GAM Run 18-007: Hickory Underground Water Conservation District No. 1 Groundwater Management Plan

Roberto Anaya, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Availability Modeling Department
(512) 463-6115
July 12, 2018

STATE OF TEXAS
Roberto Anaya
Geology
No. 480
LICENSED
PROFESSIONAL GEOSCIENTIST

7/12/18

This page is intentionally blank

GAM RUN 18-007: HICKORY UNDERGROUND WATER CONSERVATION DISTRICT NO. 1 GROUNDWATER MANAGEMENT PLAN

Roberto Anaya, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Availability Modeling Department
(512) 463-6115
July 12, 2018

EXECUTIVE SUMMARY:

Texas Water Code, Section 36.1071, Subsection (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 and this information 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 any surface-water bodies, including lakes, streams, rivers, and springs; 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 November 29, 2018, and submitted to the Executive Administrator of the TWDB on or before December 29, 2018.

The current management plan for the Hickory Underground Water Conservation District No. 1 expires on February 27, 2019.

We used the groundwater availability models for the Llano Uplift Aquifer System (Shi and others, 2016) and for the Edwards-Trinity (Plateau) Aquifer (Anaya and Jones, 2009) to estimate the management plan information for the aquifers within Hickory Underground Water Conservation District No. 1. This report replaces the results of GAM Run 13-010 (Wade, 2013). GAM Run 18-007 meets current standards set after GAM Run 13-010 was released and includes results from the recently released groundwater availability model for the Llano Uplift Aquifer System. Tables 1 through 4 summarize the groundwater availability model data required by statute and Figures 1 through 4 show the area of the models from which the values in the tables were extracted. If after review of the figures, the Hickory Underground Water Conservation District No. 1 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 Water Code, Section 36.1071, Subsection (h), groundwater availability models for the Llano Uplift Aquifer System (1980 through 2010) and the Edwards-Trinity (Plateau) and Pecos Valley aquifers (1981 through 2000) were run for this analysis. Water budgets for each year of the transient model periods were extracted using ZONEBUDGET Version 3.01 (Harbaugh, 2009). The average annual water budget values for recharge, surface-water outflow, inflow to the district, and outflow from the district for the aquifers within the district are summarized in this report.

PARAMETERS AND ASSUMPTIONS:

Hickory, Ellenburger-San Saba, and Marble Falls aquifers of the Llano Uplift Aquifer System

- We used version 1.01 of the groundwater availability model for the Llano Uplift Aquifer System 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 Llano Uplift Aquifer System contains eight active layers:

  - Layer 1 — the Trinity Aquifer, Edwards-Trinity (Plateau) Aquifer, and younger alluvium deposits
  - Layer 2 — Permian and Pennsylvanian age confining units
  - Layer 3 — the Marble Falls Aquifer and equivalent
  - Layer 4 — Mississippian age confining units
  - Layer 5 — the Ellenburger-San Saba Aquifer and equivalent
  - Layer 6 — Cambrian age confining units
  - Layer 7 — the Hickory Aquifer and equivalent
  - Layer 8 — 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.
- 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. See Anaya and Jones (2009) for assumptions and limitations of the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers. 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 — Edwards sub-aquifer unit of the Edwards-Trinity (Plateau) Aquifer
  - Layer 2 — Trinity sub-aquifer unit of the Edwards-Trinity (Plateau) Aquifer
- The model was run with MODFLOW-96 (Harbaugh and McDonald, 1996).

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 model results for the aquifers located within the district and averaged over the duration of the calibration portion of the model runs in the district. The components of the modified budget shown in tables 1 through 3 include:

- 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.

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

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

- 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 through 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 district or county boundaries, 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 (Figures 1 through 4).

TABLE 1. SUMMARIZED INFORMATION FOR THE HICKORY AQUIFER FOR 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	9,994
Estimated annual volume of water that discharges from the aquifer to springs and any surface-water body including lakes, streams, and rivers	Hickory Aquifer	17,286
Estimated annual volume of flow into the district within each aquifer in the district	Hickory Aquifer	21,475
Estimated annual volume of flow out of the district within each aquifer in the district	Hickory Aquifer	15,310
Estimated net annual volume of flow between each aquifer in the district	From Hickory Aquifer to Edwards-Trinity (Plateau) Aquifer	31
	Between Hickory Aquifer and Marble Falls Aquifer	0
	To Hickory Aquifer from Ellenburger-San Saba Aquifer	3,332
	From Hickory Aquifer to Hickory brackish zone	1,039

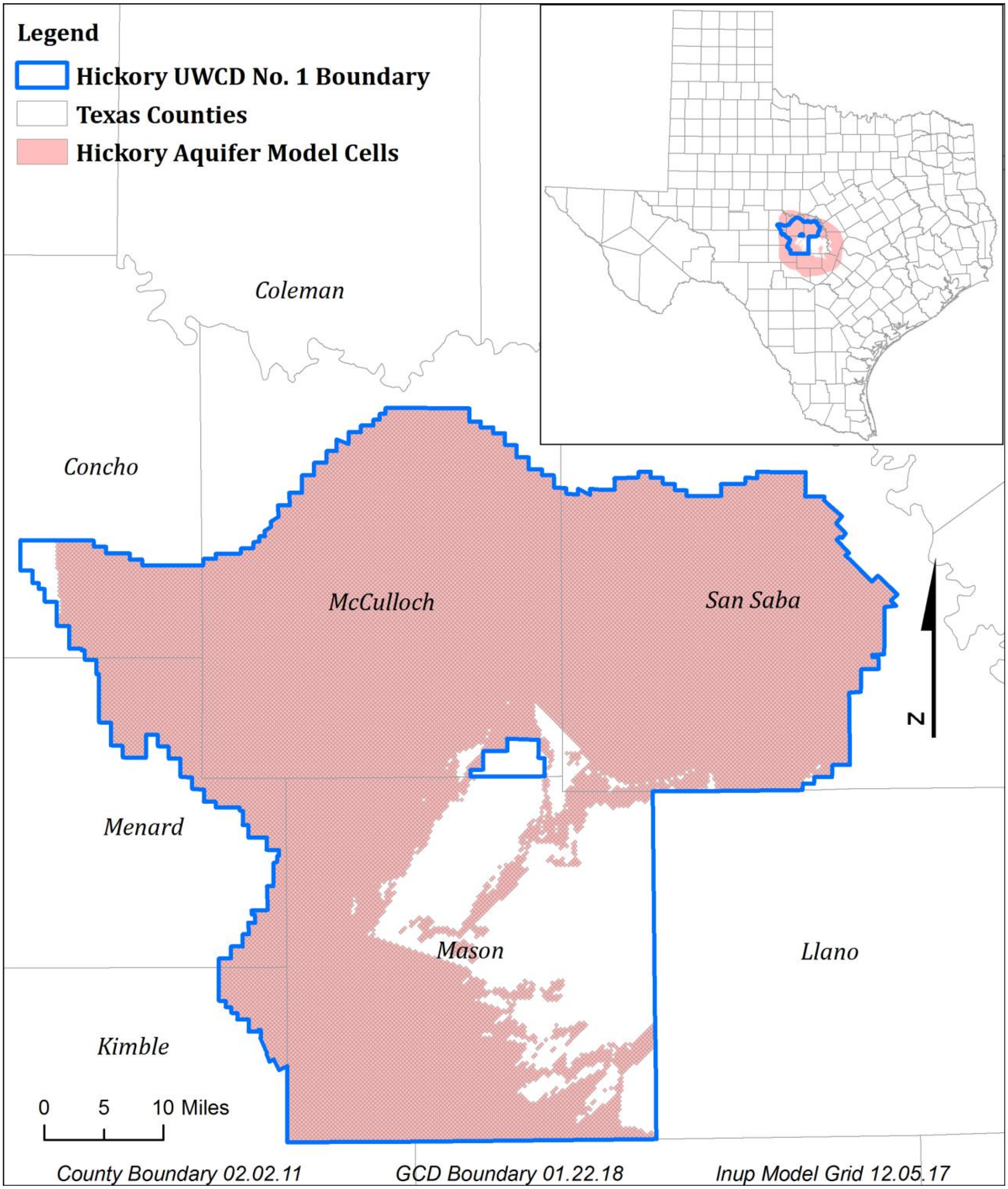

FIGURE 1. AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE LLANO UPLIFT AQUIFER SYSTEM FROM WHICH THE INFORMATION IN TABLE 1 WAS EXTRACTED (THE HICKORY AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 2. SUMMARIZED INFORMATION FOR THE ELLENBURGER-SAN SABA AQUIFER FOR 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	56,007
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	176,861
Estimated annual volume of flow into the district within each aquifer in the district	Ellenburger-San Saba Aquifer	11,160
Estimated annual volume of flow out of the district within each aquifer in the district	Ellenburger-San Saba Aquifer	31,784
Estimated net annual volume of flow between each aquifer in the district	From Ellenburger-San Saba Aquifer to Edwards-Trinity (Plateau) Aquifer	409
	From Ellenburger-San Saba Aquifer to Marble Falls Aquifer	1,840
	To Ellenburger-San Saba Aquifer from Ellenburger-San Saba brackish zone	11,084
	From Ellenburger-San Saba Aquifer to Hickory Aquifer	3,315

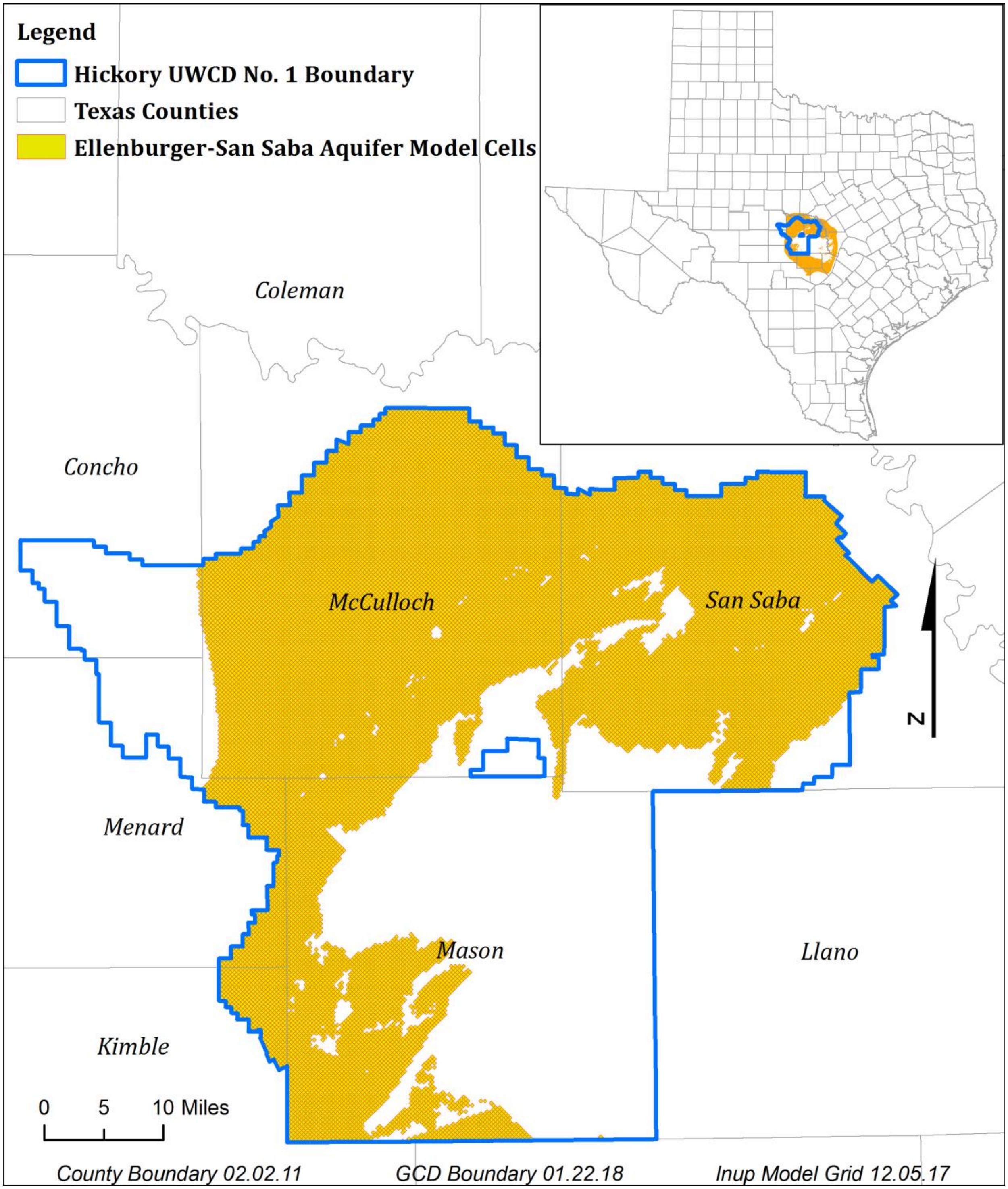

FIGURE 2. AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE LLANO UPLIFT AQUIFER SYSTEM FROM WHICH THE INFORMATION IN TABLE 2 WAS EXTRACTED (THE ELLENBURGER-SAN SABA AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 3. SUMMARIZED INFORMATION FOR THE MARBLE FALLS AQUIFER FOR 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	7,895
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	20,108
Estimated annual volume of flow into the district within each aquifer in the district	Marble Falls Aquifer	76
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	From Marble Falls Aquifer to Edwards-Trinity (Plateau) Aquifer	7
	From Marble Falls Aquifer to Marble Falls subcrop equivalent formation	2,242
	To Marble Falls Aquifer from Ellenburger-San Saba Aquifer	1,838
	Between Marble Falls Aquifer and Hickory Aquifer	0

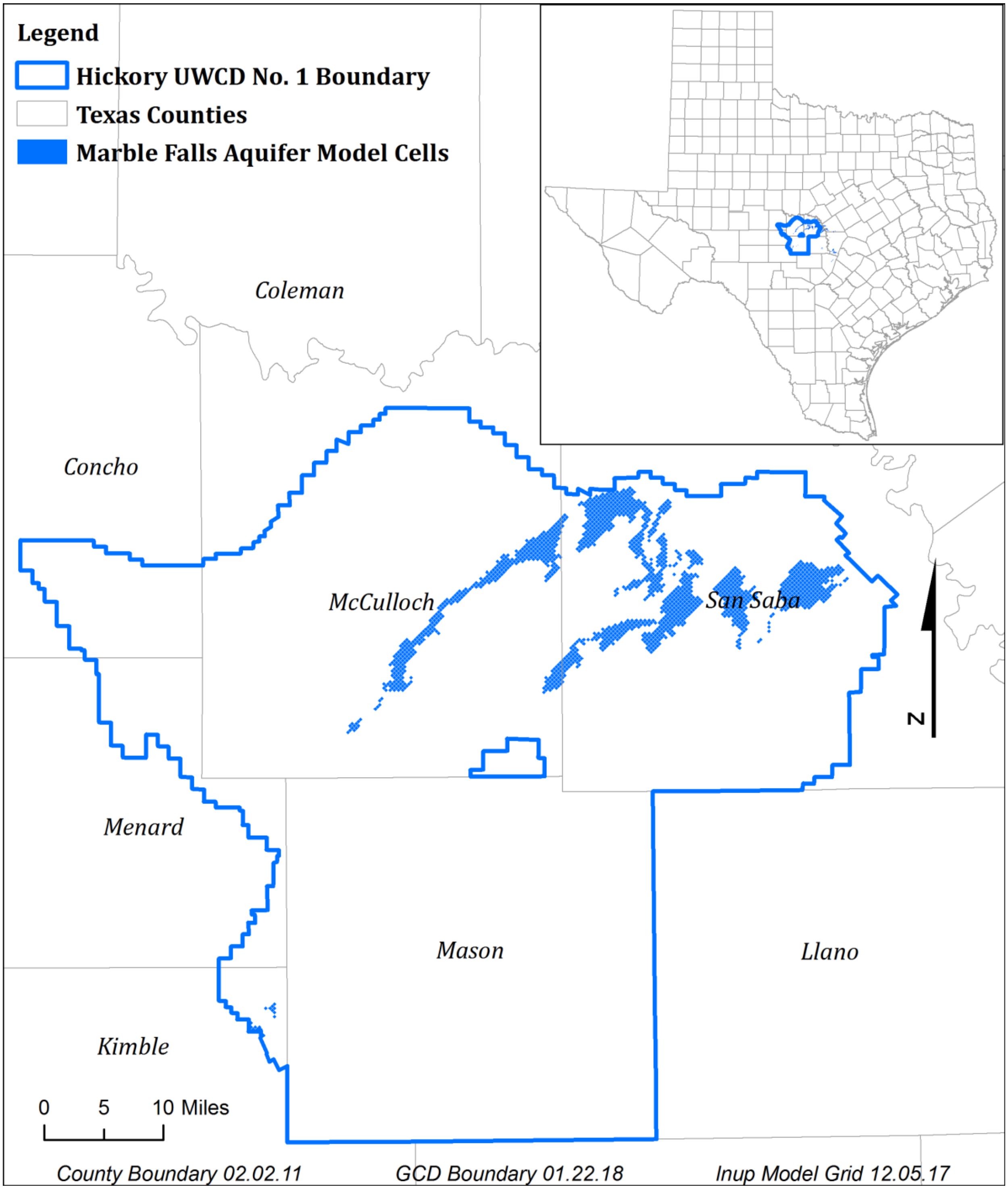

FIGURE 3. AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE LLANO UPLIFT AQUIFER SYSTEM FROM WHICH THE INFORMATION IN TABLE 3 WAS EXTRACTED (THE MARBLE FALLS AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 4: SUMMARIZED INFORMATION FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER THAT IS NEEDED FOR HICKORY UNDERGROUND WATER CONSERVATION DISTRICT NO. 1'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	Edwards-Trinity (Plateau) Aquifer	12,278
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	15,069
Estimated annual volume of flow into the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	6,885
Estimated annual volume of flow out of the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	3,857
Estimated net annual volume of flow between each aquifer in the district	To the Edwards-Trinity (Plateau) Aquifer from Hickory Aquifer	31*
	To the Edwards-Trinity (Plateau) Aquifer from Ellenburger-San Saba Aquifer	367*
	To the Edwards-Trinity (Plateau) Aquifer from Marble Falls Aquifer	7*

* Groundwater budget values calculated from the Llano Uplift Aquifer System GAM version 1.01 are more accurately calibrated flow between the Edwards-Trinity (Plateau) Aquifer and the underlying minor aquifers.

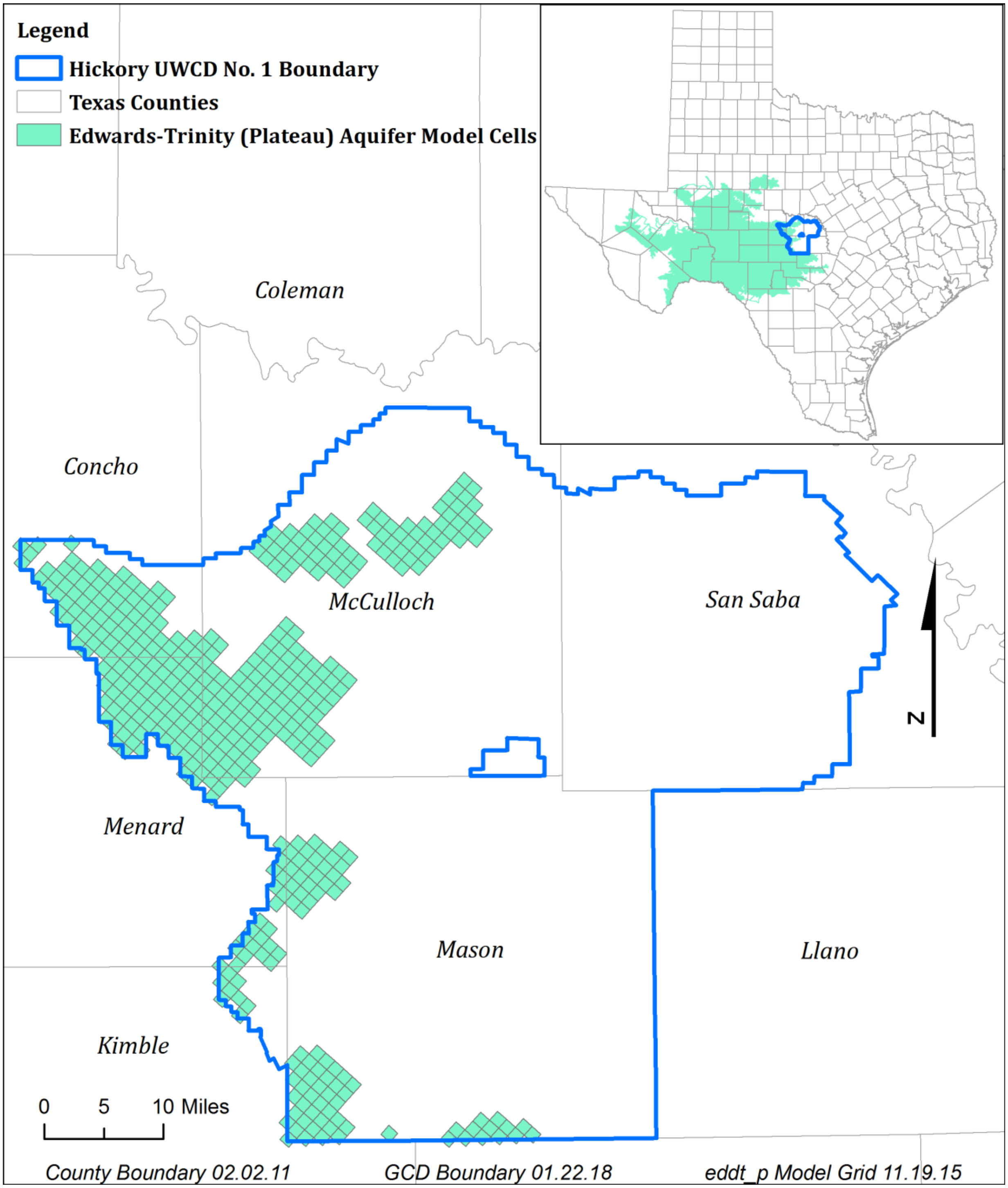

FIGURE 4: AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER FROM WHICH THE INFORMATION IN TABLE 4 WAS EXTRACTED (THE EDWARDS-TRINITY (PLATEAU) AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

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 historical groundwater flow conditions includes the assumptions about the location in the aquifer where historical 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 historical 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. Historical 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., http://www.twdb.texas.gov/groundwater/models/gam/eddt_p/ET-Plateau_Full.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., https://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., https://water.usgs.gov/nrp/gwsoftware/zonebud3/zonebudget3.html.

Wade, S., 2013, GAM Run 13-010: Hickory Underground Water Conservation District No. 1 Management Plan, 10 p. https://www.twdb.texas.gov/groundwater/docs/GAMruns/GR13-010.pdf.

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., https://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., https://pubs.usgs.gov/tm/06/a45/.

Shi, J., Boghici, R., Kohlrenken, W., and Hutchison, W.R., 2016, Conceptual Model Report: Minor Aquifers of the Llano Uplift Region of Texas. Texas Water Development Board Report, 306 p., http://www.twdb.texas.gov/groundwater/models/gam/llano/Llano_Uplift_Conceptual_Model_Report_Final.pdf.

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., http://www.twdb.texas.gov/groundwater/models/gam/llano/Llano_Uplift_Numerical_Model_Report_Final.pdf.