GAM Run 08-79

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EXECUTIVE SUMMARY:

We ran the groundwater availability model for the northern portion of the Gulf Coast Aquifer, adjusting the annual pumpage in the Southeast Texas Groundwater Conservation District to match totals requested by the district for a 2006 to 2060 predictive simulation. This model run, which used a variable growth rate scenario, results in the following:

- water level changes in the Chicot Aquifer portion of the Gulf Coast Aquifer within the district show up to a 10 foot increase to more than a 20 foot decline, with an average water level decline of 9.4 feet from 2006 to 2060;

- water levels in the Evangeline Aquifer portion of the Gulf Coast Aquifer within the district decline between 5 and 35 feet with an average water level decline of 17.9 feet from 2006 to 2060; and,

- water level changes in the Jasper Aquifer portion of the Gulf Coast Aquifer within the district range from a slight increase to a 45 foot decline with an average water level decline of 18.7 feet from 2006 to 2060. A few localized areas in the district show greater changes in water levels that correspond to recent changes in pumping in those areas.

REQUESTOR:

Mr. John Martin of Southeast Texas Groundwater Conservation District.

DESCRIPTION OF REQUEST:

Mr. John Martin asked us to run the groundwater availability model for the northern portion of the Gulf Coast Aquifer, adjusting the amount of pumping within the district for each year from 2006 to 2060 to match a variable growth rate scenario supplied by the district. The 2006 estimate of pumping was supplied by the district.

METHODS:

The pumping in the model for areas within the district was adjusted to values specified by the district for each year between 2006 and 2060. For the years 2006 to 2050, pumping in areas outside of the district was left unchanged from the predictive scenario described in Kasmarek and others (2005), which was based on regional water planning estimates as summarized in the *Water for Texas—2002* State Water Plan (TWDB, 2002). Between 2051 and 2060, the 2050 pumping from the predictive scenario described in Kasmarek and others (2005) was held constant in the areas outside the district.

PARAMETERS AND ASSUMPTIONS:

The parameters and assumptions for the run using the groundwater availability model for the northern portion of the Gulf Coast Aquifer are described below:

- We used Version 2.01 of the groundwater availability model for the northern portion of the Gulf Coast Aquifer. See Kasmarek and Robinson (2004) and Kasmarek and others (2005) for assumptions and limitations of the model.

- We used Groundwater Vistas version 5.3 Build 10 (Environmental Simulations, Inc., 2007) as the interface to process model output.

- 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).

- The root mean square error (a measure of the difference between simulated and actual water levels during model calibration) of the entire model for the year 2000 is 31 feet for the Chicot Aquifer, 45 feet for the Evangeline Aquifer, and 38 feet for the Jasper Aquifer (Kasmarek and others, 2005).

- The calibrated portion of the groundwater availability model for the northern portion of the Gulf Coast Aquifer ends in 2000. To account for changes in water levels between 2000 and the beginning of this simulation (2006), the predictive pumping scenario described in Kasmarek and others (2005) was used to represent pumping during this period. To verify that this is an appropriate assumption, measured water levels near the end of 2005 were compared to the predicted water levels in the model. Results show that root mean square errors for the end of 2005 (18.3 feet for the Chicot Aquifer, 56.7 feet for the Evangeline Aquifer, and 40.1 feet for the Jasper Aquifer) are similar to those for the year 2000 described above.

- Recharge, evapotranspiration, and surface water inflows and outflows for the 2006 to 2060 period were modeled using the MODFLOW general-head boundary package as described below and in Kasmarek and Robinson (2004).

- The pumpage specified in the district for each year of the 2006 to 2060 predictive simulation was distributed spatially and among the model layers as described in the Pumpage section below.

Pumpage

The pumpage values in the groundwater availability model were adjusted to those values requested for the variable growth rate scenario provided by the district. In this scenario, the percent increase of pumpage per year – relative to the year 2006 – is varied each decade between 0.503 percent and 2.20 percent. The pumpage values requested by the district and assigned in the groundwater availability model are shown in Table 1.

The pumpage totals in Table 1 were distributed spatially across the area of the district as well as vertically among the four layers in the model representing the Chicot Aquifer, the Evangeline Aquifer, the Burkeville Confining System, and the Jasper Aquifer. Spatially, the pumping in the year 2005 was used as a base because the pumping distribution in the predictive period of the model (2001 to 2060) is more comprehensive than that of the historic period of the model as described in Kasmarek and others (2005). From this base, the additional amount of pumping required to achieve the requested totals was distributed evenly among all model cells that contained pumping in the year 2005. For the vertical distribution, the percent of pumping in each layer of the model for each cell was held constant. For example, if 40 percent of the pumping in one area of the model in the year 2000 was in the Evangeline Aquifer, the pumping for each of the years between 2006 and 2060 was also 40 percent of the total for that area.

Pumpage in areas outside of the district was not changed from the predictive scenario for the years 2006 to 2050 described in Kasmarek and others (2005). For the years 2051 to 2060, pumping outside of the district was held constant at 2050 levels as described in Kasmarek and others (2005).

Table 1. Pumpage input into the groundwater availability model requested by Southeast Texas Groundwater Conservation District. All pumpage is reported in acre-feet per year.

Year	Pumpage	Increase (percent of 2006)	Year	Pumpage	Increase (percent of 2006)	Year	Pumpage	Increase (percent of 2006)
2006	97,565	2.200	2025	130,069	0.503	2044	142,250	0.870
2007	99,711	2.200	2026	130,560	0.503	2045	143,099	0.870
2008	101,858	2.200	2027	131,050	0.503	2046	143,947	0.870
2009	104,004	2.200	2028	131,541	0.503	2047	144,796	0.870
2010	106,151	2.200	2029	132,032	0.503	2048	145,645	0.870
2011	108,297	2.200	2030	132,523	0.503	2049	146,494	0.870
2012	110,444	2.200	2031	133,156	0.649	2050	147,343	0.870
2013	112,590	2.200	2032	133,789	0.649	2051	148,362	1.045
2014	114,736	2.200	2033	134,422	0.649	2052	149,382	1.045
2015	116,883	2.200	2034	135,055	0.649	2053	150,401	1.045
2016	119,029	2.200	2035	135,689	0.649	2054	151,421	1.045
2017	121,176	2.200	2036	136,322	0.649	2055	152,440	1.045
2018	123,322	2.200	2037	136,955	0.649	2056	153,460	1.045
2019	125,469	2.200	2038	137,588	0.649	2057	154,480	1.045
2020	127,615	2.200	2039	138,221	0.649	2058	155,499	1.045
2021	128,106	0.503	2040	138,855	0.649	2059	156,519	1.045
2022	128,597	0.503	2041	139,703	0.870	2060	157,538	1.045
2023	129,087	0.503	2042	140,552	0.870			
2024	129,578	0.503	2043	141,401	0.870			

RESULTS:

Included in Appendix A are estimates of the water budgets for each layer at the end of each decade from 2006 to 2060 for the northern portion of the Gulf Coast Aquifer in Southeast Texas Groundwater Conservation District. The components of the water budget are described below.

- Recharge—simulates areally distributed recharge due to precipitation falling on the outcrop (where the aquifer is exposed at land surface) areas of aquifers as well as inflow from surface water features such as rivers and streams. Recharge is always shown as "Inflow" into the water budget. In the groundwater availability model for the northern portion of the Gulf Coast Aquifer, recharge is modeled using the MODFLOW General Head Boundary package.

- Surface Outflow—water that flows out of an aquifer due to direct evaporation and plant transpiration (together called evapotranspiration) as well as outflow to surface water features such as rivers, streams, and springs (drains). This component of the budget will always be shown as "Outflow." In the groundwater availability model for the northern portion of the Gulf Coast Aquifer, surface outflow is modeled using the MODFLOW General Head Boundary package.

- 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 simulated in the model using the MODFLOW Well package. It is important to note that values in Appendix A for wells in the water budget may not precisely match the pumpage amounts requested in Table 1 because of dry cells, as described below.

- Change in Storage—changes in the 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 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.

- 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 that define the amount of leakage that can occur.

The results of the model run are described for the Chicot, Evangeline, and Jasper aquifer portions of the Gulf Coast Aquifer in the district.

Initial water levels (those from the end of 2005) for the Chicot, Evangeline, and Jasper aquifer portions of the Gulf Coast Aquifer used in the model run are shown in Figures 1, 2, and 3, respectively. For the Chicot Aquifer, water levels generally decrease from north to south with the lowest water levels along the western border of Jasper County, especially in southwestern Jasper County. For the Evangeline Aquifer, water levels also generally decrease from north to south with lower water levels in these areas. In the Jasper Aquifer, water levels are highest in the outcrop in northern Jasper and Newton counties and decrease in the confined portions of the aquifer toward the south.

Water level trends for each portion of the Gulf Coast Aquifer in the district at the end of the simulation (2060) are similar to those described for the initial water levels above. These water levels are shown in Figures 4, 5, and 6 for the Chicot, Evangeline, and Jasper aquifers, respectively. Because differences between initial water levels and water levels after 55 years are sometimes difficult to quantify in these figures, maps of predicted water level changes between 2006 and 2060 were made. Table 2 shows the average predicted drawdown by county and for the district as a whole for the variable growth rate increase scenario provided by the district.

For the Chicot Aquifer, water level changes between 2006 and 2060 range between an increase of up to 10 feet near the aquifer outcrop in central Newton County to a decline of more than 20 feet in southwestern Hardin County and southwestern Jasper County. The average water level decline for the Chicot Aquifer is 9.4 feet. For the Evangeline Aquifer, water levels generally decline between 5 and 35 feet, with the highest declines in southeastern Tyler County, central Hardin County, and southern Jasper and Newton Counties. On average, water levels in the Evangeline Aquifer decline by 17.9 feet in the district between 2006 and 2060 for this pumping scenario.

For the Jasper Aquifer, changes in water levels generally range between slight increases near the northernmost extent of the aquifer to declines of up to 45 feet in central Tyler County with an average water level decline of 18.7 feet. However, in a few localized areas in northern Jasper and Newton counties, large water level fluctuations were observed ranging from a water level decline in one cell of 200 feet to a water level increase in another cell of 116 feet. Upon examination, the water level increases correspond to sharp, recent (pre-2006) reductions in pumping in those cells, resulting in a rebound of water levels. Similarly, the water level decreases correspond to recent increases in pumping in those cells, resulting in sharp declines in water levels.

The amount of water actually pumped out of the aquifer in the model may differ from the pumping amounts listed in Table 1. An example of this can be seen in Appendix A, Table A-6, where the total amount of water pumped from the model (Wells) in the year 2060 is 146,323 acre-feet per year compared to the input of 157,538 acre-feet per year into the model (Table 1). The primary reason for this difference is the occurrence of dry cells. When the water level in a cell drops below the bottom of the aquifer in the cell, the cell goes dry and pumping can no longer occur. The total amount of pumpage in the district is, therefore, reduced. For the Chicot Aquifer, the amount of dry cells in the model increased from 2 to 5 from 2006 to 2060. For the Burkeville Confining Unit, one cell was dry through the model simulation. For the Jasper Aquifer, no cells were dry at the beginning of the simulation and six cells were dry by 2060. The Evangeline Aquifer did not contain any dry cells. It is important to note that dry cells were not considered when calculating the average drawdown over each aquifer. If high pumpage is the primary factor for a cell going dry, the model is indicating that the pumping may be too great for the aquifer in that area.

It is also important to note that sub-regional water budgets are not exact. This is due to the size of the model cells and the approach used to extract data from the model. To avoid double accounting, model cells that straddle county boundaries were assigned to one side of the boundary based on the location of the centroid of the model cell. For example, if a cell contains two counties, the cell is assigned to the county where the centroid of the cell is located.

Table 2. Average change in water level by county from 2006 to 2060 for each portion of the Gulf Coast Aquifer in the district. All water level changes are reported in feet.

	Hardin County	Jasper County	Newton County	Tyler County	Southeast Texas Groundwater Conservation District
Chicot Aquifer	-13.0	-7.9	-6.8	-1.9	-9.4
Evangeline Aquifer	-22.3	-18.1	-16.2	-11.3	-17.9
Jasper Aquifer	-24.6	-15.5	-13.6	-23.2	-18.7

REFERENCES:

Environmental Simulations, Inc., 2007, Guide to Using Groundwater Vistas Version 5, 381 p.

Kasmarek, M.C., and Robinson, J.L., 2004, Hydrogeology and simulation of groundwater flow and land-surface subsidence in the northern part of the Gulf Coast aquifer system, Texas: U.S. Geological Survey Scientific Investigations Report 2004-5102, 111 p.

Kasmarek, M.C., Reece, B.D., and Houston, N.A., 2005, Evaluation of groundwater flow and land-surface subsidence caused by hypothetical withdrawals in the northern part of the northern part of the Gulf Coast aquifer system, Texas: U.S. Geological Survey Scientific Investigations Report 2005-5024, 70 p.

Texas Water Development Board, 2002, Water for Texas – 2002—Volumes I-III; Texas Water Development Board Document No. GP-7-1, 155 p.

Cynthia K. Ridgeway is Manager of the Groundwater Availability Modeling Section and is responsible for oversight of work performed by employees under her direct supervision. The seal appearing on this document was authorized by Cynthia K. Ridgeway, P.G., on April 24, 2009.

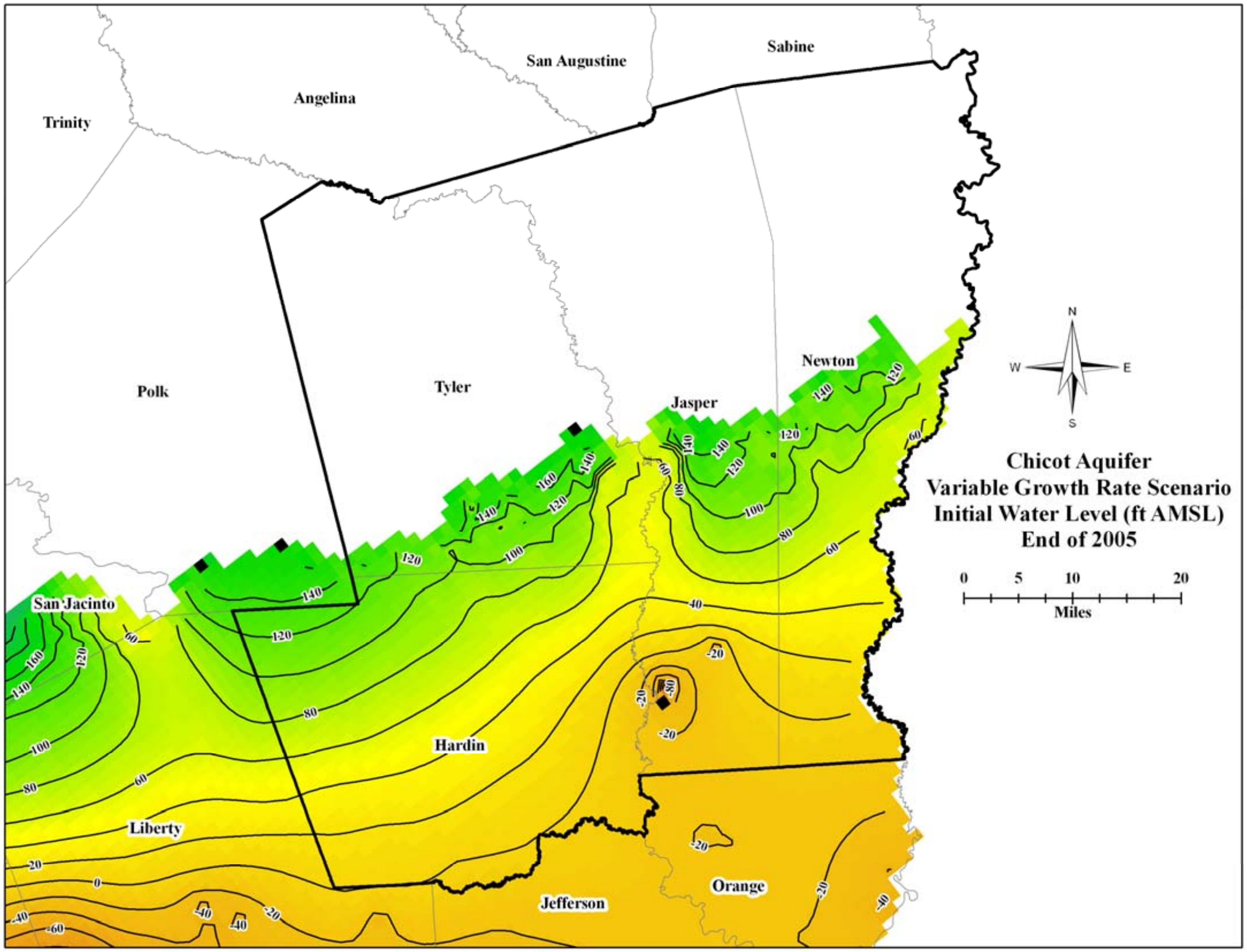

Figure 1. Initial water level elevations for the Chicot Aquifer portion of the Gulf Coast Aquifer for the predictive groundwater availability model run. Water level elevations are in feet above mean sea level (ft AMSL). Contour interval is 20 feet. Black areas indicate model grid cells that are dry. The black border indicates the boundary of the district.

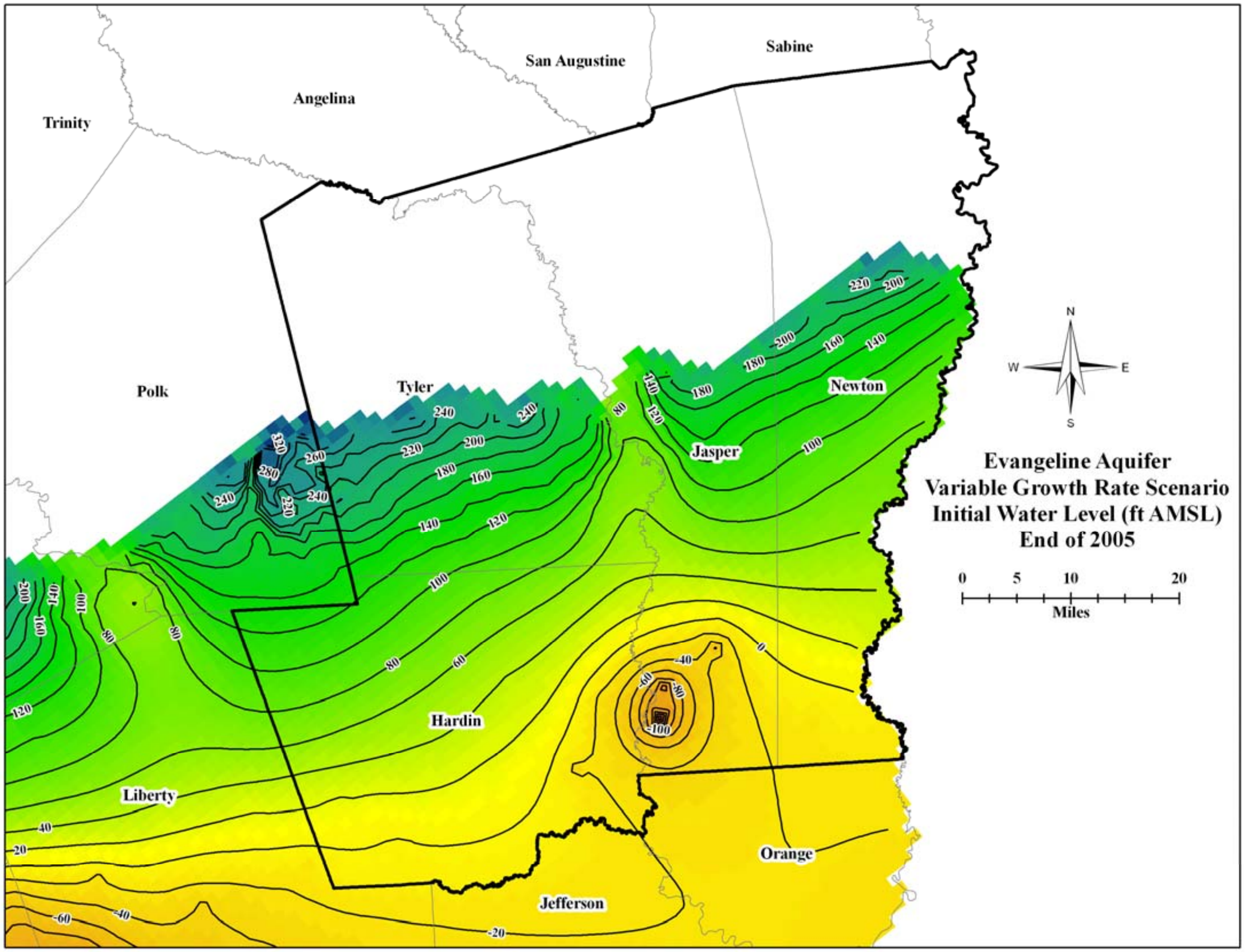

Figure 2. Initial water level elevations for the Evangeline Aquifer portion of the Gulf Coast Aquifer for the predictive groundwater availability model run. Water level elevations are in feet above mean sea level (ft AMSL). Contour interval is 20 feet. Black areas indicate model grid cells that are dry. The black border indicates the boundary of the district.

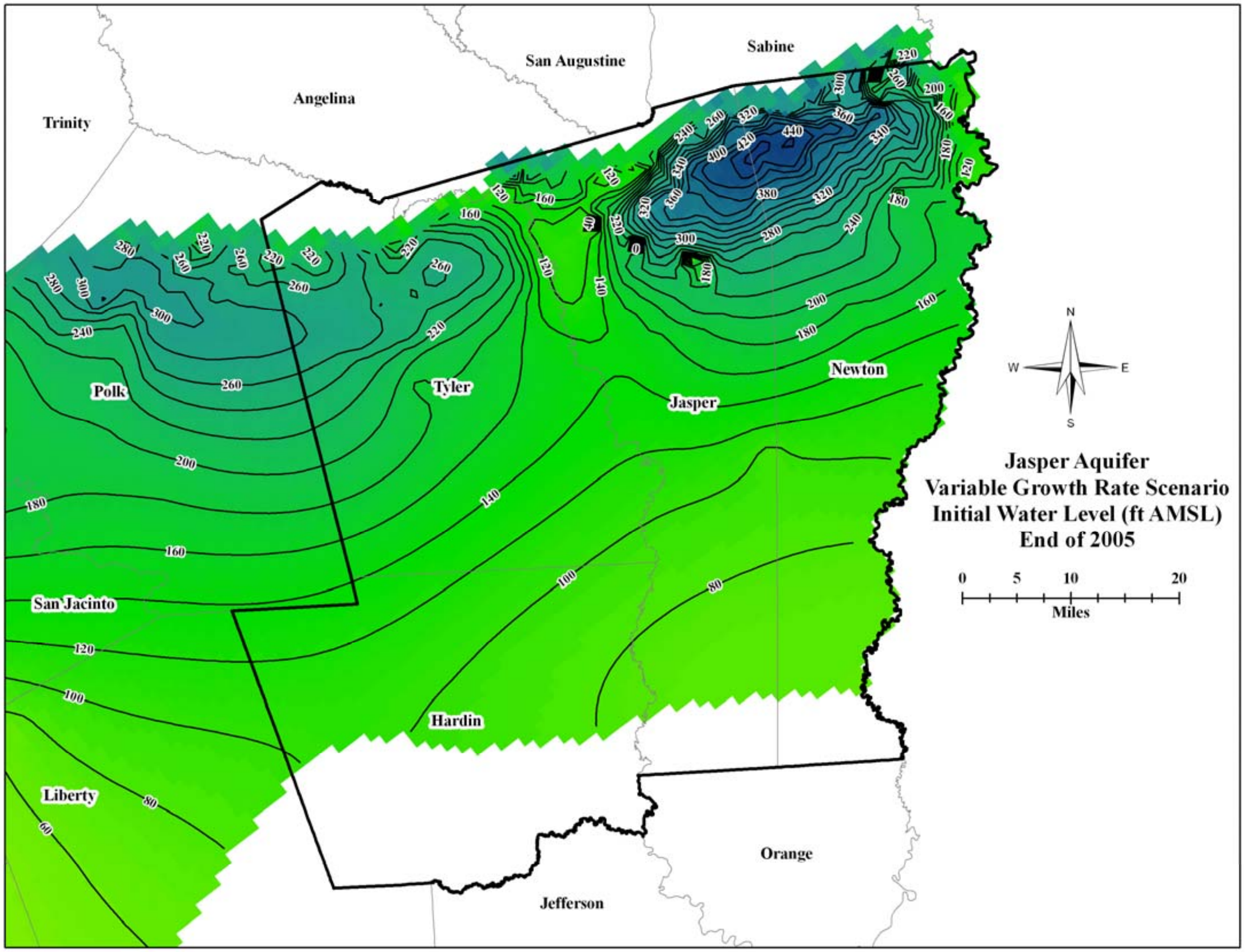

Figure 3. Initial water level elevations for the Jasper Aquifer portion of the Gulf Coast Aquifer for the predictive groundwater availability model run. Water level elevations are in feet above mean sea level (ft AMSL). Contour interval is 20 feet. Black areas indicate model grid cells that are dry. The black border indicates the boundary of the district.

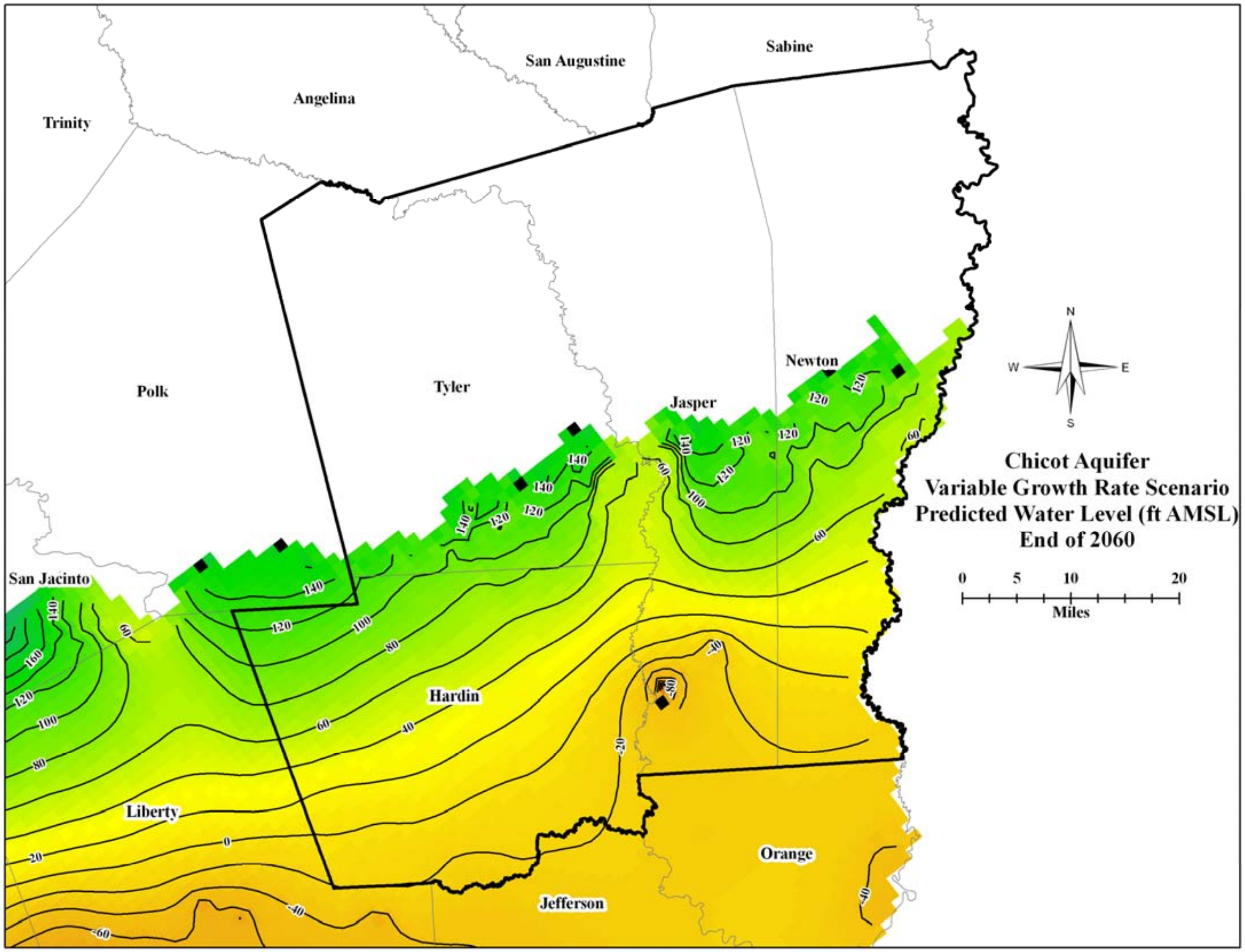

Figure 4. Predicted water level elevations at the end of 2060 for the Chicot Aquifer portion of the Gulf Coast Aquifer. Water level elevations are in feet above mean sea level (ft AMSL). Contour interval is 20 feet. Black areas indicate model grid cells that are dry. The black border indicates the boundary of the district.

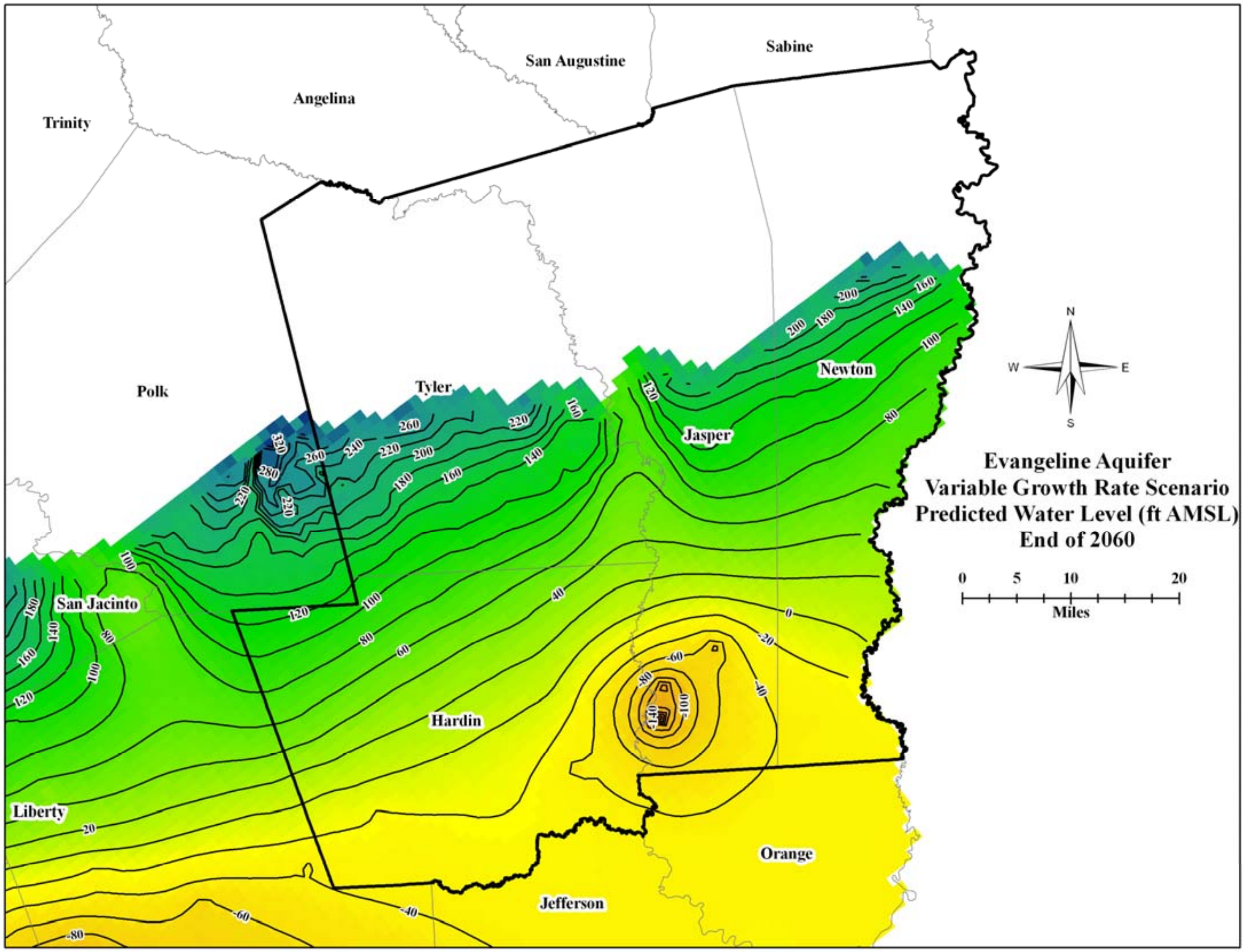

Figure 5. Predicted water level elevations at the end of 2060 for the Evangeline Aquifer portion of the Gulf Coast Aquifer. Water level elevations are in feet above mean sea level (ft AMSL). Contour interval is 20 feet. Black areas indicate model grid cells that are dry. The black border indicates the boundary of the district.

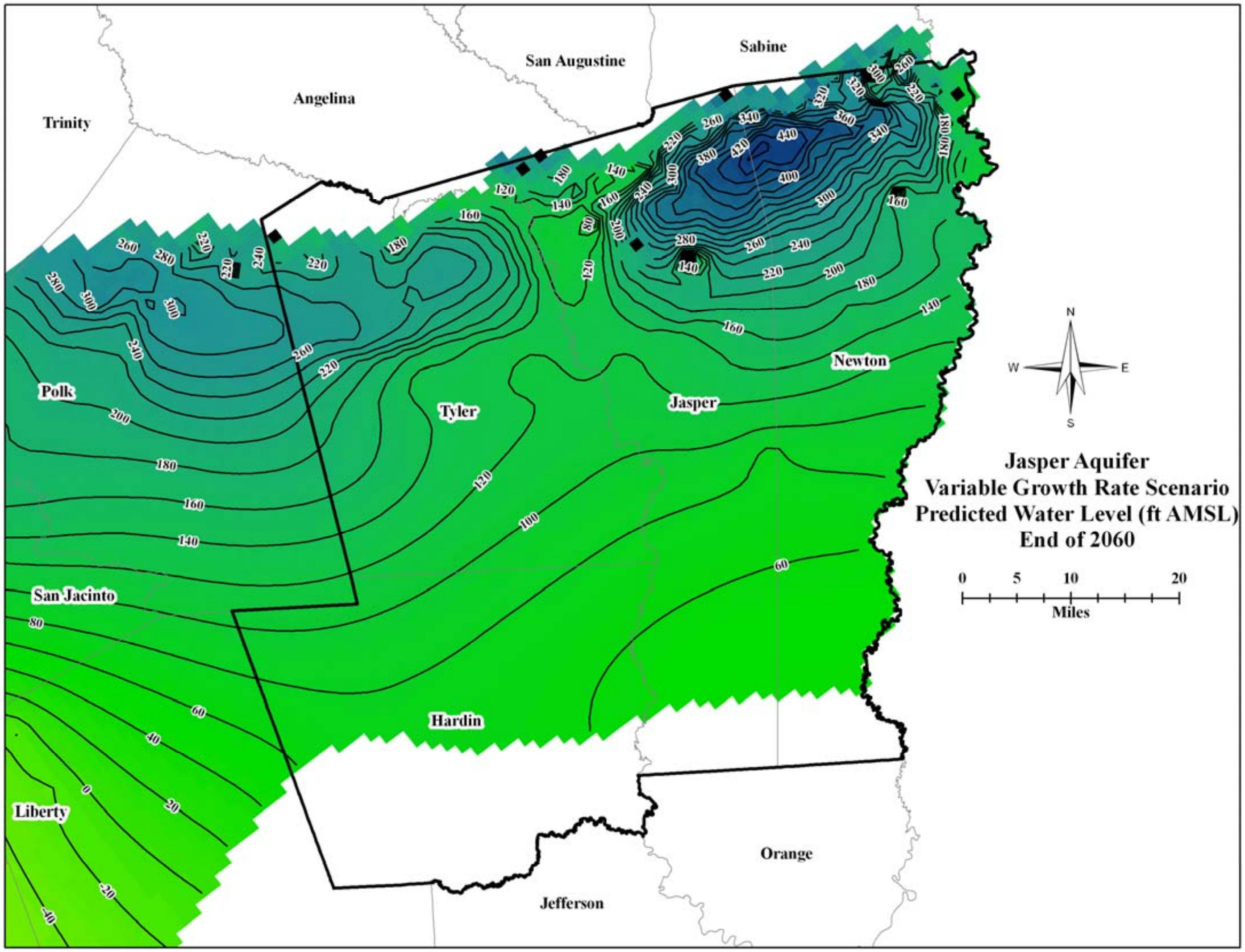

Figure 6. Predicted water level elevations at the end of 2060 for the Jasper Aquifer portion of the Gulf Coast Aquifer. Water level elevations are in feet above mean sea level (ft AMSL). Contour interval is 20 feet. Black areas indicate model grid cells that are dry. The black border indicates the boundary of the district.

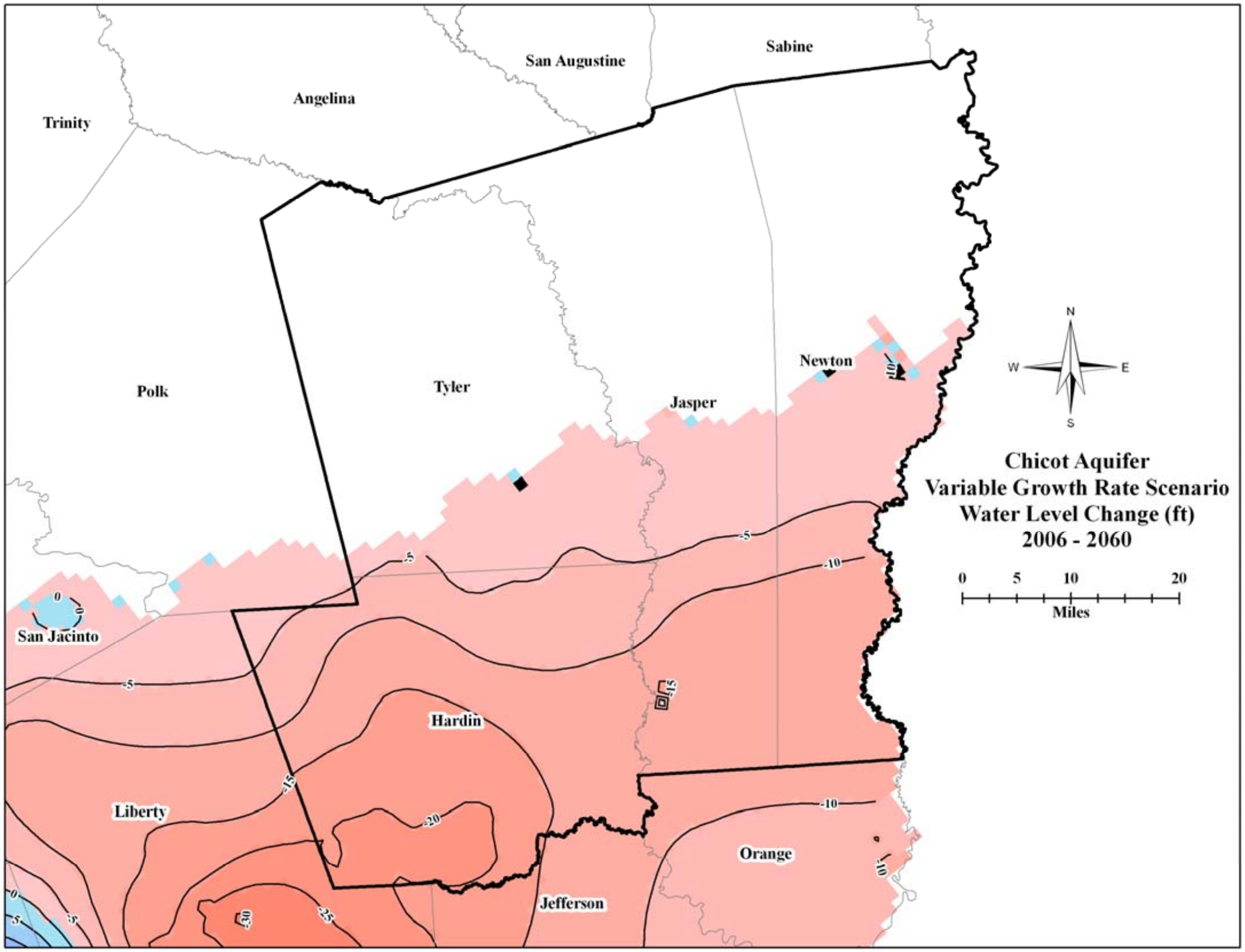

Figure 7. Change in water level in the Chicot Aquifer portion of the Gulf Coast Aquifer between 2006 and 2060. Changes in water levels are in feet (ft). Contour interval is 5 feet. Areas highlighted in red indicate a decrease in water levels. Areas highlighted in blue indicate an increase in water levels. Black areas indicate model grid cells that are dry.

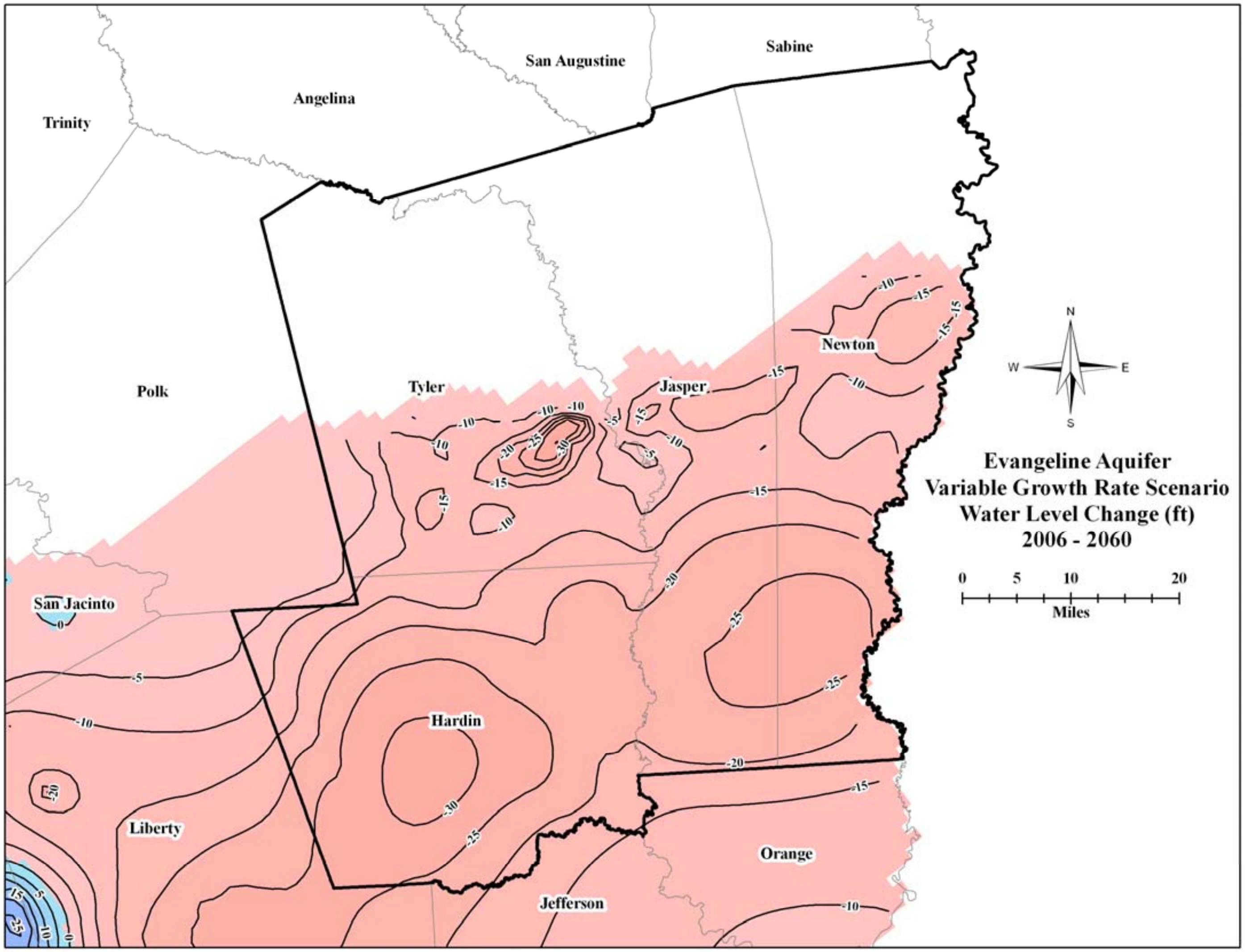

Figure 8. Change in water level in the Evangeline Aquifer portion of the Gulf Coast Aquifer between 2006 and 2060. Changes in water levels are in feet (ft). Contour interval is 5 feet. Areas highlighted in red indicate a decrease in water levels. Areas highlighted in blue indicate an increase in water levels.

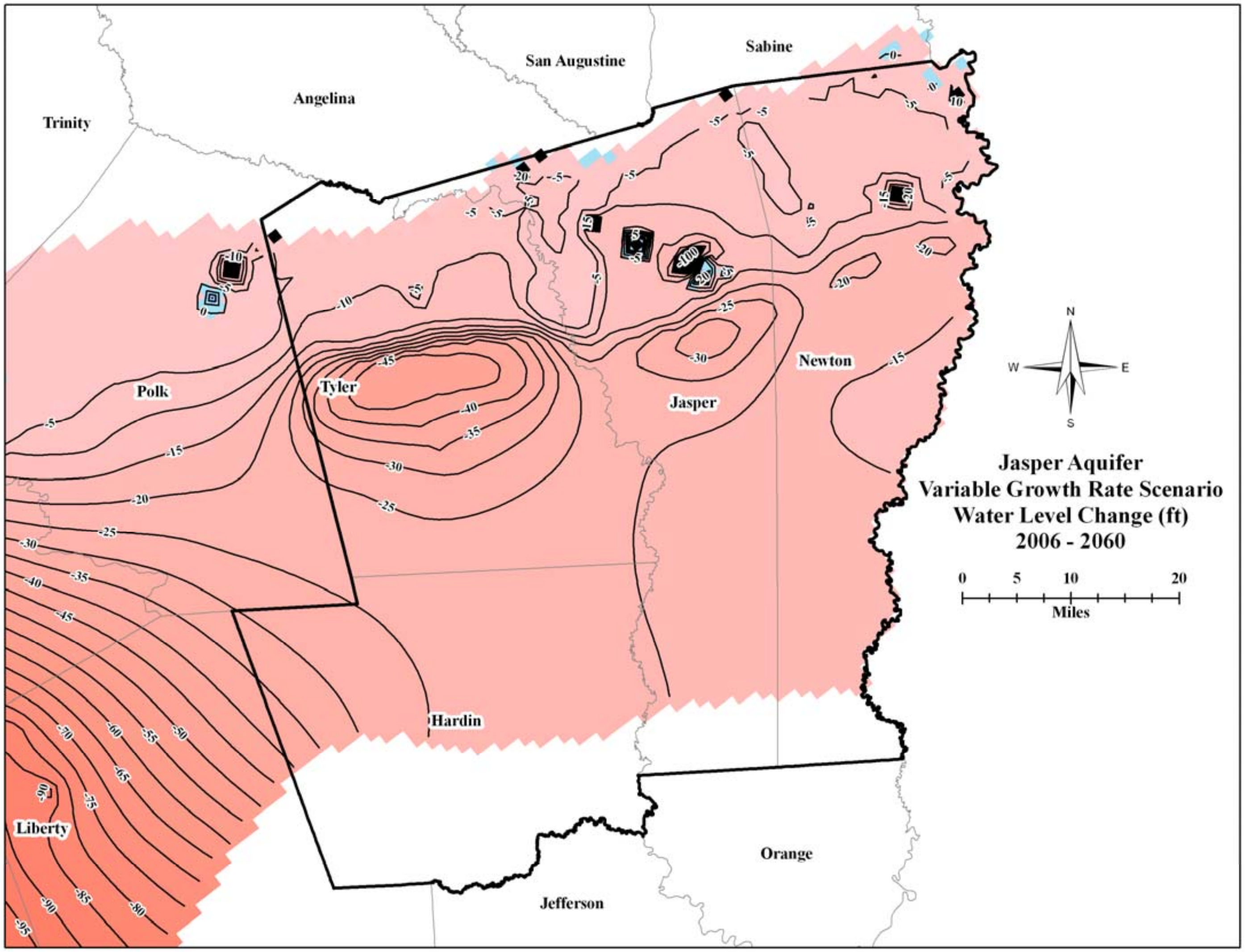

Figure 9. Change in water level in the Jasper Aquifer portion of the Gulf Coast Aquifer between 2006 and 2060. Changes in water levels are in feet (ft). Contour interval is 5 feet. Areas highlighted in red indicate a decrease in water levels. Areas highlighted in blue indicate an increase in water levels. Black areas indicate model grid cells that are dry.

Appendix A

Summary of Budgets During Predictive Model Run 2006 - 2060

Table A-1. Annual water budgets for each county in Southeast Texas Groundwater Conservation District for the year 2010 of the 55-year predictive model run from 2006 to 2060. Values are reported in acre-feet per year.

Chicot Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	3,152	0	1,500	0	1,518	0	548	0
Surface Outflow	-	1,334	-	10,450	-	15,261	-	6,652
Wells	0	1,702	0	10,399	0	165	0	0
Recharge	28,045	-	32,730	-	18,143	-	10,488	-
Vertical Leakage Upper	-	-	-	-	-	-	-	-
Lateral Flow	5,658	11,817	8,725	6,196	4,284	5,307	1,056	2,648
Vertical Leakage Lower	6	22,052	798	16,736	3,261	6,483	1,769	4,561

Evangeline Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	186	0	1,660	0	1,856	0	3,280	0
Surface Outflow	-	0	-	485	-	932	-	2,675
Wells	0	16,308	0	29,019	0	8,215	0	7,066
Recharge	0	-	1,775	-	4,486	-	6,101	-
Vertical Leakage Upper	22,052	6	16,736	798	6,483	3,261	4,561	1,769
Lateral Flow	4,857	12,159	13,169	3,952	2,776	3,861	1,012	2,617
Vertical Leakage Lower	1,291	0	1,088	498	1,418	769	357	1,191

Burkeville Confining Unit	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	35	0	598	0	599	0	694	0
Surface Outflow	-	0	-	1	-	1	-	0
Wells	0	0	0	22	0	0	0	84
Recharge	0	-	3	-	2	-	7	-
Vertical Leakage Upper	0	1,291	498	1,088	769	1,418	1,191	357
Lateral Flow	6	2	8	12	8	5	16	9
Vertical Leakage Lower	1,252	0	1,012	997	1,330	1,285	322	1,780

Jasper Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	178	0	7,459	1,141	4,580	0	5,715	17
Surface Outflow	-	0	-	2,712	-	4,660	-	2,794
Wells	0	0	0	8,880	0	5,956	0	7,331
Recharge	0	-	5,023	-	5,903	-	3,871	-
Vertical Leakage Upper	0	1,252	997	1,012	1,285	1,330	1,780	322
Lateral Flow	1,879	804	1,834	1,569	1,317	1,139	1,175	2,075
Vertical Leakage Lower	-	-	-	-	-	-	-	-

Table A-2. Annual water budgets for each county in Southeast Texas Groundwater Conservation District for the year 2020 of the 55-year predictive model run from 2006 to 2060. Values are reported in acre-feet per year.

Chicot Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	3,028	0	977	0	1,161	0	364	0
Surface Outflow	-	1,007	-	9,770	-	14,126	-	5,793
Wells	0	2,082	0	10,421	0	237	0	0
Recharge	31,934	-	34,773	-	19,525	-	11,769	-
Vertical Leakage Upper	-	-	-	-	-	-	-	-
Lateral Flow	5,795	11,668	8,788	6,215	4,356	5,133	1,048	2,725
Vertical Leakage Lower	0	26,055	573	18,761	2,503	8,057	1,254	5,917

Evangeline Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	163	0	1,855	0	1,965	0	3,784	0
Surface Outflow	-	0	-	378	-	813	-	2,356
Wells	0	20,863	0	31,960	0	11,160	0	10,109
Recharge	0	-	1,895	-	4,726	-	6,698	-
Vertical Leakage Upper	26,055	0	18,761	573	8,057	2,503	5,917	1,254
Lateral Flow	5,126	11,861	13,446	3,948	2,924	3,767	1,023	2,688
Vertical Leakage Lower	1,212	3	1,053	554	1,366	828	310	1,331

Burkeville Confining Unit	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	32	0	792	0	745	0	925	0
Surface Outflow	-	0	-	1	-	1	-	0
Wells	0	0	0	22	0	0	0	120
Recharge	0	-	3	-	2	-	7	-
Vertical Leakage Upper	3	1,212	554	1,053	828	1,366	1,331	310
Lateral Flow	6	2	8	11	8	5	16	9
Vertical Leakage Lower	1,177	4	982	1,253	1,293	1,505	283	2,123

Jasper Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	162	0	8,544	690	5,806	1	7,530	0
Surface Outflow	-	0	-	2,482	-	4,295	-	2,620
Wells	0	0	0	11,344	0	8,167	0	10,062
Recharge	0	-	5,461	-	6,308	-	4,046	-
Vertical Leakage Upper	4	1,177	1,253	982	1,505	1,293	2,123	283
Lateral Flow	1,965	954	1,861	1,621	1,326	1,187	1,312	2,047
Vertical Leakage Lower	-	-	-	-	-	-	-	-

Table A-3. Annual water budgets for each county in Southeast Texas Groundwater Conservation District for the year 2030 of the 55-year predictive model run from 2006 to 2060. Values are reported in acre-feet per year.

Chicot Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	1,587	0	481	0	598	0	158	0
Surface Outflow	-	800	-	9,461	-	13,564	-	5,388
Wells	0	2,169	0	10,426	0	253	0	0
Recharge	34,434	-	35,903	-	20,320	-	12,412	-
Vertical Leakage Upper	-	-	-	-	-	-	-	-
Lateral Flow	5,918	11,743	8,816	6,263	4,401	5,079	1,045	2,811
Vertical Leakage Lower	0	27,264	500	19,583	2,199	8,625	1,069	6,484

Evangeline Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	75	0	1,567	0	1,585	0	3,224	0
Surface Outflow	-	0	-	299	-	735	-	2,123
Wells	0	21,904	0	32,632	0	11,833	0	10,805
Recharge	0	-	2,024	-	4,948	-	7,154	-
Vertical Leakage Upper	27,264	0	19,583	500	8,625	2,199	6,484	1,069
Lateral Flow	5,260	11,968	13,599	3,937	2,964	3,792	1,028	2,750
Vertical Leakage Lower	1,131	8	997	598	1,278	871	269	1,418

Burkeville Confining Unit	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	15	0	790	0	691	0	993	0
Surface Outflow	-	0	-	1	-	1	-	0
Wells	0	0	0	22	0	0	0	129
Recharge	0	-	4	-	2	-	8	-
Vertical Leakage Upper	8	1,131	598	997	871	1,278	1,418	269
Lateral Flow	7	2	8	11	8	5	16	9
Vertical Leakage Lower	1,113	10	944	1,313	1,231	1,519	250	2,278

Jasper Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	82	0	8,109	436	5,516	1	7,524	0
Surface Outflow	-	0	-	2,287	-	3,959	-	2,462
Wells	0	0	0	11,911	0	8,673	0	10,690
Recharge	0	-	5,908	-	6,727	-	4,252	-
Vertical Leakage Upper	10	1,113	1,313	944	1,519	1,231	2,278	250
Lateral Flow	2,011	992	1,899	1,649	1,326	1,224	1,394	2,049
Vertical Leakage Lower	-	-	-	-	-	-	-	-

Table A-4. Annual water budgets for each county in Southeast Texas Groundwater Conservation District for the year 2040 of the 55-year predictive model run from 2006 to 2060. Values are reported in acre-feet per year.

Chicot Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	1,172	0	351	0	416	0	127	0
Surface Outflow	-	695	-	9,282	-	13,225	-	5,128
Wells	0	2,281	0	10,432	0	274	0	0
Recharge	36,074	-	36,621	-	20,865	-	12,827	-
Vertical Leakage Upper	-	-	-	-	-	-	-	-
Lateral Flow	5,999	11,806	8,828	6,313	4,439	5,060	1,043	2,864
Vertical Leakage Lower	0	28,515	453	20,259	1,971	9,136	940	6,945

Evangeline Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	63	0	1,505	0	1,488	0	3,089	0
Surface Outflow	-	0	-	231	-	676	-	1,937
Wells	0	23,248	0	33,500	0	12,702	0	11,702
Recharge	0	-	2,148	-	5,153	-	7,540	-
Vertical Leakage Upper	28,515	0	20,259	453	9,136	1,971	6,945	940
Lateral Flow	5,376	11,954	13,678	3,941	3,006	3,789	1,030	2,792
Vertical Leakage Lower	1,103	12	968	633	1,231	910	247	1,485

Burkeville Confining Unit	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	12	0	804	0	685	0	1,056	0
Surface Outflow	-	0	-	1	-	1	-	0
Wells	0	0	0	22	0	0	0	139
Recharge	0	-	4	-	3	-	8	-
Vertical Leakage Upper	12	1,103	633	968	910	1,231	1,485	247
Lateral Flow	7	2	8	11	8	5	16	8
Vertical Leakage Lower	1,088	14	919	1,366	1,187	1,557	229	2,399

Jasper Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	61	0	7,988	287	5,438	1	7,748	0
Surface Outflow	-	0	-	2,128	-	3,674	-	2,319
Wells	0	0	0	12,614	0	9,326	0	11,501
Recharge	0	-	6,330	-	7,126	-	4,460	-
Vertical Leakage Upper	14	1,088	1,366	919	1,557	1,187	2,399	229
Lateral Flow	2,018	1,007	1,922	1,658	1,319	1,252	1,463	2,022
Vertical Leakage Lower	-	-	-	-	-	-	-	-

Table A-5. Annual water budgets for each county in Southeast Texas Groundwater Conservation District for the year 2050 of the 55-year predictive model run from 2006 to 2060. Values are reported in acre-feet per year.

Chicot Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	1,180	0	368	0	417	0	142	0
Surface Outflow	-	613	-	9,107	-	12,889	-	4,863
Wells	0	2,431	0	10,441	0	303	0	0
Recharge	37,589	-	37,328	-	21,414	-	13,283	-
Vertical Leakage Upper	-	-	-	-	-	-	-	-
Lateral Flow	6,068	11,792	8,847	6,372	4,483	5,058	1,041	2,903
Vertical Leakage Lower	0	30,055	409	21,076	1,739	9,807	802	7,503

Evangeline Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	69	0	1,536	0	1,493	0	3,152	0
Surface Outflow	-	0	-	178	-	619	-	1,766
Wells	0	25,049	0	34,663	0	13,867	0	12,906
Recharge	0	-	2,284	-	5,357	-	7,935	-
Vertical Leakage Upper	30,055	0	21,076	409	9,807	1,739	7,503	802
Lateral Flow	5,493	11,862	13,766	3,947	3,056	3,783	1,033	2,827
Vertical Leakage Lower	1,092	15	950	669	1,196	953	229	1,556

Burkeville Confining Unit	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	13	0	841	0	710	0	1,126	0
Surface Outflow	-	0	-	1	-	1	-	0
Wells	0	0	0	23	0	0	0	153
Recharge	0	-	4	-	3	-	8	-
Vertical Leakage Upper	15	1,092	669	950	953	1,196	1,556	229
Lateral Flow	7	2	8	11	8	5	16	8
Vertical Leakage Lower	1,076	17	901	1,438	1,152	1,625	214	2,529

Jasper Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	59	0	8,191	189	5,582	0	8,219	0
Surface Outflow	-	0	-	1,982	-	3,406	-	2,178
Wells	0	0	0	13,560	0	10,200	0	12,587
Recharge	0	-	6,726	-	7,524	-	4,675	-
Vertical Leakage Upper	17	1,076	1,438	901	1,625	1,152	2,529	214
Lateral Flow	2,009	1,012	1,939	1,663	1,310	1,279	1,534	1,978
Vertical Leakage Lower	-	-	-	-	-	-	-	-

Table A-6. Annual water budgets for each county in Southeast Texas Groundwater Conservation District for the year 2060 of the 55-year predictive model run from 2006 to 2060. Values are reported in acre-feet per year.

Chicot Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	1,282	0	397	0	445	0	162	0
Surface Outflow	-	538	-	8,910	-	12,532	-	4,562
Wells	0	2,612	0	10,451	0	337	0	0
Recharge	39,190	-	38,107	-	22,015	-	13,814	-
Vertical Leakage Upper	-	-	-	-	-	-	-	-
Lateral Flow	6,142	11,691	8,875	6,403	4,517	4,996	1,043	2,945
Vertical Leakage Lower	0	31,835	360	22,029	1,504	10,619	659	8,171

Evangeline Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	78	0	1,613	0	1,552	0	3,314	0
Surface Outflow	-	0	-	138	-	566	-	1,611
Wells	0	27,212	0	36,059	0	15,266	0	14,351
Recharge	0	-	2,441	-	5,574	-	8,375	-
Vertical Leakage Upper	31,835	0	22,029	360	10,619	1,504	8,171	659
Lateral Flow	5,632	11,690	13,903	3,945	3,125	3,770	1,038	2,864
Vertical Leakage Lower	1,089	17	933	708	1,165	1,003	213	1,635

Burkeville Confining Unit	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	15	0	892	0	753	0	1,201	0
Surface Outflow	-	0	-	0	-	1	-	0
Wells	0	0	0	23	0	0	0	171
Recharge	0	-	4	-	3	-	8	-
Vertical Leakage Upper	17	1,089	708	933	1,003	1,165	1,635	213
Lateral Flow	7	2	8	11	8	5	16	8
Vertical Leakage Lower	1,072	21	884	1,529	1,120	1,716	199	2,667

Jasper Aquifer	Hardin		Jasper		Newton		Tyler	
	In	Out	In	Out	In	Out	In	Out
Storage	63	0	8,604	138	5,858	0	8,854	0
Surface Outflow	-	0	-	1,842	-	3,139	-	2,036
Wells	0	0	0	14,732	0	11,217	0	13,892
Recharge	0	-	7,175	-	7,913	-	4,910	-
Vertical Leakage Upper	21	1,072	1,529	884	1,716	1,120	2,667	199
Lateral Flow	1,995	1,009	1,958	1,670	1,300	1,308	1,620	1,927
Vertical Leakage Lower	-	-	-	-	-	-	-	-