GAM Run 08-44

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EXECUTIVE SUMMARY:

We ran the groundwater availability model for the Seymour and Blaine aquifers, using specified annual pumpage requested by Groundwater Management Area 6 for a 51-year (2000 to 2050) predictive simulation along with average recharge and evapotranspiration rates. This model run indicates that assigning this amount of pumpage in the model for the predictive period results in the following:

- Water level changes ranged from declines of 30 feet to rebounds of 35 feet across the model area for the Seymour Aquifer with an average water level decline of 2.2 feet. In general, water level declines correspond to areas with increased pumping, such as Collingsworth and Knox counties and water level increases correspond to areas of decreased pumping, such as Jones and Hardeman counties.

- Water level changes ranged from declines of 40 feet to rebounds of 40 feet across the model area for the Blaine Aquifer with an average water level decline of 2.9 feet.

- An increase in “dry” areas of the Seymour Aquifer from 21 percent of the aquifer area in 2000 to 28 percent in 2050.

REQUESTOR:

Mr. Mike McGuire of the Rolling Plains Groundwater Conservation District (on behalf of Groundwater Management Area 6).

DESCRIPTION OF REQUEST:

Mr. McGuire asked us to perform a baseline model run using the groundwater availability model for the Seymour and Blaine aquifers using current pumpage, as specified by Groundwater Management Area 6, held constant over a 50-year simulation period.

METHODS:

The simulation was set up using average recharge based on recharge from the transient calibration run representing climatic conditions from 1975 to 1999 (Ewing and others, 2004). These averages were then used for each year of the predictive simulation through 2050 along with the specified baseline pumpage. Simulated water levels and water level declines were then evaluated and are described in the results section below.

PARAMETERS AND ASSUMPTIONS:

The parameters and assumptions for the groundwater availability model for the Seymour and Blaine aquifers are described below:

- We used Version 1.01 of the groundwater availability model for the Seymour and Blaine aquifers. See Ewing and others (2004) for assumptions and limitations of the model.

- We used Groundwater Vistas version 5 (Environmental Simulations, Inc., 2007) as the interface to process model output.

- The model includes two layers representing the Seymour Aquifer (Layer 1) and the Blaine Aquifer and other Permian sediments (Layer 2).

- The areas from which average water level changes and water budgets are calculated are different for each layer of the groundwater availability model. In layer 1, all active model cells within each county are used, representing the Seymour Aquifer. In Layer 2, only those active cells within the district representing the Blaine Aquifer are used. This excludes active cells outside the Blaine Aquifer in Layer 2 representing other Permian sediments.

- The Blaine Aquifer boundary used in the groundwater availability model run was the official boundary during development of the groundwater availability model in 2004. Though the official boundary of the Blaine Aquifer has changed since model development, the model is only applicable in areas within this older boundary. The results presented in this report reflect only those areas of the Blaine Aquifer for which the groundwater availability model is applicable.

- 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 period of 1990 to 1999 is 19.6 feet for the Seymour Aquifer and 26.4 feet for the Blaine Aquifer. This represents one percent and three percent of the range of measured water levels respectively (Ewing and others, 2004).

- We used average annual recharge conditions based on climate data from 1975 to 1999 for the simulation.

- Pumpage used for each year of the 2000 to 2050 predictive simulation was specified by members of Groundwater Management Area 6 on a county-by-county basis. Details on this pumpage are given below.

Specified Pumpage

Each year of the predictive model run used pumpage specified by Groundwater Management Area 6 for the Seymour and Blaine aquifers (Tables 1 and 2). The specified pumpage is intended to reflect current annual pumpage in each aquifer per county as of 2007. For 2000, the starting year for the predictive model developed using pumpage from the 2002 State Water Plan, the vertical and spatial pumpage distribution is the same as the last year (1999) of the transient model. Therefore, the simulation pumpage for the year 2000 was adjusted on a county-wide basis to match the pumpage specified by the groundwater management area. Also, note that, for this run, we are assuming that groundwater use distribution by category does not change. For example we are assuming that the proportion of municipal to irrigation to domestic use remains constant.

In the Seymour Aquifer, if pumpage in a county was decreased, a factor was used to reduce cell-by-cell pumpage to reduce the total pumpage but preserve the pumpage distribution. For example, if the requested total pumpage in a county was 10 percent less than that of year 2000, the pumpage value for each cell was multiplied by a factor of 0.9 to result in a 10 percent reduction in the total pumpage. In areas of the Seymour Aquifer where pumpage was increased, the amount by which the pumpage was increased over year 2000 pumpage was distributed evenly over all active model cells within the county. In the Blaine Aquifer, the year 2000 pumpage was increased or decreased to the specified pumpage by applying a factor as discussed above.

Table 1. Pumpage specified by Groundwater Management Area 6 for use in this model simulation for the Seymour Aquifer. All pumpage is reported in acre-feet per year. Note: specified pumpage for *italicized* counties could not be incorporated into the model run because the aquifer is not present in the county.

County	2000 pumpage*	Specified pumpage	County	2000 pumpage*	Specified pumpage
Archer	0	35	Jones	4,045	2,970
Baylor	1,805	4,353	Kent	1,621	1,236
Childress	68	1,320	*King*	*0*	*0*
Clay	799	918	Knox	26,246	49,182
Collingsworth	14,134	25,271	Motley	1,686	2,065
Cottle	*0*	*47*	*Palo Pinto*	*0*	*0*
Dickens	*0*	*225*	*Shackelford*	*0*	*695*
Fisher	3,323	3,263	*Stephens*	*0*	*136*
Foard	5,200	4,903	Stonewall	1,040	597
Hall	8,841	20,492	Throckmorton	0	115
Hardeman	726	463	Wichita	1,778	2,334
Haskell	22,191	52,449	Wilbarger	22,838	30,161
Jack	*0*	*0*	Young	0	361

* 2000 pumpage was based on a previously developed predictive dataset using information from the 2002 State Water Plan.

Table 2. Specified annual pumpage for the Blaine Aquifer used in this model simulation. All pumpage is reported in acre-feet per year.

County	2000 pumpage*	Specified pumpage	County	2000 pumpage*	Specified pumpage
Childress	3,641	8,993	Hardeman	4,839	5,200
Collingsworth	4,325	10,698	King	291	390
Cottle	5,020	4,471	Knox	0	0
Dickens	0	0	Motley	0	0
Foard	18	23	Wilbarger	0	0
Hall	24	8			

* 2000 pumpage was based on a previously developed predictive dataset using information from the 2002 State Water Plan.

RESULTS:

Included in Appendix A are estimates of the water budgets after running the model for 51 years (2000 to 2050) by county and pod for the Seymour Aquifer and by county for the Blaine Aquifer. A location map of the pod numbers for the Seymour Aquifer is shown in Figure 1. 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. Recharge is always shown as “Inflow” into the water budget. Recharge is modeled using the MODFLOW Recharge package.

- 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 (EVT) 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 Tables 1 and 2 because of dry cells and slight deviations generated by the programs written to create the well package, as described below.

- Springs—water that naturally discharges from an aquifer when water levels rise above the elevation of the spring. This component is always shown as “Outflow,” or discharge, in the water budget. Spring flows are simulated in the model using the MODFLOW Drain package.

- Rivers and Streams—water that flows between perennial streams and rivers and an aquifer. The direction and amount of flow depends on the water level in the stream or river and the aquifer. In areas where water levels in the stream or river are above the water level in the aquifer, water flows out of the stream and 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-Routing package.

- 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. In this model, the Seymour Aquifer is not always underlain by the Blaine Aquifer and the Blaine Aquifer is not always overlain by the Seymour Aquifer. For this reason, the amount of water exiting the Seymour Aquifer may not equal the amount of water entering the Blaine Aquifer.

The results of the model run are described for the two aquifers in the model area: the Seymour Aquifer (Layer 1 in the model) and the Blaine Aquifer (Layer 2).

Initial water levels (those from the end of the transient calibration period—the end of 1999) for the Seymour and Blaine aquifers are shown in Figures 2 and 3, respectively. These figures show the starting water levels for the 51-year predictive model run. For the Seymour Aquifer, water levels generally decrease from west to east with the highest water levels found in Pod 3 in northwestern Motley County and in Pod 1 in western Collingsworth County. The Blaine Aquifer shows a similar trend with a general decrease in water levels from west to east. The highest initial water levels in the Blaine Aquifer are found in northwestern Collingsworth County and in southwestern Wheeler County.

Water levels for the Seymour and Blaine aquifers at the end of the predictive model run – the end of 2050 – are shown in Figures 4 and 5, respectively. Predicted water levels for 2050 show the same general trends described above for both the Seymour and Blaine aquifers. Because differences between initial water levels and water levels after 51 years of pumpage are sometimes difficult to quantify in these figures, maps of water level changes were made. A water level change map shows the difference between the water levels at the start and end of the predictive model run.

Water level changes over the 51-year predictive portion of the model simulation for the Seymour and Blaine aquifers are shown in Figures 6 and 7, respectively. Table 3 shows the average predicted water level change by county and pod for the Seymour Aquifer between 2000 and 2050. Water level changes in the Seymour Aquifer generally vary between increases of up to 35 feet and declines of up to 30 feet. The largest water level increases are found in northwestern Wilbarger County and eastern Hardeman County. The largest water level declines are found along the northwestern portions of Pod 7 in Knox and Haskell counties. On average, the model run predicts water levels in the Seymour Aquifer will decline by 2.2 feet between 2000 and 2050 given the specified pumpage scenario. It is important to note that this average does not take into account the effect of dry cells – model grid cells in which the water level has dropped below the bottom of the aquifer. In addition, it should be noted that because the predictive simulation is based on annual conditions, seasonal variations and the effects of high, concentrated pumpage in the summer months when recharge is typically low may not be captured in the water levels described above. This simulation shows the predicted overall trends over the 51 year model run.

Table 4 shows the average predicted water level change by county for the Blaine Aquifer between 2000 and 2050. Water level changes in the Blaine Aquifer generally vary between increases of up to 40 feet and declines of up to 40 feet. The largest water level increases are found in southern and northeastern Cottle County, eastern Childress County, and northwestern Hardeman County. The largest water level declines are found in central Foard County and central Collingsworth County. On average, the model run predicts water levels in the Blaine aquifer will decline by 2.9 feet between 2000 and 2050 given the specified pumpage scenario.

Some of the county pumping totals (Wells) listed in Appendix A differ from the amounts listed in Tables 1 and 2 as mentioned in Parameters and Assumptions above. The primary reason for this difference is the occurrences of dry cells. When the water level in a cell drops below the bottom of the aquifer in a cell, the cell goes dry and pumping can no longer occur. The total county pumpage is, therefore, reduced. Dry cells can be reactivated in the model using the MODFLOW Rewet package in which water can enter a dry cell if water levels are higher in a neighboring cell. At the beginning of the predictive model run (the end of 1999), 736 cells out of 3,436 active cells were dry in the Seymour Aquifer. At the end of the predictive model run (the end of 2050), 959 cells were dry. 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 this area. No cells went dry over the course of the model run in the Blaine Aquifer.

It is 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, a model cell that straddles a county boundary is 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 3. Average water level change in the Seymour Aquifer by county and pod. All water level changes are reported in feet. Negative values indicate an average water level decline. Positive values indicate an average water level increase.

County	Pod	Average water level change (feet)
Archer	5	-1.6
Baylor	7	0.1
	8	-1.6
Briscoe	3	-31.3
Childress	1	15.7
	4	2.3
Clay	5	0.3
Collingsworth	1	-9.0
Fisher	11	-1.4
Foard	4	1.7
Hall	2	-10.0
	3	-9.6
Hardeman	4	5.9
Haskell	7	-16.1
Jones	11	1.4
	12	1.0
	13	3.8
	14	-0.2
	15	0.2
Kent	9	-3.0
Knox	6	-12.1
	7	-18.1
Motley	3	-1.5
Stonewall	7	-24.1
	9	-3.6
	10	-5.8
Taylor	15	-3.9
Throckmorton	8	-1.0
Wichita	4	7.7
	5	-0.1
Wilbarger	4	3.6
Young	8	-4.6

Table 4. Average water level change in the Blaine Aquifer by county. All water level changes are reported in feet. Negative values indicate an average water level decline. Positive values indicate an average water level increase.

County	Average water level change (feet)
Childress	4.0
Collingsworth	-6.2
Cottle	1.0
Dickens	-10.4
Foard	-12.4
Hall	-3.2
Hardeman	-0.7
King	-6.4
Knox	-14.4
Motley	2.9
Wheeler	-8.6
Wilbarger	9.2

REFERENCES:

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

Ewing, J.E., Jones, T.L., Pickens, J.F., Chastain-Howley, A., Dean, K.E., Spear, A.A., 2004, Groundwater availability model for the Seymour Aquifer: Final report prepared for the Texas Water Development Board by INTERA, Inc., 533 p.

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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 November 7, 2008.

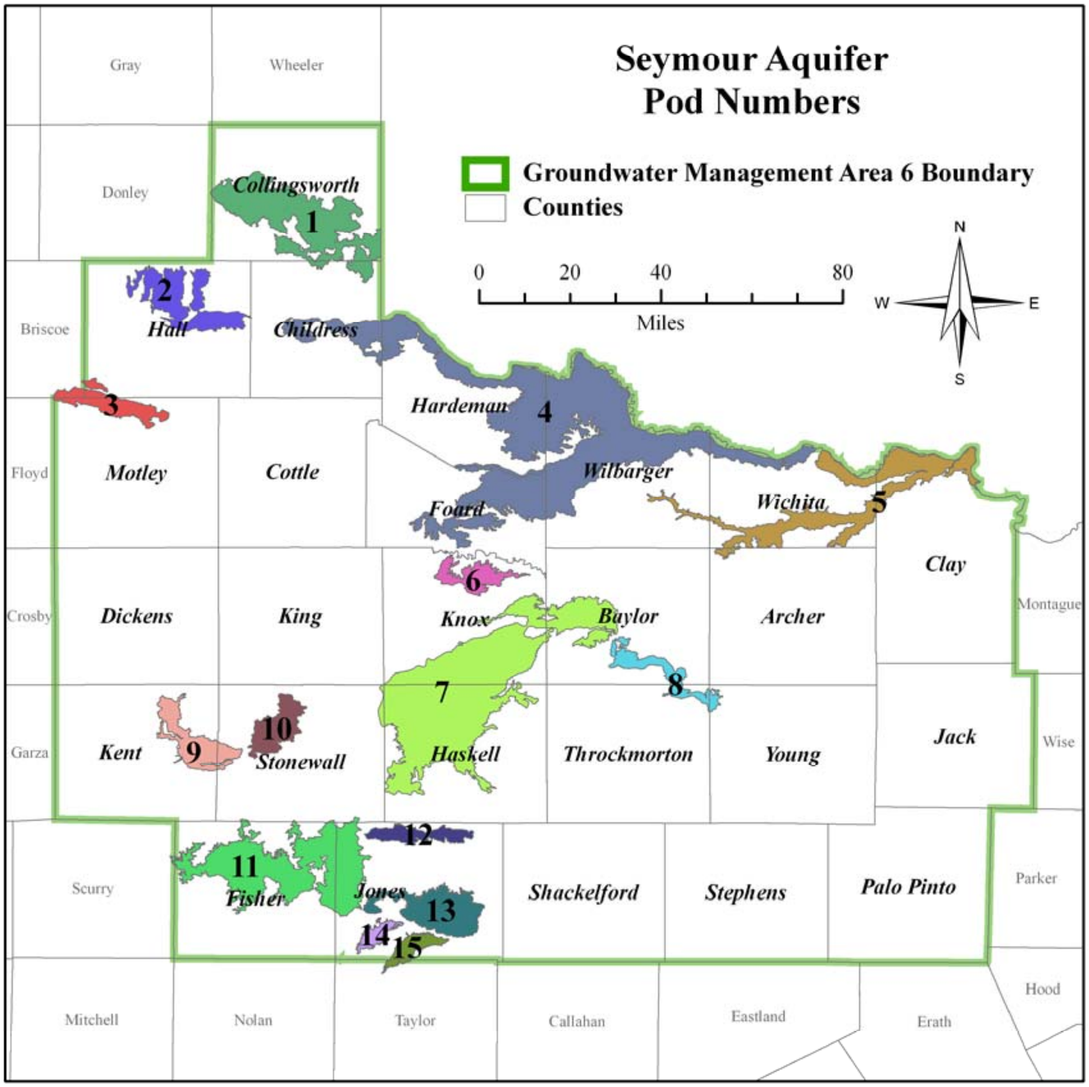

Figure 1. Location Map of Groundwater Management Area 6 showing the Seymour Aquifer and the numbers designating each pod or geologic island.

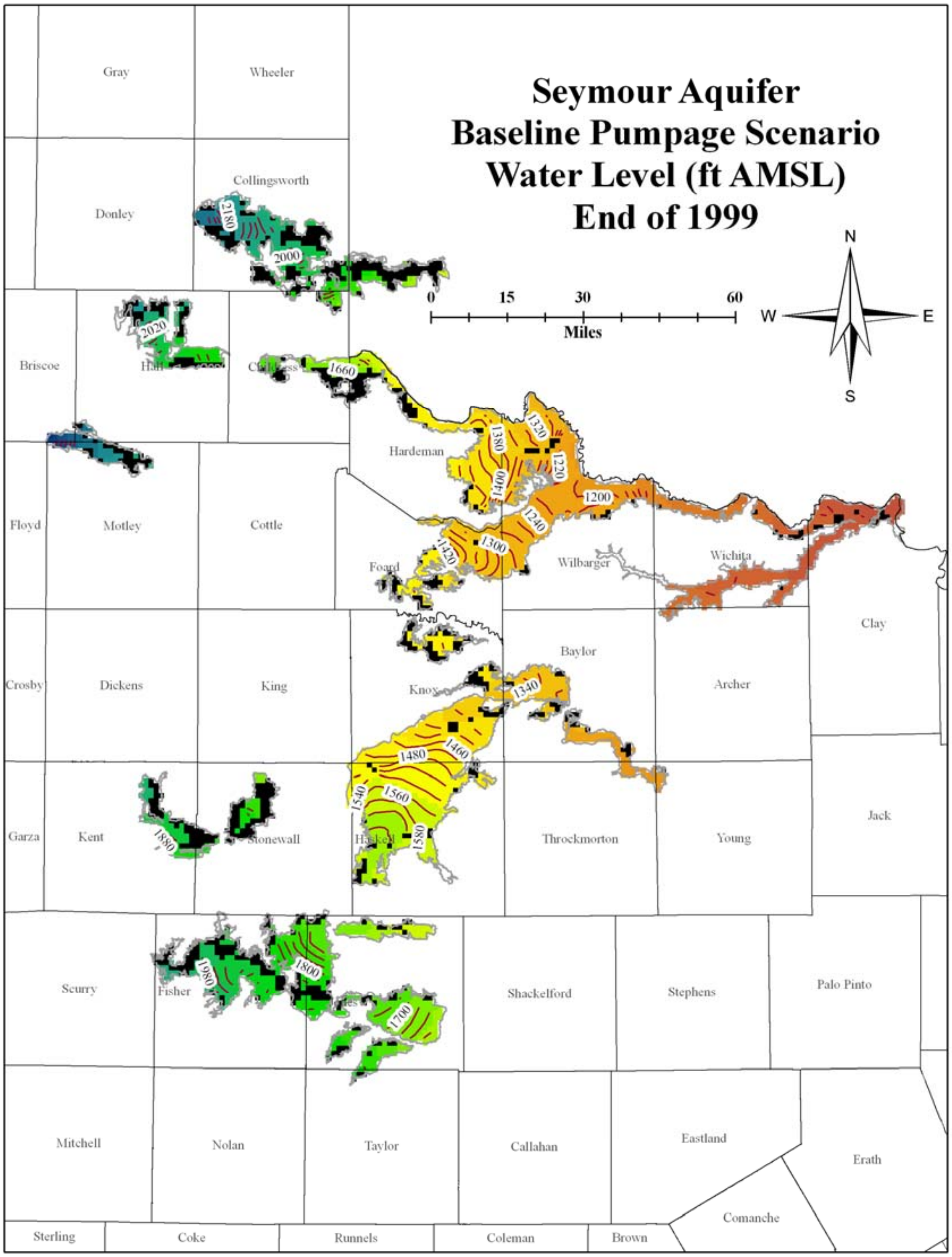

Figure 2. Initial water level elevations for the Seymour Aquifer for the predictive groundwater availability model run. Water level elevations are in feet above mean sea level (ft AMSL). Contour interval is 20 feet. Black areas indicate model grid cells that are dry.

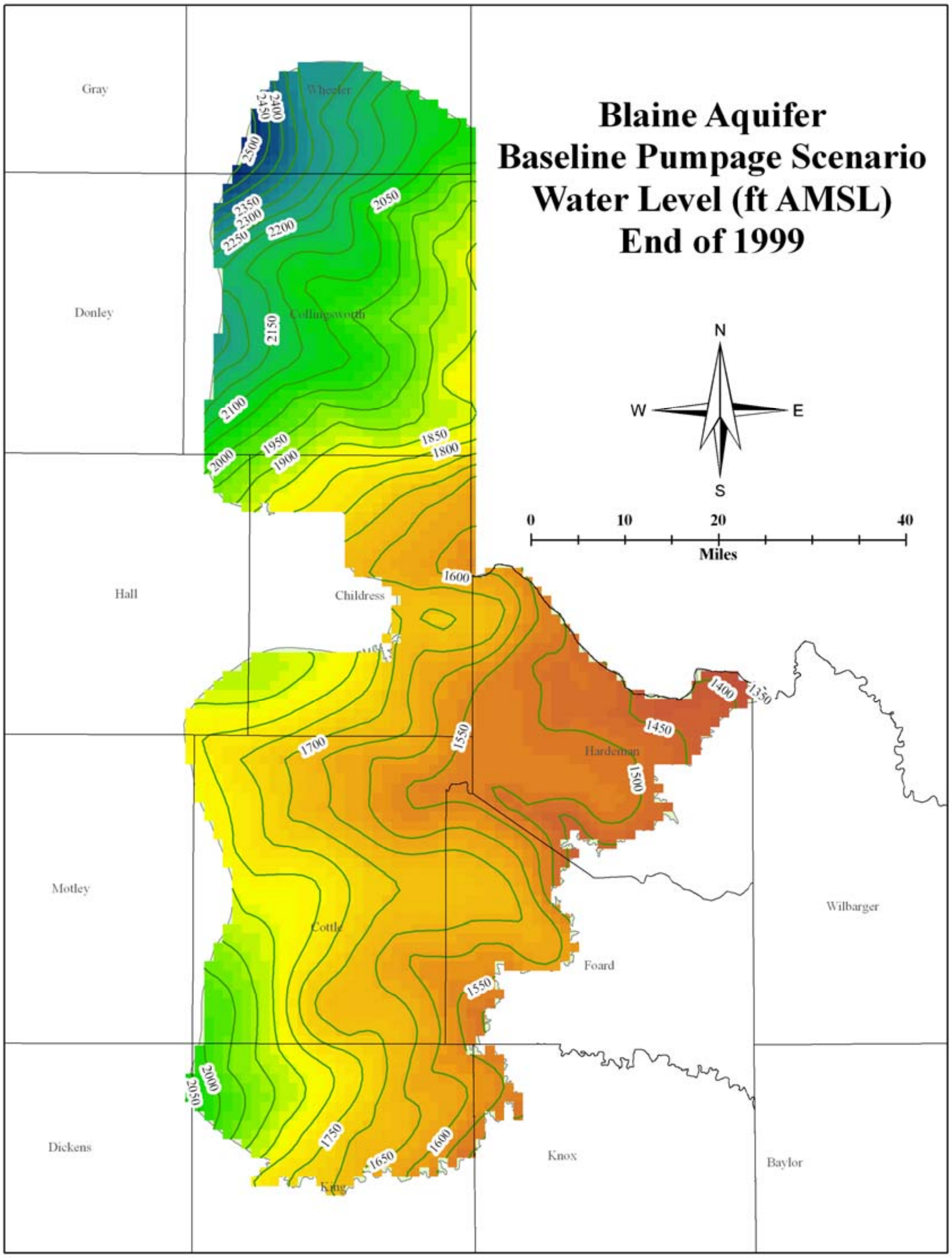

Figure 3. Initial water level elevations for the Blaine Aquifer for the predictive groundwater availability model run. Water level elevations are in feet above mean sea level (ft AMSL). Contour interval is 50 feet.

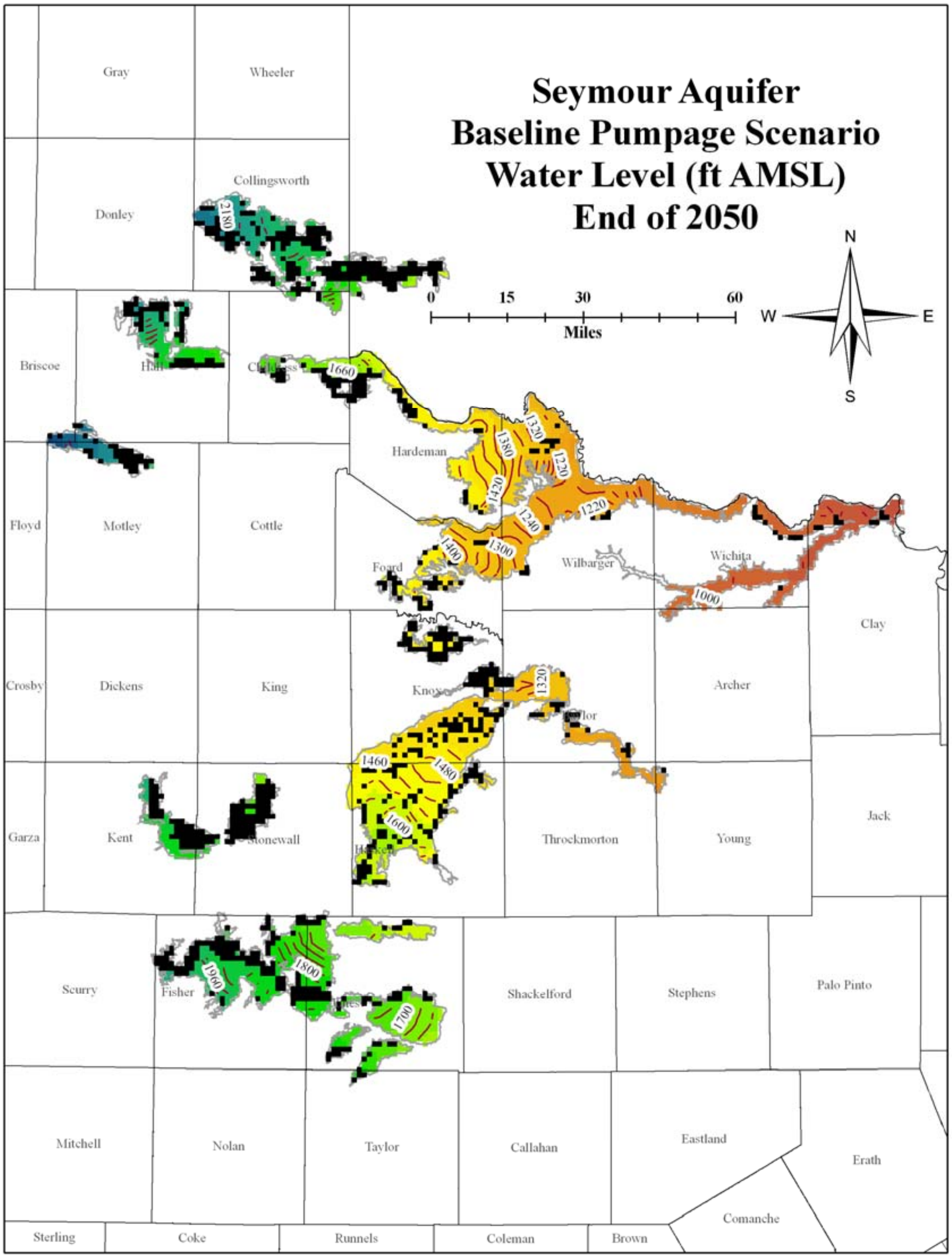

Figure 4. Water level elevations for the Seymour Aquifer at the end of 2050 for the predictive groundwater availability model run. Water level elevations are in feet above mean sea level (ft AMSL). Contour interval is 20 feet. Black areas indicate model grid cells that are dry.

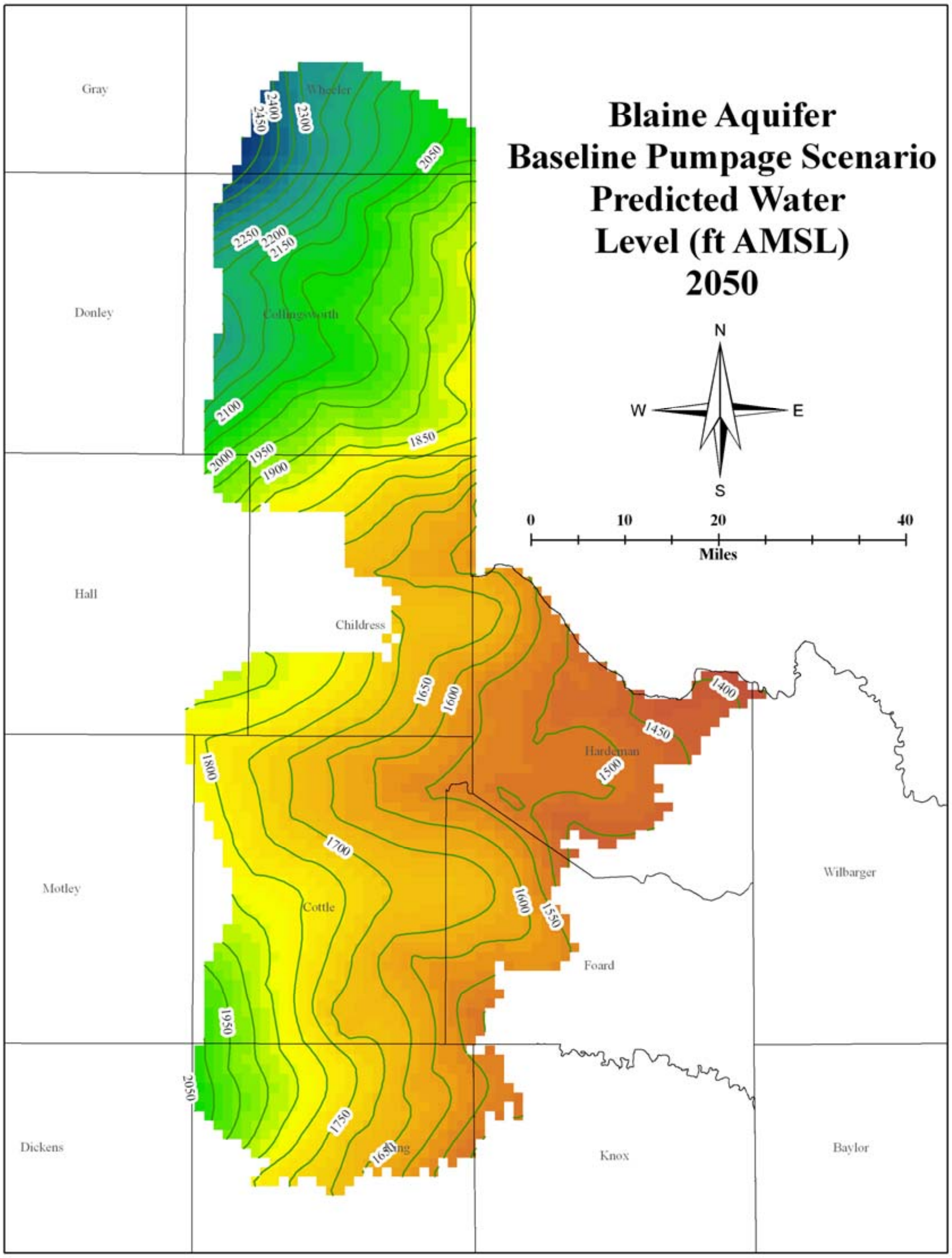

Figure 5. Water level elevations for the Blaine Aquifer at the end of 2050 for the predictive groundwater availability model run. Water level elevations are in feet above mean sea level (ft AMSL). Contour interval is 50 feet.

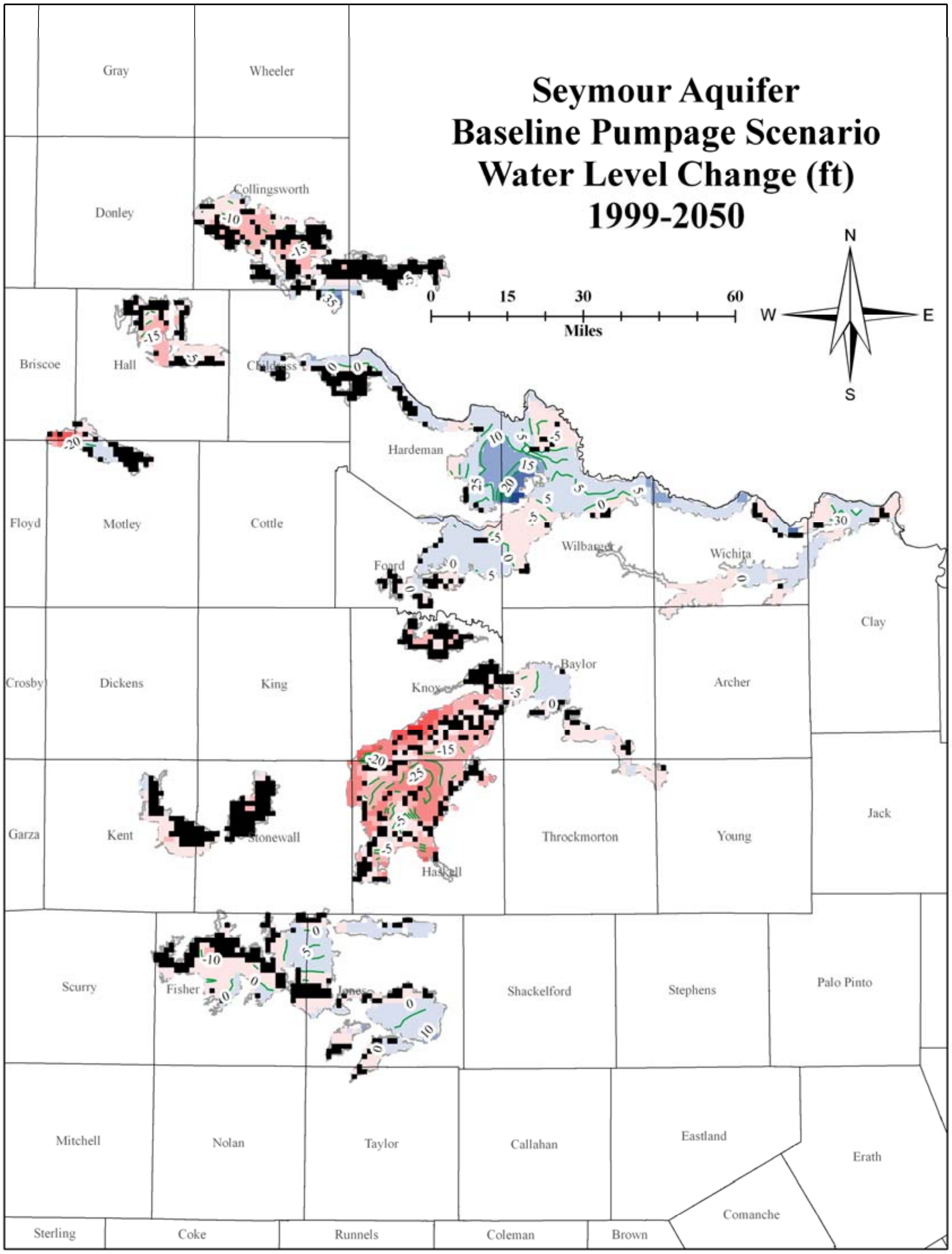

Figure 6. Changes in water levels in the Seymour Aquifer after 51 years using specified pumpage. Changes in water levels are in feet (ft). Contour interval is 5 feet. Areas highlighted in red indicate a decrease in water levels. Areas highlighted in blue indicate an increase in water levels. Black areas indicate model grid cells that are dry.

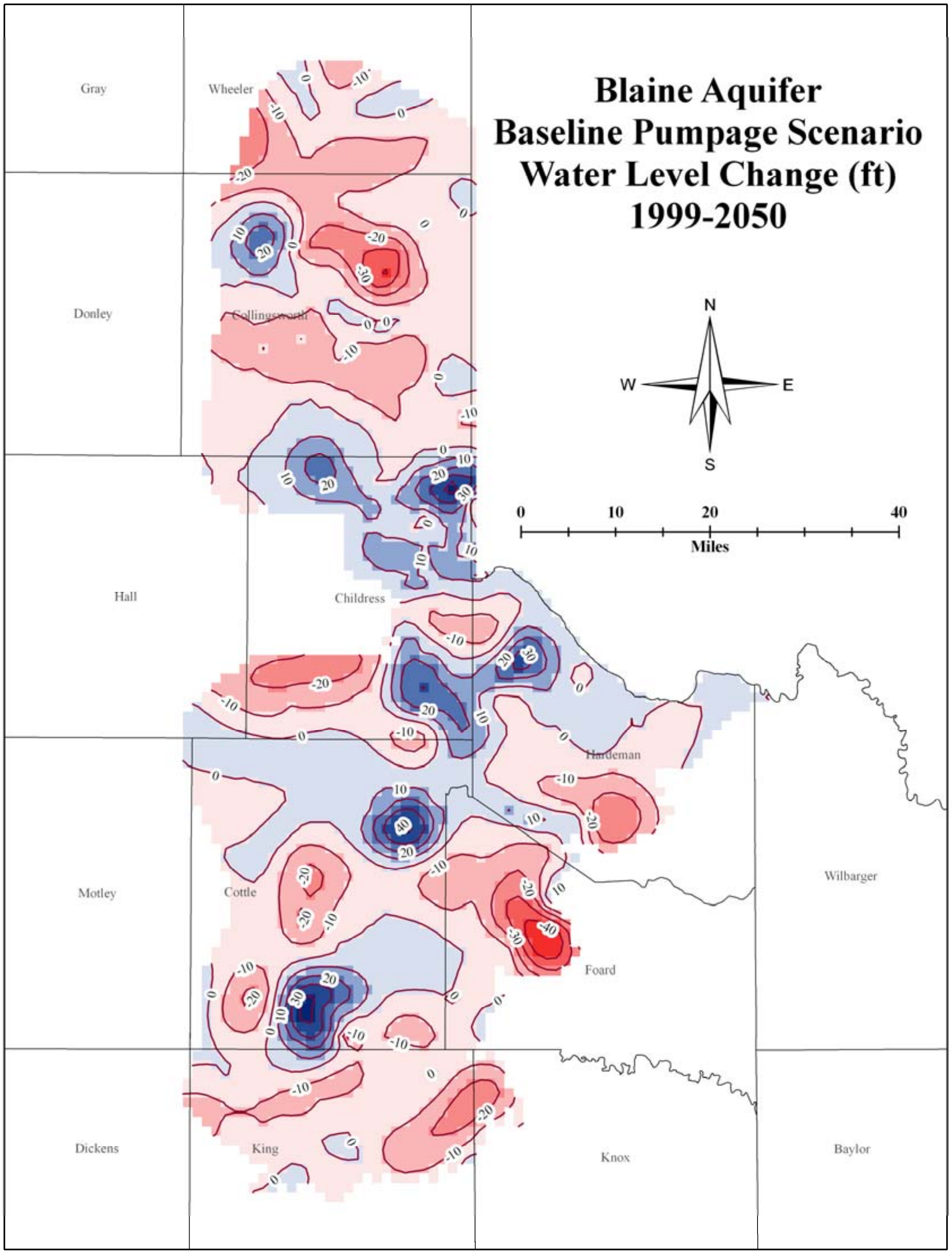

Figure 7. Changes in water levels in the Blaine Aquifer after 51 years using specified pumpage. Changes in water levels are in feet (ft). Contour interval is 10 feet. Areas highlighted in red indicate a decrease in water levels. Areas highlighted in blue indicate an increase in water levels.

Appendix A

Summary of Budgets After Predictive Model Run 2050

Table A-1. Annual water budgets for each county and pod of the Seymour Aquifer in Groundwater Management Area 6 at the end of the 51-year predictive model run using specified baseline pumpage provided by Groundwater Management Area 6. Values are reported in acre-feet per year. Components of the water budget are described in more detail in the results section of the report.

County	Pod	Flow	Recharge	Evapotranspiration	Wells	Springs	Rivers and streams	Change in storage	Lateral flow	Vertical leakage
Archer	5	In	139	0	0	0	0	0	0	242
		Out	0	129	35	0	135	0	81	0
Baylor	7	In	9,208	0	0	0	212	15	0	1,141
		Out	0	1,437	3,145	93	3,126	70	55	2,640
	8	In	1,530	0	0	0	297	19	0	1,802
		Out	0	1,497	641	92	1,154	13	181	68
	Total	In	10,739	0	0	0	509	34	0	2,942
		Out	0	2,934	3,786	184	4,280	84	237	2,708
Childress	1	In	1,355	0	0	0	56	0	729	12
		Out	0	9	245	0	295	158	0	1,444
	4	In	4,897	0	0	0	15	1	0	1,086
		Out	0	840	517	0	557	174	325	3,584
	Total	In	6,252	0	0	0	71	1	729	1,098
		Out	0	849	763	0	852	332	325	5,028
Clay	5	In	4,418	0	0	0	70	15	368	1,232
		Out	0	1,279	785	8	2,289	114	414	1,213
Collingsworth	1	In	23,765	0	0	0	274	933	0	4,639
		Out	0	391	15,753	126	2,058	47	835	10,391
Fisher	11	In	9,715	0	0	0	183	346	2	4,291
		Out	0	4,032	2,915	0	3,567	29	514	3,462
Foard	4	In	12,212	0	0	0	43	241	356	1,606
		Out	0	829	4,188	0	2,537	572	2,029	4,296

Table A-1. (continued)

County	Pod	Flow	Recharge	Evapotranspiration	Wells	Springs	Rivers and streams	Change in storage	Lateral flow	Vertical leakage
Hall	2	In	6,740	0	0	0	77	486	0	12,067
		Out	0	2,151	8,686	172	1,409	36	0	1,240
	3	In	1,687	0	0	0	63	158	600	1,634
		Out	0	0	2,842	0	0	0	110	332
	Total	In	8,427	0	0	0	140	644	600	13,700
		Out	0	2,151	11,529	172	1,409	36	110	1,572
Hardeman	4	In	25,159	0	0	0	73	43	1,494	2,831
		Out	0	3,511	436	376	4,964	1,256	9,235	9,813
Haskell	7	In	42,404	0	0	0	125	3,118	73	16,169
		Out	0	966	41,517	82	607	928	2,518	3,732
Jones	11	In	4,346	0	0	0	0	36	514	1,053
		Out	0	1,601	129	0	1,999	103	2	2,109
	12	In	3,471	0	0	0	0	4	0	2
		Out	0	651	0	0	28	62	0	2,736
	13	In	8,590	0	0	0	49	12	0	327
		Out	0	1,158	2,598	79	962	507	0	3,672
	14	In	1,303	0	0	0	0	16	0	1
		Out	0	80	42	0	0	16	0	1,181
	15	In	2,161	0	0	0	0	11	0	49
		Out	0	247	150	0	216	13	0	1,595
	Total	In	19,870	0	0	0	49	79	514	1,431
		Out	0	3,737	2,918	79	3,205	701	2	11,292
Kent	9	In	3,647	0	0	0	0	120	0	4,403
		Out	0	2,787	1,178	0	3,452	4	190	557

Table A-1. (continued)

County	Pod	Flow	Recharge	Evapotranspiration	Wells	Springs	Rivers and streams	Change in storage	Lateral flow	Vertical leakage
Knox	6	In	1,151	0	0	0	0	108	0	93
		Out	0	0	909	0	0	3	0	440
	7	In	23,581	0	0	0	225	4,112	2,079	41,135
		Out	0	1,136	30,443	65	3,224	1,412	0	701
	Total	In	24,732	0	0	0	225	4,220	2,079	41,229
		Out	0	1,136	31,352	65	3,224	1,414	0	1,141
Motley	3	In	3,040	0	0	0	110	109	110	492
		Out	0	57	1,686	0	274	52	305	1,486
Stonewall	7	In	572	0	0	0	0	67	494	0
		Out	0	414	203	0	0	0	73	443
	9	In	445	0	0	0	0	21	190	927
		Out	0	607	7	0	907	0	0	63
	10	In	634	0	0	0	0	47	0	0
		Out	0	20	6	0	0	3	0	651
	Total	In	1,651	0	0	0	0	135	684	927
		Out	0	1,041	216	0	907	3	73	1,157
Throckmorton	8	In	656	0	0	0	211	4	181	705
		Out	0	1,309	115	0	257	7	61	9
Wichita	4	In	3,518	0	0	0	49	0	575	109
		Out	0	375	340	0	760	325	0	2,450
	5	In	5,113	0	0	0	240	35	113	2,568
		Out	0	1,321	1,954	0	3,725	71	368	629
	Total	In	8,631	0	0	0	289	35	688	2,677
		Out	0	1,696	2,294	0	4,485	396	368	3,079
Wilbarger	4	In	46,510	0	0	0	38	94	8,884	5,027
		Out	0	3,546	28,920	1,950	8,843	2,613	598	14,044
Young	8	In	214	0	0	0	26	32	61	892
		Out	0	103	309	0	107	0	0	0

Table A-2. Annual water budgets for each county of the Blaine Aquifer in Groundwater Management Area 6 at the end of the 51-year predictive model run using specified baseline pumpage provided by Groundwater Management Area 6. Values are reported in acre-feet per year. Components of the water budget are described in more detail in the results section of the report.

County	Flow	Recharge	Evapotranspiration	Wells	Springs	Rivers and streams	Change in storage	Lateral flow	Vertical leakage
Childress	In	11,246	0	0	0	2,394	2,225	12,186	3,406
	Out	0	2,150	8,991	0	3,872	6,019	9,875	554
Collingsworth	In	24,386	0	0	0	984	7,463	14,746	9,736
	Out	0	5,032	10,693	2,863	19,446	708	14,037	4,547
Cottle	In	14,649	0	0	0	953	3,536	11,164	653
	Out	0	4,598	4,469	70	14,069	5,354	2,390	0
Dickens	In	45	0	0	0	0	47	823	0
	Out	0	0	0	0	0	0	915	0
Foard	In	4,742	0	0	0	352	4,367	2,073	136
	Out	0	1,002	23	0	2,385	109	8,151	0
Hall	In	911	0	0	0	109	382	3,460	10
	Out	0	261	8	0	463	54	4,083	0
Hardeman	In	10,621	0	0	0	946	2,197	3,915	7,100
	Out	0	1,612	5,198	0	2,799	2,756	10,876	1,537
King	In	7,154	0	0	0	1,133	3,662	4,762	189
	Out	0	2,149	390	0	7,006	97	7,265	0
Knox	In	568	0	0	0	0	454	1,524	0
	Out	0	0	0	0	0	0	2,545	0
Motley	In	45	0	0	0	0	0	374	0
	Out	0	0	0	0	0	5	414	0
Wilbarger	In	0	0	0	0	0	0	269	377
	Out	0	0	0	0	0	1	645	0