GAM Run 07-12

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EXECUTIVE SUMMARY:

We ran the groundwater availability model for the central part of the Gulf Coast Aquifer using a specified baseline pumpage annually for a 60-year predictive simulation along with average recharge rates, evapotranspiration rates, and initial streamflows. The results of this model run indicated that using the baseline pumpage in the model results in small (less than 10 feet) amounts of water level declines or small (less than 10 feet) amounts of water level recovery over the 60-year model run for all three aquifers throughout most of the model area. Exceptions to this are where significant changes in pumpage have occurred between the 1999 and the present, including the City of Victoria, where a reduction in groundwater pumpage has resulted in a large recovery of water levels, and the City of Kingsville, where an increase in groundwater production has resulted in a large decline in water levels in the Evangeline Aquifer. Another area of significant change in water levels is in south-central Wharton County, where a pumping center has resulted in significant declines in water levels over the predictive time period in the Chicot Aquifer. In addition, three areas in the Jasper Aquifer are predicted to experience significant water level changes, one in southern Duval County which is predicted see a decrease in water levels, and two areas in Live Oak and Bee counties which are predicted to see water level recoveries.

REQUESTOR:

Mr. Mike Mahoney from the Evergreen Underground Water Conservation District (on behalf of Groundwater Management Areas 15 and 16).

DESCRIPTION OF REQUEST:

Mr. Mahoney asked for a baseline model run using the groundwater availability model for the central part of the Gulf Coast Aquifer. This baseline model run would be a 60-year simulation using initial water levels from the end of the historic calibration simulation and average recharge conditions. Each year of the model run would use a specified baseline pumpage approved by members of Groundwater Management Areas 15 and 16.

METHODS:

Recharge and evapotranspiration rates and initial streamflows were averaged for the historic calibration-verification runs, representing 1981 to 1999. These averages were then used for each year of the 60-year predictive 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 central part of the Gulf Coast Aquifer was used for this model run. The parameters and assumptions for this model are described below:

- We used Version 1.01 of the partially-penetrating version of the groundwater availability model for the central part of the Gulf Coast Aquifer.

- See Chowdhury and others (2004), and Waterstone and others (2003) for assumptions and limitations of the groundwater availability model for the central part of the Gulf Coast Aquifer.

- The mean absolute error (a measure of the difference between simulated and actual water levels during model calibration) in the entire model for 1999 is 26 feet, which is 4.6 percent of the hydraulic head drop across the model area (Chowdhury and others, 2004).

- The model includes four layers representing: the Chicot Aquifer (Layer 1), the Evangeline Aquifer (Layer 2), the Burkeville Confining Unit (Layer 3), and the Jasper Aquifer (Layer 4).

- Recharge rates, evapotranspiration rates, and initial streamflows are averages from the 1981 to 1999 calibration and verification time period.

- Pumpage used for each year of the 60-year predictive simulation was a specified baseline pumpage. This pumpage was based on the 1999 pumpage from the transient calibration-verification run. Totals for each county were updated based on input from the groundwater conservation districts in the groundwater management area. Modifications that were done to the 1999 estimated pumpage in order to create the new baseline pumpage are shown in Table 1. 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.

1999 pumpage estimates from the model were uniformly increased or decreased in order to obtain the desired baseline pumpage amounts, with two exceptions.

1. In Victoria County, the total reduction in pumpage occurred because the City of Victoria moved from groundwater to surface water as a primary water supply between 1999 and 2006. Therefore, all of the 10,670 acre-feet per year that was removed in Victoria County was taken from eight cells where the City's pumpage was included in the 1999 pumpage dataset.

2. In Kleberg County, the increase in pumpage occurred because the City of Kingsville moved from surface water to groundwater as a primary water supply between 1999 and 2006. For the baseline pumpage dataset, a total of 3,425 acre-feet per year was added to four cells as shown in Table 2.

Table 1. 1999 estimated pumpage from the calibration-verification run of the groundwater availability model and the requested baseline pumpage used in this model simulation. Pumpage is reported in acre-feet per year. Pumpage in Jim Hogg, Brooks, Kenedy, Brazoria, Fort Bend, and Austin counties represents only the pumpage located in the active portion of the model.

County	1999 pumpage	Requested baseline pumpage	Change	County	1999 pumpage	Requested baseline pumpage	Change
GMA 14				**GMA 16**			
Austin	8,159	8,159	0	Aransas	1,827	1,827	0
Brazoria	12,674	12,674	0	Bee	4,057	4,694	+637
Fort Bend	8,808	8,808	0	Brooks	4,040	4,040	0
Washington	6	6	0	Duval	7,749	7,749	0
				Goliad	1,234	6,143	+4,909
GMA 15				Jim Hogg	981	981	0
Calhoun	1,517	1,517	0	Jim Wells	4,761	4,761	0
Colorado	33,236	33,236	0	Karnes	2,897	2,897	0
Dewitt	4,587	4,587	0	Kenedy	104	104	0
Fayette	3,750	2,197	-1,553	Kleberg	5,209	8,634	+3,425
Jackson	53,615	53,615	0	Live Oak	2,420	8,693	+6,273
Lavaca	11,376	11,376	0	McMullen	29	29	0
Matagorda	11,829	35,000	+23,171	Nueces	3,097	3,097	0
Victoria	24,542	13,872	-10,670	Refugio	1,263	1,063	-200
Wharton	214,181	180,000	-34,181	San Patricio	3,748	3,748	0
				Webb	143	143	0

Table 2. Pumpage added to the 1999 estimated historic pumpage for the City of Kingsville.

Layer	Row	Column	Percent of additional Kingsville pumpage	Number of wells in model cell	Total additional pumpage (acre-feet/year)
2	87	83	14%	1	480
2	87	85	37%	2	1,267
2	89	84	31%	1	1,062
2	89	85	18%	1	617

RESULTS:

Included in the results are estimates of the water budgets after running the model for 60 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 wetlands—water that drains from an aquifer if water levels are above the elevation of the spring or wetland. This component is always shown as “Outflow”, or discharge, from the water budget. Springs and wetlands 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.

- 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 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 using the MODFLOW Evapotranspiration 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 using the MODFLOW Stream package.

- General-Head Boundary—The model uses general-head boundaries to simulate the movement of water out of the Chicot Aquifer at the coast.

The results of the model run are described for the three aquifers in the model area; the Chicot (layer 1 in the model), the Evangeline (layer 2), and the Jasper (layer 4) aquifers. Results for the Burkeville Confining Unit (layer 3) are not discussed because this is not a major source of water in the region.

Initial water levels (which are from the end of the transient calibration run- the end of 1999) for the Chicot, Evangeline, and Jasper aquifers are shown in Figures 1, 2, and 3, respectively. These figures show the starting water levels for this 60-year predictive model run. These figures all show that water levels are the highest in the outcrop portions of the aquifers, located farthest from the coast, and that water levels decrease as groundwater flows downdip towards the coast. A cone of depression (an area of decreased water levels around an area of heavy pumpage) can be observed in the Evangeline Aquifer in south-central Wharton County, as well as around the cities of Victoria and Kingsville in Victoria and Kleberg counties, respectively (Figure 2). Small cones of depression can also be observed in the Jasper Aquifer in southern Duval County, central Live Oak County, central DeWitt County, and central Lavaca County.

Water levels at the end of the 60-year predictive simulation for the Chicot, Evangeline, and Jasper aquifers are shown in Figures 4, 5, and 6, respectively. Water levels at the end of the 60-year runs are similar to initial water levels (Figures 1 to 3). Because differences between initial water levels and water levels after 60 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 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 Chicot, Evangeline, and Jasper aquifers are shown in Figures 7, 8, and 9, respectively. These figures indicate that changes throughout most of the model area in the Chicot Aquifer (Figure 7) are less than 5 feet. Exceptions to this are in Victoria County, where significant recovery has occurred due to the City of Victoria's decrease in groundwater production between 1999 and the present, and in south-central Wharton County, where large declines in water levels are predicted to occur.

In the Evangeline Aquifer (Figure 8) the changes in water levels are mostly less than ten feet. Exceptions to this are in northern Kleberg County, due to the increased groundwater production by the City of Kingsville that has occurred between 1999 and the present, and in central Victoria County, due to the reduced groundwater production by the City of Victoria over this same time period.

It should be noted that an area of recovery is shown in both the Chicot and Evangeline aquifers at the edge of the model area in Jim Hogg, Brooks, and Kenedy counties. This is not due to a change in pumpage and appears to be an artifact of the model and resulting water levels near the edge of the model. This warrants further evaluation to determine exactly why the model is simulating recovery in this area.

In the Jasper Aquifer (Figure 9) changes in water levels in most areas are also less than ten feet in most of the model area. However, an area of higher drawdown in southern Duval County can be seen, presumably due to high pumpage in this area in the 1999 pumpage data set. Some localized areas of recovery can also be observed in Live Oak, Bee, and Fayette counties, again, presumably due to pumpage rates in the 1999 data set.

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 pulled the water budgets for each of these components for each county in the model area. These budgets are provided in Table 3. 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 model runs can be compared to these budgets to determine the impact of additional pumpage compared to this baseline run.

REFERENCES:

Chowdhury, A.H., Wade, S., Mace, R.E., and Ridgeway, C., 2004, Groundwater Availability Model of the Central Gulf Coast Aquifer System: Numerical Simulations through 1999- Model Report, 114 p.

Waterstone Engineering, Inc., and Parsons, Inc., 2003, Groundwater Availability of the Central Gulf Coast Aquifer: Numerical Simulations to 2050 Central Gulf Coast, Texas- Final Report: contract report to the Texas Water Development Board, 158 p.

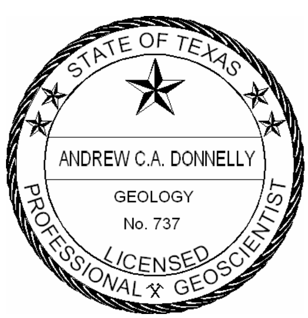

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Table 3. Annual water budgets for each county at the end of the 60-year predictive model run using the requested baseline pumpage in the groundwater availability model for the central part of the Gulf Coast Aquifer (in acre-feet per year). Budgets for Jim Hogg, Brooks, Kenedy, Brazoria, Fort Bend, and Austin counties represents only the portions of those counties located in the active portion of the model.

	Aransas		Austin		Bee		Brazoria		Brooks		Calhoun		Colorado	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Chicot														
Storage	0	0	2	0	0	15	2	0	0	3	2	1	183	15
Reservoirs (River Package)	0	0	0	0	0	0	338	0	3,431	0	2,993	0	1,408	0
Springs (Drain Package)	0	11	0	0	0	0	0	72	0	0	0	1,151	0	6
General Head Boundaries	1,104	3,497	0	0	0	0	0	1,200	0	0	144	12,828	0	0
Wells	0	1,827	0	3,118	0	1,383	0	8,727	0	359	0	1,464	0	16,930
Streams and Rivers	2,351	669	6,108	1,333	4,811	10,996	9,469	19,328	1,073	23,128	6,370	3,564	28,347	12,482
Recharge	164	0	6,758	0	18,921	0	15,152	0	23,402	0	3,039	0	35,074	0
Evapotranspiration	0	741	0	17	0	219	0	1,338	0	1,826	0	1,282	0	57
Lateral Inflow	4,229	1,161	2,481	4,051	775	8,671	12,042	4,985	5,005	4,877	11,465	3,826	8,838	21,384
Vertical Leakage Downward	58	0	0	6,830	937	4,160	0	1,353	1,365	4,081	337	234	703	23,677
Evangeline														
Storage	0	0	2	0	0	41	2	0	1	3	1	0	5	4
Reservoirs (River Package)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Springs (Drain Package)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
General Head Boundaries	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wells	0	0	0	3,931	0	2,973	0	284	0	3,681	0	27	0	15,681
Streams and Rivers	0	0	0	0	4,008	3,783	0	0	0	863	0	0	3,928	3,103
Recharge	0	0	90	0	4,993	0	0	0	340	0	0	0	2,515	0
Evapotranspiration	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Vertical Leakage Upward	0	58	6,830	0	4,160	937	1,353	0	4,081	1,365	234	337	23,677	703
Lateral Inflow	105	47	1,409	4,341	2,354	6,841	480	1,662	2,680	1,752	1,033	906	8,786	19,394
Vertical Leakage Downward	--	--	42	102	96	1,031	102	0	808	245	1	0	473	508

Table 3. (continued)

	Aransas		Austin		Bee		Brazoria		Brooks		Calhoun		Colorado	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Burkeville														
Storage	--	--	6	0	10	144	61	0	16	84	1	0	248	4
Reservoirs (River Package)	--	--	0	0	0	0	0	0	0	0	0	0	0	0
Springs (Drain Package)	--	--	0	0	0	0	0	0	0	0	0	0	0	0
General Head Boundaries	--	--	0	0	0	0	0	0	0	0	0	0	0	0
Wells	--	--	0	6	0	76	0	0	0	0	0	0	0	0
Streams and Rivers	--	--	0	0	88	0	0	0	0	0	0	0	0	0
Recharge	--	--	0	0	1	0	0	0	0	0	0	0	0	0
Evapotranspiration	--	--	0	0	0	0	0	0	0	0	0	0	0	0
Vertical Leakage Upward	--	--	102	42	1,031	96	0	102	245	808	0	1	508	473
Lateral Inflow	--	--	6	10	34	113	8	0	65	20	1	0	43	64
Vertical Leakage Downward	--	--	40	97	148	884	33	0	785	197	--	--	226	485
Jasper														
Storage	--	--	16	0	39	187	31	0	1	208	--	--	112	1
Reservoirs (River Package)	--	--	0	0	0	0	0	0	0	0	--	--	0	0
Springs (Drain Package)	--	--	0	0	0	0	0	0	0	0	--	--	0	0
General Head Boundaries	--	--	0	0	0	0	0	0	0	0	--	--	0	0
Wells	--	--	0	23	0	260	0	0	0	0	--	--	0	624
Streams and Rivers	--	--	0	0	94	96	0	0	0	0	--	--	0	0
Recharge	--	--	0	0	23	0	0	0	0	0	--	--	0	0
Evapotranspiration	--	--	0	0	0	0	0	0	0	0	--	--	0	0
Vertical Leakage Upward	--	--	97	40	884	148	0	33	197	785	--	--	485	226
Lateral Inflow	--	--	103	153	492	844	8	5	1,448	655	--	--	595	341

Table 3. (continued)

	De Witt		Duval		Fayette		Fort Bend		Goliad		Gonzales		Jackson	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Chicot														
Storage	0	0	1	0	--	--	5	0	0	0	--	--	481	1
Reservoirs (River Package)	0	0	0	0	--	--	0	0	1,500	0	--	--	4,149	0
Springs (Drain Package)	0	0	0	0	--	--	0	0	0	12	--	--	0	100
General Head Boundaries	0	0	0	0	--	--	0	0	0	0	--	--	80	610
Wells	0	98	0	394	--	--	0	5,921	0	650	--	--	0	39,090
Streams and Rivers	2,094	1,229	1,544	3,215	--	--	8,234	6,299	2,234	8,879	--	--	55,771	26,417
Recharge	4,569	0	5,270	0	--	--	884	0	10,556	0	--	--	11,805	0
Evapotranspiration	0	25	0	34	--	--	0	18	0	218	--	--	0	529
Lateral Inflow	0	1,467	671	3,467	--	--	10,575	4,483	912	4,690	--	--	21,348	16,126
Vertical Leakage Downward	0	3,845	339	715	--	--	0	2,976	783	1,535	--	--	23	10,791
Evangeline														
Storage	4	0	72	0	5	0	2	0	2	0	--	--	9	0
Reservoirs (River Package)	0	0	0	0	0	0	0	0	0	0	--	--	0	0
Springs (Drain Package)	0	0	0	0	0	0	0	0	0	0	--	--	0	0
General Head Boundaries	0	0	0	0	0	0	0	0	0	0	--	--	0	0
Wells	0	970	0	4,363	0	169	0	2,882	0	5,493	--	--	0	14,417
Streams and Rivers	8,294	8,747	2,962	8,272	94	773	0	0	16,678	15,202	--	--	0	0
Recharge	5,786	0	14,506	0	1,737	0	0	0	7,979	0	--	--	0	0
Evapotranspiration	0	60	0	335	0	0	0	0	0	43	--	--	0	0
Vertical Leakage Upward	3,845	0	715	339	--	--	2,976	0	1,535	783	--	--	10,791	23
Lateral Inflow	987	7,133	1,410	3,973	108	700	2,298	2,654	3,800	8,457	--	--	13,015	10,172
Vertical Leakage Downward	87	2,090	1,001	3,384	56	356	251	0	437	454	--	--	760	0

Table 3. (continued)

	De Witt		Duval		Fayette		Fort Bend		Goliad		Gonzales		Jackson	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Burkeville														
Storage	24	1	187	0	19	0	23	0	18	16	--	--	356	6
Reservoirs (River Package)	0	0	0	0	165	0	0	0	0	0	--	--	0	0
Springs (Drain Package)	0	0	0	0	0	0	0	0	0	0	--	--	0	0
General Head Boundaries	0	0	0	0	0	0	0	0	0	0	--	--	0	0
Wells	0	162	0	76	0	135	0	0	0	0	--	--	0	0
Streams and Rivers	327	11	43	42	33	154	0	0	0	0	--	--	0	0
Recharge	15	0	259	0	3	0	0	0	0	0	--	--	0	0
Evapotranspiration	0	0	0	52	0	19	0	0	0	0	--	--	0	0
Vertical Leakage Upward	2,090	87	3,384	1,001	356	56	0	251	454	437	--	--	0	760
Lateral Inflow	6	40	28	74	5	24	3	1	41	51	--	--	29	9
Vertical Leakage Downward	160	2,322	940	3,597	--	--	226	0	377	387	--	--	390	0
Jasper														
Storage	562	2	866	0	--	--	135	0	19	14	396	0	174	3
Reservoirs (River Package)	0	0	0	0	--	--	0	0	0	0	0	0	0	0
Springs (Drain Package)	0	0	0	0	--	--	0	0	0	0	0	1	0	0
General Head Boundaries	0	0	0	0	--	--	0	0	0	0	0	0	0	0
Wells	0	2,674	0	2,892	--	--	0	0	0	0	0	4	0	0
Streams and Rivers	780	643	0	0	--	--	0	0	0	0	12	164	0	0
Recharge	243	0	189	0	--	--	0	0	0	0	139	0	0	0
Evapotranspiration	0	0	0	412	--	--	0	0	0	0	0	70	0	0
Vertical Leakage Upward	2,322	160	3,597	940	--	--	0	226	387	377	--	--	0	390
Lateral Inflow	663	1,090	2,256	2,663	--	--	107	16	526	540	43	350	261	42

Table 3. (continued)

	Jim Hogg		Jim Wells		Karnes		Kenedy		Kleberg		Lavaca		Live Oak	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Chicot														
Storage	0	2	8	0	--	--	1	0	6	0	89	0	0	0
Reservoirs (River Package)	0	0	0	0	--	--	0	0	0	0	0	0	0	0
Springs (Drain Package)	0	0	0	14	--	--	0	0	0	1	0	0	0	0
General Head Boundaries	0	0	0	0	--	--	0	18,999	0	16,786	0	0	0	0
Wells	0	14	0	2,257	--	--	0	41	0	948	0	1,726	0	88
Streams and Rivers	0	2,024	5,557	18,173	--	--	897	6,442	19,863	12,407	8,823	5,526	177	0
Recharge	6,440	0	25,328	0	--	--	25,221	0	4,486	0	18,276	0	1,194	0
Evapotranspiration	0	443	0	237	--	--	0	2,283	0	1,137	0	3	0	6
Lateral Inflow	382	3,251	3,722	9,291	--	--	4,224	2,619	12,640	4,515	1,537	15,123	242	190
Vertical Leakage Downward	313	1,399	568	5,212	--	--	214	175	55	1,256	85	6,433	0	1,328
Evangeline														
Storage	4	42	5	0	0	0	3	0	20	0	6	0	0	8
Reservoirs (River Package)	0	0	562	0	0	0	0	0	0	0	0	0	2,634	0
Springs (Drain Package)	0	0	0	0	0	0	0	0	0	0	0	0	0	5
General Head Boundaries	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wells	0	371	0	2,491	0	104	0	62	0	7,682	0	6,907	0	1,802
Streams and Rivers	342	4,069	561	4,370	280	581	0	0	0	0	9,941	6,149	635	8,684
Recharge	7,165	0	2,234	0	884	0	0	0	0	0	6,093	0	4,205	0
Evapotranspiration	0	657	0	8	0	0	0	0	0	0	0	4	0	68
Vertical Leakage Upward	1,399	313	5,212	568	--	--	175	214	1,256	55	6,433	85	1,328	0
Lateral Inflow	504	1,996	3,693	5,521	214	539	728	663	5,789	427	4,055	13,064	2,561	767
Vertical Leakage Downward	549	2,514	865	175	36	190	33	1	1,095	0	189	513	254	284

Table 3. (continued)

	Jim Hogg		Jim Wells		Karnes		Kenedy		Kleberg		Lavaca		Live Oak	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Burkeville														
Storage	3	78	88	1	42	0	24	1	659	0	130	1	25	42
Reservoirs (River Package)	0	0	0	0	0	0	0	0	0	0	0	0	134	0
Springs (Drain Package)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
General Head Boundaries	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wells	0	0	0	4	0	58	0	0	0	0	0	149	0	1,315
Streams and Rivers	0	0	0	33	226	67	0	0	0	0	214	6	656	338
Recharge	13	0	14	0	3	0	0	0	0	0	2	0	220	0
Evapotranspiration	0	3	0	0	0	1	0	0	0	0	0	0	0	22
Vertical Leakage Upward	2,514	549	175	865	190	36	1	33	0	1,095	513	189	284	254
Lateral Inflow	12	75	61	37	20	22	11	1	7	1	17	41	120	31
Vertical Leakage Downward	533	2,370	735	132	97	395	--	--	431	0	179	669	949	386
Jasper														
Storage	11	399	100	3	1,497	8	--	--	100	0	1,331	1	1,386	65
Reservoirs (River Package)	0	0	0	0	0	0	--	--	0	0	0	0	0	0
Springs (Drain Package)	0	0	0	0	0	0	--	--	0	0	0	0	0	0
General Head Boundaries	0	0	0	0	0	0	--	--	0	0	0	0	0	0
Wells	0	594	0	7	0	2,231	--	--	0	0	0	2,404	0	2,744
Streams and Rivers	0	0	0	0	747	551	--	--	0	0	597	0	441	394
Recharge	155	0	0	0	417	0	--	--	0	0	170	0	527	0
Evapotranspiration	0	172	0	0	0	78	--	--	0	0	0	5	0	56
Vertical Leakage Upward	2,370	533	132	735	395	97	--	--	0	431	669	179	386	949
Lateral Inflow	1,355	2,194	1,765	1,251	560	652	--	--	388	57	478	656	1,955	488

Table 3. (continued)

	Matagorda		McMullen		Nueces		Refugio		San Patricio		Victoria		Washington	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Chicot														
Storage	92	0	--	--	9	0	0	1	0	63	0	20	--	--
Reservoirs (River Package)	795	0	--	--	0	0	0	0	0	0	1,046	0	--	--
Springs (Drain Package)	0	215	--	--	0	89	0	129	0	376	0	1,653	--	--
General Head Boundaries	897	10,747	--	--	91	4,039	0	7,900	30	4,366	0	594	--	--
Wells	0	27,682	--	--	0	1,862	0	597	0	2,404	0	7,680	--	--
Streams and Rivers	58,043	30,017	--	--	11,348	11,049	27,574	39,589	3,004	12,018	40,668	38,578	--	--
Recharge	23,061	0	--	--	4,795	0	14,669	0	12,704	0	24,830	0	--	--
Evapotranspiration	0	3,095	--	--	0	372	0	1,906	0	515	0	1,022	--	--
Lateral Inflow	12,254	14,546	--	--	8,976	6,697	14,002	10,469	7,138	3,500	7,789	19,437	--	--
Vertical Leakage Downward	0	8,845	--	--	1,235	2,345	4,671	325	1,601	1,234	1,250	6,601	--	--
Evangeline														
Storage	7	0	--	--	2	0	0	0	0	2	0	1	--	--
Reservoirs (River Package)	0	0	--	--	0	0	0	0	676	0	0	0	--	--
Springs (Drain Package)	0	0	--	--	0	0	0	0	0	0	0	0	--	--
General Head Boundaries	0	0	--	--	0	0	0	0	0	0	0	0	--	--
Wells	0	7,240	--	--	0	1,083	0	466	0	1,304	0	6,191	--	--
Streams and Rivers	0	0	--	--	0	0	0	0	0	657	1,611	4,238	--	--
Recharge	0	0	--	--	0	0	0	0	148	0	743	0	--	--
Evapotranspiration	0	0	--	--	0	0	0	0	0	13	0	27	--	--
Vertical Leakage Upward	8,845	0	--	--	2,345	1,235	325	4,671	1,234	1,601	6,601	1,250	--	--
Lateral Inflow	2,565	4,431	--	--	2,047	2,501	6,615	1,818	2,429	1,225	8,988	6,572	--	--
Vertical Leakage Downward	229	0	--	--	424	0	18	2	326	11	386	49	--	--

Table 3. (continued)

	Matagorda		McMullen		Nueces		Refugio		San Patricio		Victoria		Washington	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Burkeville														
Storage	233	0	20	0	97	1	0	11	7	15	25	65	--	--
Reservoirs (River Package)	0	0	0	0	0	0	0	0	0	0	0	0	--	--
Springs (Drain Package)	0	0	0	0	0	0	0	0	0	0	0	0	--	--
General Head Boundaries	0	0	0	0	0	0	0	0	0	0	0	0	--	--
Wells	0	0	0	9	0	0	0	0	0	0	0	0	--	--
Streams and Rivers	0	0	239	0	0	0	0	0	0	0	0	0	--	--
Recharge	0	0	13	0	0	0	0	0	0	0	0	0	--	--
Evapotranspiration	0	0	0	0	0	0	0	0	0	0	0	0	--	--
Vertical Leakage Upward	0	229	--	--	0	424	2	18	11	326	49	386	--	--
Lateral Inflow	6	11	4	10	1	3	32	5	16	2	38	15	--	--
Vertical Leakage Downward	--	--	0	258	330	0	--	--	315	5	393	39	--	--
Jasper														
Storage	--	--	401	0	26	1	--	--	0	26	0	99	11	0
Reservoirs (River Package)	--	--	0	0	0	0	--	--	0	0	0	0	0	0
Springs (Drain Package)	--	--	0	0	0	0	--	--	0	0	0	0	0	0
General Head Boundaries	--	--	0	0	0	0	--	--	0	0	0	0	0	0
Wells	--	--	0	19	0	0	--	--	0	0	0	0	0	6
Streams and Rivers	--	--	368	590	0	0	--	--	0	0	0	0	0	0
Recharge	--	--	249	0	0	0	--	--	0	0	0	0	1	0
Evapotranspiration	--	--	0	116	0	0	--	--	0	0	0	0	0	0
Vertical Leakage Upward	--	--	258	0	0	330	--	--	5	315	39	393	--	--
Lateral Inflow	--	--	205	756	402	98	--	--	358	23	637	184	2	8

Table 3. (continued)

	Webb		Wharton	
	In	Out	In	Out
Chicot				
Storage	--	--	740	0
Reservoirs (River Package)	--	--	537	0
Springs (Drain Package)	--	--	0	9
General Head Boundaries	--	--	0	0
Wells	--	--	0	111,755
Streams and Rivers	--	--	121,457	13,331
Recharge	--	--	21,792	0
Evapotranspiration	--	--	0	243
Lateral Inflow	--	--	36,668	19,087
Vertical Leakage Downward	--	--	0	36,773
Evangeline				
Storage	0	0	18	0
Reservoirs (River Package)	0	0	0	0
Springs (Drain Package)	0	0	0	0
General Head Boundaries	0	0	0	0
Wells	0	135	0	68,245
Streams and Rivers	0	770	0	0
Recharge	3,008	0	0	0
Evapotranspiration	0	471	0	0
Vertical Leakage Upward	--	--	36,773	0
Lateral Inflow	43	315	32,102	2,925
Vertical Leakage Downward	331	1,692	2,208	0

Table 3. (continued)

	Webb		Wharton	
	In	Out	In	Out
Burkeville				
Storage	0	0	1,185	0
Reservoirs (River Package)	0	0	0	0
Springs (Drain Package)	0	0	0	0
General Head Boundaries	0	0	0	0
Wells	0	0	0	0
Streams and Rivers	0	0	0	0
Recharge	0	0	0	0
Evapotranspiration	0	0	0	0
Vertical Leakage Upward	1,692	331	0	2,208
Lateral Inflow	1	7	66	13
Vertical Leakage Downward	325	1,680	970	0
Jasper				
Storage	5	5	803	0
Reservoirs (River Package)	0	0	0	0
Springs (Drain Package)	0	0	0	0
General Head Boundaries	0	0	0	0
Wells	0	7	0	0
Streams and Rivers	0	0	0	0
Recharge	46	0	0	0
Evapotranspiration	0	88	0	0
Vertical Leakage Upward	1,680	325	0	970
Lateral Inflow	151	1,457	274	105

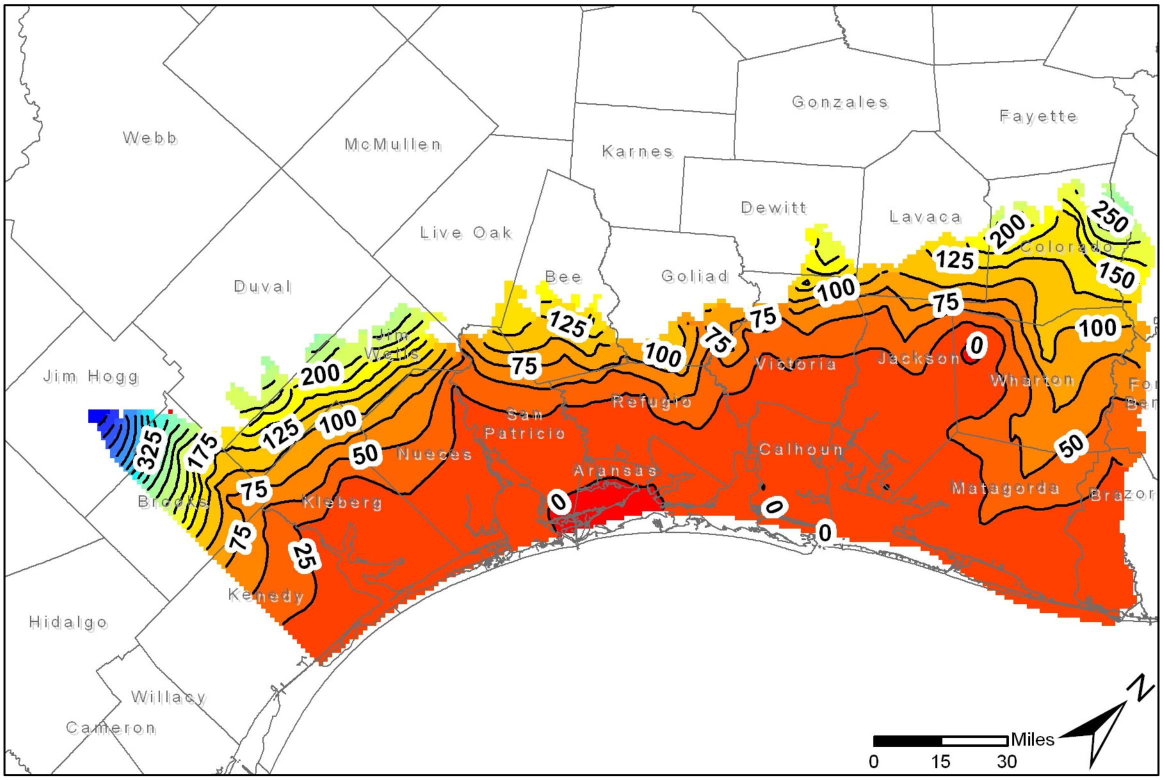

Figure 1. Initial water level elevations for the predictive model run in the Chicot Aquifer from the groundwater availability model for the central part of the Gulf Coast Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 25 feet.

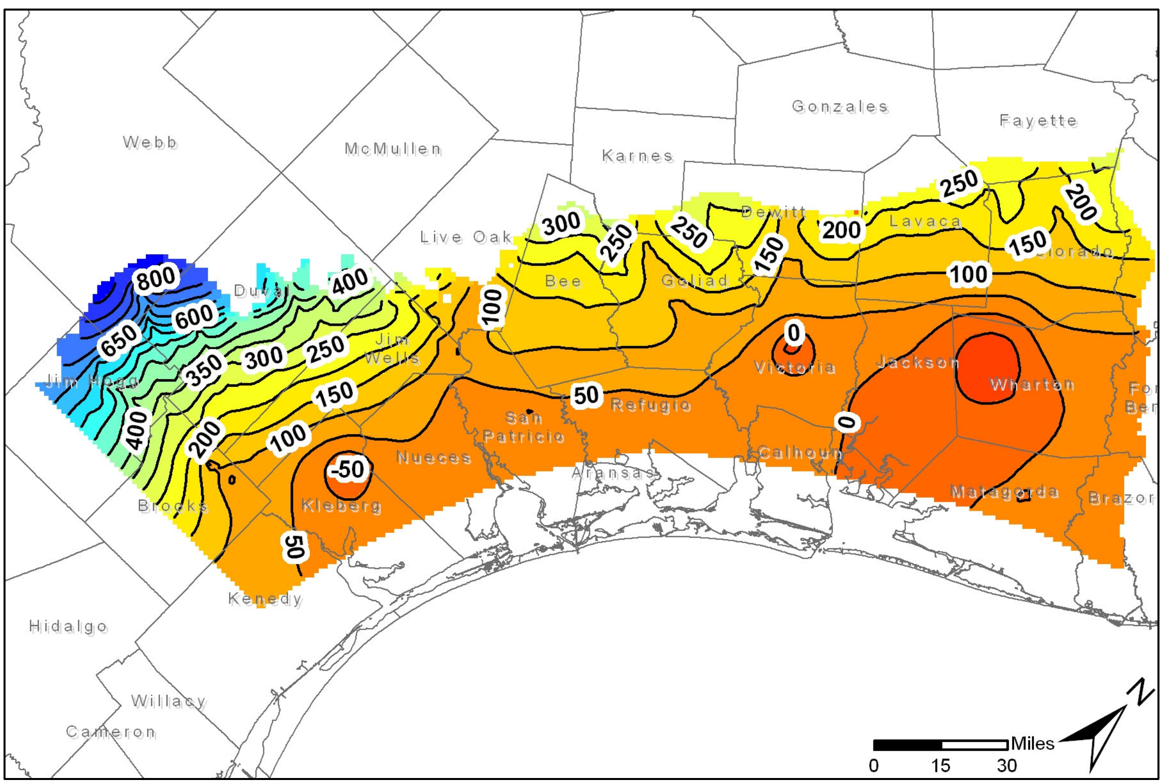

Figure 2. Initial water level elevations for the predictive model run in the Evangeline Aquifer from the groundwater availability model for the central part of the Gulf Coast Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 50 feet.

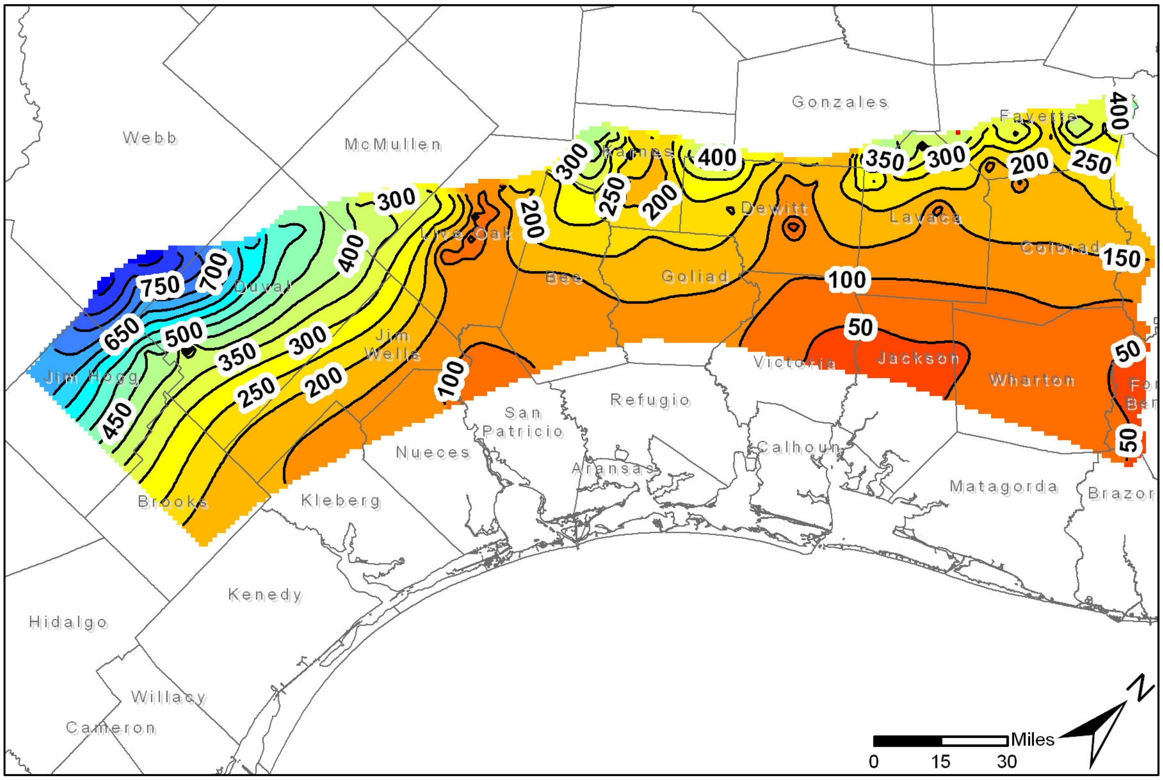

Figure 3. Initial water level elevations for the predictive model run in the Jasper Aquifer from the groundwater availability model for the central part of the Gulf Coast Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 50 feet.

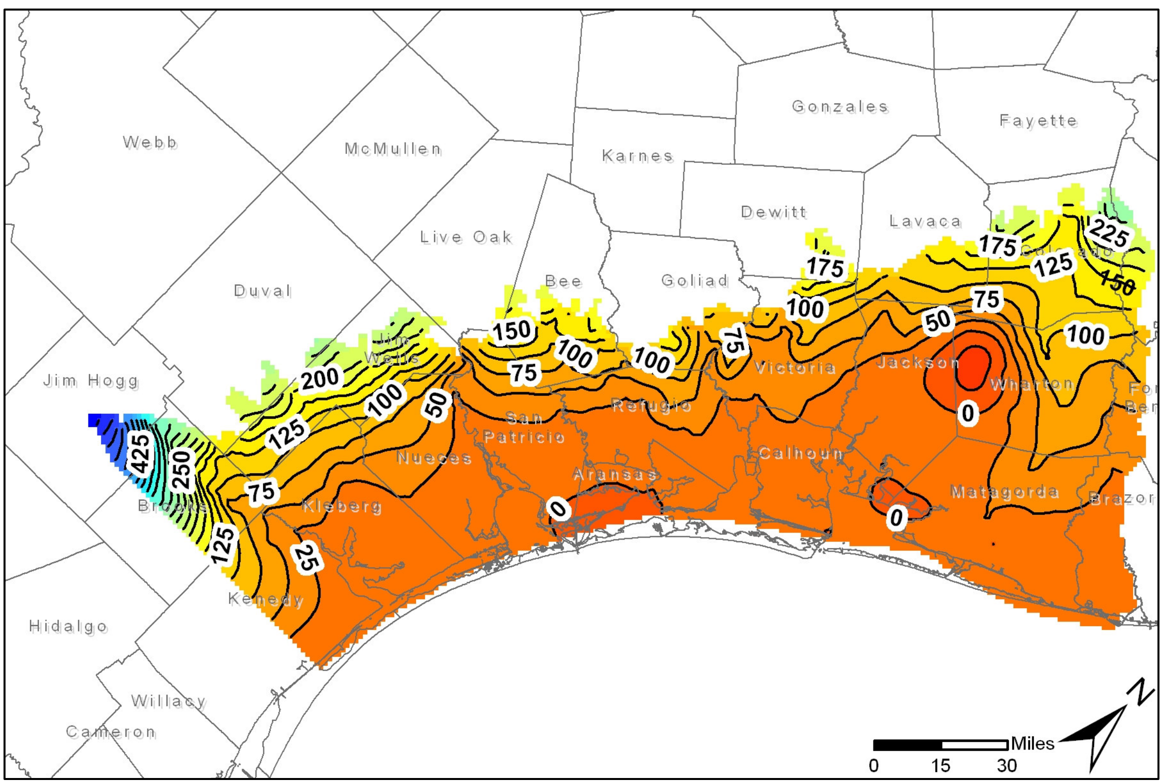

Figure 4. Water level elevations after 60 years using baseline pumpage in the Chicot Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 25 feet.

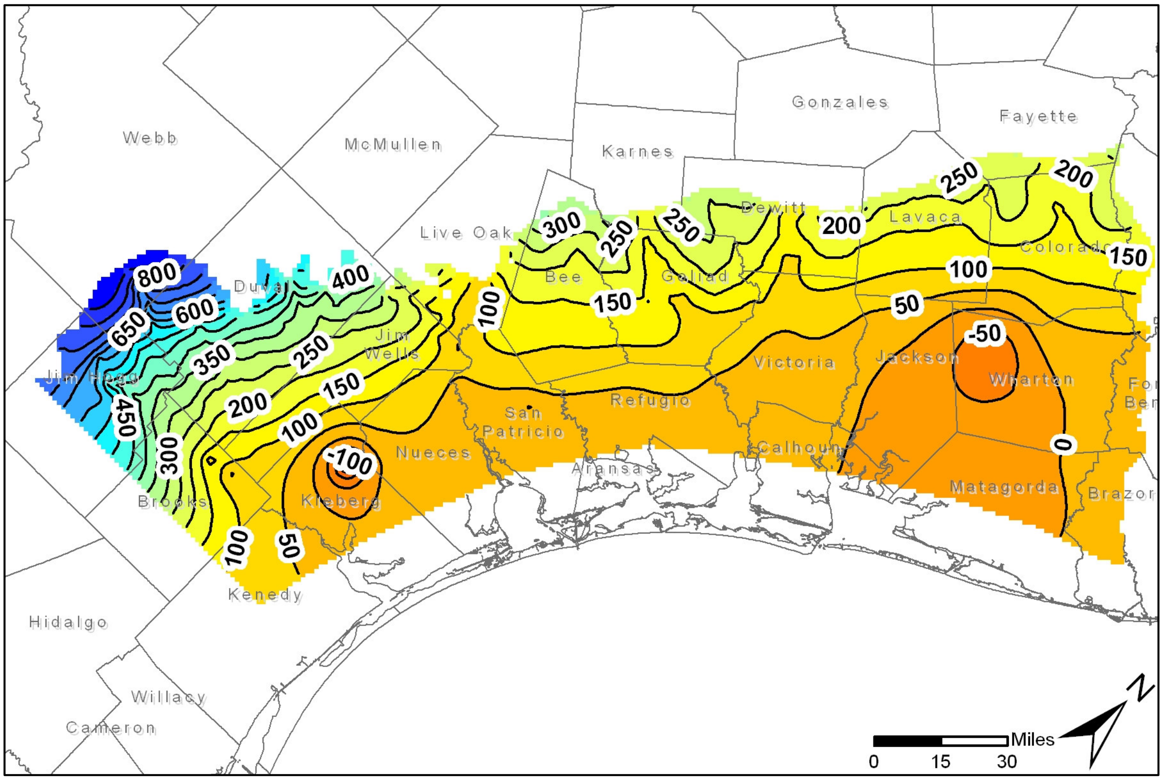

Figure 5. Water level elevations after 60 years using baseline pumpage in the Evangeline Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 50 feet.

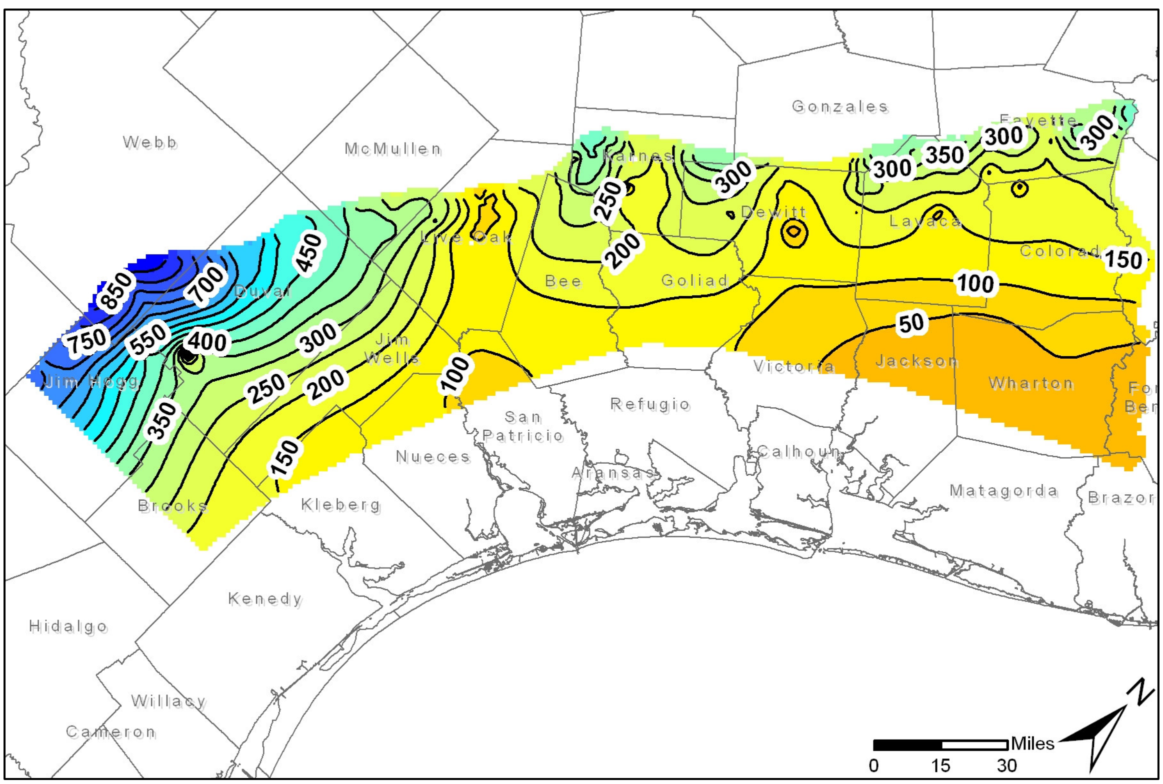

Figure 6. Water level elevations after 60 years using baseline pumpage in the Jasper Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 50 feet.

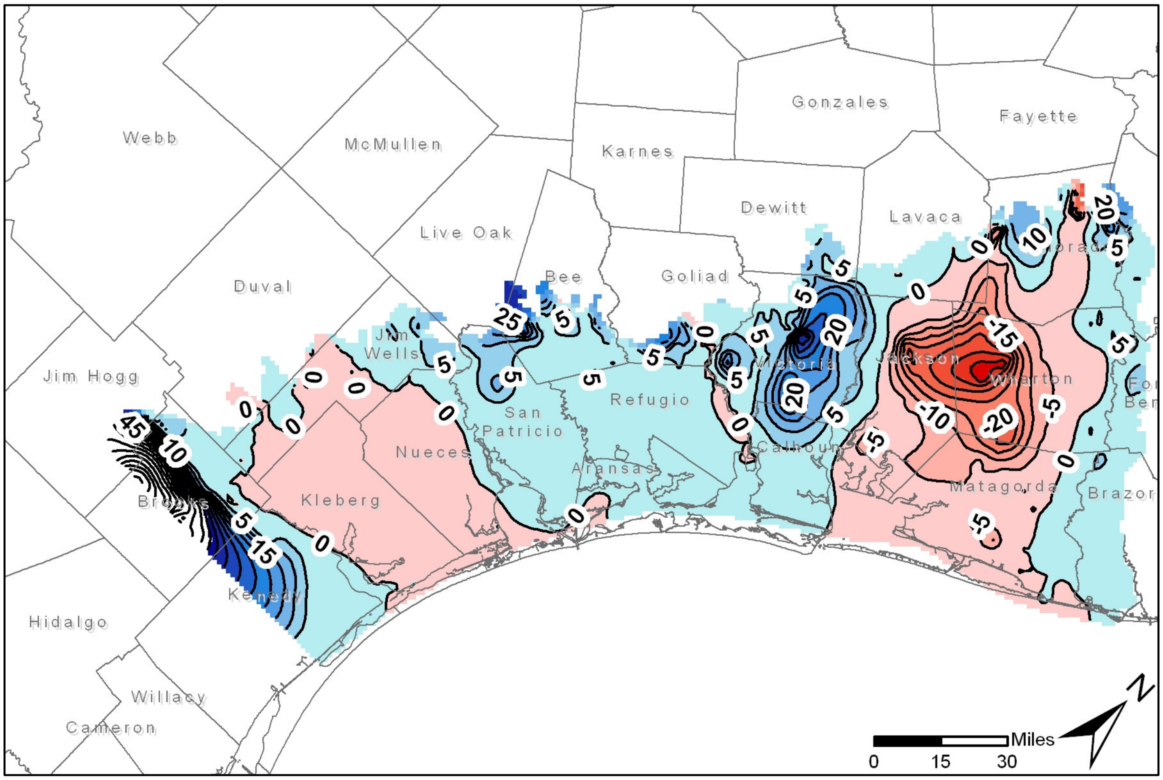

Figure 7. Changes in water levels after 60 years using baseline pumpage in the Chicot Aquifer. Drawdowns are in feet. Contour interval is 10 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue.

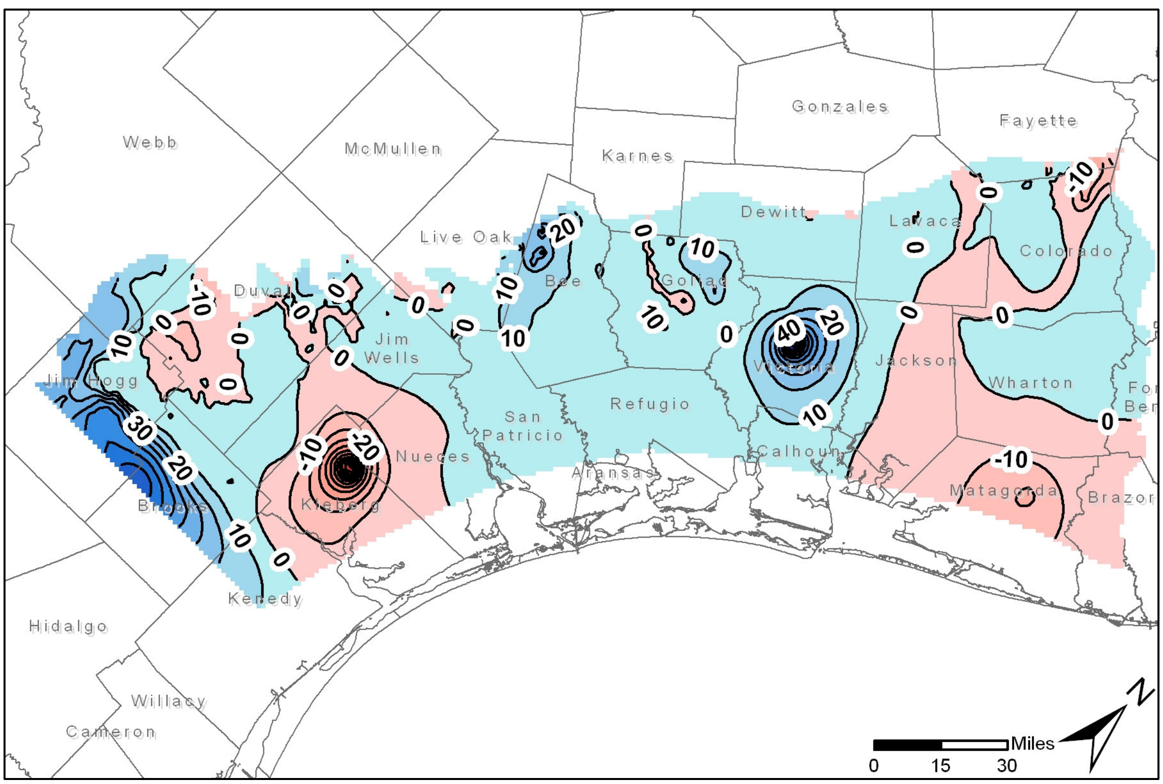

Figure 8. Changes in water levels after 60 years using baseline pumpage in the Evangeline Aquifer. Drawdowns are in feet. Contour interval is 10 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue.

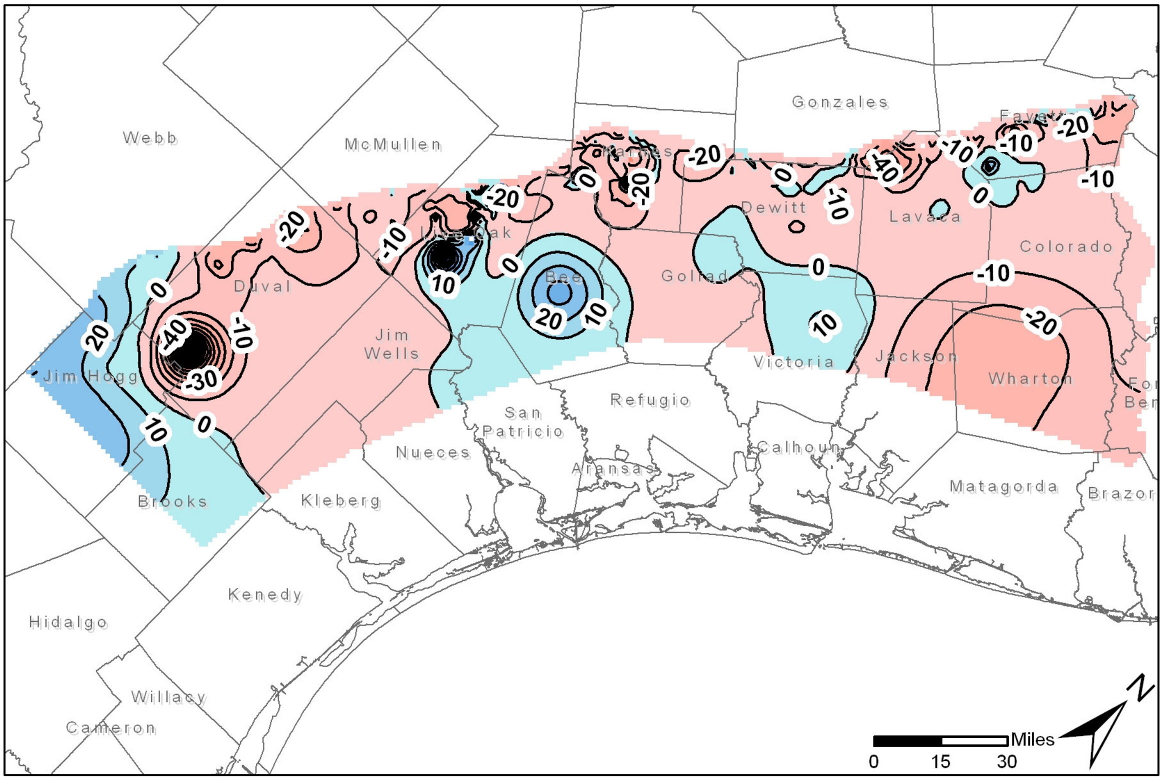

Figure 9. Changes in water levels after 60 years using baseline pumpage in the Jasper Aquifer. Drawdowns are in feet. Contour interval is 10 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue.

Appendix A

Summary of Historic Pumpage in the Groundwater Availability Model for the Central Part of the Gulf Coast Aquifer

Table A-1. Summary of estimated historic pumpage included in the groundwater availability model for the central part of the Gulf Coast Aquifer (in acre-feet per year).

Time Period	Total	Aransas	Austin	Bee	Brazoria	Brooks	Calhoun	Colorado	De Witt	Duval	Fayette
1920 - 1940	0	0	0	0	0	0	0	0	0	0	0
1940 - 1980	612,566	1,153	9,541	6,048	24,402	1,299	13,093	67,670	4,791	4,913	3,406
1981	593,921	1,263	9,333	5,594	23,841	1,295	10,970	61,521	4,665	4,576	3,313
1982	577,116	1,337	9,374	6,097	20,931	1,318	8,857	56,003	5,178	4,585	3,332
1983	552,769	1,404	9,181	5,545	19,198	1,413	6,713	50,033	4,832	4,384	3,091
1984	534,413	1,494	9,236	5,475	18,278	1,412	4,640	42,474	5,199	4,223	3,214
1985	486,448	1,467	7,948	3,221	19,829	1,321	4,516	41,977	5,068	3,620	3,491
1986	471,260	1,457	8,337	2,571	14,548	2,333	4,292	43,005	4,581	3,619	3,207
1987	411,599	1,342	7,075	2,059	15,074	1,911	3,778	37,038	4,824	4,999	3,303
1988	554,466	1,374	8,962	2,466	16,064	1,745	4,829	51,099	5,017	4,135	3,474
1989	396,370	1,440	9,265	3,786	9,736	1,824	4,536	29,221	5,316	4,853	3,510
1990	491,683	1,598	9,941	5,180	10,323	1,316	3,136	48,515	5,154	5,314	3,512
1991	429,632	1,575	9,295	5,430	10,541	1,502	3,787	45,844	4,287	4,876	3,064
1992	486,910	1,556	10,982	3,994	44,384	4,691	3,499	45,360	4,282	5,211	3,359
1993	416,265	1,598	6,378	2,594	12,175	5,947	3,219	22,012	4,212	7,830	3,617
1994	414,360	1,792	7,237	2,396	10,043	6,233	2,852	27,234	4,318	9,551	3,597
1995	432,290	1,601	6,714	1,861	11,835	6,373	3,830	25,725	4,461	8,507	3,567
1996	495,277	1,682	8,022	4,157	11,172	5,139	4,009	33,159	4,692	9,103	3,694
1997	375,675	1,555	6,711	2,819	9,943	4,536	1,476	25,214	4,487	8,352	3,603
1998	477,118	1,827	8,147	5,157	11,630	5,020	1,596	29,771	4,602	7,177	3,449
1999	437,082	1,827	8,159	4,057	12,674	4,040	1,517	33,236	4,587	7,749	3,750

Table A-1. (continued)

Time Period	Fort Bend	Goliad	Gonzales	Jackson	Jim Hogg	Jim Wells	Karnes	Kenedy	Kleberg	Lavaca	Live Oak
1920 - 1940	0	0	0	0	0	0	0	0	0	0	0
1940 - 1980	16,149	1,203	4	140,820	581	5,857	2,467	125	9,020	29,665	3,211
1981	18,187	1,194	4	131,251	699	5,572	2,357	119	7,978	28,285	3,446
1982	20,218	1,126	4	121,494	913	5,815	2,579	116	8,336	27,251	4,422
1983	22,270	1,134	4	111,267	967	5,760	2,924	115	7,649	26,231	4,323
1984	24,270	1,155	4	101,729	1,102	5,711	3,191	111	7,343	25,190	4,705
1985	14,185	1,113	4	76,278	1,136	4,828	2,702	104	6,626	19,034	5,928
1986	13,454	1,166	4	75,576	1,008	5,450	2,983	107	7,321	17,505	4,467
1987	11,288	1,131	4	73,073	944	5,003	3,047	114	6,405	15,596	4,213
1988	18,658	1,146	4	100,922	944	5,007	3,103	109	6,473	19,307	4,342
1989	14,869	1,324	4	71,208	397	4,131	1,737	103	6,438	17,094	4,037
1990	20,813	1,364	4	97,016	771	4,468	3,152	106	6,914	18,284	5,403
1991	17,700	1,238	4	79,275	1,007	4,211	2,668	105	6,396	14,618	6,363
1992	12,766	1,277	4	69,165	1,193	3,756	2,465	80	6,129	15,666	6,922
1993	13,020	1,152	4	62,536	924	3,888	2,310	89	6,118	13,361	5,671
1994	13,058	1,159	4	72,314	1,116	4,188	2,301	73	5,888	16,040	5,342
1995	12,613	1,104	4	62,385	1,047	3,916	2,506	69	6,263	14,222	4,575
1996	14,216	1,187	4	81,744	1,258	4,237	3,108	79	7,046	21,790	4,945
1997	8,983	1,160	4	44,783	713	3,807	2,416	73	6,941	10,117	3,584
1998	15,559	1,249	4	63,930	1,217	4,979	2,806	127	7,456	12,809	3,341
1999	8,808	1,234	4	53,615	981	4,761	2,897	104	5,209	11,376	2,420

Table A-1. (continued)

Time Period	Matagorda	McMullen	Nueces	Refugio	San Patricio	Victoria	Washington	Webb	Wharton
1920 - 1940	0	0	0	0	0	0	0	0	0
1940 - 1980	40,058	49	3,320	1,949	4,205	39,727	4	129	176,120
1981	39,603	38	3,447	1,890	4,449	39,963	5	139	176,386
1982	39,609	36	4,075	1,990	5,166	39,397	5	138	175,477
1983	40,643	29	4,501	1,705	5,897	37,660	5	142	172,017
1984	41,511	42	5,432	1,789	6,595	37,846	5	140	169,355
1985	35,989	28	5,488	1,625	4,491	29,071	5	135	183,435
1986	36,022	28	4,469	1,644	4,832	26,145	5	181	178,040
1987	31,127	29	3,921	1,586	4,181	26,111	5	118	139,691
1988	44,293	30	4,842	1,545	4,665	32,403	5	153	204,261
1989	19,012	27	2,817	1,545	3,896	32,826	5	158	138,217
1990	38,430	27	2,405	1,418	3,907	26,889	6	134	163,428
1991	37,859	29	2,352	1,345	3,828	24,067	6	137	134,140
1992	29,653	20	2,211	1,291	2,700	24,555	6	133	177,229
1993	29,070	19	2,394	1,271	3,059	25,946	6	144	173,646
1994	26,147	26	2,290	1,302	3,043	28,870	6	111	153,096
1995	35,867	26	2,323	1,310	3,122	26,209	5	130	177,269
1996	36,993	40	2,932	1,482	3,267	28,600	5	128	193,996
1997	14,287	28	3,242	1,344	3,201	23,953	5	122	172,970
1998	14,187	31	5,401	1,499	4,244	27,027	6	139	226,095
1999	11,829	29	3,097	1,263	3,748	24,542	6	143	214,181

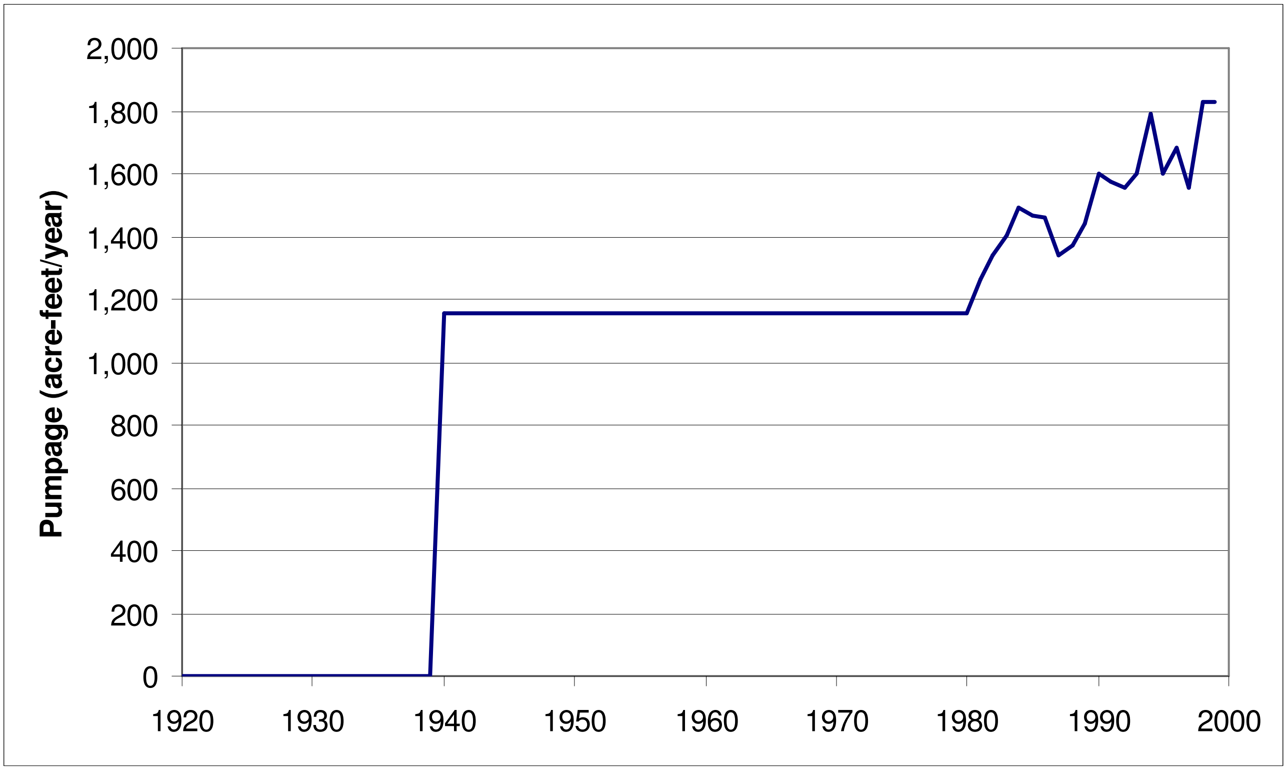

Figure A-1- Pumpage in Aransas County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

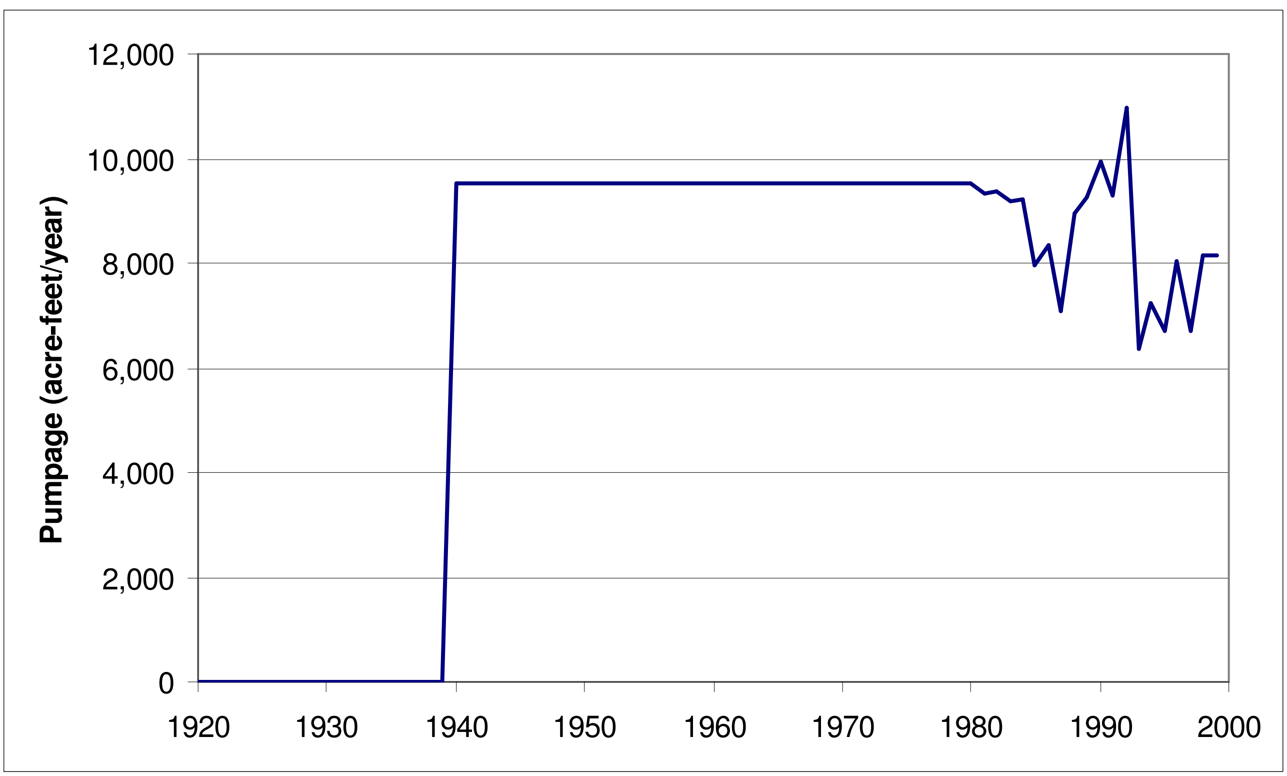

Figure A-2- Pumpage in Austin County included in groundwater availability model for the central part of the Gulf Coast Aquifer.

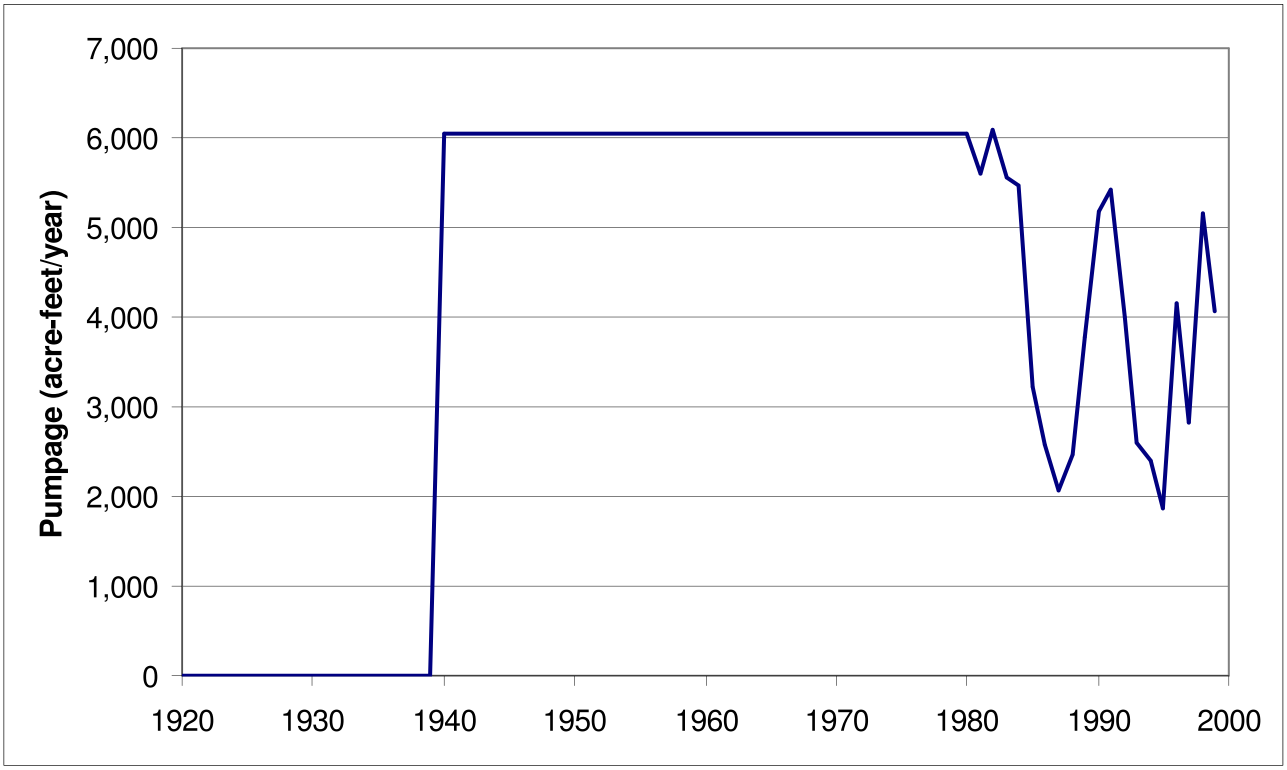

Figure A-3- Pumpage in Bee County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

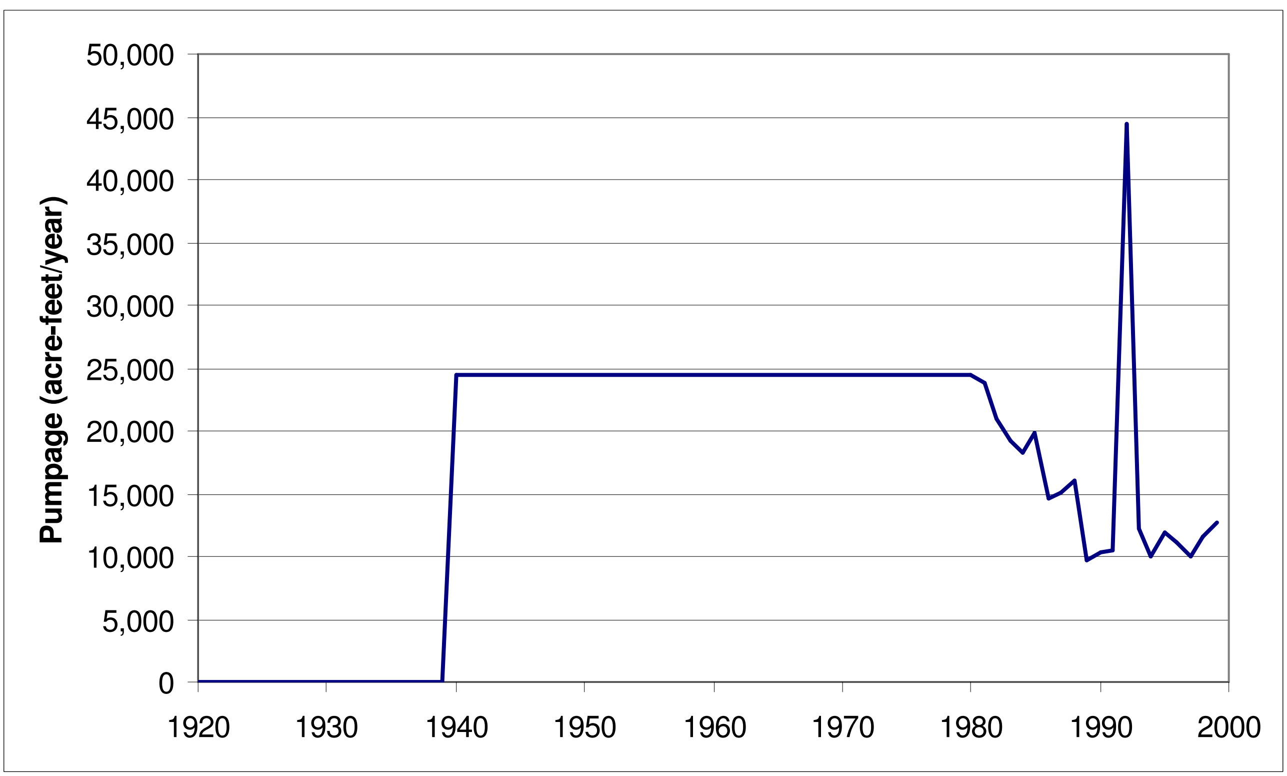

Figure A-4- Pumpage in Brazoria County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

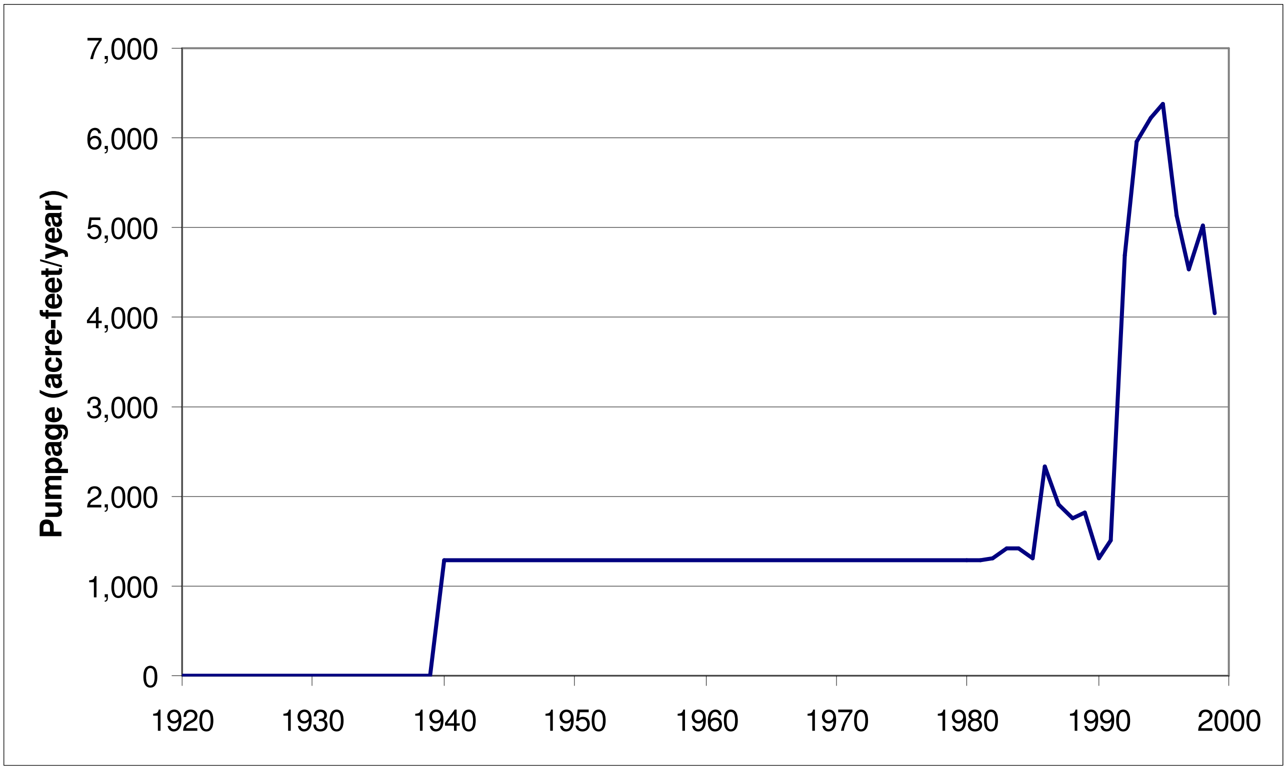

Figure A-5- Pumpage in Brooks County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

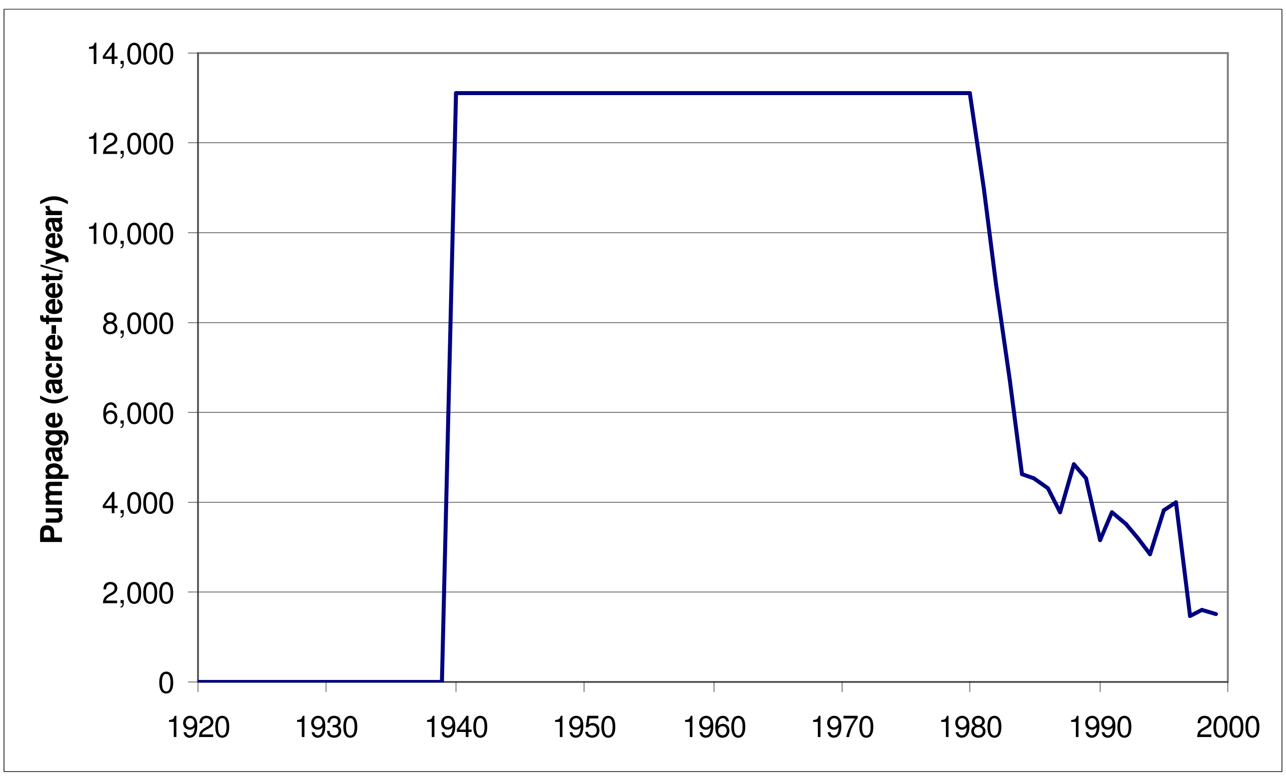

Figure A-6- Pumpage in Calhoun County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

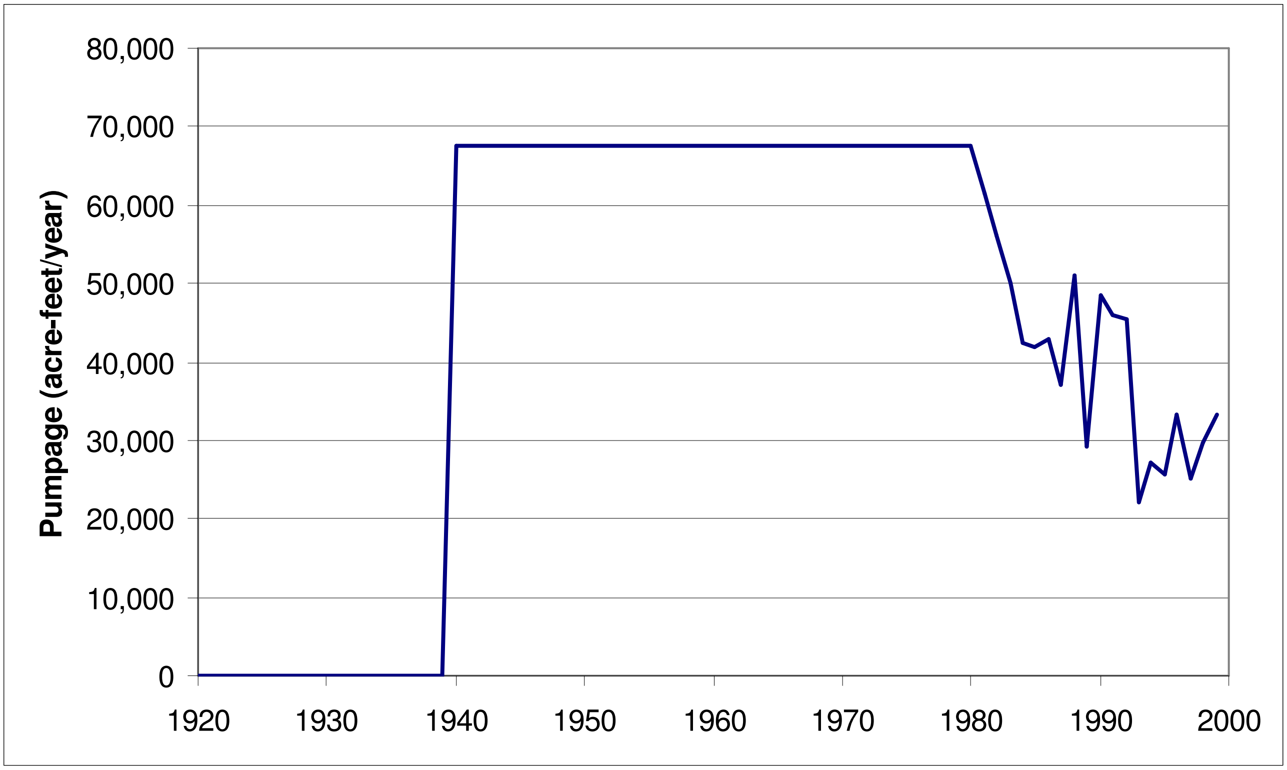

Figure A-7- Pumpage in Colorado County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

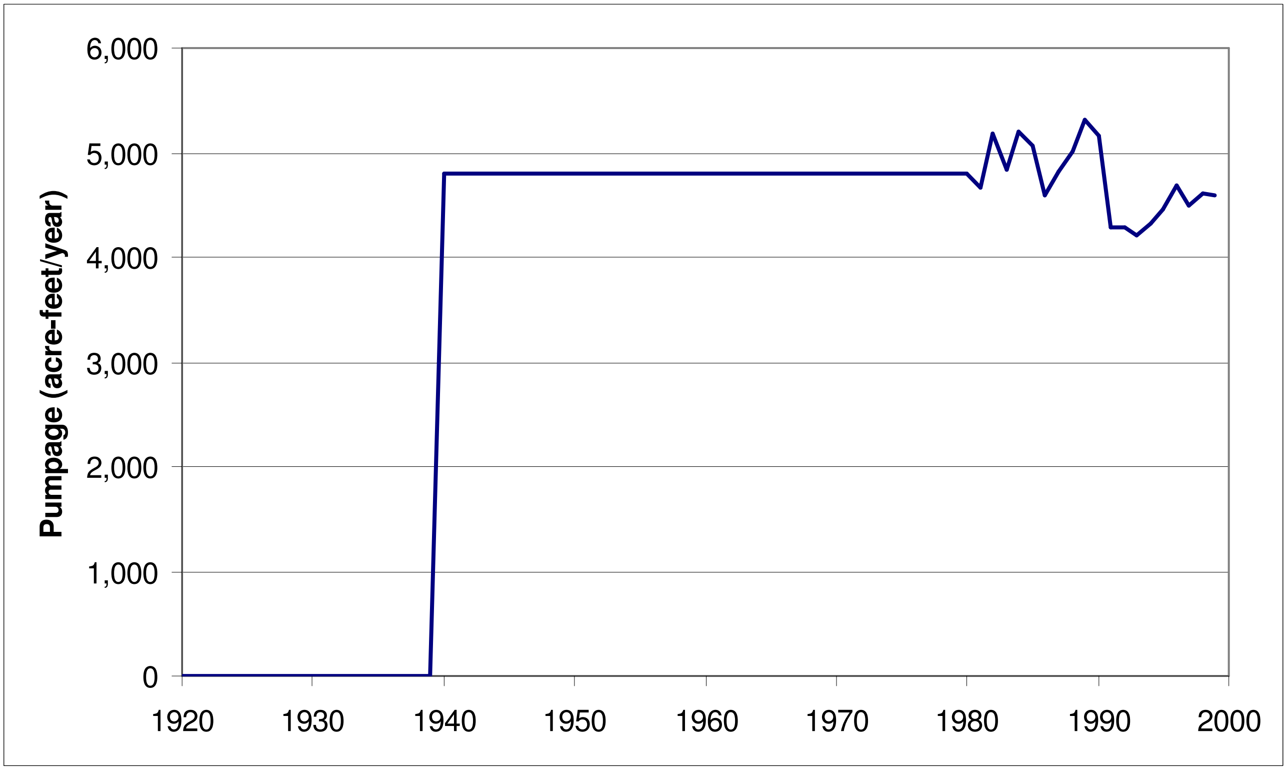

Figure A-8- Pumpage in De Witt County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

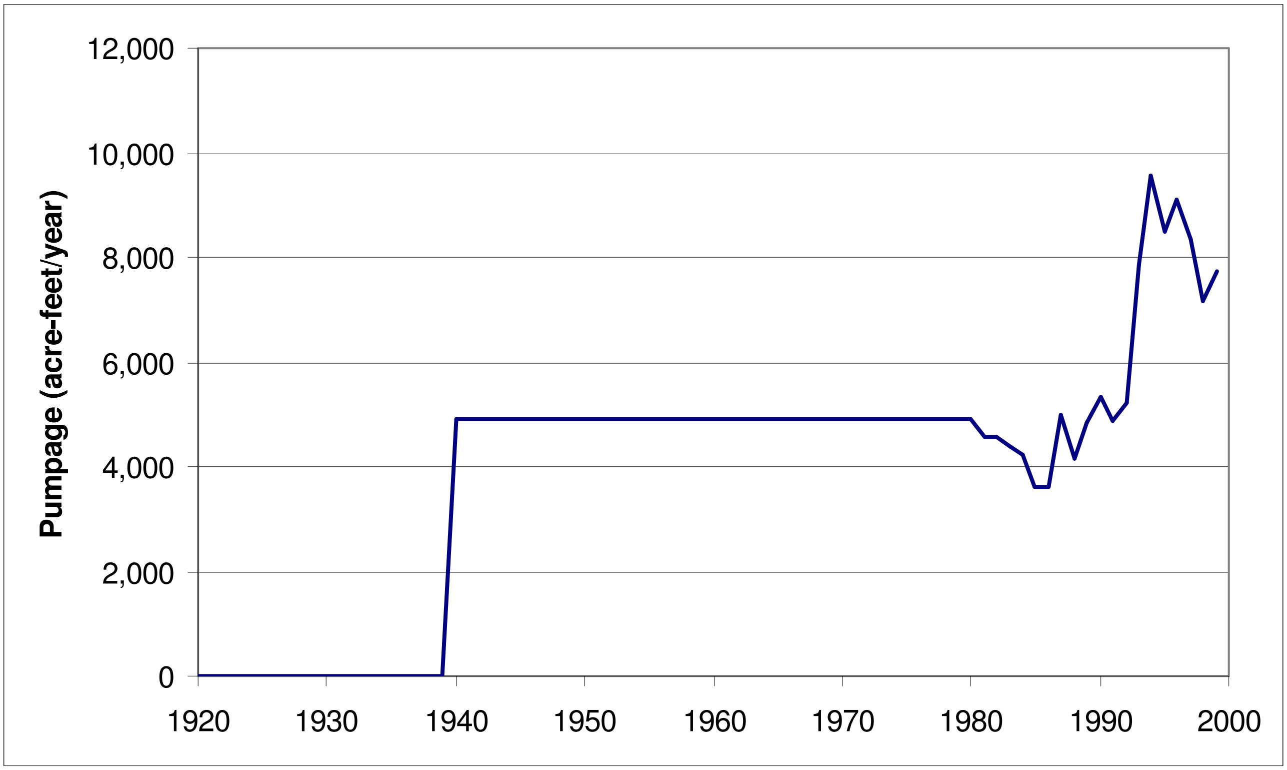

Figure A-9- Pumpage in Duval County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

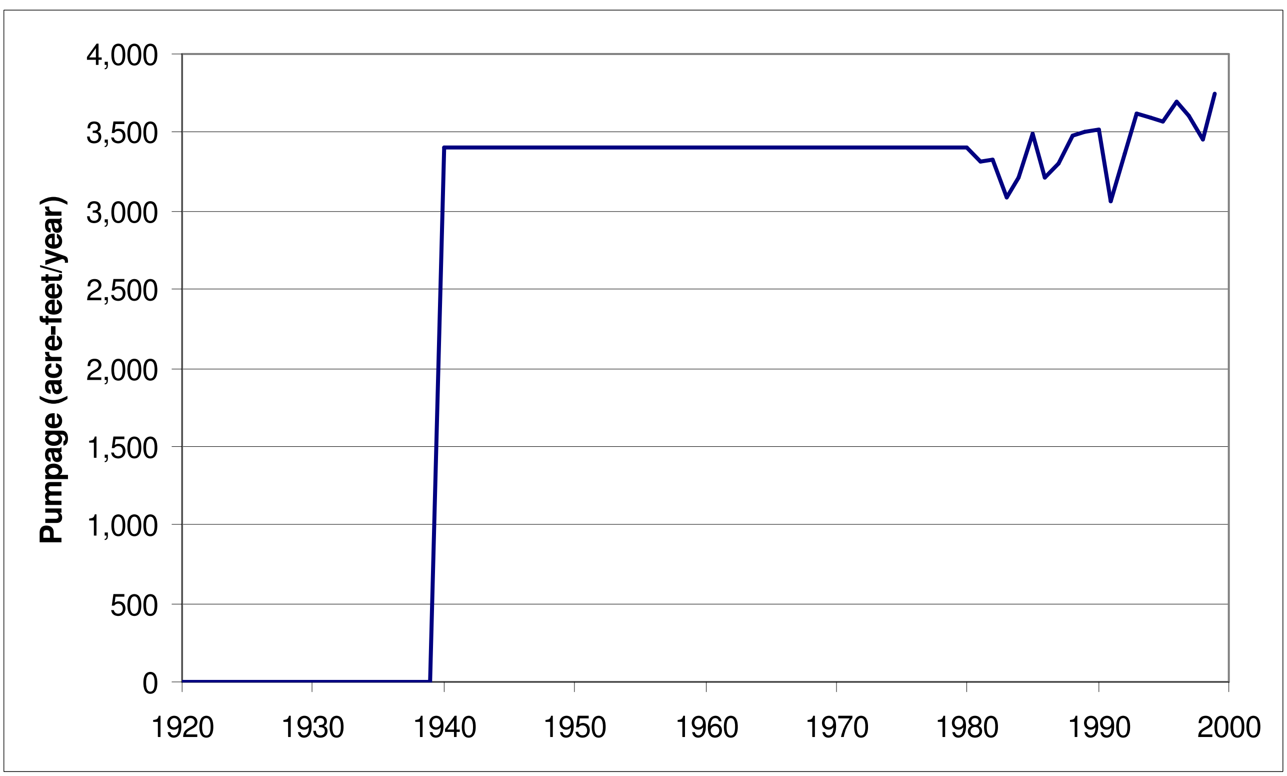

Figure A-10- Pumpage in Fayette County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

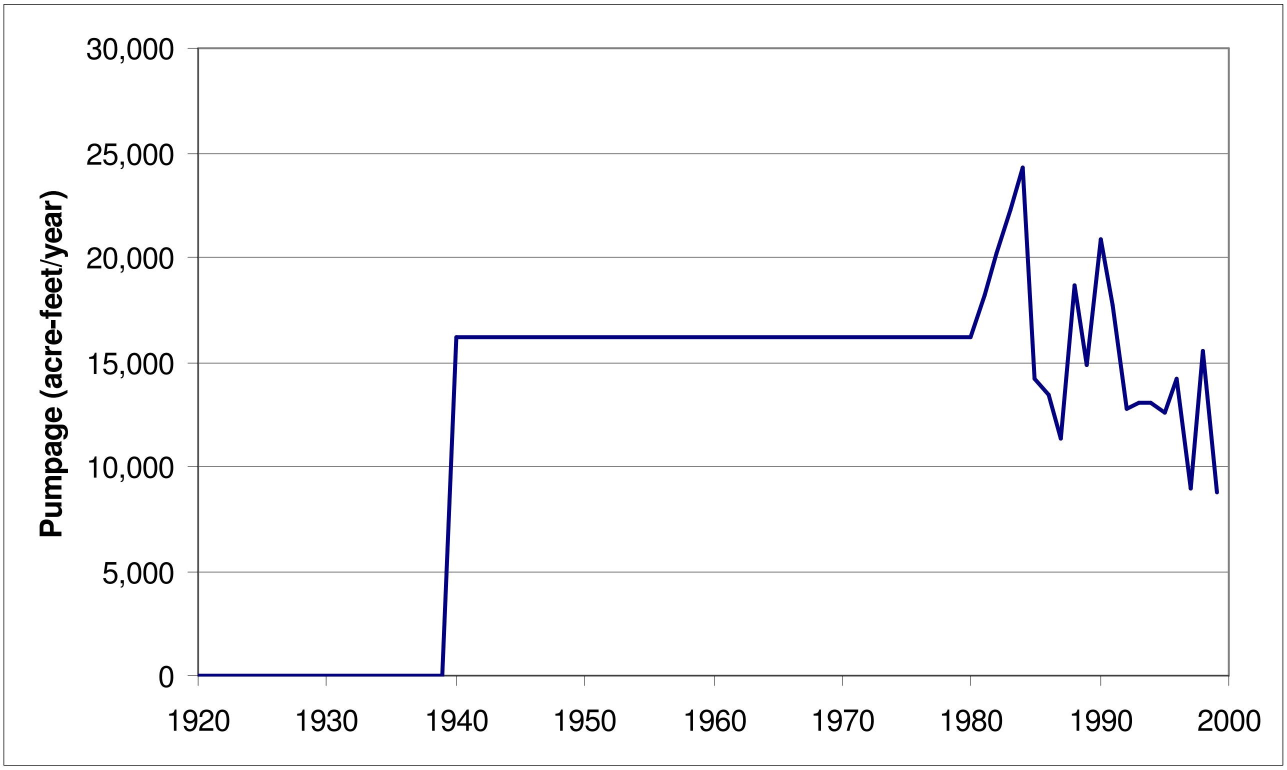

Figure A-11- Pumpage in Fort Bend County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

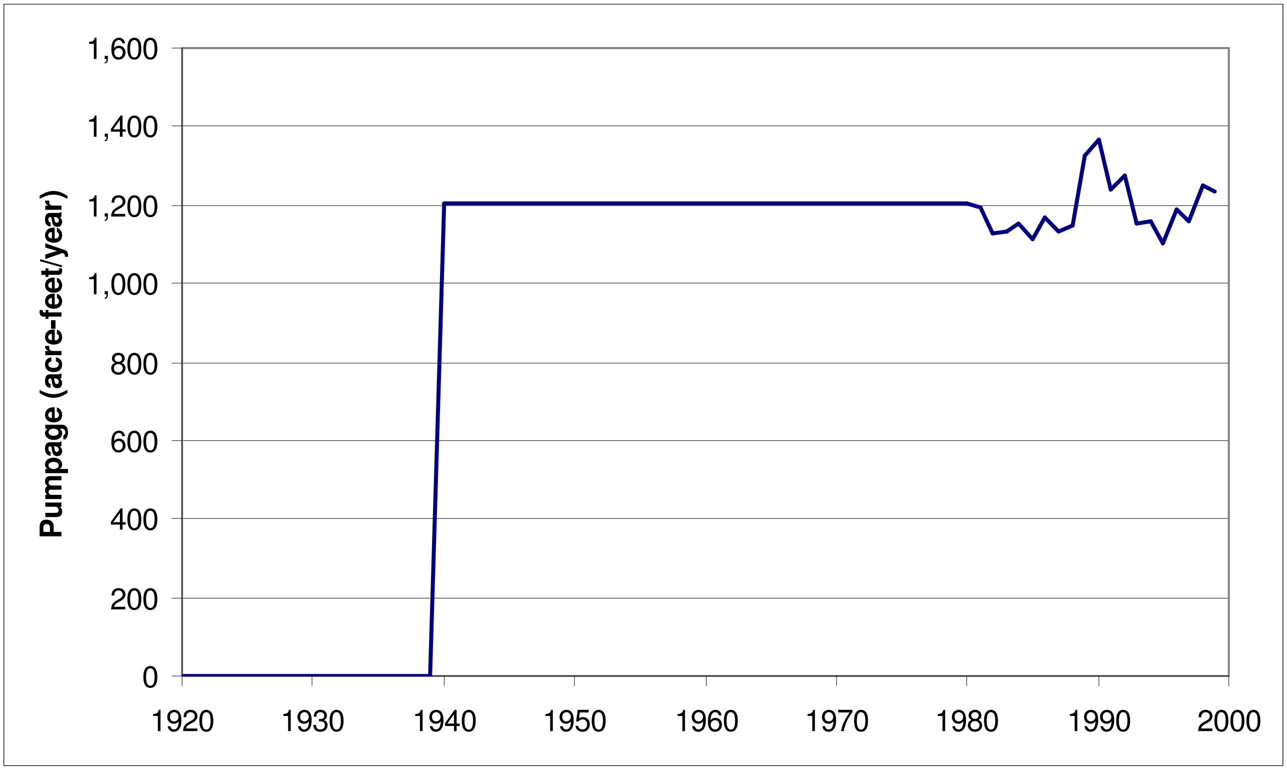

Figure A-12- Pumpage in Goliad County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

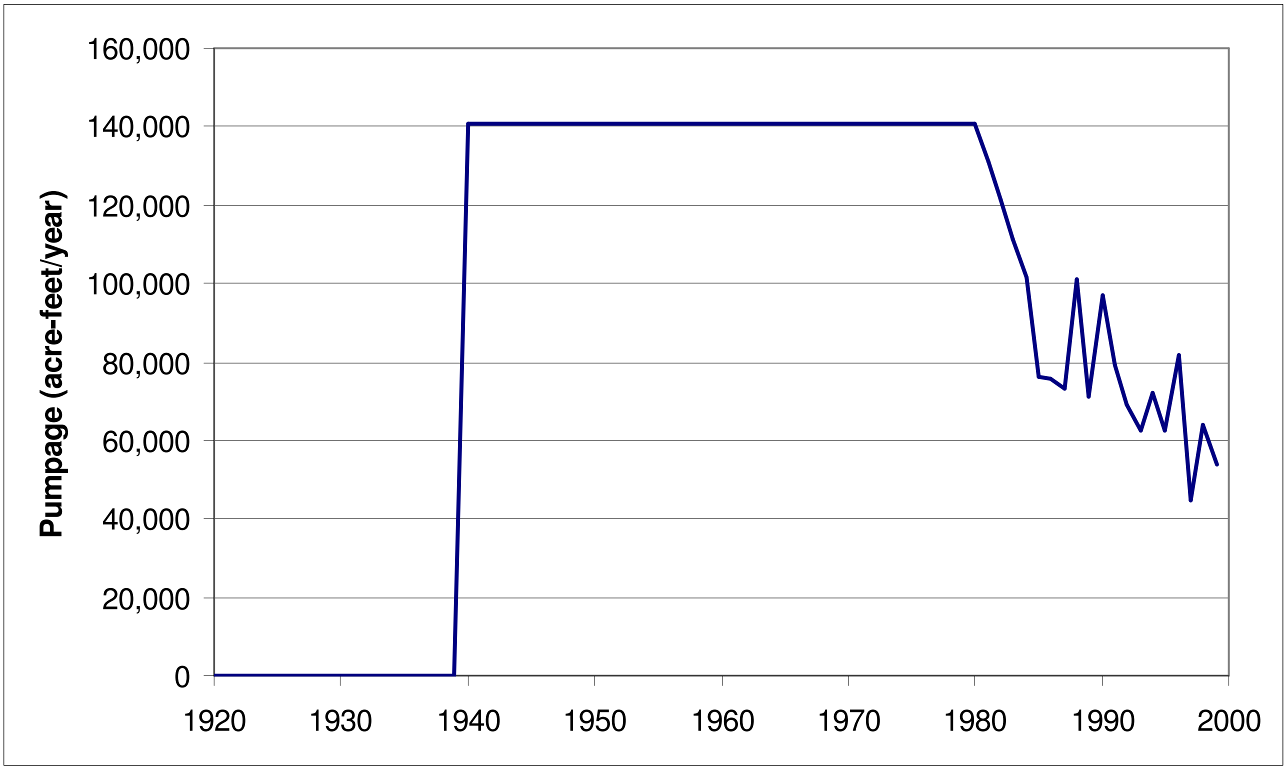

Figure A-13- Pumpage in Jackson County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

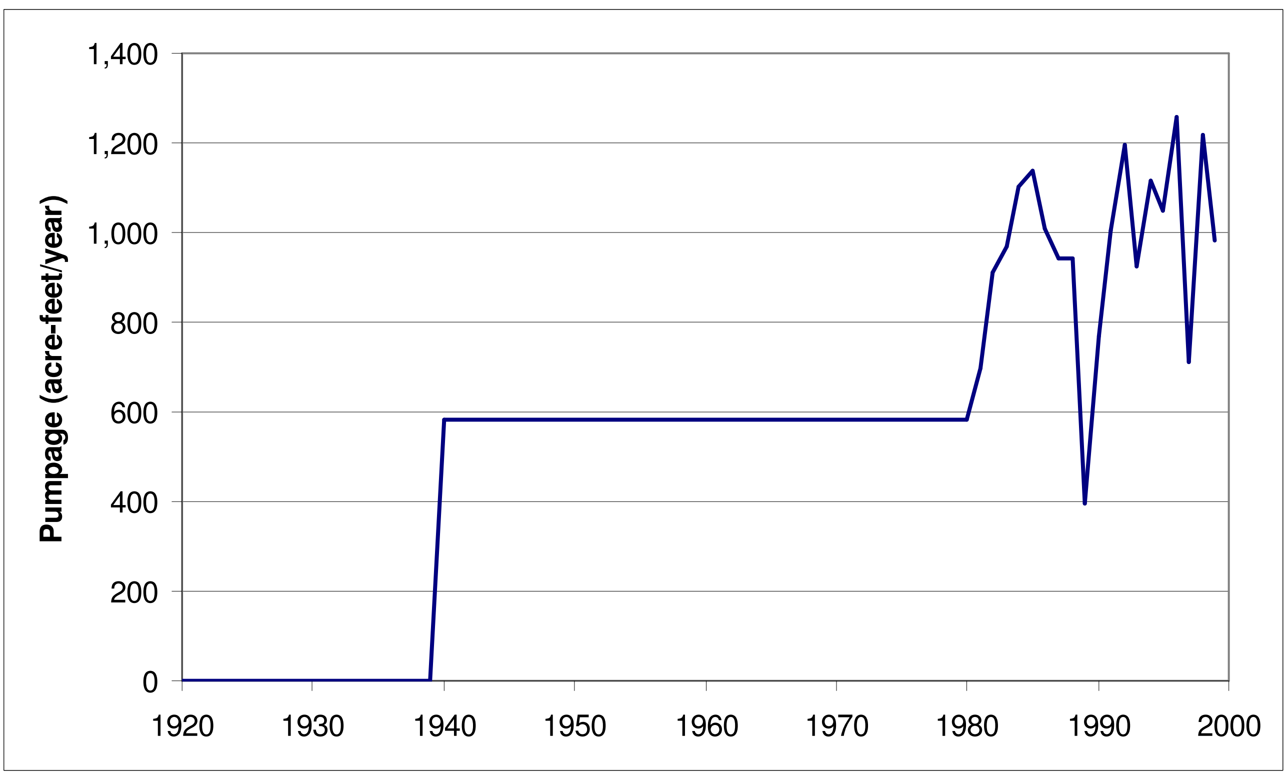

Figure A-14- Pumpage in Jim Hogg County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

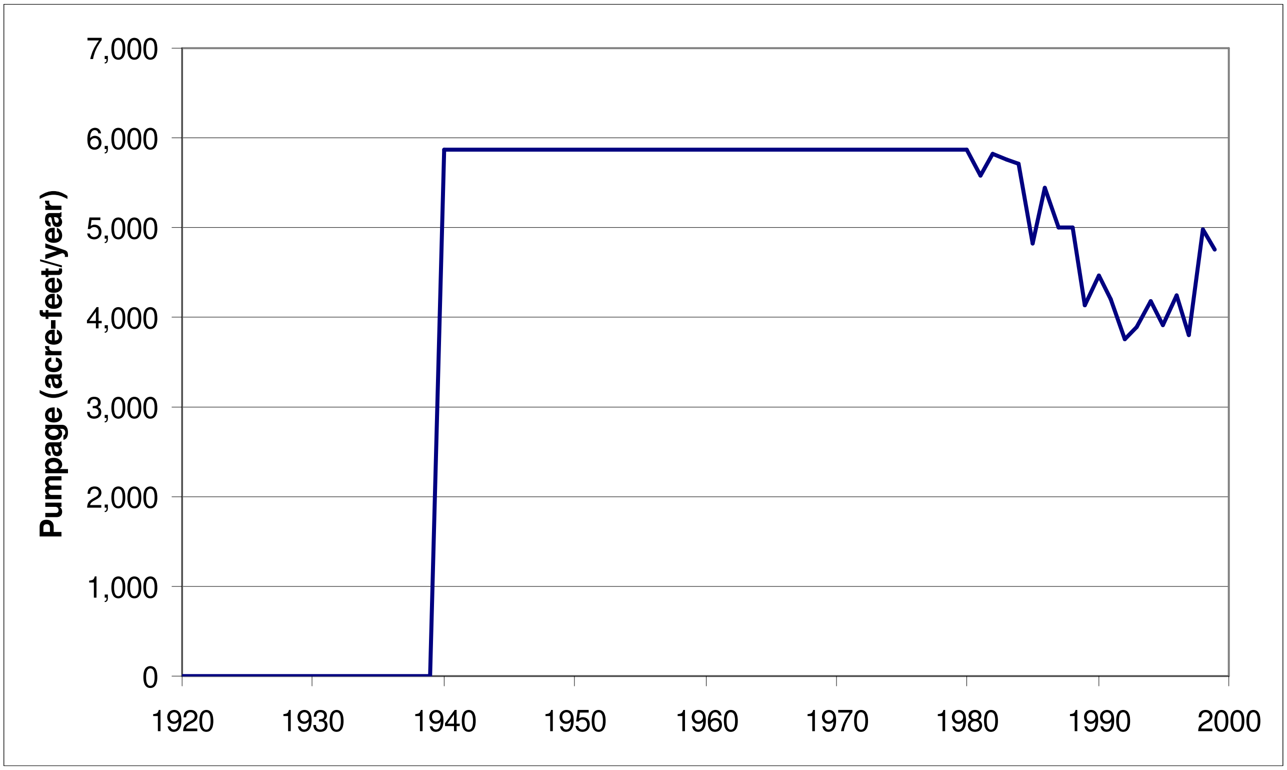

Figure A-15- Pumpage in Jim Wells County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

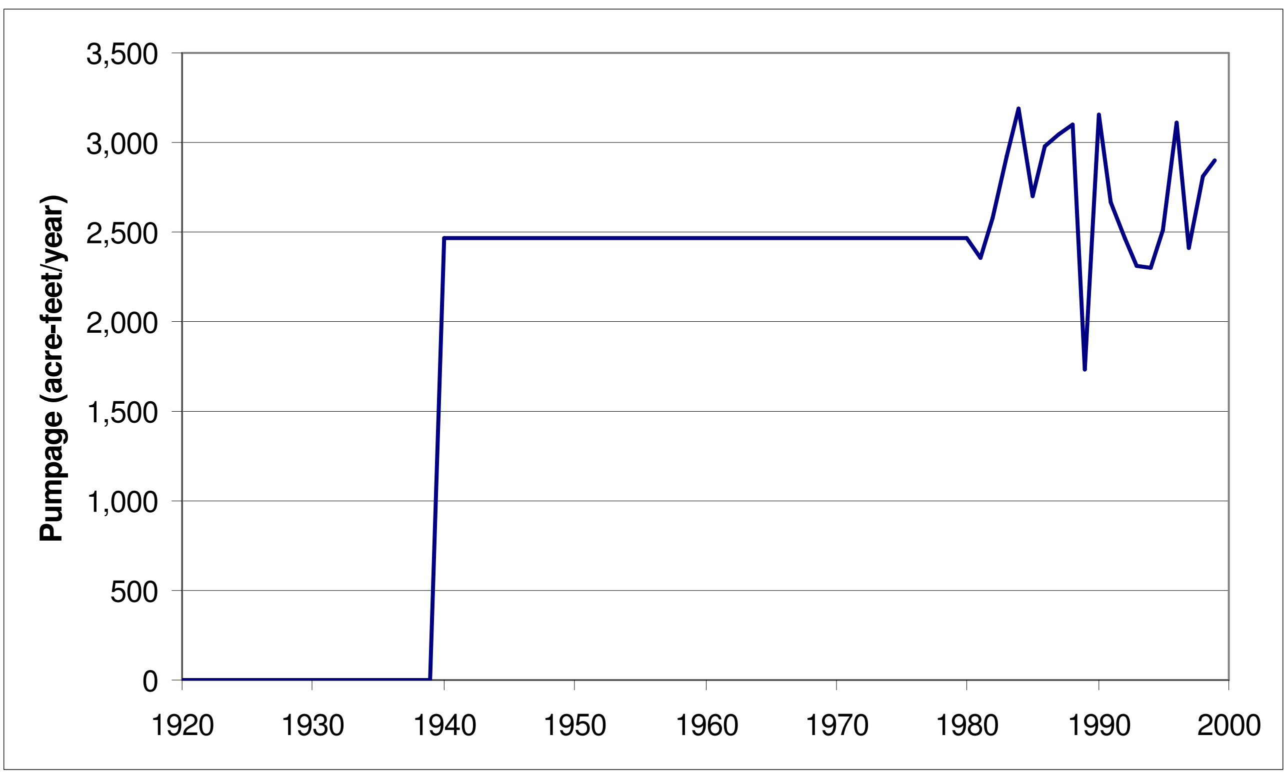

Figure A-16- Pumpage in Karnes County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

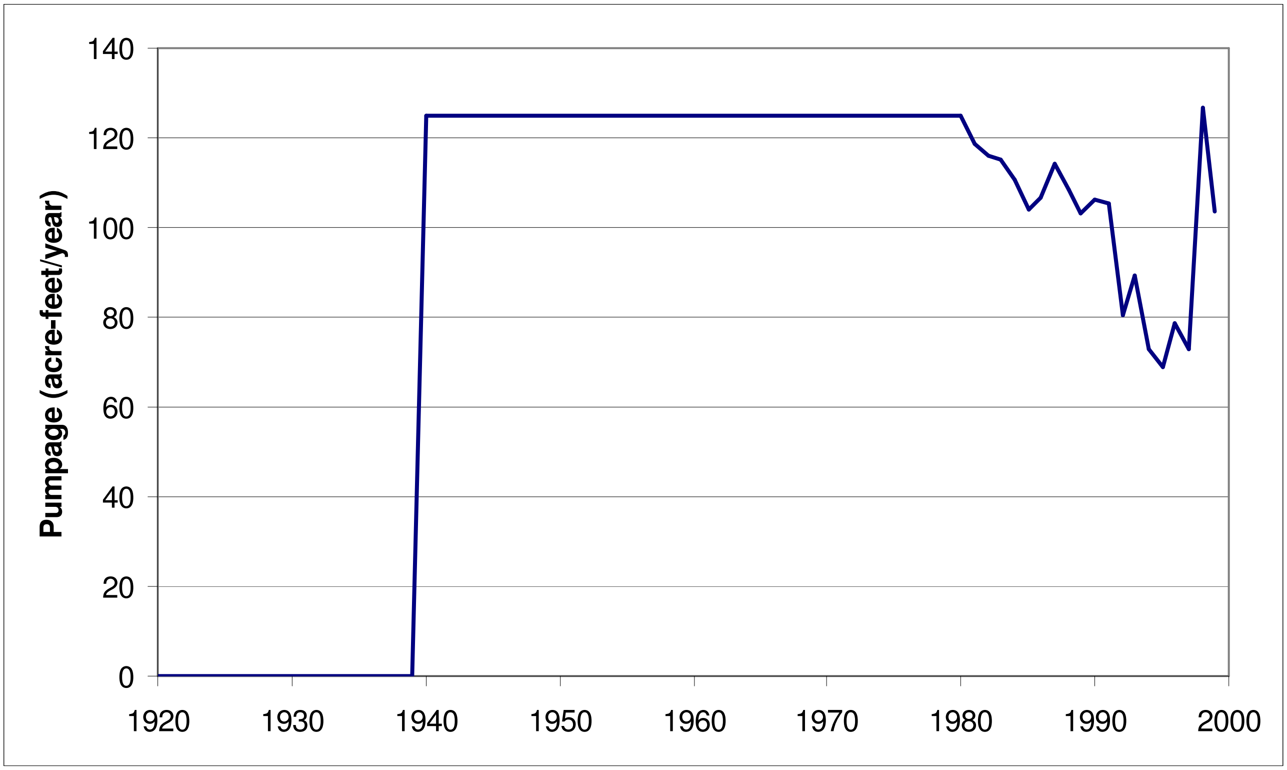

Figure A-17- Pumpage in Kenedy County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

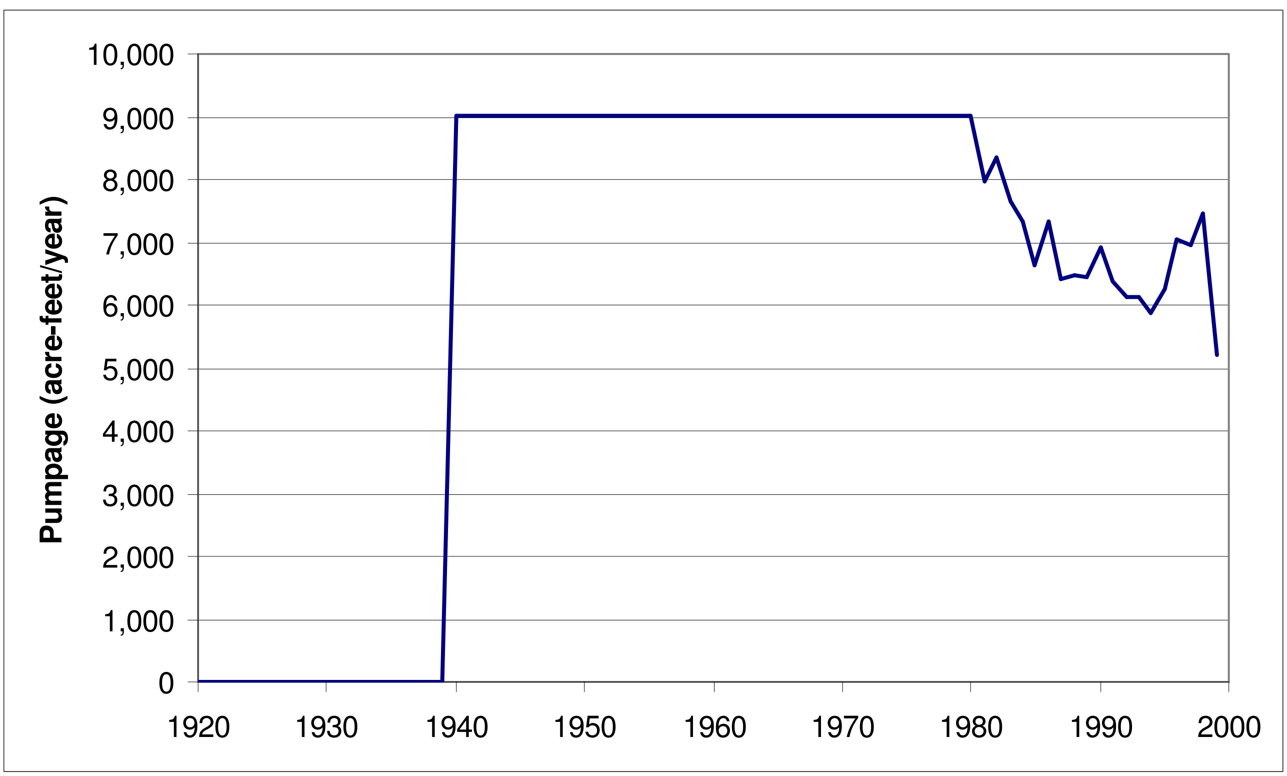

Figure A-18- Pumpage in Kleberg County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

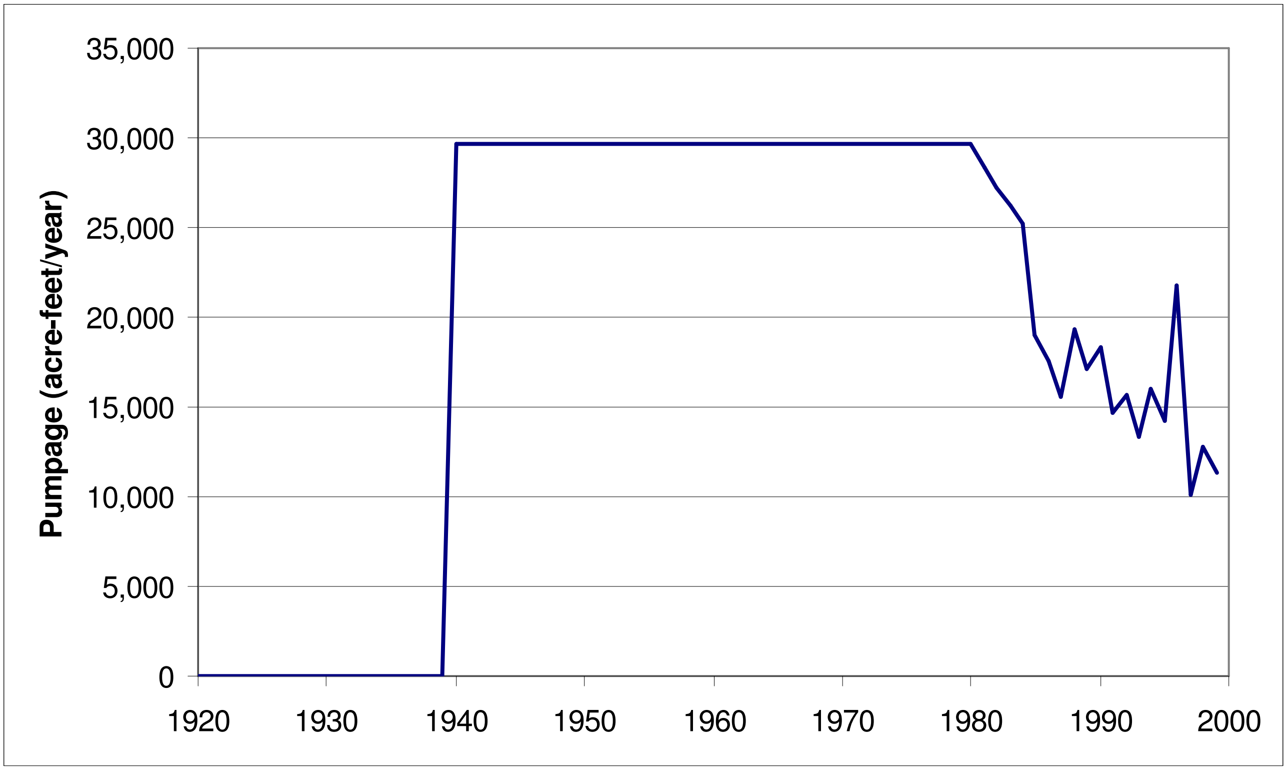

Figure A-19- Pumpage in Lavaca County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

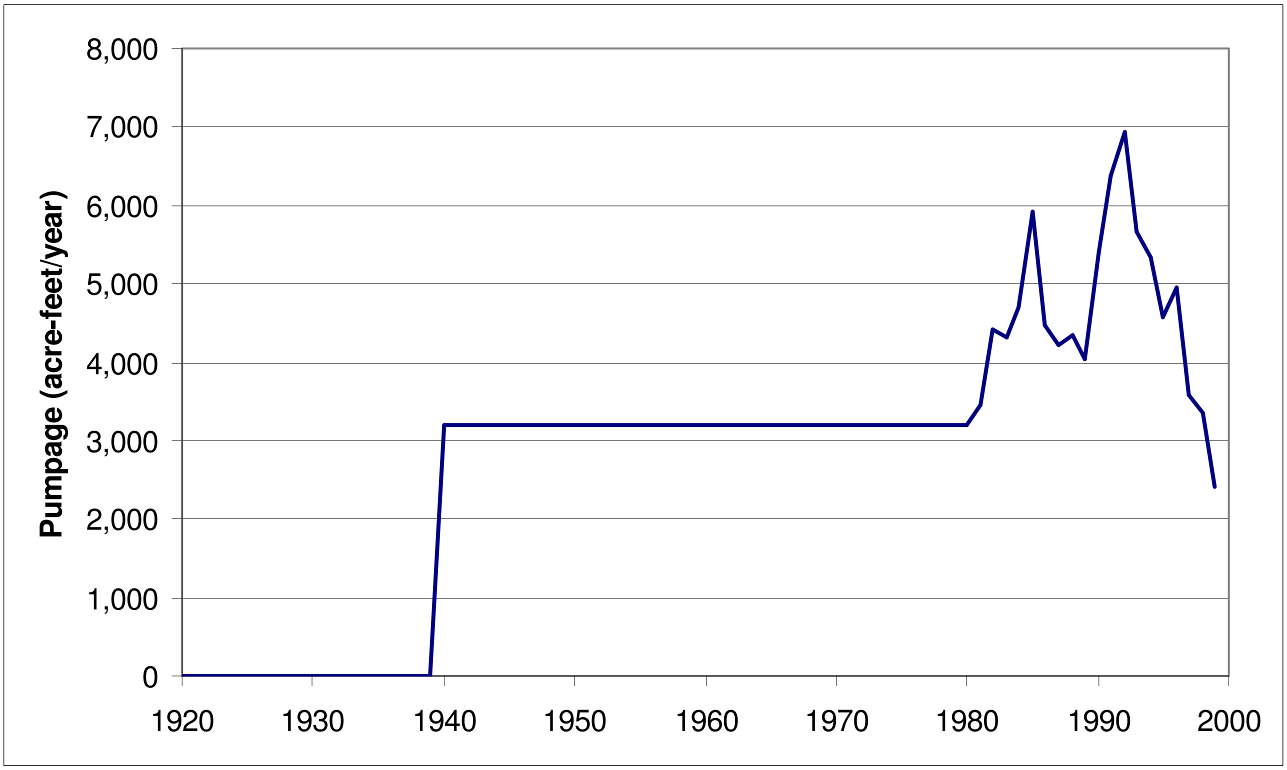

Figure A-20- Pumpage in Live Oak County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

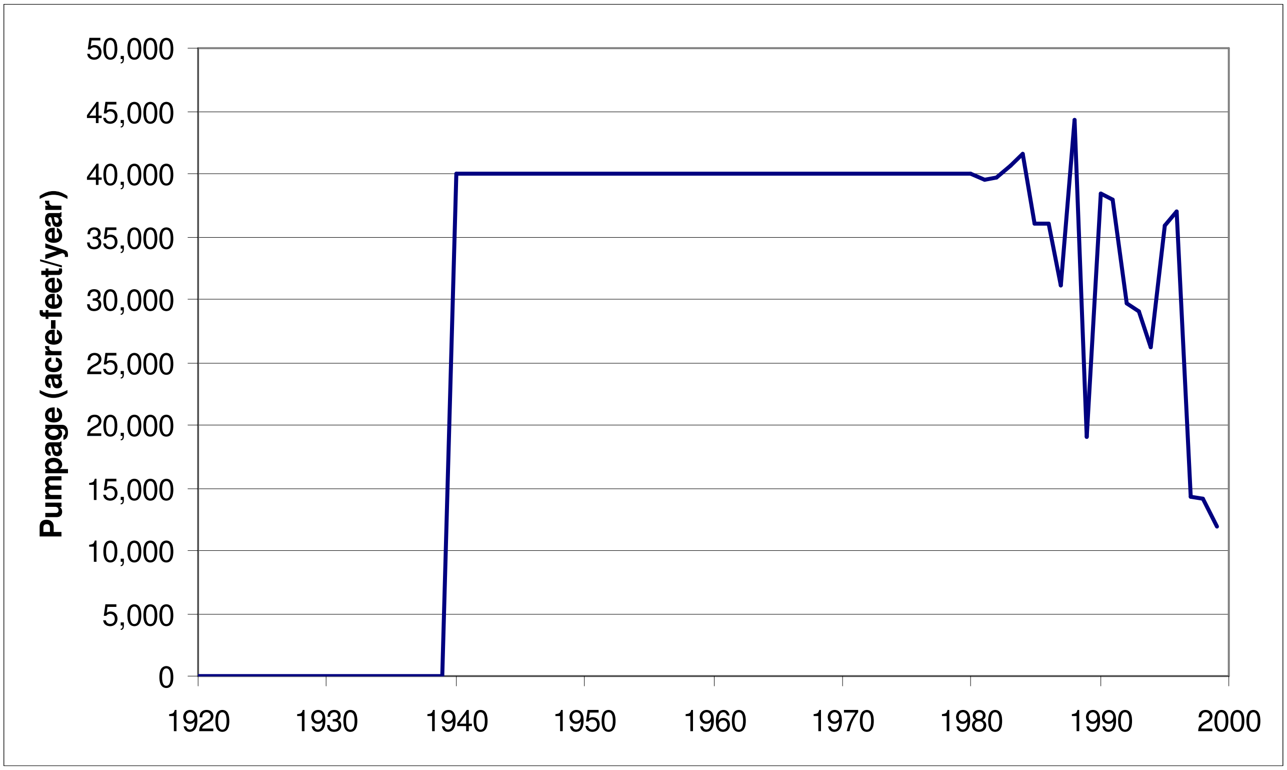

Figure A-21- Pumpage in Matagorda County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

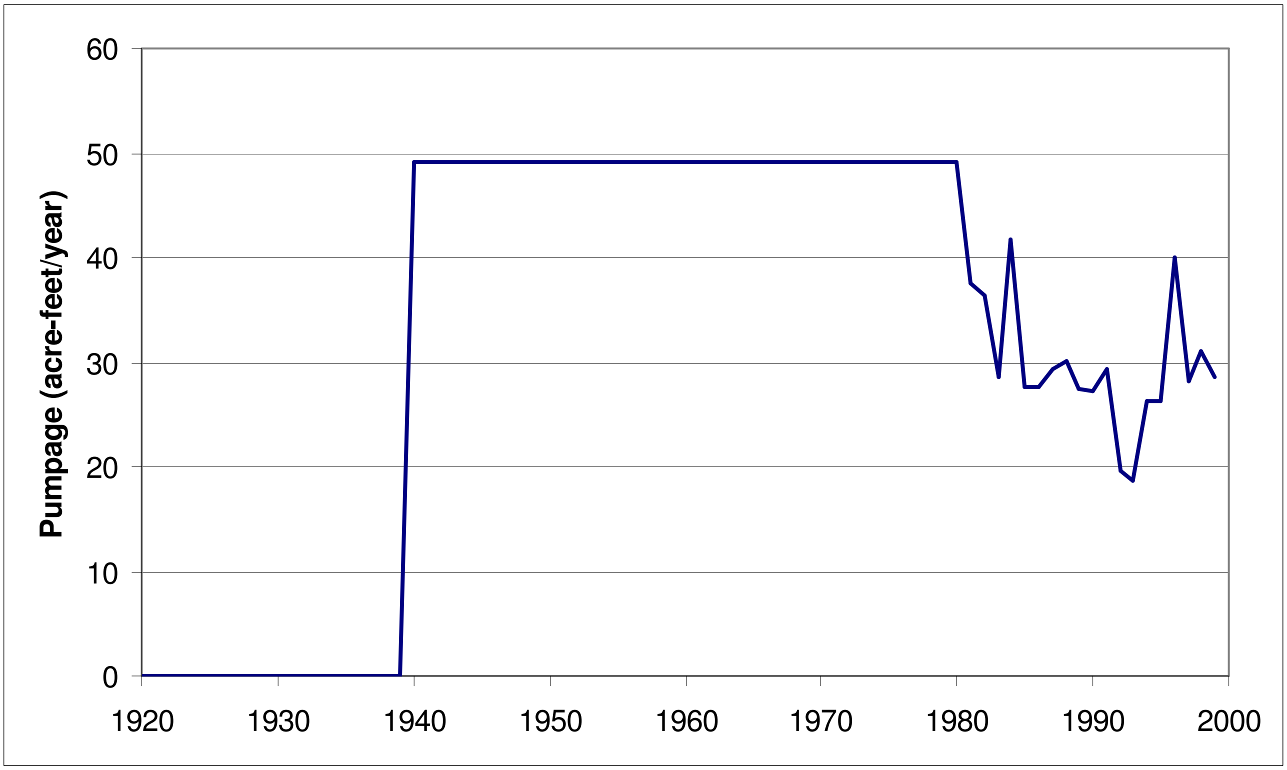

Figure A-22- Pumpage in McMullen County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

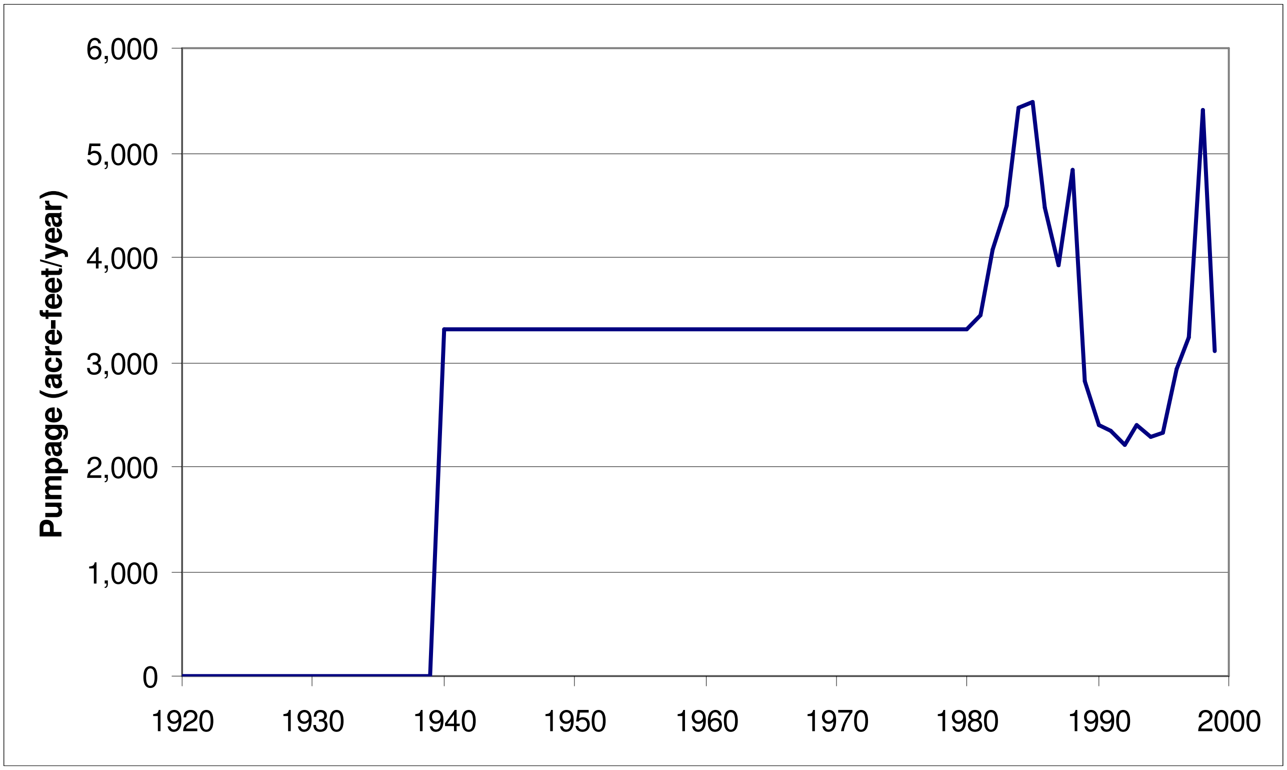

Figure A-23- Pumpage in Nueces County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

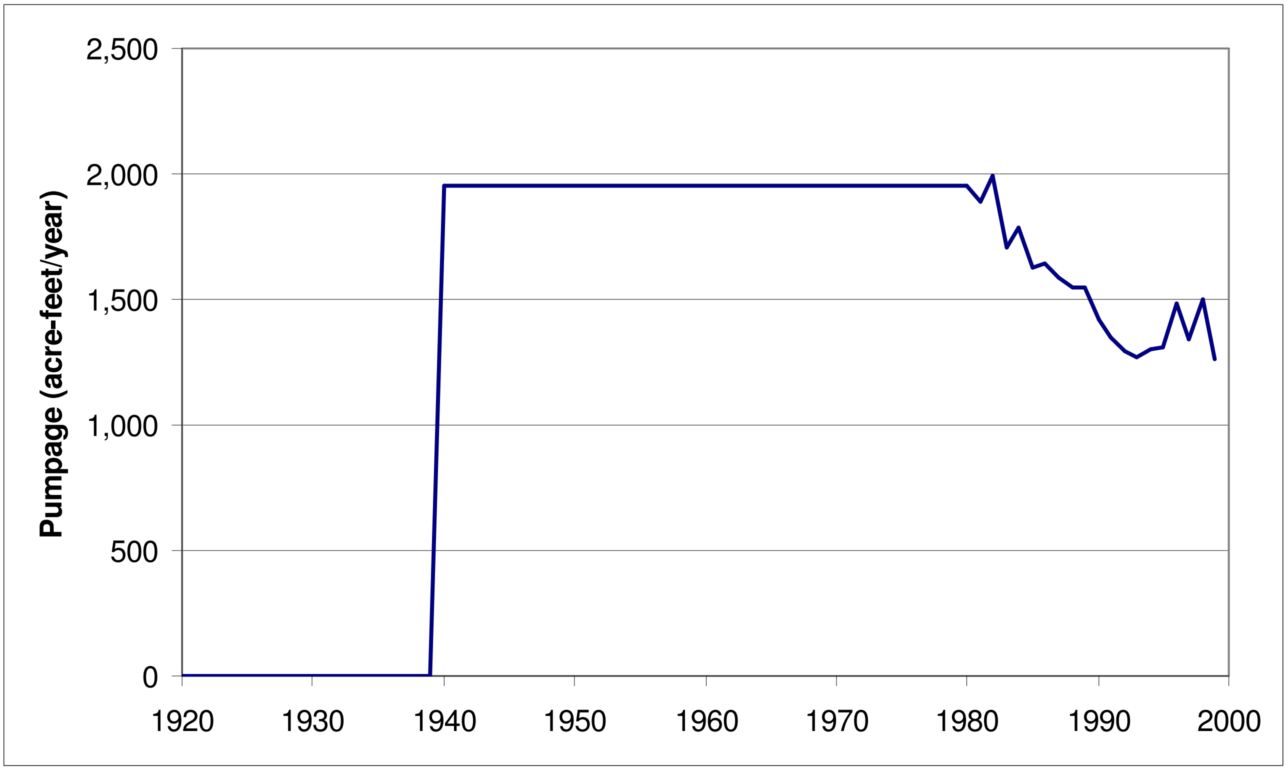

Figure A-24- Pumpage in Refugio County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

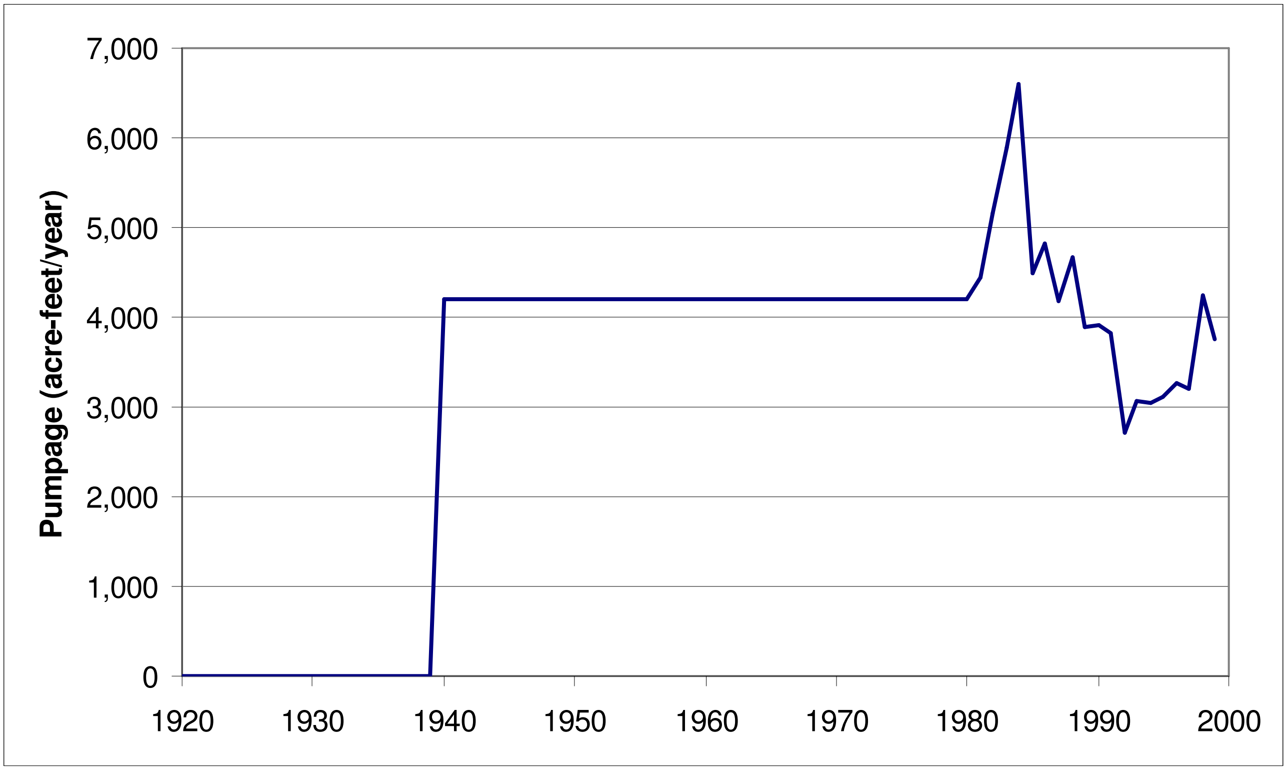

Figure A-25- Pumpage in San Patricio County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

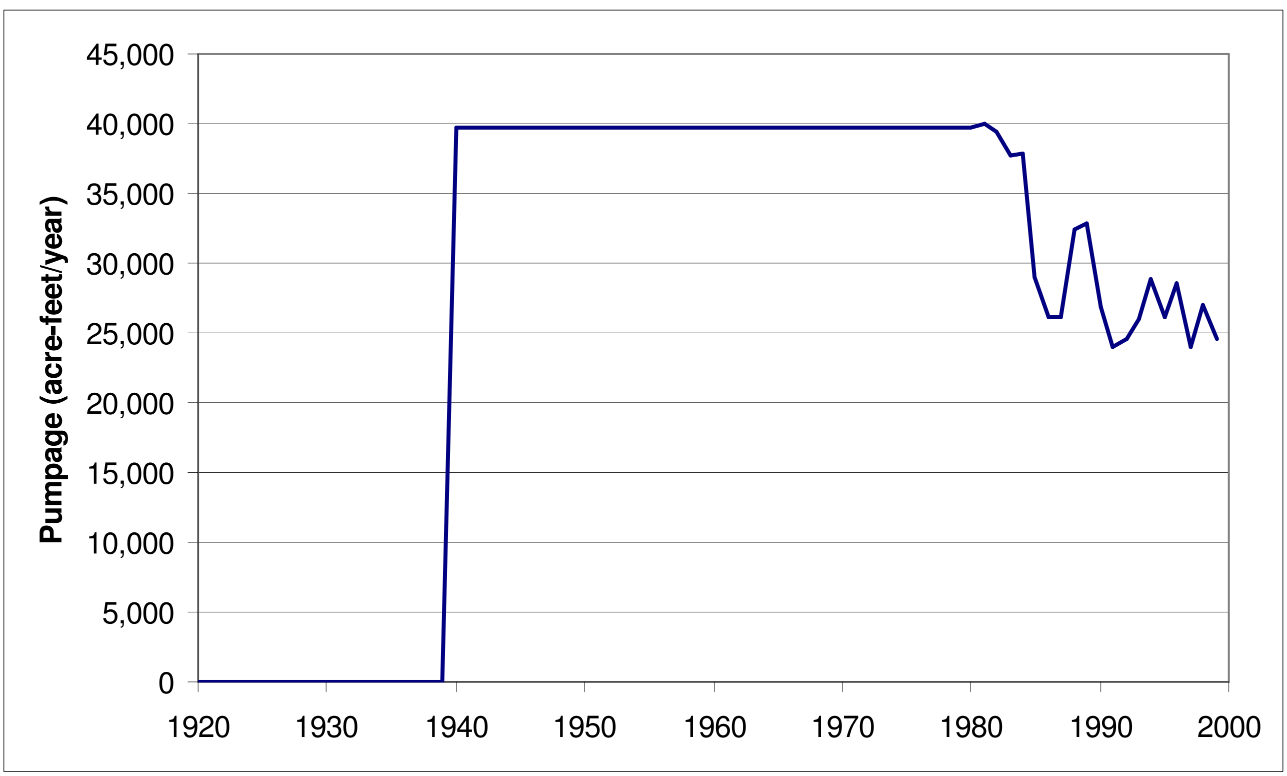

Figure A-26- Pumpage in Victoria County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.

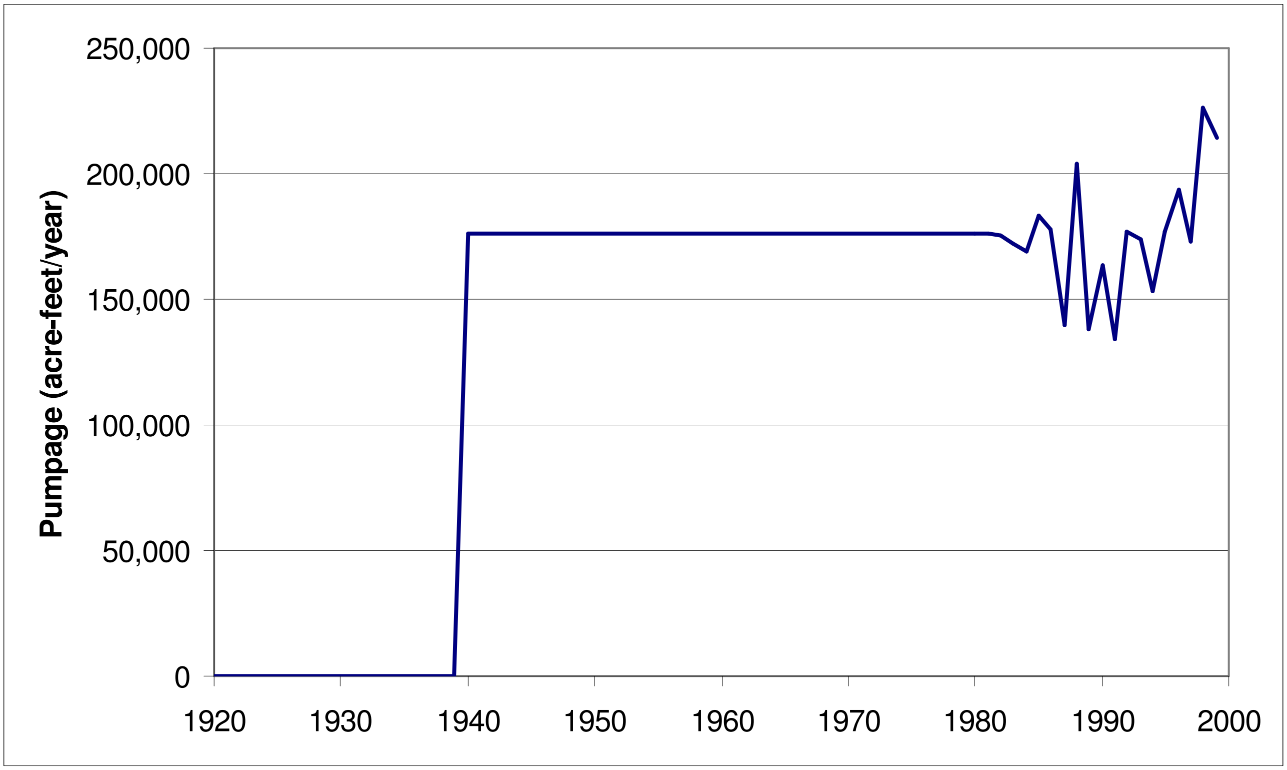

Figure A-27- Pumpage in Webb County included in the groundwater availability model for the central part of the Gulf Coast Aquifer.