GAM Run 08-70

by Ali H. Chowdhury, Ph.D., P.G.
Texas Water Development Board
Groundwater Availability Modeling Section
(512) 936-0834
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EXECUTIVE SUMMARY:

This GAM Run report consists of three separate groundwater availability model runs for the Hill Country portion of the Trinity Aquifer:

(a) Part A consists of 60-year predictive run results using 25 percent additional pumpage for the Middle Trinity Aquifer compared to 2008 baseline pumpage, using 2008 baseline pumpage for the Edwards Group and the Upper Trinity aquifers, and average recharge rates;

(b) Part B consists of 60-year predictive run results using 50 percent additional pumpage for the Middle Trinity Aquifer compared to 2008 baseline pumpage, using 2008 baseline pumpage for the Edwards Group and the Upper Trinity aquifers, and average recharge rates; and

(c) Part C consists of a steady-state model run results using no pumpage and average recharge rates in the model to estimate water levels that existed under pre-development conditions.

Part A

Model run results indicate water levels in the Middle Trinity Aquifer declined by about 60 feet in western part of Kerr County, 40 feet in southern part of Kendall County, and 20 feet in Travis County by 2060. However, these water level decreases average about 17 feet for the Middle Trinity Aquifer across the Groundwater Management Area 9. Baseflow to the local rivers, springs, and lakes/reservoirs located over the outcrop of the Middle Trinity Aquifer decreased by about 11 to 44 percent compared to the baseline run. Spring discharges also decreased by up to about 34 percent. Water levels in the Upper Trinity Aquifer declined by about 35 feet in Kendall and Kerr counties. Spring discharges decreased by up to about 16 percent in the Upper Trinity Aquifer. Water levels recovered by up to 9 feet over most of the Edwards Group Aquifer and declined by up to 3 feet where the aquifer is thin. A rise in the water levels in the Edwards Group Aquifer also resulted in a local increase in spring discharges by up to 6 percent. Comparison of baseline pumpage and increased pumpage shows that an additional 12,500 acre-feet of groundwater could potentially be pumped annually across the Groundwater Management Area 9. Final determination of managed available groundwater for counties partly included in the model, such as Bandera, Blanco, Medina, and Kerr counties, will further include county areas outside the model thus increasing the total amount of managed available groundwater for these counties.

Part B

Model run results indicate water levels in the Middle Trinity Aquifer declined by up to about 110 feet in western part of Kerr County, 60 feet in southern part of Kendall County, and 40 feet in Travis County by 2060. However, these water level decreases average about 26 feet for the Middle Trinity Aquifer across the Groundwater Management Area 9. The results of the model run indicate that the additional pumpage results in about 18 to 69 percent reduction in baseflow to the local rivers, springs, and lakes/reservoirs that are located over the outcrop of the Middle Trinity Aquifer compared to the baseline run. Spring discharges decreased by up to about 44 percent. Water level decline in the Upper Trinity Aquifer also remains the same as discussed in the Part A run with the exception of a slightly larger drawdown area around Kendall and Kerr counties. This suggests that the assigned groundwater pumping amount and distribution in the Middle Trinity Aquifer do not adversely affect water levels in the Upper or the Edwards Group aquifers. Water levels in the Edwards Group Aquifer similarly recover as discussed in the Part A run. Spring discharges in the Edwards Group and Upper Trinity aquifers remain the same as in the Part A run. Comparison of baseline pumpage and increased pumpage shows that an additional 25,000 acre-feet of groundwater could potentially be pumped annually across the Groundwater Management Area 9. Final determination of managed available groundwater for counties partly included in the model, such as Bandera, Blanco, Medina, and Kerr counties, will further include county areas outside the model thus increasing the total amount of managed available groundwater for these counties.

Part C

The steady-state model results with no pumping and average recharge conditions indicate considerable rise in water levels in the aquifers and an increase in groundwater discharges into the rivers and springs. For example, discharges to the rivers increased by up to about 9 percent in the Edwards Group Aquifer, up to 13 percent in the Upper Trinity Aquifer, and up to 22 percent in the Middle Trinity Aquifer compared to discharges during 2008. Spring discharges also locally increased by up to 9 percent in the Edwards Group, up to about 83 percent in the Upper Trinity Aquifer, and more than 180 percent in the Middle Trinity aquifers. Simulated water levels in the aquifers also show well developed v-shaped contours that point upstream when they cross the streams suggesting increased baseflow from the aquifers to the rivers and springs.

REQUESTOR:

Mr. Ron Fieseler, General Manager of the Blanco-Pedernales Groundwater Conservation District, on behalf of the groundwater conservation districts in Groundwater Management Area 9.

DESCRIPTION OF REQUEST:

Mr. Ron Fieseler requested that we:

(1) increase the 2008 baseline pumping for the Middle Trinity Aquifer (Chowdhury, 2008a, b) by 25 percent (part A) and 50 percent (part B) with no increase in pumping in the Edwards Group and Upper Trinity aquifers, and run the steady-state portion of the model with no pumping (part C) to estimate water levels that existed under natural conditions prior to any groundwater pumping;

(2) extract water levels and water budgets for the beginning of the simulation (2008) using the baseline pumpage and the end of the predictive period (2060) using the adjusted pumpage;

(3) develop water level change maps using the 2008 baseline model results compared with the results at the end of the predictive period (2060) using the adjusted pumpage; and

(4) provide managed available groundwater estimates by decade for each groundwater conservation district and for Groundwater Management Area 9 .

METHODS:

We updated the predictive pumpage in the groundwater availability model for the Hill Country portion of the Trinity Aquifer (Mace and others, 2000) to closely match current county total pumpage use according to the groundwater conservation districts located in Groundwater Management Area 9. Details on this were discussed in GAM Run 08-15 (Chowdhury, 2008a) and GAM Run 08-20 (Chowdhury, 2008b). This baseline pumpage was then uniformly increased by 25 (Part A) and 50 percent (Part B) for the Middle Trinity aquifers at existing pumpage locations in the model. No further adjustments were made to the baseline pumpage for the Edwards Group or Upper Trinity Aquifer. In addition, the steady-state portion of the model was run with no pumping (Part C) and average recharge to estimate aquifer conditions that existed prior to groundwater pumping

We extracted and contoured the simulated water levels for 2008 and 2060 in ArcMap© for both the baseline and adjusted pumpage. To improve the quality of the illustration, simulated water level and water level difference maps were finalized in Adobe Illustrator©. We obtained county drawdown values by subtracting the simulated water levels produced by the adjusted pumpage condition at the end of 2060 from the 2008 simulated water levels under the baseline pumpage condition. We spatially joined the model grid with the simulated water levels and drawdown values to determine their distribution by county and model cell numbers. We exported the attributed ArcMap© datasets generated from this join and calculated the average, minimum, and maximum drawdown values in a spreadsheet. We also extracted water budget information for the beginning (2008) of the predictive period using the baseline pumpage and the end (2060) of the predictive period using the adjusted pumpage from the zoned water budget output data in Processing Modflow for Windows. This was done because the predictive pumpage was kept constant through the 60 years simulation run and decade-by-decade water budget flow terms would essentially be the same.

PARAMETERS AND ASSUMPTIONS:

- We used the groundwater availability model for the Hill Country portion of the Trinity Aquifer developed by Mace and others (2000).

- See Mace and others (2000) for details on model construction, recharge, discharge, assumptions and limitation of the model. A slightly updated version of this model (version 1.03) was used for this run (Chowdhury, 2007).

- The model has three layers: layer 1 represents the Edwards Group, layer 2 represents the Upper Trinity Aquifer, and layer 3 represents the Middle Trinity Aquifer.

- The model has a total of 79 stress periods with 2 stress periods representing pre-development conditions, 24 monthly stress periods for representing transient conditions (1996 to 1997), and 53 predictive annual stress periods (2008 to 2060).

- The calibrated model has a root-mean squared error of 56 feet .The root-mean squared error means that, on average, the simulated water level differs by about 56 feet. This root-mean squared error is about 5 percent of the total hydraulic head drop across the modeled area.

- The rivers, streams, and springs were simulated in the model using MODFLOW's Drain package. MODFLOW's drain package was also used to simulate spring flow along bedding contacts of the Edwards Group and the Upper Trinity Aquifer in the northwestern parts of the model area. This resulted in the assignment of numerous drain cells along this outcrop contact.

- Reservoirs/lakes in the model area were simulated using constant heads.

- Pumpage used for the predictive period was developed as per instruction of the groundwater conservation districts in Groundwater Management Area 9.

- We assigned the baseline pumpage to the first predictive stress period in the model to represent 2008 pumping conditions. This was done with the assumption that the aquifers in the area recharges rapidly and groundwater movement is fast enough to bring about a dynamic equilibrium relatively quickly. Comparison of water level changes in selected hydrographs in the predictive period suggests that the aquifer attains a dynamic equilibrium within a year.

- The pumpage specified by the groundwater conservation districts in Groundwater Management Area 9 was developed using the spatial distribution of initial predictive pumpage included in the groundwater availability model (Mace and others, 2000).

- Average climatic recharge conditions were used throughout the predictive period for this model run. Average recharge in the model was estimated for normal climatic conditions by using the average precipitation for the period 1960 to 1990 and the recharge coefficients estimated from baseflow analyses for each model cell (Mace and others, 2000).

- The model was run in Processing Modflow for Windows (version 5.3; Chiang and Kinzelbach, 1998).

RESULTS:

We report model run results by the end of 2060 using 25 and 50 percent more pumpage for the Middle Trinity Aquifer compared to the 2008 baseline pumpage with no increase in pumpage in the Edwards Group and the Upper Trinity aquifers. Details of these pumpage estimates are presented in Table 1. Comparison of baseline pumpage and increased pumpage shows an annual difference of about 12,500 acre-feet (Part A) and 25,000 acre-feet (Part B).

Groundwater Management Area 9 consists of all or parts of Kerr, Bandera, Medina, Kendall, Bexar, Comal, Blanco, Hays, and Travis counties (Figure 1). Groundwater Management Area 9 contains numerous rivers and creeks, most of which historically gain groundwater from the aquifer, indicated by water level elevation contours that bend upstream along the length of the streams. Baseflow discharge that feeds most of the water courses in the area is a large component of streamflow (Mace and others, 2000). Simulated water level elevation maps for the Edwards Group (Plateau), Upper Trinity, and Middle Trinity aquifers suggest that groundwater flows from the north to the south and from the west to the east (Figures 2, 3, 4, 5, 6, and 7) as observed from the measured water levels (Mace and others, 2000). We observed a minor rise in the simulated water levels in the Edwards Group between 2008 and 2060 across Groundwater Management Area 9 (Figure 3). Simulated water levels in the Upper Trinity Aquifer also remained relatively uniform between 2008 and 2060 with the exception of lowered water levels in northern parts of Kendall and Kerr counties (Figure 5).

Table 1. Estimated total county pumpage reported in acre feet per year using 25 percent and 50 percent additional pumpage in the Middle Trinity Aquifer (Part A and Part B runs). Total county pumpage equals the sum of pumpage from the Edwards Group, Upper Trinity, and Middle Trinity aquifers. Note that this pumpage amount reported under Part A and Part B runs may equal managed available groundwater provided all desired future conditions are met.

Counties	Baseline pumpage developed per instructions by Groundwater Management Area 9	Baseline pumpage uniformly increased by 25 percent of the 2008 baseline pumpage for the Middle Trinity Aquifer for Groundwater Management Area 9 (Part A run)*[1]	Baseline pumpage uniformly increased by 50 percent of the 2008 baseline pumpage for the Middle Trinity Aquifer for Groundwater Management Area 9 (Part B run)*[1]
Bandera	4,215	5,052	5,889
Bexar	18,112	22,395	26,681
Blanco	1,564	1,936	2,307
Comal	6,255	7,702	9,149
Hays	4,842	5,945	7,048
Kendall	6,336	7,763	9,189
Kerr	7,513	9,079	10,644
Medina	403	493	584
Travis	5,596	6,857	8,118
Total	**54,836**	**67,222**	**79,609**

*Reported total county pumpage values were obtained from the well files generated for the model runs. Note that pumpage for the Edwards Group and the Upper Trinity aquifers were not increased and kept the same as in baseline pumpage for 2008. Pumpage for the Middle Trinity Aquifer was only increased. Therefore, baseline pumpage on the left column increased by 25 or 50 percents would not exactly produce the pumpage values on the right columns.

[1]Final determination of managed available groundwater for counties partly included in the model, such as Bandera, Blanco, Medina, and Kerr counties, will further include county areas outside the model thus increasing the total amount of managed available groundwater for these counties

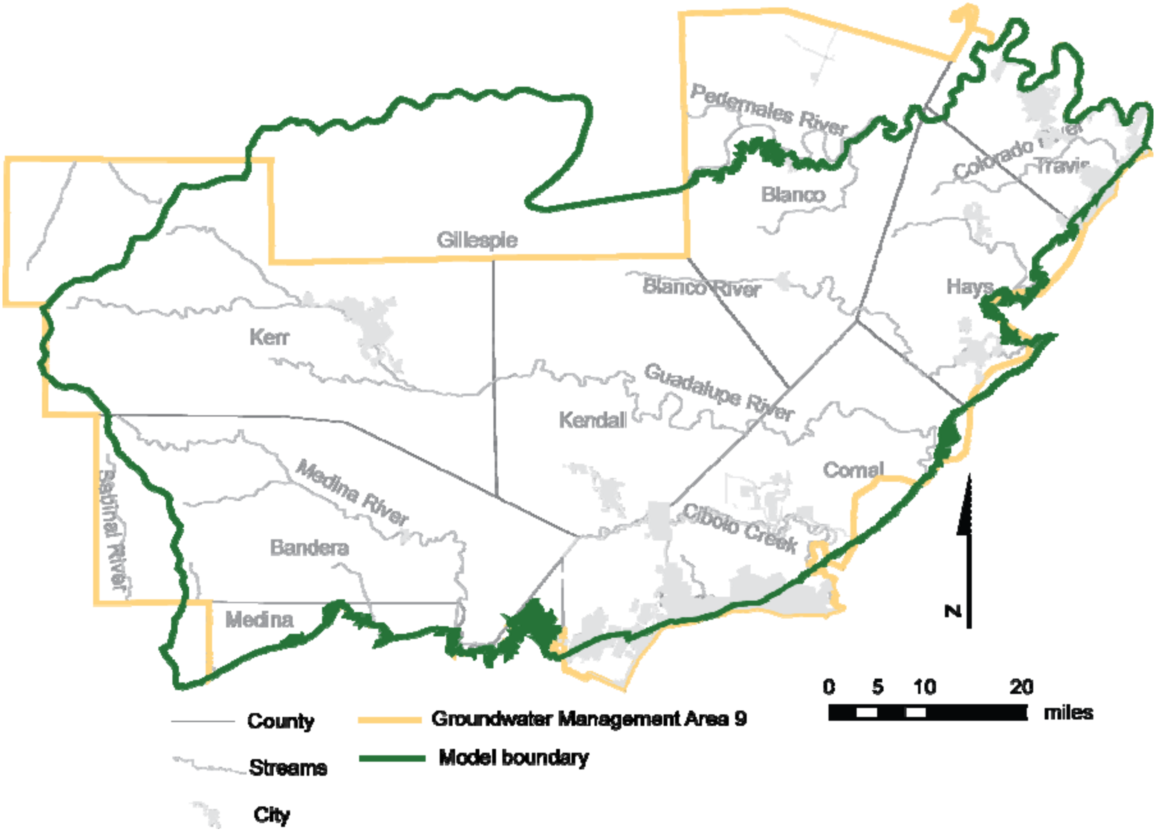

Figure 1. Map showing counties and streams in Groundwater Management Area 9. Outlines of Groundwater Management Area 9 and the model boundary are also shown. Note the groundwater model boundary also includes areas outside Groundwater Management Area 9.

Simulated water levels in the Middle Trinity Aquifer show significant changes between 2008 and 2060 (Figure 7). Simulated water levels show the greatest declines in Bexar and Kerr counties. Simulated water level maps also show development of numerous dry cells in northern parts of Bexar County suggesting that the aquifer may not be able to readily sustain the specified pumpage in this area as spatially distributed. However, note that the model does not accurately represent recharge to the Trinity Aquifer in northern Bexar County through stream flow losses in Cibolo Creek. For example, recent studies show that up to about 80,000 acre-feet of groundwater may annually recharge through infiltration of streamflow in the Cibolo Creek area and diffuse infiltration through adjacent soils and rock (Ockerman, 2007). Therefore, the water level decline results for northern Bexar County may not be representative of actual groundwater conditions in the area.

Water level change maps were developed for the Edwards Group (Plateau), Upper Trinity, and Middle Trinity aquifers (Figures 8, 9, and 10). These water level change maps were generated by subtracting simulated water levels in 2008 under baseline pumpage from simulated water levels in 2060 under adjusted pumpage. We note that the water levels increased (recover) by up to about 9 feet over the Edwards Group (Plateau) Aquifer and water level declined by up to about 3 feet in the east where the aquifer is thin during the Part A run. Water levels decrease by up to about 35 feet in the Upper Trinity Aquifer in the south western parts of Kendall County. Water levels also increase (recover) in the Upper Trinity Aquifer by up to 5 feet in parts of Gillespie and locally up to 65 feet in northern parts of Bexar County (Figure 9). Water levels rise locally in a few cells located adjacent to dry cells. These dry cells are formed during model simulation by lowered water levels below the bottom elevation of the grid cell. Once the cell goes dry, it stays dry, and the pumping is “shut off” resulting in a rise in water levels in the adjacent cells. A water level change map for the Middle Trinity Aquifer shows a significant decrease (drawdown) of up to about 160 feet in the Middle Trinity Aquifer in the northern parts of Bexar County, up to about 60 feet in western Kerr County, and up to about 20 feet in Blanco, Hays, and Travis counties (Figure 10). However, these water level decreases average about 17 feet for the Middle Trinity Aquifer across the Groundwater Management Area 9.

During the Part B run, water levels in the Edwards Group and Upper Trinity aquifers show similar results as in Part A run. Slightly larger drawdowns occur in the Upper Trinity Aquifer around Kendall and Kerr counties during Part B run. Water levels and discharges to the rivers and springs further decrease in the Middle Trinity Aquifer during Part B run (Appendix 1). A water level change map for the Middle Trinity Aquifer shows a significant decrease (drawdown) of up to about 235 feet in the Middle Trinity Aquifer in the northern parts of Bexar County, up to about 110 feet in western Kerr County, and up to about 20 to 40 feet in Blanco, Hays, and Travis counties (Figure 10). However, these water level decreases average about 26 feet for the Middle Trinity Aquifer across the Groundwater Management Area 9. Water level changes for each of the counties within Groundwater Management Area 9 are presented in Table 2.

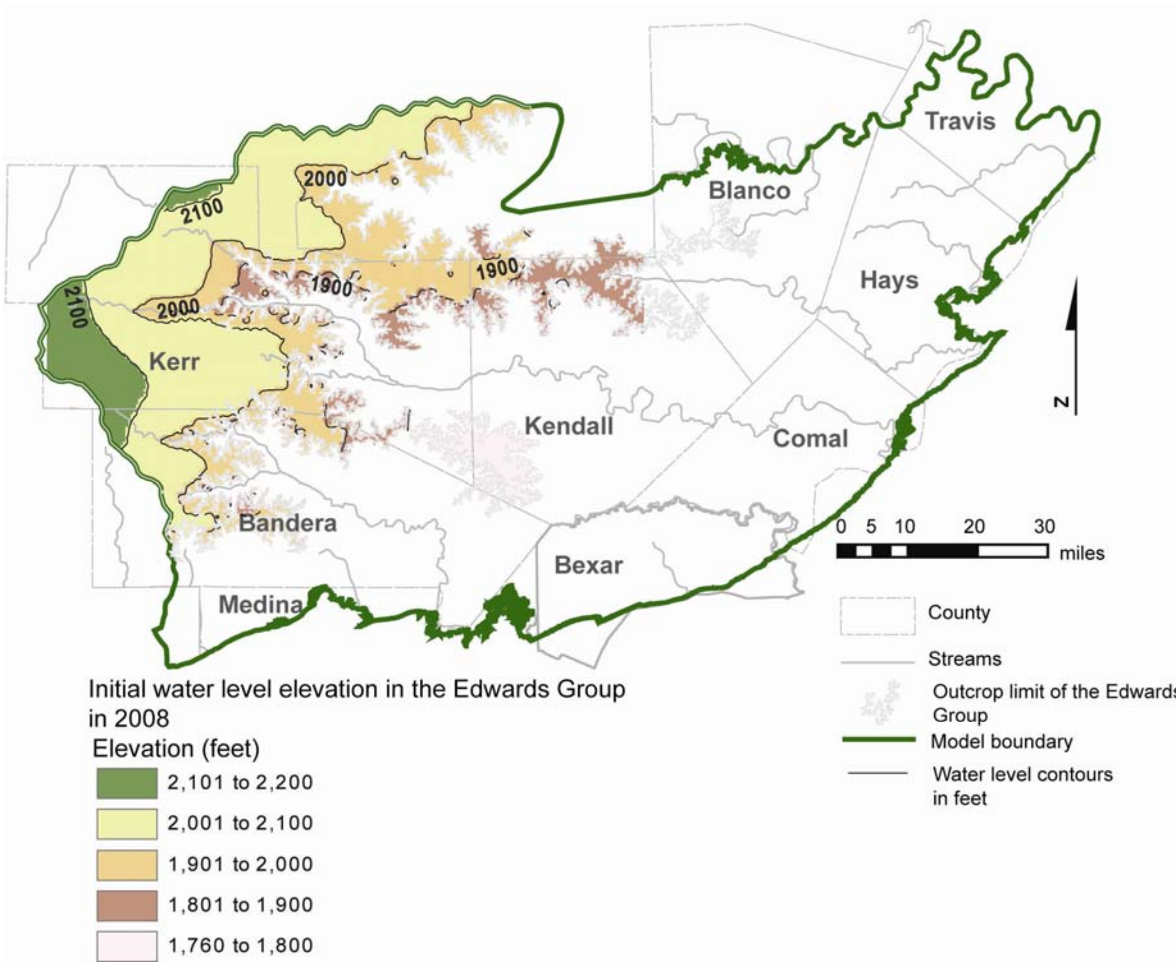

Figure 2. Initial water levels in the Edwards Group in 2008 for the beginning of the predictive period under baseline pumping from the groundwater availability model for the Hill Country portion of the Trinity Aquifer. Water level elevations are reported in feet above mean sea level. Contour interval is 100 feet. Note the water levels decrease from the west to the east following the land surface elevation.

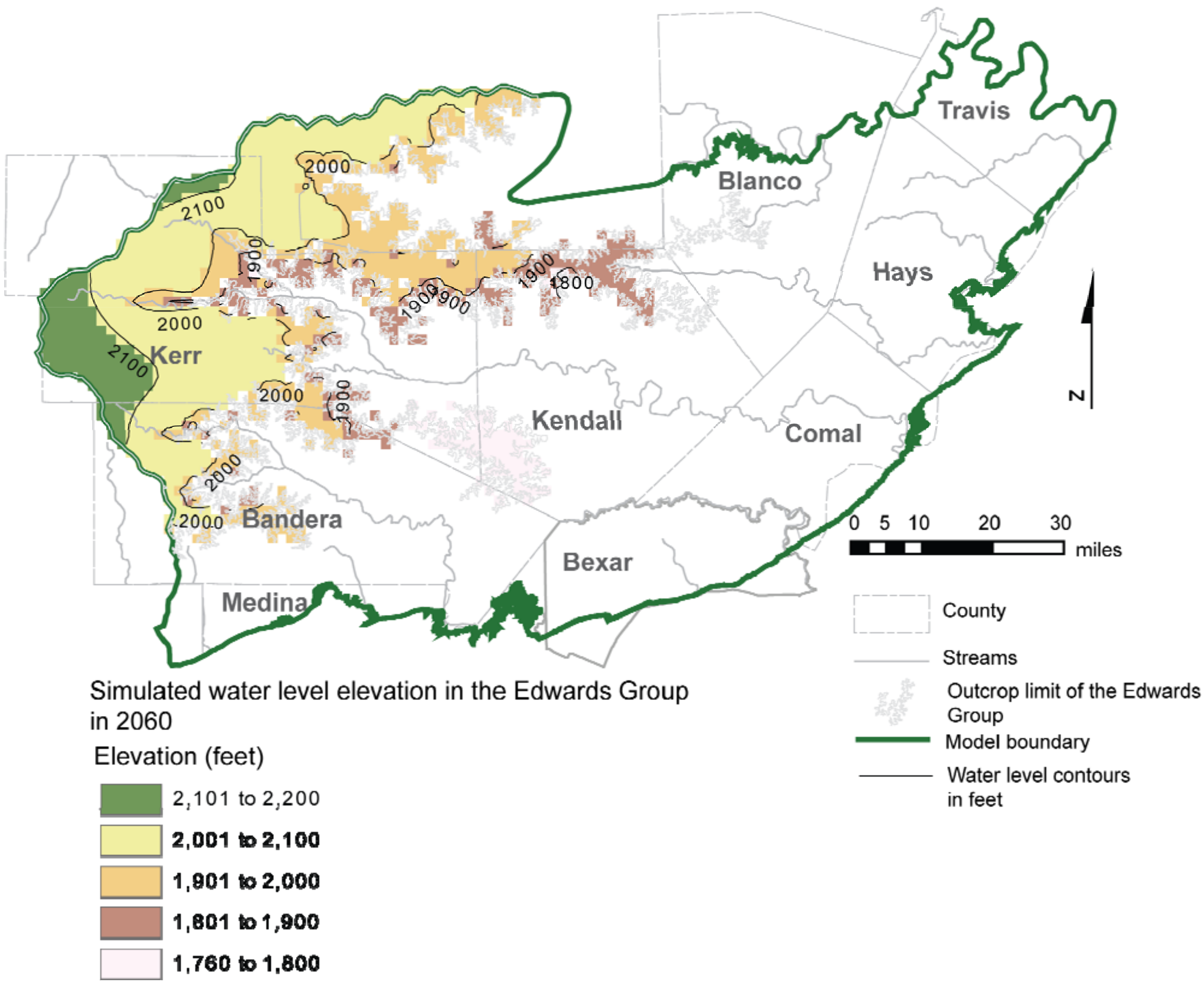

Figure 3a. Water level elevations in the Edwards Group after 60 years of maintaining the same pumpage as baseline condition and 25 percent more pumpage in the Middle Trinity Aquifer. Water level elevations are reported in feet above mean sea level. Contour interval is 100 feet. Note only slight changes in water level elevations at the end of the predictive period in 2060.

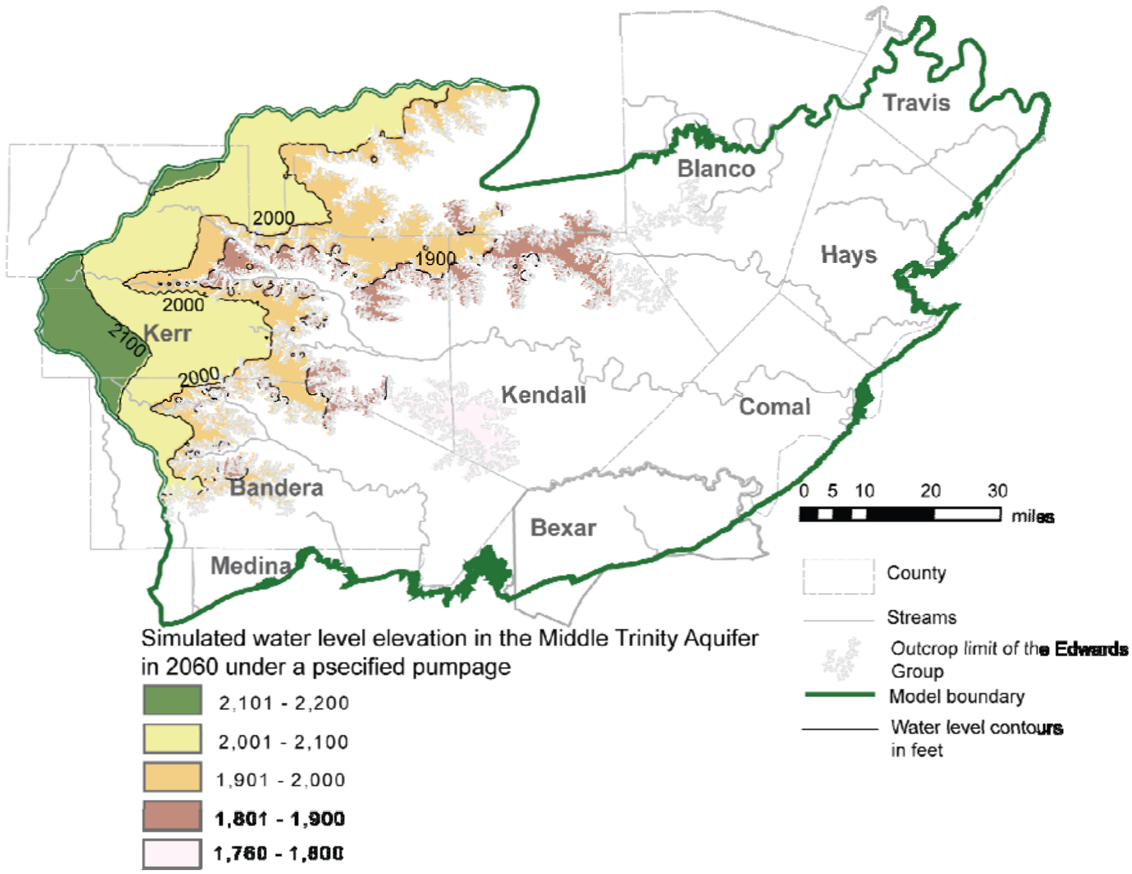

Figure 3b. Water level elevations in the Edwards Group after 60 years of maintaining the same pumpage as baseline condition and 50 percent more pumpage in the Middle Trinity Aquifer. Water level elevations are reported in feet above mean sea level. Contour interval is 100 feet. Note only slight changes in water level elevations at the end of the predictive period in 2060.

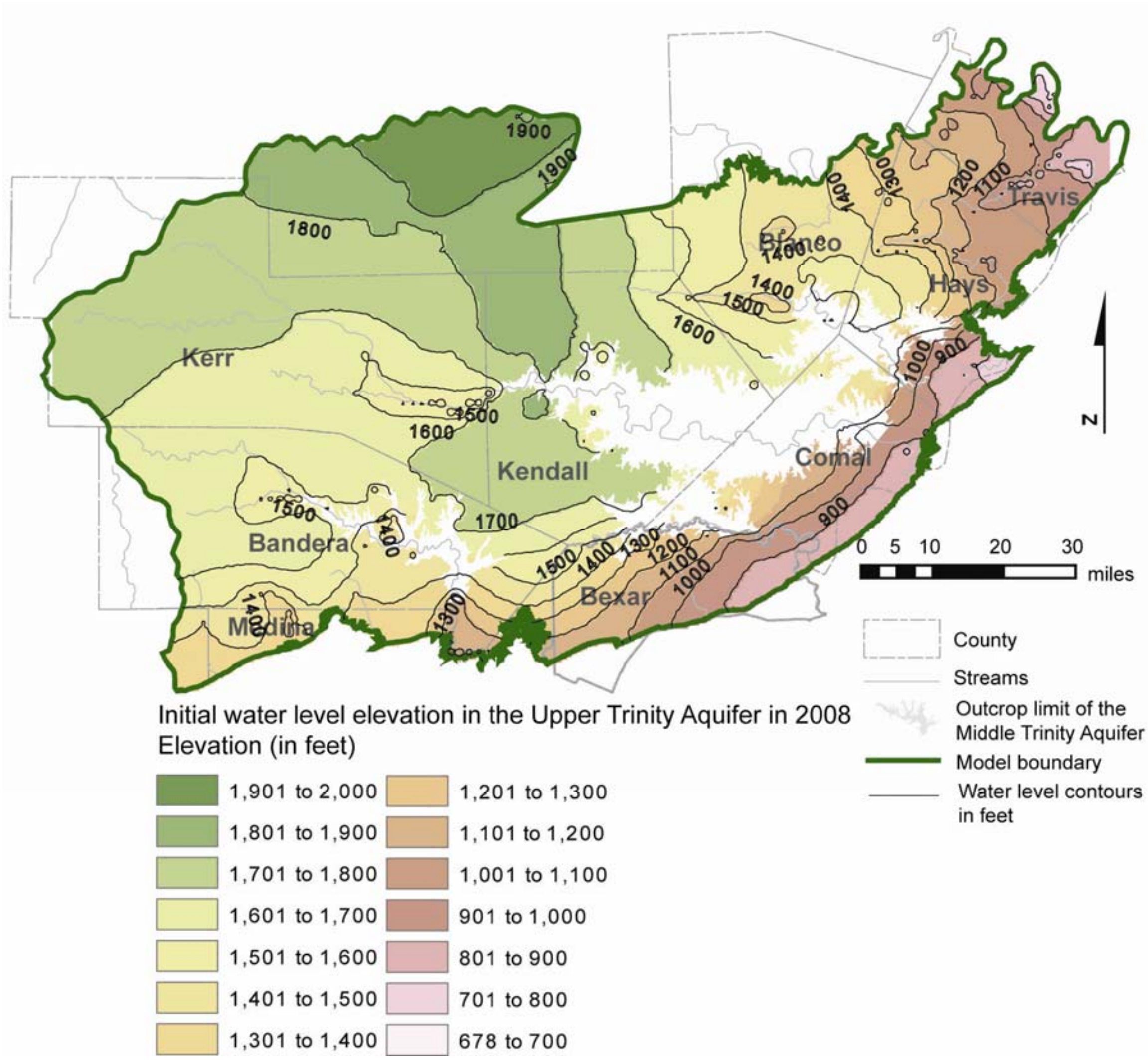

Figure 4. Initial water levels in the Upper Trinity Aquifer in 2008 for the beginning of the predictive period under baseline pumping from the groundwater availability model for the Hill Country portion of the Trinity Aquifer. Water level elevations are reported in feet above mean sea level. Contour interval is 100 feet.

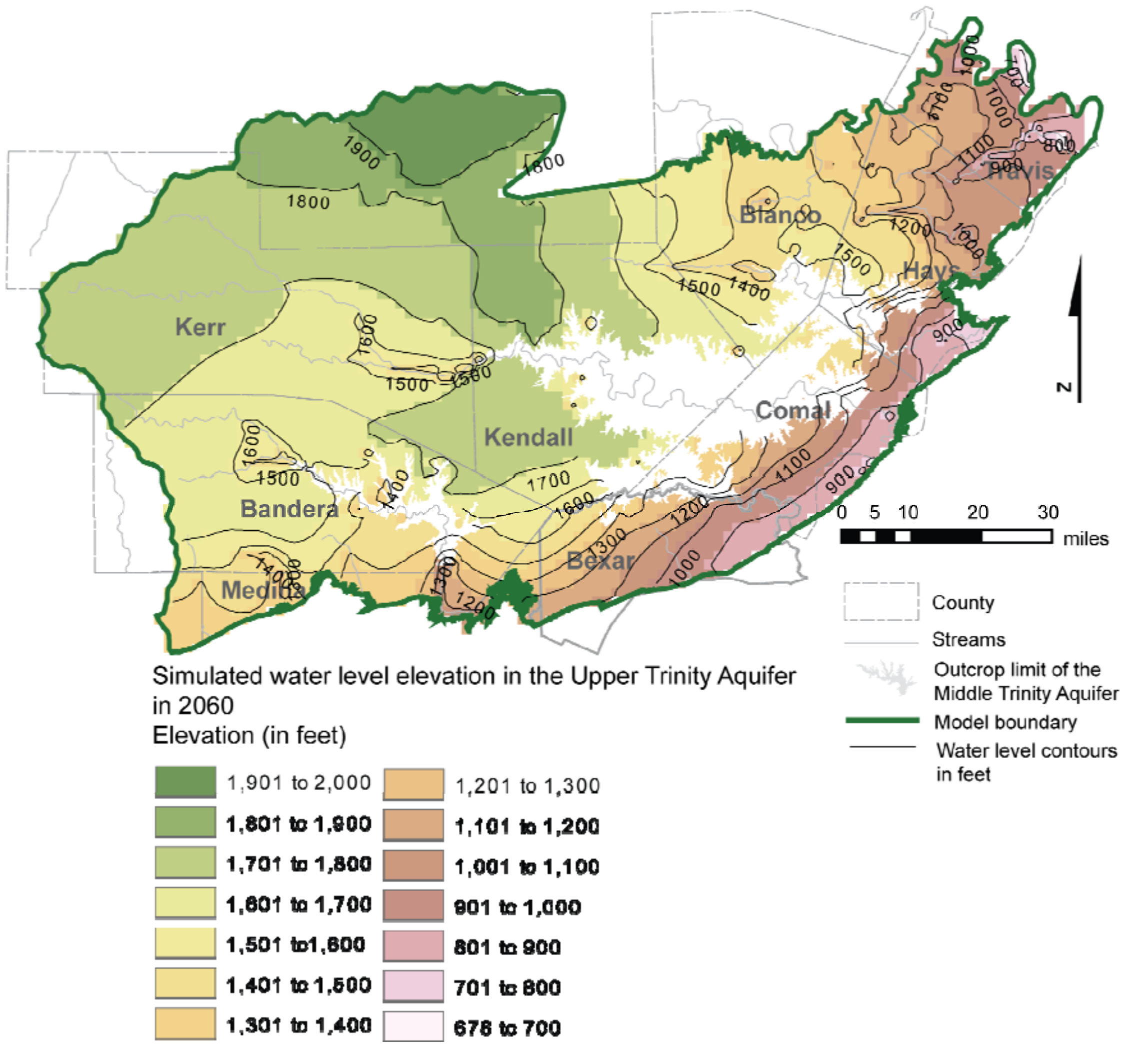

Figure 5a. Water level elevations in the Upper Trinity Aquifer after 60 years of maintaining the same pumpage as baseline condition and 25 percent more pumpage in the Middle Trinity Aquifer. Water level elevations are reported in feet above mean sea level. Contour interval is 100 feet. Note changes to water level elevations in Gillespie, Kendall, Bexar, and Travis counties. Several dry cells also occur in Comal and Bexar counties.

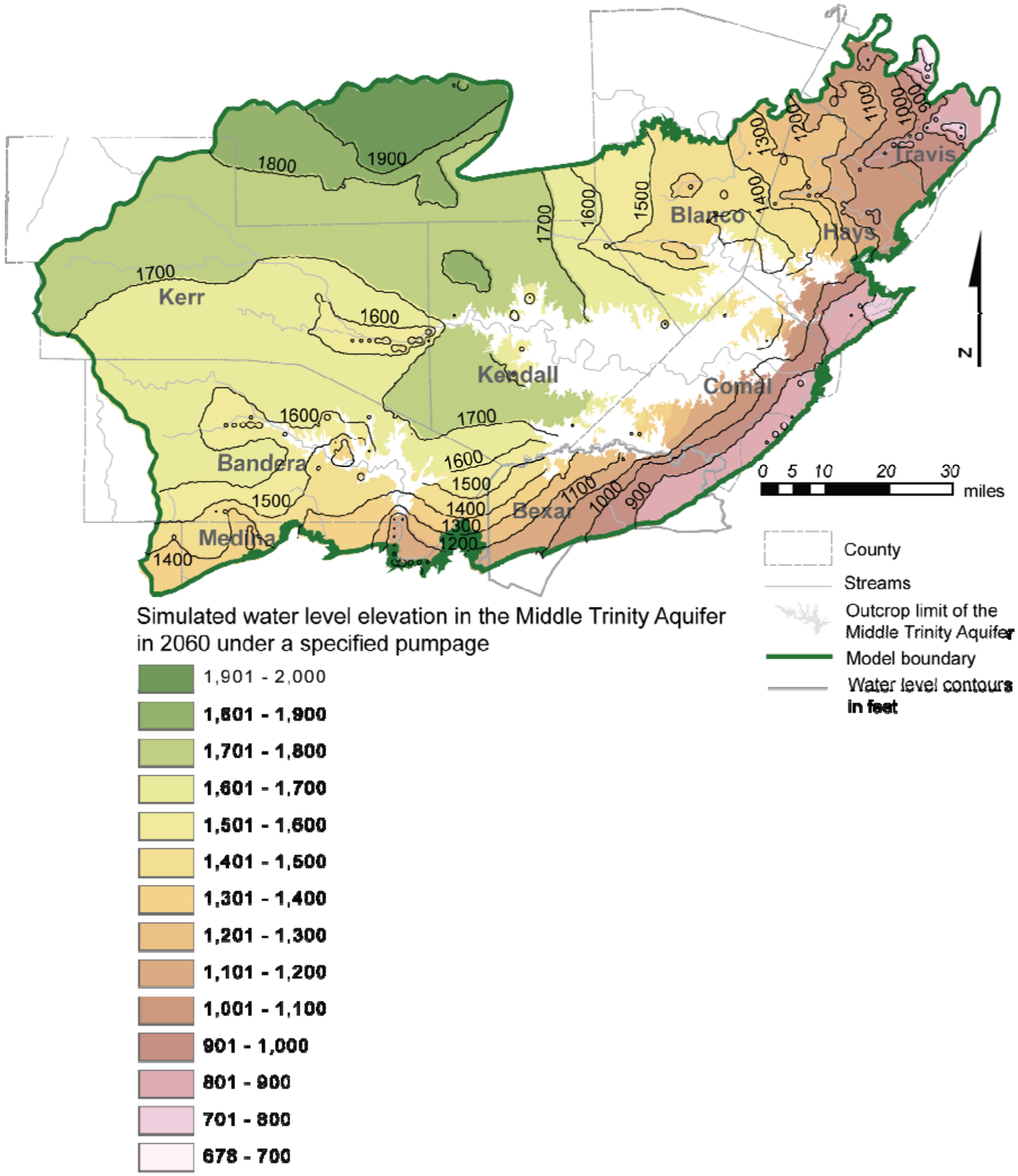

Figure 5b. Water level elevations in the Upper Trinity Aquifer after 60 years of maintaining the same pumpage as baseline condition and 50 percent more pumpage in the Middle Trinity Aquifer. Water level elevations are reported in feet above mean sea level. Contour interval is 100 feet. Note changes to water level elevations in Gillespie, Kendall, Bexar, and Travis counties. Several dry cells also occur in Comal and Bexar counties.

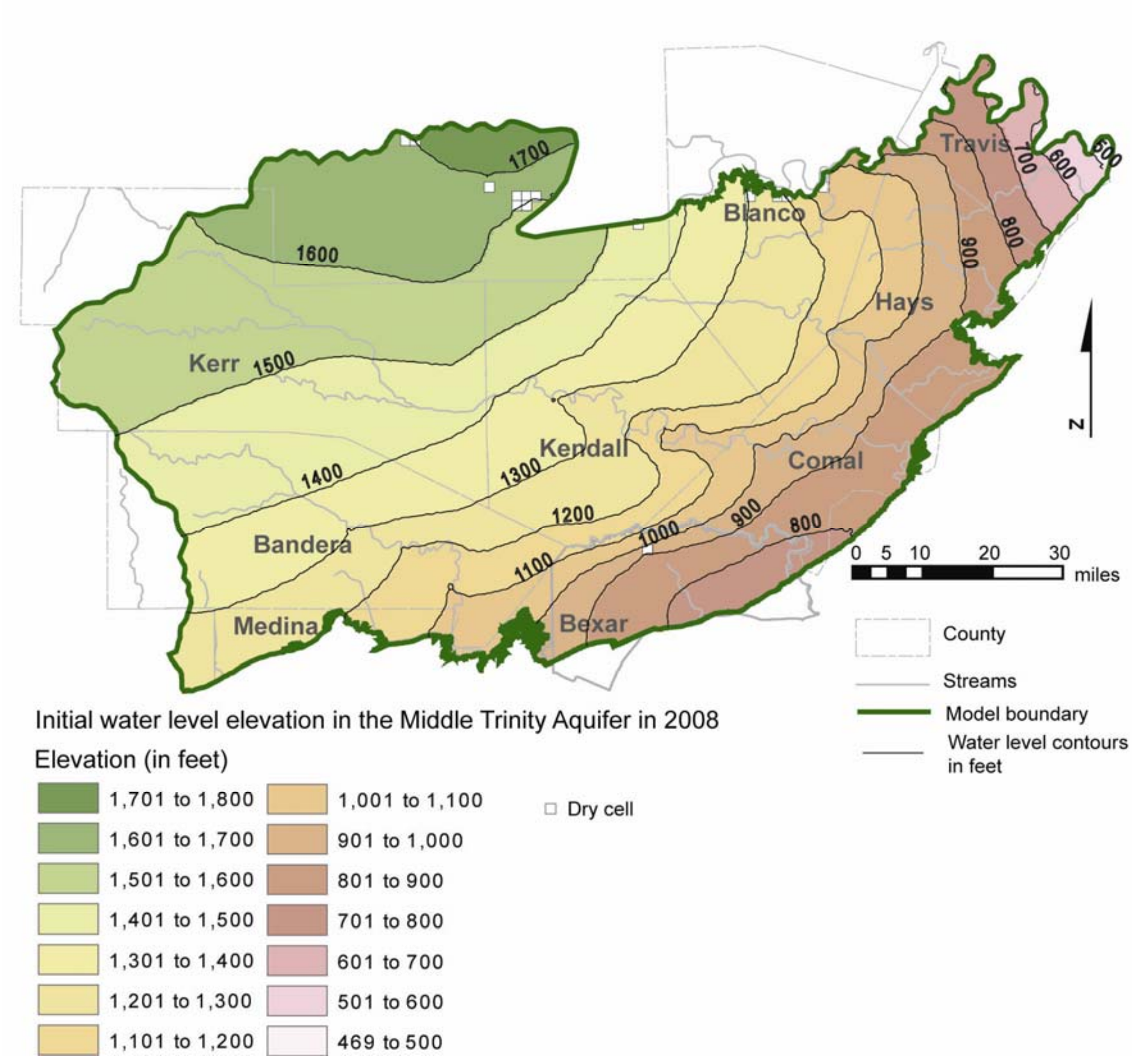

Figure 6. Initial water levels in the Middle Trinity Aquifer in 2008 for the beginning of the predictive period under baseline pumping condition from the groundwater availability model for the Hill Country portion of the Trinity Aquifer. Water level elevations are reported in feet above mean sea level. Contour interval is 100 feet. Note groundwater flow is directed from the north to the south and from the west to the east with most of the water level contours bending upstream when the contours cross the rivers which suggests gaining nature of the rivers.

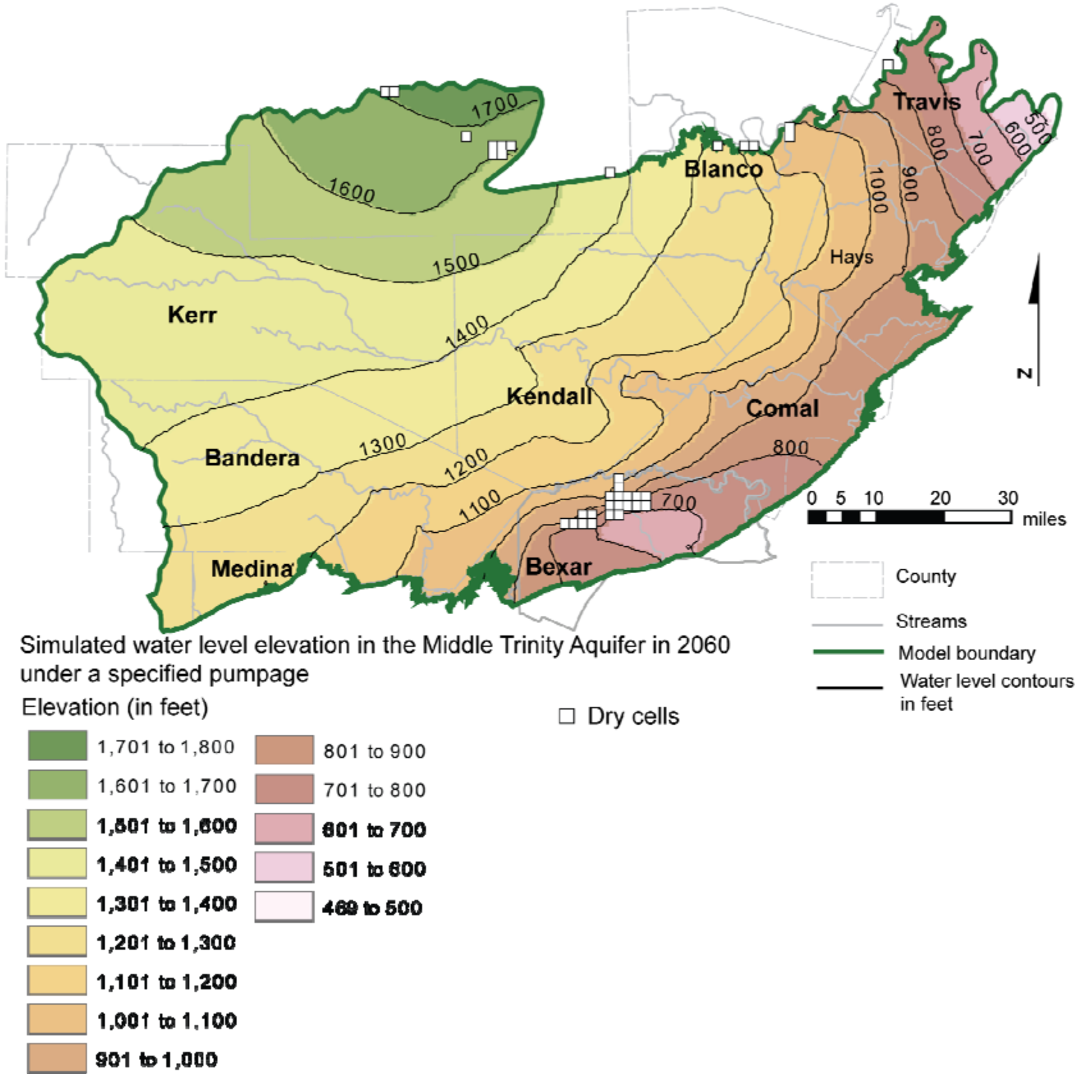

Figure 7a. Water level elevations in the Middle Trinity Aquifer after 60 years using 25 percent more pumpage than 2008 baseline pumping (Part A run). Water level elevations are reported in feet above mean sea level. Contour interval is 100 feet. Note several dry cells in Bexar, and Gillespie counties. Note slight flattening of the water level contours when they cross the rivers suggesting decreased baseflow under the specified pumpage condition.

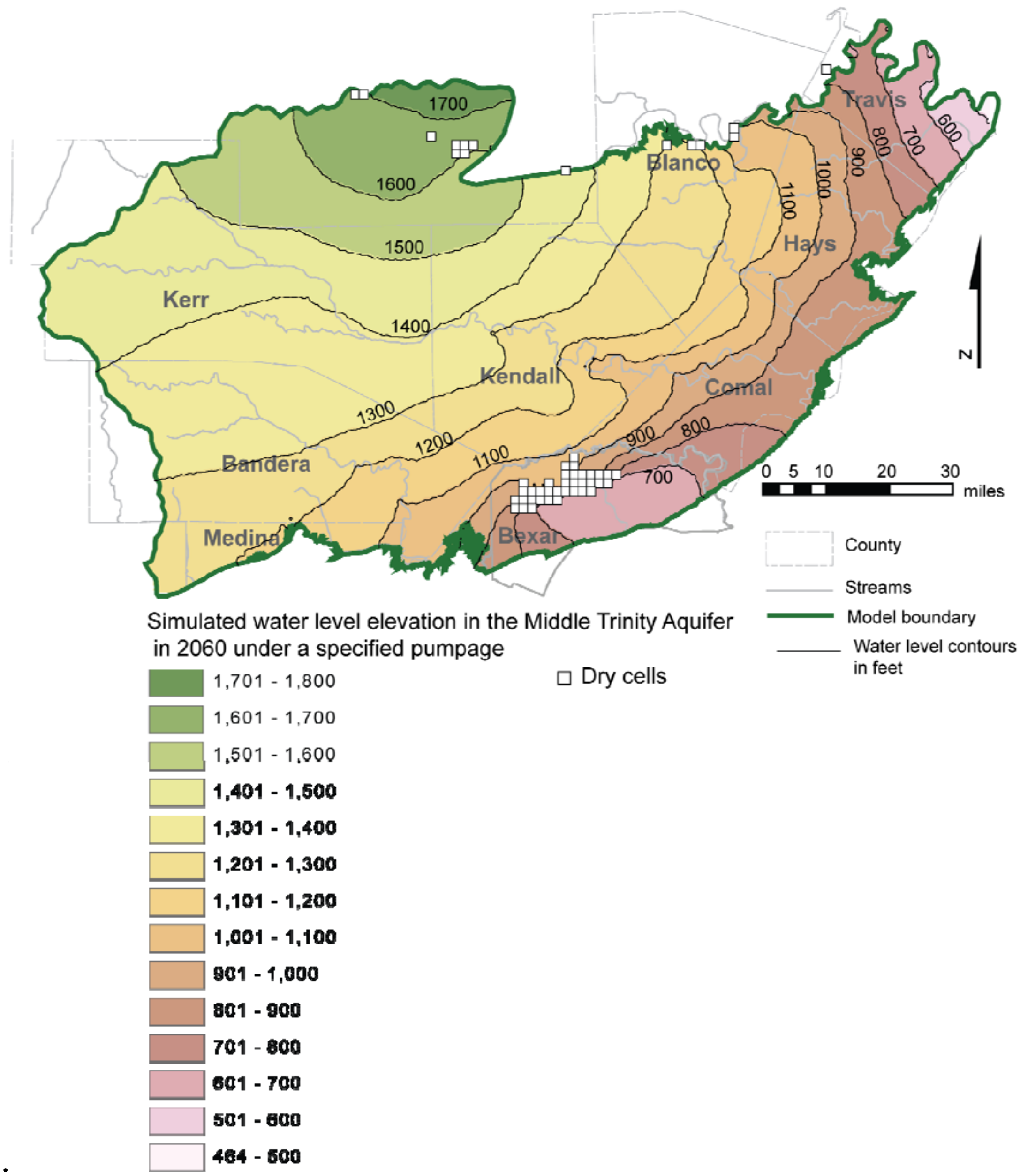

Figure 7b. Water level elevations in the Middle Trinity Aquifer after 60 years using 50 percent more pumpage than 2008 baseline pumping (Part B run) Water level elevations are reported in feet above mean sea level. Contour interval is 100 feet. Note several dry cells in Bexar, and Gillespie counties. Note slight flattening of the water level contours when they cross the rivers suggesting decreased baseflow under the specified pumpage condition

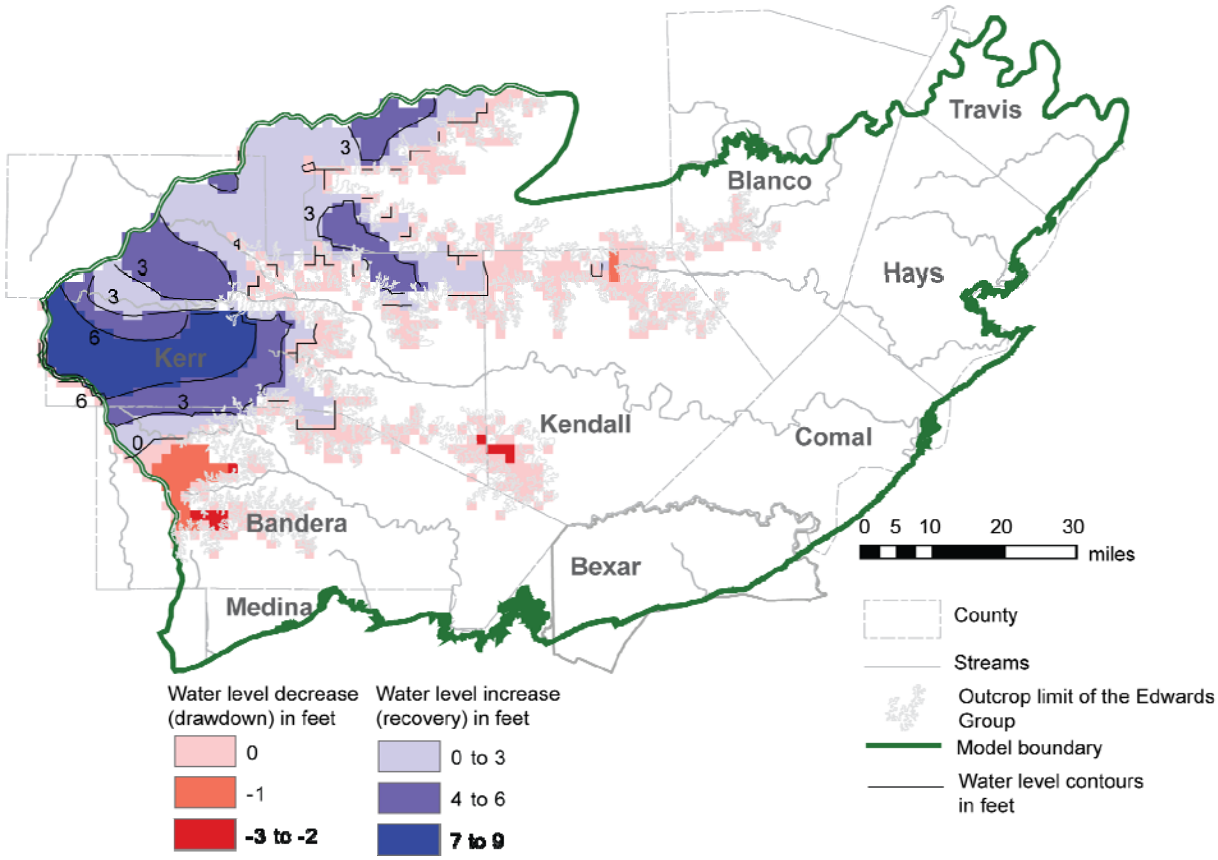

Figure 8a. Changes in water levels after 60 years using baseline 2008 pumpage in the Edwards Group and 25 percent additional pumpage in the Middle Trinity Aquifer. Drawdown and water level recovery are reported in feet. Contour interval for drawdown is 3 foot and contour interval is 3 feet for water level recovery. Decreases in water levels are shown in red and increases are shown in blue.

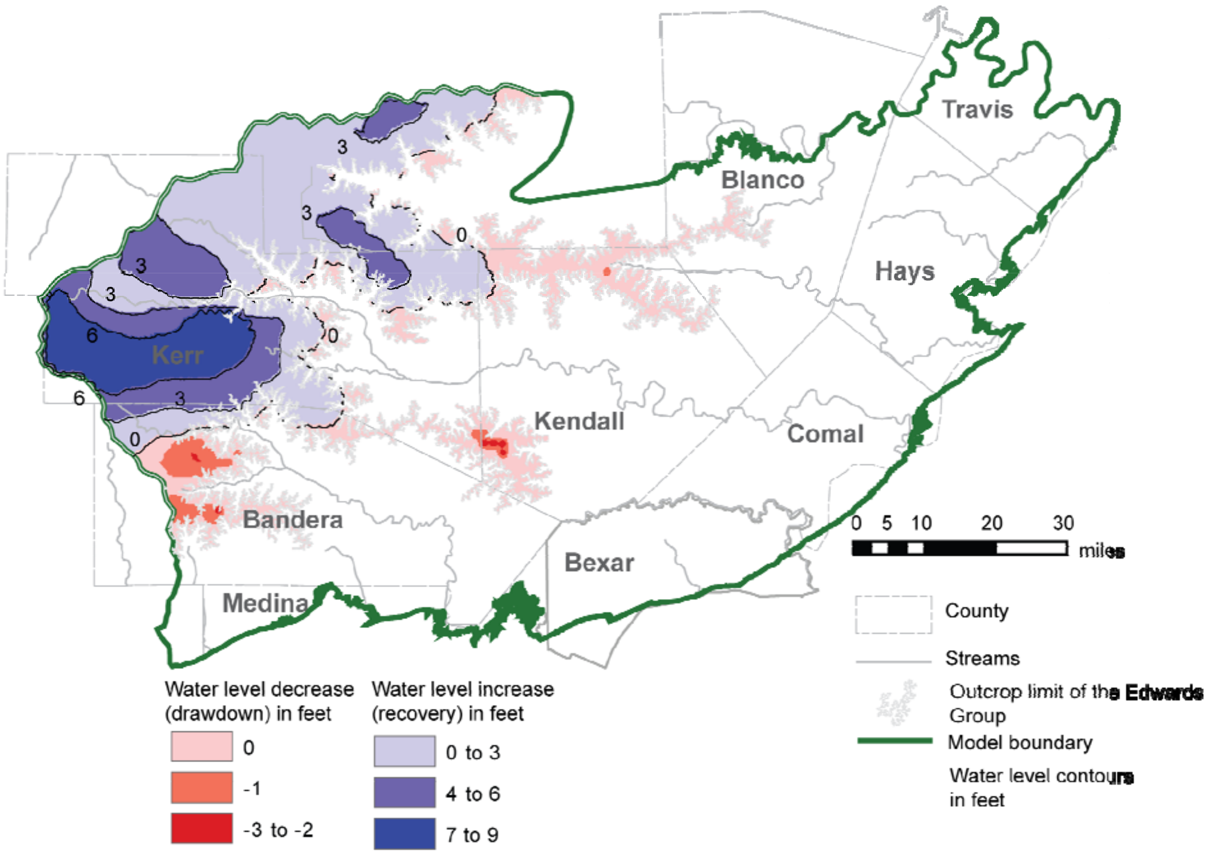

Figure 8b. Changes in water levels after 60 years using baseline 2008 pumpage in the Edwards Group and 50 percent additional pumpage in the Middle Trinity Aquifer. Drawdown and water level recovery are reported in feet. Contour interval for drawdown is 3 feet and contour interval is 3 feet for water level recovery. Decreases in water levels are shown in red and increases are shown in blue.

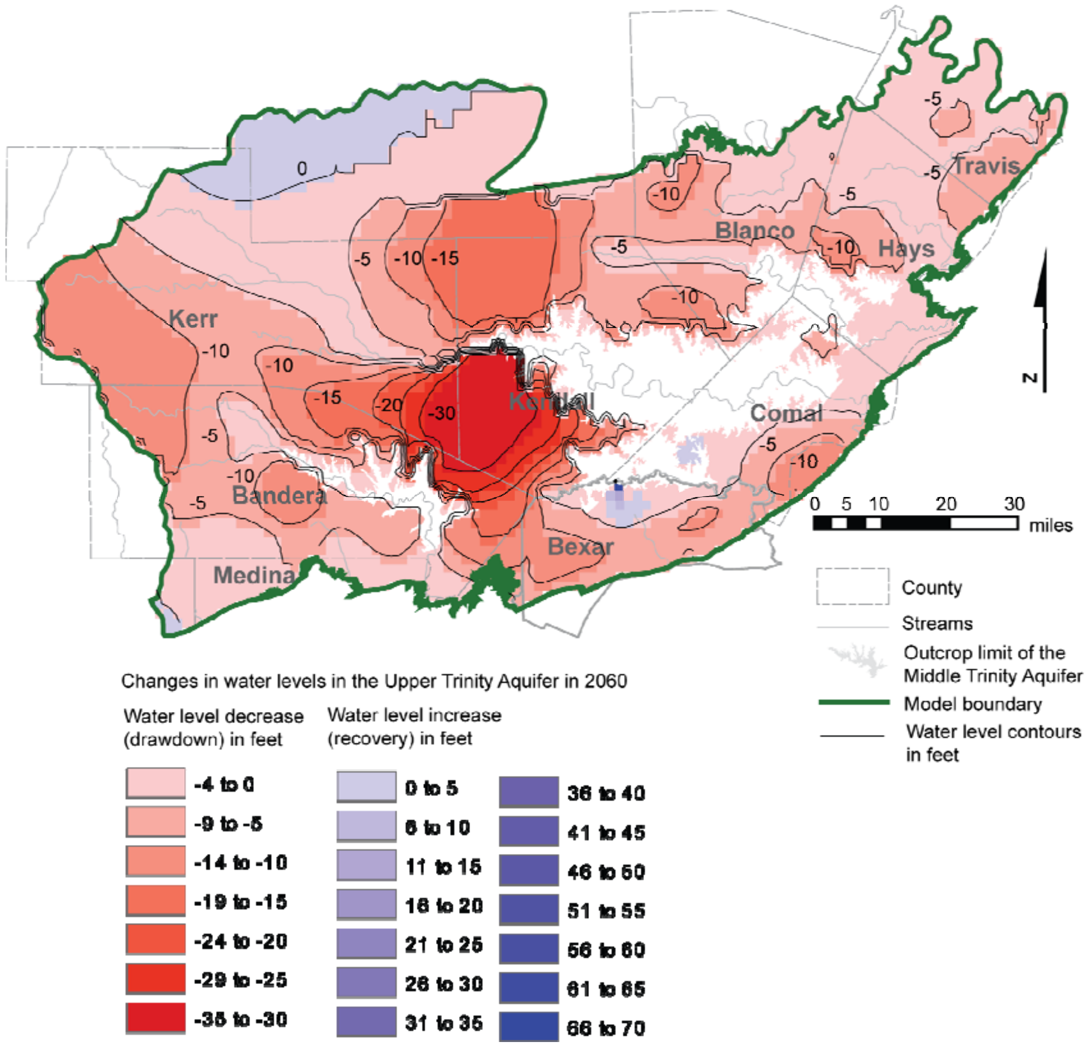

Figure 9a. Changes in water levels after 60 years using baseline 2008 pumpage in the Upper Trinity Aquifer and 25 percent additional pumpage in the Middle Trinity Aquifer. Drawdowns and water level recovery are reported in feet. Contour interval for drawdown is 5 feet. Decreases in water levels are shown in red and increases are shown in blue.

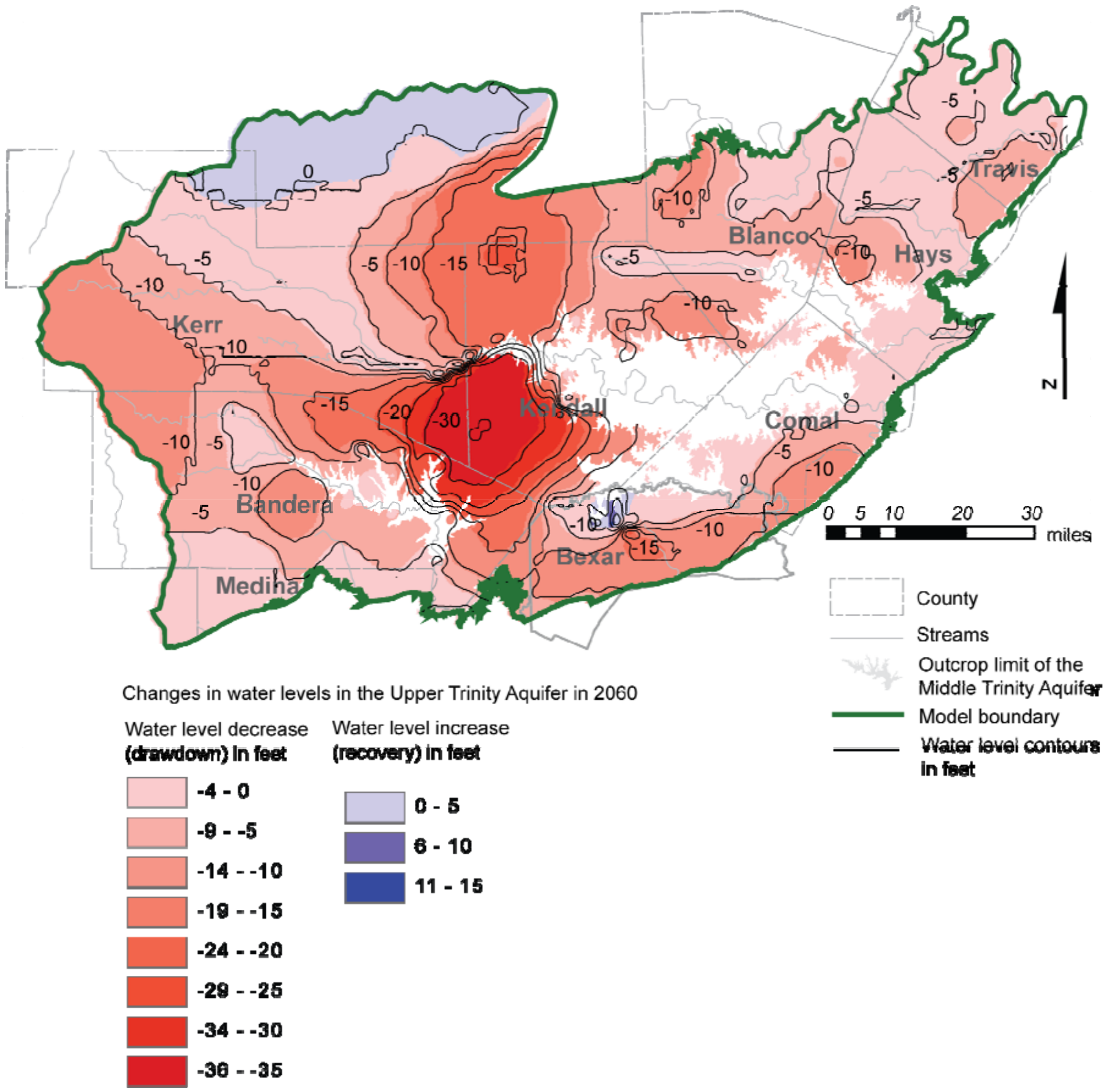

Figure 9b. **Changes in water levels after 60 years using baseline 2008 pumpage in the Upper Trinity Aquifer and 50 percent additional pumpage in the Middle Trinity Aquifer. Drawdowns and water level recovery are reported in feet. Contour interval for drawdown is 5 feet. Decreases in water levels are shown in red and increases are shown in blue.**

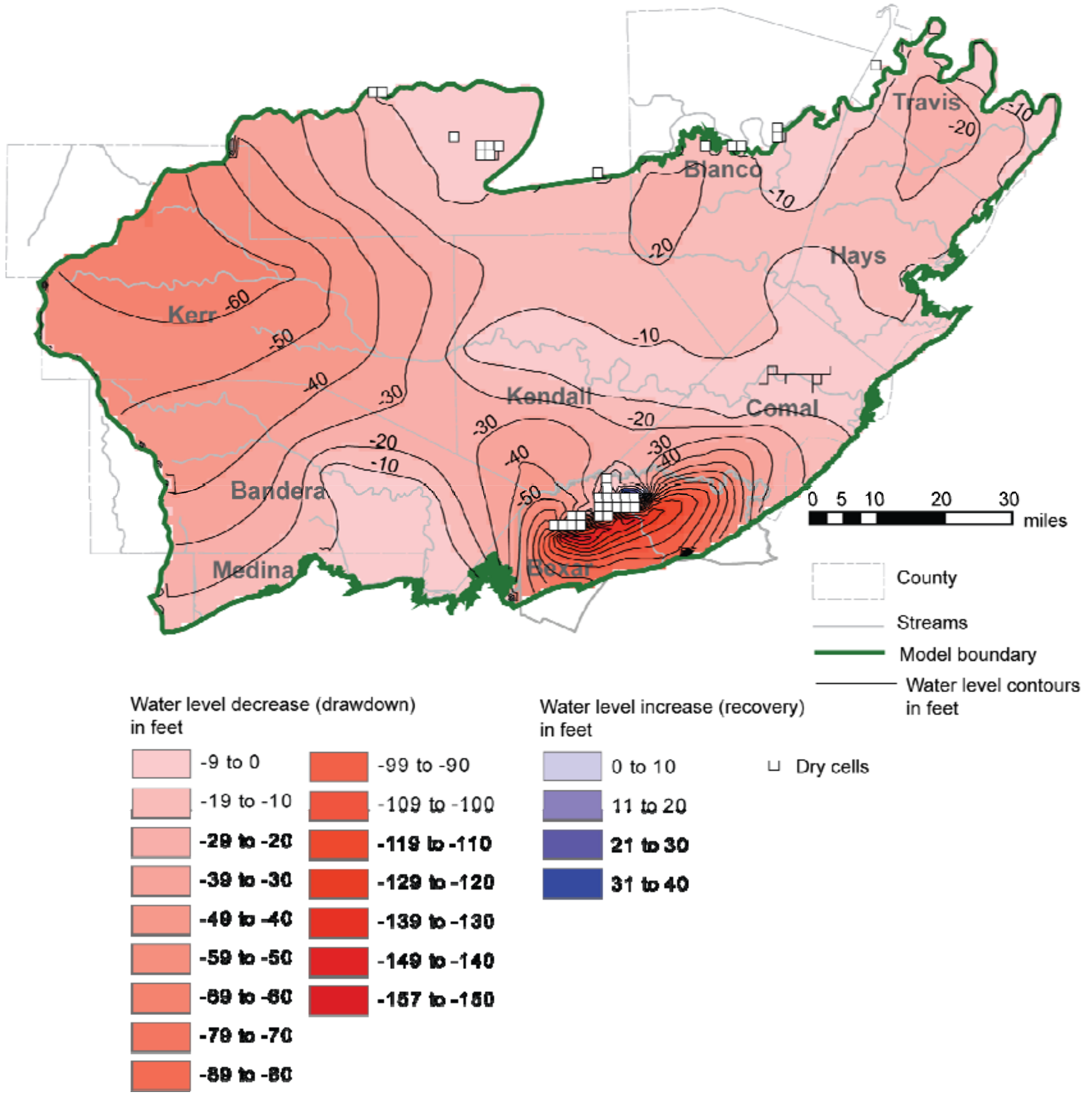

Figure 10a. Changes in water levels after 60 years using the specified pumpage in the Middle Trinity Aquifer (Part A Run). Drawdowns are in feet. Contour interval is 10 feet. Decreases in water levels are shown in red. Increases in water levels are shown in blue. Numerous dry cells occur in Bexar County..

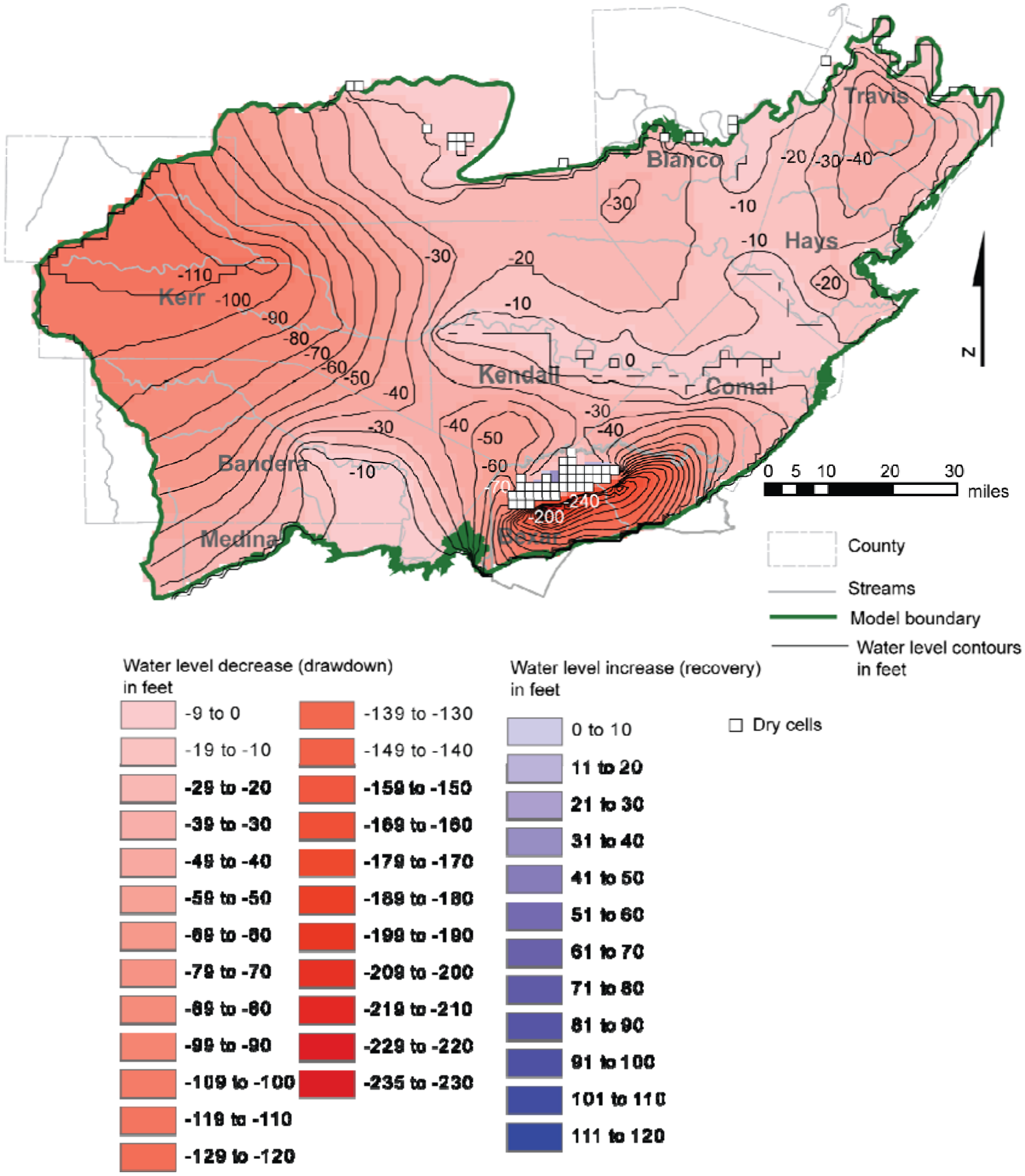

Figure 10b. Changes in water levels after 60 years using using 50 percent more pumpage than 2008 baseline pumpage in the Middle Trinity Aquifer (Part B Run). Drawdowns are in feet. Contour interval is 10 feet. Decreases in water levels are shown in red. Increases in water levels are shown in blue. Numerous dry cells occur in Bexar County.

Table 2. Average water level changes in the Edwards Group, Upper Trinity, and Middle Trinity aquifers of the Hill Country area reported by county and aquifer (Part A and Part B runs). Negative values indicate a lowering of the water levels between 2008 under baseline pumping conditions and 2060 under increased pumping condition.

County	Average water level decline (feet) in the Middle Trinity Aquifer in 2060					
	With 25 percent additional pumpage			With 50 percent additional pumpage		
	Average	Maximum	Minimum	Average	Maximum	Minimum
Edwards Group Aquifer						
Bandera	0	-3	+5	0	-3	+5
Kendall	0	-3	0	0	-3	0
Kerr	+2	-2	+9	+2	-2	+9
Average	**+1**	**-3**	**+5**	**0**	**-3**	**+5**
Upper Trinity Aquifer						
Bandera	-8	-32	0	-10	-32	0
Bexar	-3	-15	+66	-9	-23	+13
Blanco	-2	-11	0	-7	-11	0
Comal	-2	-13	0	-6	-14	0
Hays	-2	-11	0	-4	-11	0
Kendall	-12	-35	0	-18	-35	0
Kerr	-7	-35	+2	-9	-34	+2
Medina	-2	-16	0	-4	-16	0
Travis	-2	-10	0	-4	-10	0
Average	**-4**	**-20**	**+8**	**-8**	**-21**	**+2**
Middle Trinity Aquifer						
Bandera	-23	-53	0	-39	-98	0
*Bexar	-37	-157	+33	-47	-235	+112
Blanco	-7	-23	0	-10	-31	0
Comal	-10	-74	0	-14	-110	0
Hays	-6	-23	0	-10	-40	0
Kendall	-17	-45	0	-23	-56	0
Kerr	-41	-70	0	-73	-118	0
Medina	-7	-52	0	-11	-71	0
Travis	-7	-26	0	-12	-47	0
Average	**-17**	**-58**	**+4**	**-26**	**-90**	**+12**

*DISCLAIMER: Numerous dry cells occur in Bexar County in this model run that were not considered in the reported water level decline calculations; therefore, the reported water level decline may not be representative of actual groundwater conditions for Bexar County. Recent studies show that up to about 80,000 acre-feet of groundwater may annually recharge through infiltration of streamflow in the Cibolo Creek area and diffuse infiltration through adjacent soils and rock (Ockerman, 2007), which was not considered during model simulation.

Pumpage distribution in the Middle Trinity Aquifer for 2008 as assigned in the model shows high concentrations of pumping in Bexar, eastern parts of Hays, central parts of Kerr, southern parts of Kendall, and Travis counties (Figure 11).

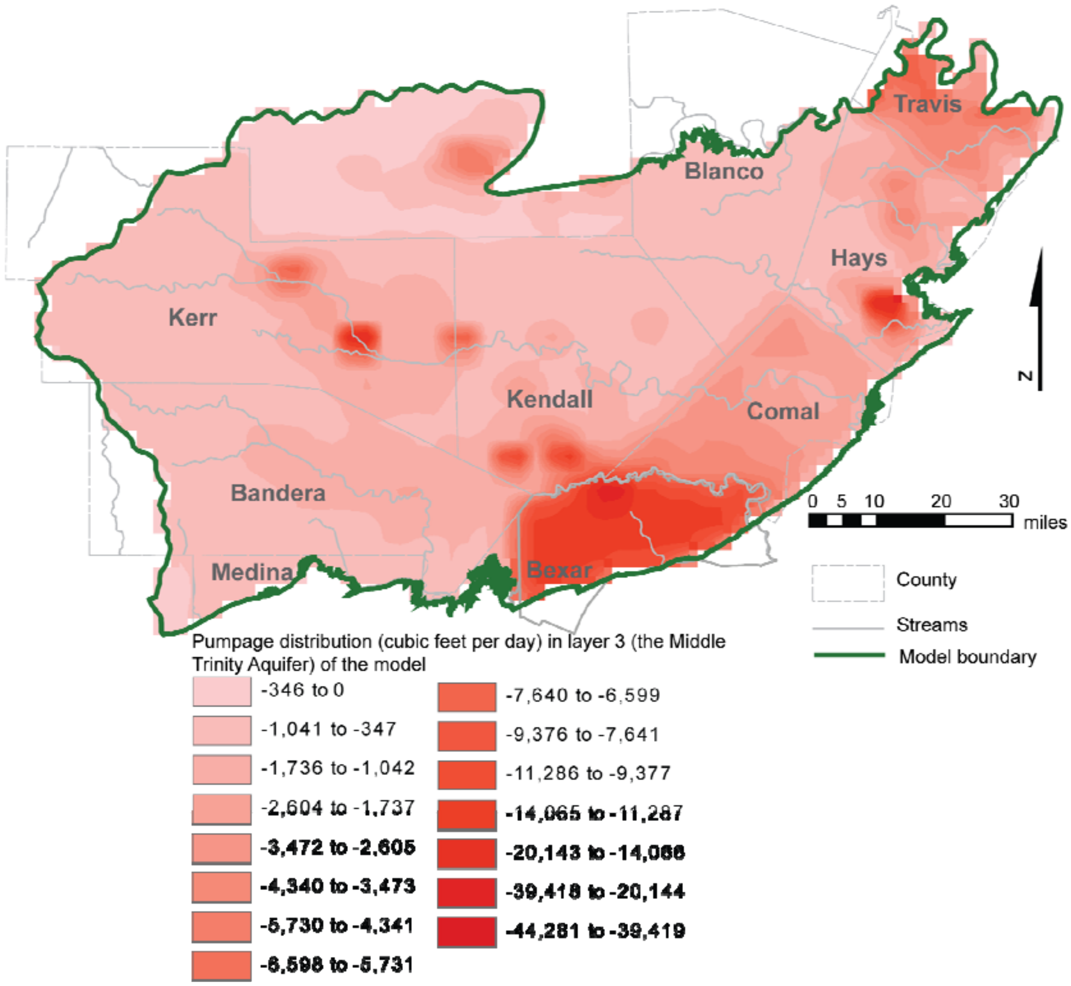

Figure 11. Pumpage distribution in 2008 for model layer 3 representing the Middle Trinity Aquifer. Pumpage values are reported in cubic feet per day as assigned in the model.

Simulated water levels in the Edwards Group, Upper Trinity and Middle Trinity aquifers under pre-development, steady-state condition are presented in Figures 12, 13, and 14, respectively. Note well developed V-shaped contours that point upstream where the contours cross the streams suggesting increased baseflow to streams and springs.

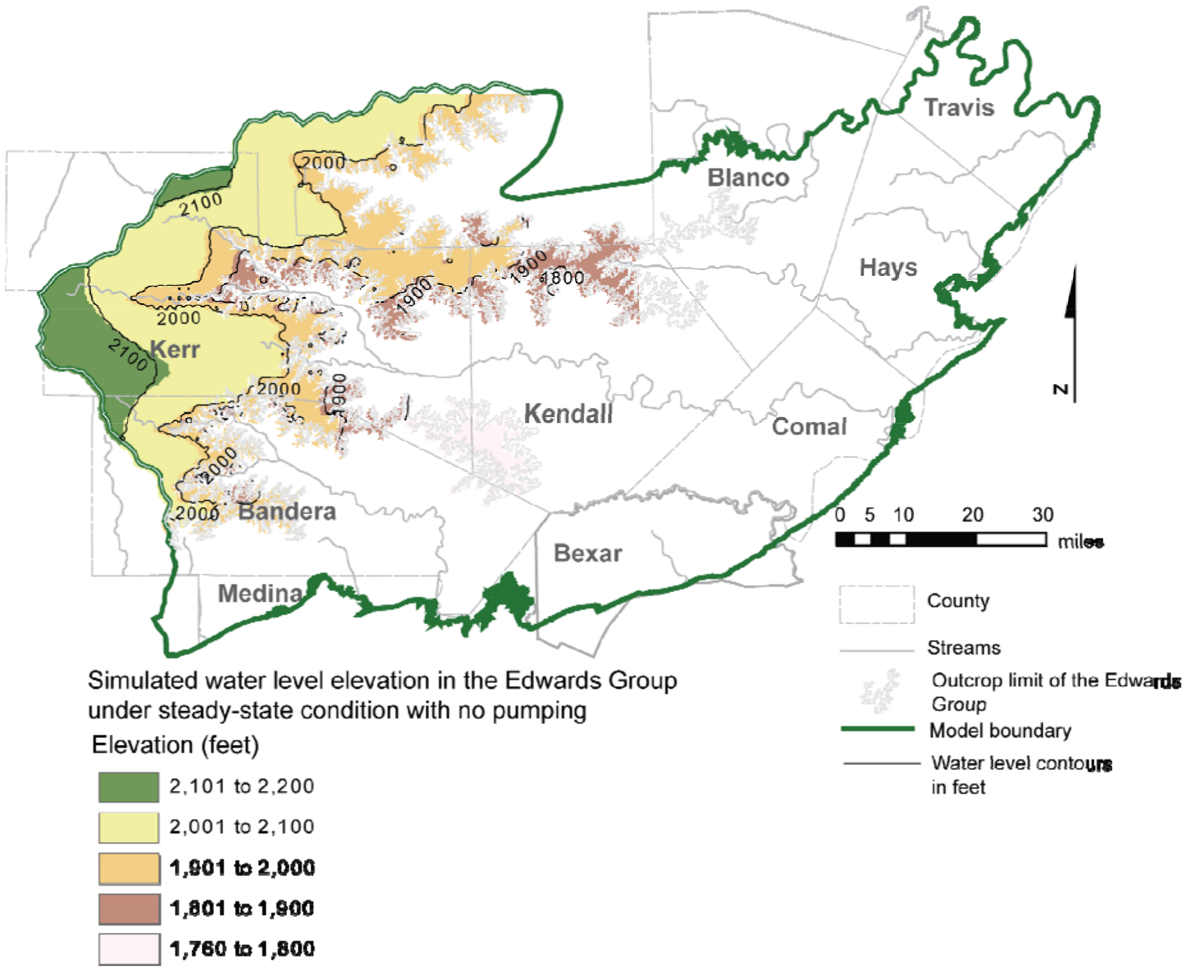

Figure 12. Water level elevations in the Edwards Group Aquifer under steady-state conditions with no pumping assigned into the model (Part C run). Water level elevations are reported in feet above mean sea level. Contour interval is 100 feet

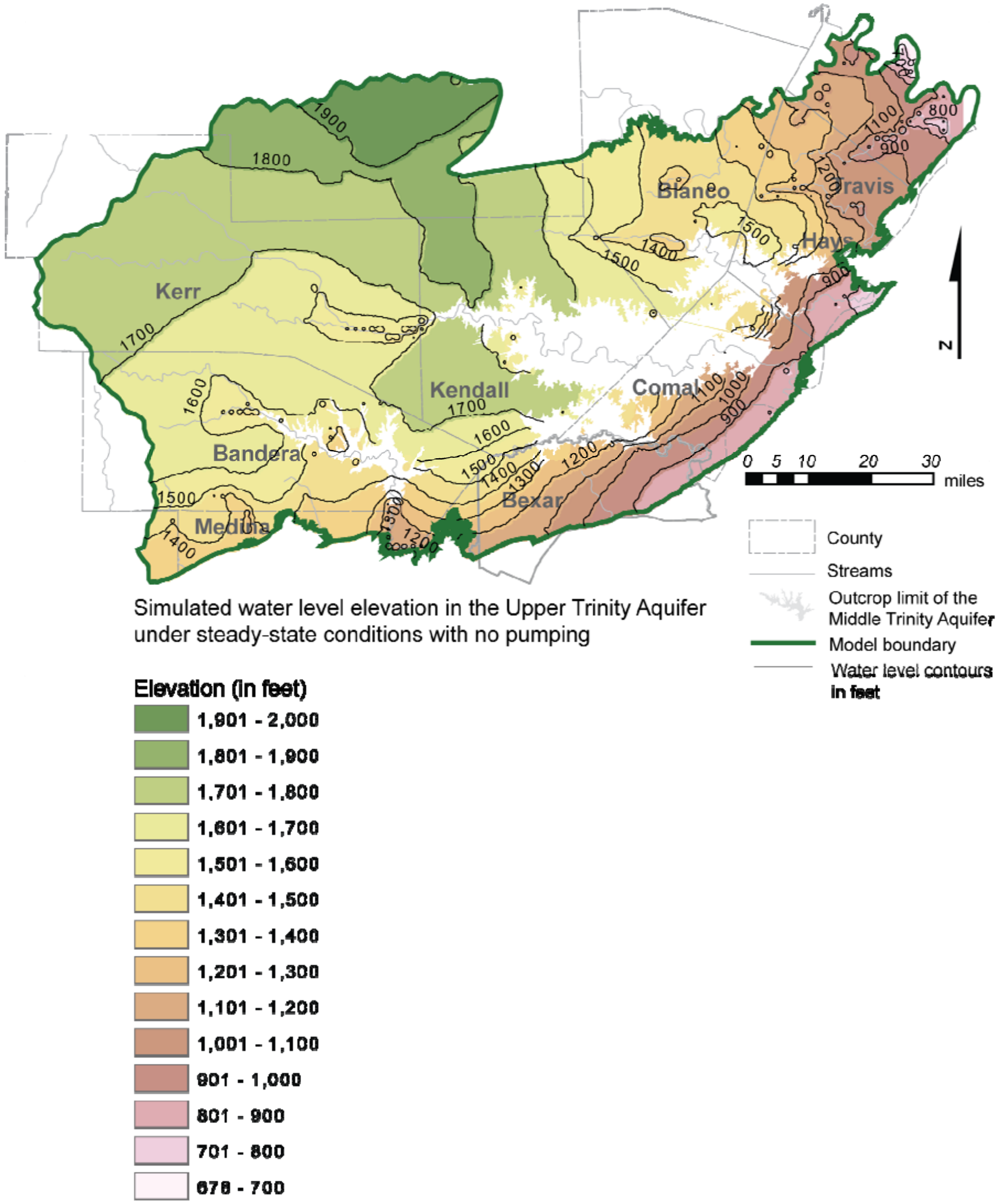

Figure 13. Water level elevations in the Upper Trinity Aquifer under steady-state conditions with no pumping assigned into the model (Part C run). Water level elevations are reported in feet above mean sea level. Contour interval is 100 feet.

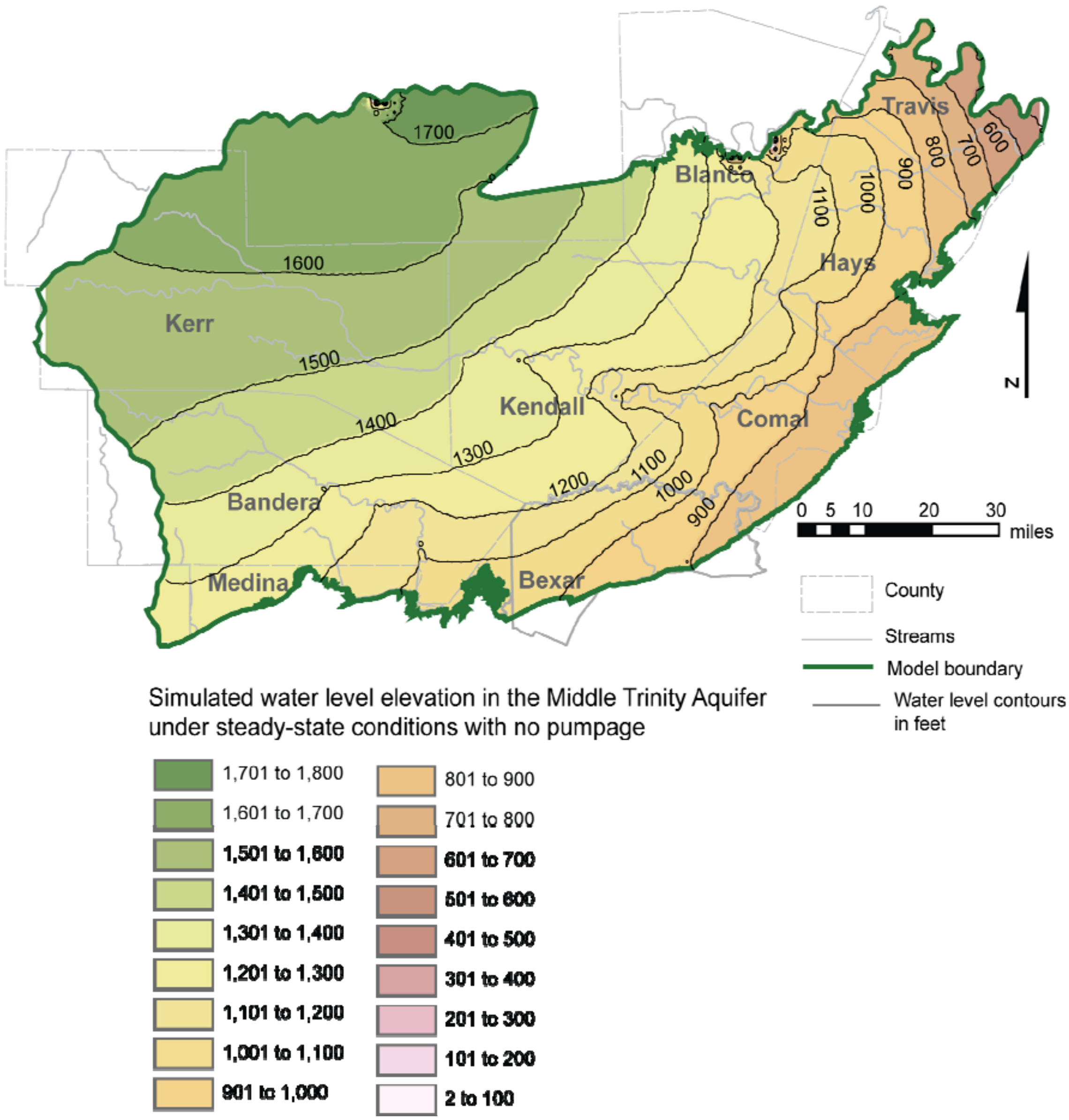

Figure 14. Water level elevations in the Middle Trinity Aquifer under steady-state conditions with no pumping assigned into the model (Part C run). Water level elevations are reported in feet above mean sea level. Contour interval is 100 feet. Note well developed V-shaped water level contours pointing upstream when they cross the rivers suggesting significant baseflow under the steady-state condition.

Estimates of the water budget are included in Appendix 1. Various components of the water budget results presented in the appendix are described below.

- Recharge—Describes amount of water that infiltrates into the aquifer from rainfall in the outcrop. Recharge is always positive as water is added into the aquifer.

- River—Describes amount of water that flows between the rivers and an aquifer. When the water levels in an aquifer lie at a higher elevation than the river stage, water discharges (negative) from the aquifer into the river as baseflow. Conversely, if the water levels in an aquifer lie at a lower elevation than the river stage, water leaks into the aquifer (positive) from the river. Rivers are simulated in the model using the MODFLOW Drain Package. The Drain Package was used because the rivers in the Hill Country area are gaining and assigning the drains will only allow the rivers to receive water from the aquifer.

- Balcones Fault Zone (General Head Boundary Package)—General head boundary was assigned in the east of the model area in model layers 2 and 3 to estimate movement of water from the Upper and Middle Trinity aquifers into the Edwards (Balcones Fault Zone) Aquifer.

- Springs—Describes flow through the discrete springs simulated in the model using the MODFLOW Drain Package. Note that drains also represent discharge from the aquifer to rivers.

- Lakes/reservoirs—Describes flow through the lakes/reservoirs simulated in the model using the MODFLOW Constant head package.

- Pumping—Describes amount of water produced from wells in each aquifer. This component of flow is reported negative as water is withdrawn from the aquifer. Pumping is represented in the model using the MODFLOW Well package.

- Vertical flow (Upper and Lower)—Describes amount of cross-formational flow along the contacts of the model layers between two aquifers. This flow is controlled by the water level elevations in each aquifer and aquifer properties of each aquifer.

- Lateral flow —Describes amount of groundwater flowing laterally along the horizontal direction in the aquifer.

- Storage—Describes net 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).

The water budget results included in Appendix 1 are for 2008 under baseline pumpage condition, for 2060 with 25 percent (Part A run) and 50 percent (Part B run) additional pumpage in the Middle Trinity Aquifer, and with no pumpage (Part C run) under steady-state conditions to reproduce water levels and groundwater discharges to rivers and springs under pre-development conditions. This comparison of water budget results for

2008, 2060, and steady-state conditions indicates how the amount of groundwater movement between the aquifers, rivers, springs, and lakes/reservoirs will likely change through time with increased pumping and under no pumping condition. The column of results under "In" indicates the amount of water that is coming into the aquifer and the column of results under "Out" indicates the amount of water that is leaving the aquifer. Recharge is always found under the "In" column as recharge infiltrates into the aquifer. Similarly, pumping is always in the "Out" column as groundwater is pumped out of the aquifer. Some parameters, such as rivers and vertical and lateral flow could occur in both "In" and "Out" columns given the variation in local hydrogeologic conditions of the aquifer.

Water budget results indicate that with the rise in the water levels in the Edwards Group Aquifer spring discharges increase by up to 6 percent between 2008 and 2060. This is probably caused by increased recharge in the predictive period compared to the previous years and a constant pumpage through the predictive period. Spring discharges decreased by up to about 16 percent in the Upper Trinity Aquifer. Changes to discharges in the springs and rivers in the Edwards Group and the Upper Trinity aquifers remain the same during Part B run. Water levels decline in the Upper Trinity Aquifer in 2060 also remains the same with the exception of a slightly larger drawdown area around Kendall and Kerr counties during Part B run. This suggests that the assigned groundwater pumping amount and distribution in the Middle Trinity Aquifer do not adversely affect water levels in the Upper or the Edwards Group aquifers.

Groundwater discharges to the springs and rivers decreased significantly in the Middle Trinity Aquifer during Part A and Part B runs. For example, baseflow to the local rivers, springs, and lakes/reservoirs located over the outcrop of the Middle Trinity Aquifer decreased by 7 to 44 percent during Part A run. During Part B run, spring discharges further decreased by about 6 to 15 percent. However, it must be noted that water budget results reported for spring discharge are based on 14 springs explicitly represented in the model. The rivers in the area are largely fed by baseflow and discharge through springs along the river beds. However, only the larger springs could be included in the model as the model was constructed with 1 mile by 1 mile grid sizes to simulate regional flow conditions. Therefore, reported baseflow discharges along the long stretches of the rivers are probably a more reliable indicator of pumpage effects on natural flow to the rivers and springs. The reported decreases in baseflow discharges to the rivers and springs may not have a significant impact on changing groundwater flow direction in the aquifers regionally or changing the rivers from gaining to losing which is supported from simulated water level contours that still bend upstream along the course of the rivers after 60 years of specified pumping.

During Part A run, water levels in the Middle Trinity Aquifer declined by 160 feet in northern parts of Bexar County, 60 feet in western parts of Kerr County, and 20 feet in Travis County. During Part B run, water levels declined by about 235 feet in the Middle Trinity Aquifer in northern parts of Bexar County, 110 feet in western parts of Kerr County, and 40 feet in Travis County. These declines in water levels and groundwater discharges were caused in response to additional pumpage of 12,500 acre-feet and 25,000 acre-feet in the Middle Trinity Aquifer in Part and Part B runs, respectively.

Water levels in the aquifers rise in the absence of groundwater pumping under steady-state conditions during Part C run. This rise in water levels caused a general increase in groundwater discharges to the spring and rivers. For example, discharges to the rivers increased by up to about 9 percent in the Edwards Group Aquifer, up to 13 percent in the Upper Trinity Aquifer, and up to 22 percent in the Middle Trinity Aquifer compared to discharges during 2008. Spring discharges also locally increased by up to 9 percent in the Edwards Group, up to about 83 percent in the Upper Trinity Aquifer, and more than 180 percent in the Middle Trinity aquifers. Simulated water levels in the aquifers also show well developed v-shaped contours that point upstream for nearly all the streams suggesting increased baseflow from the aquifers to the rivers and springs. However, not all model areas show an increase in groundwater discharges. In some parts of the model, a small decrease in discharges (up to 5 percent) occurs in the Upper Trinity Aquifer. This may be attributed to an absence of water coming from storage under steady-state conditions that reduces the overall water budget results for the area under consideration.

Occurrences of a few dry cells may inherently affect the water budget values between 2008 and 2060. If dry cells appear, the cell is shut off and is not included in the water budget calculation. Dry cells may only appear towards the end of the predictive period and not at the beginning giving minor mismatch for “In” and “Out” values between 2008 and 2060 for some flow parameters.

Various groundwater flow parameters from the water budget simulation (Appendix 1) are presented for Hays County using a block diagram to better illustrate magnitudes and directional flow components and their mutual relationships at the aquifer level (Figure 15). A template of this diagram is also presented for illustration of water budget results from other counties (Figure 16).

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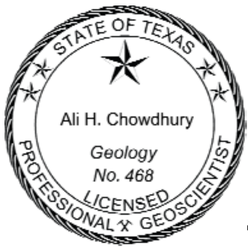

The seal appearing on this document was authorized by Ali H. Chowdhury, P.G., on December 2, 2008.

Appendix 1

Annual water budgets results for each county at the beginning (2008) of the predictive period under baseline pumping and at the end (2060) of the predictive model run using an additional 25 (Part A) and 50 percent (Part B) of pumpage for the Middle Trinity Aquifer in the groundwater availability model for the Hill Country portion of the Trinity Aquifer. In addition, we also presented results of a steady-state model run using no pumpage in the model (part C) to best reproduce water levels that existed under natural conditions prior to any groundwater pumping. Water budget values are reported in acre-feet per year. Water budgets for Kerr, Gillespie, Blanco, Medina, Kimble, Uvalde, and Bexar counties represent only the portions of those counties located in the active portion of the model. Note that the "spring" item only refers to springs discretely represented in the model. The "Rivers" term includes other spring flow.

Appendix 1 continued

Aquifer	County	Flow parameters	Water budget for 2008		Water budget for 2060 (Part A Run)		Water budget for 2060 (Part B Run)		Water budget for steady-state (Part C Run)	
			In	Out	In	Out	In	Out	In	Out
Edwards Group	Bandera	Storage	213	6	0	1	0	1	0	0
		Lakes/reservoirs (Constant Head)	0	0	0	0	0	0	0	0
		Lateral flow	2,158	20	2,364	20	2,365	20	2,421	20
		Vertical flow (upward)	0	0	0	0	0	0	0	0
		Vertical flow (downward)	0	458	0	459	0	459	0	470
		Pumping	0	596	0	596	0	596	0	0
		Rivers (Drain)	0	12,880	0	12,876	0	12,878	0	13,519
		Recharge	11,588	0	11,588	0	11,588	0	11,588	0
		Balcones Fault Zone (General Head Boundary)	0	0	0	0	0	0	0	0
		Total	13,958	13,960	13,951	13,952	13,953	13,954	14,009	14,010
Upper Trinity	Bandera	Storage	1,763	1	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	2	2,586	2	2,472	2	2,470	1	2,521
		Lateral flow	5,692	10,147	5,068	9,397	5,060	9,398	5,491	9,517
		Vertical flow (upward)	458	0	459	0	459	0	470	0
		Vertical flow (downward)	18	14,147	0	13,599	0	13,605	51	13,556
		Pumping	0	270	0	270	0	270	0	0
		Rivers (Drain)	0	13,403	0	12,482	0	12,467	0	13,143
		Recharge	33,368	0	33,368	0	33,368	0	33,368	0
		Balcones Fault Zone (General Head Boundary)	14	402	19	358	19	358	18	366
		Springs (Drain)	0	359	0	339	0	339	0	346
		Total	41,314	41,315	38,916	38,918	38,908	38,906	39,399	39,448
Middle Trinity	Bandera	Storage	1,804	0	10	0	31	0	0	0
		Lakes/reservoirs (Constant Head)	0	0	0	0	0	0	0	0
		Lateral flow	8,672	11,713	7,240	11,080	5,960	10,561	10,412	10,970
		Vertical flow (upward)	14,147	18	13,599	0	13,605	0	13,556	51
		Vertical flow (downward)	0	0	0	0	0	0	0	0
		Pumping	0	3,347	0	4,183	0	5,020	0	0
		Rivers (Drain)	0	12,694	0	9,471	0	8,036	0	15,526
		Recharge	4,432	0	4,432	0	4,432	0	4,432	0
		Balcones Fault Zone (General Head Boundary)	222	1,520	288	1,195	311	1,051	141	1,886
		Total	29,277	29,292	25,570	25,930	24,340	24,668	28,541	28,433

Appendix 1 continued.

Aquifer	County	Flow parameters	Water budget for 2008 (baseline pumpage)		Water budget for 2060 (Part A Run)		Water budget for 2060 (Part B Run)		Water budget for steady-state (Part C Run)	
			In	Out			In	Out	In	Out
Upper Trinity	Blanco	Storage	911	0	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	0	0	0	0	0	0	0	0
		Lateral flow	3,561	1,906	3,422	1,801	3,421	1,799	3,450	1,808
		Vertical flow (upward)	0	0	0	0	0	0	0	0
		Vertical flow (downward)	0	7,931	0	7,797	0	7,817	0	7,690
		Pumping	0	77	0	77	0	77	0	0
		Rivers (Drain)	0	13,745	0	12,929	0	12,908	0	13,133
		Recharge	19,175	0	19,175	0	19,175	0	19,175	0
		Balcones Fault Zone (General Head Boundary)	0	0	0	0	0	0	0	0
		Total	23,647	23,659	22,597	22,604	22,597	22,601	22,626	22,631
Middle Trinity	Blanco	Storage	902	0	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	0	0	0	0	0	0	0	0
		Lateral flow	4,904	8,993	4,503	8,513	4,332	8,416	5,308	8,823
		Vertical flow (upward)	7,931	0	7,797	0	7,817	0	7,690	0
		Vertical flow (downward)	0	0	0	0	0	0	0	0
		Pumping	0	1,469	0	1,836	0	2,203	0	0
		Rivers (Drain)	0	12,443	0	11,133	0	10,713	0	13,362
		Recharge	9,206	0	9,206	0	9,206	0	9,245	0
		Balcones Fault Zone (General Head Boundary)	197	197	0	0	0	0	0	0
		Springs (Drain)	0	30	0	27	0	26		34
		Total	23,140	23,132	21,506	21,508	21,355	21,358	22,243	22,219
Upper Trinity	Comal	Storage	546	2	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	174	254	201	228	203	227	174	255
		Lateral flow	1,825	2,611	1,776	2,553	1,771	2,555	1,879	2,584
		Vertical flow (upward)	0	0	0	0	0	0	0	0
		Vertical flow (downward)	61	3,674	57	3,641	52	3,669	90	3,559
		Pumping	0	473	0	473	0	473	0	0
		Rivers (Drain Package)	0	1,005	0	939	0	931	0	1,168
		Recharge	14,479	0	14,479	0	14,479	0	14,544	0
		Balcones Fault Zone (General Head Boundary)	0	9,066	0	8,678	0	8,650	0	9,121
		Total	17,084	17,084	16,512	16,512	16,505	16,505	16,687	16,687

Appendix 1 continued.

Aquifer	County	Flow parameters	Water budget for 2008		Water budget for 2060 (Part A Run)		Water budget for 2060 (Part B Run)		Water budget for steady-state (Part C Run)	
			In	Out	In	Out				
Middle Trinity	**Comal**	**Storage**	1,213	91	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	2,121	4,018	2,550	3,615	2,851	3,421	1,276	4,975
		Lateral flow	9,411	9,924	8,374	9,031	8,129	8,782	10,701	10,260
		Vertical flow (upward)	3,674	61	3,641	57	3,669	52	3,559	90
		Vertical flow (downward)	0	0	0	0	0	0	0	0
		Pumping	0	5,741	0	7,176	0	8,611	0	0
		Rivers (Drain Package)	0	6,818	0	5,949	0	5,611	0	8,332
		Recharge	13,278	0	13,278	0	13,278	0	13,212	0
		Balcones Fault Zone (General Head Boundary)	0	3,044	55	2,070	259	1,709	0	5,082
		Total	29,696	29,696	27,898	27,898	28,186	28,187	28,748	28,738
Upper Trinity	**Travis**	**Storage**	419	0	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	0	1,007	0	988	0	988	0	1,012
		Lateral flow	1,348	918	1,315	862	1,315	862	1,319	925
		Vertical flow (upward)	0	0	0	0	0	0	0	0
		Vertical flow (downward)	0	5,620	0	5,488	0	5,489	0	5,710
		Pumping	0	551	0	551	0	551	0	0
		Rivers (Drain)	0	5,081	0	4,917	0	4,917	0	5,121
		Recharge	12,629	0	12,629	0	12,629	0	12,710	0
		Balcones Fault Zone (General Head Boundary)	0	1,218	0	1,136	0	1,136	0	1,178
		Springs (Drain)		0		0	0	0		83
		Total	14,396	14,396	13,943	13,943	13,943	13,944	14,029	14,029
Middle Trinity	**Travis**	**Storage**	389	71	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	718	5,401	863	4,245	1,058	3,521	461	8,404
		Lateral flow	3,181	144	3,059	121	3,010	105	3,196	203
		Vertical flow (upward)	5,620	0	5,488	0	5,489	0	5,710	0
		Vertical flow (downward)	0	0	0	0	0	0	0	0
		Pumping	0	5,104	0	6,285	0	7,542	0	0
		Rivers (Drain)	0	619	0	345	0	161	0	1,453
		Recharge	2,515	0	2,456	0	2,456	0	2,434	0
		Balcones Fault Zone (General Head Boundary)	0	1,092	0	872	0	687	0	1,740
		Total	12,422	12,431	11,866	11,868	12,013	12,017	11,800	11,800

Appendix 1 continued

Aquifer	County	Flow parameters	Water budget for 2008		Water budget for 2060 (Part A Run)		Water budget for 2060 (Part B Run)		Water budget for steady-state (Part C Run)	
			In	Out	In	Out				
Edwards Group	**Kendall**	**Storage**	65	7	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	0	0	0	0	0	0	0	0
		Lateral flow	111	215	113	208	113	208	115	215
		Vertical flow (upward)	0	0	0	0	0	0	0	0
		Vertical flow (downward)	6	43	1	49	1	49	2	49
		Pumping	0	318	0	318	0	318	0	0
		Rivers (Drain)	0	5,509	0	5,449	0	5,449	0	5,760
		Recharge	5,908	0	5,908	0	5,908	0	5,908	0
		Balcones Fault Zone (General Head Boundary)	0	0	0	0	0	0	0	0
		Total	6,091	6,093	6,022	6,024	6,022	6,024	6,025	6,024
Upper Trinity	**Kendall**	**Storage**	1,951	0	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	0	0	0	0	0	0	0	0
		Lateral flow	2,046	9,455	1,725	8,450	1,720	8,443	1,809	8,603
		Vertical flow (upward)	43	6	49	1	49	1	49	2
		Vertical flow (downward)	8	15,728	0	15,106	0	15,135	24	15,130
		Pumping	0	307	0	307	0	307	0	0
		Rivers (Drain)	0	5,183	0	4,544	0	4,515	0	4,769
		Recharge	26,627	0	26,627	0	26,627	0	26,627	0
		Balcones Fault Zone (General Head Boundary)	0	0	0	0	0	0	0	0
		Total	30,676	30,679	28,402	28,408	28,397	28,401	28,509	28,503
Middle Trinity	**Kendall**	**Storage**	1,859	0	1	0	2	0	0	0
		Lakes/reservoirs (Constant Head)	0	0	0	0	0	0	0	0
		Lateral flow	9,205	12,810	7,873	11,151	7,164	10,461	9,901	12,787
		Vertical flow (upward)	15,728	8	15,106	0	15,135	0	15,130	24
		Vertical flow (downward)	0	0	0	0	0	0	0	0
		Pumping	0	5,546	0	6,933	0	8,319	0	0
		Rivers (Drain)	0	24,500	0	21,227	0	19,920	0	27,680
		Recharge	16,761	0	16,761	0	16,761	0	16,761	0
		Balcones Fault Zone (General Head Boundary)	0	0	0	0	0	0	0	0
		Springs (Drain)		690		455	0	383		1,267
		Total	43,553	43,554	39,741	39,766	39,062	39,083	41,791	41,758

Appendix 1 continued

Aquifer	County	Flow parameters	Water budget for 2008		Water budget for 2060 (Part A Run)		Water budget for 2060 (Part B Run)		Water budget for steady-state (Part C Run)	
			In	Out	In	Out	In	Out	In	Out
Upper Trinity	**Hays**	**Storage**	620	0	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	0	0	0	0	0	0	0	0
		Lateral flow	3,388	2,597	3,257	2,537	3,255	2,537	3,346	2,549
		Vertical flow (upward)	0	0	0	0	0	0	0	0
		Vertical flow (downward)	53	7,923	42	7,788	34	7,799	79	7,801
		Pumping	0	408	0	408	0	408	0	0
		Rivers (Drain Package)	0	15,309	0	14,871	0	14,853	0	15,291
		Recharge	24,929	0	24,929	0	24,929	0	24,929	0
		Balcones Fault Zone (General Head Boundary)	14	2,688	16	2,573	16	2,570	13	2,649
		Springs (Drain)		81		68	0	68		77
		Total	29,005	29,006	28,244	28,245	28,234	28,235	28,367	28,367
Middle Trinity	**Hays**	**Storage**	440	49	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	0	0	0	0	0	0	0	0
		Lateral flow	9,059	7,159	8,637	6,773	8,505	6,607	8,809	7,098
		Vertical flow (upward)	7,923	53	7,788	42	7,799	34	7,801	79
		Vertical flow (downward)	0	0	0	0	0	0	0	0
		Pumping	0	4,273	0	5,341	0	6,409	0	0
		Rivers (Drain Package)	0	8,738	0	7,736	0	7,163	0	10,268
		Recharge	5,802	0	5,802	0	5,802	0	5,841	0
		Balcones Fault Zone (General Head Boundary)	0	2,509	5	1,938	40	1,548	0	3,737
		Springs (Drain)		450		405	0	390		1,267
		Total	23,224	23,231	22,232	22,235	22,145	22,151	22,451	22,449
Edwards Group	**Kerr**	**Storage**	23	1,330	0	5	0	6	0	0
		Lakes/reservoirs (Constant Head)	0	0	0	0	0	0	0	0
		Lateral flow	2,761	4,266	2,877	4,589	2,878	4,591	3,003	4,716
		Vertical flow (upward)	0	0	0	0	0	0	0	0
		Vertical flow (downward)	0	3,401	0	3,487	0	3,488	0	3,549
		Pumping	0	1,036	0	1,036	0	1,036	0	0
		Rivers (Drain)	0	21,248	0	22,187	0	22,192	0	23,129
		Recharge	29,478	0	29,478	0	29,478	0	29,478	0
		Balcones Fault Zone (General Head Boundary)	0	0	0	0	0	0	0	0
		Springs (Drain)	0	986	0	1,042	0	1,042		1086
		Total	32,262	32,266	32,355	32,346	32,355	32,356	32,481	32,480

Appendix 1 continued.

Aquifer	County	Flow parameters	Water budget for 2008		Water budget for 2060 (Part A Run)		Water budget for 2060 (Part B Run)		Water budget for steady-state (Part C Run)	
			In	Out	In	Out				
Upper Trinity	**Kerr**	**Storage**	1,160	27	1	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	0	0	0	0	0	0	0	0
		Lateral flow	2,984	1,876	2,745	1,645	2,741	1,639	2,753	2,006
		Vertical flow (upward)	3,401	0	3,487	0	3,488	0	3,549	0
		Vertical flow (downward)	10	8,507	0	8,707	0	8,726	56	7,457
		Pumping	0	213	0	213	0	213	0	0
		Rivers (Drain)	0	13,704	0	12,450	0	12,418	0	13,891
		Recharge	16,771	0	16,771	0	16,771	0	16,771	0
		Balcones Fault Zone (General Head Boundary)	0	0	0	0	0	0	0	0
		Total	24,325	24,327	23,003	23,015	22,999	22,996	23,128	23,353
Middle Trinity	**Kerr**	**Storage**	1,786	0	28	0	85	0	0	0
		Lakes/reservoirs (Constant Head Package)	0	0	0	0	0	0	0	0
		Lateral flow	4,384	8,455	4,638	6,403	4,571	4,685	3,633	10,680
		Vertical flow (upward)	8,507	10	8,707	0	8,726	0	7,457	56
		Vertical flow (downward)	0	0	0	0	0	0	0	0
		Pumping	0	6,259	0	7,824	0	9,389	0	0
		Rivers (Drain)	0	0	0	0	0	0	0	0
		Recharge	0	0	0	0	0	0	0	0
		Balcones Fault Zone (General Head Boundary)	0	0	0	0	0	0	0	0
		Total	14,676	14,725	13,373	14,227	13,382	14,074	11,090	10,736
Upper Trinity	**Medina**	**Storage**	216	0	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	1	3,580	1	3,451	1	3,450	1	3,493
		Lateral flow	7,039	3,619	6,669	3,459	6,671	3,444	6,739	3,464
		Vertical flow (upward)	0	0	0	0	0	0	0	0
		Vertical flow (downward)	20	1,084	8	1,115	0	1,152	27	1,012
		Pumping	0	43	0	43	0	43	0	0
		Rivers (Drain)	0	2,032	0	1,990	0	1,977	0	2,028
		Recharge	7,805	0	7,805	0	7,805	0	7,805	0
		Balcones Fault Zone (General Head Boundary)	128	4,850	140	4,565	140	4,553	136	4,712
		Total	15,209	15,209	14,623	14,623	14,618	14,618	14,708	14,708

Appendix 1 continued.

Aquifer	County	Flow parameters	Water budget for 2008		Water budget for 2060 (Part A Run)		Water budget for 2060 (Part B Run)		Water budget for steady-state (Part C Run)	
			In	Out	In	Out				
Middle Trinity	**Medina**	**Storage**	198	0	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	0	0	0	0	0	0	0	0
		Lateral flow	9,760	3,963	9,256	5,199	8,905	5,641	9,539	1,402
		Vertical flow (upward)	1,084	20	1,115	8	1,152	0	1,012	27
		Vertical flow (downward)	0	0	0	0	0	0	0	0
		Pumping	0	360	0	451	0	541	0	0
		Rivers (Drain)	0	0	0	0	0	0	0	0
		Recharge	0	0	0	0	0	0	0	0
		Balcones Fault Zone (General Head Boundary)	214	6,913	640	5,373	861	4,755	0	9,113
		Total	11,256	11,256	11,011	11,030	10,919	10,937	10,551	10,542
Upper Trinity	**Bexar**	**Storage**	623	0	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	0	0	0	0	0	0	0	0
		Lateral flow	6,160	1,642	5,594	1,596	5,594	1,591	5,631	1,701
		Vertical flow (upward)	0	0	0	0	0	0	0	0
		Vertical flow (downward)	0	1,731	0	1,756	0	1,692	7	1,258
		Pumping	0	924	0	920	0	894	0	0
		Rivers (Drain Package)	0	2,354	0	1,863	0	1,875	0	2,034
		Recharge	10,242	0	10,242	0	9,988	0	10,330	0
		Balcones Fault Zone (General Head Boundary)	0	10,374	0	9,700	0	9,530	0	10,975
		Total	17,025	17,025	15,835	15,835	15,582	15,582	15,969	15,968
Middle Trinity	**Bexar**	**Storage**	3,441	0	0	0	0	0	0	0
		Lakes/reservoirs (Constant Head)	0	0	0	0	0	0	0	0
		Lateral flow	11,981	1,194	12,080	817	12,008	706	8,822	2,709
		Vertical flow (upward)	1,731	0	1,756	0	1,692	0	1,258	7
		Vertical flow (downward)	0	0	0	0	0	0	0	0
		Pumping	0	16,893	0	19,016	0	21,093	0	0
		Rivers (Drain)	0	0	0	0	0	0	0	0
		Recharge	1,638	0	1,638	0	1,638	0	1,550	0
		Balcones Fault Zone (General Head Boundary)	129	834	4,394	37	6,458	0	0	8,878
		Total	18,920	18,920	19,868	19,870	21,797	21,799	11,630	11,594

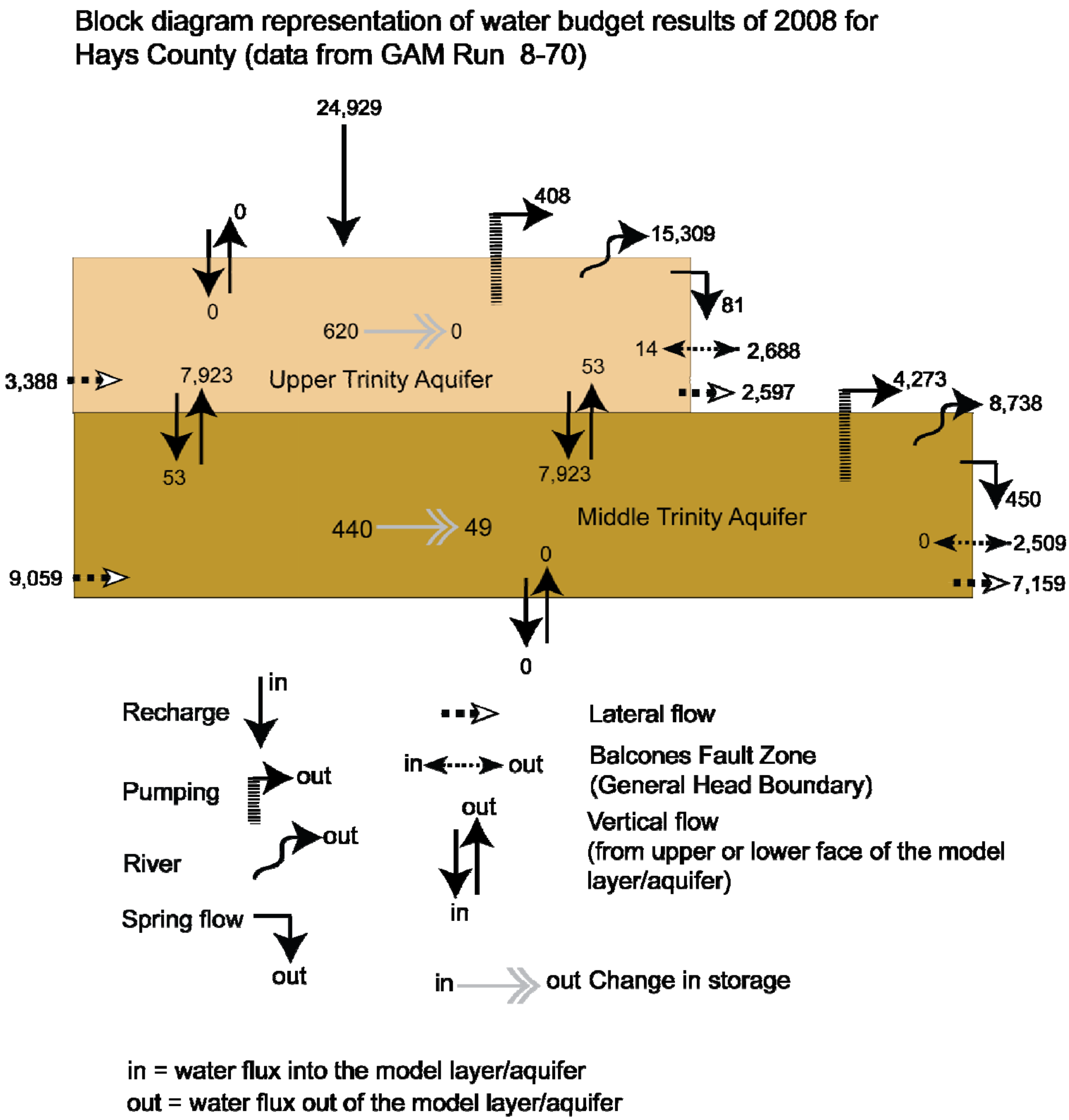

Figure 15. A block diagram representing magnitudes and directions of various groundwater flow components in Hays County. Note Edwards Group Aquifer does not occur in Hays County and is not included in the diagram. Note no vertical flow across the upper faces of the Upper Trinity and lower faces of the Middle Trinity aquifers where they are open to the land surface, and a no-flow model boundary assigned at the bottom of the Middle Trinity Aquifer, respectively.

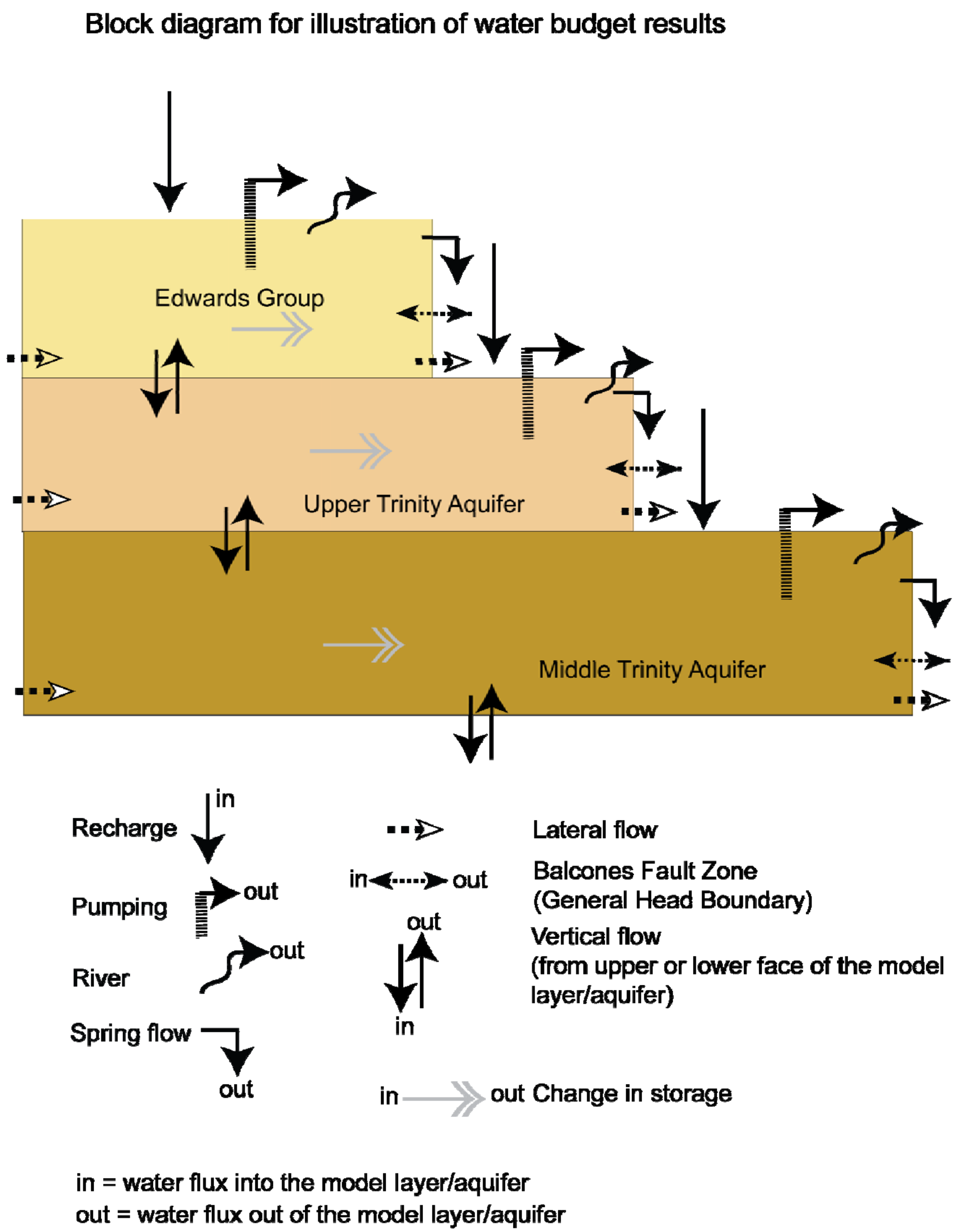

Figure 16. A template of a block diagram representing various groundwater flow components. The blank fields for each parameter can be filled-in using appropriate data from Appendix 1.