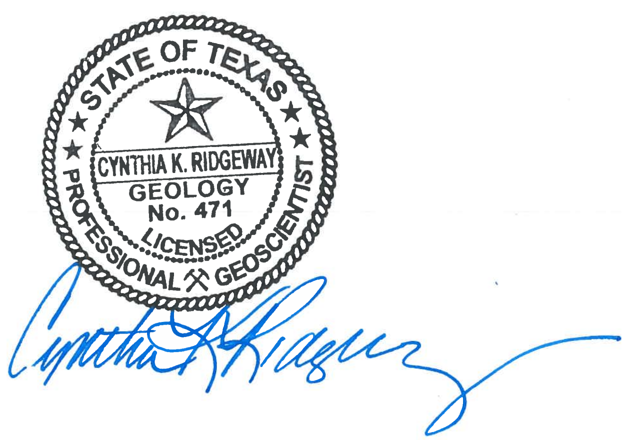
GAM Run 18-003: Blanco-Pedernales Groundwater Conservation District Groundwater Management Plan

Natalie Ballew, GIT
Texas Water Development Board
Groundwater Division
Groundwater Availability Modeling Department
512-463-2779

April 3, 2018



Cynthia K. Ridgeway is the Manager of the Groundwater Availability Modeling Department and is responsible for oversight of work performed by Natalie Ballew under her direct supervision. The seal appearing on this document was authorized by Cynthia K. Ridgeway, P.G. 471 on April 3, 2018.

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GAM RUN 18-003: BLANCO-PEDERNALES GROUNDWATER CONSERVATION DISTRICT GROUNDWATER MANAGEMENT PLAN

Natalie Ballew, GIT
Texas Water Development Board
Groundwater Division
Groundwater Availability Modeling Department
512-463-2779
March 30, 2018

EXECUTIVE SUMMARY:

Texas State Water Code, Section 36.1071, Subsection (h) (Texas Water Code, 2015), 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 Blanco-Pedernales 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 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 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 Blanco-Pedernales Groundwater Conservation District should be adopted by the district on or before October 10, 2018, and submitted to the Executive Administrator of the TWDB on or before November 9, 2018. The current management plan for the Blanco-Pedernales Groundwater Conservation District expires on January 8, 2019.

We used two groundwater availability models to estimate the management plan information for the aquifers within the Blanco-Pedernales Groundwater Conservation District. Information for the Edwards-Trinity (Plateau) and Trinity aquifers is from version 1.01 of the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers (Anaya and Jones, 2009). Information for the Marble Falls, Ellenburger-San Saba, and Hickory aquifers is from version 1.01 of the groundwater availability model for the minor aquifers in the Llano Uplift Region (Shi and others, 2016).

This report replaces the results of GAM Run 13-001 (Jones, 2013). Tables 1 through 5 summarize the groundwater availability model data required by statute and Figures 1 through 5 show the area of the models from which the values in the tables were extracted. If, after review of the figures, the Blanco-Pedernales 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 two groundwater availability models mentioned above were used to estimate information for the Blanco-Pedernales Groundwater Conservation District management plan. Water budgets were extracted for the historical model periods for the Edwards-Trinity (Plateau) and Trinity aquifers (1981 through 2000), and the Marble Falls, Ellenburger-San Saba, and Hickory aquifers (1981 through 2010) using ZONEBUDGET Version 3.01 (Harbaugh, 2009) and ZONEBUDGET USG Version 1.00 (Panday and others, 2013). 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:

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 model.

- The groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers contains 2 layers: Layer 1 (the Edwards Group and equivalent limestone hydrostratigraphic units of the Edwards-Trinity (Plateau) Aquifer System, and layer 2 (comprised of the undifferentiated Trinity Group hydrostratigraphic units or equivalent units of the Edwards-Trinity (Plateau) Aquifer System). The two layers were lumped for calculating water budgets in the Edwards-Trinity (Plateau) Aquifer System within the district. However, areas representing the Edwards-Trinity (Plateau) Aquifer were differentiated from areas representing the Trinity Aquifer to calculate flows between the two aquifers.

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

Trinity 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 model.

- The groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers contains 2 layers: Layer 1 (the Edwards Group and equivalent limestone hydrostratigraphic units of the Edwards-Trinity (Plateau) Aquifer System, and layer 2 (comprised of the undifferentiated Trinity Group hydrostratigraphic units or equivalent units of the Edwards-Trinity (Plateau) Aquifer System). The two layers were lumped for calculating water budgets in the Edwards-Trinity (Plateau) Aquifer System within the district. However, areas representing the Edwards-Trinity (Plateau) Aquifer were differentiated from areas representing the Trinity Aquifer to calculate flows between the two aquifers.

- We used the groundwater availability model for the Edwards-Trinity (Plateau) Aquifer instead of the groundwater availability model for the Hill Country portion of the Trinity Aquifer because the Edwards-Trinity (Plateau) Aquifer model covers the entire geographical area of district. Each groundwater availability model is aligned with a different model grid orientation, which prevents combining the results from each without double accounting or omitting important water budget information.

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

Marble Falls, Ellenburger-San Saba, and Hickory aquifers

- We used version 1.01 of the groundwater availability model for the minor aquifers in the Llano Uplift Region. See Shi and others (2016) for assumptions and limitations of the model.

- The groundwater availability model for the minor aquifers in Llano Uplift Region contains eight layers:

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

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

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

- These aquifers are part of a complex geological environment in the Llano Uplift Region characterized by numerous faults that can offset and/or juxtapose multiple aquifer layers with different hydrologic properties and water-quality characteristics. Therefore the water budget and flow information provided in the summary tables is footnoted where appropriate to clarify these aquifer relationships.

RESULTS:

A groundwater budget summarizes the amount of water entering and leaving the aquifers according to the groundwater availability model. Selected groundwater budget components listed below were extracted from the groundwater availability model results for the Edwards-Trinity (Plateau), Trinity, Marble Falls, Ellenburger-San Saba, and Hickory aquifers located within Blanco-Pedernales Groundwater Conservation District and averaged over the historical calibration periods, as shown in Tables 1 through 5.

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 through 5. 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 EDWARDS-TRINITY (PLATEAU) AQUIFER FOR BLANCO-PEDERNALES 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	Edwards-Trinity (Plateau) Aquifer	571
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	0
Estimated annual volume of flow into the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	0
Estimated annual volume of flow out of the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	206
Estimated net annual volume of flow between each aquifer in the district	Flow to the Edwards-Trinity (Plateau) Aquifer from the Trinity Aquifer[1]	188

[1] This simulated flow is primarily between equivalent hydrostratigraphic units of the Edwards-Trinity (Plateau) and Trinity aquifers in layer 2 of the model.

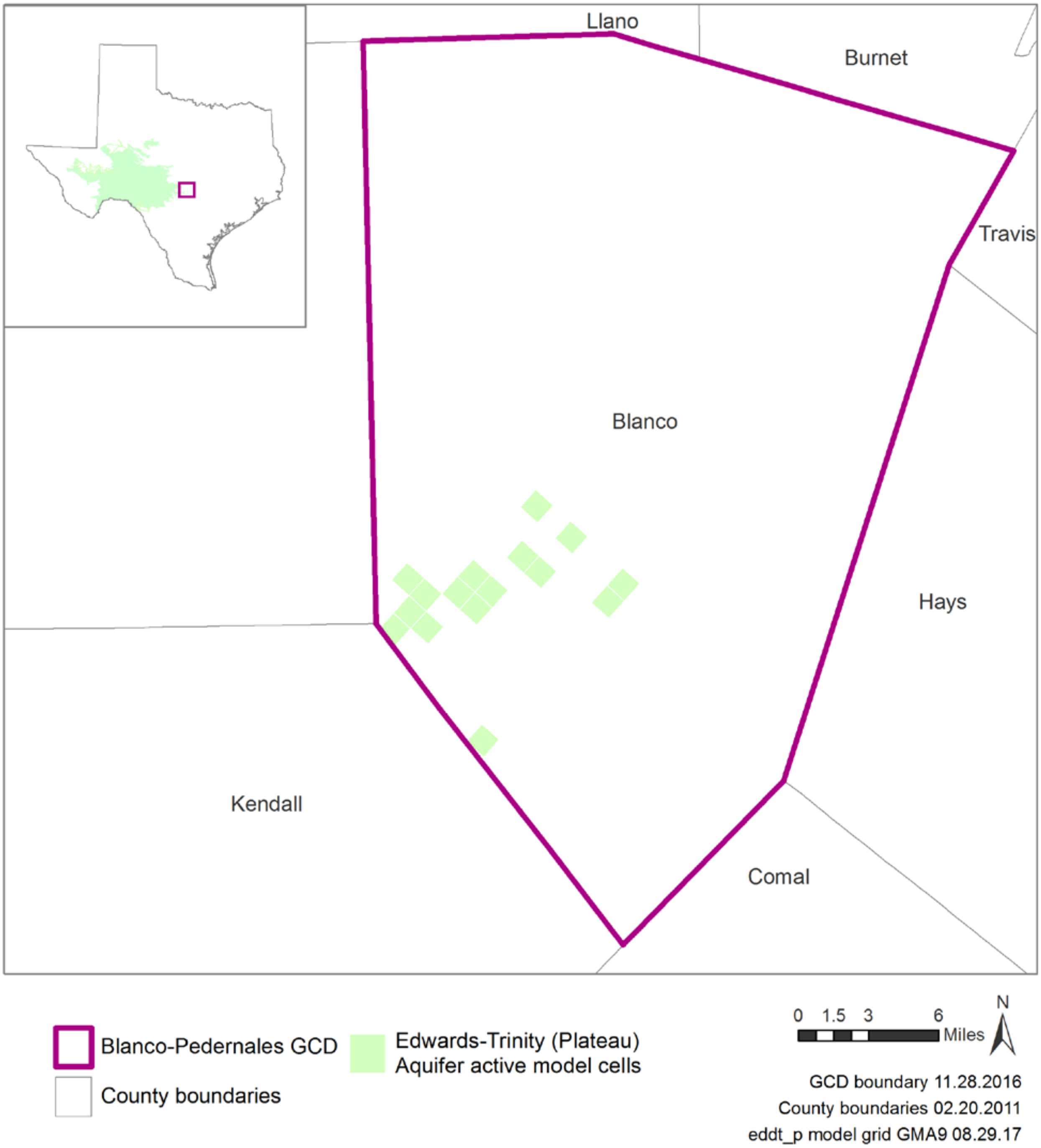

FIGURE 1. AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER FROM WHICH THE INFORMATION IN TABLE 1 WAS EXTRACTED (THE AQUIFER SYSTEM EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 2. SUMMARIZED INFORMATION FOR THE TRINITY AQUIFER FOR BLANCO-PEDERNALES 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	Trinity Aquifer	44,470
Estimated annual volume of water that discharges from the aquifer to springs and any surface-water body including lakes, streams, and rivers	Trinity Aquifer	25,448
Estimated annual volume of flow into the district within each aquifer in the district	Trinity Aquifer	4,468
Estimated annual volume of flow out of the district within each aquifer in the district	Trinity Aquifer	19,490
Estimated net annual volume of flow between each aquifer in the district	Flow from the Trinity Aquifer to the Edwards-Trinity (Plateau) Aquifer[2]	188
	Flow from the Trinity Aquifer to the Marble Falls Aquifer	97[3]
	Flow from the Trinity Aquifer to the Ellenburger-San Saba Aquifer	990[3]
	Flow to the Trinity Aquifer from the Hickory Aquifer	61[3]

[2] This simulated flow is primarily between equivalent hydrostratigraphic units of the Edwards-Trinity (Plateau) and Trinity aquifers in layer 2 of the model.
[3] The estimated net annual volume of flow between the Trinity Aquifer and the Marble Falls, Ellenburger-San Saba, and Hickory aquifers was calculated from version 1.01 of the groundwater availability model for the Minor Aquifers in the Llano Uplift Region.

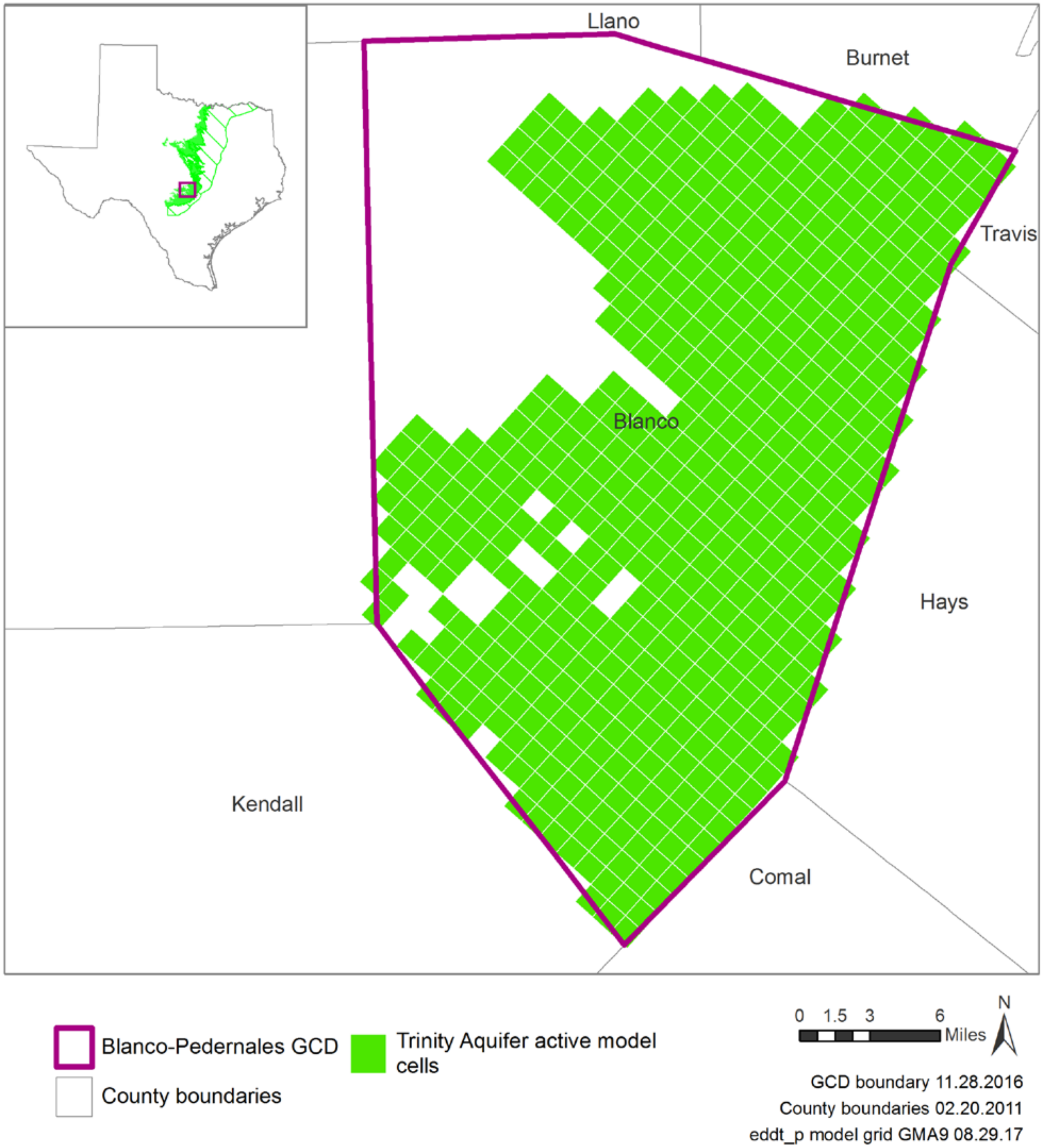

FIGURE 2. AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER FROM WHICH THE INFORMATION IN TABLE 2 WAS EXTRACTED (THE TRINITY AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 3. SUMMARIZED INFORMATION FOR THE MARBLE FALLS AQUIFER FOR BLANCO-PEDERNALES 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	Marble Falls Aquifer	199
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	7,746
Estimated annual volume of flow into the district within each aquifer in the district	Marble Falls Aquifer	0
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[4]	Flow to the Marble Falls Aquifer from the Trinity Aquifer	97
	Flow from the Marble Falls Aquifer to the confining unit between Cretaceous aquifers and the Marble Falls Formation	147
	Flow to the Marble Falls Aquifer from the brackish portion of the Marble Falls subcrop[5]	945
	Flow to the Marble Falls Aquifer from the confining unit between the Marble Falls formation and the Ellenburger-San Saba Aquifer	5,879
	Flow to the Marble Falls Aquifer from the Ellenburger-San Saba Aquifer	480
	Flow to the Marble Falls Aquifer from the Precambrian confining unit	2

[4] These aquifers are part of a complex geological environment in the Llano Uplift Region characterized by numerous faults that can offset and/or juxtapose multiple aquifer layers with different hydrologic properties and water-quality characteristics.

[5] The brackish portion of the Marble Falls subcrop is the brackish downdip portion of the formation that is outside the official aquifer extent.

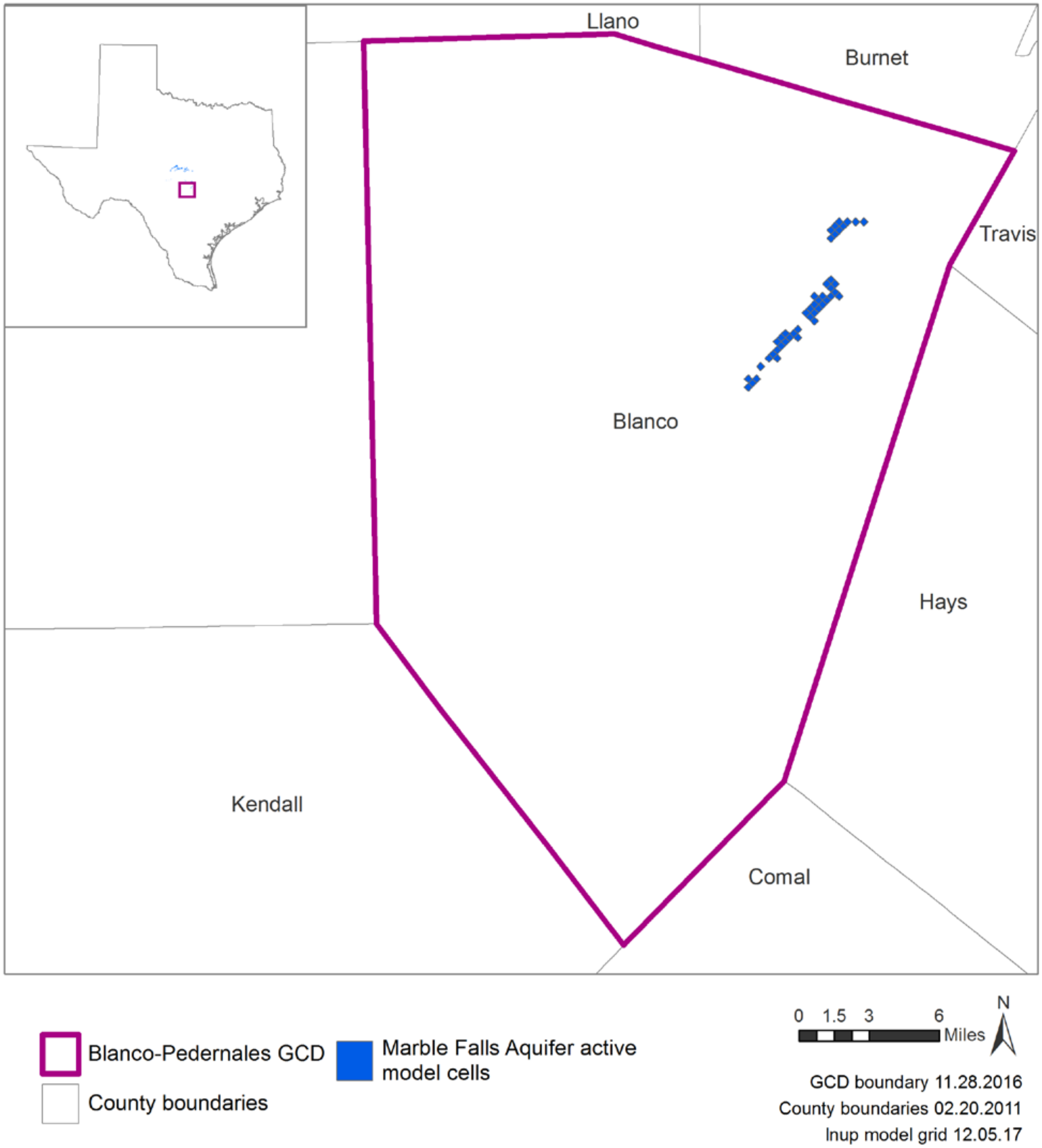

FIGURE 3. AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE MINOR AQUIFERS IN THE LLANO UPLIFT REGION FROM WHICH THE INFORMATION IN TABLE 3 WAS EXTRACTED (THE MARBLE FALLS AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 4. SUMMARIZED INFORMATION FOR THE ELLENBURGER-SAN SABA AQUIFER FOR BLANCO-PEDERNALES 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	Ellenburger-San Saba Aquifer	16,552
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	24,179
Estimated annual volume of flow into the district within each aquifer in the district	Ellenburger-San Saba Aquifer	6,902
Estimated annual volume of flow out of the district within each aquifer in the district	Ellenburger-San Saba Aquifer	12,439
Estimated net annual volume of flow between each aquifer in the district[6]	Flow to the Ellenburger-San Saba Aquifer from the Trinity Aquifer	990
	Flow to the Ellenburger-San Saba Aquifer from Quaternary alluvium	75
	Flow to the Ellenburger-San Saba Aquifer from the confining unit between Cretaceous aquifers and the Marble Falls Formation	44
	Flow from the Ellenburger-San Saba Aquifer to the Marble Falls Aquifer	480
	Flow to the Ellenburger-San Saba Aquifer from the Marble Falls subcrop[7]	248
	Flow from the Ellenburger-San Saba Aquifer to the confining unit between the Marble Falls and Ellenburger-San Saba aquifers	2,923
	Flow from the Ellenburger-San Saba Aquifer to the brackish portion of the Ellenburger-San Saba[8]	3,854
	Flow from the updip subcrop of the Ellenburger-San Saba[9] to the Ellenburger-San Saba Aquifer	3,258
	Flow from the Ellenburger-San Saba Aquifer to the confining unit between the Ellenburger-San Saba and Hickory aquifers	634
	Flow to the Ellenburger-San Saba Aquifer from the Hickory Aquifer	4,159
	Flow to the Ellenburger-San Saba Aquifer from the Precambrian confining unit	525

[6] These aquifers are part of a complex geological environment in the Llano Uplift Region characterized by numerous faults that can offset and/or juxtapose multiple aquifer layers with different hydrologic properties and water-quality characteristics.

[7] The Marble Falls subcrop is the downdip portion of the formation that is outside the official aquifer extent.

[8] The brackish portion of the Ellenburger-San Saba is the brackish downdip portion of the formation that is outside the official aquifer extent.

[9] The updip subcrop of the Ellenburger-San Saba is the portion of the formation that is updip of the official aquifer extent and unexposed at the land surface.

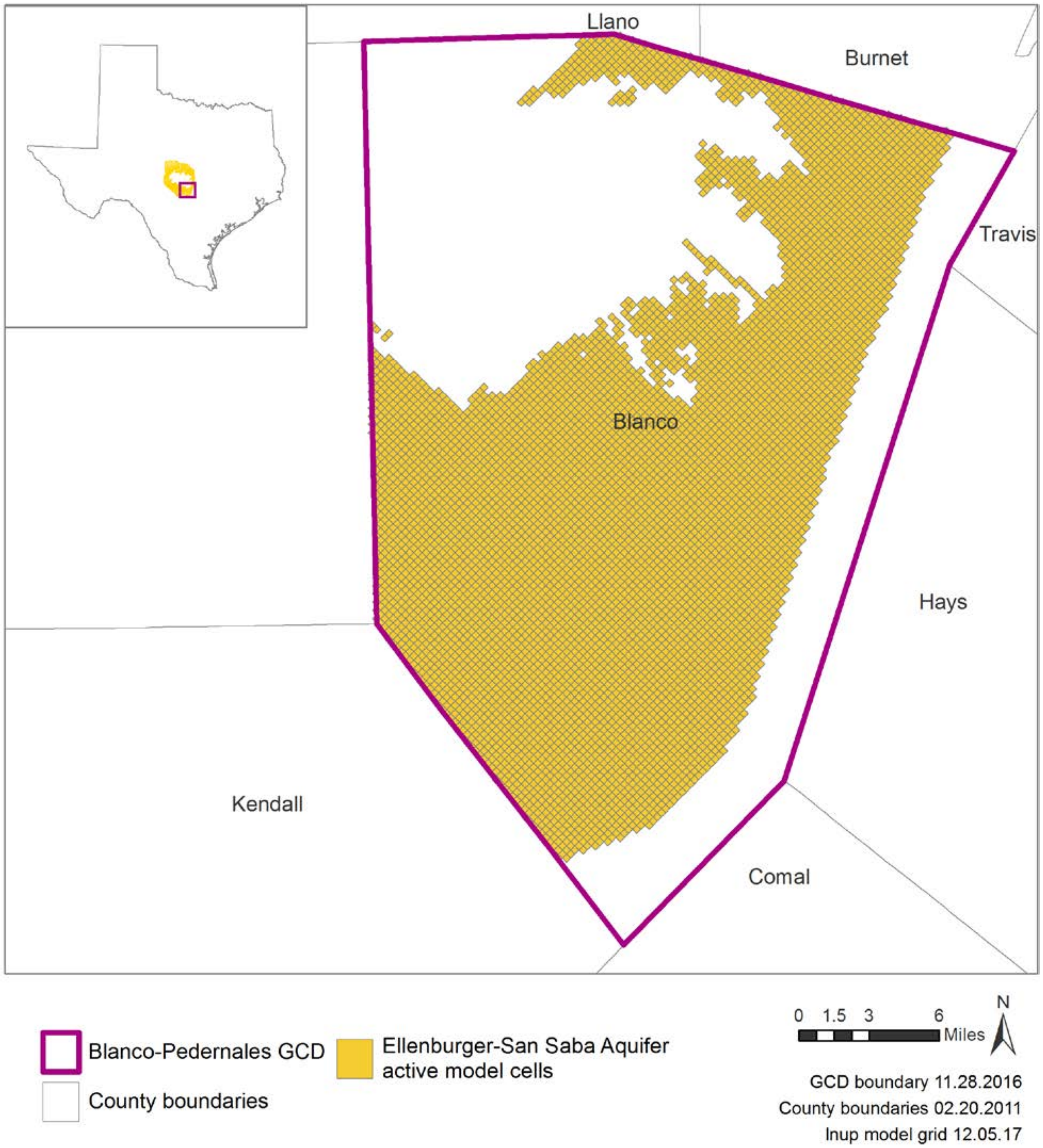

FIGURE 4. AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE MINOR AQUIFERS IN THE LLANO UPLIFT REGION FROM WHICH THE INFORMATION IN TABLE 4 WAS EXTRACTED (THE ELLENBURGER-SAN SABA AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 5. SUMMARIZED INFORMATION FOR THE HICKORY 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	2,089
Estimated annual volume of water that discharges from the aquifer to springs and any surface-water body including lakes, streams, and rivers	Hickory Aquifer	15,722
Estimated annual volume of flow into the district within each aquifer in the district	Hickory Aquifer	7,572
Estimated annual volume of flow out of the district within each aquifer in the district	Hickory Aquifer	7,270
Estimated net annual volume of flow between each aquifer in the district[10]	Flow from the Hickory Aquifer to the Trinity Aquifer	61
	Flow from the Hickory Aquifer the Quaternary alluvium	19
	Flow from the Hickory Aquifer to the Marble Falls subcrop[11]	24
	Flow from the Hickory Aquifer to the confining unit between the Marble Falls and Ellenburger-San Saba aquifers	39
	Flow from the Hickory Aquifer to the Ellenburger-San Saba Aquifer	4,159
	From the Hickory Aquifer to the brackish portion of Ellenburger-San Saba[12]	15
	Flow from the Hickory Aquifer to the updip Ellenburger-San Saba	964
	Flow to the Hickory Aquifer from the confining unit between the Ellenburger-San Saba and Hickory aquifers	4,033
	Flow from the Hickory Aquifer to the brackish portion of the Hickory[13]	4
	Flow from the updip Hickory[14] to the Hickory Aquifer	2,551
	Flow from the Hickory Aquifer to the Precambrian confining unit	467

[10] These aquifers are part of a complex geological environment in the Llano Uplift Region characterized by numerous faults that can offset and/or juxtapose multiple aquifer layers with different hydrologic properties and water-quality characteristics.
[11] The Marble Falls subcrop is the downdip portion of the formation that is outside the official aquifer extent.
[12] The brackish portion of the Ellenburger-San Saba is the brackish downdip portion of the formation that is outside the official aquifer extent.
[13] The brackish portion of the Hickory is the brackish downdip portion of the formation that is outside the official aquifer extent.
[14] The updip subcrop of the Hickory is the portion of the formation that is updip of the official aquifer extent and unexposed at the land surface.

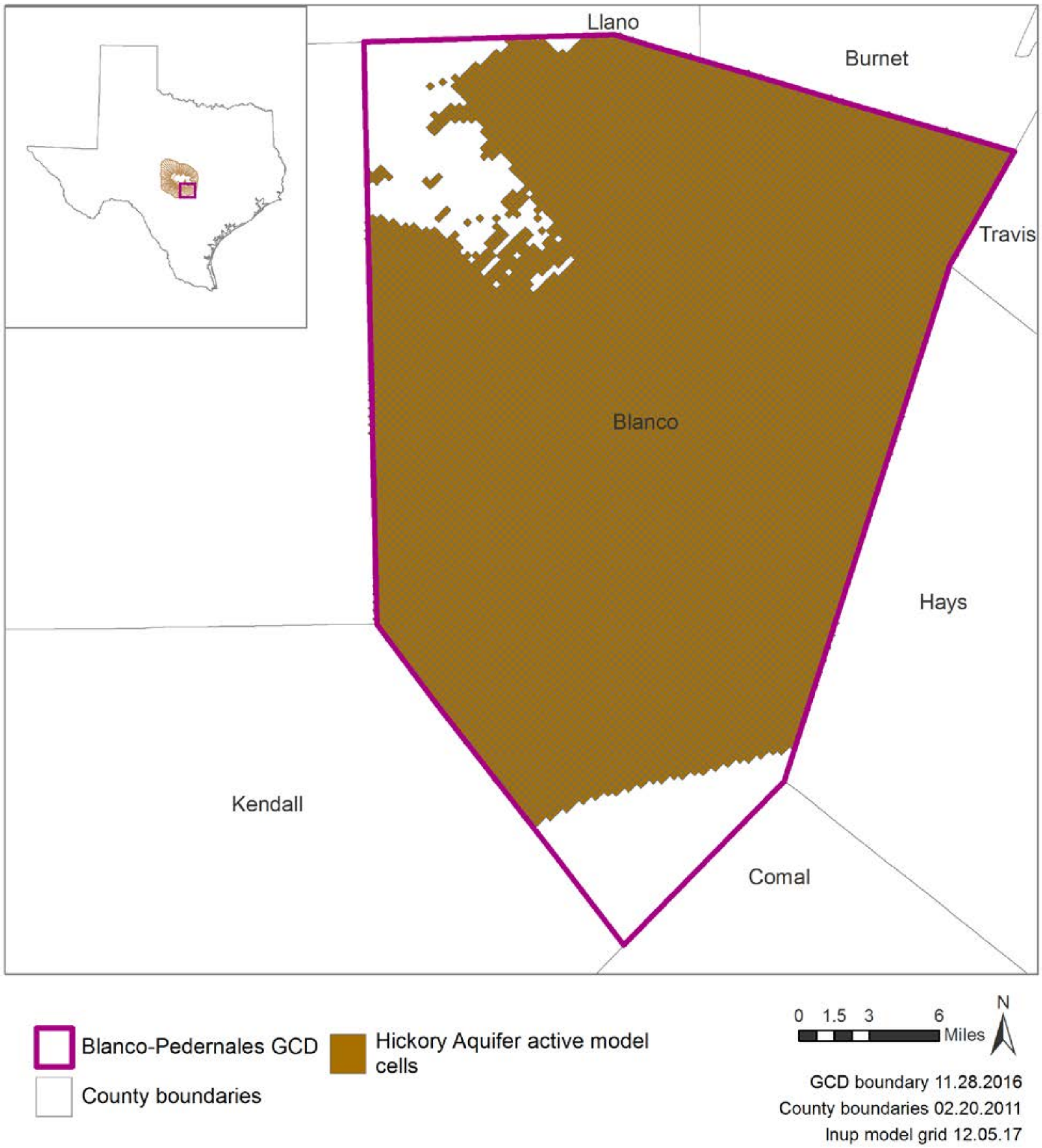

FIGURE 5. AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE MINOR AQUIFERS IN THE LLANO UPLIFT REGION FROM WHICH THE INFORMATION IN TABLE 5 WAS EXTRACTED (THE HICKORY AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

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 historic groundwater flow conditions includes the assumptions about the location in the aquifer where historic pumping was placed. Understanding the amount and location of historic 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., http://www.twdb.state.tx.us/gam/eddt_p/eddt_p.htm.

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.

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.

Jones, I., 2013, GAM Run 13-001: Blanco-Pedernales Groundwater Conservation District Management Plan, 11 p., http://www.twdb.texas.gov/groundwater/docs/GAMruns/GR13-001.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., http://www.nap.edu/catalog.php?record_id=11972.

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.

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, draft report, June 2016 (under final review), 403p.

Texas Water Code, 2015, http://www.statutes.legis.state.tx.us/docs/WA/pdf/WA.36.pdf.