

GAM run 03-06

by Shirley Wade

Texas Water Development Board
Groundwater Availability Modeling Section
(512) 463-7847
June 18, 2003

REQUESTOR:

Mr. David Alford, Pineywoods Groundwater Conservation District

DESCRIPTION OF REQUEST:

Mr. Alford requested the following information from the Northern Carrizo-Wilcox aquifer Groundwater Availability Model (GAM) for the Pineywoods Groundwater Conservation District (GCD):

- Recharge,
- Current available storage,
- Estimated annual decline, and
- Projected decline.

In addition, Mr. Alford provided Pineywoods Groundwater Conservation District production records for the period 2002 to 2003 to compare with model input pumpage for the same period.

METHODS:

To address the request, we:

- Ran the transient (1975-1999) and predictive (2000-2050) models for the Northern Carrizo-Wilcox aquifer Groundwater Availability Model (Fryar and others, 2003) and queried the budget files for each aquifer layer in Angelina and Nacogdoches counties for steady-state, 1989, 1999, 2002, and 2003.
- Estimated storage by calculating layer thickness for each model cell (layer top elevation minus bottom elevation), multiplying by cell area (1 mi²) and specific yield, and summing all of the model cells within Nacogdoches and Angelina counties.
- Plotted hydrographs of data from select wells to indicate annual decline over the transient period (1975-2000).
- Extracted maps of predicted drawdown or water level decline for the period 2000-2050 from the final model report.
- Averaged model pumpage for 2002 and 2003 to compare with the 2002-2003 district production records.

PARAMETERS AND ASSUMPTIONS:

None: Data request.

RESULTS:

Recharge and Water budget

Table 1 shows the water budget for the Northern Carrizo-Wilcox GAM model in Angelina and Nacogdoches counties for the years 1989, 1999, 2002, and 2003. A budget is also shown for the steady-state model. Recharge values from the model are listed in the table. Angelina County has zero direct recharge because there is no outcrop in that county. However, TWDB rules concerning groundwater management plan certification define recharge as "The addition of water from precipitation or runoff by seepage or infiltration to an aquifer from the land surface, streams, or lakes directly into a formation or indirectly by way of leakage from another formation." Leakage into the aquifers is listed in the columns "upper Z flow in and lower Z flow in" (Table 1).

Aquifer Storage

The total volume of storage in the aquifer is shown for each layer in Angelina and Nacogdoches counties in Table 2.

Estimated Annual Decline

Hydrographs from two Upper Wilcox wells in Nacogdoches County are shown in Figure 1. The well in the northern part of the county (37-10-302) shows less than 5 feet net decline from 1975 to 1999. The well in the central part of the county (37-20-902) shows 45 feet net decline in 25 years. Water levels from Carrizo aquifer wells in northern and southern Nacogdoches County are shown in Figures 2 and 3, respectively. The well in northern Nacogdoches shows less than 5 feet net decline from 1975-2000 (Figure 2). The well in southern Nacogdoches County shows a net water level rise of about 80 feet (Figure 3). Hydrographs from two Carrizo wells in northern Angelina County are shown in Figure 4. Well 37-36-501 shows no net decline and Well 37-35-703 shows a net decline of 160 feet from 1975 to 1999.

Projected Decline

Predicted water-level declines from 2000 to 2050 for the Carrizo and Upper Wilcox aquifers are shown in Figures 5 and 6, respectively. The figures indicate a water-level rebound over much of the area. The rebound results from a decrease in model pumpage input from the calibration/verification period (1975-1999) to the predictive period (2000 - 2050). The pumpage input used in the model for the calibration/verification period is based on water use survey and other data; whereas, the pumpage input during the predictive period is based on the Regional Water Planning Group predictions. A comparison of the model input pumpage for 1980, 1990, 1999, 2000, and 2050 is shown

in Tables 4a and 4b. The tables show a drop in total pumping from 1999 to 2000 in Nacogdoches County and a drop in pumping in Angelina County from 1999 to 2000 in layer 3.

Pumpage Comparison

A comparison between Pineywoods water production records for 2002 and 2003 and model input pumpage for Angelina and Nacogdoches counties is given in Table 3. Model pumpage inputs for 2002 and 2003 (Table 1) are very similar; therefore, the average of 2002 and 2003 model pumpage is compared with the production totals of the last 3 quarters in 2002 and the first quarter of 2003. The model pumpage is somewhat less than the production records.

REFERENCES:

Fryar, D., Senger, R., Deeds, N., Pickens, J., Jones, T., Whallon, A. J., and Dean, K.E., 2003, Groundwater Availability Model for the Northern Carrizo-Wilcox Aquifer: Final Report prepared for the Texas Water Development Board.

Table 1. Nacogdoches and Angelina counties flow budgets for the Northern Carrizo-Wilcox aquifer model in 1999, in acre-feet per year.

Nacogdoches and Angelina counties flow budget for the Northern Carrizo-Wilcox aquifer model, in acre-feet per year.																	
County	Lyr	Storage	X-flow in	X-flow out	upper		lower		Wells	Recharge	ET	GHB	Stream	Reserv. Leakage	Total		% diff
					Z flow in	Z flow out	Z flow in	Z flow out							In	Out	
2003																	
Nacogdoches	1	-5,088	640	-256	0	0	39	-7,955	-32	24,732	-16,805	6,012	-374	-914	31,424	-31,424	0
	2	-17,057	505	-769	7,955	-39	437	-9,678	-106	29,259	-7,407	0	-3,102	0	38,155	-38,157	0
	3	414	1,954	-5,297	9,678	-437	355	-5,530	-5,657	18,040	-10,981	0	-2,539	0	30,440	-30,440	0
	4	-10,343	7,808	-5,639	5,530	-355	1,062	-1,142	-4,254	13,137	-4,135	0	-1,670	0	27,537	-27,538	0
	5	-4,770	5,509	-2,033	1,142	-1,062	477	-137	-368	1,112	0	0	130	0	8,370	-8,370	0
	6	-339	1,062	-383	137	-477	0	0	-1	0	0	0	0	0	1,200	-1,200	0
	All	-37,183	17,479	-14,377	24,442	-2,370	2,370	-24,442	-10,418	86,279	-39,327	6,012	-7,555	-914	137,126	-137,129	0
Angelina	1	-14	563	-519	0	0	7	-1,773	0	0	0	1,736	0	0	2,305	-2,305	0
	2	-959	672	-72	1,773	-7	0	-1,407	0	0	0	0	0	0	2,445	-2,445	0
	3	-1,289	6,483	-542	1,407	0	524	-108	-6,475	0	0	0	0	0	8,414	-8,414	0
	4	-3,625	8,511	-1,300	108	-524	1,720	0	-4,889	0	0	0	0	0	10,339	-10,339	0
	5	-2,641	3,924	-407	0	-1,720	844	0	0	0	0	0	0	0	4,768	-4,768	0
	6	138	771	-65	0	-844	0	0	0	0	0	0	0	0	909	-909	0
	All	-8,390	20,923	-2,905	3,288	-3,094	3,094	-3,288	-11,364	0	0	1,736	0	0	29,179	-29,179	0
2002																	
Nacogdoches	1	-5,029	641	-256	0	0	38	-8,135	-32	24,646	-16,738	6,182	-404	-913	31,507	-31,507	0
	2	-17,058	519	-770	8,135	-38	413	-9,818	-105	29,230	-7,379	0	-3,128	0	38,296	-38,298	0
	3	331	2,011	-5,433	9,818	-413	434	-5,457	-5,716	18,155	-11,165	0	-2,567	0	30,750	-30,751	0
	4	-10,330	7,874	-5,649	5,457	-434	1,088	-1,145	-4,247	13,137	-4,072	0	-1,678	0	27,555	-27,556	0
	5	-4,809	5,544	-2,032	1,145	-1,088	498	-132	-368	1,112	0	0	130	0	8,429	-8,429	0
	6	-319	1,062	-377	132	-498	0	0	-1	0	0	0	0	0	1,195	-1,195	0
	All	-37,214	17,651	-14,517	24,688	-2,471	2,471	-24,688	-10,469	86,279	-39,355	6,182	-7,647	-913	137,732	-137,735	0
Angelina	1	-14	563	-520	0	0	6	-1,814	0	0	0	1,779	0	0	2,348	-2,348	0
	2	-932	678	-83	1,814	-6	0	-1,470	0	0	0	0	0	0	2,492	-2,492	0
	3	-1,757	6,748	-560	1,470	0	737	-83	-6,554	0	0	0	0	0	8,955	-8,955	0
	4	-3,343	8,578	-1,338	83	-737	1,738	0	-4,982	0	0	0	0	0	10,400	-10,400	0
	5	-2,692	3,980	-418	0	-1,738	868	0	0	0	0	0	0	0	4,848	-4,848	0
	6	170	764	-66	0	-868	0	0	0	0	0	0	0	0	934	-934	0
	All	-8,568	21,311	-2,985	3,367	-3,349	3,349	-3,367	-11,537	0	0	1,779	0	0	29,976	-29,976	0

Nacogdoches and Angelina counties flow budget for the Northern Carrizo-Wilcox aquifer model, in acre-feet per year.

County	Lyr	Storage	X-flow in	X-flow out	upper		lower		Wells	Recharge	ET	GHB	Stream	Reserv. Leakage	Total		% diff
					Z flow in	Z flow out	Z flow in	Z flow out							In	Out	
1999																	
Nacogdoches	1	28,971	649	-255	0	0	41	-8,697	-38	4,639	-29,230	6,696	-530	-2,246	40,996	-40,996	0
	2	15,349	566	-762	8,697	-41	370	-12,003	-124	4,041	-11,279	0	-4,817	0	29,023	-29,026	0
	3	25,060	2,417	-7,985	12,003	-370	1,873	-5,300	-9,134	3,658	-19,436	0	-2,788	0	45,011	-45,013	0
	4	2,298	8,397	-5,555	5,300	-1,873	1,139	-1,166	-4,079	3,261	-5,601	0	-2,122	0	20,395	-20,396	0
	5	-4,251	5,700	-2,034	1,166	-1,139	569	-116	-350	351	0	0	104	0	7,890	-7,890	0
	6	-245	1,059	-359	116	-569	0	0	-1	0	0	0	0	0	1,174	-1,174	0
	All	67,182	18,787	-16,950	27,281	-3,992	3,992	-27,281	-13,725	15,950	-65,547	6,696	-10,153	-2,246	144,490	-144,495	0
Angelina	1	-8	562	-523	0	0	6	-1,919	0	0	0	1,882	0	0	2,450	-2,450	0
	2	-519	666	-120	1,919	-6	0	-1,938	-1	0	0	0	0	0	2,584	-2,584	0
	3	293	10,251	-1,007	1,938	0	2,469	-45	-13,898	0	0	0	0	0	14,950	-14,950	0
	4	-3,071	8,610	-1,785	45	-2,469	1,761	0	-3,092	0	0	0	0	0	10,416	-10,416	0
	5	-2,898	4,166	-456	0	-1,761	948	0	0	0	0	0	0	0	5,115	-5,115	0
	6	279	739	-69	0	-948	0	0	0	0	0	0	0	0	1,017	-1,017	0
	All	-5,924	24,993	-3,961	3,902	-5,184	5,184	-3,902	-16,990	0	0	1,882	0	0	36,532	-36,532	
1989																	
Nacogdoches	1	5,399	653	-260	0	0	44	-9,194	-27	10,831	-13,339	7,260	-532	-837	24,187	-24,188	0
	2	5,553	621	-878	9,194	-44	352	-12,543	-99	11,407	-6,935	0	-6,630	0	27,127	-27,129	0
	3	12,128	2,909	-8,528	12,543	-352	2,006	-5,325	-11,547	11,489	-12,417	0	-2,908	0	41,076	-41,078	0
	4	-3,561	9,617	-6,403	5,325	-2,006	1,269	-1,191	-6,758	8,639	-2,607	0	-2,325	0	24,850	-24,851	0
	5	-5,395	6,242	-2,111	1,191	-1,269	960	-52	-368	718	0	0	84	0	9,195	-9,195	0
	6	225	980	-297	52	-960	0	0	0	0	0	0	0	0	1,257	-1,257	0
	All	14,350	21,021	-18,476	28,305	-4,632	4,632	-28,305	-18,799	43,085	-35,298	7,260	-12,311	-837	127,692	-127,697	
Angelina	1	-11	565	-528	0	0	3	-2,203	0	0	0	2,173	0	0	2,741	-2,741	0
	2	-722	749	-148	2,203	-3	0	-2,078	-1	0	0	0	0	0	2,952	-2,952	0
	3	1,397	10,858	-1,216	2,078	0	2,442	-21	-15,539	0	0	0	0	0	16,776	-16,776	0
	4	-1,289	9,896	-2,865	21	-2,442	1,900	0	-5,221	0	0	0	0	0	11,817	-11,817	0
	5	-3,756	4,978	-635	0	-1,900	1,313	0	0	0	0	0	0	0	6,291	-6,291	0
	6	801	584	-72	0	-1,313	0	0	0	0	0	0	0	0	1,385	-1,385	0
	All	-3,579	27,631	-5,464	4,302	-5,659	5,659	-4,302	-20,761	0	0	2,173	0	0	41,962	-41,962	
Steady-State																	
Nacogdoches	1	0	494	-1,083	0	0	1,352	-2,059	0	12,528	-7,831	-1,860	-1,541	0	14,374	-14,375	0
	2	0	318	-454	2,059	-1,352	1,490	-2,552	0	2,975	-714	0	-1,768	0	6,842	-6,840	0

Nacogdoches and Angelina counties flow budget for the Northern Carrizo-Wilcox aquifer model, in acre-feet per year.																	
County	Lyr	Storage	X-flow in	X-flow out	upper		lower		Wells	Recharge	ET	GHB	Stream	Reserv. Leakage	Total		% diff
					Z flow in	Z flow out	Z flow in	Z flow out							In	Out	
	3	0	1,058	-1,781	2,552	-1,490	479	-2,247	0	6,424	-3,043	0	-1,949	0	10,514	-10,512	0
	4	0	3,224	-2,342	2,247	-479	208	-737	0	3,091	-1,279	0	-3,934	0	8,770	-8,772	0
	5	0	1,228	-2,064	737	-208	25	-61	0	491	0	0	-151	0	2,482	-2,484	0
	6	0	455	-491	61	-25	0	0	0	0	0	0	0	0	516	-516	0
	All	0	6,777	-8,215	7,657	-3,555	3,555	-7,657	0	25,509	-12,867	-1,860	-9,344	0	43,498	-43,498	0
Angelina	1	0	555	-500	0	0	878	1	0	0	0	-932	0	0	1,433	-1,432	0
	2	0	228	-58	1	-878	707	0	0	0	0	0	0	0	935	-935	0
	3	0	642	-368	0	-707	432	0	0	0	0	0	0	0	1,074	-1,075	0
	4	0	881	-585	0	-432	135	0	0	0	0	0	0	0	1,016	-1,017	0
	5	0	980	-907	0	-135	61	0	0	0	0	0	0	0	1,042	-1,041	0
	6	0	425	-363	0	-61	0	0	0	0	0	0	0	0	425	-425	0
	All	0	3,712	-2,781	1	-2,212	2,212	1	0	0	0	-932	0	0	5,925	-5,925	0

Notes:

1. Layer 1: Queen City aquifer
2. Layer 2: Reklaw unit
3. Layer 3: Carrizo aquifer
4. Layer 4: Upper Wilcox aquifer (Calvert Bluff)
5. Layer 5: Middle Wilcox aquifer (Simsboro)
6. Layer 6: Lower Wilcox aquifer (Hooper)
7. All: sum of layers 1,2, 3, 4, 5, and 6
8. **GHB** refers to flow into or out of the top of the Queen City.
9. **ET** refers to groundwater extraction due to evapotranspiration.
10. **Reserv. Leakage** Refers to leakage from reservoirs (or lakes) into groundwater or from groundwater into reservoirs.
11. **X-flow in** refers to lateral flow into the county.
12. **X-flow out** refers to lateral flow out of the county.
13. **upper - Z-flow in** refers to flow into the layer from the layer above.
14. **upper - Z-flow out** refers to flow out of the layer into the layer above.
15. **lower - Z-flow in** refers to flow into the layer from the layer below.
16. **lower - Z-flow out** refers to flow out of the layer into the layer below.
17. **Wells** is for pumping input.
18. A negative sign refers to flow out of the layer in the county.
19. A positive sign refers to flow into the layer in the county.
20. The numbers are rounded to the nearest 1 acre-ft.

Table 2. Total aquifer storage based on Northern Carrizo-Wilcox Groundwater Availability Model

County	Layer	Average Thickness feet	Total Area (mi ²)	Total Storage acre-ft
Nacogdoches	1	43	674	3,732,000
	2	192	794	19,530,000
	3	112	917	13,167,000
	4	648	969	80,398,000
	5	1,074	980	134,708,000
	6	412	980	51,676,000
	Total		2,482	
Angelina	1	50	859	5,520,000
	2	209	859	22,947,000
	3	133	859	14,654,000
	4	1,023	859	112,455,000
	5	1,498	859	164,732,000
	6	625	859	68,749,000
	Total		3,538	

Note:

1. Layer 1: Queen City aquifer
2. Layer 2: Reklaw unit
3. Layer 3: Carrizo aquifer
4. Layer 4: Upper Wilcox aquifer (Calvert Bluff)
5. Layer 5: Middle Wilcox aquifer (Simsboro)
6. Layer 6: Lower Wilcox aquifer (Hooper)
7. Specific yield assumed to be a uniform value of 0.2
8. Total storage rounded to the nearest 1,000 acre-ft

Table 3. Comparison between district production records and modeled pumpage for 2002 and 2003.

Year	GCD Production Records (gallons/year)	GCD Production Records (acre-ft/year)	Model Pumpage (acre-ft/year)
2002 last 3 quarters	7.328 x 10 ⁹	22,492	-
2003 first quarter	2.105 x 10 ⁹	6,461	-
Total	9.433 x 10 ⁹	28,954	21,894

Table 4a Model input pumpage for Angelina County

Layer	Model Pumpage Input (acre-feet)				
	1980 ¹	1990 ¹	1999 ²	2000 ¹	2050 ¹
1	16,322	13,746	0	2,309	2,419
2	8	9	1	4	4
3	5,592	5,786	13,898	3,257	3,047
4	601	649	3,092	12,237	13,208
5	-	-	0	-	-
6	-	-	0	-	-
Total	22,523	20,190	16,991	17,807	18,678

Table 4b Model input pumpage for Nacogdoches County

Layer	Model Pumpage Input (acre-feet)				
	1980 ¹	1990 ¹	1999 ²	2000 ¹	2050 ¹
1	1,658	1,620	38	785	818
2	816	1,017	124	1,089	1,126
3	5,087	5,669	9,134	2,751	3,421
4	779	958	4,079	2,122	2,563
5	358	360	350	391	453
6	-	-	1	1	1
Total	8,698	9,624	13,726	7,139	8,382

1. Fryar and others, 2003 (Appendix D1)
2. Table 1, this report

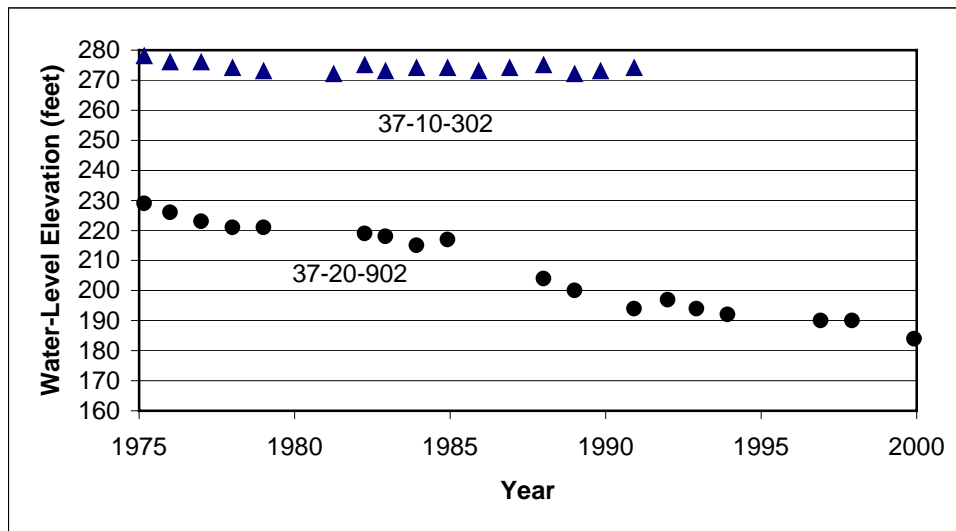


Figure 1. Measured water levels in two Upper Wilcox wells in Nacogdoches County, one in the northern part of the county (37-10-302) and one in the central part (37-20-902).

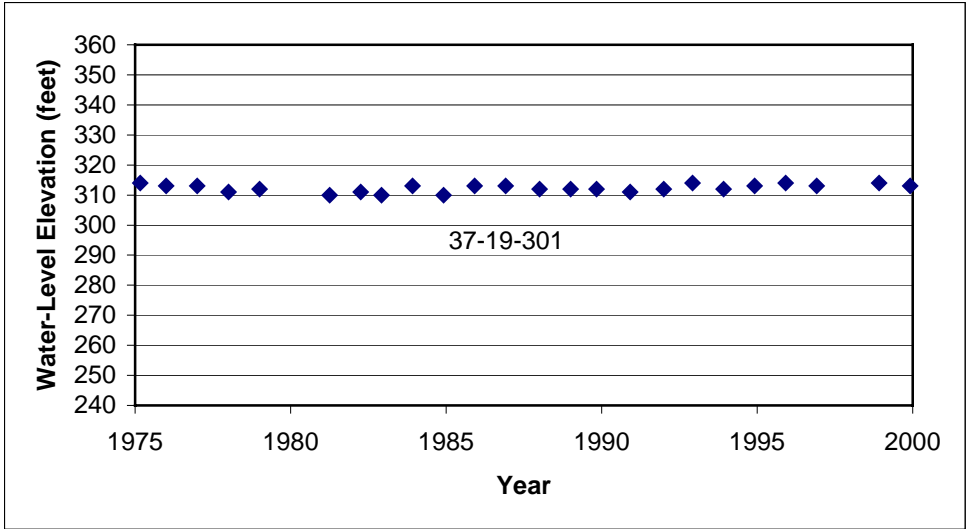


Figure 2. Measured water levels in a Carrizo aquifer well in northern Nacogdoches County.

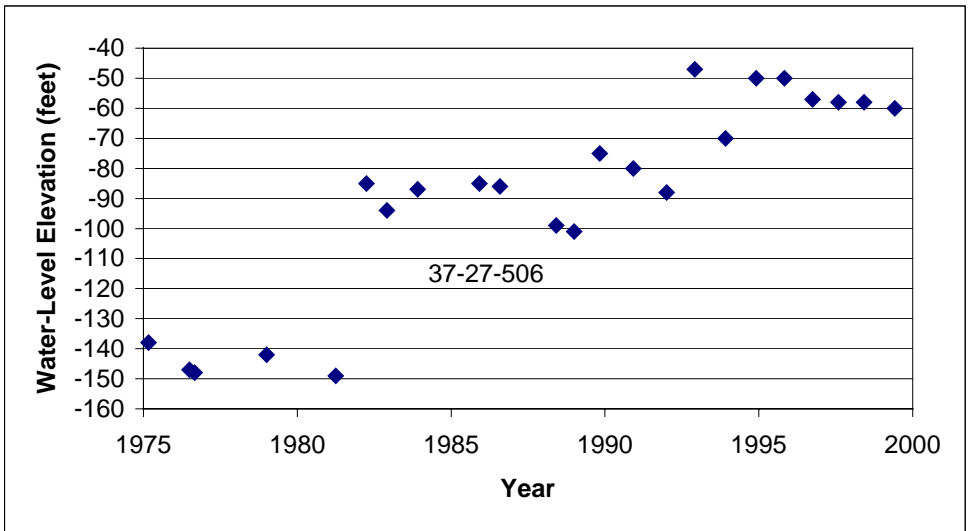


Figure 3. Measured water levels in a Carrizo aquifer well in southern Nacogdoches County.

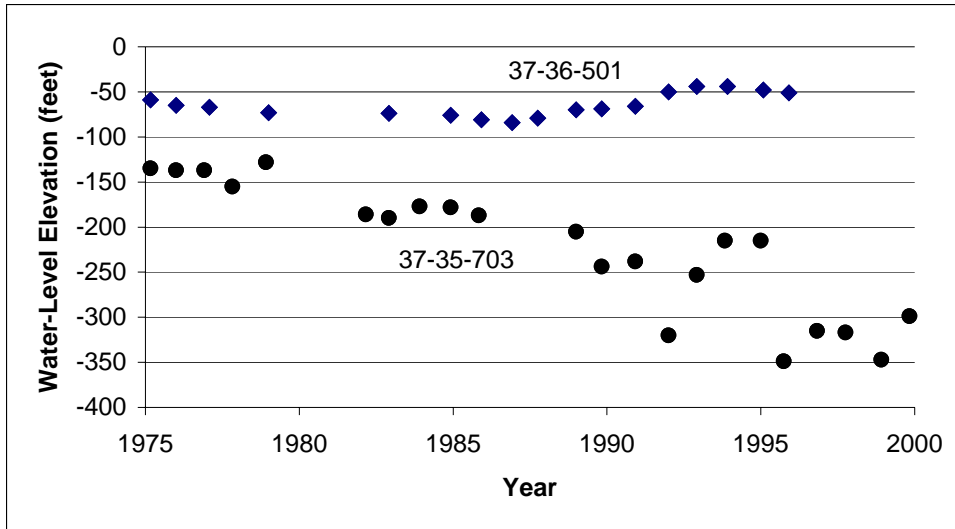


Figure 4. Measured water levels in two Carrizo aquifer wells in northern Angelina County.

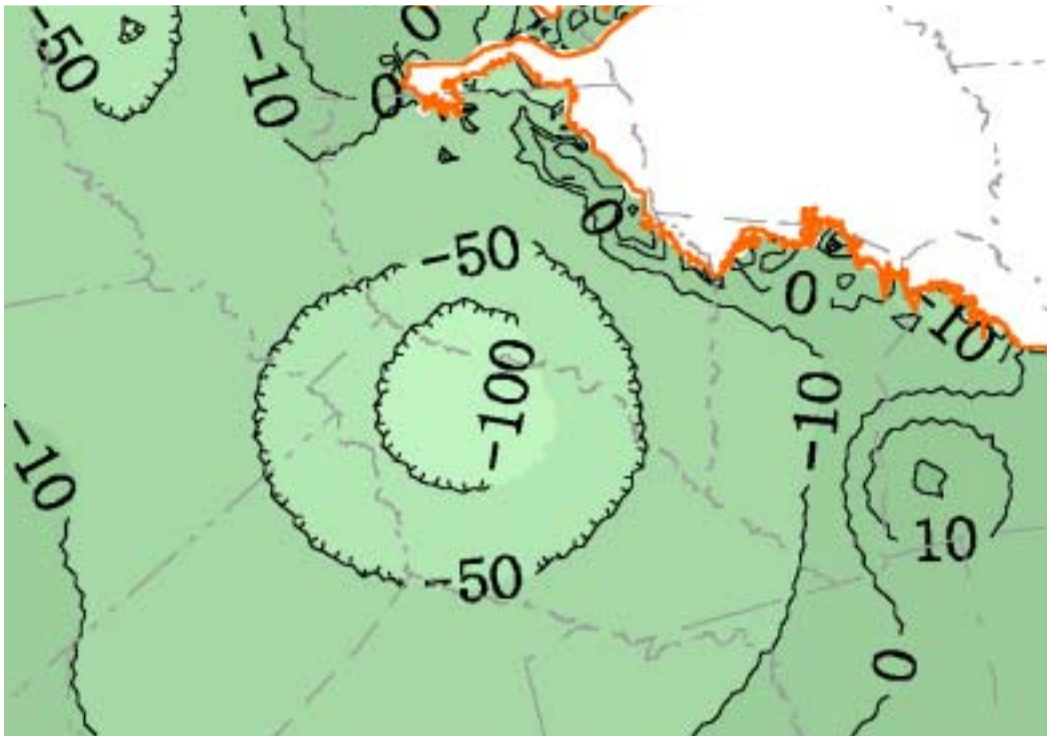


Figure 5. Model calculated water-level changes in the Carrizo aquifer between 2000 and 2050. Positive numbers refer to decline in feet, negative numbers refer to increase in feet. (Fryar and others, 2003; Figure 10.2.4)

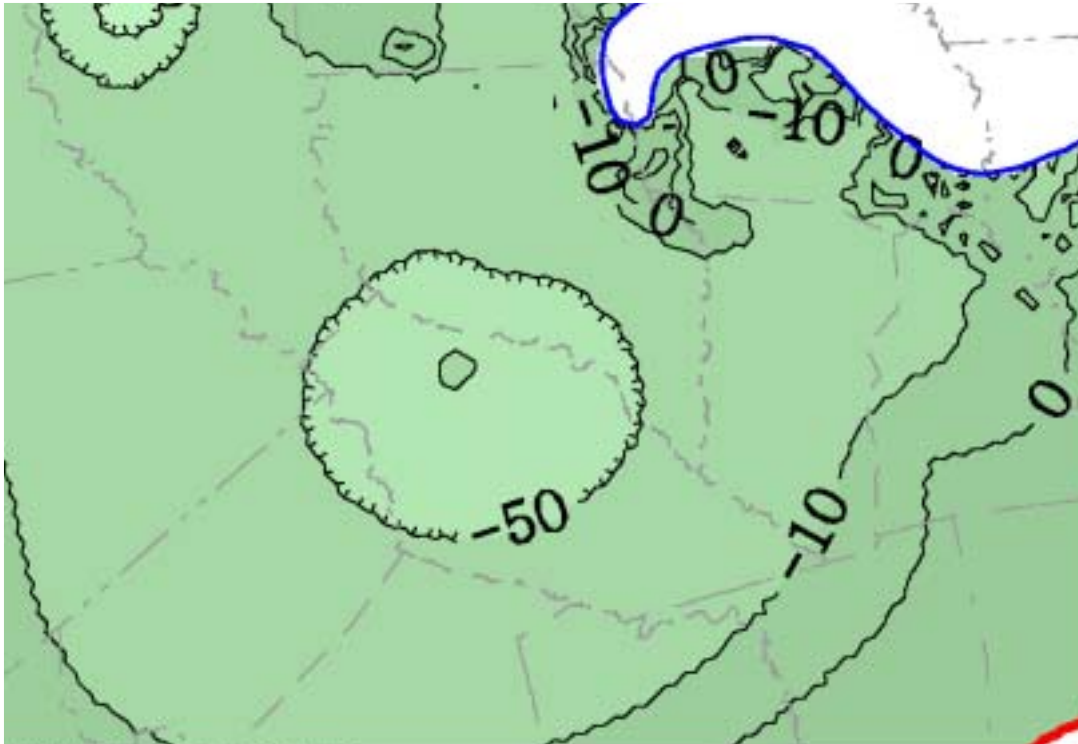


Figure 6. Model calculated water-level changes in the Upper-Wilcox aquifer between 2000 and 2050. Positive numbers refer to decline in feet, negative numbers refer to increase in feet. (Fryar and others, 2003; Figure 10.2.6)