GAM Run 06-32

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EXECUTIVE SUMMARY:

We ran the groundwater availability model for the Igneous and parts of the West Texas Bolsons aquifers for a 60-year predictive simulation using a specified baseline pumpage (the 2000 estimated historic pumpage from the original model) and average recharge rates. The results of this model run indicate that water levels decline significantly in the Salt Basin Bolson Aquifer throughout much of the model area. These water level declines are the greatest in southern Culberson County, presumably around an area of higher pumpage in the baseline pumpage data set. The model results also indicate that water levels in the underlying Igneous Aquifer also decline in this area, due to the upward movement of groundwater in response to this same pumpage stress. In addition, declines were observed in the Igneous Aquifer around the town of Alpine. An area of significant recovery was observed in Jeff Davis County west of the town of Fort Davis, presumably in response to the recovery after a large amount of pumpage that occurred during the historic transient calibration-verification model run.

REQUESTOR:

Ms. Janet Adams from the Jeff Davis Underground Water Conservation District (on behalf of Groundwater Management Area 4).

DESCRIPTION OF REQUEST:

Ms. Adams asked us to run a baseline model simulation using the groundwater availability model for the Igneous and parts of the West Texas Bolsons aquifers. This baseline model run would be a 60-year simulation using initial water levels from the end of the historic calibration model run and average recharge. Each year of the model run would use a baseline pumpage specified by the members of the Groundwater Management Area 4.

METHODS:

Recharge rates were averaged for the historic calibration-verification runs, representing 1950 to 2000. These averages were then used for each year of the 60-year predictive simulation along with the baseline pumpage. Parameters in other time-varying model packages (including the Evapotranspiration, General-Head Boundary, and Drain packages) were held at 2000 values. 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 Igneous and parts of the West Texas Bolsons aquifers was used for this simulation. The parameters and assumptions for this model are described below:

- We used Version 1.01 of the groundwater availability model for the Igneous and parts of the West Texas Bolsons aquifers.
- See Beach and others (2004) for assumptions and limitations of the model for the Igneous and West Texas Bolsons aquifers.
- The mean absolute error (a measure of the difference between simulated and actual water levels during model calibration) in the entire model for the period of 1990 to 2000 is 64 feet, or four percent of the range of measured water levels (Beach and others, 2004).
- The model includes three layers, representing the Salt Basin Bolson Aquifer (Layer 1), the Igneous Aquifer (Layer 2), and the underlying Cretaceous and Permian units (Layer 3).
- We simulated a 60-year time period for the predictive model run.
- We used average annual recharge based on recharge determined through the calibration of the transient model covering the years 1950 to 2000.
- The model uses the MODFLOW recharge package to model both recharge from alluvial fans/stream beds and precipitation. It is assumed that precipitation recharge directly to the Salt Basin Bolson Aquifer is zero; therefore, all recharge included in the recharge package to Layer 1 is from alluvial fan/stream bed infiltration. Recharge applied with the recharge package to the Igneous Aquifer (Layer 2) is both direct precipitation recharge and alluvial fan/stream bed recharge.
- Pumpage is included in the model for all three layers, although pumpage in Layer 3, representing the underlying Cretaceous and Permian units, is minimal.
- Pumpage for each year of the 60-year predictive model run was specified by members of the groundwater management area. For this model run, the specified pumpage was the pumpage from the last stress period of the historic transient calibration-verification simulation, which was for the year 2000. Historic pumpage used in the transient calibration-verification model run, including the 2000 pumpage which was used as the baseline pumpage for this model run, is shown in Appendix A.
- The model includes pumpage representing rural domestic, municipal, industrial, irrigation, and livestock uses.

- The model uses the MODFLOW drain package to simulate discharge to streams and springs. Drains are included in both the Salt Basin Bolson Aquifer and Igneous Aquifer layers of the model. Drains were used as a simplified approach that allowed water to be removed from the groundwater system but do not allow water to flow in the stream to downstream locations that would then recharge the aquifer (Beach and others, 2004). Streams in the region are intermittent. Drain parameters were held at conditions representing the year 2000 stress period for the predictive simulations.

- The model uses the MODFLOW general-head boundary package to simulate cross-formational flow into and out of Layer 3, which represents the Cretaceous and Permian units underlying the Igneous Aquifer. General-head boundary parameters were held at conditions representing the year 2000 stress period for the predictive simulations.

- The model uses the MODFLOW evapotranspiration package to simulate discharge of water due to evaporation and transpiration. Evapotranspiration parameters were held at conditions representing the year 2000 stress period for the predictive simulations.

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 model produce (rather than inject) water. Wells are modeled in the model using the MODFLOW Well package.

- Recharge—simulates areally distributed recharge from both precipitation and from alluvial fans/stream beds. It is assumed that precipitation recharge to the Salt Basin Bolson Aquifer is zero, and therefore all recharge included in the recharge package to Layer 1 is along mountain fronts from alluvial fans and stream bed infiltration. Recharge applied with the recharge package to the Igneous Aquifer (Layer 2) is from precipitation recharge as well as alluvial fan/stream bed recharge in Presidio County. 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 in the model using the MODFLOW Evapotranspiration package.

- Drains—simulate discharge to streams and springs. Drains are included in both the Salt Basin Aquifer and Igneous aquifer layers of the model. In the Salt Basin Bolson Aquifer (Layer 1) the drains are located at the northern end of the aquifer and are present to account for northward groundwater flow from the bolson aquifer to springs in the Balmorhea area. Drains are included in the Igneous Aquifer (Layer 2) to represent loss of groundwater to springs and streams. The model uses the MODFLOW Drain package to simulate discharge to streams and springs.

- General-Head Boundaries—The model uses general-head boundaries to simulate cross-formational flow into and out of Layer 3, which represents the Cretaceous and Permian units underlying the Igneous Aquifer. The heads for the general-head boundaries were based on estimated heads from the Igneous Aquifer and then adjusted downward based on a conceptual model that assumes downward movement from the Igneous to lower units.

The results of model run are described for only the Salt Basin Bolson Aquifer (Layer 1) and the Igneous Aquifer (Layer 2). The underlying Cretaceous and Permian units (Layer 3) are not discussed because there is little pumpage from this layer in the model and it 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 2000) for the Salt Basin Bolson and Igneous aquifers are shown in Figures 1 and 2, respectively. These figures show the starting water levels for this 60-year predictive model run. Initial water levels in the Salt Basin Bolson Aquifer range from approximately 3,500 to 4,500 feet above mean sea level, and decrease from the southern to northern end of the aquifer (Figure 1). Initial water levels in the Igneous Aquifer range from approximately 3,000 to 6,000 feet, and are highest in the Davis Mountains area in Jeff Davis County, decreasing in all directions from this area (Figure 2).

Water levels at the end of the 60-year predictive simulation for the Salt Basin Bolson and Igneous aquifers are shown in Figures 3 and 4, respectively. Water levels at the end of the

60-year runs are very similar to initial water levels (Figures 1 and 2). 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 Salt Basin Bolson and Igneous aquifers are shown in Figures 5 and 6, respectively. Water level changes in the Salt Basin Bolson Aquifer are all negative (drawdown) and range from less than 5 feet to over 110 feet (Figure 5). Drawdowns in this aquifer are the greatest in southern Culberson County, around a large pumping center present in the baseline (2000) pumpage data set. Drawdowns decrease away from this pumping center. Areas around the margins of the Salt Basin Bolson Aquifer are also projected to go dry during this simulation, although most of these areas were already dry at the start of the predictive run.

Water level changes in the Igneous Aquifer are mostly negative (drawdown) throughout most of the extent of the model (Figure 6). Drawdowns are mostly less than 10 feet, although higher drawdown can be observed in southern Culberson County, in the same area where the maximum drawdown in the overlying Salt Basin Bolson Aquifer was located. An area of higher drawdown is also found in western Brewster County, near the town of Alpine. An area of significant recovery is also observed in south-central Jeff Davis County, west of the town of Fort Davis. This is presumably the continued recovery from a high pumpage stress that occurred during the historic period.

Because some of the desired future conditions for the groundwater management area may be based on water budgets from the model, we also pulled the water budgets for each of these components for each county in the model area. These budgets are provided in Table 1. The components of the water budget are divided up into “In” and “Out”, representing water that is coming into and leaving from the budget. As might be expected, water from wells is only in the “Out” column, representing water that is pulled out of the budget or aquifer system from wells. Likewise, recharge is only found in the “In” column. 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:

Beach, J.A., Ashworth, J.B., Finch, Jr., S.T., Chastain-Howley, A., Calhoun, K., Urbanczyk, K.M., Sharp, J.M., and Olson, J., 2004, Groundwater availability model for the Igneous and parts of the West Texas Bolsons (Wild Horse Flat, Michigan Flat, Ryan Flat and Lobo Flat) aquifers: contract report to the Texas Water Development Board, 208 p.

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Table 1. Water budgets for each county at the end of the 60-year predictive model run using the specified baseline pumpage in the groundwater availability model for the Igneous and parts of the West Texas Bolsons aquifers (in acre-feet per year). Values are probably only accurate to two significant figures.

	Brewster		**Culberson**		**Hudspeth**		**Jeff Davis**		**Presidio**	
	In	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
Salt Basin Bolson										
Storage	--	--	9,648	0	--	--	3,169	0	881	0
Streams and Springs (Drain package)	--	--	0	0	--	--	0	0	0	0
Flow out of model (GHB Package)	--	--	0	0	--	--	0	0	0	0
Wells	--	--	0	30,278	--	--	0	117	0	795
Recharge	--	--	2,096	0	--	--	154	0	1,457	0
Evapotranspiration	--	--	0	0	--	--	0	0	0	0
Lateral Inflow	--	--	8,180	0	--	--	4,191	9,215	1,036	4,191
Vertical Leakage Downward	--	--	15,817	5,464	--	--	1,819	0	1,611	0
Igneous Aquifer										
Storage	243	2	583	0	0	0	520	28	704	1
Streams and Springs (Drain package)	0	136	0	0	0	0	0	2,402	0	2,681
Flow out of model (GHB Package)	0	0	0	0	0	0	0	0	0	0
Wells	0	2,031	0	0	0	0	0	931	0	1,973
Recharge	6,525	0	885	0	6	0	25,912	0	9,393	0
Evapotranspiration	0	1,050	0	67	0	0	0	3,011	0	680
Vertical Leakage Upward	--	--	5,464	15,817	--	--	0	1,819	0	1,611
Lateral Inflow	1,147	1,216	909	0	0	0	552	6,061	4,203	1,352
Vertical Leakage Downward	460	3,936	15,250	7,207	0	6	254	14,804	744	6,736

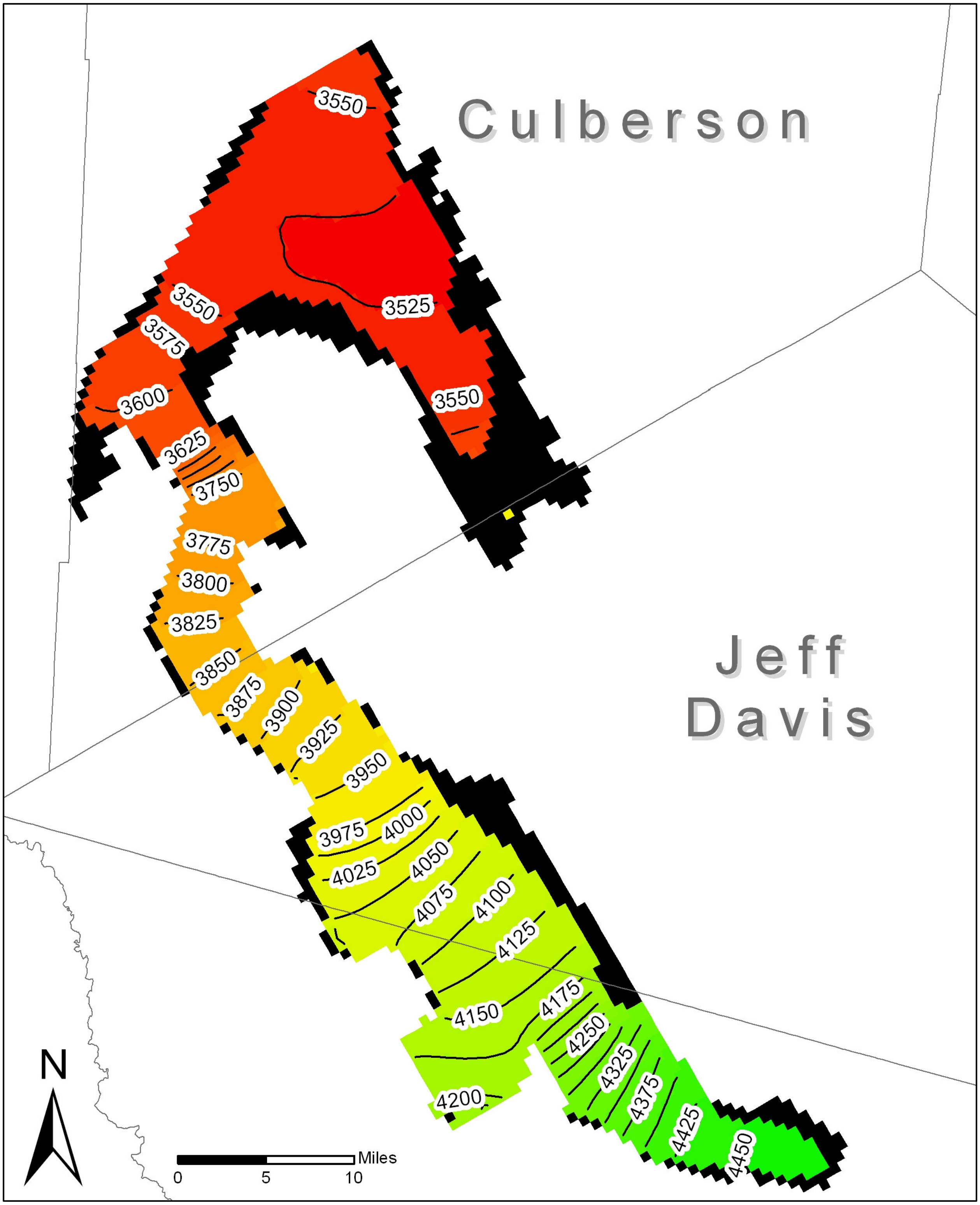

Figure 1. Initial water level elevations for the predictive model run in the Salt Basin Bolson Aquifer from the groundwater availability model for the Igneous and parts of the West Texas Bolsons aquifers. Water level elevations are in feet above mean sea level. Contour interval is 25 feet. Model cells that were dry at the start of the simulation are shown in black.

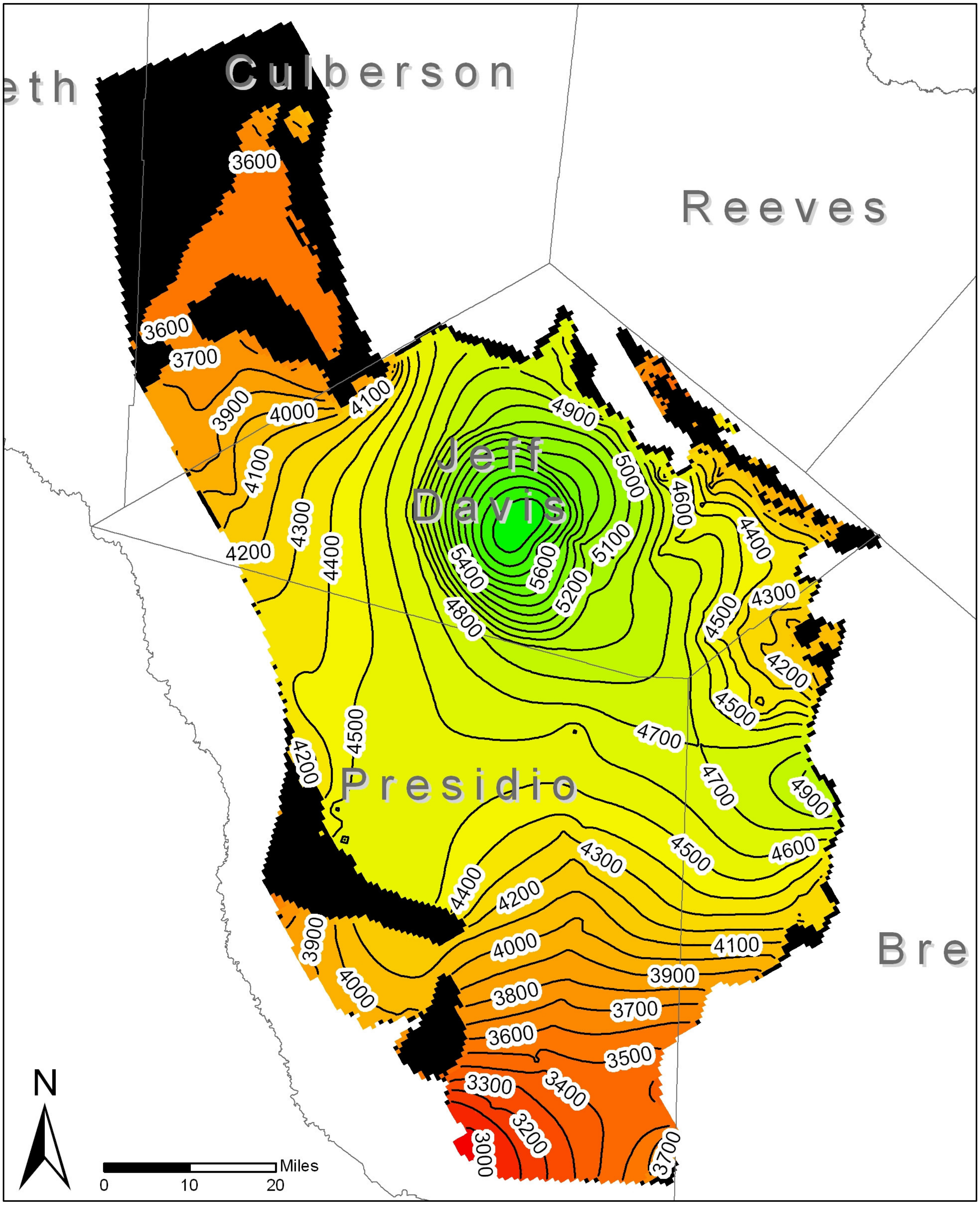

Figure 2. Initial water level elevations for the predictive model run in the Igneous Aquifer from the groundwater availability model for the Igneous and parts of the West Texas Bolsons aquifers. Water level elevations are in feet above mean sea level. Contour interval is 100 feet. Model cells that were dry at the start of the simulation are shown in black.

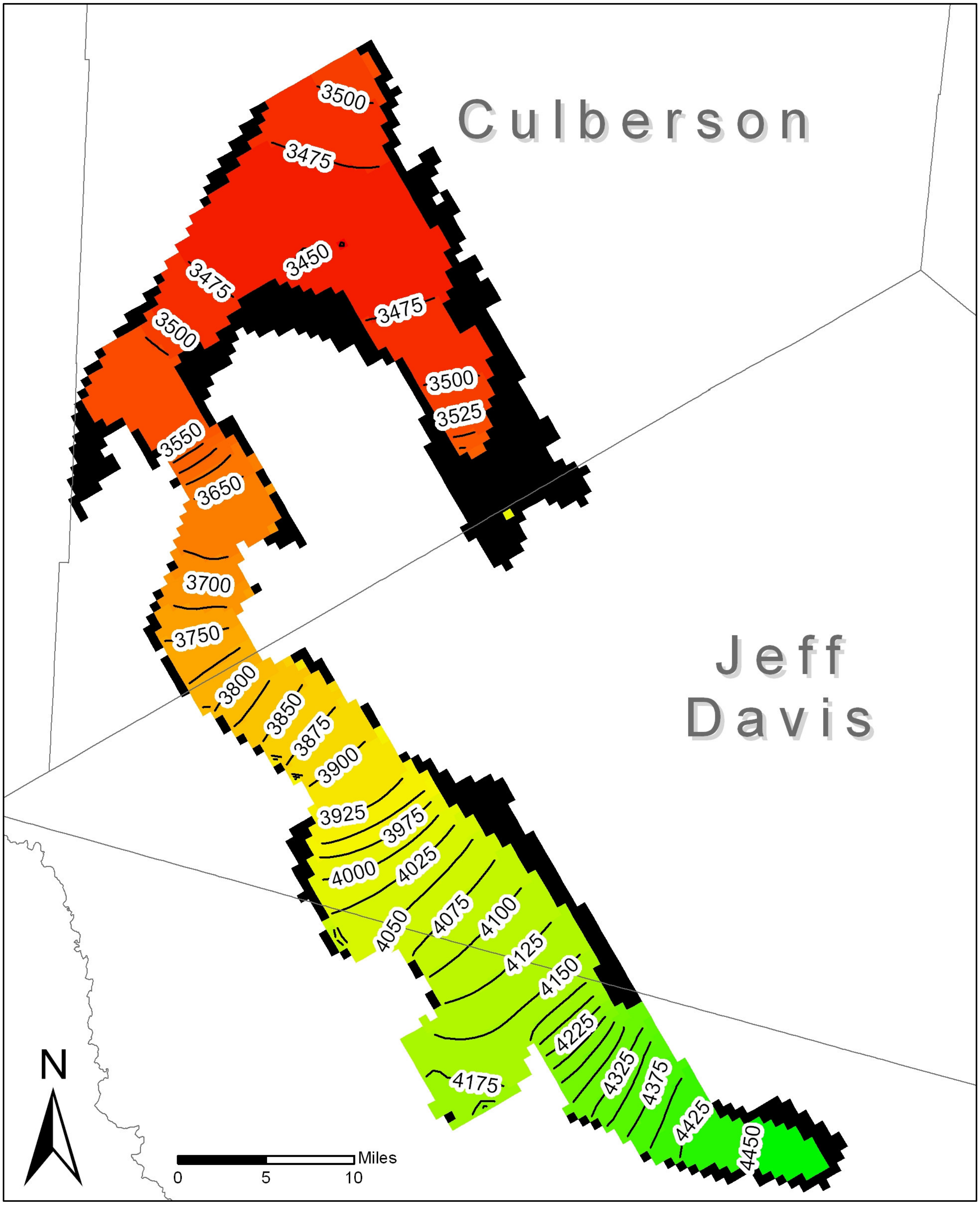

Figure 3. Water level elevations after 60 years using the specified baseline pumpage in the Salt Basin Bolson Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 25 feet. Model cells that were dry by the end of the simulation are shown in black.

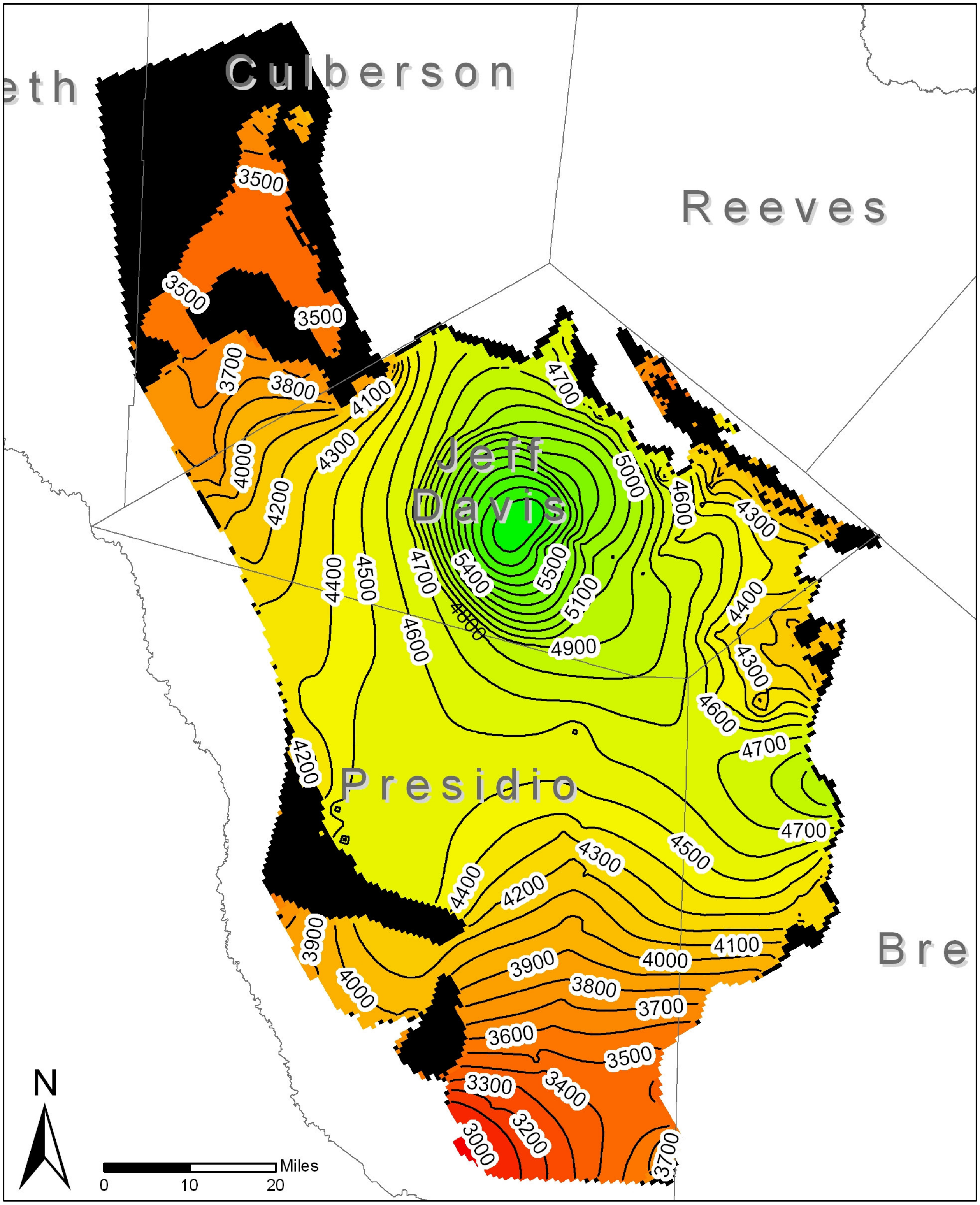

Figure 4. Water level elevations after 60 years using the specified baseline pumpage in the Igneous Aquifer. Water level elevations are in feet above mean sea level. Contour interval is 100 feet. Model cells that were dry by the end of the simulation are shown in black.

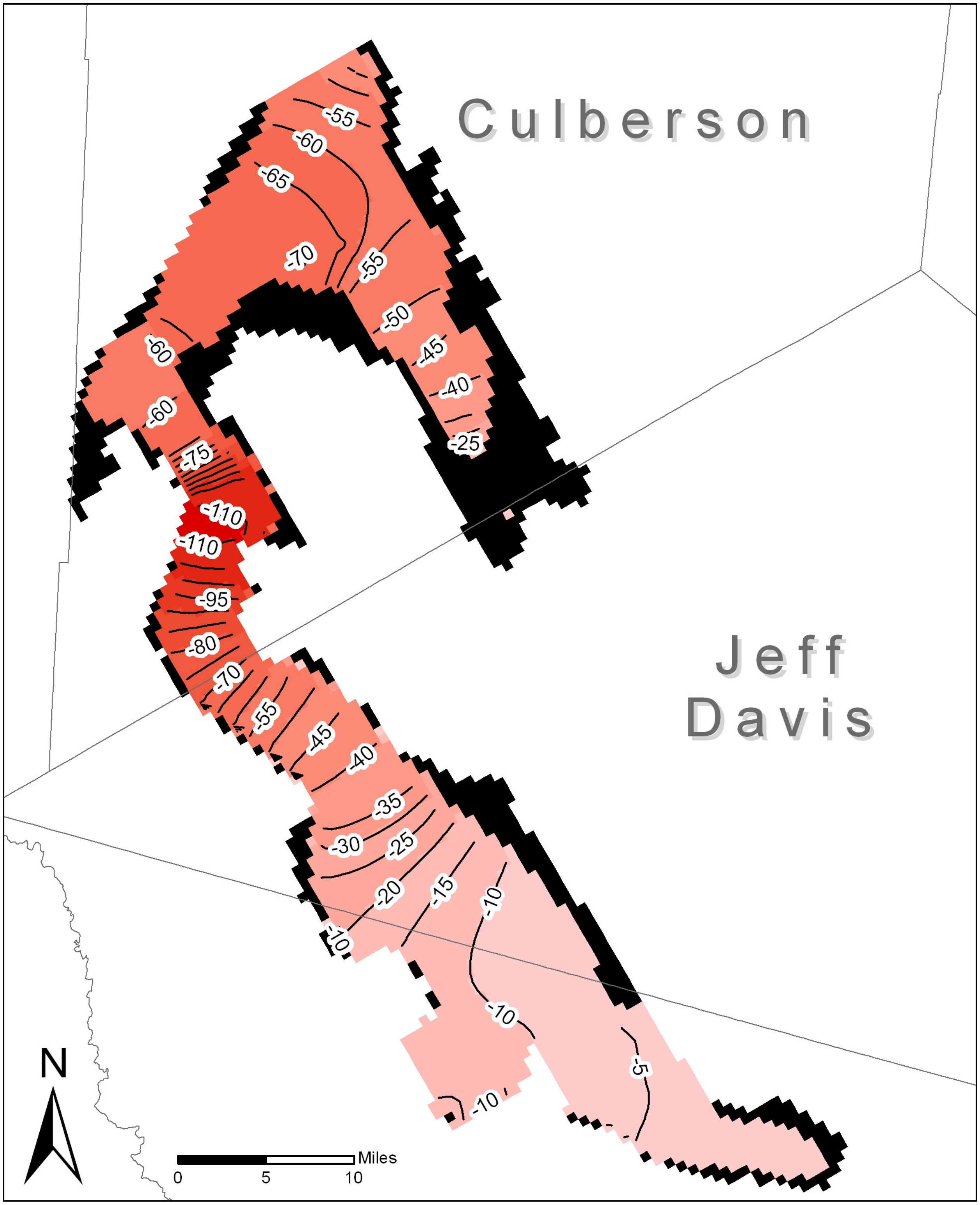

Figure 5. Water level changes (in feet) after 60 years using the specified baseline pumpage in the Bolsons Aquifer. Contour interval is 5 feet. Areas of decreasing water levels (drawdown) are shown in red. Areas of increasing water levels (recovery) are shown in blue. Model cells that were dry by the end of the simulation are shown in black.

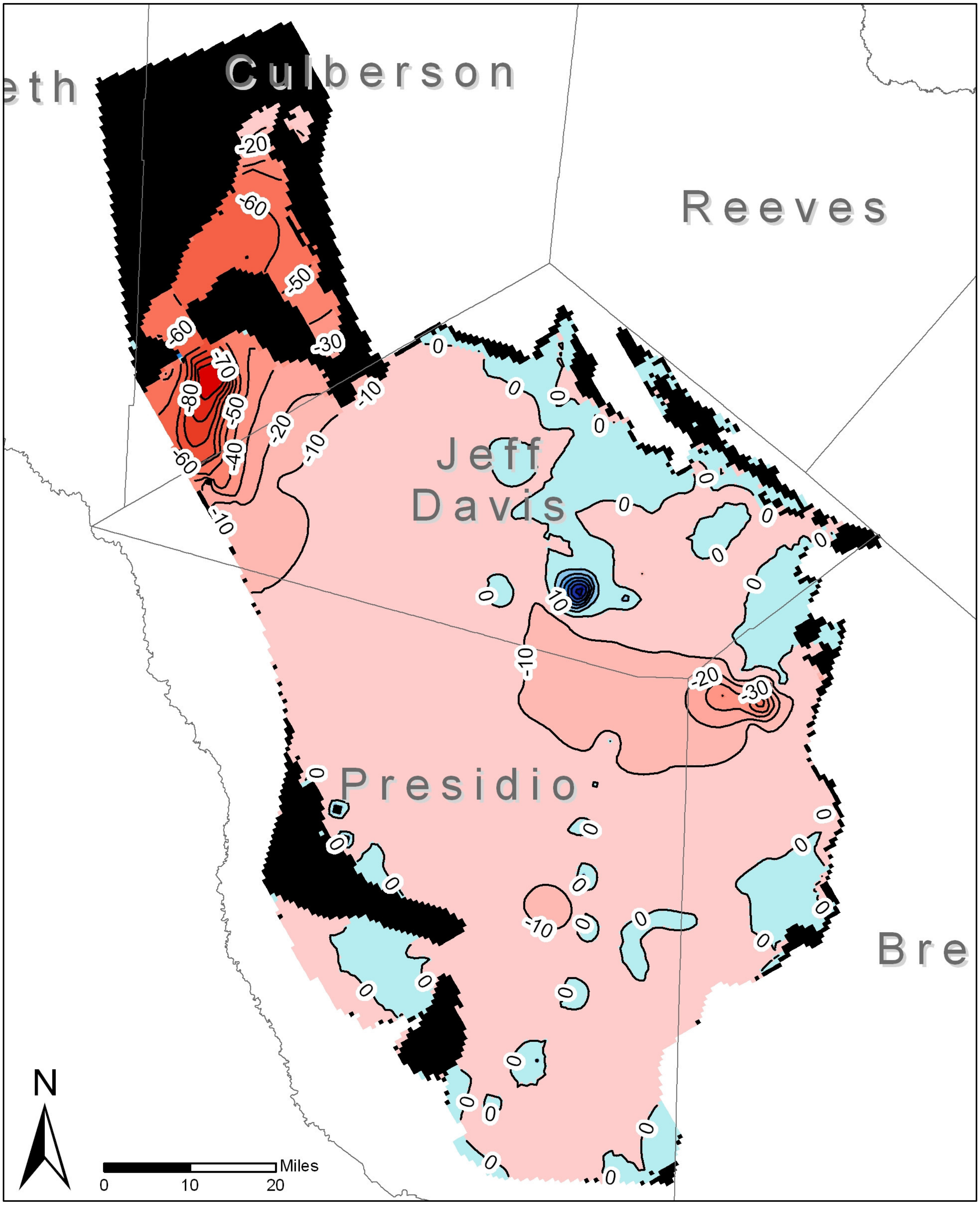

Figure 6. Water level changes (in feet) after 60 years using the specified baseline pumpage in the Igneous Aquifer. Contour interval is 10 feet. Areas of decreasing water levels (drawdown) are shown in red. Areas of increasing water levels (recovery) are shown in blue. Model cells that were dry by the end of the simulation are shown in black.

Appendix A

Summary of Historic Pumpage in the Groundwater Availability Model for the Igneous and parts of West Texas Bolsons Aquifers

Table A-1. Summary of estimated historic pumpage included in the groundwater availability model for the Igneous and parts of West Texas Bolsons Aquifers (in acre-feet per year).

Year	Total	Culberson	Jeff Davis	Presidio	Brewster
pre-1950	0	0	0	0	0
1950	20,981	18,458	763	786	972
1951	19,843	16,824	1,138	907	972
1952	22,554	19,039	1,512	1,028	972
1953	25,651	21,640	1,887	1,148	973
1954	26,952	22,446	2,261	1,269	973
1955	30,441	24,194	2,636	2,116	1,493
1956	31,547	24,612	3,011	2,266	1,656
1957	33,345	25,924	3,385	2,445	1,588
1958	35,461	27,685	3,760	2,487	1,527
1959	36,477	28,269	3,654	2,804	1,747
1960	36,994	28,312	3,549	3,193	1,939
1961	36,782	28,336	3,446	3,152	1,845
1962	36,582	28,346	3,343	3,037	1,853
1963	36,545	28,358	3,240	2,983	1,962
1964	36,727	28,417	3,137	3,001	2,170
1965	38,408	28,382	4,747	3,150	2,127
1966	37,765	28,348	4,237	3,073	2,105
1967	37,096	28,143	3,727	3,155	2,067
1968	35,808	27,418	3,217	3,103	2,067
1969	36,449	28,051	2,708	3,433	2,255
1970	37,753	29,075	2,530	4,010	2,135
1971	36,971	27,501	2,350	4,990	2,127
1972	37,052	26,847	2,207	5,861	2,135
1973	46,289	35,388	2,000	6,826	2,073
1974	52,565	40,893	1,732	7,532	2,406
1975	51,081	39,827	1,865	7,395	1,991
1976	50,071	38,764	2,045	7,294	1,966
1977	49,279	37,738	2,252	7,376	1,910
1978	47,017	27,858	10,453	6,985	1,719
1979	53,252	26,254	18,693	6,630	1,673
1980	60,290	25,046	26,975	6,364	1,904
1981	51,402	23,753	20,911	5,265	1,471
1982	43,995	22,534	15,022	4,599	1,839
1983	36,233	21,351	9,115	3,748	2,017
1984	29,169	21,405	3,202	2,839	1,723
1985	27,811	20,116	2,984	2,850	1,860
1986	26,663	18,675	3,937	2,181	1,869
1987	24,082	18,271	2,946	1,321	1,543
1988	25,685	16,714	5,025	2,266	1,679
1989	22,739	15,462	2,595	3,025	1,655

Table A-1. continued

Year	Total	Culberson	Jeff Davis	Presidio	Brewster
1990	18,728	10,520	3,868	2,748	1,591
1991	15,956	10,143	3,135	1,162	1,515
1992	18,475	11,763	3,326	1,938	1,447
1993	11,548	6,984	1,086	1,826	1,650
1994	11,970	7,079	1,113	2,095	1,682
1995	11,970	7,081	1,068	2,171	1,650
1996	12,242	7,503	1,041	2,116	1,582
1997	13,572	7,912	1,093	2,700	1,866
1998	19,548	13,266	1,426	2,821	2,034
1999	36,552	30,343	1,386	2,771	2,051
2000	36,282	30,320	1,129	2,782	2,051

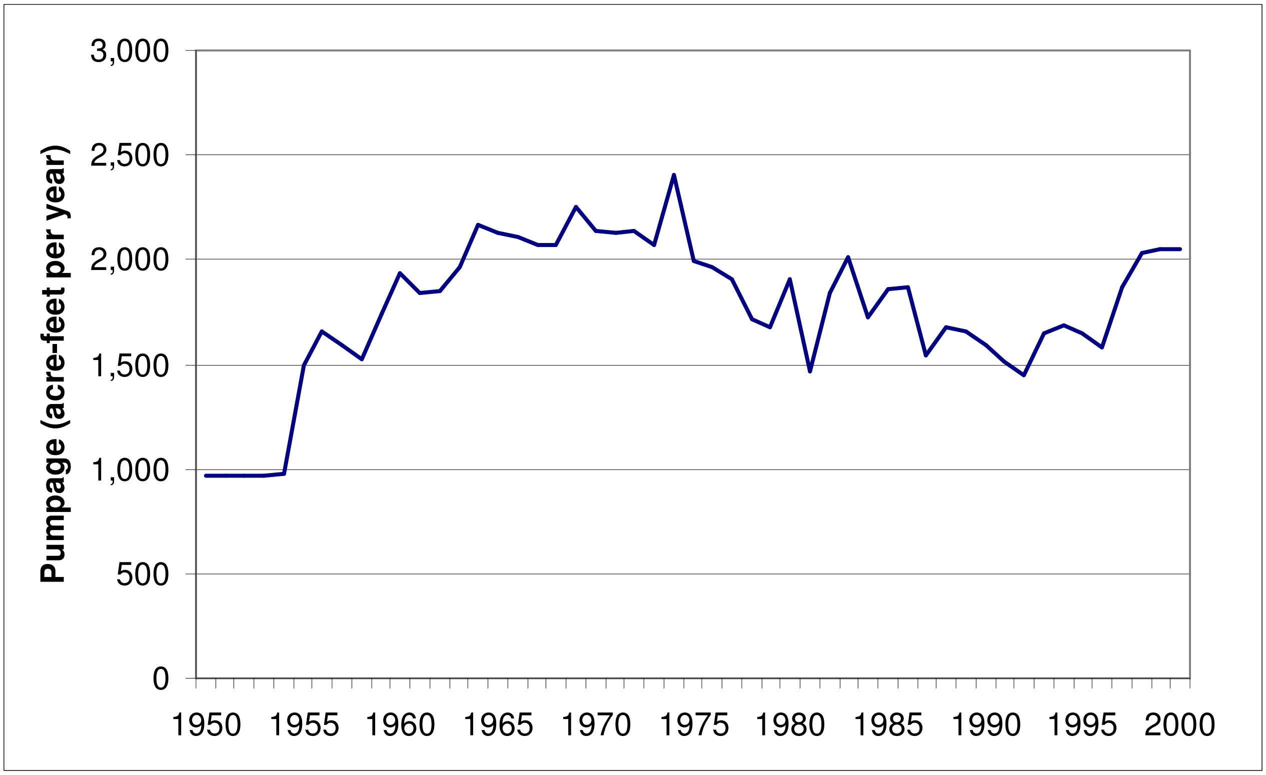

Figure A-1- Pumpage in Brewster County included in the groundwater availability model for the Igneous and parts of West Texas Bolsons Aquifers .

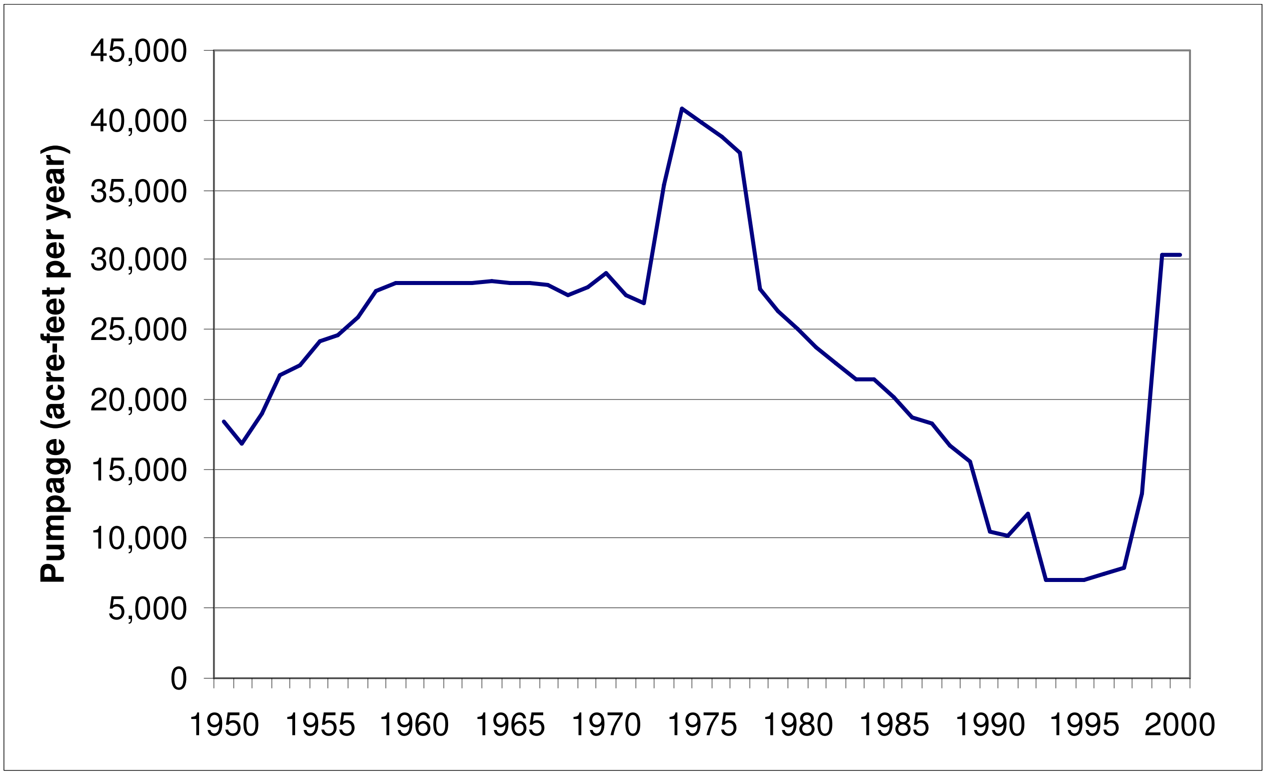

Figure A-2- Pumpage in Culberson County included in the groundwater availability model for the Igneous and parts of West Texas Bolsons Aquifers.

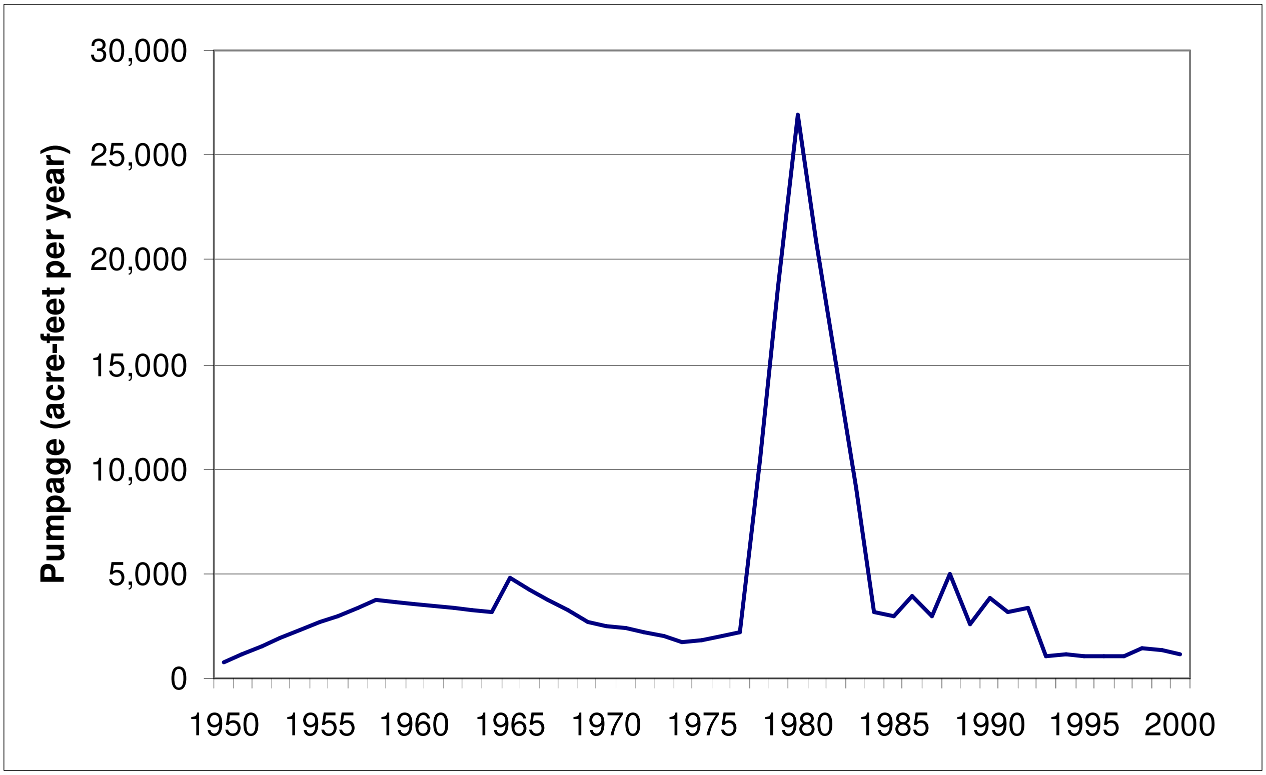

Figure A-3- Pumpage in Jeff Davis County included in the groundwater availability model for the Igneous and parts of West Texas Bolsons Aquifers.

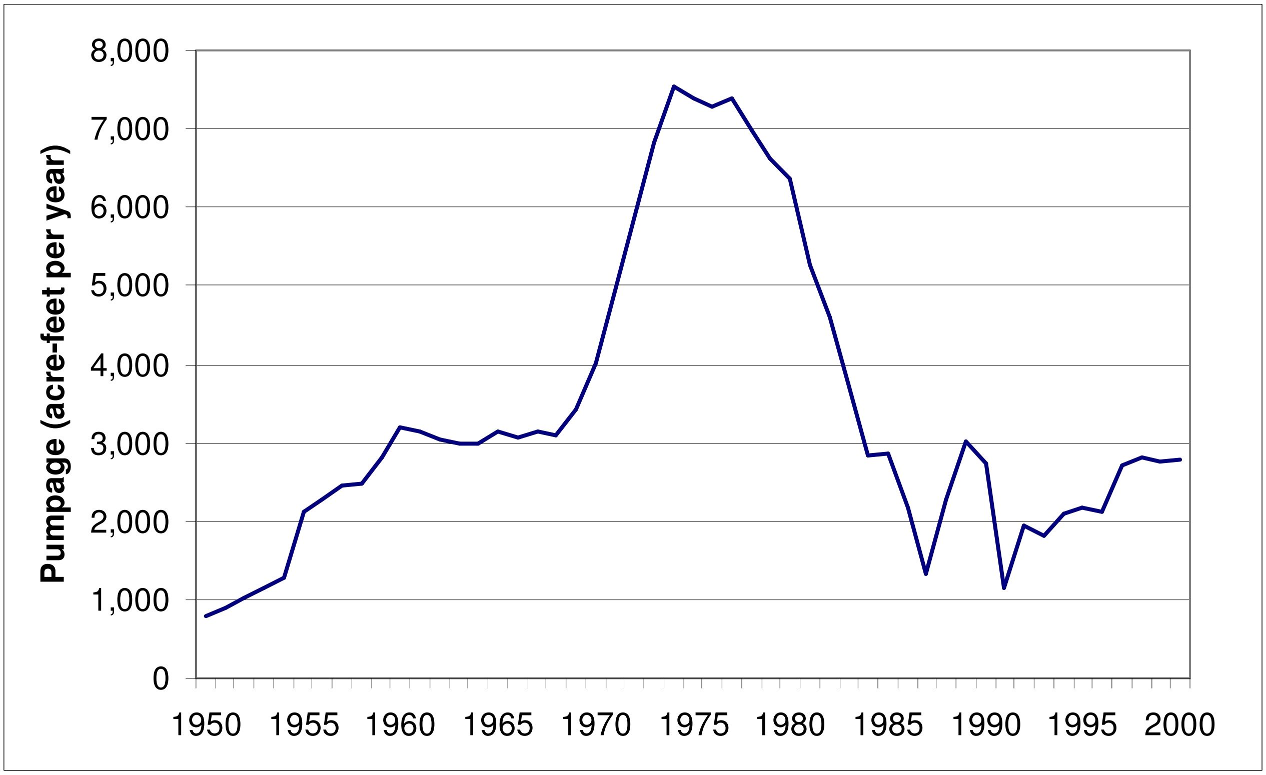

Figure A-4- Pumpage in Presidio County included in the groundwater availability model for the Igneous and parts of West Texas Bolsons Aquifers.