GAM Run 08-66

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Groundwater Availability Modeling Section
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The seal appearing on this document was authorized by Melissa E. Hill, P.G. 1316, on May 17, 2010.

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EXECUTIVE SUMMARY:

The groundwater availability model for the northern portion of the Trinity Aquifer System was used to simulate a 50-year predictive simulation of groundwater flow in the Woodbine Aquifer and northern portion of the Trinity Aquifer System. Average recharge conditions were used for the first forty-seven years of the simulation, followed by the three-year drought-of-record. Pumpage was assigned for each stress period, or year, in the simulation based on the specifications provided by the groundwater conservation districts within Groundwater Management Area 8. Specific differences between this run and the previous GAM Run 08-64 (Hill, 2010) include:

- an increase in well withdrawals for Comanche County from 25,000 acre-feet per year to 27,000 acre-feet per year,
- an increase in well withdrawals for Erath County from 30,000 acre-feet per year to 32,000 acre-feet per year,
- well withdrawals of 632 acre-feet per year for the Woodbine Aquifer (layer 1) underlying Tarrant County reported in Table 2 of Wade (2008) was applied, and
- well withdrawals in the underlying Trinity Aquifer System (layers 3, 4, 5, and 7) for Tarrant County were adjusted to 17,606 acre-feet per year. Combining the specified pumpage for the Woodbine Aquifer and Trinity Aquifer System underlying Tarrant County results in a decrease of 1,377 acre-feet per year from those specified in GAM Run 08-64.

Comparison of results from this predictive simulation to GAM Run 08-64, show decreases in average water level changes of 2 feet or less beneath Comanche and Erath counties with the increased specified pumpage for these counties. Conversely, water levels increase up to 14 feet beneath Tarrant and surrounding counties with the decrease in specified pumpage.

Comparisons between the percent of pumpage removed due to cells converting to dry relative to specified pumpage, indicates 13 percent of the specified pumpage beneath Comanche County is removed due to cells converting to dry for GAM Run 08-64, and increases to 15 percent for GAM Run 08-66. The percent of pumpage removed due to cells converting to dry relative to specified pumpage beneath Erath County remains constant at 8 percent and at 2 percent for Tarrant County for both GAM Run 08-64 and GAM Run 08-66. This indicates that increasing the specified pumpage for Comanche County in future scenarios will increase the percent of pumpage removed due to cells converting to dry relative to specified pumpage.

REQUESTOR:

Ms. Cheryl Maxwell (of the Clearwater Underground Water Conservation District) a representative of Groundwater Management Area 8.

DESCRIPTION OF REQUEST:

Ms. Maxwell requested a model run using the groundwater availability model for the northern portion of the Trinity Aquifer System. The requested model run is for a 50-year predictive simulation. Average recharge conditions are used for the first forty-seven years of the simulation, followed by the three-year drought-of-record. Pumpage used for each year of the simulation was assigned based on the specifications provided by Groundwater Management Area 8.

METHODS:

Average streamflows and evapotranspiration rates were used for each year of the predictive simulation. Average recharge was used for the first forty-seven years of the simulation, followed by a three-year drought-of-record. Simulated water levels and water levels changes at the conclusion of the 50-year predictive scenario are described in the Results Section of this report.

PARAMETERS AND ASSUMPTIONS:

The groundwater availability model for the northern portion of the Trinity Aquifer was used for this model run. A brief description of the model and caveats are described below:

- version 1.01 of the groundwater availability model for the northern portion of the Trinity Aquifer was used for this model run. See Bené and others (2004) for a detailed discussion of assumptions and limitations for the model;

- Groundwater Vistas (Environmental Simulations, Inc., 2007) version 5.30 build 10 was used as the interface to process model output;

- the groundwater availability model grid files (trnt_n_grid_poly), version 111808, were used to process model output;

- changes in pumpage between 2000 and 2010 are assumed to not significantly affect the predictive simulation’s results;

- the model includes seven layers, representing the Woodbine Aquifer (layer 1), the Washita and Fredericksburg Groups (layer 2), the Paluxy Aquifer (layer 3), the Glen Rose Formation (layer 4), the Hensell Aquifer (layer 5), the Pearsall/Cow Creek/Hammett/Sligo Members (layer 6), and the Hosston Aquifer (layer 7). The Woodbine Aquifer, Paluxy Aquifer, Hensell Aquifer, and Hosston Aquifer are the most productive water-bearing strata in the region;

- average annual recharge conditions based on climate data from 1980 to 1999 was used for the simulation. The last three years of the simulation used the drought-of-record recharge conditions, which were defined as the years from 1954 through 1956;

- the model uses the MODFLOW River Package to simulate major reservoirs. See Bené and others (2004) for a detailed discussion on the package selection for simulating reservoirs;

- the MODFLOW-96 groundwater flow simulator was used for this model run. MODFLOW-96 does not simulate three-dimensional, variable density groundwater flow that may arise in aquifers containing both fresh and non-fresh groundwater (such as the Woodbine Aquifer, Paluxy Aquifer, Hensell Aquifer, and Hosston Aquifer). See Bené and others (2004) for a detailed discussion on water quality in the aquifers;

- the Strongly Implicit Procedure (SIP) solver was used with MODFLOW-96. Therefore, model cells convert to dry when simulated water levels drop below the bottom of the model cell. Model cells that convert to dry during the simulation are removed from the groundwater flow calculations performed by MODFLOW-96 (Harbaugh and McDonald, 1996); and

- the calculated average changes in water levels presented in Table 6 and the water budget presented in Appendix A are approximations.

Assigned Pumpage

Each year of the predictive simulation was assigned pumpage following specifications provided by Groundwater Management Area 8. The following specifications were provided by Groundwater Management Area 8 for this predictive scenario:

- the simulation maintains the existing model spatial pumping distribution except in Delta, Hunt, Kaufman, and Lamar counties,

- the spatial pumping distribution underlying Delta, Hunt, Kaufman, and Lamar counties is uniform,

- the simulation maintains the existing distribution of pumping by layer (as a percentage of the total Trinity Aquifer System underlying a county area) for layers 3, 4, 5, 6, and 7; except where otherwise specified; and

- pumping underlying each area for which a pumping amount is specified remains constant, in other words, by county total for the Trinity Aquifer System, or by a layer specified underneath a county.

In addition to the aforementioned requests, pumpage totals for each county in the model were provided by Groundwater Management Area 8. These totals are shown in Tables 1 through 4.

Table 1. Assigned pumpage for the Woodbine Aquifer (layer 1) used in this model simulation based on specifications provided by Groundwater Management Area 8. All pumpage reported is in acre-feet per year and is used for each stress period (year) in the predictive simulation.

County	Specified pumpage	County	Specified pumpage
Collin	2,500	Kaufman	200
Cooke	154	Lamar	3,658
Delta	16	Limestone	33
Denton	4,126	Navarro	300
Fannin	3,300	Red River	170
Grayson	12,100	Rockwall	144
Hunt	2,840	Tarrant	632
Johnson	4,732		

Table 2. Assigned pumpage for the Trinity Aquifer System (layers 3, 4, 5, and 7) used in this model simulation based on specifications provided by Groundwater Management Area 8. All pumpage reported is in acre-feet per year and is used for each stress period (year) in the predictive simulation.

County	Specified pumpage	County	Specified pumpage
Brown	2,085	Lamar	1,320
Callahan	3,787	Lampasas	3,164
Collin	2,100	Limestone	66
Comanche	27,000	McLennan	20,694
Cooke	7,018	Milam	321
Delta	364	Mills	2,400
Denton	18,132	Montague	506
Eastland	4,853	Navarro	1,873
Erath	32,000	Parker	11,751
Falls	161	Red River	528
Fannin	700	Rockwall	958
Grayson	9,400	Tarrant	17,606
Hamilton	2,146	Taylor	679
Hood	11,001	Travis	3,900
Hunt	551	Williamson	1,810
Johnson	16,349	Wise	8,414
Kaufman	1,184		

Table 3. Assigned pumpage for the Woodbine Aquifer and Trinity Aquifer System combined (layers 1, 3, 4, 5, and 7) used in this model simulation based on specifications provided by Groundwater Management Area 8. All pumpage reported is in acre-feet per year and is used for each stress period (year) in the predictive simulation.

County	Specified pumpage	County	Specified pumpage
Bosque	7,509	Hill	5,412
Dallas	7,807	Somervell	2,485
Ellis	9,403		

Table 4. Assigned pumpage by layer for Bell, Burnet, and Coryell counties used in this model simulation based on specifications provided by Groundwater Management Area 8. All pumpage reported is in acre-feet per year and is used for each stress period (year) in the predictive simulation. Pumpage is uniformly distributed in western Coryell County (shown in Figure 1).

	Bell County	Burnet County	Coryell County	
Layer*	Specified pumpage	Specified pumpage	County Wide	Western Coryell County**
Layer 3	112	200	254	
Layer 4	880	200	783	
Layer 5	1,100	700	836	928
Layer 7	5,000	2,500	433	480

*- Paluxy Aquifer (Layer 3), the Glen Rose Formation (Layer 4), the Hensell Aquifer (Layer 5), and the Hosston Aquifer (Layer 7).

**-Pumpage distribution for Western Coryell County is assigned per Groundwater Management Area 8's specifications for GAM Run 08-64 as described in Hill (2010).

The 1999 spatial distribution of pumpage used with the calibrated historic model was used to generate the pumpage for the predictive model. Pumpage was increased or decreased to the specified totals shown in Tables 1 through 4 using a factor based on the county pumpage in the 1999 pumpage distribution and the desired total. This produced a predictive pumpage distribution similar to the 1999 pumpage distribution. The pumpage used with the predictive model was also constant throughout the 50-year simulation, as requested by Groundwater Management Area 8. Pumpage was allocated within the groundwater flow model based on the location of the model cell centroid. Additional details for the generation of the pumpage distribution are provided in GAM 07-09 (Donnelly, 2007).

Changes to the pumpage totals specified above were made for Delta and Kaufman counties. Delta County was specified to have 16 acre-feet per year of pumpage from the Woodbine Aquifer (layer 1) and 364 acre-feet per year of pumpage from the Trinity Aquifer System (layers 3, 4, 5, and 7). Kaufman County was specified to have 1,184 acre-feet per year of pumpage from the Trinity Aquifer System (layers 3, 4, 5, and 7). However, no pumpage was present in the historic pumpage distribution for the aquifers underlying these counties. Therefore, a uniform distribution was used for the pumpage distribution underlying Delta and Kaufman counties.

In addition, several counties and/or model layers were not specified in the original request. Counties with no specified pumpage are shown in Table 5. Layers 2 (Washita and Fredericksburg Groups) and 6 (Pearsall/Cow Creek/Hammett/Sligo Members) were not specified for counties throughout most of the model domain. For these layers, the 1999 historic pumpage distribution was used in the predictive simulation.

Table 5. Pumpage used for non-specified counties/layers in the model domain. These totals are based on 1999 pumpage totals from the calibrated historic model. All pumpage reported is in acre-feet per year and is used for each stress period (year) in the predictive simulation.

County	Annual pumpage
Bastrop	4
Jack	11
Lee	5
Palo Pinto	12
Non-Texas	9,541

RESULTS:

The calculated water budget at the conclusion of the 50-year simulation is provided in Appendix A. The water budget is a summary of the groundwater flow simulator’s (MODFLOW-96) calculations for water entering and leaving the model layers (Harbaugh and McDonald, 1996). Components of the water budget are described below:

- wells refer to groundwater withdrawals. This component is shown as “out” in Appendix A, because the wells in the model for the northern portion of the Trinity Aquifer System withdraw (rather than inject) water. Wells are simulated using the MODFLOW Well Package;

- recharge represents the distributed precipitation falling on the outcrop areas. Recharge is shown as “in” in Appendix A. Recharge is simulated using the MODFLOW Recharge Package;

- evapotranspiration accounts for water that flows out of an aquifer due to direct evaporation and plant transpiration. This component of the budget is shown as "out". Evapotranspiration is simulated using the MODFLOW Evapotranspiration Package. In the model for the northern portion of the Trinity Aquifer System, groundwater discharge via small seeps and springs and larger spring discharge to streams not specifically modeled by the Streamflow-Routing Package (abbreviated to Stream Package in Appendix A) are simulated using the Evapotranspiration Package (Bené and others, 2004);

- vertical leakage (upward or downward) describes the vertical flow, or leakage, between two aquifers. Fluxes to an aquifer from an overlying or underlying aquifer are represented as "in" in Appendix A. Vertical leakage out of an aquifer is referred to as "out" in Appendix A;

- change in storage refers to changes in the water stored within an aquifer. The storage component representing water that is removed from storage in the aquifer (that is, water level declines) is labeled as "in" in Appendix A. The storage component that is added back into storage within the aquifer (that is, water level increases) is labeled as "out" in Appendix A;

- lateral flow describes lateral flow within an aquifer between a county and adjacent counties. Incoming flows are shown as "in" in Appendix A and outgoing flows are shown as "out";

- rivers and streams refer to water that flows between perennial rivers or streams and an aquifer. Flows into the aquifer and out of the stream are shown as "in" in Appendix A and flows out of the aquifer and into the stream are shown as "out" in Appendix A;

- reservoirs refer to water that flows between reservoirs and an aquifer. Flows out of the reservoir and into the aquifer are shown as "in" in Appendix A. Flows out of the aquifer and into the reservoir are shown as "out" in Appendix A; and

- inter-aquifer flow refers to fluxes between model cells with general-head boundaries. In the model for the northern portion of the Trinity Aquifer, general head boundaries are used to simulate the flux of water between portions of the uppermost layer with the overlying mantle of younger deposits and between the model layers and the Colorado River (Bené and others, 2004). General head boundaries are simulated using the MODFLOW General Head Boundary (GHB) Package,

In this report, initial heads at the start of the 50-year predictive simulation (Figures 2 through 6), simulated heads at the conclusion of the 50-year predictive simulation (Figures 7 through 11), average changes in water levels (Figures 12 through 16 and Table 6), and the water budget reported in Appendix A represent values for only those portions of the aquifers that match the existing aquifer footprints (or currently delineated aquifer boundaries).

Results from the predictive simulation for the Woodbine Aquifer (layer 1), the Paluxy Aquifer (layer 3), the Glen Rose Formation (layer 4), the Hensell Aquifer (layer 5), and the Hosston Aquifer (layer 7) are included in the water budget table provided in Appendix A.

Initial water levels from the conclusion of the transient calibration (end of 1999/beginning of 2000) for layers 1, 3, 4, 5, and 7 are shown in Figures 2 through 6, respectively. These are assumed to be adequately representative of water levels at the beginning of 2010 (see Parameters and Assumptions Section in this report). These figures show the starting water levels for the 50-year predictive simulation. Initial water levels are generally higher in the updip portions of the aquifers (northward and westward) with water levels generally decreasing in the downdip aquifer portions (southward and eastward).

Water levels at the conclusion of the 50-year predictive simulation for layers 1, 3, 4, 5, and 7 are shown in Figures 7 through 11, respectively. Water levels at the conclusion of the 50-year simulation exhibit a similar trend to initial water levels (Figures 2 through 6) in that water levels are relatively higher in the updip portions, but water levels underlying large pumping centers are lower than at the start of the 50-year predictive simulation.

Qualitative changes showing the difference between water levels at the start and conclusion of the 50-year predictive simulation for layers 1, 3, 4, 5, and 7 are shown in Figures 12 through 16, respectively.

Figure 12 indicates that water levels in the Woodbine Aquifer (layer 1) at the conclusion of the 50-year simulation decrease in the downdip portions of the aquifer. These changes range from less than 25 feet near the outcrop areas to 175 feet or greater in the downdip portions of the aquifer for the 50-year predictive simulation.

Figure 13 shows decreases in water levels of 25 feet or less in the farthest updip portions of the Paluxy Aquifer (layer 3) with increasing declines greater than 200 feet in the downdip aquifer portions. Localized areas with relatively larger water level declines are found in the vicinity of large production areas underlying portions of Dallas, Collin, and Rockwall counties. Water levels decreased more than 300 feet underneath the Dallas-Rockwall county lines and near the Collin-Fannin-Hunt county lines. Additionally, declines in water levels of 325 feet or greater occur along the Navarro-Hill-Limestone, and McLennan county areas at the conclusion of the 50-year predictive simulation.

Figure 14 shows that water levels also decrease in the downdip portions of the Glen Rose Formation (layer 4). Decreases of 25 feet or less are shown in the updip extent and increase to greater than 375 feet in the downdip portion underlying eastern McLennan County.

Figure 15 shows that water levels also decrease in the downdip portions of the Hensell Aquifer (layer 5). Decreases of 25 feet or less are shown in the updip extent of the aquifer and increase to greater than 200 feet in the downdip portions of the aquifer. A large, localized cone of depression underlies eastern McLennan County. Water levels decreased more than 500 feet near the center of the cone of depression at the conclusion of the 50-year predictive simulation.

Figure 16 shows that water levels decrease in the Hosston Aquifer (layer 7). Decreases of 25 feet or less are shown in the updip portion of the aquifer and increase to greater than 300 feet in the farthest downdip portions of the aquifer. A large, localized cone of depression underlies eastern McLennan County. Declines in water levels below McLennan County exceed 600 feet at the conclusion of the 50-year predictive simulation.

In addition to the qualitative figures of water level changes (Figures 12 through 16), a quantitative summary of average water level changes underlying each county for layers 1, 3, 4, 5 and 7 has been included in Table 6. Water level changes reported in Table 6 were calculated as follows and represent the active areas of the aquifer footprint underlying a county:

- if the starting water levels for the predictive simulation did not convert to dry and the simulated water levels at the end of the 50-year predictive simulation did not convert to dry, then the difference between the starting water levels and simulated water levels at the end of the 50-year predictive simulation was calculated;

- if the starting water levels for the predictive simulation did not convert to dry, but the simulated water levels at the end of the 50-year predictive simulation converted to dry, then the difference between the starting water levels and the bottom elevation for cells that converted to dry was calculated; or

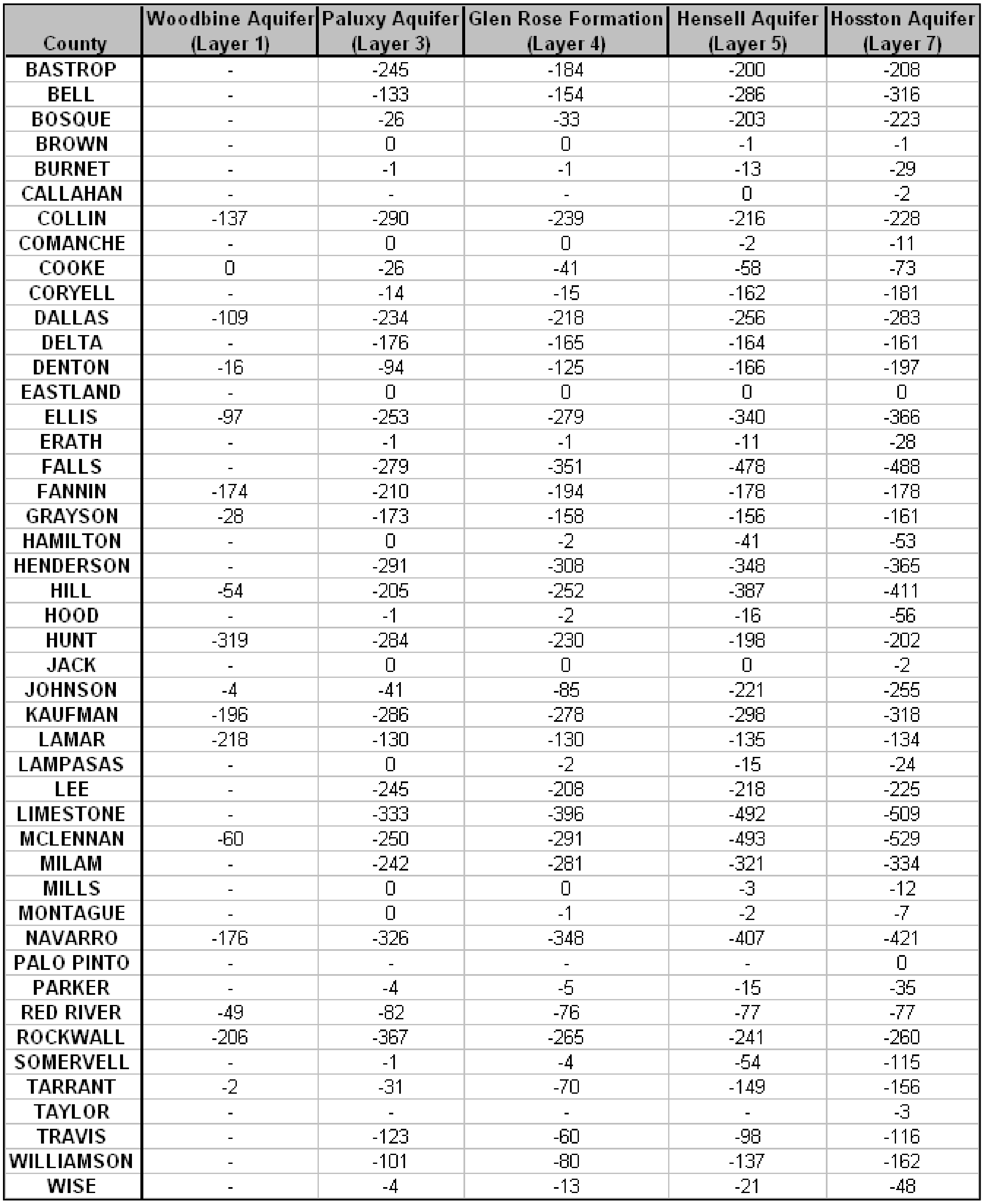
- if the starting water levels for the predictive simulation had converted to dry and the simulated water levels at the end of the 50-year predictive simulation remained dry (rewetting was not permitted), then these values were omitted from the county average water level changes reported in Table 6.

Quantitative components of the water budget shown in Appendix A are divided into “in” and “out” and represent fluxes into and out of the aquifer footprint underlying a county. Please note that county/layer pumpage totals for the water budget shown in Appendix A may be less than the specified pumpage listed in Tables 1 through 4 due to several factors. One factor is related to the extent of the aquifer footprint. For example, if the aquifer boundary occurs within a county, only the pumpage within the active aquifer footprint is reported in Appendix A. A second factor is the conversion of cells to dry during a simulation. A cell converts to dry when the simulated water level drops below the cell’s bottom elevation. The cell is then deactivated if rewetting is not permitted. Bené and others (2004) report that aquifer depletion in the outcrop areas is plausible and therefore, did not permit rewetting. The majority of cells that converted to dry during the predictive simulation are located in the outcrop areas. Bené and others (2004) note that the probable reasons for these cells converting to dry is due to the interaction between several factors: such as pumpage, aquifer properties, and the relatively thin saturated thickness of the model cells. If concentrated pumpage is the primary factor for a cell converting to dry, the model may be indicating that local pumping is too high. Technically, strata that compose an aquifer will retain some groundwater. For practical purposes however, an aquifer may become an uneconomical resource if water levels drop below the open interval of wells.

Differences in average water level changes reported in Table 6 of this report and the previous scenario (GAM Run 08-64) are shown in Table 7. Comparison of results between the two predictive runs indicate decreases of 2 feet or less beneath Comanche and Erath counties with the increased specified pumpage. Conversely, water levels increase up to 14 feet beneath Tarrant and surrounding counties with the decrease in specified pumpage.

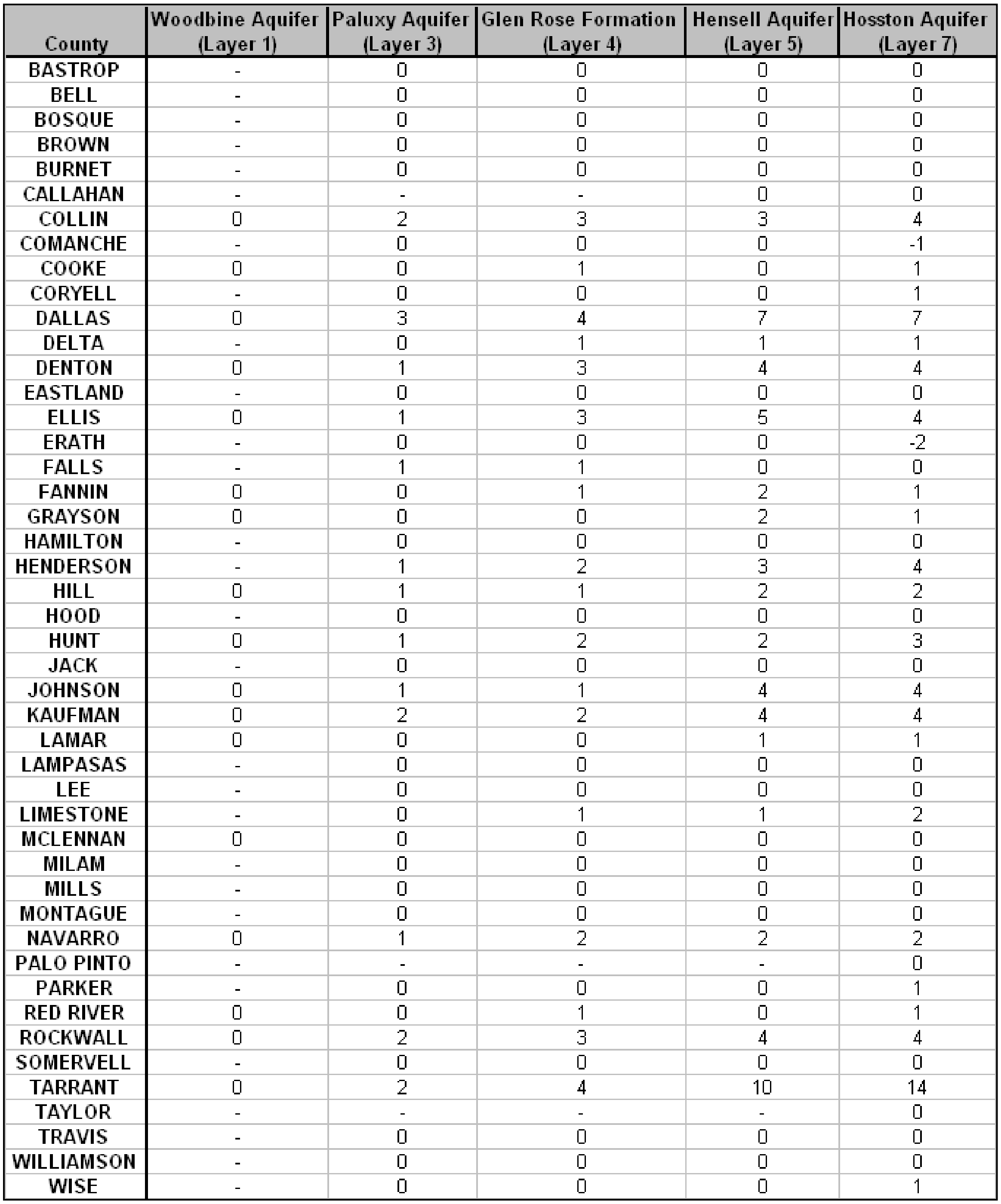
Table 8 shows the specified pumpage for Comanche, Erath, and Tarrant counties for both GAM Run 08-64 and 08-66. Included in Table 8 are the quantities of pumpage at the conclusion of the predictive simulation, the quantity of pumpage removed due to cells converting to dry beneath each county, and the percent of pumpage removed relative to specified pumpage. For GAM Run 08-64, the largest quantity of pumpage removed due to cells converting to dry occurs beneath Comanche County with 3,337 acre-feet per year removed from the water budget, followed by 2,276 acre-feet per year beneath Erath County, and 342 acre-feet per year in Tarrant County. For GAM Run 08-66, the largest quantity of pumpage removed due to cells converting to dry occurs beneath Comanche County with 3,993 acre-feet per year removed from the water budget, followed by 2,428 acre-feet per year beneath Erath County, and 318 acre-feet per year in Tarrant County. For Comanche County, the percent of pumpage removed due to cells converting to dry relative to specified pumpage increases from 13 percent for GAM Run 08-64 to 15 percent for GAM Run 08-66. Conversely, the percent of pumpage removed due to cells converting to dry relative to specified pumpage for Erath and Tarrant counties remains constant at 8 and 2 percent, respectively. This indicates that increasing the specified pumpage for Comanche County in future scenarios will increase the percent of pumpage removed due to cells converting to dry relative to specified pumpage.

Table 6. Average water level changes (feet) by county. Negative values indicate an average lowering of water levels while a positive value indicates an increase in water levels. A dashed line indicates the current delineated aquifer footprint (or strata footprint for layer 4) does not underlie a county.



County	Woodbine Aquifer (Layer 1)	Paluxy Aquifer (Layer 3)	Glen Rose Formation (Layer 4)	Hensell Aquifer (Layer 5)	Hosston Aquifer (Layer 7)
BASTROP	-	-245	-184	-200	-208
BELL	-	-133	-154	-286	-316
BOSQUE	-	-26	-33	-203	-223
BROWN	-	0	0	-1	-1
BURNET	-	-1	-1	-13	-29
CALLAHAN	-	-	-	0	-2
COLLIN	-137	-290	-239	-216	-228
COMANCHE	-	0	0	-2	-11
COOKE	0	-26	-41	-58	-73
CORYELL	-	-14	-15	-162	-181
DALLAS	-109	-234	-218	-256	-283
DELTA	-	-176	-165	-164	-161
DENTON	-16	-94	-125	-166	-197
EASTLAND	-	0	0	0	0
ELLIS	-97	-253	-279	-340	-366
ERATH	-	-1	-1	-11	-28
FALLS	-	-279	-351	-478	-488
FANNIN	-174	-210	-194	-178	-178
GRAYSON	-28	-173	-158	-156	-161
HAMILTON	-	0	-2	-41	-53
HENDERSON	-	-291	-308	-348	-365
HILL	-54	-205	-252	-387	-411
HOOD	-	-1	-2	-16	-56
HUNT	-319	-284	-230	-198	-202
JACK	-	0	0	0	-2
JOHNSON	-4	-41	-85	-221	-255
KAUFMAN	-196	-286	-278	-298	-318
LAMAR	-218	-130	-130	-135	-134
LAMPASAS	-	0	-2	-15	-24
LEE	-	-245	-208	-218	-225
LIMESTONE	-	-333	-396	-492	-509
MCLENNAN	-60	-250	-291	-493	-529
MILAM	-	-242	-281	-321	-334
MILLS	-	0	0	-3	-12
MONTAGUE	-	0	-1	-2	-7
NAVARRO	-176	-326	-348	-407	-421
PALO PINTO	-	-	-	-	0
PARKER	-	-4	-5	-15	-35
RED RIVER	-49	-82	-76	-77	-77
ROCKWALL	-206	-367	-265	-241	-260
SOMERVELL	-	-1	-4	-54	-115
TARRANT	-2	-31	-70	-149	-156
TAYLOR	-	-	-	-	-3
TRAVIS	-	-123	-60	-98	-116
WILLIAMSON	-	-101	-80	-137	-162
WISE	-	-4	-13	-21	-48

Table 7. Difference in average water level changes per county from GAM Run 08-64 (Hill, 2010) and GAM Run 08-66. Values are in feet. Negative values indicate a decrease in water levels while a positive value indicates an increase in water levels. A dashed line indicates the current delineated aquifer footprint (or strata footprint for layer 4) does not underlie a county.



County	Woodbine Aquifer (Layer 1)	Paluxy Aquifer (Layer 3)	Glen Rose Formation (Layer 4)	Hensell Aquifer (Layer 5)	Hosston Aquifer (Layer 7)
BASTROP	-	0	0	0	0
BELL	-	0	0	0	0
BOSQUE	-	0	0	0	0
BROWN	-	0	0	0	0
BURNET	-	0	0	0	0
CALLAHAN	-	-	-	0	0
COLLIN	0	2	3	3	4
COMANCHE	-	0	0	0	-1
COOKE	0	0	1	0	1
CORYELL	-	0	0	0	1
DALLAS	0	3	4	7	7
DELTA	-	0	1	1	1
DENTON	0	1	3	4	4
EASTLAND	-	0	0	0	0
ELLIS	0	1	3	5	4
ERATH	-	0	0	0	-2
FALLS	-	1	1	0	0
FANNIN	0	0	1	2	1
GRAYSON	0	0	0	2	1
HAMILTON	-	0	0	0	0
HENDERSON	-	1	2	3	4
HILL	0	1	1	2	2
HOOD	-	0	0	0	0
HUNT	0	1	2	2	3
JACK	-	0	0	0	0
JOHNSON	0	1	1	4	4
KAUFMAN	0	2	2	4	4
LAMAR	0	0	0	1	1
LAMPASAS	-	0	0	0	0
LEE	-	0	0	0	0
LIMESTONE	-	0	1	1	2
MCLENNAN	0	0	0	0	0
MILAM	-	0	0	0	0
MILLS	-	0	0	0	0
MONTAGUE	-	0	0	0	0
NAVARRO	0	1	2	2	2
PALO PINTO	-	-	-	-	0
PARKER	-	0	0	0	1
RED RIVER	0	0	1	0	1
ROCKWALL	0	2	3	4	4
SOMERVELL	-	0	0	0	0
TARRANT	0	2	4	10	14
TAYLOR	-	-	-	-	0
TRAVIS	-	0	0	0	0
WILLIAMSON	-	0	0	0	0
WISE	-	0	0	0	1

Table 8. Comparison of specified pumpage, pumpage at conclusion of the predictive simulation, quantity of pumpage removed due to cells converting to dry, and percent of pumpage removed relative to specified pumpage for Comanche, Erath, and Tarrant counties. Pumpage values reported are in acre-feet per year.

	Comanche	Erath	Tarrant	Comanche	Erath	Tarrant
	GAM Run 08-64			GAM Run 08-66		
Specified Pumpage	25000	30000	19615	27000	32000	18238
Pumpage*	21663	27724	19273	23007	29572	17920
Quantity of Pumpage Removed**	3337	2276	342	3993	2428	318
% Pumpage Removed	13	8	2	15	8	2

*- Pumpage reported in Appendix A at the conclusion of the predictive simulation. No pumpage is specified in layers 2 and 6 for these counties.

**- Quantity of pumpage removed from water budget due to cells converting to dry.

REFERENCES:

Bené, J., Harden, B., O’Rourke, D., Donnelly, A., and Yelderman, J., 2004, Northern Trinity/Woodbine Groundwater Availability Model: contract report to the Texas Water Development Board by R.W. Harden and Associates, 391 p.

Donnelly, A.C.A., 2007, GAM Run 07-09, Texas Water Development Board GAM Run Report, 24 p.

Environmental Simulations, Inc., 2007, Guide to using Groundwater Vistas Version 5, 372 p.

Harbaugh, A.W. and McDonald, M.G., 1996, User’s Documentation for MODFLOW-96, an update to the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model, U.S. Geological Survey Open-File Report 96-485, 56 p.

Hill, M.E., 2010, GAM Run 08-64, Texas Water Development Board GAM Run Report, 46 p.

Wade, S.C., 2008, GAM Run 08-14mag, Texas Water Development Board GAM Run Report, 7 p.

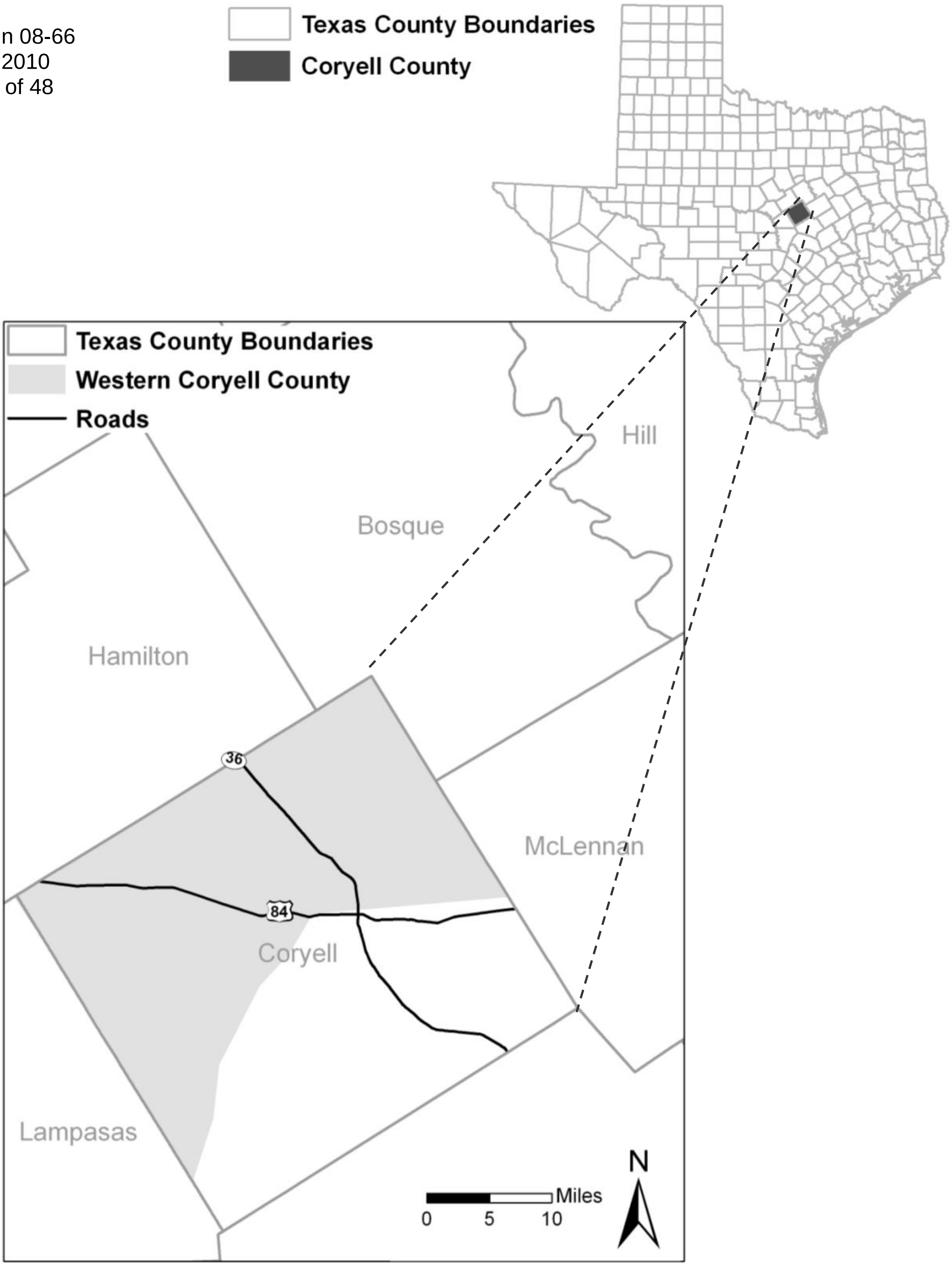


Figure 1. Western Coryell County (shaded area) delineated during the Groundwater Management Area 8 meeting held in Belton, Texas on March 24, 2008, to which an additional underlying pumpage of 928 acre-feet per year are added to layer 5 and an additional underlying pumpage of 480 acre-feet per year are added to layer 7.

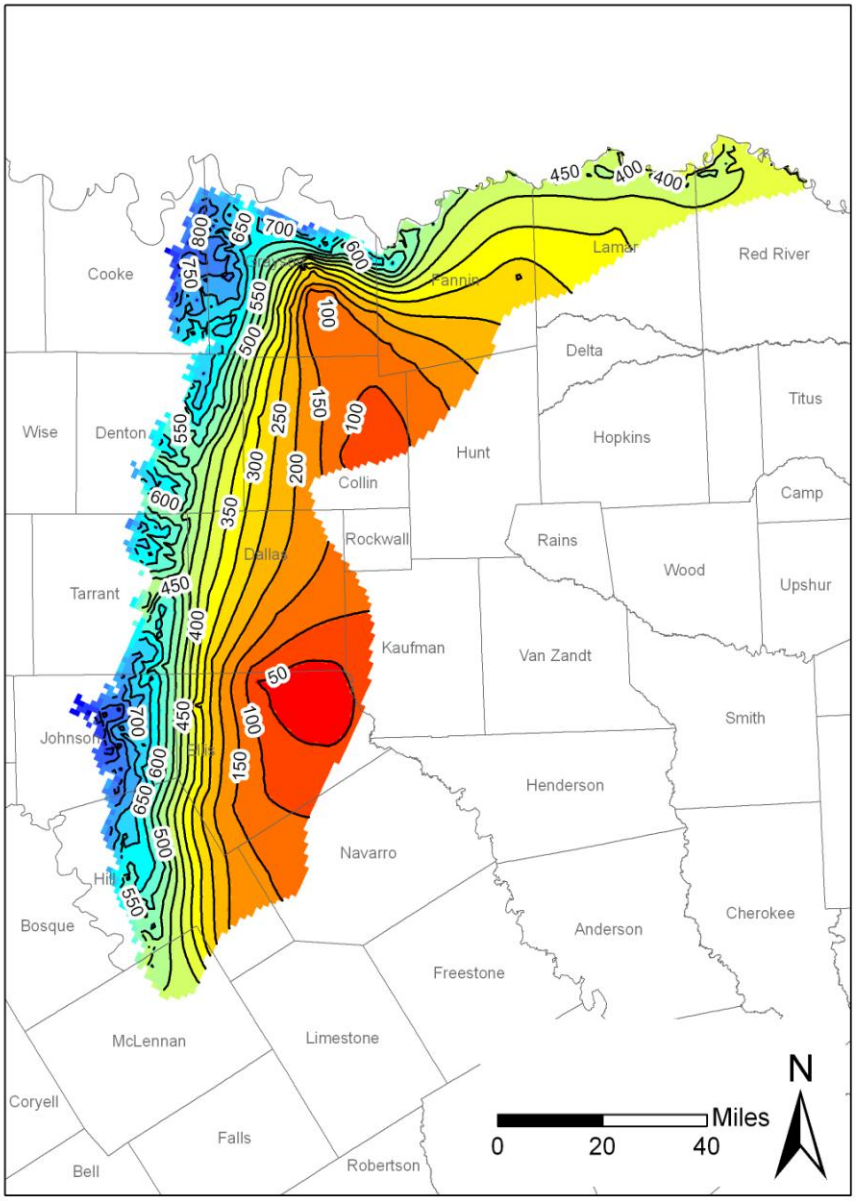


Figure 2. Initial water level elevations for the predictive model run in layer 1 (Woodbine Aquifer) of the groundwater availability model for northern part of the Trinity Aquifer System. Water level elevations are in feet above mean sea level. Contour interval is 50 feet. No cells converted to dry in layer 1.

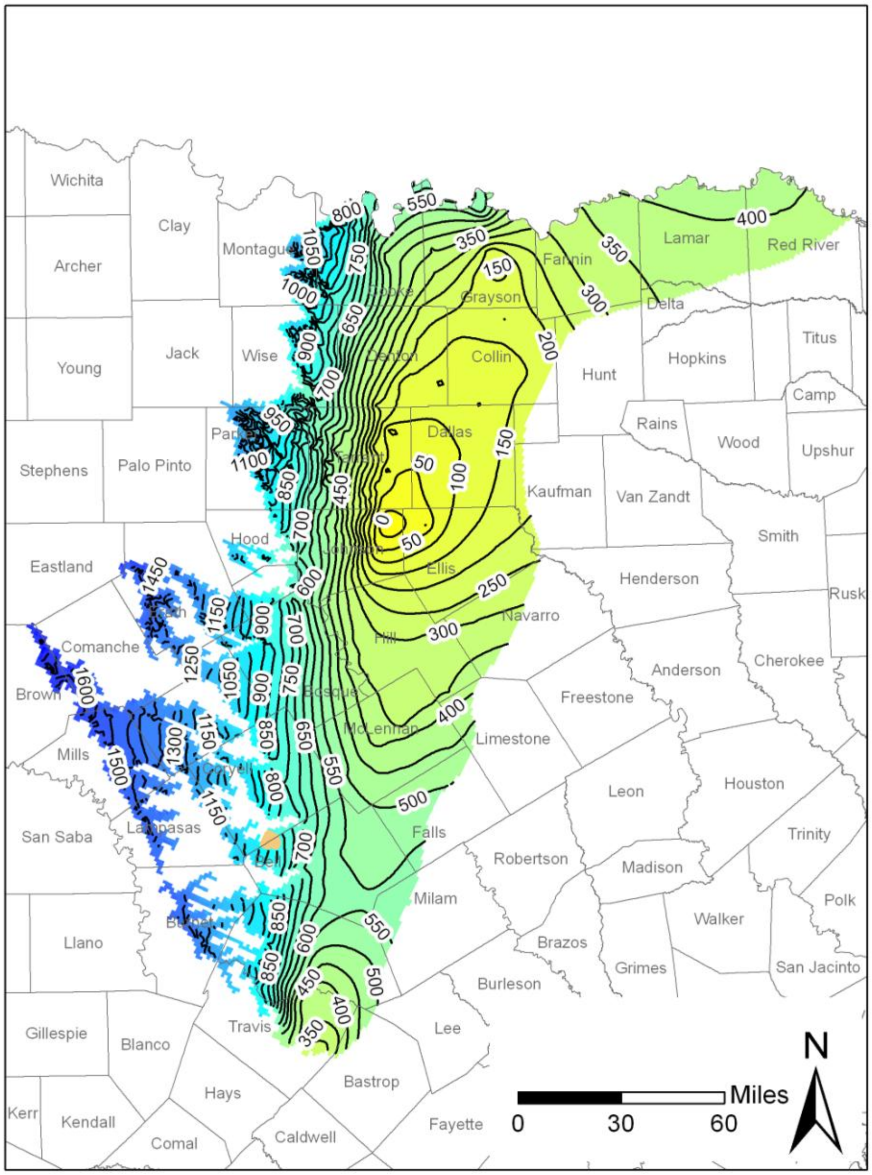


Figure 3. Initial water level elevations for the predictive model run in layer 3 (Paluxy Aquifer) of the groundwater availability model for northern part of the Trinity Aquifer System. Water level elevations are in feet above mean sea level. Contour interval is 50 feet. Cells that converted to dry (shown in tan) are located in the vicinity of the Coryell-Bell county line.

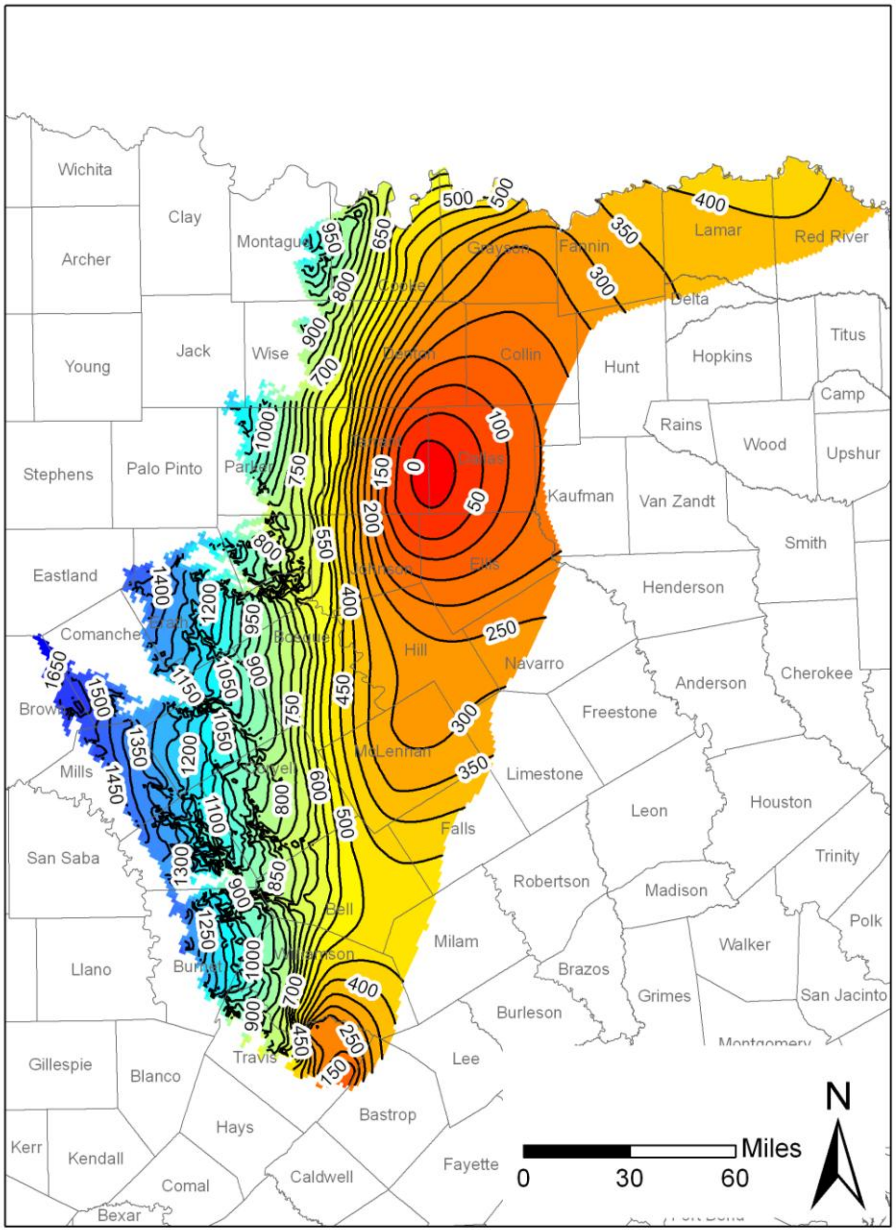


Figure 4. Initial water level elevations for the predictive model run in layer 4 (Glen Rose Formation) of the groundwater availability model for northern part of the Trinity Aquifer System. Water level elevations are in feet above mean sea level. Contour interval is 50 feet. No cells converted to dry in layer 4.

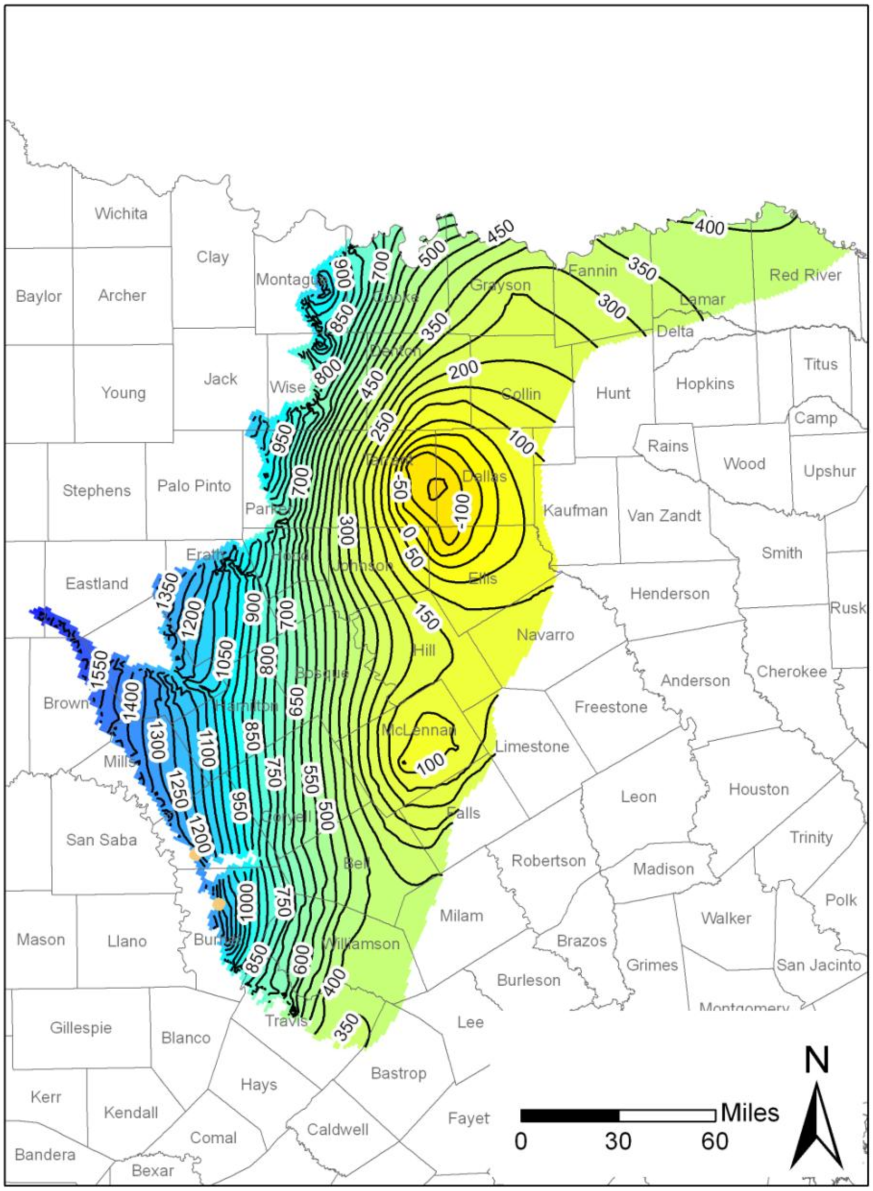


Figure 5. Initial water level elevations for the predictive model run in layer 5 (Hensell Aquifer) of the groundwater availability model for northern part of the Trinity Aquifer System. Water level elevations are in feet above mean sea level. Contour interval is 50 feet. Cells that converted to dry are shown in tan and are located in Lampasas and Burnet counties.

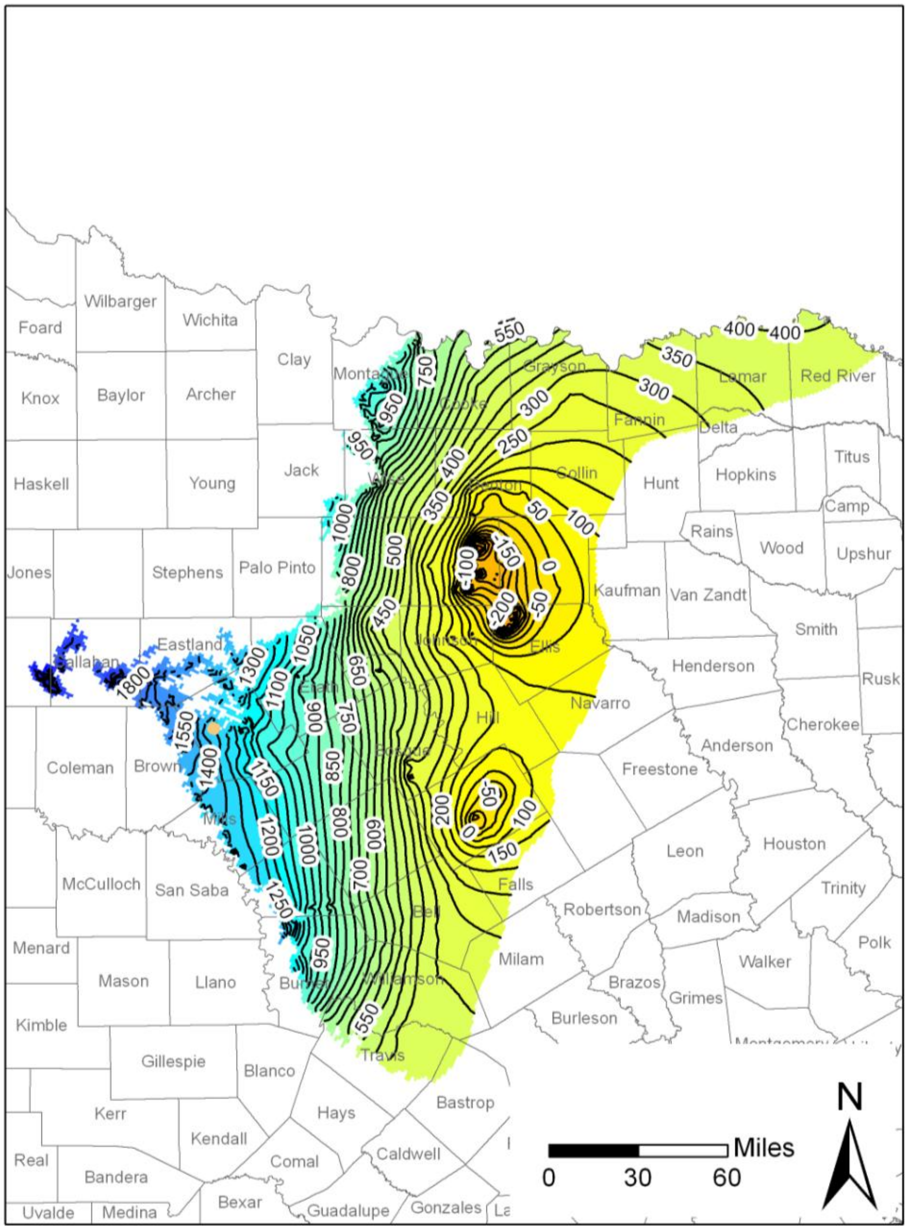


Figure 6. Initial water level elevations for the predictive model run in layer 7 (Hosston Aquifer) of the groundwater availability model for northern part of the Trinity Aquifer System. Water level elevations are in feet above mean sea level. Contour interval is 50 feet. A dry cell, shown in tan, is located in Comanche County.

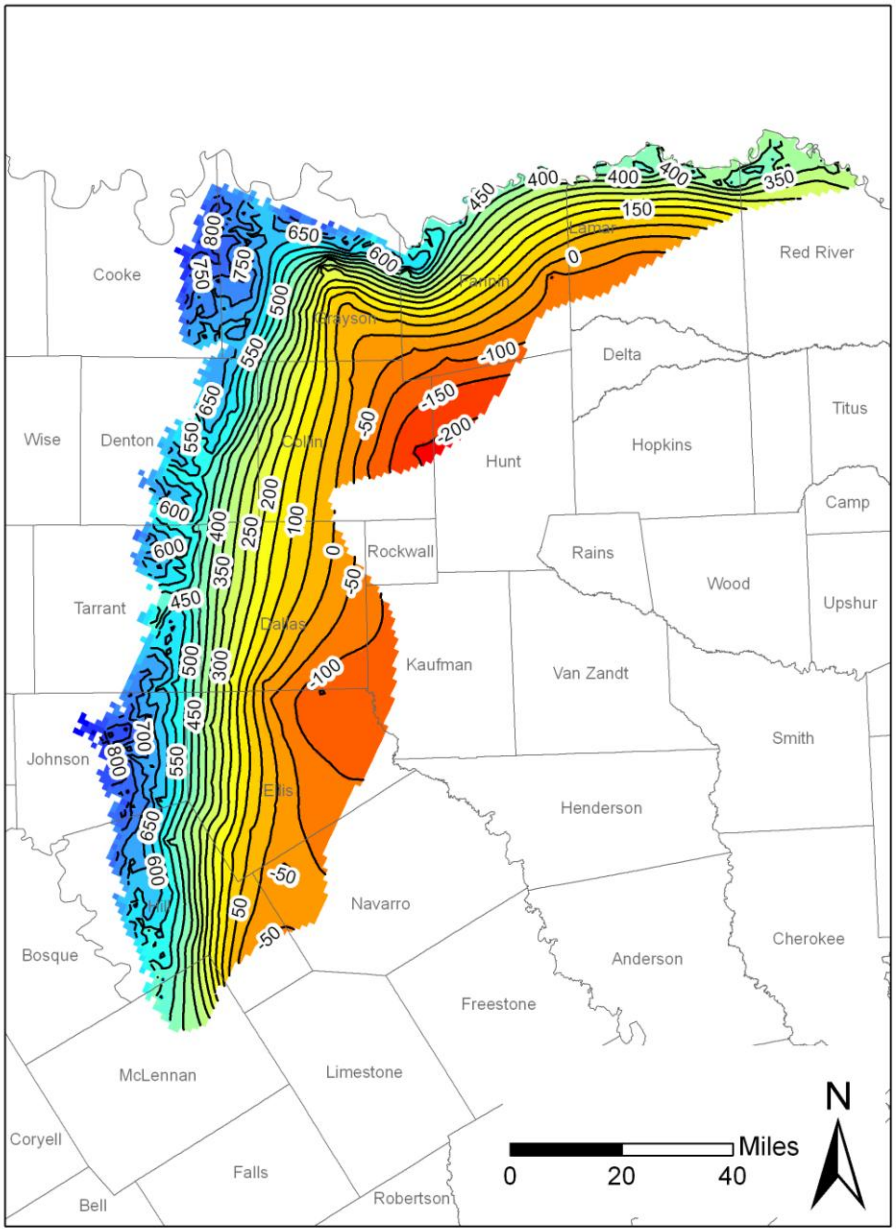


Figure 7. Water level elevations after 50 years using the specified pumpage in layer 1 (Woodbine Aquifer). Water level elevations are in feet above mean sea level. Contour interval is 50 feet. No cells converted to dry in layer 1.

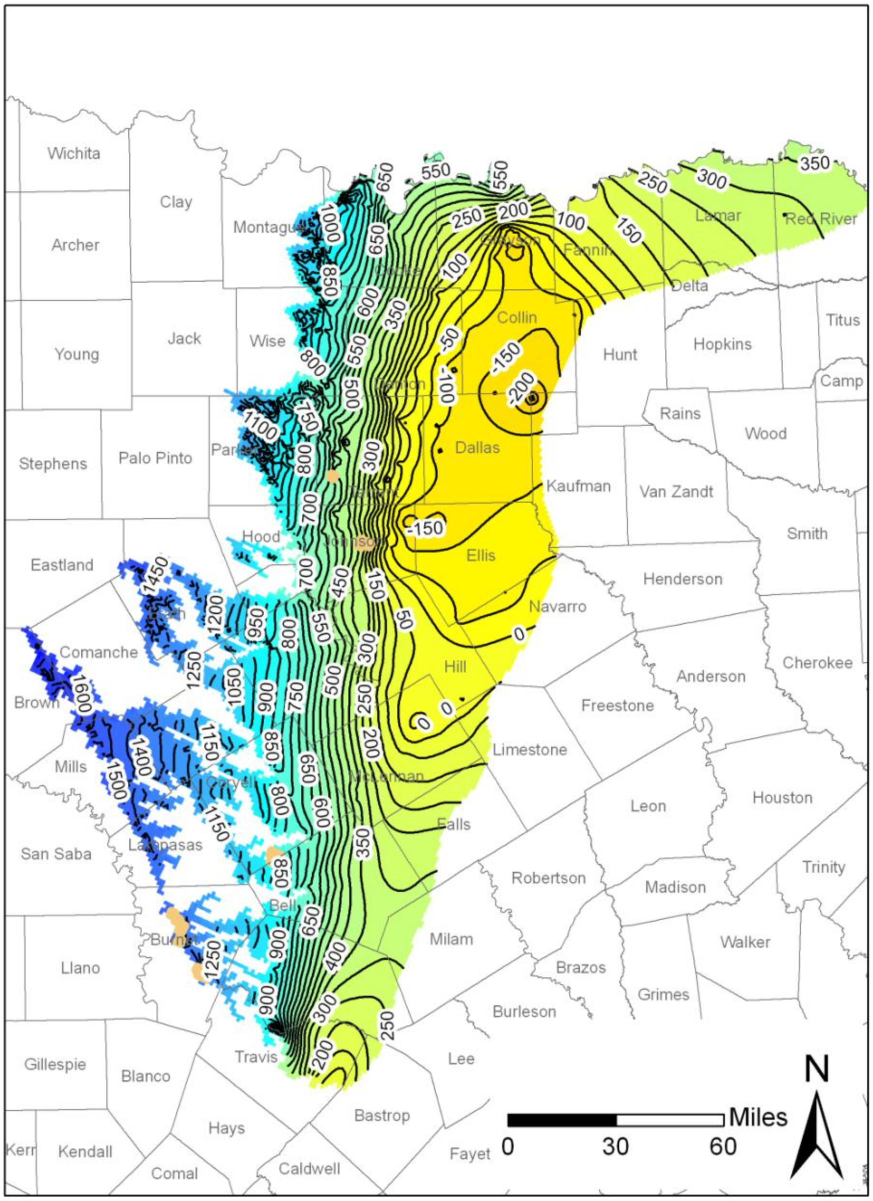


Figure 8. Water level elevations after 50 years using the specified pumpage in layer 3 (Paluxy Aquifer). Water level elevations are in feet above mean sea level. Contour interval is 50 feet. Cells that converted to dry are shown in tan and underlie Burnet, Johnson, and Tarrant counties. Dry cells are also shown in the vicinity of the Coryell-Bell county line.

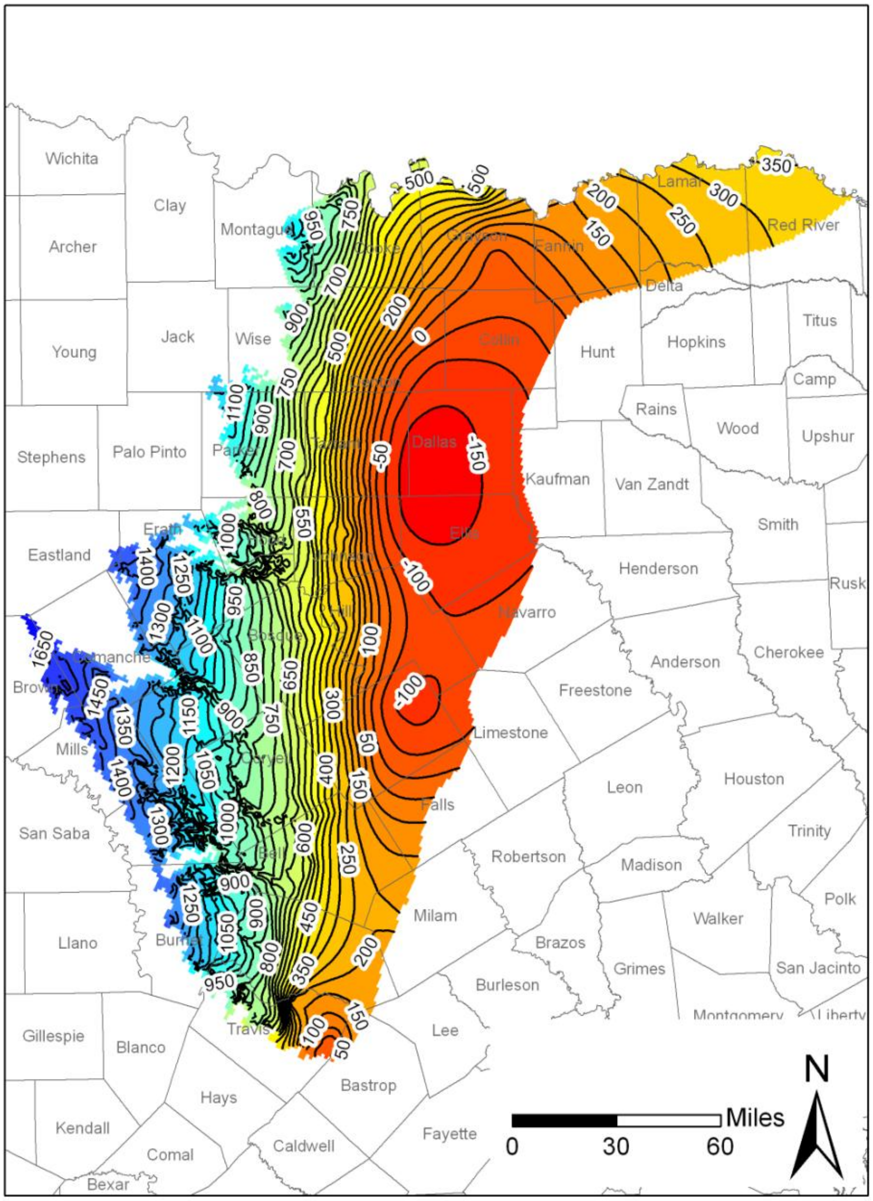


Figure 9. Water level elevations after 50 years using the specified pumpage in layer 4 (Glen Rose Formation). Water level elevations are in feet above mean sea level. Contour interval is 50 feet. No cells converted to dry in layer 4.

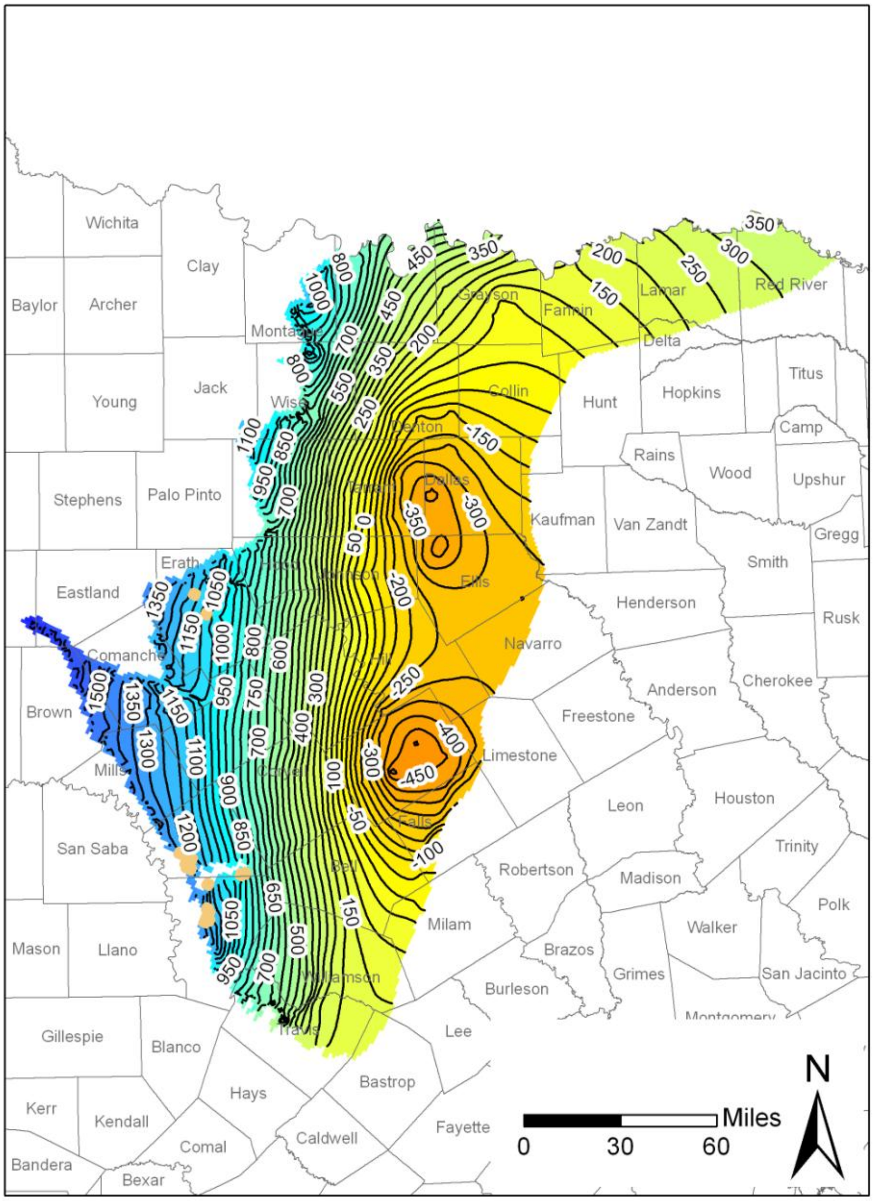


Figure 10. Water level elevations after 50 years using the specified pumpage in layer 5 (Hensell Aquifer). Water level elevations are in feet above mean sea level. Contour interval is 50 feet. Cells that converted to dry are shown in tan. Dry cells are located in Erath, Lampasas, and Burnet counties.

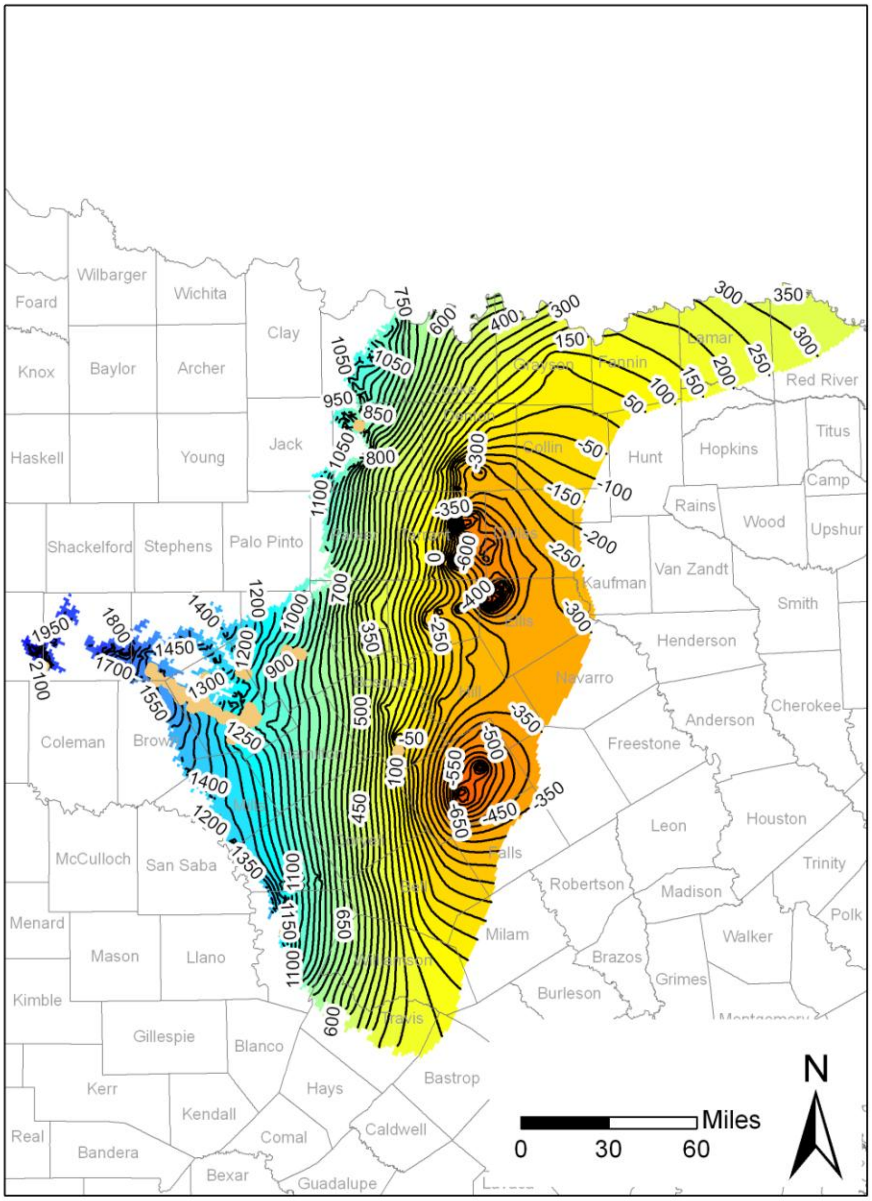


Figure 11. Water level elevations after 50 years using the specified pumpage in layer 7 (Hosston Aquifer). Water level elevations are in feet above mean sea level. Contour interval is 50 feet. Cells that converted to dry are shown in tan. Dry cells are located in Erath, Eastland, Comanche, Burnet, Bosque, Brown, and Wise counties. Additional dry cells are located in the vicinity of the Callahan-Taylor county line.

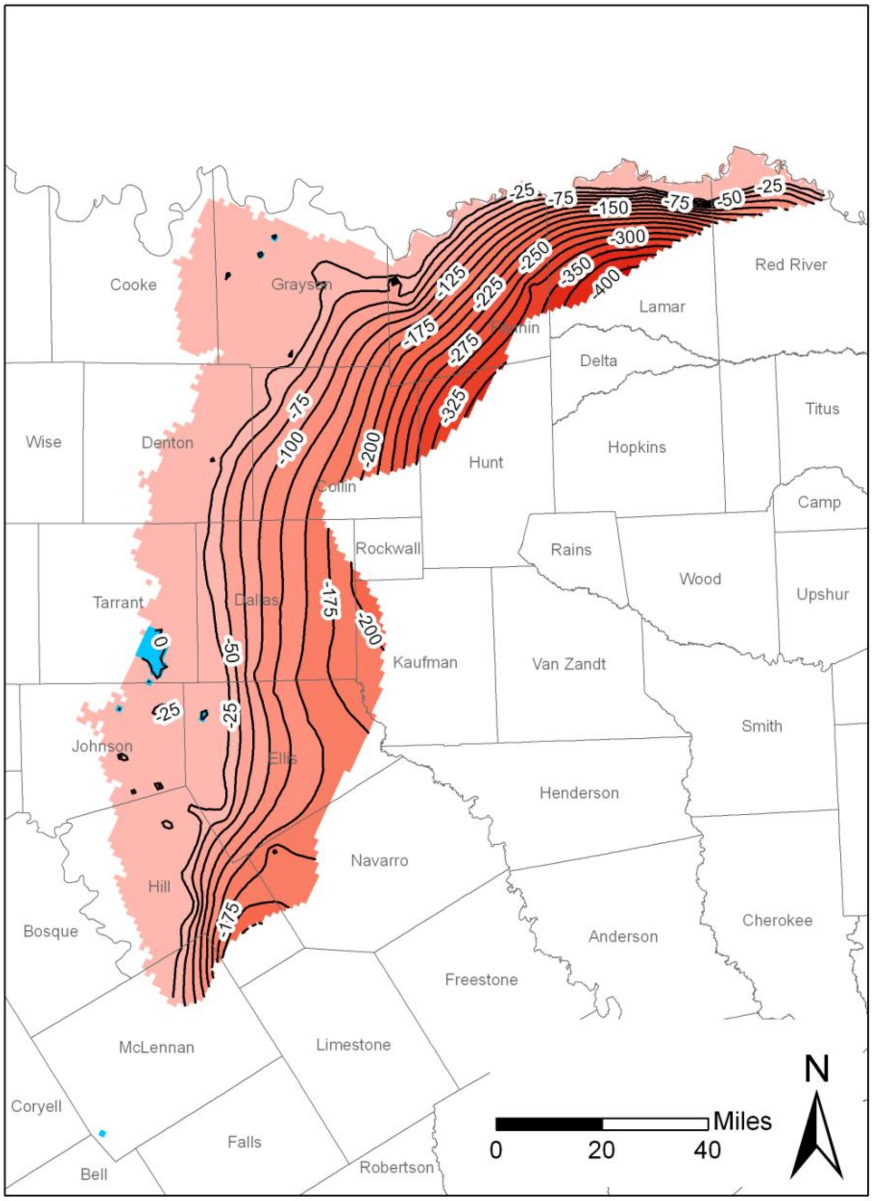


Figure 12. Changes in water levels after 50 years using the specified pumpage in layer 1 (Woodbine Aquifer). Water level changes are in feet. Contour interval is 25 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue. No cells converted to dry in layer 1.

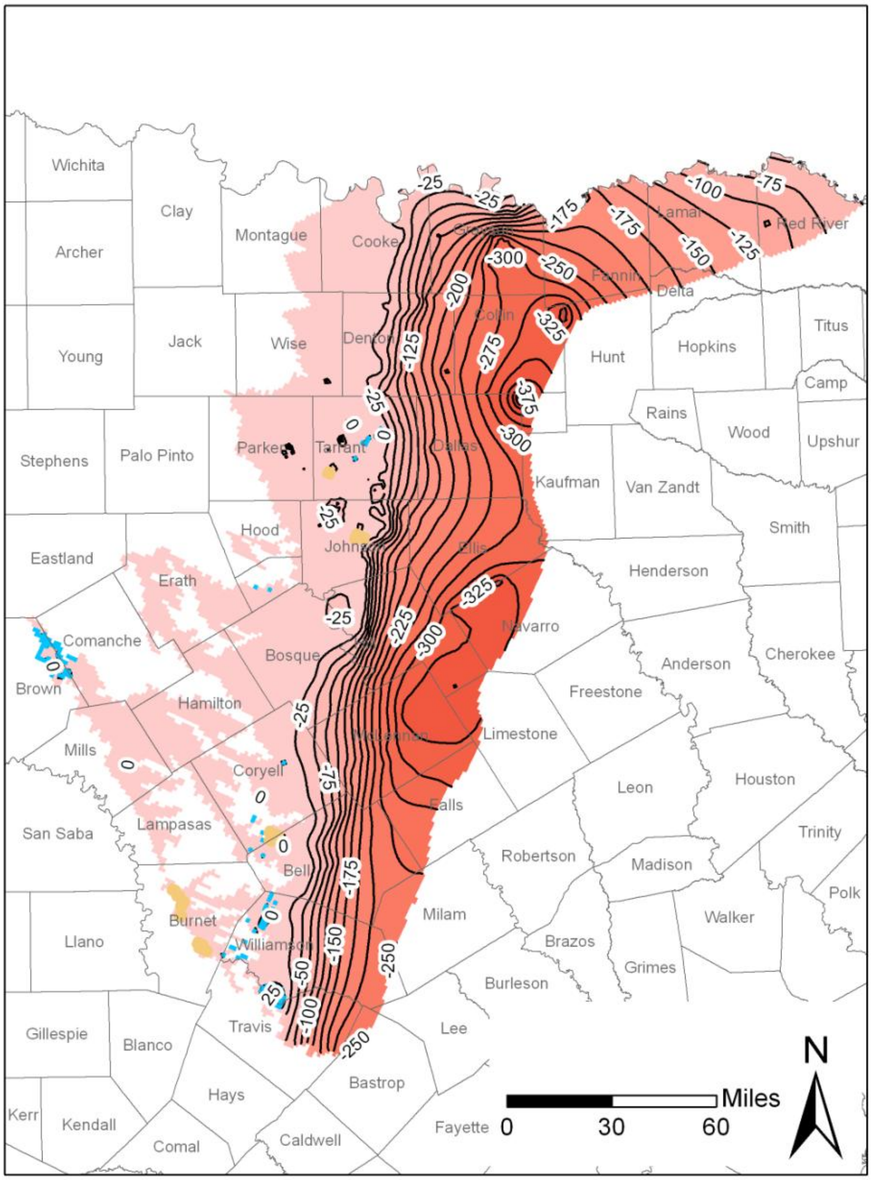


Figure 13. Changes in water levels after 50 years using the specified pumpage in layer 3 (Paluxy Aquifer). Water level changes are in feet. Contour interval is 25 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue. Cells that converted to dry are shown in tan and underlie Burnet, Johnson, and Tarrant counties. Dry cells are also shown in the vicinity of the Coryell-Bell county line.

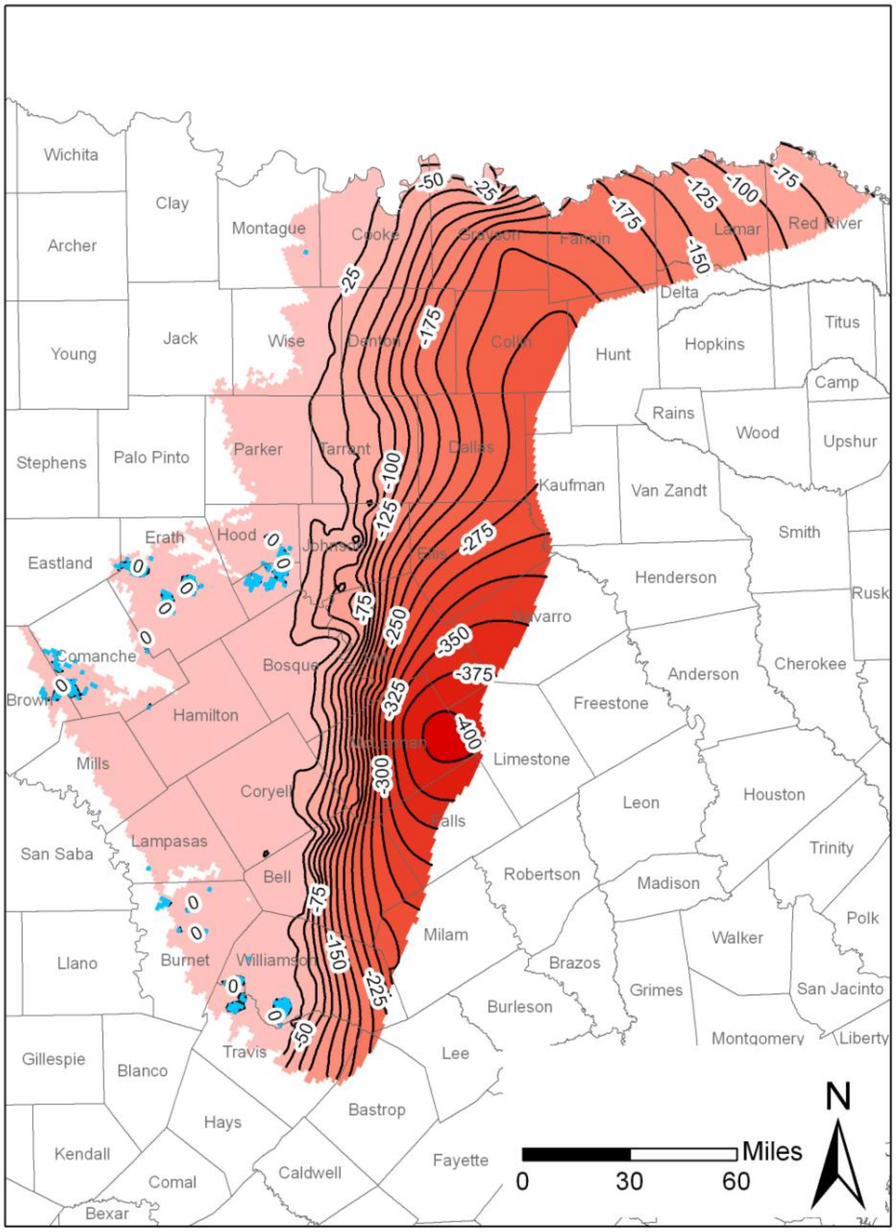


Figure 14. Changes in water levels after 50 years using the specified pumpage in layer 4 (Glen Rose Formation). Water level changes are in feet. Contour interval is 25 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue. No cells converted to dry in layer 4.

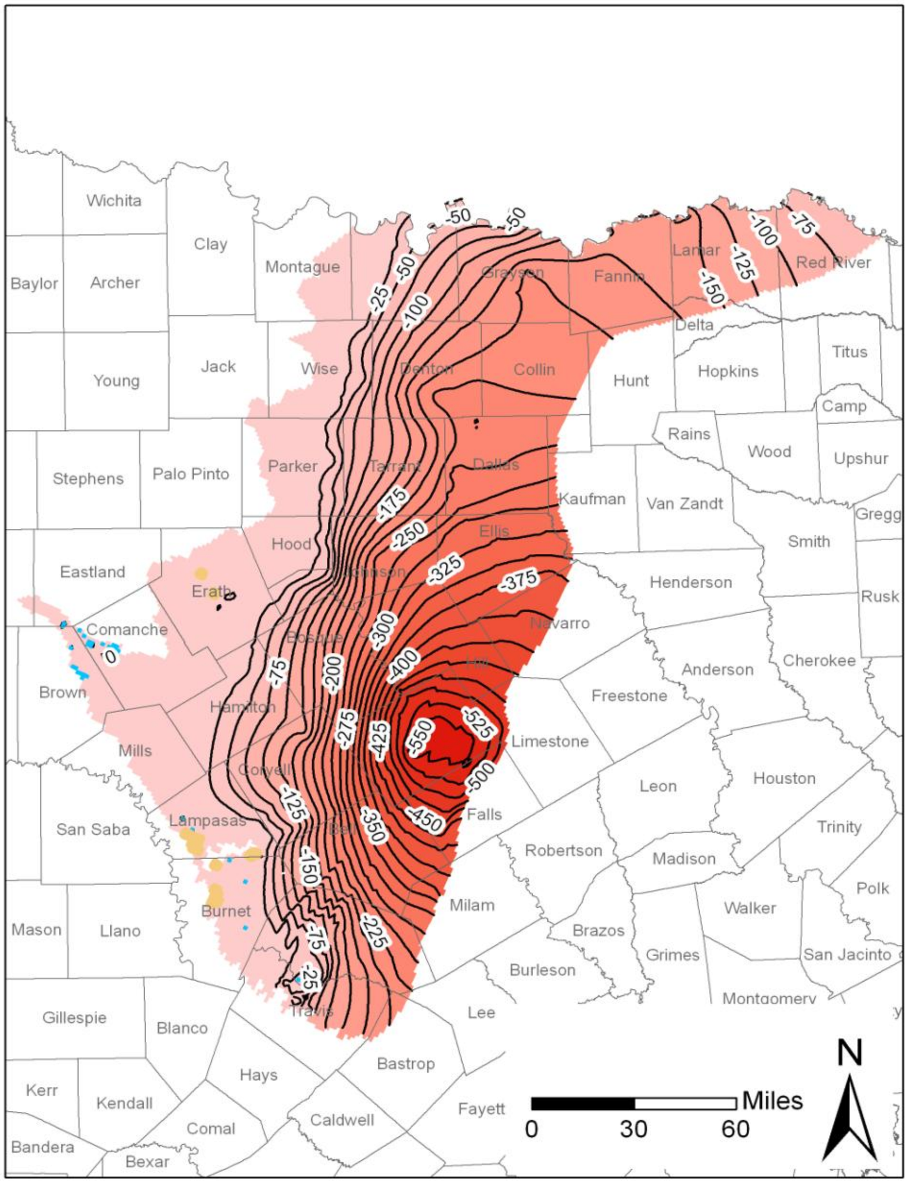


Figure 15. Changes in water levels after 50 years using the specified pumpage in layer 5 (Hensell Aquifer). Water level changes are in feet. Contour interval is 25 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue. Cells that converted to dry are shown in tan. Dry cells are located in Erath, Lampasas, and Burnet counties.

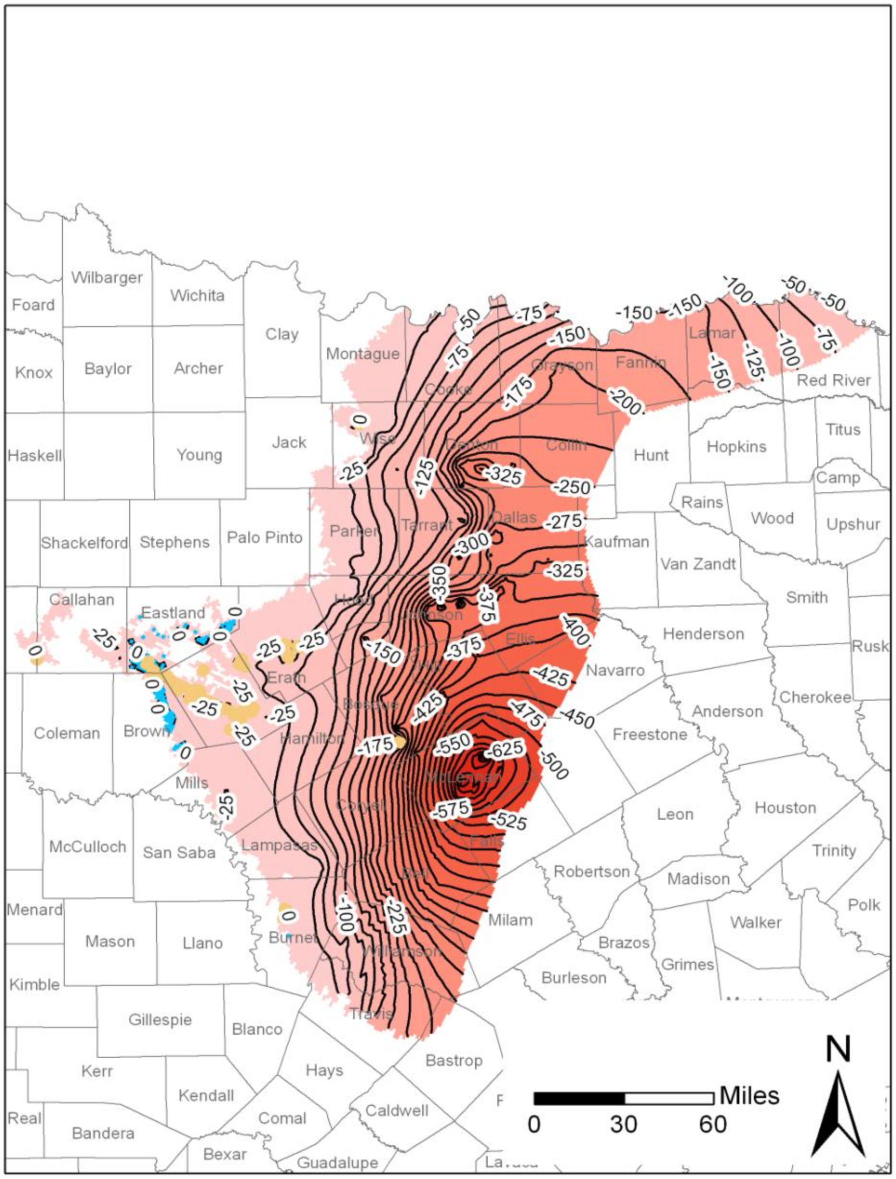


Figure 16. Changes in water levels after 50 years using the specified pumpage in layer 7 (Hosston Aquifer). Water level changes are in feet. Contour interval is 25 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue. Cells that converted to dry are shown in tan. Dry cells are located in Erath, Eastland, Comanche, Burnet, Bosque, Brown, and Wise counties. Additional dry cells are located in the vicinity of the Callahan-Taylor county line.

Appendix A

Water Budget for the 50-year Predictive Simulation

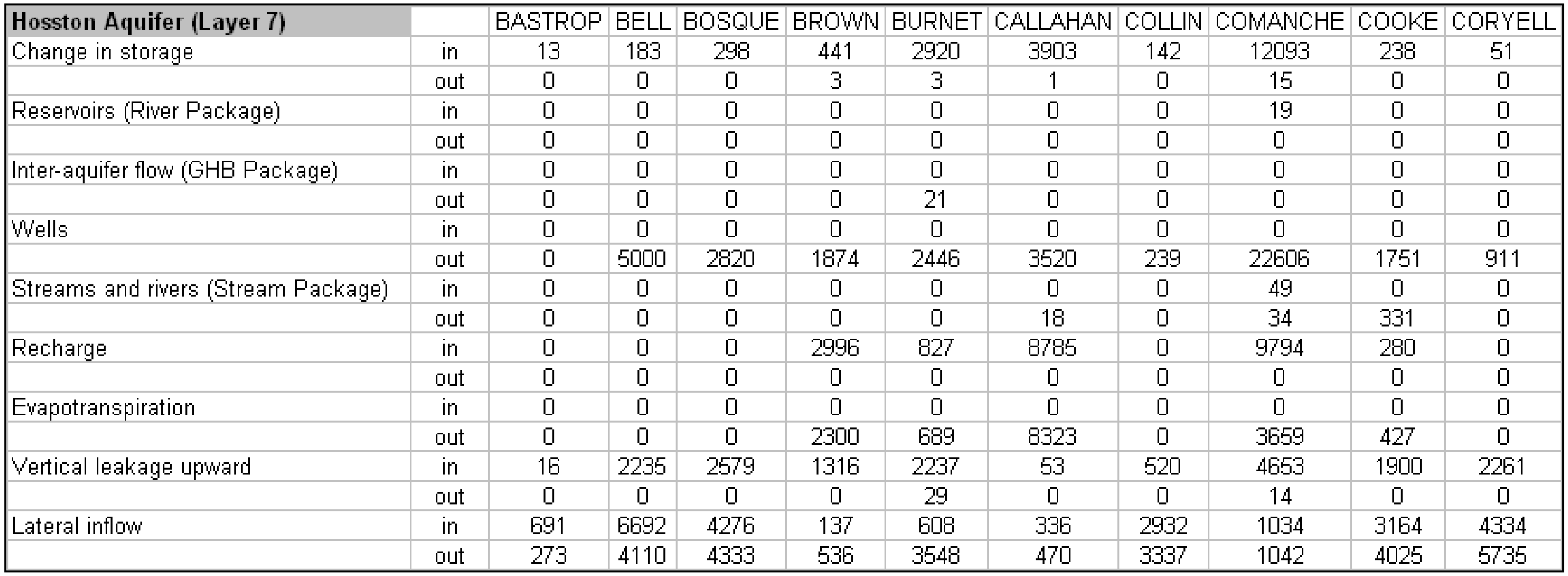
Table A-1. Annual water budgets for each county at the end of the 50-year predictive portion of the model run using the requested baseline pumpage in the groundwater availability model for the northern part of the Trinity Aquifer (in acre-feet per year).

Woodbine Aquifer (Layer 1)		BASTROP	BELL	BOSQUE	BROWN	BURNET	CALLAHAN	COLLIN	COMANCHE	COOKE	CORYELL
Change in storage	in	-	-	-	-	-	-	399	-	2074	-
	out	-	-	-	-	-	-	0	-	0	-
Reservoirs (River Package)	in	-	-	-	-	-	-	0	-	6	-
	out	-	-	-	-	-	-	0	-	0	-
Inter-aquifer flow (GHB Package)	in	-	-	-	-	-	-	112	-	0	-
	out	-	-	-	-	-	-	0	-	0	-
Wells	in	-	-	-	-	-	-	0	-	0	-
	out	-	-	-	-	-	-	2223	-	154	-
Streams and rivers (Stream Package)	in	-	-	-	-	-	-	0	-	0	-
	out	-	-	-	-	-	-	0	-	0	-
Recharge	in	-	-	-	-	-	-	0	-	8156	-
	out	-	-	-	-	-	-	0	-	0	-
Evapotranspiration	in	-	-	-	-	-	-	0	-	0	-
	out	-	-	-	-	-	-	0	-	9768	-
Lateral inflow	in	-	-	-	-	-	-	3357	-	139	-
	out	-	-	-	-	-	-	1241	-	438	-
Vertical leakage downward	in	-	-	-	-	-	-	90	-	0	-
	out	-	-	-	-	-	-	0	-	7	-
Paluxy Aquifer (Layer 3)		BASTROP	BELL	BOSQUE	BROWN	BURNET	CALLAHAN	COLLIN	COMANCHE	COOKE	CORYELL
Change in storage	in	15	203	1477	172	446	-	121	208	6669	656
	out	0	16	3	0	0	-	0	0	0	7
Reservoirs (River Package)	in	0	0	0	0	0	-	0	0	0	0
	out	0	0	0	0	0	-	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	-	0	0	0	0
	out	0	0	0	0	0	-	0	0	0	0
Wells	in	0	0	0	0	0	-	0	0	0	0
	out	0	91	1010	18	182	-	1759	17	3613	222
Streams and rivers (Stream Package)	in	0	0	0	0	0	-	0	0	84	0
	out	0	0	492	0	31	-	0	0	825	267
Recharge	in	0	46	3790	3735	5170	-	0	5468	4423	5690
	out	0	0	0	0	0	-	0	0	0	0
Evapotranspiration	in	0	0	0	0	0	-	0	0	0	0
	out	0	0	3431	3571	5306	-	0	5550	4029	5768
Vertical leakage upward	in	0	198	360	11	30	-	221	22	299	221
	out	3	12	7	0	1	-	0	0	0	5
Lateral inflow	in	0	51	472	21	2	-	1705	182	795	212
	out	3	22	654	115	6	-	905	65	2741	238
Vertical leakage downward	in	0	0	0	2	2	-	307	1	19	1
	out	13	354	500	238	122	-	0	250	1470	271

Table A-1. (continued).

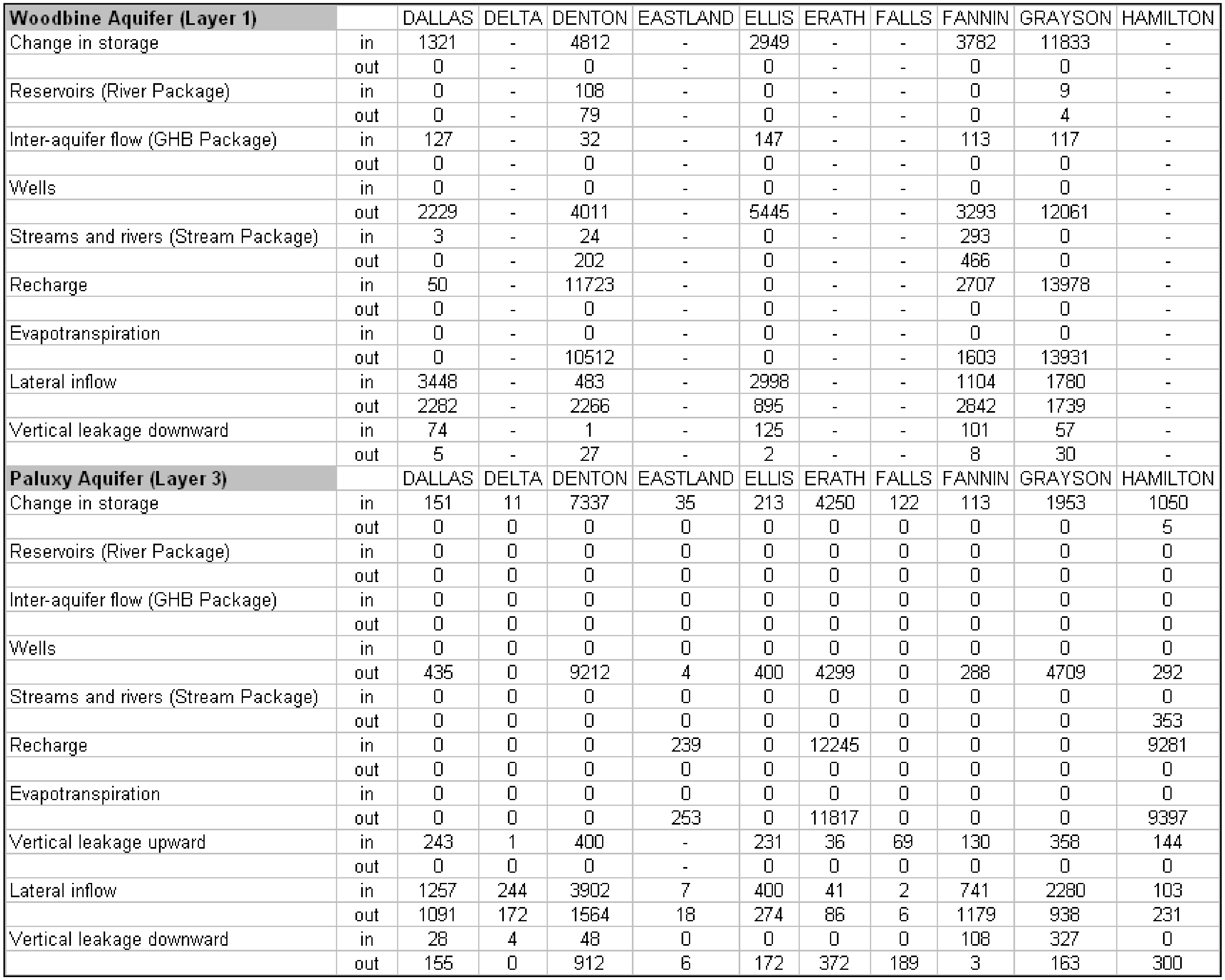
Glen Rose Formation (Layer 4)		BASTROP	BELL	BOSQUE	BROWN	BURNET	CALLAHAN	COLLIN	COMANCHE	COOKE	CORYELL
Change in storage	in	12	2681	1861	120	2804	-	117	483	36	6063
	out	0	0	0	0	23	-	0	3	0	0
Reservoirs (River Package)	in	0	15	0	0	0	-	0	0	0	6
	out	0	0	0	0	0	-	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	-	0	0	0	0
	out	0	0	0	0	0	-	0	0	0	0
Wells	in	0	0	0	0	0	-	0	0	0	0
	out	1	880	258	0	200	-	0	0	0	783
Streams and rivers (Stream Package)	in	0	276	64	0	167	-	0	0	0	435
	out	0	993	322	0	736	-	0	5	0	736
Recharge	in	0	2189	677	1937	8841	-	0	8599	0	8068
	out	0	0	0	0	0	-	0	0	0	0
Evapotranspiration	in	0	0	0	0	0	-	0	0	0	0
	out	0	2883	401	1909	9072	-	0	8658	0	10717
Vertical leakage upward	in	13	354	500	238	122	-	0	250	1470	271
	out	0	0	0	2	2	-	307	1	19	1
Lateral inflow	in	17	1247	922	19	266	-	105	268	24	951
	out	195	590	797	106	1258	-	46	238	83	993
Vertical leakage downward	in	10	0	0	0	1	-	120	0	9	0
	out	0	1415	2247	297	967	-	10	695	1442	2562
Hensell Aquifer (Layer 5)		BASTROP	BELL	BOSQUE	BROWN	BURNET	CALLAHAN	COLLIN	COMANCHE	COOKE	CORYELL
Change in storage	in	15	169	746	853	3601	119	140	4586	3970	2099
	out	0	0	0	0	1	0	0	0	0	0
Reservoirs (River Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Wells	in	0	0	0	0	0	0	0	0	0	0
	out	0	1100	1743	79	671	124	102	384	1650	1767
Streams and rivers (Stream Package)	in	0	0	0	0	0	0	0	0	139	0
	out	0	0	0	0	0	0	0	241	177	0
Recharge	in	0	0	0	3748	1167	661	0	13544	452	0
	out	0	0	0	0	0	0	0	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	3130	1371	503	0	13128	509	0
Vertical leakage upward	in	0	1415	2247	297	967	-	10	695	1442	2562
	out	10	0	0	0	1	-	120	0	9	0
Lateral inflow	in	0	3665	7757	64	244	13	1653	1009	1953	4751
	out	0	2061	6467	483	2446	112	1172	1548	4211	5397
Vertical leakage downward	in	1	0	0	0	29	0	0	14	1	0
	out	6	2088	2540	1269	1449	53	405	4546	1831	2248

Table A-1. (continued).



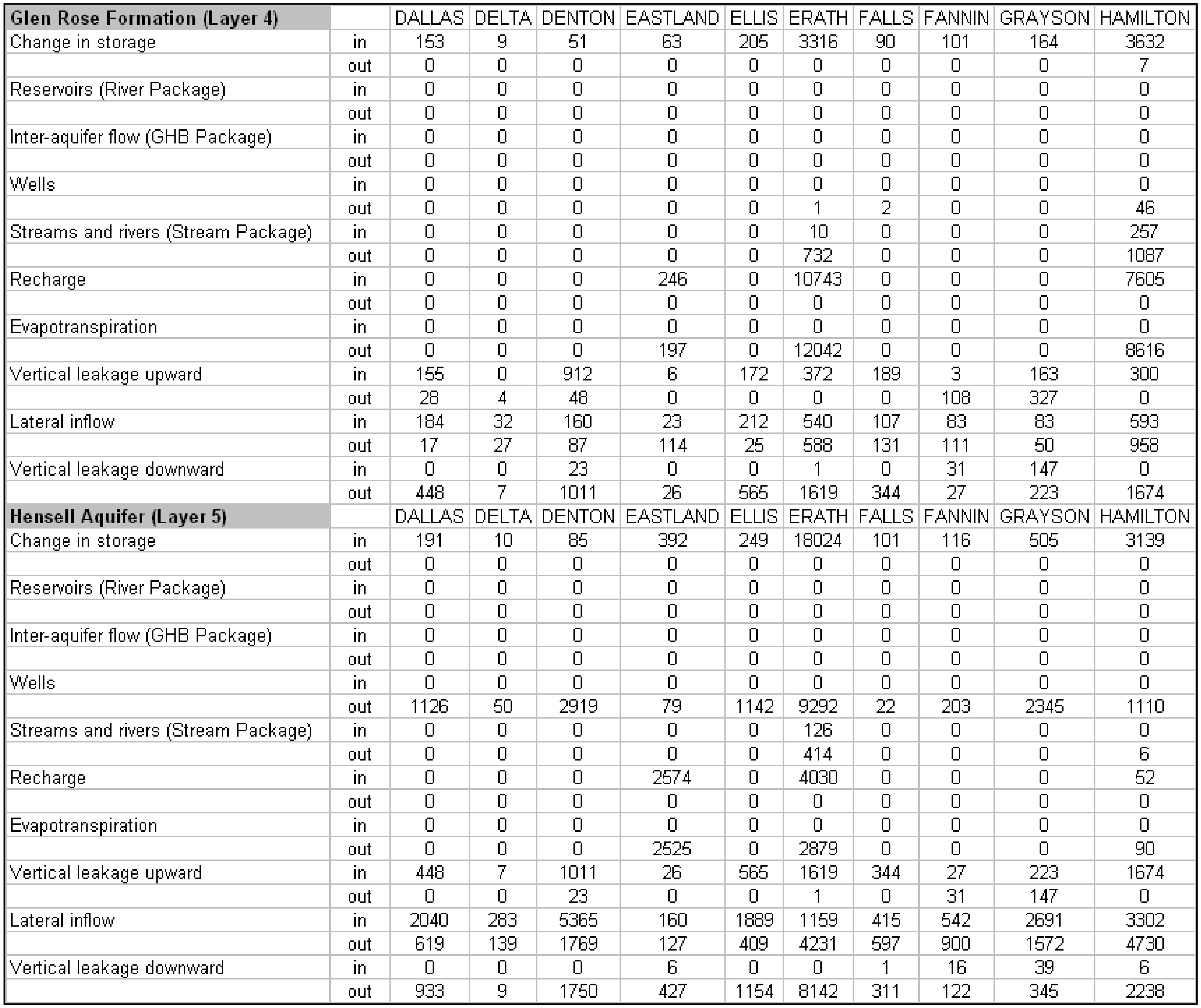
Hosston Aquifer (Layer 7)		BASTROP	BELL	BOSQUE	BROWN	BURNET	CALLAHAN	COLLIN	COMANCHE	COOKE	CORYELL
Change in storage	in	13	183	298	441	2920	3903	142	12093	238	51
	out	0	0	0	3	3	1	0	15	0	0
Reservoirs (River Package)	in	0	0	0	0	0	0	0	19	0	0
	out	0	0	0	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	21	0	0	0	0	0
Wells	in	0	0	0	0	0	0	0	0	0	0
	out	0	5000	2820	1874	2446	3520	239	22606	1751	911
Streams and rivers (Stream Package)	in	0	0	0	0	0	0	0	49	0	0
	out	0	0	0	0	0	18	0	34	331	0
Recharge	in	0	0	0	2996	827	8785	0	9794	280	0
	out	0	0	0	0	0	0	0	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	2300	689	8323	0	3659	427	0
Vertical leakage upward	in	16	2235	2579	1316	2237	53	520	4653	1900	2261
	out	0	0	0	0	29	0	0	14	0	0
Lateral inflow	in	691	6692	4276	137	608	336	2932	1034	3164	4334
	out	273	4110	4333	536	3548	470	3337	1042	4025	5735

Table A-1. (continued).



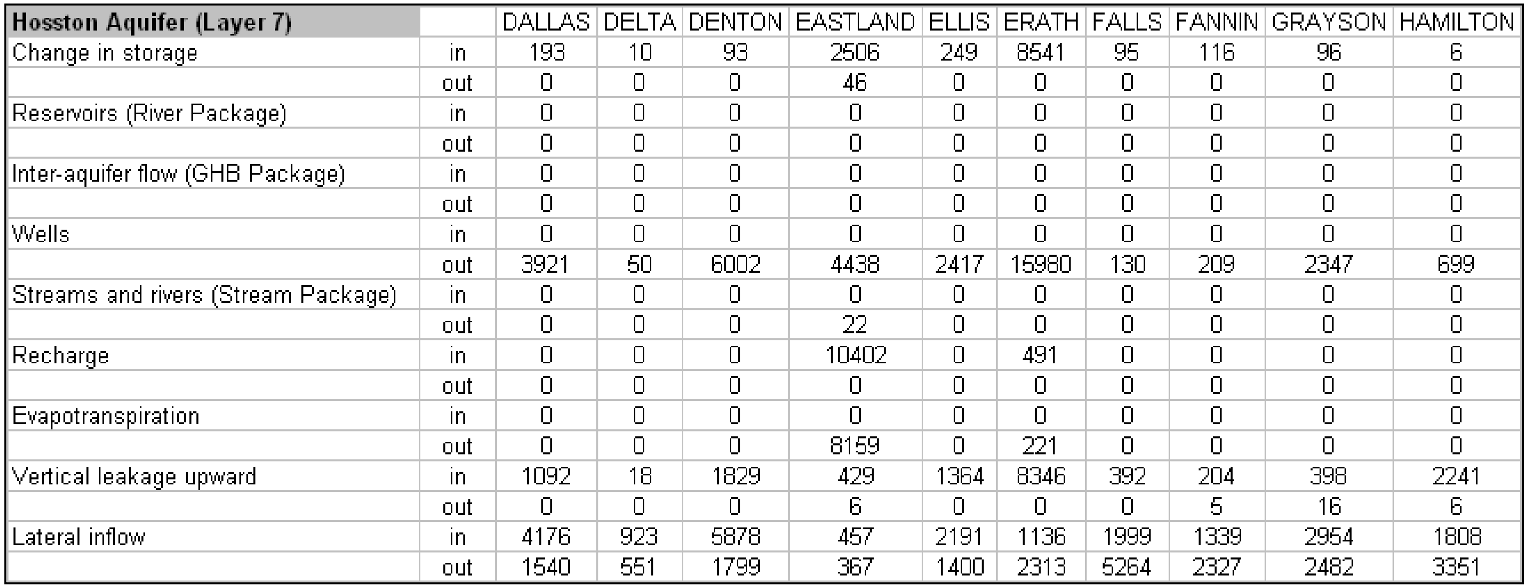
Woodbine Aquifer (Layer 1)		DALLAS	DELTA	DENTON	EASTLAND	ELLIS	ERATH	FALLS	FANNIN	GRAYSON	HAMILTON
Change in storage	in	1321	-	4812	-	2949	-	-	3782	11833	-
	out	0	-	0	-	0	-	-	0	0	-
Reservoirs (River Package)	in	0	-	108	-	0	-	-	0	9	-
	out	0	-	79	-	0	-	-	0	4	-
Inter-aquifer flow (GHB Package)	in	127	-	32	-	147	-	-	113	117	-
	out	0	-	0	-	0	-	-	0	0	-
Wells	in	0	-	0	-	0	-	-	0	0	-
	out	2229	-	4011	-	5445	-	-	3293	12061	-
Streams and rivers (Stream Package)	in	3	-	24	-	0	-	-	293	0	-
	out	0	-	202	-	0	-	-	466	0	-
Recharge	in	50	-	11723	-	0	-	-	2707	13978	-
	out	0	-	0	-	0	-	-	0	0	-
Evapotranspiration	in	0	-	0	-	0	-	-	0	0	-
	out	0	-	10512	-	0	-	-	1603	13931	-
Lateral inflow	in	3448	-	483	-	2998	-	-	1104	1780	-
	out	2282	-	2266	-	895	-	-	2842	1739	-
Vertical leakage downward	in	74	-	1	-	125	-	-	101	57	-
	out	5	-	27	-	2	-	-	8	30	-
Paluxy Aquifer (Layer 3)		DALLAS	DELTA	DENTON	EASTLAND	ELLIS	ERATH	FALLS	FANNIN	GRAYSON	HAMILTON
Change in storage	in	151	11	7337	35	213	4250	122	113	1953	1050
	out	0	0	0	0	0	0	0	0	0	5
Reservoirs (River Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Wells	in	0	0	0	0	0	0	0	0	0	0
	out	435	0	9212	4	400	4299	0	288	4709	292
Streams and rivers (Stream Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	353
Recharge	in	0	0	0	239	0	12245	0	0	0	9281
	out	0	0	0	0	0	0	0	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	253	0	11817	0	0	0	9397
Vertical leakage upward	in	243	1	400	-	231	36	69	130	358	144
	out	0	0	0	-	0	0	0	0	0	0
Lateral inflow	in	1257	244	3902	7	400	41	2	741	2280	103
	out	1091	172	1564	18	274	86	6	1179	938	231
Vertical leakage downward	in	28	4	48	0	0	0	0	108	327	0
	out	155	0	912	6	172	372	189	3	163	300

Table A-1. (continued).



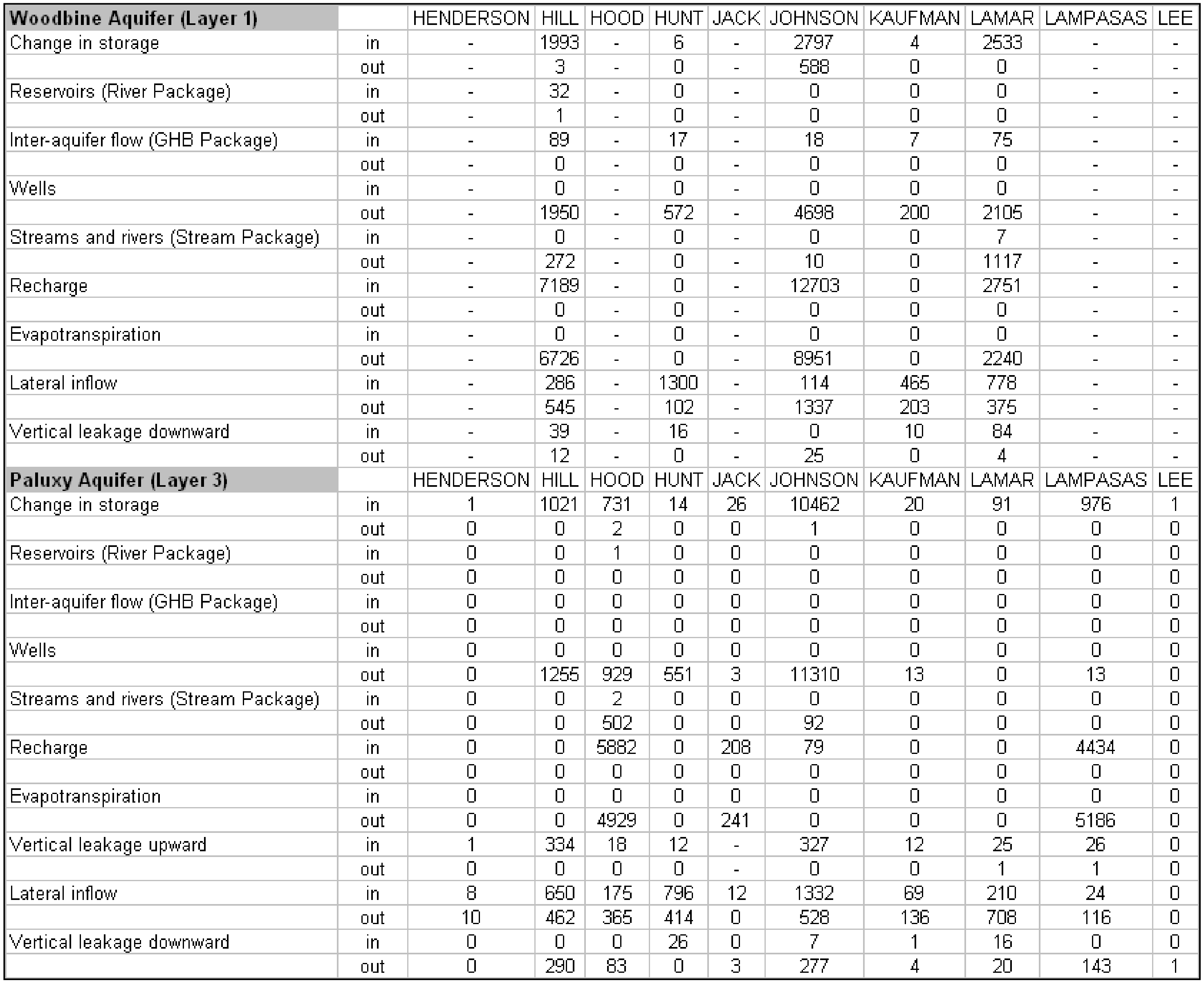
Glen Rose Formation (Layer 4)		DALLAS	DELTA	DENTON	EASTLAND	ELLIS	ERATH	FALLS	FANNIN	GRAYSON	HAMILTON
Change in storage	in	153	9	51	63	205	3316	90	101	164	3632
	out	0	0	0	0	0	0	0	0	0	7
Reservoirs (River Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Wells	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	1	2	0	0	46
Streams and rivers (Stream Package)	in	0	0	0	0	0	10	0	0	0	257
	out	0	0	0	0	0	732	0	0	0	1087
Recharge	in	0	0	0	246	0	10743	0	0	0	7605
	out	0	0	0	0	0	0	0	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	197	0	12042	0	0	0	8616
Vertical leakage upward	in	155	0	912	6	172	372	189	3	163	300
	out	28	4	48	0	0	0	0	108	327	0
Lateral inflow	in	184	32	160	23	212	540	107	83	83	593
	out	17	27	87	114	25	588	131	111	50	958
Vertical leakage downward	in	0	0	23	0	0	1	0	31	147	0
	out	448	7	1011	26	565	1619	344	27	223	1674
Hensell Aquifer (Layer 5)		DALLAS	DELTA	DENTON	EASTLAND	ELLIS	ERATH	FALLS	FANNIN	GRAYSON	HAMILTON
Change in storage	in	191	10	85	392	249	18024	101	116	505	3139
	out	0	0	0	0	0	0	0	0	0	0
Reservoirs (River Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Wells	in	0	0	0	0	0	0	0	0	0	0
	out	1126	50	2919	79	1142	9292	22	203	2345	1110
Streams and rivers (Stream Package)	in	0	0	0	0	0	126	0	0	0	0
	out	0	0	0	0	0	414	0	0	0	6
Recharge	in	0	0	0	2574	0	4030	0	0	0	52
	out	0	0	0	0	0	0	0	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	2525	0	2879	0	0	0	90
Vertical leakage upward	in	448	7	1011	26	565	1619	344	27	223	1674
	out	0	0	23	0	0	1	0	31	147	0
Lateral inflow	in	2040	283	5365	160	1889	1159	415	542	2691	3302
	out	619	139	1769	127	409	4231	597	900	1572	4730
Vertical leakage downward	in	0	0	0	6	0	0	1	16	39	6
	out	933	9	1750	427	1154	8142	311	122	345	2238

Table A-1. (continued).



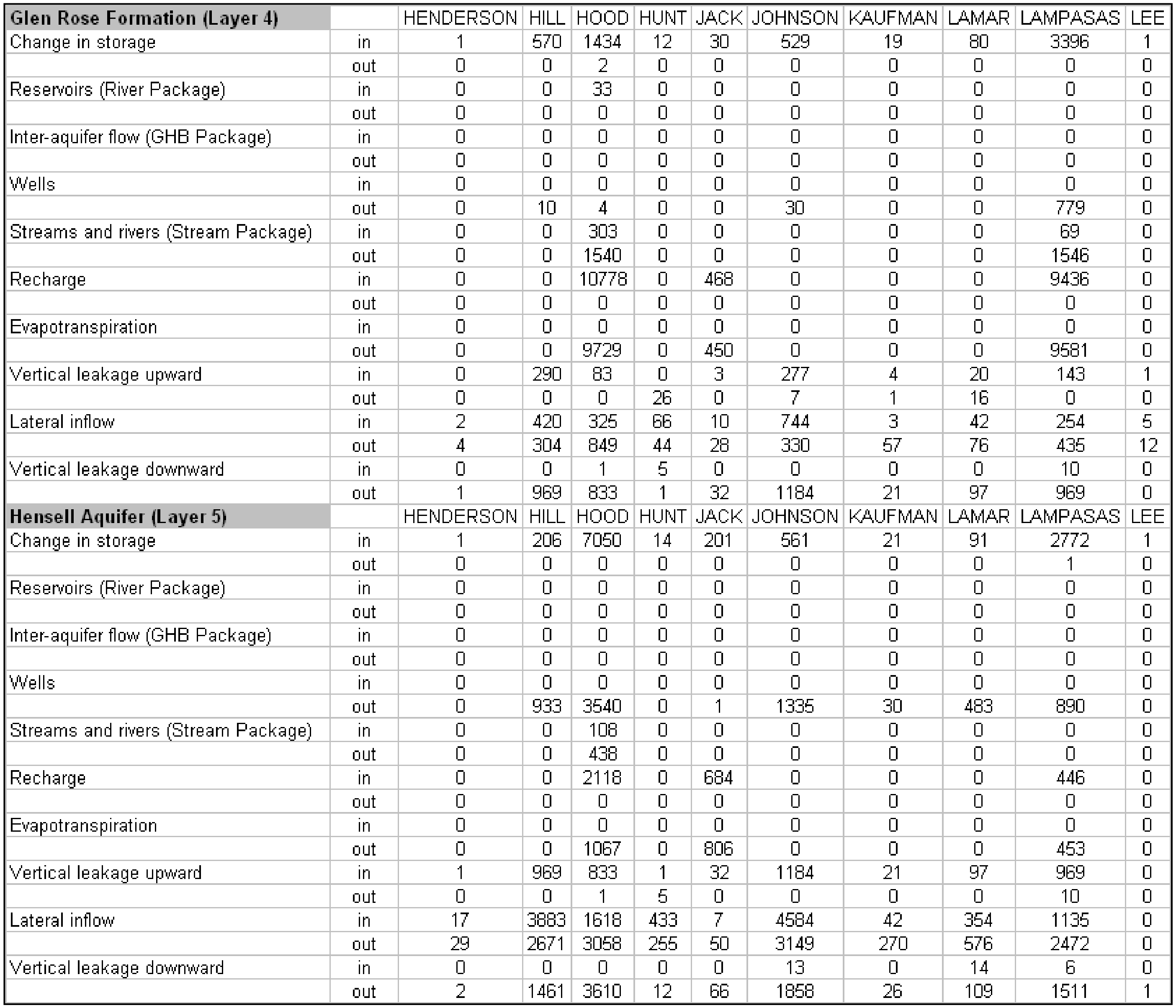
Hosston Aquifer (Layer 7)		DALLAS	DELTA	DENTON	EASTLAND	ELLIS	ERATH	FALLS	FANNIN	GRAYSON	HAMILTON
Change in storage	in	193	10	93	2506	249	8541	95	116	96	6
	out	0	0	0	46	0	0	0	0	0	0
Reservoirs (River Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Wells	in	0	0	0	0	0	0	0	0	0	0
	out	3921	50	6002	4438	2417	15980	130	209	2347	699
Streams and rivers (Stream Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	22	0	0	0	0	0	0
Recharge	in	0	0	0	10402	0	491	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	8159	0	221	0	0	0	0
Vertical leakage upward	in	1092	18	1829	429	1364	8346	392	204	398	2241
	out	0	0	0	6	0	0	0	5	16	6
Lateral inflow	in	4176	923	5878	457	2191	1136	1999	1339	2954	1808
	out	1540	551	1799	367	1400	2313	5264	2327	2482	3351

Table A-1. (continued).



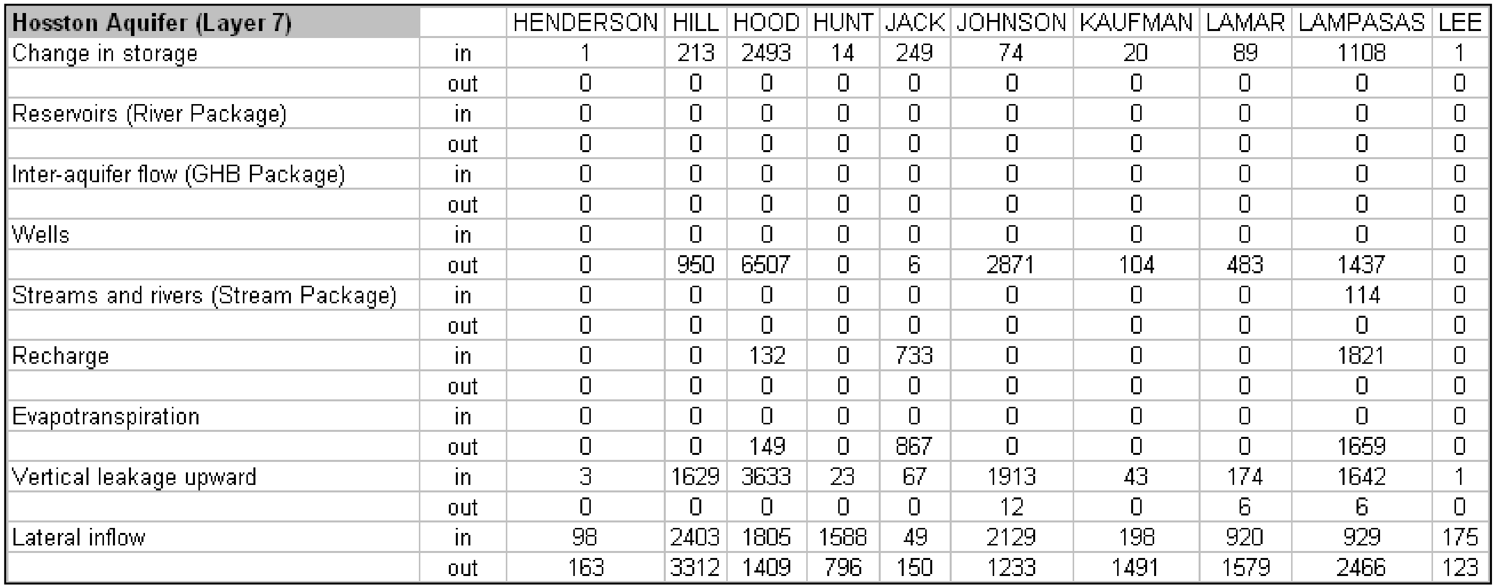
Woodbine Aquifer (Layer 1)		HENDERSON	HILL	HOOD	HUNT	JACK	JOHNSON	KAUFMAN	LAMAR	LAMPASAS	LEE
Change in storage	in	-	1993	-	6	-	2797	4	2533	-	-
	out	-	3	-	0	-	588	0	0	-	-
Reservoirs (River Package)	in	-	32	-	0	-	0	0	0	-	-
	out	-	1	-	0	-	0	0	0	-	-
Inter-aquifer flow (GHB Package)	in	-	89	-	17	-	18	7	75	-	-
	out	-	0	-	0	-	0	0	0	-	-
Wells	in	-	0	-	0	-	0	0	0	-	-
	out	-	1950	-	572	-	4698	200	2105	-	-
Streams and rivers (Stream Package)	in	-	0	-	0	-	0	0	7	-	-
	out	-	272	-	0	-	10	0	1117	-	-
Recharge	in	-	7189	-	0	-	12703	0	2751	-	-
	out	-	0	-	0	-	0	0	0	-	-
Evapotranspiration	in	-	0	-	0	-	0	0	0	-	-
	out	-	6726	-	0	-	8951	0	2240	-	-
Lateral inflow	in	-	286	-	1300	-	114	465	778	-	-
	out	-	545	-	102	-	1337	203	375	-	-
Vertical leakage downward	in	-	39	-	16	-	0	10	84	-	-
	out	-	12	-	0	-	25	0	4	-	-
Paluxy Aquifer (Layer 3)		HENDERSON	HILL	HOOD	HUNT	JACK	JOHNSON	KAUFMAN	LAMAR	LAMPASAS	LEE
Change in storage	in	1	1021	731	14	26	10462	20	91	976	1
	out	0	0	2	0	0	1	0	0	0	0
Reservoirs (River Package)	in	0	0	1	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Wells	in	0	0	0	0	0	0	0	0	0	0
	out	0	1255	929	551	3	11310	13	0	13	0
Streams and rivers (Stream Package)	in	0	0	2	0	0	0	0	0	0	0
	out	0	0	502	0	0	92	0	0	0	0
Recharge	in	0	0	5882	0	208	79	0	0	4434	0
	out	0	0	0	0	0	0	0	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	4929	0	241	0	0	0	5186	0
Vertical leakage upward	in	1	334	18	12	-	327	12	25	26	0
	out	0	0	0	0	-	0	0	1	1	0
Lateral inflow	in	8	650	175	796	12	1332	69	210	24	0
	out	10	462	365	414	0	528	136	708	116	0
Vertical leakage downward	in	0	0	0	26	0	7	1	16	0	0
	out	0	290	83	0	3	277	4	20	143	1

Table A-1. (continued).



Glen Rose Formation (Layer 4)		HENDERSON	HILL	HOOD	HUNT	JACK	JOHNSON	KAUFMAN	LAMAR	LAMPASAS	LEE
Change in storage	in	1	570	1434	12	30	529	19	80	3396	1
	out	0	0	2	0	0	0	0	0	0	0
Reservoirs (River Package)	in	0	0	33	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Wells	in	0	0	0	0	0	0	0	0	0	0
	out	0	10	4	0	0	30	0	0	779	0
Streams and rivers (Stream Package)	in	0	0	303	0	0	0	0	0	69	0
	out	0	0	1540	0	0	0	0	0	1546	0
Recharge	in	0	0	10778	0	468	0	0	0	9436	0
	out	0	0	0	0	0	0	0	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	9729	0	450	0	0	0	9581	0
Vertical leakage upward	in	0	290	83	0	3	277	4	20	143	1
	out	0	0	0	26	0	7	1	16	0	0
Lateral inflow	in	2	420	325	66	10	744	3	42	254	5
	out	4	304	849	44	28	330	57	76	435	12
Vertical leakage downward	in	0	0	1	5	0	0	0	0	10	0
	out	1	969	833	1	32	1184	21	97	969	0
Hensell Aquifer (Layer 5)		HENDERSON	HILL	HOOD	HUNT	JACK	JOHNSON	KAUFMAN	LAMAR	LAMPASAS	LEE
Change in storage	in	1	206	7050	14	201	561	21	91	2772	1
	out	0	0	0	0	0	0	0	0	1	0
Reservoirs (River Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Wells	in	0	0	0	0	0	0	0	0	0	0
	out	0	933	3540	0	1	1335	30	483	890	0
Streams and rivers (Stream Package)	in	0	0	108	0	0	0	0	0	0	0
	out	0	0	438	0	0	0	0	0	0	0
Recharge	in	0	0	2118	0	684	0	0	0	446	0
	out	0	0	0	0	0	0	0	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	1067	0	806	0	0	0	453	0
Vertical leakage upward	in	1	969	833	1	32	1184	21	97	969	0
	out	0	0	1	5	0	0	0	0	10	0
Lateral inflow	in	17	3883	1618	433	7	4584	42	354	1135	0
	out	29	2671	3058	255	50	3149	270	576	2472	0
Vertical leakage downward	in	0	0	0	0	0	13	0	14	6	0
	out	2	1461	3610	12	66	1858	26	109	1511	1

Table A-1. (continued).



Hosston Aquifer (Layer 7)		HENDERSON	HILL	HOOD	HUNT	JACK	JOHNSON	KAUFMAN	LAMAR	LAMPASAS	LEE
Change in storage	in	1	213	2493	14	249	74	20	89	1108	1
	out	0	0	0	0	0	0	0	0	0	0
Reservoirs (River Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Wells	in	0	0	0	0	0	0	0	0	0	0
	out	0	950	6507	0	6	2871	104	483	1437	0
Streams and rivers (Stream Package)	in	0	0	0	0	0	0	0	0	114	0
	out	0	0	0	0	0	0	0	0	0	0
Recharge	in	0	0	132	0	733	0	0	0	1821	0
	out	0	0	0	0	0	0	0	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	149	0	867	0	0	0	1659	0
Vertical leakage upward	in	3	1629	3633	23	67	1913	43	174	1642	1
	out	0	0	0	0	0	12	0	6	6	0
Lateral inflow	in	98	2403	1805	1588	49	2129	198	920	929	175
	out	163	3312	1409	796	150	1233	1491	1579	2466	123

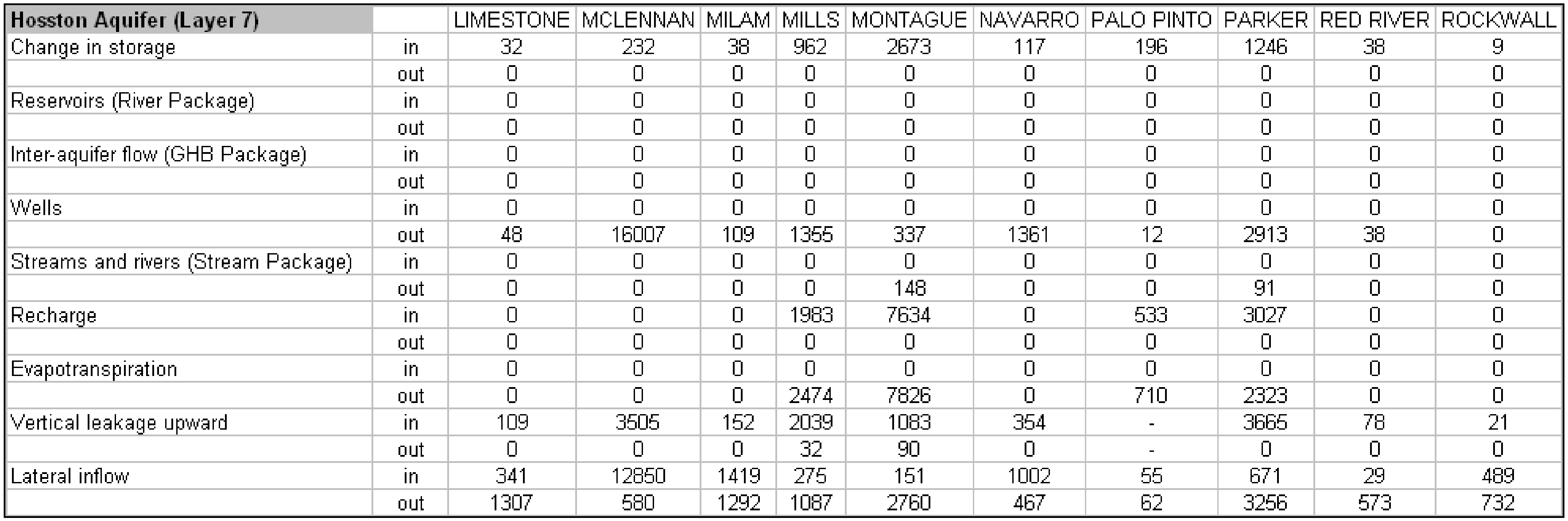
Table A-1. (continued).

Woodbine Aquifer (Layer 1)		LIMESTONE	MCLENNAN	MILAM	MILLS	MONTAGUE	NAVARRO	PALO PINTO	PARKER	RED RIVER	ROCKWALL
Change in storage	in	-	62	-	-	-	7	-	-	995	0
	out	-	0	-	-	-	0	-	-	0	0
Reservoirs (River Package)	in	-	0	-	-	-	0	-	-	0	0
	out	-	0	-	-	-	0	-	-	0	0
Inter-aquifer flow (GHB Package)	in	-	13	-	-	-	18	-	-	12	0
	out	-	0	-	-	-	0	-	-	0	0
Wells	in	-	0	-	-	-	0	-	-	0	0
	out	-	0	-	-	-	294	-	-	170	0
Streams and rivers (Stream Package)	in	-	0	-	-	-	0	-	-	2	0
	out	-	26	-	-	-	0	-	-	716	0
Recharge	in	-	673	-	-	-	0	-	-	3947	0
	out	-	0	-	-	-	0	-	-	0	0
Evapotranspiration	in	-	0	-	-	-	0	-	-	0	0
	out	-	698	-	-	-	0	-	-	3591	0
Lateral inflow	in	-	52	-	-	-	370	-	-	94	49
	out	-	60	-	-	-	77	-	-	158	0
Vertical leakage downward	in	-	4	-	-	-	27	-	-	6	0
	out	-	1	-	-	-	0	-	-	3	0
Paluxy Aquifer (Layer 3)		LIMESTONE	MCLENNAN	MILAM	MILLS	MONTAGUE	NAVARRO	PALO PINTO	PARKER	RED RIVER	ROCKWALL
Change in storage	in	43	200	47	773	1709	131	-	6249	37	9
	out	0	0	0	0	0	0	-	0	0	0
Reservoirs (River Package)	in	0	0	0	0	0	0	-	6	0	0
	out	0	0	0	0	0	0	-	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	0	-	0	0	0
	out	0	0	0	0	0	0	-	0	0	0
Wells	in	0	0	0	0	0	0	-	0	0	0
	out	0	232	0	6	96	245	-	7553	472	958
Streams and rivers (Stream Package)	in	0	0	0	0	0	0	-	133	0	0
	out	0	0	0	9	476	0	-	168	0	0
Recharge	in	0	0	0	3988	7916	0	-	18468	0	0
	out	0	0	0	0	0	0	-	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	-	0	0	0
	out	0	0	0	4518	8253	0	-	15157	0	0
Vertical leakage upward	in	18	327	7	93	12	56	-	79	7	9
	out	0	0	0	0	0	0	-	0	1	0
Lateral inflow	in	5	269	1	33	119	131	-	357	106	892
	out	19	74	1	90	294	71	-	1427	128	240
Vertical leakage downward	in	0	0	0	0	25	0	-	0	15	14
	out	52	491	54	265	664	74	-	992	3	0

Table A-1. (continued).

Glen Rose Formation (Layer 4)		LIMESTONE	MCLENNAN	MILAM	MILLS	MONTAGUE	NAVARRO	PALO PINTO	PARKER	RED RIVER	ROCKWALL
Change in storage	in	32	822	36	655	7	112	-	838	33	8
	out	0	0	0	0	0	0	-	2	0	0
Reservoirs (River Package)	in	0	0	0	0	0	0	-	2	0	0
	out	0	0	0	0	0	0	-	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	0	-	0	0	0
	out	0	0	0	0	0	0	-	0	0	0
Wells	in	0	0	0	0	0	0	-	0	0	0
	out	4	265	85	66	0	0	-	148	0	0
Streams and rivers (Stream Package)	in	0	0	0	0	0	0	-	5	0	0
	out	0	0	0	0	0	0	-	14	0	0
Recharge	in	0	0	0	2827	0	0	-	3845	0	0
	out	0	0	0	0	0	0	-	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	-	0	0	0
	out	0	0	0	2842	0	0	-	3637	0	0
Vertical leakage upward	in	52	491	54	265	664	74	-	992	3	0
	out	0	0	0	0	25	0	-	0	15	14
Lateral inflow	in	11	699	78	76	1	9	-	253	2	9
	out	45	122	18	286	15	49	-	602	26	21
Vertical leakage downward	in	0	0	0	0	17	0	-	0	0	0
	out	88	1626	68	629	649	191	-	1531	23	2
Hensell Aquifer (Layer 5)		LIMESTONE	MCLENNAN	MILAM	MILLS	MONTAGUE	NAVARRO	PALO PINTO	PARKER	RED RIVER	ROCKWALL
Change in storage	in	34	226	42	3905	2541	122	-	4301	39	9
	out	0	0	0	0	0	0	-	0	0	0
Reservoirs (River Package)	in	0	0	0	0	0	0	-	1	0	0
	out	0	0	0	0	0	0	-	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	0	-	0	0	0
	out	0	0	0	0	0	0	-	0	0	0
Wells	in	0	0	0	0	0	0	-	0	0	0
	out	14	4191	37	945	69	267	-	1111	19	0
Streams and rivers (Stream Package)	in	0	0	0	0	0	0	-	82	0	0
	out	0	0	0	0	356	0	-	821	0	0
Recharge	in	0	0	0	2588	6389	0	-	2893	0	0
	out	0	0	0	0	0	0	-	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	-	0	0	0
	out	0	0	0	2814	6645	0	-	2013	0	0
Vertical leakage upward	in	88	1626	68	629	649	191	-	1531	23	2
	out	0	0	0	0	17	0	-	0	0	0
Lateral inflow	in	124	6123	87	467	51	228	-	934	11	132
	out	293	485	40	1824	1607	150	-	2616	248	168
Vertical leakage downward	in	0	0	0	33	96	0	-	0	0	0
	out	82	3298	119	2038	1035	256	-	3181	47	13

Table A-1. (continued).



Hosston Aquifer (Layer 7)		LIMESTONE	MCLENNAN	MILAM	MILLS	MONTAGUE	NAVARRO	PALO PINTO	PARKER	RED RIVER	ROCKWALL
Change in storage	in	32	232	38	962	2673	117	196	1246	38	9
	out	0	0	0	0	0	0	0	0	0	0
Reservoirs (River Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Wells	in	0	0	0	0	0	0	0	0	0	0
	out	48	16007	109	1355	337	1361	12	2913	38	0
Streams and rivers (Stream Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	148	0	0	91	0	0
Recharge	in	0	0	0	1983	7634	0	533	3027	0	0
	out	0	0	0	0	0	0	0	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	2474	7826	0	710	2323	0	0
Vertical leakage upward	in	109	3505	152	2039	1083	354	-	3665	78	21
	out	0	0	0	32	90	0	-	0	0	0
Lateral inflow	in	341	12850	1419	275	151	1002	55	671	29	489
	out	1307	580	1292	1087	2760	467	62	3256	573	732

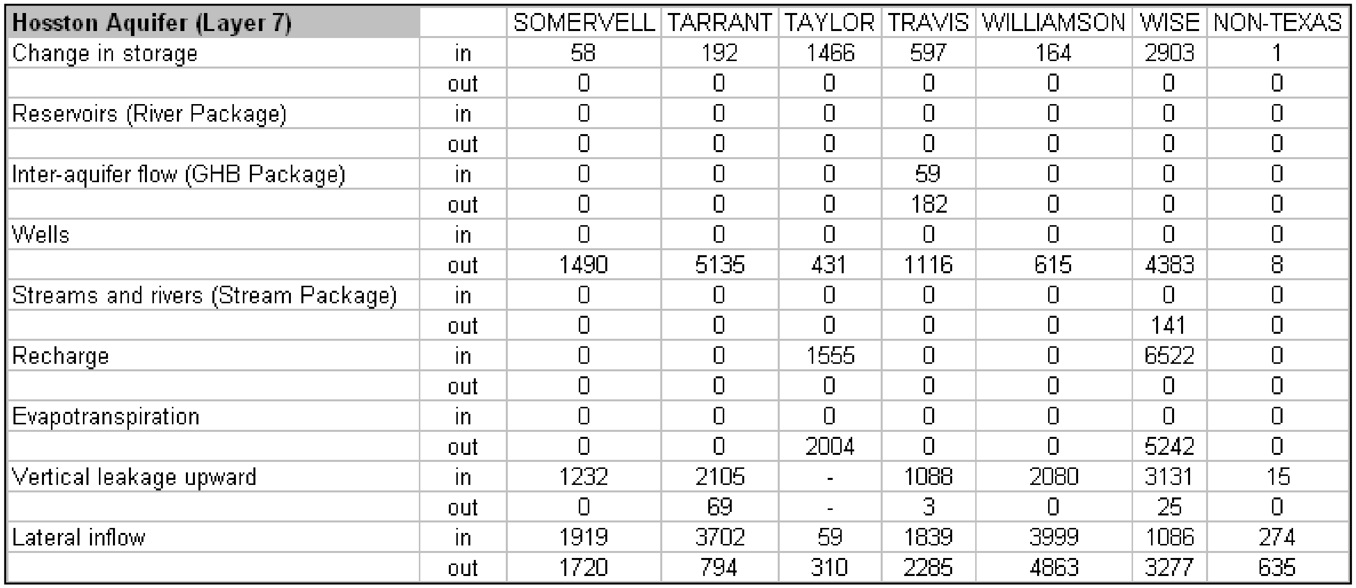
Table A-1. (continued).

Woodbine Aquifer (Layer 1)		SOMERVELL	TARRANT	TAYLOR	TRAVIS	WILLIAMSON	WISE	NON-TEXAS
Change in storage	in	-	3008	-	-	-	-	30
	out	-	213	-	-	-	-	0
Reservoirs (River Package)	in	-	10	-	-	-	-	0
	out	-	0	-	-	-	-	0
Inter-aquifer flow (GHB Package)	in	-	11	-	-	-	-	0
	out	-	0	-	-	-	-	0
Wells	in	-	0	-	-	-	-	0
	out	-	632	-	-	-	-	0
Streams and rivers (Stream Package)	in	-	68	-	-	-	-	4
	out	-	444	-	-	-	-	56
Recharge	in	-	11705	-	-	-	-	47
	out	-	0	-	-	-	-	0
Evapotranspiration	in	-	0	-	-	-	-	0
	out	-	11284	-	-	-	-	1
Lateral inflow	in	-	371	-	-	-	-	55
	out	-	2563	-	-	-	-	121
Vertical leakage downward	in	-	0	-	-	-	-	0
	out	-	27	-	-	-	-	0
Paluxy Aquifer (Layer 3)		SOMERVELL	TARRANT	TAYLOR	TRAVIS	WILLIAMSON	WISE	NON-TEXAS
Change in storage	in	101	10386	-	57	150	5029	31
	out	37	35	-	3	0	0	0
Reservoirs (River Package)	in	0	8	-	0	0	1	0
	out	0	0	-	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	-	0	0	0	0
	out	0	0	-	0	0	0	0
Wells	in	0	0	-	0	0	0	0
	out	120	9707	-	3	11	2205	11
Streams and rivers (Stream Package)	in	0	18	-	0	0	52	0
	out	213	18	-	0	0	818	105
Recharge	in	3079	1804	-	0	13	11448	57
	out	0	0	-	0	0	0	0
Evapotranspiration	in	0	0	-	0	0	0	0
	out	2625	1555	-	0	0	10893	0
Vertical leakage upward	in	16	360	-	34	135	75	1
	out	0	0	-	8	37	0	0
Lateral inflow	in	35	1933	-	22	14	294	98
	out	156	2329	-	5	27	1885	207
Vertical leakage downward	in	0	0	-	1	0	2	4
	out	79	869	-	95	238	1103	6

Table A-1. (continued).

Glen Rose Formation (Layer 4)		SOMERVELL	TARRANT	TAYLOR	TRAVIS	WILLIAMSON	WISE	NON-TEXAS
Change in storage	in	650	279	-	3713	1838	202	0
	out	27	0	-	0	0	0	0
Reservoirs (River Package)	in	7	0	-	0	0	0	0
	out	0	0	-	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	-	0	0	0	0
	out	0	0	-	327	0	0	0
Wells	in	0	0	-	0	0	0	0
	out	134	103	-	2627	763	4	0
Streams and rivers (Stream Package)	in	464	0	-	0	58	0	0
	out	2763	0	-	0	257	22	0
Recharge	in	5470	0	-	4180	2449	1907	0
	out	0	0	-	0	0	0	0
Evapotranspiration	in	0	0	-	0	0	0	0
	out	3076	0	-	5492	2703	1787	0
Vertical leakage upward	in	79	869	-	95	238	1103	6
	out	0	0	-	1	0	2	4
Lateral inflow	in	578	622	-	1150	1020	59	8
	out	626	170	-	466	1048	228	10
Vertical leakage downward	in	0	0	-	70	2	1	2
	out	623	1497	-	342	825	1229	8
Hensell Aquifer (Layer 5)		SOMERVELL	TARRANT	TAYLOR	TRAVIS	WILLIAMSON	WISE	NON-TEXAS
Change in storage	in	1991	135	-	993	479	5586	1
	out	0	0	-	0	0	0	0
Reservoirs (River Package)	in	0	0	-	0	0	0	0
	out	0	0	-	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	-	0	0	0	0
	out	0	0	-	0	0	0	0
Wells	in	0	0	-	0	0	0	0
	out	741	2343	-	156	416	1275	8
Streams and rivers (Stream Package)	in	0	0	-	0	0	66	0
	out	0	0	-	0	0	561	0
Recharge	in	0	0	-	835	0	9032	0
	out	0	0	-	0	0	0	0
Evapotranspiration	in	0	0	-	0	0	0	0
	out	0	0	-	825	0	8753	0
Vertical leakage upward	in	623	1497	-	342	825	1229	8
	out	0	0	-	70	2	1	2
Lateral inflow	in	2524	4287	-	265	2022	530	203
	out	3167	1610	-	490	947	3494	353
Vertical leakage downward	in	0	74	-	17	0	29	0
	out	1231	2041	-	911	1951	2387	14

Table A-1. (continued).



Hosston Aquifer (Layer 7)		SOMERVELL	TARRANT	TAYLOR	TRAVIS	WILLIAMSON	WISE	NON-TEXAS
Change in storage	in	58	192	1466	597	164	2903	1
	out	0	0	0	0	0	0	0
Reservoirs (River Package)	in	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	59	0	0	0
	out	0	0	0	182	0	0	0
Wells	in	0	0	0	0	0	0	0
	out	1490	5135	431	1116	615	4383	8
Streams and rivers (Stream Package)	in	0	0	0	0	0	0	0
	out	0	0	0	0	0	141	0
Recharge	in	0	0	1555	0	0	6522	0
	out	0	0	0	0	0	0	0
Evapotranspiration	in	0	0	0	0	0	0	0
	out	0	0	2004	0	0	5242	0
Vertical leakage upward	in	1232	2105	-	1088	2080	3131	15
	out	0	69	-	3	0	25	0
Lateral inflow	in	1919	3702	59	1839	3999	1086	274
	out	1720	794	310	2285	4863	3277	635