GAM Run 08-64

by Melissa E. Hill, Ph.D., P.G.
Texas Water Development Board
Groundwater Availability Modeling Section
(512) 463-1742
May 17, 2010

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

Melissa E. Hill

EXECUTIVE SUMMARY:

The groundwater availability model for the northern portion of the Trinity Aquifer 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 08-06 (Donnelly, 2008a) include:

- a decrease in pumpage underlying Coryell County from 3,777 acre-feet per year to 3,714 acre-feet per year;
- a change in the spatial distribution of pumpage underlying Coryell County per layer (254 acre-feet per year in layer 3; 783 acre-feet per year in layer 4; 836 acre-feet per year in layer 5; and 433 acre-feet per year in layer 7);
- the allocation of an additional, uniform distribution of pumpage underlying the western portion of Coryell County (shown in Figure 1) within layers 5 (928 acre-feet per year) and 7 (480 acre-feet per year);
- a decrease in pumpage underlying Comanche County from 27,000 acre-feet per year to 25,000 acre-feet per year;
- a decrease in pumpage underlying Erath County from 32,000 acre-feet per year to 30,000 acre-feet per year;
- a decrease in pumpage for the Trinity Aquifer System and the Glen Rose Formation underlying Montague County (layers 3, 4, 5 and 7) from 2,682 to 506 acre-feet per year;
- pumpage in the Woodbine Aquifer (layer 1) underlying Cooke, Denton, and Johnson Counties reported in Table 2 of Wade (2008) was applied;
- pumpage in the Trinity Aquifer System and the Glen Rose Formation (layers 3, 4, 5, and 7) underlying Cooke County is 7,018 acre-feet per year, 18,132 acre-feet per year for Denton County, and 16, 349 acre-feet per year for Johnson County; and
- pumpage in the Trinity Aquifer System (layers 3, 4, 5, and 7) underlying Hood County is 11,001 acre-feet per year, 11,751 acre-feet per year for Parker County, and 8,414 acre-feet per year for Wise County.

Results from this model run using the specified pumpage indicate a decrease in water levels for the downdip portions of the aquifers after 50 years. Water level declines are 25 feet or less in the updip aquifer areas and increase downdip. All aquifers show water level declines of 175 feet or greater in the downdip portions with localized areas of relatively higher water level declines underlying large pumping centers. The largest simulated declines in water levels for the 50-year simulation exceed 600 feet and occur in the Hosston Aquifer underlying McLennan County.

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. 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. The western portion of Coryell County delineated during the Groundwater Management Area 8 meeting held in Belton on March 24, 2008 was digitized (shaded area shown in Figure 1) and was used to assign pumpage based on specifications provided by Groundwater Management Area 8. Pumpage underlying western and eastern Coryell County maintains the same ratio assigned to the 1999 well package array for layers 2, 3, 4, 5, 6, and 7. However, an additional uniform distribution of 928 acre-feet per year was applied to western Coryell County for layer 5. Moreover, an additional uniform distribution of 480 acre-feet per year was applied to layer 7 for the shaded area of Coryell County shown in Figure 1. Simulated water levels and water level 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;

- an update to the initial heads in the predictive model was performed to remove minor discrepancies with simulated head values for the historic model;

- 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 Trinity Aquifer is comprised of the Paluxy, Hensell, and Hosston formations. 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 and that are not permitted to rewet, 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	Johnson	4,732
Cooke	154	Kaufman	200
Delta	16	Lamar	3,658
Denton	4,126	Limestone	33
Fannin	3,300	Navarro	300
Grayson	12,100	Red River	170
Hunt	2,840	Rockwall	144

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	Kaufman	1,184
Callahan	3,787	Lamar	1,320
Collin	2,100	Lampasas	3,164
Comanche	25,000	Limestone	66
Cooke	7,018	McLennan	20,694
Delta	364	Milam	321
Denton	18,132	Mills	2,400
Eastland	4,853	Montague	506
Erath	30,000	Navarro	1,873
Falls	161	Parker	11,751
Fannin	700	Red River	528
Grayson	9,400	Rockwall	958
Hamilton	2,146	Taylor	679
Hood	11,001	Travis	3,900
Hunt	551	Williamson	1,810
Johnson	16,349	Wise	8,414

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	Tarrant	19,615

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.

	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).

**- Western Coryell County shown in Figure 1.

The 1999 spatial distribution of pumpage used with the calibrated historic model was used to generate the pumpage for the predictive simulation. 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 Run 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 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 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 are 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.

Results reported for this model run are presented differently than in some previous GAM Run Reports 07-09 (Donnelly, 2007), 07-30 (Wade, 2007), 08-06 (Donnelly, 2008a), and 08-05 (Donnelly, 2008b) where active cells within and outside the aquifer footprint are presented. 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). This new procedure of reporting values for active model cells within the existing aquifer footprints excludes artifacts from the numerical model, such as exaggerated aquifer boundaries, which are often required to maintain numerical stability in modeling efforts.

Results from the predictive simulation are described 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).

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 the water levels at the start and conclusion of the 50-year predictive simulation are provided in Figures 12 through 16. Water level changes over 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 beneath 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;

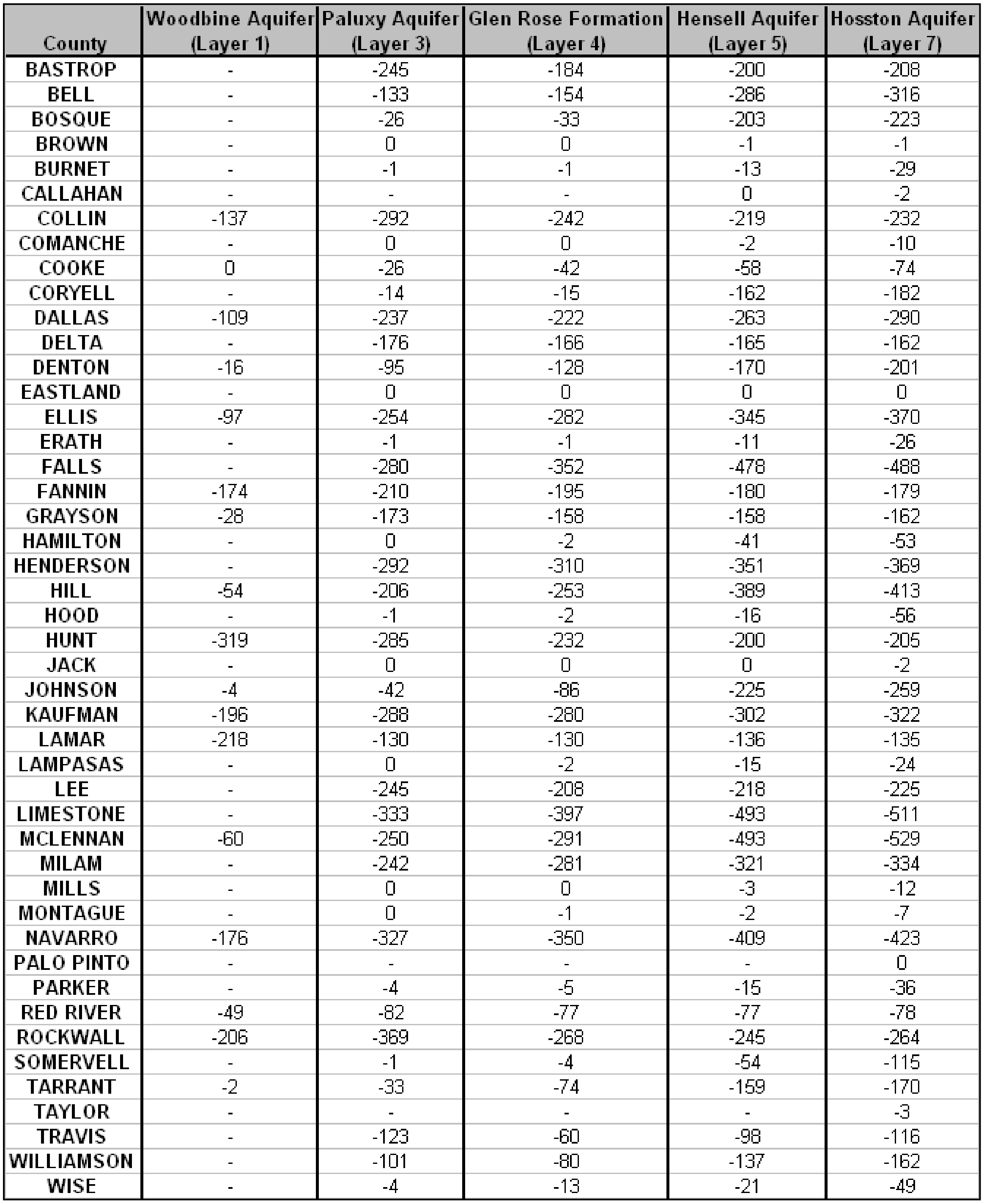
- if the starting water levels for the predictive simulation did not convert to dry, but the simulated water levels at the end of the 50-year predictive simulation converted to dry, then the difference between the starting water levels and the bottom elevation for cells that converted to dry was calculated;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

Lastly, a direct comparison between the results from this predictive simulation and any previous simulations that may have reported quantities for all active model cells (including those outside the aquifer footprint) cannot be made due to the implementation of the new reporting procedure that accounts for only those active cells within the existing aquifer footprint.

Table 6. Average water level changes 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	-292	-242	-219	-232
COMANCHE	-	0	0	-2	-10
COOKE	0	-26	-42	-58	-74
CORYELL	-	-14	-15	-162	-182
DALLAS	-109	-237	-222	-263	-290
DELTA	-	-176	-166	-165	-162
DENTON	-16	-95	-128	-170	-201
EASTLAND	-	0	0	0	0
ELLIS	-97	-254	-282	-345	-370
ERATH	-	-1	-1	-11	-26
FALLS	-	-280	-352	-478	-488
FANNIN	-174	-210	-195	-180	-179
GRAYSON	-28	-173	-158	-158	-162
HAMILTON	-	0	-2	-41	-53
HENDERSON	-	-292	-310	-351	-369
HILL	-54	-206	-253	-389	-413
HOOD	-	-1	-2	-16	-56
HUNT	-319	-285	-232	-200	-205
JACK	-	0	0	0	-2
JOHNSON	-4	-42	-86	-225	-259
KAUFMAN	-196	-288	-280	-302	-322
LAMAR	-218	-130	-130	-136	-135
LAMPASAS	-	0	-2	-15	-24
LEE	-	-245	-208	-218	-225
LIMESTONE	-	-333	-397	-493	-511
MCLENNAN	-60	-250	-291	-493	-529
MILAM	-	-242	-281	-321	-334
MILLS	-	0	0	-3	-12
MONTAGUE	-	0	-1	-2	-7
NAVARRO	-176	-327	-350	-409	-423
PALO PINTO	-	-	-	-	0
PARKER	-	-4	-5	-15	-36
RED RIVER	-49	-82	-77	-77	-78
ROCKWALL	-206	-369	-268	-245	-264
SOMERVELL	-	-1	-4	-54	-115
TARRANT	-2	-33	-74	-159	-170
TAYLOR	-	-	-	-	-3
TRAVIS	-	-123	-60	-98	-116
WILLIAMSON	-	-101	-80	-137	-162
WISE	-	-4	-13	-21	-49

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., 2008a, GAM Run 08-06, Texas Water Development Board GAM Run Report, 25 p.

Donnelly, A.C.A., 2008b, GAM Run 08-05, Texas Water Development Board GAM Run Report, 25 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.

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

Wade, S.C., 2007, GAM Run 07-30, Texas Water Development Board GAM Run Report, 25 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.

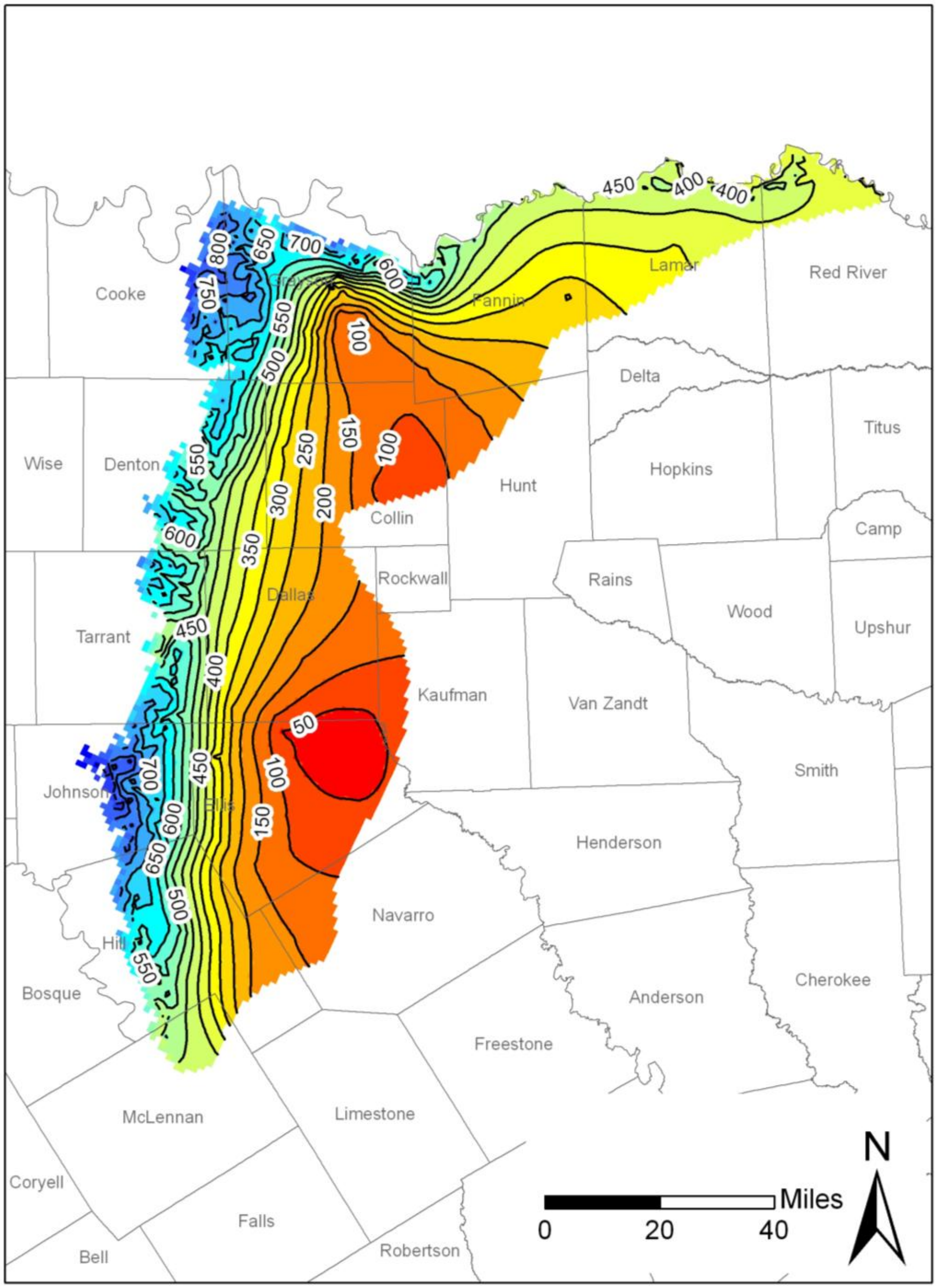


Figure 2. Initial water level elevations for the predictive model run in layer 1 (Woodbine Aquifer) of the groundwater availability model for northern part of the Trinity Aquifer System. Water level elevations are in feet above mean sea level. Contour interval is 50 feet. No cells converted to dry in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

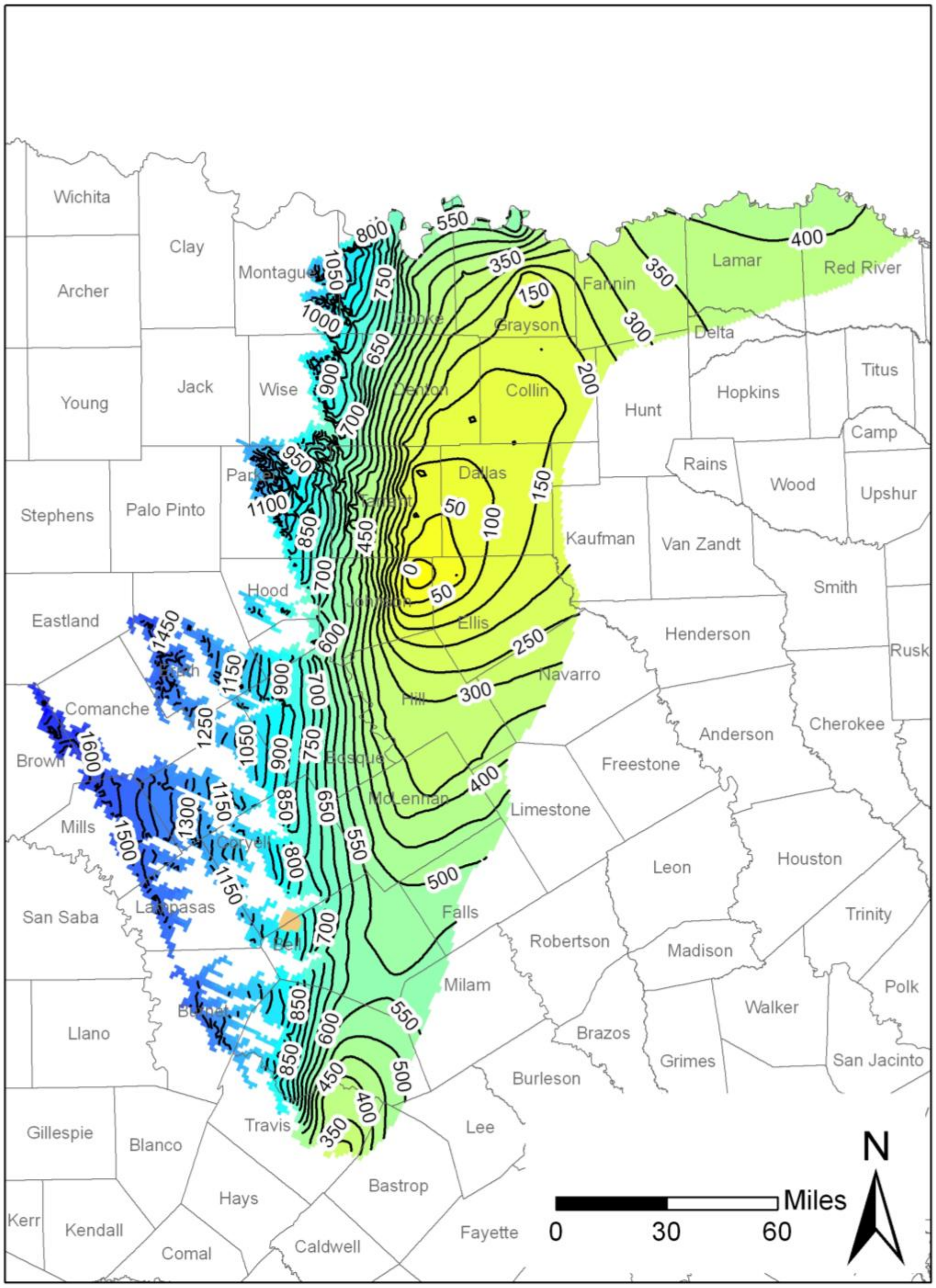


Figure 3. Initial water level elevations for the predictive model run in layer 3 (Paluxy Aquifer) of the groundwater availability model for the northern part of the Trinity Aquifer System. Water level elevations are in feet above mean sea level. Contour interval is 50 feet. Cells that converted to dry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

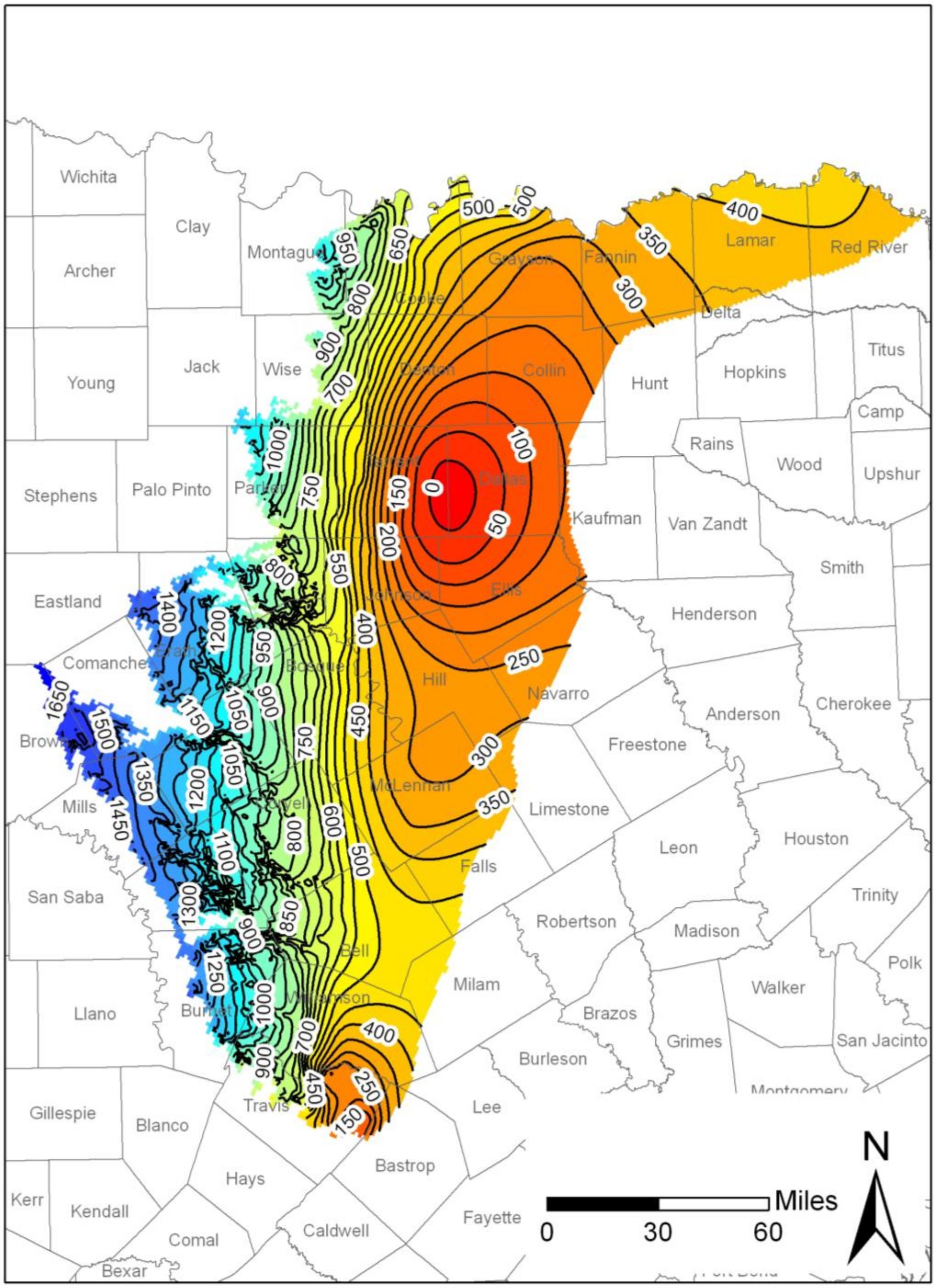


Figure 4. Initial water level elevations for the predictive model run in layer 4 (Glen Rose Formation) of the groundwater availability model for the northern part of the Trinity Aquifer System. Water level elevations are in feet above mean sea level. Contour interval is 50 feet. No cells converted to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

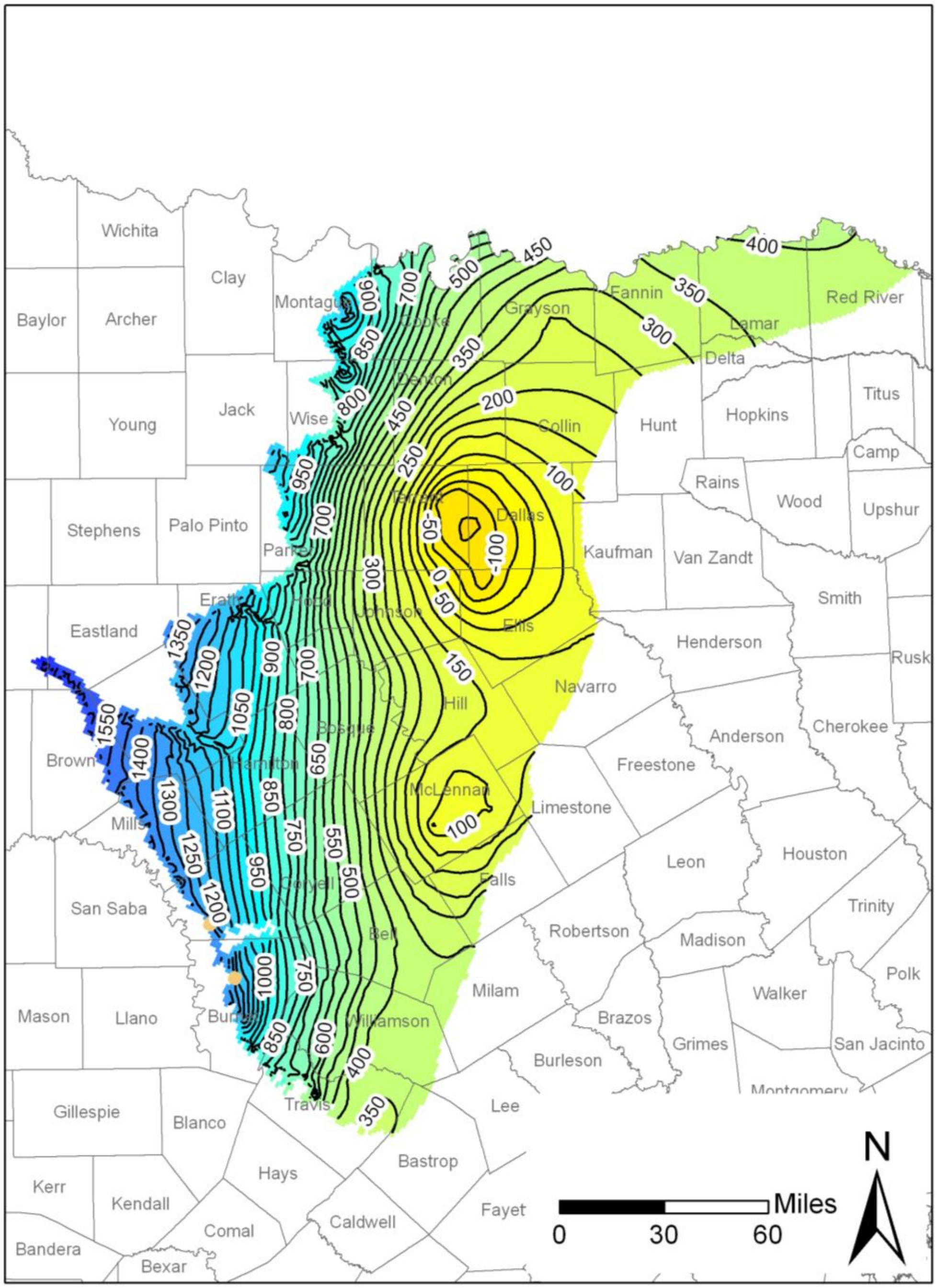


Figure 5. Initial water level elevations for the predictive model run in layer 5 (Hensell Aquifer) of the groundwater availability model for the northern part of the Trinity Aquifer System. Water level elevations are in feet above mean sea level. Contour interval is 50 feet. Cells that converted to dry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

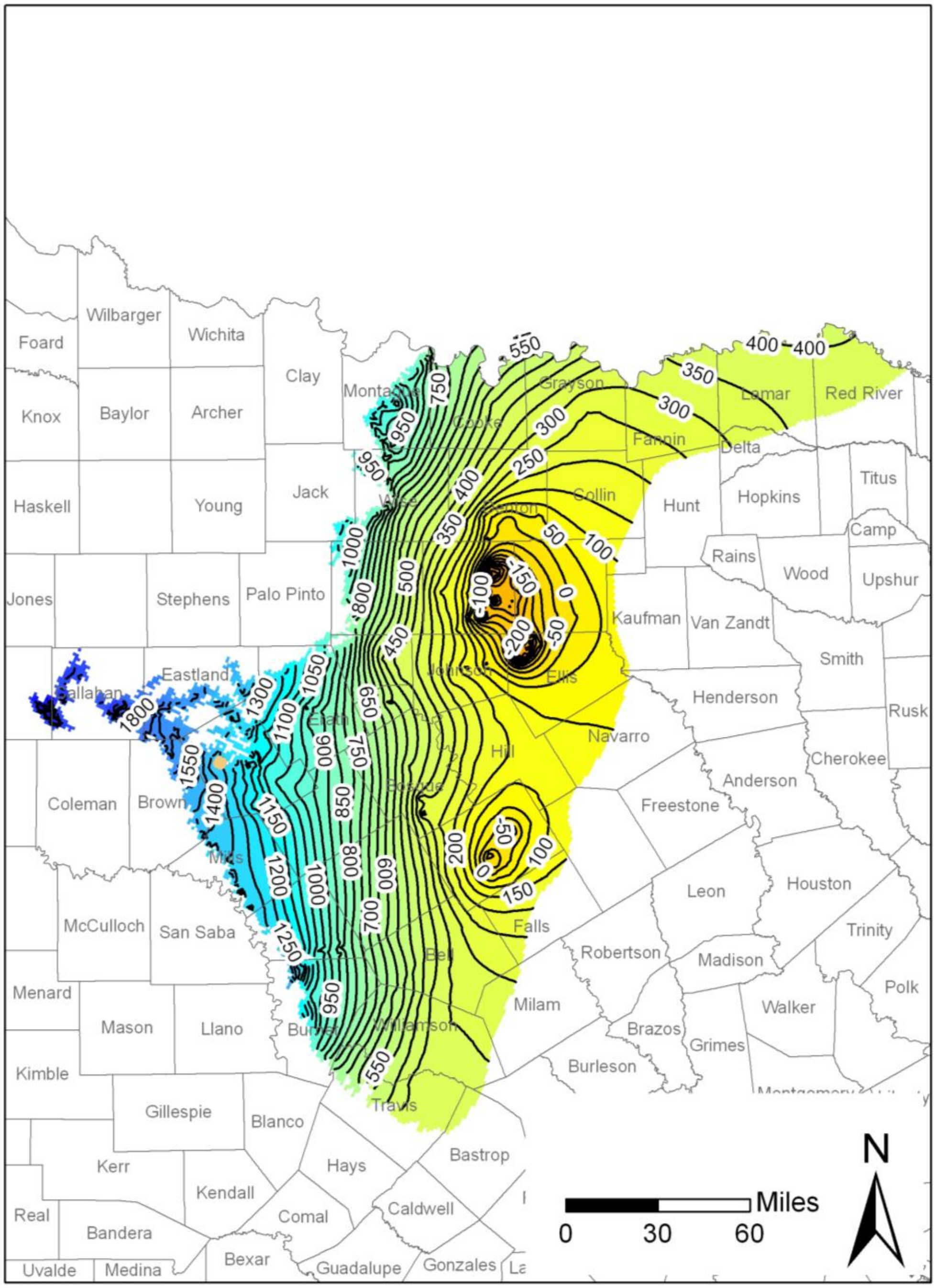


Figure 6. Initial water level elevations for the predictive model run in layer 7 (Hosston Aquifer) of the groundwater availability model for the northern part of the Trinity Aquifer System. Water level elevations are in feet above mean sea level. Contour interval is 50 feet. A dry cell, shown in tan,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

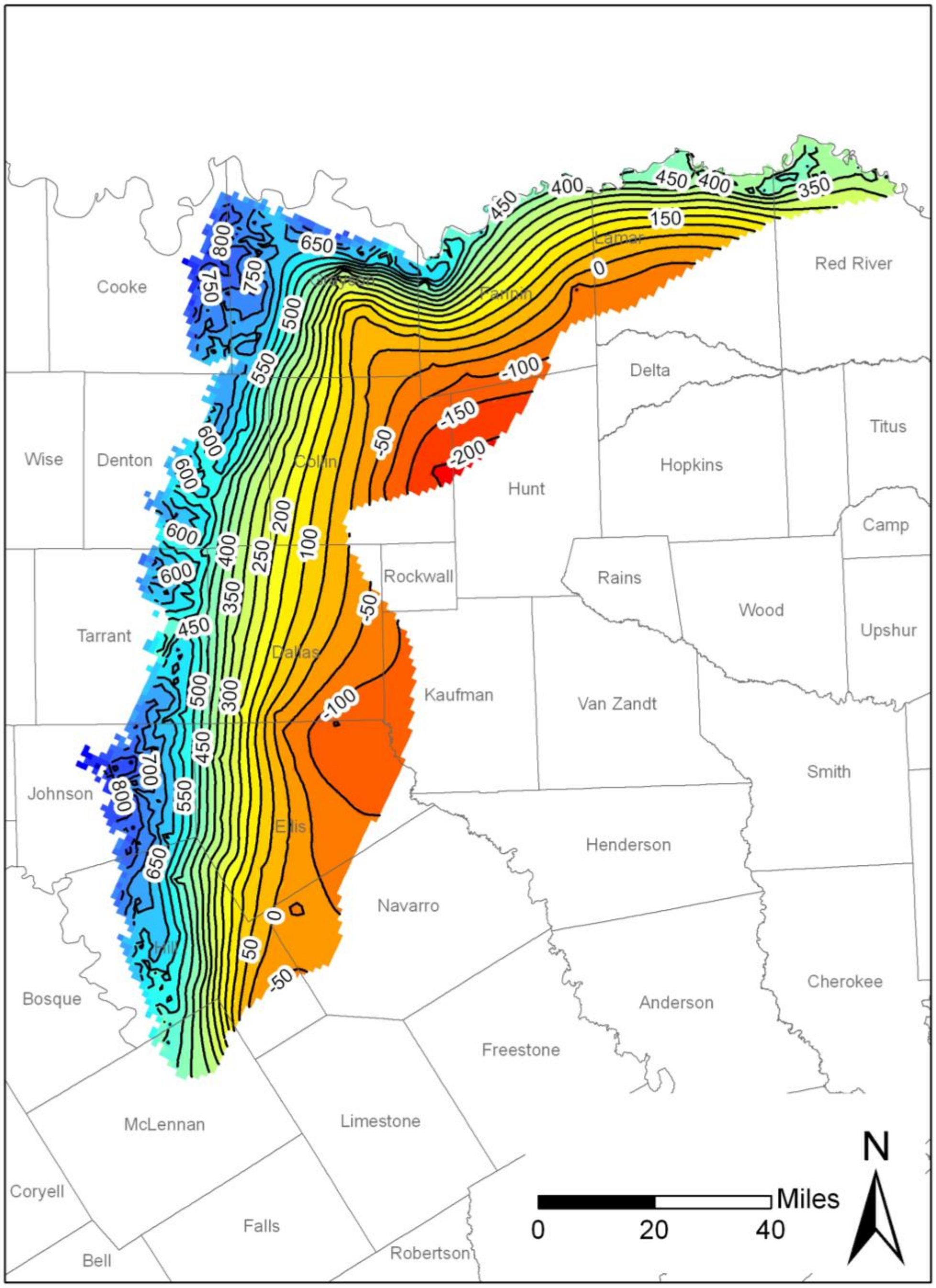


Figure 7. Water level elevations after 50 years using the specified pumpage in layer 1 (Woodbine Aquifer). Water level elevations are in feet above mean sea level. Contour interval is 50 feet. No cells converted to dry in layer 1.

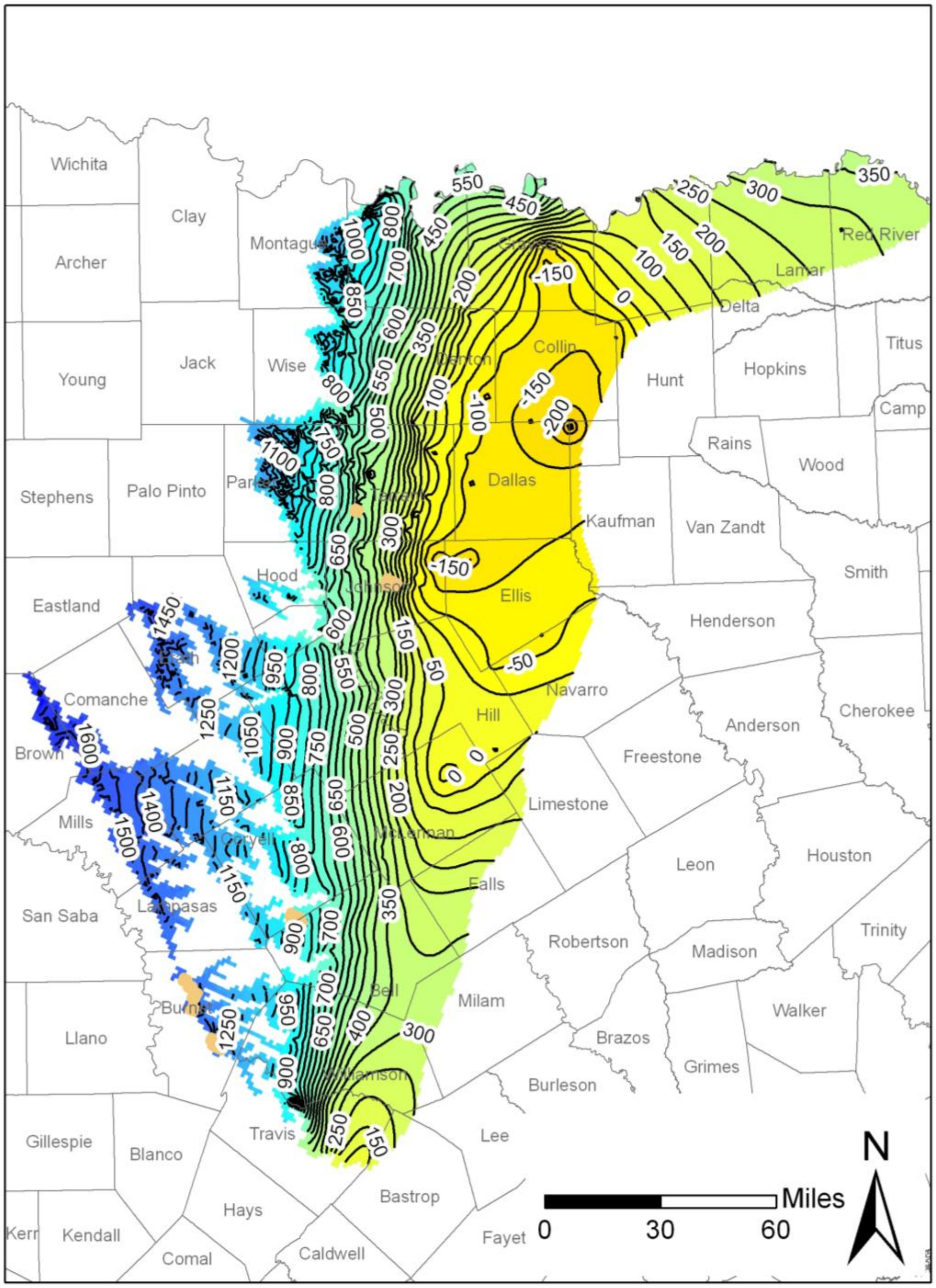


Figure 8. Water level elevations after 50 years using the specified pumpage in layer 3 (Paluxy Aquifer). Water level elevations are in feet above mean sea level. Contour interval is 50 feet. Cells that converted to dry are shown in tan. Dry cells are located in Burnet, Johnson, and Tarrant counties.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

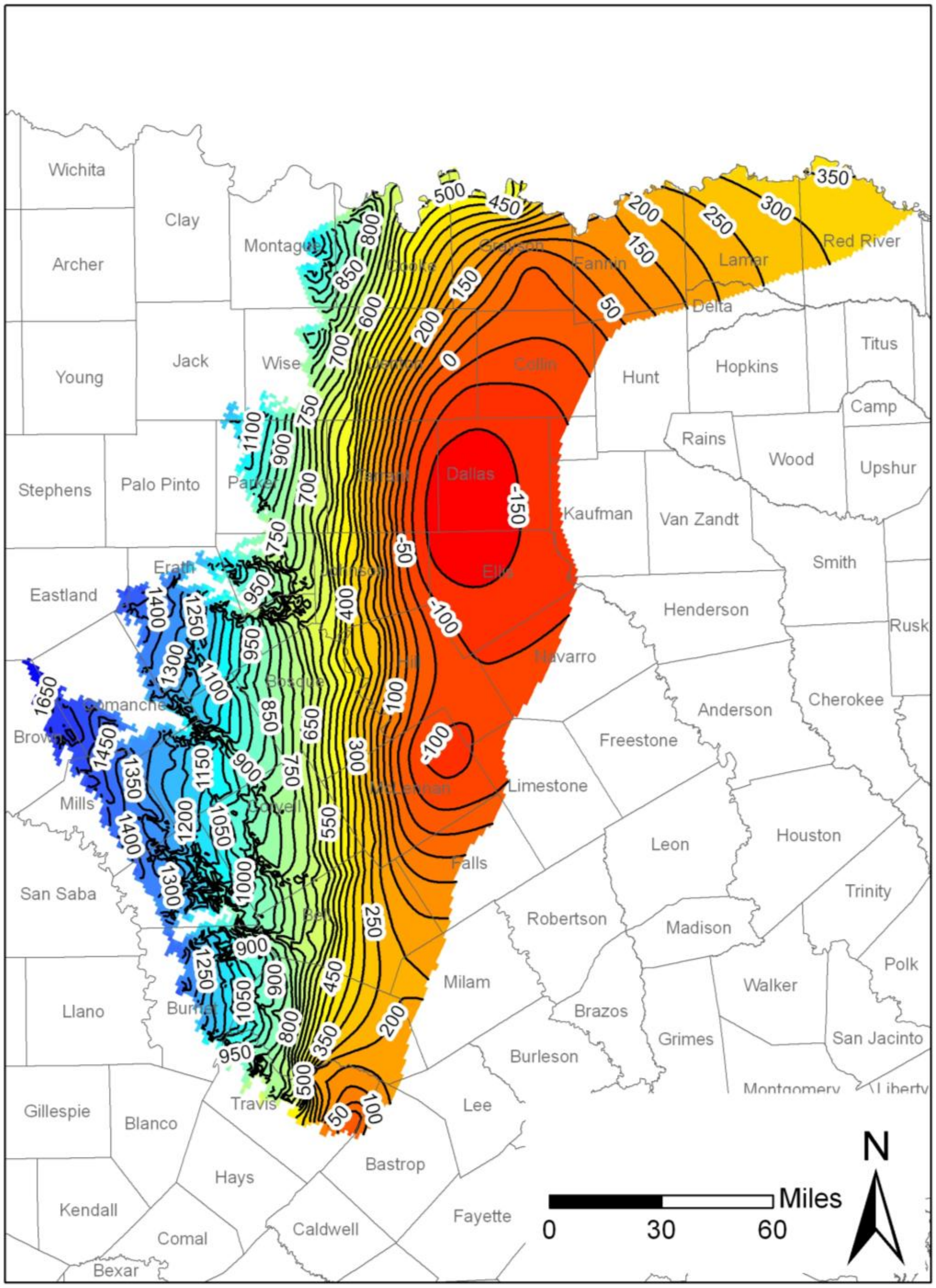


Figure 9. Water level elevations after 50 years using the specified pumpage in layer 4 (Glen Rose Formation). Water level elevations are in feet above mean sea level. Contour interval is 50 feet. No cells convert to dry in layer 4.

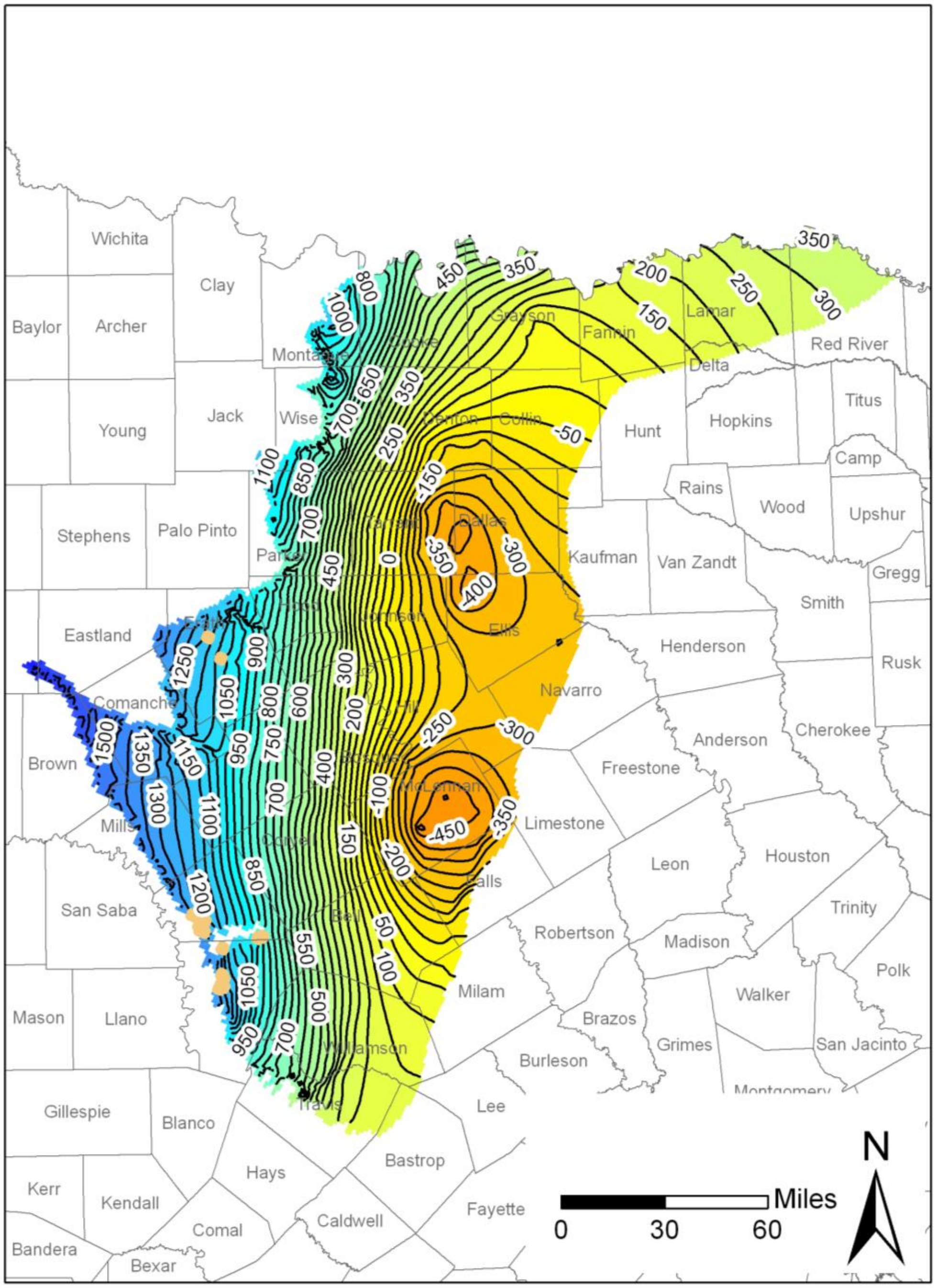


Figure 10. Water level elevations after 50 years using the specified pumpage in layer 5 (Hensell Aquifer). Water level elevations are in feet above mean sea level. Contour interval is 50 feet. Cells that converted to dry are shown in tan. Dry cells are located in Erath, Lampasas, and Burnet counties.

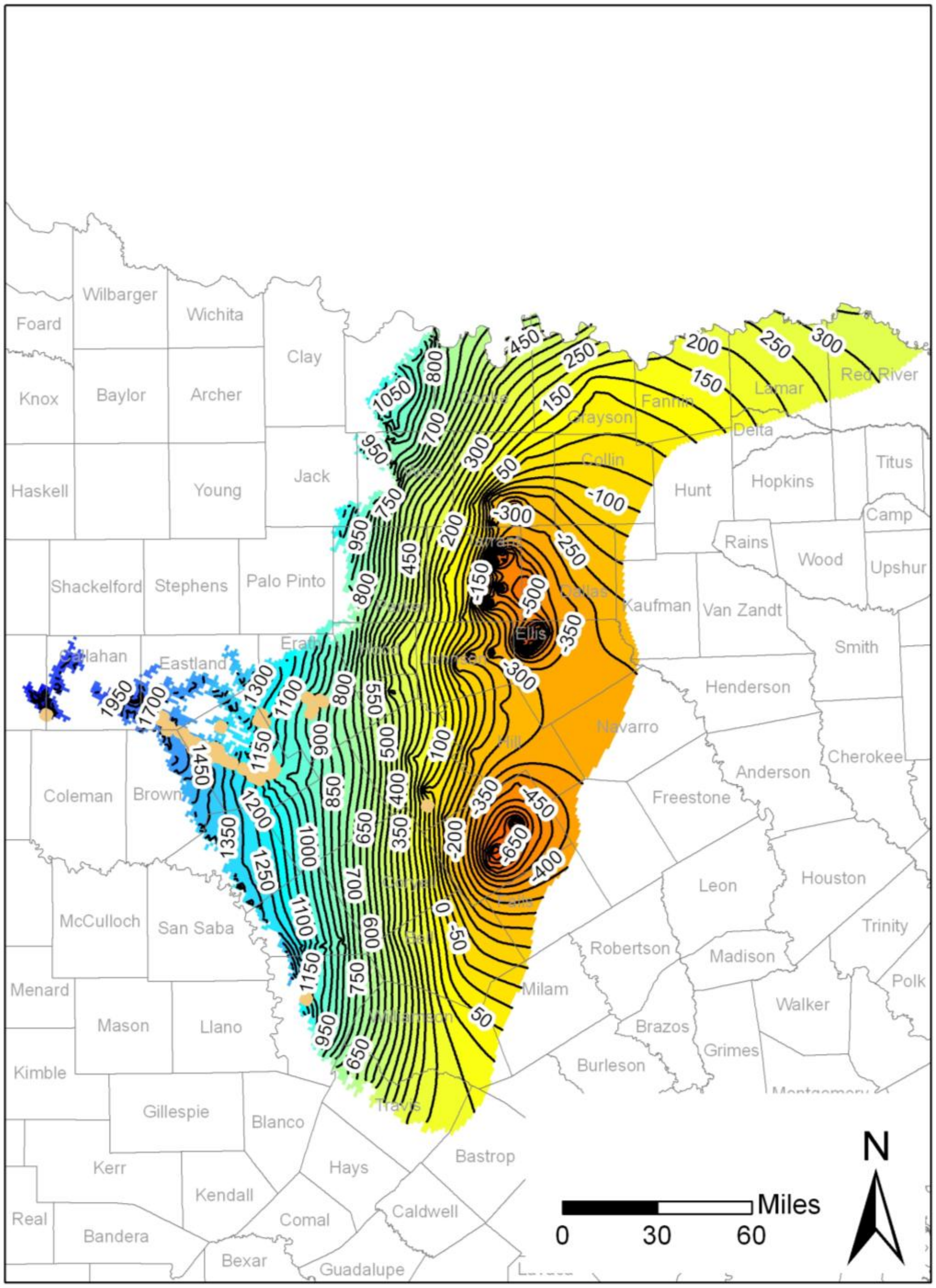


Figure 11. Water level elevations after 50 years using the specified pumpage in layer 7 (Hosston Aquifer). Water level elevations are in feet above mean sea level. Contour interval is 50 feet. Cells that converted to dry are shown in tan. Dry cells are located in Erath, Comanche, Burnet, Bosque, Brown,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

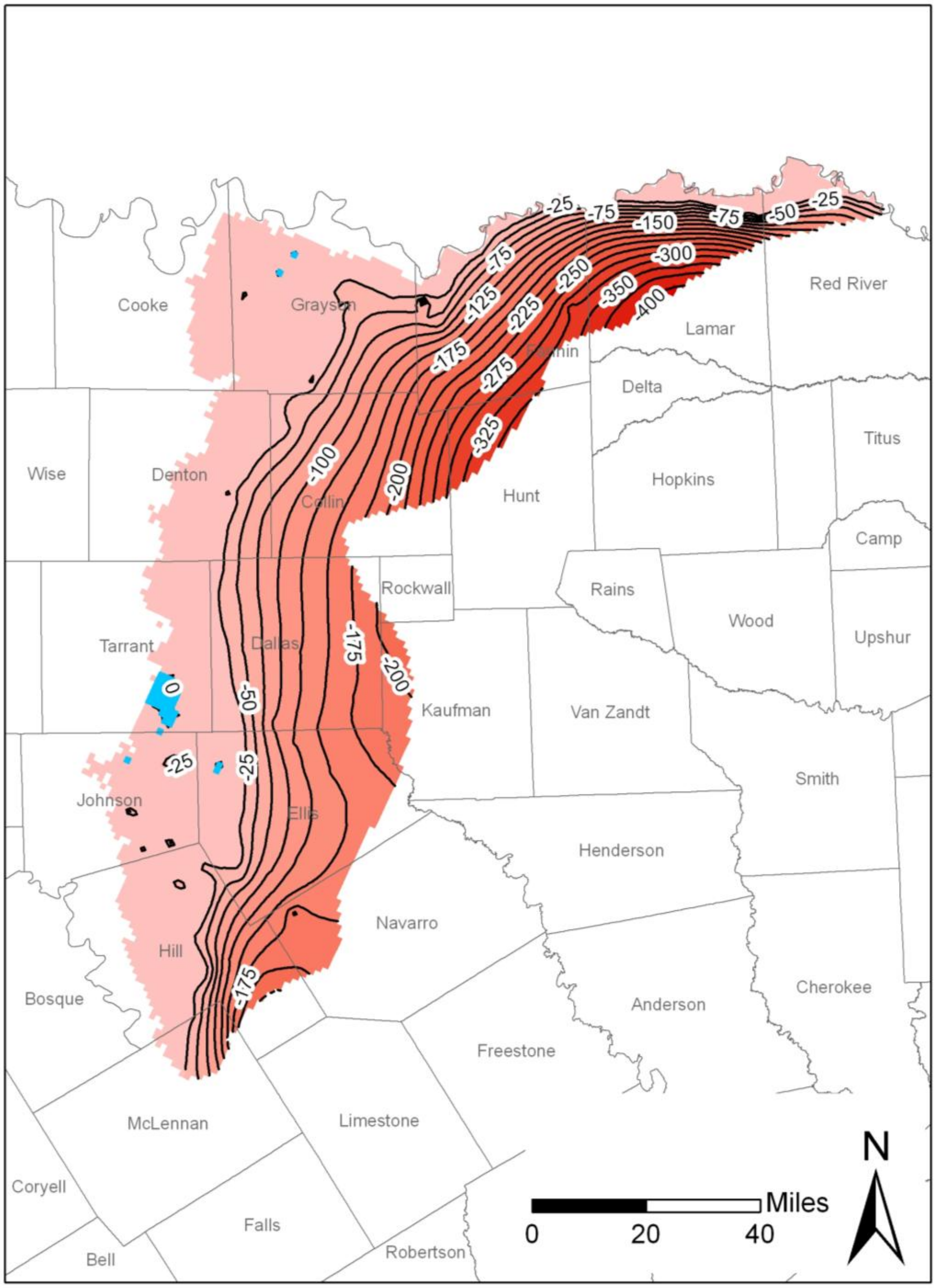


Figure 12. Changes in water levels after 50 years using the specified pumpage in layer 1 (Woodbine Aquifer). Water level changes are in feet. Contour interval is 25 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue. No cells converted to dry in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

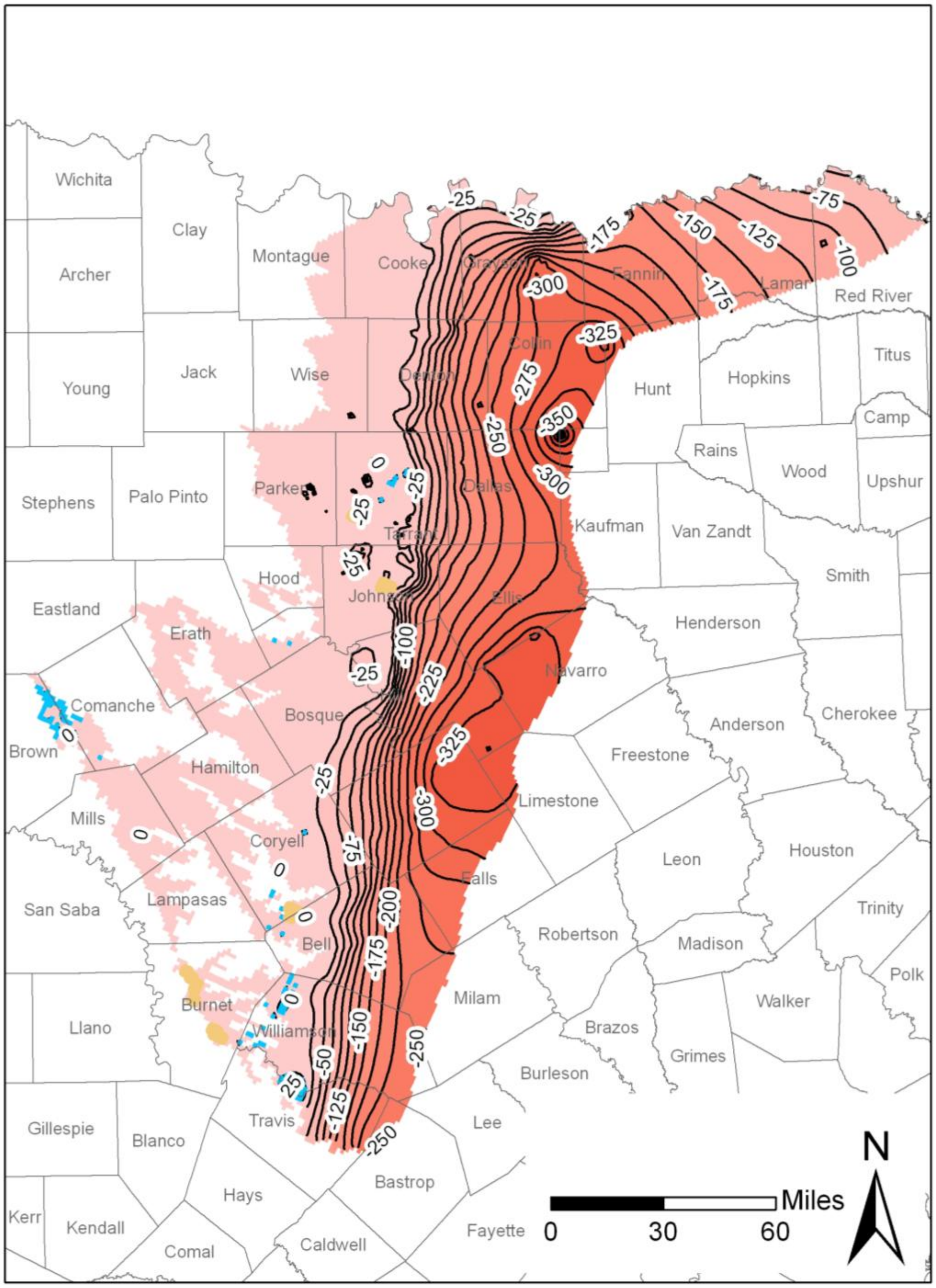


Figure 13. Changes in water levels after 50 years using the specified pumpage in layer 3 (Paluxy Aquifer). Water level changes are in feet. Contour interval is 25 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue. Cells that converted to dry are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

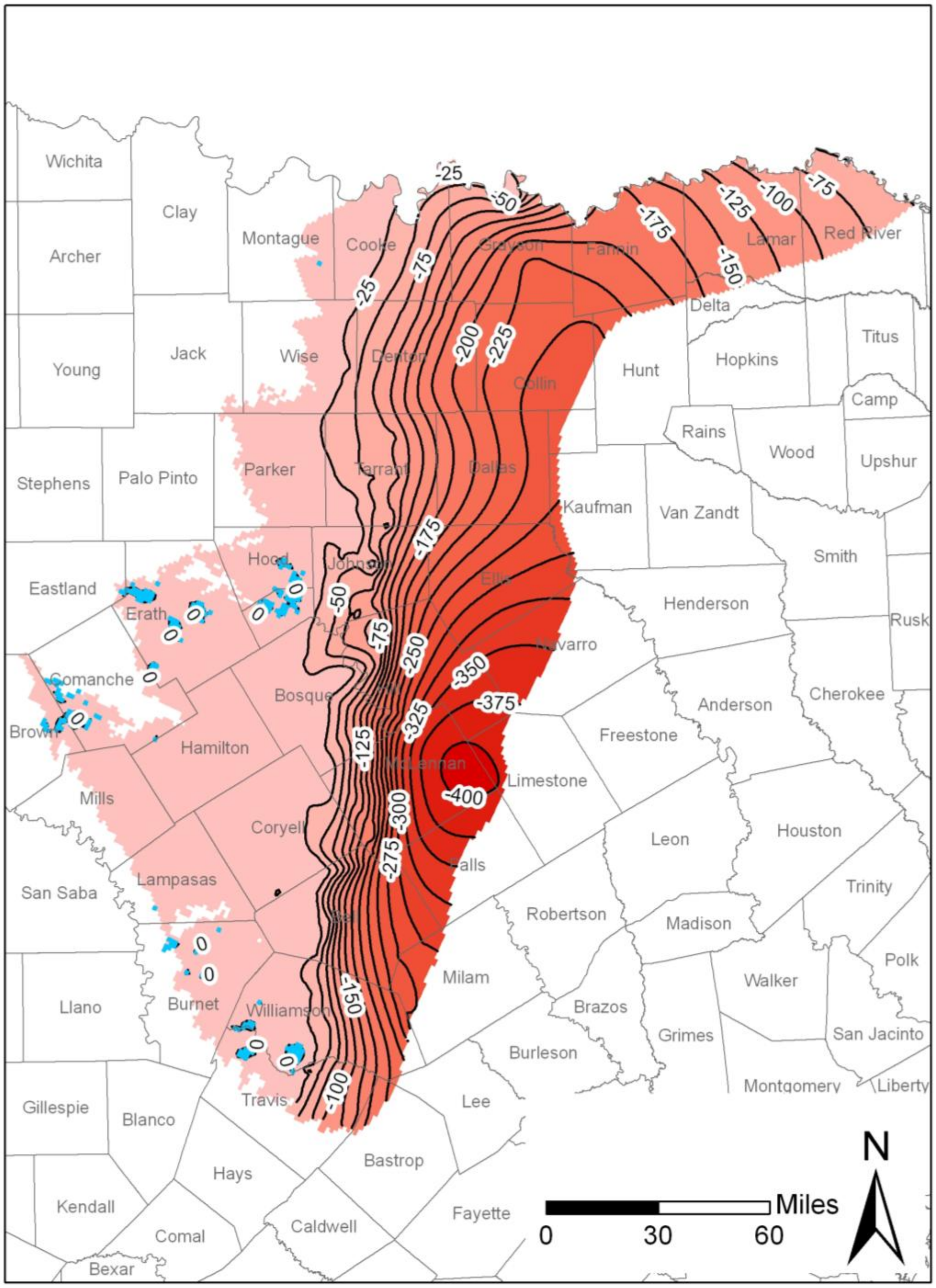


Figure 14. Changes in water levels after 50 years using the specified pumpage in layer 4 (Glen Rose Formation). Water level changes are in feet. Contour interval is 25 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue. No cells converted to dry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

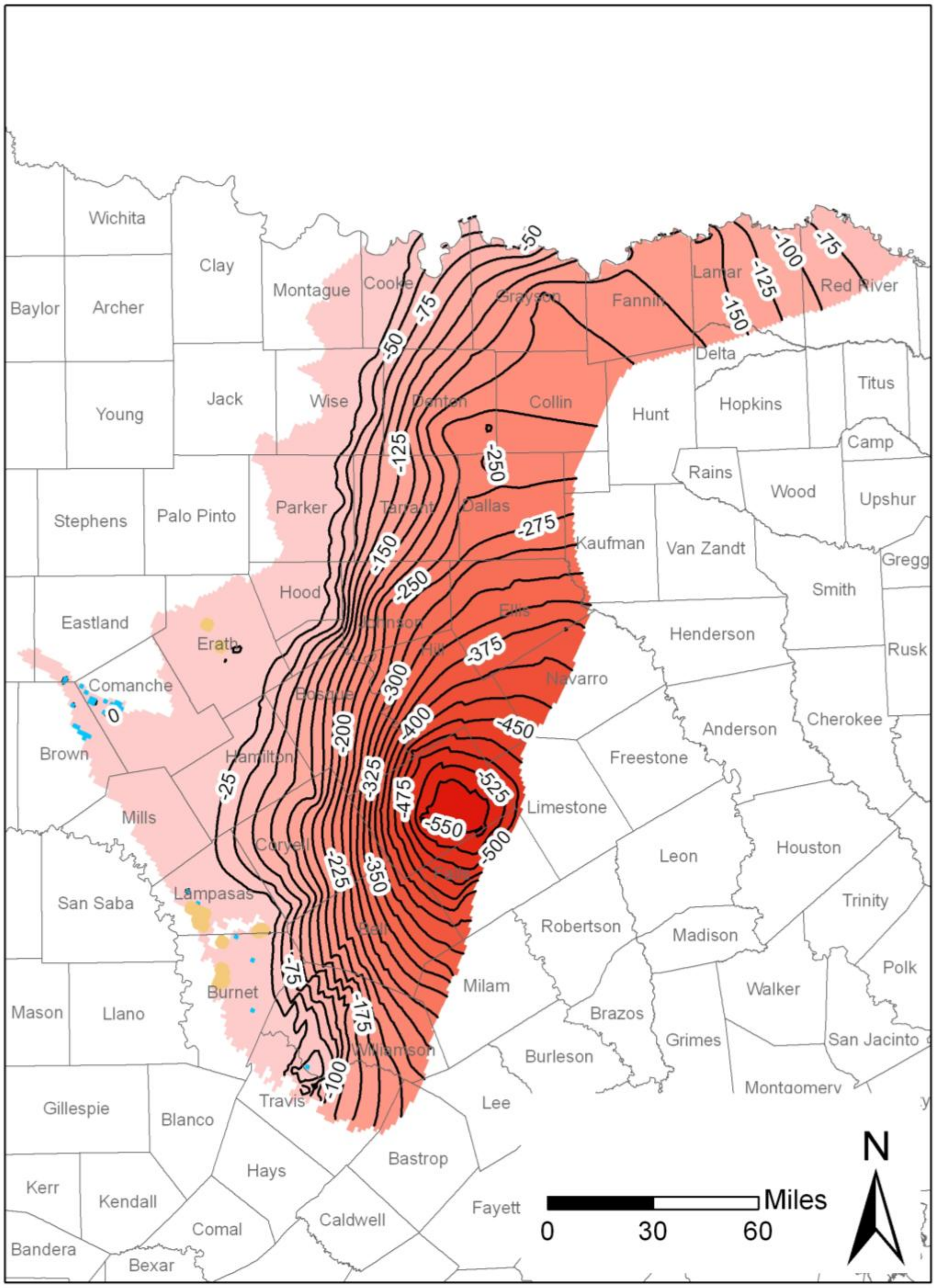


Figure 15. Changes in water levels after 50 years using the specified pumpage in layer 5 (Hensell Aquifer). Water level changes are in feet. Contour interval is 25 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue. Cells that converted to dry are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

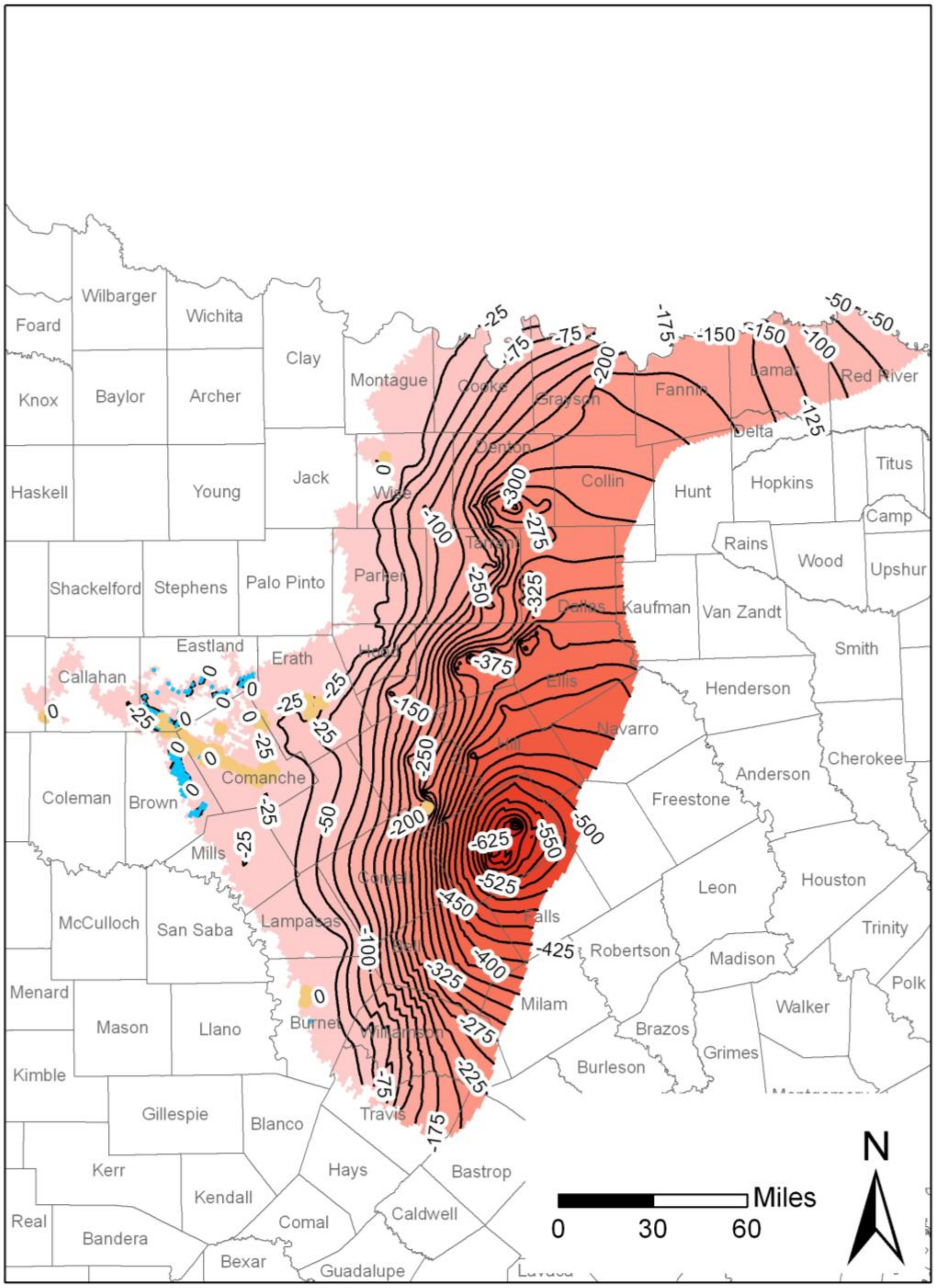


Figure 16. **Changes in water levels after 50 years using the specified pumpage in layer 7 (Hosston Aquifer). Water level changes are in feet. Contour interval is 25 feet. Decreases in water levels (drawdowns) are shown in red. Increases in water levels are shown in blue. Cells that converted to dry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

Appendix A

Water Budget for the 50-year Predictive Simulation

Table A-1. Water budget per county at the conclusion of the 50-year predictive simulation for layers 1, 3, 4, 5, and 7. Values listed are in acre-feet per year. A dashed line indicates the aquifer or strata footprint does not underlie a county.

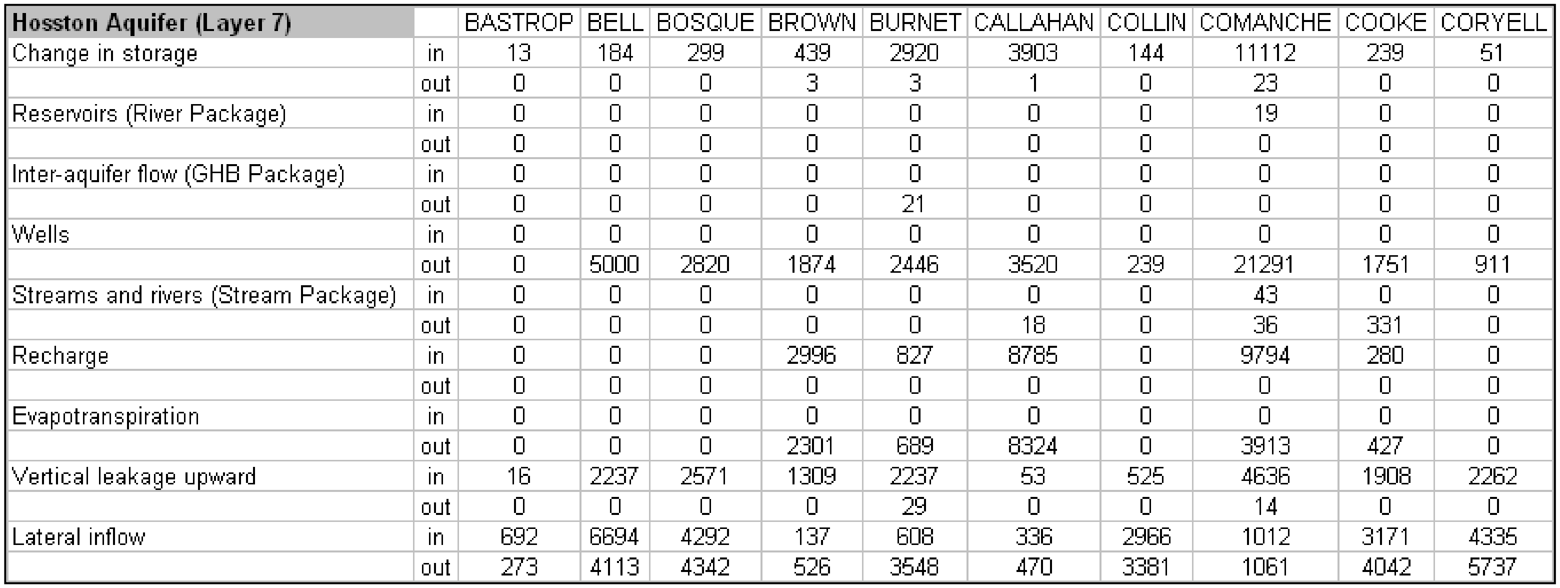
Woodbine Aquifer (Layer 1)		BASTROP	BELL	BOSQUE	BROWN	BURNET	CALLAHAN	COLLIN	COMANCHE	COOKE	CORYELL
Change in storage	in	-	-	-	-	-	-	399	-	2074	-
	out	-	-	-	-	-	-	0	-	0	-
Reservoirs (River Package)	in	-	-	-	-	-	-	0	-	6	-
	out	-	-	-	-	-	-	0	-	0	-
Inter-aquifer flow (GHB Package)	in	-	-	-	-	-	-	112	-	0	-
	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	-	122	208	6675	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	16	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	5552	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	-	1707	182	796	212
	out	3	22	655	115	6	-	905	65	2743	238
Vertical leakage downward	in	0	0	0	2	2	-	303	1	19	1
	out	13	354	500	238	122	-	0	250	1474	271

Table A-1. (continued).

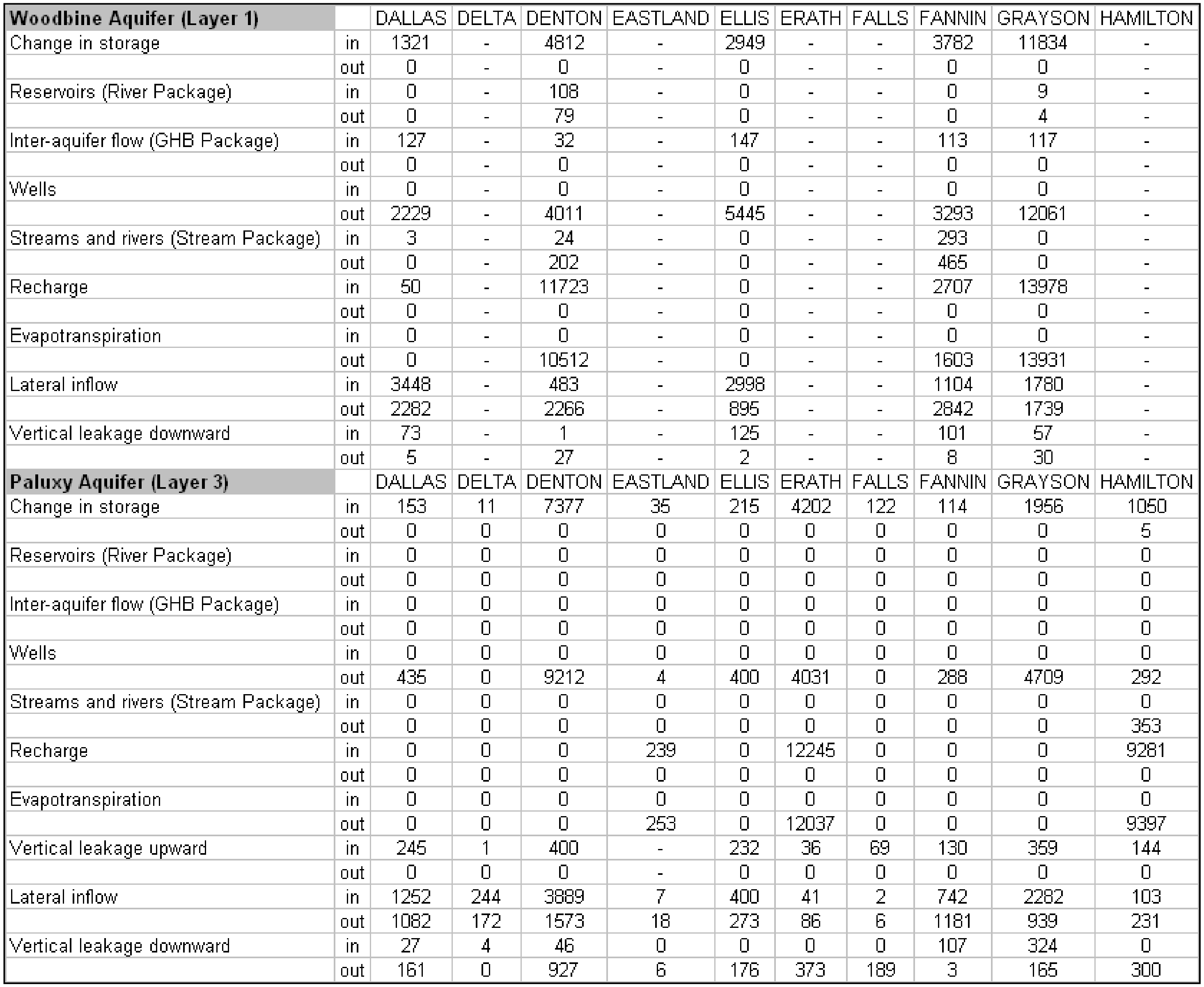
Glen Rose Formation (Layer 4)		BASTROP	BELL	BOSQUE	BROWN	BURNET	CALLAHAN	COLLIN	COMANCHE	COOKE	CORYELL
Change in storage	in	12	2681	1863	120	2804	-	118	483	37	6063
	out	0	0	0	0	23	-	0	2	0	0
Reservoirs (River Package)	in	0	15	0	0	0	-	0	0	0	6
	out	0	0	0	0	0	-	0	0	0	0
Inter-aquifer flow (GHB Package)	in	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	323	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	8659	0	10718
Vertical leakage upward	in	13	354	500	238	122	-	0	250	1474	271
	out	0	0	0	2	2	-	303	1	19	1
Lateral inflow	in	17	1247	923	19	266	-	105	268	24	951
	out	195	590	797	106	1258	-	47	238	83	993
Vertical leakage downward	in	10	0	0	0	1	-	117	0	9	0
	out	0	1416	2249	297	967	-	10	695	1446	2562
Hensell Aquifer (Layer 5)		BASTROP	BELL	BOSQUE	BROWN	BURNET	CALLAHAN	COLLIN	COMANCHE	COOKE	CORYELL
Change in storage	in	15	169	741	847	3601	119	141	4525	3986	2102
	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	356	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	13138	509	0
Vertical leakage upward	in	0	1416	2249	297	967	-	10	695	1446	2562
	out	10	0	0	0	1	-	117	0	9	0
Lateral inflow	in	0	3666	7765	64	244	13	1670	1012	1956	4751
	out	0	2062	6480	482	2446	112	1191	1546	4228	5400
Vertical leakage downward	in	1	0	0	0	29	0	0	15	1	0
	out	6	2089	2532	1263	1449	53	410	4510	1838	2249

Table A-1. (continued).



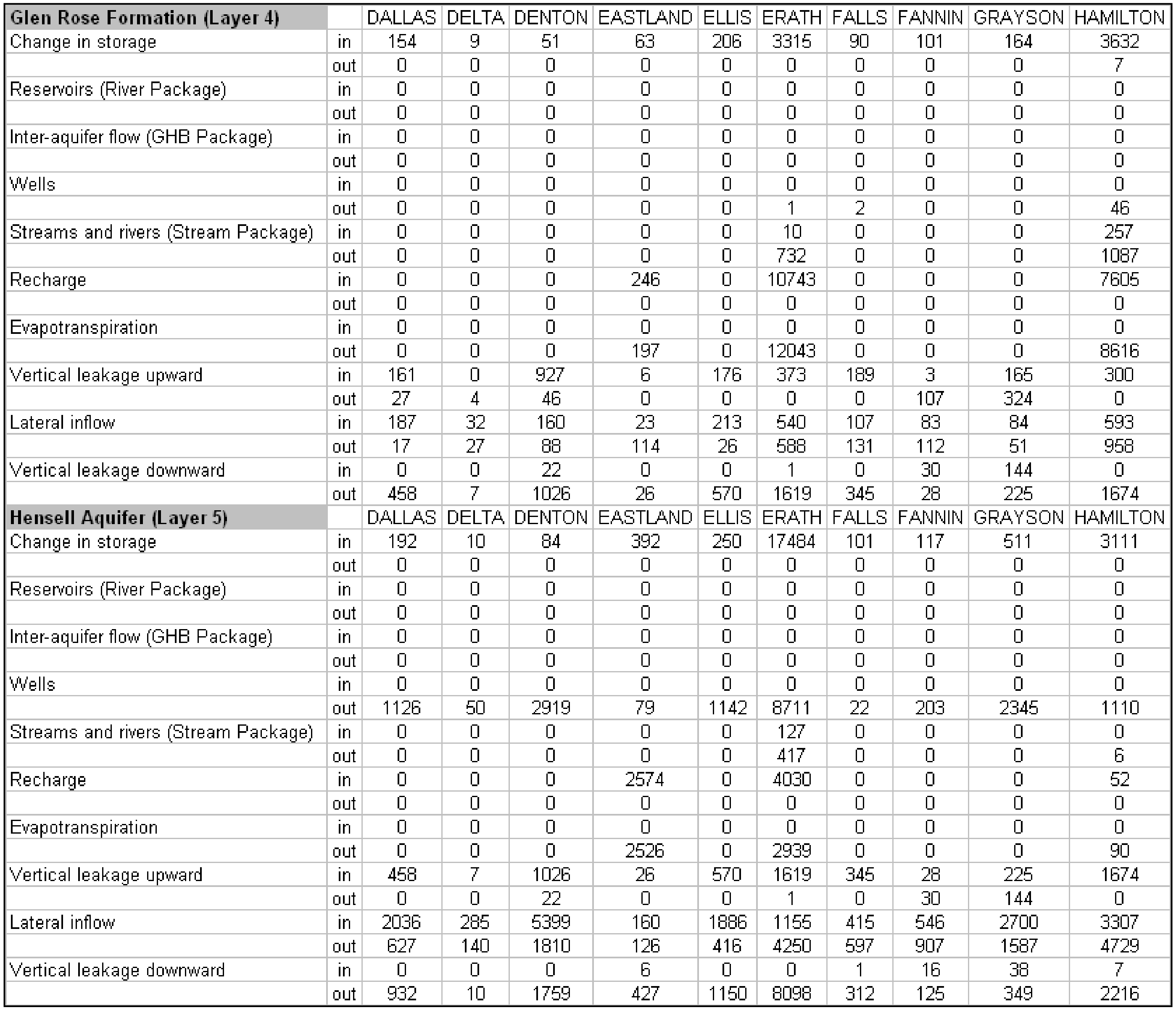
Hosston Aquifer (Layer 7)		BASTROP	BELL	BOSQUE	BROWN	BURNET	CALLAHAN	COLLIN	COMANCHE	COOKE	CORYELL
Change in storage	in	13	184	299	439	2920	3903	144	11112	239	51
	out	0	0	0	3	3	1	0	23	0	0
Reservoirs (River Package)	in	0	0	0	0	0	0	0	19	0	0
	out	0	0	0	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	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	21291	1751	911
Streams and rivers (Stream Package)	in	0	0	0	0	0	0	0	43	0	0
	out	0	0	0	0	0	18	0	36	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	2301	689	8324	0	3913	427	0
Vertical leakage upward	in	16	2237	2571	1309	2237	53	525	4636	1908	2262
	out	0	0	0	0	29	0	0	14	0	0
Lateral inflow	in	692	6694	4292	137	608	336	2966	1012	3171	4335
	out	273	4113	4342	526	3548	470	3381	1061	4042	5737

Table A-1. (continued).



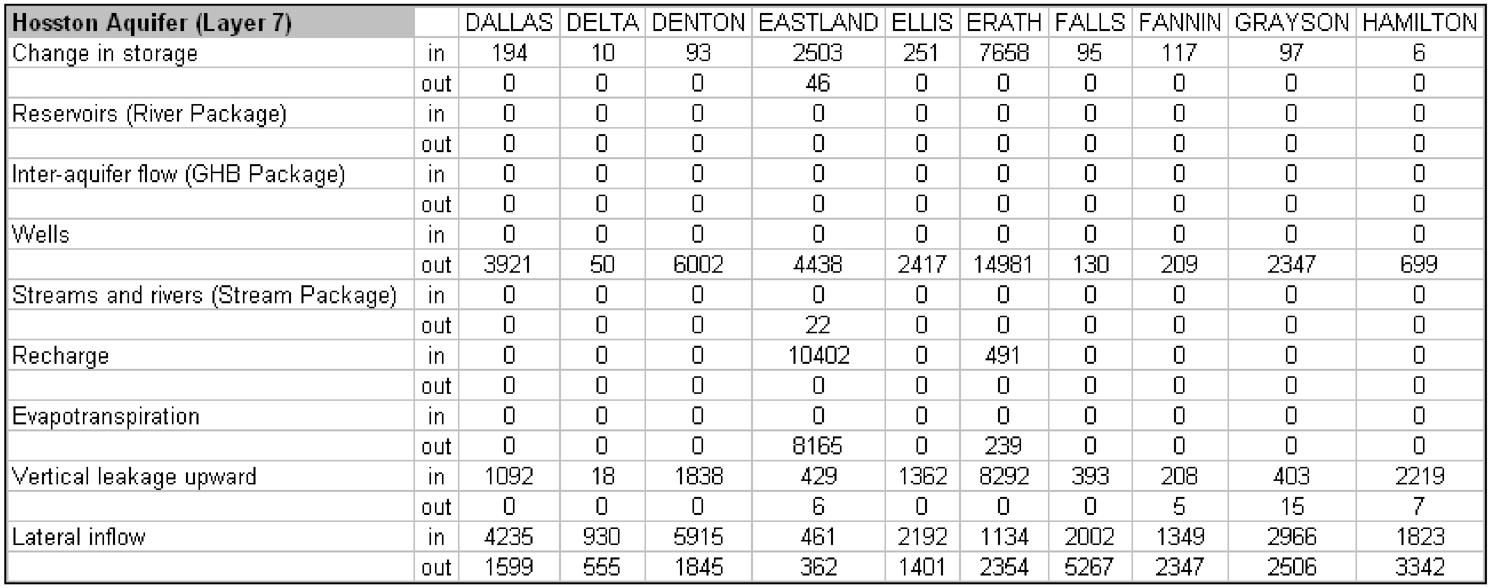
Woodbine Aquifer (Layer 1)		DALLAS	DELTA	DENTON	EASTLAND	ELLIS	ERATH	FALLS	FANNIN	GRAYSON	HAMILTON
Change in storage	in	1321	-	4812	-	2949	-	-	3782	11834	-
	out	0	-	0	-	0	-	-	0	0	-
Reservoirs (River Package)	in	0	-	108	-	0	-	-	0	9	-
	out	0	-	79	-	0	-	-	0	4	-
Inter-aquifer flow (GHB Package)	in	127	-	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	-	-	465	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	73	-	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	153	11	7377	35	215	4202	122	114	1956	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	4031	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	12037	0	0	0	9397
Vertical leakage upward	in	245	1	400	-	232	36	69	130	359	144
	out	0	0	0	-	0	0	0	0	0	0
Lateral inflow	in	1252	244	3889	7	400	41	2	742	2282	103
	out	1082	172	1573	18	273	86	6	1181	939	231
Vertical leakage downward	in	27	4	46	0	0	0	0	107	324	0
	out	161	0	927	6	176	373	189	3	165	300

Table A-1. (continued).



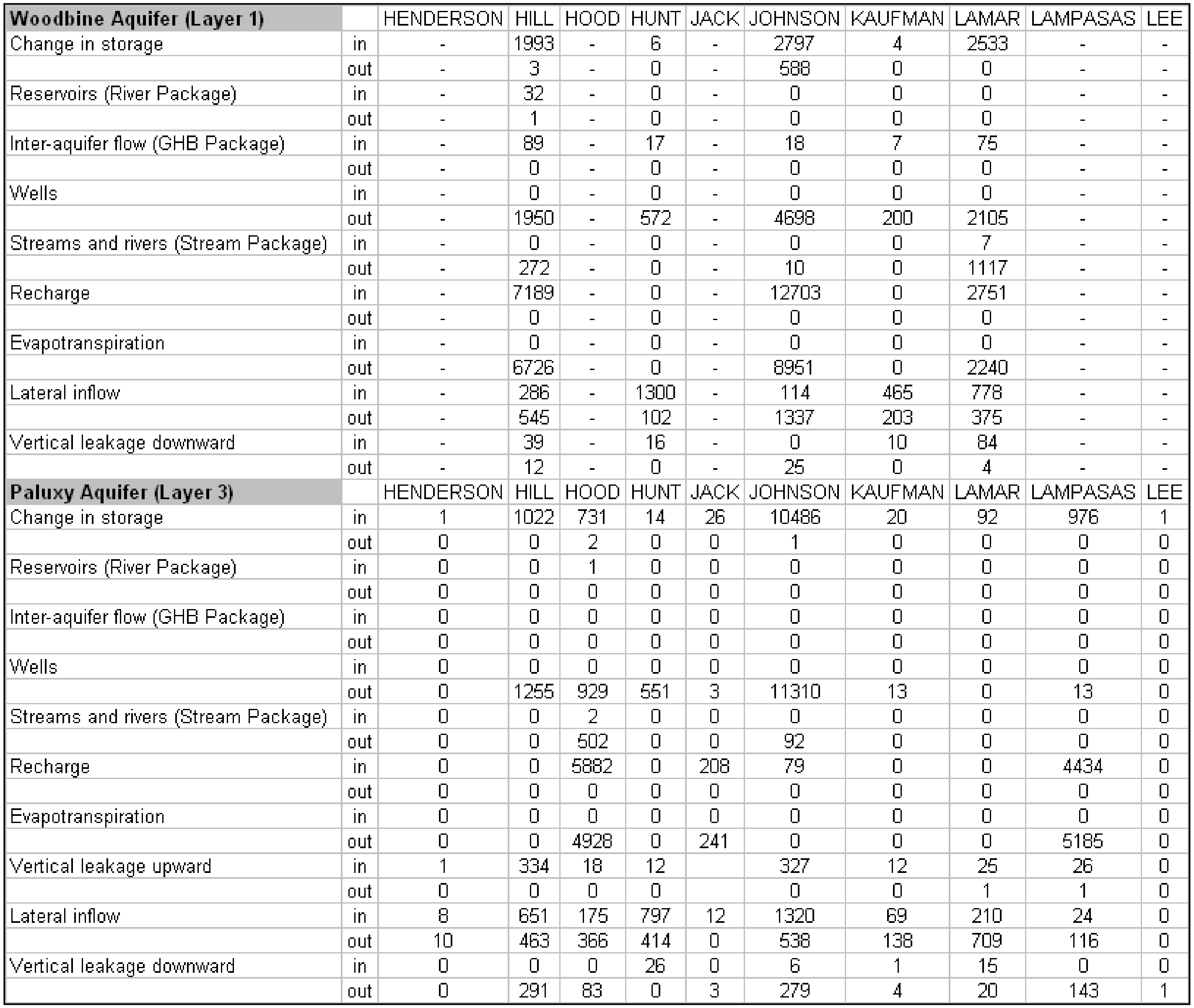
Glen Rose Formation (Layer 4)		DALLAS	DELTA	DENTON	EASTLAND	ELLIS	ERATH	FALLS	FANNIN	GRAYSON	HAMILTON
Change in storage	in	154	9	51	63	206	3315	90	101	164	3632
	out	0	0	0	0	0	0	0	0	0	7
Reservoirs (River Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	in	0	0	0	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	12043	0	0	0	8616
Vertical leakage upward	in	161	0	927	6	176	373	189	3	165	300
	out	27	4	46	0	0	0	0	107	324	0
Lateral inflow	in	187	32	160	23	213	540	107	83	84	593
	out	17	27	88	114	26	588	131	112	51	958
Vertical leakage downward	in	0	0	22	0	0	1	0	30	144	0
	out	458	7	1026	26	570	1619	345	28	225	1674
Hensell Aquifer (Layer 5)		DALLAS	DELTA	DENTON	EASTLAND	ELLIS	ERATH	FALLS	FANNIN	GRAYSON	HAMILTON
Change in storage	in	192	10	84	392	250	17484	101	117	511	3111
	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	8711	22	203	2345	1110
Streams and rivers (Stream Package)	in	0	0	0	0	0	127	0	0	0	0
	out	0	0	0	0	0	417	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	2526	0	2939	0	0	0	90
Vertical leakage upward	in	458	7	1026	26	570	1619	345	28	225	1674
	out	0	0	22	0	0	1	0	30	144	0
Lateral inflow	in	2036	285	5399	160	1886	1155	415	546	2700	3307
	out	627	140	1810	126	416	4250	597	907	1587	4729
Vertical leakage downward	in	0	0	0	6	0	0	1	16	38	7
	out	932	10	1759	427	1150	8098	312	125	349	2216

Table A-1. (continued).



Hosston Aquifer (Layer 7)		DALLAS	DELTA	DENTON	EASTLAND	ELLIS	ERATH	FALLS	FANNIN	GRAYSON	HAMILTON
Change in storage	in	194	10	93	2503	251	7658	95	117	97	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	14981	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	8165	0	239	0	0	0	0
Vertical leakage upward	in	1092	18	1838	429	1362	8292	393	208	403	2219
	out	0	0	0	6	0	0	0	5	15	7
Lateral inflow	in	4235	930	5915	461	2192	1134	2002	1349	2966	1823
	out	1599	555	1845	362	1401	2354	5267	2347	2506	3342

Table A-1. (continued).

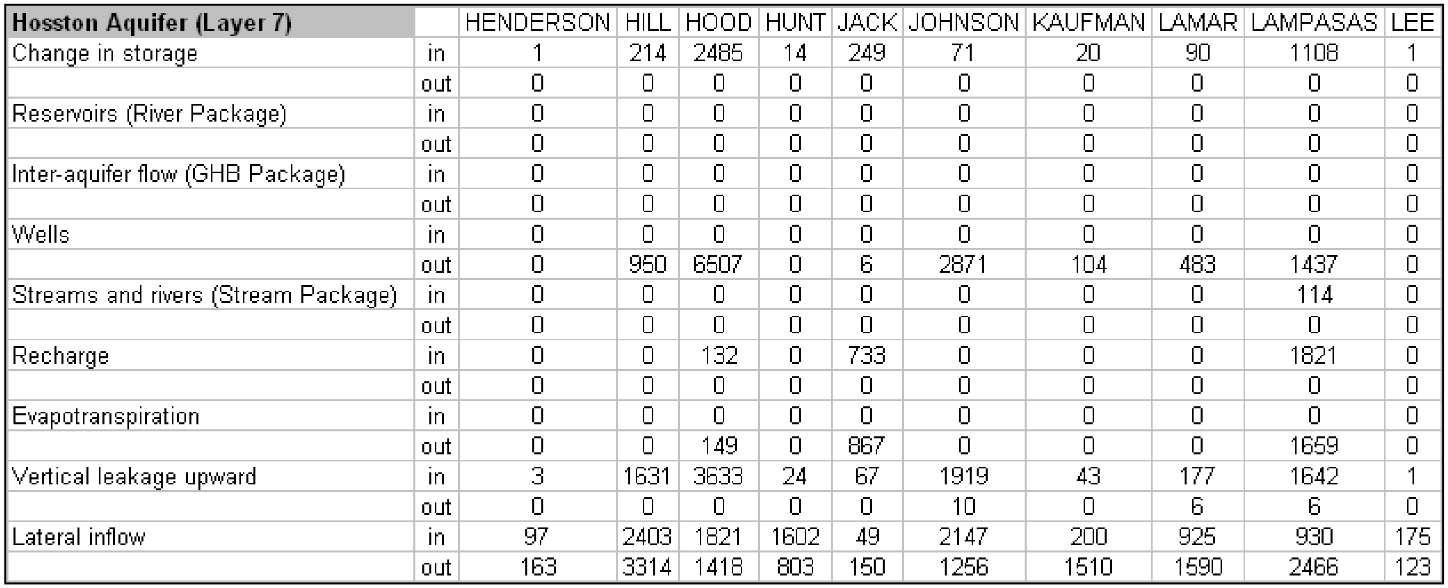


Woodbine Aquifer (Layer 1)		HENDERSON	HILL	HOOD	HUNT	JACK	JOHNSON	KAUFMAN	LAMAR	LAMPASAS	LEE
Change in storage	in	-	1993	-	6	-	2797	4	2533	-	-
	out	-	3	-	0	-	588	0	0	-	-
Reservoirs (River Package)	in	-	32	-	0	-	0	0	0	-	-
	out	-	1	-	0	-	0	0	0	-	-
Inter-aquifer flow (GHB Package)	in	-	89	-	17	-	18	7	75	-	-
	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	1022	731	14	26	10486	20	92	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	4928	0	241	0	0	0	5185	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	651	175	797	12	1320	69	210	24	0
	out	10	463	366	414	0	538	138	709	116	0
Vertical leakage downward	in	0	0	0	26	0	6	1	15	0	0
	out	0	291	83	0	3	279	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	574	1434	13	30	538	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	291	83	0	3	279	4	20	143	1
	out	0	0	0	26	0	6	1	15	0	0
Lateral inflow	in	2	421	325	66	10	745	3	42	254	5
	out	4	305	850	44	28	332	58	76	435	12
Vertical leakage downward	in	0	0	1	5	0	0	0	0	10	0
	out	1	974	833	1	32	1194	22	98	969	0
Hensell Aquifer (Layer 5)		HENDERSON	HILL	HOOD	HUNT	JACK	JOHNSON	KAUFMAN	LAMAR	LAMPASAS	LEE
Change in storage	in	1	206	7053	14	201	604	22	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	440	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	974	833	1	32	1194	22	98	969	0
	out	0	0	1	5	0	0	0	0	10	0
Lateral inflow	in	17	3889	1623	437	7	4606	42	355	1135	0
	out	29	2681	3063	258	50	3213	275	580	2472	0
Vertical leakage downward	in	0	0	0	0	0	11	0	13	6	0
	out	2	1462	3611	12	66	1868	26	111	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	214	2485	14	249	71	20	90	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	1631	3633	24	67	1919	43	177	1642	1
	out	0	0	0	0	0	10	0	6	6	0
Lateral inflow	in	97	2403	1821	1602	49	2147	200	925	930	175
	out	163	3314	1418	803	150	1256	1510	1590	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	201	47	773	1709	132	-	6255	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	-	15155	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	-	355	106	892
	out	19	74	1	90	294	71	-	1432	128	240
Vertical leakage downward	in	0	0	0	0	25	0	-	0	15	14
	out	52	491	54	265	664	75	-	992	3	0

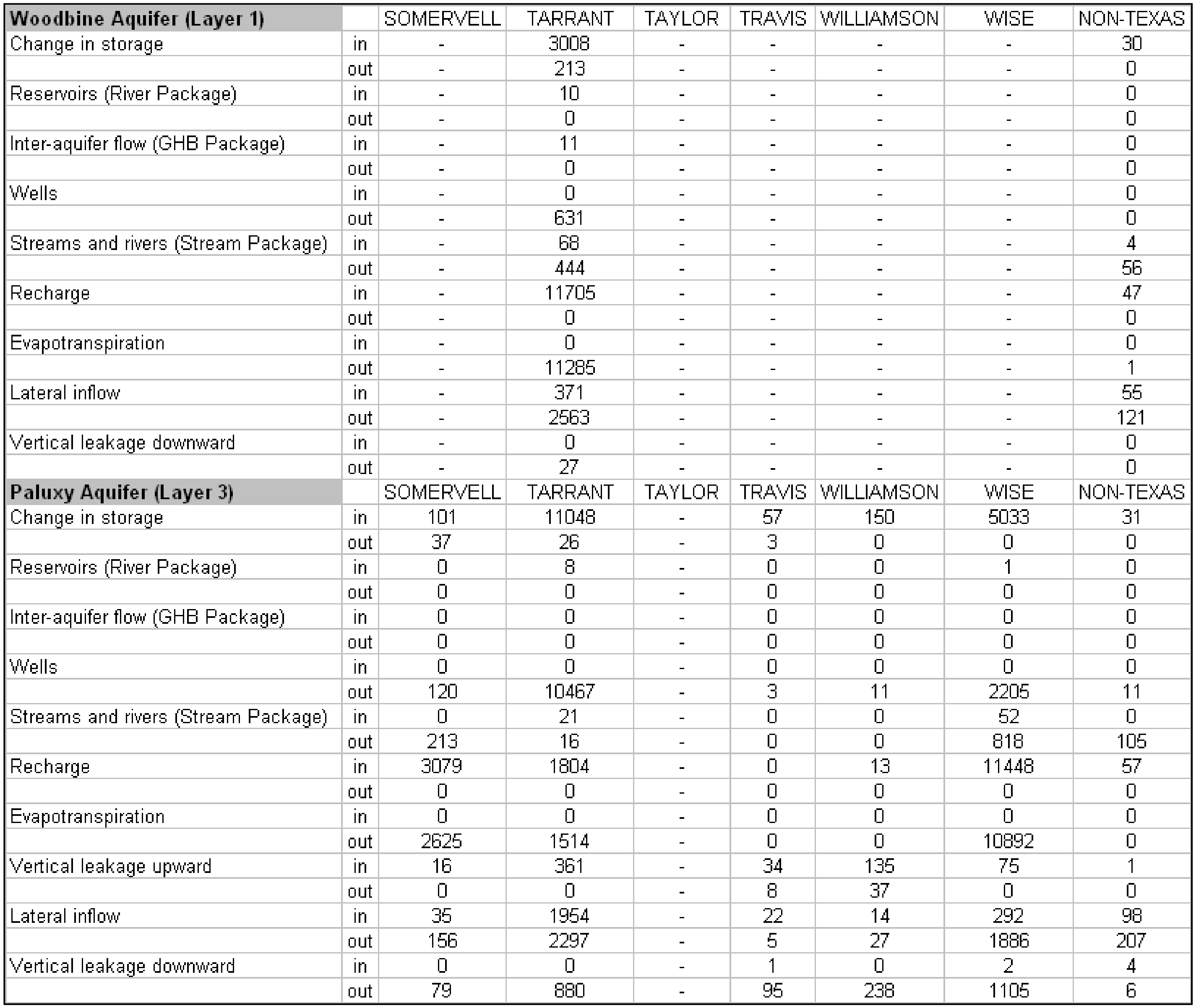
Table A-1. (continued).

Glen Rose Formation (Layer 4)		LIMESTONE	MCLENNAN	MILAM	MILLS	MONTAGUE	NAVARRO	PALO PINTO	PARKER	RED RIVER	ROCKWALL
Change in storage	in	33	824	36	655	7	113	-	843	33	9
	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	75	-	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	50	-	607	26	22
Vertical leakage downward	in	0	0	0	0	17	0	-	0	0	0
	out	88	1627	68	630	649	192	-	1532	24	3
Hensell Aquifer (Layer 5)		LIMESTONE	MCLENNAN	MILAM	MILLS	MONTAGUE	NAVARRO	PALO PINTO	PARKER	RED RIVER	ROCKWALL
Change in storage	in	35	227	42	3897	2542	123	-	4370	39	10
	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	2815	6644	0	-	2013	0	0
Vertical leakage upward	in	88	1627	68	630	649	192	-	1532	24	3
	out	0	0	0	0	17	0	-	0	0	0
Lateral inflow	in	123	6122	88	467	51	226	-	938	11	133
	out	292	486	40	1824	1607	150	-	2657	250	172
Vertical leakage downward	in	0	0	0	33	96	0	-	0	0	0
	out	82	3300	119	2031	1036	256	-	3213	47	14

Table A-1. (continued).

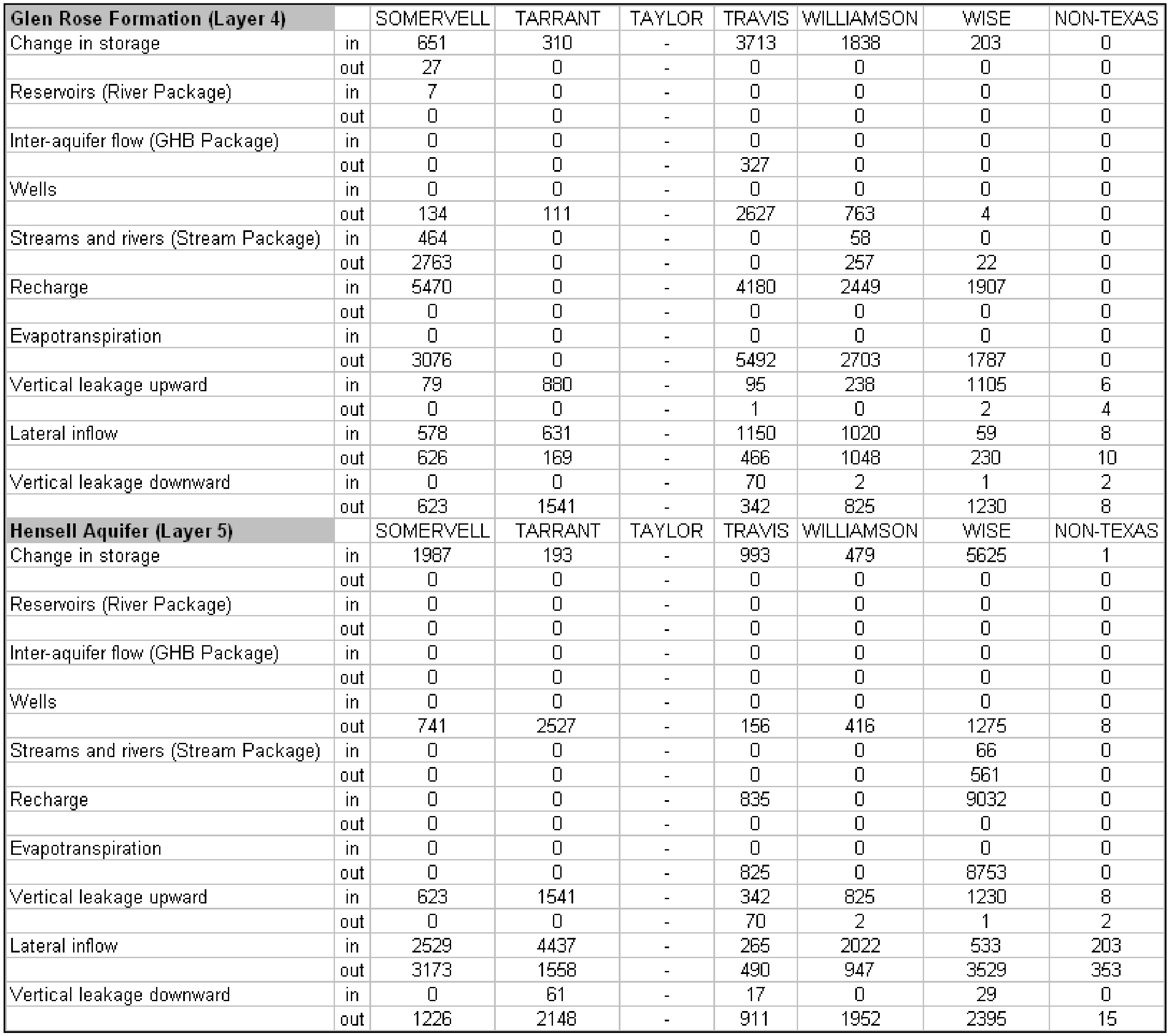
Hosston Aquifer (Layer 7)		LIMESTONE	MCLENNAN	MILAM	MILLS	MONTAGUE	NAVARRO	PALO PINTO	PARKER	RED RIVER	ROCKWALL
Change in storage	in	32	233	38	962	2675	117	196	1263	38	9
	out	0	0	0	0	0	0	0	0	0	0
Reservoirs (River Package)	in	0	0	0	0	0	0	0	0	0	0
	out	0	0	0	0	0	0	0	0	0	0
Inter-aquifer flow (GHB Package)	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	2475	7826	0	710	2323	0	0
Vertical leakage upward	in	109	3507	152	2032	1084	355	-	3703	78	21
	out	0	0	0	32	90	0	-	0	0	0
Lateral inflow	in	339	12848	1420	276	151	995	55	677	29	494
	out	1304	581	1292	1081	2763	465	61	3318	576	746

Table A-1. (continued).



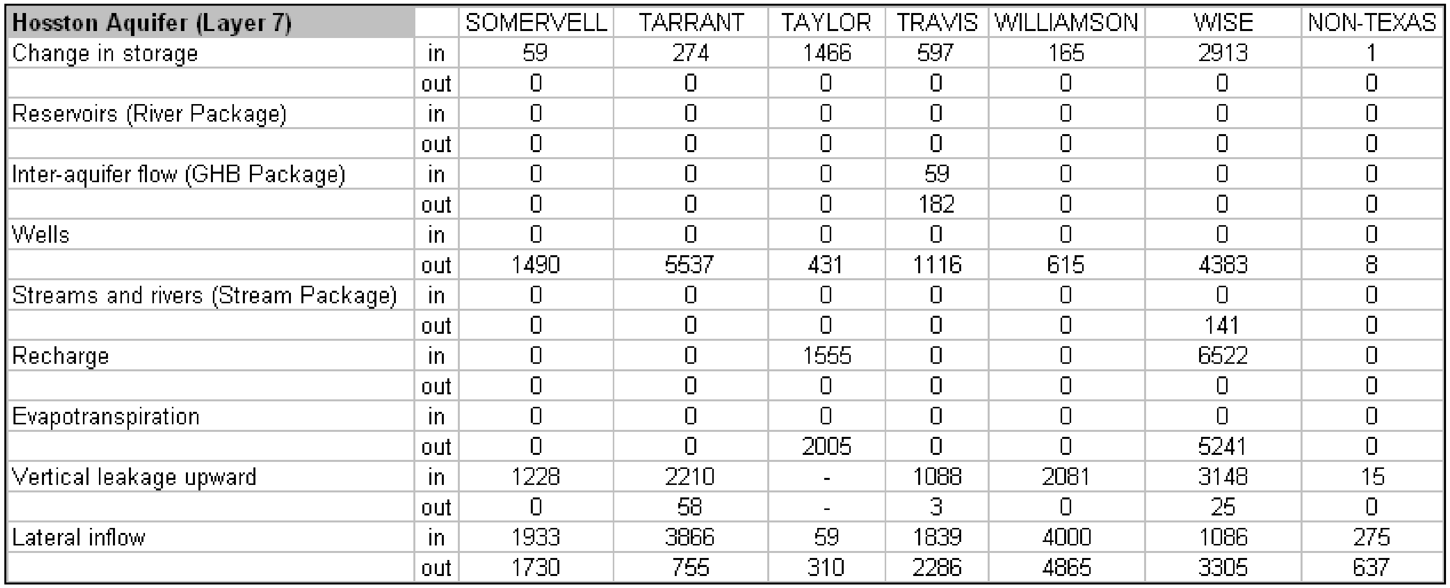
Woodbine Aquifer (Layer 1)		SOMERVELL	TARRANT	TAYLOR	TRAVIS	WILLIAMSON	WISE	NON-TEXAS
Change in storage	in	-	3008	-	-	-	-	30
	out	-	213	-	-	-	-	0
Reservoirs (River Package)	in	-	10	-	-	-	-	0
	out	-	0	-	-	-	-	0
Inter-aquifer flow (GHB Package)	in	-	11	-	-	-	-	0
	out	-	0	-	-	-	-	0
Wells	in	-	0	-	-	-	-	0
	out	-	631	-	-	-	-	0
Streams and rivers (Stream Package)	in	-	68	-	-	-	-	4
	out	-	444	-	-	-	-	56
Recharge	in	-	11705	-	-	-	-	47
	out	-	0	-	-	-	-	0
Evapotranspiration	in	-	0	-	-	-	-	0
	out	-	11285	-	-	-	-	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	11048	-	57	150	5033	31
	out	37	26	-	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	10467	-	3	11	2205	11
Streams and rivers (Stream Package)	in	0	21	-	0	0	52	0
	out	213	16	-	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	1514	-	0	0	10892	0
Vertical leakage upward	in	16	361	-	34	135	75	1
	out	0	0	-	8	37	0	0
Lateral inflow	in	35	1954	-	22	14	292	98
	out	156	2297	-	5	27	1886	207
Vertical leakage downward	in	0	0	-	1	0	2	4
	out	79	880	-	95	238	1105	6

Table A-1. (continued).



Glen Rose Formation (Layer 4)		SOMERVELL	TARRANT	TAYLOR	TRAVIS	WILLIAMSON	WISE	NON-TEXAS
Change in storage	in	651	310	-	3713	1838	203	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	111	-	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	880	-	95	238	1105	6
	out	0	0	-	1	0	2	4
Lateral inflow	in	578	631	-	1150	1020	59	8
	out	626	169	-	466	1048	230	10
Vertical leakage downward	in	0	0	-	70	2	1	2
	out	623	1541	-	342	825	1230	8
Hensell Aquifer (Layer 5)		SOMERVELL	TARRANT	TAYLOR	TRAVIS	WILLIAMSON	WISE	NON-TEXAS
Change in storage	in	1987	193	-	993	479	5625	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	2527	-	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	1541	-	342	825	1230	8
	out	0	0	-	70	2	1	2
Lateral inflow	in	2529	4437	-	265	2022	533	203
	out	3173	1558	-	490	947	3529	353
Vertical leakage downward	in	0	61	-	17	0	29	0
	out	1226	2148	-	911	1952	2395	15

Table A-1. (continued).



Hosston Aquifer (Layer 7)		SOMERVELL	TARRANT	TAYLOR	TRAVIS	WILLIAMSON	WISE	NON-TEXAS
Change in storage	in	59	274	1466	597	165	2913	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	5537	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	2005	0	0	5241	0
Vertical leakage upward	in	1228	2210	-	1088	2081	3148	15
	out	0	58	-	3	0	25	0
Lateral inflow	in	1933	3866	59	1839	4000	1086	275
	out	1730	755	310	2286	4865	3305	637