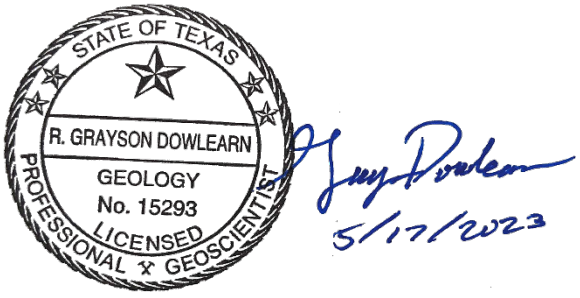
GAM RUN 23-003: PINEYWOODS GROUNDWATER CONSERVATION DISTRICT MANAGEMENT PLAN

Grayson Dowlearn, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Modeling Department
512-475-1552
May 17, 2023



This page is intentionally blank

GAM RUN 23-003: PINEYWOODS GROUNDWATER CONSERVATION DISTRICT MANAGEMENT PLAN

Grayson Dowlearn, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Modeling Department
512-475-1552
May 17, 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 Pineywoods 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 Pineywoods Groundwater Conservation District should be adopted by the district on or before July 20, 2023 and submitted to the executive administrator of the TWDB on or before August 19, 2023. The current management plan for the Pineywoods Groundwater Conservation District expires on October 18, 2023.

We used three groundwater availability models to estimate the management plan information for the five modeled aquifers located within Pineywoods Groundwater Conservation District. We used the groundwater availability model for the northern portion of the Carrizo-Wilcox, Queen City, and Sparta Aquifers (Panday and others, 2020, and Schorr and others 2020) to estimate management plan information for the Carrizo-Wilcox, Queen City, and Sparta aquifers. We used the groundwater availability model for the Yegua-Jackson Aquifer (Deeds and others, 2010) to estimate management plan information for the Yegua-Jackson Aquifer. Lastly, we used the groundwater availability model for the northern portion of the Gulf Coast Aquifer System (Kasmarek, 2013) to estimate management plan information for the Gulf Coast Aquifer System.

This report replaces the results of GAM Run 17-021 (Wade, 2017) because it includes results from the updated groundwater availability model for the northern portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers (Panday and others, 2020, and Schorr and others 2020). Values may also 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, 4, and 5 summarize the groundwater availability model data required by statute. Figures 1, 3, 5, 7, and 9 show the area of the model from which the values in Tables 1, 2, 3, 4, and 5 were extracted. Figures 2, 4, 6, 8, and 10 provide a generalized diagram of the groundwater flow components provided in Tables 1, 2, 3, 4, and 5. If the Pineywoods Groundwater Conservation District 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 State Water Code, Section 36.1071, Subsection (h), the groundwater availability models mentioned above were used to estimate information for the Pineywoods Groundwater Conservation District management plan. Water budgets were extracted for the historical calibration period for the Carrizo-Wilcox, Queen City, and Sparta aquifers (1980 through 2013) using ZONEBUDGET for MODFLOW 6 (Langevin and others, 2021). Water budgets were extracted for the historical calibration period for the Yegua-Jackson Aquifer (1980 through 1997) and the Gulf Coast Aquifer System (1980 through 2009) 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:

Carrizo-Wilcox, Queen City, and Sparta aquifers

- We used version 3.01 of the groundwater availability model for the northern portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers (Panday and others, 2020, and Schorr and others, 2020) to analyze the Carrizo-Wilcox, Queen City, and Sparta aquifers. See Panday and others (2020) and Schorr and others (2020) for assumptions and limitations of the model.

- The groundwater availability model for the northern portion of the Queen City, Sparta, and Carrizo-Wilcox aquifers contains nine layers represented as:
    - Layer 1 represents Quaternary Alluvium,
    - Layer 2 represents the Sparta Aquifer and equivalent units,
    - Layer 3 represents the Weches Formation (confining unit),
    - Layer 4 represents the Queen City Aquifer and equivalent units,
    - Layer 5 represents the Reklaw Formation (confining unit),
    - Layer 6 represents the Carrizo Formation,
    - Layer 7 represents the Upper Wilcox member,
    - Layer 8 represents the Middle Wilcox member, and
    - Layer 9 represents the Lower Wilcox member.

- Water budget values for the district were determined for the Carrizo-Wilcox (Layers 6 through 9), Queen City (Layer 4), and the Sparta (Layer 2) aquifers.

- Water budget values from the Quaternary Alluvium (Layer 1) were combined with the Carrizo-Wilcox, Queen City, and Sparta aquifers where Quaternary Alluvium falls within the respective aquifer outcrop boundaries.

- Water budget terms were averaged for the historical calibration period 1981 to 2013 (stress periods 2 through 34).

- The model was run with MODFLOW 6 (Langevin and others, 2017).

Yegua-Jackson Aquifer

- We used version 1.01 of the groundwater availability model for the Yegua-Jackson Aquifer (Deeds and others, 2010) to analyze the Yegua-Jackson Aquifer. See Deeds and others (2010) for assumptions and limitations of the groundwater availability model.

- This groundwater availability model includes five layers, which represent the following: Layer 1 (Yegua-Jackson Aquifer outcrop, the Catahoula Formation, and other younger overlying units), Layer 2 (the upper portion of the Jackson Group), Layer 3 (the lower portion of the Jackson Group), Layer 4 (the upper portion of the Yegua Group), and Layer 5 (the lower portion of the Yegua Group).

- An overall water budget for the district was determined for the Yegua-Jackson Aquifer (Layer 1 through Layer 5, collectively, for the portions of the model that represent the Yegua-Jackson Aquifer).

- The Catahoula Formation within Pineywoods Groundwater Conservation District falls within the Gulf Coast Aquifer System, which allows us to estimate the exchange between the Yegua-Jackson Aquifer and the Gulf Coast Aquifer System in this assessment.

- Water budget terms were averaged for the period 1980 through 1997 (stress periods 10 through 27).

- The model was run with MODFLOW-2000 (Harbaugh and others, 2000).

Gulf Coast Aquifer System

- We used version 3.01 of the groundwater availability model for the northern portion of the Gulf Coast Aquifer System (Kasmarek, 2013) to analyze the Gulf Coast Aquifer System. See Kasmarek (2013) for assumptions and limitations of the model.

- The model has four layers which represent the Chicot Aquifer (Layer 1), the Evangeline Aquifer (Layer 2), the Burkeville Confining Unit (Layer 3), and the Jasper Aquifer and parts of the Catahoula Formation in direct hydrologic communication with the Jasper Aquifer (Layer 4).
- Water budgets for the district were determined for the Gulf Coast Aquifer System (Layers 1 through 4 collectively).
- The model was run using MODFLOW-2000 (Harbaugh and others, 2000).

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 Carrizo-Wilcox, Queen City, Sparta, Yegua-Jackson, and the Gulf Coast Aquifer System aquifers located within the Pineywoods Groundwater Conservation District and averaged over the historical calibration period, as shown in Tables 1, 2, 3, 4, and 5.

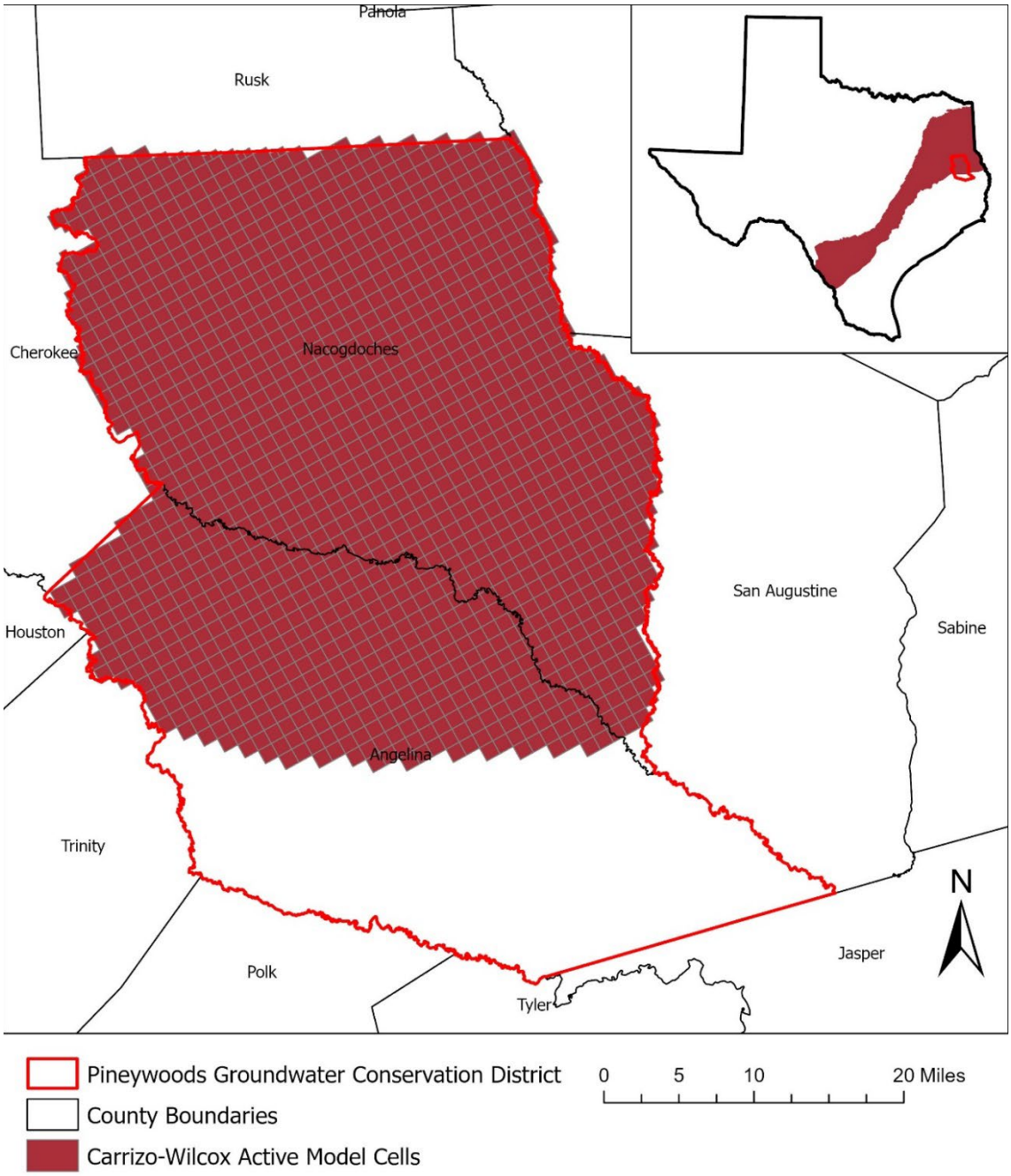
1. Precipitation recharge—the areally distributed recharge sourced from precipitation falling on the outcrop areas of the aquifers (where the aquifer is exposed at land surface) within the district.
2. Surface-water outflow—the total water discharging from the aquifer (outflow) to surface-water features 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, 2, 3, 4, and 5. Figures 2, 4, 6, 8, and 10 provide a generalized diagram of the groundwater flow components provided in Tables 1, 2, 3, 4, and 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.

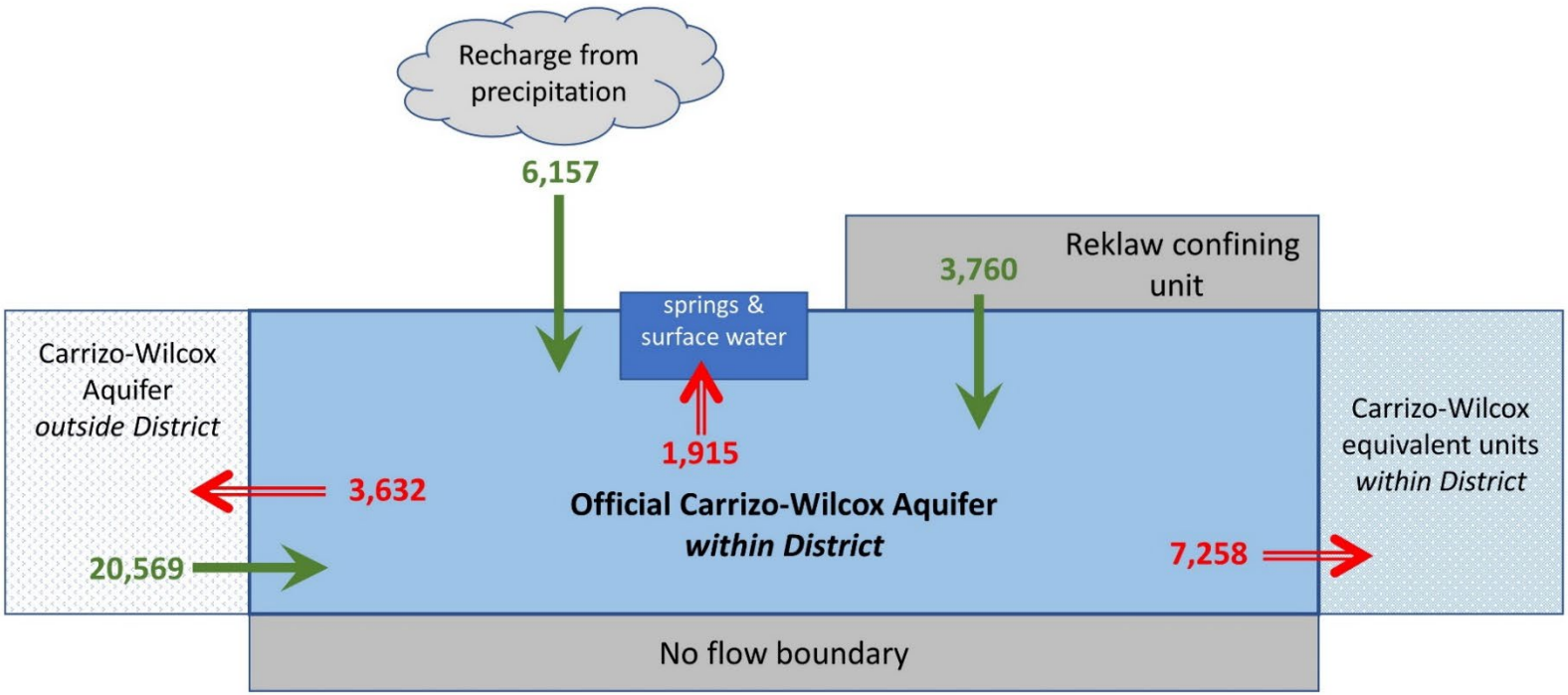
TABLE 1: SUMMARIZED INFORMATION FOR THE CARRIZO-WILCOX AQUIFER THAT IS NEEDED FOR THE PINEYWOODS GROUNDWATER CONSERVATION DISTRICT'S GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

Management plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Carrizo-Wilcox Aquifer	6,157
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Carrizo-Wilcox Aquifer	1,915
Estimated annual volume of flow into the district within each aquifer in the district	Carrizo-Wilcox Aquifer	20,569
Estimated annual volume of flow out of the district within each aquifer in the district	Carrizo-Wilcox Aquifer	3,632
Estimated net annual volume of flow between each aquifer in the district	To the Carrizo-Wilcox Aquifer from the overlying Reklaw Formation	3,760
	To the Carrizo-Wilcox Aquifer from Carrizo-Wilcox equivalent units	7,258



gcd boundary date: 06.26.2020, county boundaries date: 07.03.2019, czwx_n grid date: 06.07.2021

FIGURE 1: AREA OF THE NORTHERN PORTION OF THE CARRIZO-WILCOX, QUEEN CITY, AND SPARTA AQUIFERS GROUNDWATER AVAILABILITY MODEL FROM WHICH THE INFORMATION IN TABLE 1 WAS EXTRACTED (THE CARRIZO-WILCOX AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

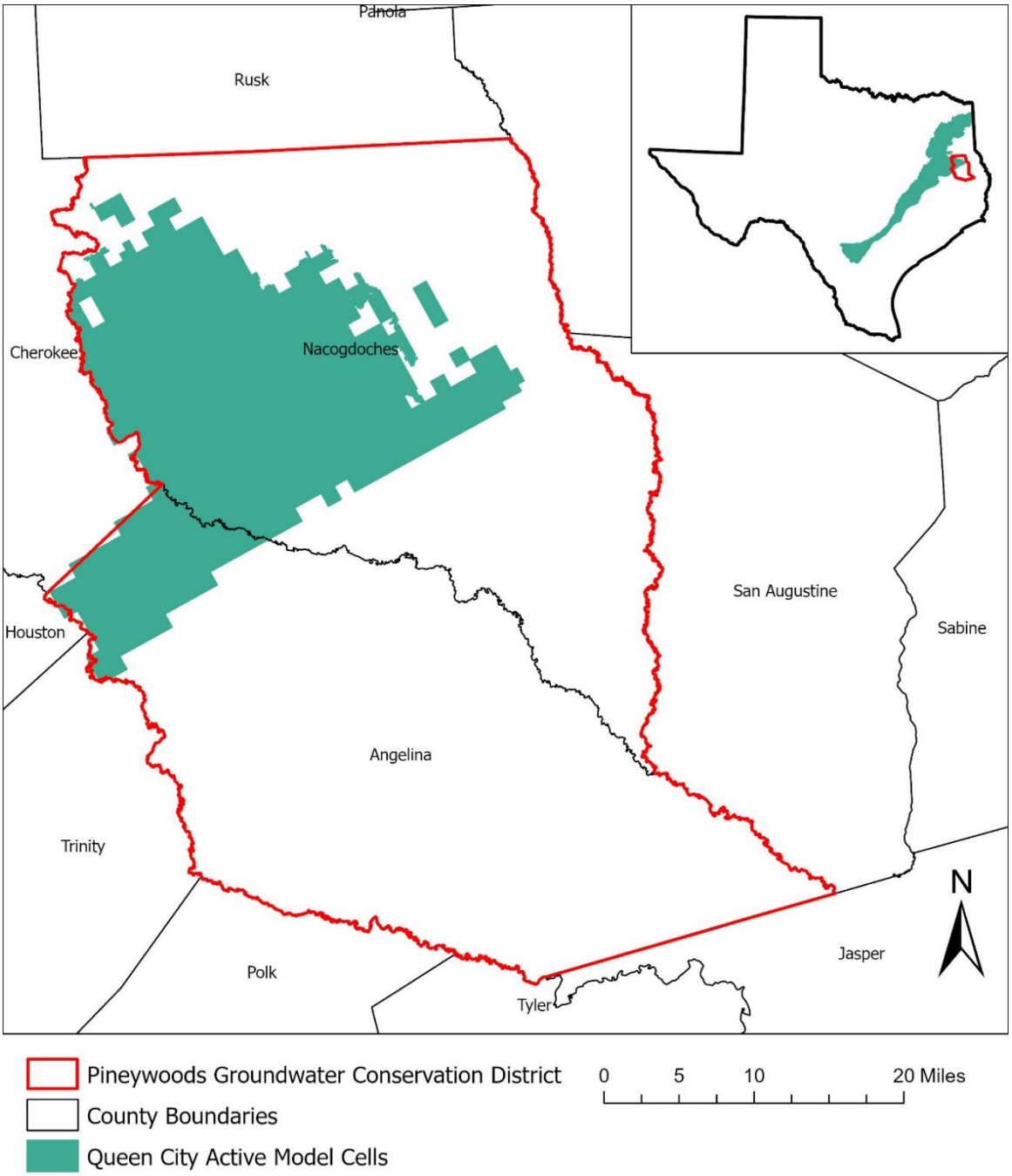


Caveat: This diagram only includes the water budget items provided in Table 1. A complete water budget would include additional inflows and outflows. For a full groundwater budget, please submit a request in writing to the Groundwater Modeling Department.

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

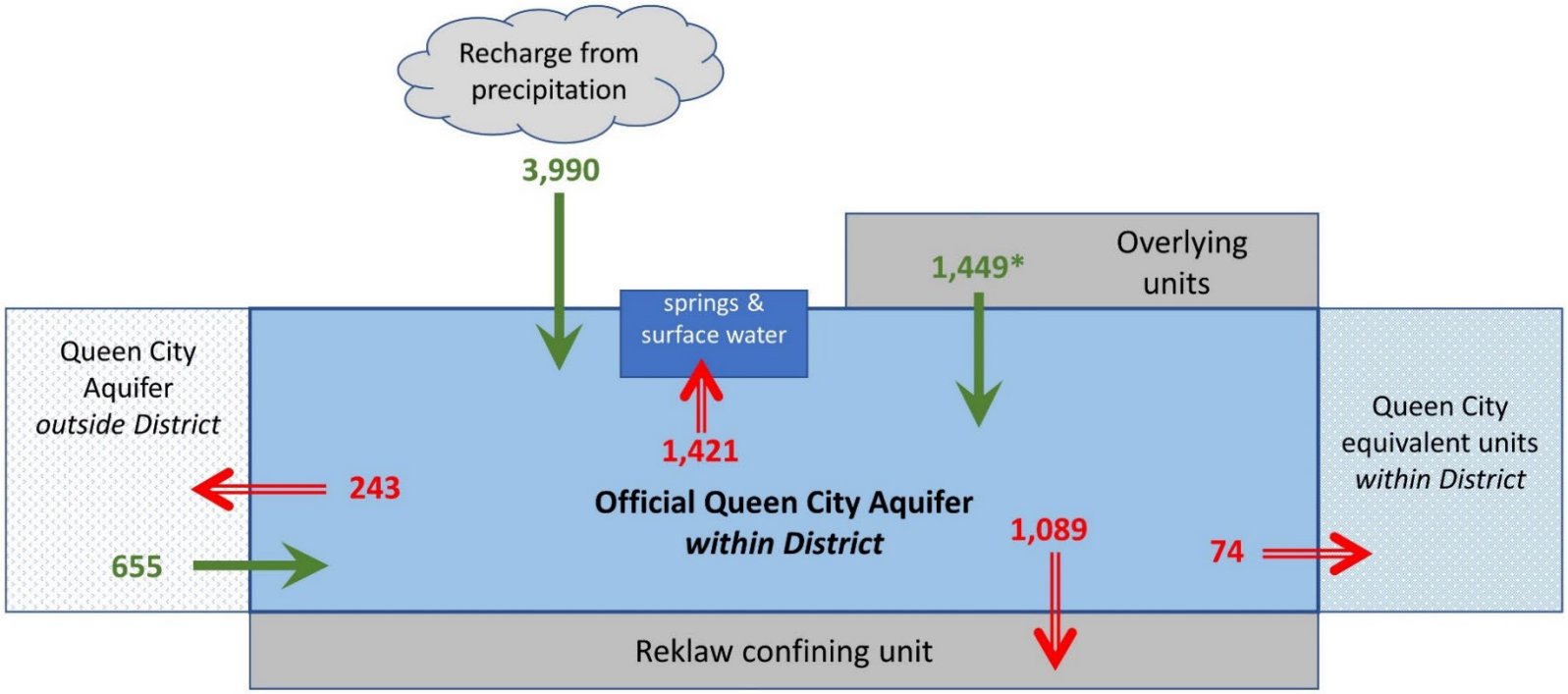
TABLE 2: SUMMARIZED INFORMATION FOR THE QUEEN CITY AQUIFER THAT IS NEEDED FOR THE PINEYWOODS GROUNDWATER CONSERVATION DISTRICT GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

Management plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Queen City Aquifer	3,990
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Queen City Aquifer	1,421
Estimated annual volume of flow into the district within each aquifer in the district	Queen City Aquifer	655
Estimated annual volume of flow out of the district within each aquifer in the district	Queen City Aquifer	243
Estimated net annual volume of flow between each aquifer in the district	From the Queen City Aquifer to the Sparta Aquifer	71
	To the Queen City Aquifer from the overlying Weches Formation	1,520
	From the Queen City Aquifer to the underlying Reklaw Formation	1,089
	From the Queen City Aquifer to Queen City equivalent units	74



gcd boundary date: 06.26.2020, county boundaries date: 07.03.2019, czwx_n grid date: 06.07.2021

FIGURE 3: AREA OF THE NORTHERN PORTION OF THE CARRIZO-WILCOX, QUEEN CITY, AND SPARTA AQUIFERS GROUNDWATER AVAILABILITY MODEL FROM WHICH THE INFORMATION IN TABLE 2 WAS EXTRACTED (THE QUEEN CITY AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).



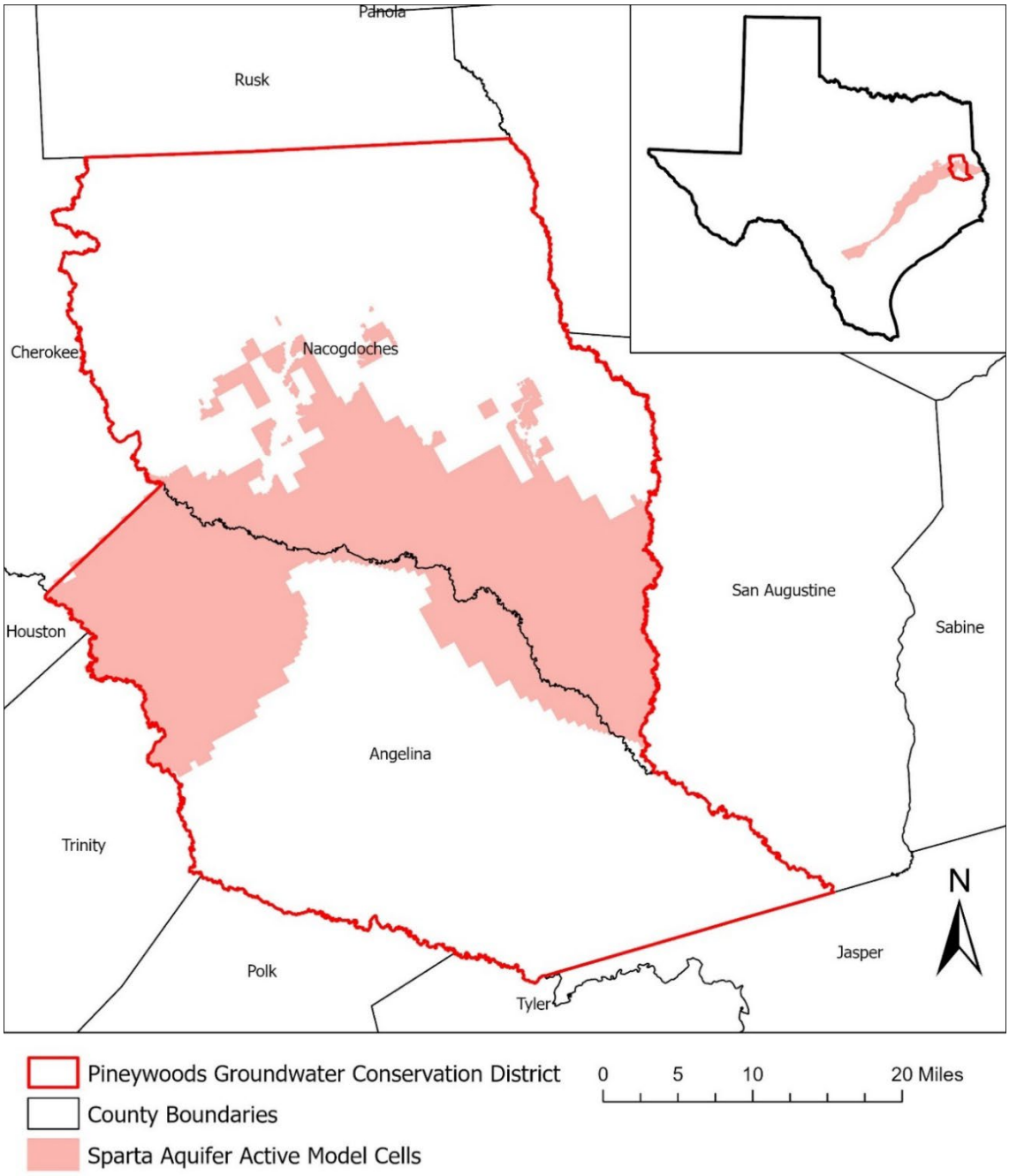
* Flow from overlying units includes net outflow of 71 acre-feet per year to the Sparta Aquifer and a new inflow of 1,520 acre-feet per year to the Weches confining unit.

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 THE QUEEN CITY AQUIFER WITHIN PINEYWOODS GROUNDWATER CONSERVATION DISTRICT. FLOW VALUES EXPRESSED IN ACRE-FEET PER YEAR.

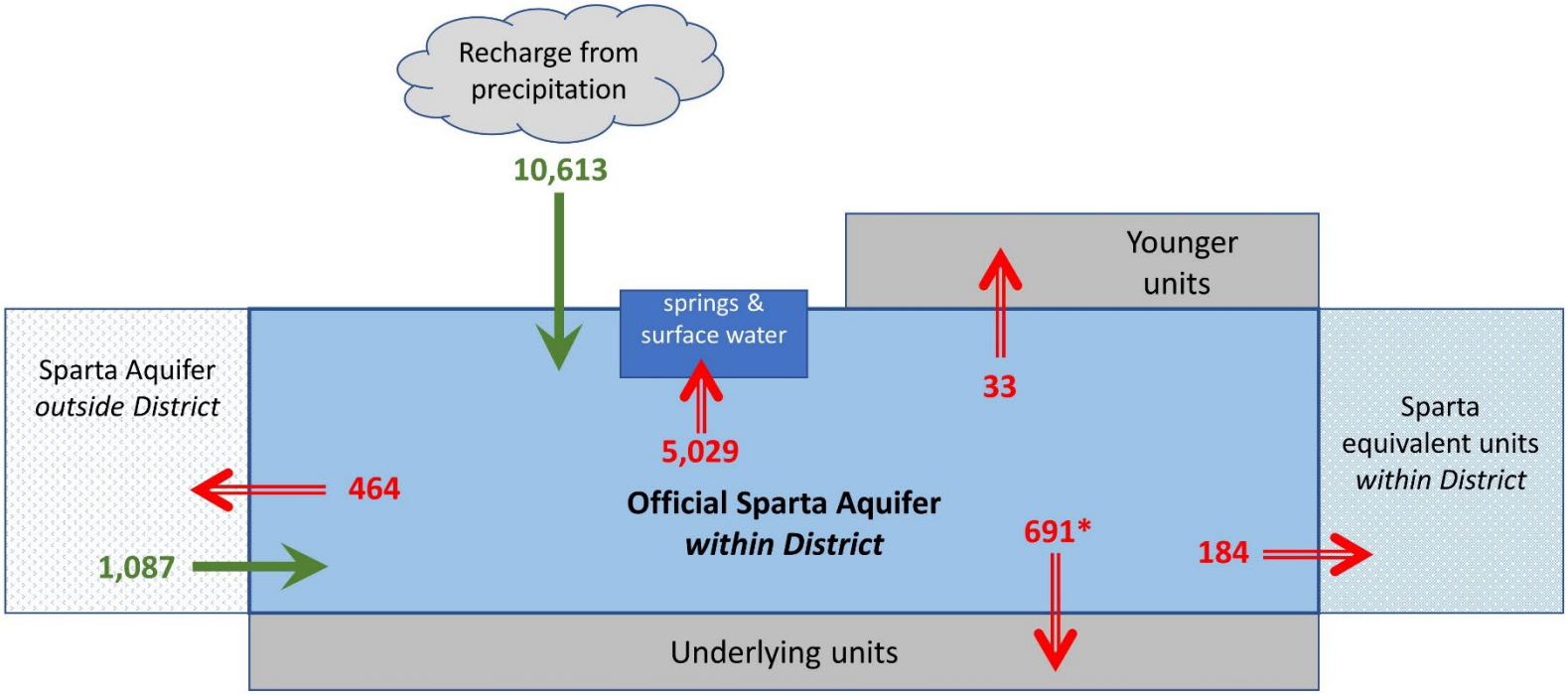
TABLE 3: SUMMARIZED INFORMATION FOR THE SPARTA AQUIFER THAT IS NEEDED FOR THE PINEYWOODS GROUNDWATER CONSERVATION DISTRICT GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

Management plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Sparta Aquifer	10,613
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Sparta Aquifer	5,029
Estimated annual volume of flow into the district within each aquifer in the district	Sparta Aquifer	1,087
Estimated annual volume of flow out of the district within each aquifer in the district	Sparta Aquifer	464
Estimated net annual volume of flow between each aquifer in the district	From the Sparta Aquifer to younger units	33
	From the Sparta Aquifer to the underlying Weches Formation	762
	To the Sparta Aquifer from the Queen City Aquifer	71
	From the Sparta Aquifer to Sparta equivalent units	184



gcd boundary date: 06.26.2020, county boundaries date: 07.03.2019, czwx_n grid date: 06.07.2021

FIGURE 5: AREA OF THE NORTHERN PORTION OF THE CARRIZO-WILCOX, QUEEN CITY, AND SPARTA AQUIFERS GROUNDWATER AVAILABILITY MODEL FROM WHICH THE INFORMATION IN TABLE 3 WAS EXTRACTED (THE SPARTA AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).



* Flow to underlying units includes net inflow of 71 acre-feet per year from the Queen City Aquifer and net outflow of 762 acre-feet per year to the Weches confining unit.

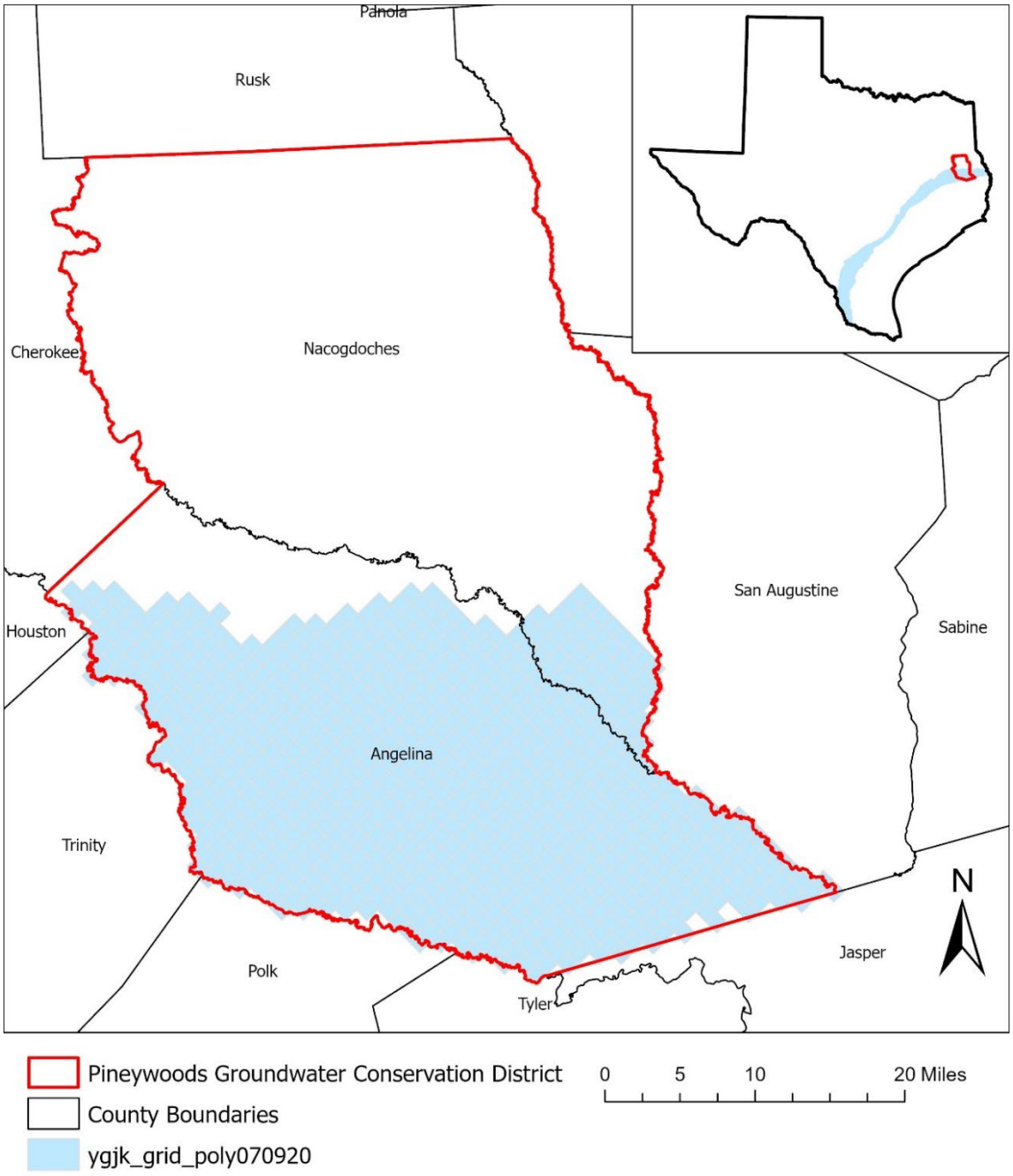
Caveat: This diagram only includes the water budget items provided in Table 3. A complete water budget would include additional inflows and outflows. For a full groundwater budget, please submit a request in writing to the Groundwater Modeling Department.

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

TABLE 4: SUMMARIZED INFORMATION FOR THE YEGUA-JACKSON AQUIFER THAT IS NEEDED FOR THE PINEYWOODS GROUNDWATER CONSERVATION DISTRICT'S GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

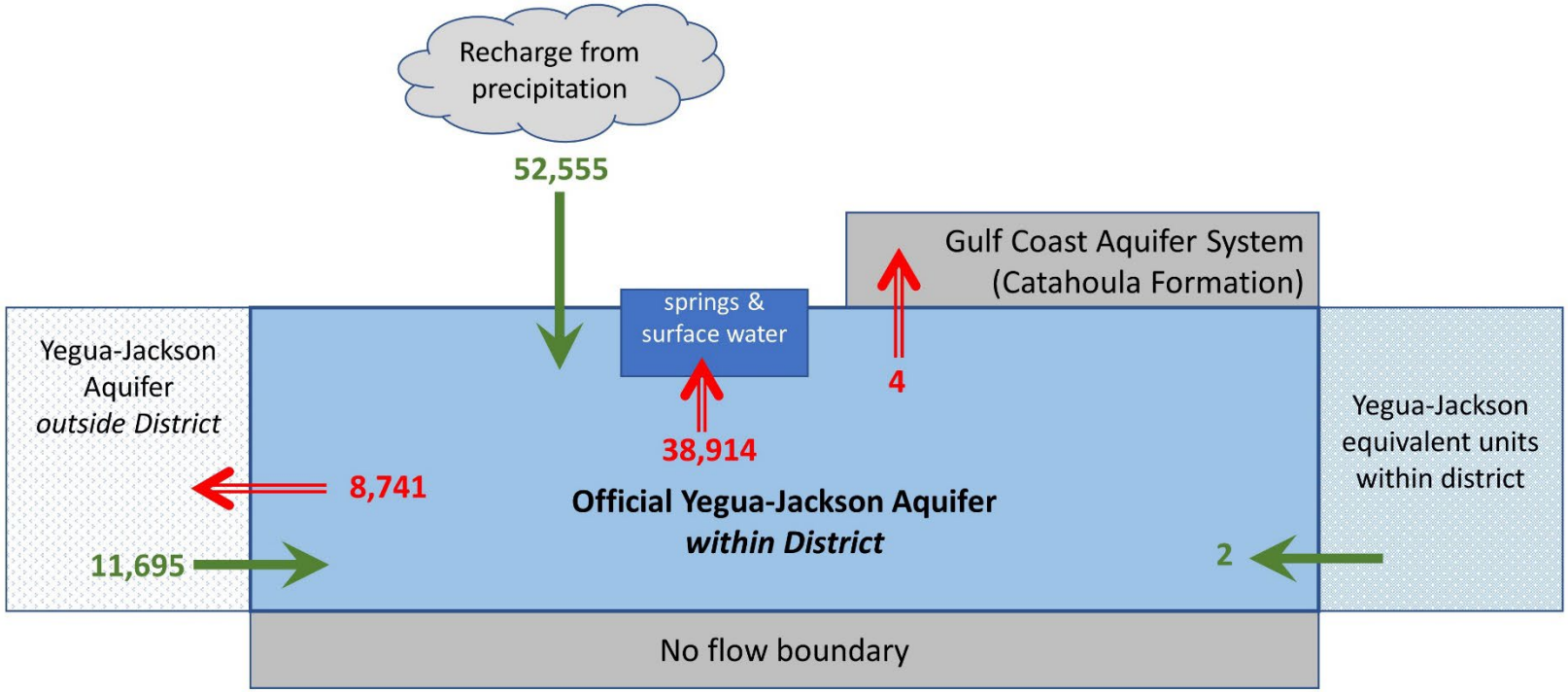
Management plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Yegua-Jackson Aquifer	52,555
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Yegua-Jackson Aquifer	38,914
Estimated annual volume of flow into the district within each aquifer in the district	Yegua-Jackson Aquifer	11,695
Estimated annual volume of flow out of the district within each aquifer in the district	Yegua-Jackson Aquifer	8,741
Estimated net annual volume of flow between each aquifer in the district	From Yegua-Jackson Aquifer to Gulf Coast Aquifer System*	4
	To Yegua-Jackson Aquifer from Yegua-Jackson equivalent units	2

* The Catahoula Formation in model Layer 1 represents the base of the Gulf Coast Aquifer System within the Pineywoods Groundwater Conservation District.



gcd boundary date: 06.26.2020, county boundaries date: 07.03.2019, ygjk grid date: 03.17.2023

FIGURE 7: AREA OF THE YEGUA-JACKSON AQUIFER GROUNDWATER AVAILABILITY MODEL FROM WHICH THE INFORMATION IN TABLE 4 WAS EXTRACTED (THE YEGUA-JACKSON AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).



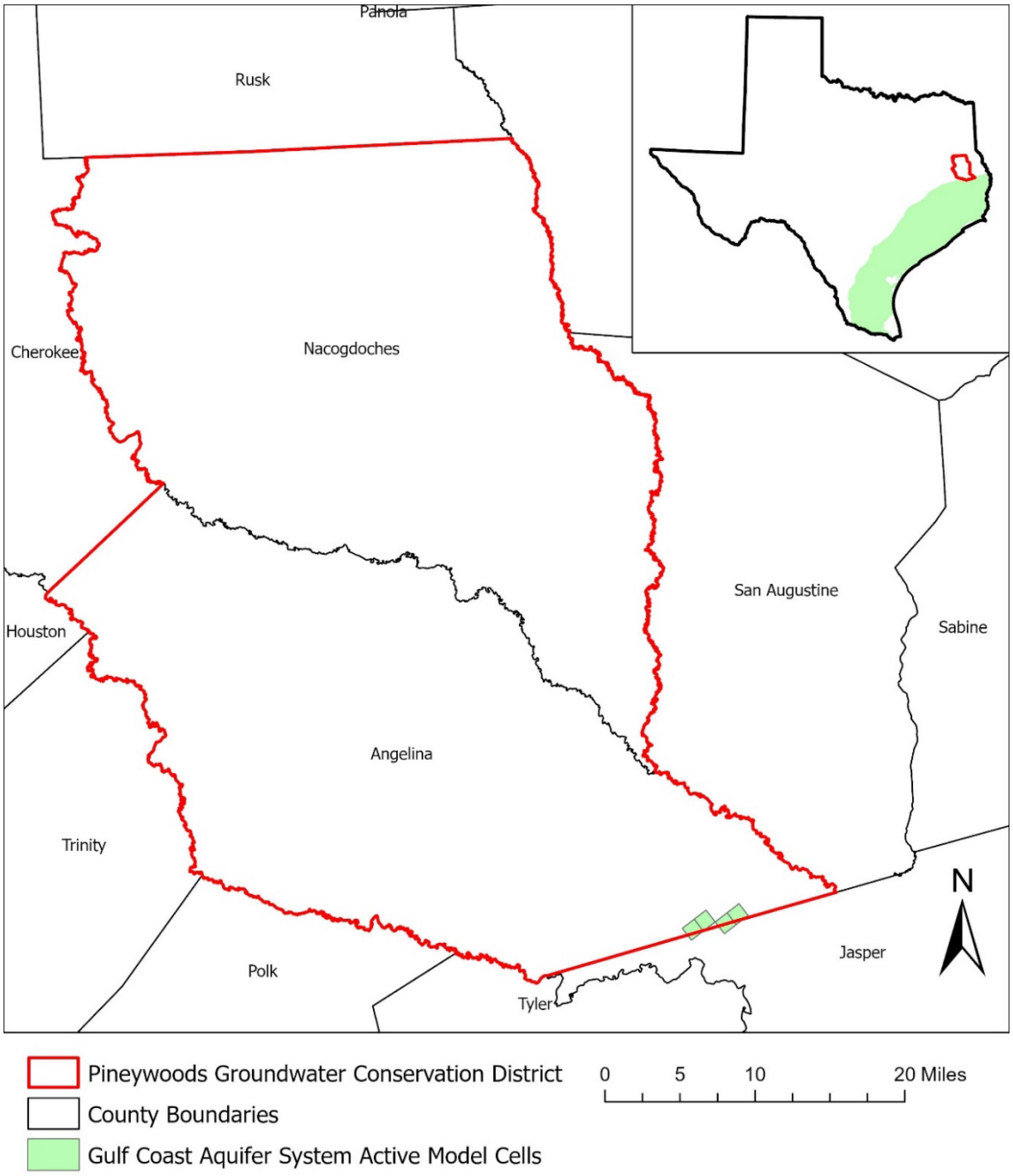
Caveat: This diagram only includes the water budget items provided in Table 4. A complete water budget would include additional inflows and outflows. For a full groundwater budget, please submit a request in writing to the Groundwater Modeling Department.

FIGURE 8: GENERALIZED DIAGRAM OF THE SUMMARIZED BUDGET INFORMATION FROM TABLE 4, REPRESENTING DIRECTIONS OF FLOW FOR THE YEGUA-JACKSON AQUIFER WITHIN PINEYWOODS GROUNDWATER CONSERVATION DISTRICT. FLOW VALUES EXPRESSED IN ACRE-FEET PER YEAR.

TABLE 5: SUMMARIZED INFORMATION FOR THE GULF COAST AQUIFER SYSTEM THAT IS NEEDED FOR THE PINEYWOODS GROUNDWATER CONSERVATION DISTRICT GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

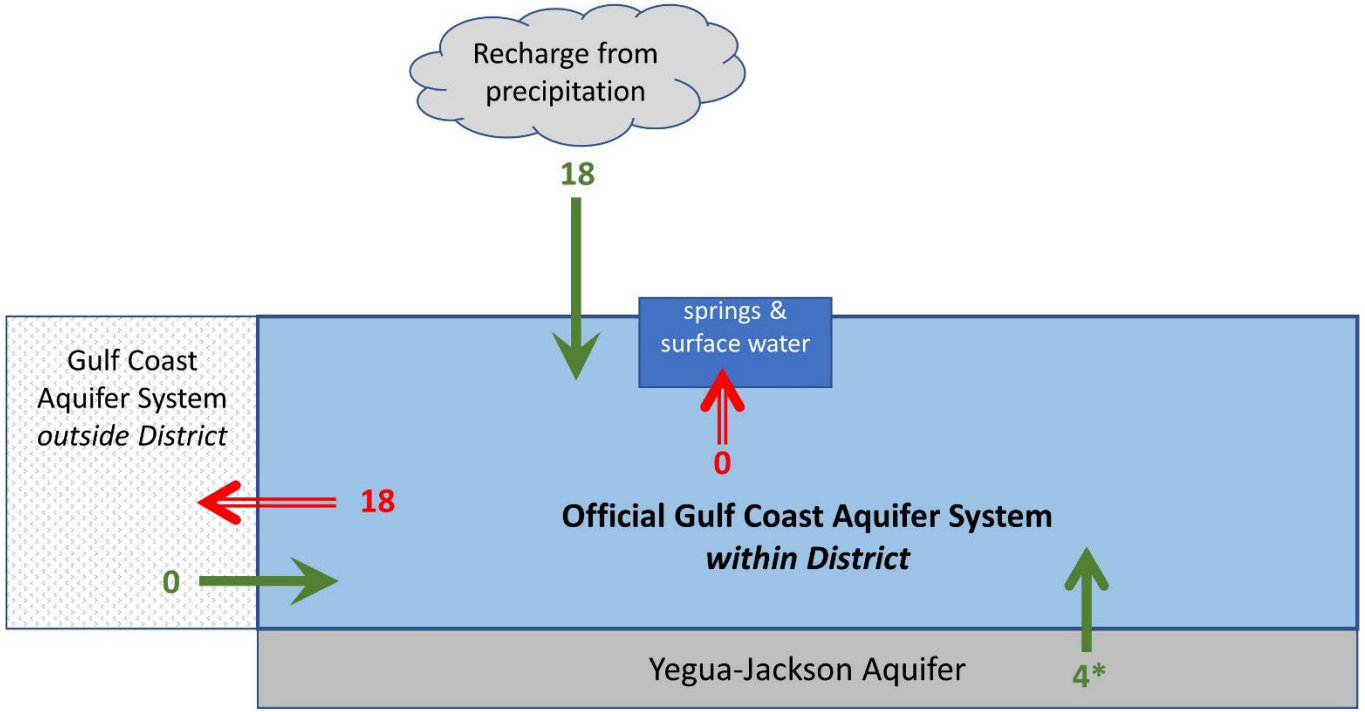
Management plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Gulf Coast Aquifer System	18
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Gulf Coast Aquifer System	0
Estimated annual volume of flow into the district within each aquifer in the district	Gulf Coast Aquifer System	0
Estimated annual volume of flow out of the district within each aquifer in the district	Gulf Coast Aquifer System	18
Estimated net annual volume of flow between each aquifer in the district	To Gulf Coast Aquifer System from Yegua-Jackson Aquifer	4*

* Budget value comes from the groundwater availability model for the Yegua-Jackson Aquifer (Deeds and others, 2010)



gcd boundary date: 06.26.2020, county boundaries date: 07.03.2019, glfc_n grid date: 01.06.2020

FIGURE 9: AREA OF THE NORTHERN PORTION OF THE GULF COAST AQUIFER SYSTEM GROUNDWATER AVAILABILITY MODEL FROM WHICH THE INFORMATION IN TABLE 5 WAS EXTRACTED (THE GULF COAST AQUIFER SYSTEM EXTENT WITHIN THE DISTRICT BOUNDARY).



* Flow value to the Yegua-Jackson Aquifer comes from the Groundwater Availability Model for the Yegua-Jackson Aquifer (Deeds and others, 2010)

Caveat: This diagram only includes the water budget items provided in Table 5. 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 10: GENERALIZED DIAGRAM OF THE SUMMARIZED BUDGET INFORMATION FROM TABLE 5, REPRESENTING DIRECTIONS OF FLOW FOR THE GULF COAST AQUIFER SYSTEM WITHIN PINEYWOODS 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., Yan, T., Singh, A., Jones, T. L., Kelley, V. A., Knox, P. R., and Young, S. C., 2010, Groundwater availability model for the Yegua-Jackson Aquifer: Final report prepared for the Texas Water Development Board by INTERA, Inc., 582 p., http://www.twdb.texas.gov/groundwater/models/gam/ygjk/YGJK_Model_Report.pdf.

Harbaugh, A. W., Banta, E. R., Hill, M. C., and McDonald, M. G., 2000, MODFLOW-2000, the U.S. Geological Survey modular ground-water model -- User guide to modularization concepts and the Ground-Water Flow Process: U.S. Geological Survey Open-File Report 00-92, 121 p.

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.

Kasmarek, M. C., 2013, Hydrogeology and simulation of groundwater flow and land-surface subsidence in the northern part of the Gulf Coast Aquifer System, Texas, 1891-2009: U. S. Geological Survey Scientific Investigations Report 2012-5154, 55 p., http://www.twdb.texas.gov/groundwater/models/gam/glfc_n/HAGM.SIR.Version1.1.November2013.pdf?d=4223

Langevin, C.D., Hughes, J.D., Banta, E.R., Provost, A.M., Niswonger, R.G., and Panday, Sorab, 2021, ZONEBUDGET for MODFLOW 6, 14 p., https://doi.org/10.5066/F76Q1VQV

Langevin, C.D., Hughes, J.D., Banta, E.R., Provost, A.M., Niswonger, R.G., and Panday, Sorab, 2017, MODFLOW 6 Modular Hydrologic Model: U.S. Geological Survey Software, https://doi.org/10.5066/F76Q1VQV

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., Rumbaugh, J., Hutchison, W., and Schorr, S., 2020, Numerical Model Report: Groundwater Availability Model for the Northern Portion of the Queen City, Sparta, and Carrizo-Wilcox Aquifers, 201 p., http://www.twdb.texas.gov/groundwater/models/gam/czwx_n/2020_12_08_Numerical_Model_Report_Accessible.pdf

Schorr, S., Zivic, M., Hutchison, W., Panday, S., and Rumbaugh, J., 2020, Conceptual Model Report: Groundwater Availability Model for Northern Portion of the Queen city, Sparta, and Carrizo-Wilcox Aquifers, 240 p., http://www.twdb.texas.gov/groundwater/models/gam/czwx_n/North_QCSCW_GAM_Conceptual_Model_Report_FullRpt_Appendices.pdf

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

Wade, S., 2017, GAM Run 17-021: Texas Water Development Board, GAM Run 17-021 Report, 20 p., https://www.twdb.texas.gov/groundwater/docs/GAMruns/GR17-021.pdf.