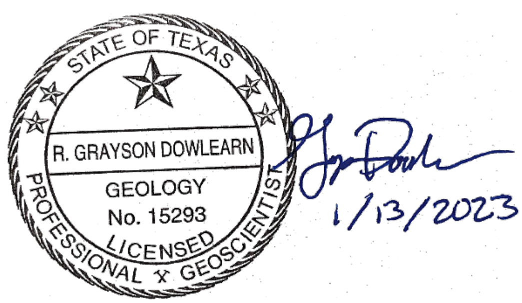
GAM RUN 22-015: NORTH PLAINS GROUNDWATER CONSERVATION DISTRICT MANAGEMENT PLAN

Grayson Dowlearn, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Modeling Department
512-475-1552
January 13, 2023



This page is intentionally blank

GAM RUN 22-015: NORTH PLAINS GROUNDWATER CONSERVATION DISTRICT MANAGEMENT PLAN

Grayson Dowlearn, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Modeling Department
512-475-1552
January 13, 2023

EXECUTIVE SUMMARY:

Texas State Water Code, Section 36.1071, Subsection (h) (Texas Water Code, 2011), states that, in developing its groundwater management plan, a groundwater conservation district shall use groundwater availability modeling information provided by the Executive Administrator of the Texas Water Development Board (TWDB) in conjunction with any available site-specific information provided by the district for review and comment to the Executive Administrator.

The TWDB provides data and information to the North Plains Groundwater Conservation District in two parts. Part 1 is the Estimated Historical Water Use/State Water Plan dataset report, which will be provided to you separately by the TWDB Groundwater Technical Assistance Department. Please direct questions about the water data report to Mr. Stephen Allen at 512-463-7317 or stephen.allen@twdb.texas.gov. Part 2 is the required groundwater availability modeling information, which includes:

1. the annual amount of recharge from precipitation, if any, to the groundwater resources within the district;

2. for each aquifer within the district, the annual volume of water that discharges from the aquifer to springs and any surface-water bodies, including lakes, streams, and rivers; and

3. the annual volume of flow into and out of the district within each aquifer and between aquifers in the district.

The groundwater management plan for the North Plains Groundwater Conservation District should be adopted by the district on or before January 25, 2023 and submitted to the executive administrator of the TWDB on or before February 24, 2023. The current management plan for the North Plains Groundwater Conservation District expires on April 25, 2023.

We used the groundwater availability model for the High Plains Aquifer System groundwater availability model (Deeds and others, 2015; Deeds and Jigmond, 2015) to estimate the management plan information for the Dockum, Rita Blanca, and Ogallala aquifers within the North Plains Groundwater Conservation District.

This report replaces the results of GAM Run 17-008 (Goswami, 2017). Values may differ from the previous report as a result of routine updates to the spatial grid file used to define county, groundwater conservation district, and aquifer boundaries, which can impact the calculated water budget values. Additionally, the approach used for analyzing model results is reviewed during each update and may have been refined to better delineate groundwater flows. Tables 1, 2, and 3 summarize the groundwater availability model data required by statute. Figures 1, 3, and 5 shows the area of the model from which the values in Tables 1, 2, and 3 were extracted. Figures 2, 4, and 6 provide a generalized diagram of the groundwater flow components provided in Tables 1, 2, and 3. Full water budgets for each aquifer within the district are provided in Appendix A. These budgets are included to assist North Plains Groundwater Conservation District in analyzing the effects of pumping and recharge on the aquifers within the district. If, after review of the figures, the North Plains Groundwater Conservation District determines that the district boundaries used in the assessment do not reflect current conditions, please notify the TWDB at your earliest convenience.

METHODS:

In accordance with the provisions of the Texas State Water Code, Section 36.1071, Subsection (h), the groundwater availability model mentioned above was used to estimate information for the North Plains Groundwater Conservation District management plan. Water budgets were extracted for the historical model period for the Dockum, Rita Blanca, and Ogallala aquifers (1980-2012) using ZONEBUDGET Version 3.01 (Harbaugh, 2009). The average annual water budget values for recharge, surface-water outflow, inflow to the district, outflow from the district, and the flow between aquifers within the district are summarized in this report.

PARAMETERS AND ASSUMPTIONS:

Dockum, Rita Blanca, and Ogallala aquifers

- We used version 1.01 of the groundwater availability model for the High Plains Aquifer System to analyze the Dockum, Rita Blanca, and Ogallala aquifers. See Deeds and others (2015) and Deeds and Jigmond (2015) for assumptions and limitations of the model.

- The groundwater availability model for the High Plains Aquifer System contains four layers. In the model, Layer 1 represents the Ogallala Aquifer, Layer 2 represents the Rita Blanca, Edwards-Trinity (High Plains), and Edwards-Trinity (Plateau) aquifers where present, Layer 3 represents the upper portion of the Dockum Aquifer and equivalent units, and Layer 4 represents the lower portion of the Dockum Aquifer and equivalent units.

- Water budget values for the district were determined for the Ogallala Aquifer (Layer 1), Rita Blanca Aquifer (Layer 2), and the Dockum Aquifer (Layers 3 and 4). The Edwards-Trinity (High Plains) Aquifer does not occur within the North Plains Groundwater Conservation District and therefore no groundwater budget values are included for it in this report.

- The River package used in the model can represent a river, reservoir, or a general head boundary, however, the River package only represents rivers and reservoirs within North Plains Groundwater Conservation District.

- Water budget terms were averaged for the historical calibration period 1980 to 2012 (stress periods 52 through 84).

- The model was run with MODFLOW-NWT (Niswonger and others, 2011).

RESULTS:

A groundwater budget summarizes the amount of water entering and leaving the aquifer according to the groundwater availability model. Selected groundwater budget components listed below were extracted from the groundwater availability model results for the Dockum, Rita Blanca, and Ogallala aquifers located within the North Plains Groundwater Conservation District and averaged over the historical calibration period, as shown in Tables 1, 2 and 3.

1. Precipitation recharge—the areally distributed recharge sourced from precipitation falling on the outcrop areas of the aquifers (where the aquifer is exposed at land surface) within the district.

2. Surface-water outflow—the total water discharging from the aquifer (outflow) to surface-water features such as streams, reservoirs, and springs.

3. Flow into and out of district—the lateral flow within the aquifer between the district and adjacent counties.

4. Flow between aquifers—the net vertical flow between the aquifer and adjacent aquifers or confining units. This flow is controlled by the relative water levels in each aquifer and aquifer properties of each aquifer or confining unit that define the amount of leakage that occurs.

The information needed for the district's management plan is summarized in Table 1, 2, and 3. Figures 2, 4, and 6 provide a generalized diagram of the groundwater flow components provided in Tables 1, 2, and 3. Full water budgets for each aquifer within the district are provided in Appendix A. These budgets are included to assist North Plains Groundwater Conservation District in analyzing the effects of pumping and recharge on the aquifers within the district.

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

TABLE 1: SUMMARIZED INFORMATION FOR THE DOCKUM AQUIFER THAT IS NEEDED FOR THE NORTH PLAINS GROUNDWATER CONSERVATION DISTRICT'S GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Dockum Aquifer	49
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Dockum Aquifer	0
Estimated annual volume of flow into the district within each aquifer in the district	Dockum Aquifer	402
Estimated annual volume of flow out of the district within each aquifer in the district	Dockum Aquifer	1,821
Estimated net annual volume of flow between each aquifer in the district	From Dockum Aquifer to Rita Blanca Aquifer	488
	To Dockum Aquifer from Ogallala Aquifer	908
	To Dockum Aquifer from Dockum equivalent units within district	55
	To Dockum Aquifer from equivalent units in Oklahoma and New Mexico	809

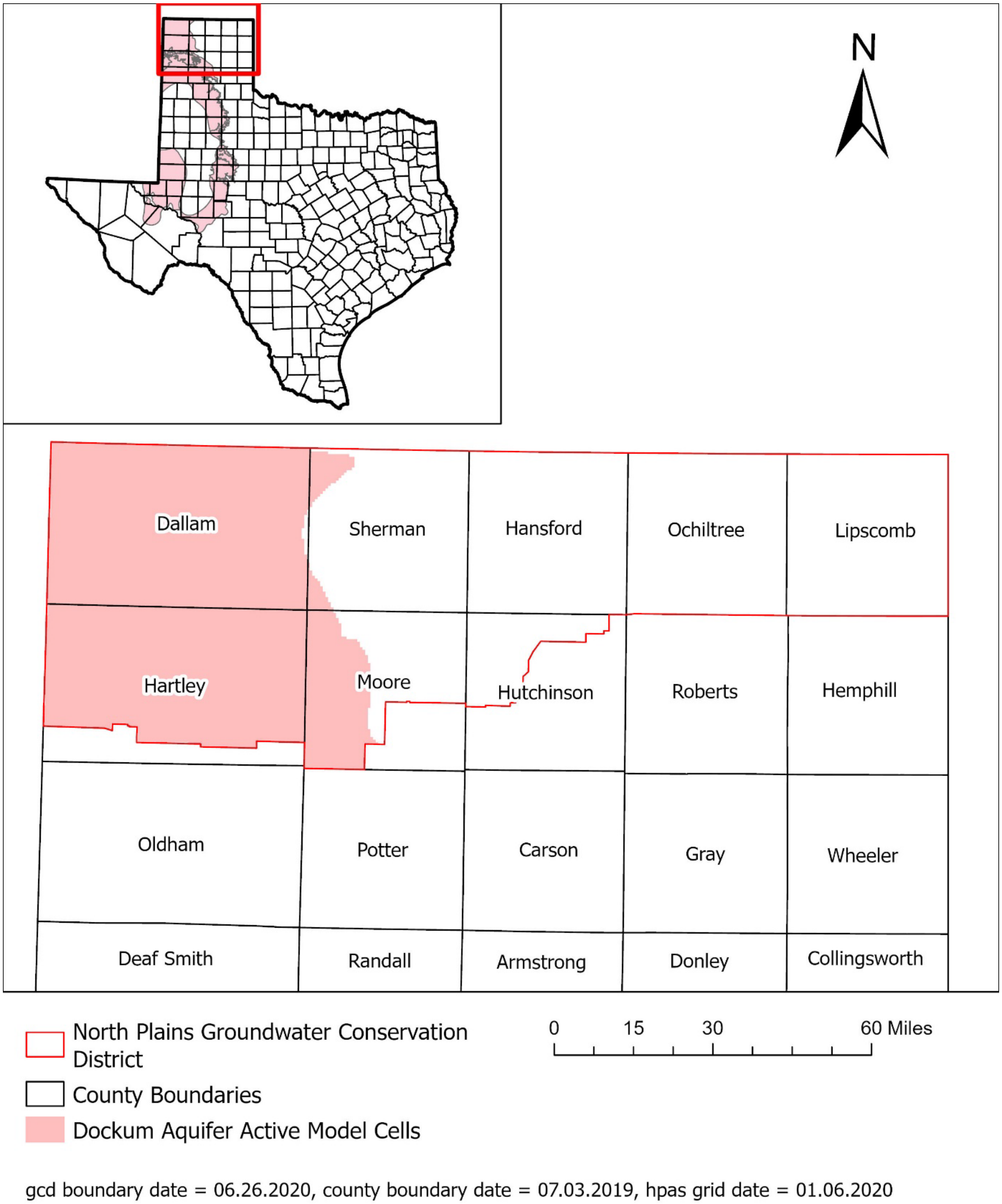
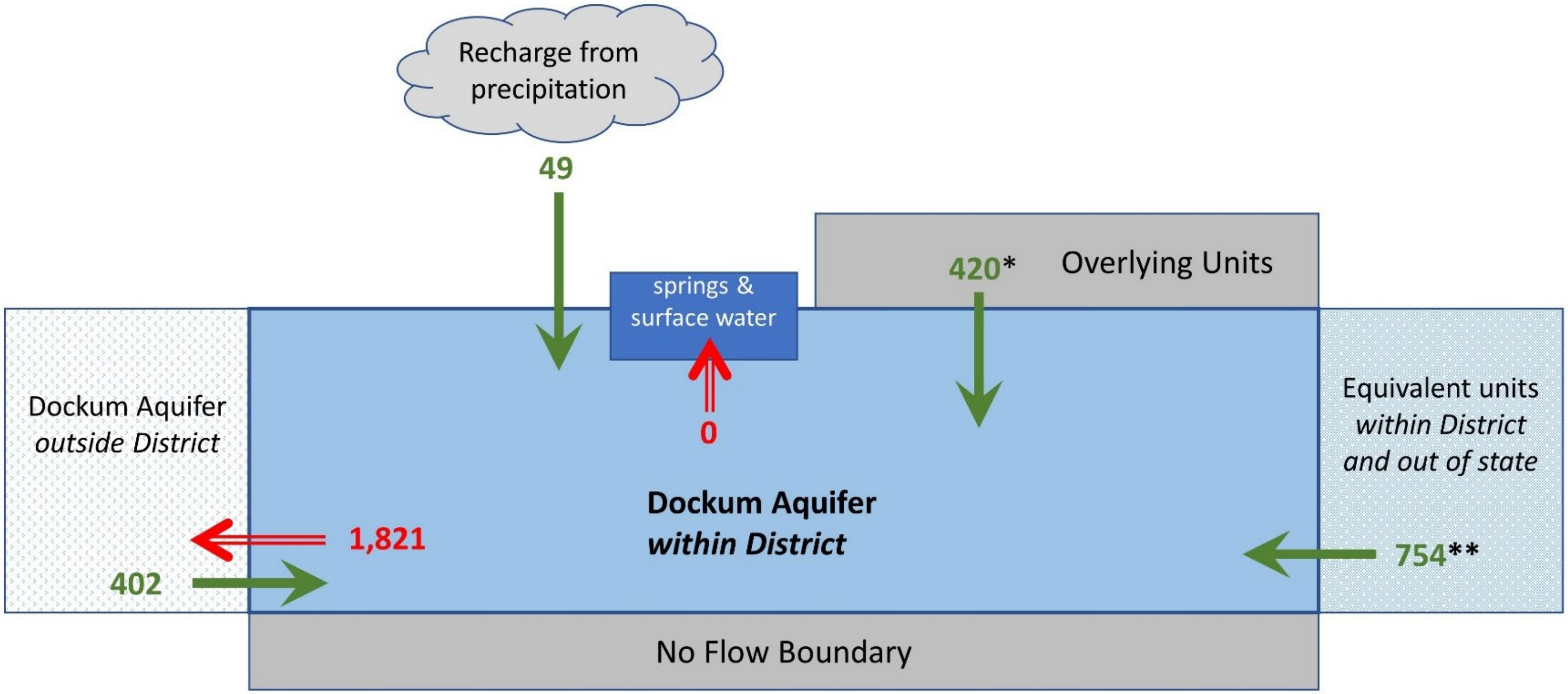


FIGURE 1: AREA OF THE HIGH PLAINS AQUIFER SYSTEM GROUNDWATER AVAILABILITY MODEL FROM WHICH THE INFORMATION IN TABLE 1 WAS EXTRACTED (THE DOCKUM AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).



* Flow from Overlying Units includes net outflow of 488 acre-feet per year from the Rita Blanca Aquifer and a net inflow of 908 acre-feet per year from the Ogallala Aquifer.

** Flow from Equivalent units within District and Out of State includes net outflow of 55 acre-feet per year to equivalent units within district and net inflow of 809 acre-feet per year from equivalent units in Oklahoma and New Mexico

Caveat: This diagram only includes the water budget items provided in Table 1. A complete water budget would include additional inflows and outflows. Please see Appendix A for a full water budget.

FIGURE 2: GENERALIZED DIAGRAM OF THE SUMMARIZED BUDGET INFORMATION FROM TABLE 1, REPRESENTING DIRECTIONS OF FLOW FOR THE DOCKUM AQUIFER WITHIN NORTH PLAINS GROUNDWATER CONSERVATION DISTRICT. FLOW VALUES EXPRESSED IN ACRE-FEET PER YEAR.

TABLE 2: SUMMARIZED INFORMATION FOR THE RITA BLANCA AQUIFER THAT IS NEEDED FOR THE NORTH PLAINS GROUNDWATER CONSERVATION DISTRICT'S GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

<table>
<tr><th>Management Plan requirement</th><th>Aquifer or confining unit</th><th>Results</th></tr>
<tr><td>Estimated annual amount of recharge from precipitation to the district</td><td>Rita Blanca Aquifer</td><td>0</td></tr>
<tr><td>Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers</td><td>Rita Blanca Aquifer</td><td>0</td></tr>
<tr><td>Estimated annual volume of flow into the district within each aquifer in the district</td><td>Rita Blanca Aquifer</td><td>0</td></tr>
<tr><td>Estimated annual volume of flow out of the district within each aquifer in the district</td><td>Rita Blanca Aquifer</td><td>0</td></tr>
<tr><td rowspan="4">Estimated net annual volume of flow between each aquifer in the district</td><td>To the Rita Blanca Aquifer from the Dockum Aquifer</td><td>488</td></tr>
<tr><td>To the Rita Blanca Aquifer from the Ogallala Aquifer</td><td>2,984</td></tr>
<tr><td>From the Rita Blanca Aquifer to Rita Blanca equivalent units within district</td><td>126</td></tr>
<tr><td>To the Rita Blanca Aquifer from equivalent units in Oklahoma and New Mexico</td><td>811</td></tr>
</table>

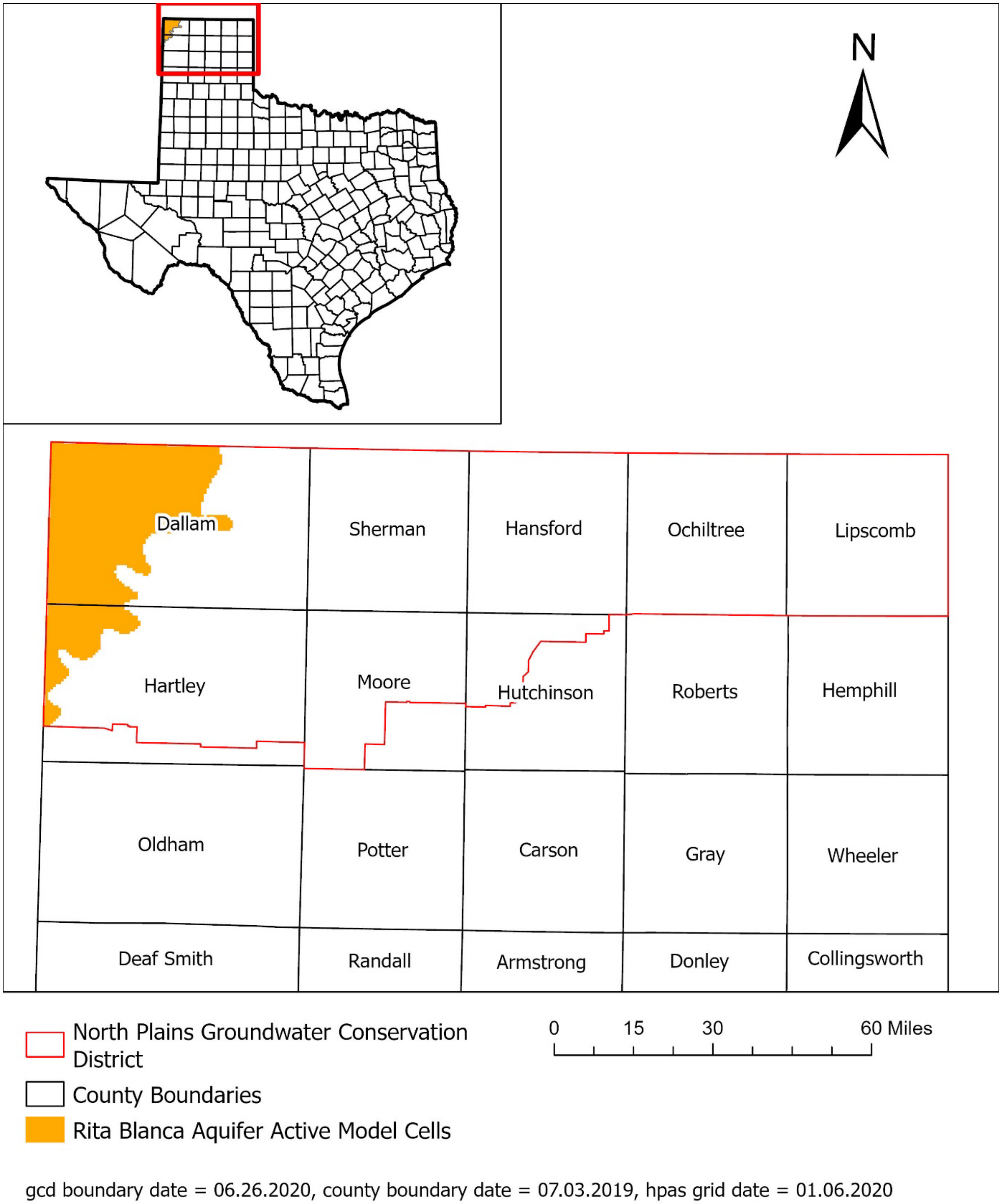
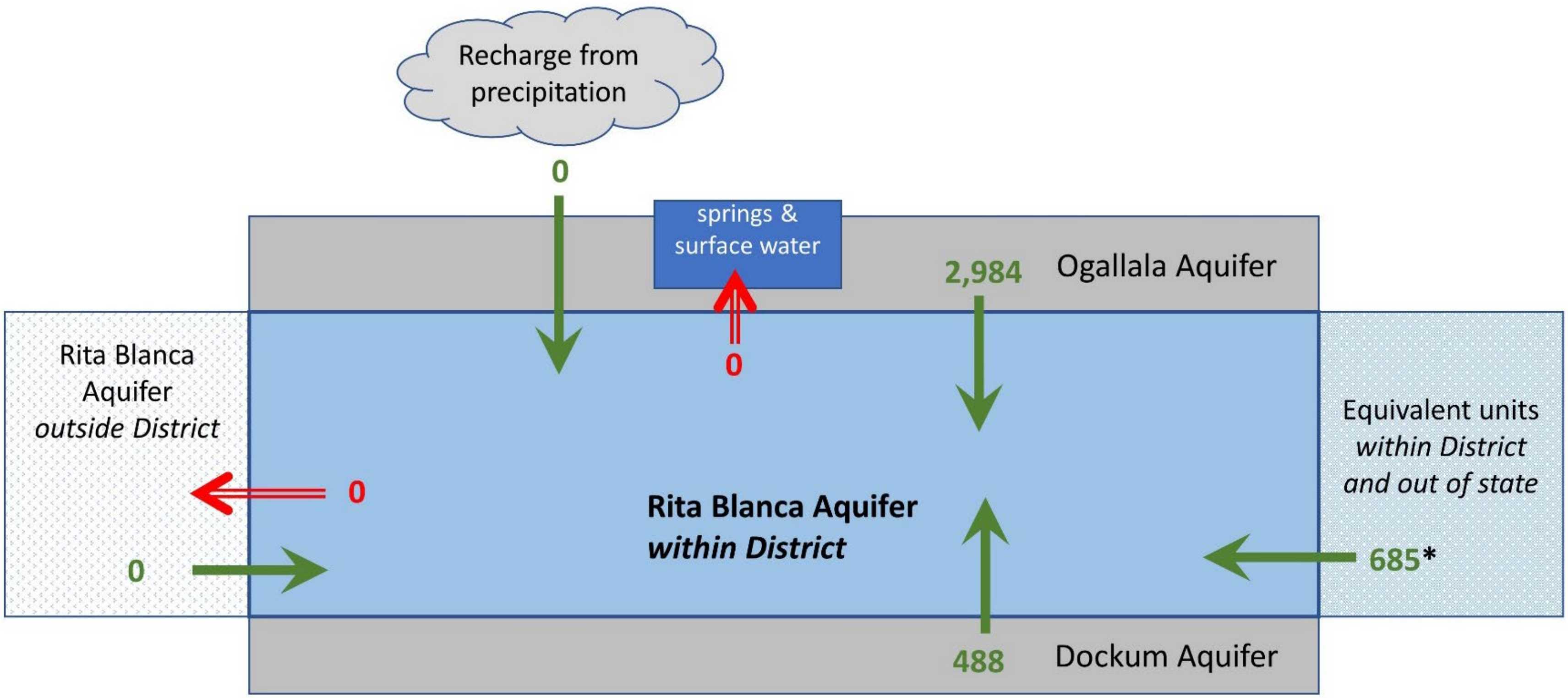


FIGURE 3: AREA OF THE HIGH PLAINS AQUIFER SYSTEM GROUNDWATER AVAILABILITY MODEL FROM WHICH THE INFORMATION IN TABLE 2 WAS EXTRACTED (THE RITA BLANCA AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).



* Flow from Equivalent Units within District and Out of State includes net outflow of 126 acre-feet per year from equivalent units within the district and net inflow of 811 acre-feet per year from equivalent units in Oklahoma and New Mexico.

Caveat: This diagram only includes the water budget items provided in Table 2. A complete water budget would include additional inflows and outflows. Please see Appendix A for a full water budget.

FIGURE 4: GENERALIZED DIAGRAM OF THE SUMMARIZED BUDGET INFORMATION FROM TABLE 2, REPRESENTING DIRECTIONS OF FLOW FOR THE RITA BLANCA AQUIFER WITHIN NORTH PLAINS GROUNDWATER CONSERVATION DISTRICT. FLOW VALUES EXPRESSED IN ACRE-FEET PER YEAR.

TABLE 3: SUMMARIZED INFORMATION FOR THE OGALLALA AQUIFER THAT IS NEEDED FOR THE NORTH PLAINS GROUNDWATER CONSERVATION DISTRICT'S GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Ogallala Aquifer	137,004
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Ogallala Aquifer	26,369
Estimated annual volume of flow into the district within each aquifer in the district	Ogallala Aquifer	7,324
Estimated annual volume of flow out of the district within each aquifer in the district	Ogallala Aquifer	50,907
Estimated net annual volume of flow between each aquifer in the district	From the Ogallala Aquifer to the Dockum Aquifer	908
	From the Ogallala Aquifer to the Rita Blanca Aquifer	2,984
	From the Ogallala Aquifer to Ogallala equivalent units within district	3,060
	To the Ogallala Aquifer from equivalent units in Oklahoma and New Mexico	1,887

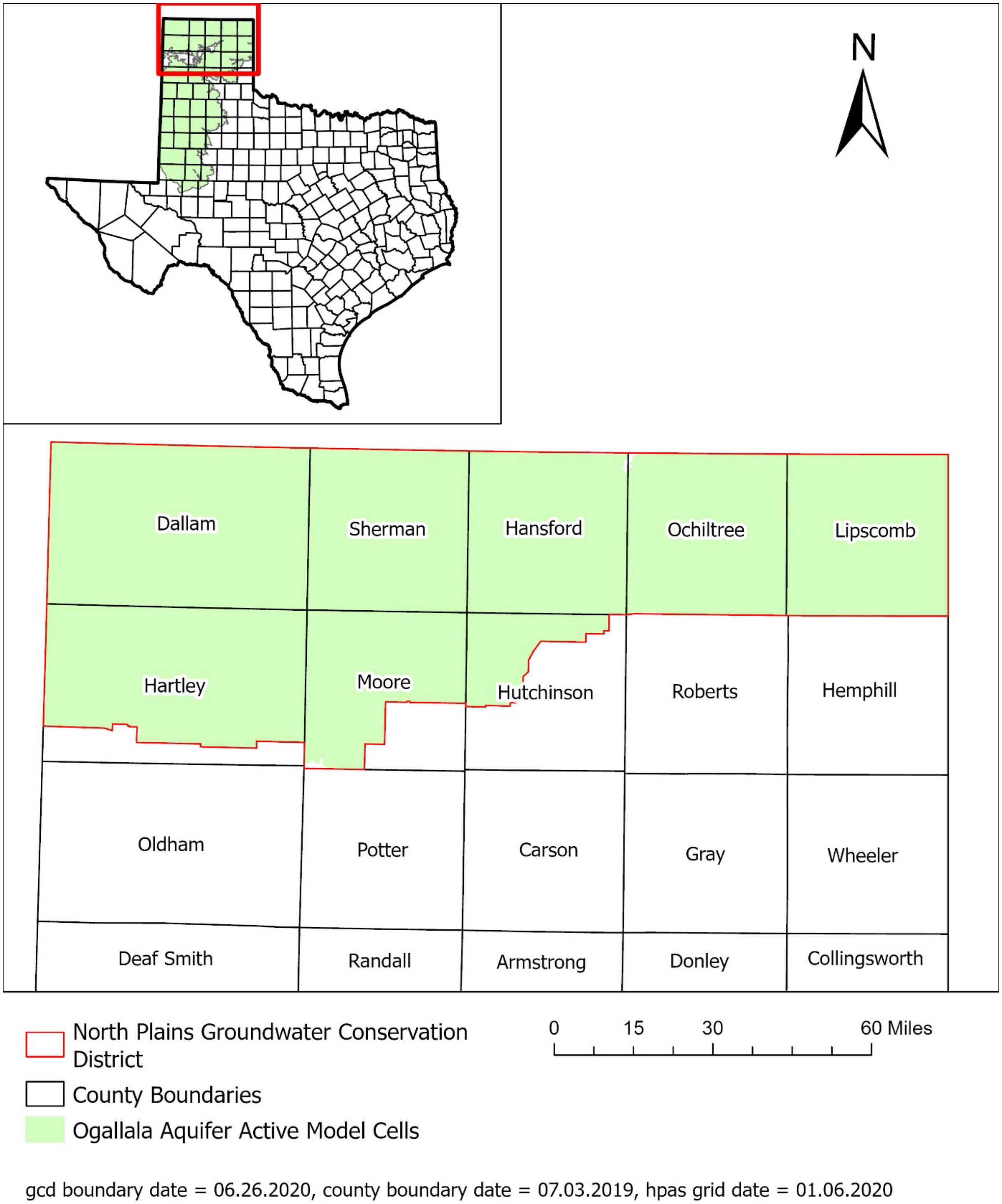
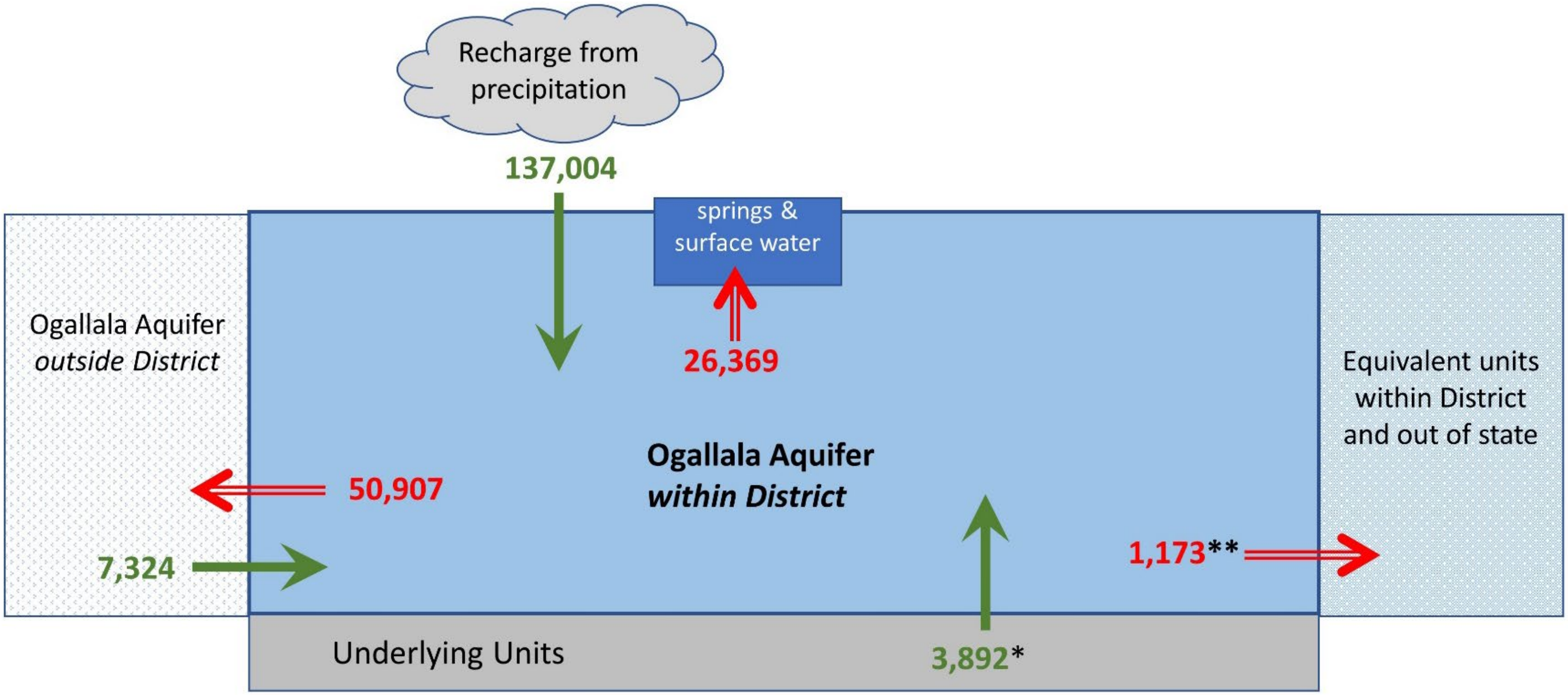


FIGURE 5: AREA OF THE HIGH PLAINS AQUIFER SYSTEM GROUNDWATER AVAILABILITY MODEL FROM WHICH THE INFORMATION IN TABLE 3 WAS EXTRACTED (THE OGALLALA AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).



* Flow from Underlying Units includes net outflows of 908 acre-feet per year from the Dockum Aquifer and 2,984 acre-feet per year from the Rita Blanca Aquifer.

** Flow from Equivalent Units within District and Out of State includes net outflow of 3,060 acre-feet per year from equivalent units within district and net inflow of 1,887 acre-feet per year from equivalent units in Oklahoma and New Mexico.

Caveat: This diagram only includes the water budget items provided in Table 3. A complete water budget would include additional inflows and outflows. Please see Appendix A for a full water budget.

FIGURE 6: GENERALIZED DIAGRAM OF THE SUMMARIZED BUDGET INFORMATION FROM TABLE 3, REPRESENTING DIRECTIONS OF FLOW FOR THE OGALLALA AQUIFER WITHIN NORTH PLAINS GROUNDWATER CONSERVATION DISTRICT. FLOW VALUES EXPRESSED IN ACRE-FEET PER YEAR.

LIMITATIONS:

The groundwater models used in completing this analysis are the best available scientific tools that can be used to meet the stated objectives. To the extent that this analysis will be used for planning purposes and/or regulatory purposes related to pumping in the past and into the future, it is important to recognize the assumptions and limitations associated with the use of the results. In reviewing the use of models in environmental regulatory decision making, the National Research Council (2007) noted:

> *"Models will always be constrained by computational limitations, assumptions, and knowledge gaps. They can best be viewed as tools to help inform decisions rather than as machines to generate truth or make decisions. Scientific advances will never make it possible to build a perfect model that accounts for every aspect of reality or to prove that a given model is correct in all respects for a particular regulatory application. These characteristics make evaluation of a regulatory model more complex than solely a comparison of measurement data with model results."*

A key aspect of using the groundwater model to evaluate historic groundwater flow conditions includes the assumptions about the location in the aquifer where historic pumping was placed. Understanding the amount and location of historical pumping is as important as evaluating the volume of groundwater flow into and out of the district, between aquifers within the district (as applicable), interactions with surface water (as applicable), recharge to the aquifer system (as applicable), and other metrics that describe the impacts of that pumping. In addition, assumptions regarding precipitation, recharge, and interaction with streams are specific to particular historic time periods.

Because the application of the groundwater models was designed to address regional scale questions, the results are most effective on a regional scale. The TWDB makes no warranties or representations related to the actual conditions of any aquifer at a particular location or at a particular time.

It is important for groundwater conservation districts to monitor groundwater pumping and overall conditions of the aquifer. Because of the limitations of the groundwater model and the assumptions in this analysis, it is important that the groundwater conservation districts work with the TWDB to refine this analysis in the future given the reality of how the aquifer responds to the actual amount and location of pumping now and in the future. Historic precipitation patterns also need to be placed in context as future climatic conditions, such as dry and wet year precipitation patterns, may differ and affect groundwater flow conditions.

REFERENCES:

Deeds, N. E., Harding, J. J., Jones, T. L., Singh, A., Hamlin, S. and Reedy, R. C., 2015, Final Conceptual Model Report for the High Plains Aquifer System Groundwater Availability Model, 590 p., https://www.twdb.texas.gov/groundwater/models/gam/hpas/HPAS_GAM_Conceptual_Report.pdf

Deeds, N. E. and Jigmond, M., 2015, Numerical Model Report for the High Plains Aquifer System Groundwater Availability Model, 640 p., https://www.twdb.texas.gov/groundwater/models/gam/hpas/HPAS_GAM_Numerical_Report.pdf?d=4324

Goswami, R., 2017, GAM Run 17-008: Texas Water Development Board, GAM Run 17-008 Report, 13 p., https://www.twdb.texas.gov/groundwater/docs/GAMruns/GR17-008.pdf.

Harbaugh, A. W., 2009, Zonebudget Version 3.01, A computer program for computing subregional water budgets for MODFLOW ground-water flow models, U.S. Geological Survey Groundwater Software.

National Research Council, 2007, Models in Environmental Regulatory Decision Making Committee on Models in the Regulatory Decision Process, National Academies Press, Washington D.C., 287 p., http://www.nap.edu/catalog.php?record_id=11972.

Niswonger, R.G., Panday, S., and Ibaraki, M., 2011, MODFLOW-NWT, a Newton formulation for MODFLOW-2005: USGS, Techniques and Methods 6-A37, 44 p.

Texas Water Code, 2011, http://www.statutes.legis.state.tx.us/docs/WA/pdf/WA.36.pdf

Appendix A – Full Groundwater Budget Diagrams

Full water budget diagrams presented in Figures A-1 through A-6 are included to assist the North Plains Groundwater Conservation District in analyzing the effects of pumping and recharge on the aquifers within the district. These diagrams are intended to provide additional insight for groundwater conservation districts to better understand their aquifers and to provide more detailed information to inform groundwater management.

Figures A-1, A-3, and A-5 show the full water budgets for the years of minimum and maximum pumping within each aquifer in the district during the historical calibration period described in the Parameters and Assumptions section (years 1980 to 2012). Figures A-2, A-4, and A-6 show the full water budgets for the first and last years of the historical calibration period of the model. Years of minimum and maximum recharge are not included because the model keeps recharge constant for each stress period within the district during the historical calibration period. Table A-1 lists each component and provides an explanation of each component contained in the full water budget diagrams.

TABLE A-1: EXPLANATION OF EACH BUDGET COMPONENT INCLUDED IN THE FULL WATER BUDGETS FOR NORTH TEXAS GROUNDWATER CONSERVATION DISTRICT.

Full water budget component	Explanation
Recharge	Representative of recharge to the aquifer from areally distributed rainfall that reaches the water table of the aquifer.
Pumping	The amount of water pumped out of the aquifer through water wells located within the aquifer.
Natural Discharge	Represents the combination of water leaving the aquifer through ephemeral streams, evapotranspiration, springs, and free flowing wells. - Ephemeral streams are streams that do not flow year-round - Springs are locations where groundwater is directly connected to the ground surface and water leaves the aquifer - Free flowing wells are wells which connect to the aquifer where the water level is above ground surface and water will flow without the need of pumping
River Leakage	Only representative of the net exchange of water between the rivers/reservoirs and the aquifer in the model

TABLE A-1: EXPLANATION OF EACH BUDGET COMPONENT INCLUDED IN THE FULL WATER BUDGETS FOR NORTH TEXAS GROUNDWATER CONSERVATION DISTRICT.

Full water budget component	Explanation
Evapotranspiration	Only represents the amount of water removed from the water table by vegetation or direct evaporation from the water table. This does not include total evapotranspiration for all plants or water features covering the modeled area
Groundwater Exchanges	The sum of the net exchange of groundwater between the aquifer of interest within the district and all geologic units within and outside of the district boundaries
Storage	Represents the difference from the previous year in the amount of water contained within the aquifer and indicates a relative water level rise (negative Storage value) or water level decline (positive Storage value). Change in storage (dS) is the difference between inflows and outflows (Equation 1). To solve the zero-sum budget over the volume of the aquifer within the district, the term dS must be subtracted from both sides of Equation 1 (Equation 2). If total inflows are greater than outflow, Storage will be negative. If total outflows are greater than total inflows, Storage will be positive. $dS = Inflows - Outflows$ **Equation 1** $0 = Inflows - Outflows - dS$ **Equation 2**

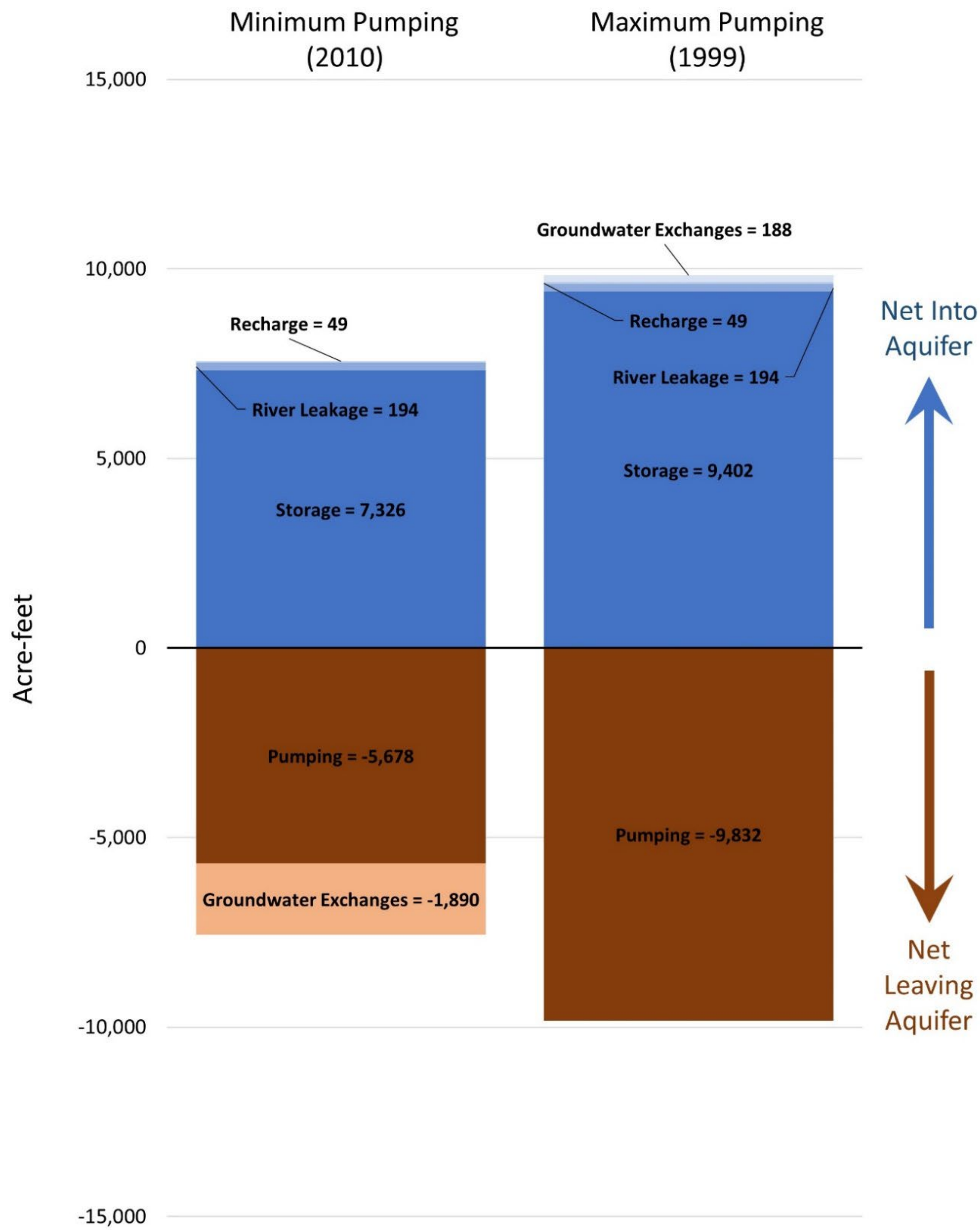


FIGURE A-1: FULL WATER BUDGETS FOR THE DOCKUM AQUIFER WITHIN THE NORTH PLAINS GROUNDWATER CONSERVATION DISTRICT SHOWING THE YEAR OF MINIMUM PUMPING AND THE YEAR OF MAXIMUM PUMPING BETWEEN 1980 AND 2012.

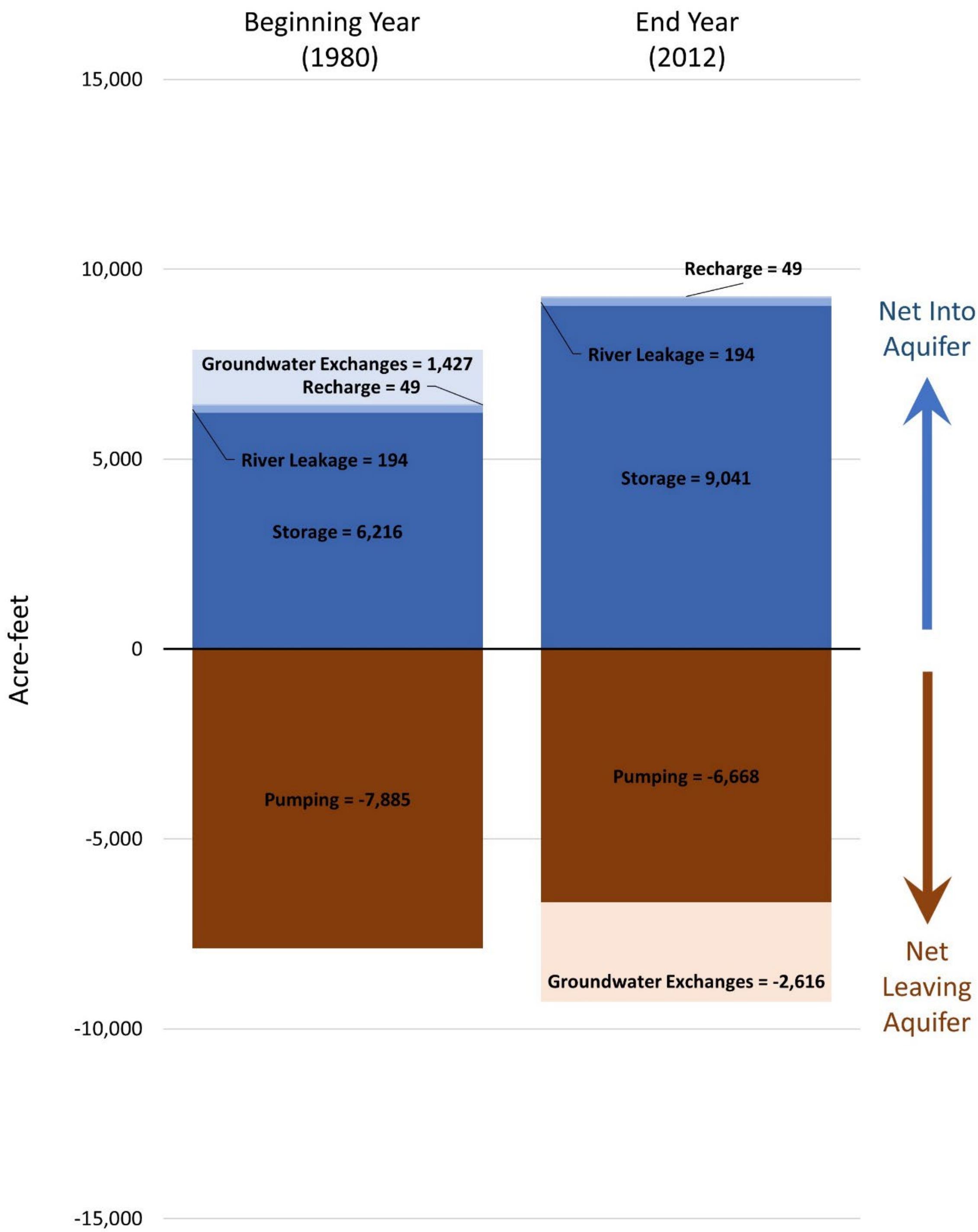


FIGURE A-2: FULL WATER BUDGETS FOR THE DOCKUM AQUIFER WITHIN THE NORTH PLAINS GROUNDWATER CONSERVATION DISTRICT SHOWING THE FIRST AND LAST YEAR OF THE HISTORICAL TRANSIENT PERIOD BETWEEN 1980 AND 2012.

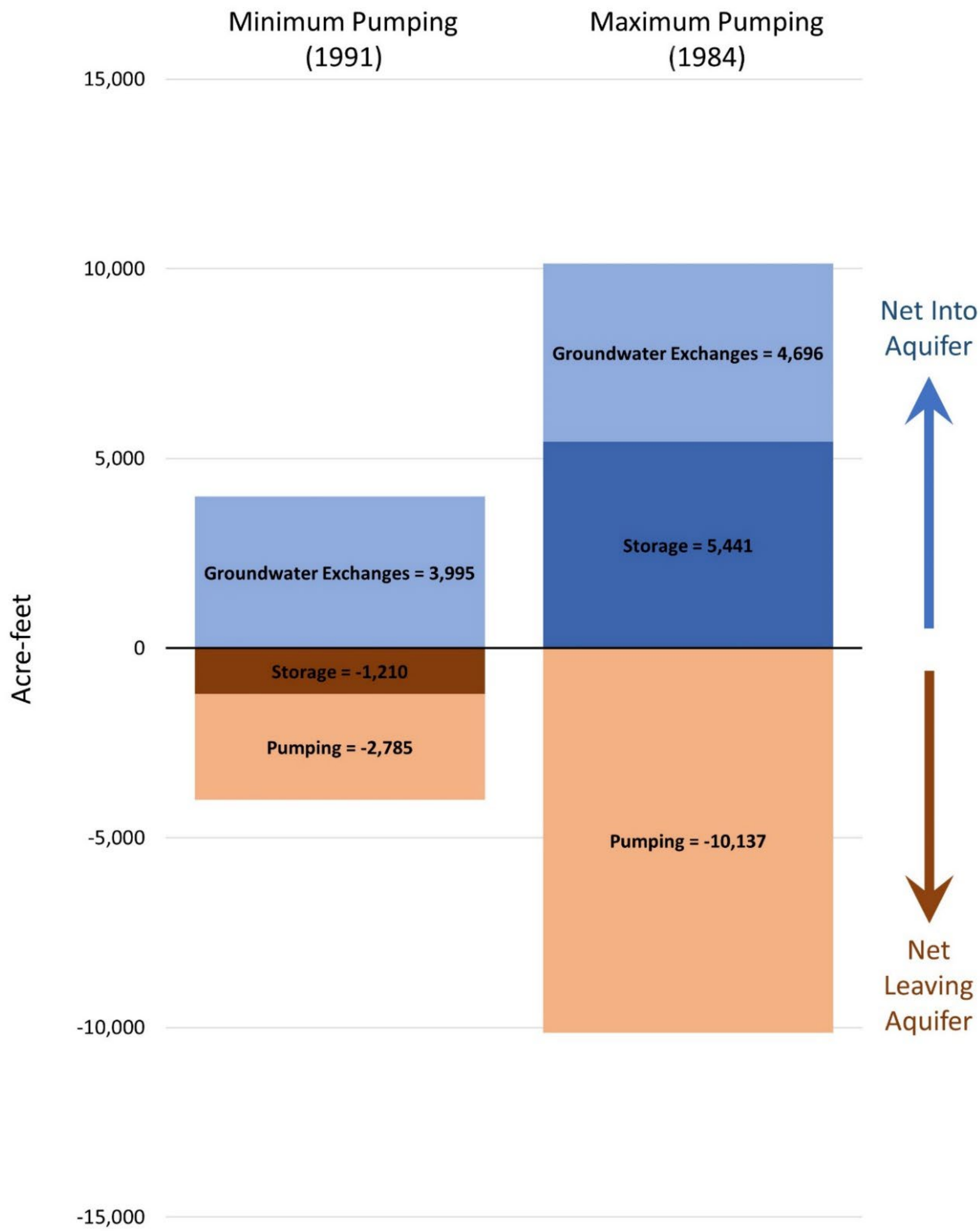


FIGURE A-3: FULL WATER BUDGETS FOR THE RITA BLANCA AQUIFER WITHIN NORTH PLAINS GROUNDWATER CONSERVATION DISTRICT SHOWING THE YEAR OF MINIMUM PUMPING AND THE YEAR OF MAXIMUM PUMPING BETWEEN 1980 AND 2012.

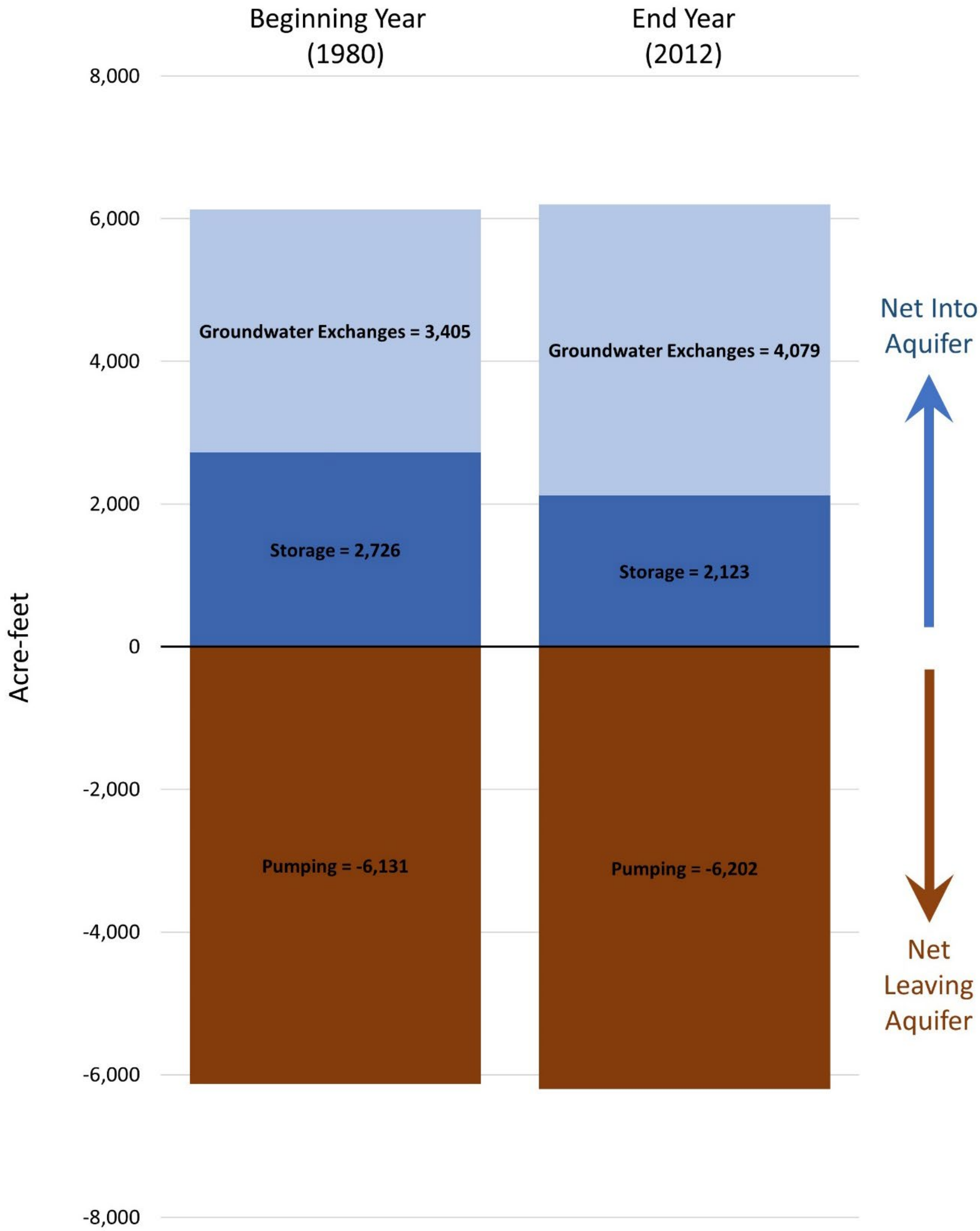


FIGURE A-4: FULL WATER BUDGETS FOR THE RITA BLANCA AQUIFER WITHIN THE NORTH PLAINS GROUNDWATER CONSERVATION DISTRICT SHOWING THE FIRST AND LAST YEAR OF THE HISTORICAL TRANSIENT MODEL BETWEEN 1980 AND 2012.

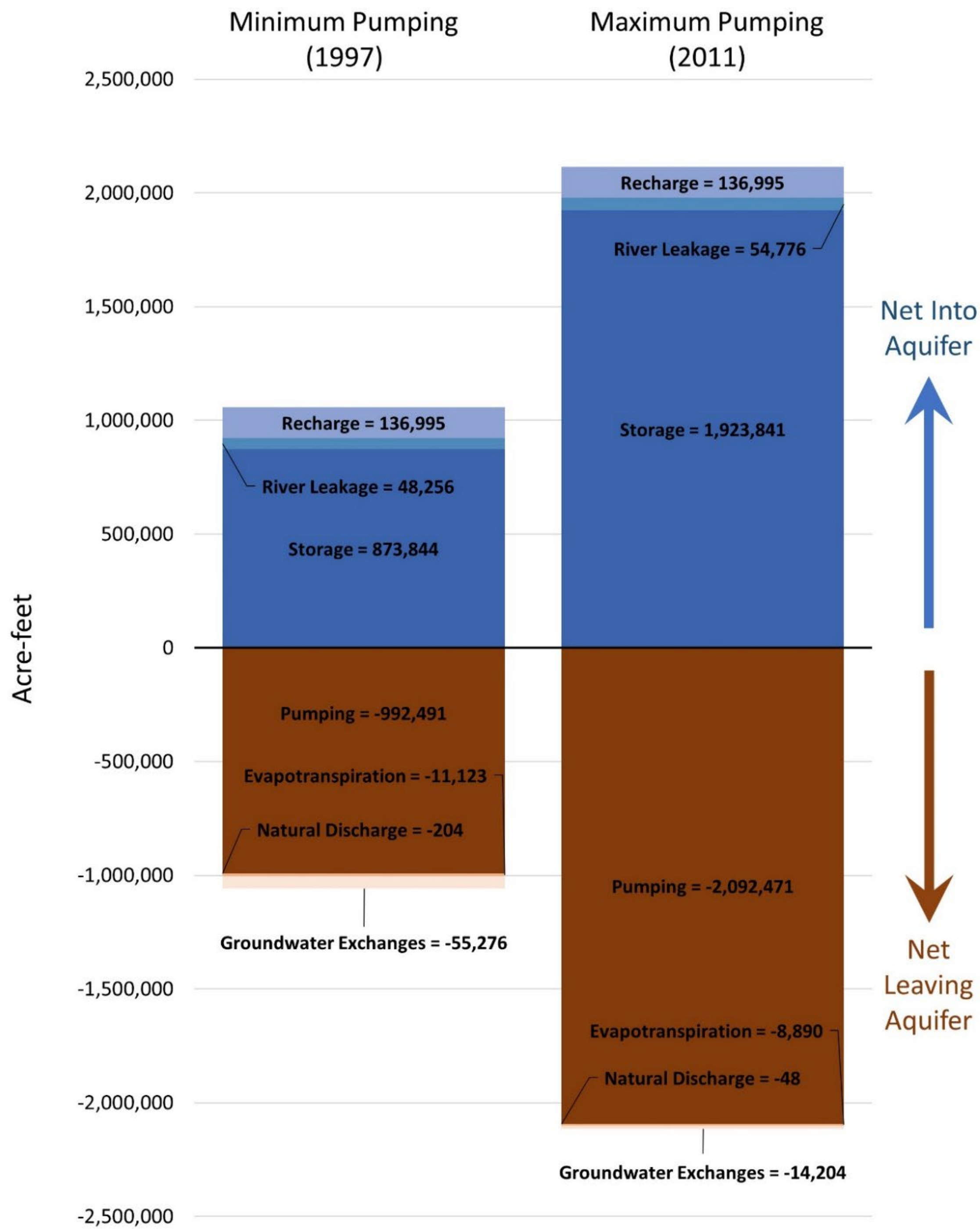


FIGURE A-5: FULL WATER BUDGETS FOR THE OGALLALA AQUIFER WITHIN NORTH PLAINS GROUNDWATER CONSERVATION DISTRICT SHOWING THE YEAR OF MINIMUM PUMPING AND THE YEAR OF MAXIMUM PUMPING BETWEEN 1980 AND 2012.

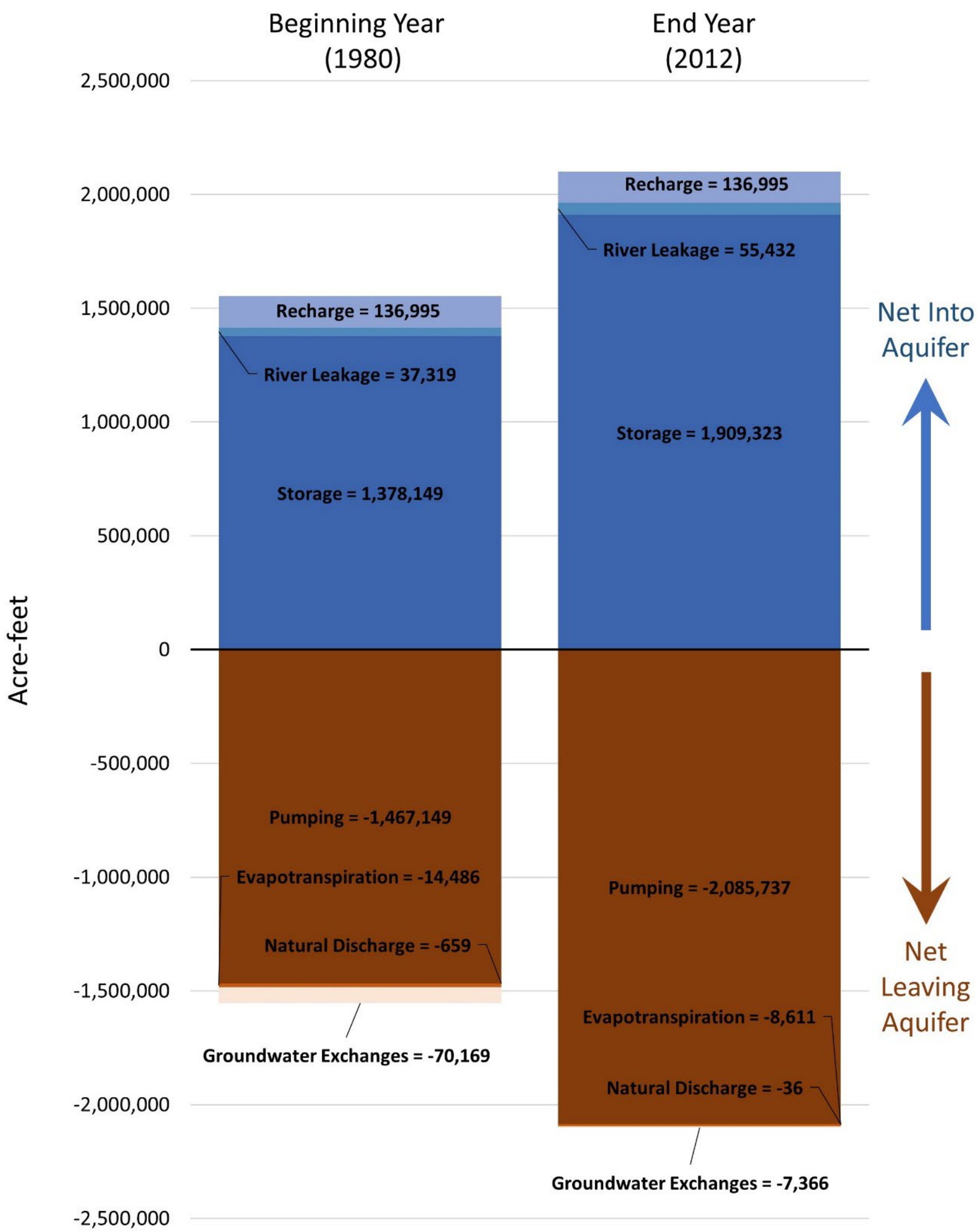


FIGURE A-6: FULL WATER BUDGETS FOR THE OGALLALA AQUIFER WITHIN THE NORTH PLAINS GROUNDWATER CONSERVATION DISTRICT SHOWING THE FIRST AND LAST YEAR OF THE HISTORICAL TRANSIENT MODEL BETWEEN 1980 AND 2012.