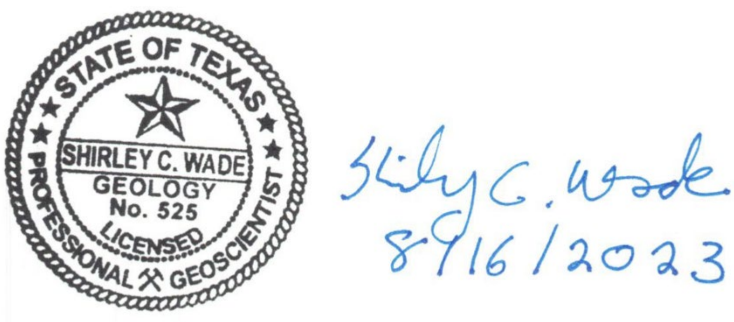
GAM RUN 23-019: HICKORY UNDERGROUND WATER CONSERVATION DISTRICT NO. 1 GROUNDWATER MANAGEMENT PLAN

Micaela Pedrazas, GIT and Shirley Wade, Ph.D., P.G.
Texas Water Development Board
Groundwater Division
Groundwater Modeling Department
512-463-3075
August 16, 2023



This page is intentionally blank

GAM RUN 23-019: HICKORY UNDERGROUND WATER CONSERVATION DISTRICT NO. 1 GROUNDWATER MANAGEMENT PLAN

Micaela Pedrazas, GIT and Shirley Wade, Ph.D., P.G.
Texas Water Development Board
Groundwater Division
Groundwater Modeling Department
512-463-3075
August 16, 2023

EXECUTIVE SUMMARY:

Texas Water Code § 36.1071 (h), 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 Hickory Underground Water Conservation District No. 1 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. the annual volume of water that discharges from the aquifer to springs and any surface-water bodies, including lakes, streams, and rivers, for each aquifer within the district; 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 Hickory Underground Water Conservation District No. 1 should be adopted by the district on or before October 31, 2023 and submitted to the executive administrator of the TWDB on or before November 30, 2023. The current management plan for the Hickory Underground Water Conservation District No. 1 expires on January 29, 2024.

The management plan information for the aquifers within Hickory Underground Water Conservation District No. 1 was extracted from two groundwater availability models. We used the groundwater availability model for the Minor Aquifers of the Llano Uplift (Shi and others, 2016) to estimate management plan information for the Hickory, Ellenburger-San Saba, and Marble Falls aquifers. We used the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers (Anaya and Jones, 2009) to estimate management plan information for the Edwards-Trinity (Plateau) Aquifer.

While a small portion of the Cross Timbers Aquifer exists in the northern portion of the district, there is currently no groundwater availability model for Cross Timbers Aquifer. For more information concerning this aquifer, please contact Mr. Stephen Allen at 512-463-7317 or stephen.allen@twdb.texas.gov.

This report replaces the results of GAM Run 18-007 (Anaya, 2018). 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, 3, and 4 summarize the groundwater availability model data required by statute. Figures 1, 3, 5, and 7 show the area of the model from which the values in Tables 1, 2, 3, and 4 were extracted. Figures 2, 4, 6, and 8 provide a generalized diagram of the groundwater flow components provided in Tables 1, 2, 3, and 4. If the Hickory Underground Water Conservation District No. 1 determines that the district boundaries used in the assessment do not reflect current conditions after reviewing the figures, please notify the TWDB Groundwater Modeling Department at your earliest convenience.

The flow components presented in this report do not represent the full groundwater budget. If additional inflow and outflow information would be helpful for planning purposes, the district may submit a request in writing to the TWDB Groundwater Modeling Department for the full groundwater budget.

METHODS:

In accordance with the provisions of the Texas Water Code § 36.1071 (h), the groundwater availability models mentioned above were used to estimate information for the Hickory Underground Water Conservation District No. 1 management plan. Water budgets were extracted for the historical calibration period for the Hickory, Ellenburger-San Saba, and Marble Falls aquifers (1980 through 2010) using ZONEBUDGET for MODFLOW USG Version 1.0 (Panday and others, 2013). Water budgets were extracted for the historical calibration period for the Edwards-Trinity (Plateau) Aquifer (1981 through 2000) 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:

Hickory, Ellenburger-San Saba, and Marble Falls aquifers

- We used version 1.01 of the groundwater availability model for the Minor Aquifers of the Llano Uplift to analyze the Hickory, Ellenburger-San Saba, and Marble Falls aquifers. See Shi and others (2016) for assumptions and limitations of the model.

- The groundwater availability model for the Minor Aquifers of the Llano Uplift contains eight active layers:

    - Layer 1 represents the Trinity Aquifer, Edwards-Trinity (Plateau) Aquifer, and younger alluvium deposits
    - Layer 2 represents Permian and Pennsylvanian age confining units
    - Layer 3 represents the Marble Falls Aquifer and equivalent units
    - Layer 4 represents Mississippian age confining units
    - Layer 5 represents the Ellenburger-San Saba Aquifer and equivalent units
    - Layer 6 represents Cambrian age confining units
    - Layer 7 represents the Hickory Aquifer and equivalent units
    - Layer 8 represents Precambrian age confining units

- Perennial rivers and reservoirs were simulated using the MODFLOW-USG river package. Springs were simulated using the MODFLOW-USG drain package. For this management plan, groundwater discharge to surface water includes groundwater leakage to the river and drain boundaries.

- Individual water budgets for the district were determined for the Marble Falls Aquifer (Layer 3), Ellenburger-San Saba Aquifer (Layer 5), and the Hickory Aquifer (Layer 7).

- The model was run with MODFLOW-USG (Panday and others, 2013).

Edwards-Trinity (Plateau) Aquifer

- We used version 1.01 of the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers to analyze the Edwards-Trinity (Plateau) Aquifer. See Anaya and Jones (2009) for assumptions and limitations of the model.

- The Pecos Valley Aquifer does not occur within Hickory Underground Conservation Water District No. 1 and therefore no groundwater budget values are included for it in this report.

- The groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers contains two active layers:

    - Layer 1 represents the Edwards Group and equivalent limestone hydrostratigraphic units of the Edwards-Trinity (Plateau) Aquifer

    - Layer 2 represents the Trinity Group hydrostratigraphic units or equivalent units of the Edwards-Trinity (Plateau) and Trinity aquifers

- The model was run with MODFLOW-96 (Harbaugh and McDonald, 1996).

- The water budget for the district was determined for the Edwards-Trinity (Plateau) Aquifer (Layers 1 and 2, collectively).

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 Hickory, Ellenburger-San Saba, Marble Falls, and Edwards-Trinity (Plateau) aquifers located within Hickory Underground Water Conservation District No. 1 and averaged over the historical calibration period, as shown in Tables 1, 2, 3, and 4.

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 Tables 1, 2, 3, and 4. Figures 1, 3, 5, and 7 show the area of the model from which the values in Tables 1, 2, 3, and 4 were extracted. Figures 2, 4, 6, and 8 provide a generalized diagram of the groundwater flow components provided in Tables 1, 2, 3, and 4. 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 Hickory Aquifer for the Hickory Underground Water Conservation District No. 1 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	Hickory Aquifer	10,000
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Hickory Aquifer	17,298
Estimated annual volume of flow into the district within each aquifer in the district	Hickory Aquifer	21,523
Estimated annual volume of flow out of the district within each aquifer in the district	Hickory Aquifer	15,341
Estimated net annual volume of flow between each aquifer in the district	To Hickory Aquifer from Edwards-Trinity (Plateau) Aquifer	31
	To Hickory Aquifer from Quaternary alluvium	12
	To Hickory Aquifer from Permian/Pennsylvanian confining units	122
	To Hickory Aquifer from Marble Falls equivalent units	3
	To Hickory Aquifer from Mississippian confining unit	164
	From Hickory Aquifer to Ellenburger-San Saba Aquifer	3,318
	From Hickory Aquifer to Ellenburger-San Saba equivalent units	306
	To Hickory Aquifer from Cambrian confining unit	14,128
	To Hickory Aquifer from Hickory equivalent units	1,072
	From Hickory Aquifer to Precambrian confining unit	1,136

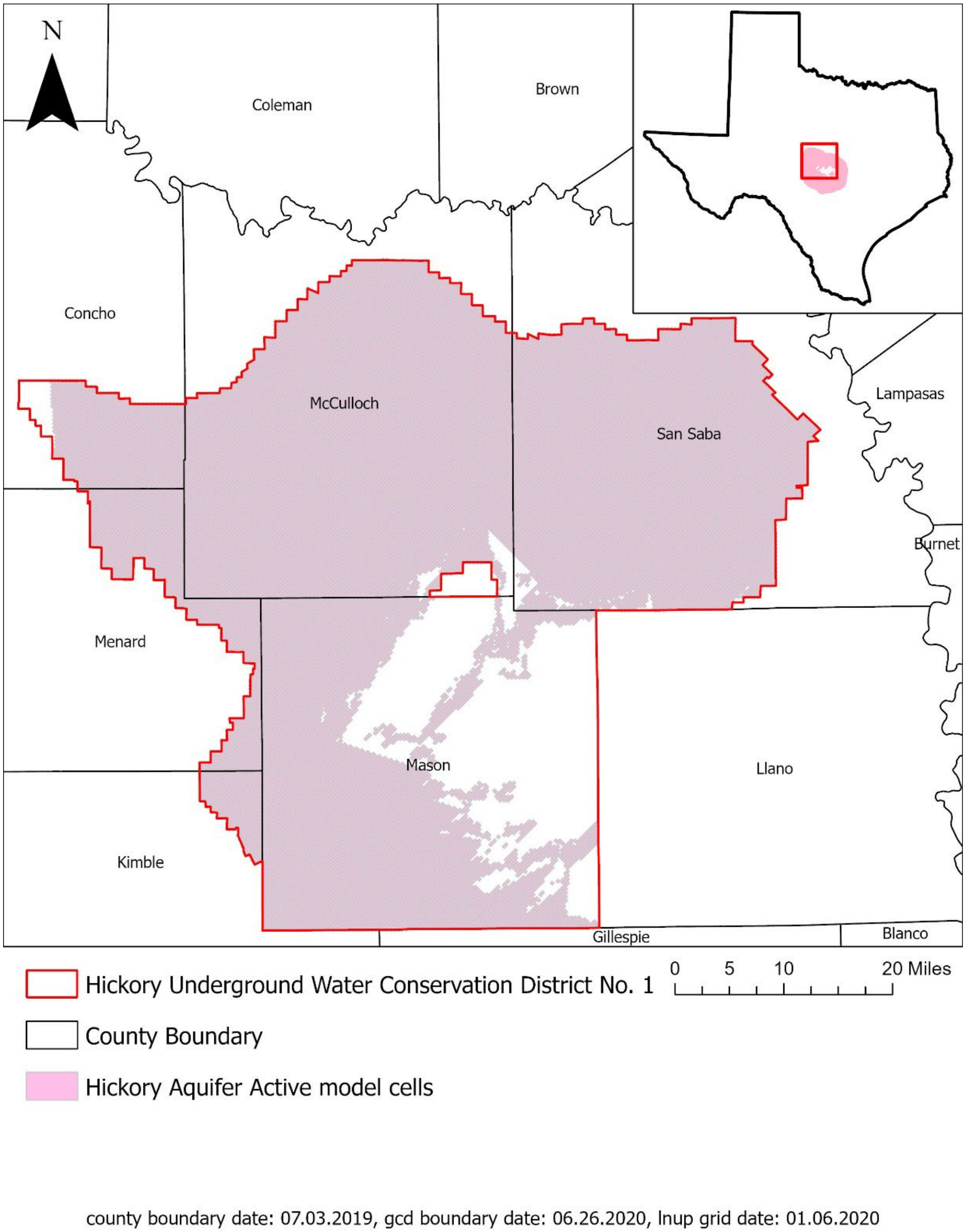
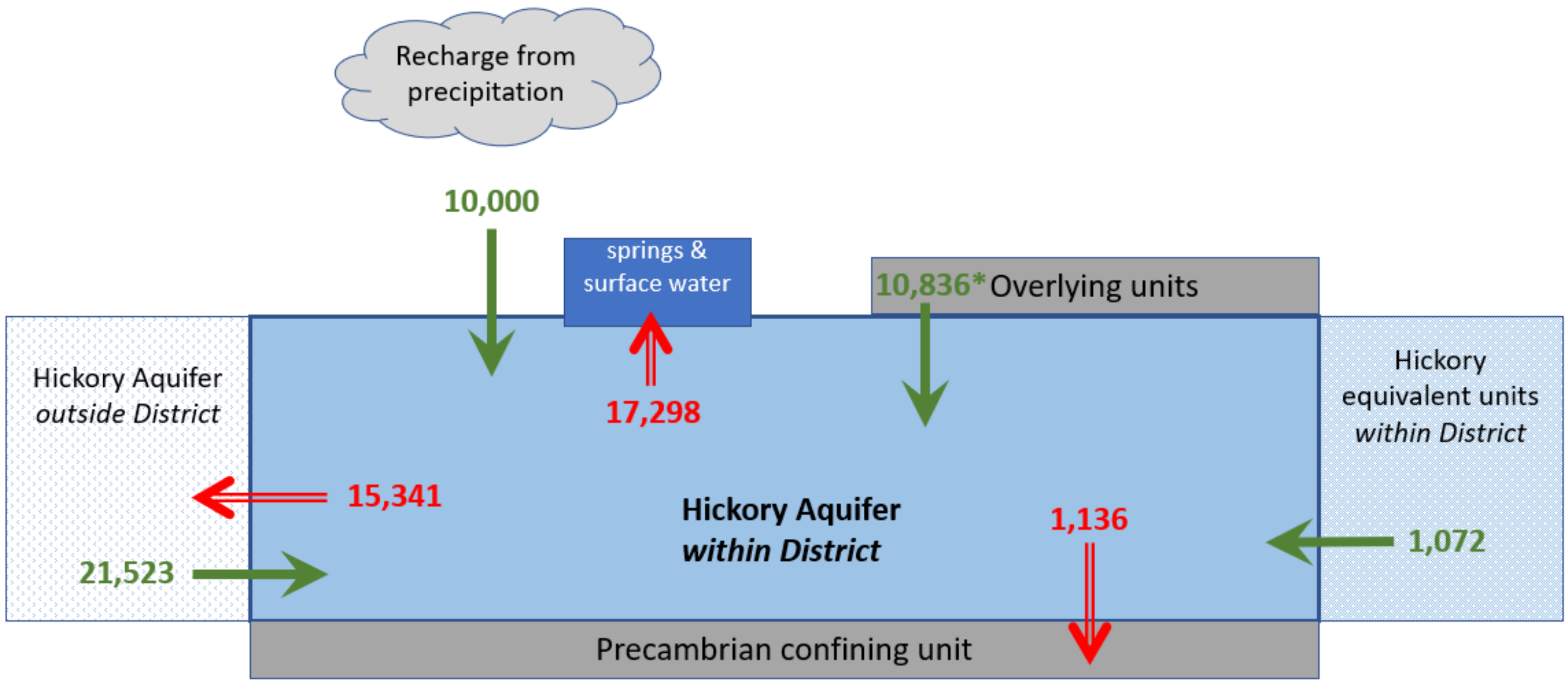


Figure 1: Area of the groundwater availability model for the Minor Aquifers of the Llano Uplift from which the information in Table 1 was extracted (the Hickory Aquifer extent within the district boundary).



*Flow from Overlying units within district includes net flow of 31 acre-feet per year from Edwards-Trinity (Plateau) Aquifer, 12 acre-feet per year from Quaternary alluvium, 122 acre-feet per year from Permian and Pennsylvanian confining unit, 3 acre-feet per year from Marble Falls equivalent units, 164 acre-feet per year from Mississippian confining unit, 3,318 acre-feet per year to Ellenburger-San Saba Aquifer, 306 acre-feet per year to Ellenburger-San Saba equivalent units, and 14,128 acre-feet per year from Cambrian confining unit.

Caveat: This diagram only includes the water budget items provided in Table 1. A complete water budget would include additional inflows and outflows. For a full groundwater budget, please submit a request in writing to the Groundwater Modeling Department.

Figure 2: Generalized diagram of the summarized budget information from Table 1, representing directions of flow for the Hickory Aquifer within the Hickory Underground Water Conservation District No. 1. Flow values are expressed in acre-feet per year.

Table 2: Summarized information for the Ellenburger-San Saba Aquifer for the Hickory Underground Water Conservation District No. 1 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	Ellenburger-San Saba Aquifer	56,040
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Ellenburger-San Saba Aquifer	176,982
Estimated annual volume of flow into the district within each aquifer in the district	Ellenburger-San Saba Aquifer	11,154
Estimated annual volume of flow out of the district within each aquifer in the district	Ellenburger-San Saba Aquifer	31,836
Estimated net annual volume of flow between each aquifer in the district	To Ellenburger-San Saba Aquifer from Edwards-Trinity (Plateau) Aquifer	394
	To Ellenburger-San Saba Aquifer from Quaternary alluvium	75
	To Ellenburger-San Saba Aquifer from Permian/Pennsylvanian confining unit	420
	To Ellenburger-San Saba Aquifer from Marble Falls Aquifer	1,843
	To Ellenburger-San Saba Aquifer from Marble Falls equivalent units	3,164
	To Ellenburger-San Saba Aquifer from Mississippian confining unit	3,689
	From Ellenburger-San Saba Aquifer to Ellenburger-San Saba equivalent units	11,034
	From Ellenburger-San Saba Aquifer to Cambrian confining unit	17,243
	To Ellenburger-San Saba Aquifer from Hickory Aquifer	3,318
	From Ellenburger-San Saba Aquifer to Hickory equivalent units	136
	To Ellenburger-San Saba Aquifer from Precambrian confining unit	329

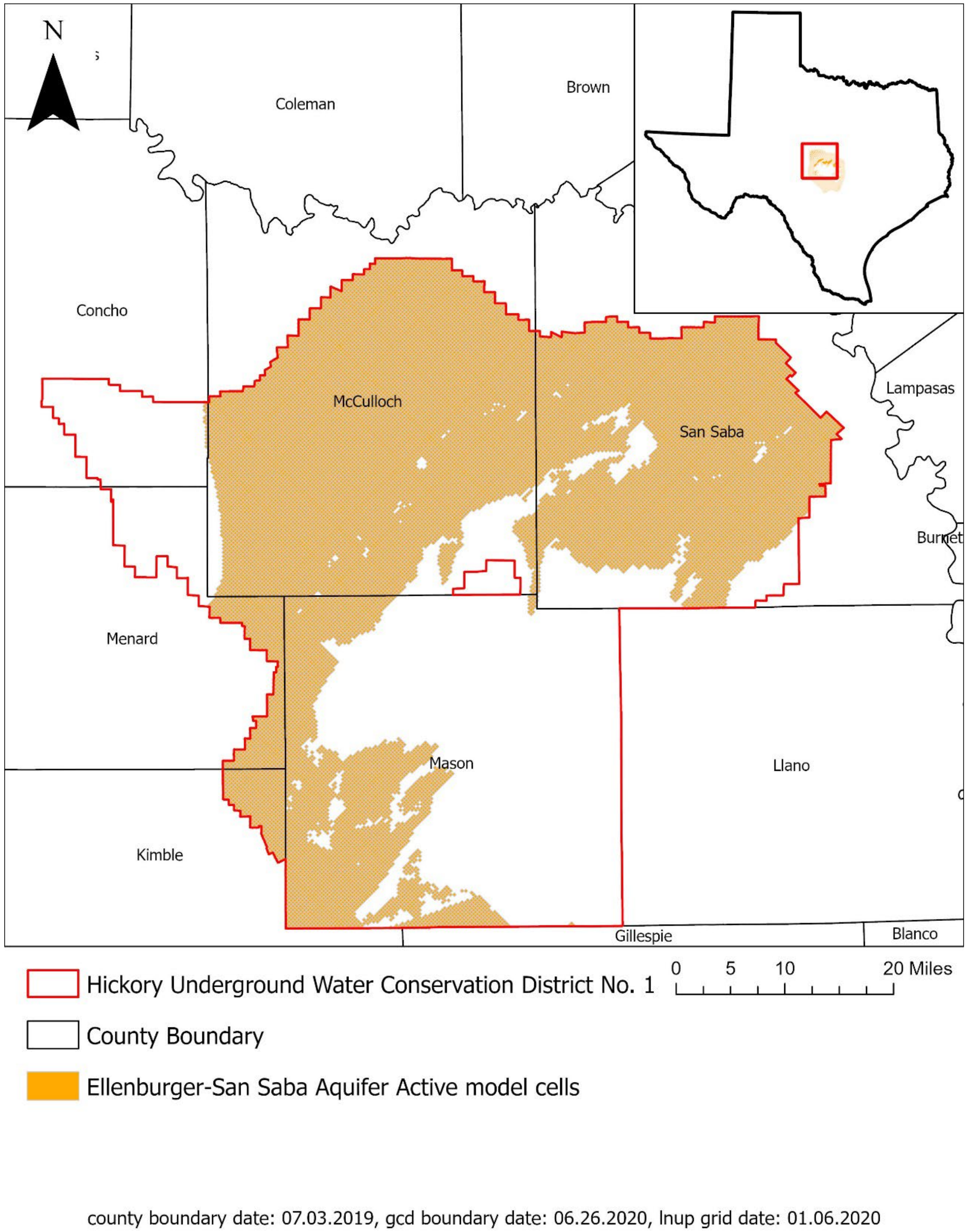
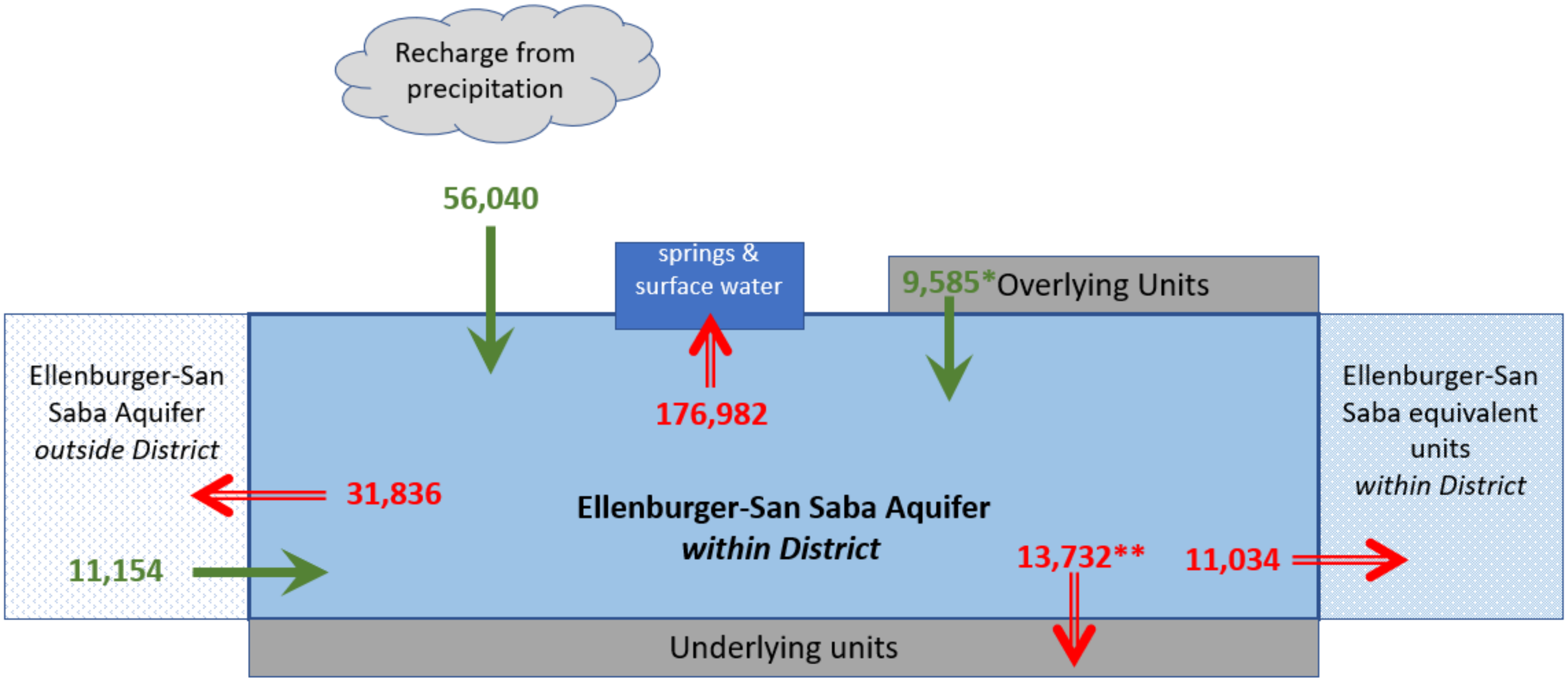


Figure 3: Area of the groundwater availability model for the Minor Aquifers of the Llano Uplift from which the information in Table 2 was extracted (the Ellenburger-San Saba Aquifer extent within the district boundary).



*Flow from Overlying units within district includes net flow of 75 acre-feet per year from Quaternary alluvium, 394 acre-feet per year from Edwards-Trinity (Plateau) Aquifer, 420 acre-feet per year from Permian and Pennsylvanian confining unit, 1,843 acre-feet per year from Marble Falls Aquifer, 3,164 acre-feet per year from Marble Falls equivalent units, and 3,689 acre-feet per year from Mississippian confining unit.

**Flow to Underlying units within district includes net flow of 17,243 acre-feet per year to Cambrian confining unit, 136 acre-feet per year to Hickory equivalent units, 3,318 acre-feet per year from Hickory Aquifer, 329 acre-feet per year from Precambrian confining unit.

Caveat: This diagram only includes the water budget items provided in Table 2. A complete water budget would include additional inflows and outflows. For a full groundwater budget, please submit a request in writing to the Groundwater Modeling Department.

Figure 4: Generalized diagram of the summarized budget information from Table 2, representing directions of flow for Ellenburger-San Saba Aquifer within Hickory Underground Water Conservation District No. 1. Flow values are expressed in acre-feet per year.

Table 3: Summarized information for the Marble Falls Aquifer for the Hickory Underground Water Conservation District No. 1 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	Marble Falls Aquifer	7,900
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Marble Falls Aquifer	20,122
Estimated annual volume of flow into the district within each aquifer in the district	Marble Falls Aquifer	77
Estimated annual volume of flow out of the district within each aquifer in the district	Marble Falls Aquifer	0
Estimated net annual volume of flow between each aquifer in the district	To Marble Falls Aquifer from Marble Falls equivalent units	2,204
	To Marble Falls Aquifer from Mississippian confining unit	3,600
	From Marble Falls Aquifer to Ellenburger-San Saba Aquifer	1,843
	To Marble Falls Aquifer from Ellenburger-San Saba equivalent units	5,190
	To Marble Falls Aquifer from Cambrian confining unit	4

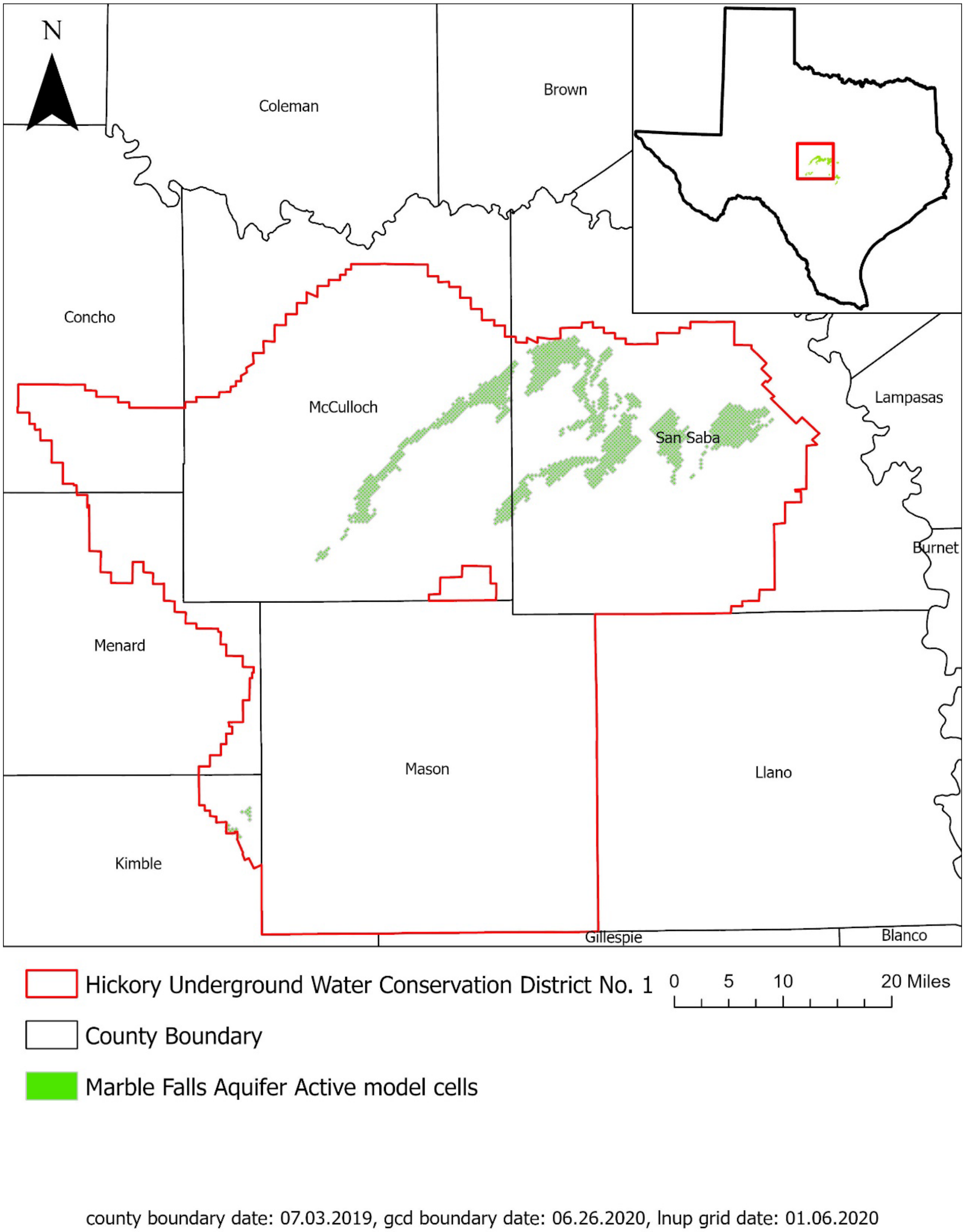
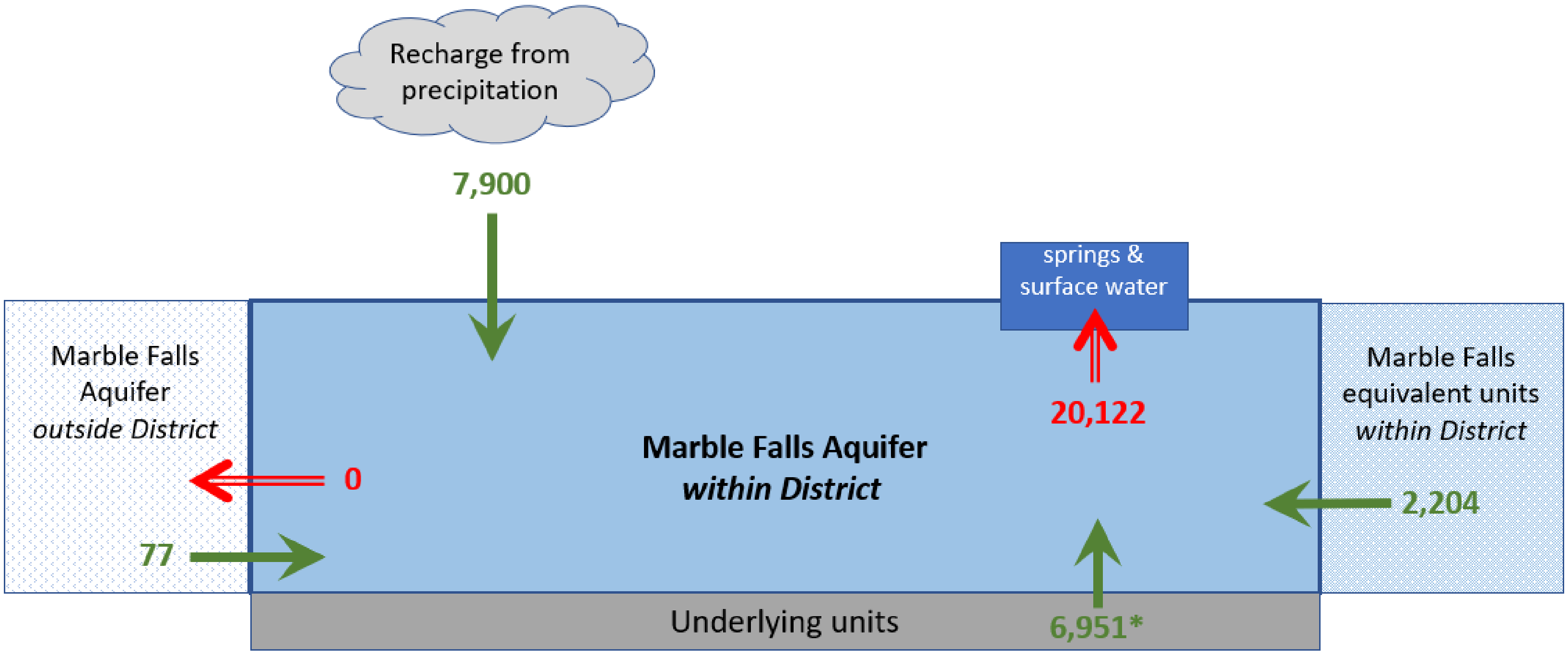


Figure 5: Area of the groundwater availability model for the Minor Aquifers of the Llano Uplift from which the information in Table 3 was extracted (the Marble Falls Aquifer extent within the district boundary).



* Flow from Underlying units within district includes net flow of 3,600 acre-feet per year from Mississippian confining unit, 5,190 acre-feet per year from Ellenburger San-Saba equivalent units, 4 acre-feet per year from Cambrian confining unit, and 1,843 acre-feet per year to Ellenburger-San Saba Aquifer.

Caveat: This diagram only includes the water budget items provided in Table 3. A complete water budget would include additional inflows and outflows. For a full groundwater budget, please submit a request in writing to the Groundwater Modeling Department.

Figure 6: Generalized diagram of the summarized budget information from Table 3, representing directions of flow for the Marble Falls Aquifer within the Hickory Underground Water Conservation District No. 1. Flow values are expressed in acre-feet per year.

Table 4: Summarized information for the Edwards-Trinity (Plateau) Aquifer for the Hickory Underground Water Conservation District No. 1 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	Edwards-Trinity (Plateau) Aquifer	12,359
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Edwards-Trinity (Plateau) Aquifer	15,070
Estimated annual volume of flow into the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	6,494
Estimated annual volume of flow out of the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	3,548
Estimated net annual volume of flow between each aquifer in the district	From Edwards-Trinity (Plateau) Aquifer to Quaternary alluvium*	881
	From Edwards-Trinity (Plateau) Aquifer to Permian/Pennsylvanian confining unit*	6,061
	From Edwards-Trinity (Plateau) Aquifer to Marble Falls equivalent units*	545
	From Edwards-Trinity (Plateau) Aquifer to Mississippian confining unit*	50
	From Edwards-Trinity (Plateau) Aquifer to Ellenburger-San Saba Aquifer*	394
	To Edwards-Trinity (Plateau) Aquifer from Ellenburger-San Saba equivalent units*	29
	From Edwards-Trinity (Plateau) Aquifer to Cambrian confining unit*	140
	From Edwards-Trinity (Plateau) Aquifer to Hickory Aquifer*	31
	From Edwards-Trinity (Plateau) Aquifer to Hickory equivalent units*	5
	From Edwards-Trinity (Plateau) Aquifer to Precambrian confining unit*	1

**Budget value comes from the groundwater availability model for the Minor Aquifers of the Llano Uplift (Shi and others, 2016).*

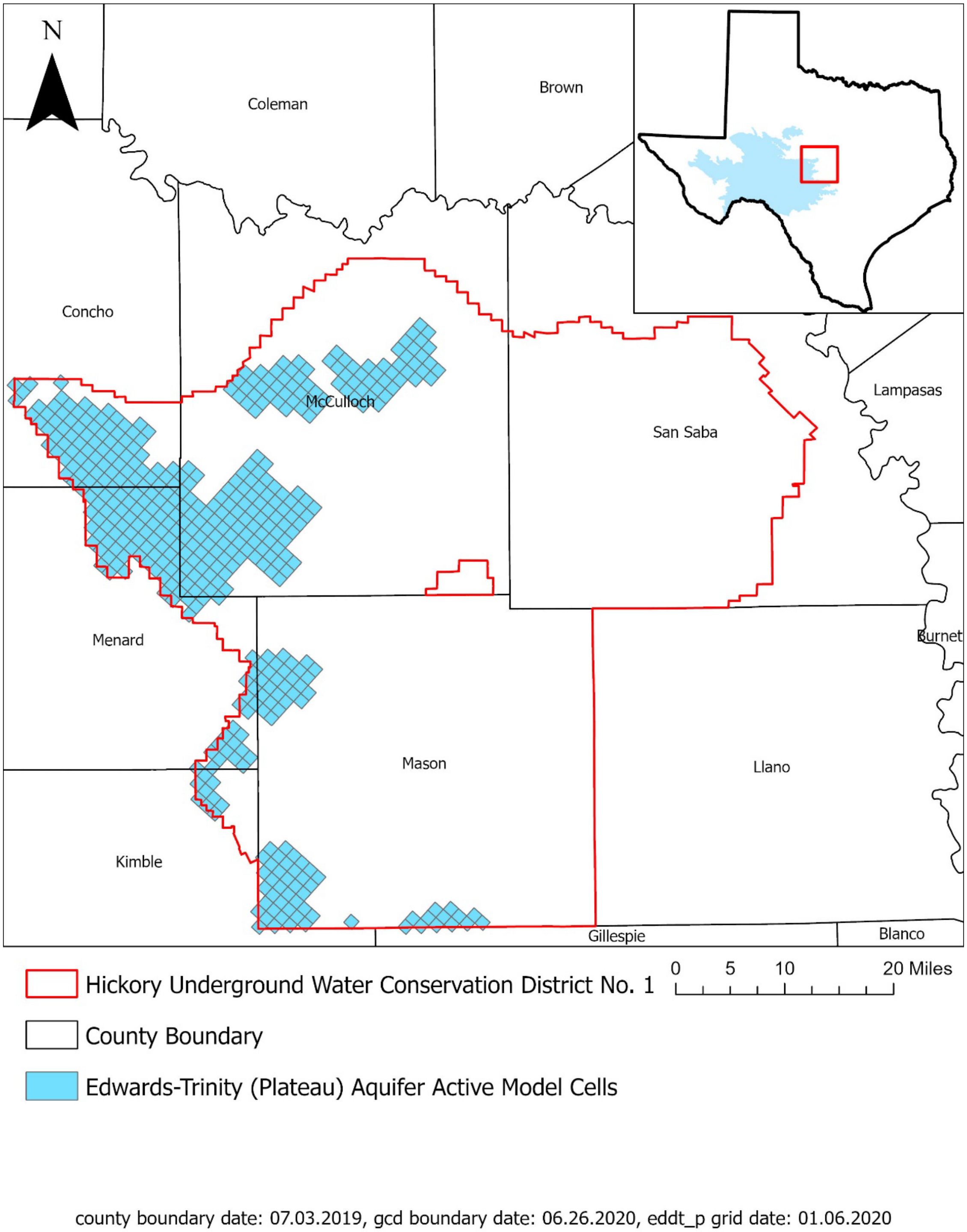
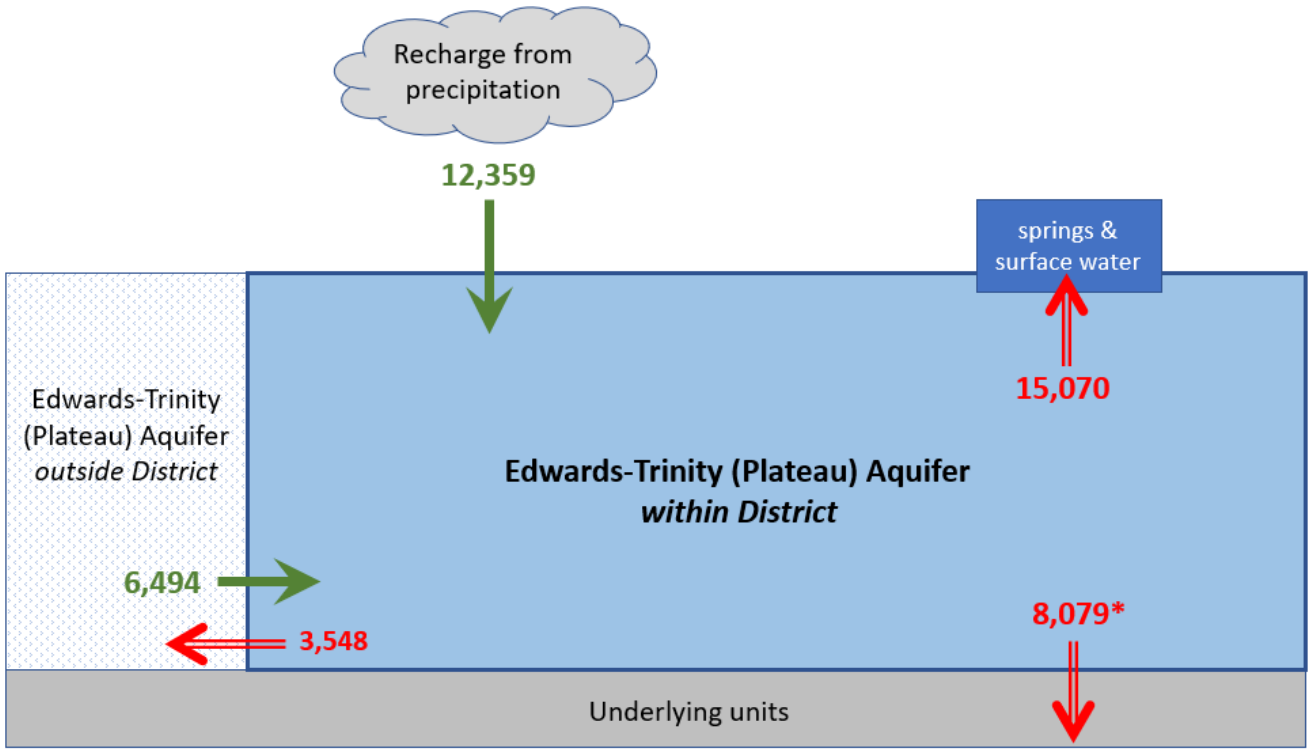


Figure 7: Area of the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers from which the information in Table 4 was extracted (the Edwards-Trinity [Plateau] Aquifer extent within the district boundary).



* Flow to Underlying units within district includes net flow of 881 acre-feet per year to Quaternary alluvium, 6,061 acre-feet per year to Permian and Pennsylvanian confining unit, 545 acre-feet per year to Marble Falls equivalent units, 50 acre-feet per year to Mississippian confining unit, 394 acre-feet per year to Ellenburger-San Saba Aquifer, 29 acre-feet per year from Ellenburger San-Saba equivalent units, 140 acre-feet per year to Cambrian confining unit, 31 acre-feet per year to Hickory Aquifer, 5 acre-feet per year to Hickory equivalent units and 1 acre-feet per year to Precambrian confining unit.

Caveat: This diagram only includes the water budget items provided in Table 4. A complete water budget would include additional inflows and outflows. For a full groundwater budget, please submit a request in writing to the Groundwater Modeling Department.

Figure 8: Generalized diagram of the summarized budget information from Table 4, representing directions of flow for the Edwards-Trinity (Plateau) Aquifer within the Hickory Underground Water Conservation District No. 1. Flow values are 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:

Anaya, R., and Jones, I., 2009, Groundwater Availability Model for the Edwards-Trinity (Plateau) and Pecos Valley Aquifers of Texas: Texas Water Development Board Report 373, 103 p., www.twdb.texas.gov/groundwater/models/gam/eddt_p/ET-Plateau_Full.pdf.

Anaya, R., 2018, GAM Run 18-007: Texas Water Development Board, GAM Run 18-007 Report, 16 p., www.twdb.texas.gov/groundwater/docs/GAMruns/GR18-007.pdf

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., water.usgs.gov/software/MODFLOW-96/.

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., water.usgs.gov/nrp/gwsoftware/zonebud3/zonebudget3.html.

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., www.nap.edu/catalog/11972/models-in-environmental-regulatory-decision-making.

Panday, S., Langevin, C.D., Niswonger, R.G., Ibaraki, M., and Hughes, J.D., 2013, MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: U.S. Geological Survey Techniques and Methods, book 6, chap. A45, 66 p., pubs.usgs.gov/tm/06/a45/.

Shi, J., Boghici, R., Kohlrenken, W., and Hutchison, W.R., 2016, Numerical Model Report: Minor Aquifers of the Llano Uplift Region of Texas (Marble Falls, Ellenburger-San Saba, and Hickory). Texas Water Development Board Report, 435 p., www.twdb.texas.gov/groundwater/models/gam/llano/Llano_Uplift_Numerical_Model_Report_Final.pdf.

Texas Water Code § 36.1071