	878	2,095	24,636	1,997	270	1,000	131	2,177	3,903	791
1993	29	9,681	1,020	2,212	39,165	2,204	197	1,148	115	2,802	4,263	761
1994	26	5,595	1,050	3,465	50,123	2,369	267	408	111	2,858	4,043	790
1995	21	5,538	1,007	3,481	59,280	2,530	337	432	95	3,058	3,972	843
1996	23	5,596	946	3,970	47,649	2,719	345	370	95	3,303	4,595	806
1997	25	3,727	876	3,395	45,315	2,655	481	417	91	3,377	4,210	746
1998	34	2,992	941	3,340	53,774	3,151	365	362	134	3,375	4,207	748
1999	37	3,425	1,005	2,305	21,338	2,818	585	367	141	3,515	4,181	794

Table A-1. continued

Year	Kinney	Loving	Martin	Mason	McCulloch	Medina	Menard	Midland	Nolan	Pecos	Reagan	Real
1980	8,150	52	71	3	33	64	593	6,712	394	110,679	23,670	678
1981	8,091	45	72	3	33	62	540	7,758	375	106,985	25,578	562
1982	8,035	38	75	3	32	59	487	8,760	359	103,830	27,788	625
1983	7,979	32	77	3	31	57	439	9,575	341	100,556	29,996	640
1984	7,923	26	79	3	29	55	392	10,354	324	97,039	32,599	435
1985	4,110	28	78	3	31	50	392	9,731	343	85,700	22,338	419
1986	4,464	30	76	3	27	51	519	8,543	246	71,226	23,782	425
1987	2,102	31	74	3	25	55	488	5,533	227	65,161	20,098	436
1988	2,635	33	74	3	27	54	471	9,500	255	64,021	22,259	444
1989	9,057	29	71	3	26	60	431	10,366	347	71,054	32,913	823
1990	5,946	30	85	3	27	58	465	11,705	305	67,911	36,668	722
1991	5,960	31	85	3	26	58	501	7,789	269	64,879	31,482	732
1992	4,903	43	88	3	33	63	639	9,852	234	63,820	24,118	444
1993	7,741	42	90	3	32	73	610	11,299	379	78,239	23,790	571
1994	6,359	55	89	3	31	67	968	14,521	105	74,592	30,975	599
1995	5,098	53	92	3	31	73	917	21,140	120	85,511	41,659	596
1996	6,832	42	88	3	29	74	826	17,485	151	79,210	42,496	589
1997	5,929	53	90	3	31	72	813	12,816	116	81,160	45,099	497
1998	5,376	45	95	3	30	66	757	16,411	105	83,052	61,816	488
1999	3,838	32	94	3	29	69	922	18,163	89	81,733	19,951	501

Table A-1. continued

Year	Reeves	Schleicher	Sterling	Sutton	Taylor	Terrell	Tom Green	Travis	Upton	Uvalde	Val Verde	Ward	Winkler
1980	112,605	2,179	773	3,656	345	1,361	362	1,926	14,156	617	1,612	8,506	4,848
1981	104,041	2,114	736	3,208	298	1,238	321	2,051	13,686	610	1,421	8,668	3,772
1982	95,286	2,220	687	2,997	250	1,160	286	2,093	13,221	604	4,597	8,338	2,858
1983	87,594	2,222	638	2,757	201	1,009	249	2,255	12,758	600	4,123	8,235	1,839
1984	80,226	2,253	589	2,880	153	990	211	2,432	12,294	596	5,761	7,681	850
1985	62,238	2,260	662	3,097	145	1,136	184	2,458	8,576	570	2,655	7,982	1,305
1986	59,381	2,157	516	2,707	141	1,185	194	2,104	8,747	416	5,659	7,365	1,300
1987	40,758	1,451	405	2,584	141	1,096	184	2,111	7,067	436	5,034	6,712	1,400
1988	49,337	1,647	432	2,708	126	1,351	182	2,243	10,615	418	7,952	6,264	1,514
1989	70,695	2,443	558	2,688	137	1,114	195	2,524	11,672	424	5,867	6,200	479
1990	38,642	1,923	548	2,504	111	1,080	228	2,216	11,404	445	4,238	6,124	416
1991	33,778	1,983	557	2,564	119	1,106	227	2,240	13,546	458	7,479	5,999	1,897
1992	33,624	2,162	617	2,369	187	1,055	270	2,230	12,937	615	6,275	6,200	1,915
1993	380,202	2,400	550	2,840	151	1,111	312	2,299	11,745	593	8,019	7,231	510
1994	103,476	2,723	421	2,876	112	1,109	643	2,249	15,245	570	7,317	6,748	509
1995	107,749	2,353	375	2,933	117	1,015	741	2,349	16,245	569	6,362	6,555	497
1996	101,218	2,541	320	3,434	114	983	508	2,594	15,112	742	7,384	6,243	505
1997	102,090	2,506	360	3,445	97	935	702	2,144	12,737	559	7,284	6,131	468
1998	100,968	3,330	351	1,928	54	1,017	485	2,109	20,603	573	12,154	6,424	601
1999	94,887	3,732	339	3,445	98	1,029	397	1,721	6,073	564	14,562	5,821	559

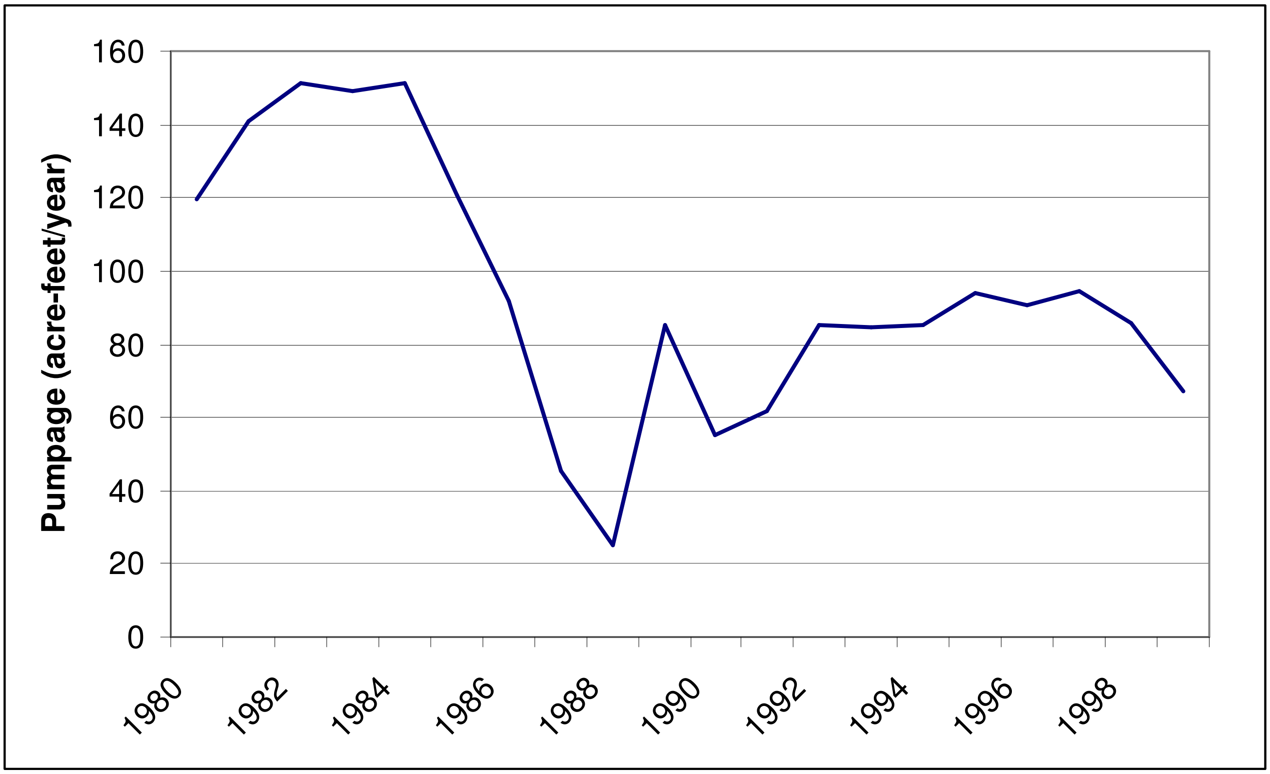

Figure A-1- Pumpage in Andrews County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

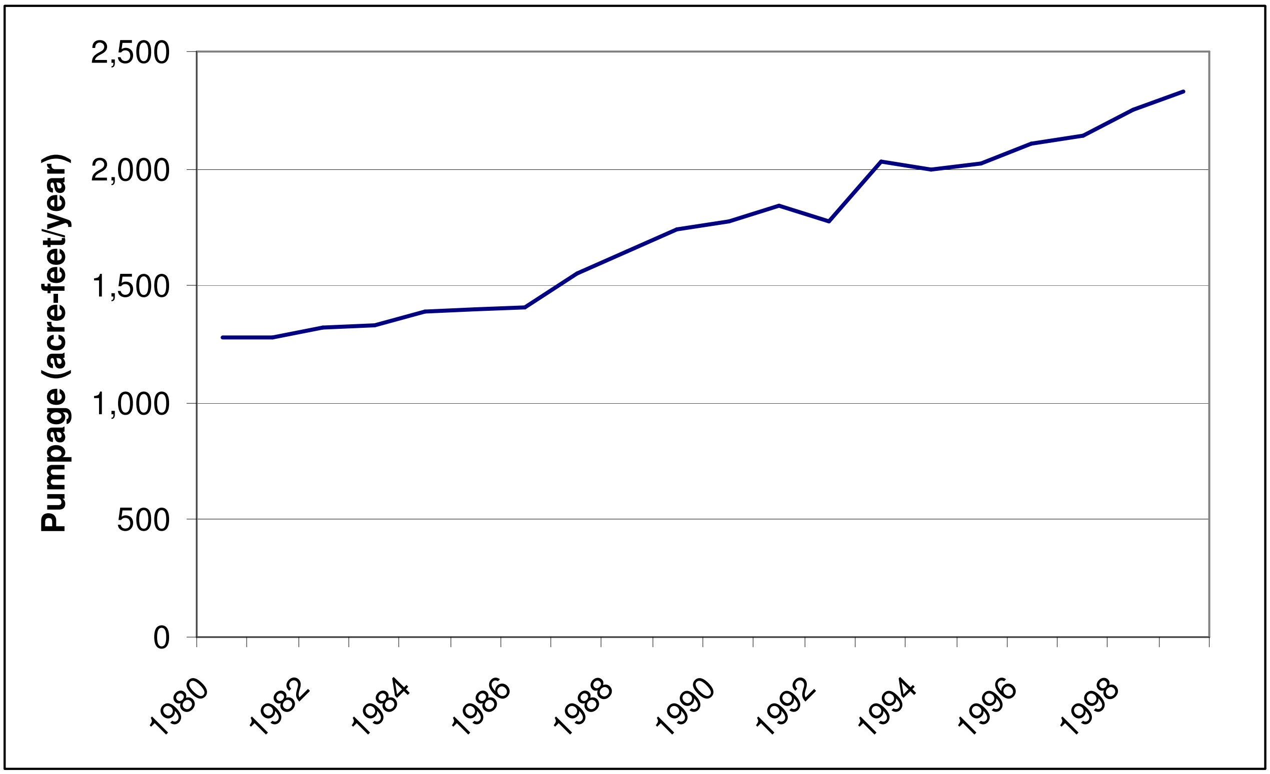

Figure A-2- Pumpage in Bandera County included in GAM for the Edwards-Trinity (Plateau) Aquifer.

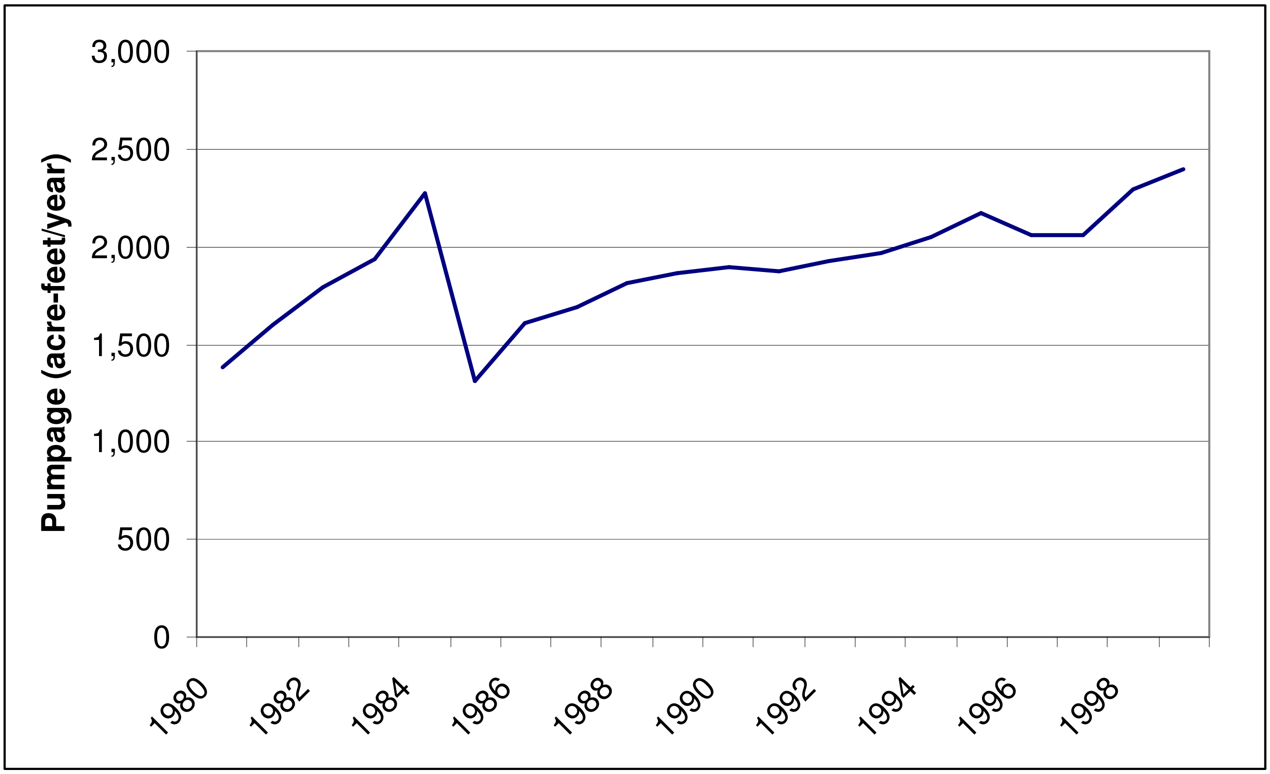

Figure A-3- Pumpage in Bexar County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

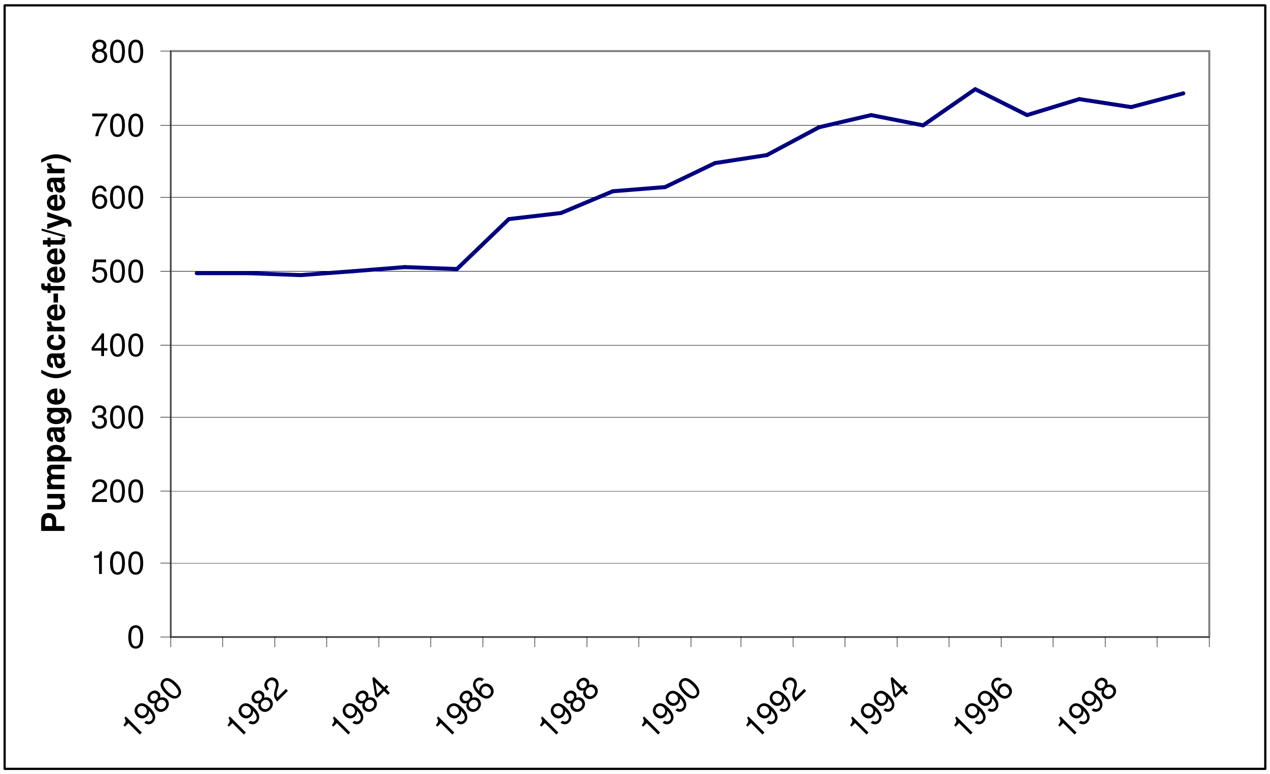

Figure A-4- Pumpage in Blanco County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

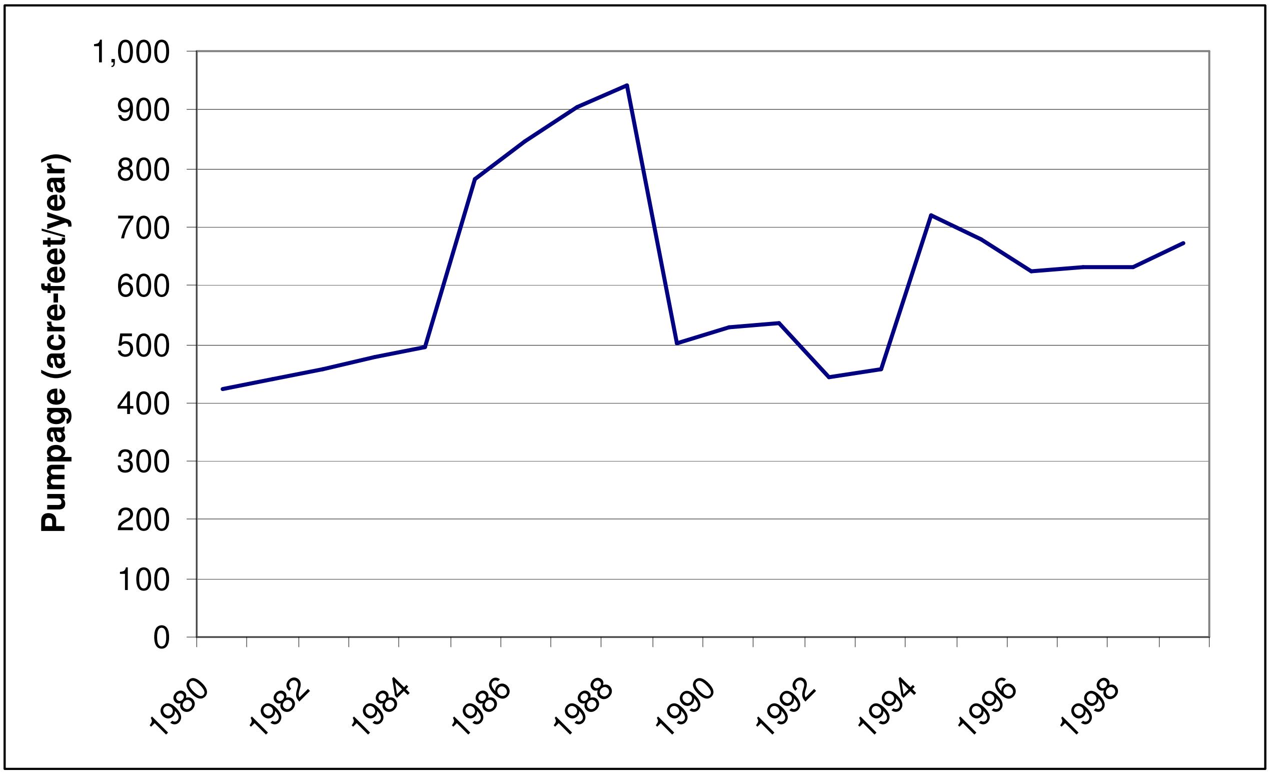

Figure A-5- Pumpage in Brewster County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

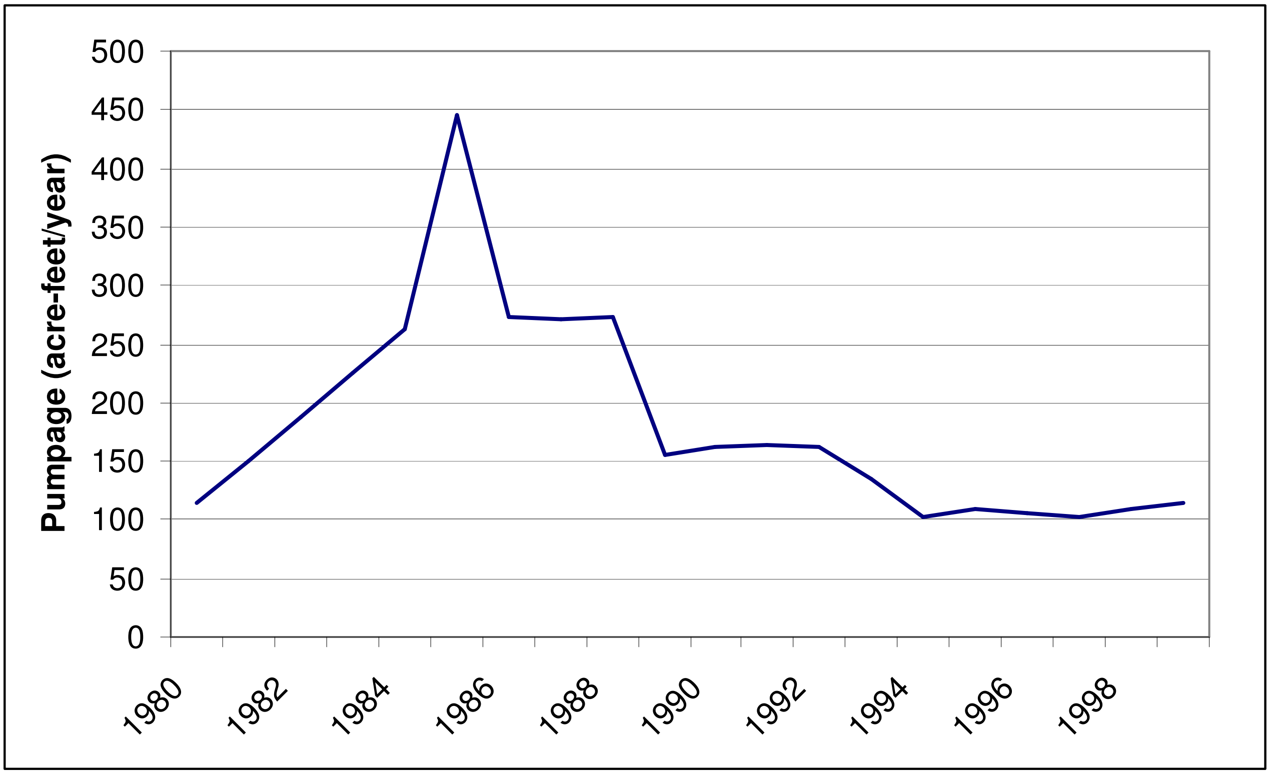

Figure A-6- Pumpage in Burnet County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

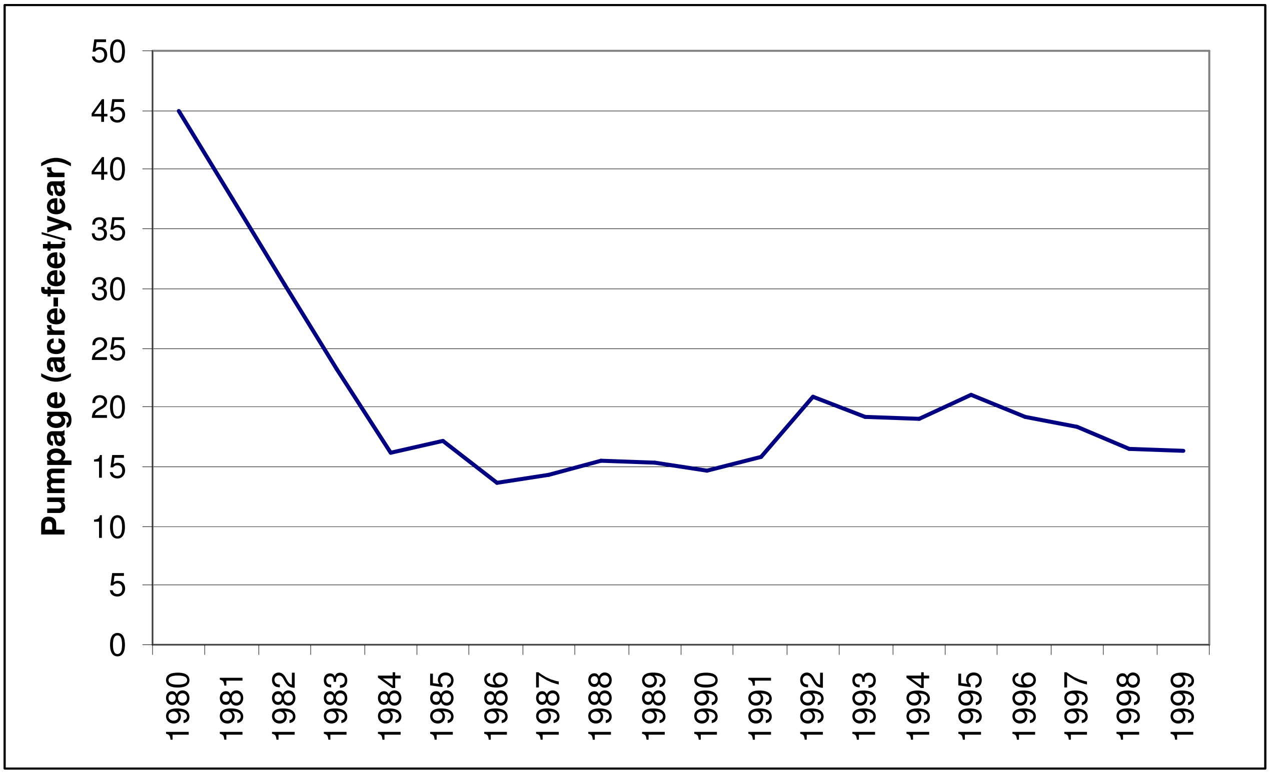

Figure A-7- Pumpage in Coke County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

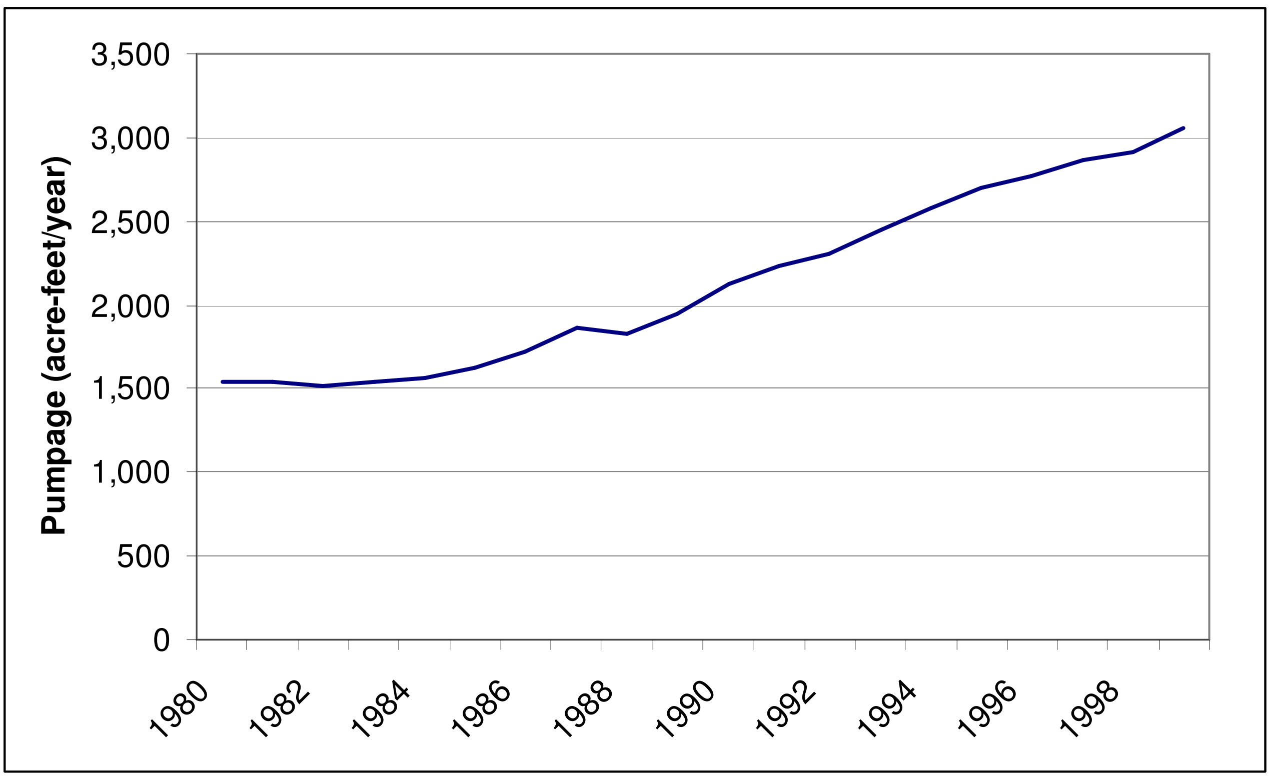

Figure A-8- Pumpage in Comal County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

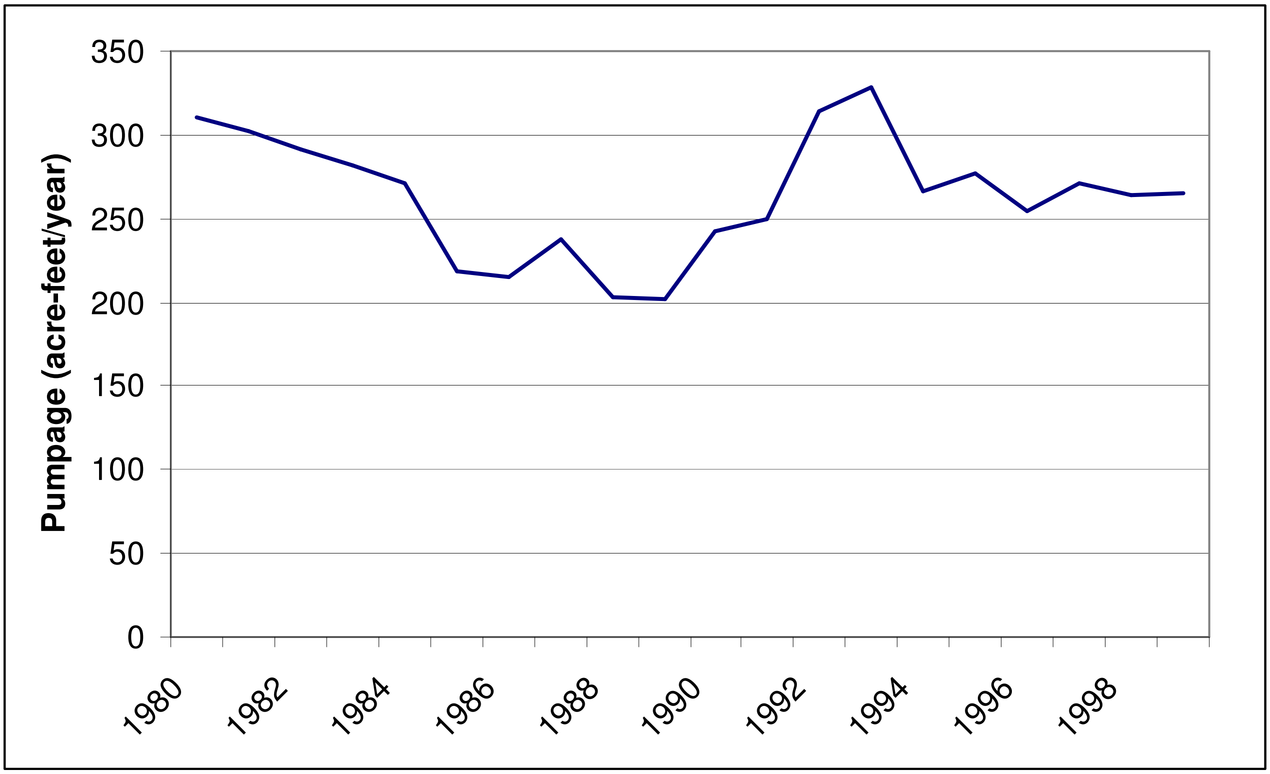

Figure A-9- Pumpage in Concho County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

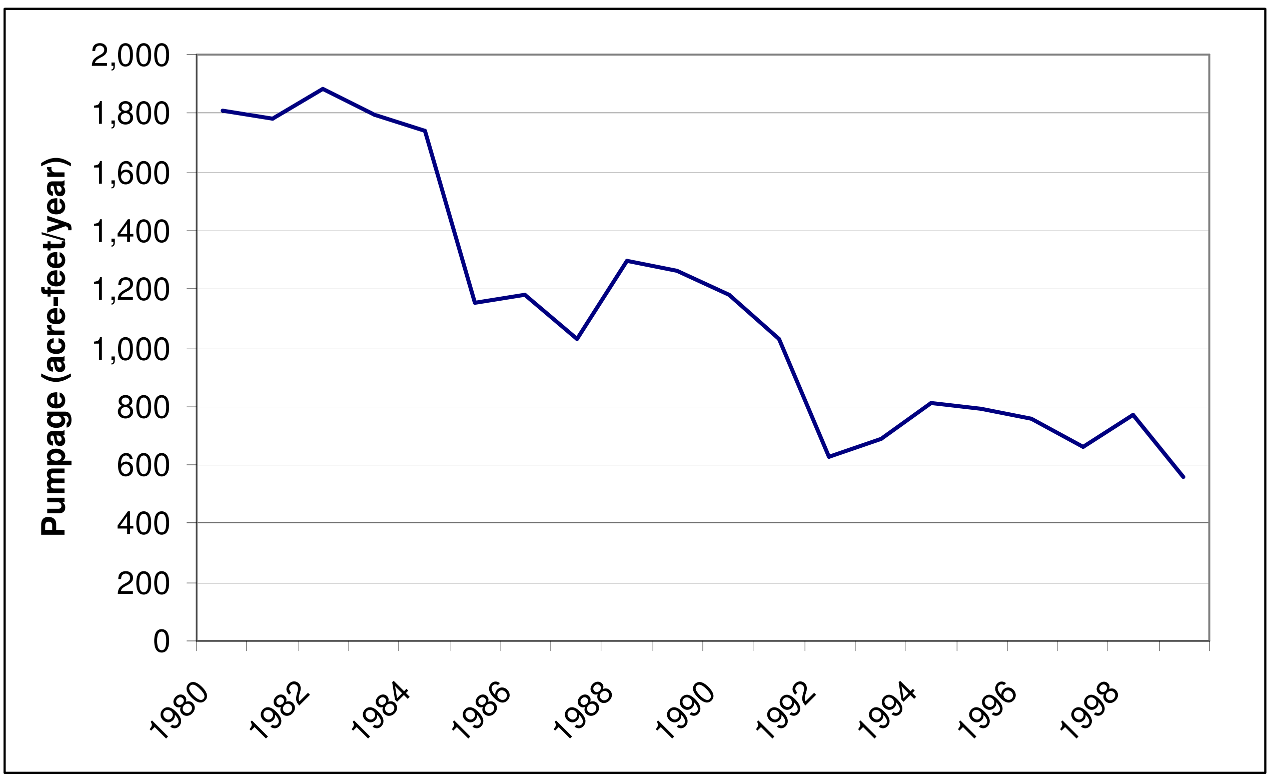

Figure A-10- Pumpage in Crane County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

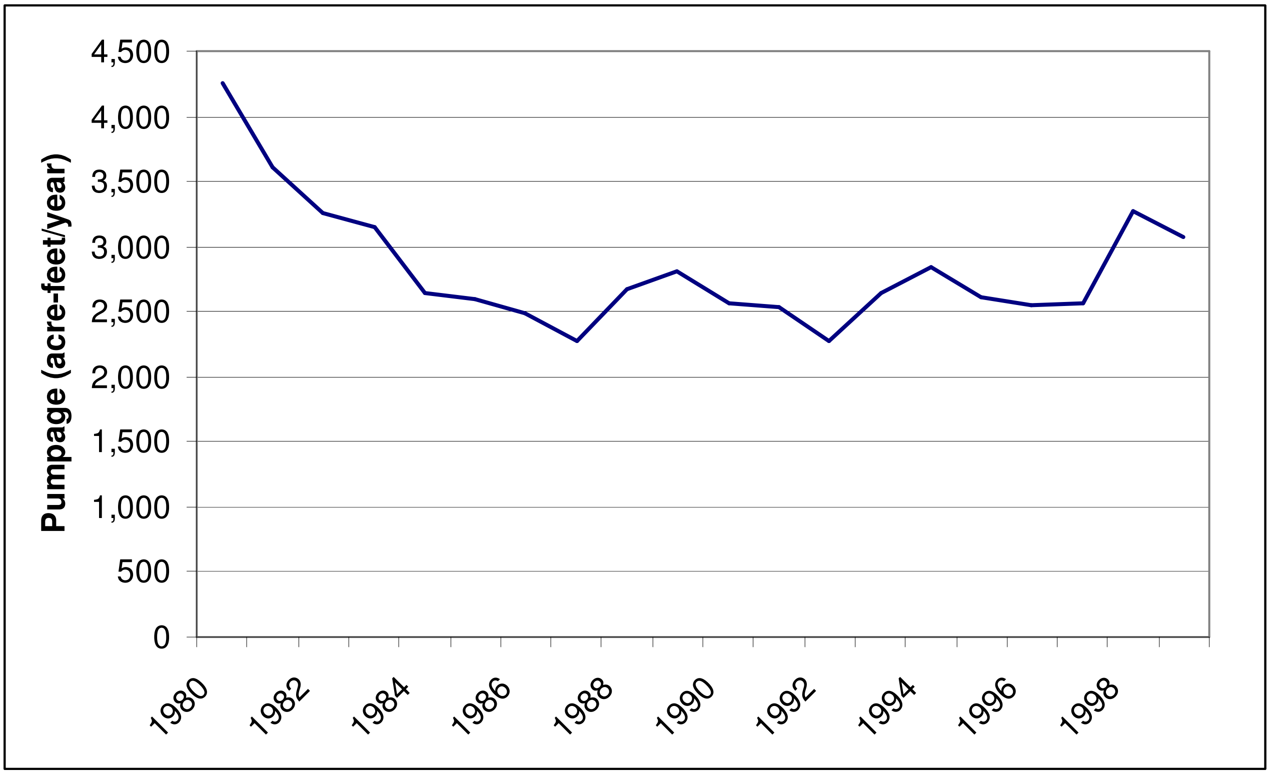

Figure A-11- Pumpage in Crockett County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

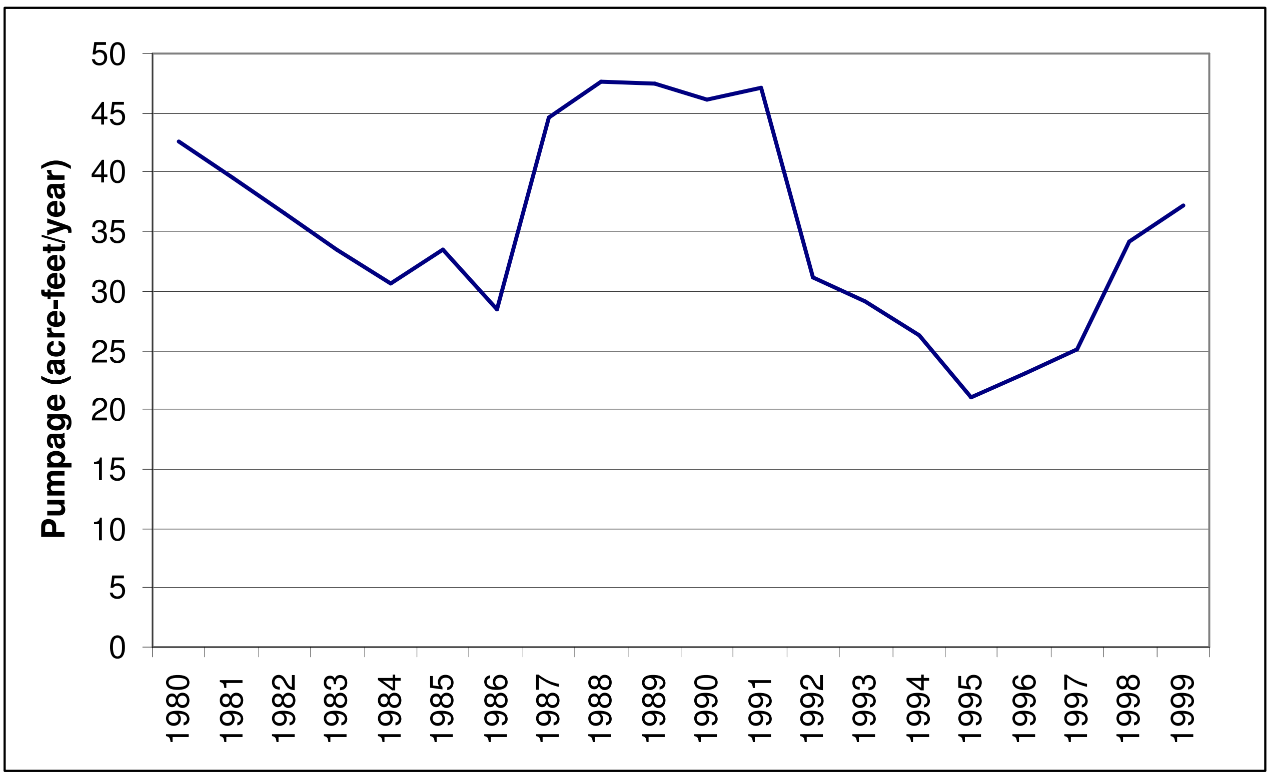

Figure A-12- Pumpage in Culberson County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

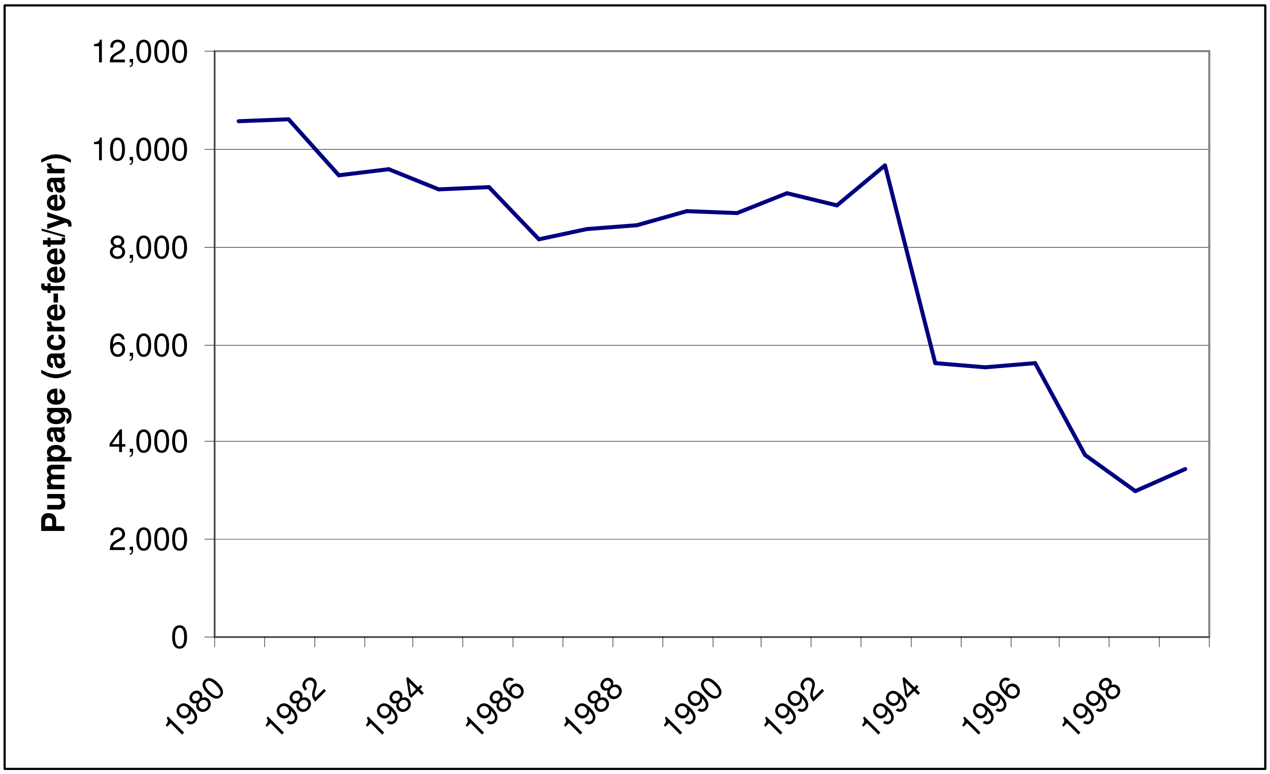

Figure A-13- Pumpage in Ector County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

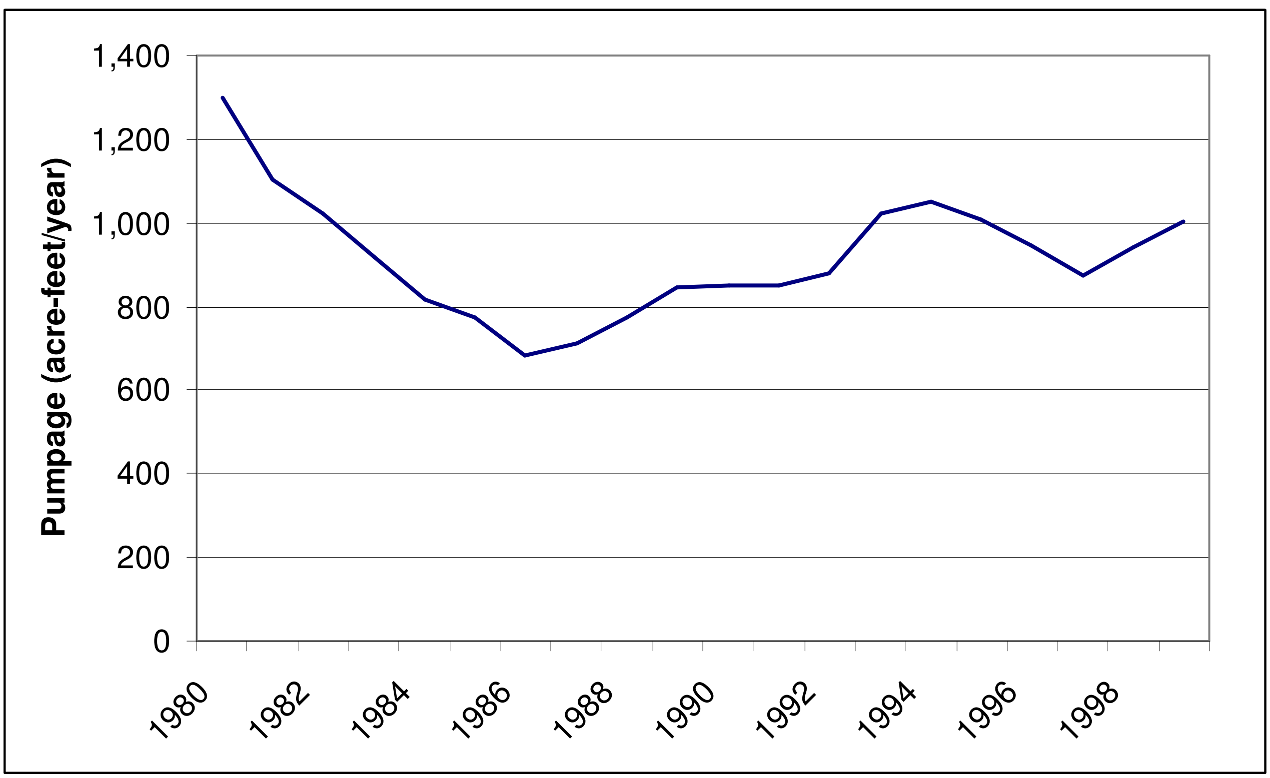

Figure A-14- Pumpage in Edwards County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

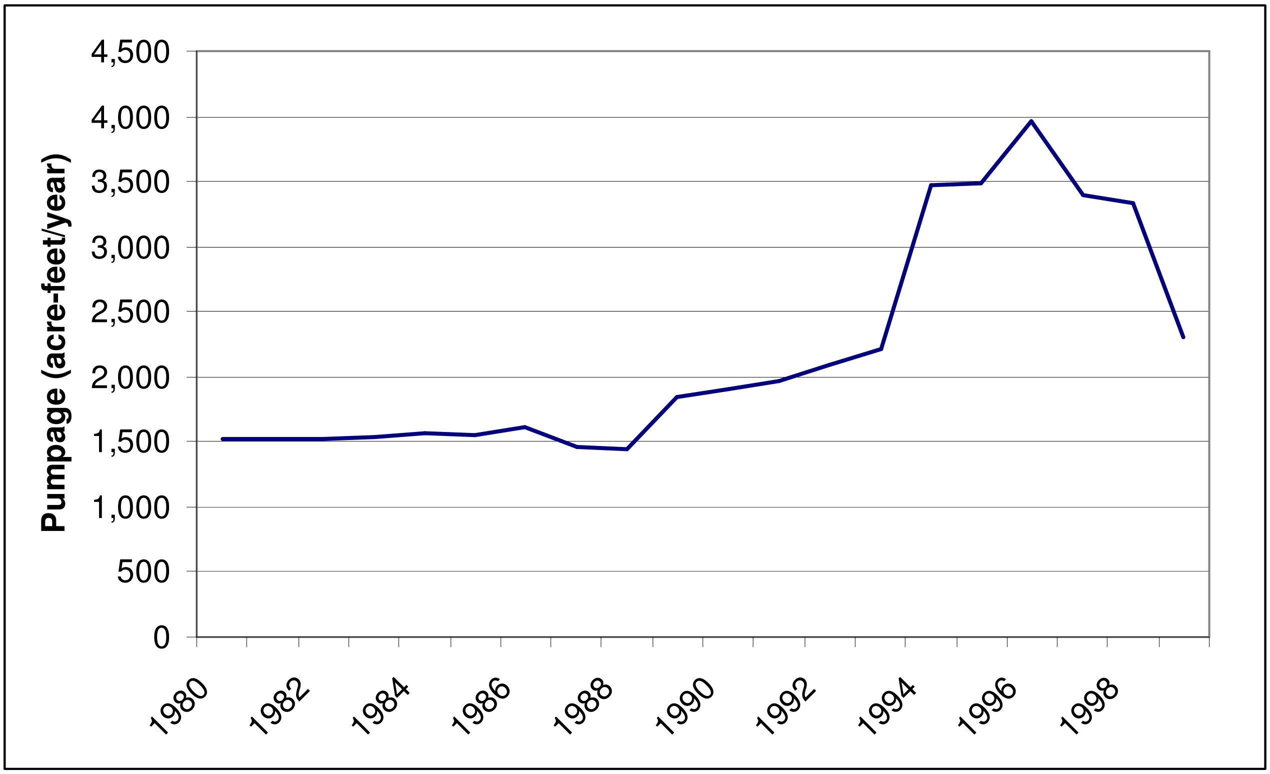

Figure A-15- Pumpage in Gillespie County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

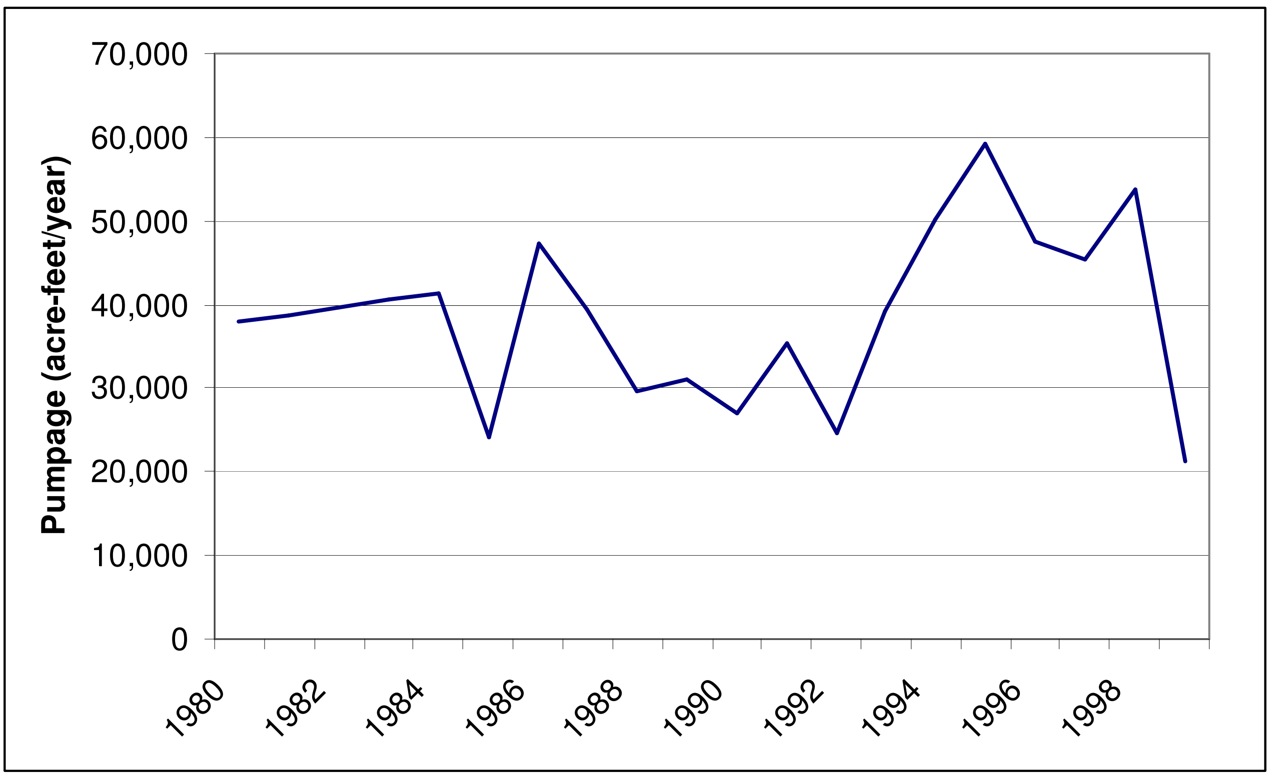

Figure A-16- Pumpage in Glasscock County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

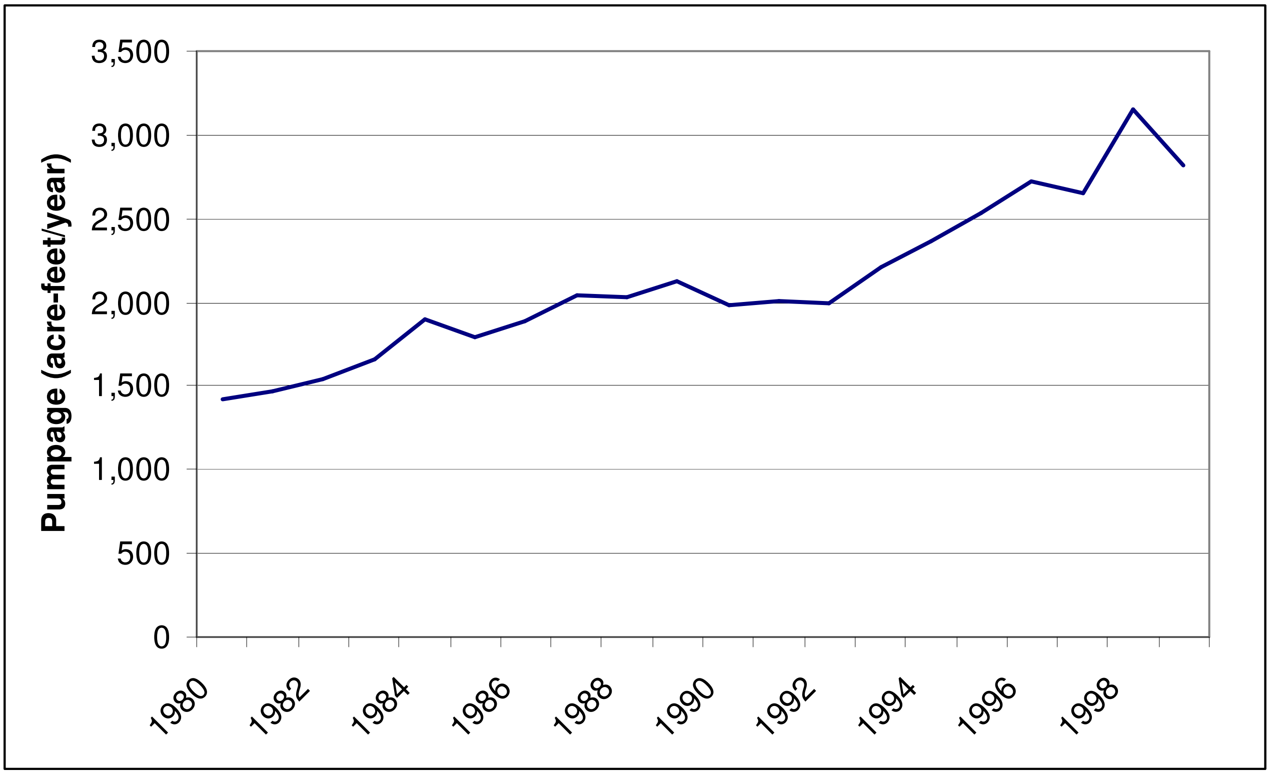

Figure A-17- Pumpage in Hays County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

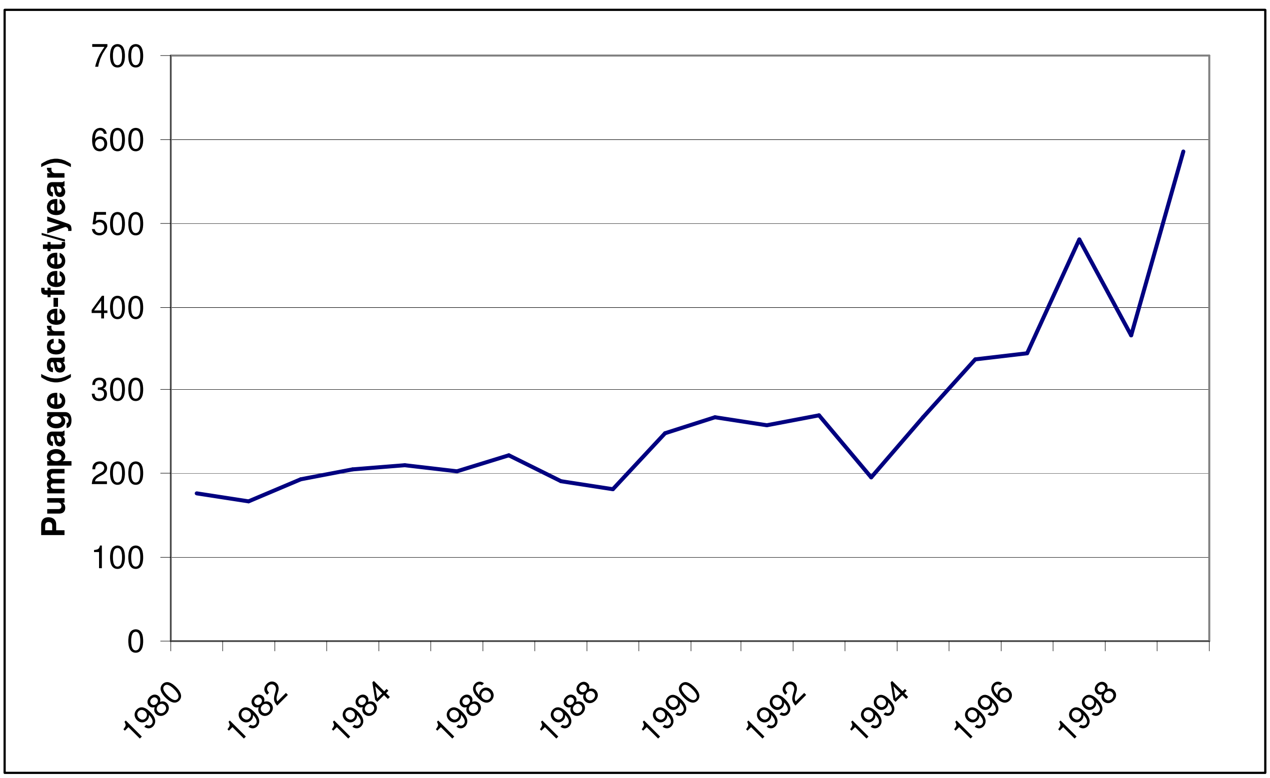

Figure A-18- Pumpage in Howard County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

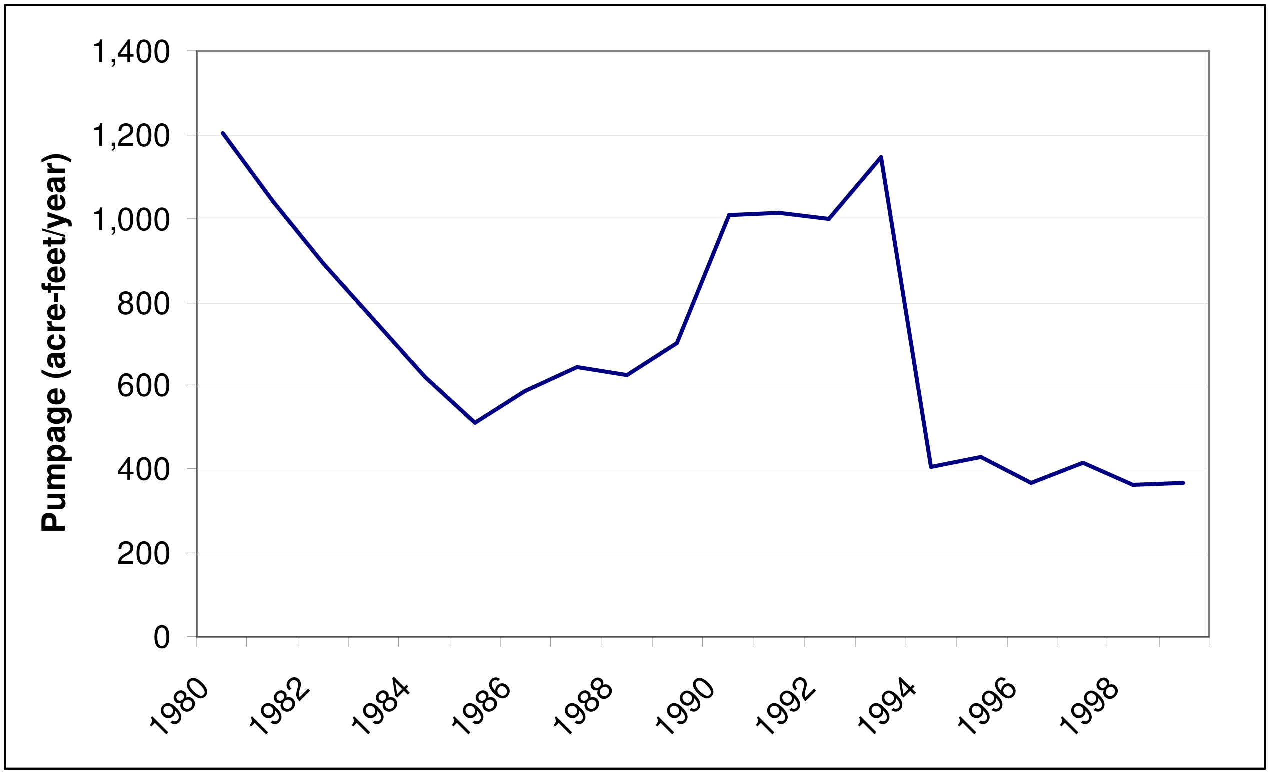

Figure A-19- Pumpage in Irion County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

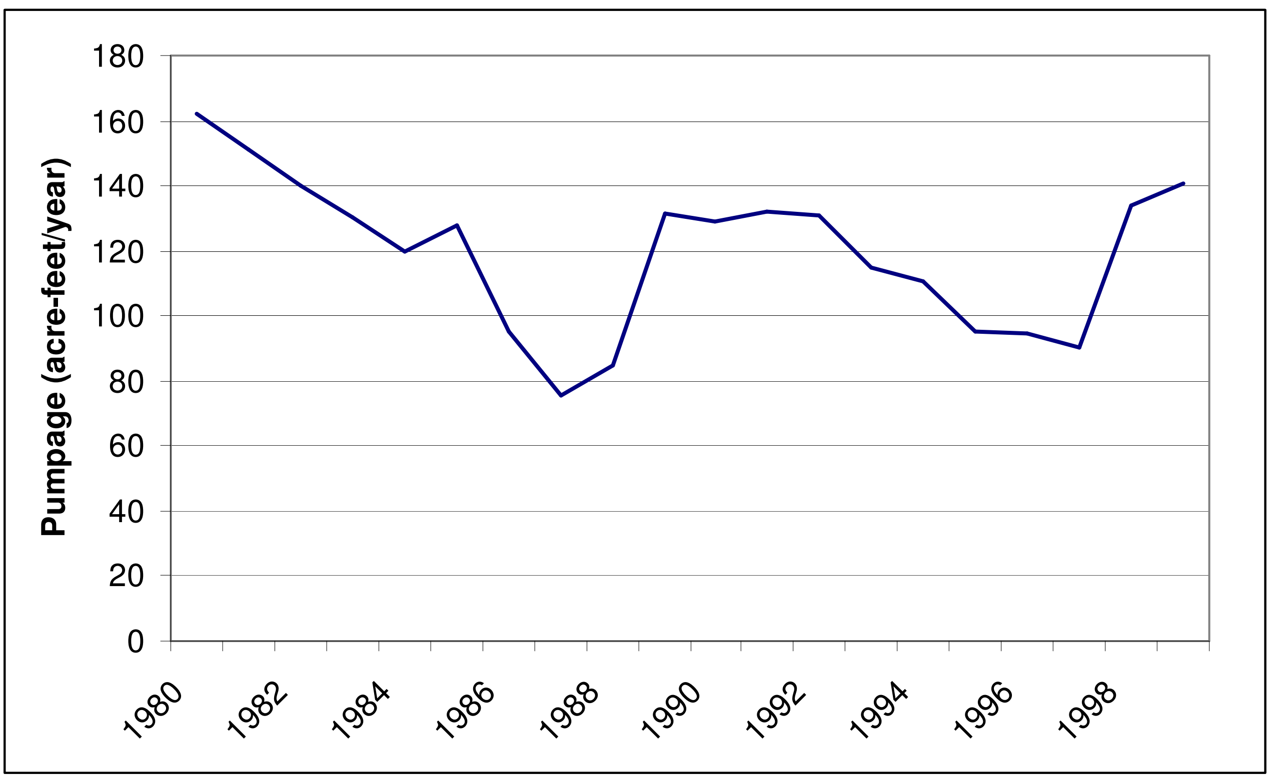

Figure A-20- Pumpage in Jeff Davis County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

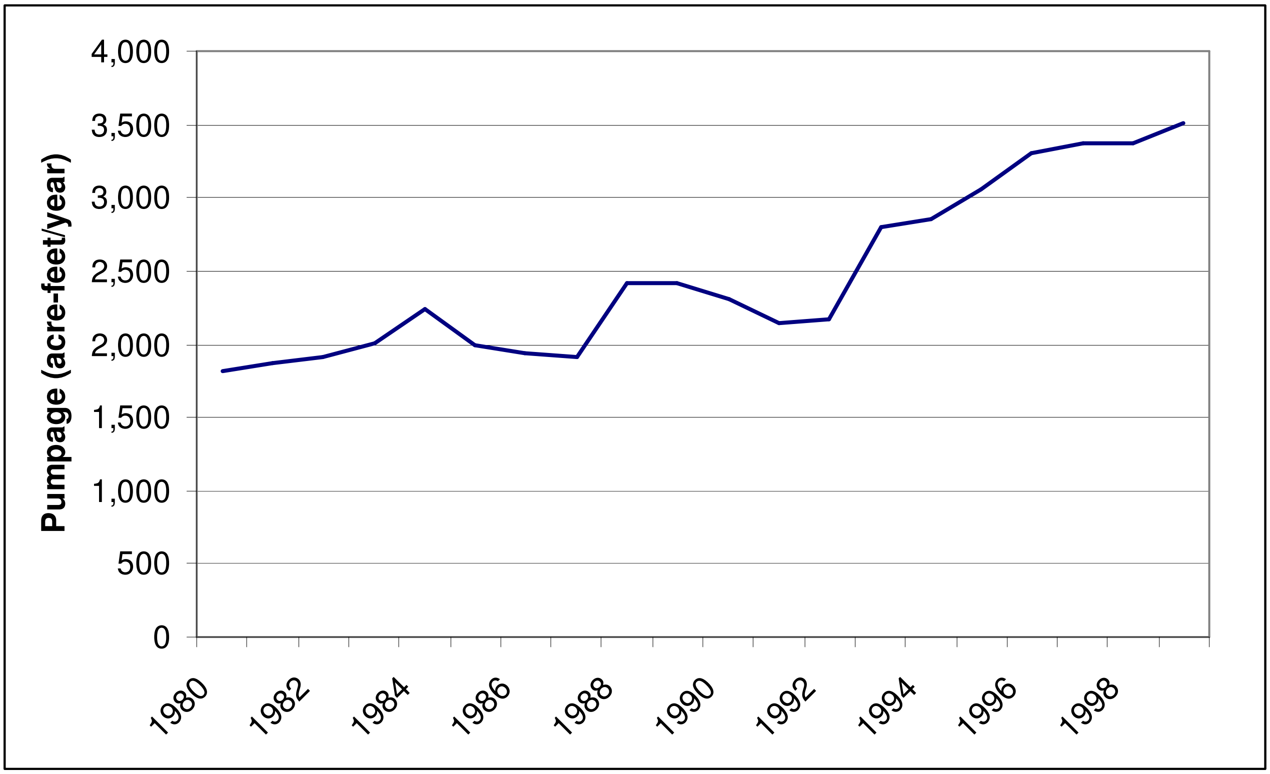

Figure A-21- Pumpage in Kendall County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

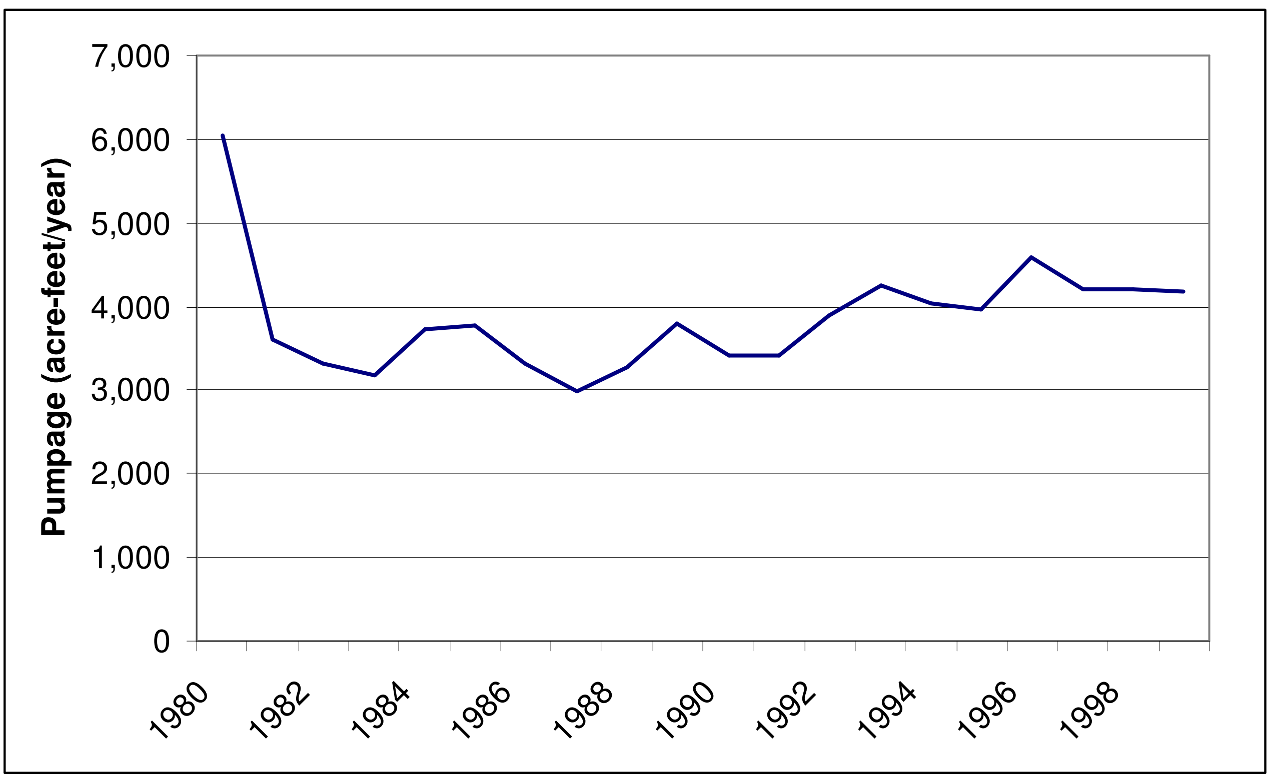

Figure A-22- Pumpage in Kerr County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

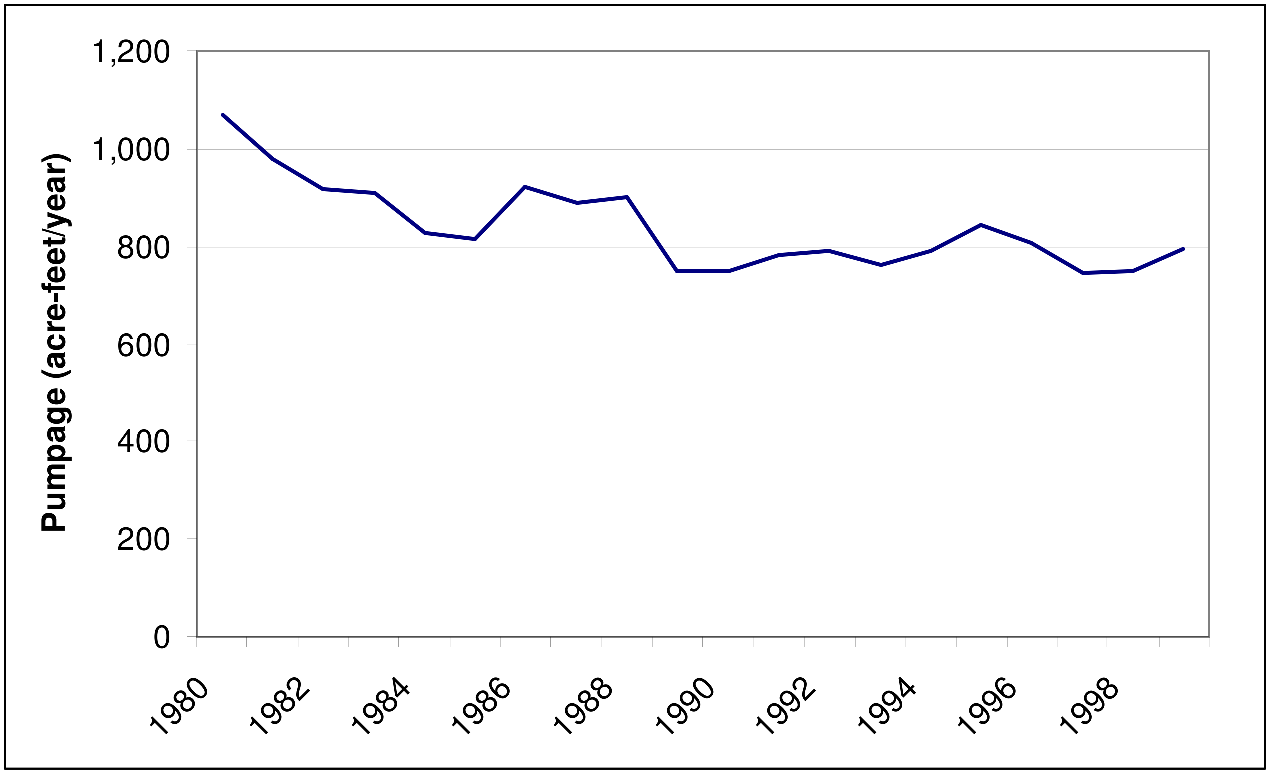

Figure A-23- Pumpage in Kimble County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

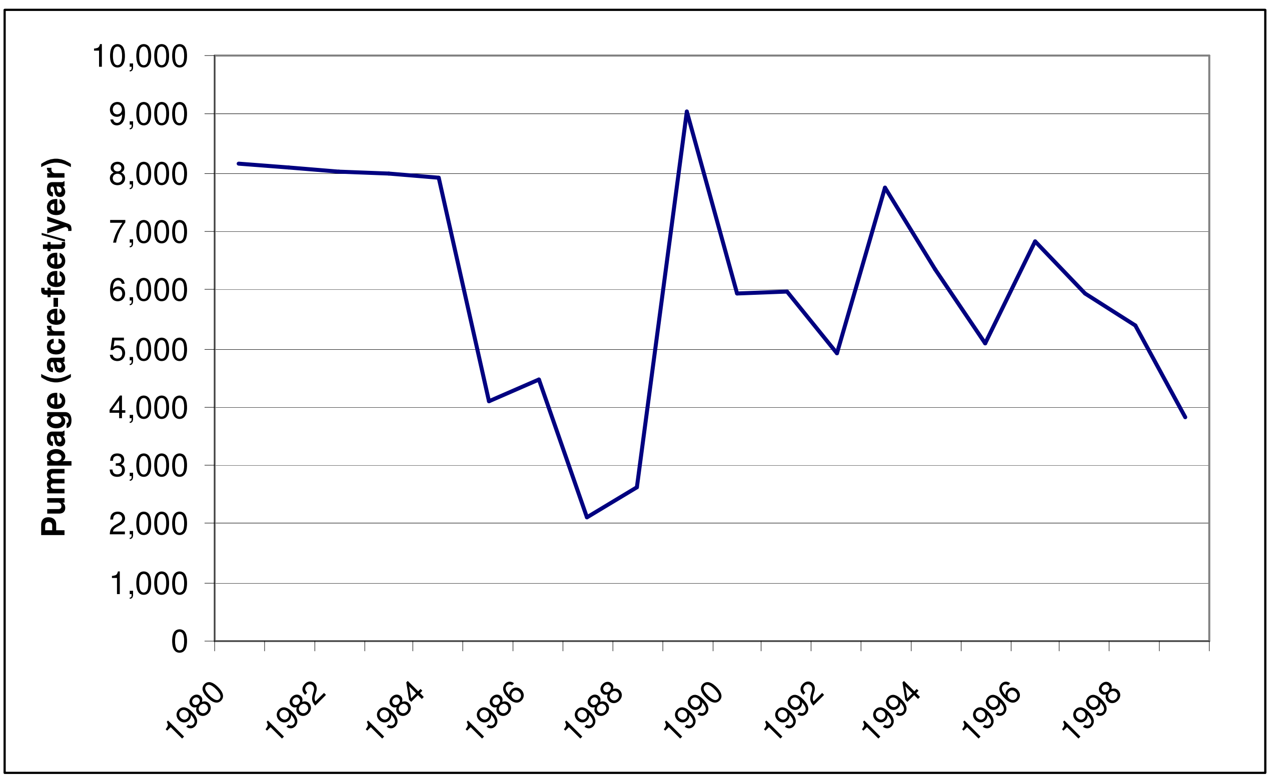

Figure A-24- Pumpage in Kinney County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

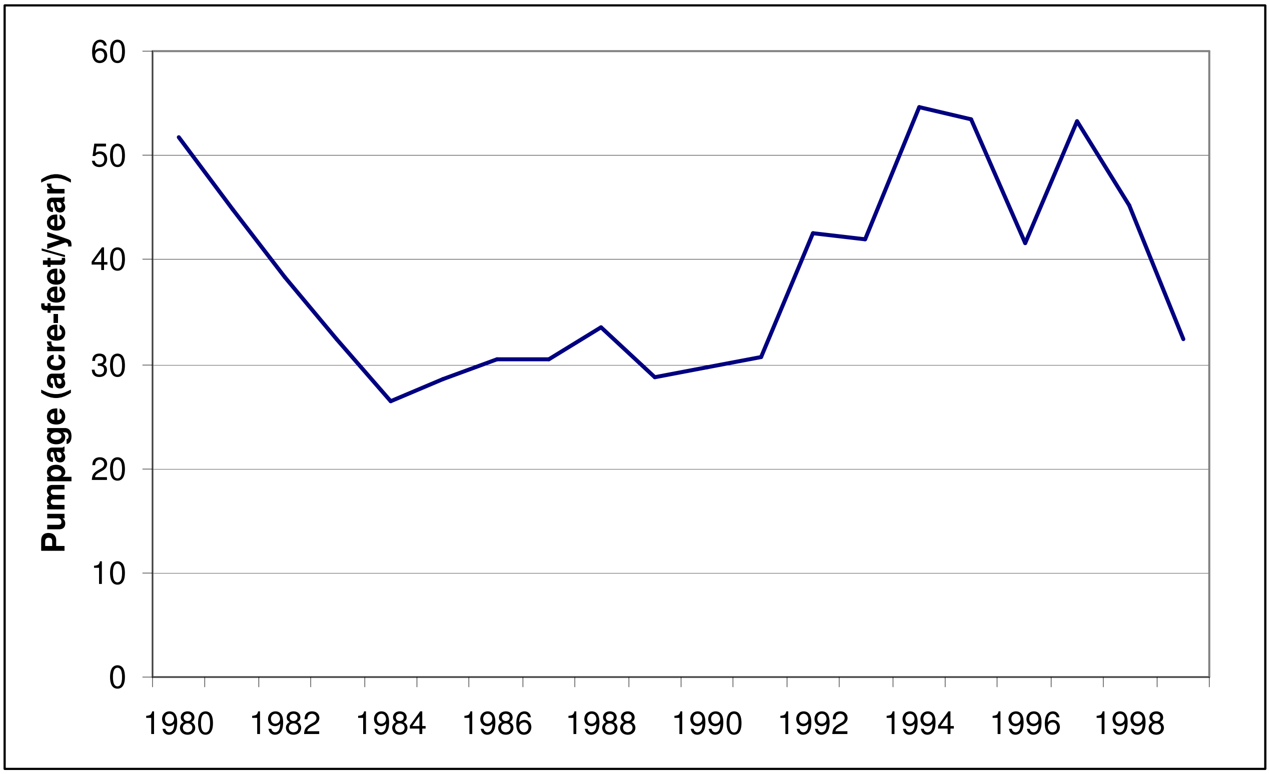

Figure A-25- Pumpage in Loving County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

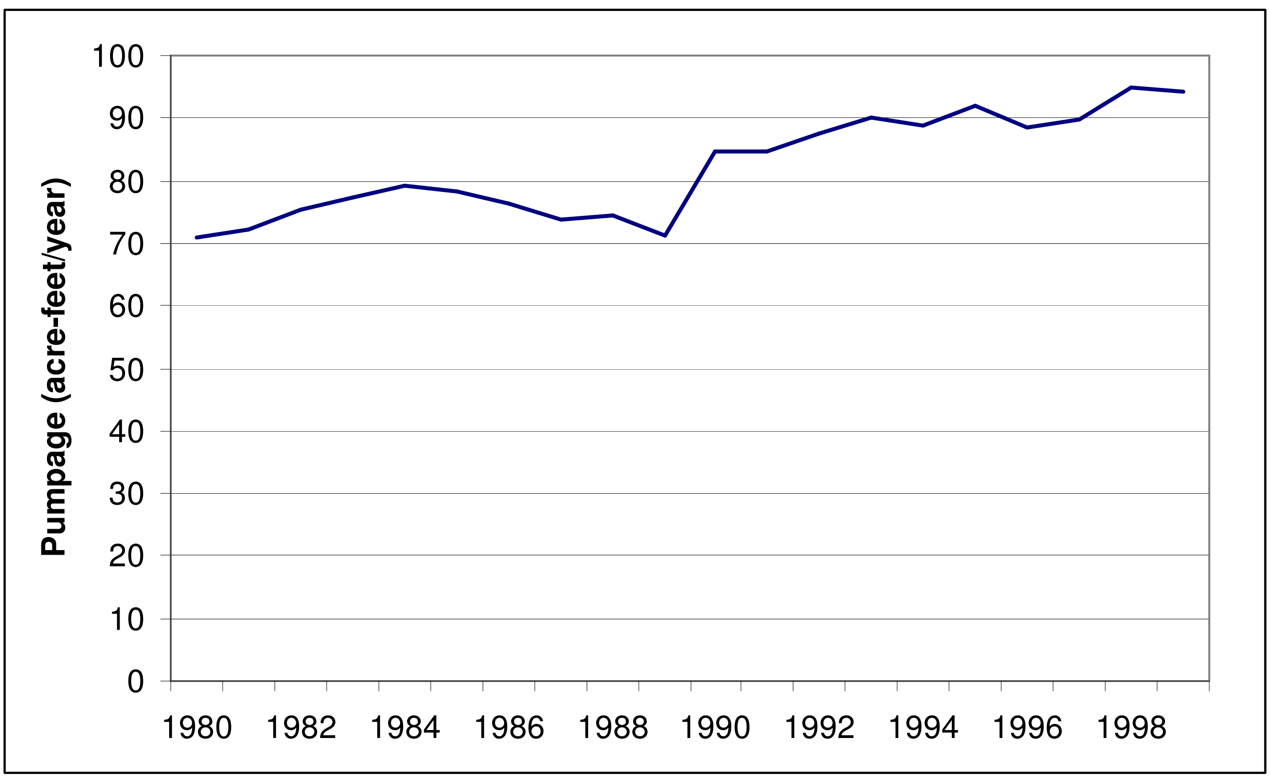

Figure A-26- Pumpage in Martin County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

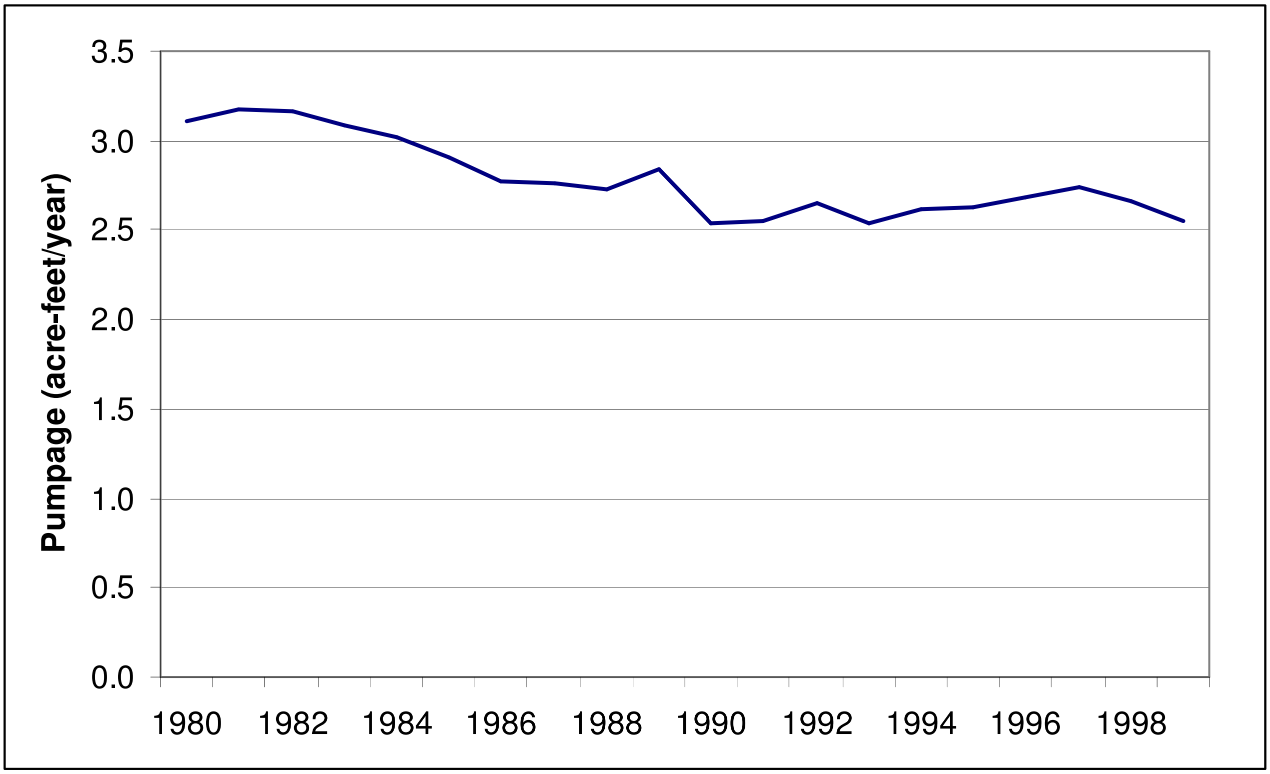

Figure A-27- Pumpage in Mason County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

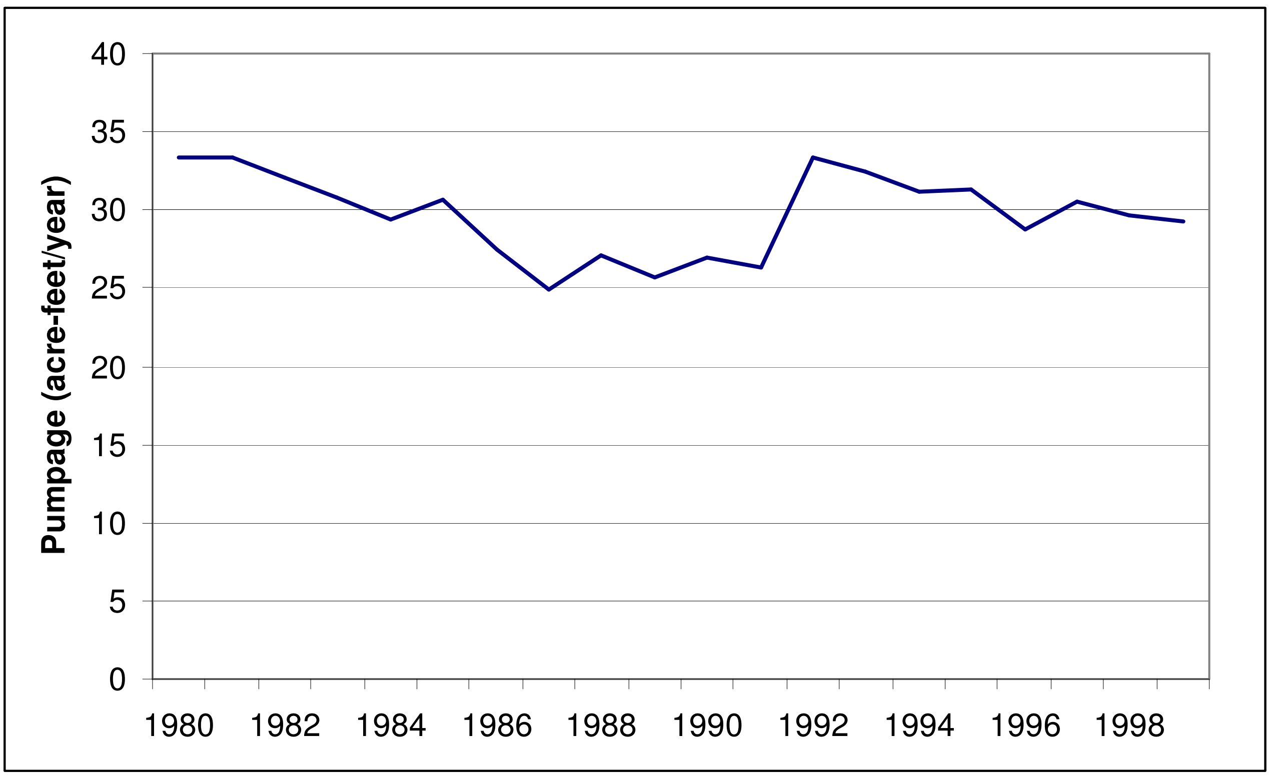

Figure A-28- Pumpage in McCulloch County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

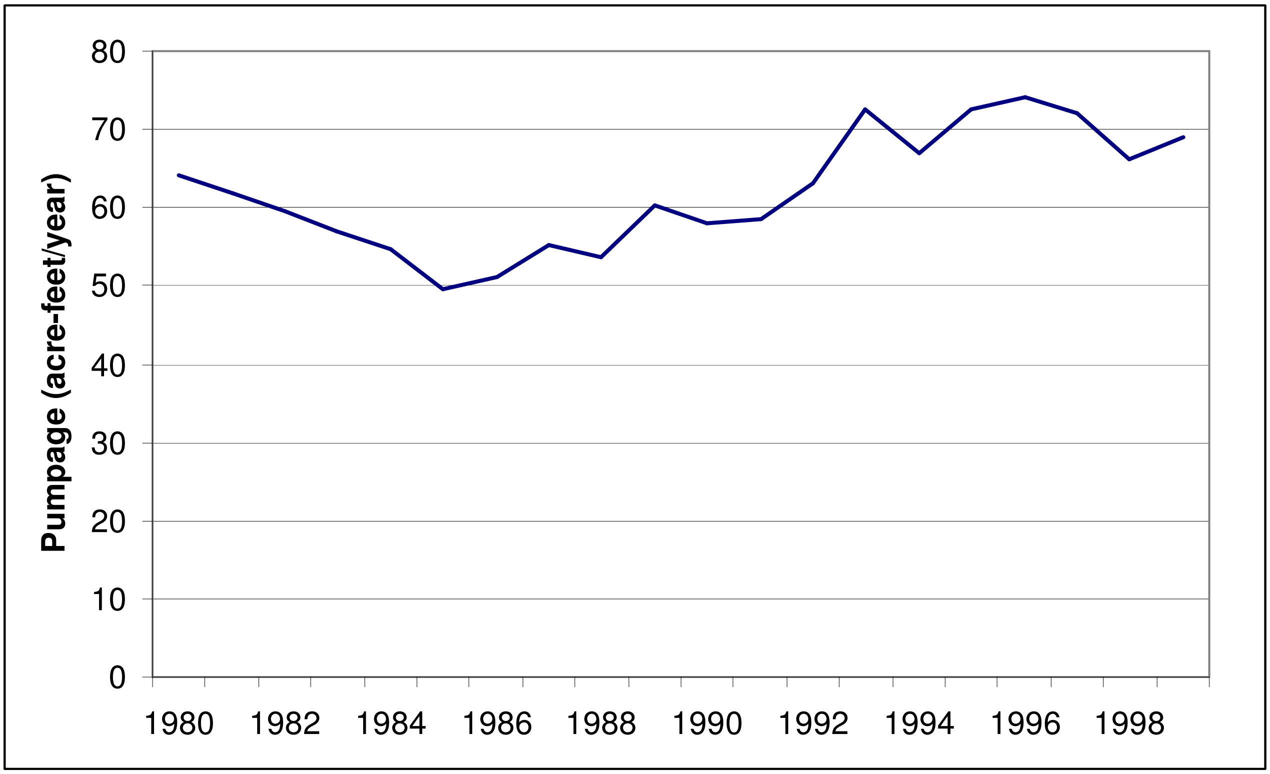

Figure A-29- Pumpage in Medina County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

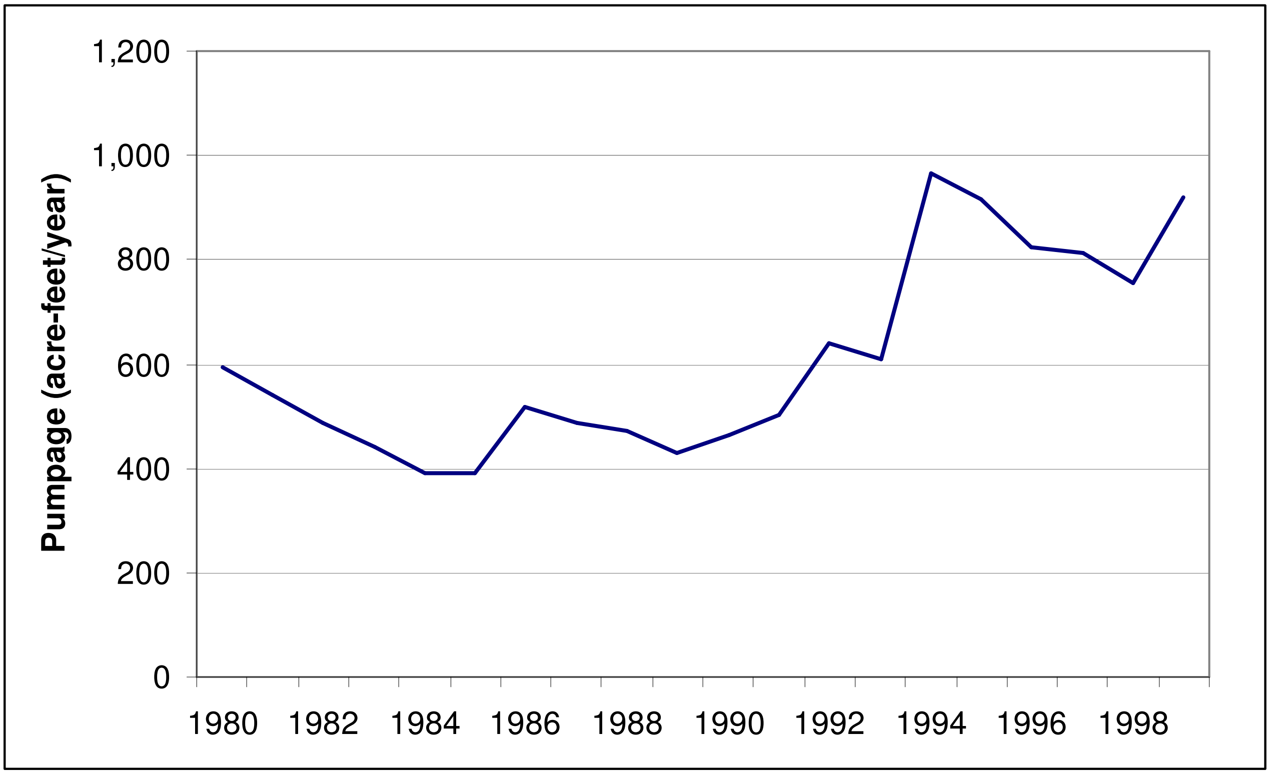

Figure A-30- Pumpage in Menard County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

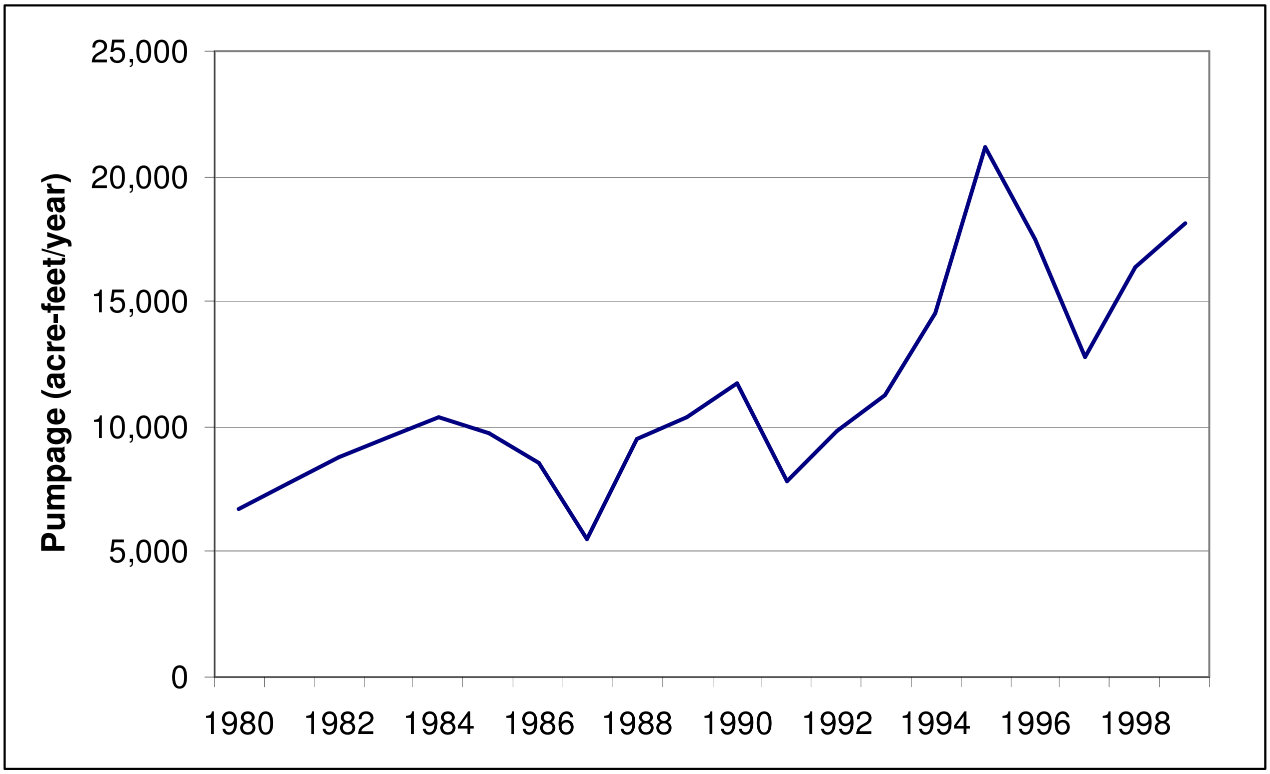

Figure A-31- Pumpage in Midland County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

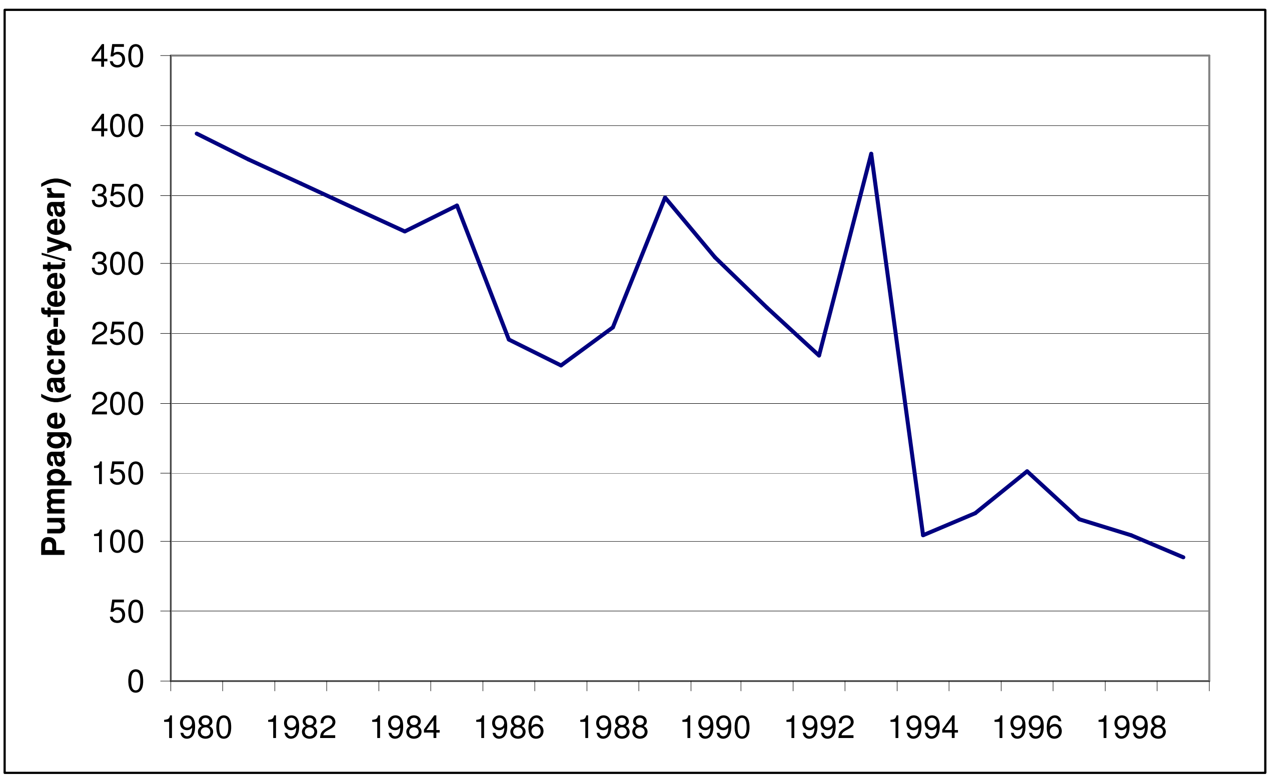

Figure A-32- Pumpage in Nolan County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

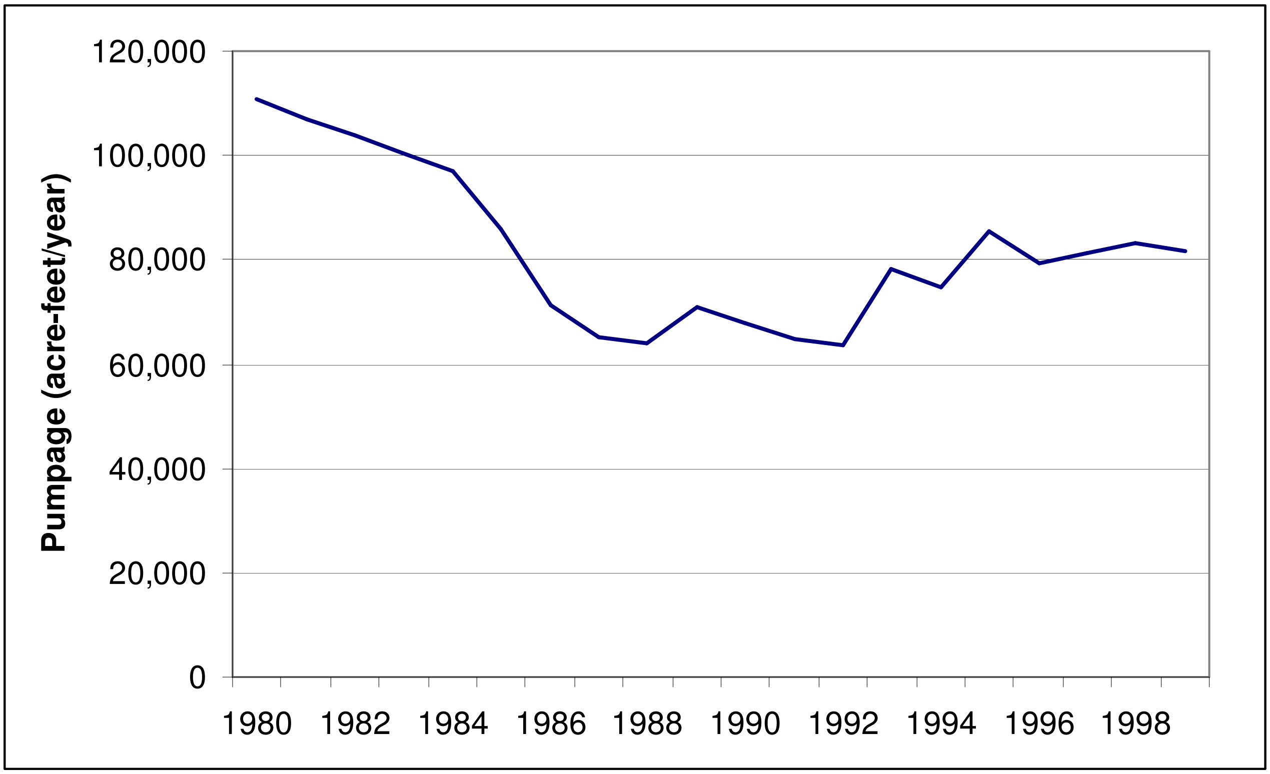

Figure A-33- Pumpage in Pecos County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

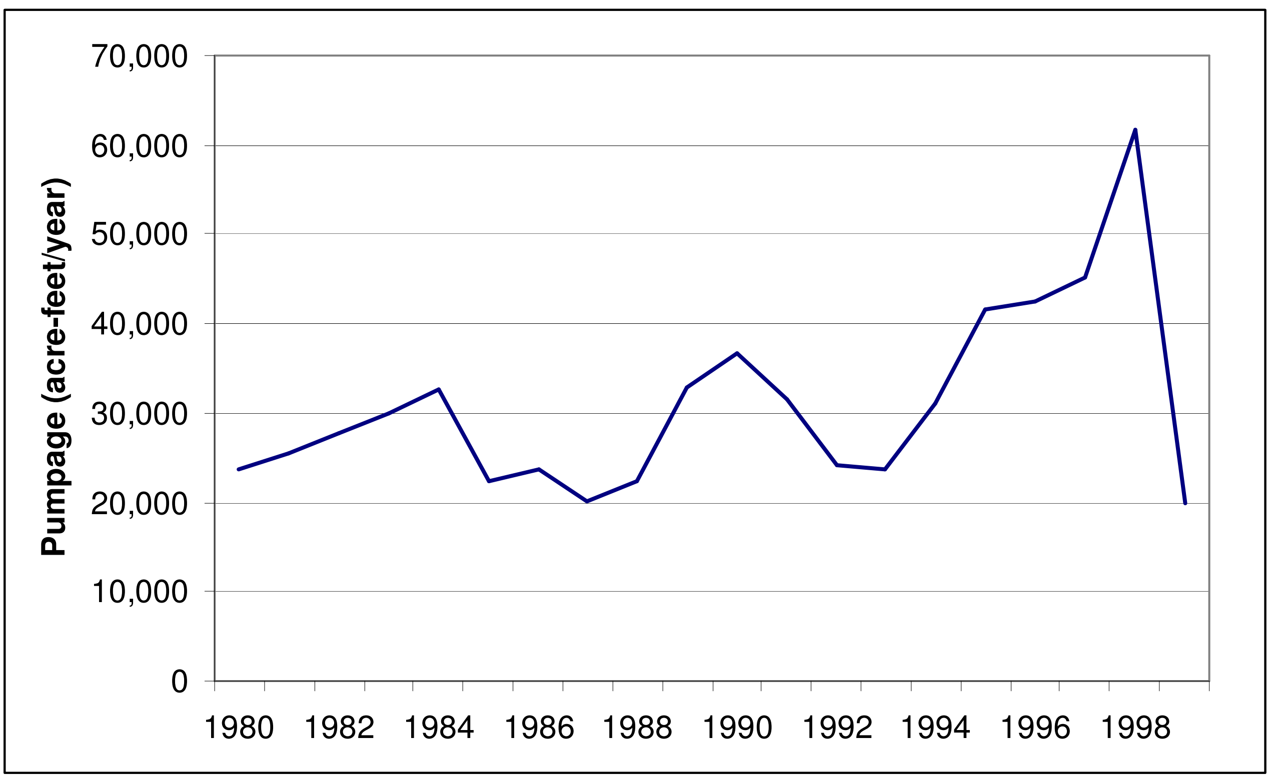

Figure A-34- Pumpage in Reagan County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

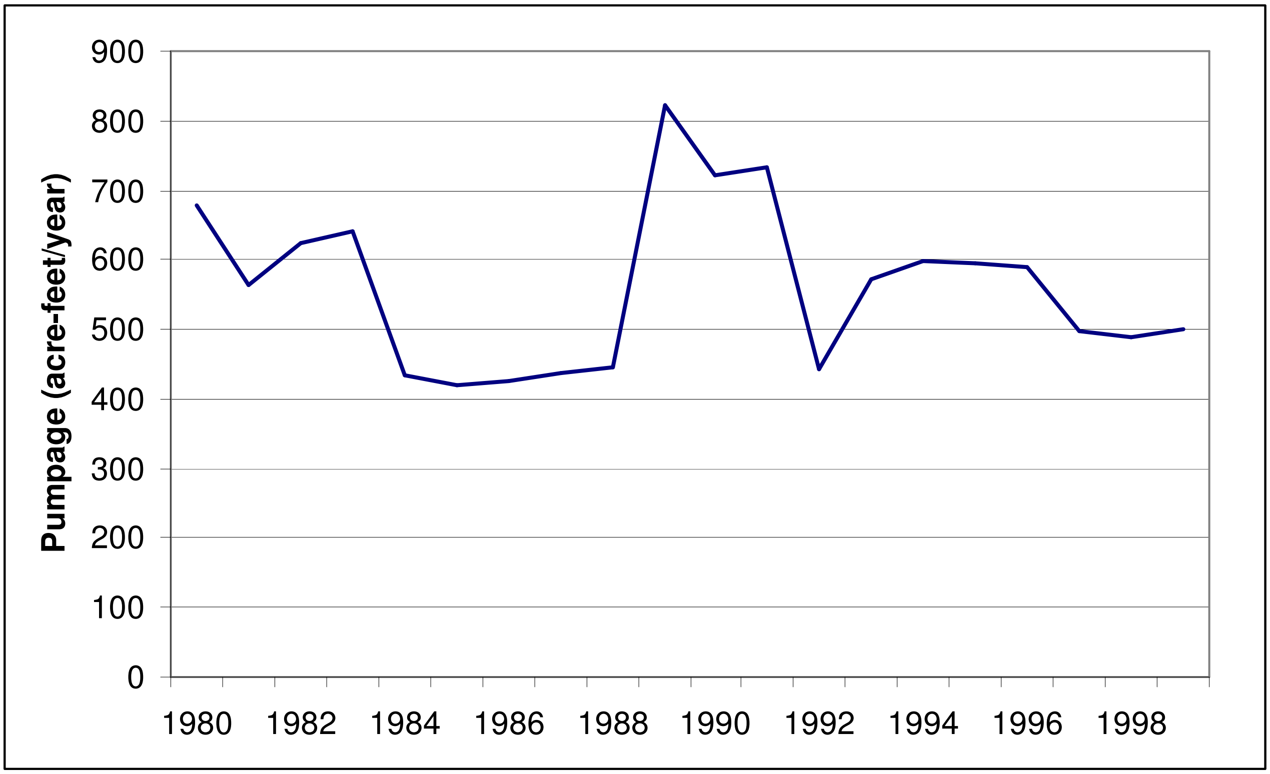

Figure A-35- Pumpage in Real County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

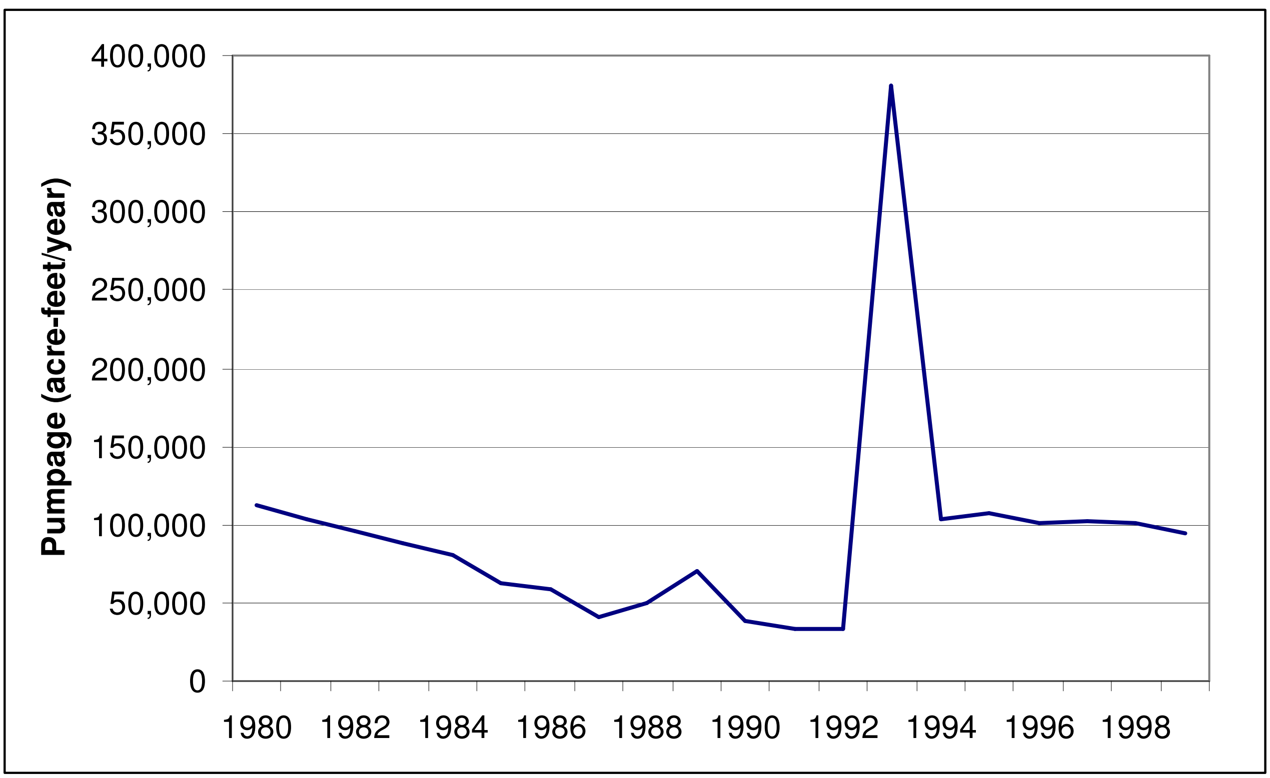

Figure A-36- Pumpage in Reeves County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

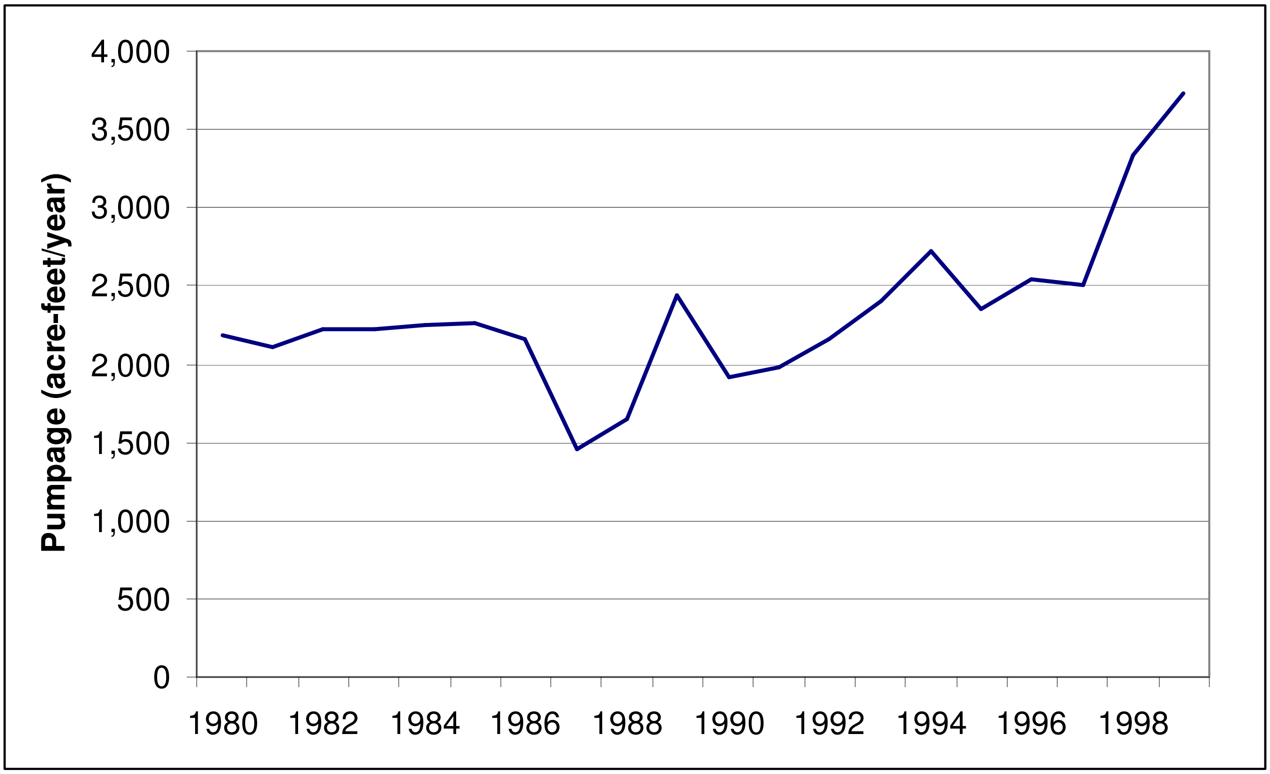

Figure A-37- Pumpage in Schleicher County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

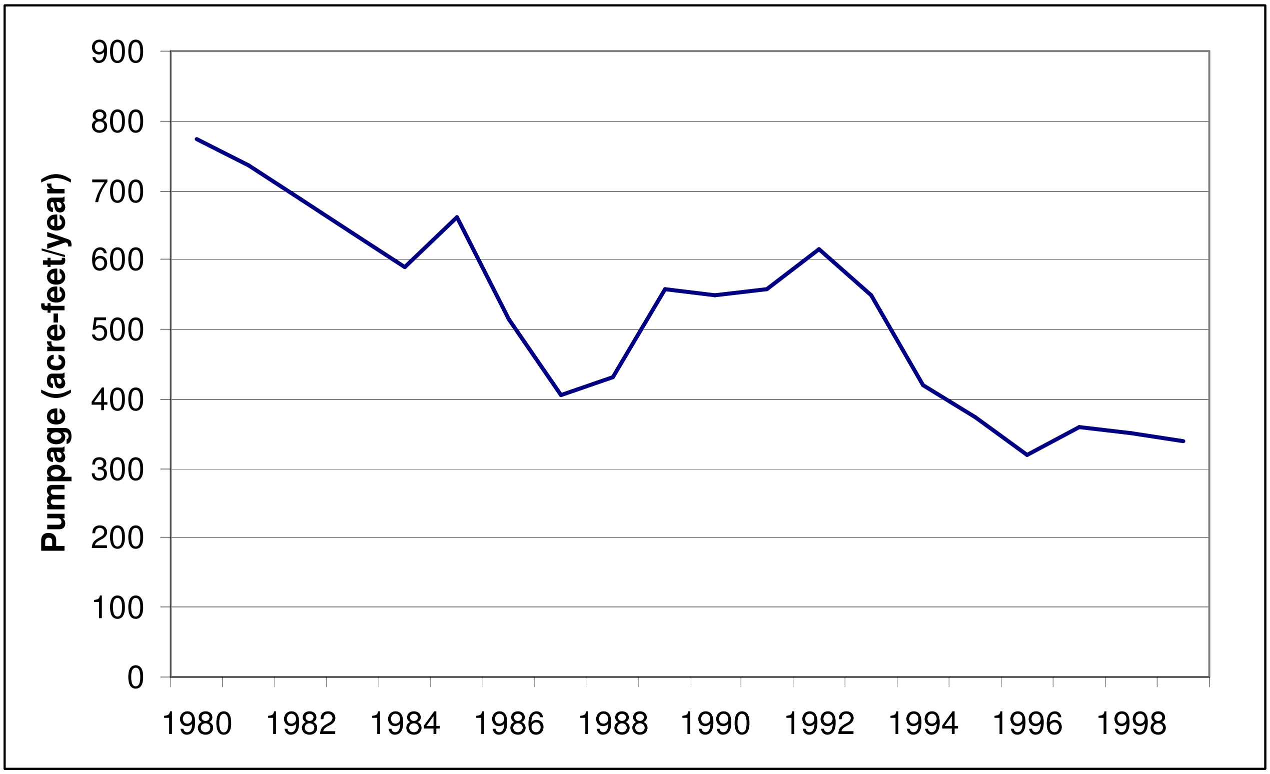

Figure A-38- Pumpage in Sterling County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

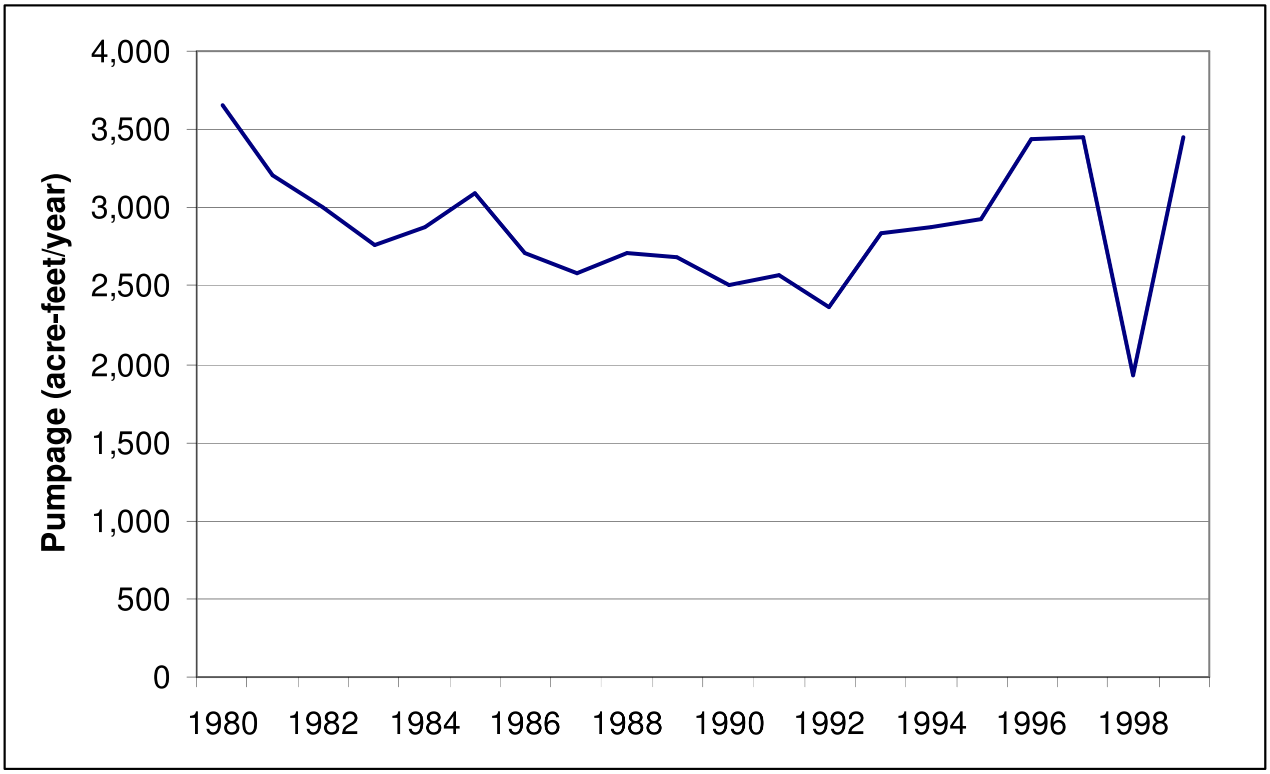

Figure A-39- Pumpage in Sutton County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

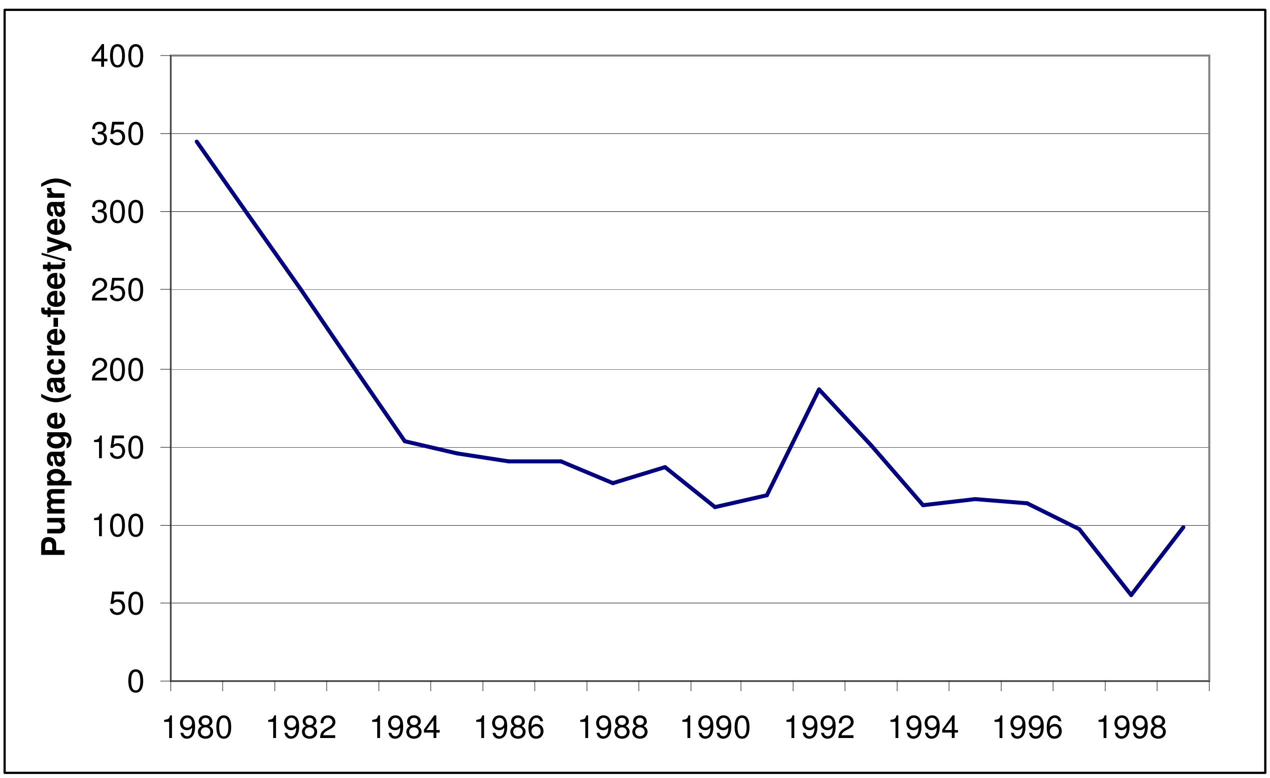

Figure A-40- Pumpage in Taylor County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

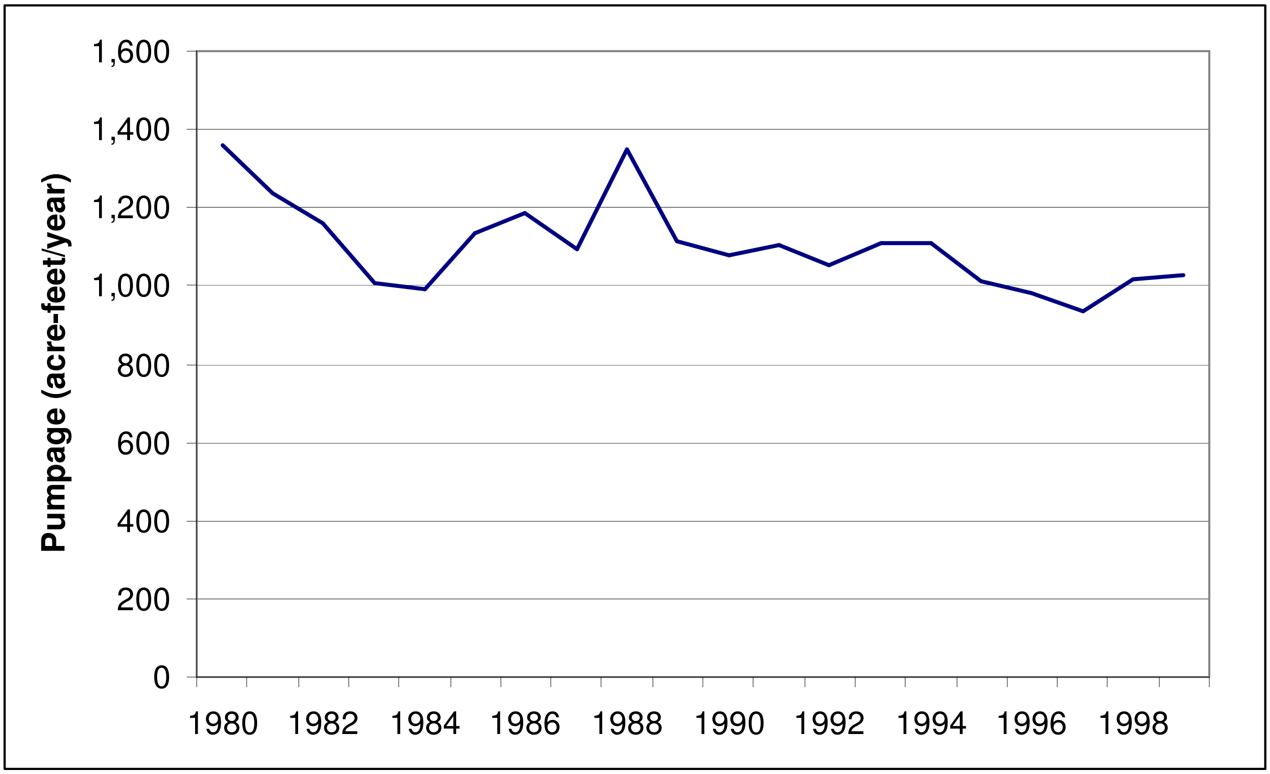

Figure A-41- Pumpage in Terrell County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

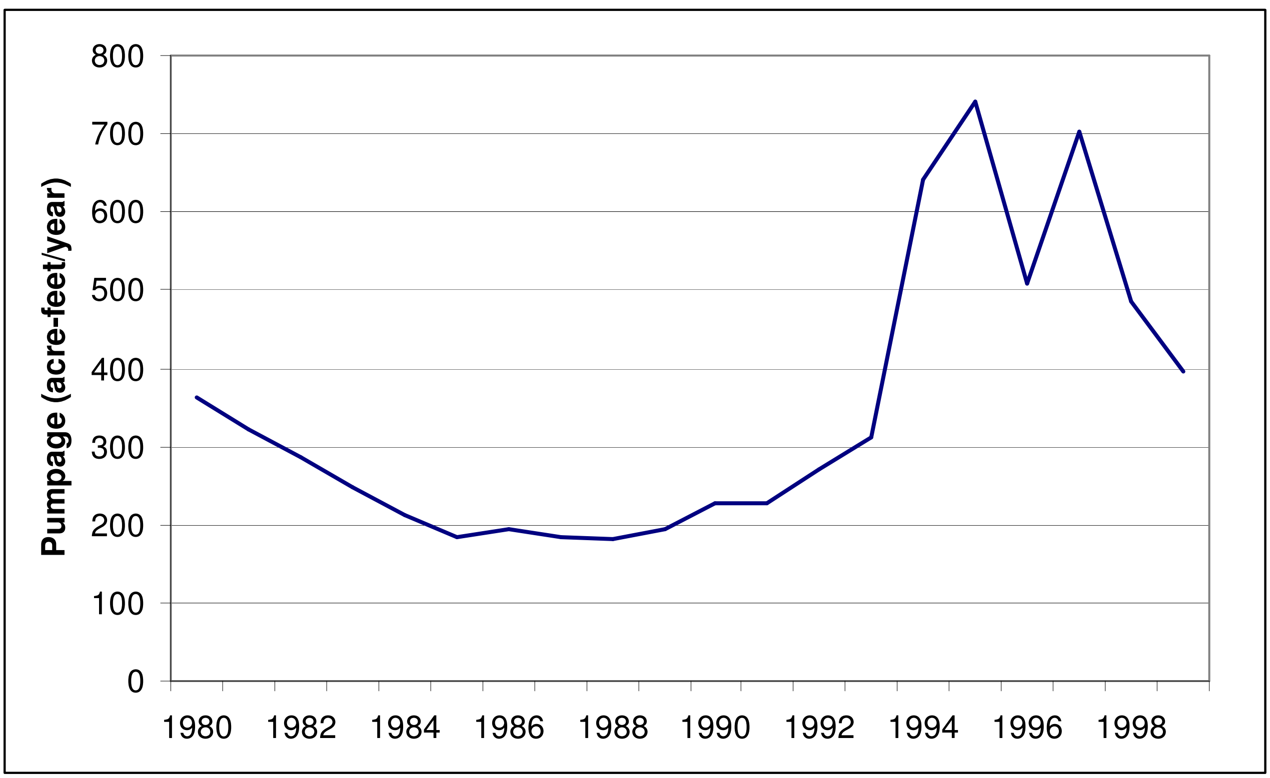

Figure A-42- Pumpage in Tom Green County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

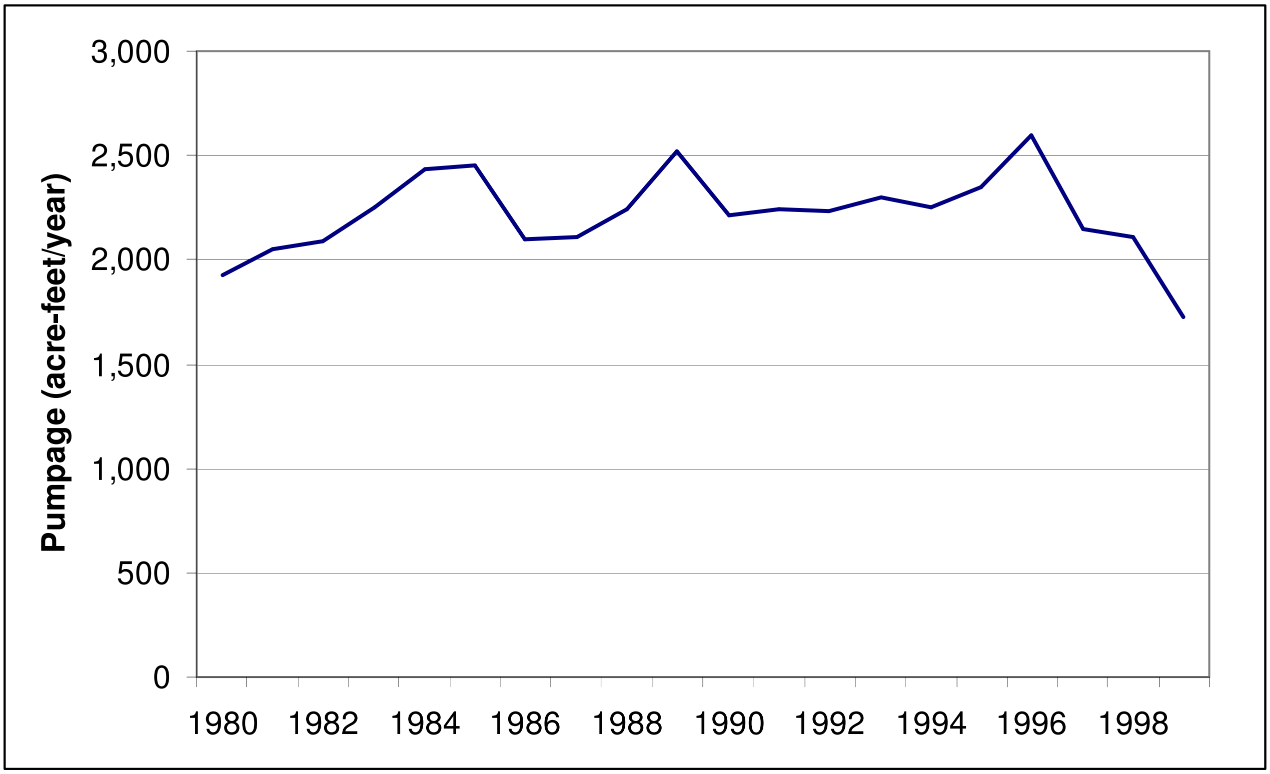

Figure A-43- Pumpage in Travis County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

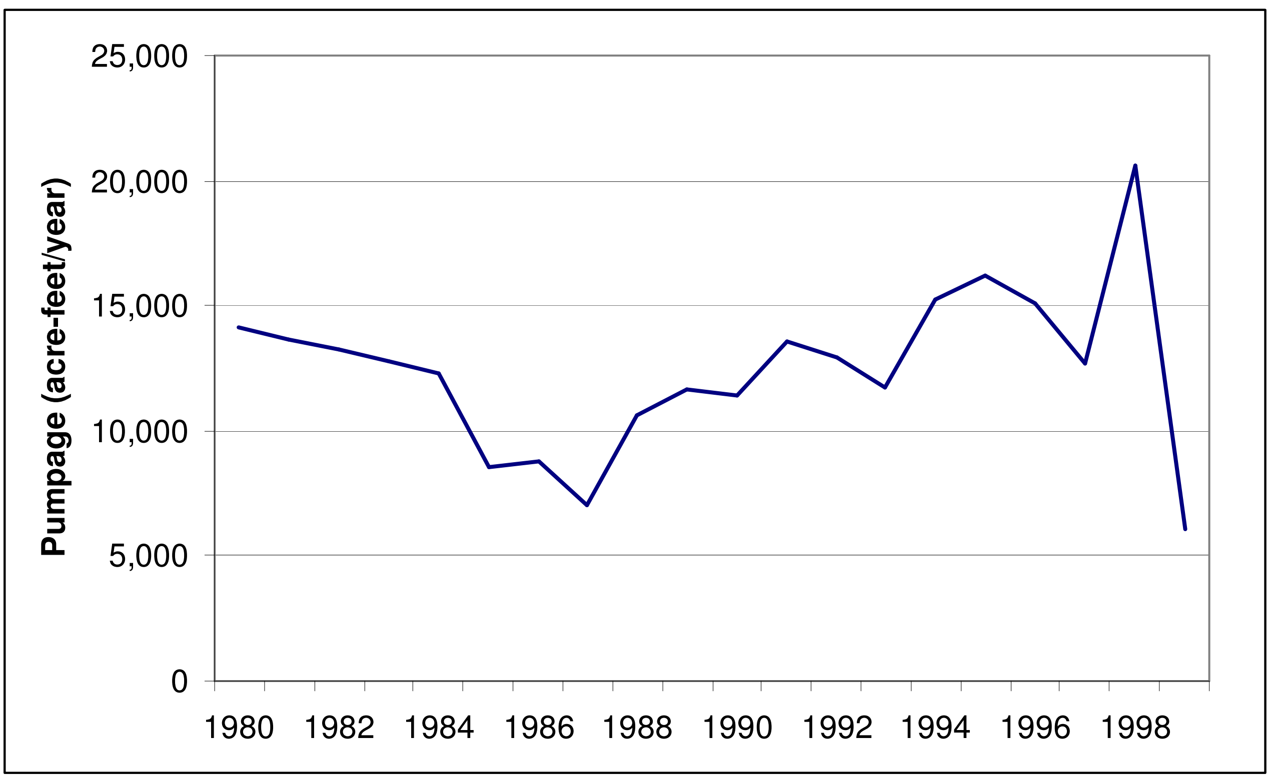

Figure A-44- Pumpage in Upton County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

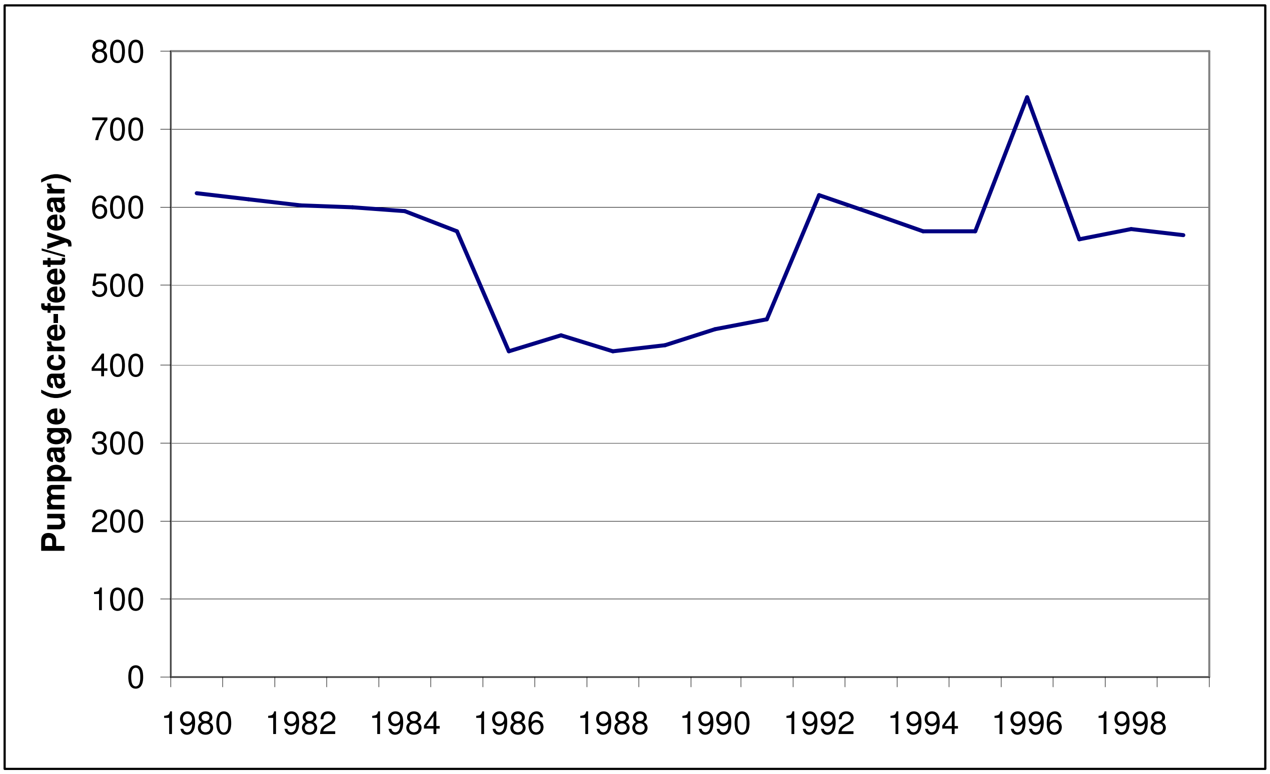

Figure A-45- Pumpage in Uvalde County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

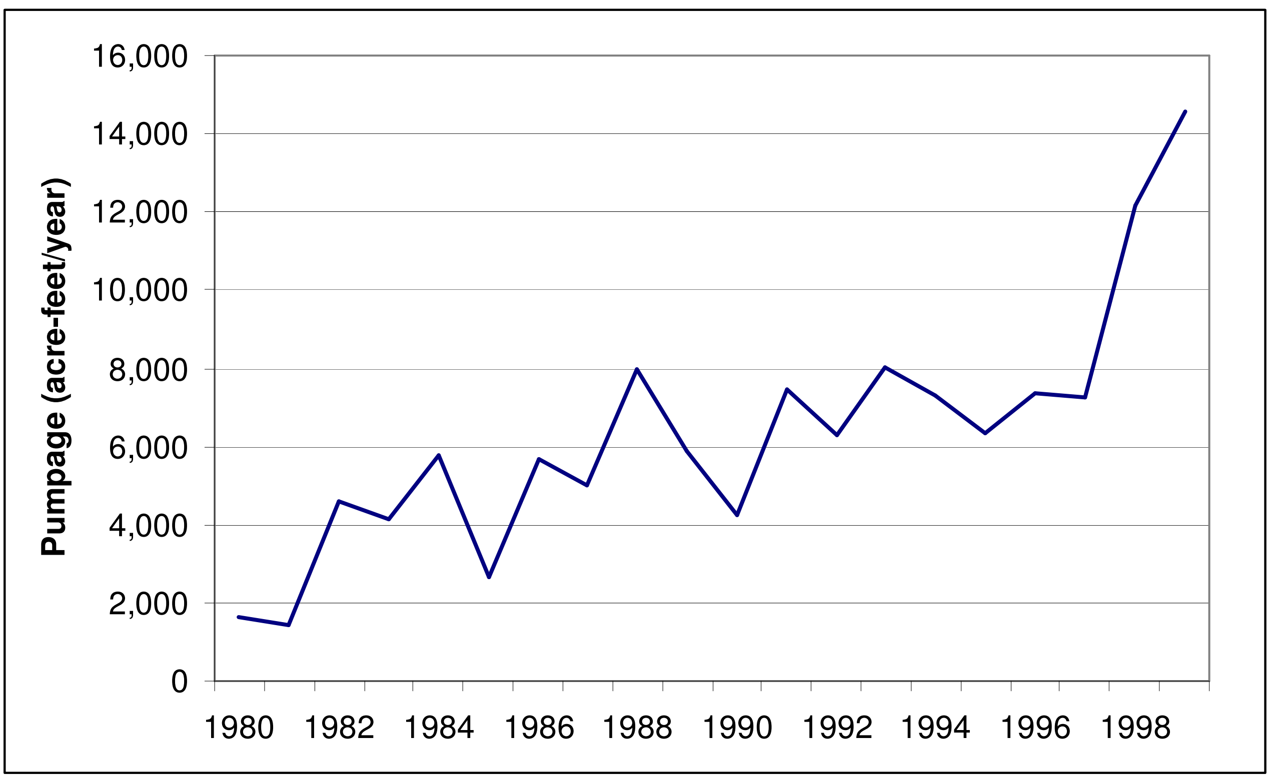

Figure A-46- Pumpage in Val Verde County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

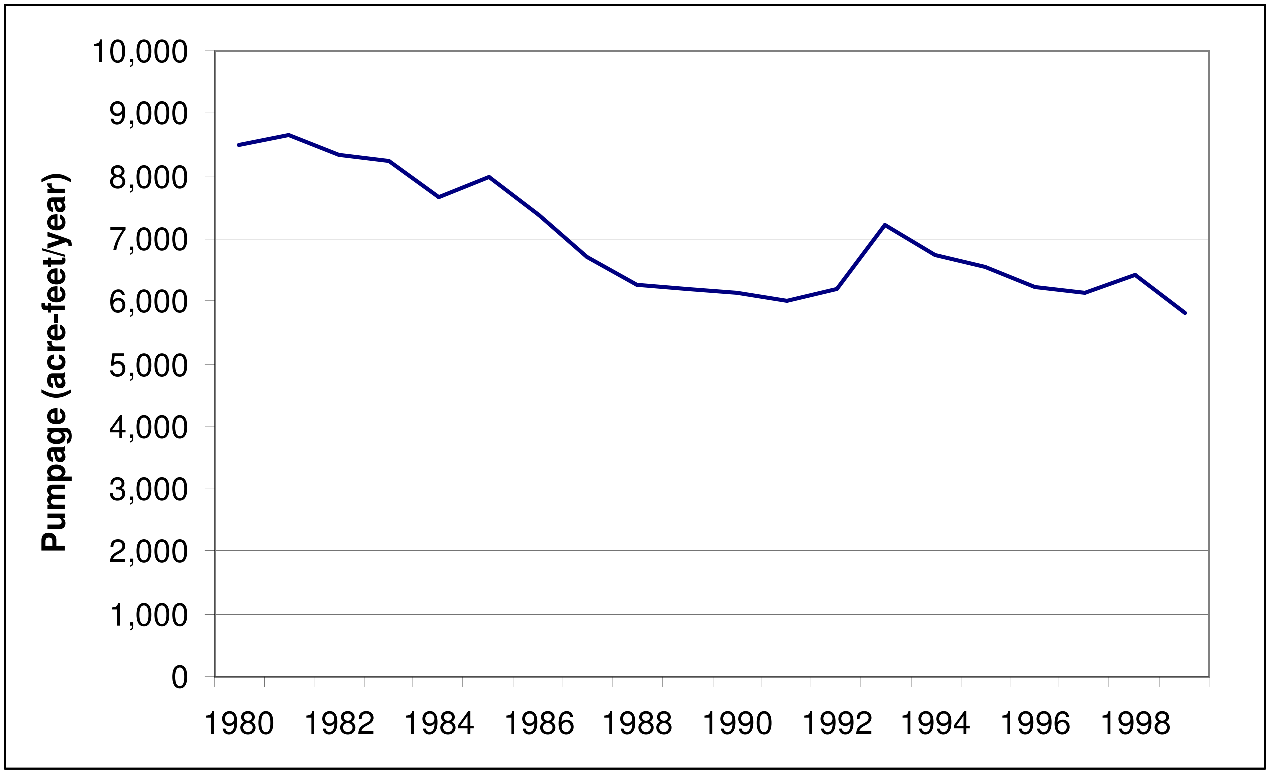

Figure A-47- Pumpage in Ward County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.

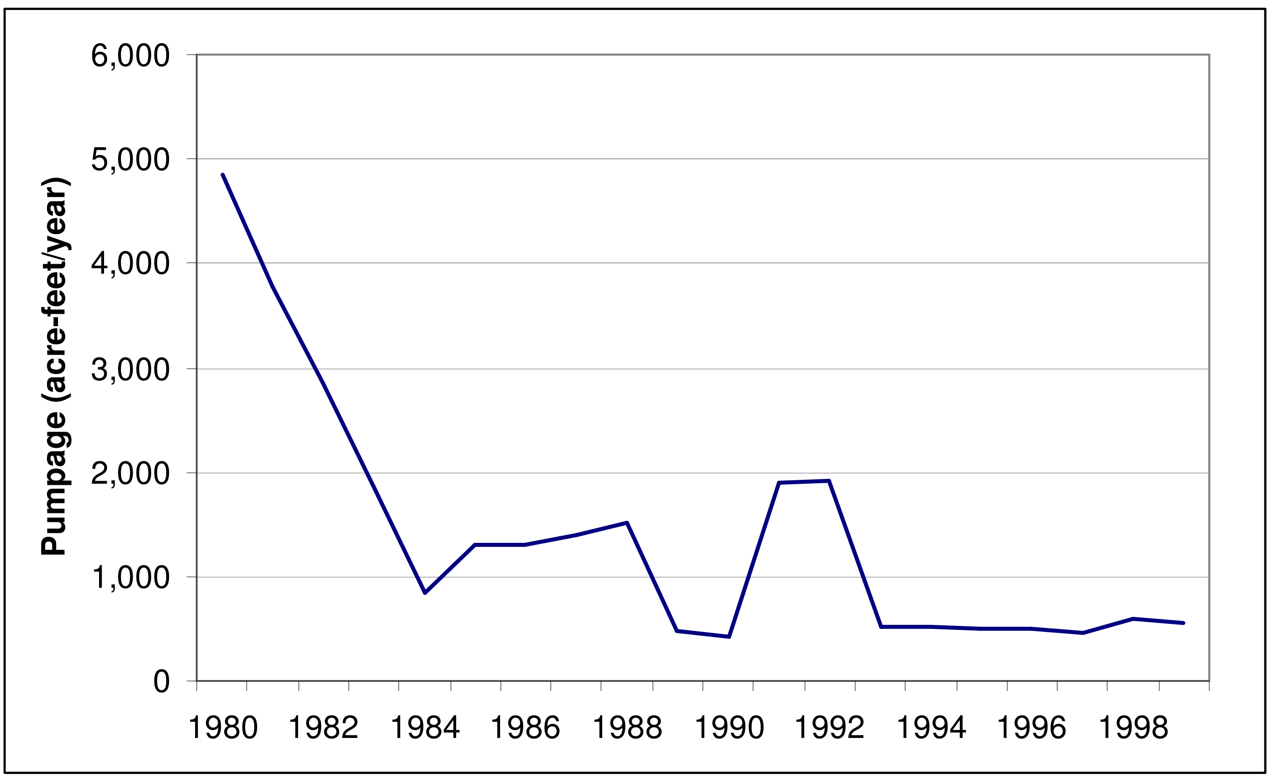

Figure A-48- Pumpage in Winkler County included in the GAM for the Edwards-Trinity (Plateau) Aquifer.