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Numerical Model Report: Groundwater Availability Model for the Northern Portion of the Queen City, Sparta, and Carrizo-Wilcox Aquifers

by:

Sorab Panday, GSI Environmental Inc.
Kate E. Richards, GSI Environmental Inc.
James Rumbaugh, Environmental Simulations, Inc.
William R. Hutchison, Independent Groundwater Consultant
Staffan Schorr, Montgomery & Associates

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Executive Summary

The Texas Water Development Board (TWDB) Groundwater Availability Model (GAM) program intent is that numerical models are to be used as living tools that would be updated as data and modeling technology improved. Groundwater is a vital resource in the norther portions of the Queen City Sand, Sparta Sand, and Carrizo-Wilcox Aquifer System (QCSCW) and groundwater pumping is expected to increase in response to increased municipal demands. The primary objective of the project is to update the existing GAM for the northern QCSCW to simulate impacts of groundwater pumping on groundwater resources in northeast Texas.

Challenges to the modeling effort included a large domain (greater than 38,000 square miles); complex geology (deep, multi-layered system with outcrops and pinch-outs); fine resolution to effectively handle groundwater-surface water interaction; inconsistent pumping data; water level elevations with quality control issues; and a 33-year model time-frame (1980 to 2013); all contributing to a considerable computational effort and uncertainty.

Modeling challenges were addressed by selecting a robust and flexible software to best alleviate the computational burdens and still provide results at the scale of the modeling objectives. The MODFLOW 6 groundwater flow model was used for the simulations with the Groundwater Vistas graphic user interface (GUI). The numerical model was built in accordance with the conceptual model and consisted of 9 model layers to represent the 9 hydrostratigraphic units of interest, consisting of the Quaternary Alluvium, Sparta Sand, Weches Formation, Queen City Sand, Reklaw Formation, Carrizo Sand, and Wilcox Aquifer (Upper, Middle, and Lower). These layers have structural features such as pinch-outs and vertical displacements which were successfully represented using MODFLOW 6.

A model grid measuring 193 miles by 201 miles with a base cell size of one square mile (5,280 feet on a side) was used to discretize the domain. Quadpatch refinement was then applied to reduce the cell size to a level of 4 resulting in square grids size of 660 feet. This refinement was done in the Quaternary Alluvium hydrostratigraphic unit and provided a higher resolution for modeling surface water to groundwater interaction. The grid coarsens for deeper layers, with a coarsening of one level for every active layer found beneath the alluvium cells.

Model boundary conditions were constructed in model layer 2 (Sparta Sand) to represent the Younger Units hydrostratigraphic unit which was not explicitly modeled and in deeper layers to represent a southern boundary for flow within the lower aquifers (Queen City Sand, Carrizo Sand, and Wilcox Aquifers). Aquifer and hydrogeologic properties such as hydraulic conductivity, aquifer storage, rivers, recharge, and evapotranspiration were simulated using various MODFLOW 6 packages. Specifically, hydraulic conductivity of each unit was parameterized using correlation with available sand fraction estimates.

Simulation of groundwater extraction was initially attempted as individual analytic element wells using conceptual model data. However, due to domain-wide data discrepancies, the conceptual extraction data was replaced with pumping from previous modeling (Intera, 2004) and extrapolated through 2013.

The model simulation consisted of a steady-state period representing 1980 conditions followed by transient conditions from 1981 through 2013 using annual stress periods for recharge and pumping. The steady-state 1980 period was simulated using average aquifer conditions.

The model calibration was guided by available data. Quantitative and qualitative metrics were implemented in evaluating representativeness of the model. Observed water levels in wells and groundwater to surface water flow estimates were used to constrain the model. Calibration statistics show the model was well calibrated for the spatial and temporal scales of investigation. Mass balance errors were negligible, and water fluxes at the various boundaries into and out of the domain were reasonable and consistent with the conceptual model. Qualitative comparison of estimated conceptual groundwater elevation contours to simulated contours confirm that the calibration matched observed conditions across the model domain.

Sensitivity analyses were conducted on the calibrated model to evaluate impact of parameter uncertainties and variations in boundary fluxes. Parameters evaluated quantitatively were hydraulic conductivity, recharge, evapotranspiration, and groundwater pumping. Medium to high changes in calibration statistics were noted for changes in the recharge and pumping values and noted for hydraulic conductivity within the Queen City Sand, the Middle Wilcox, and Lower Wilcox. Parameters evaluated qualitatively consisted of no pumping, constant recharge, and increased storage. Increased storage results showed that storage is not significant to the model calibration. Simulation of no-pumping and constant recharge both affected the model results, causing a decrease in water level elevation fluctuations across the model domain. A better estimation of pumping changes through time would have provided better transient calibration to water level changes. As data collection continues and the conceptual model is improved, the uncertainties associated with the model can be reduced.

A predictive model was developed for the period 2014 through 2080. Predictive simulations were conducted to evaluate the impact of baseline pumping and average recharge. Baseline pumping choices were limited to total pumping from the calibrated model for years 2010, 2011, 2012, and 2013. Average recharge was evaluated as 80%, 90%, 110% and 120% of the calibrated model steady-state period (1980). The predictive simulations found that the groundwater model does not show unreasonable continual increases in water level elevations as the previous Groundwater Availability Model had done.

Since pumping and recharge values were held constant across the model for all counties, local variabilities in pumping were not accounted for, nor variability in other model parameters which were held constant through 2080. Predictive modeling from 2014 to 2080 using these various conditions showed that drawdown at Groundwater Management Area 11 counties may be significantly affected by the chosen baseline pumping or average recharge. However, these predictive county-model layer drawdown charts may still be useful in guiding the Joint Planning Process and development of desired future conditions.

1.0 Introduction and Purpose of the Model

The Texas Water Development Board (TWDB) Groundwater Availability Model (GAM) program intent is that numerical models are to be used as living tools that would be updated as data and modeling technology improved. Given this directive, the primary objective of the project is to update the existing GAM for the norther portions of the Queen City Sand, Sparta Sand, and Carrizo-Wilcox Aquifer System (QCSCW) to simulate impacts of groundwater pumping on groundwater resources in northeast Texas. This model, referred to as the Northern QCSCW GAM, will update the existing GAM for the northern Carrizo-Wilcox Aquifer (Fryar and others, 2003) and the existing GAMs for the Queen City and Sparta Sand Aquifers (Kelley and others, 2004). The Northern QCSCW model is based on the conceptual hydrogeologic model, which is summarized in the Draft Conceptual Model Report (Montgomery and Associates, 2018). The study area, as shown on Figure 1.2-1.

The Northern QCSCW GAM will be used to assess future regional impacts from current pumping and projected future pumping. Model results will be used to evaluate long-term groundwater pumping impacts on surface water and groundwater. In addition, the model may be used to assist groundwater conservation districts in groundwater Management Area 11 with groundwater planning and management.

2.0 Model Overview and Packages

A conceptual model of the hydrogeologic system of the area of interest in Northern QCSCW aquifers was developed by Montgomery and Associates (2018). The conceptual model along with the existing GAM for the northern Carrizo-Wilcox Aquifer (Fryar and others, 2003) and the existing GAMs for the Queen City and Sparta Sand Aquifers (Kelley and others, 2004) were the basis of the numerical model described in this report. The groundwater system comprises Quaternary Alluvium and eight southward-dipping aquifers including (from top to bottom), Sparta Sand, Weches Formation, Queen City Sand, Reklaw Formation, Carrizo Sand, Upper Wilcox, Middle Wilcox, and Lower Wilcox. The numerical model honors this conceptual model layering including pinch-outs and outcrop of the geologic units. Figure 2.1-1 shows the aquifer outcrops simulated in the groundwater model. The Queen City and Sparta Sand Aquifers are classified as minor aquifers in Texas and extend from the Frio River region in south Texas to east Texas with the Sparta Sand Aquifer extending into Louisiana and Arkansas. The Carrizo-Wilcox Aquifer is classified as a major aquifer in Texas and extends from the Rio Grande region in south Texas to northeast Texas and into Louisiana and Arkansas. The Sparta Sands are overlain by Younger Units which are not actively simulated in the numerical model.

The numerical groundwater-flow model was constructed to simulate the conceptualized groundwater-flow system for steady-state 1980 conditions and transient conditions using annual stress periods from 1981 through 2013. This time period was selected principally based on pumping and groundwater level data availability. The three-dimensional modular groundwater-flow model code MODFLOW 6 (Langevin and others, 2017) was used for the simulations with the Groundwater Vistas, Version 7 (Rumbaugh and Rumbaugh, 2017), Graphic User Interface (GUI).

Construction of the numerical model required several tasks. The first task was to assess the conceptual model including the hydrogeologic framework, hydrostratigraphy, and assignment of boundaries such as rivers, recharge, evapotranspiration, and groundwater pumping. Flows in and out of the model domain were discussed in the conceptual model sections related to pumping, exchange with the Younger Units, recharge, rivers, and evapotranspiration. These flows have been translated into the model boundary conditions using the boundary condition packages of MODFLOW 6. Boundary condition packages essentially allow water to flow into or out of the model domain (i.e., interaction of the model with the "outside world"). The processes that govern this flow determine which package may be used to numerically implement the conceptualized interactions. This understanding provided the guidelines for discretization of the domain and for selection of relevant packages within MODFLOW 6 to appropriately simulate the required process at the necessary spatial and temporal scales.

Spatial resolution requirements were established and the hydrostratigraphic conceptual model (Montgomery and Associates, 2018) that was developed in Leapfrog® Geo (developed by Seequent) was imported into Groundwater Vistas. Other base-maps were also imported into Groundwater Vistas to identify county boundaries, rivers, and other features that generally orient the model. A grid was subsequently developed for the groundwater model domain; preliminary model parameter estimates were generated; and boundary conditions (rivers, wells, recharge, evapotranspiration, and general head boundaries) were developed for steady-state 1980 conditions as well as for transient conditions from 1981 through 2013 using annual stress periods. Calibration targets were then developed for water levels for the steady-state and transient stress periods and imported into Groundwater Vistas. The model was run in steady-state and transient modes to debug the datasets, establish convergence, and tune solver parameters for optimal simulation performance before moving on to the model calibration phase.

2.1 MODFLOW6 Overview and Packages

MODFLOW 6 is the newest version of the MODFLOW code, released in 2017 by the United States Geological Survey. The code is appropriate for this work as it can meet all the simulation requirements and challenges for this project. Elements of the code and packages pertinent to the Northern QCSCW model flow simulations are discussed here.

The MODFLOW 6 groundwater model (Langevin and others, 2017) contains most of the functionality of previous MODFLOW codes, including MODFLOW-2005 (Harbaugh, 2005), MODFLOW-NWT (Niswonger and others, 2011), MODFLOW-USG (Panday and others, 2013), and MODFLOW-LGR (Mehl and Hill, 2006). MODFLOW 6 solves for three-dimensional flow of water in the subsurface using the control-volume finite-difference (CVFD) approach. The CVFD numerical method "discretizes" the modeled domain into model cells that may have different sizes and shapes. Each model cell represents a part of the domain that is encompassed by that model cell and model inputs and outputs are generated for this discretized system. The CVFD methodology allows for flexible gridding of the subsurface domain including: ability to refine the computational grid locally using nested grids to provide spatial resolution where required and accurately represent pinch-outs, faults, displacements and outcrops of geological layers.

As with the other MODFLOW codes, MODFLOW 6 consists of groups of "modules" or "packages" that perform various functions related to groundwater flow simulations. These packages compartmentalize the model into its various functional elements and includes packages to define the model domain and its discretization, parameterize the aquifer and flow processes, and implement various pumping and boundary conditions to the modeled system. Table 2.1-1 shows the various packages of MODFLOW 6 that were used for the Northern QCSCW model. Model input files were then developed for each of the packages to represent the conceptual model of the system.

MODFLOW 6 is structured slightly differently from MODFLOW, in that the solution is separated from the model. With the MODFLOW code, the entire domain is represented by one model, but in MODFLOW 6 it is possible to have multiple models (of different domains or different types) use the same solution. Therefore, in addition to the model related files shown on Table 2.1-1, MODFLOW 6 also includes files for the solution that contains the models (only one model in this case).

MODFLOW 6 simulation output is contained in several files. The main output listing is written in a run list file (LST) which also includes the mass balance information. Water level output is provided in the heads file with the extension HDS. Modeled flows, storage flux, and boundary flux are output to the cell-by-cell flow file with extension CBB. Table 2.1-2 shows the relevant output files generated by MODFLOW 6. A description of how the Northern QCSCW groundwater flow model was developed using these packages is provided in the subsections that follow.

2.2 NAME File

A MODFLOW 6 simulation includes two NAME files, one for the solution and another for the groundwater flow model.

The solution NAME file includes solution-related information such as solution options, time-stepping file name, NAME files for the various models (only one in this case), file names for the exchanges between models (none in this case), and file name for the solver. The CONTINUE option was used in the solution which would allow for continuation of failed iterations; however, final model results were all converged to the prescribed tolerance limit.

The model NAME file of the MODFLOW 6 model contains the model options and the abbreviations of all packages used in developing the model along with a file name for the input (or output) files that are used in the model. The Newton Raphson option was selected for linearizing the model flow equations.

2.3 Initial Conditions (IC) Package

The IC Package of MODFLOW 6 specifies initial water levels at all groundwater model cells in the domain. Since the first stress period of the model is a steady-state condition, the starting head values do not affect the result but are required to begin the iterative process. However, because the numerical burden is reduced by starting from values close to the result, the starting heads were taken from the closest simulation results of a previous simulation of the calibration process. The binary output result file of a simulation was thus renamed as "start.hds" such that the first stress period values (the steady-state result of the previous calibration simulation) were used as the starting condition for the current simulation.

2.4 Discretization (DIS) Package

A MODFLOW 6 simulation includes two discretization packages, one for time discretization of the solution and the other for defining the discretization of the unstructured grid for the model.

The DIS Package of MODFLOW 6 was used and defines the model discretization information for the 3-dimensional groundwater cells.

2.4.1 Stress Period Setup (TDIS)

The QCSCW model was discretized into 34 stress periods. The first stress-period was simulated as steady-state representing 1980 conditions. The remaining stress periods are yearly and represented transient conditions from 1981 through 2013. This temporal discretization using annual stress periods was considered sufficient for the regional planning objectives of the modeling effort. Table 2.4-1 shows the stress period details.

2.4.2 Model Domain Discretization (DIS)

The QCSCW model domain and stratigraphy were established during conceptual model development. The model domain northern and north-western boundary represents the northern portion of the Carrizo-Wilcox Aquifer; the model domain southern boundary extends beyond the Carrizo-Wilcox Aquifer as shown on Figure 2.1-1 (Figure 4.1.3 of the Conceptual Model Report). The model domain includes the north-eastern portions of the Sparta Sand and Queen City Sand Aquifers (Figure 2.1-1) (Figure 4.1.3 of the Conceptual Model Report). The Major and Minor aquifers are described in detail in in the Conceptual Model Report (Montgomery and Associates, 2018) (Figures 2.0.2 and 2.0.3 of the Conceptual Model Report). Nine geologic units in the model domain were discretized into 9 numerical layers (Figure 2.4-1). The hydrostratigraphic unit Younger Units was excluded from the model domain and is discussed further in the general head boundary section (Section 2.8). Figures 2.4-2 through 2.4-20 (Figures 4.1.5 through 4.1.22 of the Conceptual Model Report) show the stratigraphic elevations and thicknesses of the geologic units simulated by the model.

The structural features described in the Conceptual Model Report, which include the East Texas Embayment, Houston Embayment, Sabine Uplift, and Sabine Arch, are shown on Figure 2.4-21 (Figure 2.2.2 of the Conceptual Model Report). These structural features dictate the outcrop pattern of the geologic units. The Carrizo Sand and Wilcox hydrostratigraphic units outcrop along a belt along the northern extent of the model domain and also in the eastern portion of the model domain in the Sabine Uplift. The Sparta Sand and Queen City Sand hydrostratigraphic units outcrop in the central portion of the model domain along the East Texas Embayment. In the southern portion of the model domain, the surface geology and outcrop pattern are oriented southwest-northeast and the hydrostratigraphic units dip to the southeast.

The domain was discretized using a parent grid-block size of one square mile (5,280 feet length of each side) on a base grid containing 193 rows, 201 columns, and 9 layers. An oct-patch refinement procedure was implemented along the rivers to provide a finer spatial resolution along these features. The oct-patch feature refines the grid in the horizontal and vertical direction. Figures 2.4-22 through 2.4-30 show the discretization of the groundwater domain. Model Layer 1, representing the Quaternary Alluvium hydrostratigraphic unit, has the greatest refinement level of 4 giving square grids of size 660 feet for each side along the river. The grid coarsens for deeper layers, with a coarsening of one level for every active layer found beneath the alluvium cells. The model layers were eliminated where a geologic layer pinches out or where the underlying layer outcrops to the surface, as shown on Figures 2.4-22 through 2.4-30. The model grid consists of 637,536 cells.

MODFLOW 6 accommodates pinch-outs and Groundwater Vistas eliminates pinched-out model cells automatically, resulting in much more efficient and robust simulations. MODFLOW 6 also accommodates displaced model layers along faults and Groundwater Vistas creates the cross-layer connections between the hydrogeologic units. Figure 2.4-31 shows cross-sections of the numerical model with a north-south cross-section A-A' and northwest to southeast cross-section B-B'. The cross-sections show the model layering honors the conceptual model including the salt dome feature shown in cross-section A-A', and pinch outs as shown in both cross sections (Figure 2.4-31).

2.5 Node Property Flow (NPF) Package

The NPF Package and STO Package replace pervious MODFLOW packages that characterize the aquifer properties including the Layer Property Flow (LPF), Block-Centered Flow (BCF), and Upstream Weighting (UPW) packages. The NPF Package was used to specify aquifer flow parameters (hydraulic properties) and define individual cells as confined or convertible for the groundwater domain. Aquifer flow parameters required by the NPF Package include horizontal and vertical hydraulic conductivities. The parameter values were established during calibration using the automated parameter estimation software, PEST; this process is discussed further in the Calibration Section (Section 3.0). The approach towards parameterization is discussed here.

Hydraulic conductivity values for the aquifers in the domain have previously been estimated at various locations as noted in the Conceptual Model Report; however, it is difficult to partition these values into the various geologic units that comprise each aquifer. Estimated distributions of sand fraction within each of the geologic units were therefore used to parameterize the hydraulic conductivity for each model layer throughout the domain. Figures 2.5-1 through 2.5-5 show the sand fraction distributions for the Sparta Sand (model layer 2), Queen City Sand (model layer 4), Upper Wilcox (model layer 7), Middle Wilcox (model layer 8), and Lower Wilcox (model layer 9) units, respectively.

Sand fraction information was not available for the transmissive units, the Quaternary Alluvium (model layer 1) and the Carrizo Sand (model layer 6); or for the aquitards, the Welches Formation (model layer 3) and the Reklaw Formation (model layer 5). A uniform value was used to parameterize these units. The sand fraction value of 0.70 was used for the transmissive units; the sand fraction value of 0.10 was used for the aquitards. Sand fractions are summarized in Table 2.5-1.

Hydraulic conductivity parameterization was conducted as follows. A higher parameterization hydraulic conductivity value was associated with a sand fraction of unity, and a lower value was associated with a sand fraction of zero for each geologic layer (the assumption being that each geologic unit has its own type of soil or rock and that, within each unit, less sand implies higher clay or rock content with an associated lower effective hydraulic conductivity). The horizontal hydraulic conductivity for any computational cell in the domain is computed as an average, weighted by the sand fraction value of the cell; this provides a linear relationship between the highest and lowest value within each geologic unit. The relationship between sand fraction, parameterized hydraulic conductivity values, and model hydraulic conductivity can be written as:

$$K_h = f_s K_s + (1 - f_s) K_c$$

Where K_h is the horizontal hydraulic conductivity of a cell; f_s is the sand fraction of a cell; K_s is the parameterization hydraulic conductivity value for sand for a geologic unit, and K_c is the parameterization hydraulic conductivity value for clay or rock for the geologic unit. For vertical hydraulic conductivity, a weighted harmonic mean value was applied. Thus,

$$K_v = \frac{1}{f_s / K_s + (1 - f_s) / K_c}$$

Where K_v is the vertical hydraulic conductivity of a cell.

To understand flow behavior for this parameterization, it is generally noted that the sand hydraulic conductivity would govern horizontal flow in the model since the arithmetic average tends towards the mid-point value for equal fractions of sand and clay. The clay hydraulic conductivity would generally govern vertical flow in the model since the harmonic average tends to be biased towards the lower (clay) conductivity value for equal fractions of sand and clay.

The sand fraction information is stored in the "Leakance" property within Groundwater Vistas. When the MODFLOW comment-line includes the phrase "Sand Fractions stored as Leakance", Groundwater Vistas performs the computations for horizontal hydraulic conductivity, K_h, and vertical hydraulic conductivity, K_v, for each cell using the formulas above to create the NPF datasets. Note that this computation is also done during PEST simulations for calibration.

The specific storage and specific yield parameters were estimated as uniform within each geologic unit. There is less data available for these parameters and therefore adding complexity was deemed unwarranted. Instead, the influence of these parameters on the system and model solution was tested with a sensitivity analysis, discussed in Section 4.0.

Faults or flow barriers were not implemented in the calibrated model. However, the Mount Enterprise Fault Zone shown on Figure 2.4-21 (Figure 2.2.2 of the Conceptual Model Report) contains displacements along the faults causing inter-unit connections. MODFLOW6 handles such connections allowing lateral flow from one geologic layer to multiple layers across a fault with displacement. Groundwater Vistas generates these cross-layer connections at the Enterprise Fault location as an "OPTION" under the "vertical geometry" tab depending on layer elevations across the fault.

2.6 Storage (STO) Package

The STO Package is only used for transient conditions to provide compressible storage contributions. The STO package was used in the model to specify the aquifer storage parameters which include specific storage and specific yield. Input for the STO package includes the specific storage and specific yield of each model cell. If the STO package is not included in the model NAME file, then a steady-state simulation is conducted. The mass balance output for the STO package provides information on the confined and unconfined components of the total storage. Thus,

$Q_{STO} = Q_{SS} + Q_{Sy}$

Where Q_{SS} is the volumetric flow rate from specific storage (L^3/T) and Q_{Sy} is the volumetric flow rate from specific yield (L^3/T).

2.7 WEL Package

The WEL package was used in the model to simulate groundwater pumping wells. During initial model development, raw pumping data from the Conceptual Model Report was input into Groundwater Vistas as analytical element wells. Each well was screened within a single model layer as developed from available data in the Conceptual Model. After analyzing the raw pumping data, additional data clean up and the following changes to the raw pumping data were applied.

1. Wells placed in one of the two aquitards (model layers 3 and 5) were moved into the layer above;
2. Pumping records for the years 1981, 1982, and 1983 were not available, thus values for these years were established by linearly interpolating between 1980 and 1984;
3. Pumping outliers were removed for the dataset; and
4. An apparent shift in the pumping rate that occurred after 1999 was smoothed out for data in counties that displayed this pattern.

Simulations using the corrected data further identified further issues with the pumping or water level data. Specifically, water levels were rising with increasing pumping and vice versa at several instances. Mostly however, the pumping data did not show a general trend in pumping changes between 1980 and 2013, while water levels showed a general decline at several wells. The water level datasets were considered to be more reliable because pumping numbers in the TWDB database were largely estimates supplied by the districts. In addition, it was identified that several counties changed the way they estimated pumping volumes after 1999; these individual practices introduced large inconsistencies and uncertainties within the pumping dataset. Therefore, it was further decided to calibrate the pumping variations via PEST on a county-by-county basis. However, upon implementation, it was noticed that the sensitivity of water level changes to variations in pumping was very small and therefore the PEST optimization process failed. Finally, the pumping data from the previous GAM (Intera, 2004) model was further examined against water levels and it was noted that cumulative increases in pumping within that dataset caused appropriate declines in observed water levels. Therefore, this data was processed further for use in the current numerical model.

Table 2.7-1 compares the total pumping per layer between the raw conceptual model data, the corrected conceptual model data, and the current model (based on previous GAM model pumping). The pumping data presented in the previous GAM (Intera, 2004) consists of pumping wells in 54,729 model cells and in single model layers. The previous model data represents pumping from 1980 through 2005. In order to establish pumping rates for the time period from 2006 through 2013, the conceptual model pumping data was compared to the 2005 value with the assumption that domain wide changes in pumping from the 2005 value were appropriate in the conceptual model. A list of multiplication factors was thus generated, which was applied to the 2005 pumping value of the previous GAM. The list of pumping factors is summarized on Table 2.7-2. Figure 2.7-1 compares the original county well data and the pumping data used in the current model.

Since the previous model does not have a layer representing the alluvium, this model update contains no pumping in model layer 1 (Table 2.7-1). As there is little pumping in the alluvium layer in the conceptual model, the loss of pumping in layer 1 is minor. The majority of the pumping in the previous model is in the Carrizo Sand, and the Upper, Middle, and Lower Wilcox, which compares well to the original conceptual model pumping (Table 2.7-1) at least in terms of bulk cumulative values between 1980 and 2013.

Each well is screened within a single model layer. Figures 2.7-2 through 2.7-7 show the total pumping volume of each well during the model time period for each layer. There are no wells screened within the Weches Formation (model layer 3) or the Reklaw Formation (model layer 5), which are aquitards. Groundwater is pumped from the Queen City Sand, Sparta Sand, and Carrizo-Wilcox aquifers for municipal, irrigation, industrial, domestic, and stock uses. Figures 2.7-8a through 2.7-8e show the pumping sums for each county per stress period (per year) and hydrostratigraphic unit. Pumping sums for counties that straddle the model boundary do not reflect total pumping from that county but only the pumping portion that overlaps the model. In general, most pumping is from the Upper, Middle, and Lower Wilcox stratigraphic units.

The WEL package of MODFLOW 6 was used to apply a sink within the cell for each pumping well. The sink was applied on an annual stress period for 34 stress periods representing 1980-2013 conditions. The WEL Package includes an "AUTOFLOWREDUCE" option that ensures that pumping demand does not draw water levels below the bottom elevation of the cell. This option is turned on for the simulations and any associated simulated reduction in pumping is reported in a "well flow-reduction" file. All wells were pumping their desired volumes during model calibration.

2.8 General Head Boundary (GHB) Package

Flow into or out of the model domain from the southern model boundary was simulated using the general head boundary (GHB) package. The GHB package was also used to simulate the interaction of the model with the Younger Units which were not explicitly simulated. Figure 2.8-1 shows the modeled GHB locations. The GHB condition in model layer 2 conceptualizes exchange of water with the Younger Units. The GHB condition in model layers 4 and 6 through 9 along the southern model boundary allow flow of water into the model domain in the respective aquifers. This accounts for the southern boundary not being a natural aquifer boundary. The heads along the GHB boundaries were set according to interpolated head contours in the region and are not changed through time. Table 2.8-1 shows the GHB head and conductance values for each layer.

2.9 RIV Package

The RIV Package of MODFLOW 6 was used to model the rivers in the model area. The RIV package simulates flow in or out of the aquifer to surface-water features such as canals, rivers and streams. Thus, flow within the surface-water features is not simulated, but the groundwater interaction is taken into account. Figures 2.9-1 through 2.9-5 show the annual stream flows at stream gages located on the major rivers in the model domain, which include the Trinity River, Neches River, Sabine River, Big Cypress Creek, and Sulphur River. Rivers generally flow from north to south. The flow difference between stream gages was calculated at select river segments with unmanaged flows. A positive difference in season flow means the river is gaining along the reach, and a negative difference in seasonal flow means the river is losing along the reach. The rivers simulated in the model are primarily gaining streams.

Figure 2.9-6 shows the simulated river boundary condition within the model domain. River width, bed thickness and bed conductance were taken as 1 foot, 1 foot, and 25 feet per day (feet/day), respectively, and the river segment length intersecting each groundwater cell was calculated by Groundwater Vistas for computation of the conductance coefficient. The river stage was estimated from the topography and the riverbed elevation was taken as a foot below the stage.

It is noted that preliminary simulations attempted using the STR package of MODFLOW6. However, the simulations encountered long runtimes and occasional convergence difficulties. Upon evaluation of the data with controlled releases from the reservoirs, it was determined that estimating baseflow numbers for the gaged reaches would be difficult and therefore the RIV package would satisfy the objectives considering the available data.

2.10 RCH Package

Estimation of recharge as a result of percolation of precipitation was discussed during conceptual model development. Annual average recharge rates were estimated to be up to 2.5 inches per year over the model area, as described in the Conceptual Model Report. Figure 2.10-1 (Figure 2.1.8 of the Conceptual Model Report) shows the model 1980 recharge rates which represent annual average estimates of recharge within the domain and across the various aquifers that crop out at the surface. Recharge spatial distribution was noted to be generally similar between years, with locations of higher recharge having higher recharge throughout the simulation period. Therefore, the 1980 recharge distribution shown on Figure 2.10-1 was used in the model and scaled using a factor to represent greater or lower precipitation of subsequent years. The scaling factors are summarized on Table 2.10-1. Groundwater Vistas allows import of these as "multiplication factors" applied to the 1980 recharge conditions and this produces the recharge values for years 1981 through 2013 in the model. The recharge values were implemented in MODFLOW 6 via the RCH package, with recharge applied to the topmost active cell as computed by Groundwater Vistas.

2.11 EVT Package

The EVT package of MODFLOW 6 was used to apply evapotranspiration to the model. The EVT Package applies a Potential Evapotranspiration (PET) flux (in units of length per time) to each associated model cell in the domain. The actual evapotranspiration flux depends on a user-defined PET that is applied to each cell when the water table is at or above the "evapotranspiration surface" of that cell (taken equal to the land surface elevation). The PET declines linearly to zero as the water table depth drops down to an "extinction depth".

Estimation of PET and the extinction depth are discussed in the conceptual model. The distribution of maximum evapotranspiration rates in the model is shown on Figure 2.11-1. Evapotranspiration was applied to the topmost active cell as computed by Groundwater Vistas.

2.12 OC Package

The Output Control Package of MODFLOW 6 controls how water levels, fluxes and water budget information is saved during a simulation. The Output Control file was set up to save these results at the end of each stress period. Thus, output was provided for the steady-state 1980 stress-period and at the end of each year of the 1980-2013 transient simulation period.

2.13 IMS Package

The Iterative Matrix Solver (IMS) package of MODFLOW 6 sets up the solution methodologies and linear solver selection for a simulation.

Nonlinear iterations using the Newton-Raphson linearization scheme were controlled using residual reduction and under-relaxation. The under-relaxation parameters that are a default for MODFLOW 6 (the default parameters in Groundwater Vistas interface reflect these parameter values) are not very sensitive and were not changed for the simulations. The residual reduction parameters are generally tightened when nonlinear convergence difficulties are encountered but are relaxed when convergence eases. Specifically, the residual change tolerance term (BACKTRACKING_TOLERANCE) was varied between 10,000 and 1.1 at various stages of simulation. The final optimal value selected was 1.1.

The BiCGSTAB scheme was selected to solve the asymmetric system of linear equations. Linear solver parameters that were significant to the simulation included the matrix ordering scheme (REORDERING_METHOD), the level of fill (PRECONDITIONER_LEVELS), and number of orthogonal directions (NUMBER_ORTHOGONALIZATIONS). These parameters were varied depending on convergence behavior during calibration. Final calibrated simulation values were: PRECONDITIONER_LEVELS = 3; the RCM Ordering scheme; and NUMBER_ORTHOGONALIZATIONS = 14. The "drop tolerance" scheme was used with a drop-tolerance factor (PRECONDITIONER_DROP_TOLERANCE) equal to 1.0×10^{-3}.

Solver parameter tuning was done throughout model development and calibration. This was done to make sure that the simulations progressed as quickly as possible at every stage of the project.

3.0 Model Calibration and Results

The model was constructed as discussed above in Section 2. As discussed earlier, the horizontal and vertical hydraulic conductivities were parameterized in the model using sand fraction data for each of the simulated geologic layers and estimates of the hydraulic conductivity value for sand and for the remaining material (assumed clay) for each of the layers. Thus, initial estimates were provided for the hydraulic conductivity value for sand and clay for each geologic unit, and preliminary simulations were conducted to ensure that the model was appropriately assembled and that the simulations perform successfully. Initial estimates were also provided for the recharge rates, specific storage and specific yield values, and for the general head boundary condition heads and conductivities. Solver parameters were initially adjusted for robustness and efficiency and were tuned throughout the calibration process.

During model calibration, the hydraulic conductivity values for sand and clay were adjusted within reasonable parameter value bounds to provide appropriate flow behavior in the model domain. The recharge rate multipliers were adjusted within reasonable parameter values to provide appropriate fluctuations in water levels. The specific storage and specific yield values of the units were adjusted within reasonable parameter value bounds to provide appropriate magnitude of fluctuations of water levels. The conductance values for the general head boundary conditions in layers 2, 4, and 6 through 9 were adjusted within reasonable parameter values to provide appropriate fluxes into and out of the model domain.

The model was calibrated using an interactive expert approach (manual calibration evaluations) in conjunction with automatic model calibration using the parameter estimation code PEST (Doherty, 2010). Preliminary model results were first evaluated to note model behavior and sensitivity. Consistency with the conceptual model was also evaluated and various adjustments were made to model aquifer parameters or conceptual elements until the model was considered calibrated.

3.1 Calibration Procedures

Groundwater level elevations were used to constrain the model to observed conditions during the simulation period. Groundwater and surface-water interaction flux estimates were used to further evaluate the model calibration. These fluxes were not used during calibration because the baseflow is largely unknown and differences between gages may contain other losses. Baseflow estimates are better obtained by evaluating the recession hydrographs after storms.

A two-period steady-state model, representing 1980 and 2013 conditions was first developed and calibrated using the automatic calibration method PEST. The two-period steady-state model provided short run times, allowing PEST to be used effectively during calibration of hydraulic conductivity parameters for widely differing stress conditions. Even though it is understood that the system is not at steady state, the water levels change very slowly during these times thus providing a good estimate for calibration. The transient model was then calibrated for the 1980 through 2013 period with appropriate fluctuations being determined by changes in recharge and pumping, and amplitude of water level changes controlled by the storage parameters of the aquifer materials. Preliminary transient calibration simulations indicated that there were issues with the pumping data as discussed earlier in Section 2.7. Preliminary sensitivity analyses further indicated that wells largely in the unconfined outcrop regions of an aquifer unit responded to changes in recharge, while wells in confined regions of an aquifer responded to changes in pumping. This section discusses the methods used to calibrate the model, including adjusting the recharge, aquifer parameters, and GHBs.

3.1.1 Calibration of Recharge

The recharge rate scaling factors were adjusted during calibration to provide a best fit between observed and simulated groundwater levels. As discussed in the Conceptual Model Report, annual average recharge rates were estimated to be up to 2.5 inches per year over the model area with recharge being proportional to the hydraulic conductivity of the outcrop material. The 1980 recharge distribution was used in the first stress period of the transient simulation, with scaling of that recharge for each subsequent year. The multiplication factors were manually adjusted during calibration to better simulate water level elevation fluctuations at observation wells that responded to recharge mainly in outcrop areas of aquifer units where there is a strong correlation between water level elevation fluctuations and recharge. The calibrated recharge multiplication factors are summarized on Table 3.1-1. These values average to unity over the simulation period as they do for the original estimates of Table 2.10-1.

3.1.2 Calibration of Aquifer Parameters

The hydraulic conductivity parameters for sand and clay were adjusted during calibration, to provide a best fit between observed and simulated groundwater levels. As described in Section 2.5, estimated distributions of sand fraction within each of the geologic units were used to parameterize the hydraulic conductivity for each model layer throughout the domain. The hydraulic conductivity of the sand is stored as the horizontal hydraulic conductivity for each layer and the hydraulic conductivity of clay is stored as the vertical hydraulic conductivity for each layer in Groundwater Vistas with formulas that compute the combined horizontal and vertical hydraulic conductivities depending on the composition of sand and clay at a location.

The hydraulic conductivity parameters for sand and clay were adjusted manually and by automatic calibration using PEST. The two-period steady-state model was used for the

PEST simulations and the transient model was used during focused manual calibration evaluations. The storage terms were noted to be insensitive overall, and mainly affected the nature and magnitude of fluctuations in simulated water levels. The storage coefficient and specific yield were adjusted manually resulting in 3.898 x 10^{-8} and 0.0007, respectively. The low specific yield values indicate that there may be partial confinement of the aquifer systems even in the outcrop regions.

Table 3.1-2 shows the parameterized hydraulic conductivity values for sand and clay within the various geologic units in the calibrated model. These parameters along with sand fraction distributions provide the calibrated horizontal and vertical hydraulic conductivity distributions for the various geologic units as shown in Figures 3.1-1 through 3.1-10 and summarized on Table 3.1-2. For the Quaternary Alluvium (model layer 1) and the Carrizo Sand (model layer 6), the sand fraction was assumed to be uniform at 0.7 providing the calibrated horizontal hydraulic conductivity values of 6.56 feet/day and 0.12 feet/day, respectively, and calibrated vertical hydraulic conductivity values of 5.87 feet/day and 0.04 feet/day, respectively. For the Weches Formation (model layer 3) and the Reklaw Formation (model layer 5), the sand fraction was assumed to be uniform at 0.1, providing the calibrated horizontal hydraulic conductivity values of 6.08 feet/day and 0.1 feet/day, respectively, and calibrated vertical hydraulic conductivity values of 1.08e-4 feet/day and 8.63e-6 feet/day, respectively.

The calibrated horizontal hydraulic conductivity values for the Sparta Sand (model layer 2) ranged from 0.15 to 2.78 feet/day and that of the Queen City Aquifer (model layer 4) ranged from 1.05 to 1.95 feet/day. The calibrated vertical hydraulic conductivity values for the Sparta Sand (model layer 2) ranged from 7.7e-6 to 1.5e-4 feet/day and that of the Queen City Aquifer (model layer 4) ranged from 1.03 to 1.90 feet/day. The calibrated horizontal hydraulic conductivity units of the Wilcox Aquifer (Upper, Middle, and Lower Wilcox) (model layers 7, 8, and 9) ranged from 0.12 to 18.05 feet/day. The calibrated vertical hydraulic conductivity units of the Wilcox Aquifer (Upper, Middle, and Lower Wilcox) (model layers 7, 8, and 9) ranged from 4.3e-5 to 15.25 feet/day.

The calibrated hydraulic conductivity values were compared to the estimated hydraulic conductivity values presented in the Conceptual Model Report in Section 4.5 (Montgomery and Associates, 2018). Table 3.1-2 summarizes the range of calibrated hydraulic conductivity values and the estimated horizontal hydraulic conductivity range and geometric mean for each layer. The calibrated modeled horizontal hydraulic conductivity values are within the range of the estimated values. However, some of the calibrated values are on the lower side of the estimated range. The calibrated horizontal hydraulic conductivity values for the Sparta Sand (model layer 2) and Carrizo Sand (model layer 6) are lower than the estimated range. The calibrated horizontal hydraulic conductivity values for the remaining layers are within the estimated range, with the Weches Formation (model layer 3), and the Upper, Middle, and Lower Wilcox Aquifer (model layers 7, 8, and 9) calibrated horizontal conductivity values matching the estimated geometric mean, as shown on Table 3.1-2. Additional work may be needed to further correlate appropriate hydraulic conductivity zones with sand fraction distributions as noted in Section 7 which outlines further suggested research to improve understanding of flow.

3.1.3 Calibration of GHB

The GHB conductance was adjusted during calibration to provide a best fit between observed and simulated groundwater levels. As described in Section 2.8, The GHB controls flow in or out of the model domain along the southern model boundary. GHBs were using in model layers 2, 4, and 6 through 9. The heads along the GHB boundaries were set according to interpolated head contours in the region and the conductance values were adjusted using PEST and the two-period steady-state model. Table 2.8-1 shows the calibrated GHB head and conductance values and associated model cell number and hydraulic features. GHBs were also used to represent interaction of the Sparta Sand with the overlying Younger Units. Preliminary values of the GHB conductance were retained through calibration. Since the GHB water levels were kept constant through the calibration process, wells within the Sparta Sand beneath the Younger Units show little simulated fluctuations if any.

3.2 Model Simulated Versus Measured Heads

Groundwater level elevations were used to constrain the model to observed conditions during the simulation period. This section discusses the development of the water level elevation target data set and the various qualitative as well as quantitative measures that were used to evaluate the simulated water level elevations.

3.2.1 Water Level Elevation Targets

A total of 19,765 water level elevation records from 1,859 wells are within the model domain, in the simulated model layers (Younger Units, Midway Group, and Older Units are not simulated), and during the simulated model timeframe (1980 through 2013). 250 water level elevation records from 104 wells were removed due to following questionable data flags.

- pumping-level measurement;
- presence of oil and grease in well;
- possible incorrect well identification;
- flooding/runoff into the well casing;
- air leak in the sampling line;
- re-completion in different zone;
- well bridged or caved;
- previously flagged as questionable; and
- well water levels previously marked for exclusion.

The data was further evaluated to note well elevations compared to water level elevations. There were wells with water level elevations below the bottom of the assigned layer or where water level elevations were below the top of the assigned layer in regions where the aquifer was confined. These water levels were moved into an appropriate aquifer layer below such that the data is realistic. The observed water level dataset (target dataset) used for the model therefore consists of 18,606 water level elevation records from 1,797 wells. The observed water level wells are present in all model layers except for the two layers representing the aquitards (Weches and Reklaw Formations, model layers 3 and 5). Distribution of wells in each layer is shown on Figures 3.2-1 through 3.2-7. The number of observed water level measurements at each well location is also shown.

The target dataset was further evaluated for additional quality control issues that may warrant applying a weight to individual water level elevation records. A weight factor applied to a water level measurement represents a measure of uncertainty in the data. A weight factor was applied for the following conditions.

- Reported recent pumping;
- nearby pumping;
- possible recharge activities nearby;
- measurements from ground surface prior to wellhead completion;
- wet or leaking casing; and
- tape does not fall freely in well;
- well screened across multiple model layers;
- and wells with a single water level measurement.

A weight factor of 0.7 was applied to water level elevation records with a single condition. However, in the case that more than one condition applied to a water level elevation record, the cumulative weighting factor was assigned as 0.5. Data without quality issues or multi-layer screens were given a weight of 1. It is possible for a given well to have water level elevation records with varying weights. However, most records have a weight of 1. Within the target dataset, 1,739 records from 717 wells have a weight of 0.7; 585 records from 569 wells have a weight of 0.5; and 16,282 records from 707 wells have a weight of 1.

Although the target dataset set consists of 18,606 water level elevation records, the model targets consist of 18,421 water level elevation records. Water level elevation records were averaged for the 1980 steady-state stress period for each well, resulting in 185 less records for calibration. The water level elevation records with target weights and aquifer type designation are shown on Table 3.2-1.

3.2.2 Simulated Versus Observed Heads

Table 3.2-2 shows the summary for weighted head calibration statistics for the steady-state model representing 1980 conditions, and for the steady-state model representing 2013 conditions. The residual mean of 5.97 is relatively close to zero, indicating a good calibration and no overall bias in the calibration. The absolute residual mean was 30.83 feet and the RMS error was 44.91 feet. Table 3.2-3 shows the summary for weighted head calibration statistics for the transient simulation period for 1980 through 2013 conditions. The residual mean of -9.10 feet is slightly negative indicating simulated water level elevations are slightly higher than observed overall. However, given the large range of water level elevation measurements of 901.4 feet, the residual mean is relatively close to zero, indicating a good calibration. The absolute residual mean was 47.05 feet and the RMS error was 70.0 feet. The standard deviation of 69.4 feet is less than 10% of the range of observed values, indicating a good calibration. Table 3.2-4 shows the summary for the weighted head calibration statistics for the transient simulation period for 1980 through 2013 conditions for each model layer. The Upper, Middle, and Lower Wilcox (model layers 7, 8, and 9) calibration statistics indicate these layers have the best calibration. The Queen City Sand (model layer 4) calibration statistics indicate this layer has the worst calibration as simulated water level elevations are higher than observed. The Queen City Sand is between two aquitard layers. The steady-state and transient error statistics are less than 10% of the range of observations which is generally considered a reasonably good calibration. This number could not be improved further considering all the uncertainties in pumping and water level measurement locations discussed in Sections 2.7 and 3.2.1 respectively. All residuals are computed as observed minus simulated metrics. Thus positive residuals indicate that simulated water levels are lower than observed, while negative residuals indicate that simulated water levels are higher than observed.

A transient 1980 through 2013 simulation was performed for this domain using the MODFLOW-NWT code, with the 1-mile by 1-mile parent grid and parameterization from the calibrated model. This simulation was performed to evaluate the impact of coarser discretization on the calibration metrics. The residual mean was -7.9 feet, the Absolute Residual Mean was 48.1 feet, and the RMS error was 70.8 feet which are all similar to the respective values in Table 3.2-3. This indicates that the finer discretization did not affect calibration given the coarseness of pumping estimates even though it provides finer resolution around the stream locations, to better capture riparian head values and the stream-aquifer interaction.

Figure 3.2-8 shows the observed versus simulated water levels for the steady-state 1980 and 2013 conditions while Figure 3.2-9 s and Figure 3.2-10 separate this information into confined and unconfined water levels. The left panel shows the 1980 regression plot while the right panel shows the 2013 regression plot. For the steady-state conditions, the results tightly surround the best-fit line with no noticeable bias across the range of observations. The regression coefficient (R^2) for the three plots are all greater than 0.9, indicating a good match between observed and simulated water levels for both confined and unconfined conditions.

Figure 3.2-11 shows the regression plot of observed versus simulated water levels for the entire 1980 through 2013 transient simulation period. Figure 3.2-12 shows the confined water level regression plot and Figure 3.2-13 shows the unconfined water level regression plot for the 1980 through 2013 simulation period. The 1980 through 2013 simulation results tightly surround the best-fit line with no noticeable bias across the range of observations. The regression coefficient (R^2) for the three plots are all greater than 0.9, indicating a good match between observed and simulated water levels of the transient simulation for both confined and unconfined conditions. Figure 3.2-14 shows the unconfined water levels for the 1980 through 2013 simulation period and categorizes the unconfined targets as those outcropped and those overlain by the Quaternary Alluvium (model layer 1). There is no bias noted for unconfined targets outcropped or those overlain by Quaternary Alluvium.

Figures 3.2-15a through 15c show the observed versus simulated water levels for the 1980 through 2013 simulation period for each aquifer layer. The regression coefficient (R^2) for the plots range from about 0.84 to 0.99, indicating a good match between observed and simulated values in all layers. The Queen City Sand (Layer 4) showed the poorest match with a regression coefficient of 0.84 while all other aquifer layers had regression coefficients above 0.95.

3.2.3 Spatial Distribution of Residuals

The spatial distribution of head residuals for the 1980 through 2013 simulation period are shown on Figure 3.2-16. The residual values plotted are an average of all residuals (from 1980 to 2013) at each well. Target wells without quality control issues, with an average weight of 1 are shown; these are 541 of the 1,797 total targets used for model calibration. Residuals at these wells range from -249 to 257 feet. The largest cluster of negative and positive residuals occur in Rusk, Smith, and Van Zandt Counties indicate that these could possibly be resolved by a finer resolution on sand and clay categorization to give heterogeneity at a finer scale or better definition of pumping locations than that implemented from the previous GAM (Intera, 2004). These counties also have high pumping rates as shown on Figures 2.7-2 through 2.7-7. Negative and Positive residuals are evenly distributed across the model domain with no noticeable bias.

3.2.4 Water Level Hydrographs

Figures 3.2-17 through 3.2-23 show the observed and simulated hydrographs for select wells with observations spanning the simulation period from 1980 through 2013 within the various aquifer units. Observed water level fluctuations are noted to be generally similar in frequency and amplitude. Simulated water level elevations match well to observed in the Quaternary Alluvium (model layer 1), except for the well in Caddo County, where simulated water levels are than observed; also simulated water level fluctuations are higher than observed at the Caddo County well, as shown on Figure 3.2-17. Simulated water level elevations in the Sparta Sand (model layer 2) are higher and lower compared to observed, depending on the location. However, fluctuations are of similar magnitude, as shown on Figure 3.2-18. Simulated water level elevations in the Queen City Sand (model layer 4) are generally lower than observed to the north and higher to the south, but general water level trends and fluctuations match observed trends and amplitudes, as shown on Figure 3.2-19. Simulated water level elevations in the Carrizo Sand (model layer 6) are generally lower than observed water level elevations, except for Cass County where simulated and observed water levels match well and Leon county where simulated water levels are greater than observed, as shown on Figure 3.2-20. Simulated water level elevations in the Upper Wilcox (model layer 7) are generally lower than observed water level elevations, except for Sabine and Rusk Counties where simulated and observed water levels match well, as shown on Figure 3.2-21. Frequency and amplitude of fluctuations are similar at most wells except the well in Leon County where simulated water level declines are smaller than measured. Simulated water level elevations in the Middle Wilcox (model layer 8) generally match well to observed water level elevations, except for Camp county, where the simulated water levels do not follow the observed water level trend, as shown on Figure 3.2-22. A better definition of increase in pumping through time in that area would better match the observed decline in water levels during the simulation period. Simulated water level elevations in model layer 9 are higher than observed at some wells and lower in others, as shown on Figure 3.2-23. The simulated water level elevations in Panola County show a dip in 2003 that is not shown in the observed data. Appendix A provides water level hydrographs for target wells with no quality control issues (all water level elevations with a calibration target weight of 1) and also containing 30 or more observed water level elevations at the well.

3.2.5 Simulated Water Levels

Figures 3.2-24 through 3.2-32 show the simulated water level elevations in the 9 modeled layers, respectively, at the end of the simulation period in 2013. Water level elevations show water flows generally to the southern boundary in all layers. Model layer 1, representing the Quaternary Alluvium, reflects flow in the river channels, as shown on Figure 3.2-24. Water level contours in deeper units show drawdown cones at pumping wells. The northern portion of the Queen City sand shows numerous water level nonconformities Figure 3.2-28. There is a large simulated cone of depression extending across Angelina and Nacogdoches Counties in the Carrizo Sand and Wilcox Aquifers (layers 6 through 9), as shown on Figure 3.2-29 through 3.2-32. Slightly smaller drawdown cones are noted in Smith County within the Carrizo Sand and Wilcox Aquifers (model layers 6 through 9).

Figures 3.2-33 through 3.2-41 show the change in water levels within each layer from 1980 to 2013. Generally, water level changes in the upper four layers, the Quaternary Alluvium (model layer 1) to the Queen City Sand (model layer 4), are small with most changes within 10 feet and limited pockets of greater water level change such as in Wood County, as shown on Figures 3.2-33 through 3.2-36. Generally, water level changes in the lower five layers, the Reklaw Formation (model layer 5) to the Lower Wilcox (model layer 9), are larger with a large area in the northern portion of the model, centered about Smith County and extending southward, showing groundwater levels decreasing up to 50 feet, as shown on Figures 3.2-37 through 3.2-41. Another significant change in water level elevations occurs in Arkansas, in Miller County, located in the northernmost corner of the model. In this area, groundwater levels decrease which are greater with depth, up to 500 feet of decrease in the Middle Wilcox (model layer 8), as shown on Figure 3.2-40. The remainder of the model domain shows relatively stable water levels from 1980 to 2013. There is a general area of groundwater mounding between 1980 and 2013 centered about Nacogdoches and Angelina Counties within the Reklaw Formation, Corrizo Sand, and Upper Wilcox (model layers 5, 6, and 7), as shown on Figures 3.2-37 through 3.2-39, with largest rebound of over 60 feet in the Carrizo Sand (model layer 6).

Figures 3.2-42 through 3.2-47 compare simulated groundwater level elevation contours from the end of the model simulation period, 2013, to the Conceptual Model groundwater level elevation contours using 2015 data previously presented in the Conceptual Model Report (Montgomery and Associates, 2018). The Conceptual Model Report used observed data to interpolate the 2015 groundwater level elevation surface. The 2015 groundwater level elevation surface for this discussion is referred to the observed groundwater level elevations. Comparisons are provided for the Sparta Sand, Queen City Sand, Carrizo Sand,

and Wilcox Aquifer (model layers 2, 4, 6, 7, 8, and 9). Even though comparisons are made between 2013 modeled conditions and 2015 observed conditions there is minimal change in average water level conditions between the two years.

The Sparta Sand (model layer 2) conceptual contours are uncertain over much of the layer, as indicated on Figure 3.2-42 using dashed lines. Generally, 2013 simulated groundwater level elevations are consistent with the elevations of the observed 2015 water level surface with similar gradients pointed in the southward direction. The Queen City Sand (model layer 4) 2013 simulated and 2015 observed groundwater contours are similar, and both show southward flow, as shown on Figure 3.2-43. The 2015 observed pumping centers near Wood and Cherokee Counties are not clearly present in the 2013 simulated contours, however, the two-year time difference between the observed and simulated contours may account for some of these differences. The Carrizo Sand and Upper Wilcox (model layers 6 and 7) observed and simulated contours match more closely in terms and both show pumping centers in Nacogdoches and Smith Counties with elevations of similar values, showing flow to the south, as shown on Figures 3.2-44 and 3.2-45.

The Middle and Lower Wilcox (model layers 8 and 9) 2015 observed contours are uncertain in the south portion of the model, as shown on Figures 3.2-46 and 3.2-47. In the Middle Wilcox (model layer 8), the 2013 simulated contours show similar features as the 2015 observed contours, including an elevation trough in the southern portion of the model, pumping in Smith County, and areas of groundwater mounding in Rusk and Harrison Counties, shown on Figure 3.2-46, though a cone of depression indicated by data in Cass County was not simulated. The Lower Wilcox (model layer 9) 2013 simulated contours show details such as areas of pumping and areas of groundwater mounding not captured in the 2015 observed contours, however, most of the 2015 contours are uncertain in the Lower Wilcox within the model domain, as shown on Figure 3.2-47.

3.3 Model Simulated Versus Measured Baseflow

Surface-water/groundwater fluxes were used to constrain the model. The major rivers in the model domain were simulated with the RIV package as described in Section 2.9. Figures 2.9-1 through 2.9-5 show the annual flows at stream gages located on the major rivers in the model domain, which include the Trinity River, Neches River, Sabine River, Big Cypress Creek, and Sulphur River. The flow difference between stream gages was calculated at select river segments with unmanaged flows. A positive difference in flow signifies the river is gaining along the reach, and a negative difference in flow signifies the river is losing along the reach. The rivers simulated in the model are primarily gaining streams.

Measured stream gage data was used to evaluate simulated surface-water/groundwater fluxes. However, since the model does not simulate surface water flow, the flux between river and groundwater was evaluated qualitatively. Figure 3.3-1 shows the simulated flux between the simulated rivers and the groundwater in the model domain. A negative flux value indicates a gaining reach and a positive flux value indicates a losing reach. Most of the reaches shown on Figure 3.3-1 are gaining, which matches measured gage data, as shown Figures 2.9-1 through 2.9-5. In addition, the simulated water budget for river inflow and outflow was evaluated. Figure 3.3-2 shows the inflow from the river boundary condition, outflow to the river boundary condition, and net river gain. The inflow from the river boundary condition, which represents water flowing from the river boundary condition into groundwater, is flat during the simulation period, with an average of approximately 38,000 acre-feet per year (acre-feet/year). The outflow to the river boundary, which represents water flowing from groundwater into the river boundary condition, varies during the simulation period, with an average of approximately 260,000 acre-feet/year. The net flux from the groundwater to the river boundary condition average of approximately 222,000 acre-feet/year. Measured stream gage fluxes cannot be directly compared to simulated fluxes, as measured stream gage data is not measuring base flow. However, the measured and simulated river flux both result in gaining stream conditions.

3.4 Model Simulated Water Budgets

The water budget for steady-state 1980 simulation is show in Table 3.4-1. The largest inflow in the model domain (besides internal flow between layers) is recharge contribution in all layers and especially within the Quaternary Alluvium (model layer 1). Simulated rivers contribute a minor amount of inflow into the Quaternary Alluvium (model layer 1) as does the GHB into the Sparta sand and Carrizo Sand (model layers 2 and 6). Within the 1980 simulation, the largest total outflows (besides internal layer outflows) are to the simulated rivers in the Quaternary Alluvium (model layer 1), followed by evapotranspiration and groundwater pumping. Although total extraction of groundwater not the largest outflow for the steady-state 1980 simulation period, it is the largest outflow in the Carrizo Sand and Wilcox Aquifers (model layers 6, 7, 8, and 9).

The water budget for the transient simulation from 1980 through 2013 is shown in Figure 3.4-1 and summarized in Table 3.4-2. The largest model inflows and outflows are similar to those in the steady-state 1980 simulation. Inflows and outflows are dominated by recharge for inflow and rivers and evapotranspiration for outflow. Within individual layers, outflow was dominated by groundwater extraction in the Carrizo Sand and Wilcox Aquifers (model layers 6, 7, 8, and 9). Storage provided a negligible amount of inflow and outflow across the model.

Figure 3.4-1 shows how the water budget fluctuates during the simulation period. Recharge (inflow), is the largest component in the model water budget, and showed the greatest changes year to year. Recharge over time did not display a noticeable trend from 1980 to 2013 although recent drought conditions were reflected as an extended period of decreasing flux (2004 to 2012). River and evapotranspiration (outflows) showed some variability with time. Drought conditions were also reflect in the river and evapotranspiration water budget components with declining flows between 2004 and 2012. Groundwater extraction did not vary significantly year to year but showed an increasing trend from 1980 to 2013. Other inflow and outflow components were generally consistent across the model time interval and generally smaller in magnitude.

4.0 Sensitivity Analyses

A sensitivity analysis was conducted on the calibrated model to determine the impact of conceptual or parameter changes to the calibration results. The current section discusses the sensitivity analyses to calibration.

4.1 Procedure of Sensitivity Analysis

Sensitivity analyses were performed to evaluate the effects of hydraulic conductivity, pumping, recharge, evapotranspiration, and specific yield. Both transient and steady-state analyses were performed to evaluate parameters that have a high impact on calibration.

Evaluation of sensitivity was qualitative for the transient 1980-2013 model sensitivities. The parameters tested were evaluated by comparing water level hydrographs from the sensitivities to the calibrated model and observed values. The evaluated parameters/stresses included: a no-pumping case, a simulation with constant recharge, and a sensitivity simulation on the specific yield value.

Evaluation of sensitivity was quantitative for the two-period steady-state model sensitivity analyses. Recall that the two stress periods reflect 1980 and 2013 stress conditions. The evaluated parameters included: hydraulic conductivity, recharge, evapotranspiration, and pumping. For these sensitivities, the parameter values were raised and lowered by prescribed factors and the change in model calibration errors were evaluated for each case. These parameters were then categorized into high, medium and low sensitivity groups considering the change in the calibration statistics resulting from the change in the parameter value. The possible "sensitivity types" are defined by ASTM (1994, 2000) and are used for uncertainty evaluations of the predictive analyses. The sensitivity types categorize how parameters change the model calibration versus changing the model predictions and are as follows:

Type I sensitivity is defined for parameters that cause insignificant changes to the calibration residuals as well as to model conclusions/predictions of interest. Type I sensitivity is of no concern because regardless of the value of the input, the prediction is also insensitive.

Type II sensitivity is defined for parameters that cause significant changes to the calibration residuals but are not sensitive to model conclusions/predictions of interest. Type II sensitivity is of no concern because the prediction is not sensitive to the calibration.

Type III sensitivity is defined for parameters that cause significant changes to the calibration residuals as well as to the model conclusions/predictions. Type III sensitivity is of no concern because even though the model's predictions change as a result of variation of the input variable value, the calibration residuals are also sensitive, and the model becomes uncalibrated as a result. Thus, model calibration ensures that the predictions considered are appropriate for the modeled system.

Type IV sensitivity is defined for parameters that cause insignificant changes to model calibration residuals but significant changes to the model predictions. Type IV sensitivity is of concern because over the range of that parameter in which the model can be considered calibrated, the conclusions/predictions of the model can change. Additional data collection for such parameters can help narrow the band of uncertainty in the prediction.

Based on the model calibration statistics alone, parameters with low residual mean, absolute residual mean head, or RMS error were categorized as possible Sensitivity Type I or IV. Parameters with high residual mean, absolute residual mean head, or RMS error were categorized as possible Sensitivity Type II or III. Following the completion of predictive model simulations, if parameter changes result in large prediction changes, parameters of Type I or IV will be classified as Type I and those with small prediction changes will be classified as Type IV. The Type IV sensitivity indicates that predictions would be more accurate for better estimates of that parameter even though the parameter may not affect calibration.

4.2 Results of Sensitivity Analysis

For parameters evaluated using the two-period steady-state model, the sensitivity model statistics, absolute residual mean head, the residual mean head, and the RMS head error, were compared to the calibrated steady-state model. The absolute residual mean head and residual mean head indicate sensitivity of the residuals to the parameter value showing whether the heads have overall increased or decreased as a result of the parameter change. The RMS head error sensitivity indicates how the spread in observed versus modeled water levels has changed.

For parameters evaluated using the transient model, the evaluation of sensitivity utilized groundwater hydrographs. Detailed discussions of each parameter evaluation are provided below.

4.2.1 Sensitivity to Aquifer Hydraulic Conductivity Parameters

Sensitivity of the model calibration to hydraulic conductivity values of the various geologic units was evaluated for the two-period steady-state model. The transient time periods were not considered as they do not add to the evaluation.

The parameter sensitivity study was conducted by using the automated sensitivity analysis option in Groundwater Vistas Version 7.24 (Rumbaugh and Rumbaugh, 2020). The automated sensitivity evaluated the stead-state model while adjusting hydraulic conductivity one layer at a time. The sand and clay hydraulic conductivities for each layer were evaluated individually as separate simulations. For each layer, sand and clay hydraulic conductivity values were multiplied by factors of 0.3, 0.7, 1.3, and 1.7. The factors of 0.3 and 1.7 represent a 70% reduction and increase in the hydraulic conductivity, while the factors of 0.7 and 1.3 represent a 30% reduction and increase in the hydraulic conductivity. The automated sensitivity analysis calculated the calibration statistics for each parameter change and compiled the results in the autosens.out file.

Most model layers were not sensitivity to changes in sand or clay hydraulic conductivity; however, those that were showed various degrees of sensitivity. Figures 4.2-1 and 4.2-2 show the absolute residual mean for the hydraulic conductivity sensitivity and Figures 4.2-3 and 4.2-4 show the RMS head error for the hydraulic conductivity sensitivity. For the sand sensitivities, which generally control the horizontal hydraulic conductivity, the Middle Wilcox (model layer 8) had the greatest sensitivity, followed by the Lower Wilcox (model layer 9), as shown on Figures 4.2-1 and 4.2-2. The Queen City Sand (model layer 4) showed a slight improvement in model calibration with a decrease in sand hydraulic conductivity. The remaining layers showed little to no sensitivity to increases or decreases in the sand hydraulic conductivity. For the clay sensitivities, which generally control the vertical hydraulic conductivity, the Upper Wilcox (model layer 7) had the highest sensitivity, followed by the Middle Wilcox (model layer 8) and Reklaw Formation (model layer 5), as shown on Figure 4.2-3 and 4.2-4. The remaining layers showed little to no sensitivity to increases or decreases in the clay hydraulic conductivity.

Table 4.2-1 categorizes the sensitivity simulations into low, medium and high sensitivity values. Parameters with low, medium, or high sensitivity to calibration based on the absolute residual mean head and RMS error were categorized as possible Sensitivity Type II or III. These included the sand hydraulic conductivities for the Queen City Sand, the Middle Wilcox, and the Lower Wilcox (model layers 4, 8, and 9), and the clay hydraulic conductivities for the Reklaw Formation, the Upper Wilcox, and the Middle Wilcox (model layers 5, 7, and 8). The remaining layers showed little to no sensitivity to increases or decreases in the sand or clay hydraulic conductivity values and were therefore categorized as possible Sensitivity Type I or IV.

4.2.2 Sensitivity to Model Stresses Using the Two-Period Steady-State Model

The sensitivity of the model calibration to recharge, evapotranspiration, and groundwater pumping was evaluated to note the impact of variations of these parameters on the calibrated model. These sensitivity analyses were conducted using the two-period 1980 and 2013 steady-state model. In addition, the transient model was used to evaluate the effect of no pumping and of constant recharge on simulated water level elevations.

For each steady-state sensitivity analysis, the stress values were multiplied by factors of 0.3, 0.7, 1.3 and 1.7 to note the impact on calibration errors. The factors of 0.3 and 1.7 represent a 70% reduction and increase in the respective flux values, while the factors of 0.7 and 1.3 represent a 30% reduction and increase in the respective flux values.

The mean head residual and the RMS head error were evaluated to establish model behavior. The mean head residual indicates sensitivity of the residuals to the parameter value showing whether the heads have overall increased or decreased as a result of the parameter change. The RMS head error sensitivity indicates how the spread in observed versus modeled water levels has changed.

Figure 4.2-5 shows the steady-state sensitivity to the mean head residual to recharge, evapotranspiration rate, and groundwater pumping. Recharge has the largest impact on the mean head value computed at the target groundwater cells, while the evapotranspiration rate had the smallest impact.

Figure 4.2-6 shows the steady-state sensitivity of recharge, evapotranspiration rate, and groundwater pumping to the RMS head error. The largest sensitivity again was to recharge. Evapotranspiration rate did not impact the RMS head error by any appreciable amount.

Evapotranspiration showed no sensitivity as reflected in the residual mean and RMS error, which categorizes evapotranspiration as possible Sensitivity Type I or IV, as shown on Table 4.2-1. Recharge and pumping resulted in high and medium sensitivity as reflected in the residual mean and RMS error, which categorizes these parameters as possible Sensitivity Type II or III, as shown on Table 4.2-1. If predictive sensitivity simulations for evapotranspiration indicate large prediction changes, evapotranspiration will be classified as Sensitivity Type IV, indicating that predictions would be more accurate for better estimates of this parameter even though it may not affect the calibration. It is further noted that the model water level statistics were sensitive to recharge decreases but not to increases in recharge. This is because baseflow and evapotranspiration fluxes increase to compensate, with only small increases in water levels.

4.2.3 Sensitivity to Model Stresses Using the Transient Model

The transient model was used to evaluate the effects of no pumping and constant recharge. The no pumping model in comparison to the calibration simulation indicates impact of pumping and their fluctuations on water levels. The constant recharge model in comparison to the calibration simulation indicates impact of recharge fluctuations on water levels. Figures 4.2-7 through 4.2-13 show the hydrographs at select wells for these sensitivity studies. The transient model with no pumping generally results in increased water levels, which at a few observation wells, improved calibration, as shown on Figures 4.2-7 through 4.2-13. This could be indicative of pumping within the wrong layer at those locations. In addition, the no pumping sensitivity resulted in dampened water level fluctuations at some of the observation wells. The transient model with a constant recharge rate generally resulted in the same magnitude of water level elevations, but with dampened water level fluctuations at most of the observation wells and some showing no water level fluctuations. Sensitivities reveal both pumping and recharge stresses contribute to water level fluctuations. In general, unconfined aquifer water level fluctuations are primarily controlled by variations in recharge; and confined aquifer water level fluctuations are primarily controlled by variations in pumping rates, as shown on Figures 4.2-7 through 4.2-13.

4.2.4 Sensitivity to Aquifer Storage Properties

A sensitivity analysis was conducted to note the impact of aquifer storage properties on water level fluctuations in the domain. Since the focus of this sensitivity was to evaluate water fluctuations and not calibration, the transient model was used, and the results were not categorized as ASTM sensitivity types. To evaluate the effect of the specific yield, specific yield was increased from 0.0007 to 0.05 for the transient model.

Figures 4.2-7 through 4.2-13 show the hydrographs at select wells for this sensitivity study. Water level fluctuations are generally dampened for the sensitivity simulation with increased specific yield, as compared to the calibrated simulation. Within the model calibration results, most simulated water level elevations at unconfined and confined monitoring well locations exhibit this flattened response. However, the general trends in the hydrographs for calibration and specific yield simulations are similar indicating the storage parameters are not very significant to the calibrated simulation. Also, considering the annual time scale of evaluation for model stress periods, water level fluctuations are generally more dampened due to dampening of peak stresses into average values.

5.0 Modeling Limitations

Several simplifications, assumptions, and approximations have been made in developing the Northern QCSCW model. Representation of the domain by discrete finite-volumes, approximation of groundwater flow by the continuity equation and Darcy's Law, and approximation of the various boundary conditions and stresses by steady-state or annual average conditions create an idealized representation of the flow system. This enables regional evaluations at long time-scales (of years to decades), but such an idealized system contains inherent divergence from actual conditions though the effect of these differences can be assessed. Errors are also associated with mesh design, aquifer or boundary geometry or areal extent, and the configuration of hydrologic components (conceptualization errors). These errors were minimized during model development and further evaluated and reduced during model calibration and sensitivity analysis as described below.

Data that is incorporated into a model may be incomplete, may contain errors, or may be incompatible with the modeled spatial and temporal scale. Possible measurement errors were accounted for in this model by using a lower calibration weighting when these errors were discernable. Also, water levels that are measured instantly may be compared to simulated water levels that result from annual stress periods. Pumping information from the conceptual model derived from TWDB databases were also incomplete causing model limitations. The calibrated model used pumping information derived from the previous GAM (Intera, 2004) which lumped pumping into the large model grid centers. This also affected the model calibration and therefore sensitivity analyses of this stress were conducted to evaluate its significance. Better transient pumping information can provide better transient calibrated water level responses; however, automatic calibration methods applied to pumping transients were not effective in resolving the data due to low/moderate sensitivity.

A groundwater flow model requires that the entire domain be appropriately parameterized. Although information exists on general aquifer characteristics, and more detailed sand fraction distributions were available for the geologic units, detailed hydrologic characterization is not possible except by extrapolating information from areas where data is available. This lack of hydrogeologic information can introduce uncertainty and errors in model results, especially in complex systems such as the Northern QCSCW. Also, the hydraulic averaging formulas applied to determine horizontal and vertical hydraulic conductivities from sand and clay fractions may contain errors causing further limitations to the model. Sensitivity analyses helped to quantify the impact of these sand and clay fraction data and hydrogeologic averaging approaches.

The spatial resolution of the model was set to provide a regional evaluation of groundwater flow with refined discretization around surface-water features to capture the groundwater/surface-water interaction in a detailed manner. The temporal resolution of the model was set to annual stress periods for recharge, pumping, and boundary flows for long-term planning purposes. Annually average stresses were calibrated to all available water levels and therefore it is also assumed that the calibration is representative considering the different time scales of water level data and simulated stresses.

The model limitations further include uncertainty in predictions. Predictive sensitivity analyses should also be conducted with predictions of significance, to evaluate the impact of parameter variations on the prediction. Categorizing the predictive sensitivities along with calibration sensitivities as per ASTM (1994, 2000) provides further information on the significance of data to the predictions.

6.0 Summary and Conclusions

The northern QCSCW has been updated to simulate impacts of groundwater pumping on groundwater resources in northeast Texas. The large model domain, complex geology, fine resolution, inconsistent pumping data, water level elevation quality control issues, and the 33-year time frame proved challenging and contributed to the considerable computational effort and model uncertainty.

Modeling challenges were addressed by selecting a robust and flexible software to best alleviate the computational burdens and still provide results at the scale of the modeling objectives. The MODFLOW 6 groundwater flow model was used for the simulations with the Groundwater Vistas graphic user interface (GUI). The numerical model was built in accordance with the conceptual model and consisted of 9 model layers to represent the 9 hydrostratigraphic units of interest, consisting of the Quaternary Alluvium, Sparta Sand, Weches Formation, Queen City Sand, Reklaw Formation, Carrizo Sand, and Wilcox Aquifer (Upper, Middle, and Lower).

The model simulation consisted of a steady-state period representing 1980 conditions followed by transient conditions from 1981 through 2013 using annual stress periods for recharge and pumping. The steady-state 1980 period was simulated using average aquifer conditions.

The model calibration was guided by available data. Quantitative and qualitative metrics were implemented in evaluating representativeness of the model. Observed water levels in wells and groundwater to surface water flow estimates were used to constrain the model. Calibration statistics show the model was well calibrated for the spatial and temporal scales of investigation. Mass balance errors were negligible, and water fluxes at the various boundaries into and out of the domain were reasonable and consistent with the conceptual model. Qualitative comparison of estimated conceptual groundwater elevation contours to simulated contours confirm that the calibration matched observed conditions across the model domain.

Sensitivity analyses were conducted on the calibrated model to evaluate impact of parameter uncertainties and variations in boundary fluxes. Parameters evaluated were storage, hydraulic conductivity, recharge, evapotranspiration, and groundwater pumping. The model proved to be sensitive to pumping. A better estimation of pumping changes through time would have provided better transient calibration to water level changes. As data collection continues and the conceptual model is improved, the uncertainties associated with the model can be reduced.

A predictive model was developed for the period 2014 through 2080. Predictive simulations are summarized in Appendices B, C, and D. Predictive simulations were conducted to evaluate the impact of baseline pumping and average recharge and are discussed in Appendices B, C, and D. The predictive simulations found that the groundwater model does not show unreasonable continual increases in water level elevations as the previous Groundwater Availability Model had done. Since pumping and recharge values were held constant across the model for all counties, local variabilities in pumping were not accounted for, nor variability in other model parameters which were held constant through 2080. Predictive modeling from 2014 to 2080 using these various conditions showed that drawdown at Groundwater Management Area 11 counties may be significantly affected by the chosen baseline pumping or average recharge. However, these predictive county-model layer drawdown charts may still be useful in guiding the Joint Planning Process and development of desired future conditions.

7.0 Future Improvements

A groundwater flow and transport model of Northern QCSCW GAM was developed in this project using the MODFLOW 6 software. Use of oct-patch grids facilitated providing finer resolution to the numerical discretization near surface-water features to accurately capture the interactions. Pinch-outs and outcrops were handled in a geologically consistent manner. The Groundwater Vistas GUI was used to develop the model. Multiple calibration metrics were used to constrain the model. The groundwater flow model generally depicts conditions within the domain during the 1980-2013 simulation period for annually averaged stress conditions.

There were several challenges overcome by this study. A regional domain was simulated with sufficient resolution of the solution near surface-water features by use of oct-patch grid refinement which provides resolution horizontally as well as vertically near to the river.

Further research suggested by this work includes:

- A further evaluation of sand fraction distributions along with hydraulic conductivity data for the Quaternary Alluvium, Carrizo Sand, Weches Formation, and Reklaw Formation would improve calibration, as there were no sand fraction data for these units and a uniform sand fraction was used;
- Improved pumping estimates, as there were clear data errors in the provided pumping estimates and calibrating the pumping rates proved to be impractical; and
- More reliable water level elevation data and well construction data to better correlate observed water level elevation data to the hydrostratigraphic units these data represent.
- More processing, QA and refinement of the water level data using data science techniques to associate water level fluctuations among different wells (evaluate clustering) to identify proximity, a common dominant aquifer unit, or other connections between well locations such as conduits or displaced geologic layering across fractures.
- More processing of data using data science techniques to associate pumping stresses and their associated hydrogeologic units to water level drawdowns for more reliable data, such that pumping data gaps can be filled where the data is inadequate.

8.0 Acknowledgements

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9.0 References

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FIGURES

TABLES

APPENDICES

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Table 2.1-1 Summary of Model Input Packages

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Package Type	Abbreviation	Description
Internal Packages		
Namefile	NAM	Controls all other model files and names
Initial Conditions	IC	Reads the starting heads
Discretization	DIS	Discretizes groundwater domain
Node Property Flow	NPF	Calculates flow between cells
Storage	STO	Calculates the change in water volume
Stress Packages		
Well	WEL	Implement sources/sinks
General Head Boundary	GHB	Implement head-dependent flux boundary
River	RIV	Implement river boundary
Recharge	RCH	Implement recharge
Evaportanspiration	EVT	Implement evaportanspiration

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Table 2.1-2 Summary of Model Output Packages

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Package Type	Abbreviation	Description
List file	LST	Lists model input, simulation summary, and mass balance
Groundwater Flow Head output	HDS	Contains head output for all GWF cells at all stress periods
Cell-by-cell flows	CBB	Contains CBB output for all cells at all stress periods
Output Control	OC	Control simulation output

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Table 2.4-1 Stress Period Setup

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Stress Period	Time Steps	Representative Year	Length (days)	Type
1	1	1980	1	Steady State
2	5	1981	365	Transient
3	5	1982	365	Transient
4	5	1983	365	Transient
5	5	1984	366	Transient
6	5	1985	365	Transient
7	5	1986	365	Transient
8	5	1987	365	Transient
9	5	1988	366	Transient
10	5	1989	365	Transient
11	5	1990	365	Transient
12	5	1991	365	Transient
13	5	1992	366	Transient
14	5	1993	365	Transient
15	5	1994	365	Transient
16	5	1995	365	Transient
17	5	1996	366	Transient
18	5	1997	365	Transient
19	6	1998	365	Transient
20	5	1999	365	Transient
21	5	2000	366	Transient
22	5	2001	365	Transient
23	5	2002	365	Transient
24	5	2003	365	Transient
25	5	2004	366	Transient
26	5	2005	365	Transient
27	5	2006	365	Transient
28	5	2007	365	Transient
29	5	2008	366	Transient
30	5	2009	365	Transient
31	5	2010	365	Transient
32	5	2011	365	Transient
33	5	2012	366	Transient
34	5	2013	365	Transient

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Table 2.4-2 Summary of Model Domain Discretization

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Layer	Hydrostratigraphic Unit	Number of cells	Smallest grid cell size (feet)	Largest grid cell size (feet)
1	Quaternary Alluvium	307,787	660	5,280
2	Sparta Sand	63,072	1,320	5,280
3	Weches Formation	23,916	1,320	5,280
4	Queen City Sand	39,640	1,320	5,280
5	Reklaw Formation	33,467	1,320	5,280
6	Carrizo Sand	28,480	1,320	5,280
7	Upper Wilcox	50,692	1,320	5,280
8	Middle Wilcox	50,843	1,320	5,280
9	Lower Wilcox	39,639	1,320	5,280

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Table 2.5-1 Sand Fraction Range for Each Layer

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Hydrostratigraphic Unit	Sand Fraction Range
1	Quaternary Alluvium	0.70
2	Sparta Sand	0.05 - 0.95
3	Weches Formation	0.10
4	Queen City Sand	0.05 - 0.95
5	Reklaw Formation	0.10
6	Carrizo Sand	0.70
7	Upper Wilcox	0.05 - 0.95
8	Middle Wilcox	0.05 - 0.95
9	Lower Wilcox	0.05 - 0.95

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Table 2.7-1 Pumping Dataset Comparison

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Hydrostratigraphic Unit	Model Layer	Conceptual Model Report Pumping (acre-ft)	Corrected Conceptual Model Report Pumping (acre-ft)	Current Model Total Pumping (acre-ft)
Quaternary Alluvium	1	79,896	155,763	0
Sparta Sand	2	274,874	537,688	140,745
Weches Formation	3	115,826	0	0
Queen City Sand	4	529,423	1,000,226	346,221
Reklaw Formation	5	301,848	0	0
Carrizo Sand	6	750,757	910,271	3,292,702
Upper Wilcox	7	2,299,622	2,660,318	1,219,102
Middle Wilcox	8	1,394,278	1,608,434	1,100,444
Lower Wilcox	9	1,110,469	1,324,976	287,559
Total Model Pumping		6,856,993	8,197,676	6,386,773

NOTES

1. Total pumping shown is for the model period 1981 to 2013.
2. Conceptual Model Report: Schorr and others, 2019.
3. The current model pumping is based on pumping from the previous GAM groundwater model.

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Table 2.7-2 Model Multiplication Factors

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

2020 Model Stress Period	Year	Basis for Multiplication Factor	2020 Model Pumping Multiplication Factor
1 to 26	1980 - 2005	Previous GAM pumping used	1
27	2006	Ratio with 2005 pumping	1.0962053
28	2007	Ratio with 2005 pumping	0.990607505
29	2008	Ratio with 2005 pumping	1.054691786
30	2009	Ratio with 2005 pumping	0.96743175
31	2010	Ratio with 2005 pumping	1.048868364
32	2011	Ratio with 2005 pumping	1.143274073
33	2012	Ratio with 2005 pumping	1.059654573
34	2013	Ratio with 2005 pumping	0.998830209

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Table 2.8-1 General Head Boundary Conditions

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Layer	Hydrostratigraphic Unit	Number of GHB Cells	GHB Head (feet)	GHB Conductance (feet/day)	Hydraulic Feature
Layer 2	Sparta Sand	59,512	min = 52.864	min = 0.378125	Lateral boundary
			max = 482.014	max = 83.83	
Layer 4	Queen City Sand	244	min = 150	90.961681	Lateral boundary
			max = 179.61772		
Layer 6	Carrizo Sand	241	min = 150.225917	993.24725	Lateral boundary
			max = 224.730862		
Layer 7	Upper Wilcox	240	min = 75.047346	10.839841	Lateral boundary
			max = 174.242096		
Layer 8	Middle Wilcox	234	min = 0	11.325211	Lateral boundary
			max = 118.782266		
Layer 9	Lower Wilcox	236	min = 50	58.1002	Lateral boundary
			max = 118.377152		

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Table 2.10-1 Recharge Multiplication Factors

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Stress Period	Representative Year	Recharge Multiplier
1	1980	1
2	1981	1
3	1982	0.9235
4	1983	0.9627
5	1984	0.9988
6	1985	0.9669
7	1986	0.7067
8	1987	1.0482
9	1988	1.1294
10	1989	1.2864
11	1990	1.0412
12	1991	0.9706
13	1992	1.147
14	1993	0.9042
15	1994	0.8246
16	1995	1.152
17	1996	1.0659
18	1997	0.8142
19	1998	1.0351
20	1999	1.2623
21	2000	1.0902
22	2001	0.8916
23	2002	1.256
24	2003	0.6938
25	2004	0.99031
26	2005	1.0678
27	2006	0.967
28	2007	1.1605
29	2008	0.6912
30	2009	0.6571
31	2010	0.9698
32	2011	0.9923
33	2012	0.8996
34	2013	1.4333

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Table 3.1-1 Calibration of Recharge Multiplication Factors

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Stress Period	Representative Year	Recharge Multiplier
1	1980	1
2	1981	**0.95**
3	1982	0.9235
4	1983	0.9627
5	1984	**1.15**
6	1985	0.9669
7	1986	0.7067
8	1987	**0.85**
9	1988	**1.2**
10	1989	**1.2**
11	1990	1.0412
12	1991	**1**
13	1992	**1.25**
14	1993	0.9042
15	1994	0.8246
16	1995	1.152
17	1996	**0.81**
18	1997	**1.1**
19	1998	1.0351
20	1999	1.2623
21	2000	1.0902
22	2001	**1**
23	2002	**1**
24	2003	**1.1**
25	2004	**1.05**
26	2005	1.0678
27	2006	0.967
28	2007	**0.95**
29	2008	**0.95**
30	2009	**0.85**
31	2010	**0.88**
32	2011	**0.8**
33	2012	0.9
34	2013	**1.1**

Note:
Multiplication factors modified during calibration are indicated in bold font.

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Table 3.1-2 Calibrated Hydraulic Conductivity for Modeled Geologic Units

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Hydrostratigraphic Unit	Model Sand Fraction	Parameterized Hydraulic Conductivity Values (feet per day)		Calibrated Model Hydraulic Conductivity (feet per day)		Conceptual Model Estimated Hydraulic Conductivity (feet per day)	
			Sand	Clay	Horizontal	Vertical	Range	Geometric Mean
1	Quaternary Alluvium	0.70	7.77	3.73	6.56	5.87	1 - 1000	165
2	Sparta Sand	0.05 - 0.95	2.92	7.31E-06	0.15 - 2.78	7.7E-06 - 1.5E-04	1 - 808	14
3	Weches Formation	0.10	60.75	9.70E-05	6.08	1.08E-04	0.2 - 65	5
4	Queen City Sand	0.05 - 0.95	2	1	1.05 - 1.95	1.03 - 1.90	0.1 - 451	5
5	Reklaw Formation	0.10	1	7.76E-06	0.10	8.63E-06	0.05 - 385	5
6	Carrizo Sand	0.70	0.16	1.33E-02	0.12	3.72E-02	0.3 - 198	6
7	Upper Wilcox	0.05 - 0.95	18.82	3.309378	4.09 - 18.05	3.45 - 15.25	0.06 - 278	4
8	Middle Wilcox	0.05 - 0.95	8.67	4.10E-05	0.43 - 8.24	4.3E-05 - 8.2E-04	0.04 - 671	4
9	Lower Wilcox	0.05 - 0.95	2.31	6.82E-03	0.12 - 2.19	7.2E-03 - 0.13	0.01 - 97	3

NOTES:

1. Calibrated horizontal and vertical hydraulic conductivities are based on sand fraction and parameterized hydraulic conductivity values. Equations for calculating horizontal and vertical hydraulic conductivity are discussed in Section 3.1.
2. Estimated hydraulic conductivities are from the 2019 Conceptual Model Report (Schorr and others, 2019).

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
1	314542093043701	1/11/1980 - 10/17/2013	229	1	Unconfined
1	315743093204601	3/6/1980 - 10/21/2013	142	1	Unconfined
1	321743093354201	1/7/1980 - 10/21/2013	172	1	Unconfined
1	324207093484801	1/8/1980 - 10/22/2013	201	1	Unconfined
2	3438912	3/16/1981 - 1/26/1995	13	1	Unconfined
2	3726202	11/11/1982	1	0.7	Unconfined
2	3733204	3/17/1981 - 11/14/1984	3	1	Unconfined
2	3734403	3/25/1982 - 12/4/2009	29	1	Unconfined
2	3734404	2/7/1984 - 5/17/1988	2	0.7	Unconfined
2	3738403	11/11/1982 - 11/19/2013	28	1	Unconfined
2	3738404	8/23/2003	1	0.5	Unconfined
2	3740702	11/10/1999 - 11/20/2013	15	1	Unconfined
2	3741401	4/9/2002	1	0.5	Unconfined
2	3745301	4/27/1998 - 7/24/2003	2	0.7	Unconfined
2	3832802	3/18/1982 - 11/12/2013	31	1	Unconfined
2	3837901	3/16/1982 - 11/16/2009	28	1	Unconfined
2	3844503	3/9/1981 - 11/16/2009	25	1	Unconfined
2	3844701	4/11/2006	1	0.5	Unconfined
2	3844906	8/23/1982	1	0.7	Unconfined
2	3845403	3/15/1982 - 11/14/1996	16	1	Unconfined
2	3850301	7/22/1993 - 10/31/2013	17	1	Unconfined
2	3851301	3/15/1982 - 11/15/1996	14	1	Unconfined
2	3852701	3/9/1981 - 11/13/1998	16	1	Unconfined
2	3857502	3/17/1982 - 11/13/2002	21	1	Unconfined
2	3964901	3/17/1982 - 10/31/2013	28	0.99	Unconfined
2	5908201	3/18/1982 - 11/4/1997	7	1	Unconfined
2	5908403	10/17/1991	1	0.5	Unconfined
2	5908701	3/17/1982 - 10/31/2013	30	0.96	Unconfined
2	5916102	12/16/1982 - 10/31/2013	27	0.99	Unconfined
2	6001401	9/30/1987	1	0.5	Unconfined
2	6001502	3/10/1981 - 10/31/2013	16	1	Unconfined
2	6001602	3/17/1982 - 2/21/2001	14	0.94	Unconfined
2	6003201	7/19/1995 - 9/7/2007	16	0.94	Unconfined
2	6003202	3/10/1981 - 9/7/2007	29	0.92	Unconfined
2	6003902	3/10/1981 - 10/9/2012	17	1	Unconfined
2	313121092512401	3/12/1980 - 10/17/2013	172	1	Unconfined
2	313925093044401	6/14/1996 - 10/24/2013	8	0.7	Unconfined
4	1652901	3/18/1981 - 11/13/2013	32	1	Unconfined
4	1655602	11/3/1982 - 11/13/2013	29	0.98	Unconfined
4	1655702	11/4/1982 - 11/30/2010	28	0.99	Unconfined
4	1659706	3/18/1993	1	0.7	Unconfined
4	1660901	8/9/1993	1	0.7	Unconfined
4	1661701	3/18/1981 - 11/7/1996	15	1	Unconfined
4	1664506	4/9/1998 - 10/17/2002	2	1	Unconfined
4	3406610	6/11/1998	1	0.7	Unconfined
4	3408905	3/17/1981 - 11/14/2013	33	1	Unconfined
4	3414408	8/12/1993	1	0.7	Unconfined
4	3414409	5/21/1998	1	0.7	Unconfined
4	3414410	6/14/2006	1	0.7	Unconfined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
4	3414801	3/12/1981 - 11/12/2013	32	1	Unconfined
4	3414902	3/16/1982 - 11/17/2000	18	1	Unconfined
4	3416602	5/19/1998 - 4/29/2010	2	1	Unconfined
4	3421404	3/1/1999	1	0.7	Unconfined
4	3421904	8/16/1987 - 8/5/1993	3	1	Unconfined
4	3422301	3/16/1982 - 11/3/2004	16	0.98	Unconfined
4	3422801	3/12/1981 - 11/10/1986	5	1	Unconfined
4	3423101	3/16/1982 - 11/10/1986	5	1	Unconfined
4	3423405	3/12/1981 - 3/15/1982	2	0.7	Confined
4	3423408	3/12/1981 - 2/24/1993	12	0.7	Confined
4	3423503	6/13/2002	1	0.5	Confined
4	3423504	7/2/2002	1	0.5	Confined
4	3423505	6/5/2002	1	0.5	Confined
4	3423805	6/8/2002	1	0.5	Confined
4	3424904	5/19/1998 - 4/28/2010	4	0.93	Unconfined
4	3428902	9/9/1993 - 7/23/2002	2	1	Unconfined
4	3428904	9/20/1985	1	0.7	Unconfined
4	3429502	6/5/1980 - 4/17/1989	2	1	Unconfined
4	3429606	5/25/1984	1	0.7	Unconfined
4	3430301	3/12/1981 - 11/12/2013	31	0.99	Unconfined, Under Layer 1
4	3430907	1/31/1987 - 12/30/2013	1312	1	Unconfined
4	3431701	3/16/1981	1	0.7	Unconfined
4	3435503	11/12/1981 - 11/13/2012	28	1	Unconfined
4	3436311	6/13/2006	1	0.7	Unconfined
4	3436803	11/12/1981 - 11/28/2001	18	1	Unconfined
4	3437106	6/23/2001	1	0.5	Confined
4	3437204	9/23/1985 - 4/18/1989	2	1	Confined
4	3439103	7/7/1987 - 11/12/2013	22	0.97	Unconfined
4	3439206	10/15/1981	1	0.7	Unconfined, Under Layer 1
4	3439207	6/29/1985 - 9/9/1993	3	1	Unconfined, Under Layer 1
4	3439301	11/10/1981 - 11/11/1986	4	1	Unconfined
4	3440301	3/16/1981 - 11/12/2013	29	1	Unconfined
4	3443909	9/19/2002	1	0.7	Unconfined
4	3444205	6/18/1998	1	0.7	Confined
4	3444303	3/9/2004	1	0.7	Unconfined
4	3444304	8/1/1995	1	0.7	Unconfined
4	3444505	11/17/1981 - 11/5/1986	3	1	Unconfined
4	3445407	9/18/1991	1	0.7	Unconfined
4	3446104	11/11/1981 - 11/12/2013	30	0.7	Confined
4	3446114	8/28/1985	1	0.5	Confined
4	3446306	5/19/1988	1	0.5	Confined
4	3447706	11/8/1988	1	0.7	Unconfined
4	3448701	3/16/1981 - 11/21/1996	15	1	Unconfined
4	3451103	3/18/1981 - 11/15/2013	25	1	Unconfined
4	3451906	7/19/1993 - 9/19/2002	2	1	Unconfined
4	3452507	11/17/1981 - 11/15/2013	27	1	Unconfined
4	3453301	11/11/1981 - 11/9/1999	17	0.7	Confined
4	3453303	5/2/1988	1	0.5	Confined
4	3453304	1/6/1989	1	0.5	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
4	3453305	9/18/1984	1	0.5	Confined
4	3455106	9/8/1985	1	0.7	Unconfined
4	3455301	3/23/1982	1	0.7	Unconfined
4	3455401	3/25/1998	1	0.7	Unconfined
4	3458802	3/18/1981 - 10/22/1993	12	1	Unconfined
4	3460409	5/9/1988	1	0.7	Unconfined
4	3460502	6/9/1982 - 11/15/2013	33	1	Unconfined
4	3460506	7/10/1985 - 11/7/1989	2	1	Unconfined
4	3460604	3/19/1981	1	0.7	Unconfined
4	3461905	3/17/1981 - 11/12/2013	35	1	Unconfined
4	3462305	3/17/1981 - 11/13/2012	32	1	Confined
4	3462704	2/14/1989	1	0.7	Unconfined
4	3463204	11/20/1981 - 11/13/2012	33	1	Unconfined
4	3463504	6/10/1982 - 11/13/2013	33	1	Unconfined
4	3501806	11/10/1981 - 11/14/2013	32	1	Unconfined
4	3501807	5/1/1984	1	0.7	Unconfined
4	3502503	8/2/1995 - 11/13/2013	21	1	Unconfined
4	3503704	8/13/1991 - 11/9/1992	7	1	Unconfined, Under Layer 1
4	3505101	4/16/1998	1	0.7	Unconfined
4	3506302	11/4/1982 - 11/8/1996	14	1	Unconfined
4	3506401	11/3/1982 - 11/13/2013	32	1	Unconfined
4	3507402	3/18/1981 - 11/13/2013	28	0.99	Unconfined
4	3508506	8/7/1982	1	0.7	Unconfined
4	3509303	5/19/1998	1	0.7	Unconfined
4	3510102	3/17/1981 - 11/15/2000	20	1	Unconfined
4	3510501	11/10/1981 - 11/14/2012	30	1	Unconfined
4	3510502	3/17/1981 - 11/14/2013	33	1	Unconfined
4	3511202	3/18/1981 - 11/14/2013	33	1	Unconfined
4	3512403	5/13/1998 - 9/11/2002	2	1	Unconfined
4	3517208	7/20/1985 - 4/13/1989	2	1	Unconfined
4	3517701	3/17/1981 - 11/4/2004	23	1	Unconfined, Under Layer 1
4	3518701	3/17/1981 - 11/14/1995	15	1	Unconfined
4	3518706	5/19/1998	1	0.7	Unconfined
4	3520903	3/20/1981 - 1/17/2006	25	1	Unconfined
4	3521401	11/12/1981 - 12/10/2008	27	1	Unconfined
4	3525603	5/13/1998	1	0.7	Unconfined
4	3526401	3/16/1981 - 11/12/2012	32	1	Unconfined
4	3526404	7/25/2002	1	0.7	Unconfined
4	3527101	11/10/1981 - 11/12/2012	29	1	Unconfined
4	3527104	5/12/1998	1	0.7	Unconfined
4	3527402	11/10/1981 - 11/11/2004	23	1	Unconfined
4	3528101	11/12/1981 - 11/17/1986	5	1	Unconfined
4	3529101	3/20/1981 - 12/3/2010	28	1	Unconfined
4	3717907	4/9/2000	1	0.7	Unconfined
4	3718104	9/12/1993	1	0.7	Unconfined
4	3726804	11/11/1982 - 11/18/2013	23	1	Confined
4	3727103	2/17/1980 - 11/19/2013	23	1	Confined
4	3748305	12/7/1982 - 11/30/1989	5	1	Confined
4	3803101	3/19/1981 - 11/13/2013	31	0.99	Unconfined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
4	3804102	3/13/2002	1	0.7	Unconfined
4	3804403	11/18/1981 - 11/11/1996	12	1	Unconfined
4	3805703	3/14/2002	1	0.5	Unconfined, Under Layer 1
4	3805806	3/14/1988	1	0.7	Unconfined
4	3806106	3/17/1981 - 12/16/1993	13	1	Unconfined
4	3806107	5/31/1983	1	0.7	Unconfined
4	3806205	3/17/1982 - 11/13/2012	30	0.98	Unconfined
4	3806409	9/29/1987	1	0.7	Unconfined
4	3806608	10/28/1987	1	0.7	Unconfined
4	3807105	8/15/1984	1	0.7	Unconfined
4	3807106	3/15/1988	1	0.7	Unconfined
4	3807203	11/20/1981 - 11/9/1995	13	1	Unconfined
4	3807403	4/26/1988	1	0.7	Unconfined
4	3807404	4/26/1988	1	0.7	Unconfined
4	3807509	3/28/2002	1	0.7	Unconfined
4	3808207	3/17/1981 - 11/9/2006	23	0.92	Unconfined
4	3811802	11/18/1981 - 11/12/1996	12	1	Unconfined
4	3812501	11/18/1981	1	0.7	Unconfined
4	3812903	7/3/1986	1	0.7	Unconfined
4	3815107	10/27/1982	1	0.7	Unconfined
4	3815803	3/16/1981 - 11/9/1995	16	1	Unconfined
4	3820201	11/6/1991	1	0.5	Unconfined
4	3821507	3/20/1981 - 11/18/1981	2	1	Unconfined
4	3821904	11/18/1981 - 11/14/2013	29	1	Unconfined, Under Layer 1
4	3822802	3/26/2002	1	0.7	Unconfined
4	3823203	3/18/1982 - 11/13/1992	11	1	Unconfined
4	3824101	3/18/1982 - 11/9/1995	14	1	Unconfined
4	3824102	3/18/1982 - 11/12/2013	32	1	Unconfined
4	3826706	3/10/1981 - 10/30/2013	29	1	Unconfined
4	3828604	7/3/1987	1	0.5	Confined
4	3830202	11/18/1981 - 10/11/1990	8	1	Unconfined
4	3830501	11/13/1984 - 11/11/2013	26	1	Unconfined
4	3832903	3/18/1982 - 11/12/2013	31	0.97	Confined
4	3834104	9/15/1993	1	0.7	Unconfined, Under Layer 1
4	3841203	3/19/1982 - 11/1/2013	30	1	Unconfined
4	3841701	3/18/1982 - 11/14/1984	4	0.85	Unconfined
4	3842702	4/28/1981 - 11/19/1996	16	0.93	Confined
4	3849601	9/14/1993	1	0.5	Confined
4	3850101	3/18/1982 - 12/19/1990	9	1	Confined
4	3850102	11/15/1991 - 10/31/2013	20	1	Confined
4	3940303	3/10/1981 - 10/30/2013	33	1	Unconfined
4	3947605	9/14/1993	1	0.7	Unconfined
4	3947906	5/31/1995	1	0.7	Unconfined
4	3947907	5/31/1995	1	0.7	Unconfined
4	3955701	3/10/1981 - 10/29/2013	30	1	Unconfined
4	3956703	9/5/2003	1	0.5	Confined
4	3956902	3/18/1982 - 11/7/1995	7	1	Confined
4	3963301	9/16/1993	1	0.5	Confined
4	3963302	3/10/1981 - 11/15/1991	10	1	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
4	3963303	11/18/1983 - 12/1/1986	2	1	Confined
4	3964703	3/10/1981 - 12/13/1984	5	1	Confined
4	5907202	3/18/1982 - 11/19/1982	2	1	Confined
4	6001204	1/26/1983 - 7/23/1993	2	0.7	Confined
6	1655901	8/1/1995 - 11/14/2012	16	1	Confined
6	1655904	2/27/1992	1	0.5	Confined
6	1656716	3/18/1981 - 11/13/2013	26	0.98	Confined
6	1659902	11/3/1982 - 10/13/1989	7	0.7	Confined
6	1661603	11/3/1982 - 10/13/1988	6	1	Confined
6	1663402	3/18/1981 - 11/14/2012	31	1	Confined
6	1663503	11/4/1981	1	0.5	Confined
6	1663803	3/18/1981 - 11/13/2013	28	0.99	Confined
6	1663905	9/19/2001	1	0.5	Confined
6	1664204	6/17/1980	1	0.5	Confined
6	3406608	4/5/1989	1	0.5	Unconfined
6	3406609	9/21/1988 - 8/15/1991	2	0.7	Unconfined
6	3407503	11/2/2010 - 11/12/2013	4	1	Unconfined
6	3408104	5/20/1998	1	0.7	Unconfined
6	3412803	3/12/1981 - 11/12/2013	33	1	Unconfined
6	3412902	3/12/1981 - 11/12/2013	32	1	Confined
6	3413309	4/27/2010 - 11/12/2013	5	1	Unconfined
6	3413501	4/5/1989	1	0.7	Confined
6	3413503	4/5/1989	1	0.7	Confined
6	3415106	9/29/1997	1	0.5	Confined
6	3415802	2/28/1989	1	0.5	Confined
6	3416704	9/1/1988	1	0.5	Confined
6	3420309	4/8/1994	1	0.5	Confined
6	3420310	4/14/1994	1	0.5	Confined
6	3420903	4/8/1999	1	0.5	Confined
6	3421405	3/7/2007	1	0.5	Confined
6	3421501	3/12/1981 - 11/12/2013	30	1	Confined
6	3421502	10/30/1980 - 4/7/1989	2	0.7	Confined
6	3421702	4/4/1989	1	0.5	Confined
6	3421703	11/27/1980 - 4/4/1989	2	1	Confined
6	3421704	11/4/1988	1	0.5	Confined
6	3423205	6/9/1987	1	0.5	Confined
6	3423303	2/27/1990 - 11/30/1998	2	1	Confined
6	3423409	2/14/1983	1	0.5	Confined
6	3428807	8/19/1982 - 4/14/1989	2	1	Confined
6	3428808	12/8/1982	1	0.7	Confined
6	3429604	8/22/1985 - 11/10/1988	2	0.7	Confined
6	3429605	4/16/1986 - 11/10/1988	3	0.63	Confined
6	3429704	8/25/1988	1	0.5	Confined
6	3429901	4/9/1987	1	0.5	Confined
6	3430205	8/31/1990 - 5/7/1991	2	0.7	Confined
6	3430908	3/25/1987 - 4/5/2006	3	0.7	Confined
6	3431222	4/7/1989	1	0.5	Confined
6	3431505	7/27/1983	1	0.5	Confined
6	3431506	8/24/1989 - 11/13/2003	9	1	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
6	3431507	8/2/1989 - 9/18/1990	2	0.7	Confined
6	3432403	3/17/1981 - 11/16/1999	17	1	Confined
6	3434801	3/13/1981 - 11/26/2007	24	1	Confined
6	3435304	9/26/1980	1	0.7	Confined
6	3436204	6/18/2002	1	0.5	Confined
6	3436205	12/19/2002	1	0.5	Confined
6	3436703	3/20/1989	1	0.5	Confined
6	3436903	6/30/1980	1	0.7	Confined
6	3437203	11/9/1988	1	0.5	Confined
6	3437305	11/11/1981 - 11/29/2011	28	1	Confined
6	3438201	11/10/1988 - 11/12/2013	5	0.7	Confined
6	3438311	3/16/1981 - 6/14/1994	13	0.86	Confined
6	3438312	1/7/1985 - 11/10/1988	2	0.7	Confined
6	3438313	11/10/1988	1	0.5	Confined
6	3438404	6/14/1999	1	0.5	Confined
6	3438510	4/8/1987 - 11/11/1988	2	0.7	Confined
6	3438608	6/24/1999	1	0.5	Confined
6	3439102	6/19/1987	1	0.5	Confined
6	3439602	3/28/2002	1	0.5	Confined
6	3440102	3/16/1981 - 11/27/2001	16	1	Confined
6	3441305	9/18/1995 - 3/13/1996	2	1	Unconfined
6	3441309	3/13/1996	1	0.7	Unconfined
6	3442902	8/11/1986	1	0.5	Confined
6	3442903	9/18/2002	1	0.5	Confined
6	3444803	9/16/1999	1	0.5	Confined
6	3444908	12/3/1999 - 10/16/2002	2	0.7	Confined
6	3445103	11/17/1981	1	0.7	Confined
6	3445401	11/17/1981	1	0.7	Confined
6	3445507	3/14/2000	1	0.5	Confined
6	3445609	5/6/1988	1	0.5	Confined
6	3445803	3/16/1981 - 11/15/2012	24	0.68	Confined
6	3445804	3/16/1981	1	0.7	Confined
6	3446111	4/15/1987	1	0.5	Confined
6	3447103	11/10/1981 - 11/21/1996	12	1	Confined
6	3447704	8/1/1983 - 10/21/2013	24	0.96	Confined
6	3447707	12/29/1984	1	0.5	Confined
6	3448702	8/28/1985 - 4/18/1989	2	0.7	Confined
6	3448704	5/14/1994 - 5/20/1999	2	1	Confined
6	3448705	9/27/2004	1	0.5	Confined
6	3452609	10/20/1988	1	0.5	Confined
6	3452610	10/20/1991 - 10/16/2002	2	0.6	Confined
6	3453204	3/4/2003	1	0.7	Confined
6	3453205	3/20/1999	1	0.5	Confined
6	3453503	10/31/2004	1	0.5	Confined
6	3453604	9/26/1983 - 10/21/2013	26	1	Confined
6	3453606	6/2/1999	1	0.5	Confined
6	3453607	6/12/2004	1	0.5	Confined
6	3453804	12/6/1988	1	0.5	Confined
6	3454105	11/18/1998	1	0.5	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
6	3454503	11/11/1981 - 11/12/2013	21	0.99	Confined
6	3454504	5/20/1988	1	0.5	Confined
6	3454602	3/16/1981 - 11/15/2012	23	0.96	Confined
6	3454603	3/11/1987	1	0.5	Confined
6	3454802	7/20/1995 - 11/9/1999	6	1	Confined
6	3456703	11/11/1981 - 11/15/1984	3	1	Confined
6	3457301	3/18/1981 - 11/15/2013	33	1	Confined
6	3457806	10/11/1989	1	0.5	Confined
6	3460505	2/19/1988 - 11/15/2013	24	1	Confined
6	3460602	1/18/1991 - 11/13/2012	18	0.97	Confined
6	3460605	3/3/1983 - 10/16/1989	2	0.7	Confined
6	3460802	4/16/1987	1	0.5	Confined
6	3460904	6/6/1989 - 3/19/1996	2	0.6	Confined
6	3460905	10/16/1989	1	0.5	Confined
6	3460906	6/22/2004	1	0.5	Confined
6	3461902	3/17/1981 - 11/12/2013	27	0.96	Confined
6	3461906	8/28/1985	1	0.5	Confined
6	3462705	4/20/1983	1	0.5	Confined
6	3462706	2/5/1998	1	0.5	Confined
6	3463106	6/6/1988 - 2/14/1989	2	0.7	Confined
6	3463503	11/1/1982 - 11/6/2008	22	0.99	Confined
6	3464302	3/17/1981 - 11/12/2013	28	0.99	Unconfined
6	3464708	7/8/1985	1	0.5	Confined
6	3464711	5/25/1988	1	0.7	Confined
6	3464712	5/13/1988	1	0.7	Confined
6	3464713	5/16/1985 - 2/15/1989	2	1	Confined
6	3464714	7/1/1985 - 2/15/1989	2	0.7	Confined
6	3464805	5/15/1985 - 3/16/1988	2	1	Confined
6	3503403	11/4/1982 - 11/11/1991	9	1	Confined
6	3505503	8/18/1999	1	0.5	Confined
6	3507303	3/15/2001	1	0.5	Confined
6	3508512	9/30/1981	1	0.5	Confined
6	3509202	3/17/1981 - 11/12/1990	7	0.96	Confined
6	3509403	11/10/1981 - 11/14/2013	24	1	Confined
6	3509805	6/30/1985 - 10/21/1987	2	0.7	Confined
6	3511404	8/4/1993	1	0.5	Confined
6	3511407	4/13/1989	1	0.5	Confined
6	3514101	9/11/2002	1	0.5	Confined
6	3514510	4/14/1998 - 9/12/2002	2	1	Unconfined, Under Layer 1
6	3517802	10/20/1987	1	0.5	Confined
6	3517903	5/8/2006	1	0.5	Confined
6	3518301	11/9/1981 - 11/6/1984	3	1	Confined
6	3518401	3/17/1981 - 11/14/2013	29	0.99	Confined
6	3518707	3/1/2002	1	0.5	Confined
6	3518805	10/23/1987	1	0.7	Confined
6	3525403	10/20/1987	1	0.5	Confined
6	3525602	11/10/1981 - 2/11/1988	6	0.7	Confined
6	3526204	10/14/1987	1	0.5	Confined
6	3527407	7/5/2000	1	0.5	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
6	3527408	5/9/2000	1	0.5	Confined
6	3533503	1/25/1987	1	0.5	Confined
6	3535501	3/17/1981 - 11/15/1995	15	1	Confined
6	3542505	2/18/2010 - 12/12/2013	15	1	Unconfined
6	3542506	8/1/2010 - 12/12/2013	14	1	Confined
6	3542508	9/1/2009 - 12/12/2013	16	1	Unconfined
6	3542509	5/1/2009 - 12/12/2013	18	1	Unconfined
6	3542704	9/1/2009 - 12/12/2013	16	1	Unconfined
6	3542801	11/12/1981 - 11/17/1994	11	1	Unconfined
6	3549406	7/29/2011 - 12/13/2013	10	1	Unconfined, Under Layer 1
6	3549608	9/1/2009 - 12/13/2013	15	1	Unconfined
6	3549609	2/10/2010 - 12/13/2013	15	1	Unconfined
6	3549610	2/10/2010 - 4/21/2011	6	0.7	Unconfined
6	3550407	9/1/2009 - 4/21/2011	6	0.7	Unconfined
6	3557205	7/14/1981	1	0.7	Unconfined
6	3557409	2/7/1981 - 3/8/1988	2	1	Unconfined, Under Layer 1
6	3557503	3/31/1981 - 7/14/1981	2	1	Unconfined
6	3557506	3/31/1981	1	0.7	Unconfined, Under Layer 1
6	3557508	7/14/1981	1	0.7	Unconfined
6	3701204	2/21/2012 - 12/19/2013	7	1	Confined
6	3701405	7/3/1985 - 3/15/1988	2	0.7	Confined
6	3701501	1/3/1980 - 11/17/1992	803	1	Confined
6	3702502	2/16/2010 - 12/19/2013	13	1	Confined
6	3705101	6/24/1986	1	0.7	Unconfined
6	3709104	11/9/1982 - 11/13/2013	28	0.99	Unconfined
6	3710402	3/26/1982 - 12/6/2005	24	0.98	Confined
6	3710408	12/25/2003	1	0.5	Confined
6	3710703	3/19/1982 - 11/19/2013	31	1	Confined
6	3711504	3/26/1982 - 12/6/1988	6	0.7	Unconfined
6	3717306	7/1/1988	1	0.5	Confined
6	3717307	1/20/1989	1	0.5	Confined
6	3717908	10/21/2008	1	0.5	Confined
6	3719301	3/26/1982 - 11/19/2013	22	0.99	Confined
6	3719401	5/10/1988	1	0.7	Confined
6	3719406	7/13/2004	1	0.5	Confined
6	3719803	3/31/1999 - 7/24/2003	2	0.6	Confined
6	3726201	3/19/1991	1	0.5	Confined
6	3726602	8/14/2000	1	0.5	Confined
6	3727304	5/18/1988 - 11/19/2013	3	0.63	Confined
6	3727504	5/18/1988	1	0.5	Confined
6	3727505	5/18/1988	1	0.5	Confined
6	3727506	3/26/1982 - 11/16/2011	27	0.99	Confined
6	3727508	9/14/1987	1	0.5	Confined
6	3727601	5/19/1988	1	0.5	Confined
6	3727605	11/7/2000	1	0.5	Confined
6	3727802	5/18/1988	1	0.5	Confined
6	3727808	3/27/2003	1	0.5	Confined
6	3728303	5/12/1988	1	0.5	Confined
6	3728401	2/7/1985	1	0.5	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
6	3728503	3/11/1985	1	0.5	Confined
6	3728505	3/18/2002 - 7/24/2003	2	0.7	Confined
6	3728604	9/5/2001	1	0.5	Confined
6	3728902	3/25/1982 - 11/19/2013	23	1	Confined
6	3729102	3/25/1982 - 12/3/2009	28	1	Confined
6	3729103	11/10/2010 - 11/19/2013	4	1	Confined
6	3729402	3/25/1982 - 11/19/2013	29	1	Confined
6	3729406	1/8/2003	1	0.5	Confined
6	3729505	11/19/1990	1	0.5	Confined
6	3730801	3/25/1982 - 11/19/2013	33	1	Confined
6	3732111	3/22/1982 - 11/20/2013	31	1	Unconfined
6	3732405	11/5/1984	1	0.7	Unconfined, Under Layer 1
6	3732709	11/18/1998 - 11/20/2013	17	0.95	Confined
6	3733202	3/9/1988 - 11/12/2013	24	0.99	Confined
6	3733205	1/29/1981	1	0.7	Confined
6	3733207	6/20/1996	1	0.5	Confined
6	3734103	5/10/1988	1	0.5	Confined
6	3734104	2/28/1998	1	0.7	Confined
6	3734405	8/5/2013	1	0.5	Confined
6	3734505	3/25/1982 - 11/15/2011	24	0.99	Confined
6	3734508	9/24/2003 - 4/19/2006	2	0.7	Confined
6	3734509	4/22/1991	1	0.5	Confined
6	3734603	3/26/1998 - 2/28/2013	18	1	Confined
6	3734604	12/31/2007 - 4/23/2011	12	0.7	Confined
6	3734605	12/31/2007 - 2/28/2013	14	0.7	Confined
6	3734806	9/16/1982 - 12/12/1988	3	1	Confined
6	3734807	10/9/2003	1	0.5	Confined
6	3734902	2/24/1982 - 2/28/2013	22	1	Confined
6	3735408	2/24/1982 - 2/28/2013	24	1	Confined
6	3735409	1/31/1980 - 2/28/2013	18	1	Confined
6	3735701	3/1/2006 - 2/28/2013	17	0.7	Confined
6	3735702	2/24/1982 - 2/28/2013	23	1	Confined
6	3735703	2/24/1982 - 2/28/2013	25	1	Confined
6	3735705	2/24/1982 - 2/24/1988	6	1	Confined
6	3735714	9/1/2006 - 2/28/2013	17	1	Confined
6	3735715	4/24/1980	1	0.7	Confined
6	3735716	6/15/1993 - 2/28/2013	18	0.7	Confined
6	3735903	12/13/1988	1	0.5	Confined
6	3735904	12/14/1988 - 3/5/2002	2	0.7	Confined
6	3736403	11/12/1982 - 11/8/1985	4	1	Confined
6	3736501	11/12/1982 - 11/14/1995	13	1	Confined
6	3736802	11/8/1984 - 10/10/1989	4	1	Confined
6	3737804	11/11/1982 - 11/18/1993	10	1	Confined
6	3742202	5/16/1988	1	0.7	Confined
6	3742304	3/6/2002	1	0.5	Confined
6	3743102	5/15/1988 - 12/12/1988	2	0.7	Confined
6	3744202	10/23/1999 - 11/1/2005	3	0.63	Confined
6	3801504	9/8/1981 - 3/12/2002	3	1	Confined
6	3803603	11/19/1986 - 9/15/1989	2	0.6	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
6	3803703	11/18/1981 - 2/23/1993	11	0.7	Confined
6	3804307	8/18/2011	1	0.5	Confined
6	3804805	11/18/1981	1	0.7	Confined
6	3805607	2/16/1989	1	0.7	Confined
6	3805608	9/22/1988	1	0.5	Confined
6	3805903	7/15/1984	1	0.5	Confined
6	3806408	11/8/1982 - 11/7/2001	18	0.98	Confined
6	3806503	5/17/1986	1	0.5	Confined
6	3806805	11/10/1987	1	0.5	Confined
6	3807703	4/26/1988	1	0.5	Confined
6	3808112	6/30/1983	1	0.7	Confined
6	3808113	8/3/1983	1	0.7	Confined
6	3808114	8/17/1983 - 3/16/1988	2	1	Confined
6	3808115	7/13/1985 - 3/16/1988	2	0.7	Confined
6	3808117	7/16/1985	1	0.5	Confined
6	3808118	7/10/1987	1	0.7	Confined
6	3808119	2/15/1989	1	0.7	Confined
6	3808120	10/25/1985 - 2/15/1989	2	0.85	Confined
6	3808206	8/11/1981	1	0.7	Confined
6	3808406	5/28/1985	1	0.5	Confined
6	3808806	1/6/1983 - 3/15/1988	2	1	Unconfined
6	3808807	5/31/1983 - 3/15/1988	2	1	Unconfined
6	3808808	6/2/1988	1	0.7	Unconfined
6	3812303	6/28/2003	1	0.5	Confined
6	3812502	3/20/1981 - 11/15/2012	26	0.95	Confined
6	3812703	3/11/2002	1	0.5	Confined
6	3812904	5/4/1989	1	0.5	Confined
6	3813106	11/17/1983 - 11/15/2012	27	0.99	Confined
6	3813107	1/26/1982 - 3/14/2002	3	0.9	Confined
6	3813305	6/6/2000	1	0.5	Confined
6	3814308	7/26/2000	1	0.5	Confined
6	3814509	3/18/1985 - 4/20/1988	2	0.6	Confined
6	3815105	11/1/1985	1	0.5	Confined
6	3815106	11/3/1982 - 4/26/1988	2	0.7	Confined
6	3815108	2/1/1988	1	0.5	Confined
6	3815203	2/27/1981	1	0.7	Confined
6	3815501	4/20/1988	1	0.7	Confined
6	3818703	11/4/1996 - 11/19/1998	3	1	Confined
6	3819404	3/20/1981 - 11/6/2001	17	1	Confined
6	3819603	9/13/1989	1	0.7	Confined
6	3819604	3/15/1995	1	0.5	Confined
6	3819605	3/15/1995	1	0.5	Confined
6	3819802	11/19/1981 - 11/14/2013	29	0.99	Confined
6	3820105	8/28/1982 - 3/20/1996	3	0.7	Confined
6	3820106	9/2/1999	1	0.5	Confined
6	3820503	12/15/1984 - 11/9/1989	2	0.7	Confined
6	3820804	8/8/1992	1	0.5	Confined
6	3823406	3/16/1981 - 11/12/2013	25	1	Confined
6	3824802	3/18/1982 - 10/16/1989	9	1	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
6	3824806	6/5/1986 - 11/12/2013	16	0.98	Confined
6	3826109	9/12/2000 - 11/18/2009	9	1	Confined
6	3826111	10/30/2013	1	0.5	Confined
6	3826401	12/20/1993 - 10/30/2013	8	0.96	Confined
6	3828701	3/15/1982 - 11/28/1989	8	0.7	Confined
6	3829701	10/14/1991	1	0.5	Confined
6	3829802	7/31/1980	1	0.7	Confined
6	3830502	5/31/1983	1	0.5	Confined
6	3834301	4/29/1981	1	0.7	Confined
6	3836702	9/22/2010	1	0.5	Confined
6	3837105	3/9/1981 - 2/10/1988	5	0.82	Confined
6	3838705	6/16/1980	1	0.7	Confined
6	3839503	8/31/1983	1	0.5	Confined
6	3841901	11/2/1989	1	0.5	Confined
6	3841902	8/21/2003	1	0.5	Confined
6	3843101	4/28/1981 - 10/30/2013	32	1	Confined
6	3844505	8/8/1983	1	0.5	Confined
6	3846502	11/27/1983	1	0.5	Confined
6	3849502	10/10/1989	1	0.5	Confined
6	3849802	3/18/1982 - 10/31/2013	32	1	Confined
6	3857701	3/10/1981 - 12/13/2006	16	0.91	Confined
6	3940601	4/28/1981 - 11/1/2013	33	1	Confined
6	3940702	6/11/1984	1	0.5	Confined
6	3946601	4/30/1981	1	0.7	Unconfined
6	3947905	2/3/1982	1	0.7	Confined
6	3948101	4/28/1981 - 1/31/1989	8	1	Confined
6	3948401	4/30/1981	1	0.7	Confined
6	3948701	5/3/1995 - 7/8/2002	2	0.7	Confined
6	3948702	5/3/1995	1	0.5	Confined
6	3954604	1/30/1981 - 10/29/2013	649	1	Confined
6	3955203	4/30/1981	1	0.7	Confined
6	3955302	3/10/1981 - 11/1/2013	26	1	Confined
6	3955804	5/1/1981	1	0.5	Confined
6	3955902	3/18/1982 - 10/29/2013	30	0.99	Confined
6	3956102	4/29/1981	1	0.7	Confined
6	3956301	11/18/1982 - 11/1/2013	25	1	Confined
6	3956802	9/5/1989	1	0.5	Confined
6	3964704	11/3/1986	1	0.5	Confined
6	3964705	6/30/1991 - 10/31/2013	20	0.93	Confined
6	6001101	9/17/1981	1	0.7	Confined
7	1639703	2/2/1981	1	0.5	Unconfined
7	1639704	5/28/1984	1	0.5	Unconfined
7	1640706	3/23/1993	1	0.7	Unconfined
7	1640708	7/22/1986	1	0.7	Unconfined
7	1640709	11/7/1990	1	0.7	Unconfined
7	1640714	9/12/1994	1	0.7	Unconfined
7	1646602	11/2/1982 - 11/15/2013	31	1	Unconfined
7	1646604	4/7/1998	1	0.7	Unconfined
7	1646901	10/31/1980	1	0.7	Unconfined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
7	1647102	11/2/1982 - 11/7/1996	14	1	Unconfined, Under Layer 1
7	1648102	10/25/1985	1	0.7	Unconfined
7	1649212	3/11/1981 - 11/12/2012	24	0.99	Unconfined
7	1649213	5/18/2006	1	0.7	Unconfined
7	1650501	11/5/1982 - 11/9/1990	8	1	Unconfined
7	1653602	3/18/1981 - 11/13/2013	29	1	Unconfined
7	1654602	6/16/2003	1	0.5	Confined
7	1654603	6/2/2003	1	0.5	Confined
7	1654604	4/29/2003	1	0.5	Confined
7	1654605	5/15/2003	1	0.5	Confined
7	1654606	1/31/1986	1	0.5	Confined
7	1655307	8/1/2002	1	0.5	Confined
7	1657407	10/25/1982 - 10/11/1988	6	1	Confined
7	1659710	3/10/1981 - 11/16/2011	30	0.99	Confined
7	1661201	6/25/1999	1	0.5	Confined
7	1661301	9/28/1984	1	0.5	Confined
7	1662403	5/19/2004	1	0.5	Confined
7	1662602	1/22/1991	1	0.5	Confined
7	1663902	3/18/1981 - 10/13/1988	7	1	Confined
7	3406102	6/10/1998	1	0.7	Confined
7	3406304	3/11/1981 - 12/10/1986	5	0.94	Confined
7	3406607	10/21/1988	1	0.5	Confined
7	3407802	8/16/1986	1	0.5	Confined
7	3408501	3/17/1981 - 11/11/1983	3	0.9	Confined
7	3412905	5/4/2005	1	0.5	Confined
7	3413203	10/7/1984	1	0.5	Confined
7	3413507	4/5/1989	1	0.7	Confined
7	3413809	4/10/1989	1	0.5	Confined
7	3414603	5/9/1991	1	0.5	Confined
7	3416703	5/15/1985 - 4/12/1989	2	0.7	Confined
7	3416901	3/21/1980	1	0.7	Confined
7	3419423	6/18/1988 - 2/20/1989	2	1	Unconfined
7	3420306	6/27/1980	1	0.7	Confined
7	3420307	5/23/1991	1	0.5	Confined
7	3420308	5/26/1999	1	0.7	Confined
7	3420608	5/30/1986	1	0.5	Confined
7	3420707	3/12/1981 - 11/13/2013	29	1	Unconfined, Under Layer 1
7	3421302	3/16/1982 - 11/12/2013	30	1	Confined
7	3421403	2/23/1987 - 5/7/1991	2	0.6	Confined
7	3421701	3/16/1982 - 11/8/1984	4	1	Confined
7	3421804	8/1/1989 - 5/9/1991	2	0.7	Confined
7	3421805	2/28/1995 - 8/25/1999	2	1	Confined
7	3422205	6/1/1983 - 5/7/1991	2	0.7	Confined
7	3423302	7/20/1985	1	0.5	Confined
7	3423410	8/15/1991 - 11/13/2012	3	0.7	Confined
7	3423705	5/7/1991	1	0.7	Confined
7	3424401	11/30/1998	1	0.7	Confined
7	3424402	11/27/1981 - 10/20/1987	2	1	Confined
7	3424703	2/14/1983 - 10/20/1987	2	0.7	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
7	3426606	3/15/1989	1	0.5	Unconfined
7	3426904	9/11/1985 - 3/15/1989	2	1	Unconfined
7	3427905	3/16/1989	1	0.7	Unconfined
7	3428408	11/12/1981 - 11/13/2013	30	1	Unconfined
7	3428801	3/16/1981 - 11/14/1991	11	1	Confined
7	3429403	10/23/1986 - 11/9/1988	2	0.7	Confined
7	3429902	4/9/1987 - 11/12/2013	26	0.99	Confined
7	3429905	10/23/1996	1	0.5	Confined
7	3431221	4/7/1989	1	0.7	Confined
7	3431902	11/4/2010 - 11/12/2013	3	0.7	Confined
7	3434101	11/12/1981 - 11/13/2013	28	1	Unconfined
7	3434906	7/30/1980 - 3/16/1989	2	1	Confined
7	3434907	11/14/1988 - 3/20/1989	2	0.7	Confined
7	3435305	9/25/1980	1	0.7	Confined
7	3435501	11/12/1981 - 11/29/1989	8	1	Confined
7	3436306	1/23/1986 - 11/7/1988	3	0.63	Confined
7	3437104	11/20/1984 - 11/9/1988	2	0.7	Confined
7	3437105	8/18/1980 - 4/17/1989	2	1	Confined
7	3437202	11/9/1988	1	0.5	Confined
7	3437304	1/9/1999 - 5/26/1999	2	1	Confined
7	3437307	4/9/1987 - 11/10/1988	2	0.5	Confined
7	3437308	11/9/1988	1	0.5	Confined
7	3437309	12/7/1981 - 11/10/1988	2	1	Confined
7	3437310	4/16/1987 - 11/14/1988	2	0.7	Confined
7	3437311	6/30/1989 - 12/15/1999	12	0.98	Confined
7	3437405	11/11/1988	1	0.5	Confined
7	3437406	11/11/1988	1	0.7	Confined
7	3437407	7/12/1982 - 11/11/1988	2	1	Confined
7	3437901	4/7/1987 - 11/14/1988	2	0.7	Confined
7	3437902	3/31/1985 - 11/9/1988	3	0.63	Confined
7	3438403	4/18/1989	1	0.5	Confined
7	3438405	10/6/2004	1	0.5	Confined
7	3438805	11/11/1981 - 6/17/2010	27	1	Confined
7	3438913	11/15/1988	1	0.5	Confined
7	3438914	2/3/1987 - 9/9/1993	3	0.7	Confined
7	3439506	12/31/2005	1	0.5	Confined
7	3439507	6/27/2006	1	0.5	Confined
7	3439901	4/1/1998	1	0.7	Confined
7	3440203	12/20/1997	1	0.7	Confined
7	3440503	12/6/2005	1	0.5	Confined
7	3440504	12/10/2005	1	0.5	Confined
7	3440709	12/14/1988	1	0.5	Confined
7	3440710	1/27/1984	1	0.5	Confined
7	3441304	7/26/1995 - 11/9/1998	19	0.62	Confined
7	3441306	9/18/1995 - 3/13/1996	2	0.7	Unconfined
7	3441307	3/13/1996	1	0.7	Unconfined
7	3441308	3/13/1996	1	0.5	Unconfined
7	3441316	5/5/2009 - 5/31/2011	3	0.7	Confined
7	3442108	3/13/1981 - 11/13/2013	34	1	Unconfined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
7	3443603	11/17/1981 - 11/15/2013	29	0.98	Confined
7	3444104	10/13/1981	1	0.7	Confined
7	3444105	10/21/1981	1	0.7	Confined
7	3444707	5/7/1991	1	0.5	Confined
7	3445206	10/8/1998	1	0.5	Confined
7	3445304	1/23/1996	1	0.5	Confined
7	3446113	11/8/1988 - 10/21/2013	24	1	Confined
7	3446511	12/14/1987 - 6/17/2010	22	0.99	Confined
7	3446512	2/14/1982	1	0.7	Confined
7	3446809	12/9/1982 - 5/20/1986	2	1	Confined
7	3446812	4/11/1996	1	0.5	Confined
7	3447205	3/19/1998	1	0.7	Confined
7	3447302	7/15/1988 - 11/16/1988	2	0.7	Confined
7	3447305	10/15/1998	1	0.7	Confined
7	3447902	12/14/2001 - 5/7/2002	3	0.7	Confined
7	3448204	1/21/1987 - 11/15/2012	24	0.99	Confined
7	3448303	4/10/1986 - 2/9/1987	2	0.7	Confined
7	3448304	7/15/2011 - 11/15/2012	4	0.7	Confined
7	3448501	3/25/1998	1	0.7	Confined
7	3448503	3/18/1986 - 11/15/2000	11	1	Confined
7	3448604	3/12/1987 - 12/8/2010	20	0.99	Confined
7	3448802	11/10/1981 - 11/13/1995	8	1	Confined
7	3448804	9/24/1982	1	0.7	Confined
7	3448805	3/23/1981 - 8/17/1989	2	1	Confined
7	3450307	12/28/1998 - 8/27/1999	2	0.7	Confined
7	3451107	9/5/1983 - 4/10/1987	2	0.7	Confined
7	3452313	1/7/2002	1	0.5	Confined
7	3452504	3/18/1981 - 11/17/1981	2	1	Confined
7	3452608	6/5/1987	1	0.7	Confined
7	3453608	8/30/2004	1	0.5	Confined
7	3454207	11/8/1988	1	0.5	Confined
7	3454306	9/16/1985	1	0.5	Confined
7	3454307	5/9/2002	1	0.5	Confined
7	3454505	7/9/2007	1	0.5	Confined
7	3454604	4/6/1989	1	0.5	Confined
7	3454705	12/27/2006	1	0.5	Confined
7	3455303	4/10/1987 - 11/8/2007	20	1	Confined
7	3455304	3/16/1984 - 8/17/1989	2	0.6	Confined
7	3455408	8/29/1990	1	0.5	Confined
7	3455410	7/15/2008	1	0.5	Confined
7	3455411	5/28/2008	1	0.5	Confined
7	3455914	8/8/1984	1	0.5	Confined
7	3457309	12/1/2011	1	0.5	Confined
7	3457801	10/11/1989	1	0.5	Unconfined
7	3457804	10/11/1989	1	0.5	Confined
7	3457805	10/11/1989	1	0.5	Confined
7	3459302	3/19/1981 - 11/5/1986	4	0.93	Confined
7	3459306	8/16/1988 - 11/8/1989	2	0.7	Confined
7	3461108	10/16/1989	1	0.5	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
7	3461203	5/28/1998	1	0.7	Confined
7	3461205	5/30/2009	1	0.5	Confined
7	3461307	11/3/1993 - 10/21/2013	20	1	Confined
7	3461501	3/19/1981 - 11/13/2013	32	0.98	Confined
7	3462203	10/19/1981 - 3/10/1987	2	1	Confined
7	3463501	11/1/1982 - 12/3/2011	27	0.99	Confined
7	3464402	11/13/1981 - 11/9/1985	4	0.85	Confined
7	3464507	4/13/2004	1	0.5	Confined
7	3501102	10/25/1982 - 12/9/1986	4	1	Confined
7	3501116	11/18/1981	1	0.7	Confined
7	3501502	5/13/1992	1	0.5	Confined
7	3501803	3/17/1981 - 11/12/2008	22	1	Confined
7	3501902	3/30/1992	1	0.5	Confined
7	3507902	3/18/1981 - 11/8/1996	14	1	Confined
7	3510303	5/21/1987	1	0.5	Confined
7	3510401	9/17/1992	1	0.5	Confined
7	3511402	3/17/1981 - 11/14/2013	31	1	Confined
7	3512505	6/5/1981	1	0.5	Confined
7	3517103	11/7/1984 - 11/6/1997	9	1	Confined
7	3517209	10/21/1987	1	0.5	Confined
7	3517304	3/14/1985	1	0.5	Confined
7	3517402	4/30/1986	1	0.5	Confined
7	3517403	10/20/1987	1	0.5	Confined
7	3517404	10/20/1987 - 12/31/1998	2	1	Confined
7	3517405	3/22/1987 - 11/14/2012	19	0.94	Confined
7	3517501	11/9/1981 - 12/5/1985	4	1	Confined
7	3517505	10/22/1987	1	0.7	Confined
7	3517704	11/25/1987 - 4/12/1989	2	0.7	Confined
7	3517803	5/10/1985 - 10/20/1987	2	0.7	Confined
7	3517804	12/18/1998 - 11/18/2009	11	0.95	Confined
7	3517806	7/25/2003	1	0.5	Confined
7	3518303	9/30/1996 - 11/14/2013	19	0.98	Confined
7	3518602	6/21/1980 - 10/23/1987	2	1	Confined
7	3518806	6/16/1983	1	0.5	Confined
7	3518901	12/6/2000	1	0.5	Confined
7	3518903	7/9/2002	1	0.5	Confined
7	3519202	8/16/1986 - 10/23/1987	2	0.6	Confined
7	3520504	2/9/1988	1	0.5	Confined
7	3520802	8/19/1987	1	0.5	Confined
7	3520803	12/15/1988	1	0.5	Confined
7	3520804	3/23/1995	1	0.5	Confined
7	3520805	11/21/1994	1	0.5	Confined
7	3522401	3/18/1981 - 11/14/2013	25	1	Unconfined
7	3525202	5/3/1985 - 8/14/1997	2	1	Confined
7	3526706	3/16/1981 - 11/12/2012	29	1	Confined
7	3527401	11/10/1981 - 11/17/1986	4	1	Confined
7	3528202	11/15/1982	1	0.7	Confined
7	3528804	3/17/2010	1	0.5	Confined
7	3533402	11/16/1988	1	0.5	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
7	3533504	10/21/1987	1	0.5	Confined
7	3533603	2/17/1984	1	0.5	Confined
7	3534102	10/15/1987 - 11/20/1996	8	1	Confined
7	3535402	3/17/1981 - 12/2/2010	29	1	Confined
7	3535701	10/20/1987	1	0.5	Confined
7	3536104	8/27/1984	1	0.5	Confined
7	3536105	7/29/1992	1	0.5	Confined
7	3536601	10/30/1984	1	0.7	Confined
7	3541102	7/16/1981	1	0.7	Confined
7	3541402	2/1/2006 - 4/5/2010	50	0.7	Confined
7	3541501	11/12/1981 - 11/18/1983	3	1	Confined
7	3541601	11/12/1981 - 11/13/2013	32	1	Confined
7	3541602	7/16/1981	1	0.7	Confined
7	3541701	3/16/1981 - 11/5/1985	5	1	Confined
7	3541905	3/3/1988	1	0.5	Confined
7	3542207	10/1/2010 - 12/12/2013	12	1	Confined
7	3542406	2/15/2010 - 9/10/2012	10	0.7	Confined
7	3542502	12/16/1987	1	0.7	Unconfined, Under Layer 1
7	3542504	5/1/2009 - 7/1/2010	4	0.7	Unconfined, Under Layer 1
7	3542703	11/8/1987 - 3/12/1988	2	0.7	Confined
7	3542802	12/12/1987 - 12/12/2013	13	1	Unconfined, Under Layer 1
7	3542804	9/1/2010 - 12/12/2013	14	1	Unconfined, Under Layer 1
7	3542805	5/1/2009 - 12/20/2013	19	1	Unconfined, Under Layer 1
7	3543303	7/4/1984	1	0.5	Confined
7	3543402	2/19/2010 - 12/17/2013	16	1	Unconfined, Under Layer 1
7	3543501	3/3/1981 - 11/13/2013	30	1	Confined
7	3543601	3/3/1981 - 10/26/2011	27	1	Unconfined
7	3543702	4/23/1981	1	0.7	Confined
7	3543903	8/3/1983 - 3/15/1988	2	1	Unconfined
7	3545705	9/14/1984	1	0.7	Unconfined
7	3549104	7/28/2011 - 6/14/2012	4	1	Confined
7	3549210	9/12/2005	1	0.5	Confined
7	3549306	3/23/2012 - 12/20/2013	8	1	Confined
7	3549407	12/1/2010 - 3/23/2012	6	1	Confined
7	3549606	5/19/1988 - 11/15/1988	2	0.7	Confined
7	3549801	11/12/1981 - 11/14/2013	32	1	Confined
7	3549808	7/15/1981	1	0.7	Unconfined, Under Layer 1
7	3550202	4/21/1981	1	0.7	Unconfined, Under Layer 1
7	3550302	11/12/1981 - 11/12/1990	8	1	Confined
7	3550405	5/1/2009 - 9/1/2009	2	0.7	Confined
7	3550406	9/1/2009 - 12/13/2013	16	1	Confined
7	3550501	11/12/1981 - 11/14/2013	32	1	Unconfined, Under Layer 1
7	3550502	3/17/1981	1	0.7	Unconfined, Under Layer 1
7	3550505	10/10/1988	1	0.7	Unconfined, Under Layer 1
7	3550506	9/19/1988 - 12/8/1988	2	1	Unconfined, Under Layer 1
7	3550507	9/1/2010 - 3/23/2012	7	1	Unconfined, Under Layer 1
7	3550508	2/19/2010 - 12/13/2013	15	1	Unconfined, Under Layer 1
7	3550603	7/31/1986 - 4/12/1988	2	1	Unconfined
7	3550605	5/1/2009 - 12/20/2013	19	1	Unconfined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
7	3550706	5/1/2009 - 12/20/2013	18	1	Unconfined
7	3550909	5/17/1981	1	0.7	Unconfined
7	3551301	4/11/1988	1	0.7	Unconfined
7	3551503	4/1/1981	1	0.7	Unconfined
7	3551703	9/1/2009 - 3/25/2010	2	1	Unconfined
7	3551705	9/1/2009 - 3/25/2010	2	1	Unconfined
7	3552401	3/20/1981	1	0.7	Unconfined
7	3553103	9/11/1983	1	0.7	Unconfined
7	3557206	7/14/1981	1	0.7	Confined
7	3557207	7/14/1981	1	0.7	Confined
7	3557404	7/14/1981	1	0.7	Unconfined, Under Layer 1
7	3557405	7/14/1981	1	0.7	Unconfined, Under Layer 1
7	3557407	3/31/1981	1	0.7	Unconfined, Under Layer 1
7	3557505	3/31/1981	1	0.7	Confined
7	3557509	7/14/1981	1	0.7	Confined
7	3557510	7/14/1981	1	0.7	Confined
7	3557702	7/14/1981	1	0.7	Confined
7	3557703	7/14/1981	1	0.7	Confined
7	3557704	7/14/1981	1	0.7	Confined
7	3557804	11/15/1988	1	0.5	Confined
7	3558101	3/17/1981 - 11/14/2013	31	1	Unconfined
7	3558104	3/16/1996	1	0.7	Unconfined
7	3558106	5/1/2009 - 12/19/2013	17	1	Unconfined
7	3558107	5/1/2009 - 3/26/2012	9	1	Unconfined
7	3558203	5/1/2009 - 12/19/2013	15	1	Unconfined
7	3558204	2/22/2010 - 6/20/2012	9	1	Unconfined, Under Layer 1
7	3558401	11/20/1981 - 11/16/1995	11	1	Confined
7	3558403	3/18/1981	1	0.7	Confined
7	3558503	5/1/2009 - 12/18/2013	17	1	Unconfined
7	3558602	5/1/2009 - 12/18/2013	17	1	Unconfined
7	3559105	9/1/2009 - 3/22/2010	2	1	Unconfined
7	3559109	9/1/2009 - 6/15/2012	10	1	Unconfined
7	3559205	9/1/2009 - 12/18/2013	16	1	Unconfined
7	3559403	11/14/1987 - 4/8/1988	2	1	Unconfined
7	3559503	8/1/2009 - 12/18/2013	16	1	Unconfined
7	3559705	5/1/2009 - 12/18/2013	16	1	Unconfined
7	3559706	9/1/2009 - 12/21/2012	9	1	Unconfined
7	3559801	11/18/1983 - 11/16/1995	8	1	Unconfined
7	3559806	12/1/2010 - 12/18/2013	13	1	Unconfined
7	3559905	10/2/2006 - 4/5/2010	43	1	Unconfined, Under Layer 1
7	3560102	3/20/1981	1	0.7	Unconfined, Under Layer 1
7	3617502	11/18/1981 - 11/5/2003	23	1	Unconfined
7	3617802	11/18/1981 - 11/8/2006	24	1	Unconfined
7	3625504	3/23/1982 - 11/20/2013	31	1	Unconfined
7	3626101	7/2/1986 - 11/4/2004	16	0.96	Unconfined
7	3634303	3/23/1982 - 11/20/2013	28	1	Unconfined
7	3701104	9/1/2006 - 4/5/2010	44	0.7	Confined
7	3702201	7/14/1981	1	0.7	Confined
7	3702205	4/24/1981	1	0.7	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
7	3702301	11/19/1981 - 11/13/2013	28	0.99	Unconfined
7	3702802	11/19/1981 - 11/13/2013	31	1	Confined
7	3702906	5/1/2009 - 12/19/2013	19	1	Unconfined
7	3703502	4/3/1981 - 11/18/1992	8	1	Confined
7	3703602	4/13/1987	1	0.5	Confined
7	3704301	11/17/1981 - 12/10/2013	29	0.99	Unconfined
7	3704302	1/16/1986 - 6/18/1986	2	1	Unconfined
7	3704601	11/19/1981 - 11/13/2013	30	0.98	Confined
7	3704802	10/2/2006 - 4/5/2010	40	1	Confined
7	3705201	11/17/1981 - 12/10/2013	30	1	Unconfined
7	3705202	11/21/1985 - 6/23/1986	2	1	Unconfined
7	3705701	11/19/1981 - 11/19/2013	32	0.99	Unconfined
7	3705702	3/5/1982	1	0.7	Unconfined
7	3705703	8/2/1984 - 11/19/2013	26	0.99	Unconfined
7	3706101	3/21/1984 - 11/21/2013	26	1	Unconfined
7	3706401	11/18/1981 - 11/7/2012	29	1	Unconfined, Under Layer 1
7	3706701	8/24/1984	1	0.7	Unconfined
7	3709105	3/15/1988	1	0.5	Confined
7	3710403	3/26/1982 - 12/6/2005	19	1	Confined
7	3710407	5/1/1999	1	0.5	Confined
7	3711204	4/11/2006 - 4/5/2010	47	1	Unconfined
7	3712303	4/20/1981	1	0.7	Unconfined
7	3712903	5/17/1988	1	0.7	Unconfined
7	3713105	5/1/2009 - 12/18/2013	19	1	Unconfined
7	3713106	5/1/2009 - 11/28/2011	8	1	Unconfined, Under Layer 1
7	3713302	6/26/1986 - 11/21/2013	27	1	Unconfined
7	3713403	3/25/1982 - 11/19/2013	31	1	Unconfined
7	3713404	5/11/1988	1	0.7	Unconfined
7	3713407	3/16/1981	1	0.7	Unconfined
7	3713408	4/30/1998 - 7/22/2003	2	1	Unconfined
7	3714501	11/18/1981 - 11/21/2013	33	1	Unconfined, Under Layer 1
7	3714701	11/19/1981 - 11/21/2013	32	0.99	Unconfined, Under Layer 1
7	3714703	3/11/1983	1	0.7	Unconfined, Under Layer 1
7	3714803	3/22/1985	1	0.7	Unconfined
7	3714901	5/31/1985 - 11/20/1996	12	1	Unconfined
7	3715401	11/17/1981 - 11/21/2013	32	1	Unconfined
7	3717909	10/21/2008	1	0.5	Confined
7	3720105	9/22/1988 - 12/7/1988	2	0.7	Confined
7	3720404	4/5/2002 - 7/23/2003	2	0.6	Confined
7	3720501	5/12/1988	1	0.5	Confined
7	3720902	3/25/1982 - 11/11/1999	13	0.98	Confined
7	3720904	4/17/1985 - 5/12/1988	2	0.7	Confined
7	3720905	3/10/1997 - 7/23/2003	2	0.6	Confined
7	3720906	4/21/2000 - 7/23/2003	2	0.6	Confined
7	3721204	3/25/1982 - 11/19/2013	28	0.98	Unconfined, Under Layer 1
7	3721701	3/25/1982 - 11/19/2013	30	1	Confined
7	3722501	7/10/1981	1	0.7	Unconfined
7	3723603	6/10/1984	1	0.7	Unconfined
7	3723803	4/20/1981	1	0.7	Unconfined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
7	3724601	11/18/1981 - 11/20/2013	32	1	Unconfined
7	3727201	11/6/1985 - 11/19/2013	25	0.99	Confined
7	3727301	3/26/1982 - 1/7/1999	19	0.97	Confined
7	3728304	5/12/1988	1	0.5	Confined
7	3730802	3/23/1982 - 11/10/2006	25	1	Confined
7	3732301	11/18/1981 - 11/20/2013	33	1	Unconfined
7	3732302	3/31/1980	1	0.7	Unconfined
7	3732603	3/23/1982 - 12/3/1986	5	1	Unconfined
7	3736102	11/11/1982 - 11/12/1992	7	1	Confined
7	3801807	3/18/1996	1	0.5	Confined
7	3801808	7/5/1989	1	0.5	Confined
7	3801905	9/12/1989 - 3/18/1996	2	0.7	Confined
7	3802304	12/21/1984 - 10/13/1989	2	0.7	Confined
7	3802402	11/18/1981 - 11/14/2013	30	0.98	Confined
7	3804202	7/10/1995	1	0.5	Confined
7	3806603	11/9/1982 - 11/13/2013	21	0.94	Confined
7	3807305	11/20/1981 - 2/2/1995	15	1	Confined
7	3807409	7/15/1985	1	0.7	Confined
7	3807705	2/1/1988	1	0.5	Confined
7	3807902	3/17/1982 - 11/9/2000	11	0.97	Confined
7	3807907	8/23/2007	1	0.5	Confined
7	3808105	11/20/1981 - 11/13/2013	30	0.93	Confined
7	3808108	5/31/1988	1	0.5	Confined
7	3808208	3/2/1990 - 6/18/1990	2	0.7	Confined
7	3808209	1/31/2007	1	0.5	Confined
7	3808903	12/4/1987	1	0.5	Confined
7	3809701	4/22/1981	1	0.7	Confined
7	3810302	2/13/1989 - 11/15/1989	2	0.7	Confined
7	3810303	2/8/1989 - 11/15/1989	2	0.7	Confined
7	3811606	10/14/1989	1	0.5	Confined
7	3813805	3/20/1981 - 2/6/2008	25	1	Confined
7	3814205	6/17/1980 - 2/16/1989	2	1	Confined
7	3815505	9/1/1994	1	0.5	Confined
7	3815607	3/18/1982 - 11/13/2013	24	0.91	Confined
7	3815804	2/17/1989	1	0.7	Confined
7	3816803	11/9/1982 - 11/12/2013	30	1	Confined
7	3819405	10/10/1986	1	0.7	Confined
7	3820203	11/18/1981 - 10/19/1989	6	0.8	Confined
7	3820801	3/20/1981	1	0.7	Confined
7	3820803	1/10/1990	1	0.5	Confined
7	3825105	4/5/1985	1	0.5	Confined
7	3825707	7/17/1984	1	0.5	Confined
7	3833403	4/7/1980	1	0.7	Confined
7	3833504	3/19/1982 - 11/17/1983	2	1	Confined
7	3833505	8/17/1984	1	0.5	Confined
7	3841706	6/28/1986	1	0.5	Confined
7	3841707	5/31/1994	1	0.5	Confined
7	3841708	11/18/2003	1	0.5	Confined
7	3916802	9/28/2011 - 10/30/2013	3	1	Unconfined, Under Layer 1

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
7	3924603	4/5/1994	1	0.5	Unconfined
7	3924801	8/22/1981	1	0.7	Unconfined
7	3924907	4/22/1981 - 11/18/1998	10	1	Confined
7	3931305	4/7/1994	1	0.7	Unconfined
7	3931411	2/1/1983	1	0.7	Unconfined
7	3931803	4/23/1981	1	0.7	Unconfined
7	3932205	4/23/1981 - 10/30/2013	32	1	Unconfined
7	3938503	2/7/1981	1	0.7	Unconfined
7	3938601	4/24/1981 - 10/2/1981	2	1	Unconfined
7	3938801	4/2/1980 - 3/9/1982	3	1	Unconfined
7	3938804	3/25/1983	1	0.7	Unconfined, Under Layer 1
7	3938805	7/3/2003	1	0.7	Unconfined, Under Layer 1
7	3938902	3/11/1980 - 10/29/2013	35	0.99	Unconfined
7	3938903	10/20/1981	1	0.7	Unconfined
7	3939301	4/20/1981 - 4/16/1984	3	0.9	Confined
7	3939405	4/29/1981	1	0.7	Unconfined
7	3939703	4/29/1981	1	0.7	Confined
7	3939903	2/2/1984	1	0.5	Confined
7	3940205	3/17/1980	1	0.7	Confined
7	3940304	4/28/1981 - 11/17/1983	4	1	Confined
7	3940401	4/29/1981	1	0.7	Confined
7	3940604	12/1/1992 - 7/8/1997	2	0.7	Confined
7	3940605	4/29/1995	1	0.5	Confined
7	3940906	4/28/1981 - 11/1/2013	32	1	Confined
7	3946105	10/20/1981	1	0.7	Unconfined
7	3946301	4/30/1981	1	0.7	Unconfined
7	3946405	4/28/1981 - 12/18/2013	6	1	Unconfined
7	3946702	4/23/1980 - 12/17/2013	46	0.99	Unconfined, Under Layer 1
7	3946901	4/28/1981 - 12/15/1994	11	1	Confined
7	3946902	4/28/1981 - 11/8/2004	23	1	Confined
7	3947102	4/30/1981	1	0.7	Confined
7	3947304	9/27/1983	1	0.5	Confined
7	3947403	7/9/1984	1	0.5	Confined
7	3947503	4/21/2004	1	0.5	Confined
7	3947602	4/28/1981 - 12/2/1986	4	0.93	Confined
7	3954305	5/22/1981	1	0.7	Confined
7	3954306	10/2/1991	1	0.5	Confined
7	3954405	7/23/1980 - 11/7/1985	6	0.9	Confined
7	3954602	7/20/1995 - 10/23/2012	17	1	Confined
7	3954803	7/24/1980 - 4/28/1981	2	1	Confined
7	3955204	4/21/2004	1	0.5	Confined
7	312725093325301	1/30/1980 - 10/21/2013	93	1	Confined
7	313748093451001	9/11/1980 - 10/24/2013	56	1	Unconfined
7	3525604_49678	7/25/2006	1	0.5	Confined
8	1645603	3/10/1981 - 11/15/2013	30	0.98	Confined
8	1646603	11/3/1982	1	0.7	Confined
8	1647302	3/10/1981 - 10/14/1988	7	1	Confined
8	1649703	11/5/1982 - 11/9/1990	9	1	Confined
8	1650402	3/10/1981 - 11/12/2013	31	0.99	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
8	1650607	11/4/1982 - 11/16/2011	26	1	Confined
8	1651410	5/27/1982	1	0.7	Confined
8	1651704	11/4/1982 - 11/7/1995	12	0.95	Confined
8	1652301	11/7/1996 - 11/11/1999	2	1	Confined
8	1653107	3/18/1981 - 11/10/1983	3	1	Confined
8	1653402	9/26/2004	1	0.5	Confined
8	1655102	4/18/1994	1	0.7	Confined
8	1655305	7/10/1981	1	0.5	Confined
8	1657309	4/29/1985 - 6/9/1998	2	0.7	Confined
8	1657804	8/31/1981	1	0.7	Confined
8	1657901	3/17/1981 - 5/20/1998	18	1	Confined
8	1657905	1/15/1992	1	0.5	Confined
8	1658811	2/15/1992	1	0.5	Confined
8	1660202	11/3/1982	1	0.7	Confined
8	1661202	10/25/2003	1	0.5	Confined
8	1661901	11/7/1996 - 11/16/2011	15	0.98	Confined
8	1662704	10/10/1982	1	0.5	Confined
8	1662705	10/25/2005	1	0.5	Confined
8	1663804	4/27/2001	1	0.5	Confined
8	1663805	6/27/2001	1	0.5	Confined
8	1756304	11/5/1982 - 11/11/2013	30	1	Unconfined
8	1761301	3/11/1981 - 11/14/2013	34	0.99	Unconfined
8	1762701	5/31/1984	1	0.5	Confined
8	1763401	8/30/1983	1	0.5	Confined
8	1763806	3/11/1981 - 11/12/2013	31	0.98	Confined
8	1763905	6/7/1982	1	0.5	Confined
8	1764412	8/14/1986	1	0.5	Confined
8	1764701	10/25/1982 - 11/17/1998	17	1	Confined
8	1764703	8/3/1980	1	0.7	Confined
8	1764706	2/28/1998	1	0.5	Confined
8	1764807	2/10/1995	1	0.5	Confined
8	1764808	5/21/1986	1	0.5	Confined
8	3404202	8/1/2001	1	0.5	Unconfined, Under Layer 1
8	3404803	4/10/2000	1	0.5	Confined
8	3405101	3/11/1981 - 11/4/1997	15	1	Confined
8	3405510	11/2/2001	1	0.5	Confined
8	3406310	10/26/1982	1	0.7	Confined
8	3406506	11/3/1988	1	0.5	Confined
8	3406807	4/13/1987	1	0.5	Confined
8	3407309	5/22/2002	1	0.7	Confined
8	3407803	7/14/2004	1	0.5	Confined
8	3408105	10/25/1982 - 11/12/2013	32	1	Confined
8	3408302	4/28/2008	1	0.5	Confined
8	3408904	3/17/1981 - 12/9/1986	5	0.88	Confined
8	3408906	11/10/1988 - 4/11/1989	2	0.6	Confined
8	3411908	2/29/1996	1	0.5	Confined
8	3411909	11/6/1996	1	0.5	Confined
8	3412407	10/8/1985	1	0.5	Confined
8	3412705	10/27/1981	1	0.7	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
8	3412906	4/20/2005	1	0.5	Confined
8	3413308	4/27/2010 - 11/14/2012	4	0.7	Confined
8	3413601	3/16/1982 - 11/3/2004	18	1	Confined
8	3414407	9/13/1988	1	0.5	Confined
8	3416203	7/9/1988	1	0.5	Confined
8	3416204	1/20/1980	1	0.7	Confined
8	3419804	11/13/1981 - 10/7/1993	10	0.97	Confined
8	3419805	1/23/1985 - 3/15/1989	2	0.7	Confined
8	3420202	4/6/1989	1	0.7	Confined
8	3420206	4/6/1989	1	0.7	Confined
8	3420207	6/24/1988	1	0.5	Confined
8	3420607	5/28/1987	1	0.5	Confined
8	3420803	11/7/1988	1	0.7	Confined
8	3422204	5/7/1991	1	0.7	Confined
8	3422306	10/23/1996	1	0.5	Confined
8	3422502	2/21/2001	1	0.5	Confined
8	3423204	4/12/1989	1	0.7	Confined
8	3424202	11/15/1983	1	0.7	Confined
8	3424301	12/31/1998	1	0.5	Confined
8	3424601	5/27/1988 - 4/12/1989	2	0.7	Confined
8	3426605	3/12/1981 - 10/8/1993	9	0.9	Confined
8	3426704	10/1/1987 - 3/14/1989	2	0.7	Confined
8	3426804	2/26/1985	1	0.5	Confined
8	3426805	4/6/1988 - 3/14/1989	2	0.7	Confined
8	3426807	5/13/1999	1	0.5	Confined
8	3426905	9/8/1988 - 3/15/1989	2	0.7	Confined
8	3427104	11/8/1988	1	0.5	Confined
8	3427204	3/15/1989	1	0.7	Confined
8	3427205	3/15/1989	1	0.5	Confined
8	3427704	9/22/1987	1	0.5	Confined
8	3427705	3/15/1989	1	0.5	Confined
8	3427805	1/7/1997	1	0.5	Confined
8	3428202	2/9/1987 - 11/7/1988	2	0.7	Confined
8	3428203	4/12/1986 - 11/7/1988	2	0.7	Confined
8	3428204	11/15/1988	1	0.5	Confined
8	3428302	4/14/1987	1	0.7	Confined
8	3428304	3/8/2004	1	0.5	Confined
8	3428706	10/14/1984 - 3/16/1989	2	0.7	Confined
8	3428805	11/7/1988	1	0.5	Confined
8	3428809	1/23/1981	1	0.7	Confined
8	3428810	6/14/1989	1	0.5	Confined
8	3429503	11/11/1981 - 11/12/2013	25	0.99	Confined
8	3429703	11/9/1988	1	0.5	Confined
8	3429804	11/9/1988	1	0.5	Confined
8	3429805	7/2/2002	1	0.5	Confined
8	3429806	12/27/2006	1	0.5	Confined
8	3429904	11/9/1988	1	0.5	Confined
8	3429906	3/31/1998 - 5/18/1999	3	1	Confined
8	3431804	11/14/1988	1	0.5	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
8	3433502	12/8/1988 - 4/25/1994	3	1	Unconfined
8	3433801	3/13/1981 - 11/6/1986	5	1	Unconfined
8	3434601	3/13/1981 - 11/12/1981	2	1	Confined
8	3434802	1/30/1988 - 3/16/1989	2	0.7	Confined
8	3434905	3/16/1989	1	0.5	Confined
8	3435301	3/13/1981 - 11/10/1995	13	0.98	Confined
8	3435307	2/8/1988	1	0.5	Confined
8	3436106	12/23/1988 - 4/17/1989	2	0.7	Confined
8	3436305	4/14/1987 - 11/7/1988	2	1	Confined
8	3436307	12/21/1985 - 11/11/1988	3	0.7	Confined
8	3436904	7/8/2005	1	0.5	Confined
8	3437205	9/20/1990 - 3/26/1998	2	1	Confined
8	3437312	7/2/1997 - 5/18/1999	2	0.85	Confined
8	3437313	7/5/2001	1	0.5	Confined
8	3440403	2/23/2001	1	0.5	Confined
8	3440502	3/13/2007	1	0.5	Confined
8	3440603	8/30/1982 - 4/18/1989	2	1	Confined
8	3440604	1/4/1989	1	0.5	Confined
8	3441310	9/10/1995 - 5/31/2011	27	0.89	Confined
8	3441312	11/9/1998 - 5/31/2011	8	1	Confined
8	3441313	2/15/1999 - 5/31/2011	9	1	Confined
8	3441315	5/5/2009 - 5/31/2011	3	0.7	Confined
8	3443104	11/17/1981 - 10/17/1990	9	1	Confined
8	3443201	3/20/1989	1	0.5	Confined
8	3443206	3/20/1989	1	0.5	Confined
8	3443207	3/20/1989	1	0.5	Confined
8	3443904	3/18/1981 - 4/11/1987	2	1	Confined
8	3444706	3/18/1981 - 11/17/1981	2	1	Confined
8	3445610	6/23/2005	1	0.5	Confined
8	3446404	5/20/1982 - 10/21/2013	17	1	Confined
8	3447504	11/11/1988 - 10/21/2013	22	1	Confined
8	3448103	12/9/1986 - 9/15/2011	24	0.98	Confined
8	3448803	11/16/1988 - 1/15/2012	19	0.97	Confined
8	3449810	7/25/1980 - 12/15/2005	21	1	Confined
8	3450206	4/13/1987 - 1/13/1995	8	0.7	Confined
8	3450306	11/17/1981 - 11/15/2013	29	0.96	Confined
8	3450408	4/14/1987	1	0.5	Confined
8	3450508	8/4/1985	1	0.5	Confined
8	3451805	2/25/1988	1	0.5	Confined
8	3455107	7/1/1995	1	0.5	Confined
8	3455108	9/5/2007	1	0.5	Confined
8	3455903	11/16/2012	1	0.5	Confined
8	3456207	11/15/1984 - 11/12/2013	20	0.99	Confined
8	3456208	1/31/1986 - 11/13/1995	7	0.7	Confined
8	3456705	8/23/1993	1	0.5	Confined
8	3457205	6/28/1990	1	0.5	Confined
8	3457401	11/17/1981 - 11/3/1986	5	0.88	Confined
8	3457405	12/28/1989 - 11/14/2013	25	0.99	Confined
8	3458403	6/6/1983 - 4/6/1987	2	0.7	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
8	3458504	3/18/1981 - 10/22/1993	12	1	Confined
8	3458904	10/7/1986 - 3/12/2002	3	0.63	Confined
8	3459702	11/25/1981	1	0.5	Confined
8	3460104	9/18/1995	1	0.5	Confined
8	3460503	3/19/1981 - 11/15/2013	31	1	Confined
8	3464403	11/12/1987 - 11/12/1997	9	0.97	Confined
8	3501115	10/7/1992	1	0.5	Confined
8	3501121	9/13/1982	1	0.7	Confined
8	3501705	12/8/1988 - 4/11/1989	2	0.6	Confined
8	3502504	10/19/1982	1	0.7	Confined
8	3502505	9/20/1995	1	0.5	Confined
8	3503107	11/8/1989	1	0.5	Confined
8	3507801	3/18/1981 - 11/13/2003	20	1	Confined
8	3507808	2/2/1988	1	0.5	Confined
8	3509302	7/10/1992	1	0.5	Confined
8	3511408	7/10/1987	1	0.5	Confined
8	3511904	9/10/1980 - 10/23/1987	2	1	Confined
8	3512805	3/10/1983	1	0.5	Confined
8	3515703	3/18/1981 - 11/14/2013	26	1	Confined
8	3517406	6/21/2002	1	0.5	Confined
8	3517606	6/2/1989	1	0.5	Confined
8	3518502	10/14/1983	1	0.5	Confined
8	3518902	1/31/2001	1	0.5	Confined
8	3519102	8/6/1982 - 10/23/1987	2	1	Confined
8	3519402	10/23/1987	1	0.5	Confined
8	3520202	5/17/2006	1	0.5	Confined
8	3521301	4/14/1998	1	0.7	Confined
8	3521902	3/10/1995	1	0.5	Confined
8	3522708	11/11/1981 - 11/14/2013	26	0.92	Confined
8	3523101	7/15/1991 - 11/10/1992	7	1	Unconfined, Under Layer 1
8	3523301	7/15/1991 - 11/10/1992	7	1	Unconfined, Under Layer 1
8	3523505	6/25/1991 - 11/10/1992	7	1	Unconfined, Under Layer 1
8	3523506	6/25/1991 - 11/10/1992	7	1	Unconfined, Under Layer 1
8	3523603	6/27/1991 - 11/10/1992	6	1	Unconfined
8	3529303	4/29/1982	1	0.5	Confined
8	3529304	5/20/1982	1	0.7	Confined
8	3529602	2/25/1981	1	0.7	Confined
8	3530705	3/19/1981 - 11/14/2013	32	0.99	Confined
8	3531602	11/11/1981 - 11/14/2013	31	1	Confined
8	3533403	4/30/1980	1	0.7	Confined
8	3533501	11/10/1981 - 11/7/2001	14	0.91	Confined
8	3533915	11/11/1988	1	0.5	Confined
8	3534403	3/17/1981 - 11/20/1996	14	1	Confined
8	3536206	3/20/1981 - 11/10/1981	2	1	Confined
8	3536801	9/1/2009	1	0.5	Confined
8	3536802	9/1/2009 - 12/17/2013	14	1	Confined
8	3536803	5/1/2009 - 9/1/2009	2	0.7	Confined
8	3536804	5/1/2009 - 9/1/2009	2	0.7	Confined
8	3536805	9/1/2009	1	0.5	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
8	3537201	11/11/1981 - 11/12/1999	17	1	Confined
8	3538402	3/19/1981 - 11/16/1983	4	1	Confined
8	3538608	11/30/1993	1	0.5	Confined
8	3540507	11/11/1981 - 11/14/2013	32	1	Unconfined
8	3541603	7/16/1981	1	0.7	Confined
8	3541604	2/15/2010 - 12/15/2013	219	1	Confined
8	3541605	2/15/2010 - 12/12/2013	16	0.7	Confined
8	3541808	3/19/1981	1	0.7	Confined
8	3541809	1/31/1980	1	0.7	Confined
8	3541811	8/29/1985 - 3/10/1988	2	0.7	Confined
8	3541901	3/18/1981	1	0.7	Confined
8	3541906	11/6/1987 - 3/11/1988	2	0.7	Confined
8	3541907	2/15/2010 - 12/12/2013	15	1	Confined
8	3542202	11/12/1981 - 4/5/2010	71	0.97	Confined
8	3542203	9/26/1995	1	0.5	Confined
8	3542204	5/21/2000	1	0.5	Confined
8	3542205	12/18/2003 - 12/6/2005	2	0.6	Confined
8	3542206	5/1/2009 - 7/1/2009	2	0.7	Confined
8	3542208	5/1/2009 - 9/10/2013	12	0.7	Confined
8	3542209	7/1/2009 - 12/12/2013	12	1	Confined
8	3542404	4/4/1988 - 11/14/1988	2	0.7	Confined
8	3542405	4/5/1993	1	0.5	Confined
8	3542407	2/15/2010 - 3/15/2013	11	1	Confined
8	3542503	2/15/2010 - 12/12/2013	15	1	Confined
8	3542507	2/15/2010 - 12/12/2013	15	1	Confined
8	3542702	5/22/1984 - 3/12/1988	2	0.7	Confined
8	3542803	1/16/1999 - 8/26/1999	2	0.85	Confined
8	3543101	10/22/1987	1	0.5	Confined
8	3543102	9/1/2009 - 12/17/2013	16	0.7	Confined
8	3543103	5/1/2010	1	0.5	Confined
8	3543404	9/1/2010 - 12/17/2013	13	1	Confined
8	3543602	4/23/1981	1	0.7	Confined
8	3543605	12/1/2010 - 12/17/2013	11	0.7	Confined
8	3543703	5/1/2009 - 12/17/2013	18	0.7	Confined
8	3543902	7/6/1986 - 3/15/1988	2	0.7	Confined
8	3543904	2/22/1993 - 7/15/2012	39	0.98	Confined
8	3543906	5/1/2009 - 12/30/2013	165	1	Confined
8	3544102	9/8/1984 - 3/14/1988	2	0.7	Confined
8	3544104	9/16/1984 - 3/14/1988	2	0.7	Confined
8	3544105	9/1/2009	1	0.5	Confined
8	3544106	9/1/2009	1	0.5	Confined
8	3544107	5/1/2009 - 9/1/2009	2	0.7	Confined
8	3544109	9/1/2009	1	0.5	Confined
8	3544110	9/1/2009	1	0.5	Confined
8	3544111	9/1/2010 - 12/17/2013	14	1	Confined
8	3544112	9/1/2010 - 12/17/2013	14	1	Confined
8	3544113	5/1/2009 - 12/17/2013	18	1	Confined
8	3544114	9/1/2009	1	0.5	Confined
8	3544205	5/1/2009 - 12/17/2013	17	1	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
8	3544206	9/1/2009 - 12/17/2013	16	1	Confined
8	3544207	9/1/2009 - 12/17/2013	15	1	Confined
8	3544208	5/1/2009 - 12/17/2013	16	1	Confined
8	3544402	11/13/1981 - 11/16/1994	13	1	Confined
8	3544407	3/17/2010 - 12/17/2013	15	1	Confined
8	3544408	3/17/2010 - 12/17/2013	15	1	Confined
8	3544507	3/17/2010 - 12/17/2013	15	1	Confined
8	3544508	2/19/2010 - 3/6/2012	8	1	Confined
8	3544509	2/19/2010 - 3/6/2012	8	1	Confined
8	3544510	2/19/2010 - 12/17/2013	15	1	Confined
8	3544703	4/2/1981 - 2/1/2008	21	1	Confined
8	3544705	6/18/2012 - 12/18/2013	6	1	Confined
8	3544806	4/15/1991	1	0.5	Confined
8	3545706	11/1/1984	1	0.5	Confined
8	3546202	3/19/1981 - 11/16/1994	15	0.98	Confined
8	3547501	3/19/1981 - 11/9/1995	15	0.98	Confined
8	3548101	3/19/1981 - 12/3/2013	42	1	Unconfined
8	3548202	8/24/1983	1	0.7	Unconfined
8	3548203	12/3/1985	1	0.7	Unconfined
8	3549203	3/19/1981	1	0.7	Confined
8	3549405	3/31/1984	1	0.5	Confined
8	3549502	11/12/1981 - 11/20/1997	14	1	Confined
8	3549512	9/19/1981	1	0.7	Confined
8	3549601	3/12/1981	1	0.7	Confined
8	3549607	9/1/2009 - 9/12/2013	10	1	Confined
8	3549809	7/16/1981	1	0.7	Confined
8	3549811	7/16/1981	1	0.7	Confined
8	3549813	12/20/1982	1	0.7	Confined
8	3549814	8/25/1980 - 3/11/1988	2	1	Confined
8	3550105	8/17/1988	1	0.5	Confined
8	3550106	7/5/1983 - 11/14/1988	4	0.7	Confined
8	3550207	2/27/1988	1	0.5	Confined
8	3550304	8/5/1985 - 11/15/1988	3	0.7	Confined
8	3550606	12/1/2010 - 12/20/2013	12	1	Confined
8	3550704	9/25/1980 - 4/12/1988	2	1	Confined
8	3550801	4/22/1981 - 11/13/2013	32	0.99	Confined
8	3550802	3/17/1981	1	0.7	Confined
8	3550901	4/1/1981	1	0.7	Confined
8	3550903	2/28/1981	1	0.7	Confined
8	3550904	2/28/1981	1	0.7	Confined
8	3550907	2/28/1981	1	0.7	Confined
8	3550908	4/23/1981	1	0.7	Confined
8	3550914	4/4/1984 - 10/31/1988	3	0.7	Confined
8	3551103	1/30/1988 - 4/11/1988	2	0.7	Confined
8	3551104	9/2/1983 - 11/11/1988	3	0.7	Confined
8	3551105	1/24/1990 - 5/20/1992	2	0.7	Confined
8	3551106	2/28/1990	1	0.5	Confined
8	3551402	3/25/2010	1	0.5	Confined
8	3551502	11/12/1981 - 12/2/2004	18	0.87	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
8	3551601	12/2/2004 - 4/5/2010	54	0.69	Confined
8	3551602	4/1/1981	1	0.7	Confined
8	3551604	10/21/2008 - 12/18/2013	12	1	Confined
8	3551704	9/1/2009 - 3/25/2010	2	0.7	Confined
8	3551706	9/1/2009 - 3/25/2010	2	0.7	Confined
8	3551707	9/1/2009 - 9/1/2010	4	1	Confined
8	3551803	9/1/2009 - 3/25/2010	2	0.7	Confined
8	3552101	4/2/1981 - 11/13/2013	32	0.97	Confined
8	3552102	4/2/1981	1	0.7	Confined
8	3552301	11/17/1981 - 12/10/2013	17	0.93	Confined
8	3552502	5/20/1986	1	0.5	Confined
8	3552503	8/22/1995	1	0.5	Confined
8	3552701	11/19/1981 - 11/13/2013	28	1	Confined
8	3553102	1/7/1986	1	0.5	Confined
8	3553702	3/19/1981 - 12/10/2013	33	0.95	Unconfined, Under Layer 1
8	3553902	11/22/1982 - 12/1/2009	26	0.97	Unconfined
8	3554401	7/28/1981	1	0.7	Unconfined
8	3554402	6/19/1986	1	0.5	Unconfined
8	3554501	10/19/1984 - 5/13/1986	2	0.7	Unconfined, Under Layer 1
8	3554503	8/10/1983	1	0.5	Unconfined
8	3554601	3/19/1981 - 12/9/2005	24	0.99	Unconfined, Under Layer 1
8	3554704	5/13/1986	1	0.5	Unconfined
8	3554901	11/30/1985 - 6/24/1986	2	0.7	Unconfined, Under Layer 1
8	3555101	3/19/1981 - 11/21/1996	12	1	Unconfined
8	3555503	9/18/1991 - 9/18/1991	2	0.5	Unconfined
8	3555901	3/19/1981 - 12/9/2013	35	1	Unconfined
8	3556501	11/16/1981 - 10/17/1989	4	0.93	Unconfined, Under Layer 1
8	3556702	6/17/1986	1	0.7	Unconfined
8	3556703	6/17/1986	1	0.5	Unconfined
8	3557209	9/1/2010 - 12/20/2013	12	1	Confined
8	3557210	9/1/2010 - 12/19/2013	14	1	Confined
8	3557302	2/24/2011 - 12/19/2013	12	1	Confined
8	3557303	2/10/2010 - 11/1/2010	3	0.7	Confined
8	3557304	2/10/2010 - 12/1/2010	3	0.7	Confined
8	3557305	2/10/2010	1	0.7	Confined
8	3557306	2/10/2010	1	0.5	Confined
8	3557307	5/1/2009 - 12/19/2013	18	1	Confined
8	3557309	5/1/2009 - 2/22/2010	3	0.7	Confined
8	3557310	9/1/2010 - 12/1/2010	2	0.7	Confined
8	3557311	2/10/2010 - 12/19/2013	15	1	Confined
8	3557312	2/10/2010 - 12/1/2010	3	0.7	Confined
8	3557313	9/15/2010 - 11/1/2010	2	0.7	Confined
8	3557314	9/1/2010 - 12/1/2010	2	0.7	Confined
8	3557315	2/10/2010 - 12/1/2010	3	0.7	Confined
8	3557316	5/1/2009 - 12/1/2010	5	0.7	Confined
8	3557511	7/7/2003 - 4/5/2010	49	0.7	Confined
8	3557512	9/1/2010 - 12/19/2013	13	1	Confined
8	3557802	5/3/2006	1	0.5	Confined
8	3558103	7/14/1981	1	0.7	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
8	3558105	10/17/2003	1	0.5	Confined
8	3558303	3/10/1988	1	0.5	Confined
8	3558304	5/1/2009 - 12/18/2013	18	1	Confined
8	3558305	9/1/2009 - 12/19/2013	14	1	Confined
8	3558306	3/24/2010 - 12/20/2013	16	1	Confined
8	3558402	3/19/1981	1	0.7	Confined
8	3558404	7/8/1996	1	0.7	Confined
8	3558405	2/22/2011 - 12/30/2013	118	1	Confined
8	3558408	5/1/2009 - 12/19/2013	18	1	Confined
8	3558901	5/1/2009 - 12/18/2013	13	1	Confined
8	3559102	2/1/2006 - 4/5/2010	51	1	Confined
8	3559103	6/18/1983 - 4/9/1988	2	0.7	Confined
8	3559104	9/1/2009	1	0.5	Confined
8	3559106	9/1/2009 - 9/1/2010	2	0.7	Confined
8	3559107	9/1/2009 - 12/18/2013	7	1	Confined
8	3559108	9/1/2009 - 12/18/2013	14	1	Confined
8	3559204	9/1/2009 - 3/22/2010	2	0.7	Confined
8	3559206	9/1/2009 - 12/18/2013	17	1	Confined
8	3559404	9/1/2010 - 12/18/2013	14	1	Confined
8	3559405	5/1/2009 - 12/18/2013	18	1	Confined
8	3559601	11/19/1981 - 11/13/2013	31	0.98	Confined
8	3559703	9/1/2009 - 12/21/2012	12	1	Confined
8	3559704	9/1/2009 - 12/21/2012	13	1	Confined
8	3559804	5/1/2009 - 12/18/2013	17	1	Confined
8	3559805	5/1/2009 - 12/18/2013	16	1	Confined
8	3559902	11/19/1981 - 11/19/2009	24	0.98	Confined
8	3559903	7/15/1981	1	0.7	Confined
8	3559906	2/24/2010 - 12/18/2013	13	1	Confined
8	3560502	11/17/1981 - 12/10/2013	30	0.99	Confined
8	3561303	5/14/1986	1	0.5	Unconfined
8	3561304	5/14/1986	1	0.5	Unconfined
8	3561401	7/27/1981 - 6/24/1986	2	1	Unconfined, Under Layer 1
8	3561501	3/19/1981 - 11/7/2002	21	1	Unconfined, Under Layer 1
8	3561502	1/3/1985	1	0.5	Unconfined
8	3561802	4/30/1981	1	0.7	Confined
8	3561803	12/10/1985	1	0.5	Unconfined, Under Layer 1
8	3562301	11/17/1981 - 12/3/2013	43	0.99	Unconfined
8	3562302	6/19/1986	1	0.5	Unconfined
8	3563303	10/28/1984	1	0.7	Unconfined, Under Layer 1
8	3563701	3/19/1981 - 12/9/2013	32	1	Unconfined
8	3563801	1/18/1983 - 6/16/1986	2	0.7	Unconfined
8	3564101	12/29/1981	1	0.7	Unconfined
8	3564102	5/22/1986	1	0.5	Unconfined, Under Layer 1
8	3564201	3/17/1984 - 6/25/1986	2	0.7	Unconfined
8	3564401	9/6/1985	1	0.7	Unconfined, Under Layer 1
8	3564502	12/4/1998 - 12/4/1998	2	0.5	Unconfined
8	3601801	7/1/1986	1	0.7	Unconfined
8	3610701	11/18/1981 - 11/21/2013	31	1	Confined
8	3617201	5/14/1980 - 7/2/1986	2	1	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
8	3617601	8/2/1980 - 7/2/1986	2	1	Confined
8	3633209	1/21/2002	1	0.5	Confined
8	3702202	3/30/1981	1	0.7	Confined
8	3702207	9/30/1981 - 4/9/1988	2	1	Confined
8	3702702	8/14/1985 - 4/7/1988	2	0.7	Confined
8	3702703	6/5/1998 - 8/26/1999	2	1	Confined
8	3702704	7/28/2011 - 12/19/2013	9	1	Confined
8	3704303	6/18/1986	1	0.5	Confined
8	3705301	2/2/1982 - 12/11/2005	2	1	Confined
8	3705803	5/30/1981 - 4/29/1986	2	1	Confined
8	3705902	1/5/1980 - 11/9/1981	128	1	Confined
8	3705905	4/30/1986 - 11/21/2013	26	0.92	Confined
8	3707201	3/19/1981 - 12/9/2013	32	0.99	Unconfined
8	3707202	11/18/1981 - 11/3/2010	26	0.99	Unconfined
8	3707401	11/9/2006 - 11/21/2013	6	0.95	Unconfined
8	3707403	1/5/1992	1	0.5	Unconfined
8	3707404	12/8/1999	1	0.5	Unconfined
8	3708501	7/22/1982	1	0.7	Unconfined
8	3708606	5/1/2009	1	0.5	Unconfined
8	3708701	11/18/1981 - 11/21/2013	33	0.99	Unconfined
8	3708801	11/18/1981 - 11/17/1998	15	1	Unconfined, Under Layer 1
8	3708804	4/1/1987	1	0.5	Unconfined
8	3711404	12/14/1988	1	0.5	Confined
8	3712806	9/22/1988 - 12/7/1988	2	0.7	Confined
8	3712909	2/25/2007	1	0.5	Confined
8	3713104	7/13/1981	1	0.7	Confined
8	3713107	5/1/2009 - 11/28/2011	8	1	Confined
8	3713402	5/11/1988	1	0.7	Confined
8	3713603	11/19/1981 - 1/11/1989	7	1	Confined
8	3713604	4/29/1986	1	0.5	Confined
8	3713605	6/15/1992	1	0.5	Confined
8	3713804	5/21/1981	1	0.7	Confined
8	3713805	9/11/2000	1	0.5	Confined
8	3714204	6/26/2006	1	0.5	Confined
8	3714502	5/1/1986	1	0.5	Confined
8	3715102	4/29/1986	1	0.5	Unconfined
8	3715103	7/25/1980 - 10/12/1989	6	1	Unconfined
8	3715104	4/16/1982	1	0.7	Unconfined
8	3715105	7/18/1985 - 11/21/2013	27	0.99	Unconfined
8	3715601	5/16/1981	1	0.7	Unconfined
8	3716201	11/18/1981 - 11/21/2013	30	1	Unconfined
8	3716302	11/18/1981 - 11/20/2013	30	1	Unconfined
8	3721102	12/15/1992 - 2/27/2006	3	0.63	Confined
8	3722301	6/28/1986 - 1/11/1989	3	0.63	Confined
8	3723402	5/20/2004	1	0.5	Confined
8	3723501	1/15/1992	1	0.5	Confined
8	3801102	3/19/1981 - 11/14/2013	28	1	Confined
8	3802303	3/5/1987	1	0.5	Confined
8	3802606	10/12/1989 - 3/18/1996	2	0.7	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
8	3803805	3/12/2002	1	0.5	Confined
8	3803806	9/10/2003	1	0.5	Confined
8	3809609	10/8/1986 - 3/22/1996	3	0.7	Confined
8	3809610	11/10/2005	1	0.5	Confined
8	3810111	1/15/1981 - 11/14/2013	19	0.95	Confined
8	3810205	11/18/1981 - 11/12/2012	28	1	Confined
8	3810503	4/9/1986	1	0.5	Confined
8	3810803	4/1/1982	1	0.5	Confined
8	3810903	3/18/1999	1	0.5	Confined
8	3811603	3/13/2002	1	0.5	Confined
8	3818203	5/19/1982	1	0.5	Confined
8	3818204	3/21/1983	1	0.5	Confined
8	3818206	10/17/1989	1	0.5	Confined
8	3819304	10/25/1987	1	0.5	Confined
8	3819406	6/3/1986 - 10/10/1989	2	0.7	Confined
8	3819408	7/22/1993	1	0.5	Confined
8	3821704	3/20/1981 - 11/19/1981	2	1	Confined
8	3821705	11/13/1989	1	0.5	Confined
8	3829105	11/13/1989	1	0.5	Confined
8	3829106	11/13/1989	1	0.5	Confined
8	3915503	4/22/1981 - 4/17/1984	3	1	Confined
8	3923101	4/23/1981 - 10/30/2013	24	0.96	Unconfined, Under Layer 1
8	3923105	4/4/1985	1	0.7	Unconfined, Under Layer 1
8	3923302	11/11/1985 - 11/30/1988	4	0.7	Confined
8	3923404	4/23/1981 - 10/30/2013	31	0.98	Confined
8	3924204	4/24/2000	1	0.5	Confined
8	3924508	3/16/2000	1	0.5	Confined
8	3924704	1/8/2001	1	0.5	Confined
8	3930605	4/20/1981 - 10/30/2013	31	0.99	Confined
8	3930609	11/10/1998	1	0.5	Confined
8	3930702	1/16/1981 - 3/9/1982	2	1	Confined
8	3930717	4/15/1992	1	0.7	Confined
8	3930906	4/20/1981	1	0.7	Confined
8	3931301	4/23/1981 - 10/30/2013	31	1	Confined
8	3932209	7/25/1984	1	0.7	Confined
8	3937910	1/30/1981 - 3/10/1982	2	1	Confined
8	3938201	2/8/1980 - 3/9/1982	3	1	Confined
8	3938203	3/9/1982	1	0.7	Confined
8	3938401	2/6/1981 - 3/9/1982	2	1	Confined
8	3938501	2/7/1981 - 3/9/1982	2	1	Confined
8	3938703	10/21/1981	1	0.7	Confined
8	3938704	2/6/1981	1	0.7	Confined
8	3938706	3/10/1982	1	0.7	Confined
8	3938802	8/7/1980 - 3/9/1982	2	1	Confined
8	3939406	3/2/1981	1	0.7	Confined
8	3939705	1/2/2002	1	0.5	Confined
8	3946101	3/10/1982	1	0.7	Confined
8	3946102	7/30/1980 - 3/10/1982	3	1	Confined
8	3946104	2/19/1981	1	0.7	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
8	3946106	10/22/1981	1	0.7	Confined
8	3946107	4/27/1987	1	0.5	Confined
8	320153093583601	7/20/1982 - 10/21/2013	137	1	Unconfined
8	320849093505001	8/3/2004 - 12/30/2013	28	1	Unconfined
8	325805093594001	10/1/2012 - 10/24/2013	4	0.7	Confined
8	3525605_49679	7/19/2006	1	0.5	Confined
8	3811605_51535	12/6/1987	1	0.5	Confined
9	1641102	3/11/1981 - 11/11/2013	31	0.99	Unconfined
9	1641902	11/5/1982 - 11/21/2002	22	1	Confined
9	1643401	11/5/1982 - 11/13/2012	30	0.98	Confined
9	1646601	11/20/1981	1	0.7	Confined
9	1650207	3/10/1981 - 11/12/2013	25	0.99	Confined
9	1651402	4/15/1998	1	0.7	Confined
9	1651411	6/28/1994	1	0.5	Confined
9	1653401	7/28/2004	1	0.5	Confined
9	1654403	3/23/1993 - 11/13/2013	17	0.96	Confined
9	1657412	7/17/1985	1	0.5	Confined
9	1755407	3/11/1981 - 1/14/1986	5	1	Confined
9	1755706	3/16/1993	1	0.5	Confined
9	1756417	3/11/1981 - 11/11/2013	35	1	Confined
9	1756711	11/17/1981 - 2/9/1988	7	1	Confined
9	1756901	3/11/1981 - 11/11/2013	32	1	Confined
9	1759501	3/11/1981 - 12/20/2005	24	1	Unconfined
9	1759602	5/16/1987	1	0.7	Unconfined, Under Layer 1
9	1759603	6/11/1998	1	0.7	Unconfined, Under Layer 1
9	1760401	10/28/1982 - 11/14/1996	11	0.95	Unconfined
9	1760804	3/5/1986	1	0.5	Confined
9	1760902	3/2/1983	1	0.5	Confined
9	1761302	1/16/1986	1	0.5	Confined
9	1761402	8/20/1991	1	0.5	Confined
9	1761501	11/1/1990	1	0.5	Unconfined, Under Layer 1
9	1761901	10/28/1982 - 12/10/1991	5	1	Confined
9	1761902	10/11/1990	1	0.5	Confined
9	1764504	8/21/1980	1	0.5	Confined
9	1764707	10/7/1987	1	0.5	Confined
9	3348615	6/8/1982 - 11/15/2013	19	0.98	Unconfined
9	3348905	4/20/1994	1	0.7	Unconfined
9	3348906	9/25/1999	1	0.5	Confined
9	3355902	4/29/1981	1	0.7	Unconfined, Under Layer 1
9	3356901	3/18/1981 - 10/22/1993	13	1	Unconfined, Under Layer 1
9	3363901	11/9/1982 - 12/8/1988	6	1	Unconfined, Under Layer 1
9	3364105	4/21/1994	1	0.7	Unconfined, Under Layer 1
9	3364201	11/17/1981 - 11/4/2004	17	1	Unconfined, Under Layer 1
9	3364701	4/29/1981 - 11/5/1996	13	1	Unconfined
9	3403101	10/27/1982 - 10/7/1993	11	1	Unconfined
9	3403103	8/14/1991	1	0.7	Unconfined
9	3403402	8/14/1991	1	0.7	Unconfined, Under Layer 1
9	3403503	4/15/1983	1	0.7	Unconfined
9	3403504	3/12/1981 - 10/7/1993	12	0.98	Unconfined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
9	3403704	10/27/1982 - 11/13/2013	24	1	Unconfined
9	3403801	10/27/1982 - 11/13/2013	31	0.99	Unconfined, Under Layer 1
9	3403808	3/21/1980	1	0.7	Confined
9	3404401	3/11/1981 - 6/14/2006	19	0.98	Confined
9	3404507	4/4/1989	1	0.5	Confined
9	3404509	4/4/1989	1	0.5	Confined
9	3404602	3/11/1981 - 11/19/1996	15	1	Confined
9	3404606	10/31/1986 - 4/7/1989	2	0.7	Confined
9	3404607	8/31/1986 - 4/7/1989	2	0.7	Confined
9	3404801	8/19/1981	1	0.7	Confined
9	3405508	4/11/1989	1	0.5	Confined
9	3405509	12/20/1985 - 4/11/1989	2	0.7	Confined
9	3406703	7/23/1998 - 4/27/2010	2	0.7	Confined
9	3410202	3/12/1981 - 11/7/1986	5	1	Unconfined
9	3410501	11/13/1984 - 11/7/1986	2	1	Unconfined
9	3410802	4/4/1988	1	0.7	Unconfined, Under Layer 1
9	3411101	8/14/1991	1	0.7	Unconfined
9	3411207	11/21/1986	1	0.5	Confined
9	3411401	3/12/1981 - 11/15/1983	3	1	Confined
9	3411403	4/2/1991 - 8/14/1991	2	1	Unconfined
9	3411503	6/17/1998	1	0.5	Confined
9	3411602	10/27/1981	1	0.7	Confined
9	3411603	10/20/1981	1	0.7	Confined
9	3411605	6/23/1984	1	0.5	Confined
9	3412302	8/10/1999	1	0.5	Confined
9	3412303	1/4/2005	1	0.5	Confined
9	3412401	2/24/1993	1	0.7	Confined
9	3412406	5/25/1988 - 5/8/1991	2	0.6	Confined
9	3412706	7/10/1990	1	0.5	Confined
9	3413401	3/11/1981 - 11/12/2013	33	1	Confined
9	3418507	8/8/1980	1	0.7	Confined
9	3418609	7/31/1980	1	0.7	Confined
9	3418610	2/21/1989	1	0.7	Confined
9	3418804	3/12/1981 - 11/6/1986	6	1	Unconfined, Under Layer 1
9	3418904	2/21/1989	1	0.5	Confined
9	3418905	8/17/1993	1	0.5	Confined
9	3419103	11/18/1988	1	0.5	Confined
9	3419303	1/5/1998	1	0.5	Confined
9	3419416	11/11/1983 - 1/5/1989	5	0.66	Confined
9	3419417	2/20/1989	1	0.5	Confined
9	3419418	2/20/1989	1	0.5	Confined
9	3419421	3/10/1980 - 2/20/1989	2	1	Confined
9	3419422	10/28/1985	1	0.5	Confined
9	3419424	12/13/2005	1	0.5	Confined
9	3419502	3/12/1981 - 11/12/2013	33	1	Confined
9	3419706	1/14/1988	1	0.5	Confined
9	3420102	4/6/1989	1	0.7	Confined
9	3425202	11/13/1981 - 11/13/2013	28	1	Unconfined
9	3425206	2/22/1989	1	0.7	Unconfined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
9	3425208	4/25/1994 - 4/25/1994	2	0.85	Unconfined
9	3425402	4/27/1994 - 4/27/1994	2	0.85	Unconfined
9	3425505	10/17/1988	1	0.7	Unconfined
9	3425604	3/12/1981 - 11/13/2013	31	0.99	Unconfined, Under Layer 1
9	3425605	2/22/1989	1	0.5	Confined
9	3425606	2/23/1989	1	0.5	Confined
9	3425607	2/23/1989	1	0.5	Confined
9	3426103	11/13/1981 - 11/15/1983	2	1	Confined
9	3426106	3/14/1989	1	0.7	Confined
9	3426405	6/9/1984	1	0.5	Confined
9	3426407	6/25/1984	1	0.5	Confined
9	3426705	2/6/2006	1	0.5	Confined
9	3427105	4/13/2005	1	0.5	Confined
9	3427402	3/15/1989	1	0.7	Confined
9	3427403	5/25/1984 - 3/15/1989	2	0.7	Confined
9	3428505	11/7/1988	1	0.7	Confined
9	3428806	10/8/1984 - 11/7/1988	2	0.7	Confined
9	3428905	3/13/2002	1	0.5	Confined
9	3433302	3/12/1981 - 11/13/2013	25	0.98	Confined
9	3433303	3/16/1989	1	0.7	Confined
9	3433401	11/12/1981 - 11/13/2013	31	0.99	Unconfined
9	3433702	6/16/1998	1	0.7	Unconfined
9	3433905	3/16/1989	1	0.7	Confined
9	3435302	6/22/1985 - 3/17/1989	2	0.7	Confined
9	3435303	3/17/1989	1	0.5	Confined
9	3440605	4/30/1998 - 5/20/1999	2	0.85	Confined
9	3440606	12/4/1997	1	0.5	Confined
9	3441204	3/20/1989	1	0.5	Confined
9	3442109	10/17/1983	1	0.5	Confined
9	3442403	3/18/1981 - 11/15/2013	28	0.94	Confined
9	3442503	11/17/1981 - 10/12/1993	10	1	Confined
9	3449510	8/9/1999	1	0.5	Confined
9	3449511	7/23/2003	1	0.5	Confined
9	3450407	4/8/1987	1	0.5	Confined
9	3450409	7/22/1981	1	0.5	Confined
9	3457406	8/5/1992	1	0.5	Confined
9	3511702	4/11/1991 - 11/14/2013	20	0.97	Confined
9	3514703	11/11/1981 - 11/14/2013	32	0.99	Confined
9	3516801	3/18/1981 - 11/14/2013	33	1	Confined
9	3522802	3/26/1984	1	0.5	Confined
9	3523202	10/7/1992	1	0.5	Confined
9	3523203	12/9/1992	1	0.5	Confined
9	3523508	11/10/1988	1	0.5	Confined
9	3523509	5/11/2006 - 11/14/2013	5	0.94	Confined
9	3523605	9/23/1981	1	0.7	Confined
9	3523802	11/11/1981 - 11/16/1982	2	1	Confined
9	3532102	11/25/1986	1	0.5	Confined
9	3532702	7/18/2003	1	0.5	Confined
9	3536806	5/1/2009 - 9/1/2009	2	0.7	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
9	3537604	1/19/1986	1	0.5	Confined
9	3537801	11/11/1981 - 11/8/2000	20	0.99	Confined
9	3539502	12/3/1993	1	0.5	Confined
9	3540105	1/4/1983	1	0.5	Confined
9	3540107	5/11/2006	1	0.7	Unconfined, Under Layer 1
9	3540108	4/27/1982	1	0.7	Confined
9	3540109	11/11/1983	1	0.5	Confined
9	3540110	8/31/1981	1	0.7	Unconfined, Under Layer 1
9	3540111	9/25/1987	1	0.5	Unconfined, Under Layer 1
9	3543201	3/3/1981	1	0.7	Confined
9	3543203	2/19/2010 - 12/17/2013	16	1	Confined
9	3543403	9/1/2009	1	0.5	Confined
9	3544103	10/7/1984 - 4/5/2010	85	0.7	Confined
9	3544108	9/1/2009 - 12/17/2013	16	1	Confined
9	3544202	12/1/2010 - 12/17/2013	13	1	Confined
9	3544203	9/1/2009 - 12/17/2013	16	1	Confined
9	3544204	9/1/2010 - 12/17/2013	13	1	Confined
9	3544304	9/1/2010 - 12/18/2013	14	1	Confined
9	3544305	9/1/2009 - 12/18/2013	17	1	Confined
9	3544405	9/1/2009 - 12/17/2013	17	1	Confined
9	3544406	9/1/2009	1	0.5	Confined
9	3544504	5/19/1986 - 3/15/1988	2	0.7	Confined
9	3544505	11/17/2005 - 4/5/2010	42	0.70	Confined
9	3544506	9/9/2011	1	0.5	Confined
9	3544804	4/11/1988	1	0.7	Confined
9	3544805	12/14/1984	1	0.5	Confined
9	3545701	3/19/1981 - 12/3/2013	42	1	Confined
9	3545802	9/25/1983 - 6/18/1986	2	0.7	Confined
9	3545901	6/17/1986	1	0.5	Confined
9	3546701	11/17/1981 - 11/22/1982	2	1	Confined
9	3546703	11/6/2001 - 12/9/2013	12	1	Confined
9	3547205	5/20/1986	1	0.5	Confined
9	3547502	3/19/1981 - 11/9/2012	23	0.97	Confined
9	3547503	11/9/1988 - 12/10/2013	13	0.88	Confined
9	3547701	6/24/1986	1	0.5	Confined
9	3549511	8/2/1984 - 6/9/1988	2	0.7	Confined
9	3549806	8/25/1980	1	0.7	Confined
9	3549812	10/15/1980 - 7/15/1981	2	1	Confined
9	3549815	9/2/1983	1	0.5	Confined
9	3550902	11/19/2007	1	0.5	Confined
9	3551302	4/11/1988	1	0.5	Confined
9	3552106	9/24/2002 - 4/5/2010	5	0.7	Confined
9	3554702	11/17/1983	1	0.7	Confined
9	3561305	5/14/1986	1	0.5	Confined
9	3561307	5/14/1986	1	0.5	Confined
9	3561902	2/27/1980	1	0.7	Confined
9	3562101	6/19/1986	1	0.5	Confined
9	3562702	3/19/1981 - 10/20/2011	31	1	Confined
9	3562705	5/21/1986	1	0.5	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
9	3562706	5/21/1986	1	0.5	Confined
9	3562707	5/21/1986	1	0.5	Confined
9	3563302	7/31/1983 - 6/24/1986	2	0.7	Confined
9	3563601	11/16/1981 - 12/3/2013	42	1	Confined
9	3609601	8/28/1980 - 7/1/1986	2	1	Confined
9	3703201	4/1/1981 - 11/13/2013	20	0.96	Confined
9	3703202	4/3/1981 - 12/2/2004	2	1	Confined
9	3703304	1/2/1992 - 12/15/1993	3	0.7	Confined
9	3706501	4/29/1986	1	0.5	Confined
9	3706502	5/9/2001 - 7/22/2003	2	0.7	Confined
9	3708301	11/18/1981 - 11/9/1990	7	1	Confined
9	3708302	11/18/1981 - 11/11/1986	6	1	Confined
9	3708601	11/18/1981 - 1/10/1989	7	1	Confined
9	3709102	3/18/1982 - 11/13/2013	34	0.97	Confined
9	3710302	3/19/1982 - 11/8/1990	10	1	Confined
9	3711901	6/6/1987	1	0.5	Confined
9	3711908	1/28/1992	1	0.5	Confined
9	3712804	3/26/1982 - 11/19/2013	29	1	Confined
9	3712805	11/13/2000	1	0.7	Confined
9	3715501	11/17/1981 - 11/23/1982	2	1	Confined
9	3715503	11/11/1981 - 11/11/1992	7	1	Confined
9	3716701	11/18/1981 - 11/20/2013	32	1	Confined
9	3720106	9/22/1988 - 12/7/1988	2	0.7	Confined
9	3721904	5/12/1988 - 12/12/1988	2	1	Confined
9	3723602	4/30/1986	1	0.7	Confined
9	3729304	5/12/1988	1	0.7	Confined
9	3732205	8/5/1985	1	0.5	Confined
9	3809607	11/18/1981 - 6/1/2006	22	0.86	Confined
9	3809903	3/30/1995	1	0.5	Confined
9	3810112	2/21/2001	1	0.5	Confined
9	3810804	4/13/1981 - 10/17/1989	2	1	Confined
9	3810805	11/1/1994	1	0.5	Confined
9	3811703	9/3/1986	1	0.5	Confined
9	3818205	8/7/1989	1	0.5	Confined
9	3819407	7/20/1993 - 3/21/1996	2	0.7	Confined
9	3820104	11/9/1989	1	0.5	Confined
9	3906902	4/21/1981	1	0.7	Unconfined
9	3906903	4/8/1994	1	0.7	Unconfined
9	3907202	5/29/1998	1	0.7	Unconfined
9	3907604	5/25/1996	1	0.7	Unconfined
9	3908407	4/22/1981	1	0.7	Confined
9	3914501	4/21/1981	1	0.7	Unconfined
9	3914702	4/21/1981 - 10/30/2013	29	1	Unconfined
9	3915408	3/24/1981	1	0.7	Confined
9	3915707	8/11/1985	1	0.5	Confined
9	3915802	4/22/1981 - 10/30/2013	33	1	Confined
9	3915813	9/18/2001	1	0.5	Confined
9	3916204	4/22/1981 - 4/11/1984	3	1	Confined
9	3921901	4/21/1981	1	0.7	Unconfined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
9	3921903	1/14/1981 - 3/9/1982	2	1	Unconfined
9	3921904	1/14/1981 - 3/9/1982	2	1	Unconfined
9	3922411	4/21/1981 - 11/11/2003	21	1	Unconfined
9	3922513	7/24/1999 - 9/16/1999	2	1	Unconfined
9	3923104	9/6/2005	1	0.5	Confined
9	3923303	11/19/1981	1	0.7	Confined
9	3923311	1/16/1987	1	0.5	Confined
9	3923314	6/29/1999 - 8/11/1999	2	0.7	Confined
9	3923315	12/7/2002	1	0.5	Confined
9	3923410	5/31/1983	1	0.5	Confined
9	3923411	4/26/2005	1	0.5	Confined
9	3923508	4/11/1991	1	0.5	Confined
9	3923509	7/17/1991	1	0.5	Confined
9	3923606	4/15/1982	1	0.5	Confined
9	3923903	12/23/2008	1	0.5	Confined
9	3929201	3/9/1982	1	0.7	Unconfined
9	3929203	9/24/1980 - 3/9/1982	2	1	Unconfined
9	3929301	3/9/1982	1	0.7	Unconfined
9	3929501	1/15/1981	1	0.7	Unconfined
9	3929502	1/15/1981 - 3/9/1982	2	1	Unconfined
9	3929504	1/14/1981 - 3/9/1982	2	1	Unconfined
9	3929505	1/14/1981	1	0.7	Unconfined
9	3929511	1/15/1981 - 3/9/1982	2	1	Unconfined
9	3929601	2/7/1981 - 3/9/1982	2	1	Unconfined
9	3929602	4/24/1981	1	0.7	Unconfined
9	3929605	1/15/1981	1	0.7	Unconfined
9	3929606	2/17/1981 - 3/9/1981	2	1	Unconfined
9	3929801	3/11/1980 - 10/29/2013	38	0.99	Unconfined
9	3929803	1/15/1981 - 1/29/1981	2	1	Unconfined
9	3929804	3/10/1982	1	0.7	Unconfined, Under Layer 1
9	3929806	1/29/1981 - 3/9/1982	2	1	Unconfined
9	3929807	1/16/1981 - 3/9/1982	2	1	Unconfined
9	3929901	1/15/1981 - 3/9/1982	2	1	Confined
9	3930303	5/2/1994	1	0.5	Confined
9	3930703	3/11/1980 - 11/20/1997	22	1	Confined
9	3930704	3/27/1981 - 3/8/1982	2	1	Confined
9	3930706	1/16/1981 - 3/9/1982	2	1	Confined
9	3930708	8/30/1982	1	0.7	Confined
9	3930709	8/30/1982	1	0.7	Confined
9	3930711	1/29/1981 - 3/9/1982	2	1	Confined
9	3930712	1/16/1981 - 3/9/1982	2	1	Confined
9	3930713	1/16/1981	1	0.7	Confined
9	3930714	3/9/1982	1	0.7	Confined
9	3930715	11/5/1982	1	0.7	Confined
9	3931105	10/22/1998	1	0.5	Confined
9	3937102	3/11/1980 - 11/13/1995	18	1	Confined
9	3937201	4/10/1981 - 3/10/1982	2	1	Confined
9	3937202	5/19/1981	1	0.7	Confined
9	3937301	7/24/1980 - 2/3/1982	3	1	Confined

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Table 3.2-1 Model Targets and Weights for 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Layer	Target Name	Date Range	Number of Water Levels	Average Water Level Weight	Aquifer Type Designation
9	3937302	3/9/1982	1	0.7	Confined
9	3937306	3/9/1982	1	0.7	Confined
9	3937307	3/13/1981	1	0.7	Confined
9	3937401	1/29/1981 - 3/10/1982	2	1	Confined
9	3937501	3/10/1982	1	0.7	Confined
9	3937502	3/6/1981	1	0.7	Confined
9	3937503	3/10/1982	1	0.7	Confined
9	3937505	3/10/1982	1	0.7	Confined
9	3937601	10/9/1980 - 10/29/2013	887	1	Confined
9	3937602	1/30/1981 - 3/10/1981	2	1	Confined
9	3937801	3/11/1980 - 10/29/2013	33	0.99	Confined
9	3937802	9/30/1980 - 4/28/1981	2	1	Confined
9	3937807	3/10/1982	1	0.7	Confined
9	3937907	1/29/1981 - 3/10/1982	2	1	Confined
9	3937908	3/10/1982	1	0.7	Confined
9	3938102	2/6/1981 - 3/9/1982	2	1	Confined
9	3938207	9/15/1982	1	0.7	Confined
9	3938208	11/19/1982	1	0.7	Confined
9	3938209	8/25/1987	1	0.5	Confined
9	3938402	1/29/1981	1	0.7	Confined
9	3938403	3/10/1982	1	0.7	Confined
9	3938701	2/17/1981 - 3/9/1982	2	1	Confined
9	3945102	3/10/1982	1	0.7	Confined
9	3945201	1/30/1981 - 3/10/1982	2	1	Confined
9	3945202	3/11/1980 - 10/29/2013	36	1	Confined
9	3945207	2/19/1981 - 3/10/1982	2	1	Confined
9	3945208	1/30/1981 - 3/10/1982	2	1	Confined
9	3945209	4/28/1981	1	0.7	Confined
9	321311093380501	3/3/1980 - 10/21/2013	24	0.7	Confined
9	3544601_49674	7/23/1980 - 11/13/2013	27	0.66	Confined
9	3544607_49676	4/30/1991 - 4/23/2002	2	0.6	Confined
9	3544608_49677	4/7/2004	1	0.5	Confined
9	3545707_49672	4/26/1990 - 4/19/2006	2	0.7	Confined

NOTES:

1. There are 1,797 transient model targets in total, listed in this table. See Section 3.2 for a description of targets.
2. Aquifer types for model targets are defined as follows:
   - unconfined when target layer is at the surface
   - confined when target layer is overlain by one or more model layers
   - unconfined, under Layer 1 when target layer is overlain only by Layer 1 quaternary alluvium (81 wells).

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Table 3.2-2 Weighted Calibration Statistics for Steady-State 1980 and 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Statistic	1980 Values	2013 Values
Number of targets	695	386
Number of observations	695	386
Range in observed values	805.78	852.77
Minimum residual	-146.16	-228.53
Maximum residual	241.84	183.35
Sum of squared residuals	1.40E+06	1.45E+06
RMS error	44.91	61.37
Residual mean	5.97	-8.04
Absolute residual mean	30.83	45.58
Standard deviation	44.51	60.84
Scaled residual mean	0.007	-0.009
Scaled absolute residual mean	0.038	0.053
Scaled standard deviation	0.055	0.071
Scaled RMS error	0.056	0.072

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Table 3.2-3 Weighted Calibration Statistics for Transient 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Statistic	Value
Number of targets	1,797
Number of observations	18,421
Range in observed values	901.40
Minimum residual	-314.43
Maximum residual	270.80
Sum of squared residuals	9.03E+07
RMS error	70.00
Residual mean	-9.10
Absolute residual mean	47.05
Standard deviation	69.40
Scaled residual mean	-0.010
Scaled absolute residual mean	0.052
Scaled standard deviation	0.077
Scaled RMS error	0.078

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Table 3.2-4 Weighted Calibration Statistics by Layer for Transient 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Statistic	Layer 1 (Quaternary Alluvium)	Layer 2 (Sparta Sand)	Layer 4 (Queen City Sand)	Layer 6 (Carrizo Sand)	Layer 7 (Upper Wilcox)	Layer 8 (Middle Wilcox)	Layer 9 (Lower Wilcox)
Number of observations	707	626	3,072	3,581	3,458	4,147	2,830
Range in observed values	77.62	449.07	503.04	897.10	738.15	752.00	616.16
Residual mean	-8.73	-31.56	-70.38	26.11	4.87	-6.36	-3.33
Absolute residual mean	11.04	36.45	99.21	45.77	47.28	32.12	25.01
Standard deviation	13.16	26.96	106.91	54.30	61.00	46.60	35.27
RMS error	15.79	41.51	128.00	60.25	61.20	47.03	35.42
Scaled residual mean	-0.112	-0.070	-0.140	0.029	0.007	-0.008	-0.005
Scaled absolute residual mean	0.142	0.081	0.197	0.051	0.064	0.043	0.041
Scaled standard deviation	0.169	0.06	0.213	0.061	0.083	0.062	0.057
Scaled RMS error	0.203	0.092	0.254	0.067	0.083	0.063	0.057

NOTE
Layers 3 and 5 (Weches and Reklaw Formations) do not contain water level targets.

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Table 3.4-1 Water Budget by Layer for Steady-State 1980 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

	Mass Balance Components	Layer 1 Flow (Quaternary Alluvium)	Layer 2 Flow (Sparta Sand)	Layer 3 Flow (Weches Formation)	Layer 4 Flow (Queen City Sand)	Layer 5 Flow (Reklaw Formation)	Layer 6 Flow (Carrizo Sand)	Layer 7 Flow (Upper Wilcox)	Layer 8 Flow (Middle Wilcox)	Layer 9 Flow (Lower Wilcox)	Total Model Component Flows
		(acre-feet per year)									
Inflows	Storage	--	--	--	--	--	--	--	--	--	--
	Layer Top	--	415.4	19,164.6	130,832.9	25,015.9	63,422.6	194,456.0	31,317.8	20,040.3	484,665.6
	Layer Bottom	322,145.4	3,729.5	932.7	1,947.1	236.3	55,995.5	8,034.7	2,976.0	0.0	395,997.2
	Well	--	--	--	--	--	--	--	--	--	--
	GHB	--	33,539.6	--	--	--	7,918.9	--	--	--	41,458.5
	River	26,105.2	--	--	--	--	--	--	--	--	26,105.2
	Recharge	337,212.0	17,916.6	6,039.9	43,695.4	13,533.8	8,741.4	25,257.6	12,579.2	2,702.9	467,678.8
	ET	--	--	--	--	--	--	--	--	--	--
	Total Inflows	685,462.5	55,601.1	26,137.2	176,475.4	38,786.0	136,078.5	227,748.3	46,873.0	22,743.2	1,415,905.2
Outflows	Storage	--	--	--	--	--	--	--	--	--	--
	Layer Top	--	7,018.7	5,348.5	144,272.2	506.3	16,922.2	191,968.6	14,465.1	15,495.7	395,997.2
	Layer Bottom	262,938.6	20,018.8	24,079.6	29,295.1	36,672.6	74,559.3	26,806.7	10,295.2	0.0	484,665.9
	Well	--	3,890.7	--	8,699.9	--	55,947.8	33,044.7	25,015.8	7,984.7	134,583.6
	GHB	--	30,859.0	--	1,284.1	--	1,333.9	840.0	143.8	369.3	34,830.1
	River	239,620.0	--	--	--	--	--	--	--	--	239,620.0
	Recharge	--	--	--	--	--	--	--	--	--	--
	ET	181,618.3	6,833.9	1,840.3	20,220.6	7,772.2	138.0	3,922.5	5,823.2	1,249.5	229,418.4
	Total Outflows	684,176.8	68,621.1	31,268.4	203,771.9	44,951.2	148,901.2	256,582.5	55,743.1	25,099.1	1,519,115.2
Net Flows	In-Out	1,285.7	-13,020.0	-5,131.1	-27,296.4	-6,165.2	-12,822.7	-28,834.2	-8,870.1	-2,355.9	-103,210.0
	Percent Discrepancy	0.19%	-20.96%	-17.88%	-14.36%	-14.73%	-9.00%	-11.91%	-17.29%	-9.85%	-7.03%

NOTE

Pumping was not simulated in model layers 1, 3, and 5 (Quaternary Alluvium, Weches Formation, and Reklaw Formation).

GSI ENVIRONMENTAL

DRAFT

Table 3.4-2 Water Budget by Layer for Transient 1980 to 2013 Simulation

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

	Mass Balance Components	Layer 1 Flow (Quaternary Alluvium)	Layer 2 Flow (Sparta Sand)	Layer 3 Flow (Weches Formation)	Layer 4 Flow (Queen City Sand)	Layer 5 Flow (Reklaw Formation)	Layer 6 Flow (Carrizo Sand)	Layer 7 Flow (Upper Wilcox)	Layer 8 Flow (Middle Wilcox)	Layer 9 Flow (Lower Wilcox)	Total Model Component Flows
		(acre-feet per year)									
Inflows	Storage	4.06E-07	13.1	--	--	4.06	--	--	0.01	38.6	55.76
	Layer Top	--	67.5	16,521.9	208,597.3	20,578.7	61,781.0	232,708.6	40,696.1	31,447.3	612,398.2
	Layer Bottom	427,745.4	1,233.9	772.9	1,592.4	421.5	60,990.2	7,467.7	3,695.2	--	503,919.1
	Well	--	--	--	--	--	--	--	--	--	--
	GHB	--	33,096.9	--	0.76	--	12,734.7	--	--	--	45,832.3
	River	41,578.9	--	--	--	--	--	--	--	--	41,578.9
	Recharge	370,360.7	19,704.9	6,637.6	48,327.9	14,849.0	9,651.1	27,917.3	13,787.0	2,977.2	514,212.6
	ET	--	--	--	--	--	--	--	--	--	--
	Total Inflows	839,684.9	54,116.3	23,932.3	258,518.3	35,853.3	145,157.0	268,093.5	58,178.3	34,463.1	1,717,996.9
Outflows	Storage	1,145.6	827.8	734.0	5,036.7	826.7	3,980.9	8,020.2	4,118.7	1,198.8	25,889.3
	Layer Top	--	3,374.7	3,026.4	230,556.1	845.8	10,513.0	217,051.8	13,223.1	25,328.2	503,919.1
	Layer Bottom	383,983.7	17,536.3	26,158.8	26,923.1	32,492.5	76,547.2	35,944.9	12,812.5	--	612,399.0
	Well	--	3,952.8	--	9,096.3	--	68,456.4	36,173.7	32,174.0	7,433.2	157,286.5
	GHB	--	31,891.0	--	1,414.3	--	150.6	1,263.0	2,253.2	2,294.6	39,266.6
	River	272,526.5	--	--	--	--	--	--	--	--	272,526.5
	Recharge	--	--	--	--	--	--	--	--	--	--
	ET	180,358.5	8,543.2	993.6	18,687.2	8,432.6	37.9	3,272.1	5,189.7	1,188.3	226,703.0
	Total Outflows	838,014.3	66,125.9	30,912.8	291,713.7	42,597.6	159,685.9	301,725.7	69,771.1	37,443.1	1,837,990.1
Net Flows	In-Out	1,670.6	-12,009.6	-6,980.4	-33,195.4	-6,744.4	-14,528.9	-33,632.2	-11,592.8	-2,980.0	-119,993.2
	Percent Discrepancy	0.20%	-19.98%	-25.46%	-12.07%	-17.19%	-9.53%	-11.80%	-18.12%	-8.29%	-6.75%

NOTE
Pumping was not simulated in model layers 1, 3, and 5 (Quaternary Alluvium, Weches Formation, and Reklaw Formation).

GSI ENVIRONMENTAL

DRAFT

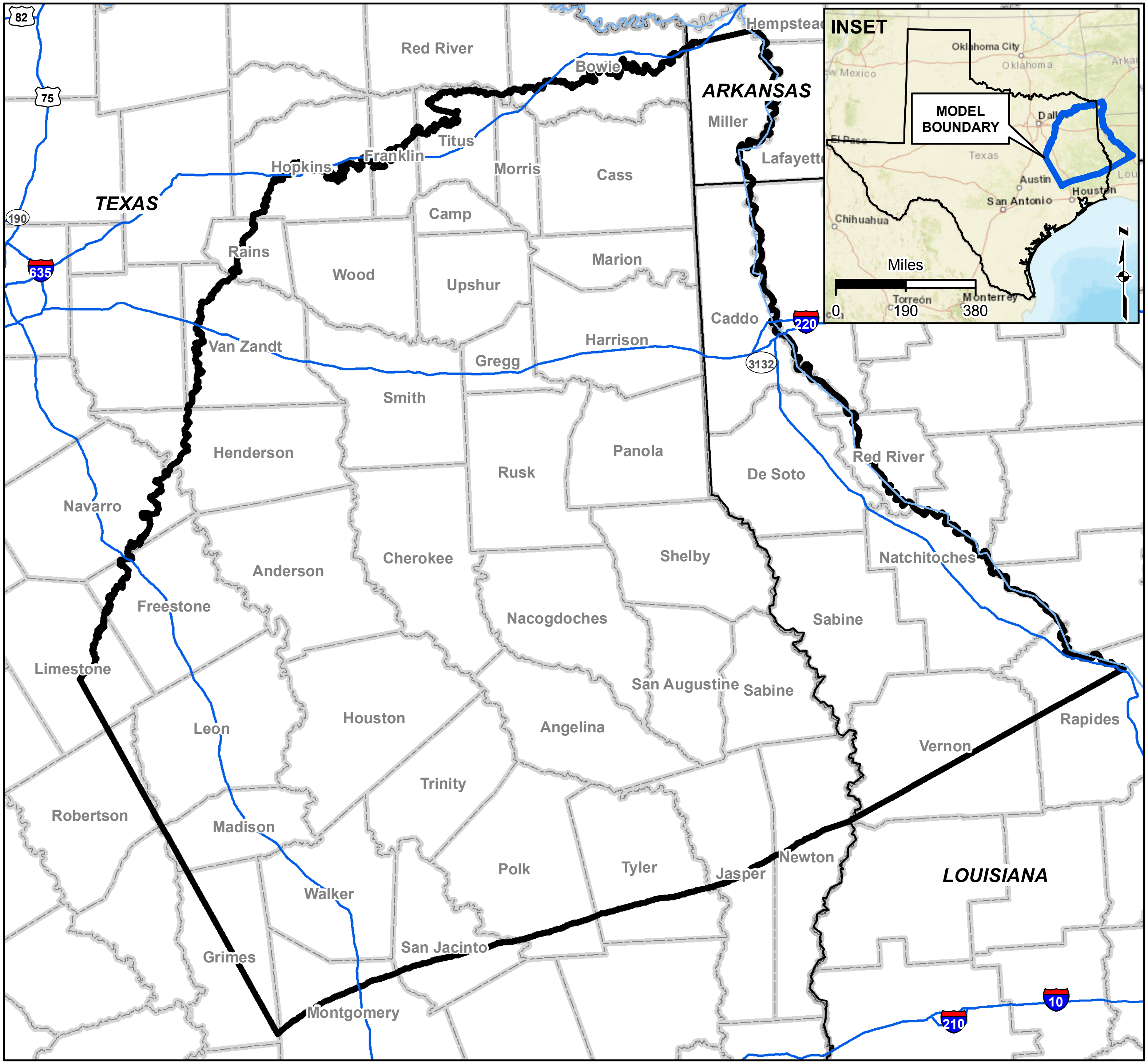
Table 4.2-1 Model Parameter Sensitivity Type

Northern Portion of the Queen City, Sparta and Carrizo Wilcox Aquifers

Model Parameter	Residual Mean Sensitivity	RMS Head Error Sensitivity	Possible ASTM Sensitivity Type
Horizontal Hydraulic Conductivity (Sand)			
Quaternary Alluvium (Layer 1)	No sensitivity	No sensitivity	Type I or IV
Sparta Sand (Layer 2)	No sensitivity	No sensitivity	Type I or IV
Weches Formation (Layer 3)	No sensitivity	No sensitivity	Type I or IV
Queen City Sand (Layer 4)	Low	Low	Type II or III
Reklaw Formation (Layer 5)	No sensitivity	No sensitivity	Type I or IV
Carrizo Sand (Layer 6)	No sensitivity	No sensitivity	Type I or IV
Upper Wilcox (Layer 7)	No sensitivity	No sensitivity	Type I or IV
Middle Wilcox (Layer 8)	Medium	Medium	Type II or III
Lower Wilcox (Layer 9)	Low	Low	Type II or III
Vertical Hydraulic Conductivity (Clay)			
Quaternary Alluvium (Layer 1)	No sensitivity	No sensitivity	Type I or IV
Sparta Sand (Layer 2)	No sensitivity	No sensitivity	Type I or IV
Weches Formation (Layer 3)	No sensitivity	No sensitivity	Type I or IV
Queen City Sand (Layer 4)	No sensitivity	No sensitivity	Type I or IV
Reklaw Formation (Layer 5)	Low	Low	Type II or III
Carrizo Sand (Layer 6)	No sensitivity	No sensitivity	Type I or IV
Upper Wilcox (Layer 7)	High	High	Type II or III
Middle Wilcox (Layer 8)	Medium	Low	Type II or III
Lower Wilcox (Layer 9)	No sensitivity	No sensitivity	Type I or IV
Recharge	High	High	Type II or III
Pumping	Medium	Medium	Type II or III
Evapotranspiration	No sensitivity	No sensitivity	Type I or IV

NOTES:

1. The specific yield model sensitivity was evaluated for change in head fluctuations and is not categorized by ASTM sensitivity type.
2. ASTM sensitivity types are from ASTM D 5611-94 dated 1994, reappproved 2000.



LEGEND

Model Boundary

County or Parish Boundary

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

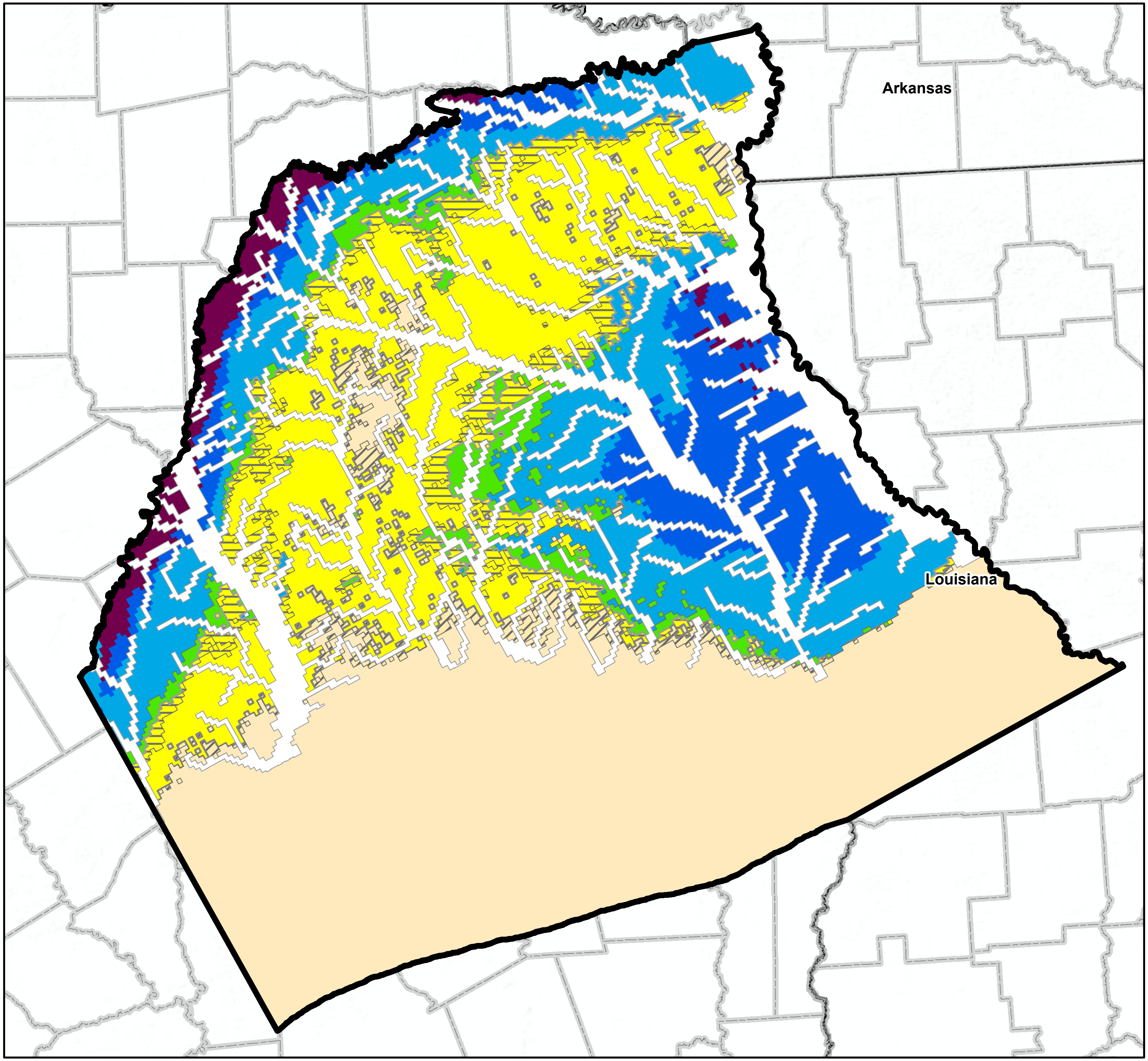
GSI ENVIRONMENTAL

SITE LOCATION MAP

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: AV
Issued: 26-May-2020	Chk'd By: KER
Map ID: NCW_SLM	Appv'd By: DRAFT

FIGURE 1.2-1



LEGEND

- Model Boundary
- County or Parish Boundary
- Layer 1 (Alluvium)
- Layer 2 (Sparta Sand)
- Layer 3 (Weches Formation)
- Layer 4 (Queen City Sand)
- Layer 5 (Reklaw Formation)
- Layer 6 (Carrizo Sand)
- Layer 7 (Upper Wilcox)
- Layer 8 (Middle Wilcox)
- Layer 9 (Lower Wilcox)

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles: 0, 16, 32

Projected Coordinate System
Datum: GAM

GSI ENVIRONMENTAL

AQUIFER OUTCROPS SIMULATED IN THE GROUNDWATER MODEL

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 29-May-2020	Chk'd By: KER
Map ID: NCW_Fig_2_1_1	Appv'd By: DRAFT

FIGURE 2.1-1

MODEL LAYER	HYDROSTRATIGRAPHIC UNITS
Layer 1	Quaternary Alluvium
Layer 2	Sparta Sand
Layer 3	Weches Formation
Layer 4	Queen City Sand
Layer 5	Reklaw Formation
Layer 6	Carrizo Sand
Layer 7	Upper Wilcox
Layer 8	Middle Wilcox
Layer 9	Lower Wilcox

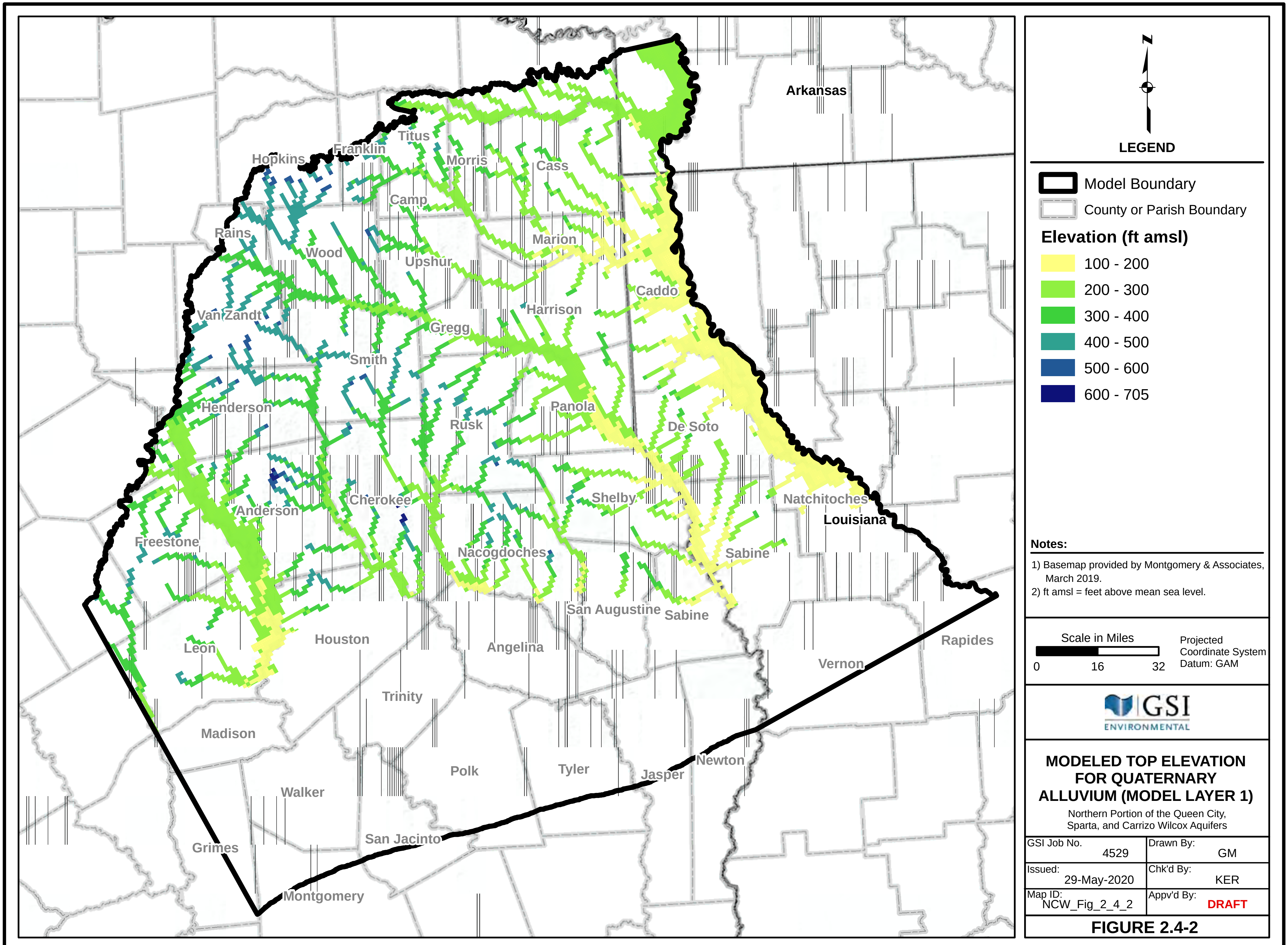
GSI ENVIRONMENTAL

GEOLOGIC UNITS AND MODEL LAYERS

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 29-May-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_1	Appv'd By: DRAFT

FIGURE 2.4-1



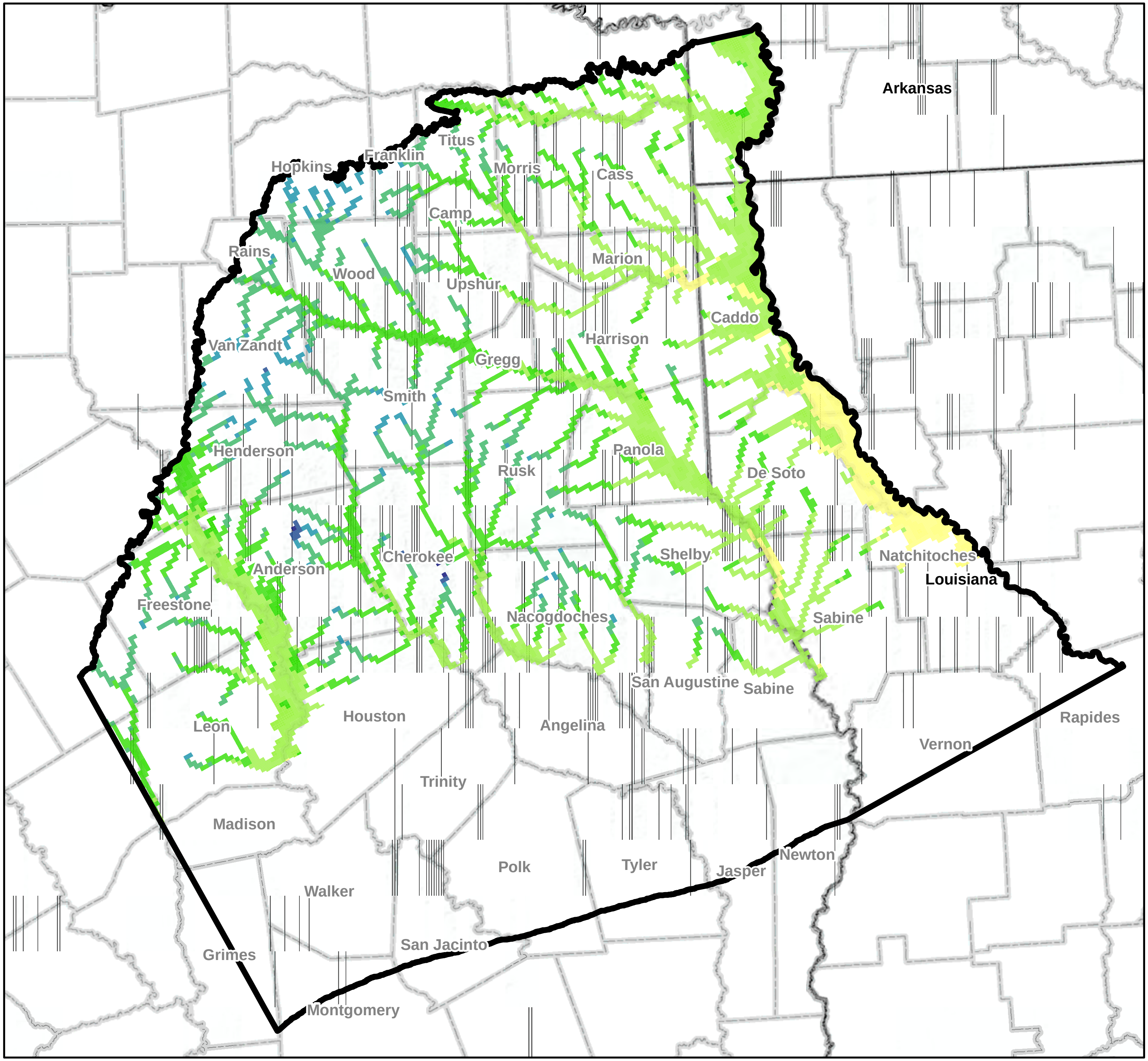
GSI ENVIRONMENTAL

MODELED TOP ELEVATION FOR QUATERNARY ALLUVIUM (MODEL LAYER 1)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 29-May-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_2	Appv'd By: DRAFT

FIGURE 2.4-2



LEGEND

- Model Boundary
- County or Parish Boundary

Elevation (ft amsl)

- 28 - 100
- 100 - 200
- 200 - 300
- 300 - 400
- 400 - 500
- 500 - 600
- 600 - 645

Notes:

1) Basemap provided by Montgomery & Associates, March 2019.
2) ft amsl = feet above mean sea level.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

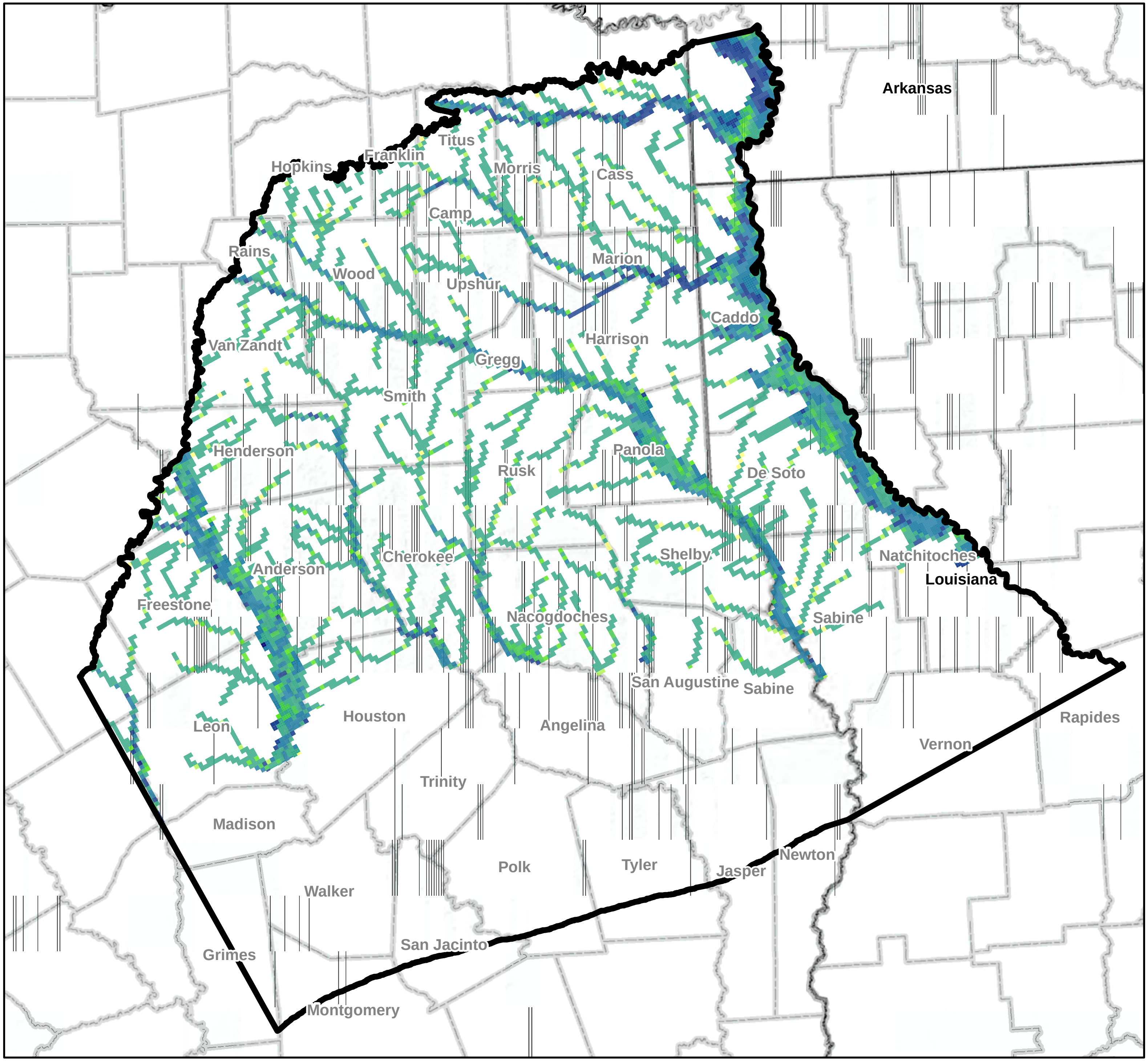
GSI ENVIRONMENTAL

MODELED BOTTOM ELEVATION FOR QUATERNARY ALLUVIUM (MODEL LAYER 1)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 29-May-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_3	Appv'd By: DRAFT

FIGURE 2.4-3



LEGEND

Model Boundary
County or Parish Boundary

Thickness (feet)

- 10.5 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 85.4

Note:

1) Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

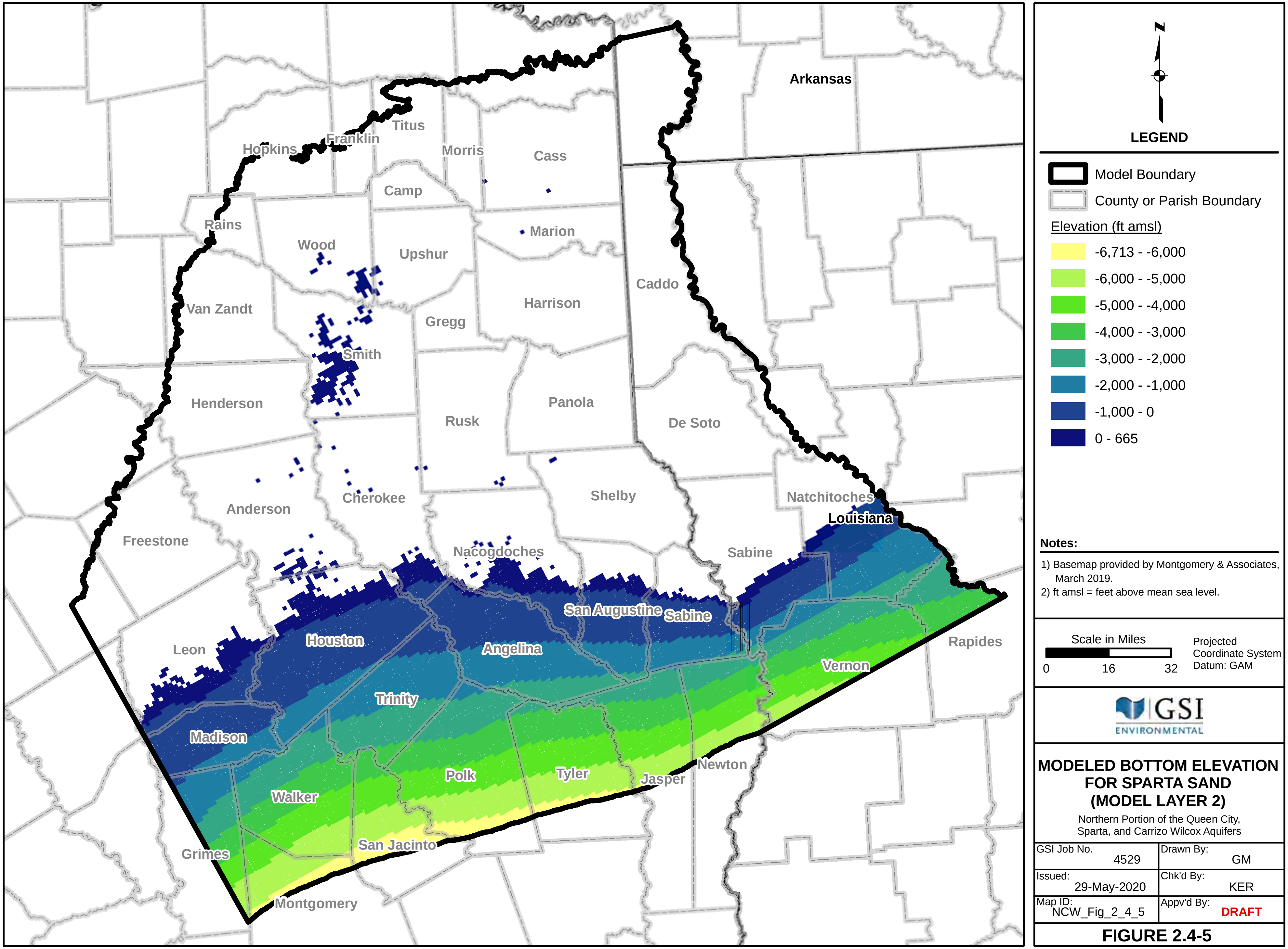
GSI ENVIRONMENTAL

MODELED THICKNESS OF QUATERNARY ALLUVIUM (MODEL LAYER 1)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 29-May-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_4	Appv'd By: DRAFT

FIGURE 2.4-4



Notes:

1) Basemap provided by Montgomery & Associates, March 2019.
2) ft amsl = feet above mean sea level.

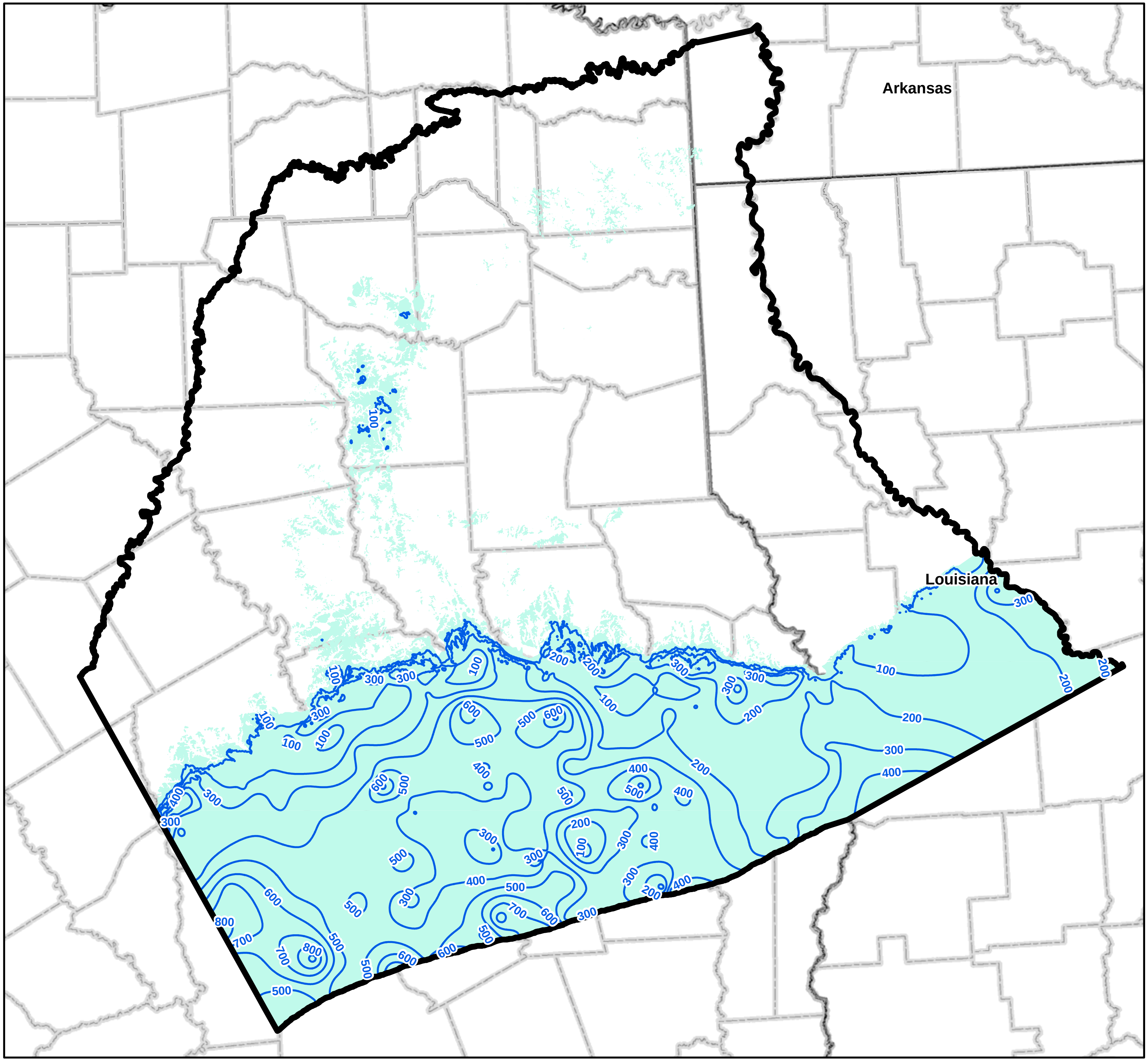
GSI ENVIRONMENTAL

MODELED BOTTOM ELEVATION FOR SPARTA SAND (MODEL LAYER 2)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 29-May-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_5	Appv'd By: DRAFT

FIGURE 2.4-5



N

LEGEND

- Model Boundary
- County or Parish Boundary
- Layer Extent
- Thickness Contour (Feet)

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

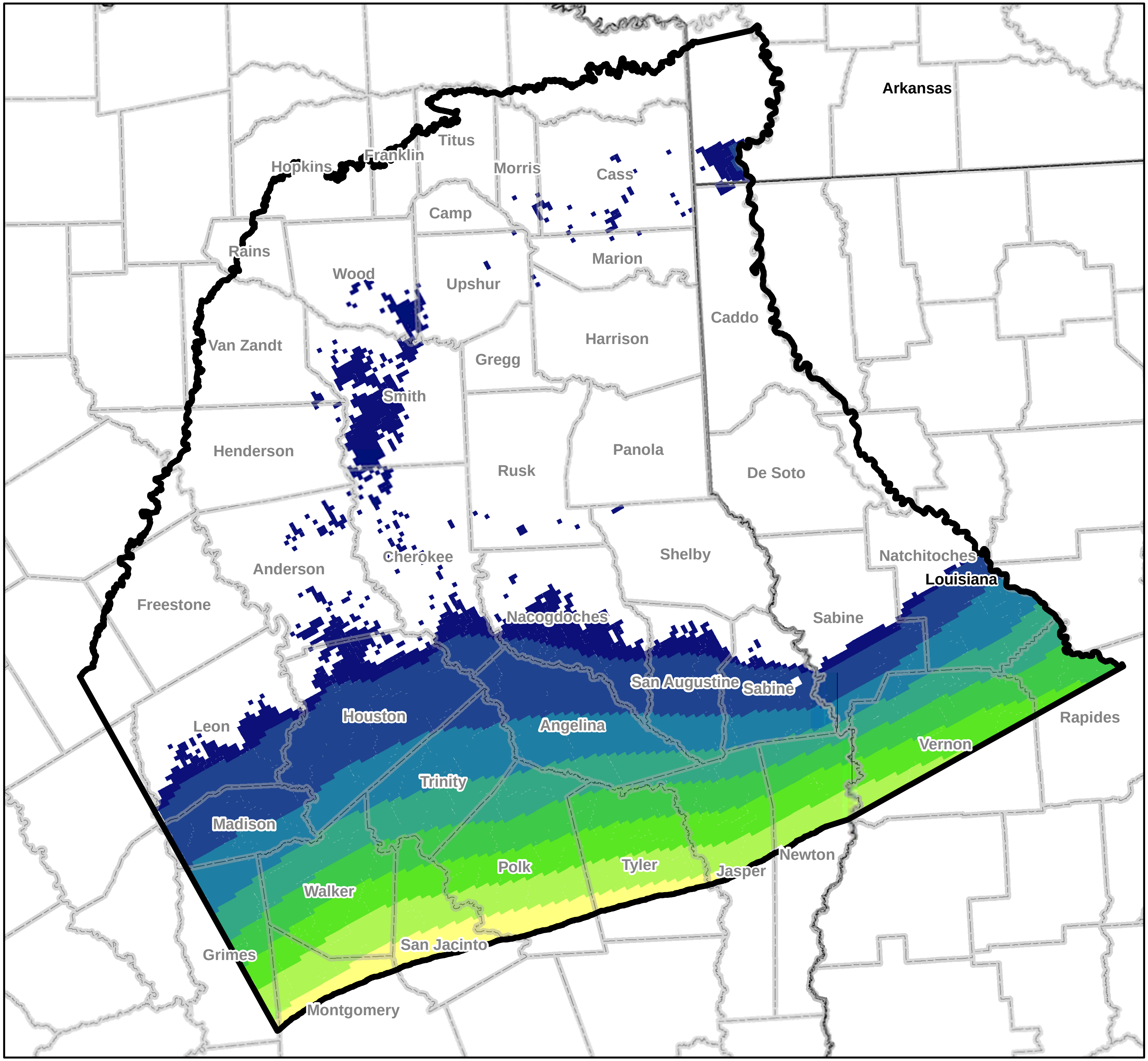
GSI ENVIRONMENTAL

MODELED THICKNESS CONTOURS FOR SPARTA SAND (MODEL LAYER 2)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: GM
Issued: 29-May-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_6	Appv'd By: DRAFT

FIGURE 2.4-6



N

LEGEND

Model Boundary

County or Parish Boundary

Elevation (ft amsl)

-6,902 - -6,000

-6,000 - -5.000

-5.000 - -4.000

-4.000 - -3.000

-3.000 - -2.000

-2.000 - -1.000

-1.000 - 0

0 - 703

Notes:

1) Basemap provided by Montgomery & Associates, March 2019.

2) ft amsl = feet above mean sea level.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

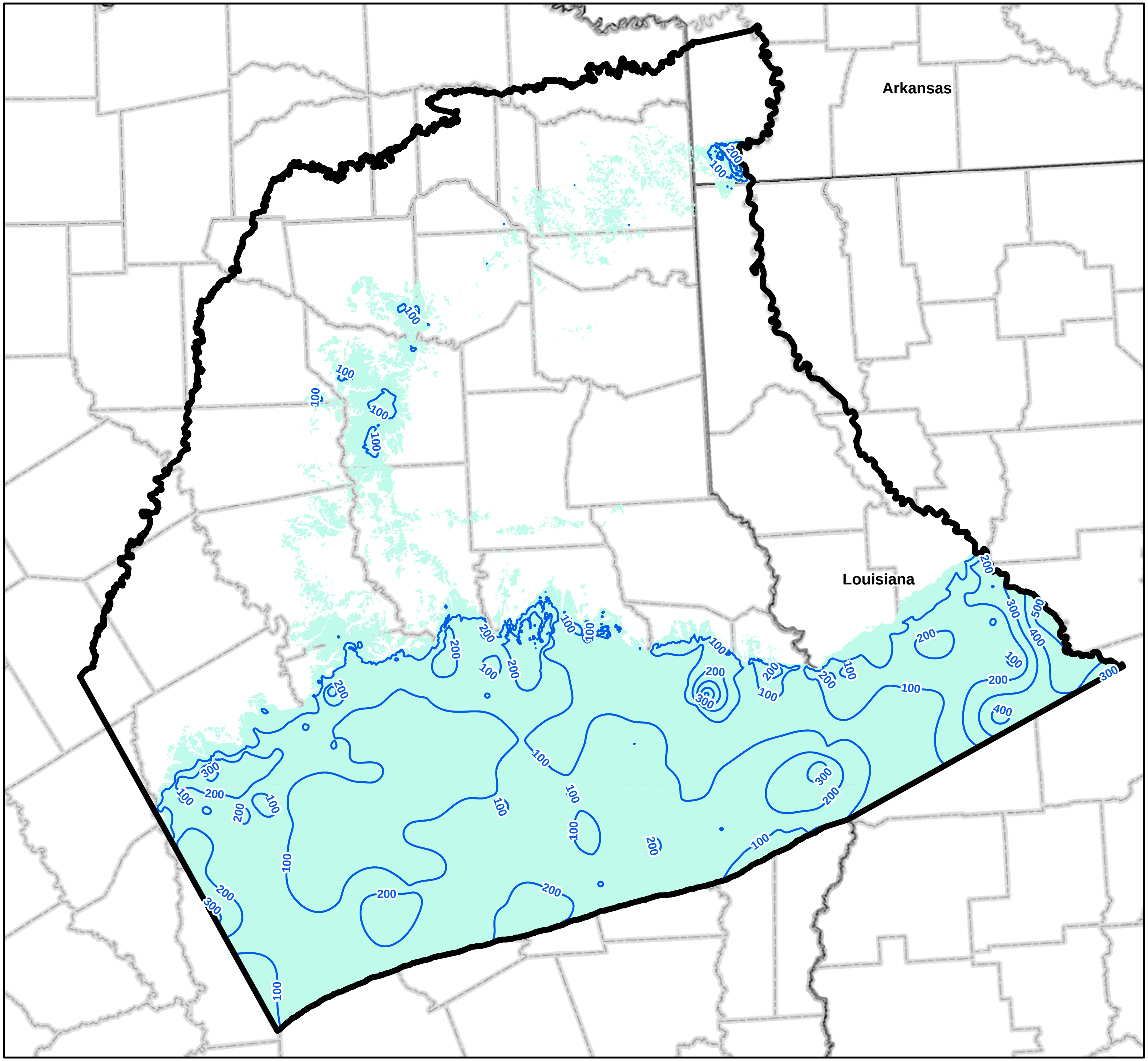
GSI ENVIRONMENTAL

MODELED BOTTOM ELEVATION FOR WECHES FORMATION (MODEL LAYER 3)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 29-May-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_7	Appv'd By: DRAFT

FIGURE 2.4-7



LEGEND

- Model Boundary
- County or Parish Boundary
- Layer Extent
- Thickness Contour (Feet)

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

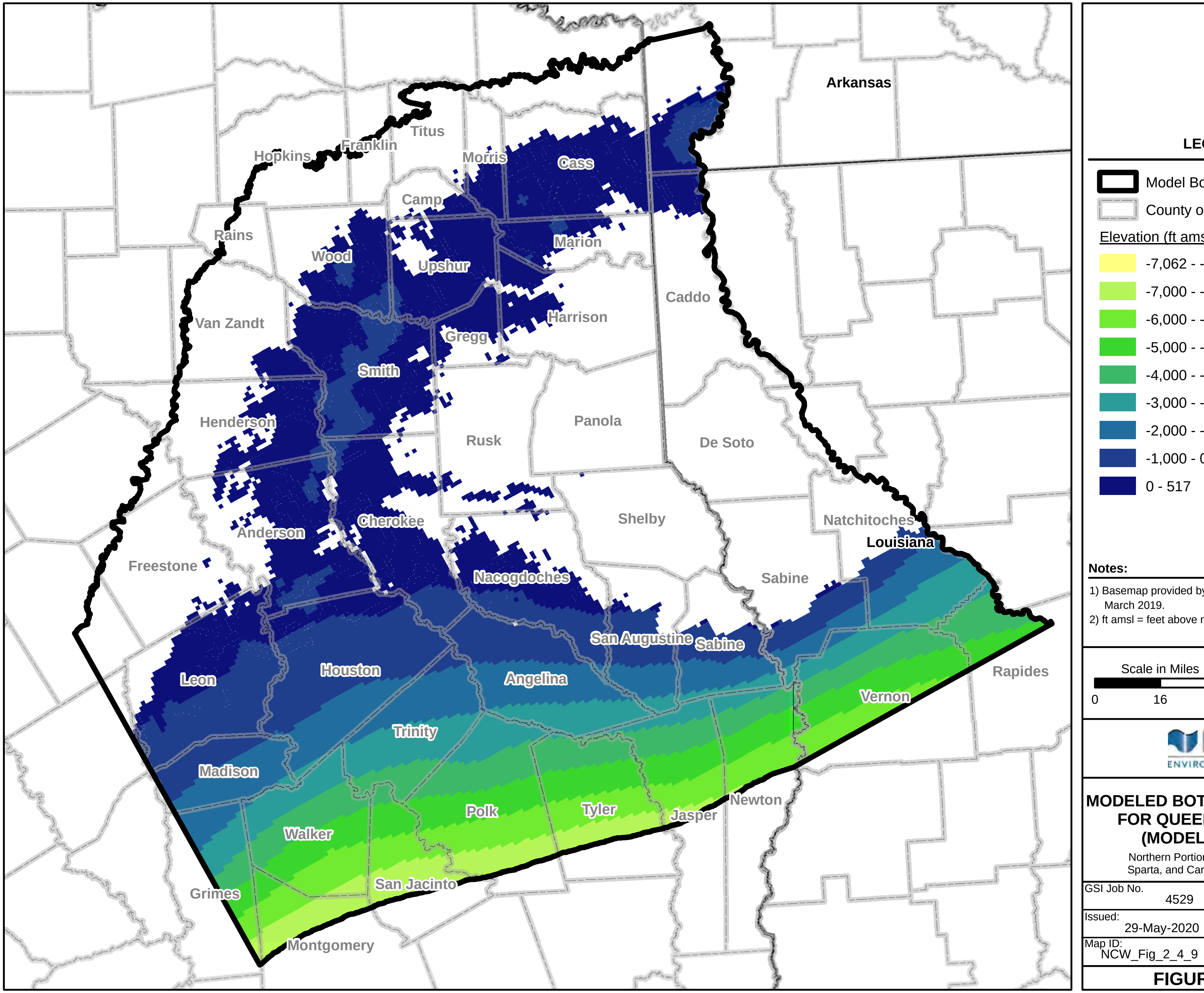
GSI ENVIRONMENTAL

MODELED THICKNESS CONTOURS FOR WECHES FORMATION (MODEL LAYER 3)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 29-May-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_8	Appv'd By: DRAFT

FIGURE 2.4-8



Notes:

1) Basemap provided by Montgomery & Associates, March 2019.
2) ft amsl = feet above mean sea level.

Projected Coordinate System
Datum: GAM

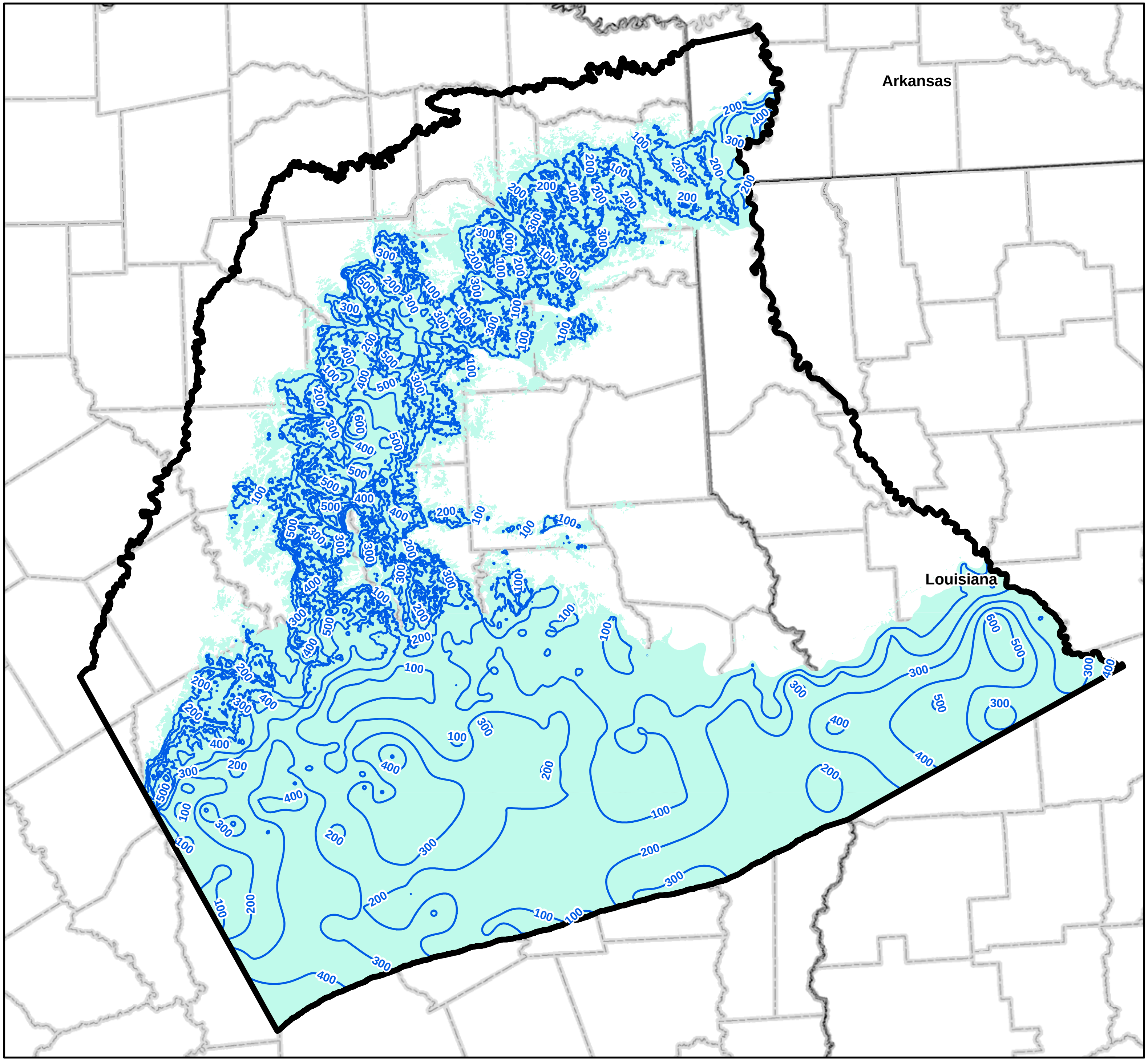
GSI ENVIRONMENTAL

MODELED BOTTOM ELEVATION FOR QUEEN CITY SAND (MODEL LAYER 4)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 29-May-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_9	Appv'd By: DRAFT

FIGURE 2.4-9

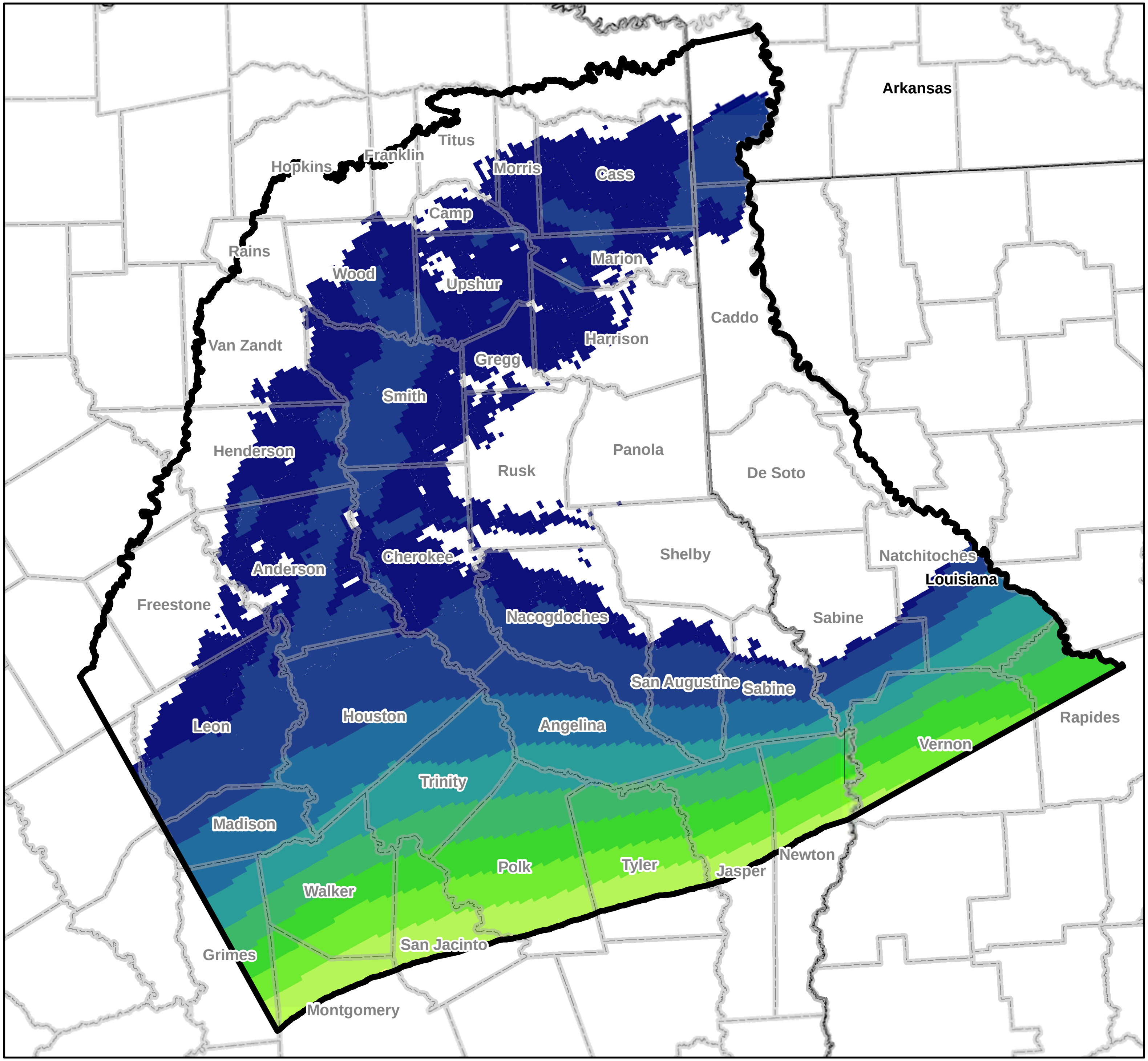


MODELED THICKNESS CONTOURS FOR QUEEN CITY SAND (MODEL LAYER 4)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: AV
Issued: 29-May-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_10	Appv'd By: DRAFT

FIGURE 2.4-10



N

LEGEND

- Model Boundary
- County or Parish Boundary

Elevation (ft amsl)

- -7,062 - -7,000
- -7,000 - -6,000
- -6,000 - -5,000
- -5,000 - -4,000
- -4,000 - -3,000
- -3,000 - -2,000
- -2,000 - -1,000
- -1,000 - 0
- 0 - 517

Notes:

1) Basemap provided by Montgomery & Associates, March 2019.
2) ft amsl = feet above mean sea level.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

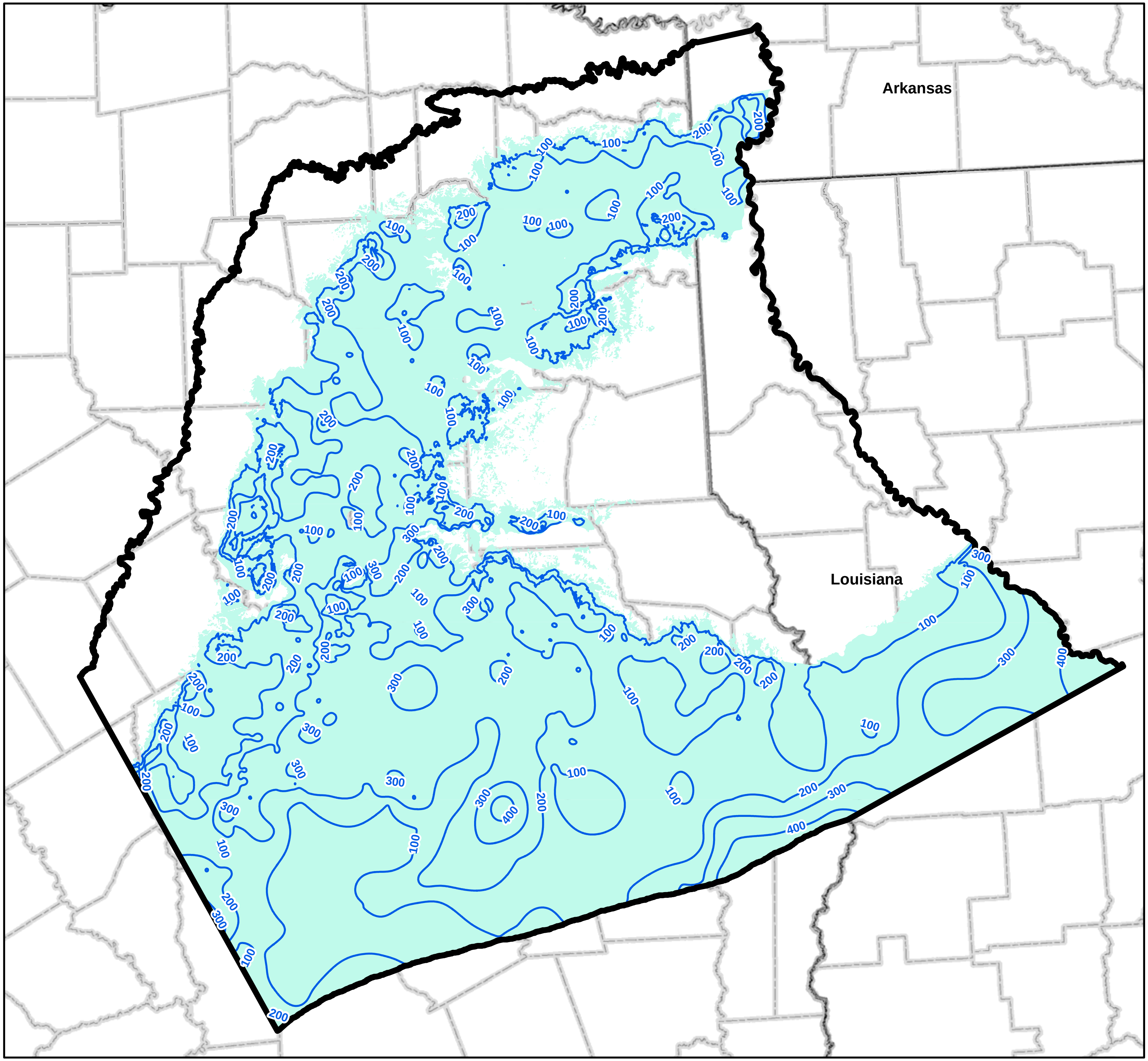
GSI ENVIRONMENTAL

MODELED BOTTOM ELEVATION FOR REKLAW FORMATION (MODEL LAYER 5)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_11	Appv'd By: DRAFT

FIGURE 2.4-11



N

LEGEND

- Model Boundary
- County or Parish Boundary
- Layer Extent
- Thickness Contour (Feet)

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

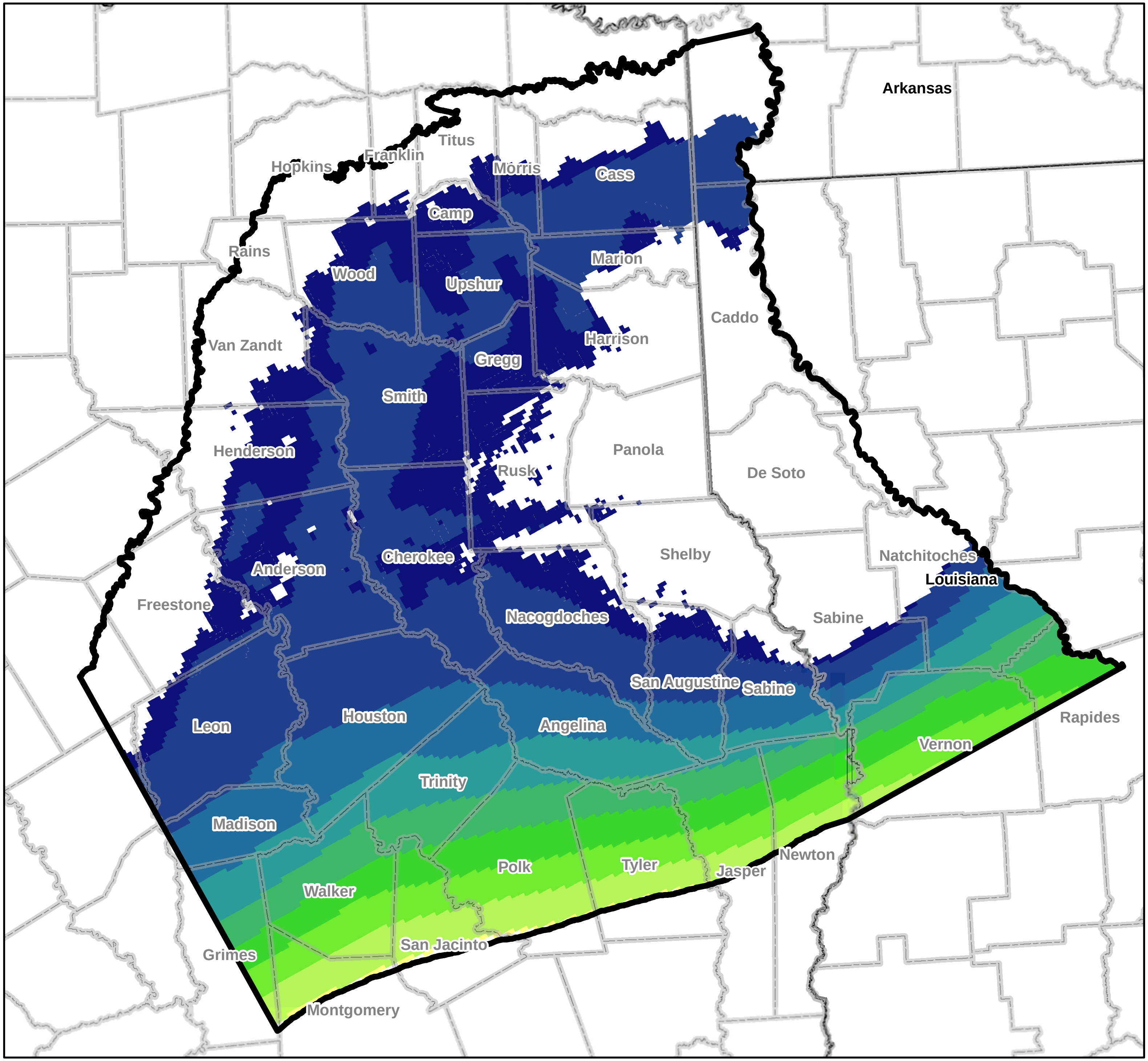
GSI ENVIRONMENTAL

MODELED THICKNESS CONTOURS FOR REKLAW FORMATION (MODEL LAYER 5)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_12	Appv'd By: DRAFT

FIGURE 2.4-12



LEGEND

Model Boundary

County or Parish Boundary

Elevation (ft amsl)

- -7,062 - -7,000
- -7,000 - -6,000
- -6,000 - -5,000
- -5,000 - -4,000
- -4,000 - -3,000
- -3,000 - -2,000
- -2,000 - -1,000
- -1,000 - 0
- 0 - 571

Notes:

1) Basemap provided by Montgomery & Associates, March 2019.
2) ft amsl = feet above mean sea level.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

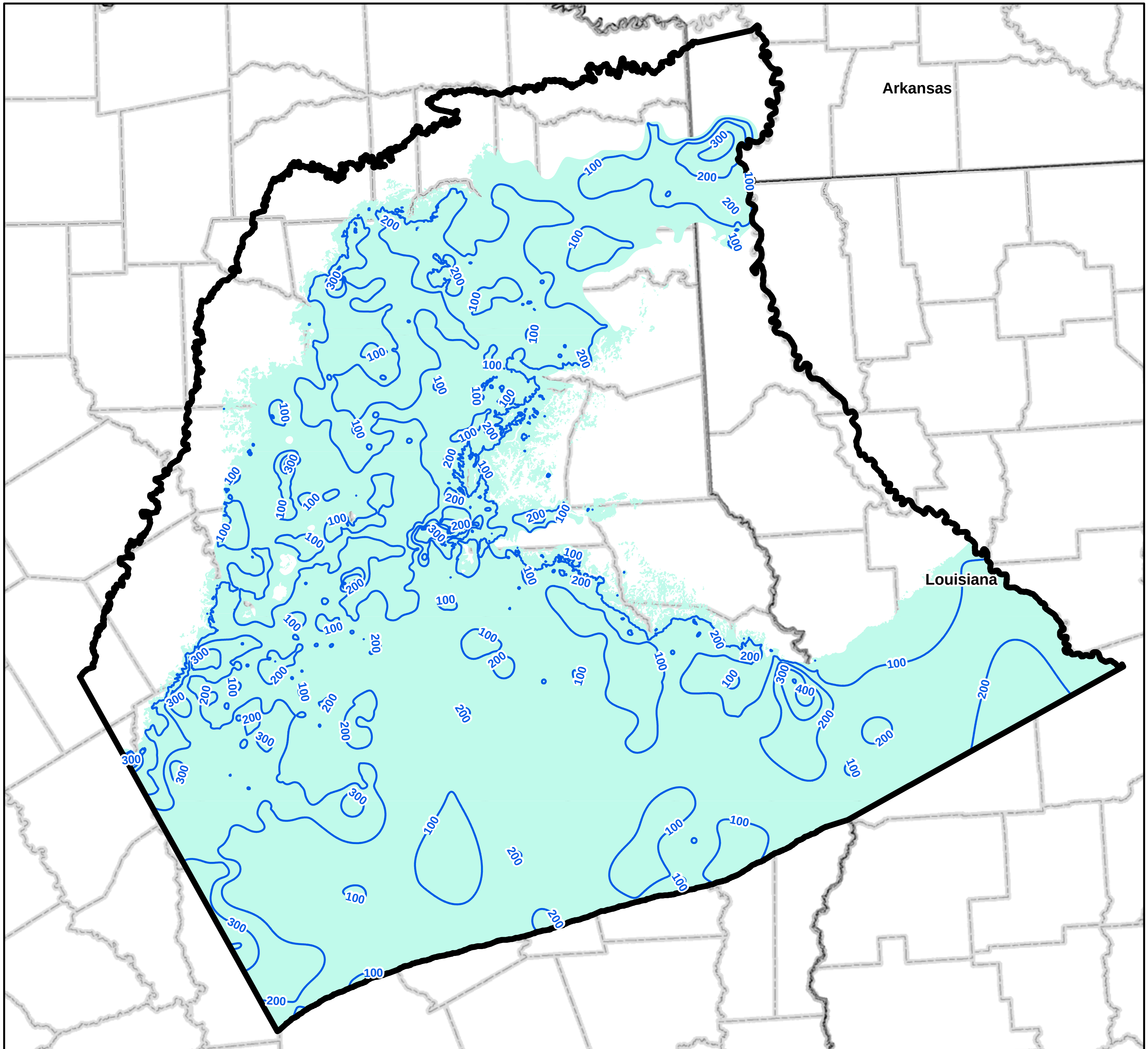
GSI ENVIRONMENTAL

MODELED BOTTOM ELEVATION FOR CARRIZO SAND (MODEL LAYER 6)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_13	Appv'd By: DRAFT

FIGURE 2.4-13



LEGEND

- Model Boundary
- County or Parish Boundary
- Layer Extent
- Thickness Contour (Feet)

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

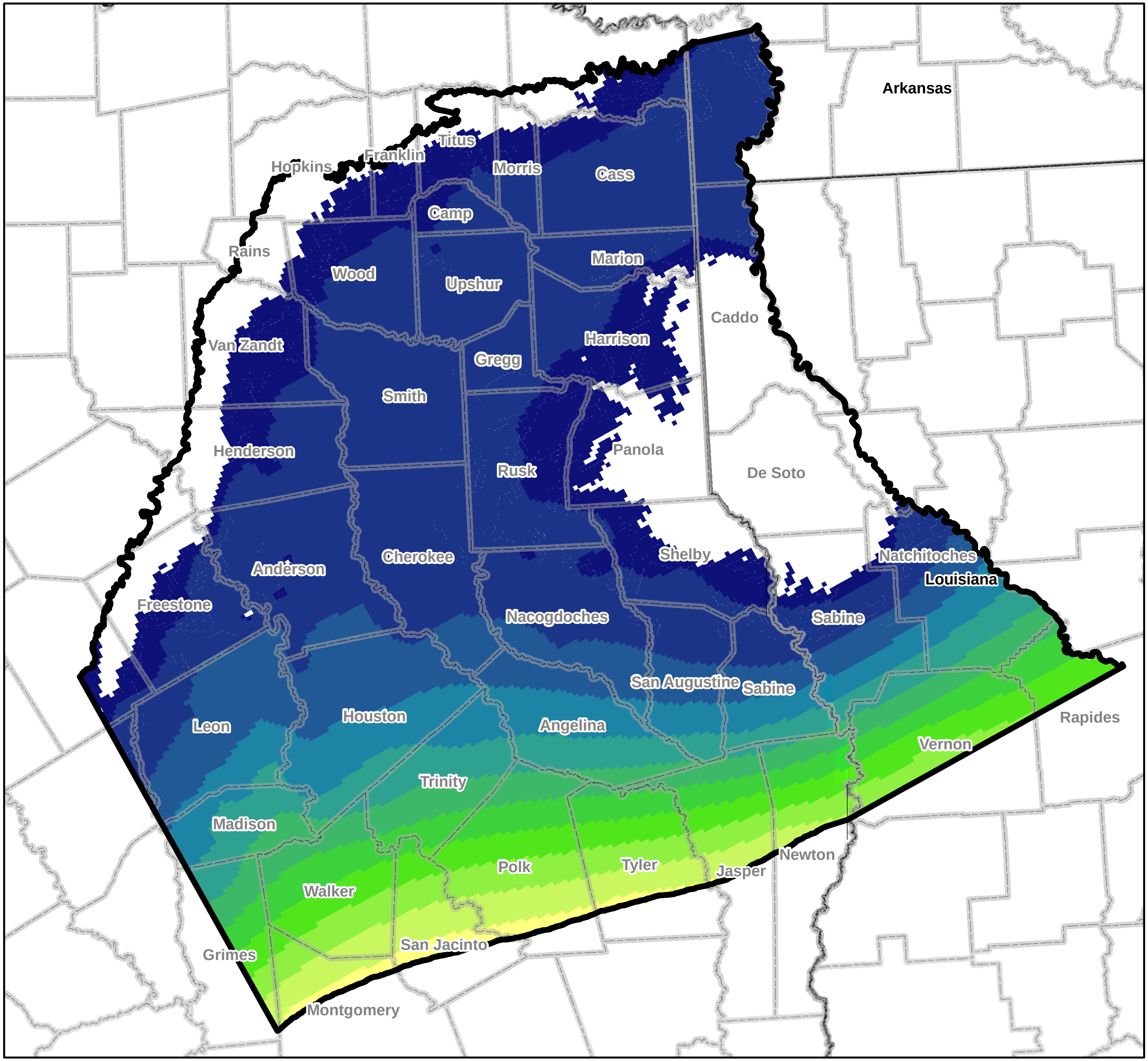
GSI ENVIRONMENTAL

MODELED THICKNESS CONTOURS FOR CARRIZO SAND (MODEL LAYER 6)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_14	Appv'd By: DRAFT

FIGURE 2.4-14



LEGEND

Model Boundary

County or Parish Boundary

Elevation (ft amsl)

- -9,491 - -9,000
- -9,000 - -8,000
- -8,000 - -7,000
- -7,000 - -6,000
- -6,000 - -5,000
- -5,000 - -4,000
- -4,000 - -3,000
- -3,000 - -2,000
- -2,000 - -1,000
- -1,000 - 0
- 0 - 546

Notes:

1) Basemap provided by Montgomery & Associates, March 2019.
2) ft amsl = feet above mean sea level.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

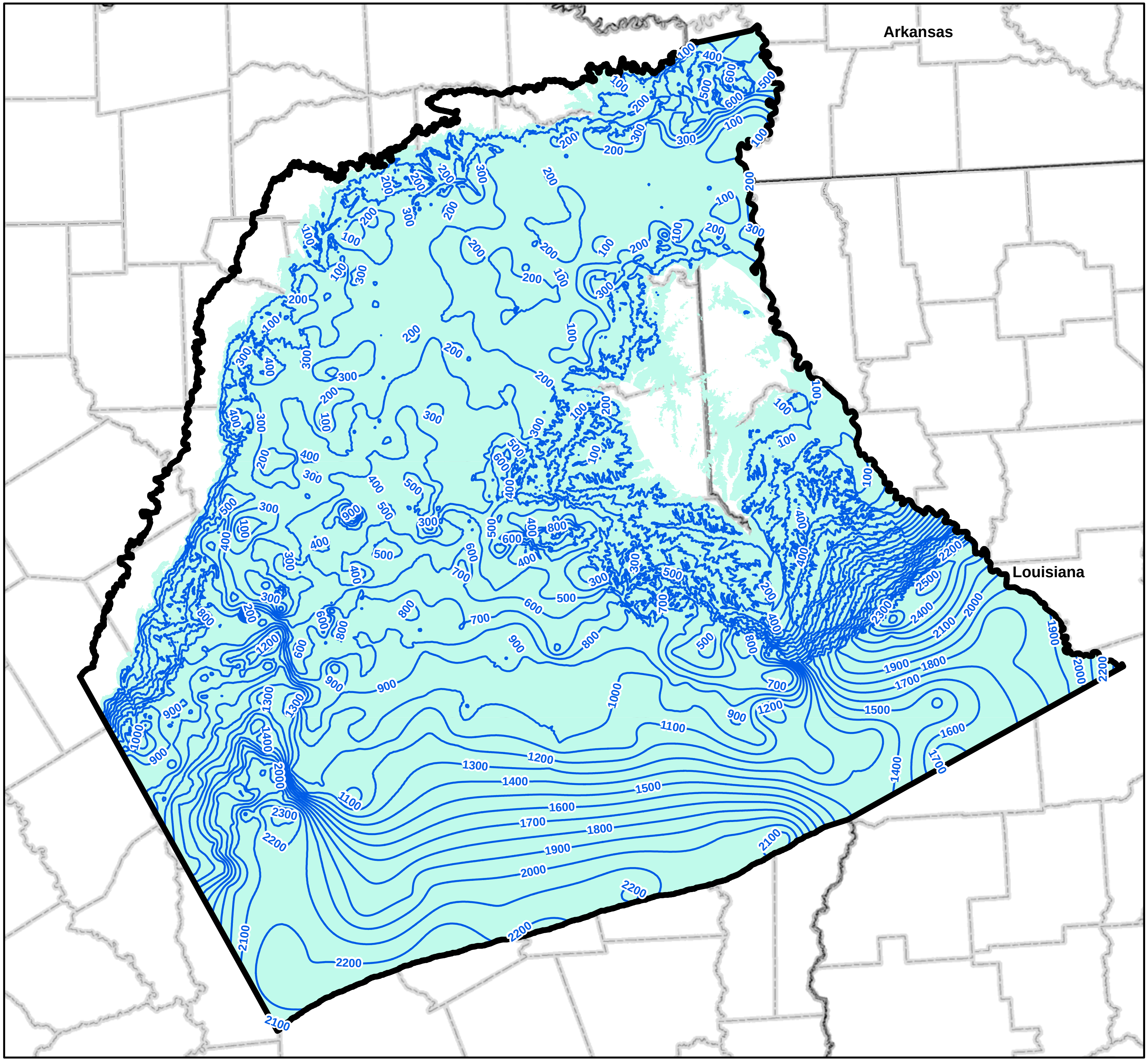
GSI ENVIRONMENTAL

MODELED BOTTOM ELEVATION FOR UPPER WILCOX (MODEL LAYER 7)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_15	Appv'd By: DRAFT

FIGURE 2.4-15



N

LEGEND

- Model Boundary
- County or Parish Boundary
- Layer Extent
- Thickness Contour (Feet)

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

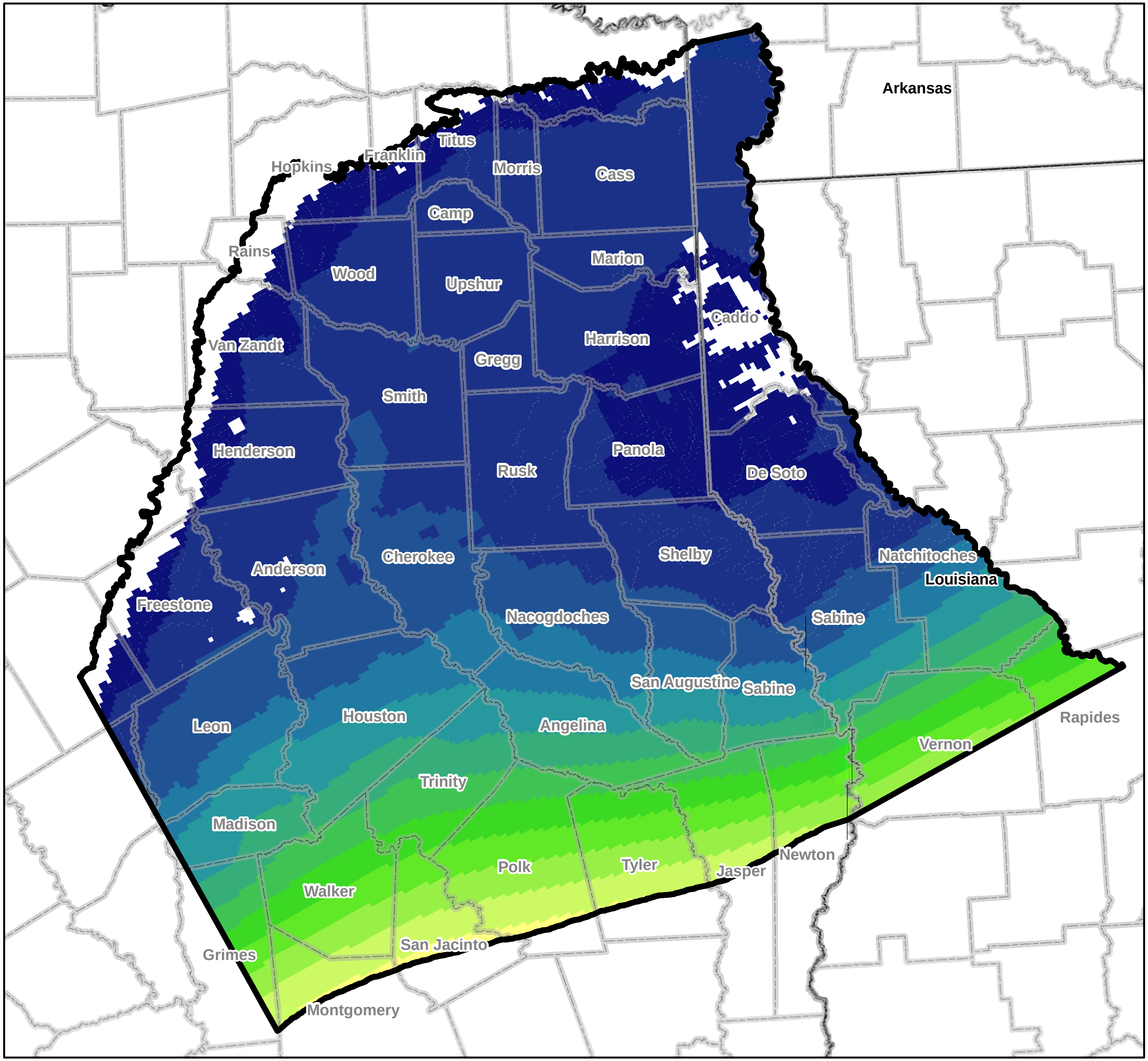
GSI ENVIRONMENTAL

MODELED THICKNESS CONTOURS FOR UPPER WILCOX (MODEL LAYER 7)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_16	Appv'd By: DRAFT

FIGURE 2.4-16



N

LEGEND

Model Boundary

County or Parish Boundary

Elevation (ft amsl)

- -10,406 - -10,000
- -10,000 - -9,000
- -9,000 - -8,000
- -8,000 - -7,000
- -7,000 - -6,000
- -6,000 - -5,000
- -5,000 - -4,000
- -4,000 - -3,000
- -3,000 - -2,000
- -2,000 - -1,000
- -1,000 - 0
- 0 - 512

Notes:

1) Basemap provided by Montgomery & Associates, March 2019.
2) ft amsl = feet above mean sea level.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

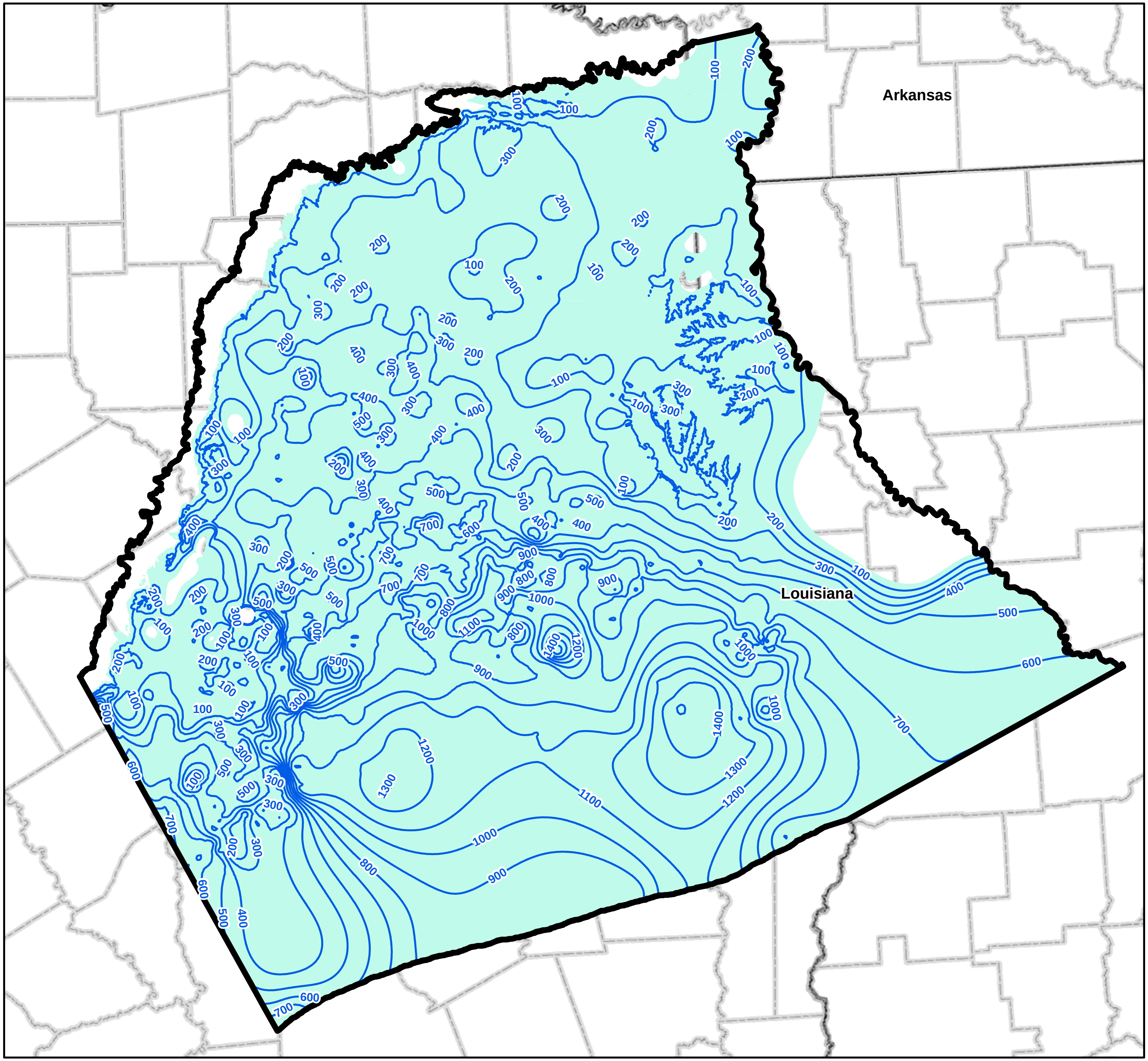
GSI ENVIRONMENTAL

MODELED BOTTOM ELEVATION FOR MIDDLE WILCOX (MODEL LAYER 8)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_17	Appv'd By: DRAFT

FIGURE 2.4-17



N

LEGEND

- Model Boundary
- County or Parish Boundary
- Layer Extent
- Thickness Contour (Feet)

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

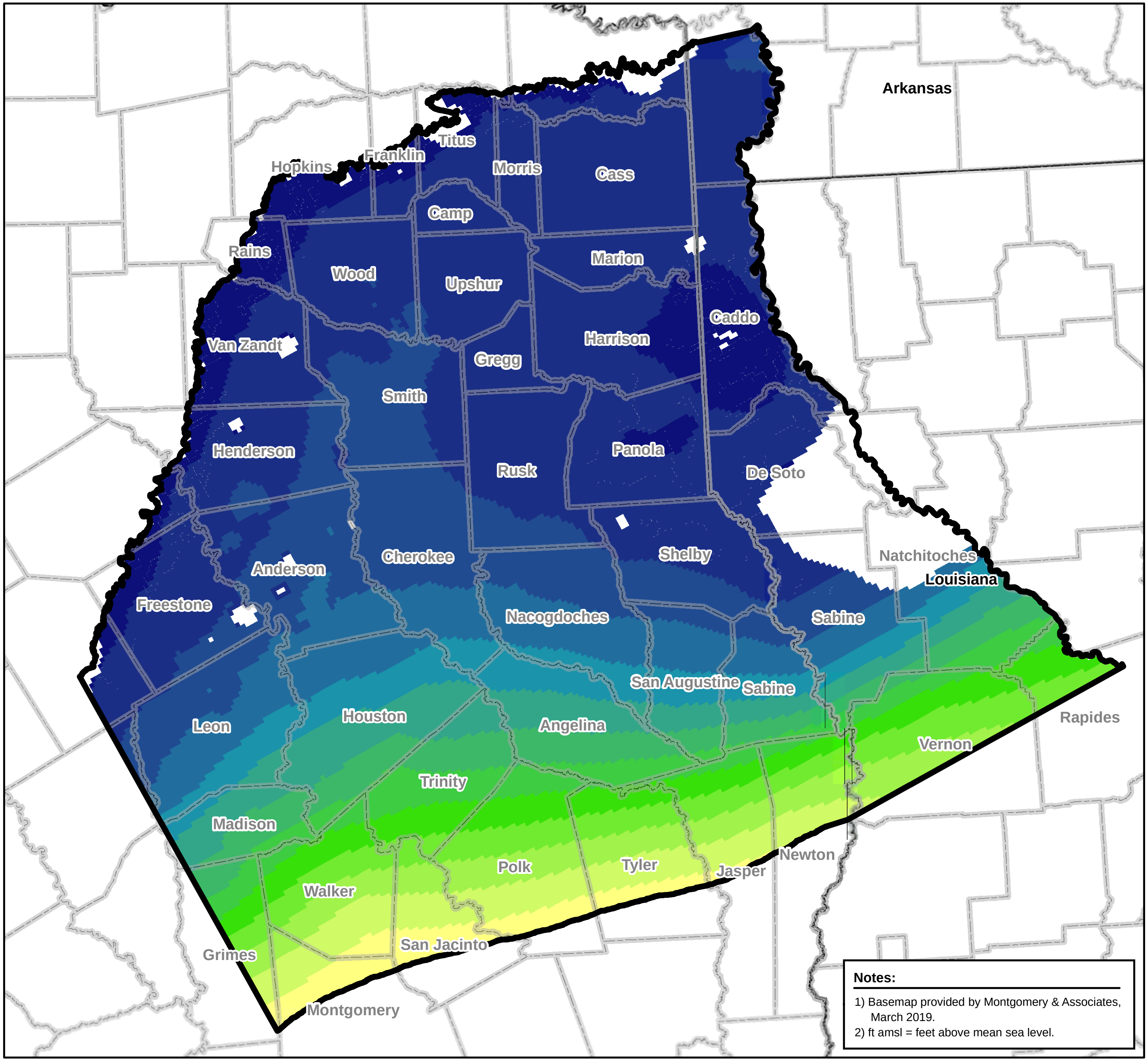
GSI ENVIRONMENTAL

MODELED THICKNESS CONTOURS FOR MIDDLE WILCOX (MODEL LAYER 8)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_18	Appv'd By: DRAFT

FIGURE 2.4-18



Notes:

1) Basemap provided by Montgomery & Associates, March 2019.

2) ft amsl = feet above mean sea level.

N

LEGEND

Model Boundary

County or Parish Boundary

Elevation (ft amsl)

- -11,685 - -11,000
- -11,000 - -10,000
- -10,000 - -9,000
- -9,000 - -8,000
- -8,000 - -7,000
- -7,000 - -6,000
- -6,000 - -5,000
- -5,000 - -4,000
- -4,000 - -3,000
- -3,000 - -2,000
- -2,000 - -1,000
- -1,000 - 0
- 0 - 507

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

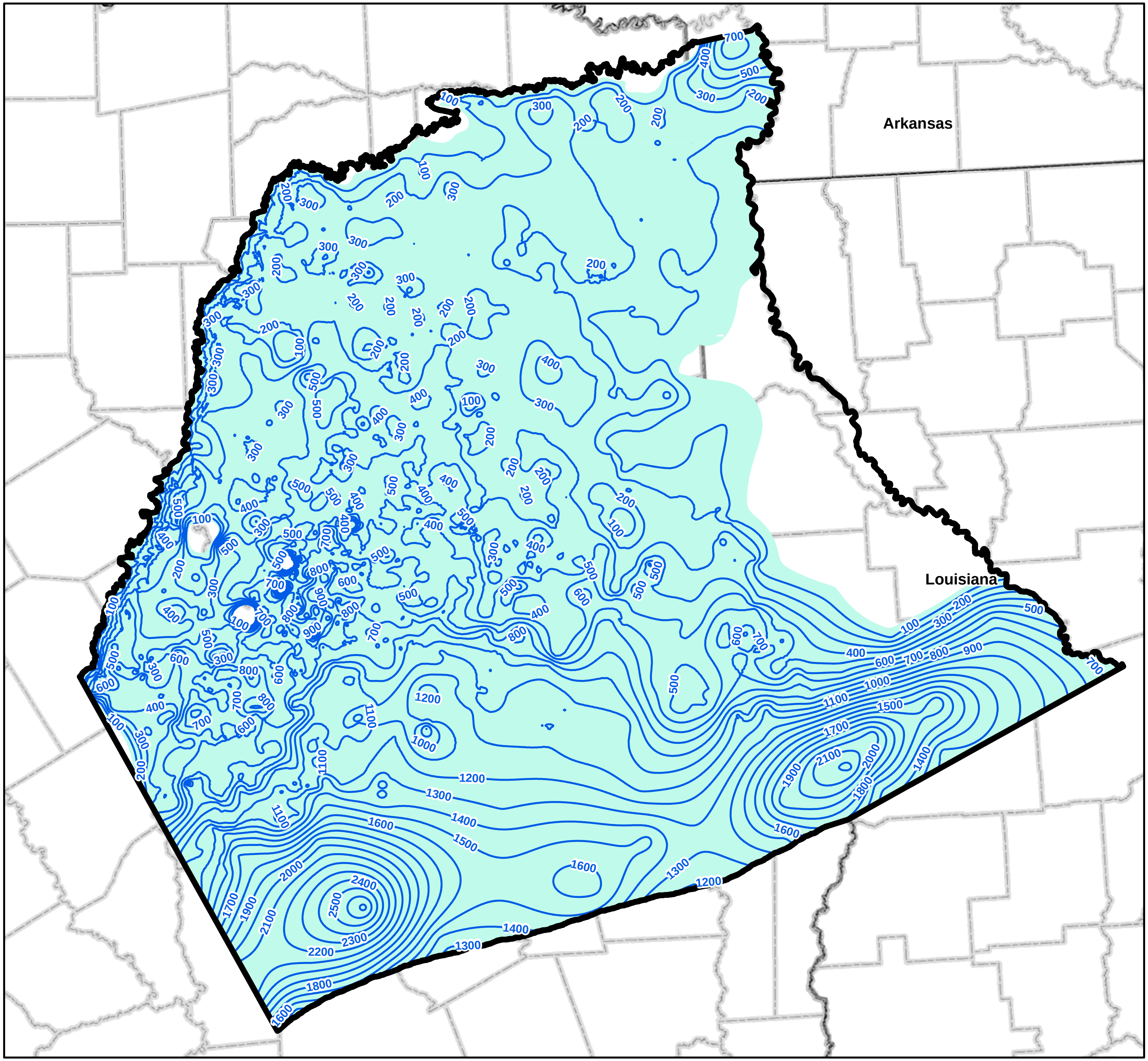
GSI ENVIRONMENTAL

MODELED BOTTOM ELEVATION FOR LOWER WILCOX (MODEL LAYER 9)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_19	Appv'd By: DRAFT

FIGURE 2.4-19



LEGEND

- Model Boundary
- County or Parish Boundary
- Layer Extent
- Thickness Contour (Feet)

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles: 0 16 32

Projected Coordinate System
Datum: GAM

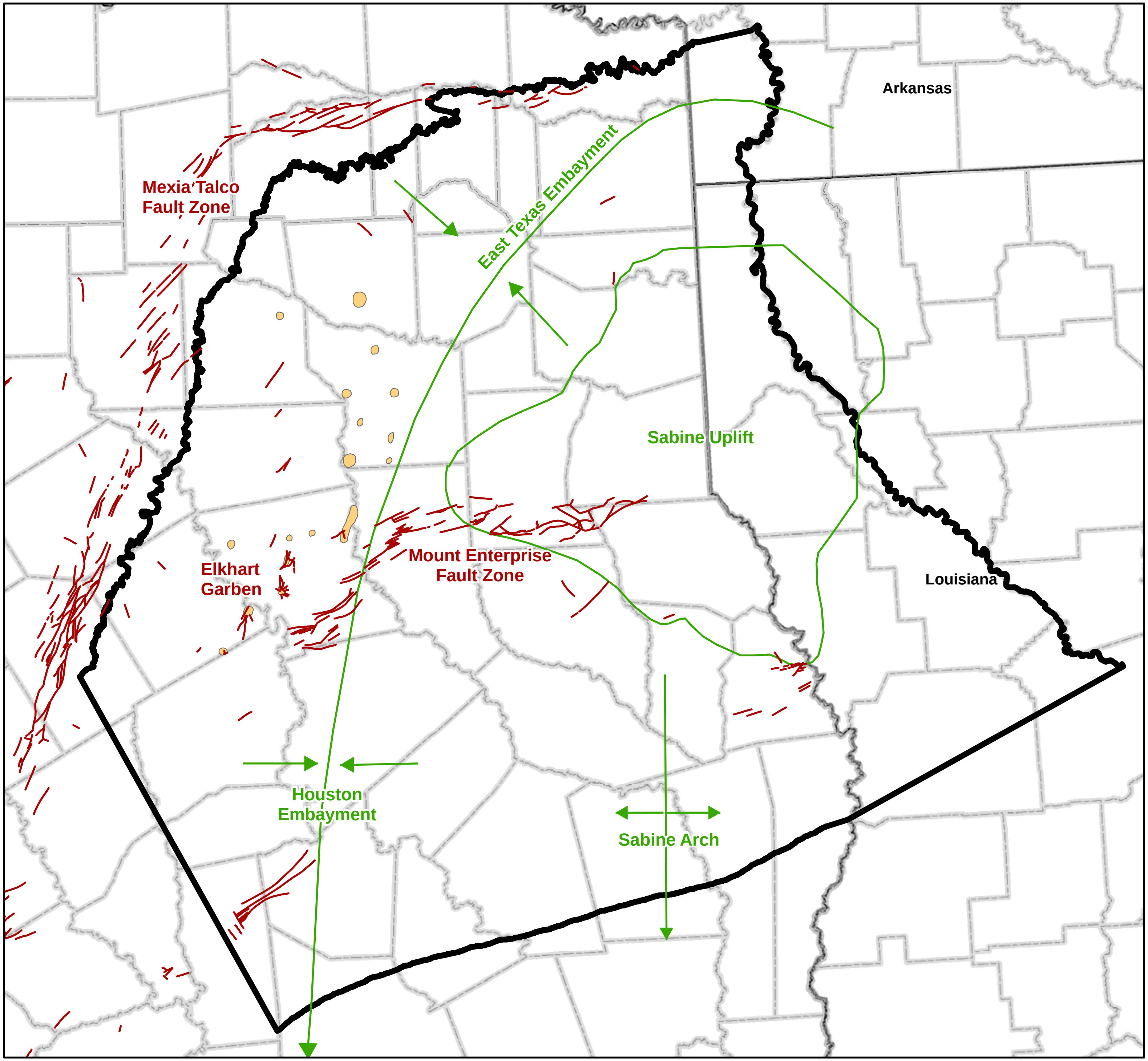
GSI ENVIRONMENTAL

MODELED THICKNESS CONTOURS FOR LOWER WILCOX (MODEL LAYER 9)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_20	Appv'd By: DRAFT

FIGURE 2.4-20



N

LEGEND

- Model Boundary
- County or Parish Boundary
- Salt Dome
- Normal Fault
- Anticline Showing Dip Direction
- Syncline Showing Dip Direction

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

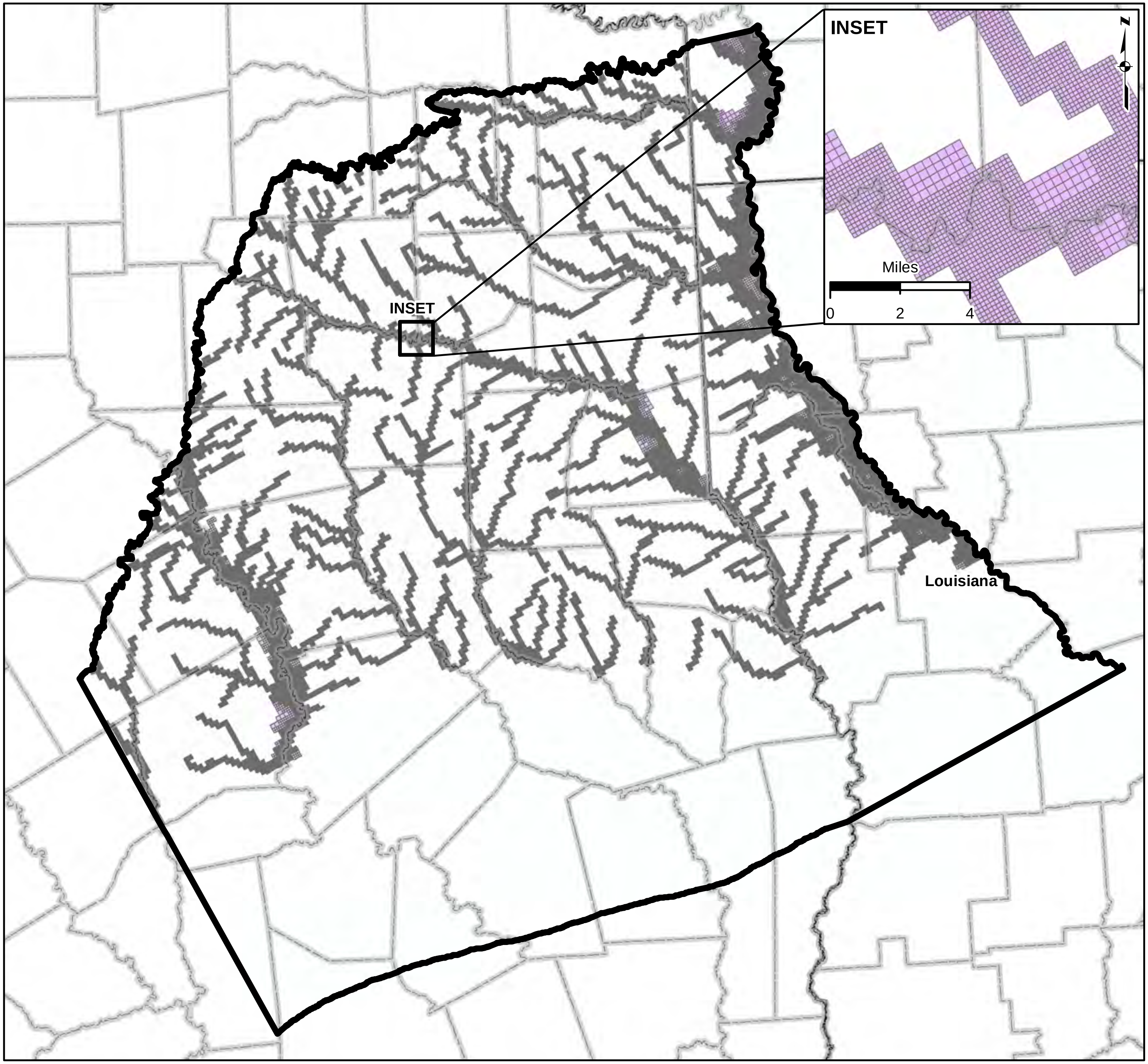
GSI ENVIRONMENTAL

GENERAL STRUCTURAL SETTING

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_21	Appv'd By: DRAFT

FIGURE 2.4-21



LEGEND

- Model Boundary
- County or Parish Boundary
- Model Layer 1 Cells

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

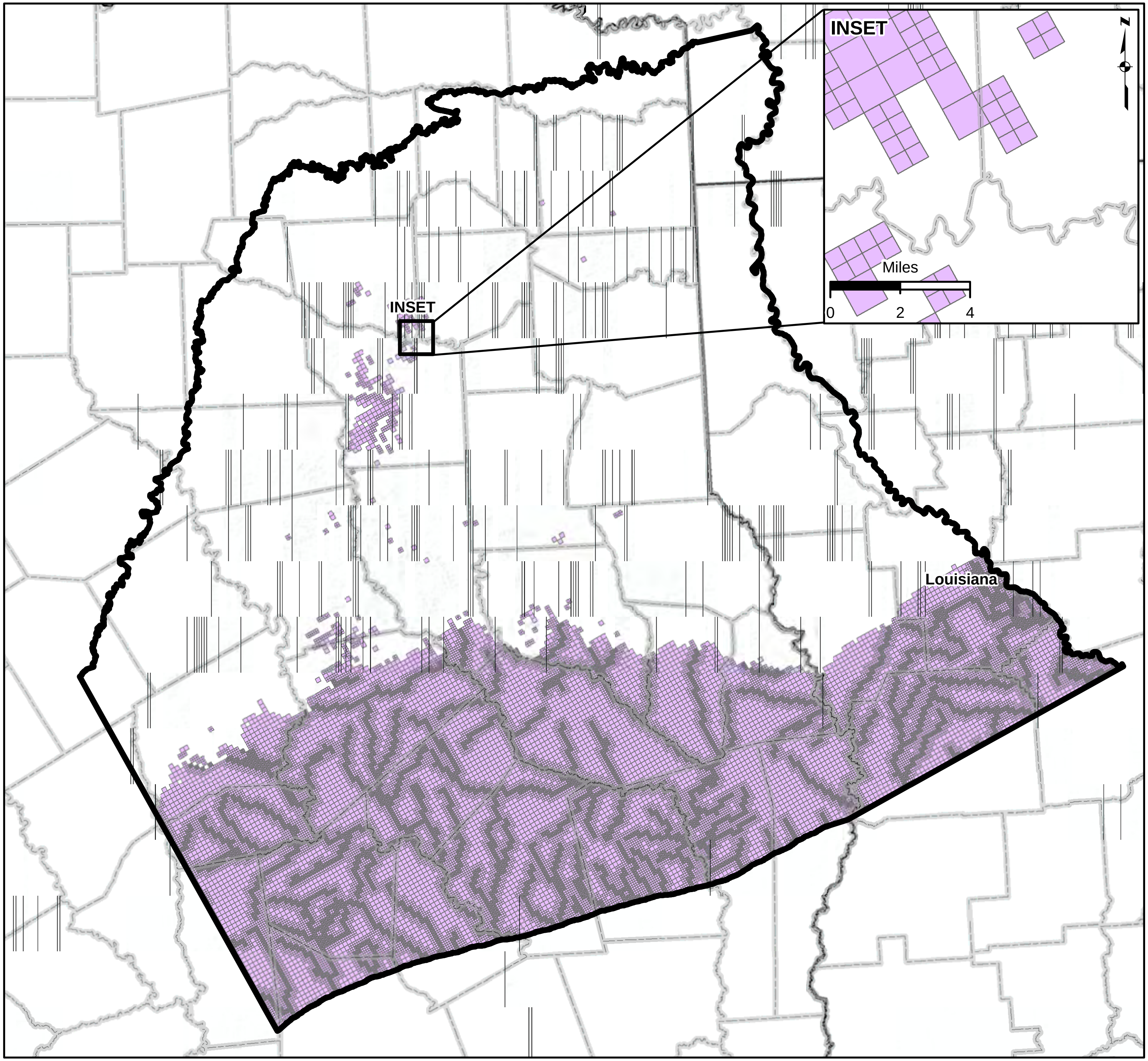
GSI ENVIRONMENTAL

GROUNDWATER MODEL DOMAIN DISCRETIZATION FOR QUATERNARY ALLUVIUM (MODEL LAYER 1)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_22	Appv'd By: DRAFT

FIGURE 2.4-22



LEGEND

Model Boundary
County or Parish Boundary
Model Layer 2 Cells

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

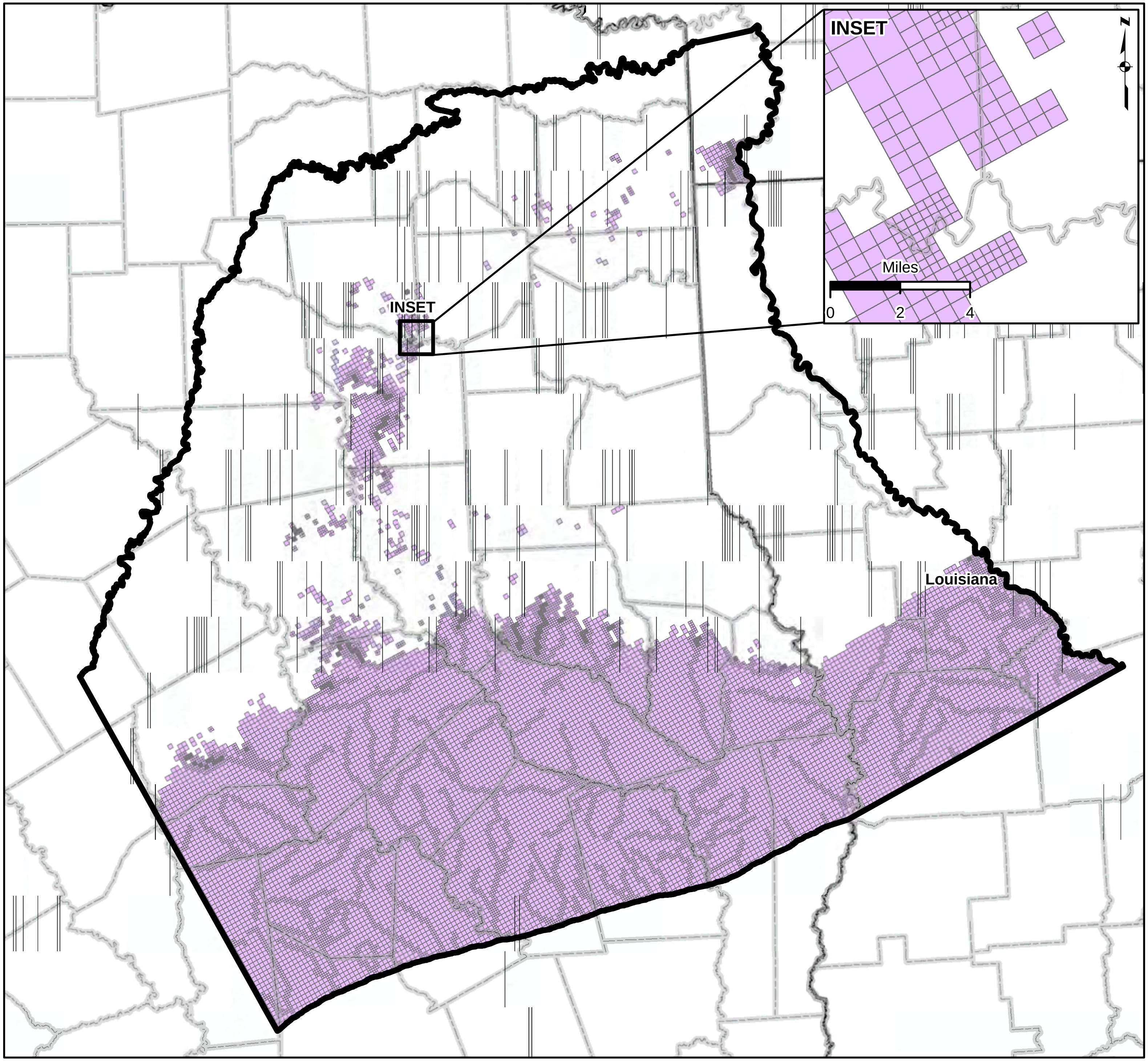
GSI ENVIRONMENTAL

GROUNDWATER MODEL DOMAIN DISCRETIZATION FOR SPARTA SAND (MODEL LAYER 2)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_23	Appv'd By: DRAFT

FIGURE 2.4-23



LEGEND

Model Boundary

County or Parish Boundary

Model Layer 3 Cells

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

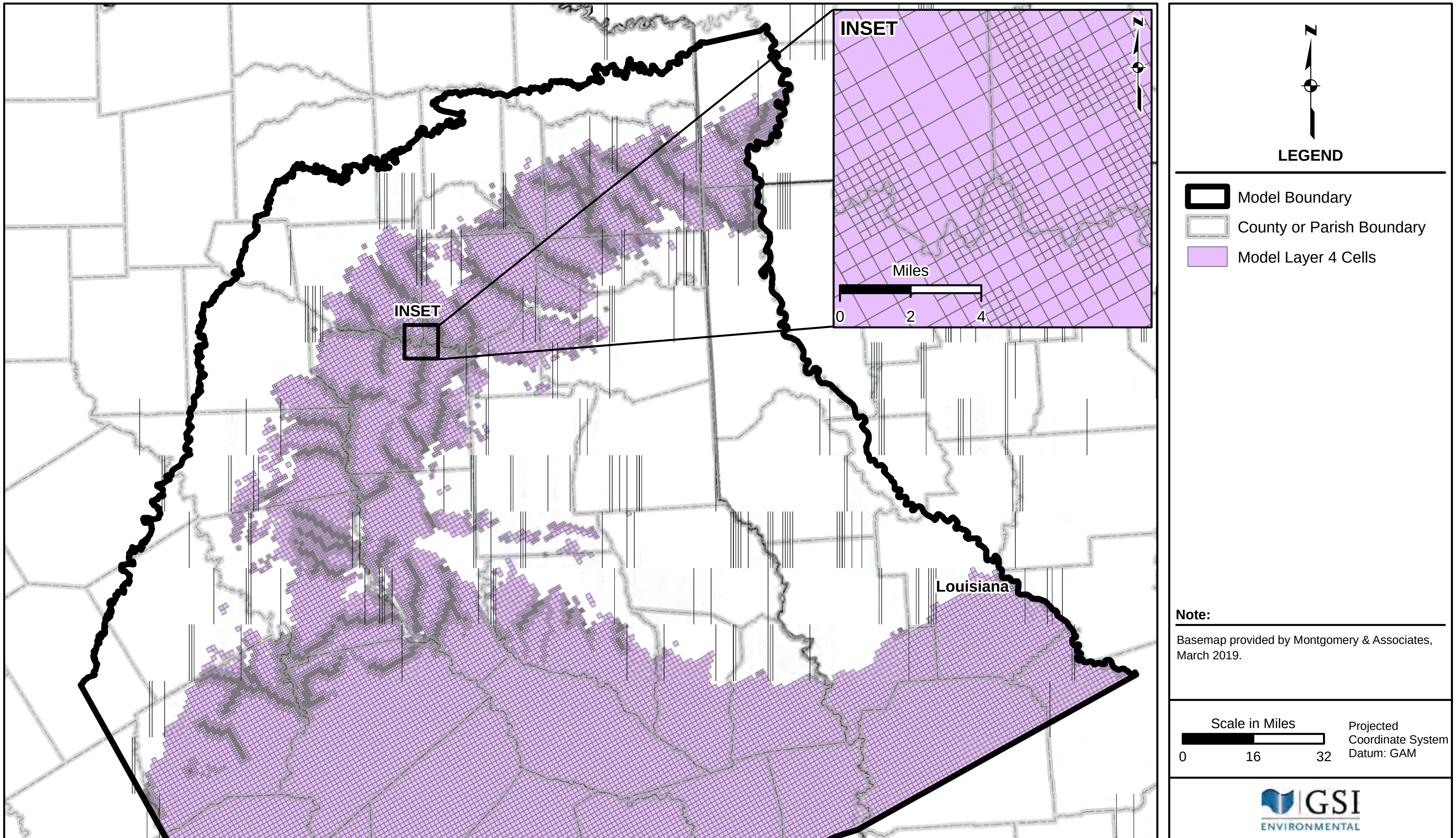
GSI ENVIRONMENTAL

GROUNDWATER MODEL DOMAIN DISCRETIZATION FOR WECHES FORMATION (MODEL LAYER 3)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_24	Appv'd By: DRAFT

FIGURE 2.4-24

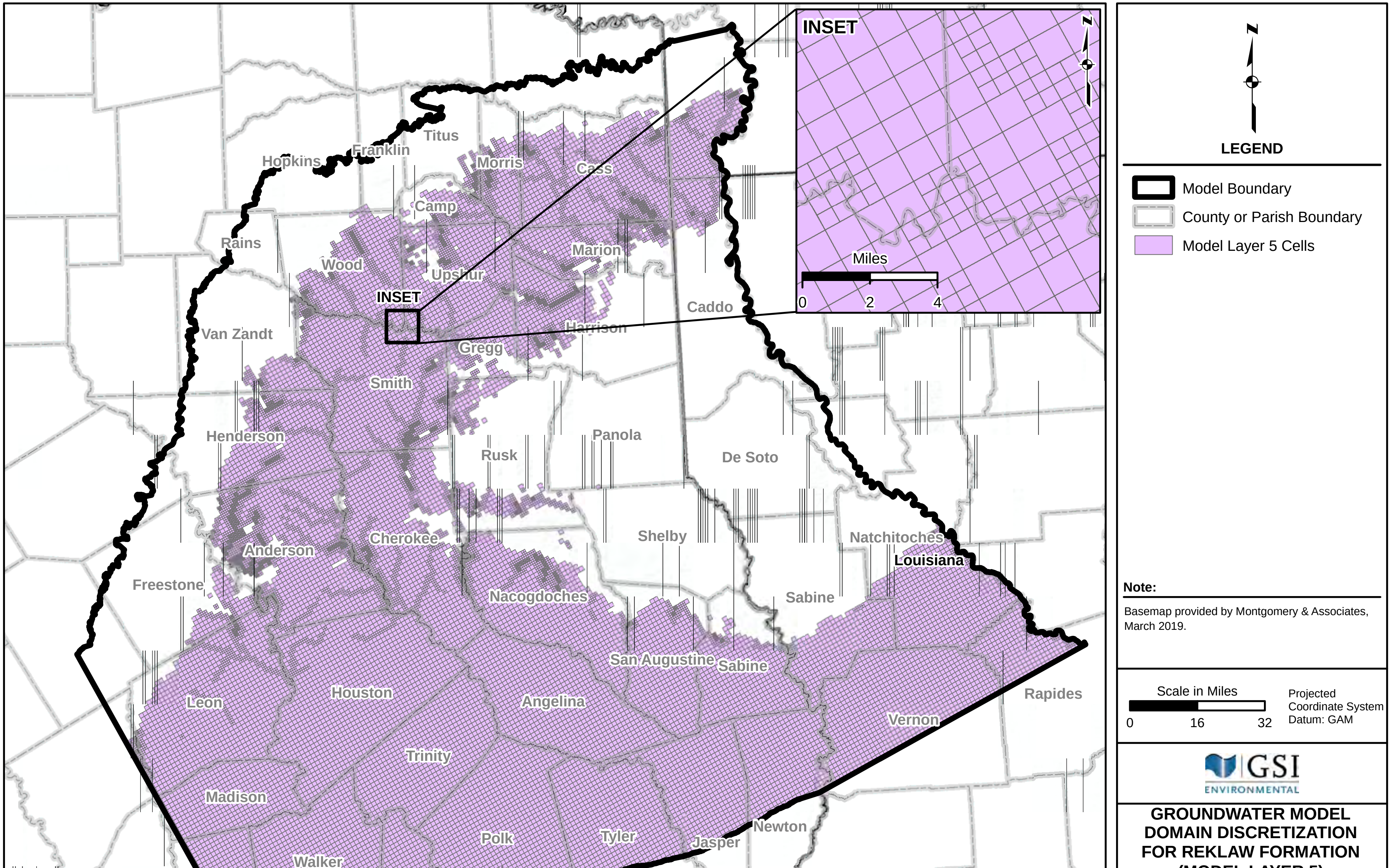


GROUNDWATER MODEL DOMAIN DISCRETIZATION FOR QUEEN CITY SAND (MODEL LAYER 4)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_25	Appv'd By: DRAFT

FIGURE 2.4-25



Note:

Basemap provided by Montgomery & Associates, March 2019.

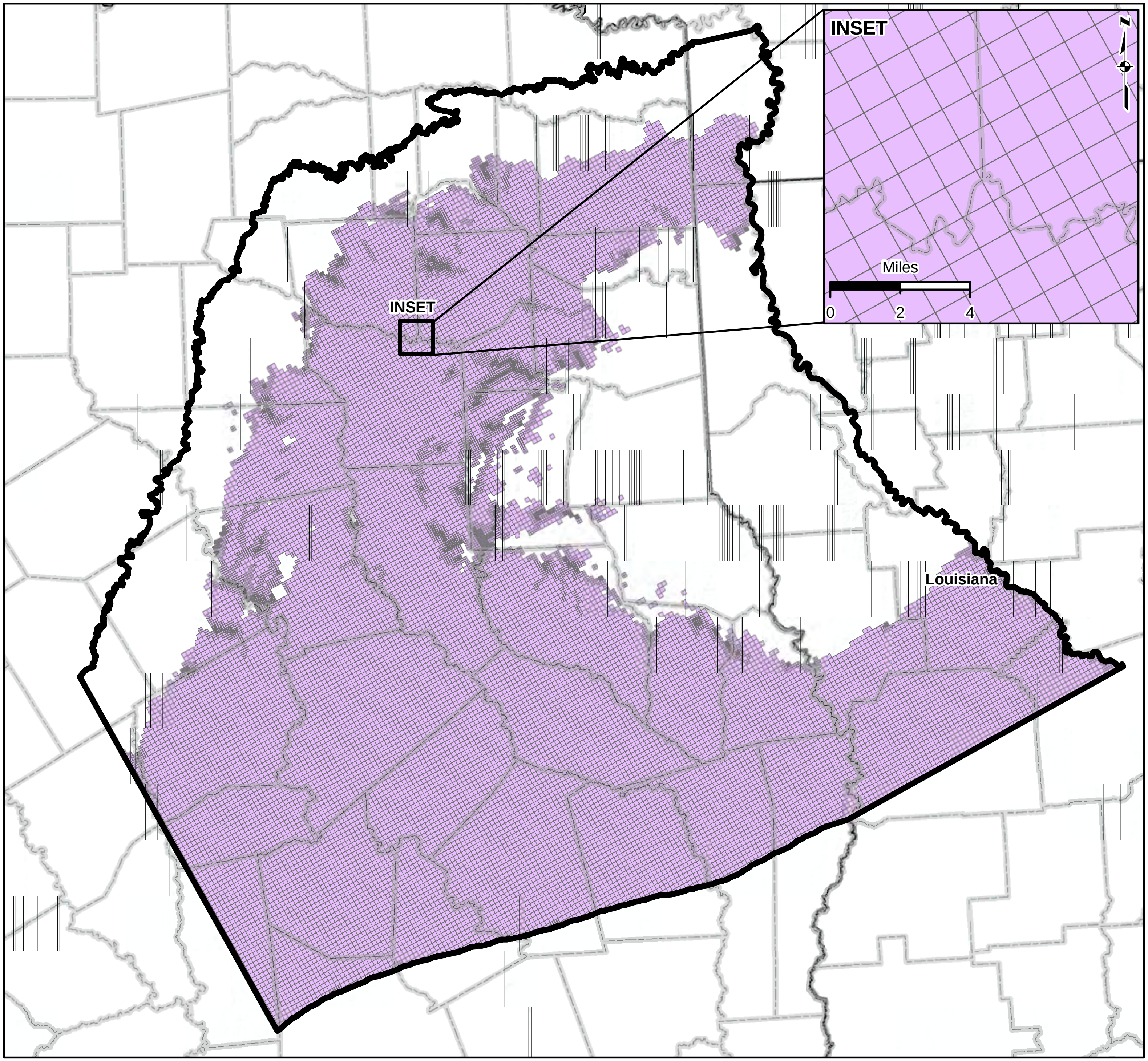
GSI ENVIRONMENTAL

GROUNDWATER MODEL DOMAIN DISCRETIZATION FOR REKLAW FORMATION (MODEL LAYER 5)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_26	Appv'd By: DRAFT

FIGURE 2.4-26



LEGEND

- Model Boundary
- County or Parish Boundary
- Model Layer 6 Cells

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

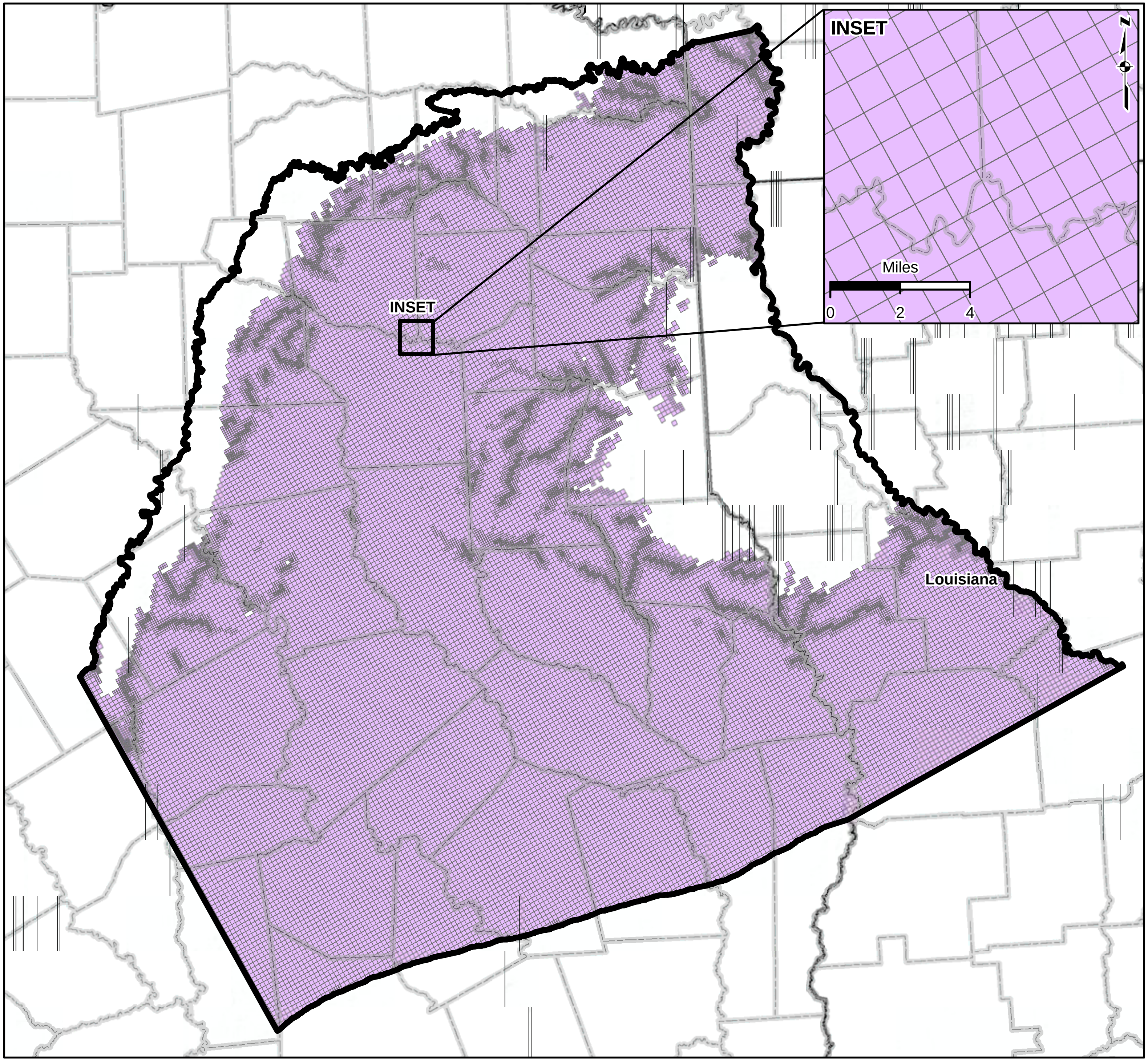
GSI ENVIRONMENTAL

GROUNDWATER MODEL DOMAIN DISCRETIZATION FOR CARRIZO SAND (MODEL LAYER 6)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_27	Appv'd By: DRAFT

FIGURE 2.4-27



LEGEND

- Model Boundary
- County or Parish Boundary
- Model Layer 7 Cells

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

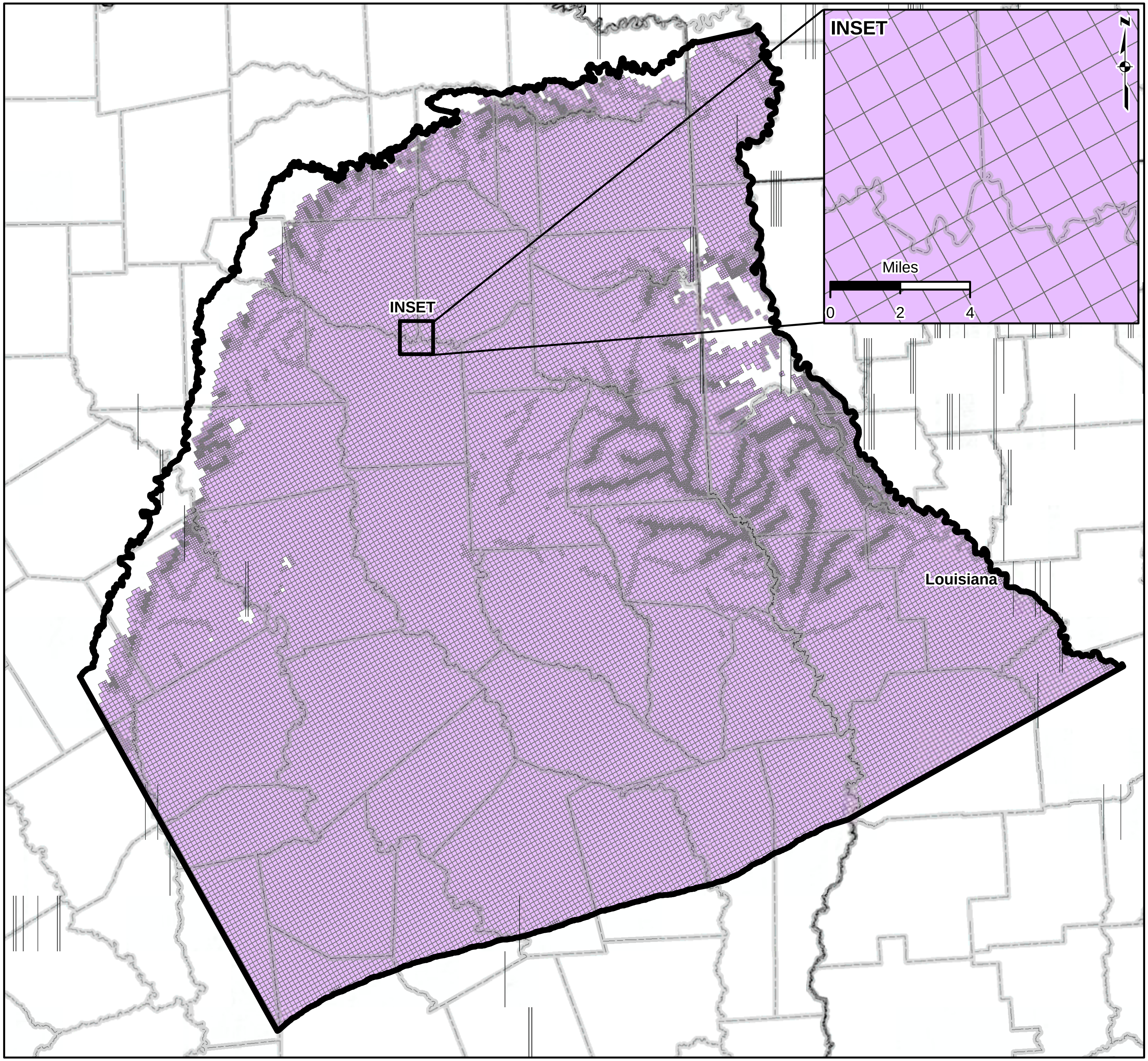
GSI ENVIRONMENTAL

GROUNDWATER MODEL DOMAIN DISCRETIZATION FOR UPPER WILCOX (MODEL LAYER 7)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_28	Appv'd By: DRAFT

FIGURE 2.4-28



LEGEND

- Model Boundary
- County or Parish Boundary
- Model Layer 8 Cells

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

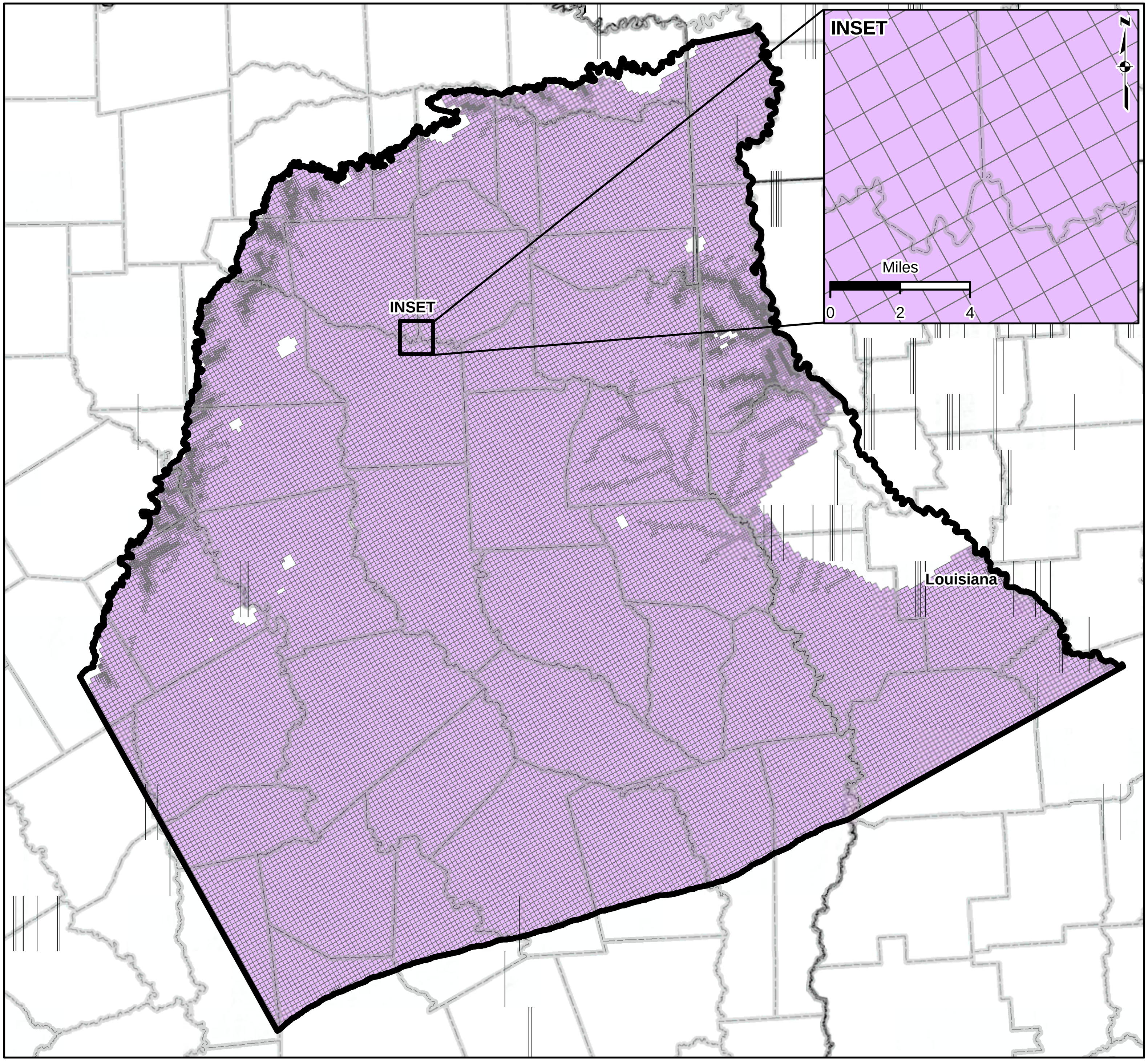
GSI ENVIRONMENTAL

GROUNDWATER MODEL DOMAIN DISCRETIZATION FOR MIDDLE WILCOX (MODEL LAYER 8)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_29	Appv'd By: DRAFT

FIGURE 2.4-29



LEGEND

Model Boundary

County or Parish Boundary

Model Layer 9 Cells

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

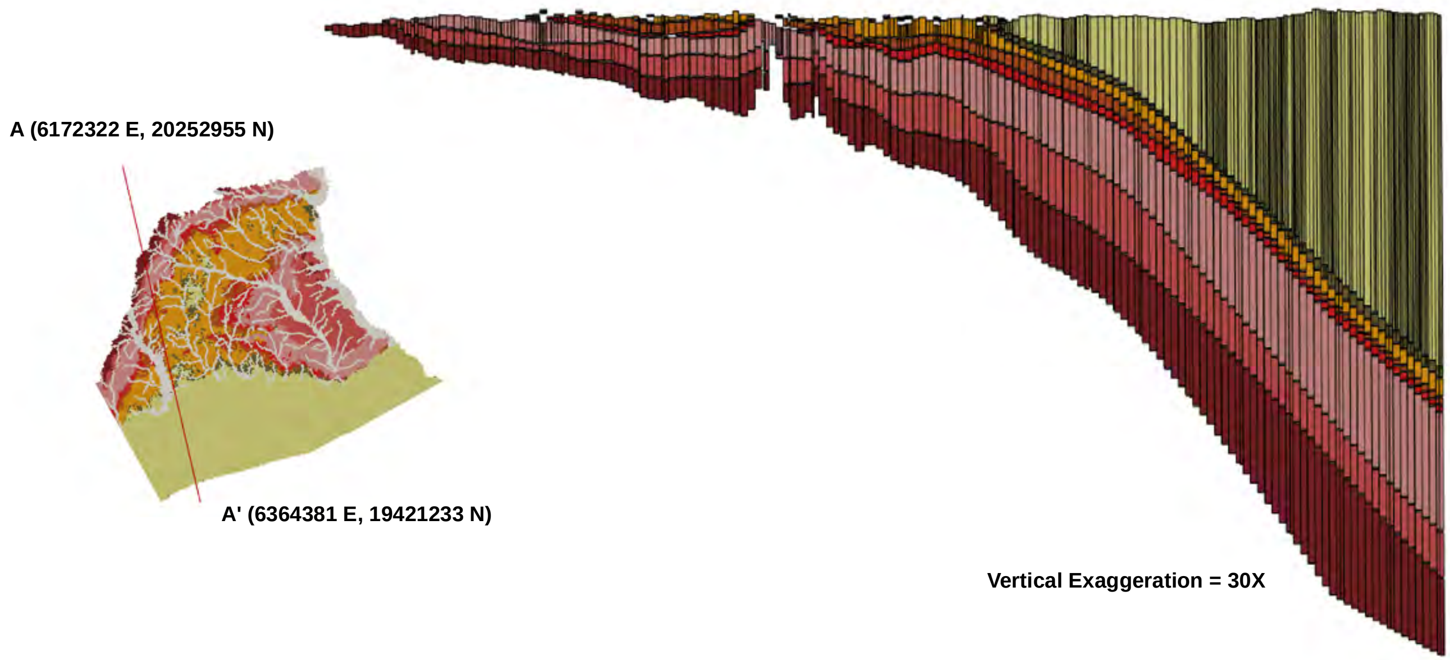
GSI ENVIRONMENTAL

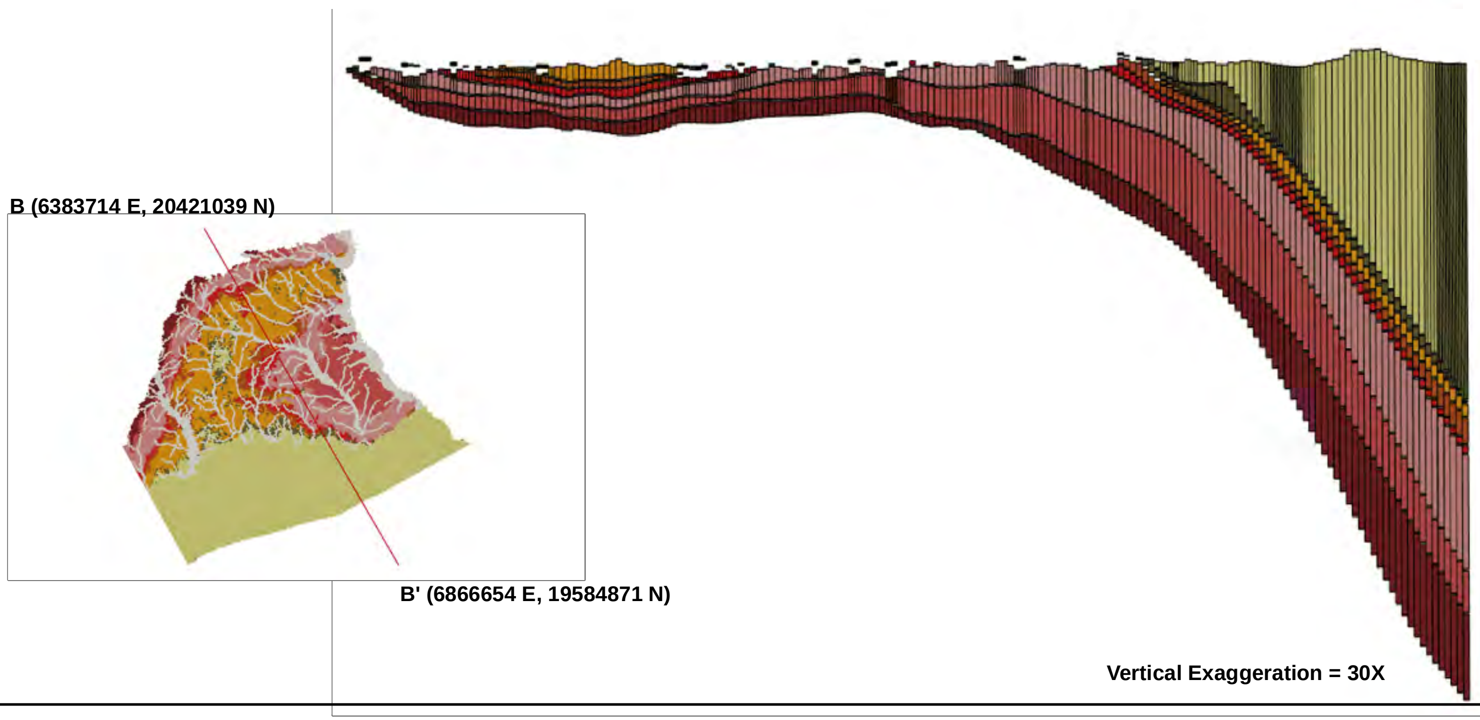
GROUNDWATER MODEL DOMAIN DISCRETIZATION FOR LOWER WILCOX (MODEL LAYER 9)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_30	Appv'd By: DRAFT

FIGURE 2.4-30





- Layer 1 (Alluvium)
- Layer 2 (Sparta Sand)
- Layer 3 (Weches Formation)
- Layer 4 (Queen City Sand)
- Layer 5 (Reklaw Formation)
- Layer 6 (Carrizo Sand)
- Layer 7 (Upper Wilcox)
- Layer 8 (Middle Wilcox)
- Layer 9 (Lower Wilcox)

Note: Groundwater Desktop is used to show groundwater model cross section

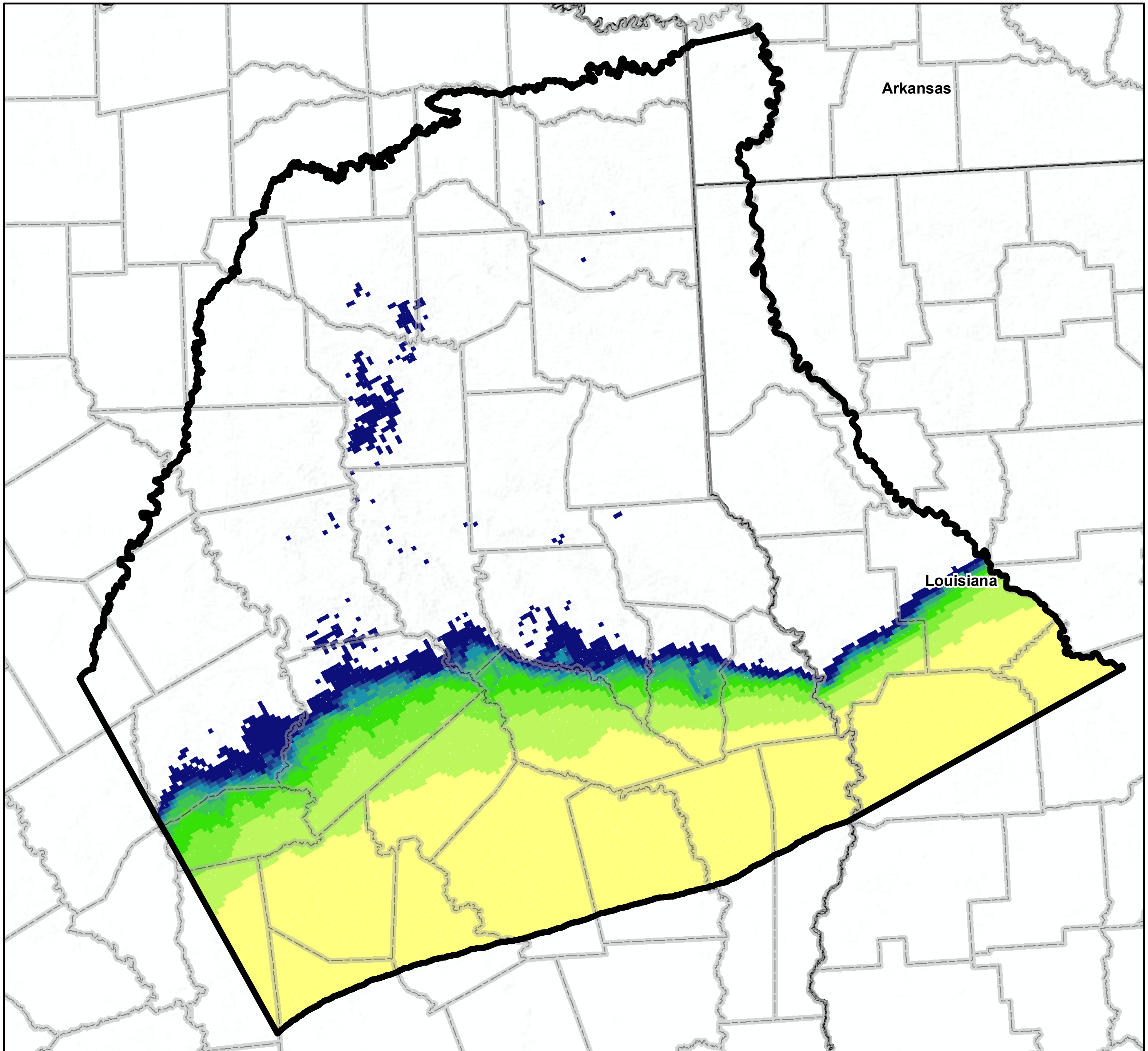
GSI ENVIRONMENTAL

CROSS SECTIONS OF GRIDDED MODEL LAYERS IN THE GROUNDWATER FLOW MODEL

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: AV
Issued: 6-Jan-2020	Chk'd By: KER
Map ID: NCW_Fig_2_4_31	Appv'd By: DRAFT

FIGURE 2.4-31



LEGEND

- Model Boundary
- County or Parish Boundary

Sand Fraction

- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 0.95

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles: 0, 16, 32

Projected Coordinate System
Datum: GAM

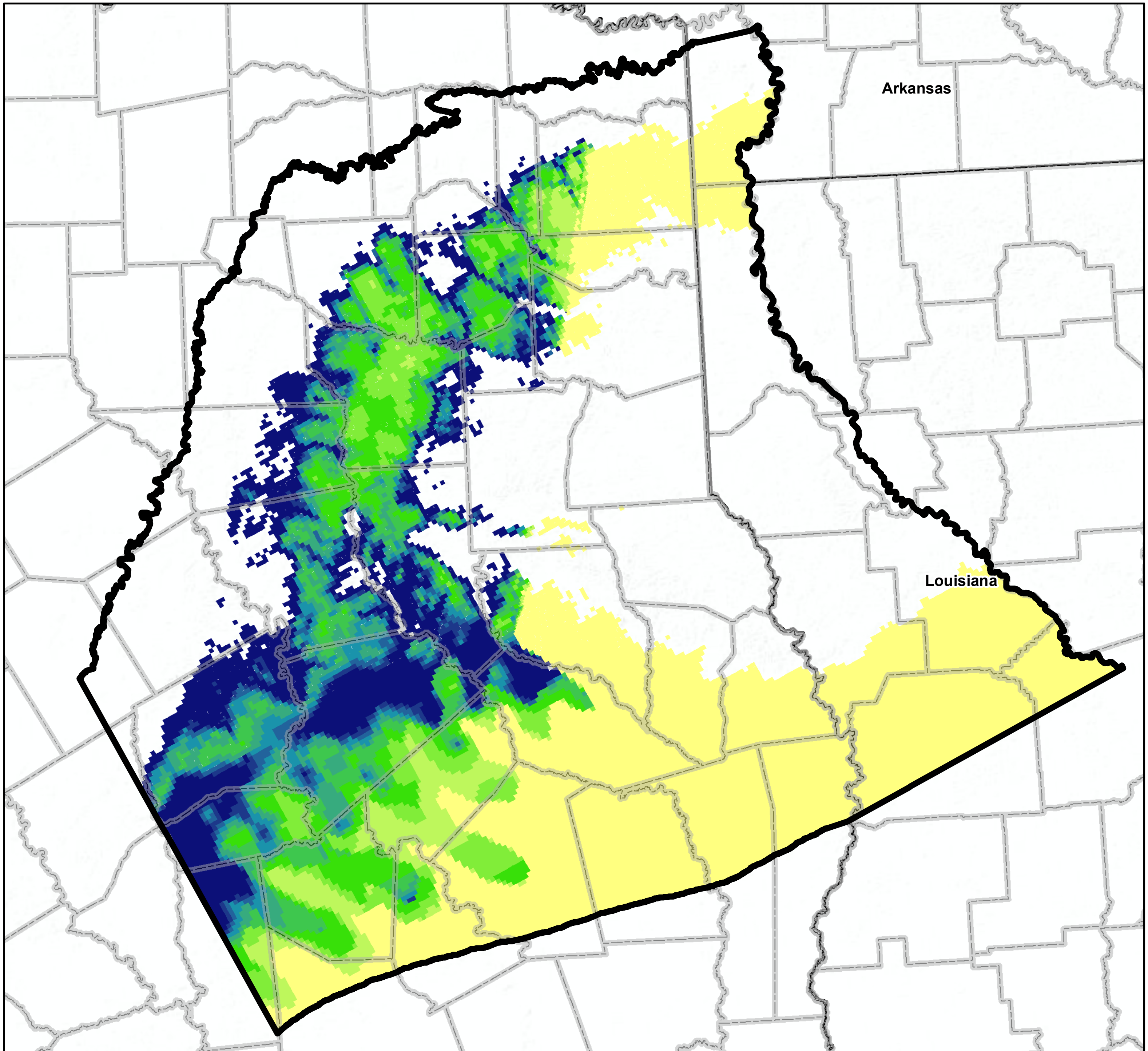
GSI ENVIRONMENTAL

ESTIMATED SAND FRACTION DISTRIBUTION FOR SPARTA SAND (MODEL LAYER 2)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: AV
Issued: 31-Mar-2020	Chk'd By: KER
Map ID: NCW_Fig_2_5_1	Appv'd By: DRAFT

FIGURE 2.5-1



N

LEGEND

Model Boundary
County or Parish Boundary

Sand Fraction

- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 0.95

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

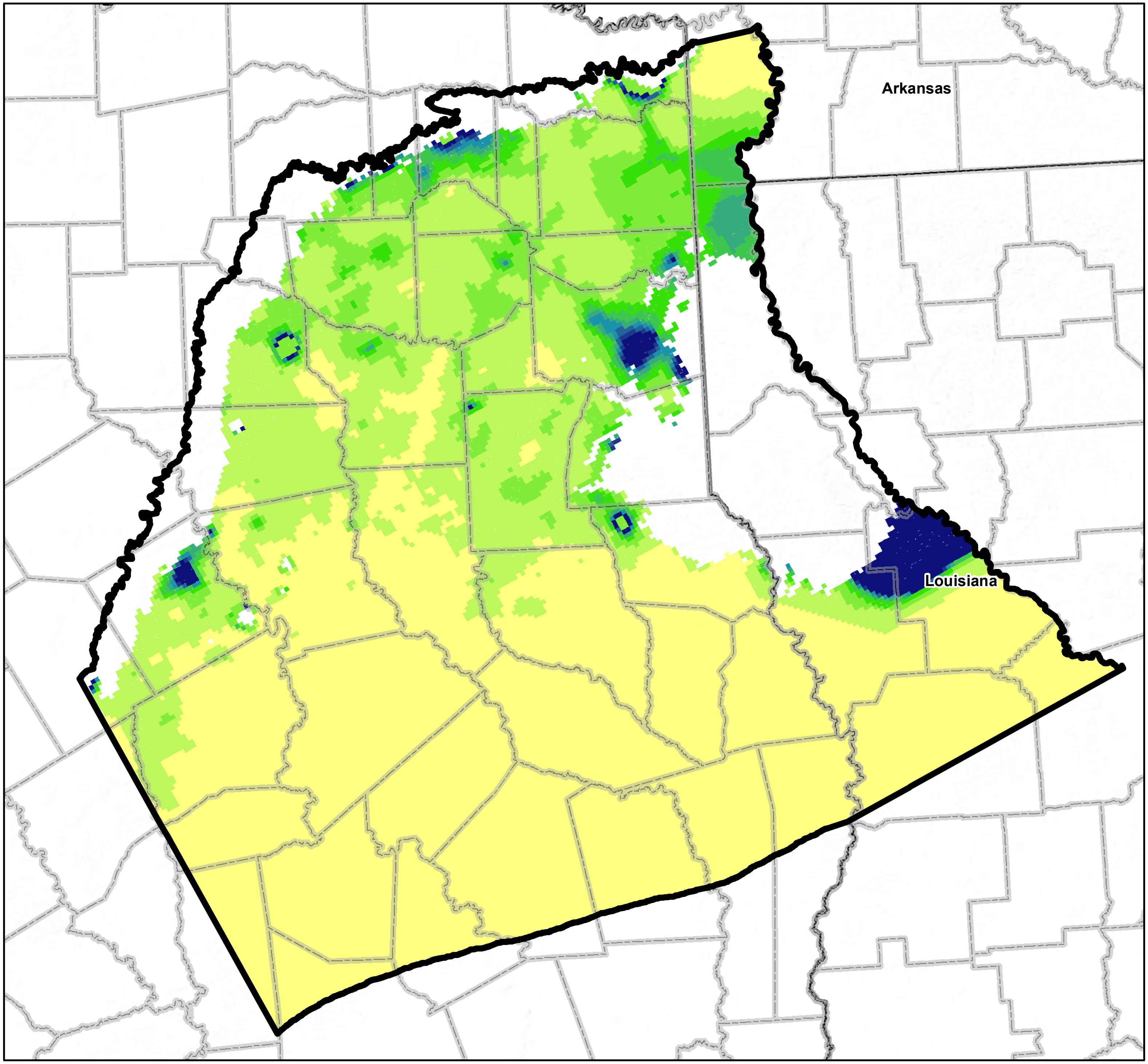
GSI ENVIRONMENTAL

ESTIMATED SAND FRACTION DISTRIBUTION FOR QUEEN CITY SAND (MODEL LAYER 4)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: AV
Issued: 31-Mar-2020	Chk'd By: KER
Map ID: NCW_Fig_2_5_2	Appv'd By: DRAFT

FIGURE 2.5-2



LEGEND

- Model Boundary
- County or Parish Boundary

Sand Fraction

- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 0.95

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles: 0, 16, 32

Projected Coordinate System Datum: GAM

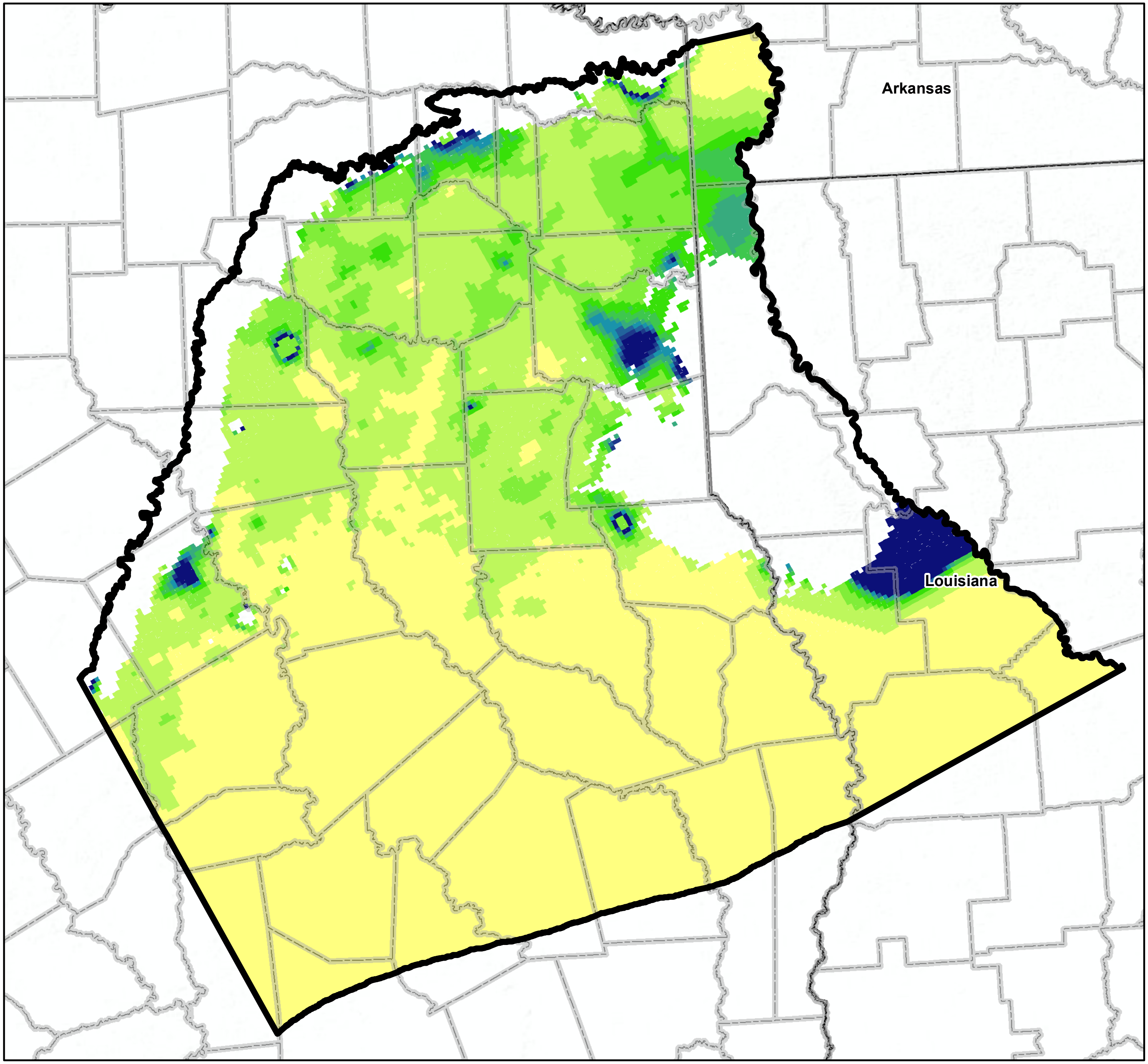
GSI ENVIRONMENTAL

ESTIMATED SAND FRACTION DISTRIBUTION FOR UPPER WILCOX (MODEL LAYER 7)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: AV
Issued: 31-Mar-2020	Chk'd By: KER
Map ID: NCW_Fig_2_5_3	Appv'd By: DRAFT

FIGURE 2.5-3



LEGEND

Model Boundary
County or Parish Boundary
Sand Fraction
0.050000 - 0.100000
0.100001 - 0.200000
0.200001 - 0.300000
0.300001 - 0.400000
0.400001 - 0.500000
0.500001 - 0.600000
0.600001 - 0.700000
0.700001 - 0.800000
0.800001 - 0.900000
0.900001 - 0.950000

Note:
Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

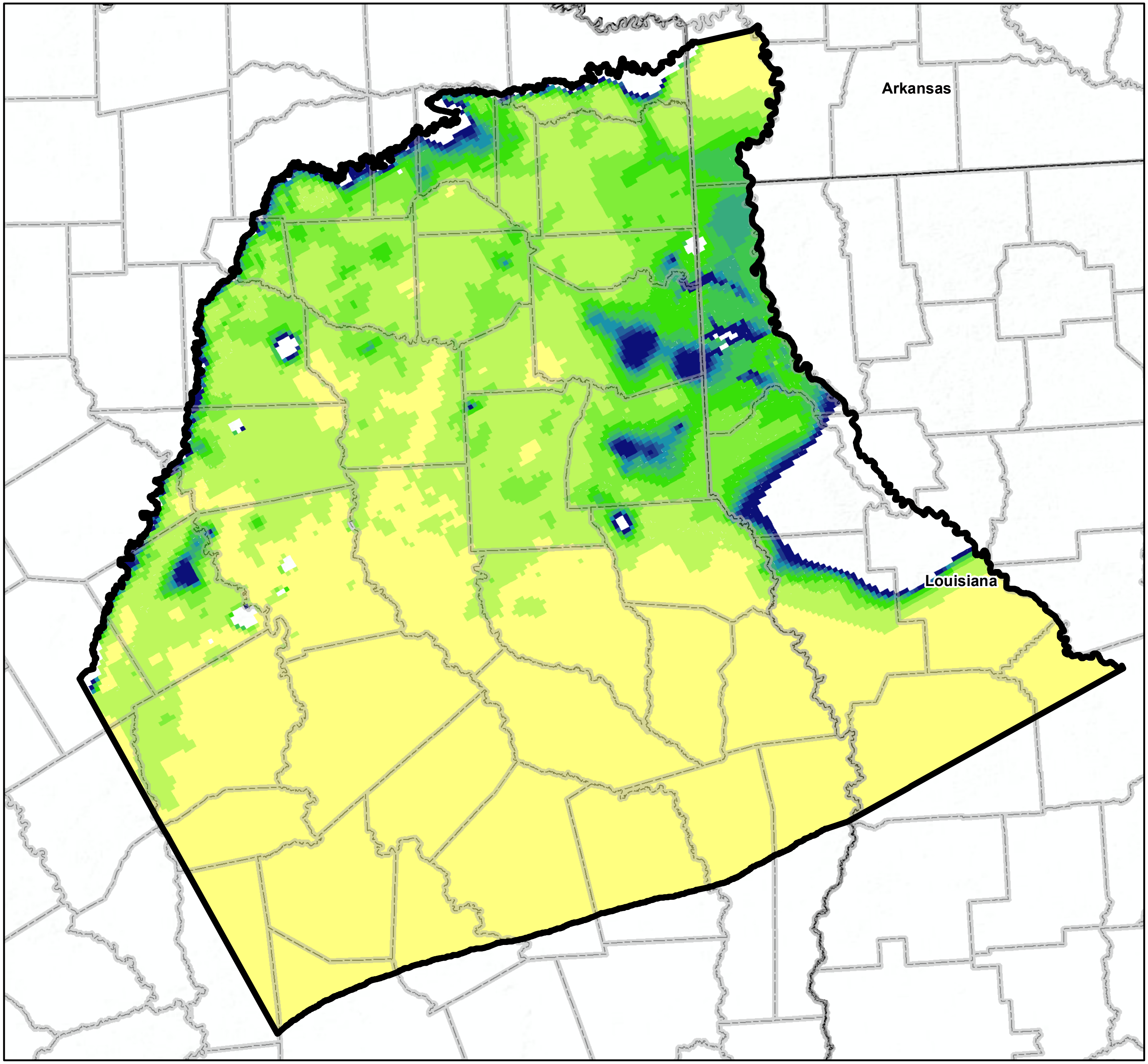
GSI ENVIRONMENTAL

ESTIMATED SAND FRACTION DISTRIBUTION FOR MIDDLE WILCOX (MODEL LAYER 8)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: AV
Issued: 31-Mar-2020	Chk'd By: KER
Map ID: NCW_Fig_2_5_4	Appv'd By: DRAFT

FIGURE 2.5-4

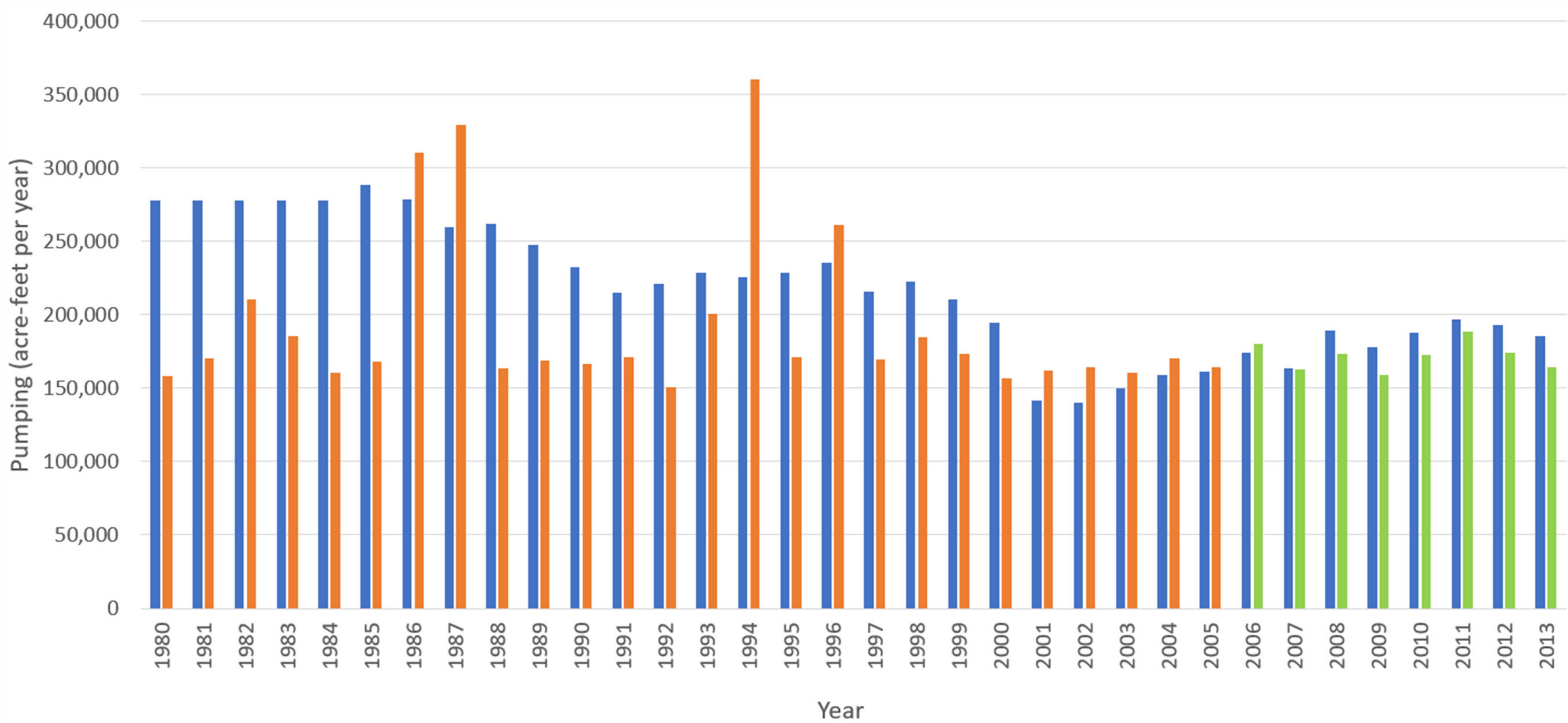


ESTIMATED SAND FRACTION DISTRIBUTION FOR LOWER WILCOX (MODEL LAYER 9)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: AV
Issued: 31-Mar-2020	Chk'd By: KER
Map ID: NCW_Fig_2_5_5	Appv'd By: DRAFT

FIGURE 2.5-5



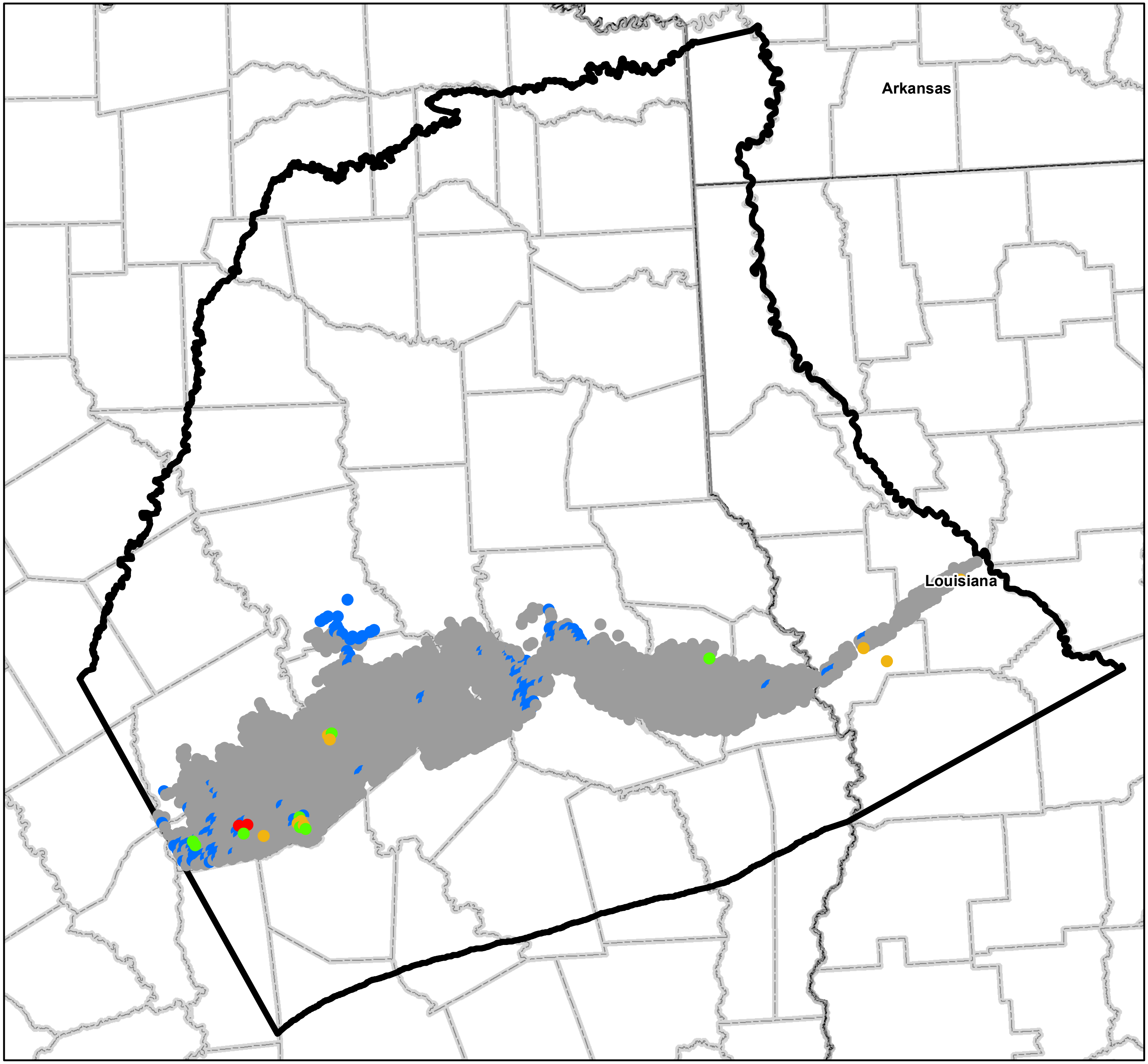
Note: Pumping interpolation for 2006 through 2013 was based on ratio with 2005 pumping.
Multiplication factors are shown in Table 2.7-2.

GSI ENVIRONMENTAL

GSI Job No.	4529	Drawn By:	GM
Issued:	1-Jul-2020	Chk'd By:	
Revised:		Aprv'd By:	DRAFT
Scale:		Figure 2.7-1	

MODEL PUMPING COMPARISON

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers



LEGEND

Total Pumping (Acre-feet)

- 0.01 - 100
- 100 - 500
- 500 - 1,000
- 1,000 - 10,000
- 10,000 - 17,373
- Model Boundary
- County or Parish Boundary

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

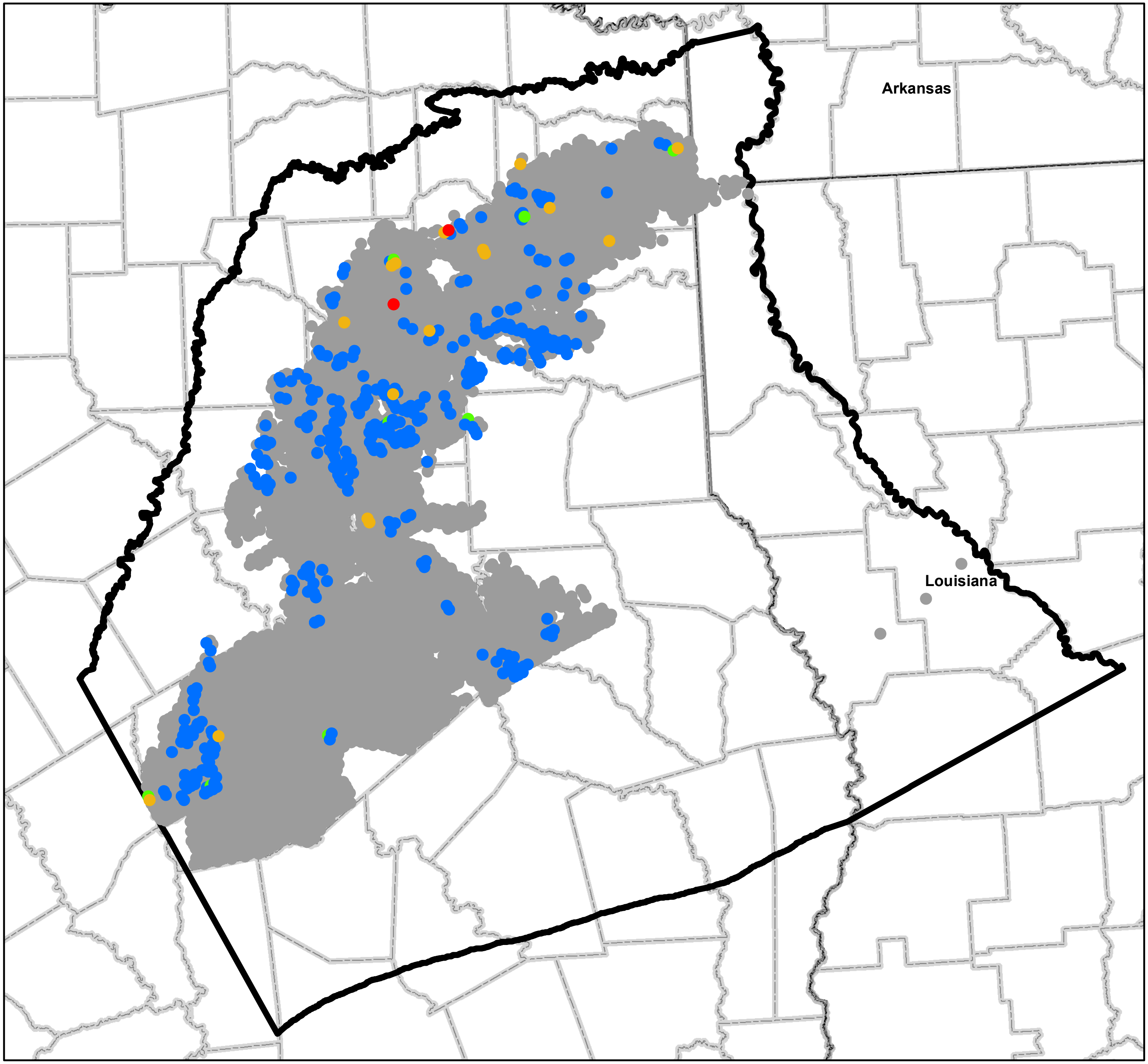
GSI ENVIRONMENTAL

PUMPING WELL TOTAL PUMPING VOLUME IN SPARTA SAND (LAYER 2)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: GM
Issued: 30-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_7_2	Appv'd By: DRAFT

FIGURE 2.7-2



N

LEGEND

Total Pumping (Acre-feet)

- 0.01 - 100
- 100 - 500
- 500 - 1,000
- 1,000 - 10,000
- 10,000 - 38,114
- Model Boundary
- County or Parish Boundary

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

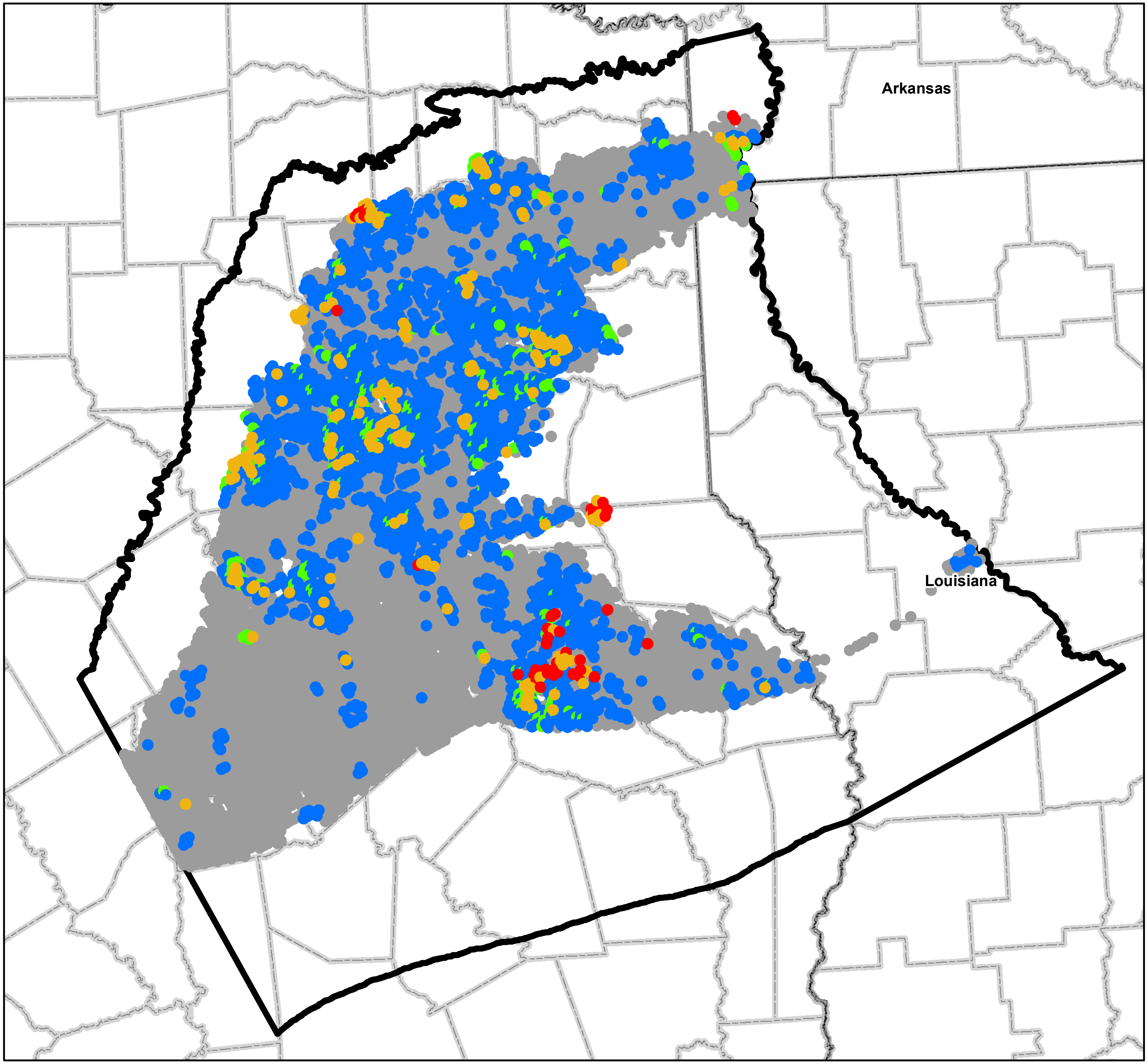
GSI ENVIRONMENTAL

PUMPING WELL TOTAL PUMPING VOLUME IN QUEEN CITY SAND (LAYER 4)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 30-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_7_3	Appv'd By: DRAFT

FIGURE 2.7-3



N

LEGEND

Total Pumping (Acre-feet)

- 0.01 - 100
- 100 - 500
- 500 - 1,000
- 1,000 - 10,000
- 10,000 - >100,000
- Model Boundary
- County or Parish Boundary

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

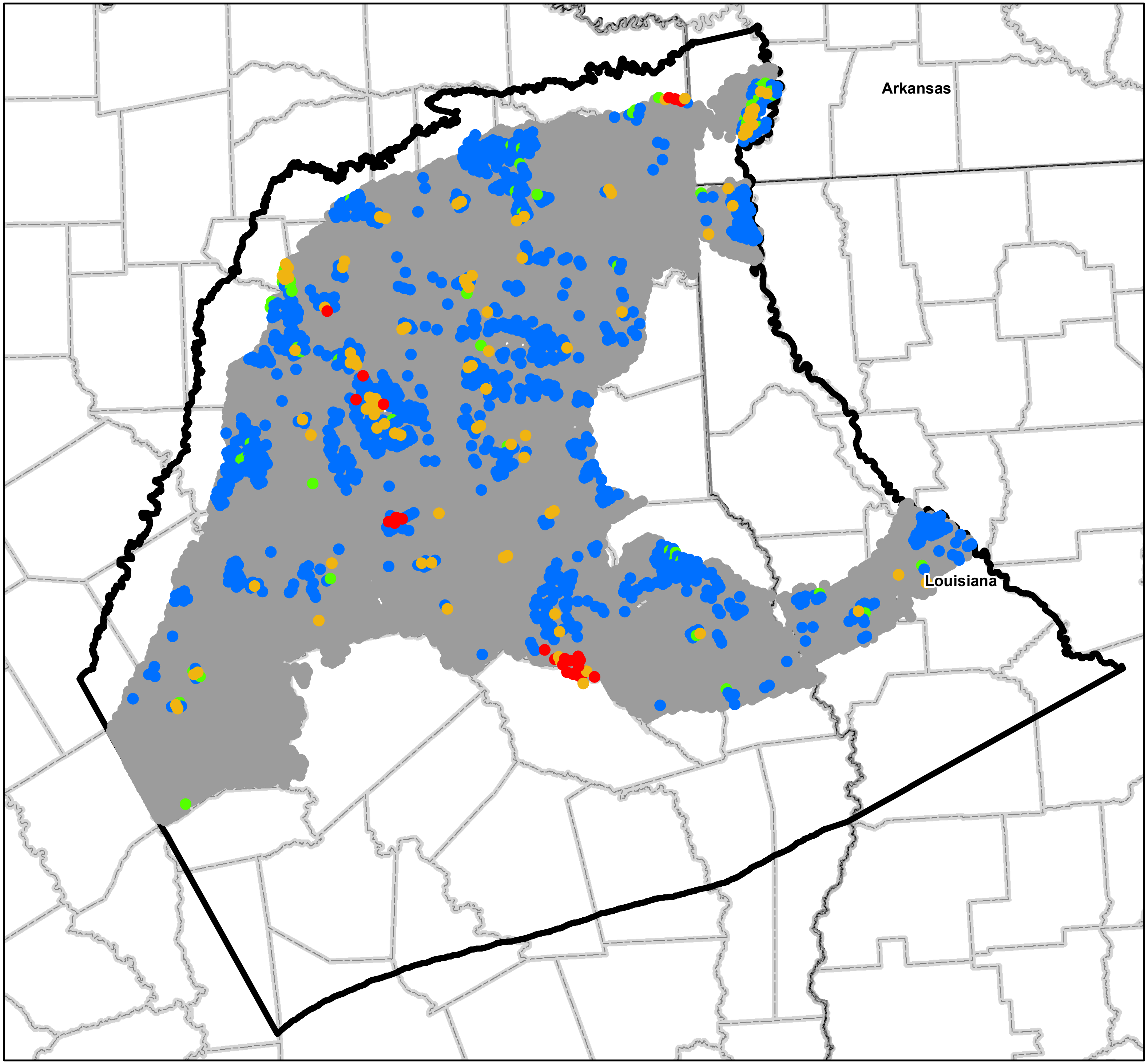
GSI ENVIRONMENTAL

PUMPING WELL TOTAL PUMPING VOLUME IN CARRIZO SAND (LAYER 6)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: GM
Issued: 30-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_7_4	Appv'd By: DRAFT

FIGURE 2.7-4



N

LEGEND

Total Pumping (Acre-feet)

- 0.01 - 100
- 100 - 500
- 500 - 1,000
- 1,000 - 10,000
- 10,000 - 35,770
- Model Boundary
- County or Parish Boundary

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

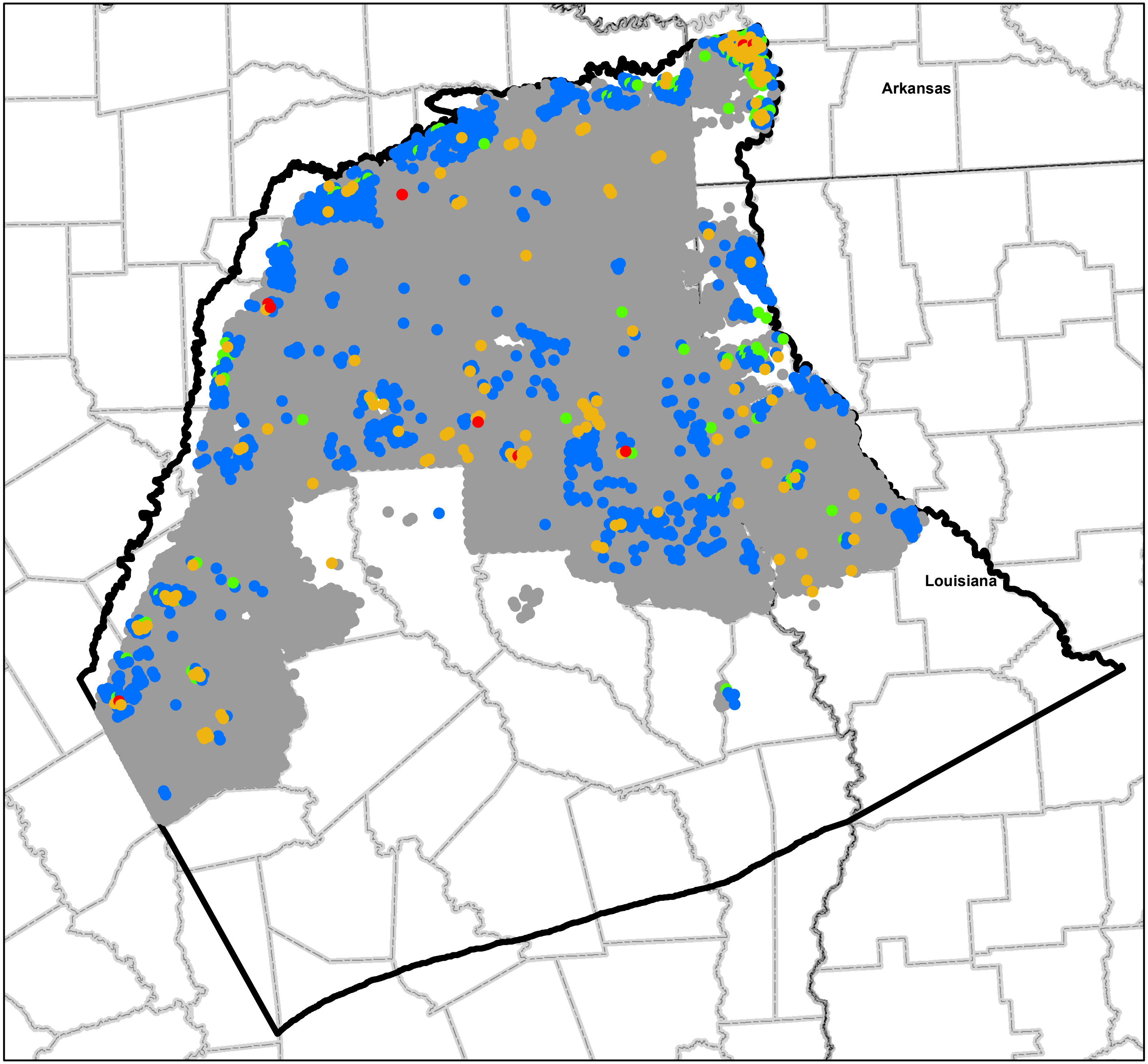
GSI ENVIRONMENTAL

PUMPING WELL TOTAL PUMPING VOLUME IN UPPER WILCOX (LAYER 7)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: GM
Issued: 30-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_7_5	Appv'd By: DRAFT

FIGURE 2.7-5



N

LEGEND

Total Pumping (Acre-feet)

- 0.01 - 100
- 100 - 500
- 500 - 1,000
- 1,000 - 10,000
- 10,000 - 24,770
- Model Boundary
- County or Parish Boundary

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

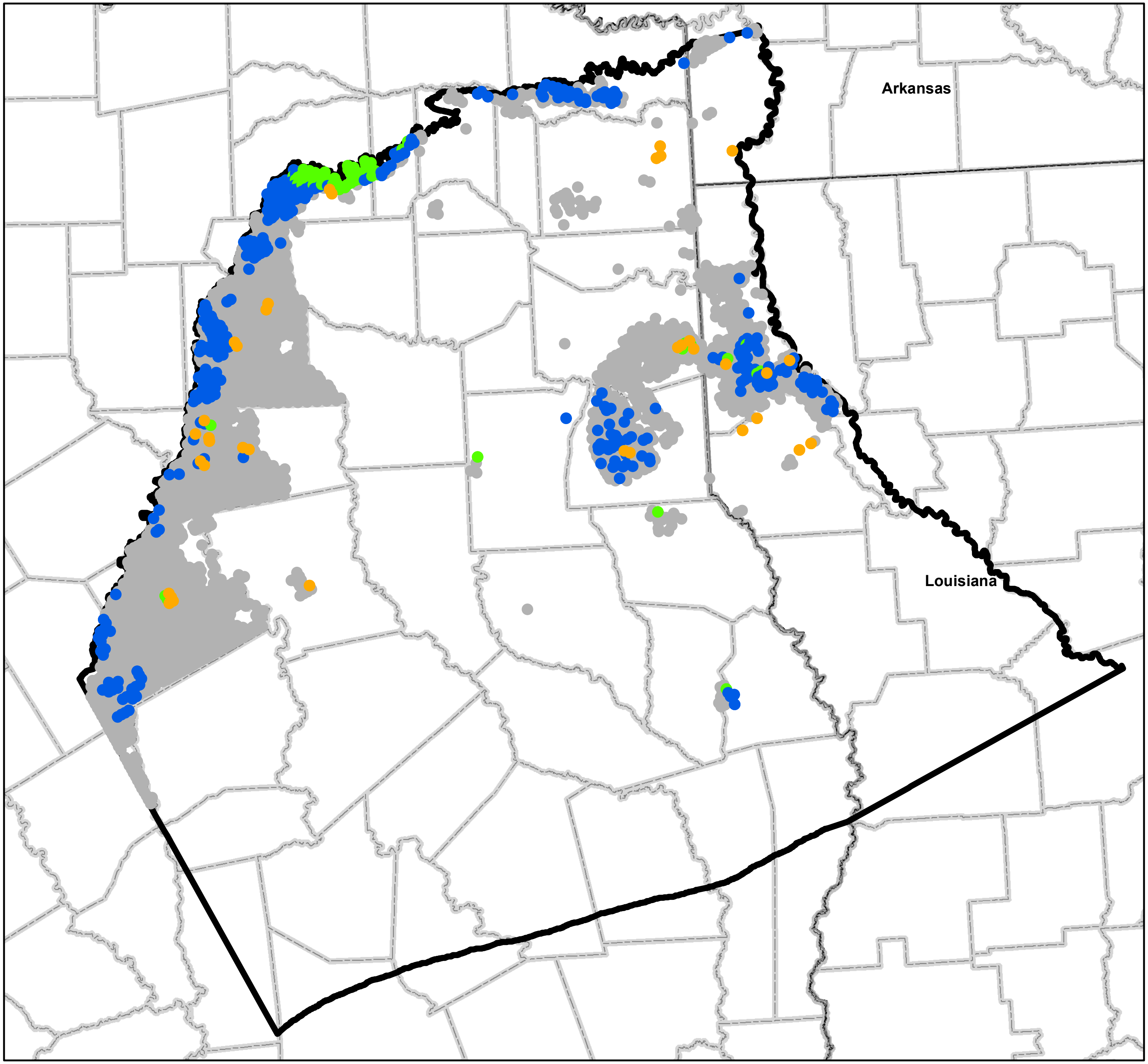
GSI ENVIRONMENTAL

PUMPING WELL TOTAL PUMPING VOLUME IN MIDDLE WILCOX (LAYER 8)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: GM
Issued: 30-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_7_6	Appv'd By: DRAFT

FIGURE 2.7-6



LEGEND

Total Pumping (Acre-feet)

- 0.01 - 100
- 100 - 500
- 500 - 1,000
- 1,000 - 9,750
- Model Boundary
- County or Parish Boundary

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles: 0 16 32

Projected Coordinate System Datum: GAM

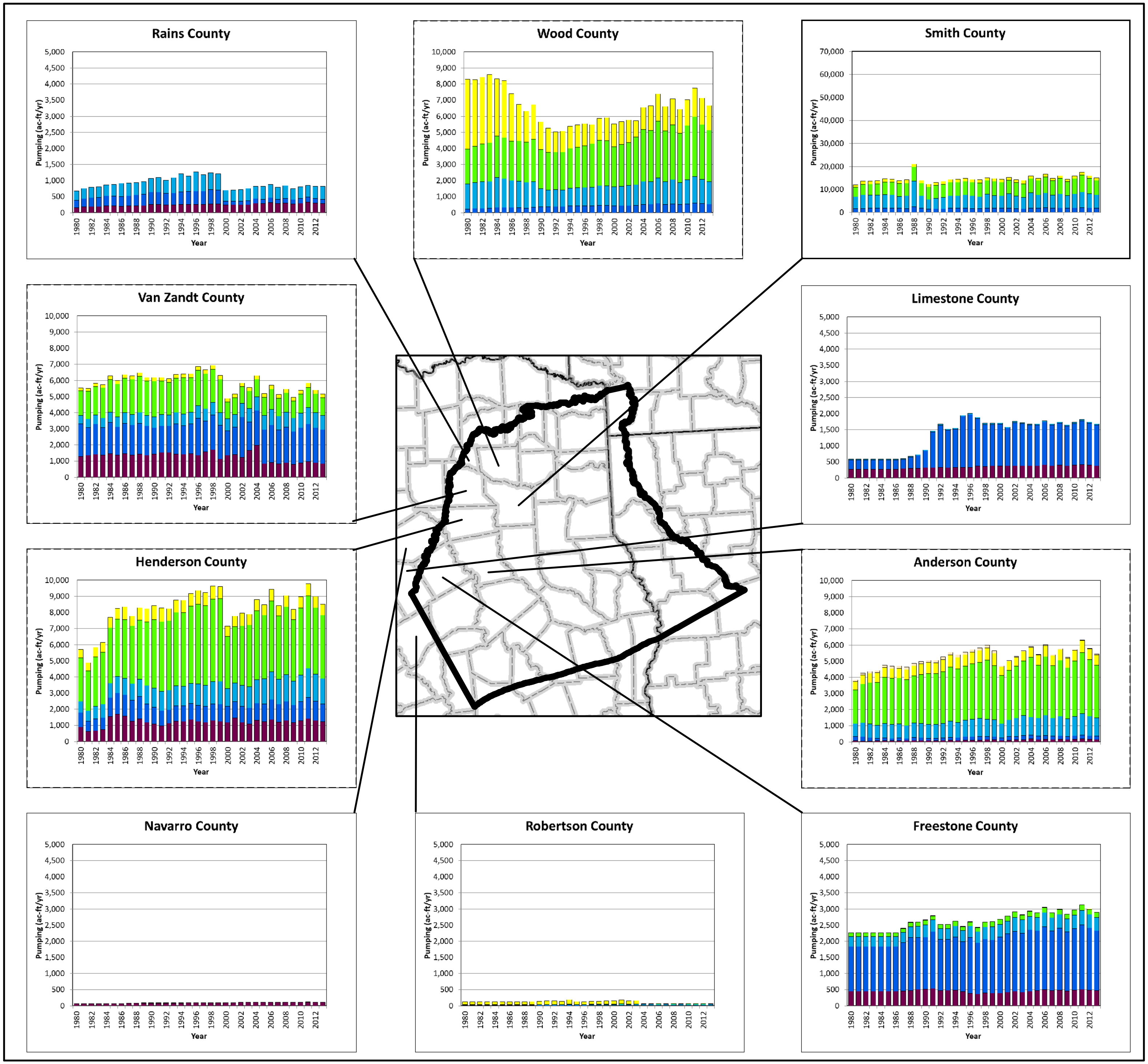
GSI ENVIRONMENTAL

PUMPING WELL TOTAL PUMPING VOLUME IN LOWER WILCOX (LAYER 9)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: GM
Issued: 30-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_7_7	Appv'd By: **DRAFT**

FIGURE 2.7-7



LEGEND

- Model Boundary
- County or Parish Boundary

Layer Color

- Quaternary Alluvium (Layer 1)
- Sparta Sand (Layer 2)
- Queen City Sand (Layer 4)
- Carrizo Sand (Layer 6)
- Upper Willcox (Layer 7)
- Middle Wilcox (Layer 8)
- Lower Willcox (Layer 9)

Pumping Y-axis Range

- 70,000 Acre Feet/Year
- 20,000 Acre Feet/Year
- 10,000 Acre Feet/Year
- 5,000 Acre Feet/Year

Note:
Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 50 100

Projected Coordinate System
Datum: GAM

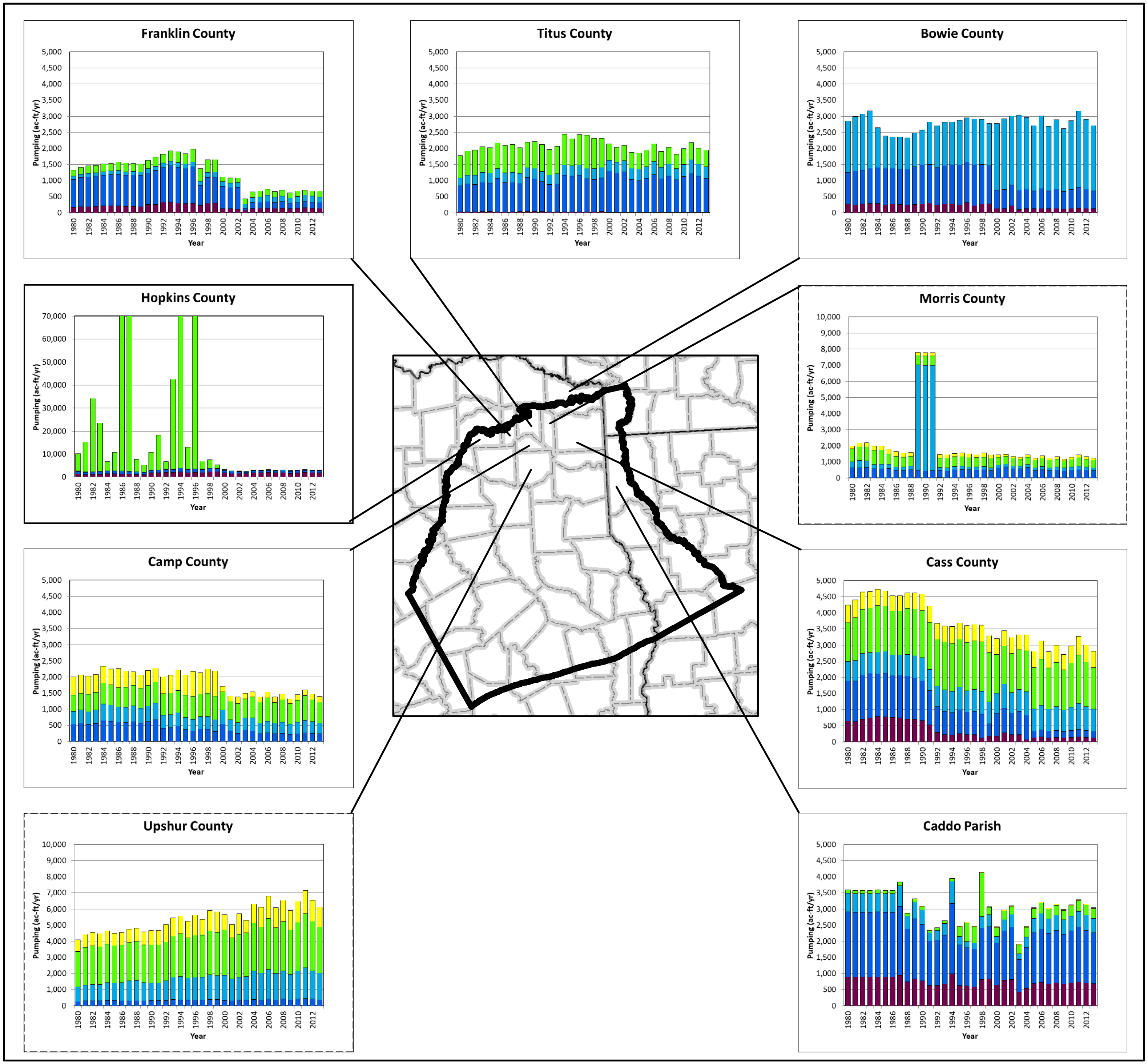
GSI ENVIRONMENTAL

PUMPING PER COUNTY

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 30-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_7_8a	Appv'd By: DRAFT

FIGURE 2.7-8a



LEGEND

- Model Boundary
- County or Parish Boundary

Layer Color

- Quaternary Alluvium (Layer 1)
- Sparta Sand (Layer 2)
- Queen City Sand (Layer 4)
- Carrizo Sand (Layer 6)
- Upper Wilcox (Layer 7)
- Middle Wilcox (Layer 8)
- Lower Wilcox (Layer 9)

Pumping Y-axis Range

- 70,000 Acre Feet/Year
- 20,000 Acre Feet/Year
- 10,000 Acre Feet/Year
- 5,000 Acre Feet/Year

Note:
Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles: 0, 50, 100

Projected Coordinate System
Datum: GAM

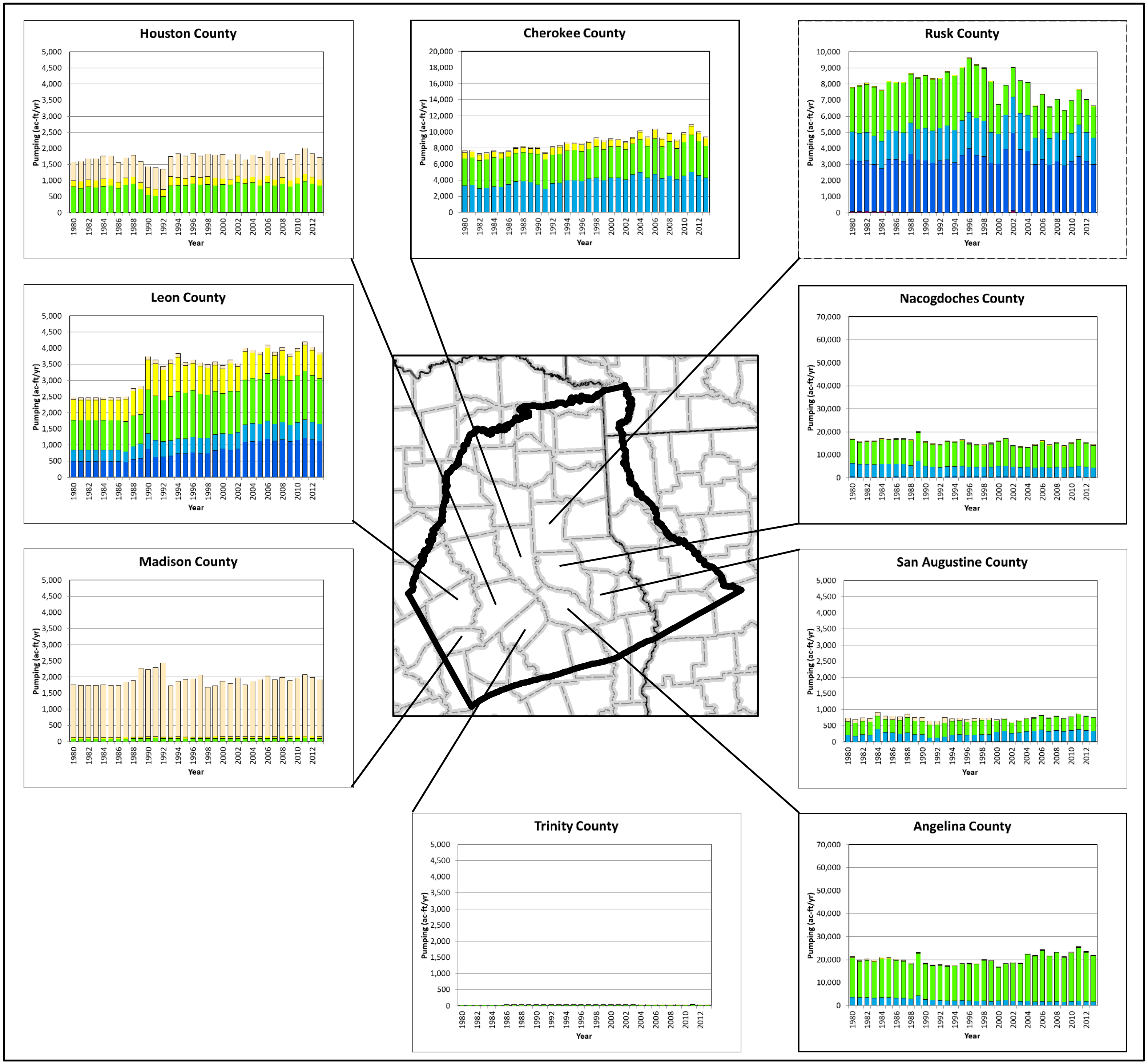
GSI ENVIRONMENTAL

PUMPING PER COUNTY

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 30-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_7_8b	Appv'd By: DRAFT

FIGURE 2.7-8b



N

LEGEND

- Model Boundary
- County or Parish Boundary

Layer Color

- Quaternary Alluvium (Layer 1)
- Sparta Sand (Layer 2)
- Queen City Sand (Layer 4)
- Carrizo Sand (Layer 6)
- Upper Wilcox (Layer 7)
- Middle Wilcox (Layer 8)
- Lower Wilcox (Layer 9)

Pumping Y-axis Range

- 70,000 Acre Feet/Year
- 20,000 Acre Feet/Year
- 10,000 Acre Feet/Year
- 5,000 Acre Feet/Year

Note:
Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 50 100

Projected Coordinate System
Datum: GAM

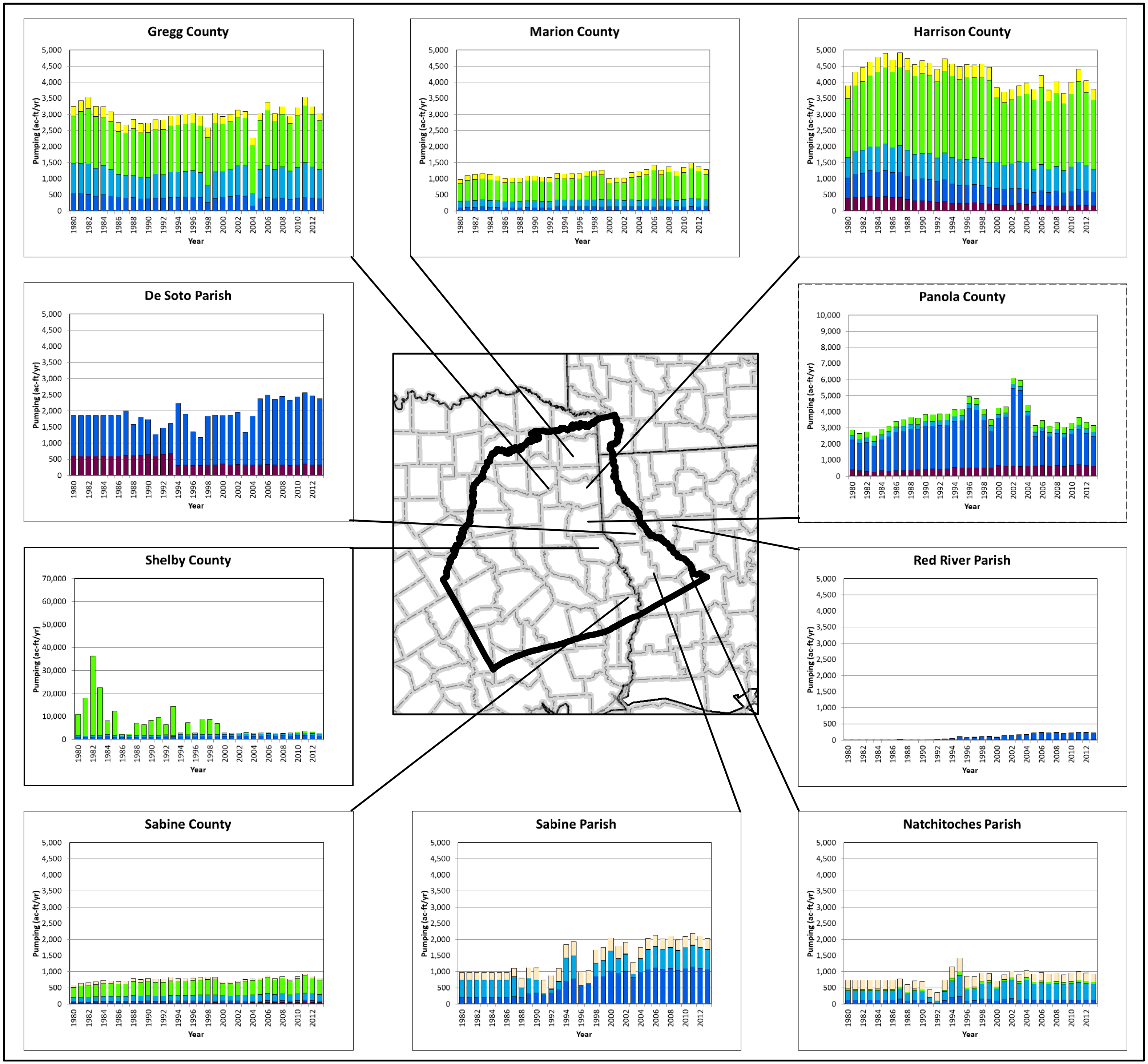
GSI ENVIRONMENTAL

PUMPING PER COUNTY

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 30-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_7_8c	Appv'd By: DRAFT

FIGURE 2.7-8c



N

LEGEND

Model Boundary
County or Parish Boundary

Layer Color

- Quaternary Alluvium (Layer 1)
- Sparta Sand (Layer 2)
- Queen City Sand (Layer 4)
- Carrizo Sand (Layer 6)
- Upper Wilcox (Layer 7)
- Middle Wilcox (Layer 8)
- Lower Wilcox (Layer 9)

Pumping Y-axis Range

- 70,000 Acre Feet/Year
- 20,000 Acre Feet/Year
- 10,000 Acre Feet/Year
- 5,000 Acre Feet/Year

Note:
Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 50 100

Projected Coordinate System
Datum: GAM

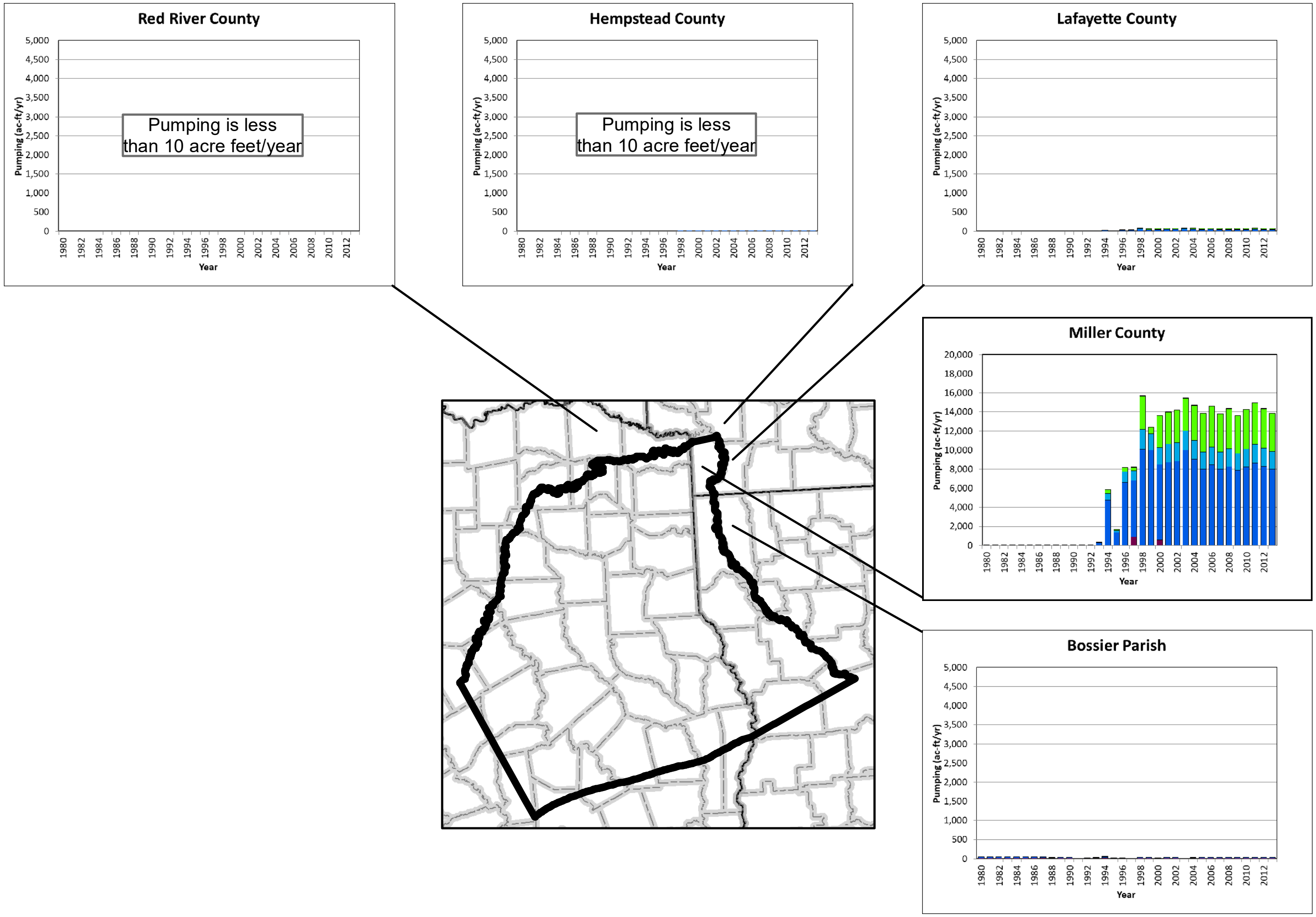
GSI ENVIRONMENTAL

PUMPING PER COUNTY

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 30-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_7_8d	Appv'd By: DRAFT

FIGURE 2.7-8d



N

LEGEND

Model Boundary

County or Parish Boundary

Layer Color

Quaternary Alluvium (Layer 1)

Sparta Sand (Layer 2)

Queen City Sand (Layer 4)

Carrizo Sand (Layer 6)

Upper Willcox (Layer 7)

Middle Wilcox (Layer 8)

Lower Willcox (Layer 9)

Pumping Y-axis Range

70,000 Acre Feet/Year

20,000 Acre Feet/Year

10,000 Acre Feet/Year

5,000 Acre Feet/Year

Note:
Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 50 100

Projected Coordinate System
Datum: GAM

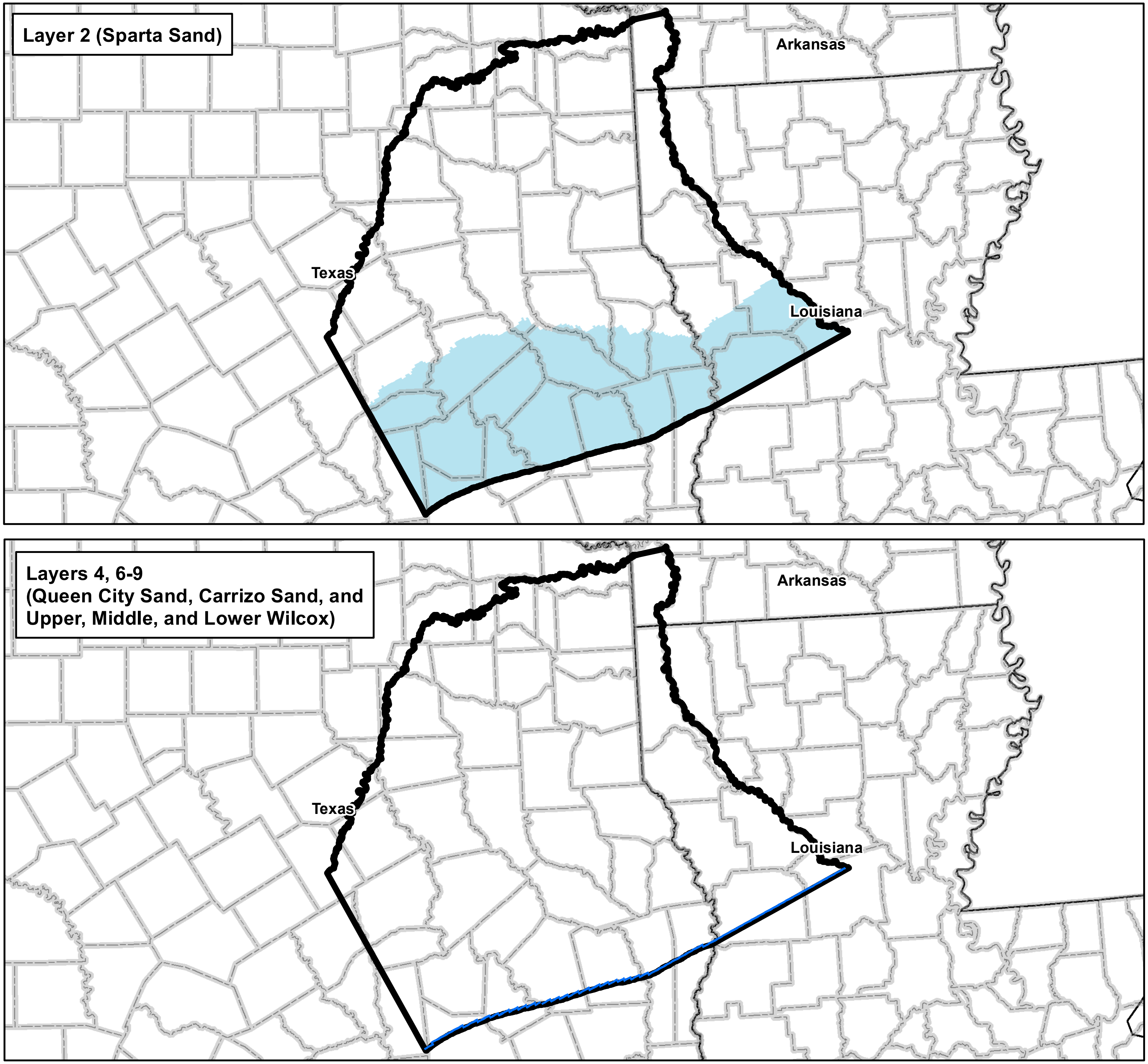
GSI ENVIRONMENTAL

PUMPING PER COUNTY

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: BC
Issued: 30-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_7_8e	Appv'd By: DRAFT

FIGURE 2.7-8e



N

LEGEND

- Model Boundary
- County or Parish Boundary
- Modeled General Head Boundary (Layer 2)
- Modeled General Head Boundary (Layers 4, 6-9)

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 32 64

Projected Coordinate System Datum: GAM

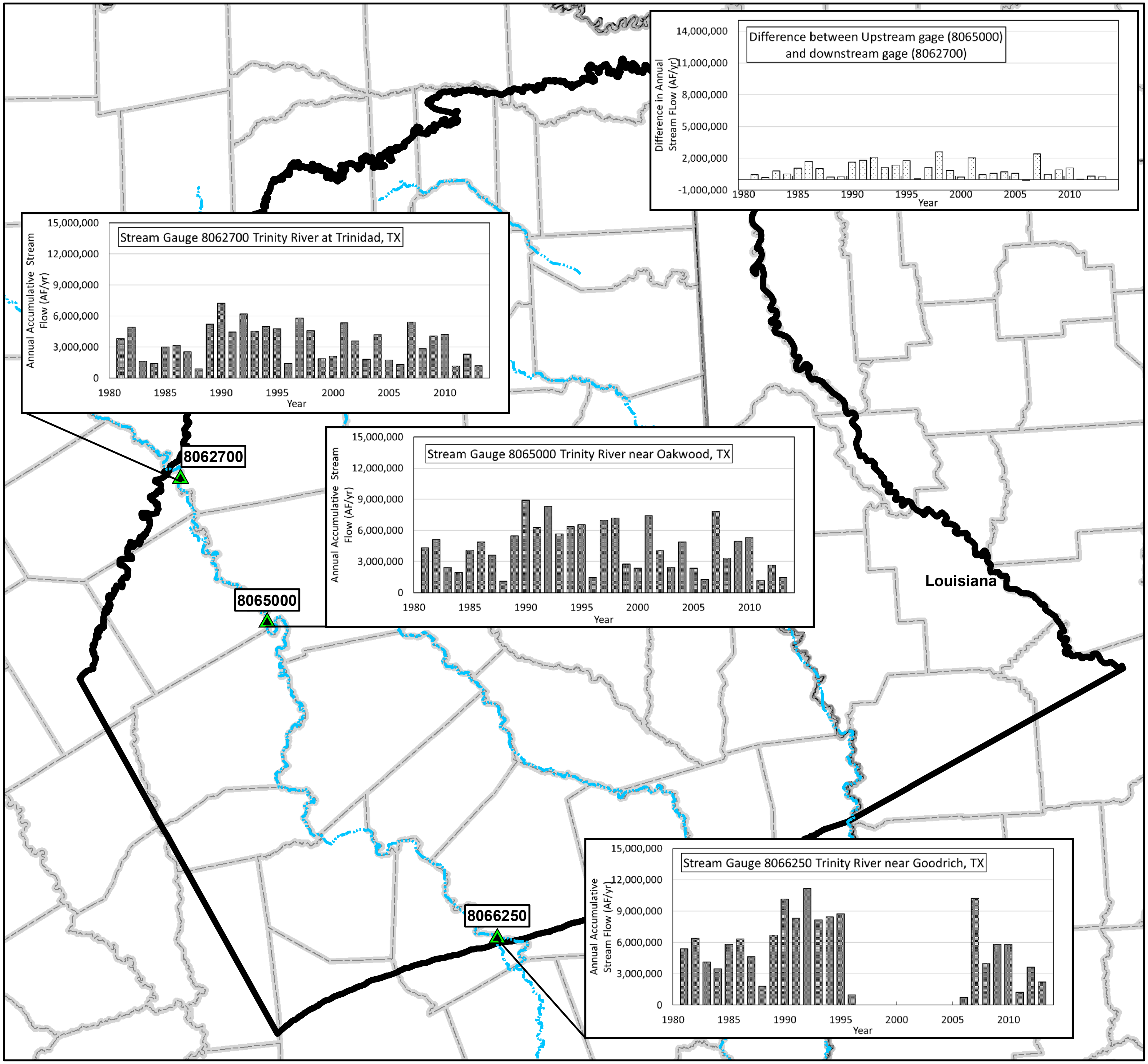
GSI ENVIRONMENTAL

MODELED LATERAL BOUNDARY CONDITIONS

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 30-Jun-2020	Chk'd By: KER
Map ID: NCW_Fig_2_8_1	Appv'd By: DRAFT

FIGURE 2.8-1



N

LEGEND

- USGS Stream Gage
- River
- Model Boundary
- County or Parish Boundary

Notes:

1) Basemap provided by Montgomery & Associates, March 2019.
2) USGS = United States Geological Survey.
3) AF/yr = acre feet per year.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

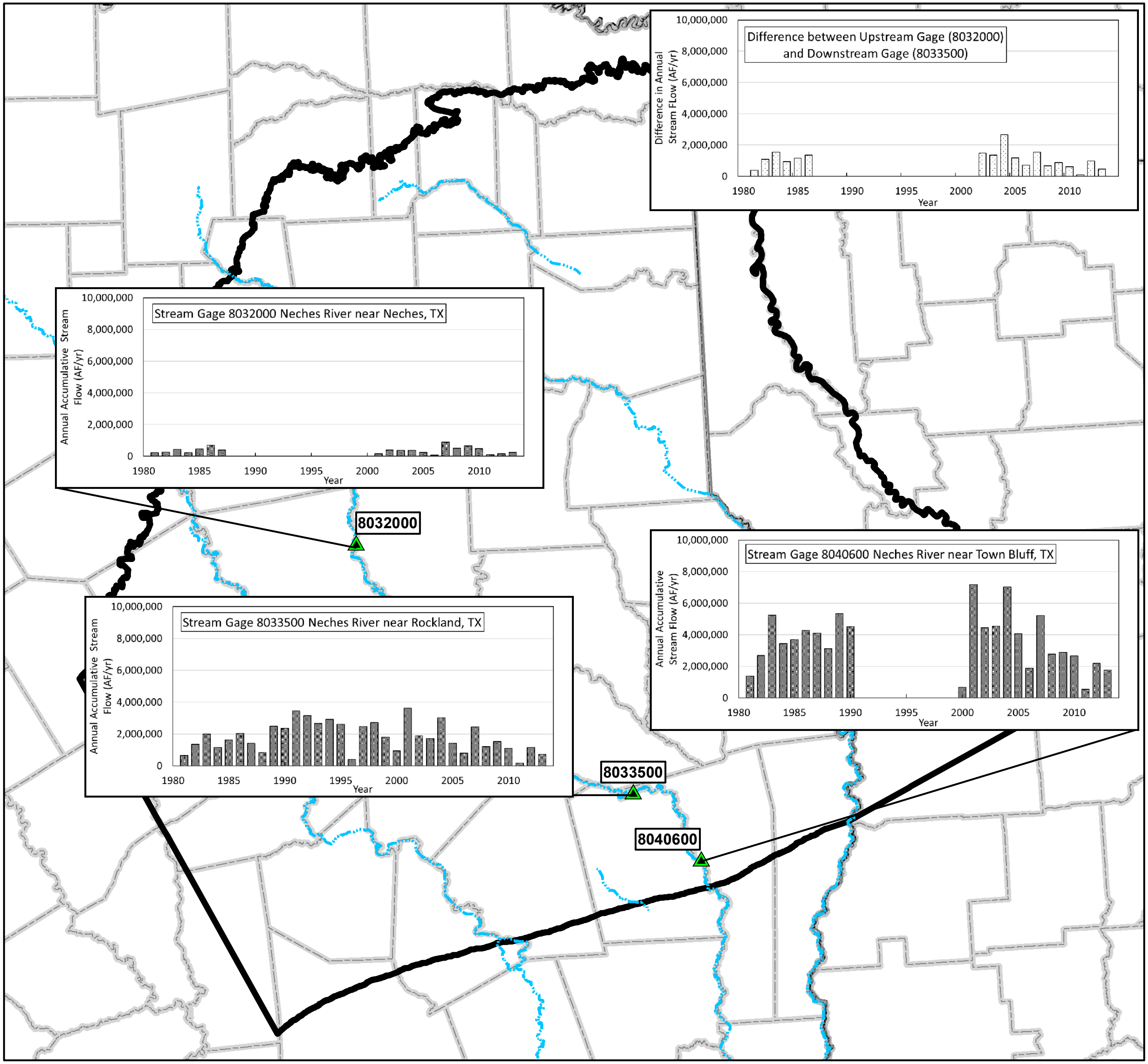
GSI ENVIRONMENTAL

ESTIMATED ANNUAL STREAMFLOWS FOR TRINITY RIVER

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: AV
Issued: 31-Oct-2019	Chk'd By: KER
Map ID: NCW_Fig_2_6_1	Appv'd By: DRAFT

FIGURE 2.9-1



Notes:

1) Basemap provided by Montgomery & Associates, March 2019.
2) USGS = United States Geological Survey.
3) AF/yr = acre feet per year.

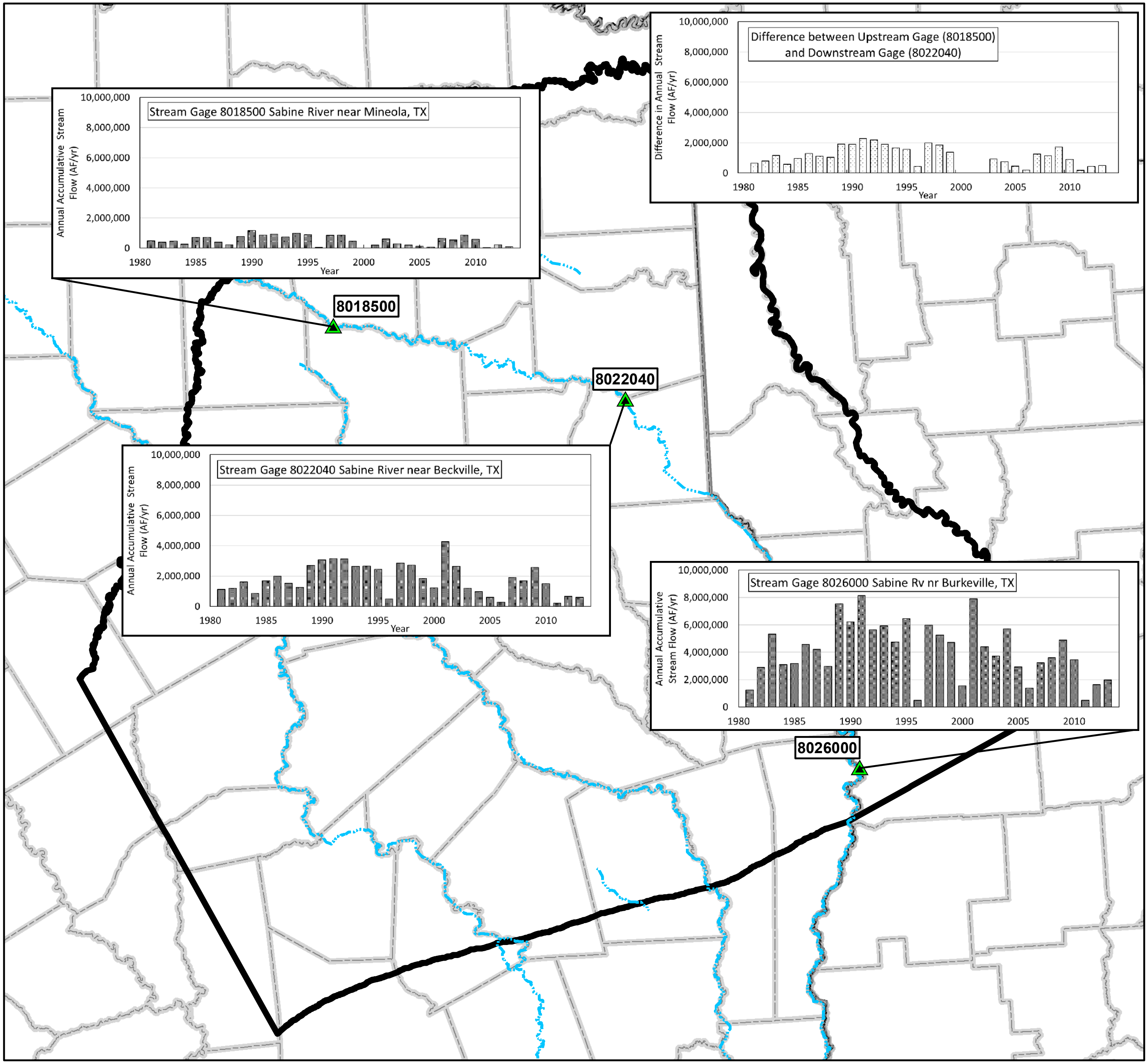
GSI ENVIRONMENTAL

ESTIMATED ANNUAL STREAMFLOWS FOR NECHES RIVER

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: AV
Issued: 31-Oct-2019	Chk'd By: KER
Map ID: NCW_Fig_2_6_2	Appv'd By: DRAFT

FIGURE 2.9-2



Notes:

1) Basemap provided by Montgomery & Associates, March 2019.
2) USGS = United States Geological Survey.
3) AF/yr = acre feet per year.

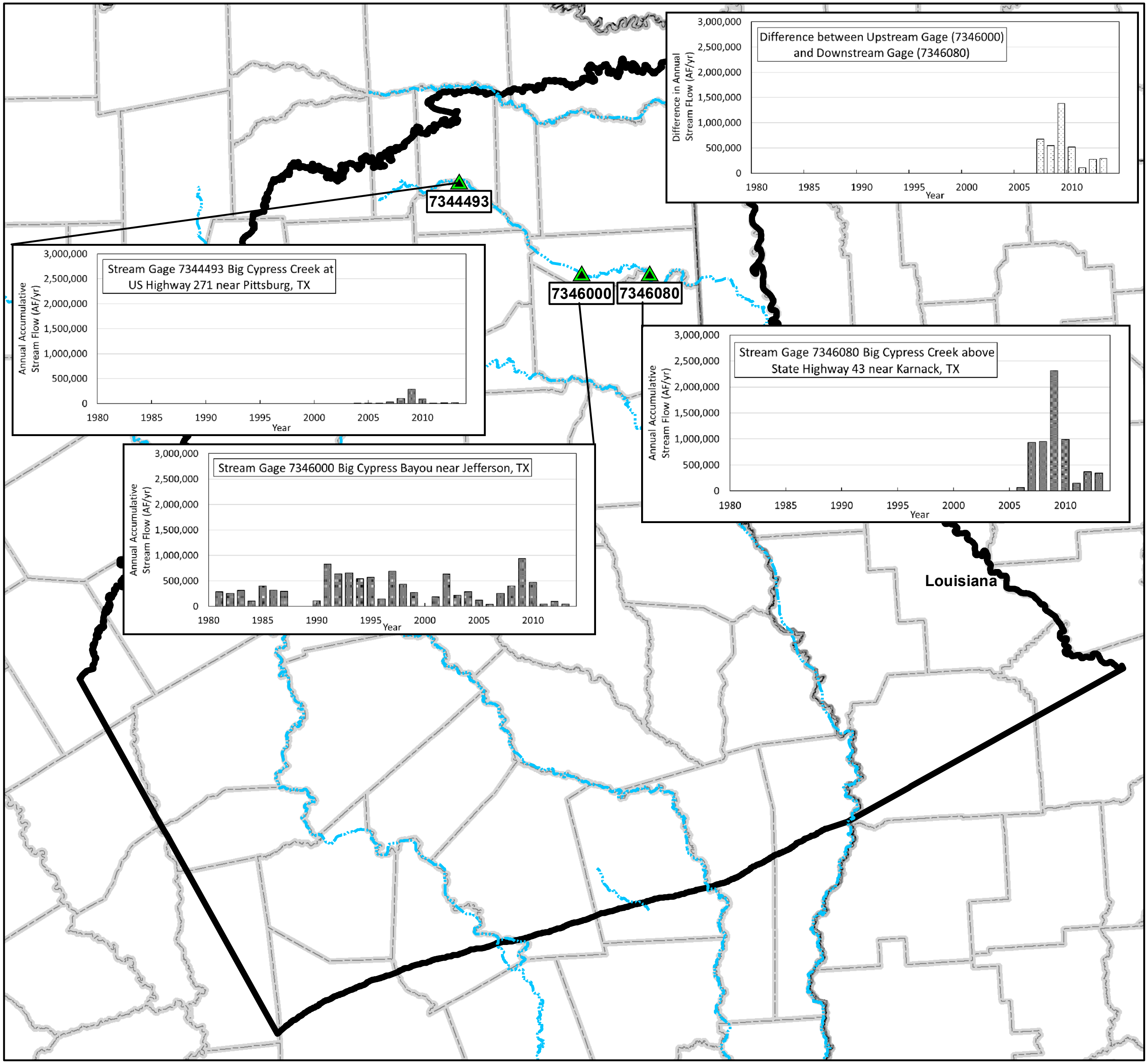
GSI ENVIRONMENTAL

ESTIMATED ANNUAL STREAMFLOWS FOR SABINE RIVER

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: AV
Issued: 31-Oct-2019	Chk'd By: KER
Map ID: NCW_Fig_2_6_3	Appv'd By: DRAFT

FIGURE 2.9-3



N

LEGEND

- USGS Stream Gage
- River
- Model Boundary
- County or Parish Boundary

Notes:

1) Basemap provided by Montgomery & Associates, March 2019.
2) USGS = United States Geological Survey.
3) AF/yr = acre feet per year.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

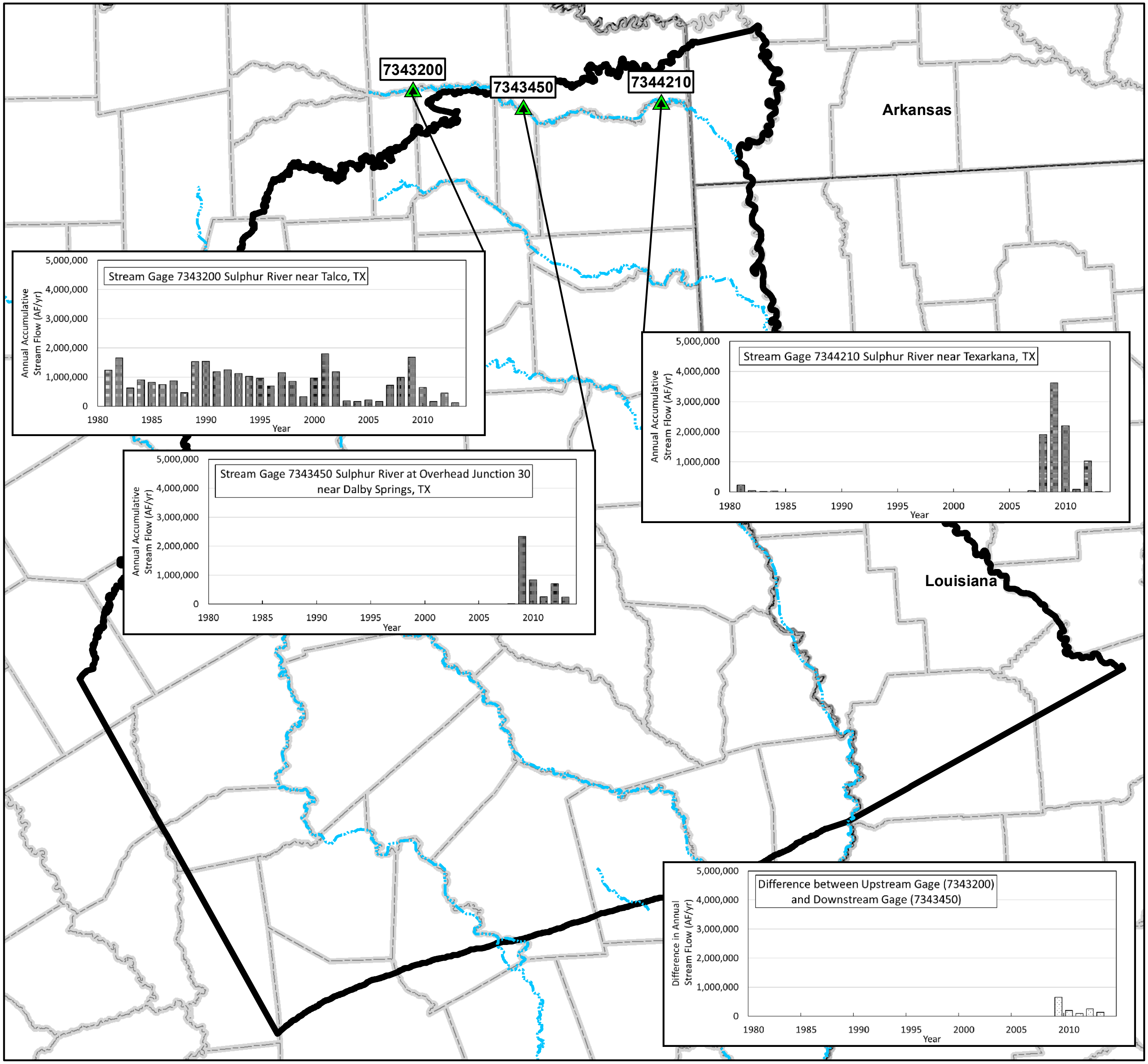
GSI ENVIRONMENTAL

ESTIMATED ANNUAL STREAMFLOWS FOR BIG CYPRESS CREEK

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: AV
Issued: 7-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_2_9_4	Appv'd By: DRAFT

FIGURE 2.9-4



Notes:

1) Basemap provided by Montgomery & Associates, March 2019.
2) USGS = United States Geological Survey.
3) AF/yr = acre feet per year.

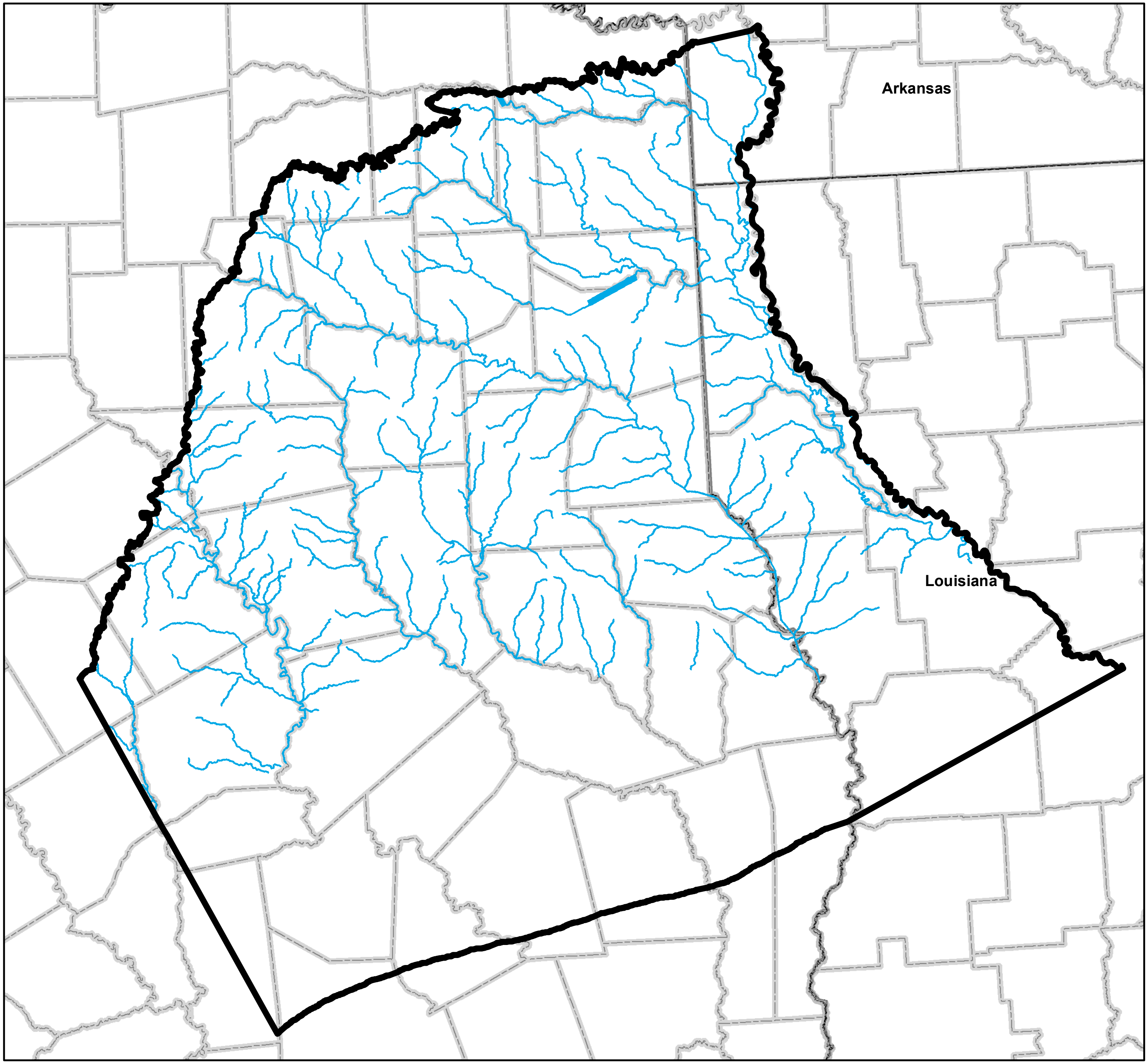
GSI ENVIRONMENTAL

ESTIMATED ANNUAL STREAMFLOWS FOR SULPHUR RIVER

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: AV
Issued: 7-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_2_9_5	Appv'd By: DRAFT

FIGURE 2.9-5



LEGEND

- Model Boundary
- County or Parish Boundary
- River Boundary Conditions

Note:

1) Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

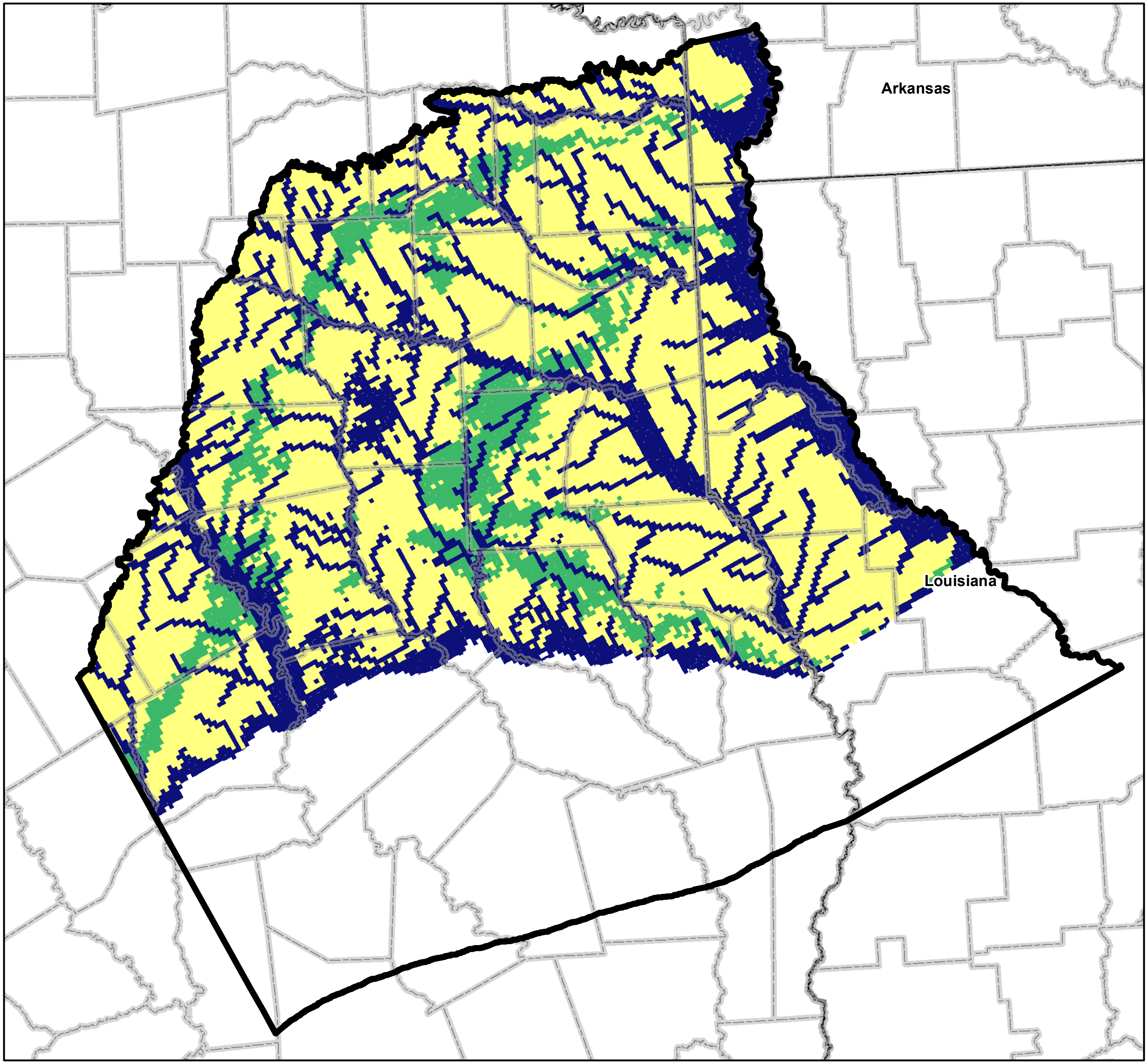
GSI ENVIRONMENTAL

SIMULATED RIVER BOUNDARY CONDITIONS

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: GM
Issued: 9-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_2_9_6	Appv'd By: DRAFT

FIGURE 2.9-6



N

LEGEND

Estimated Recharge (Inches/Year)

- 0.22 - 0.40
- 0.40 - 0.80
- 0.80 - 1.14
- Model Boundary
- County or Parish Boundary

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

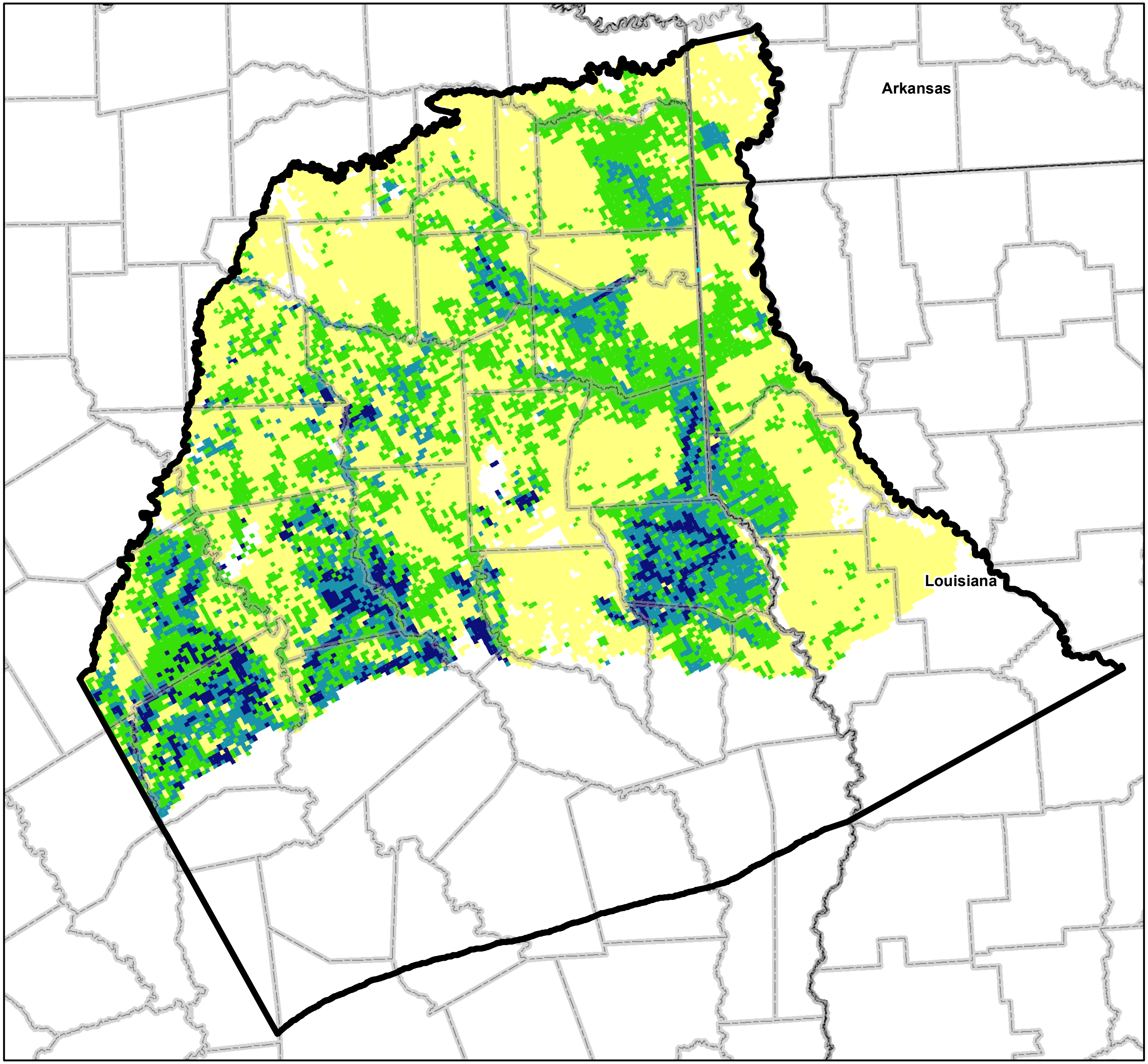
GSI ENVIRONMENTAL

DISTRIBUTION OF AVERAGE ESTIMATED ANNUAL RECHARGE RATES FOR 1980

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: AV
Issued: 4-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_2_10_1	Appv'd By: DRAFT

FIGURE 2.10-1



LEGEND

Model Boundary

County or Parish Boundary

Maximum Modeled Evapotranspiration Rate (inches/day)

- 0 - 0.01
- 0.01 - 0.02
- 0.02 - 0.03
- 0.03 - 0.046

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles: 0, 16, 32

Projected Coordinate System Datum: GAM

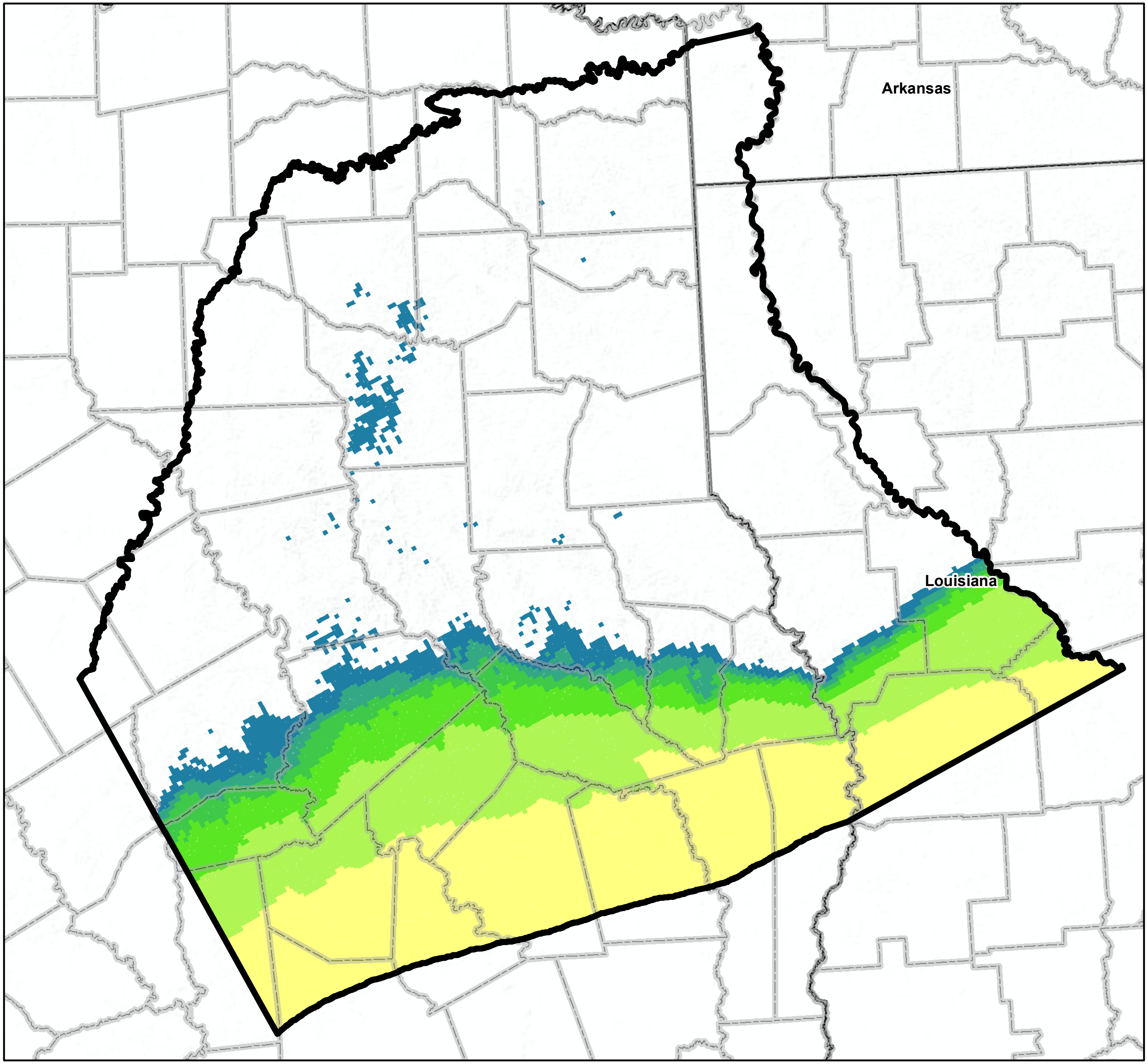
GSI ENVIRONMENTAL

DISTRIBUTION OF MODELED MAXIMUM EVAPOTRANSPIRATION RATES

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: AV
Issued: 4-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_2_11_1	Appv'd By: DRAFT

FIGURE 2.11-1



Note:

Basemap provided by Montgomery & Associates, March 2019.

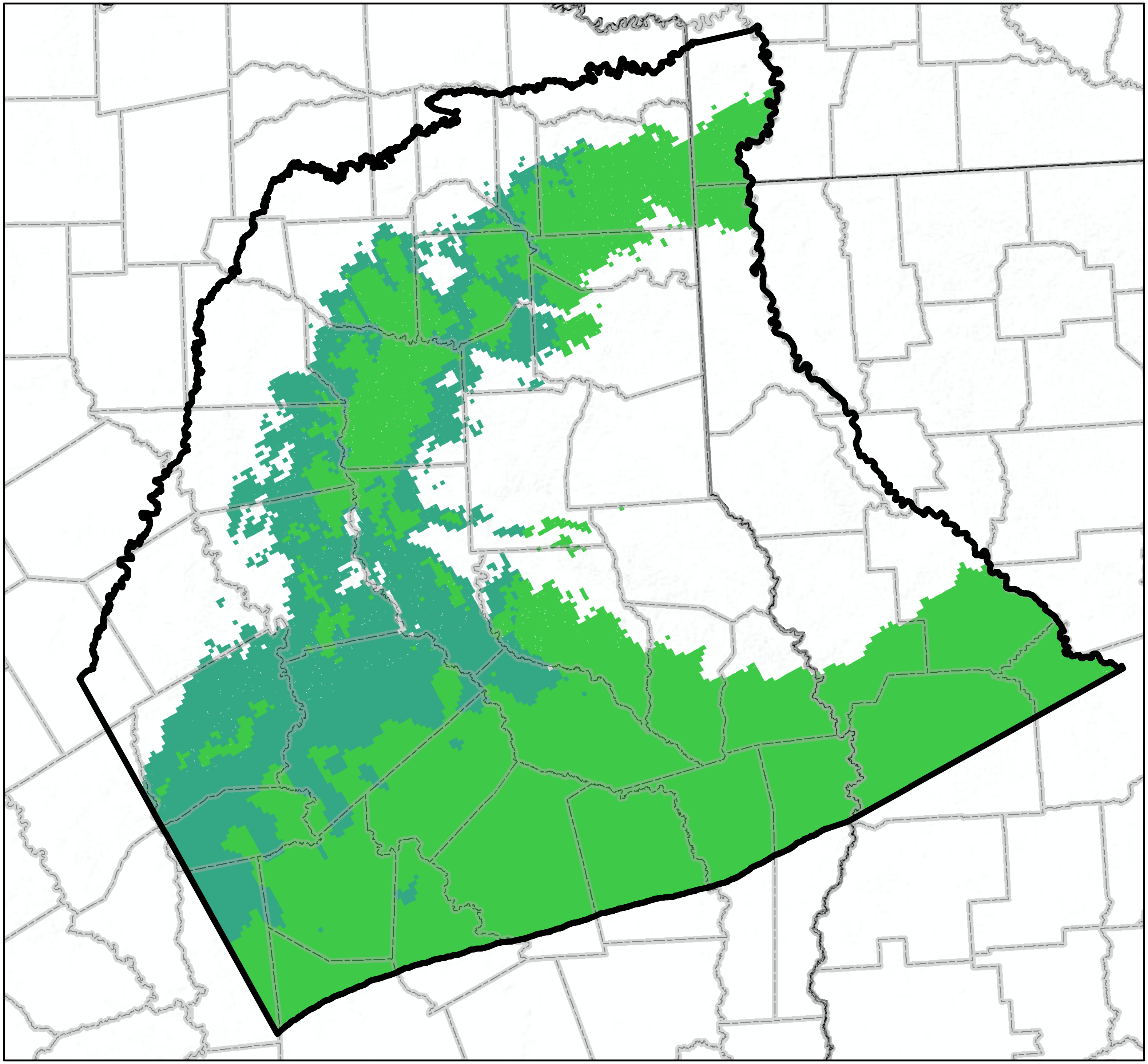
GSI ENVIRONMENTAL

CALCULATED HORIZONTAL HYDRAULIC CONDUCTIVITY FOR SPARTA SAND (MODEL LAYER 2)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 2-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_1_1	Appv'd By: DRAFT

FIGURE 3.1-1



LEGEND

Model Boundary

County or Parish Boundary

Calculated Hydraulic Conductivity (Feet/Day)

0 - 0.1

0.1 - 0.5

0.5 - 1

1 - 1.5

1.5 - 2.5

2.5 - 5

5 - 10

10 - 18.05

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System

Datum: GAM

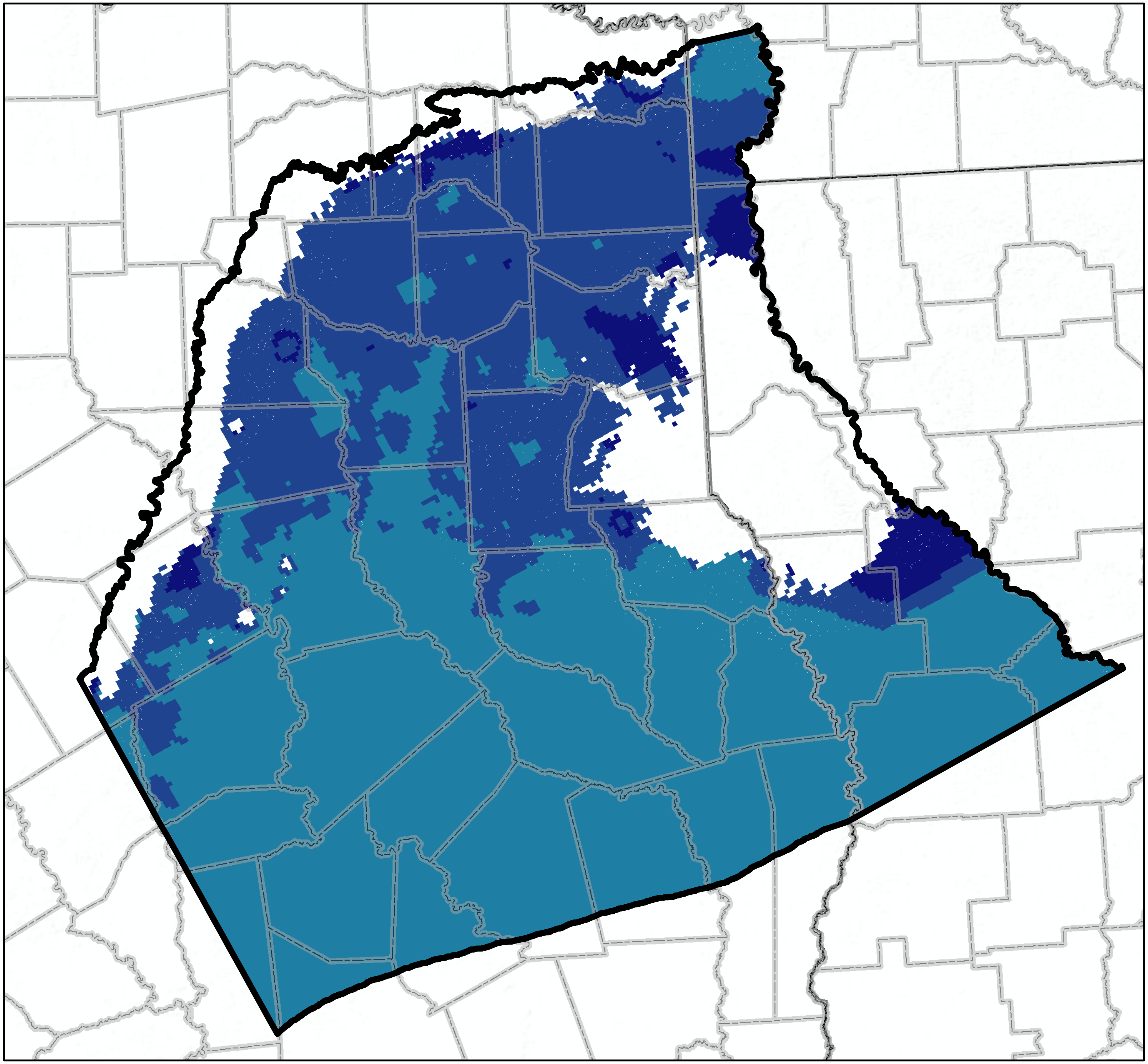
GSI ENVIRONMENTAL

CALCULATED HORIZONTAL HYDRAULIC CONDUCTIVITY FOR QUEEN CITY SAND (MODEL LAYER 4)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 2-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_1_2	Appv'd By: DRAFT

FIGURE 3.1-2



N

LEGEND

- Model Boundary
- County or Parish Boundary

Calculated Hydraulic Conductivity (Feet/Day)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2.5
- 2.5 - 5
- 5 - 10
- 10 - 18.05

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

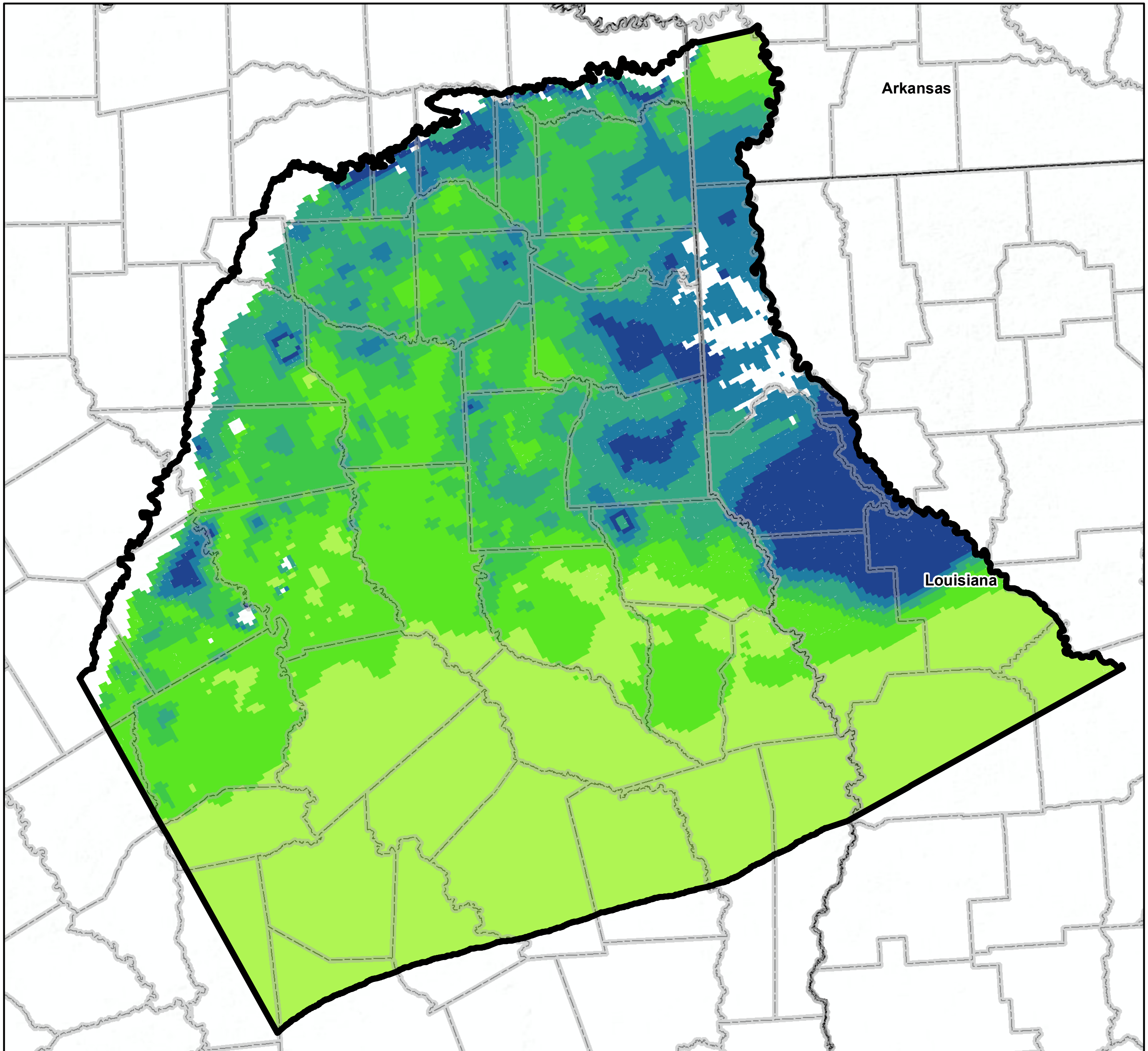
GSI ENVIRONMENTAL

CALCULATED HORIZONTAL HYDRAULIC CONDUCTIVITY FOR UPPER WILCOX (MODEL LAYER 7)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 2-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_1_3	Appv'd By: DRAFT

FIGURE 3.1-3



LEGEND

- Model Boundary
- County or Parish Boundary

Calculated Hydraulic Conductivity (Feet/Day)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2.5
- 2.5 - 5
- 5 - 10
- 10 - 18.05

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

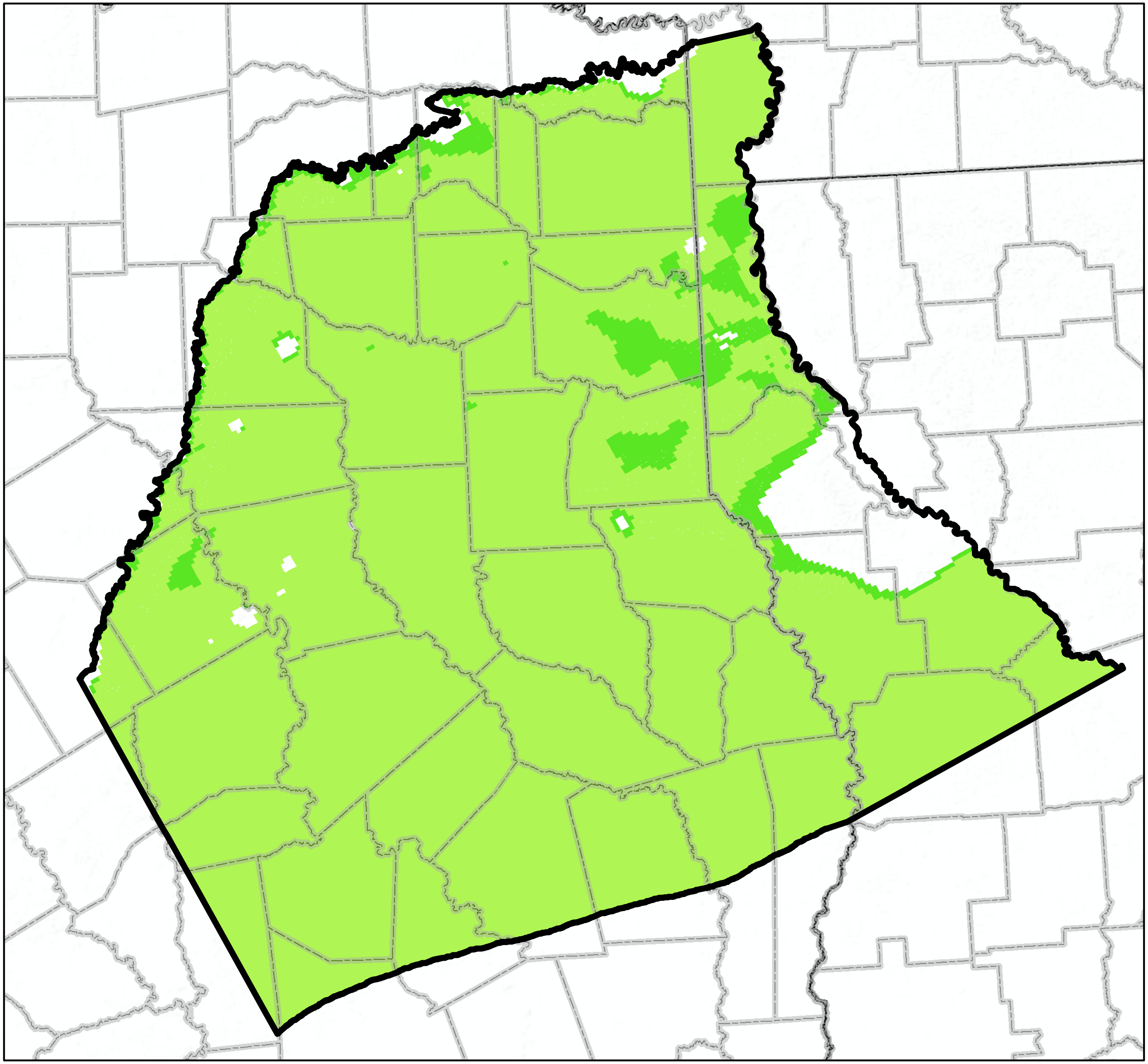
GSI ENVIRONMENTAL

CALCULATED HORIZONTAL HYDRAULIC CONDUCTIVITY FOR MIDDLE WILCOX (MODEL LAYER 8)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: BC
Issued: 2-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_1_4	Appv'd By: DRAFT

FIGURE 3.1-4

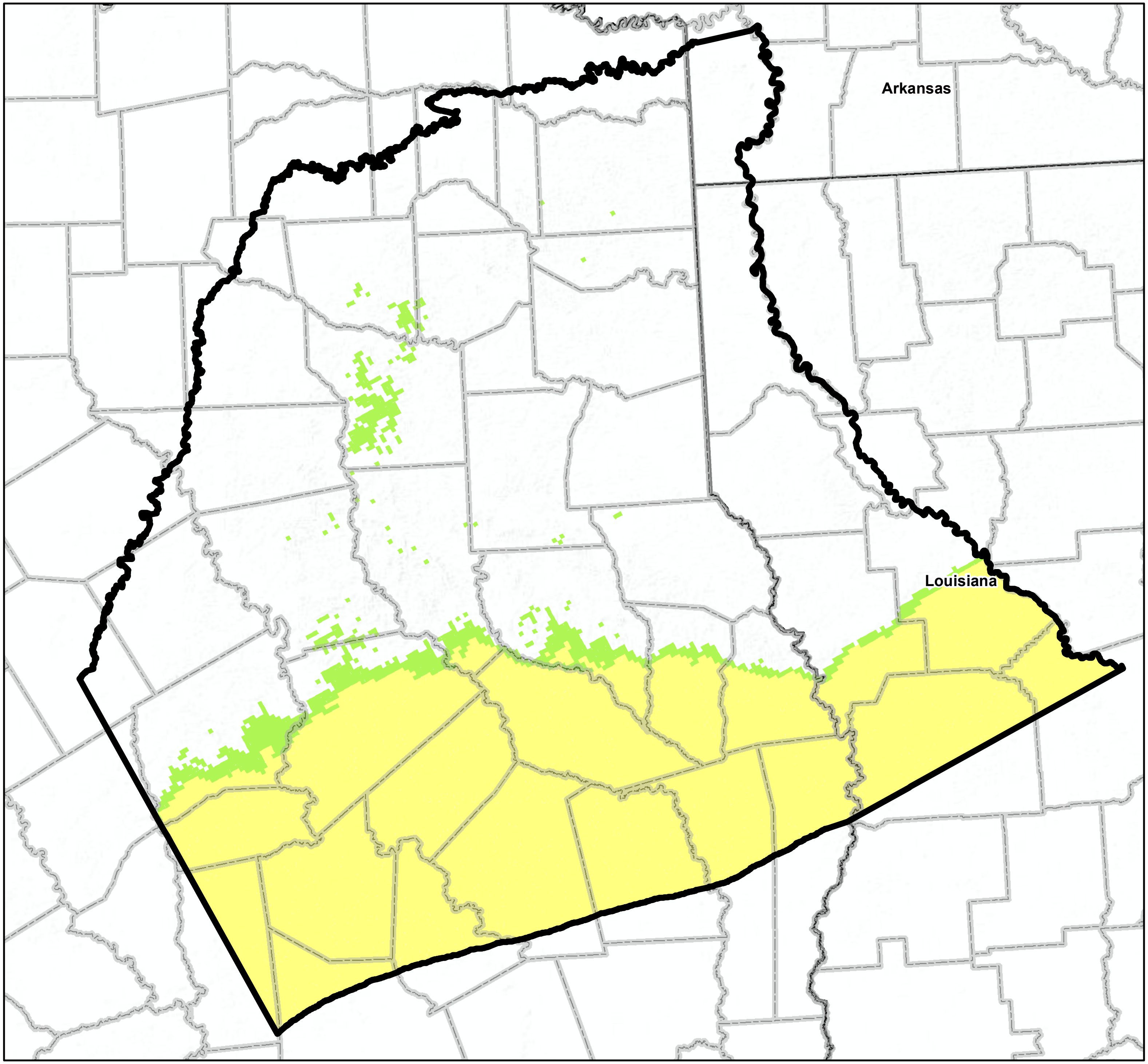


CALCULATED HORIZONTAL HYDRAULIC CONDUCTIVITY FOR LOWER WILCOX (MODEL LAYER 9)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: BC
Issued: 2-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_1_5	Appv'd By: DRAFT

FIGURE 3.1-5



LEGEND

Model Boundary

County or Parish Boundary

Calculated Hydraulic Conductivity (Feet/Day)

- 0 - 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1
- 1 - 1.5
- 1.5 - 2

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles: 0, 16, 32

Projected Coordinate System Datum: GAM

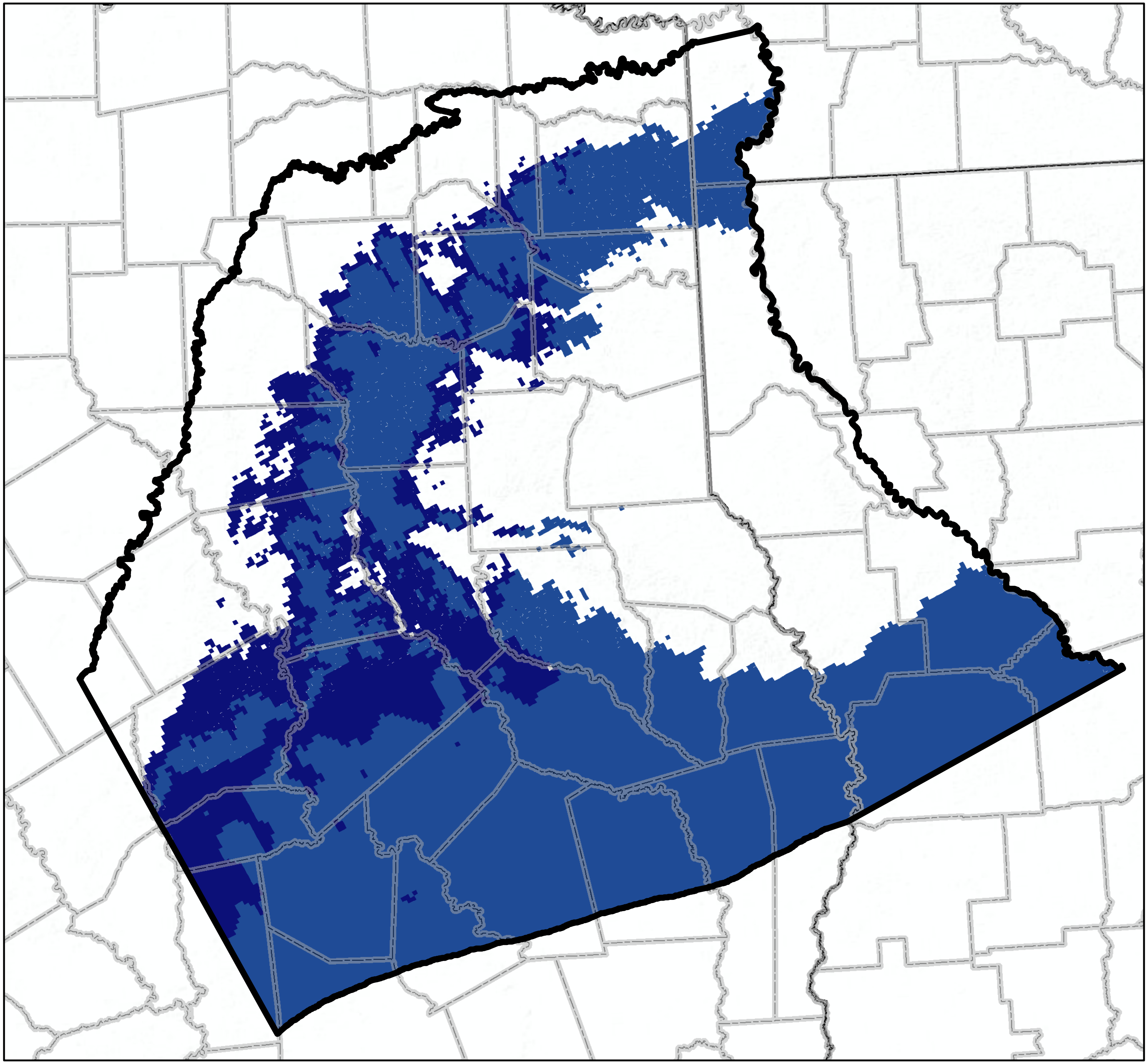
GSI ENVIRONMENTAL

CALCULATED VERTICAL HYDRAULIC CONDUCTIVITY FOR SPARTA SAND (MODEL LAYER 2)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 2-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_1_6	Appv'd By: DRAFT

FIGURE 3.1-6



LEGEND

Model Boundary
County or Parish Boundary

Calculated Hydraulic Conductivity (Feet/Day)

0 - 0.0001
0.0001 - 0.001
0.001 - 0.01
0.01 - 0.1
0.1 - 1
1 - 1.5
1.5 - 2

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

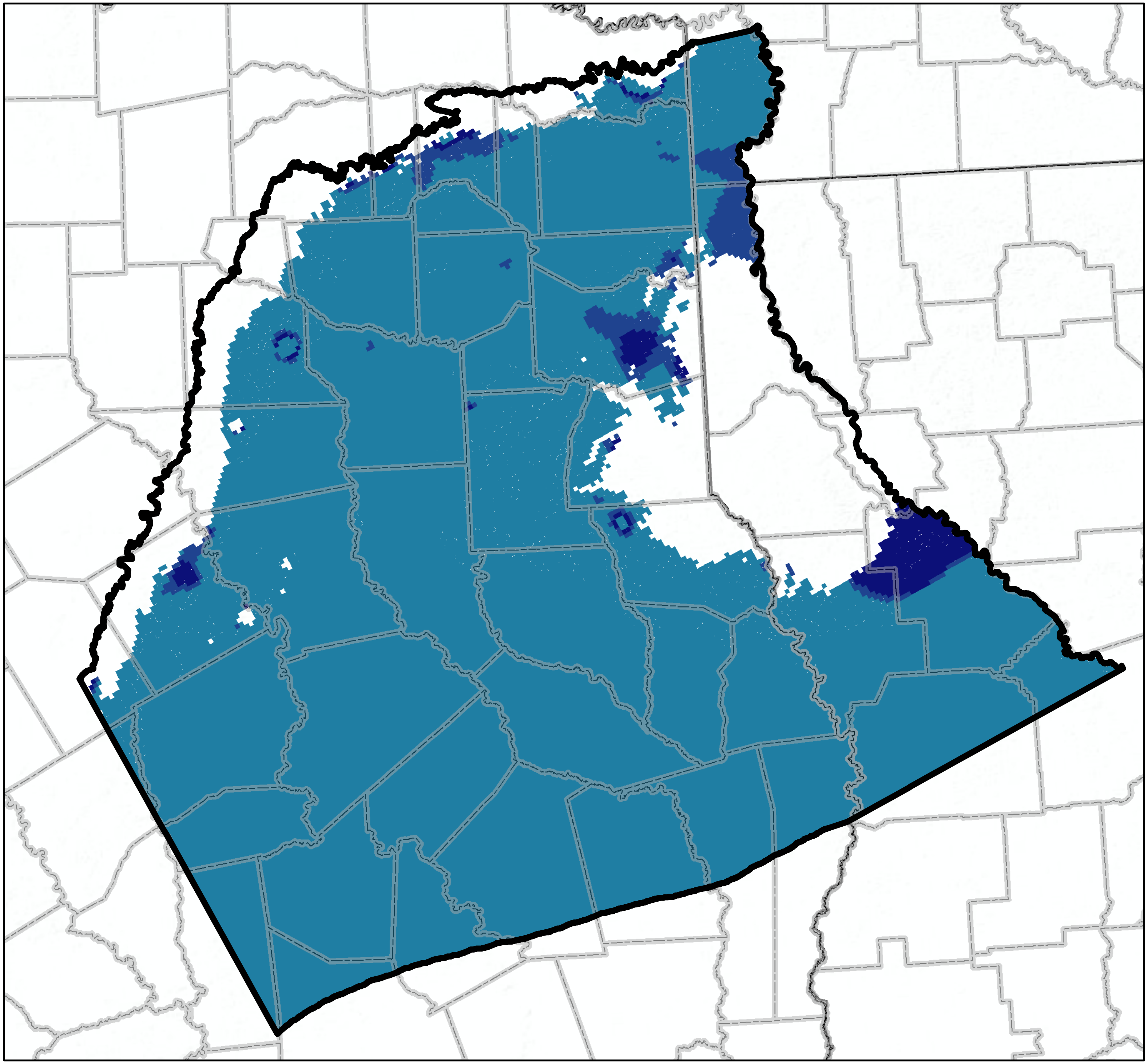
GSI ENVIRONMENTAL

CALCULATED VERTICAL HYDRAULIC CONDUCTIVITY FOR QUEEN CITY SAND (MODEL LAYER 4)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 2-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_1_7	Appv'd By: DRAFT

FIGURE 3.1-7



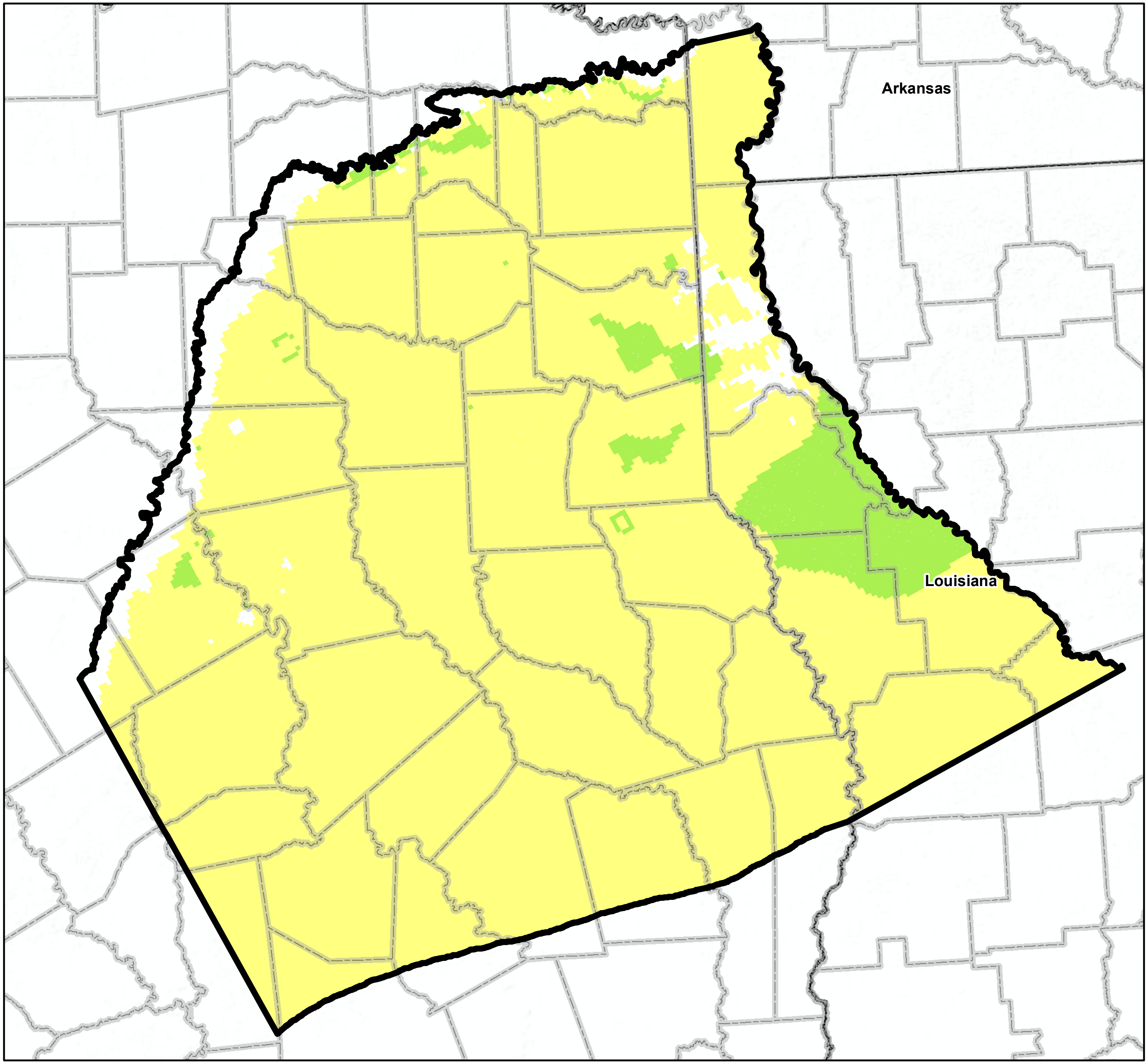
GSI ENVIRONMENTAL

CALCULATED VERTICAL HYDRAULIC CONDUCTIVITY FOR UPPER WILCOX (MODEL LAYER 7)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 2-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_1_8	Appv'd By: DRAFT

FIGURE 3.1-8



LEGEND

- Model Boundary
- County or Parish Boundary

Calculated Hydraulic Conductivity (Feet/Day)

- 0 - 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1
- 1 - 1.5
- 1.5 - 2

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

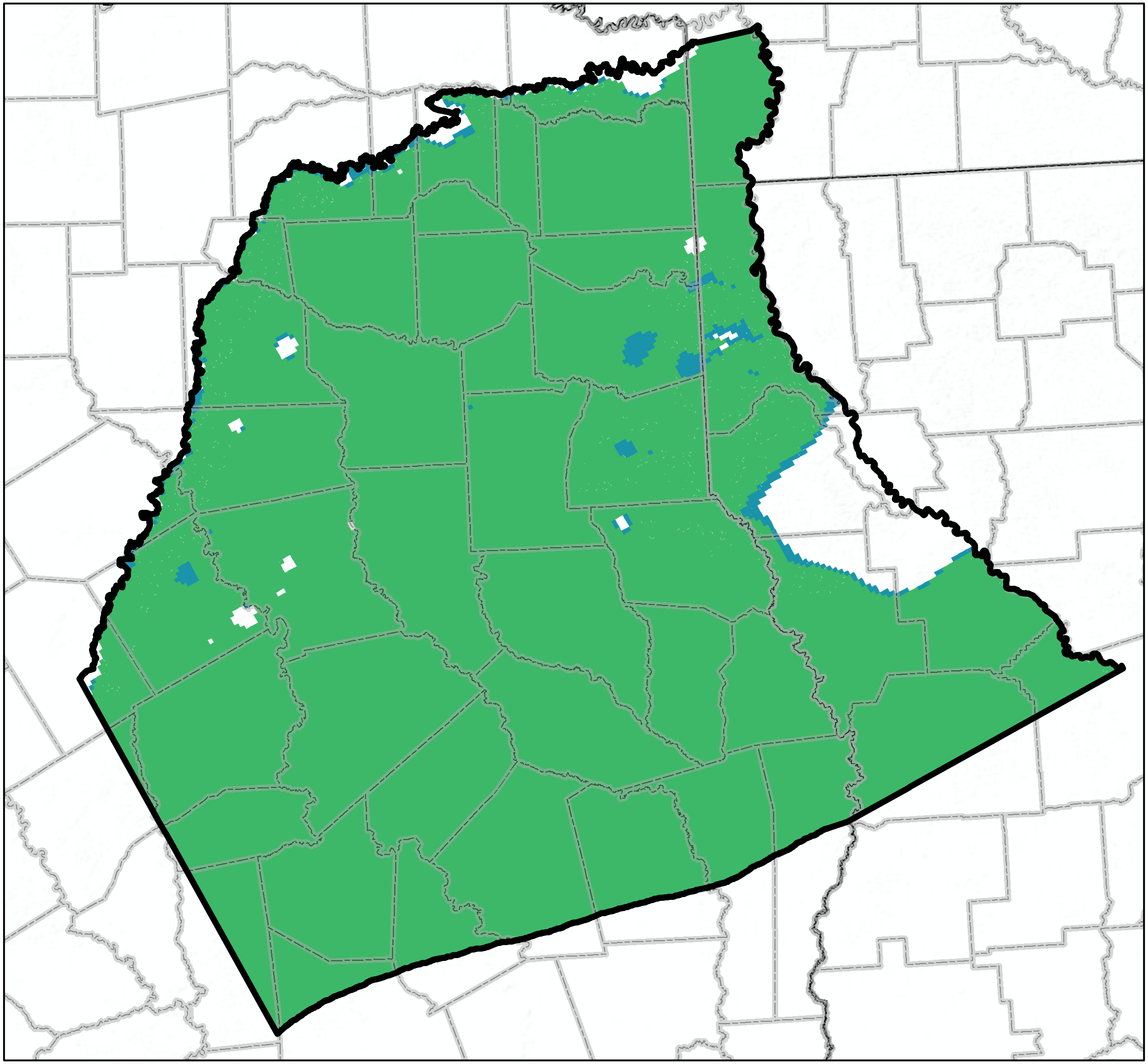
GSI ENVIRONMENTAL

CALCULATED HORIZONTAL HYDRAULIC CONDUCTIVITY FOR MIDDLE WILCOX (MODEL LAYER 8)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 2-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_1_9	Appv'd By: DRAFT

FIGURE 3.1-9



N

LEGEND

Model Boundary

County or Parish Boundary

Calculated Hydraulic Conductivity (Feet/Day)

- 0 - 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1
- 1 - 1.5
- 1.5 - 2

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

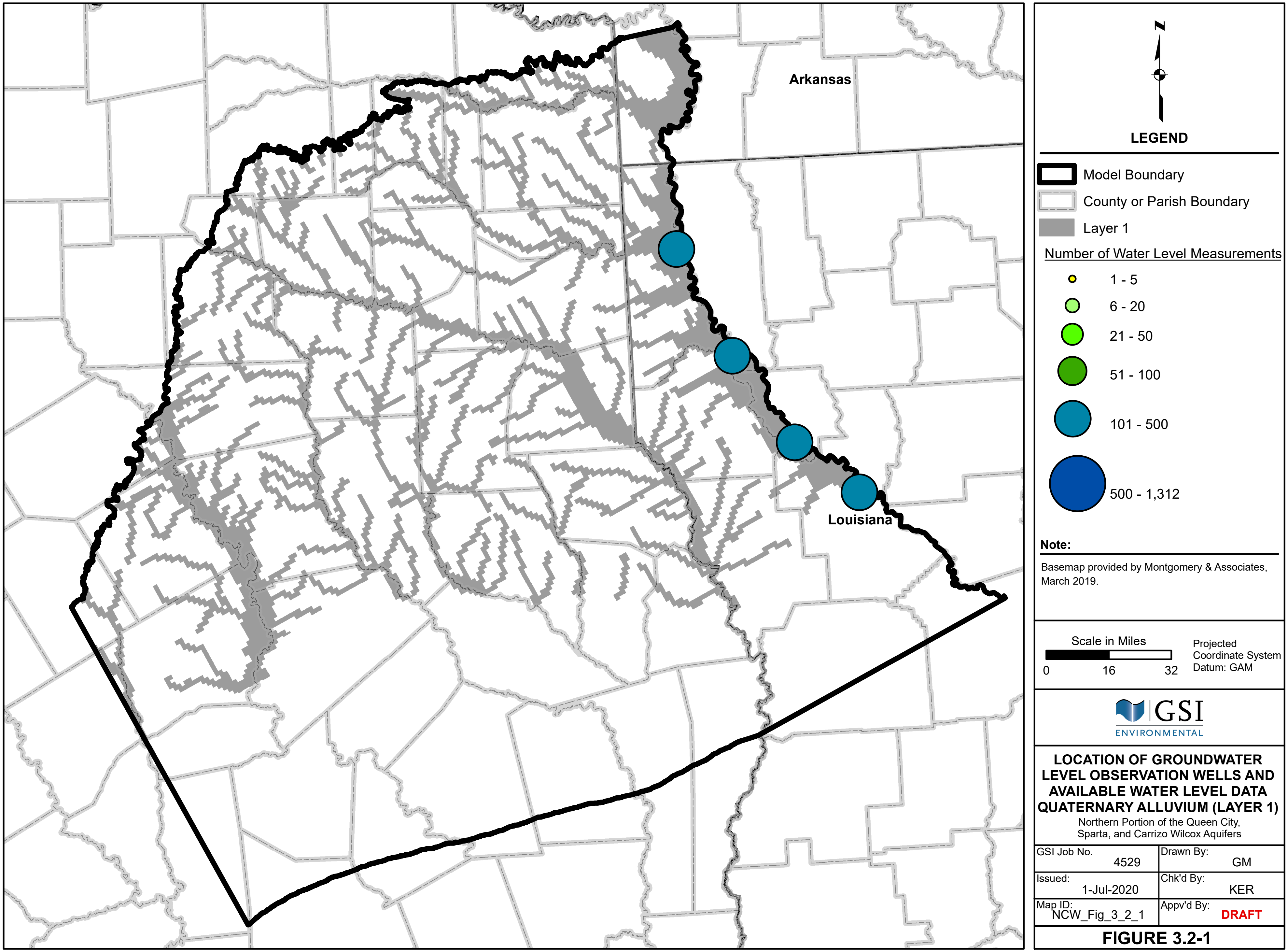
GSI ENVIRONMENTAL

CALCULATED VERTICAL HYDRAULIC CONDUCTIVITY FOR LOWER WILCOX (MODEL LAYER 9)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 2-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_1_10	Appv'd By: DRAFT

FIGURE 3.1-10



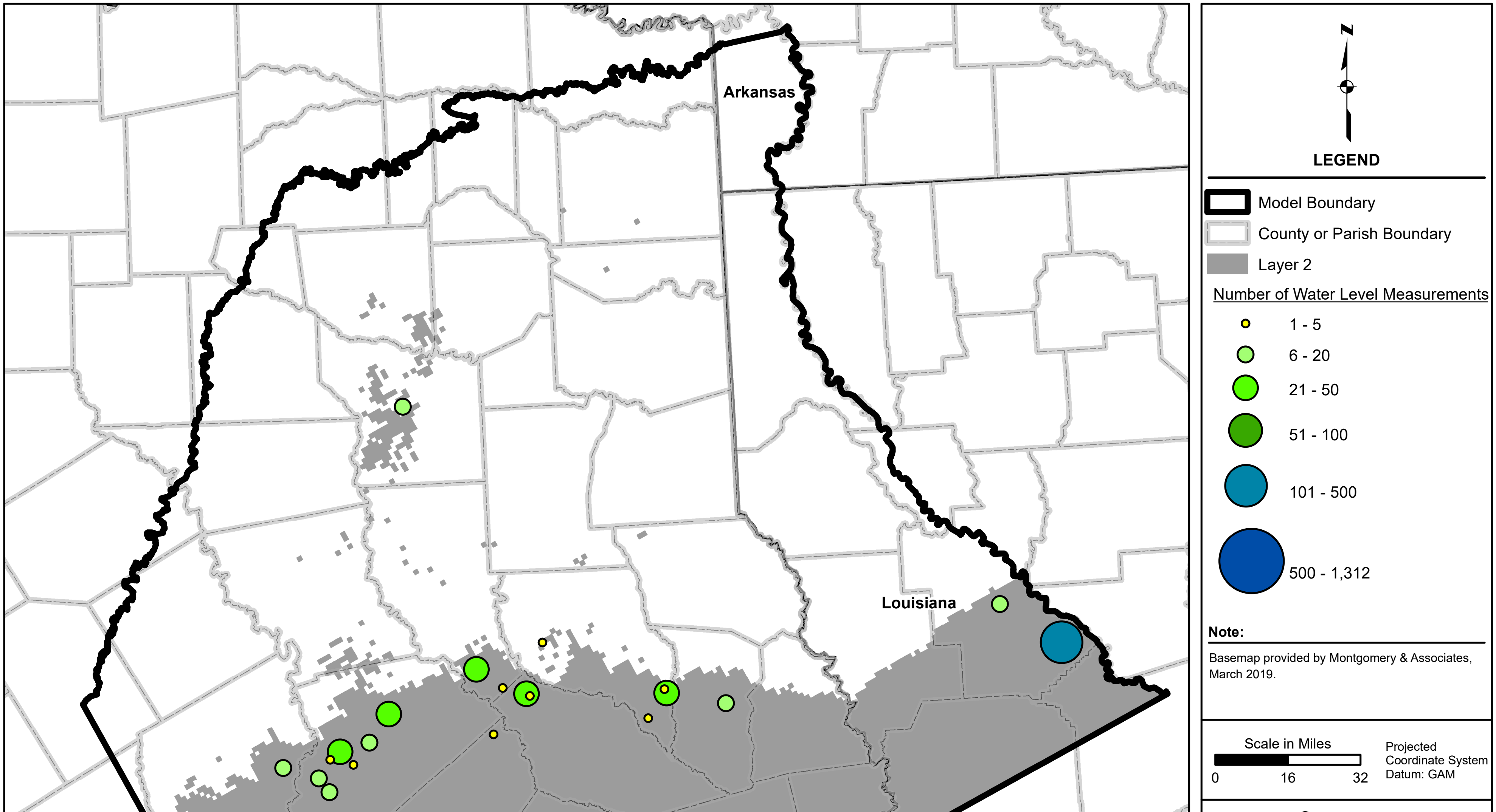
GSI ENVIRONMENTAL

LOCATION OF GROUNDWATER LEVEL OBSERVATION WELLS AND AVAILABLE WATER LEVEL DATA QUATERNARY ALLUVIUM (LAYER 1)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_1	Appv'd By: DRAFT

FIGURE 3.2-1



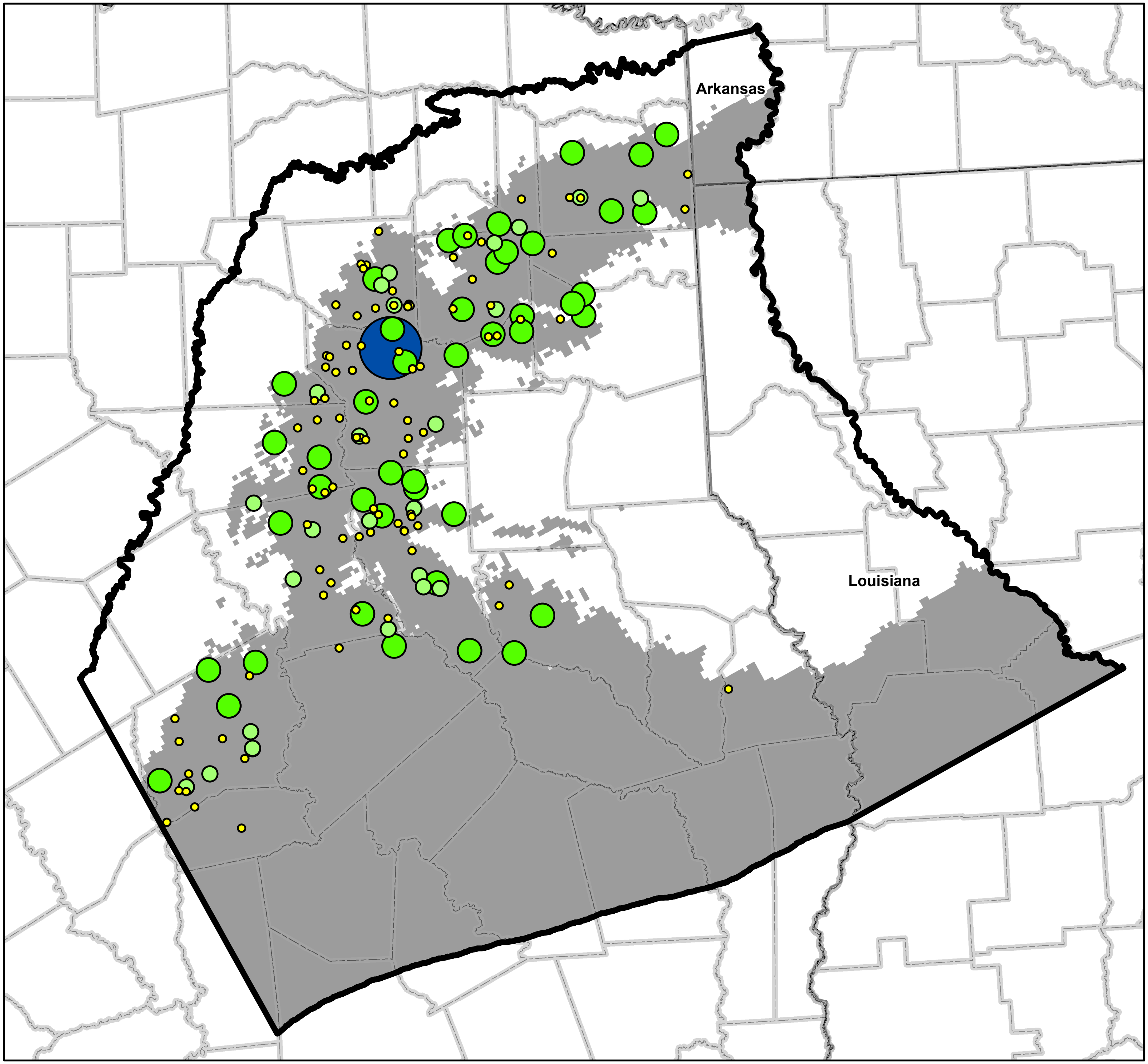
GSI ENVIRONMENTAL

LOCATION OF GROUNDWATER LEVEL OBSERVATION WELLS AND AVAILABLE WATER LEVEL DATA SPARTA SAND (LAYER 2)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.	4529	Drawn By:	GM
Issued:	1-Jul-2020	Chk'd By:	KER
Map ID:	NCW_Fig_3_2_2	Appv'd By:	DRAFT

FIGURE 3.2-2



LEGEND

- Model Boundary
- County or Parish Boundary
- Layer 4

Number of Water Level Measurements

- 1 - 5
- 6 - 20
- 21 - 50
- 51 - 100
- 101 - 500
- 500 - 1,312

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

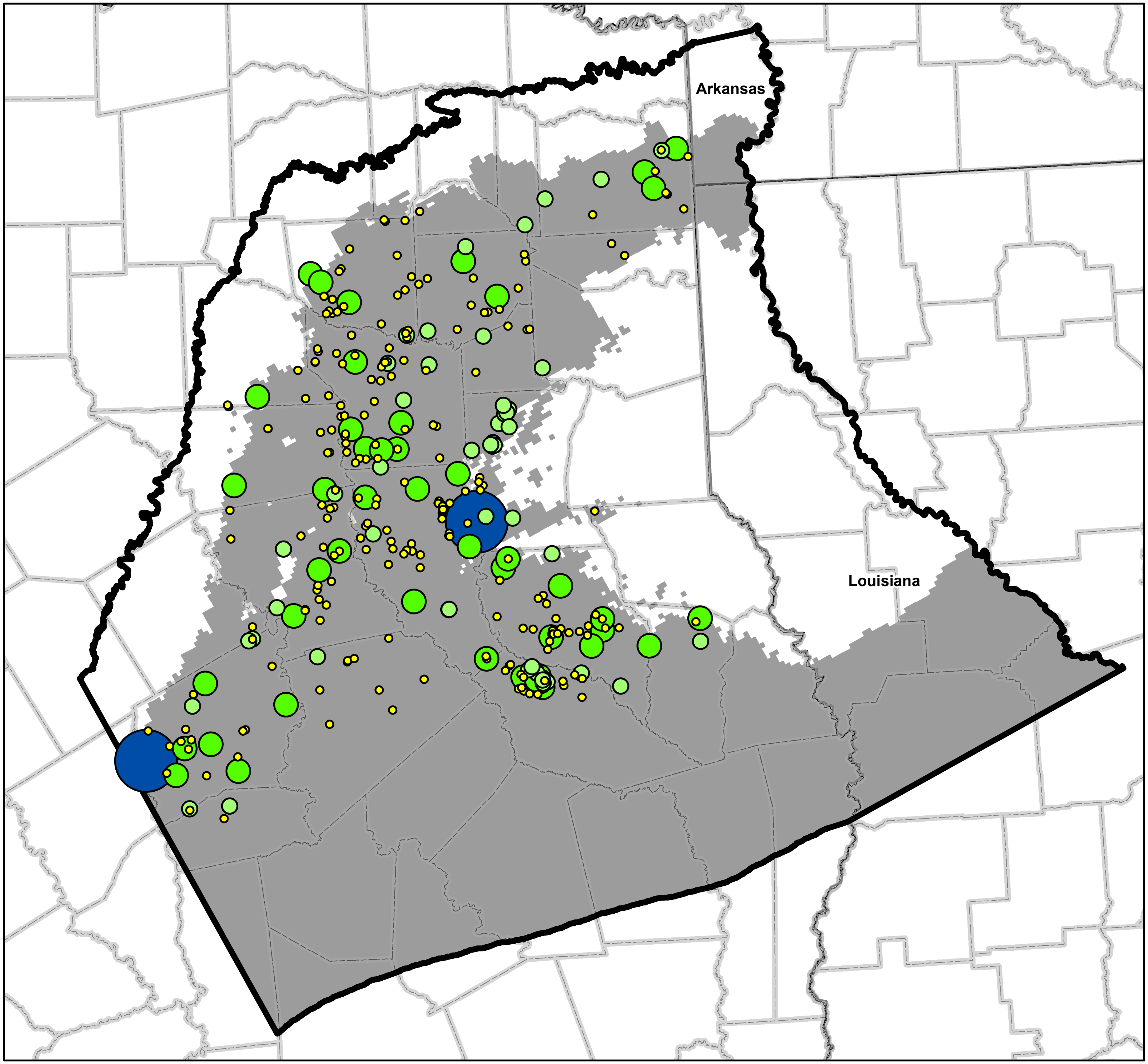
GSI ENVIRONMENTAL

LOCATION OF GROUNDWATER LEVEL OBSERVATION WELLS AND AVAILABLE WATER LEVEL DATA QUEEN CITY SAND (LAYER 4)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_3	Appv'd By: DRAFT

FIGURE 3.2-3



LEGEND

- Model Boundary
- County or Parish Boundary
- Layer 6

Number of Water Level Measurements

- 1 - 5
- 6 - 20
- 21 - 50
- 51 - 100
- 101 - 500
- 500 - 1,312

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

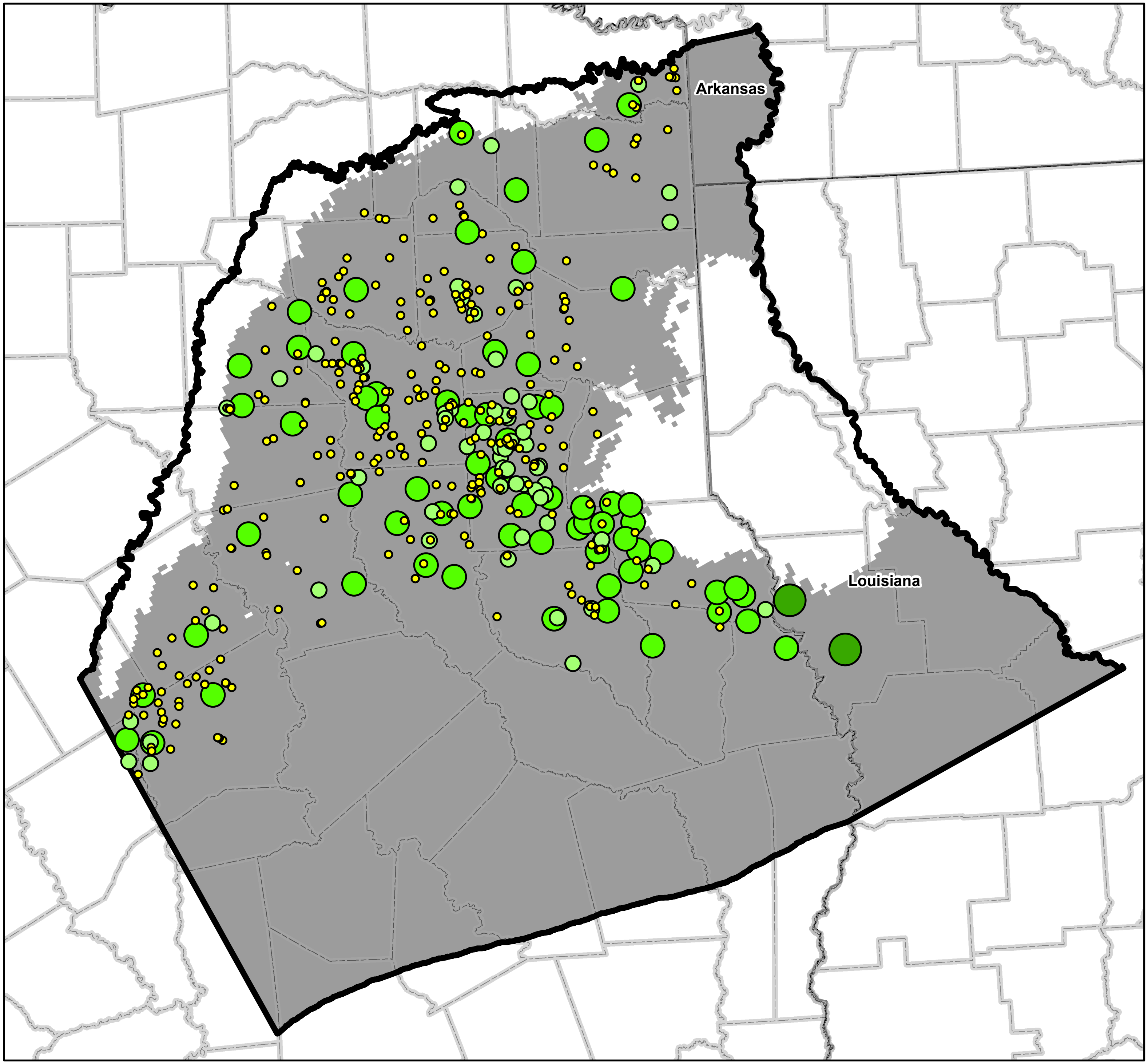
GSI ENVIRONMENTAL

LOCATION OF GROUNDWATER LEVEL OBSERVATION WELLS AND AVAILABLE WATER LEVEL DATA CARRIZO SAND (LAYER 6)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_4	Appv'd By: DRAFT

FIGURE 3.2-4

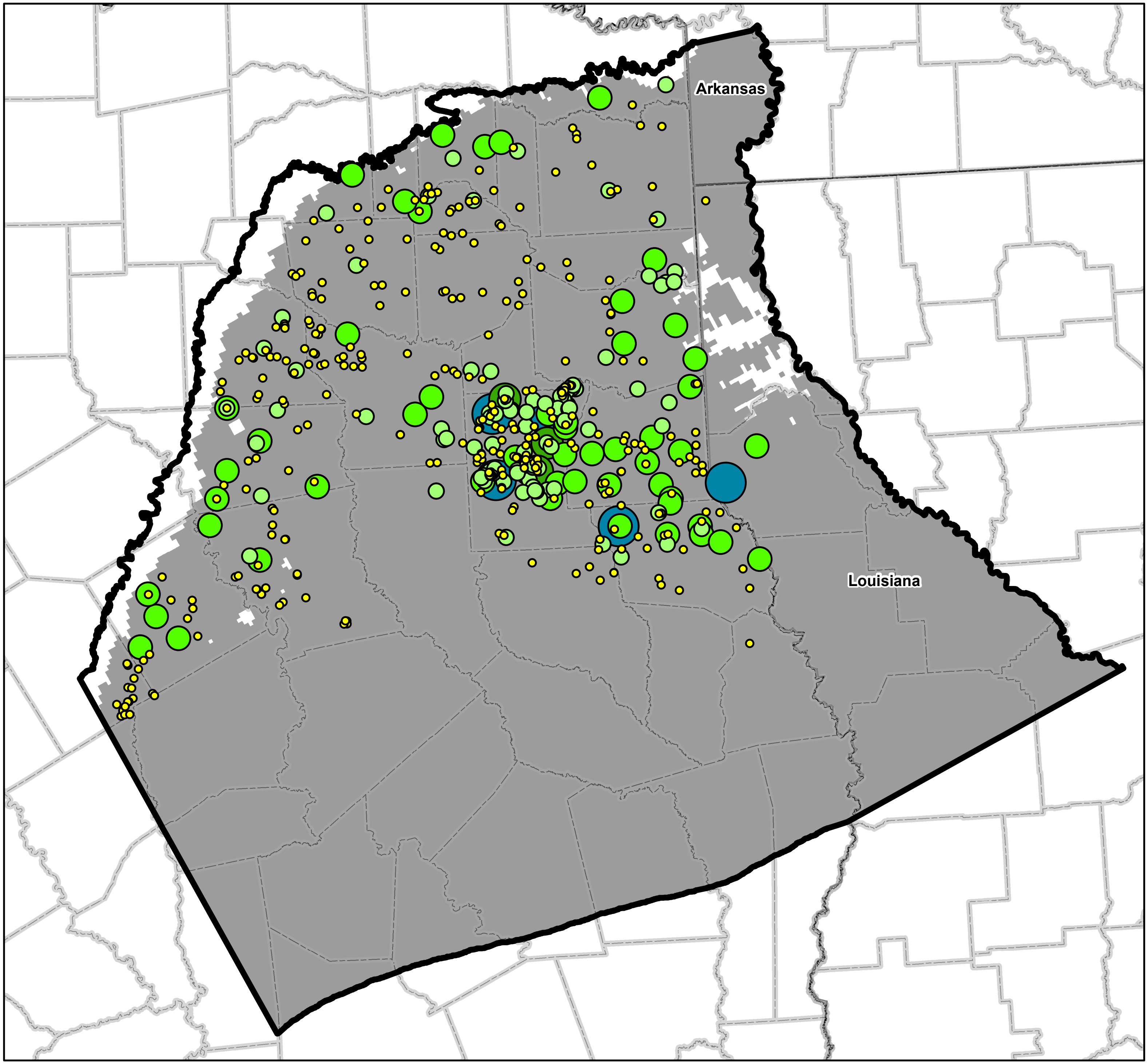


LOCATION OF GROUNDWATER LEVEL OBSERVATION WELLS AND AVAILABLE WATER LEVEL DATA UPPER WILCOX (LAYER 7)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_5	Appv'd By: DRAFT

FIGURE 3.2-5



Note:

Basemap provided by Montgomery & Associates, March 2019.

Projected Coordinate System
Datum: GAM

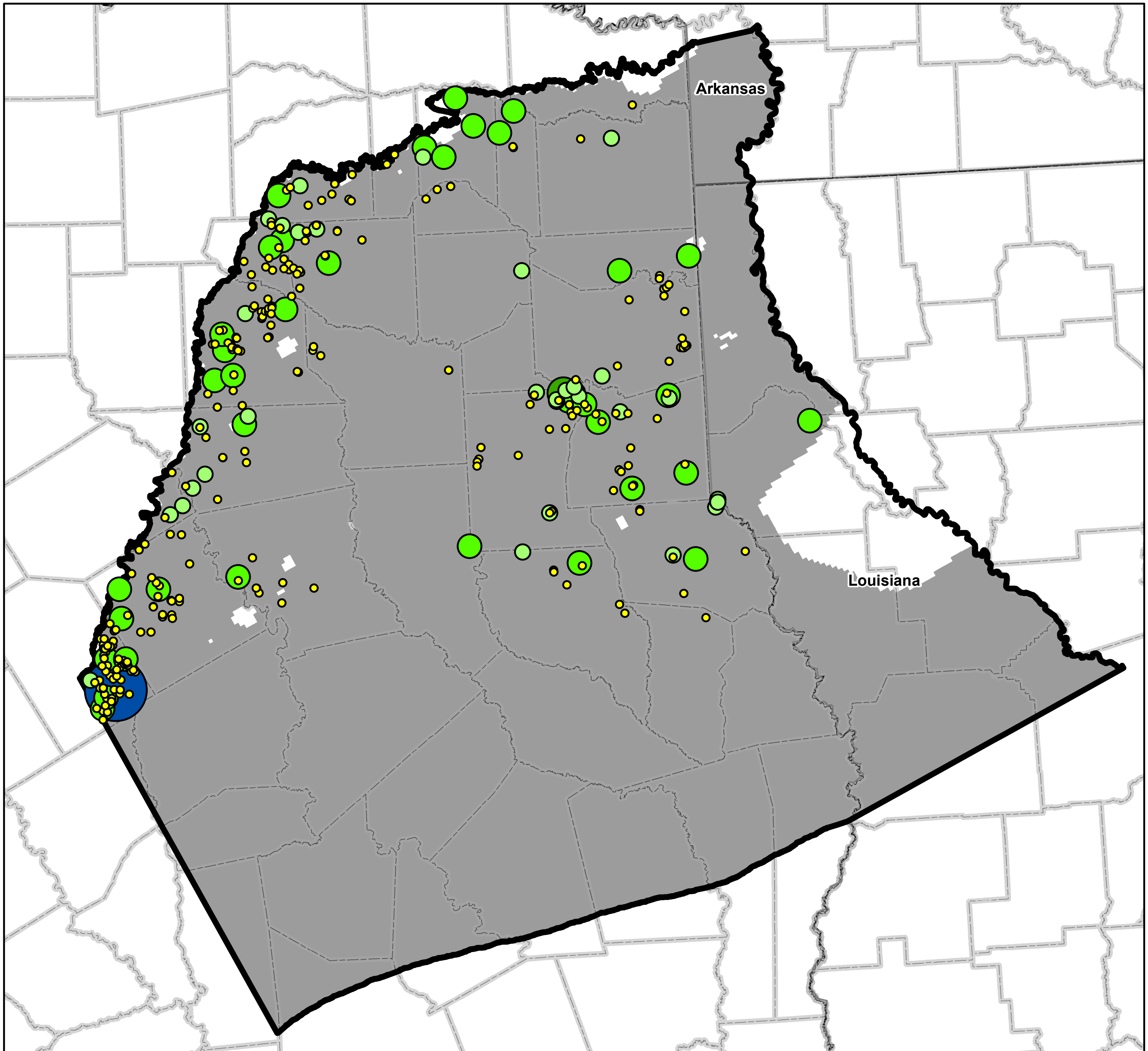
GSI ENVIRONMENTAL

LOCATION OF GROUNDWATER LEVEL OBSERVATION WELLS AND AVAILABLE WATER LEVEL DATA MIDDLE WILCOX (LAYER 8)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_6	Appv'd By: DRAFT

FIGURE 3.2-6



LEGEND

- Model Boundary
- County or Parish Boundary
- Layer 9

Number of Water Level Measurements
- 1 - 5
- 6 - 20
- 21 - 50
- 51 - 100
- 101 - 500
- 500 - 1,312

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

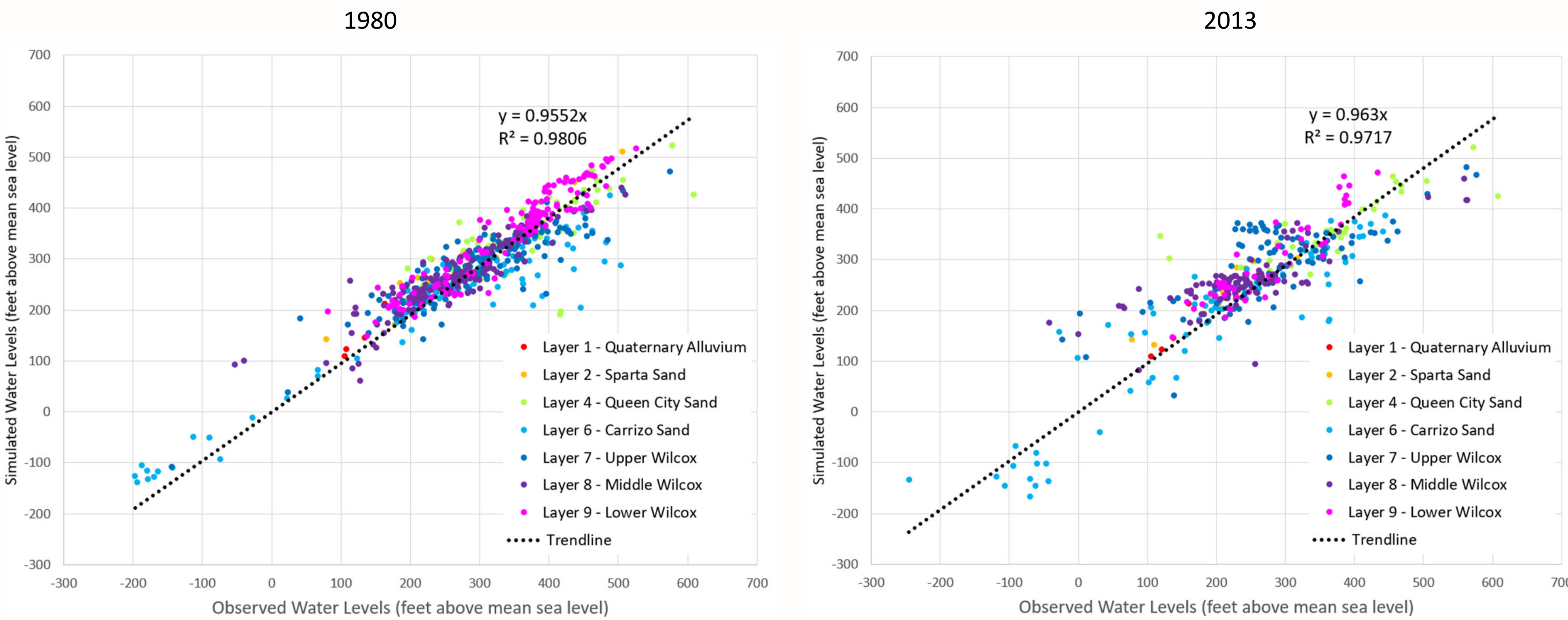
GSI ENVIRONMENTAL

LOCATION OF GROUNDWATER LEVEL OBSERVATION WELLS AND AVAILABLE WATER LEVEL DATA LOWER WILCOX (LAYER 9)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_7	Appv'd By: DRAFT

FIGURE 3.2-7

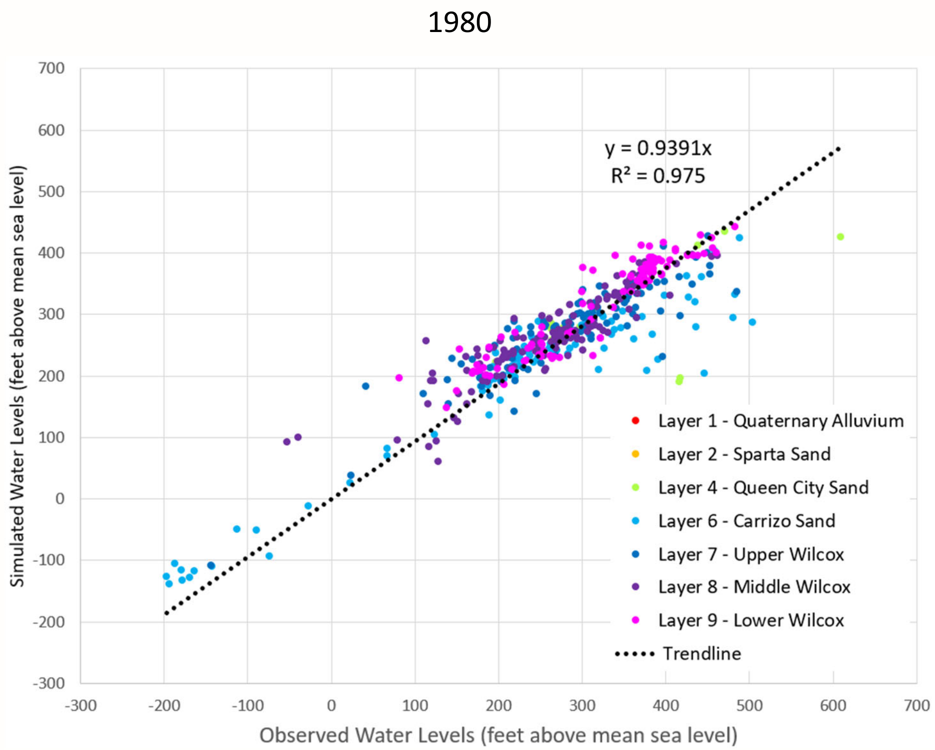


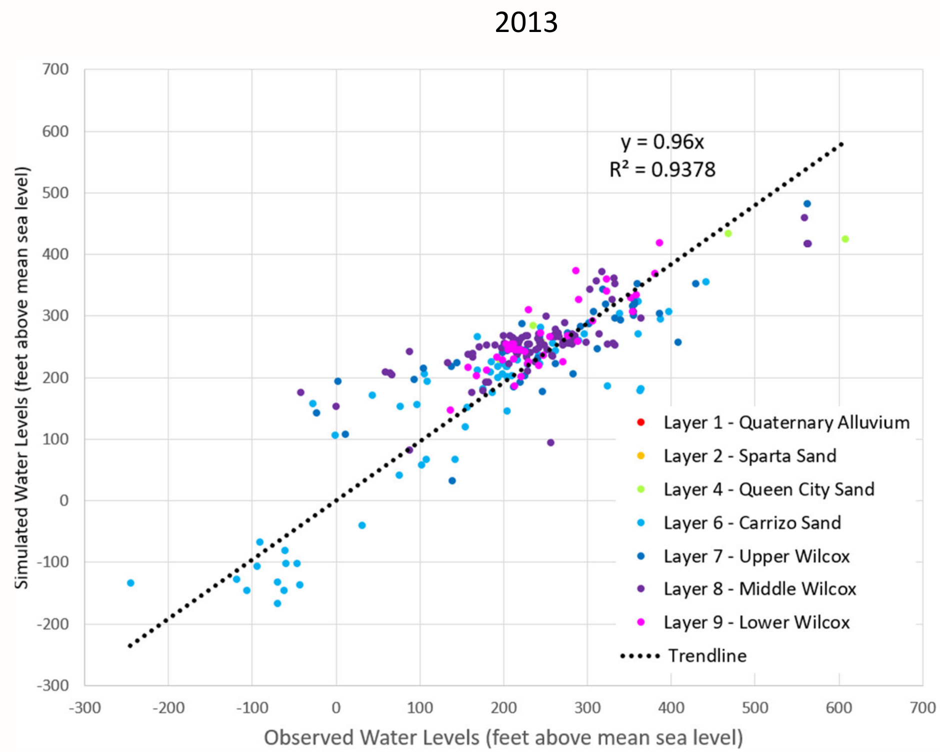
GSI ENVIRONMENTAL

GSI Job No.	4529	Drawn By:	GM
Issued:	1-Jul-2020	Chk'd By:	
Revised:		Aprv'd By:	DRAFT
Scale:			Figure 3.2-8

Observed vs. Simulated Water Levels for Calibrated 1980 and 2013 Conditions

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers





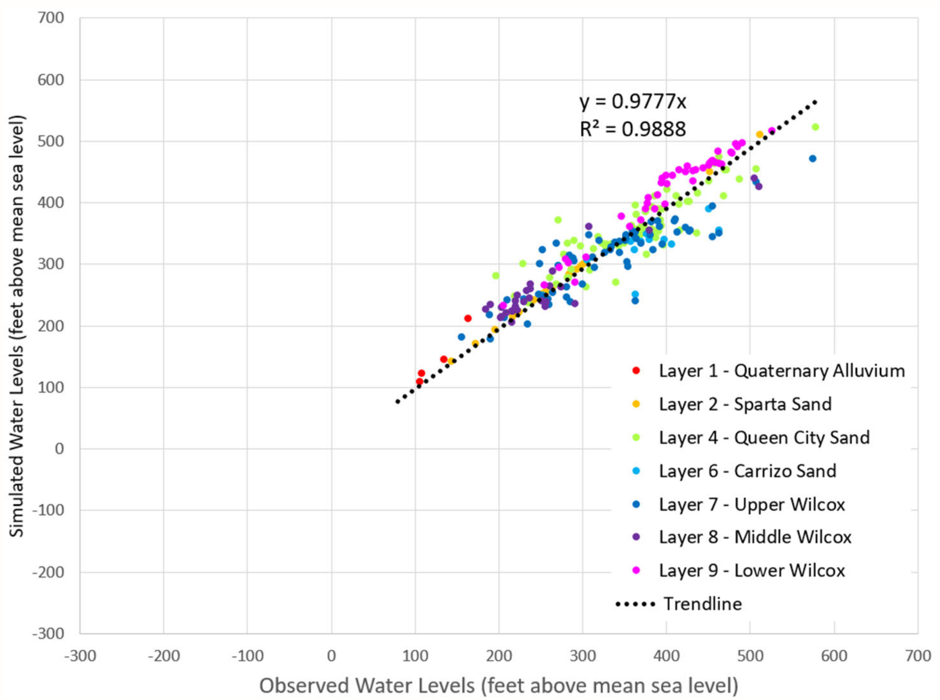
GSI ENVIRONMENTAL

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By:
Revised:	Aprv'd By: DRAFT
Scale:	Figure 3.2-9

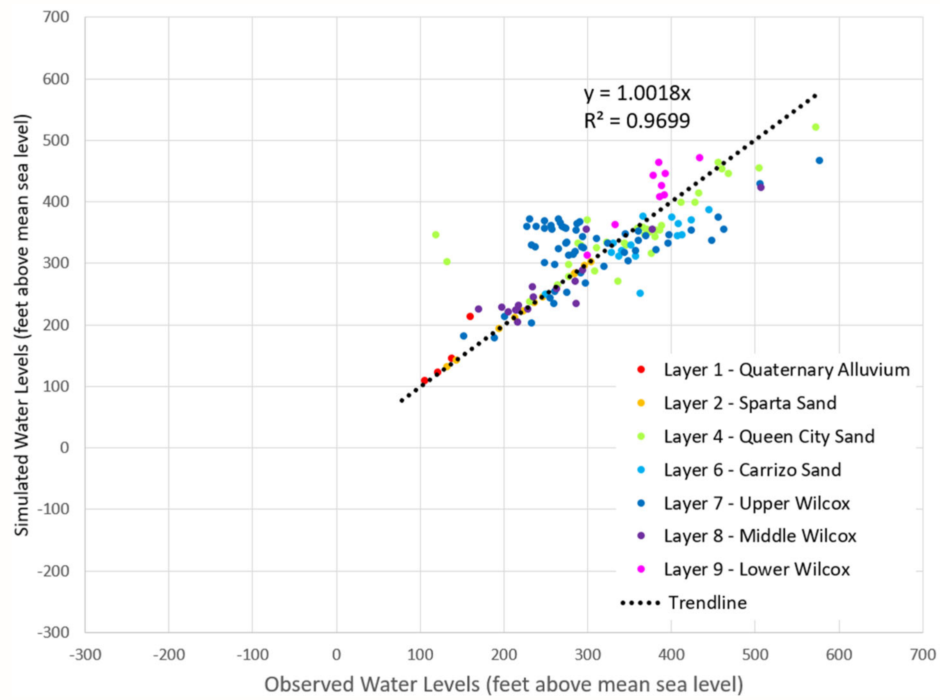
Observed vs. Simulated Confined Water Levels for Calibrated 1980 and 2013 Conditions

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

1980



2013

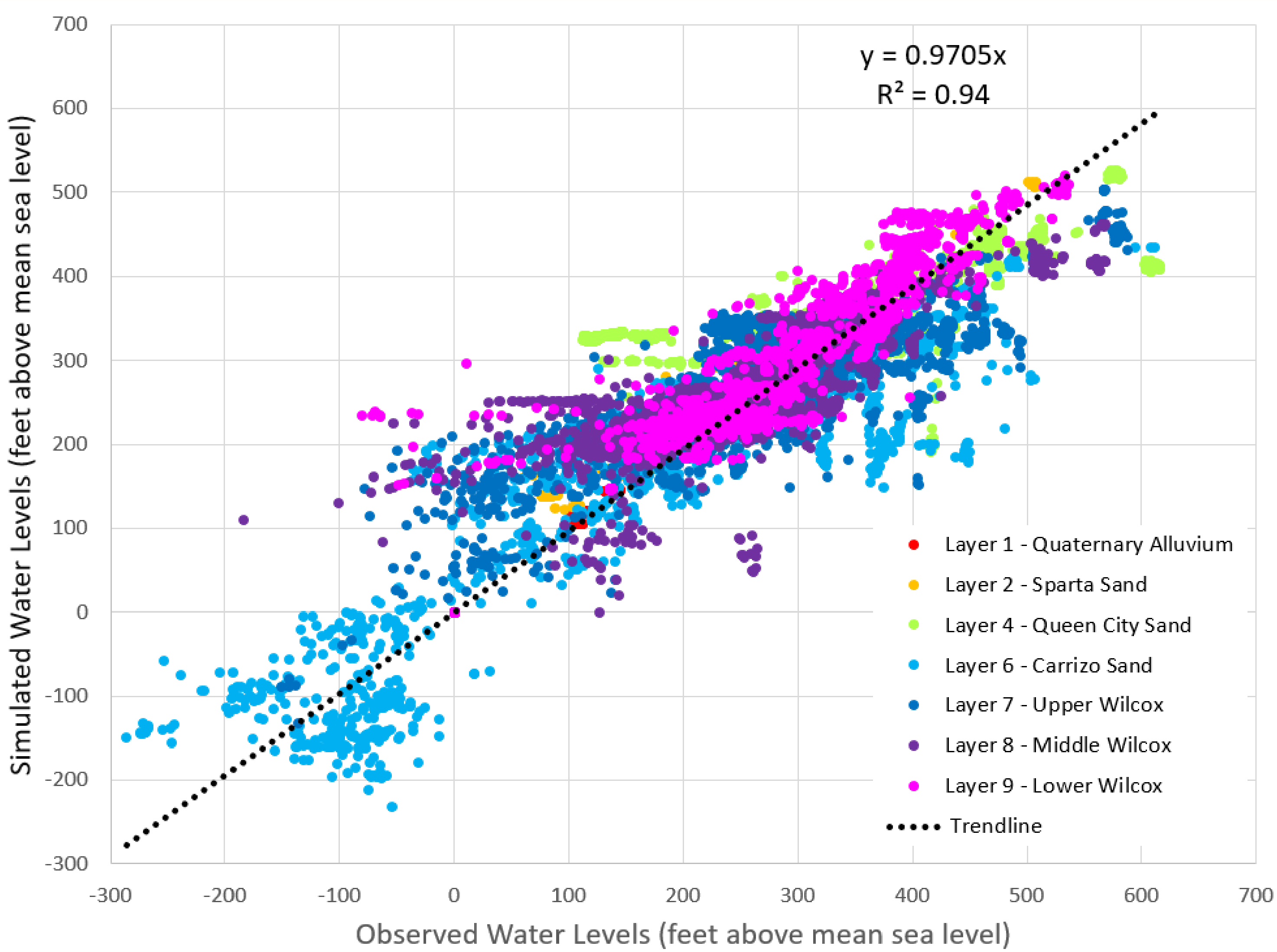


GSI ENVIRONMENTAL

GSI Job No.	4529	Drawn By:	GM
Issued:	1-Jul-2020	Chk'd By:	
Revised:		Aprv'd By:	DRAFT
Scale:			Figure 3.2-10

Observed vs. Simulated Unconfined Water Levels for Calibrated 1980 and 2013 Conditions

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

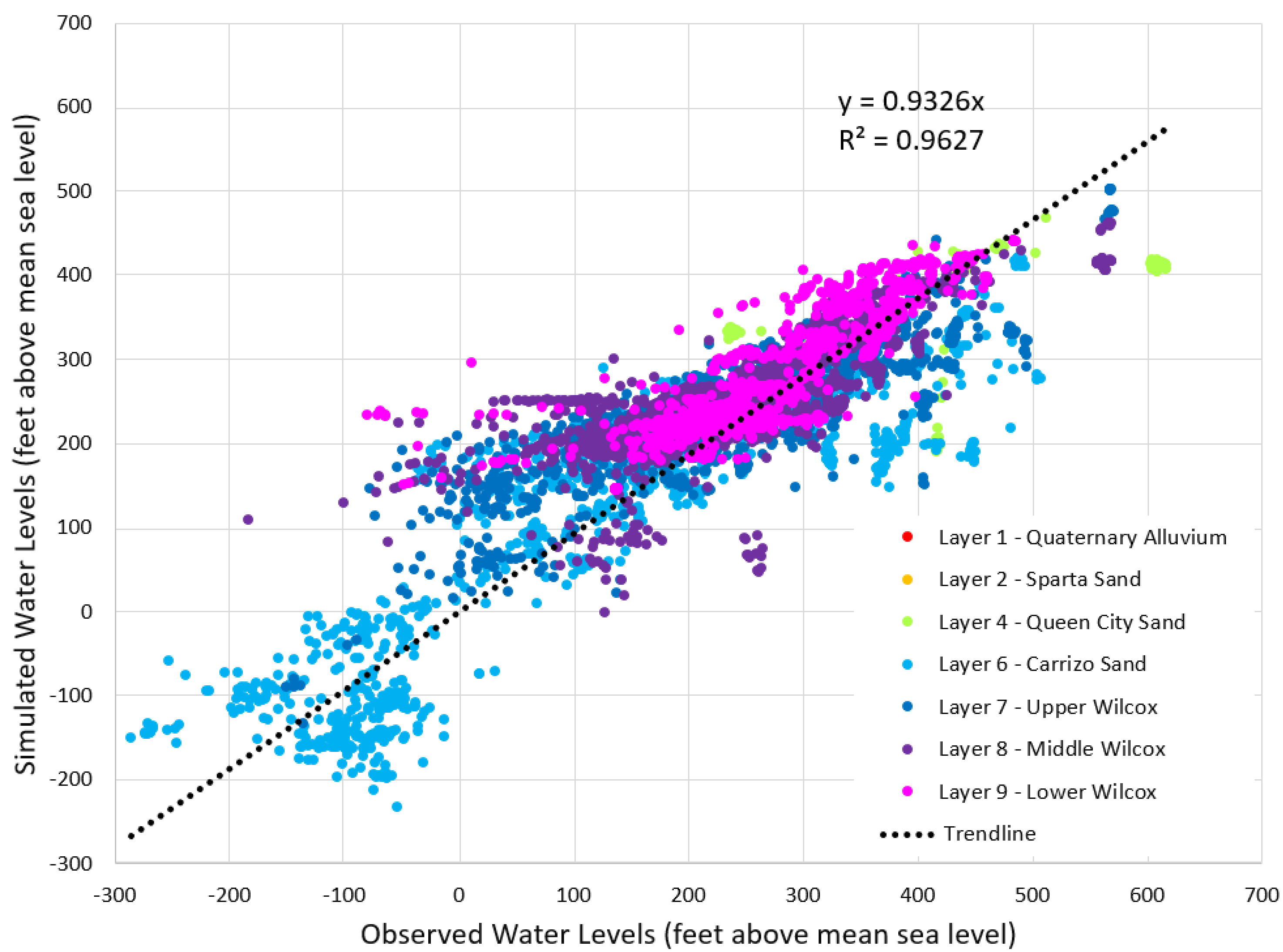


GSI ENVIRONMENTAL

GSI Job No. 4529	Drawn By: BC		
Issued: 1-Jul-2020	Chk'd By:		
Revised:	Aprv'd By: DRAFT		
Scale:	Figure 3.2-11		

Observed vs. Simulated Water Levels for Calibrated 1980-2013 Simulation

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

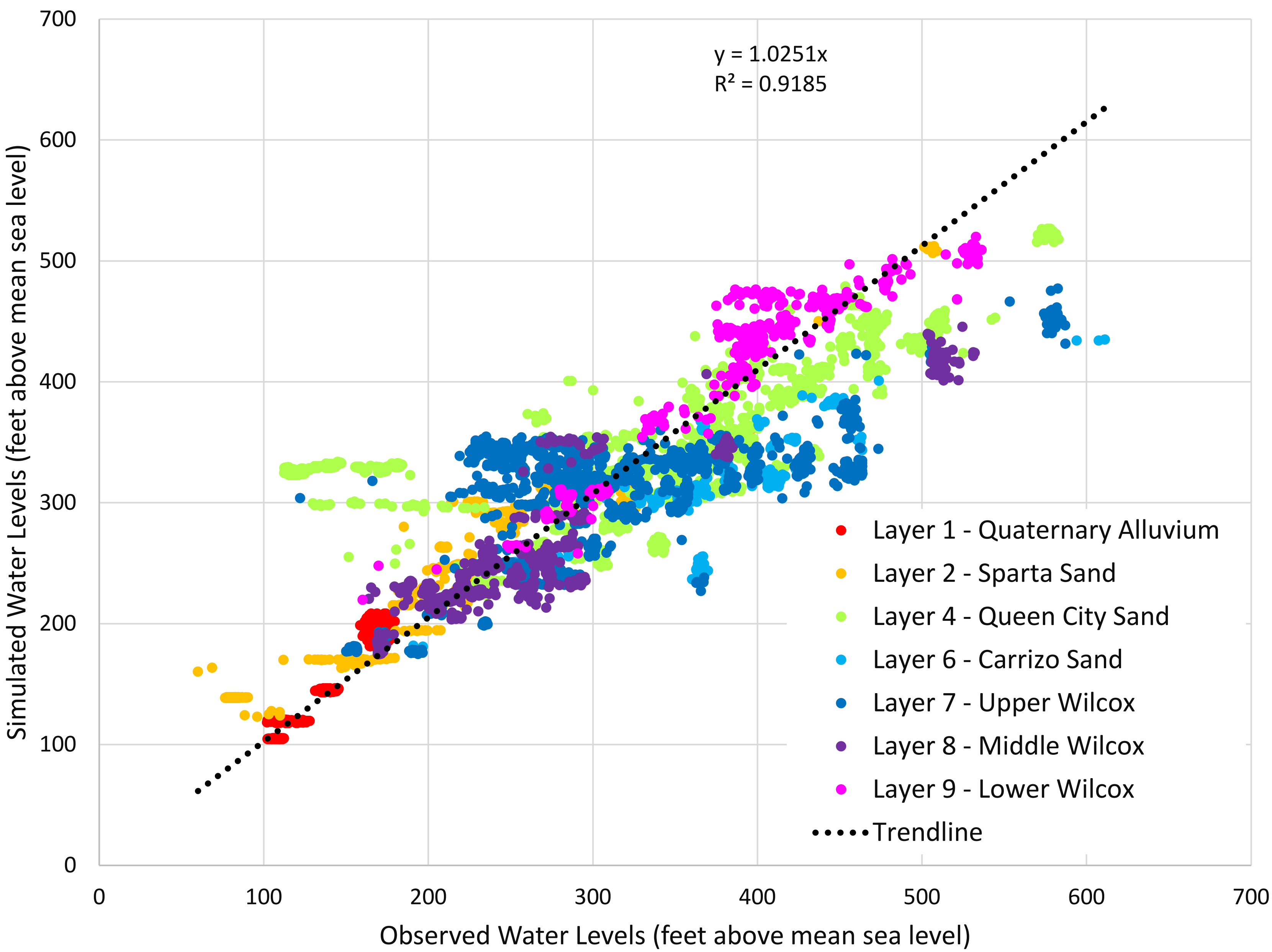


GSI ENVIRONMENTAL

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By:
Revised:	Aprv'd By: DRAFT
Scale:	Figure 3.2-12

Observed vs. Simulated Confined Water Levels for Calibrated 1980-2013 Simulation

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

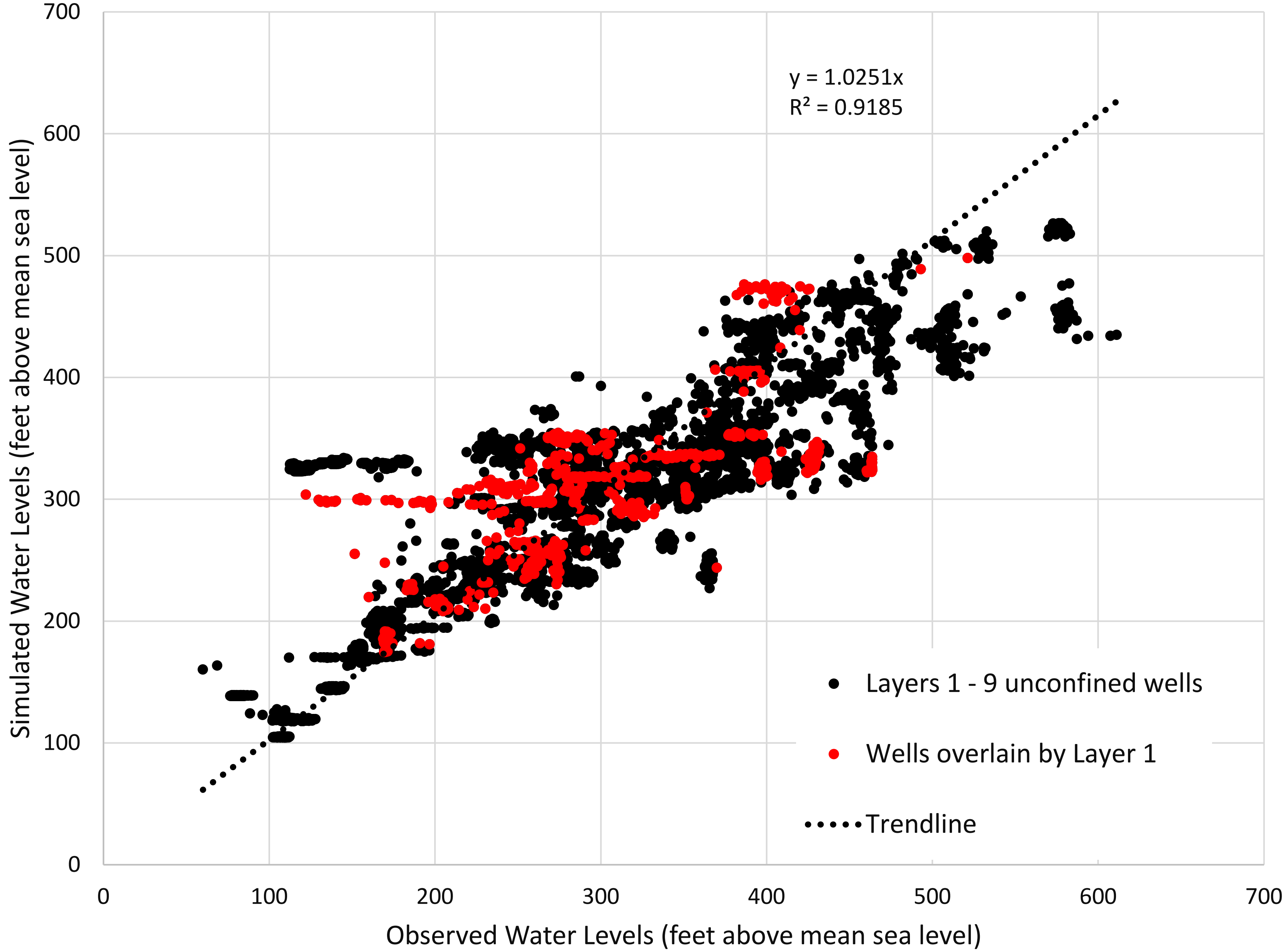


GSI ENVIRONMENTAL

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By:
Revised:	Aprv'd By: DRAFT
Scale:	Figure 3.2-13

Observed vs. Simulated Unconfined Water Levels for Calibrated 1980-2013 Simulation

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

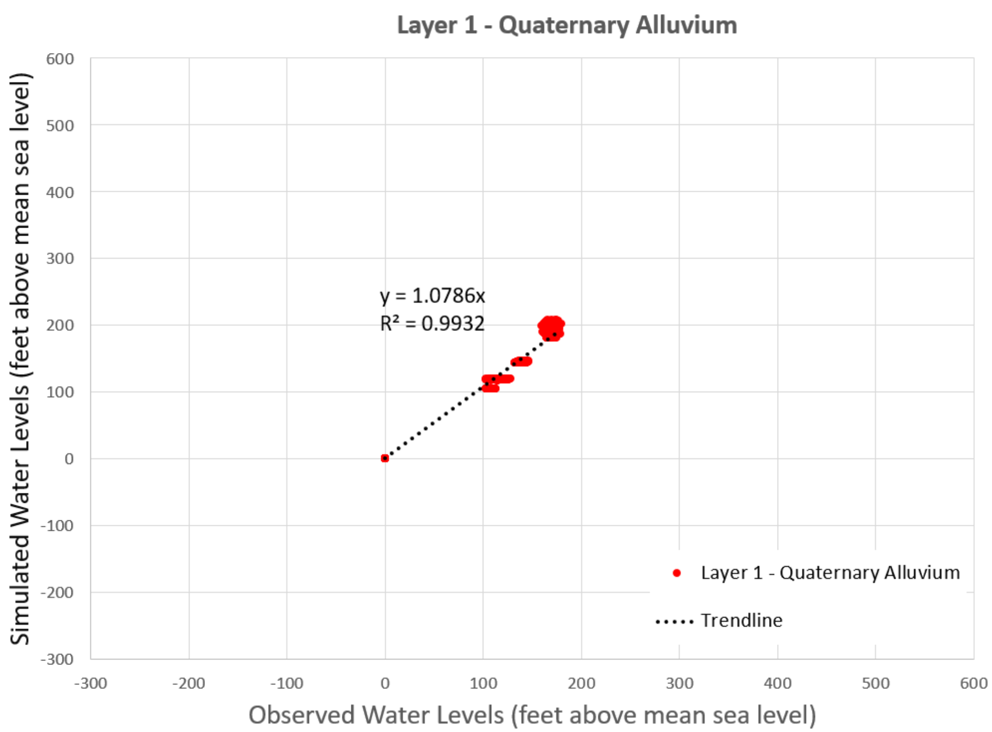


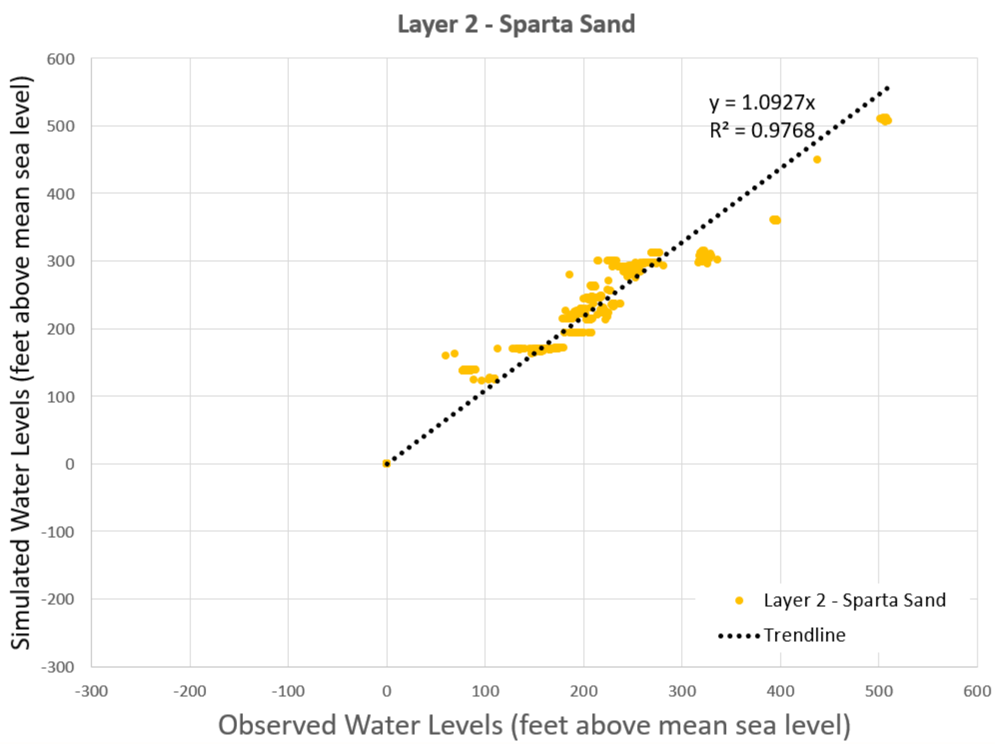
GSI ENVIRONMENTAL

GSI Job No.	4529	Drawn By:	GM
Issued:	1-Jul-2020	Chk'd By:	
Revised:		Aprv'd By:	DRAFT
Scale:			Figure 3.2-14

Observed vs. Simulated Unconfined Water Levels for Calibrated 1980-2013 Simulation showing Wells Overlain by Layer 1

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers



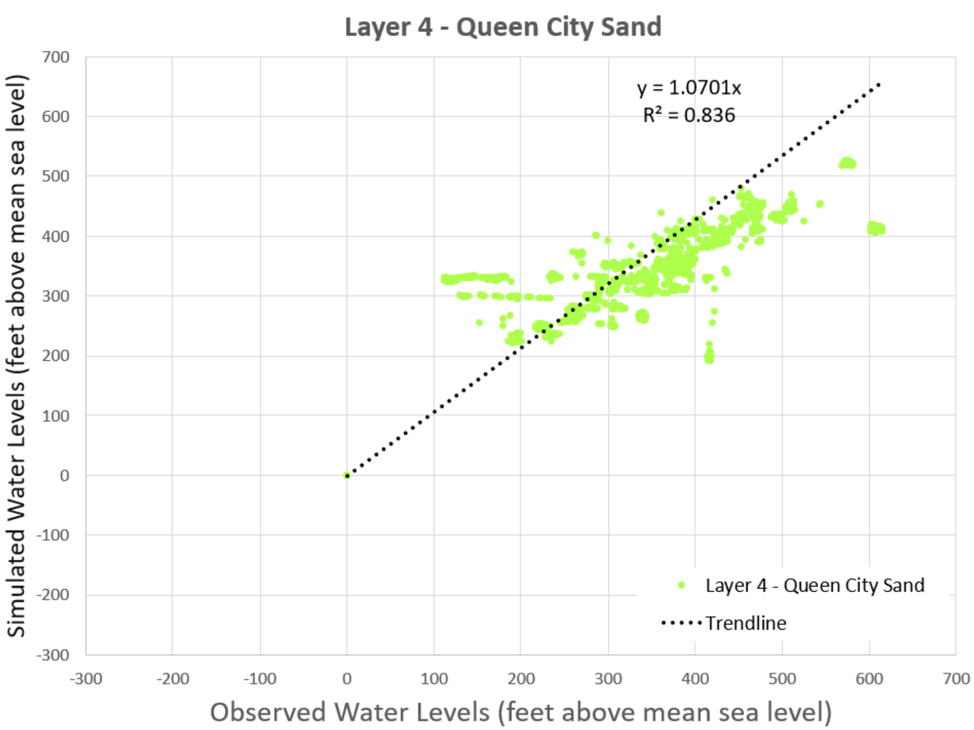


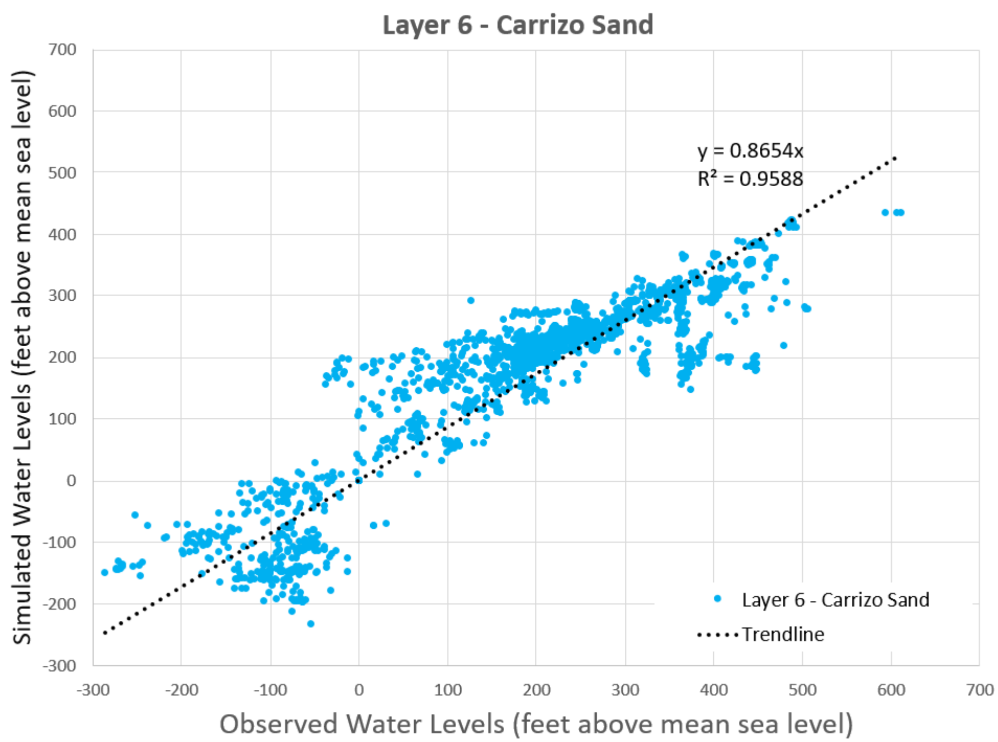
GSI ENVIRONMENTAL

GSI Job No.	4529	Drawn By:	BC
Issued:	1-Jul-2020	Chk'd By:	
Revised:		Aprv'd By:	DRAFT
Scale:			Figure 3.2-15a

Observed vs. Simulated Water Levels for Calibrated 1980-2013 Simulation by Layer

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers



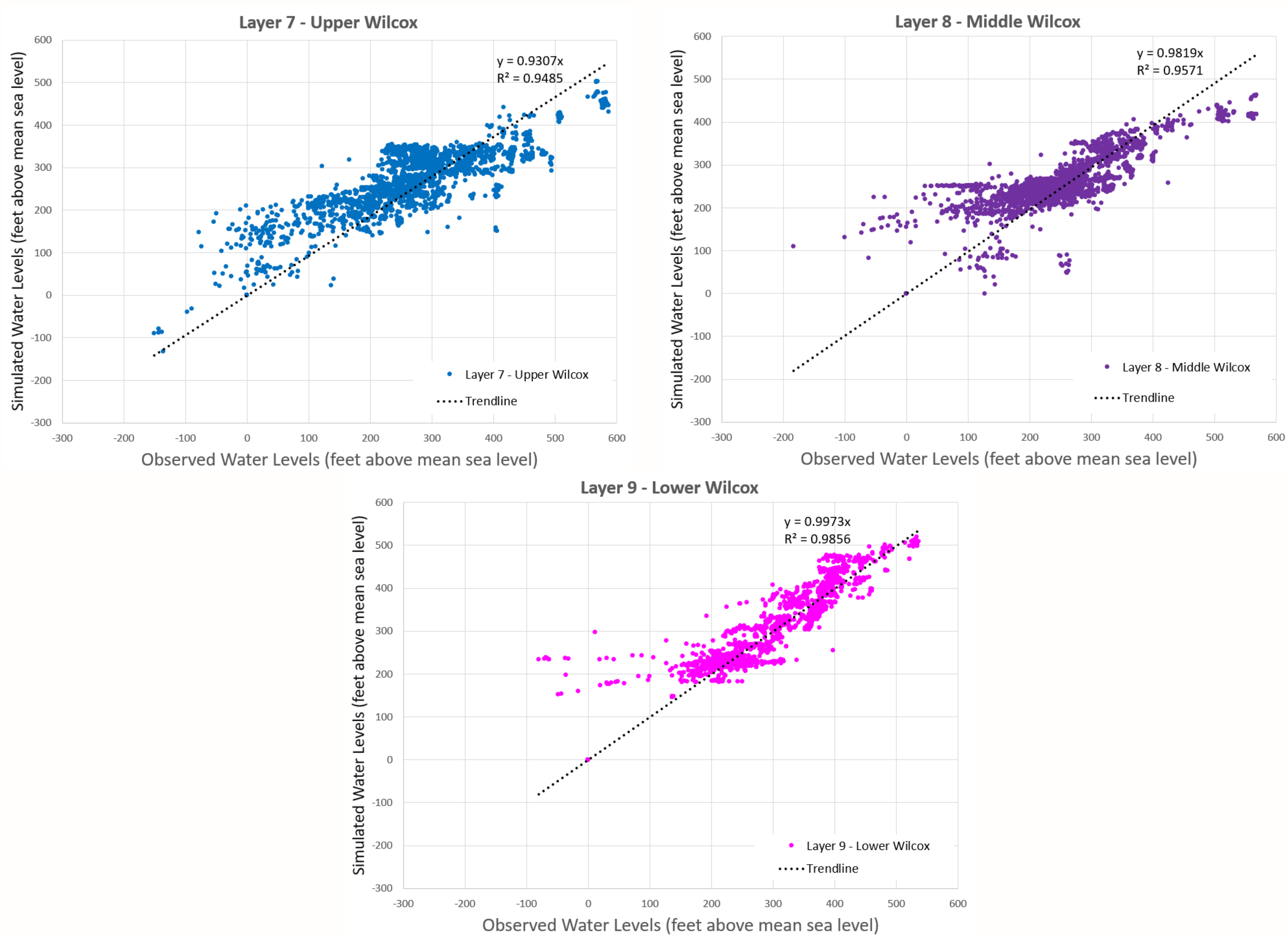


GSI ENVIRONMENTAL

GSI Job No.	4529	Drawn By:	BC
Issued:	1-Jul-2020	Chk'd By:	
Revised:		Aprv'd By:	DRAFT
Scale:			Figure 3.2-15b

Observed vs. Simulated Water Levels for Calibrated 1980-2013 Simulation by Layer

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

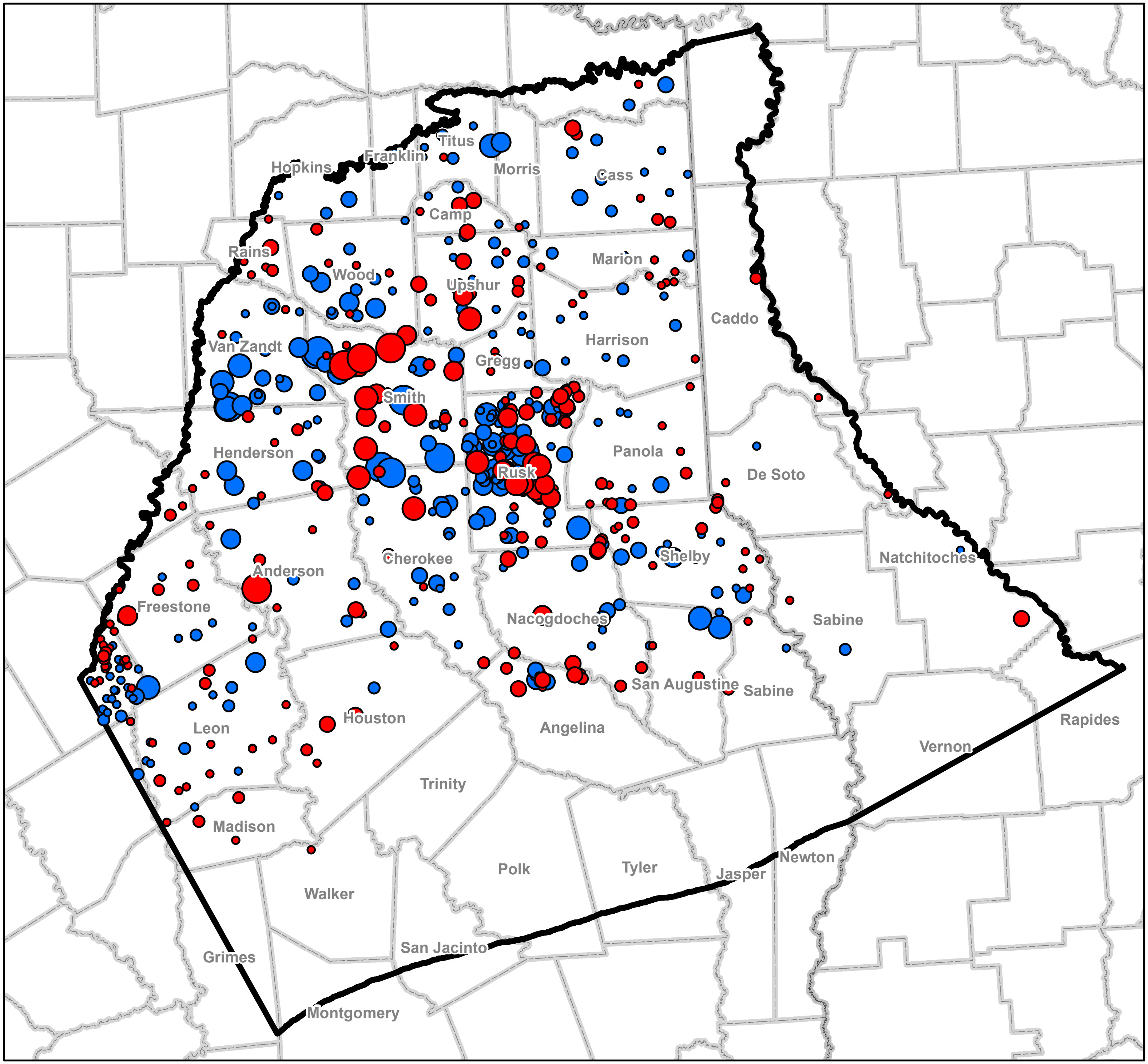


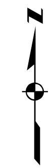
GSI ENVIRONMENTAL

GSI Job No.	4529	Drawn By:	BC
Issued:	1-Jul-2020	Chk'd By:	
Revised:		Aprv'd By:	DRAFT
Scale:			Figure 3.2-15c

Observed vs. Simulated Water Levels for Calibrated 1980-2013 Simulation by Layer

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers





LEGEND

- Model Boundary
- County or Parish Boundary

Average Residual Head from 1980 - 2013 at Targets with a Weight of 1 (feet)

- -249 - -150
- -149 - -100
- -99 - -75
- -74 - -50
- -49 - -25
- -24 - 0
- 1 - 25
- 26 - 50
- 51 - 75
- 76 - 100
- 101 - 150
- 151 - 257

Notes:

1. Residuals shown have a weight of 1. 541 of 1,797 targets shown.
2. Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

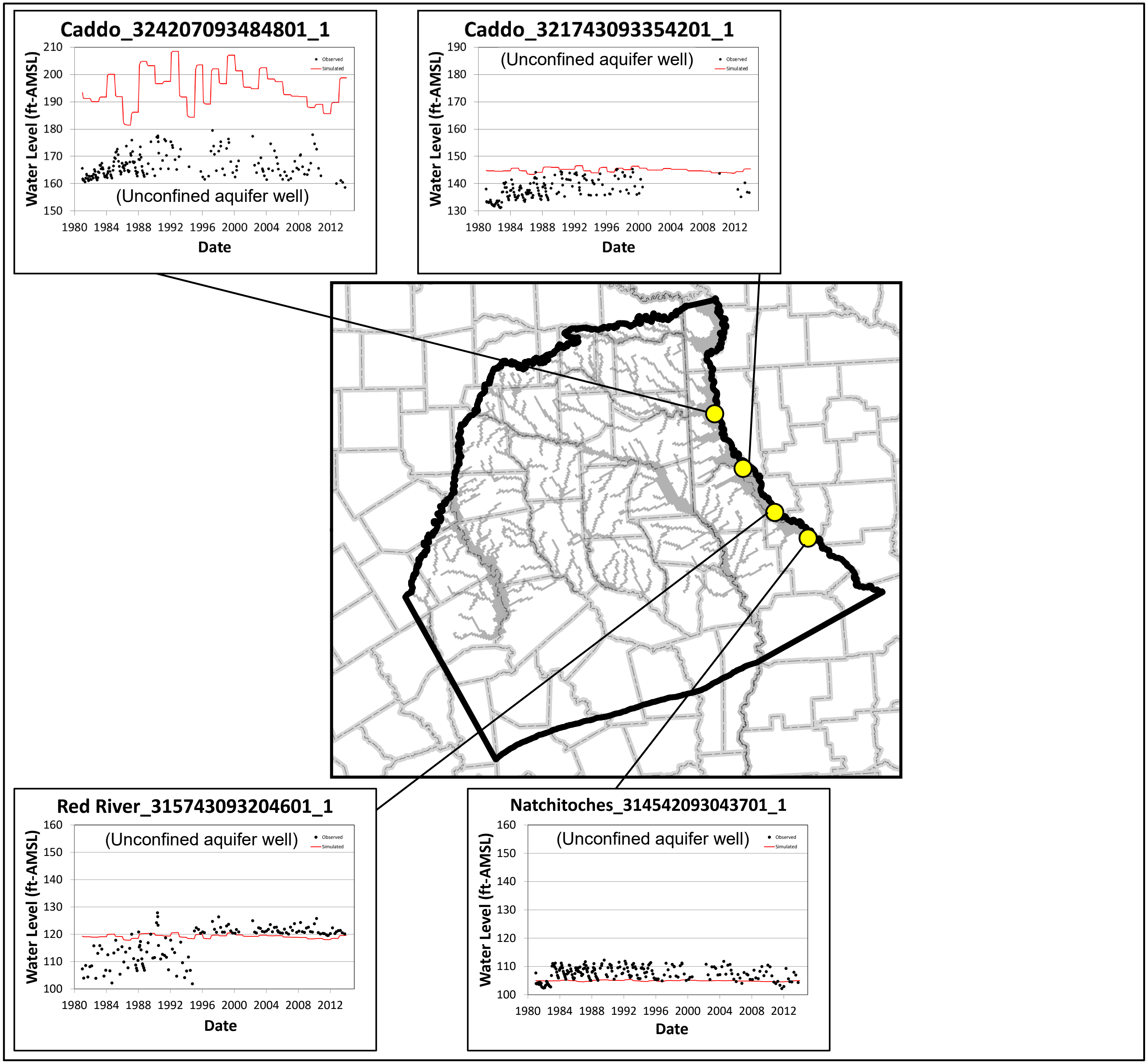
GSI ENVIRONMENTAL

DISTRIBUTION OF WATER LEVEL ERRORS FOR CALIBRATED 1980-2013 SIMULATION

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_16	Appv'd By: DRAFT

FIGURE 3.2-16



N

LEGEND

- Model Boundary
- County or Parish Boundary
- Layer 1
- Layer 1 Wells

Chart Name

County, Well Name, Model Layer, Aquifer Type

Chart Legend

- Observed Water Level
- Simulated Water Level

Chart Outline Color for Y-Axis Range

- Y-Axis = 200 feet
- Y-Axis = 60 feet

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 25 50

Projected Coordinate System Datum: GAM

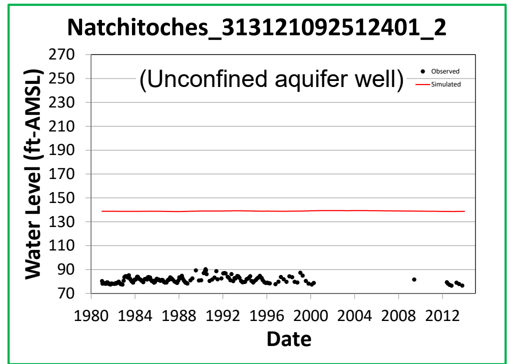
GSI ENVIRONMENTAL

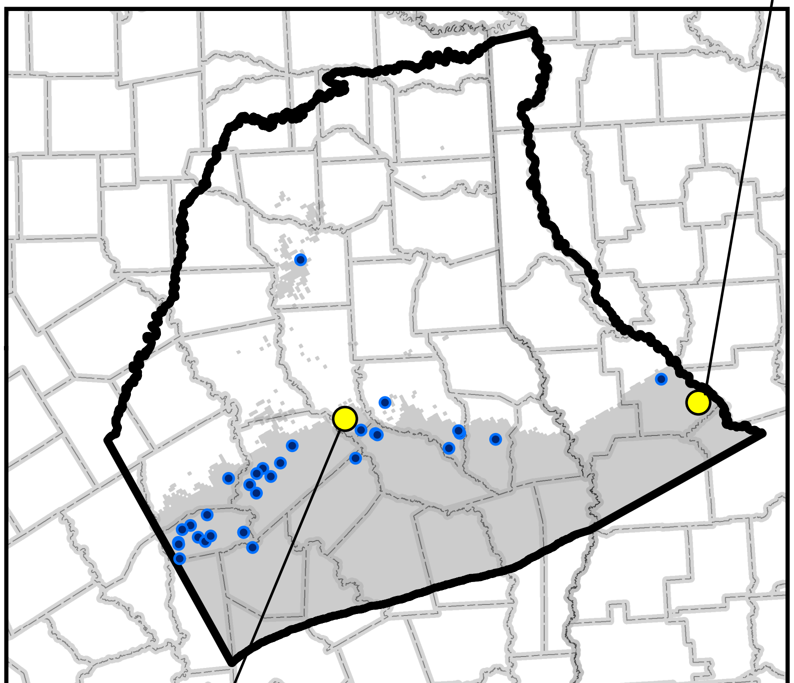
MEASURED AND SIMULATED WATER LEVEL HYDROGRAPHS FOR SELECT WELLS QUATERNARY ALLUVIUM (LAYER 1)

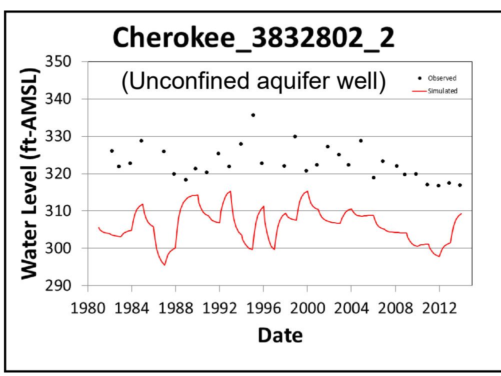
Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_17	Appv'd By: DRAFT

FIGURE 3.2-17







N

LEGEND

- Model Boundary
- County or Parish Boundary
- Layer 2
- Select Layer 2 Wells
- Layer 2 Wells

Chart Name

County, Well Name, Model Layer, Aquifer Type

Chart Legend

- Observed Water Level
- Simulated Water Level

Chart Outline Color for Y-Axis Range

- Y-Axis = 200 feet
- Y-Axis = 60 feet

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 25 50

Projected Coordinate System Datum: GAM

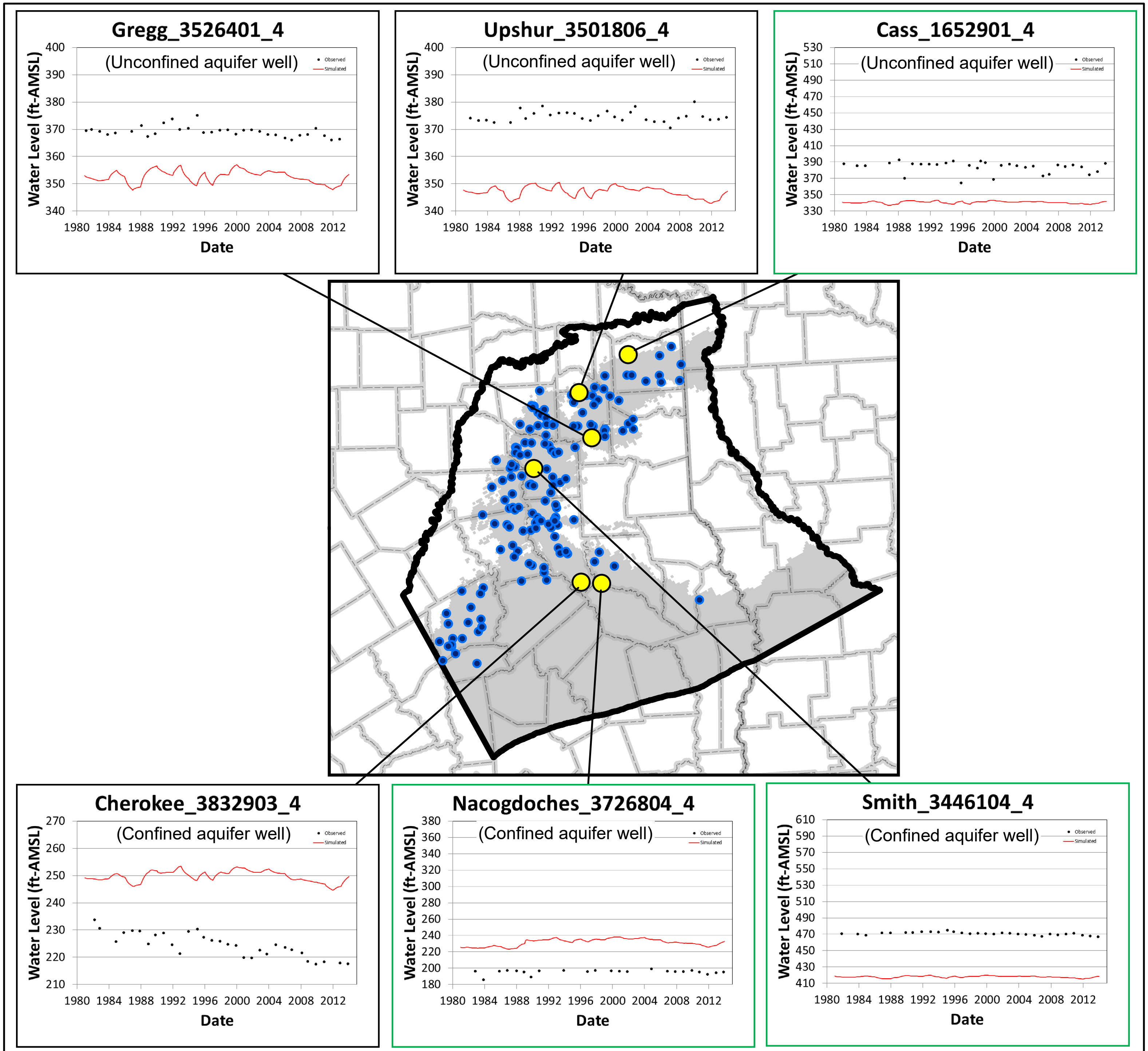
GSI ENVIRONMENTAL

MEASURED AND SIMULATED WATER LEVEL HYDROGRAPHS FOR SELECT WELLS SPARTA SAND (LAYER 2)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_18	Appv'd By: DRAFT

FIGURE 3.2-18



N

LEGEND

Model Boundary
County or Parish Boundary
Layer 4
Select Layer 4 Wells
Layer 4 Wells

Chart Name
County, Well Name, Model Layer, Aquifer type

Chart Legend
Observed Water Level
Simulated Water Level

Chart Outline Color for Y-Axis Range
Y-Axis = 200 feet
Y-Axis = 60 feet

Note:
Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 25 50

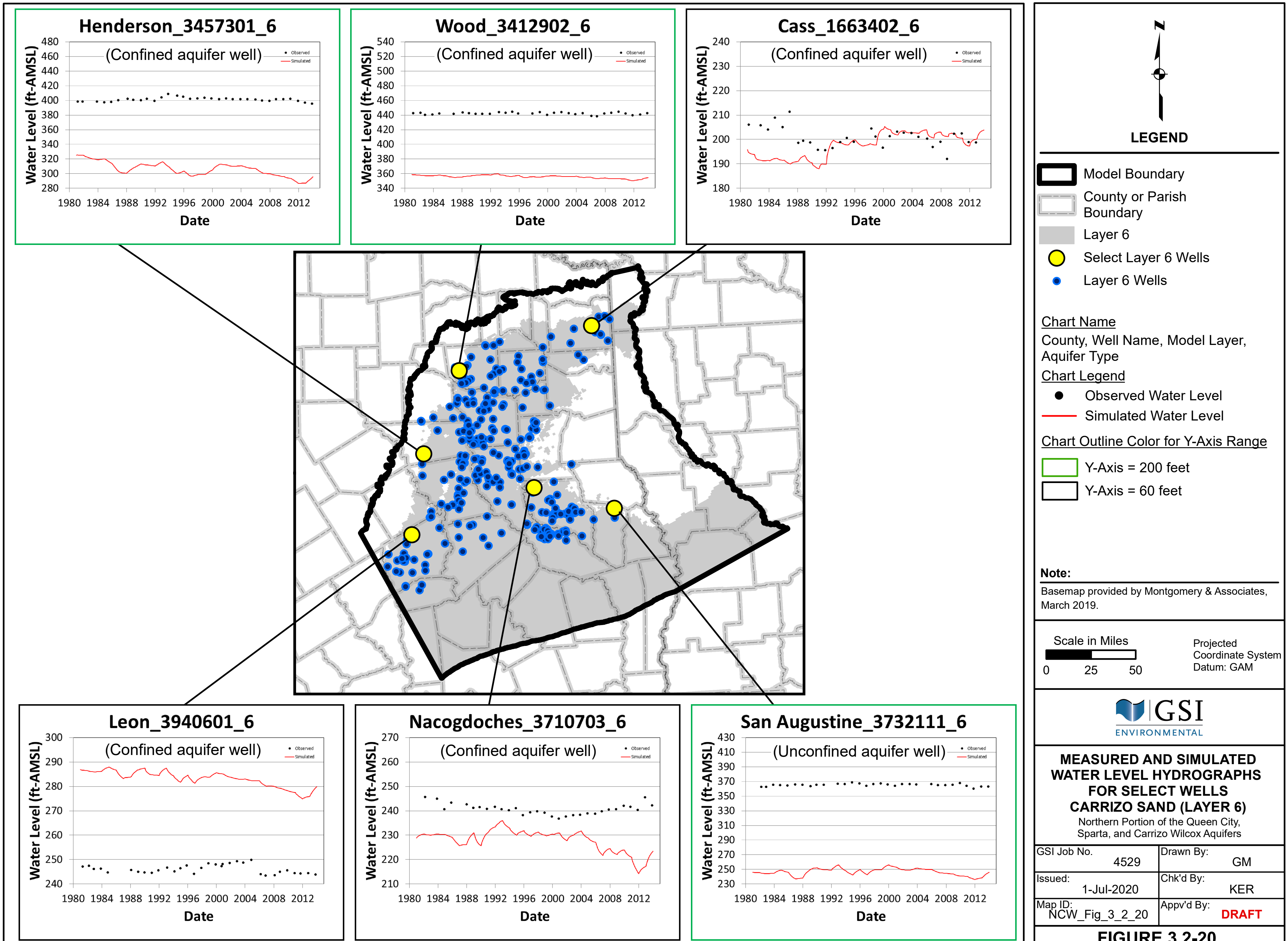
Projected Coordinate System
Datum: GAM

GSI ENVIRONMENTAL

MEASURED AND SIMULATED WATER LEVEL HYDROGRAPHS FOR SELECT WELLS QUEEN CITY SAND (LAYER 4)
Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_19	Appv'd By: DRAFT

FIGURE 3.2-19



Note:
Basemap provided by Montgomery & Associates, March 2019.

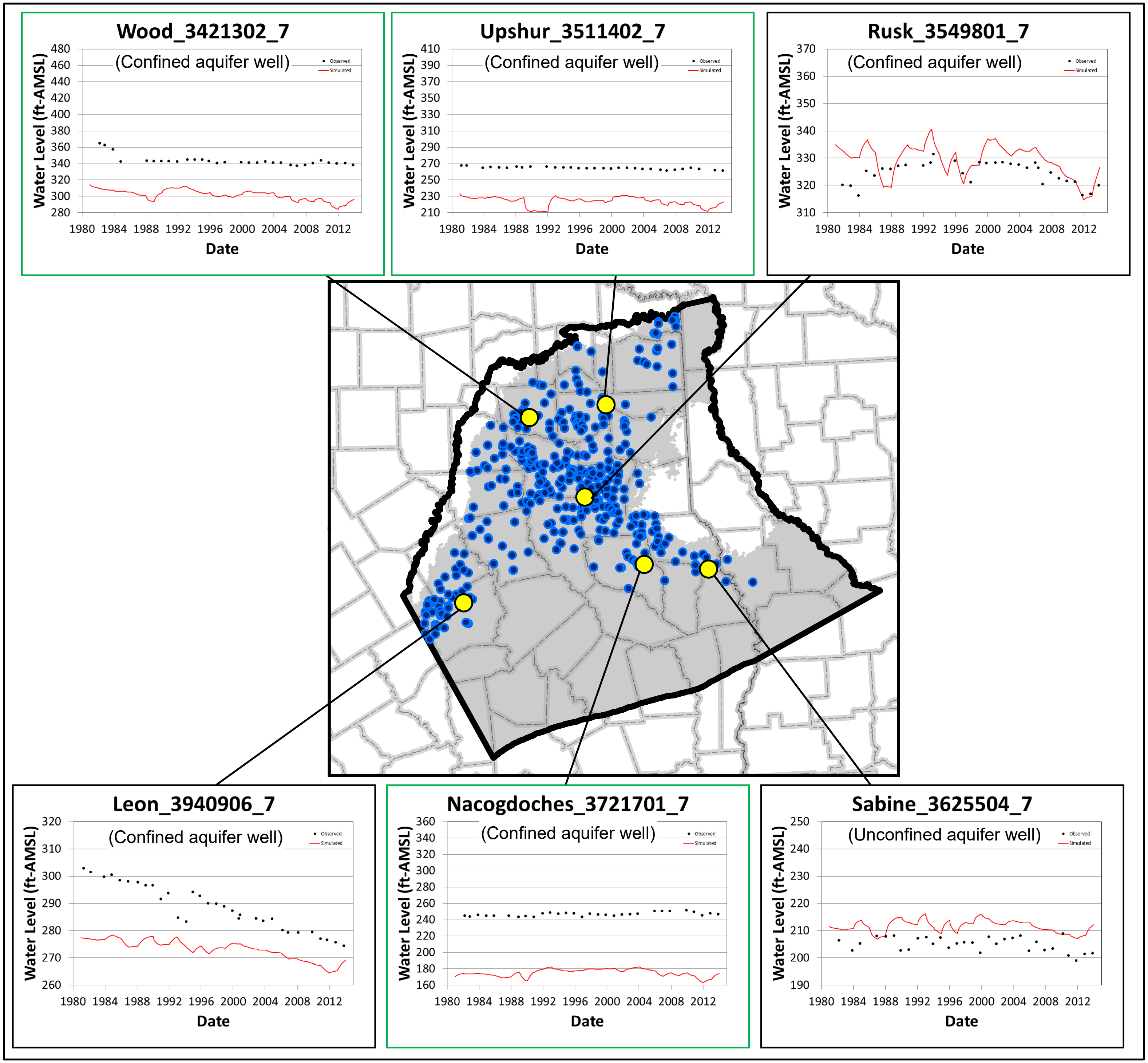
GSI ENVIRONMENTAL

MEASURED AND SIMULATED WATER LEVEL HYDROGRAPHS FOR SELECT WELLS CARRIZO SAND (LAYER 6)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_20	Appv'd By: DRAFT

FIGURE 3.2-20



LEGEND

- Model Boundary
- County or Parish Boundary
- Layer 7
- Select Layer 7 Wells
- Layer 7 Wells

Chart Name

County, Well Name, Model Layer, Aquifer Type

Chart Legend

- Observed Water Level
- Simulated Water Level

Chart Outline Color for Y-Axis Range

- Y-Axis = 200 feet
- Y-Axis = 60 feet

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 25 50

Projected Coordinate System
Datum: GAM

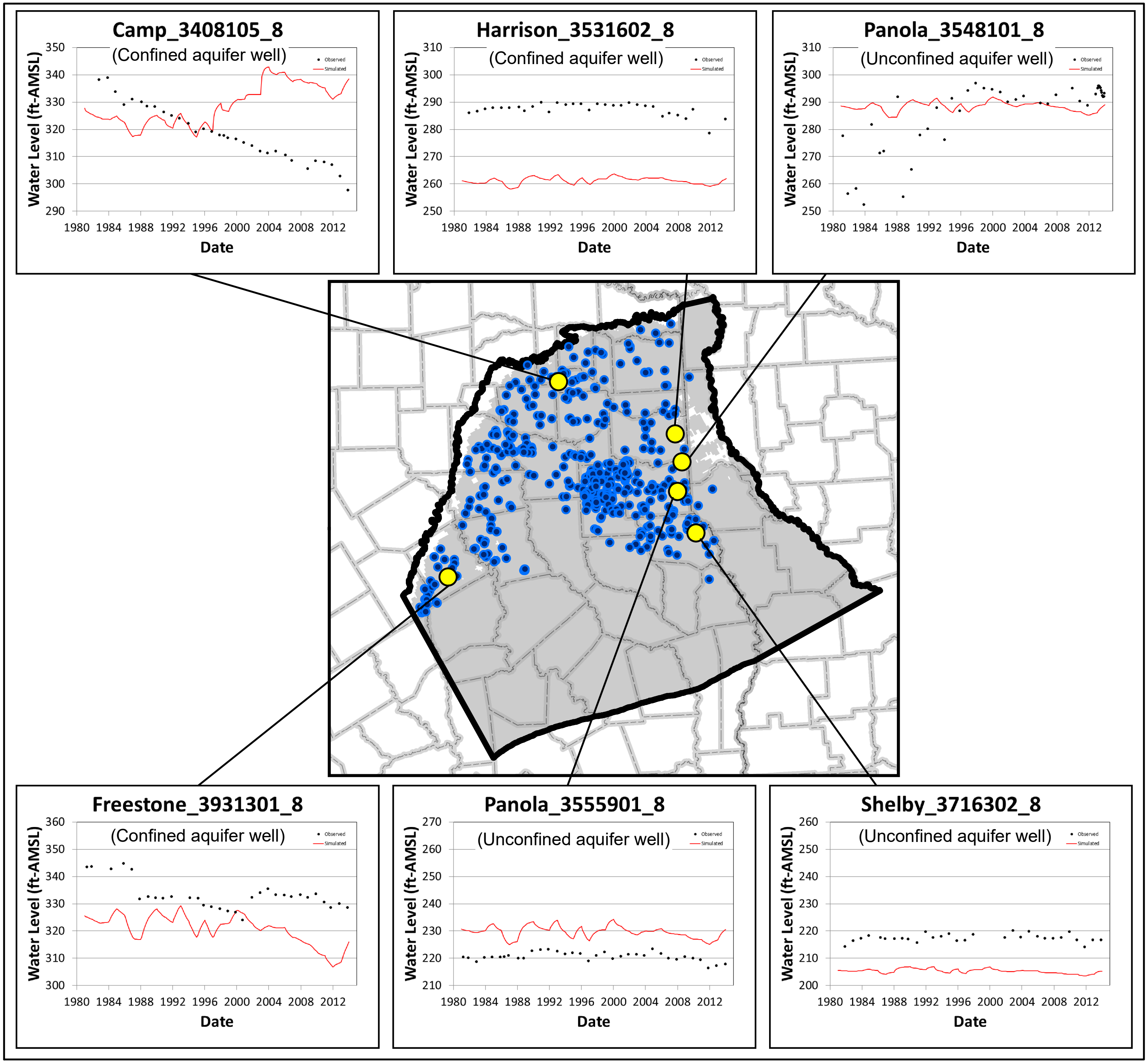
GSI ENVIRONMENTAL

MEASURED AND SIMULATED WATER LEVEL HYDROGRAPHS FOR SELECT WELLS UPPER WILCOX (LAYER 7)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_21	Appv'd By: DRAFT

FIGURE 3.2-21



LEGEND

Model Boundary
County or Parish Boundary
Layer 8
Select Layer 8 Wells
Layer 8 Wells

Chart Name
County, Well Name, Model Layer, Aquifer Type

Chart Legend
Observed Water Level
Simulated Water Level

Chart Outline Color for Y-Axis Range
Y-Axis = 200 feet
Y-Axis = 60 feet

Note:
Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 25 50

Projected Coordinate System
Datum: GAM

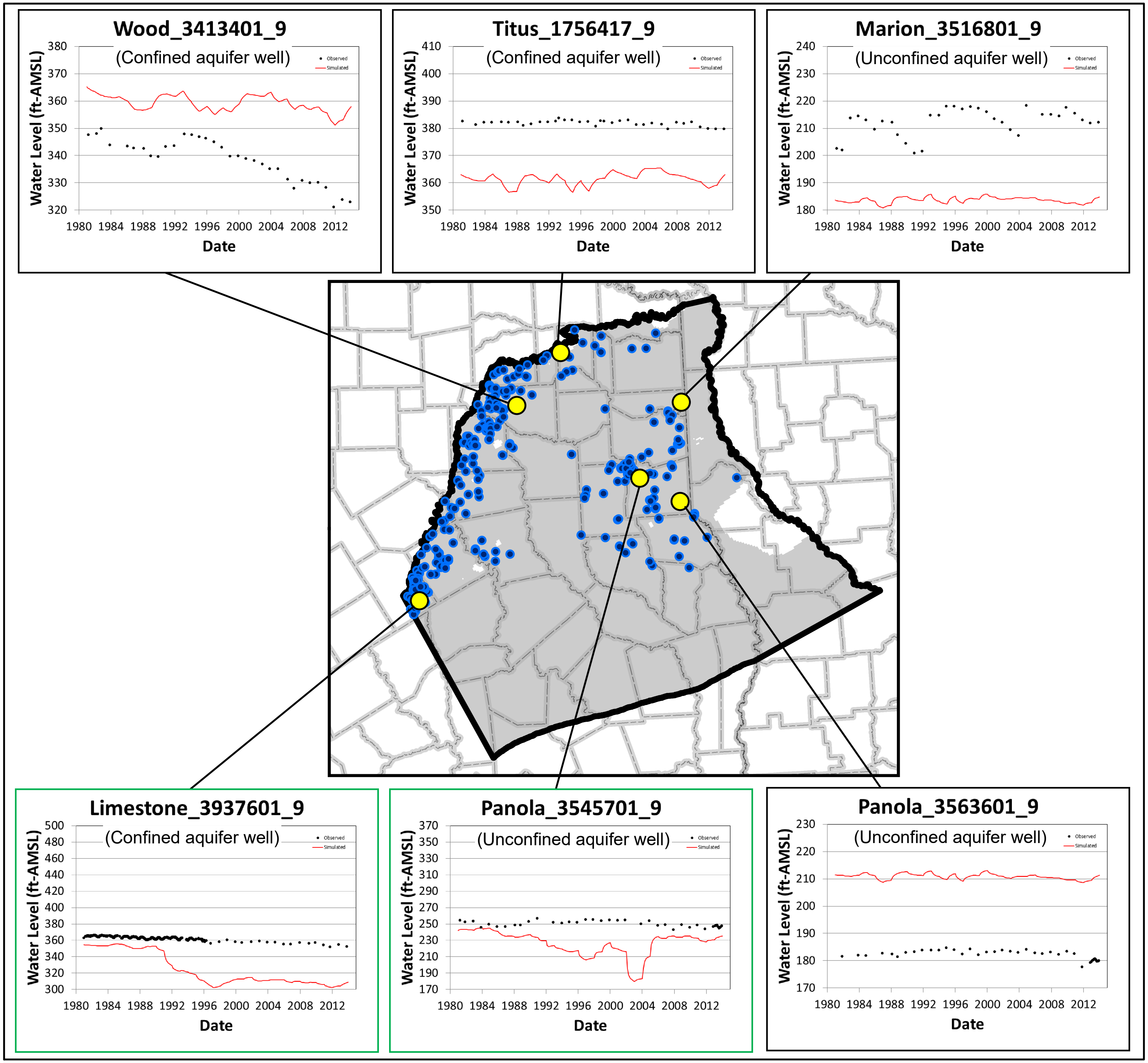
GSI ENVIRONMENTAL

MEASURED AND SIMULATED WATER LEVEL HYDROGRAPHS FOR SELECT WELLS MIDDLE WILCOX (LAYER 8)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_22	Appv'd By: DRAFT

FIGURE 3.2-22



LEGEND

Model Boundary

County or Parish Boundary

Layer 9

Select Layer 9 Wells

Layer 9 Wells

Chart Name

County, Well Name, Model Layer, Aquifer Type

Chart Legend

Observed Water Level

Simulated Water Level

Chart Outline Color for Y-Axis Range

Y-Axis = 200 feet

Y-Axis = 60 feet

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 25 50

Projected Coordinate System
Datum: GAM

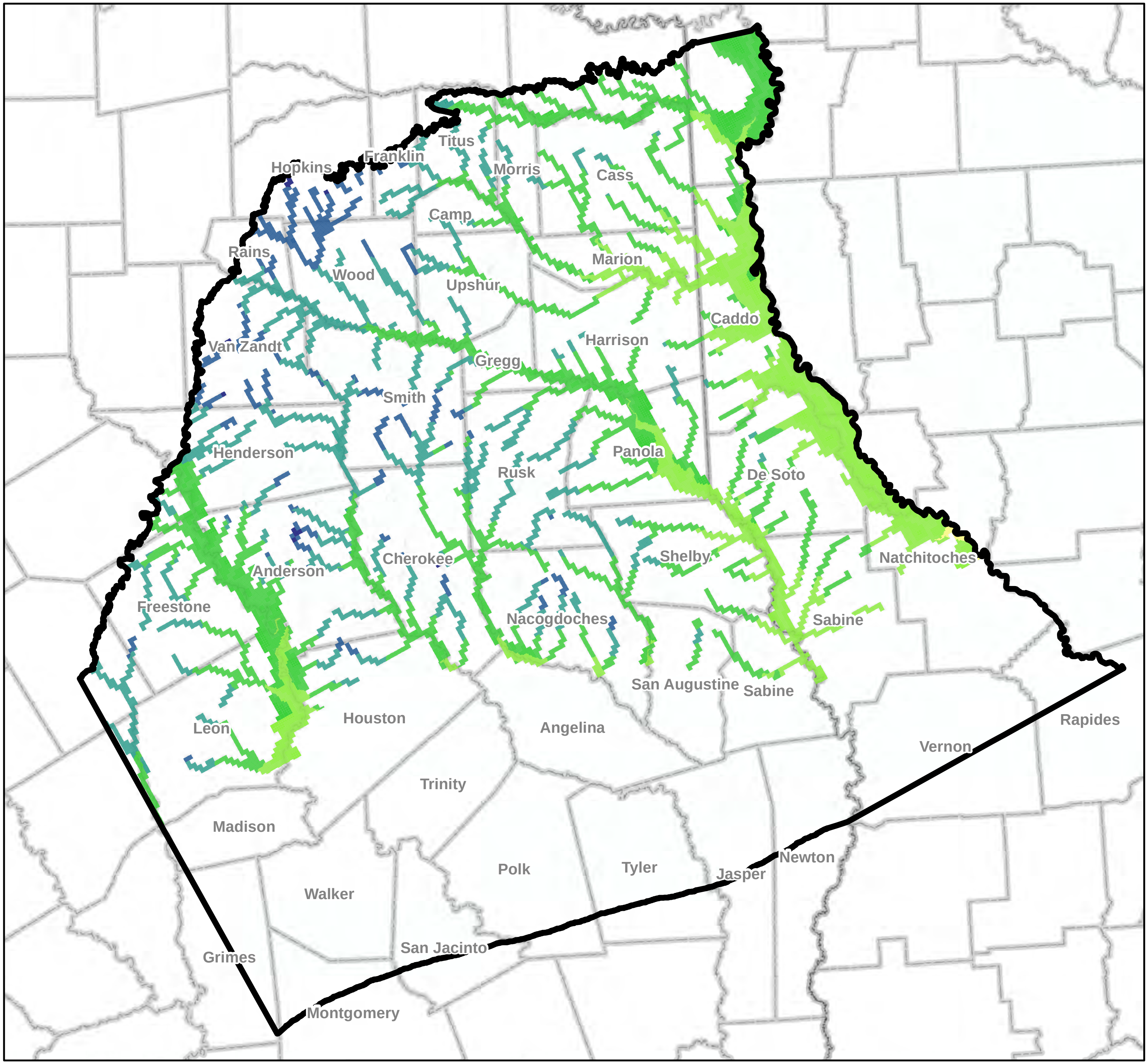
GSI ENVIRONMENTAL

MEASURED AND SIMULATED WATER LEVEL HYDROGRAPHS FOR SELECT WELLS LOWER WILCOX (LAYER 9)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_23	Appv'd By: DRAFT

FIGURE 3.2-23



N

LEGEND

Model Boundary

County or Parish Boundary

Simulated Water Level Elevations (feet above mean sea level)

- 85 - 100
- 100 - 200
- 200 - 300
- 300 - 400
- 400 - 500
- 500 - 536

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

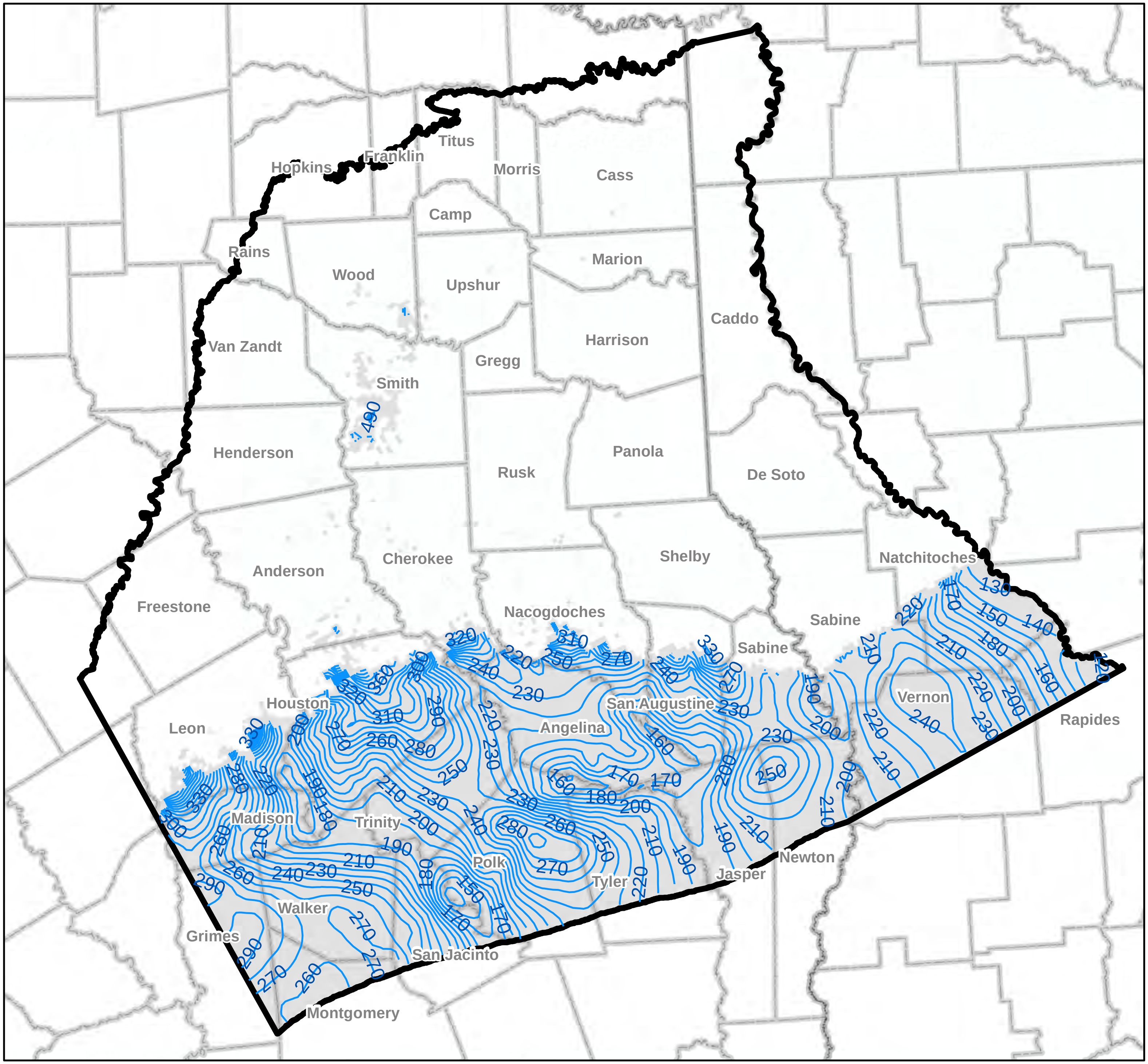
GSI ENVIRONMENTAL

SIMULATED WATER LEVEL ELEVATIONS IN QUATERNARY ALLUVIUM (LAYER 1) FOR 2013

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_24	Appv'd By: DRAFT

FIGURE 3.2-24



Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

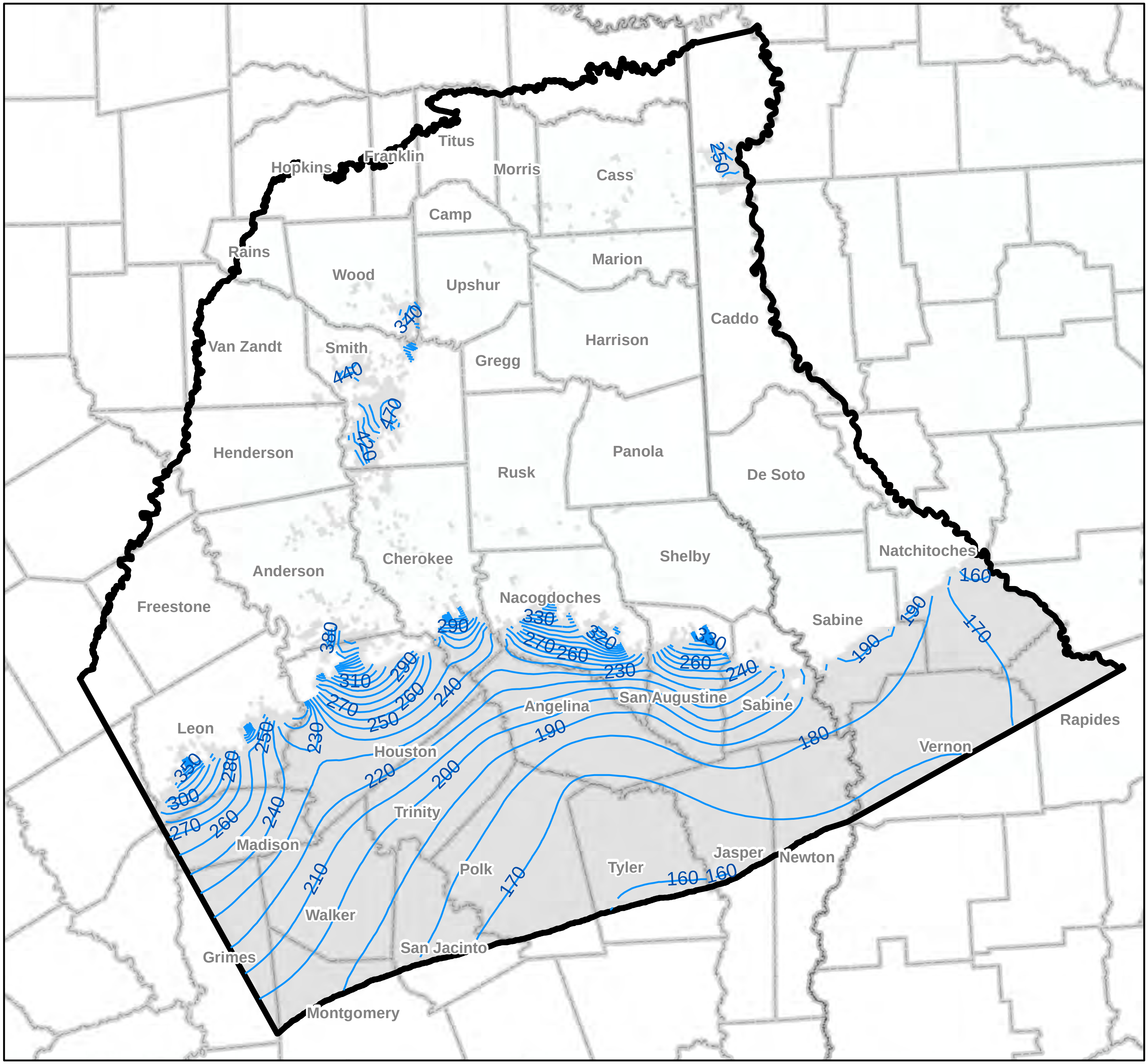
GSI ENVIRONMENTAL

SIMULATED WATER LEVEL ELEVATION CONTOURS IN SPARTA SAND (LAYER 2) FOR 2013

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_25	Appv'd By: DRAFT

FIGURE 3.2-25



N

LEGEND

Simulated Water Level Elevations Contours (feet above mean sea level)

Model Boundary

County or Parish Boundary

Layer Extent

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

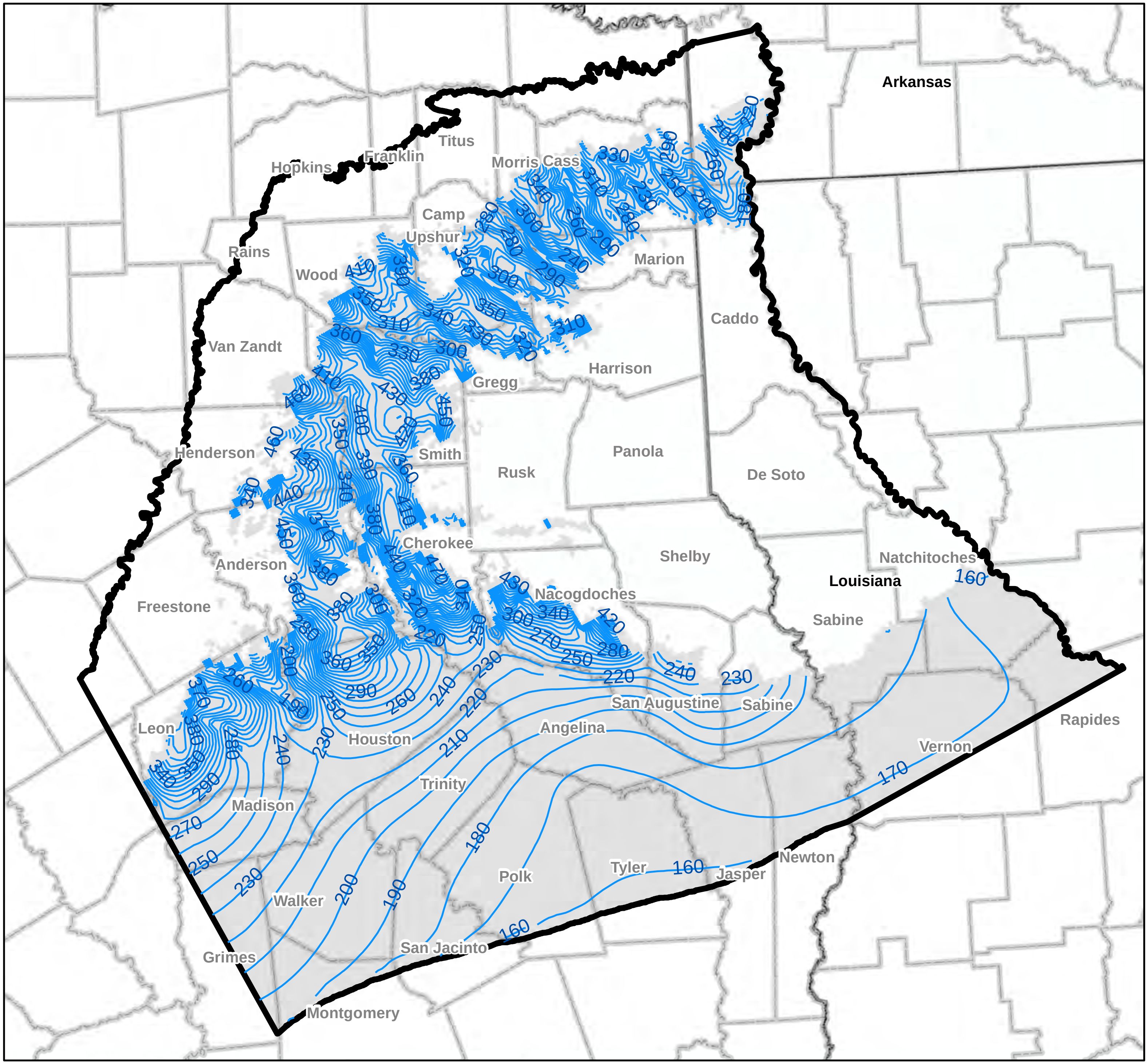
GSI ENVIRONMENTAL

SIMULATED WATER LEVEL ELEVATIONS CONTOURS IN WECHES FORMATION (LAYER 3) FOR 2013

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_26	Appv'd By: DRAFT

FIGURE 3.2-26



N

LEGEND

- Simulated Water Level Elevations Contours (feet above mean sea level)
- Model Boundary
- County or Parish Boundary
- Layer Extent

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

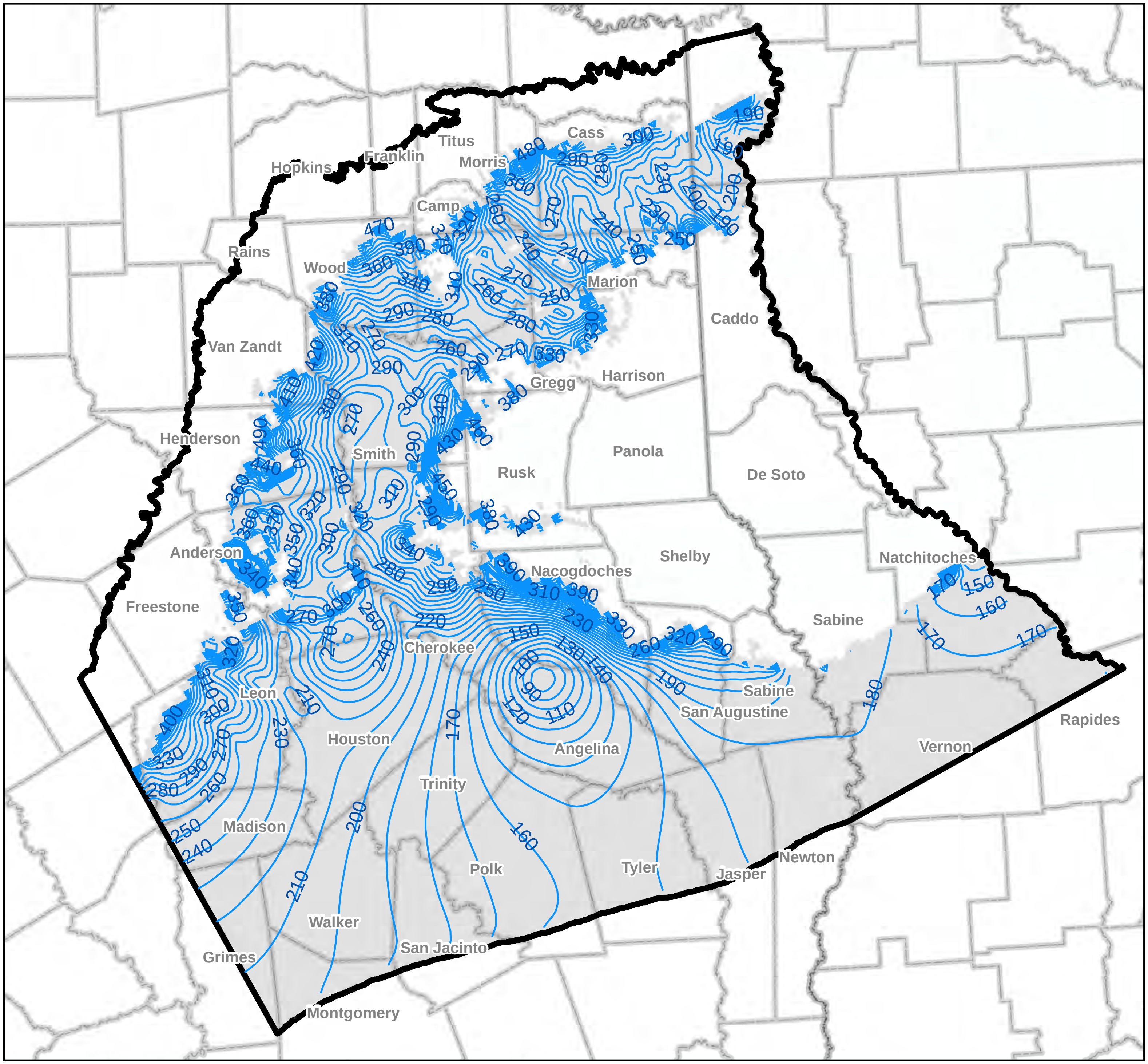
GSI ENVIRONMENTAL

SIMULATED WATER LEVEL ELEVATIONS CONTOURS IN QUEEN CITY SAND (LAYER 4) FOR 2013

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_27	Appv'd By: DRAFT

FIGURE 3.2-27



LEGEND

- Simulated Water Elevations Level Contours (feet above mean sea level)
- Model Boundary
- County or Parish Boundary
- Layer Extent

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles: 0, 16, 32

Projected Coordinate System Datum: GAM

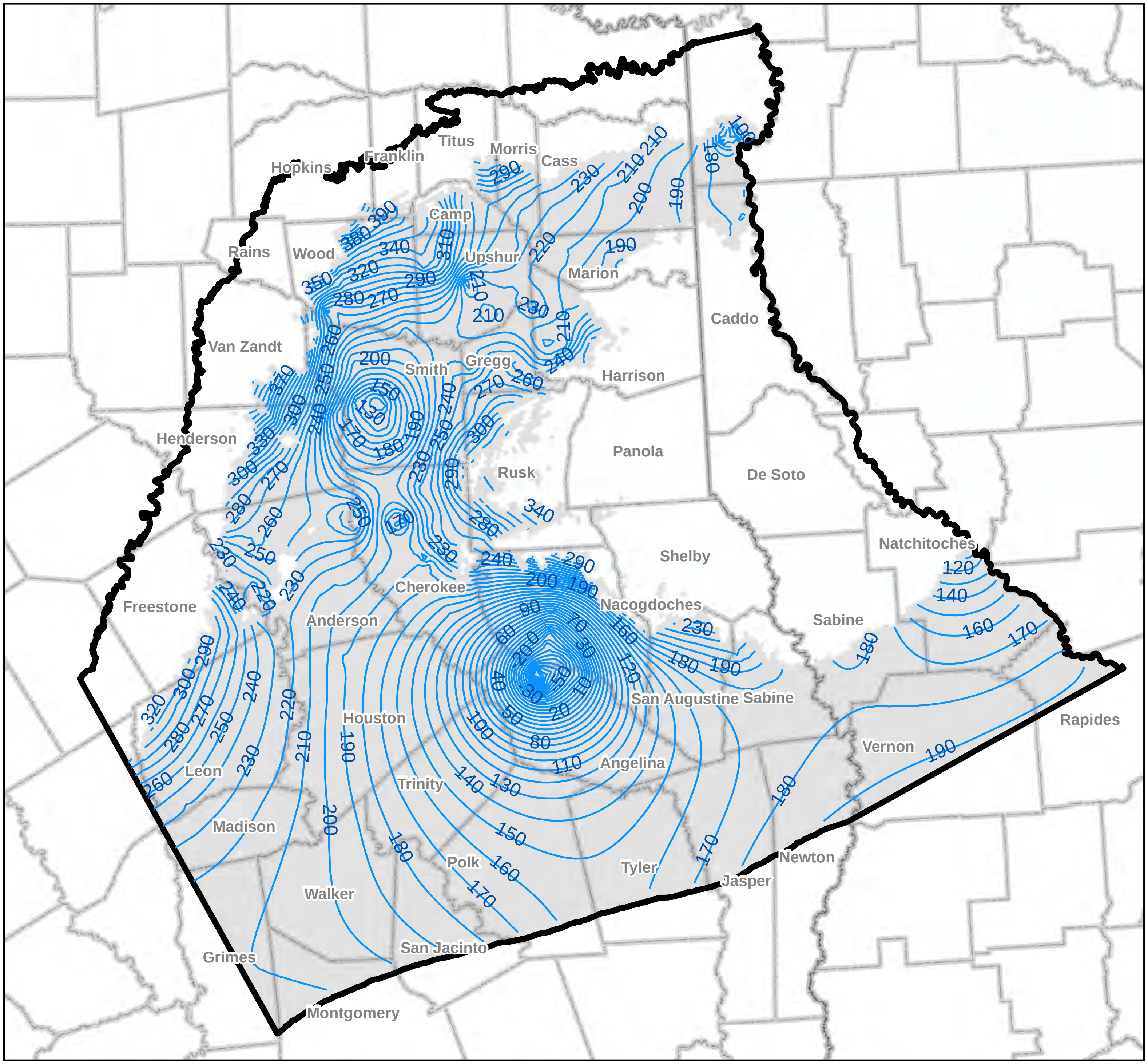
GSI ENVIRONMENTAL

SIMULATED WATER LEVEL ELEVATIONS CONTOURS IN REKLAW FORMATION (LAYER 5) FOR 2013

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_28	Appv'd By: DRAFT

FIGURE 3.2-28



N

LEGEND

- Simulated Water Level Elevations Contours (feet above mean sea level)
- Model Boundary
- County or Parish Boundary
- Layer Extent

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

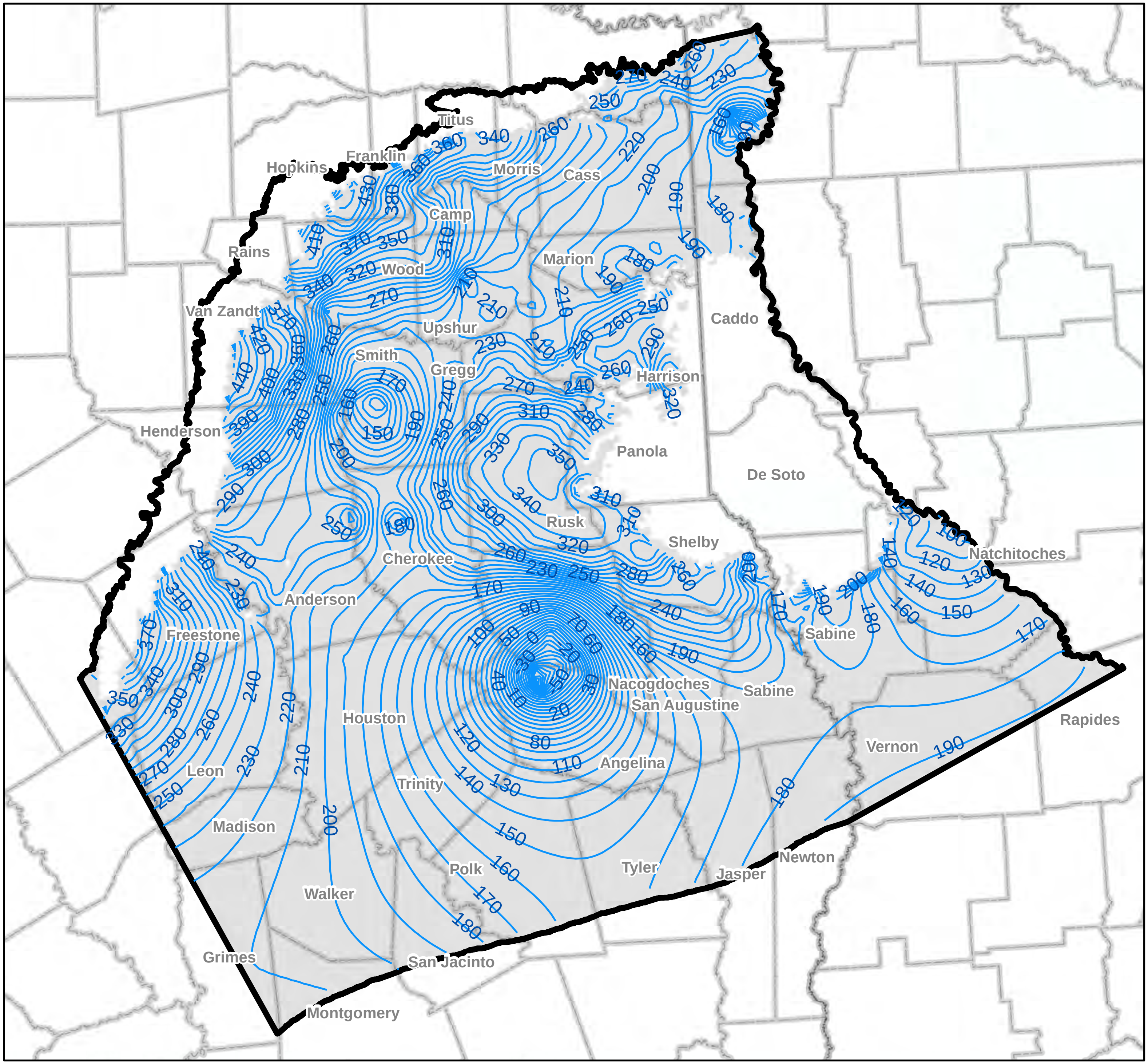
GSI ENVIRONMENTAL

SIMULATED WATER LEVEL ELEVATIONS CONTOURS IN CARRIZO SAND (LAYER 6) FOR 2013

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_29	Appv'd By: DRAFT

FIGURE 3.2-29



LEGEND

- Simulated Water Level Elevations Contours (feet above mean sea level)
- Model Boundary
- County or Parish Boundary
- Layer Extent

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles: 0, 16, 32

Projected Coordinate System Datum: GAM

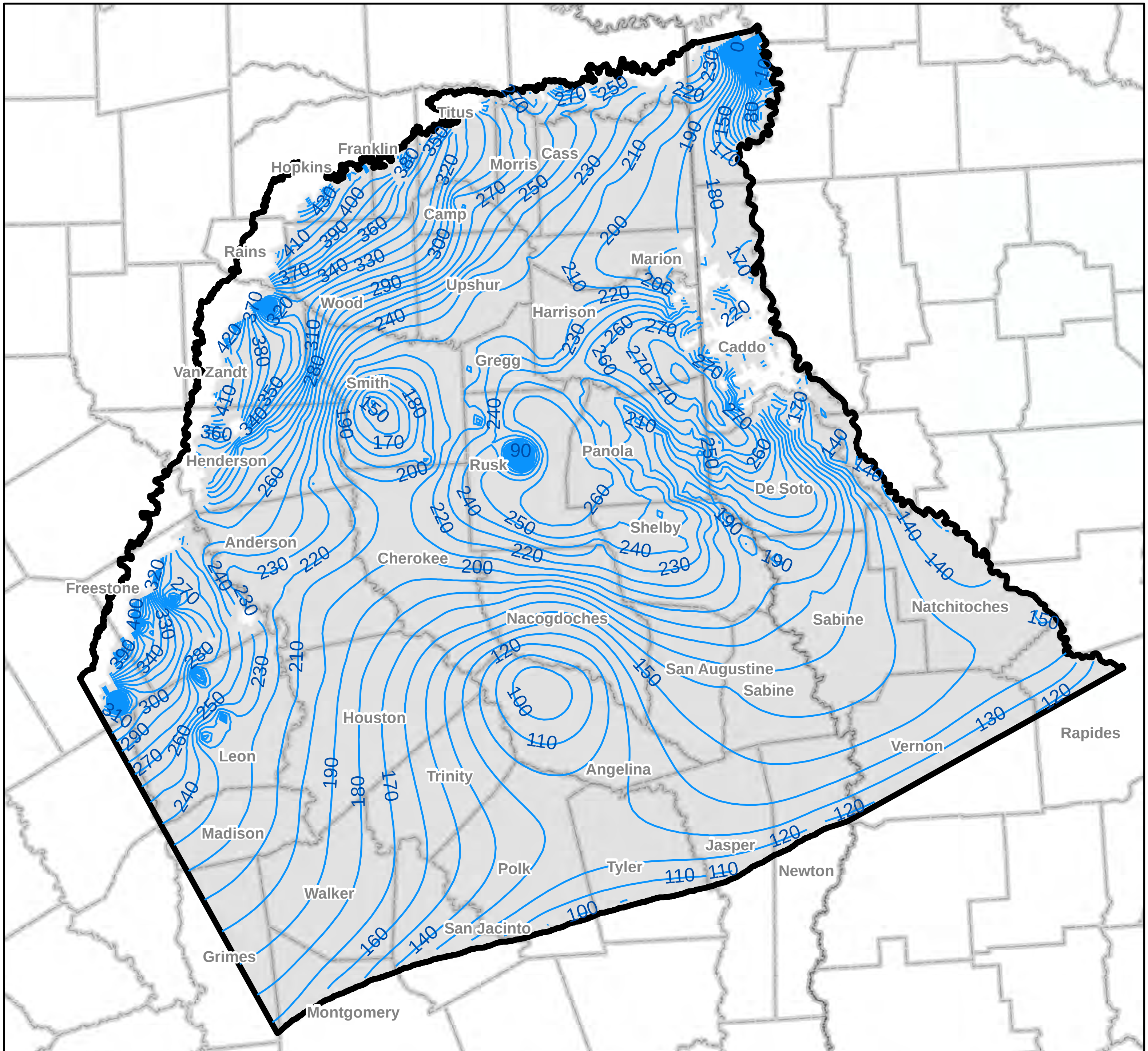
GSI ENVIRONMENTAL

SIMULATED WATER LEVEL ELEVATIONS CONTOURS IN UPPER WILCOX (LAYER 7) FOR 2013

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_30	Appv'd By: DRAFT

FIGURE 3.2-30



N

LEGEND

Simulated Water Level Elevations Contours (feet above mean sea level)

Model Boundary

County or Parish Boundary

Layer Extent

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

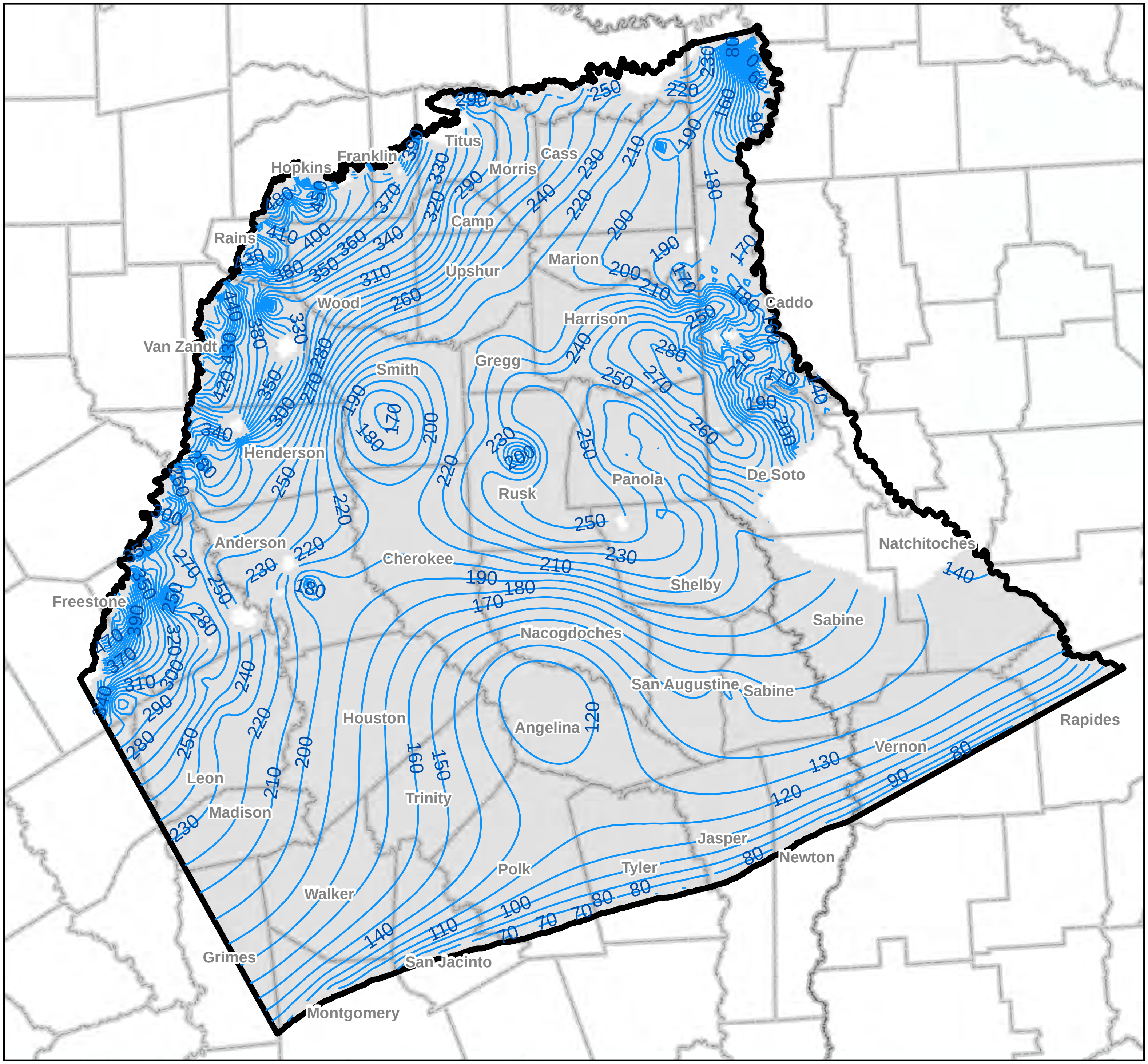
GSI ENVIRONMENTAL

SIMULATED WATER LEVEL ELEVATIONS CONTOURS IN MIDDLE WILCOX (LAYER 8) FOR 2013

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_31	Appv'd By: DRAFT

FIGURE 3.2-31



N

LEGEND

Simulated Water Level Elevations Contours (feet above mean sea level)

Model Boundary

County or Parish Boundary

Layer Extent

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

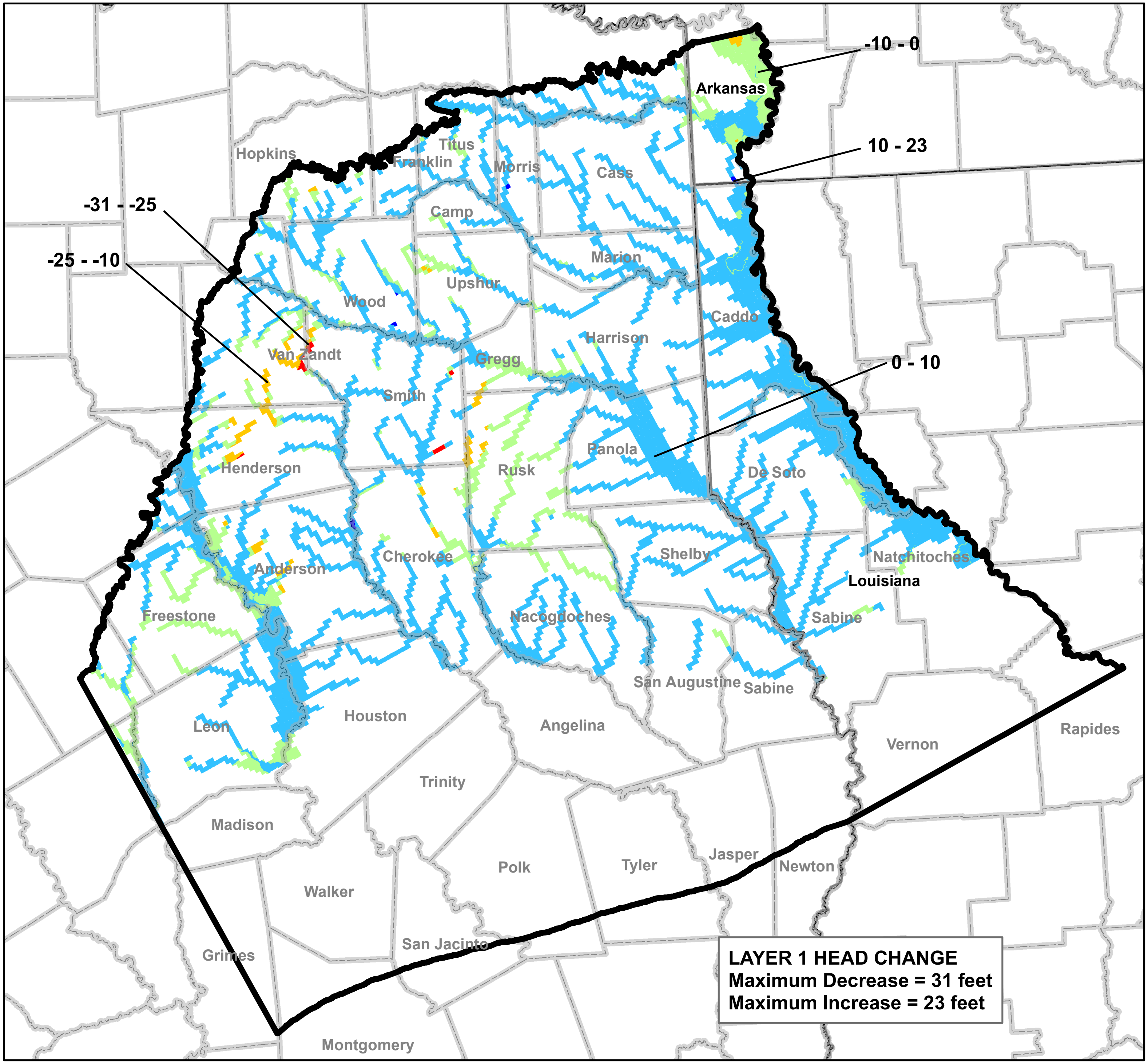
GSI ENVIRONMENTAL

SIMULATED WATER LEVEL ELEVATIONS CONTOURS IN LOWER WILCOX (LAYER 9) FOR 2013

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.	Drawn By:
4529	BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_32	Appv'd By: DRAFT

FIGURE 3.2-32



N

LEGEND

- County or Parish Boundary
- Model Boundary
- States

Head Change from 1980 to 2013 (feet)

- -31 - -25
- -25 - -10
- -10 - 0
- 0 - 10
- 10 - 23

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

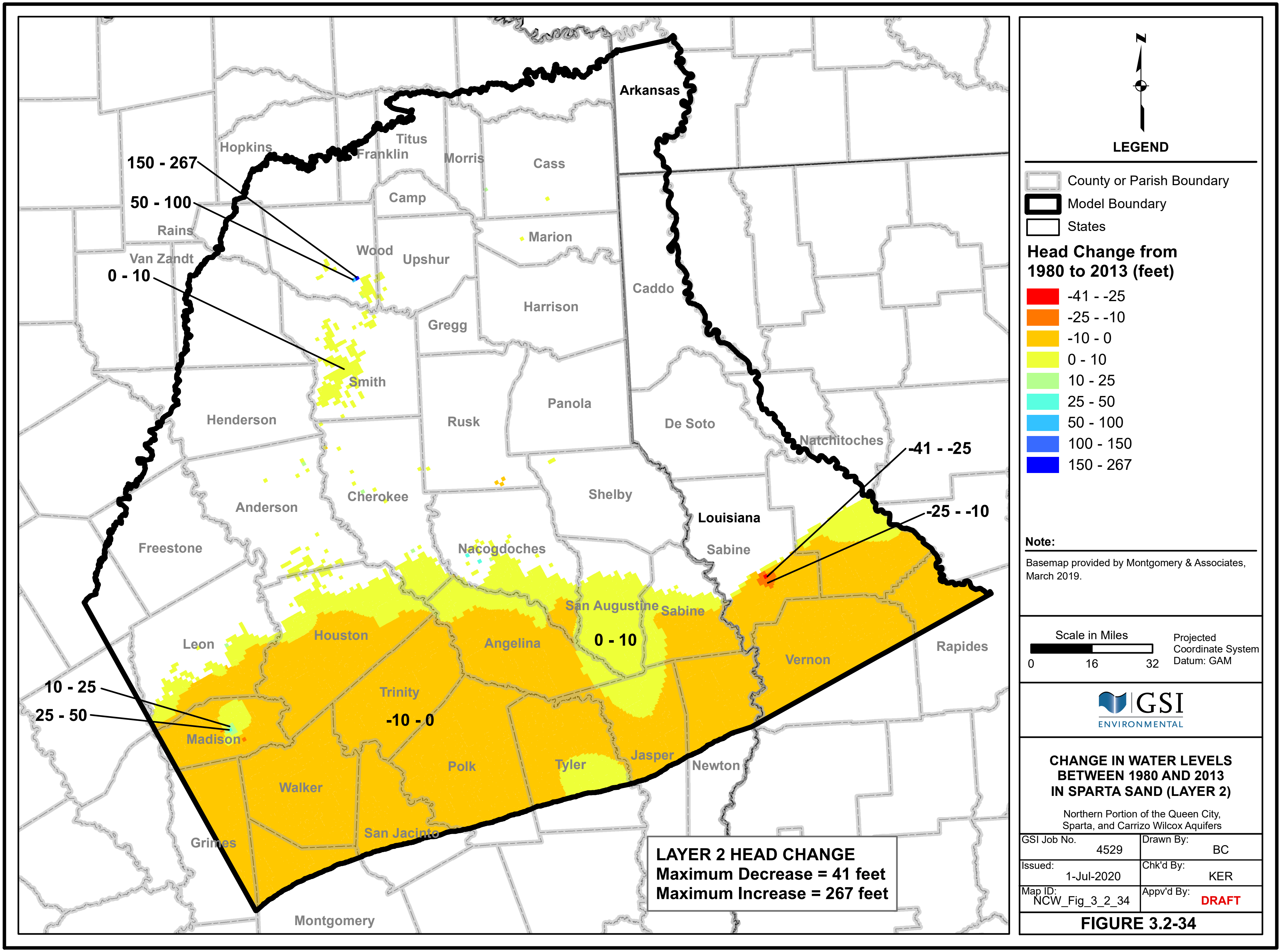
GSI ENVIRONMENTAL

CHANGE IN WATER LEVELS BETWEEN 1980 AND 2013 IN QUATERNARY ALLUVIUM (LAYER 1)

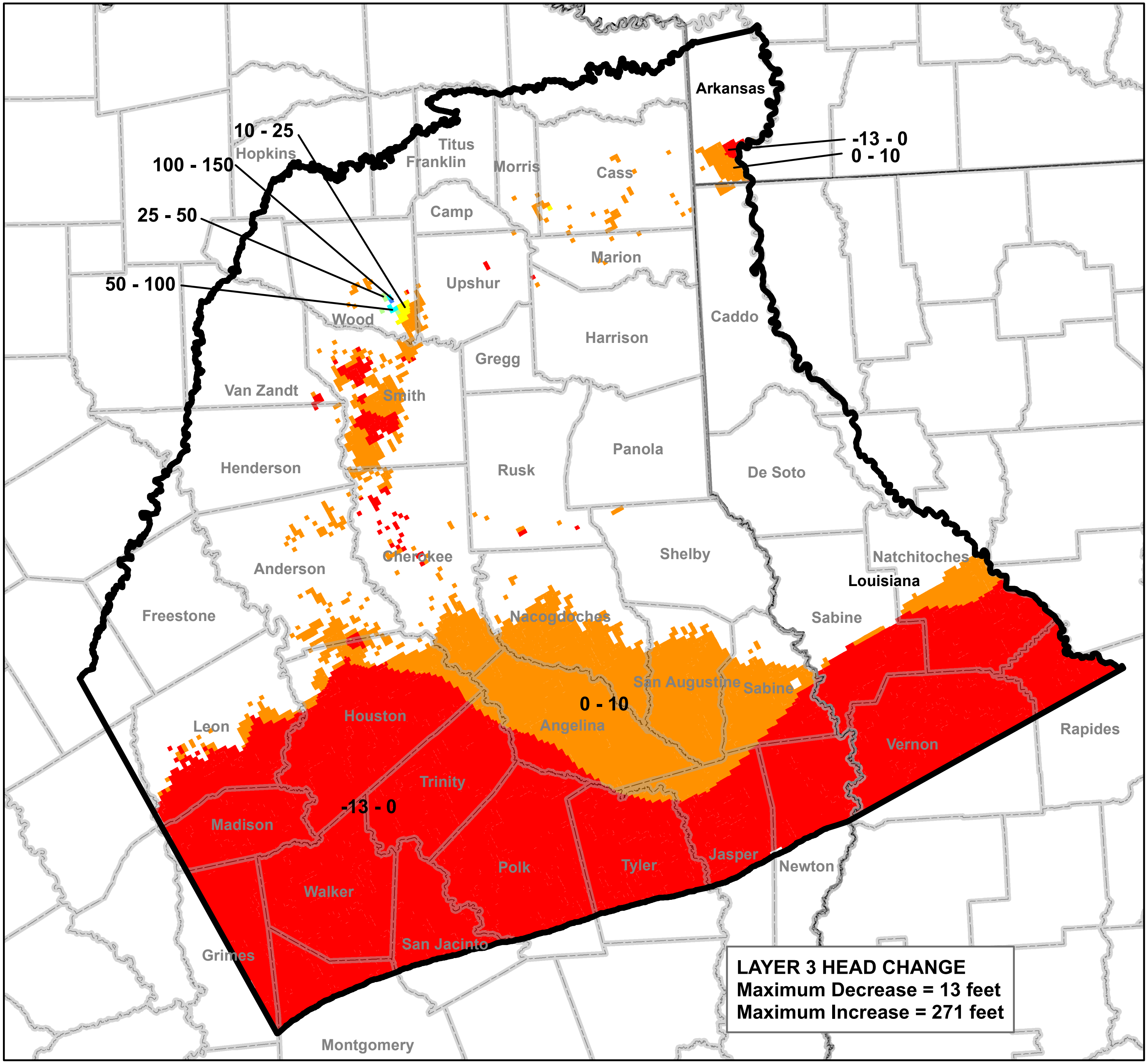
Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_33	Appv'd By: DRAFT

FIGURE 3.2-33



Arkansas
Hopkins
Titus
Franklin
Morris
Cass
Camp
Marion
Rains
Wood
Upshur
Van Zandt
Caddo
Harrison
Gregg
Smith
Panola
Henderson
Rusk
De Soto
Natchitoches
Cherokee
Anderson
Shelby
Louisiana
Freestone
Nacogdoches
Sabine
San Augustine
Sabine
Leon
Houston
Angelina
Rapides
Vernon
Trinity
Madison
Polk
Tyler
Jasper
Newton
Walker
San Jacinto
Grimes
Montgomery
150 - 267
50 - 100
0 - 10
-41 - -25
-25 - -10
0 - 10
-10 - 0
10 - 25
25 - 50
LAYER 2 HEAD CHANGE
Maximum Decrease = 41 feet
Maximum Increase = 267 feet
N
LEGEND
County or Parish Boundary
Model Boundary
States
Head Change from 1980 to 2013 (feet)
-41 - -25
-25 - -10
-10 - 0
0 - 10
10 - 25
25 - 50
50 - 100
100 - 150
150 - 267
Note:
Basemap provided by Montgomery & Associates, March 2019.
Scale in Miles
0
16
32
Projected Coordinate System
Datum: GAM
GSI
ENVIRONMENTAL
CHANGE IN WATER LEVELS BETWEEN 1980 AND 2013 IN SPARTA SAND (LAYER 2)
Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers
GSI Job No. 4529
Drawn By: BC
Issued: 1-Jul-2020
Chk'd By: KER
Map ID: NCW_Fig_3_2_34
Appv'd By: DRAFT
FIGURE 3.2-34



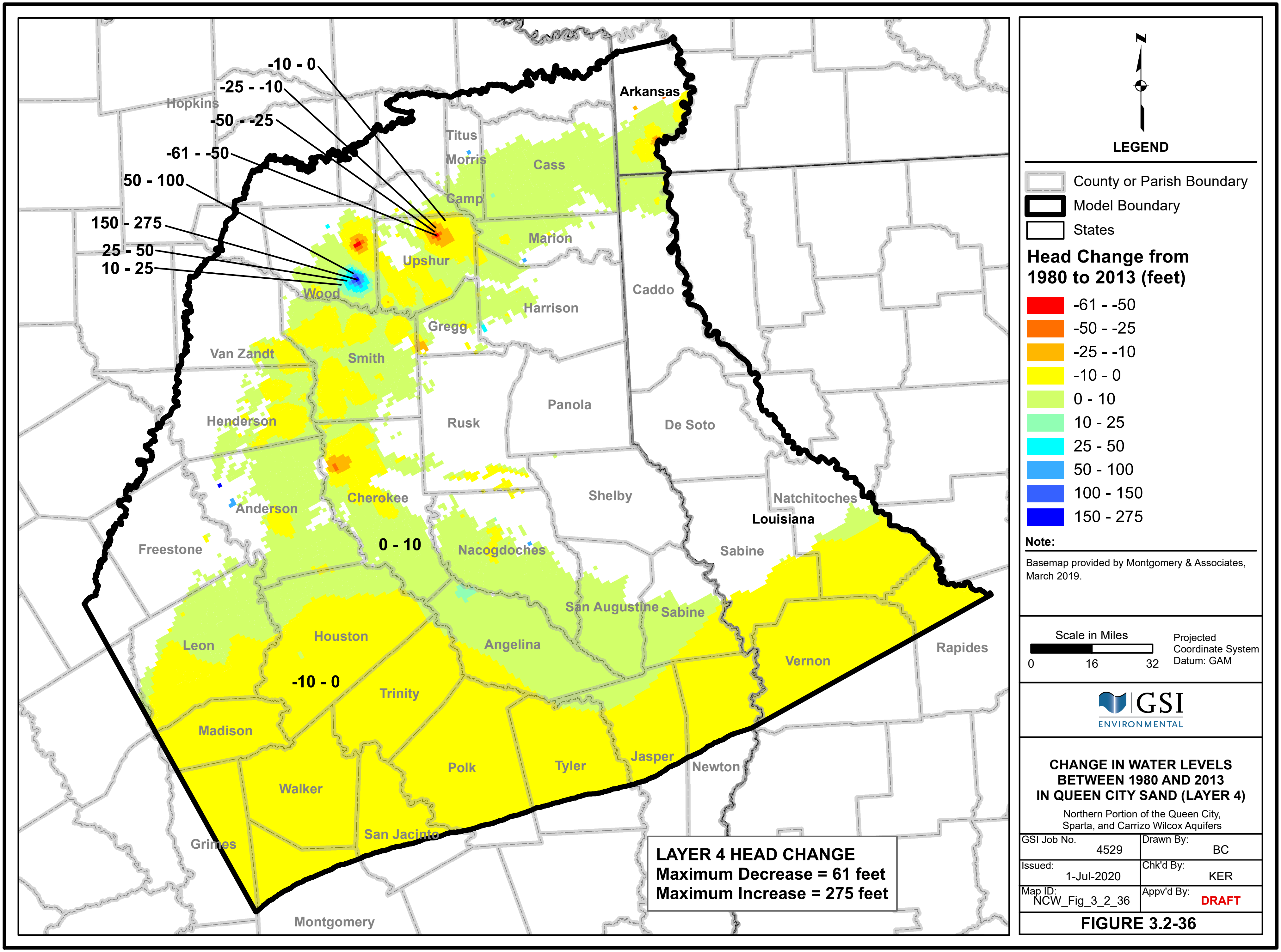
GSI ENVIRONMENTAL

CHANGE IN WATER LEVELS BETWEEN 1980 AND 2013 IN WECHES FORMATION (LAYER 3)

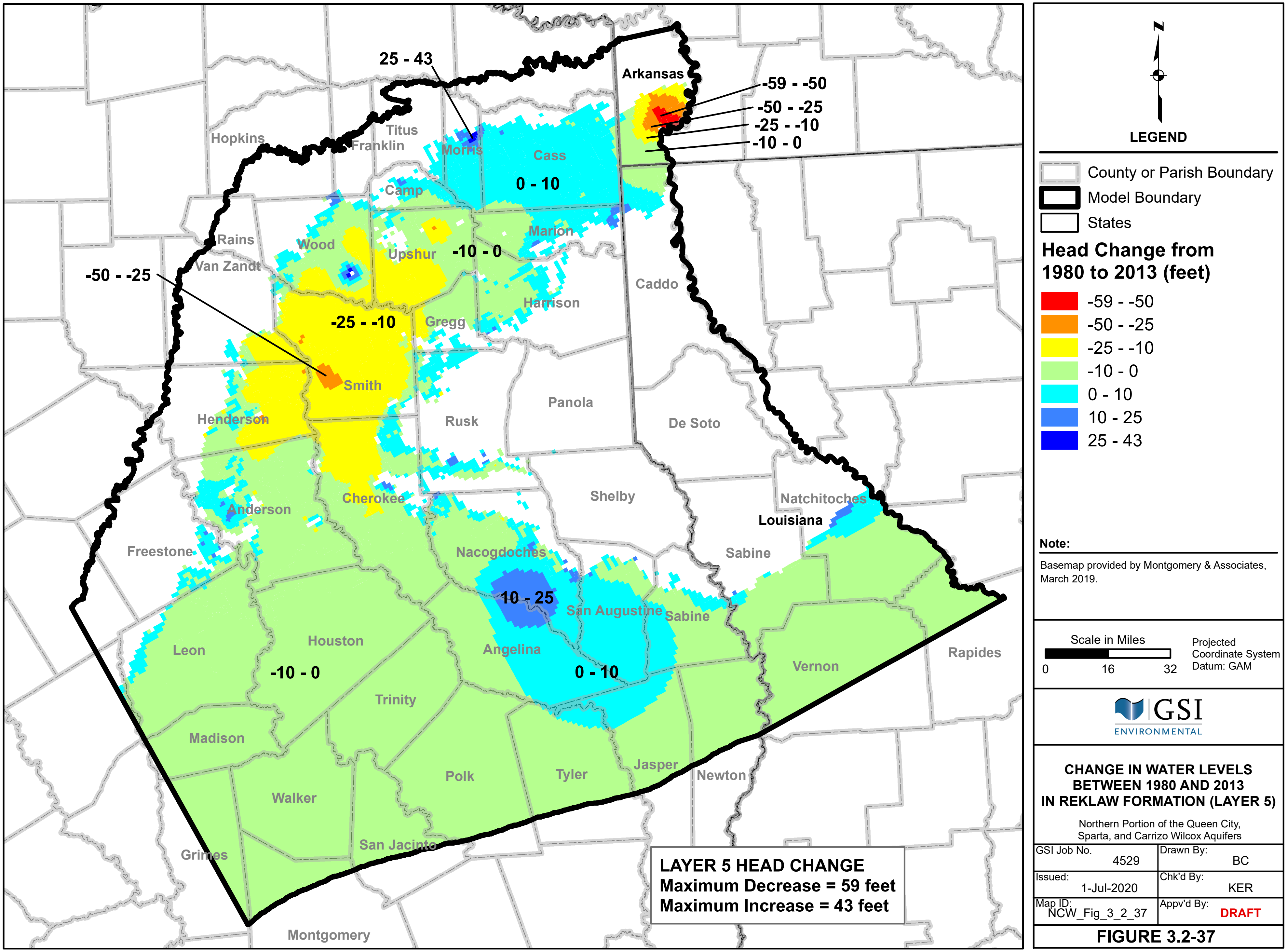
Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_35	Appv'd By: DRAFT

FIGURE 3.2-35



-10 - 0
-25 - -10
-50 - -25
-61 - -50
50 - 100
150 - 275
25 - 50
10 - 25
Hopkins
Titus
Morris
Cass
Camp
Arkansas
Marion
Upshur
Wood
Harrison
Caddo
Gregg
Van Zandt
Smith
Panola
Rusk
Henderson
De Soto
Cherokee
Shelby
Anderson
Natchitoches
Louisiana
Freestone
0 - 10
Nacogdoches
Sabine
San Augustine
Sabine
Leon
Houston
Angelina
Rapides
Vernon
-10 - 0
Trinity
Madison
Jasper
Newton
Polk
Tyler
Walker
San Jacinto
Grimes
Montgomery
LAYER 4 HEAD CHANGE
Maximum Decrease = 61 feet
Maximum Increase = 275 feet
N
LEGEND
County or Parish Boundary
Model Boundary
States
Head Change from 1980 to 2013 (feet)
-61 - -50
-50 - -25
-25 - -10
-10 - 0
0 - 10
10 - 25
25 - 50
50 - 100
100 - 150
150 - 275
Note:
Basemap provided by Montgomery & Associates, March 2019.
Scale in Miles
0
16
32
Projected Coordinate System Datum: GAM
GSI ENVIRONMENTAL
CHANGE IN WATER LEVELS BETWEEN 1980 AND 2013 IN QUEEN CITY SAND (LAYER 4)
Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers
GSI Job No. 4529
Drawn By: BC
Issued: 1-Jul-2020
Chk'd By: KER
Map ID: NCW_Fig_3_2_36
Appv'd By: DRAFT
FIGURE 3.2-36

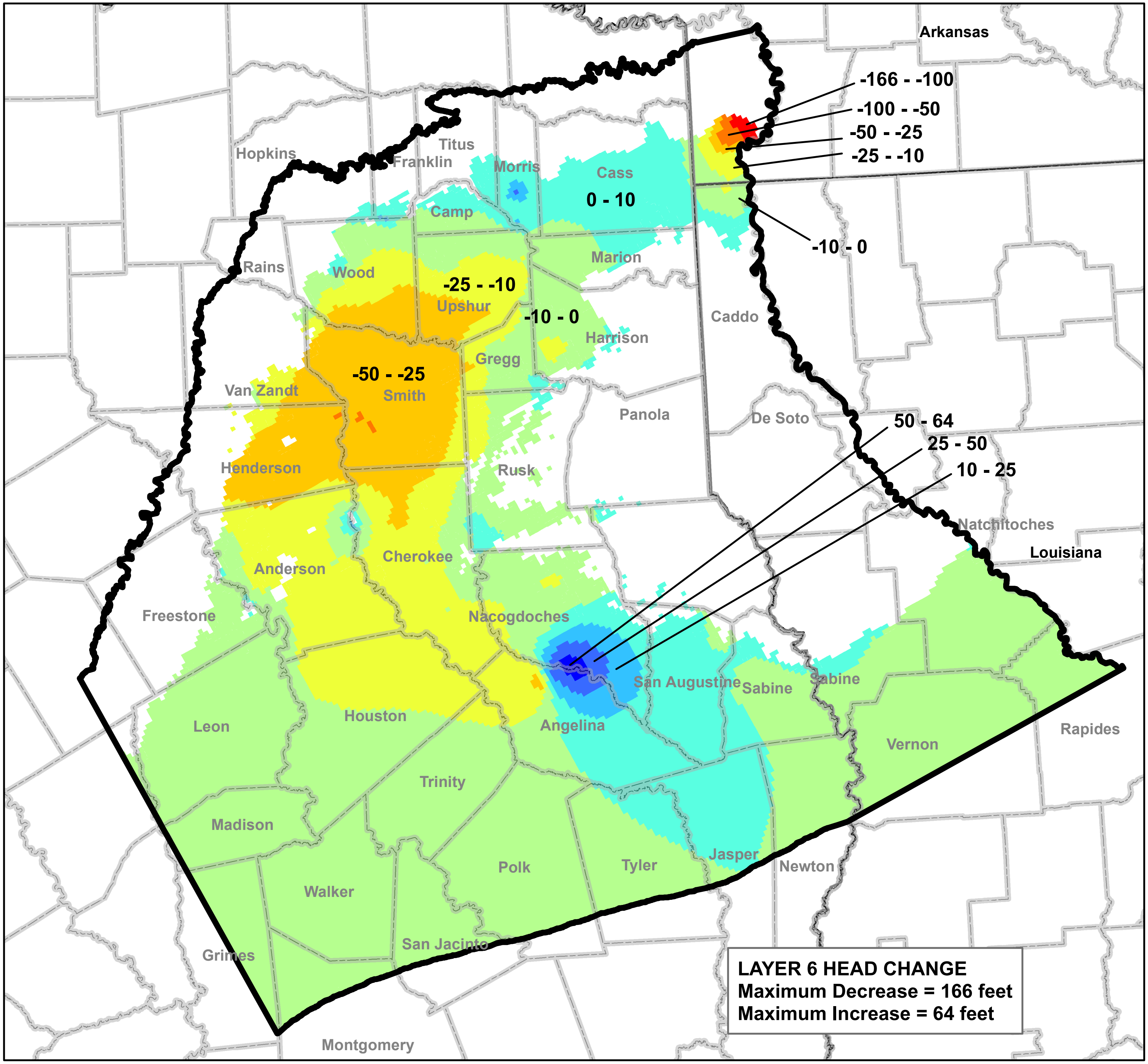


CHANGE IN WATER LEVELS BETWEEN 1980 AND 2013 IN REKLAW FORMATION (LAYER 5)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_37	Appv'd By: DRAFT

FIGURE 3.2-37

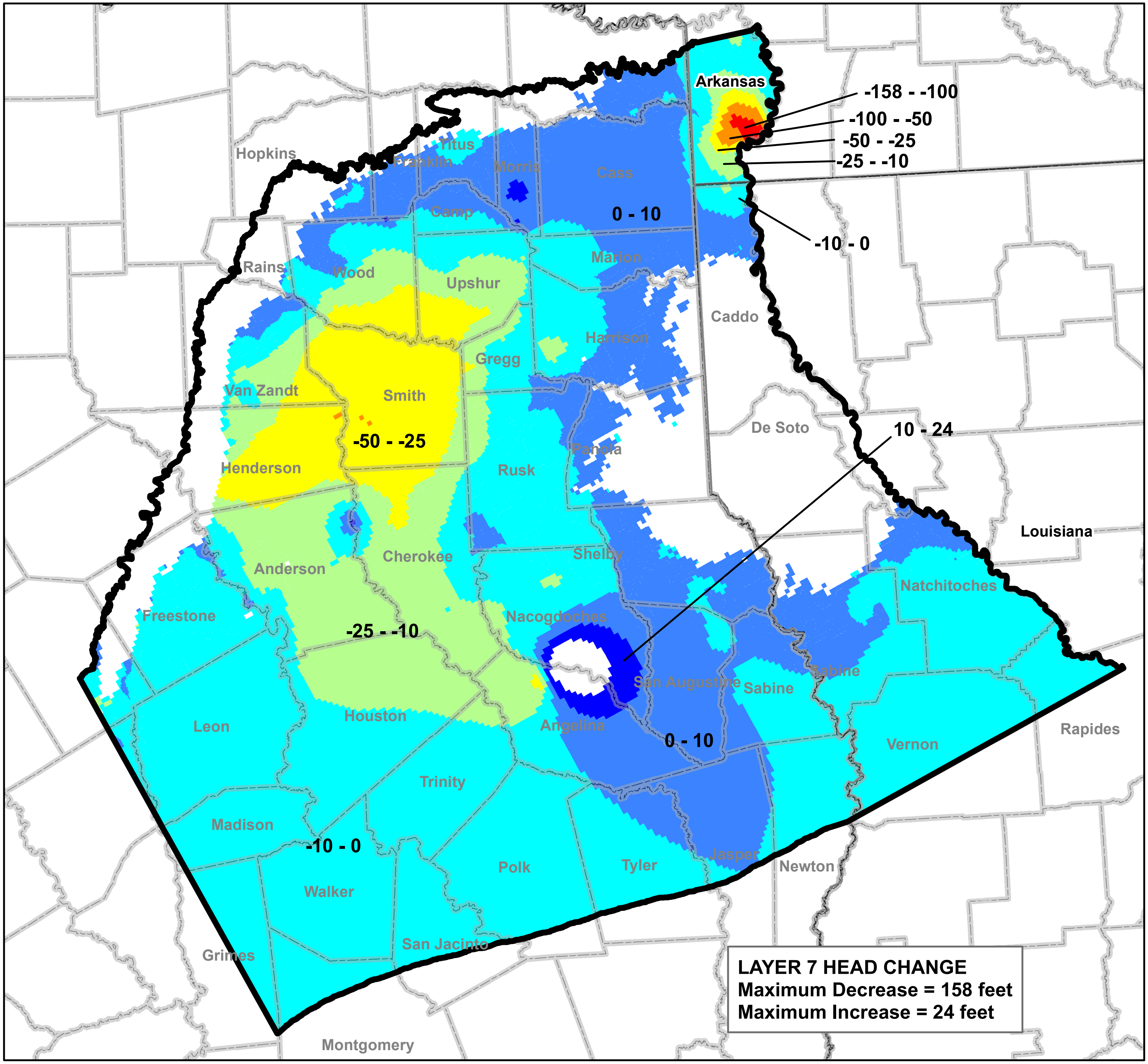


CHANGE IN WATER LEVELS BETWEEN 1980 AND 2013 IN CARRIZO SAND (LAYER 6)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_38	Appv'd By: DRAFT

FIGURE 3.2-38

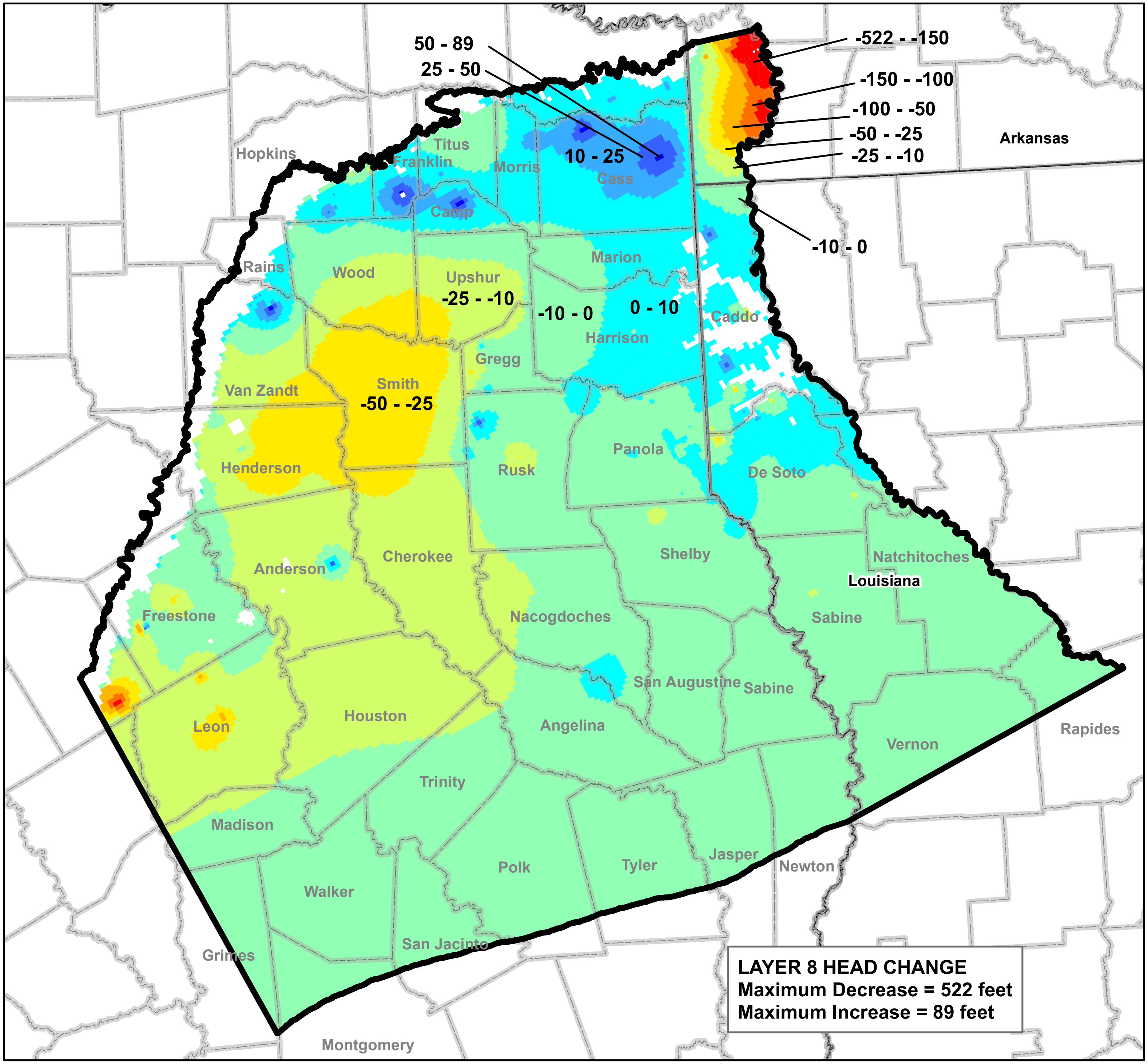


CHANGE IN WATER LEVELS BETWEEN 1980 AND 2013 IN UPPER WILCOX (LAYER 7)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_39	Appv'd By: DRAFT

FIGURE 3.2-39



N

LEGEND

- County or Parish Boundary
- Model Boundary
- States

Head Change from 1980 to 2013 (feet)

- -522- -150
- -150 - -100
- -100 -50
- -50 - -25
- -25 - -10
- -10 - 0
- 0 - 10
- 10 - 25
- 25 - 50
- 50 - 89

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

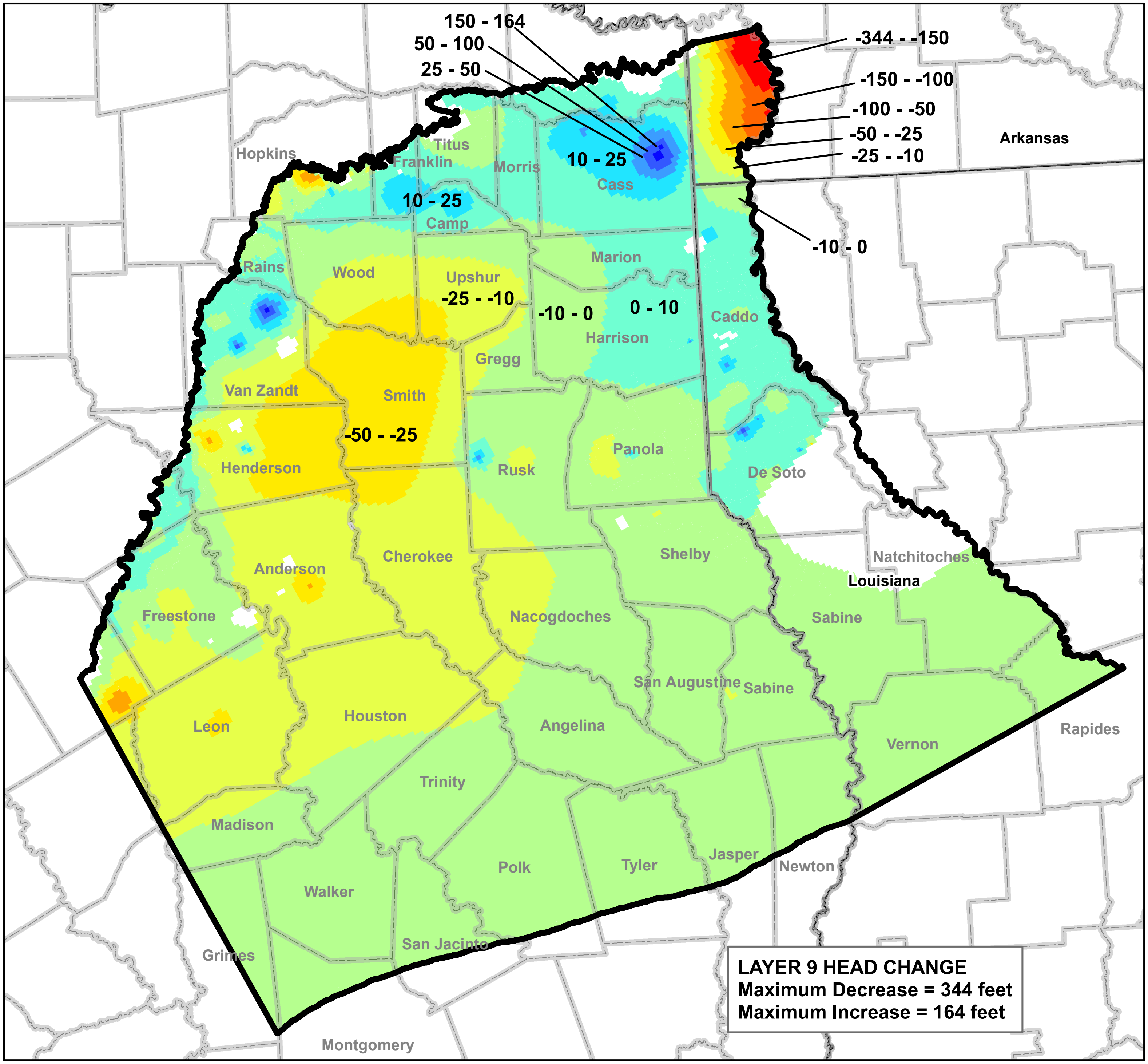
GSI ENVIRONMENTAL

CHANGE IN WATER LEVELS BETWEEN 1980 AND 2013 IN MIDDLE WILCOX (LAYER 8)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_40	Appv'd By: DRAFT

FIGURE 3.2-40



LEGEND

- County or Parish Boundary
- Model Boundary
- States

Head Change from 1980 to 2013 (feet)

- -344 - -150
- -150 - -100
- -100 - -50
- -50 - -25
- -25 - -10
- -10 - 0
- 0 - 10
- 10 - 25
- 25 - 50
- 50 - 100
- 100 - 164

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles: 0, 16, 32

Projected Coordinate System Datum: GAM

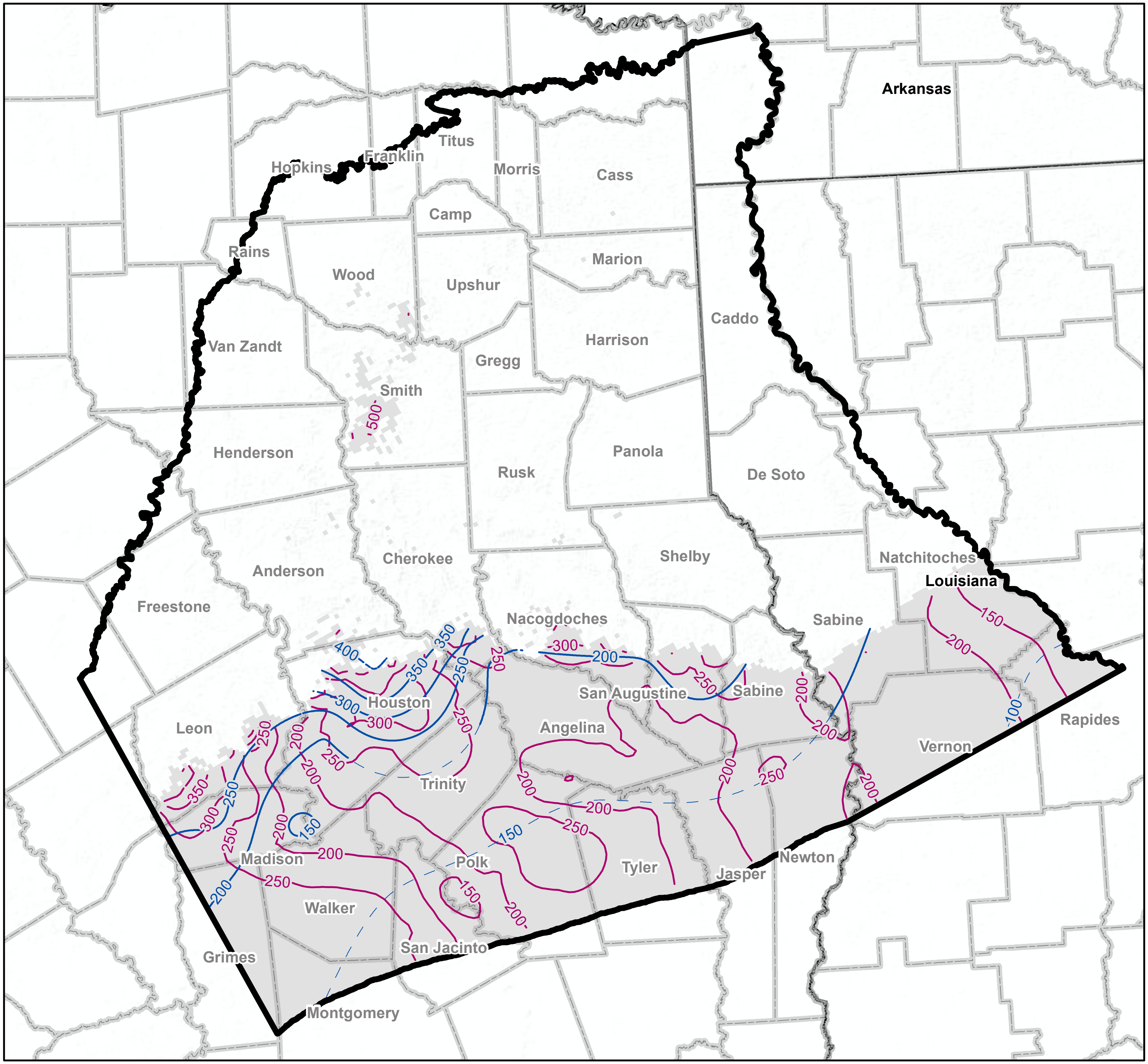
GSI ENVIRONMENTAL

CHANGE IN WATER LEVELS BETWEEN 1980 AND 2013 IN LOWER WILCOX (LAYER 9)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: GM
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_41	Appv'd By: DRAFT

FIGURE 3.2-41



LEGEND

- Observed Groundwater Level Elevation Contour for 2015 (Dashed where uncertain)
- Modeled Groundwater Level Elevation Contour for 2013
- Layer Extent
- County or Parish Boundary
- Model Boundary

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles
0 16 32

Projected Coordinate System
Datum: GAM

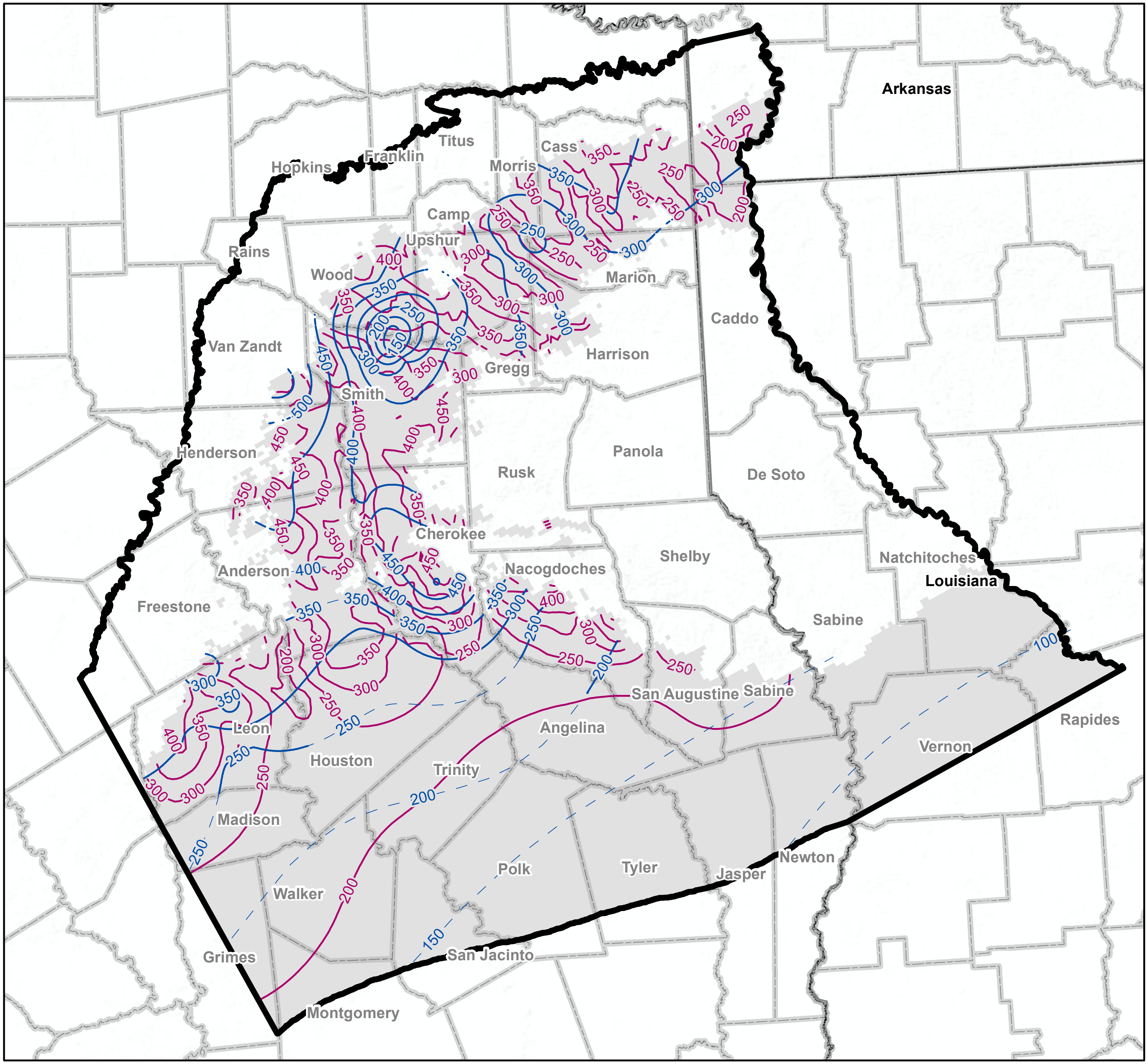
GSI ENVIRONMENTAL

OBSERVED AND MODELED GROUNDWATER LEVEL ELEVATION CONTOURS FOR SPARTA SAND (LAYER 2)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_42	Appv'd By: DRAFT

FIGURE 3.2-42



LEGEND

- Observed Groundwater Level Elevation Contour for 2015 (Dashed where uncertain)
- Modeled Groundwater Level Elevation Contour for 2013
- Layer Extent
- County or Parish Boundary
- Model Boundary

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles: 0 16 32

Projected Coordinate System Datum: GAM

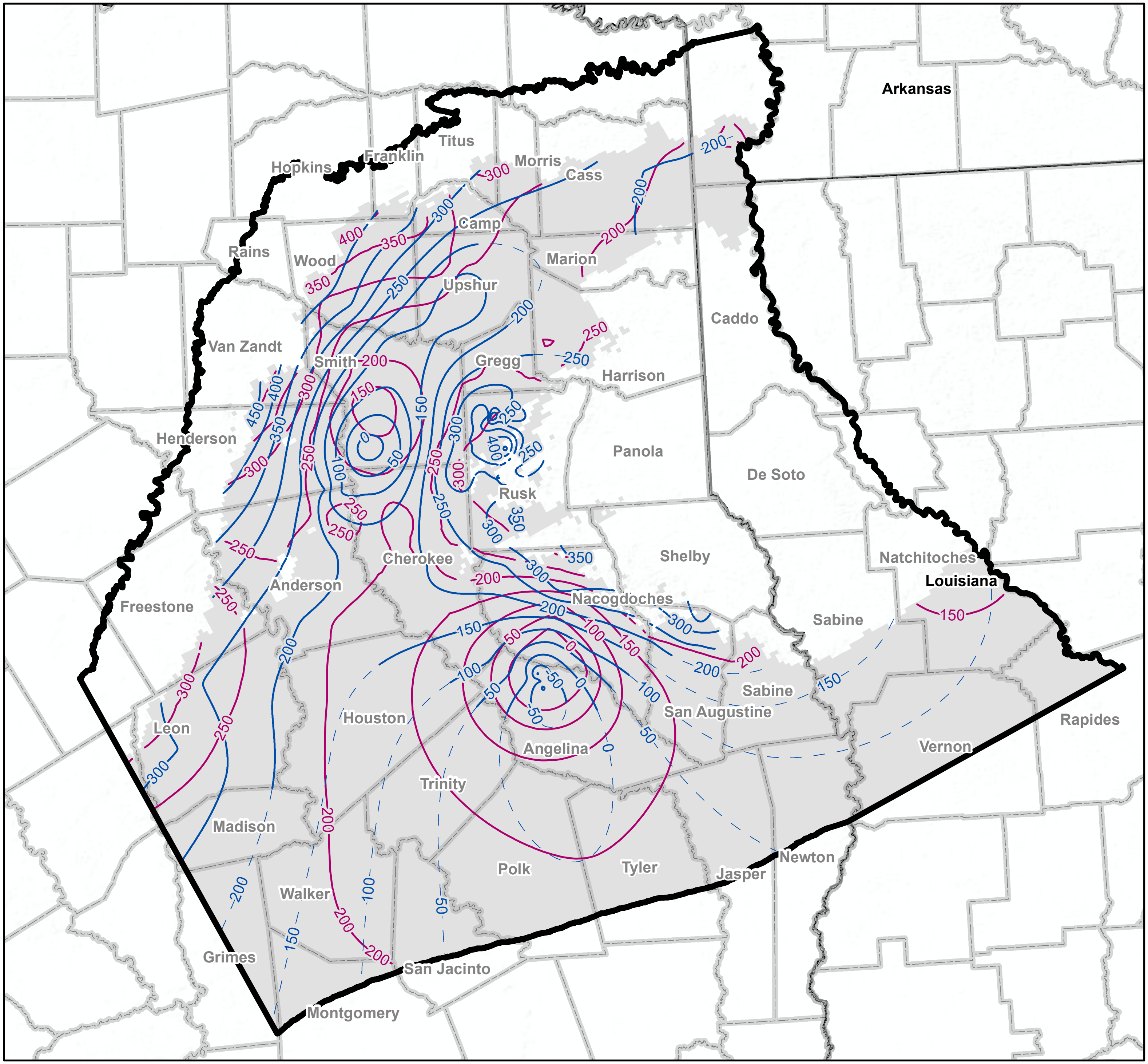
GSI ENVIRONMENTAL

OBSERVED AND MODELED GROUNDWATER LEVEL ELEVATION CONTOURS FOR QUEEN CITY SAND (LAYER 4)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_43	Appv'd By: DRAFT

FIGURE 3.2-43



N

LEGEND

- Observed Groundwater Level Elevation Contour for 2015 (Dashed where uncertain)
- Modeled Groundwater Level Elevation Contour for 2013
- Layer Extent
- County or Parish Boundary
- Model Boundary

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

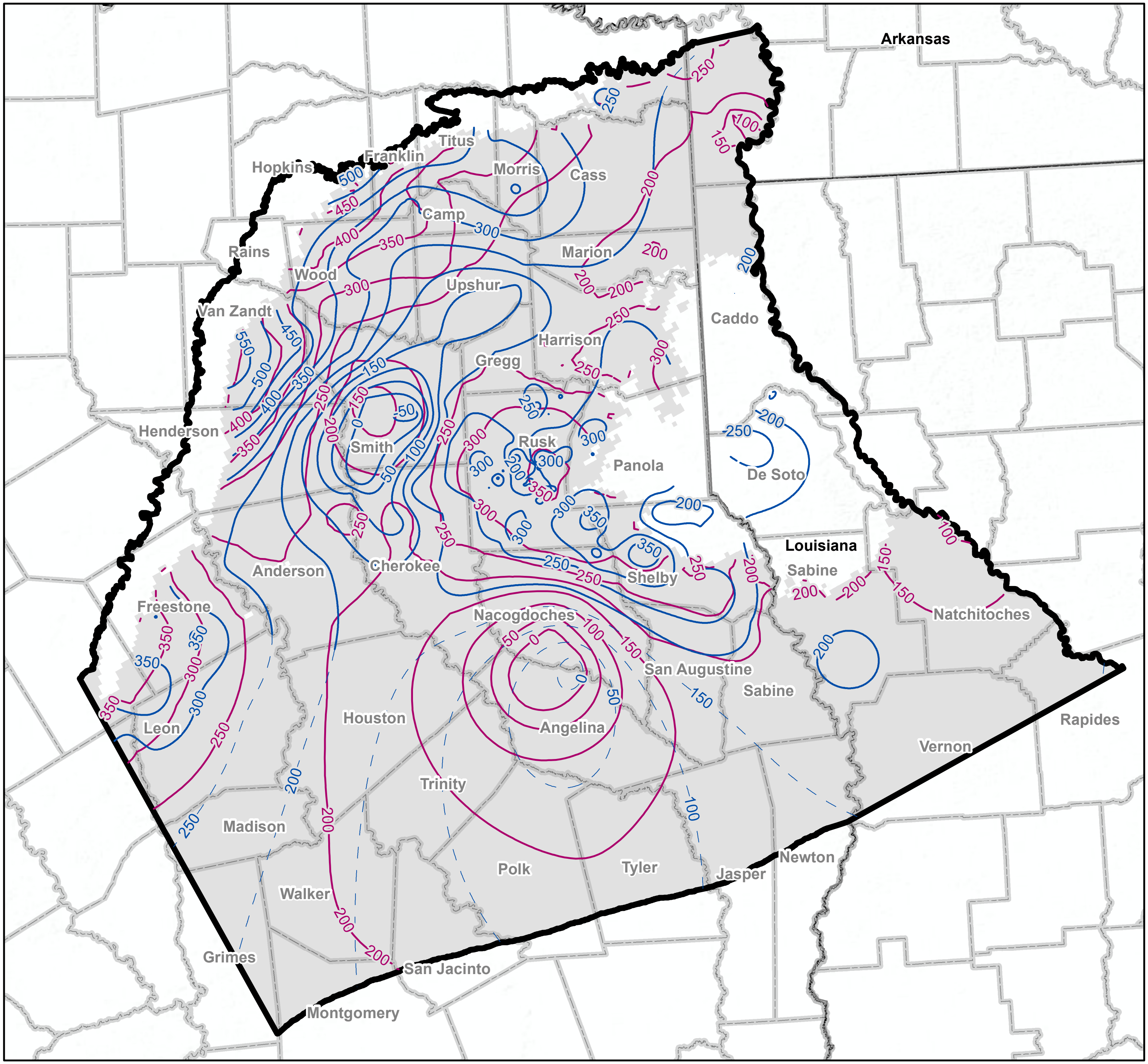
GSI ENVIRONMENTAL

OBSERVED AND MODELED GROUNDWATER LEVEL ELEVATION CONTOURS FOR CARRIZO SAND (LAYER 6)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_44	Appv'd By: DRAFT

FIGURE 3.2-44



N

LEGEND

Observed Groundwater Level Elevation Contour for 2015 (Dashed where uncertain)

Modeled Groundwater Level Elevation Contour for 2013

Layer Extent

County or Parish Boundary

Model Boundary

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

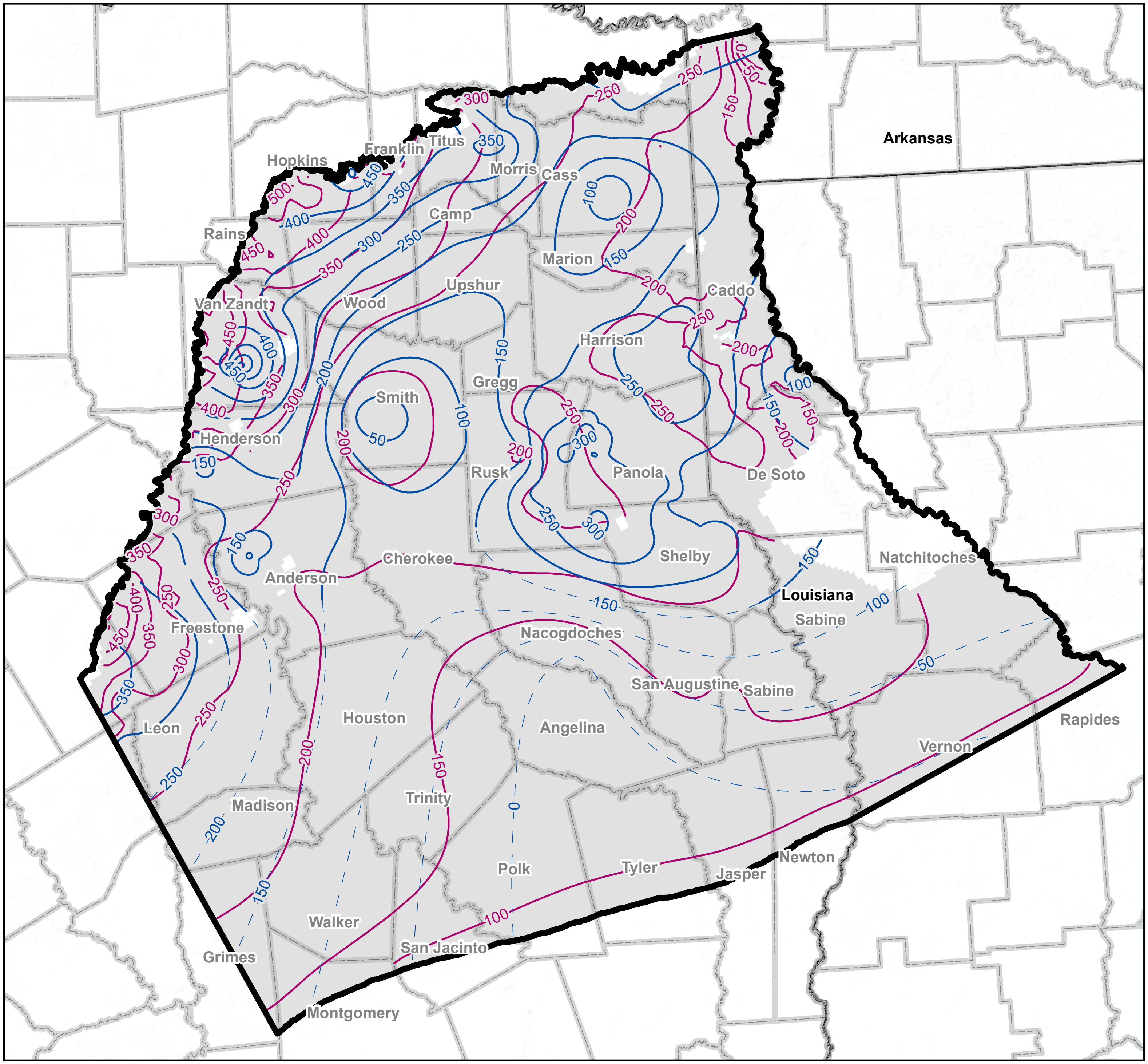
GSI ENVIRONMENTAL

OBSERVED AND MODELED GROUNDWATER LEVEL ELEVATION CONTOURS FOR UPPER WILCOX (LAYER 7)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_45	Appv'd By: DRAFT

FIGURE 3.2-45



N

LEGEND

Observed Groundwater Level Elevation Contour for 2015 (Dashed where uncertain)

Modeled Groundwater Level Elevation Contour for 2013

Layer Extent

County or Parish Boundary

Model Boundary

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System
Datum: GAM

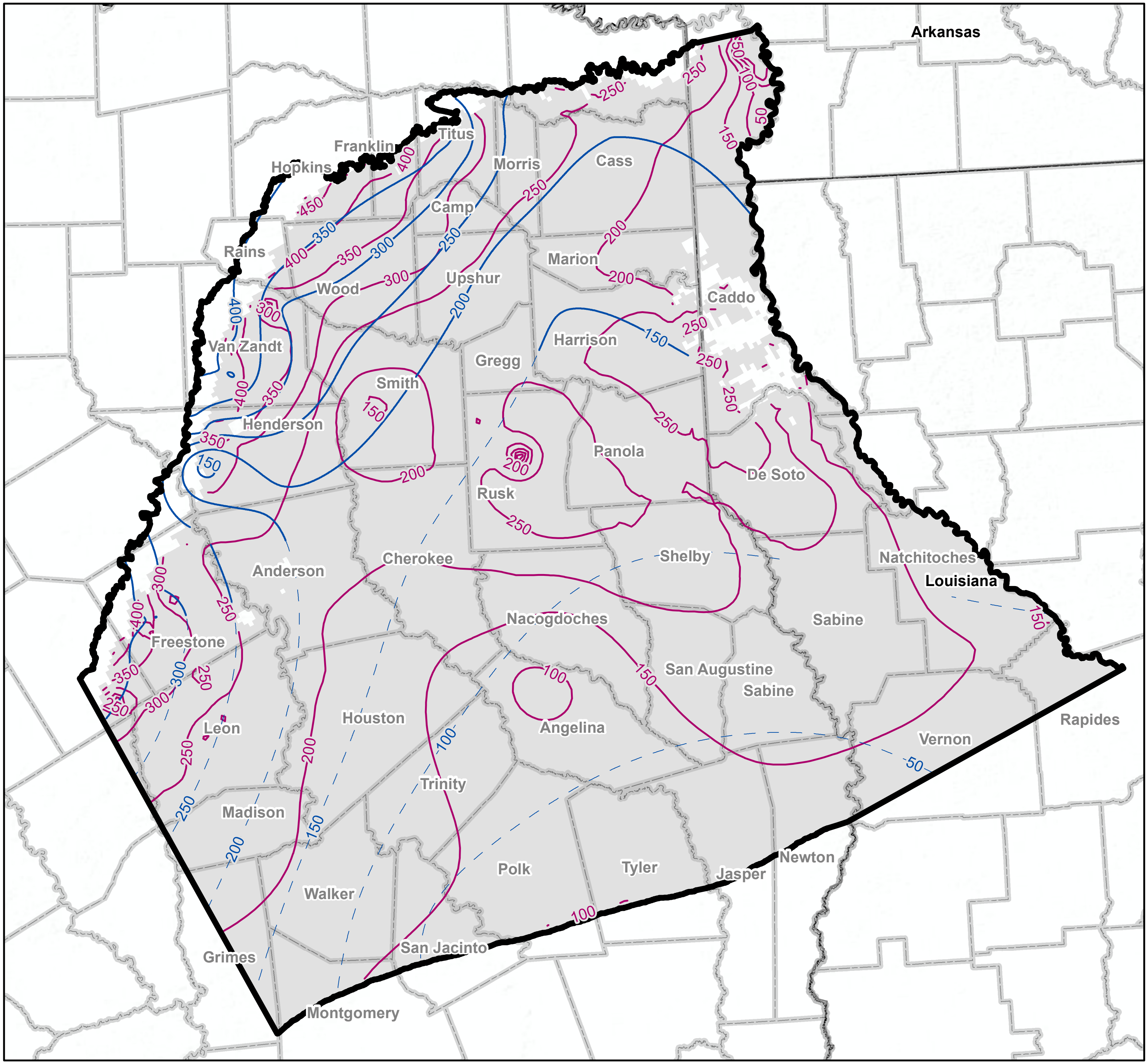
GSI ENVIRONMENTAL

OBSERVED AND MODELED GROUNDWATER LEVEL ELEVATION CONTOURS FOR MIDDLE WILCOX (LAYER 8)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No.: 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_46	Appv'd By: DRAFT

FIGURE 3.2-46



N

LEGEND

Observed Groundwater Level Elevation Contour for 2015 (Dashed where uncertain)

Modeled Groundwater Level Elevation Contour for 2013

Layer Extent

County or Parish Boundary

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 16 32

Projected Coordinate System Datum: GAM

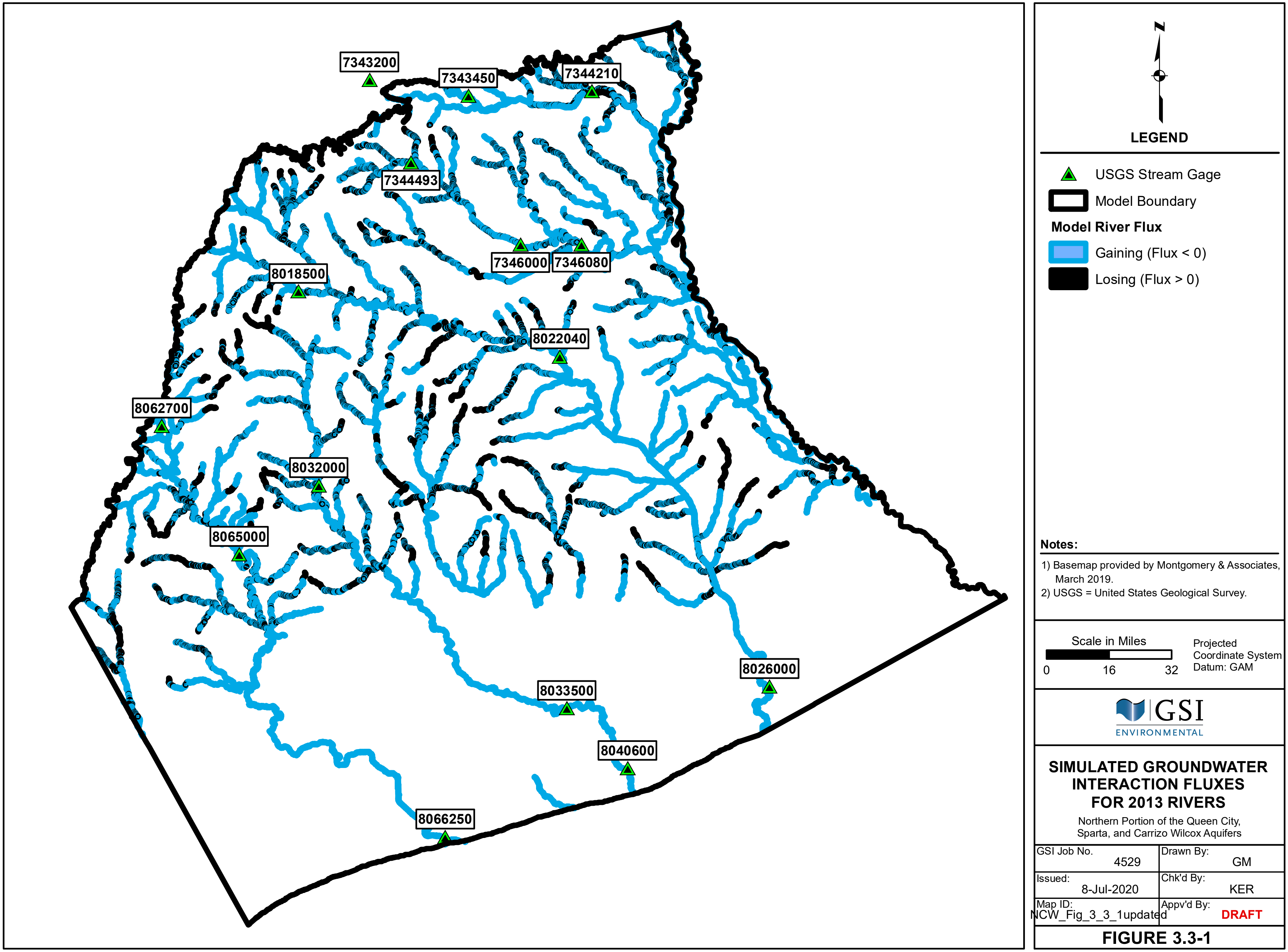
GSI ENVIRONMENTAL

OBSERVED AND MODELED GROUNDWATER LEVEL ELEVATION CONTOURS FOR LOWER WILCOX (LAYER 9)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: BC
Issued: 1-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_2_47	Appv'd By: DRAFT

FIGURE 3.2-47

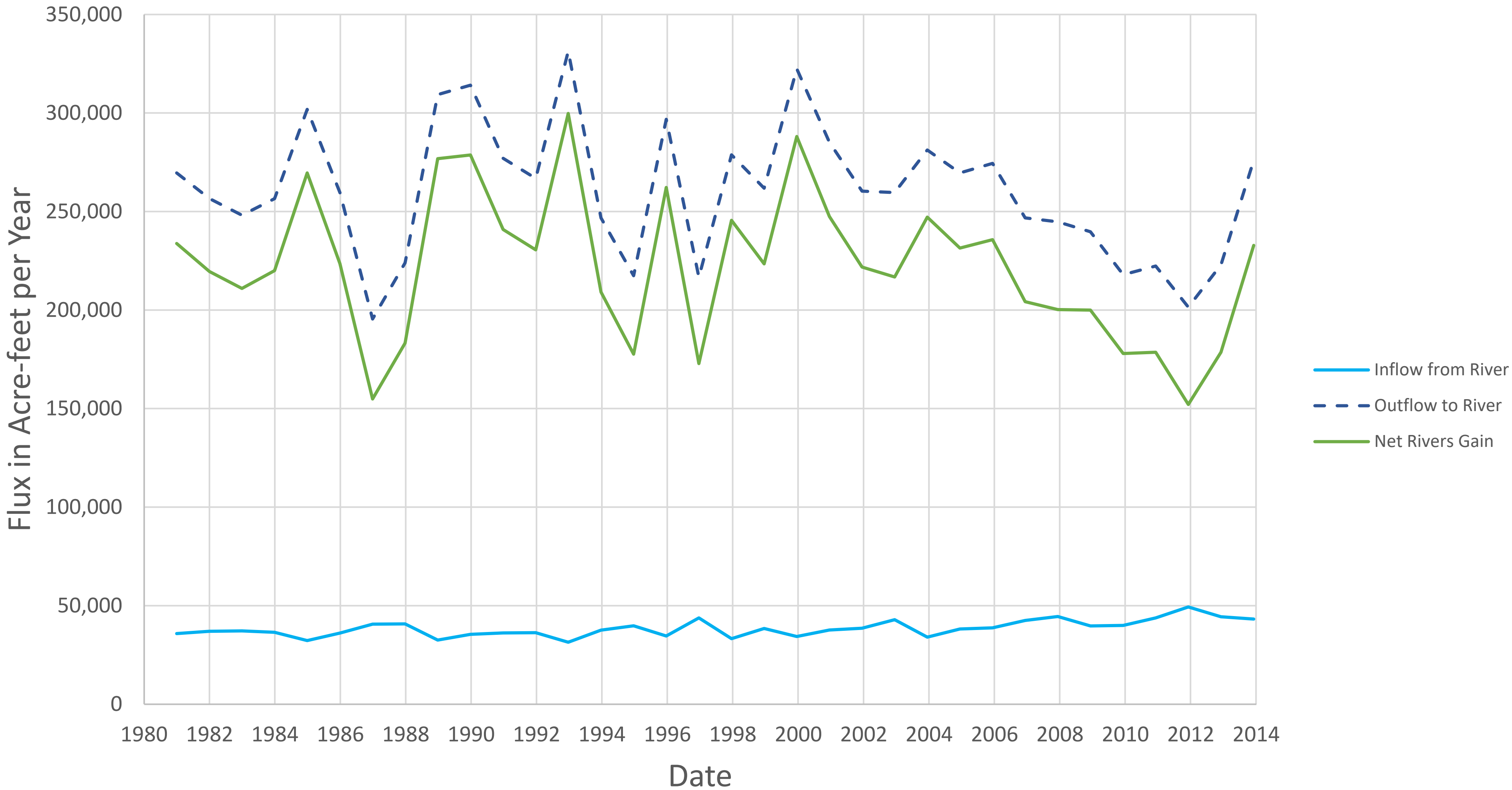


SIMULATED GROUNDWATER INTERACTION FLUXES FOR 2013 RIVERS

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 8-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_3_3_1updated	Appv'd By: DRAFT

FIGURE 3.3-1

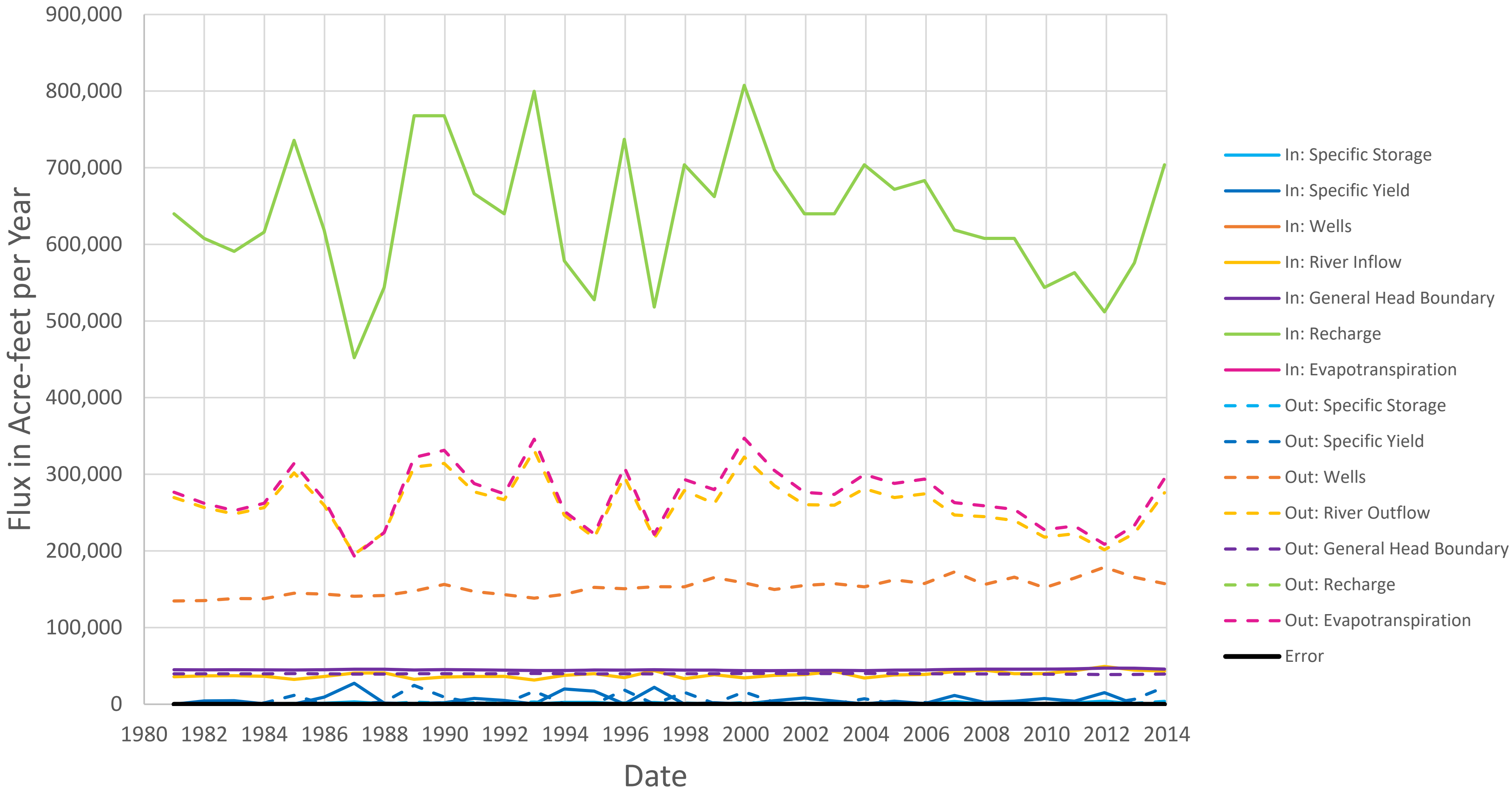


GSI ENVIRONMENTAL

GSI Job No.	4529	Drawn By:	GM
Issued:	06-Jul-2020	Chk'd By:	
Revised:		Aprv'd By:	DRAFT
Scale:			Figure 3.3-2

Groundwater Budget for River Flux
1980 to 2013 Calibration Simulation

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

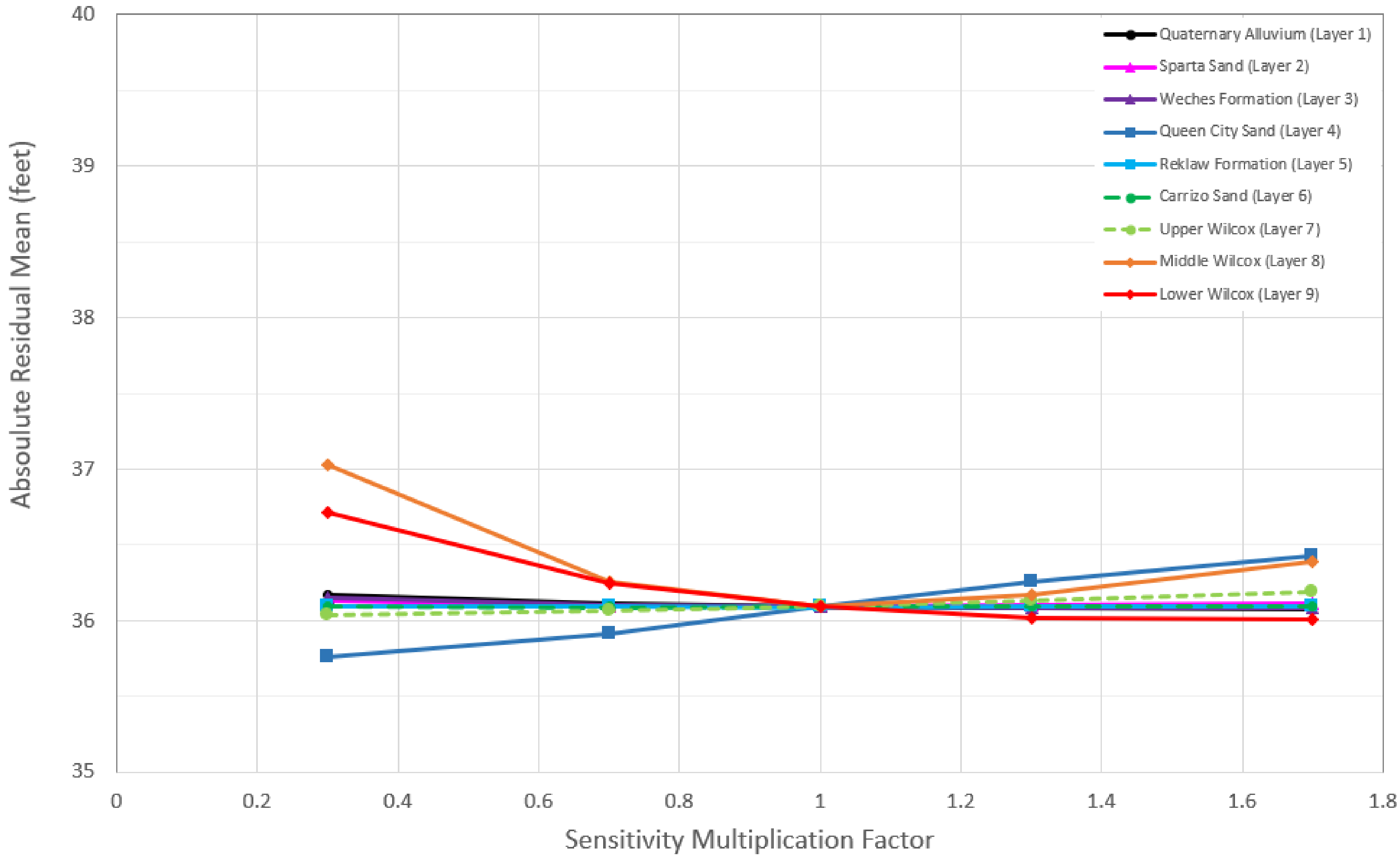


GSI ENVIRONMENTAL

GSI Job No. 4529	Drawn By: GM	
Issued: 17-Jun-2020	Chk'd By:	
Revised:	Aprv'd By:	
Scale:	Figure 3.4-1	

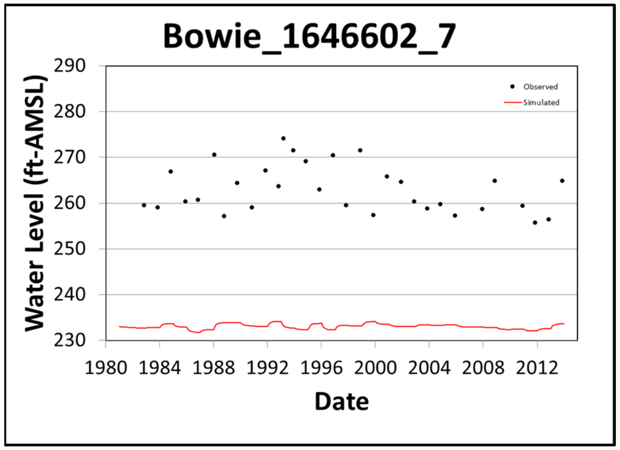
Water Budget for the 1980 to 2013 Calibration Simulation

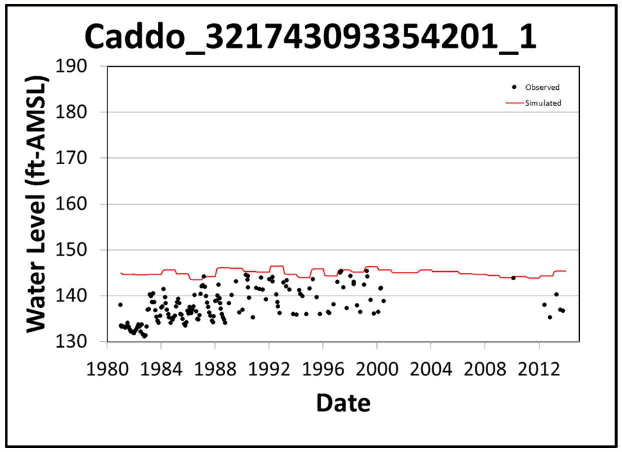
Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

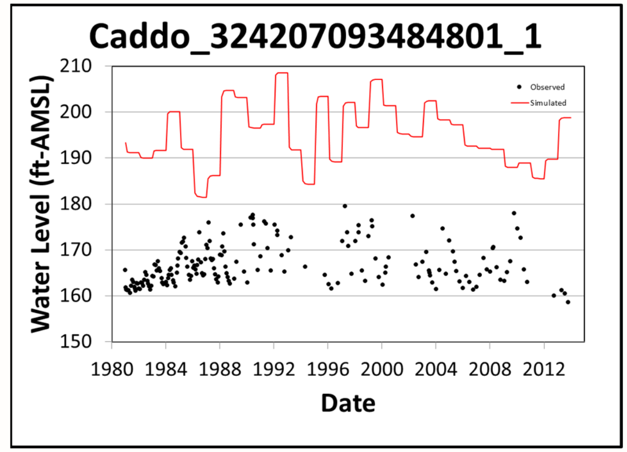


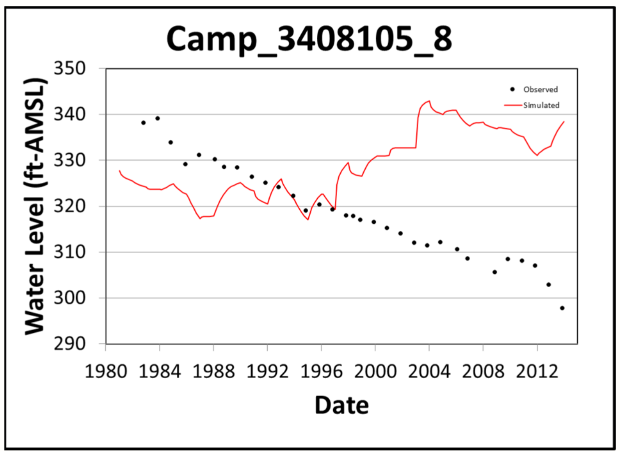
GSI ENVIRONMENTAL

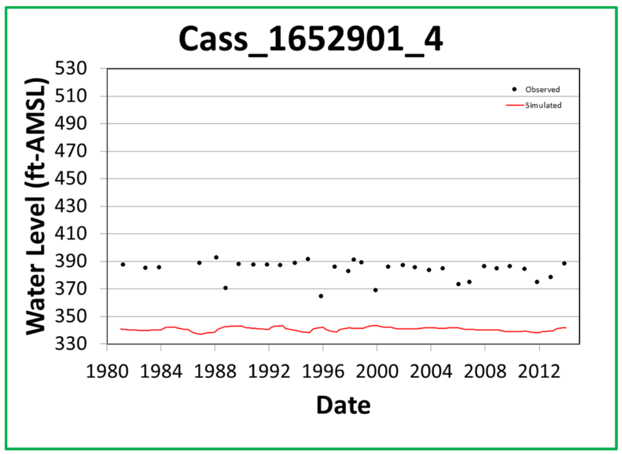
GSI Job No.	4529	Drawn By:	GM	**SENSITIVITY OF WEIGHTED MEAN HEAD ERROR TO THE SAND HYDRAULIC CONDUCTIVITY VALUE FOR THE VARIOUS GEOLOGIC UNITS**
Issued:	12-Jun-2020	Chk'd By:		
Revised:		Aprv'd By:	DRAFT	
Scale:		Figure 4.2-1		Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

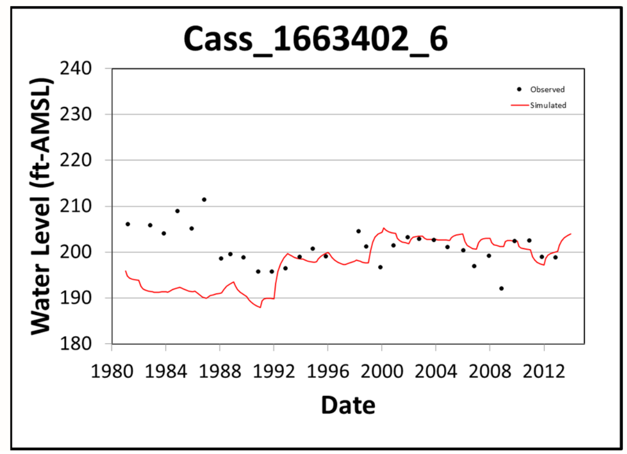












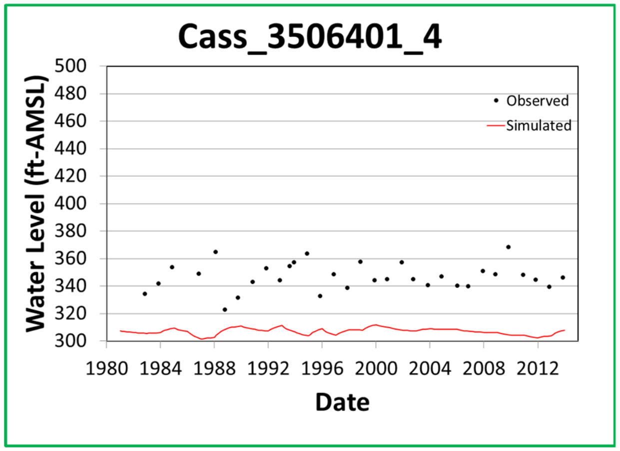
Notes:

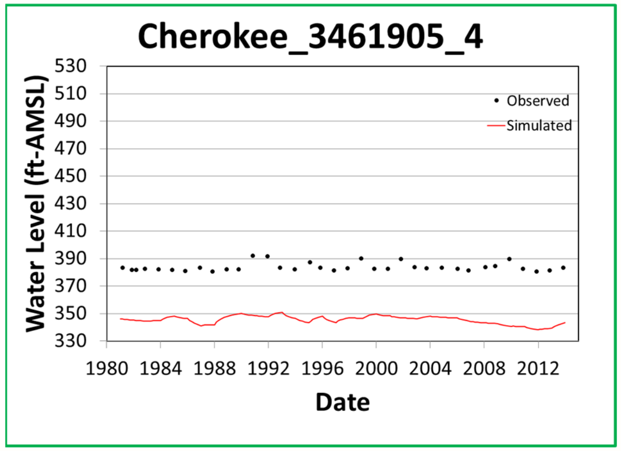
1. Select wells represent model targets with a dataset that is unweighted (data weights = 1).
2. Chart name: county name, well name, model layer; ft-AMSL = feet above mean sea level
3. Chart outline color Y-axis: yellow = 400 feet; green = 200 feet; black = 60 feet.

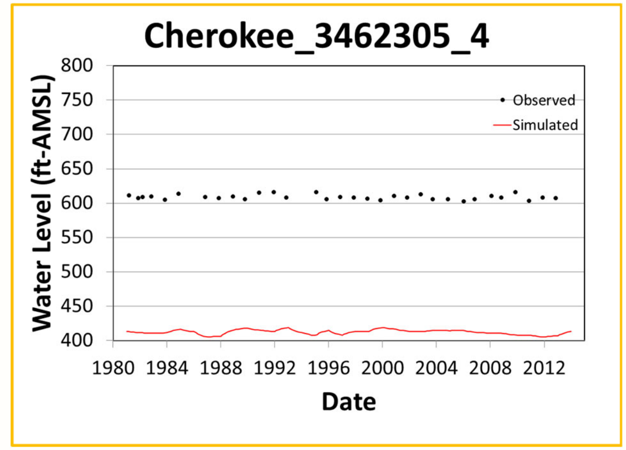
GSI ENVIRONMENTAL

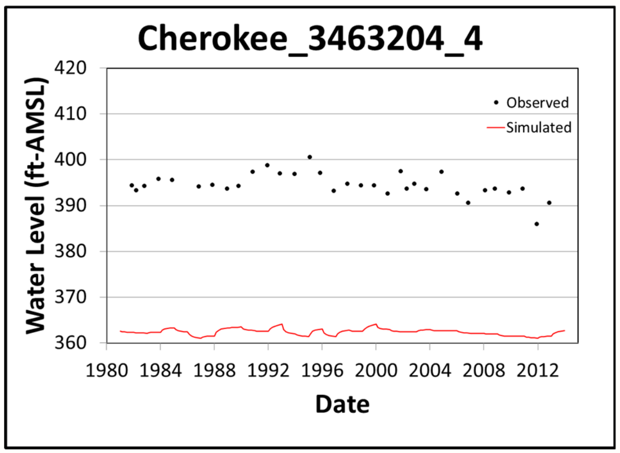
GSI Job No. 4529	Drawn By: HMH
Issued: 2020/07/09	Chk'd By:
Revised:	Aprv'd By:
Scale:	

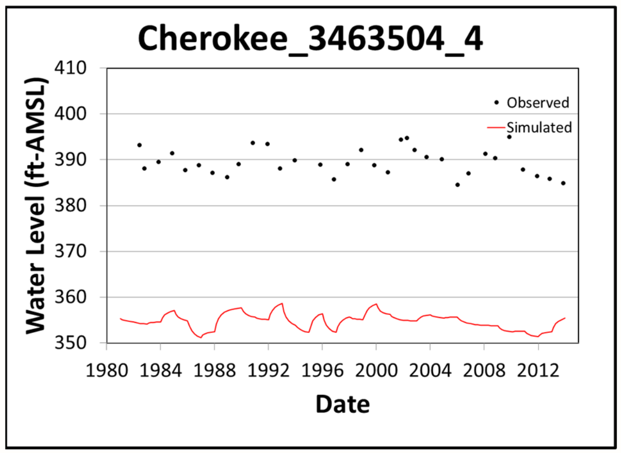
Appendix A – Hydrographs for Select Target Wells

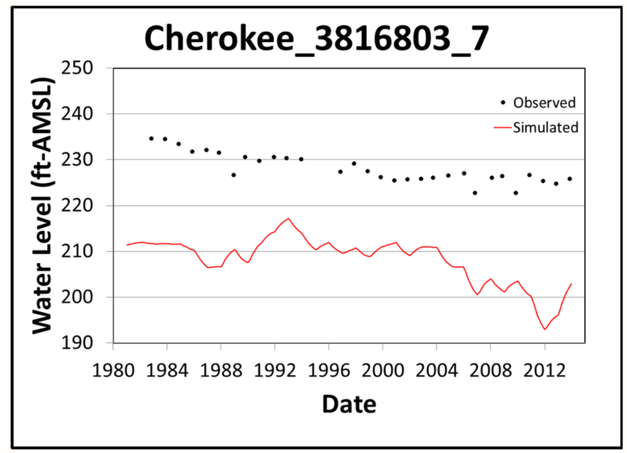












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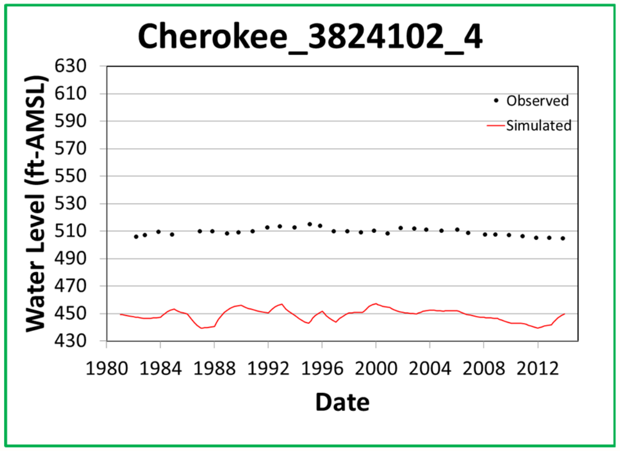
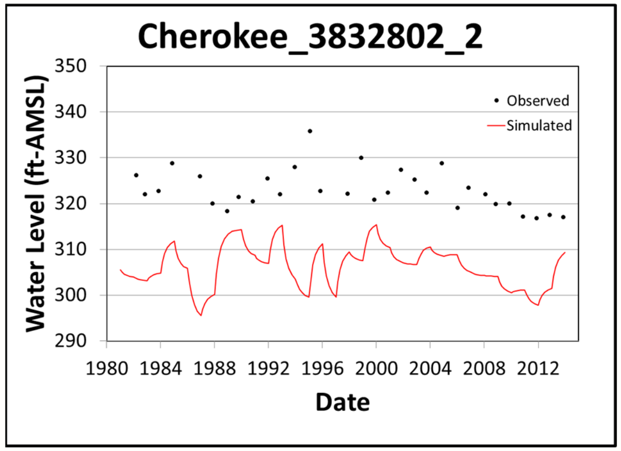
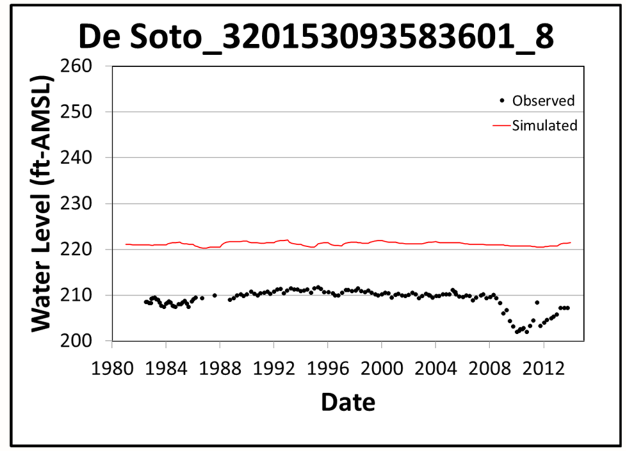
GSI ENVIRONMENTAL

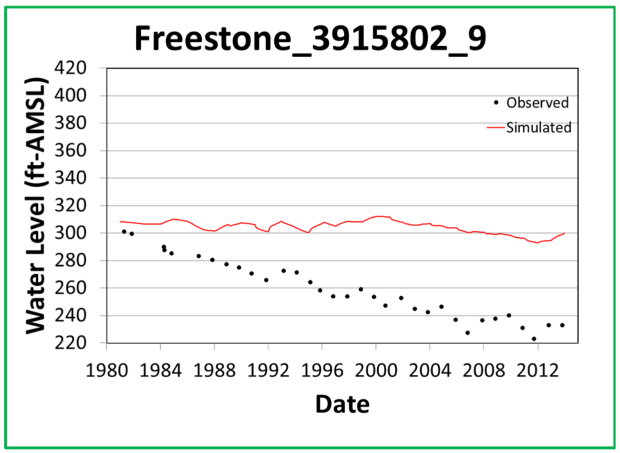
GSI Job No. 4529	Drawn By: HMH
Issued: 2020/07/09	Chk'd By:
Revised:	Aprv'd By:
Scale:	

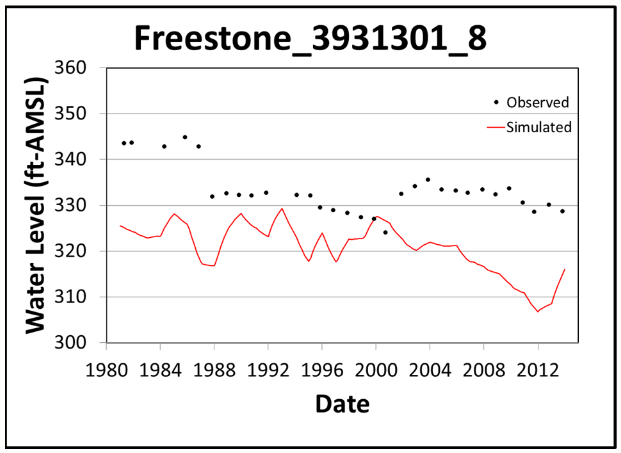
Appendix A – Hydrographs for Select Target Wells

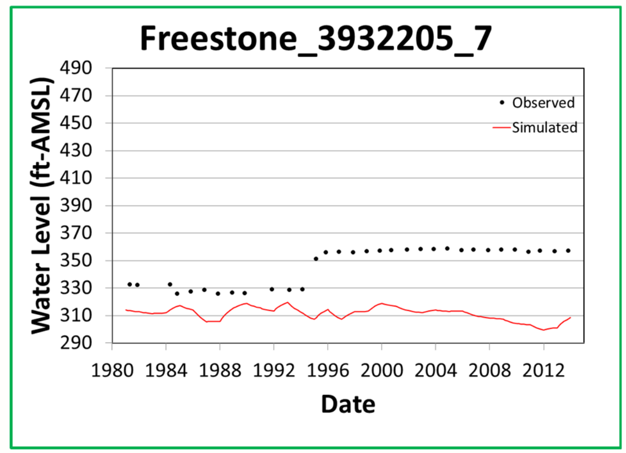












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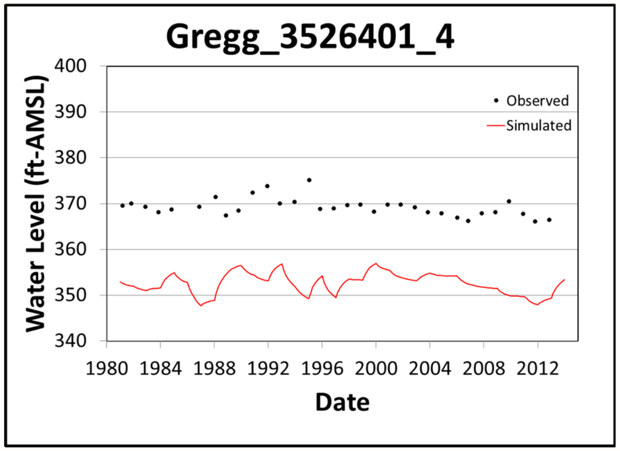
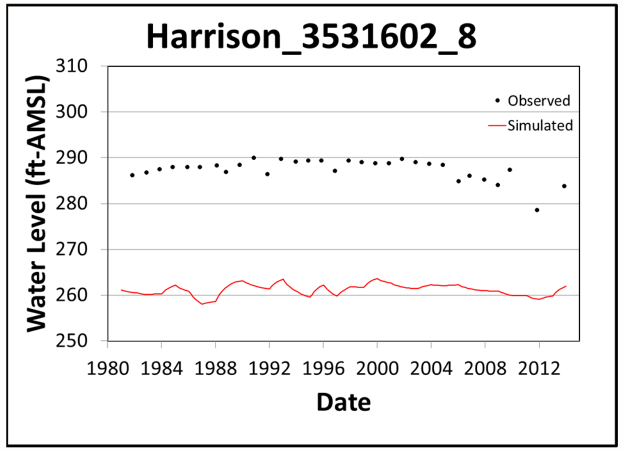
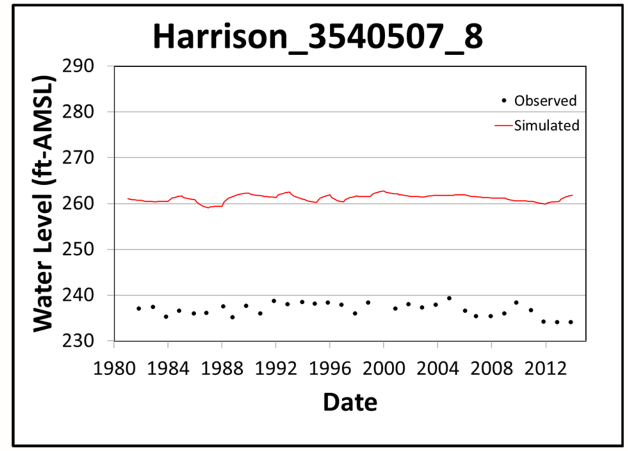
GSI ENVIRONMENTAL

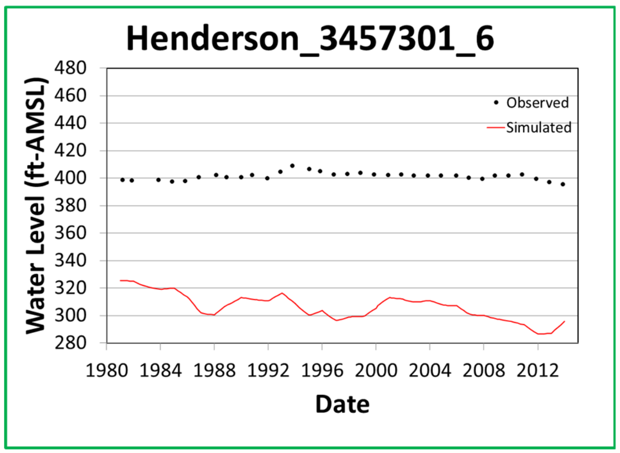
GSI Job No. 4529	Drawn By: HMH
Issued: 2020/07/09	Chk'd By:
Revised:	Aprv'd By:
Scale:	

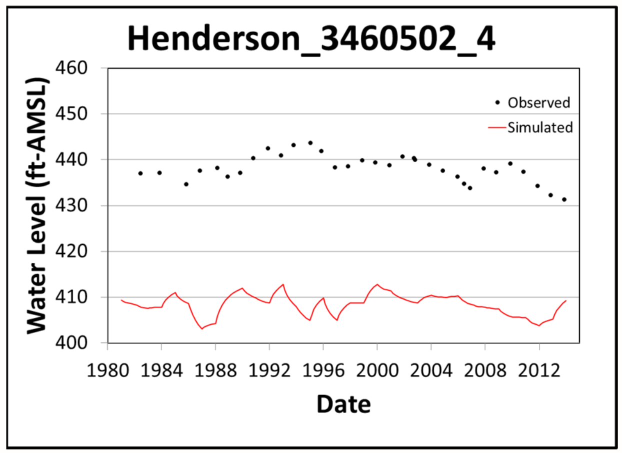
Appendix A – Hydrographs for Select Target Wells

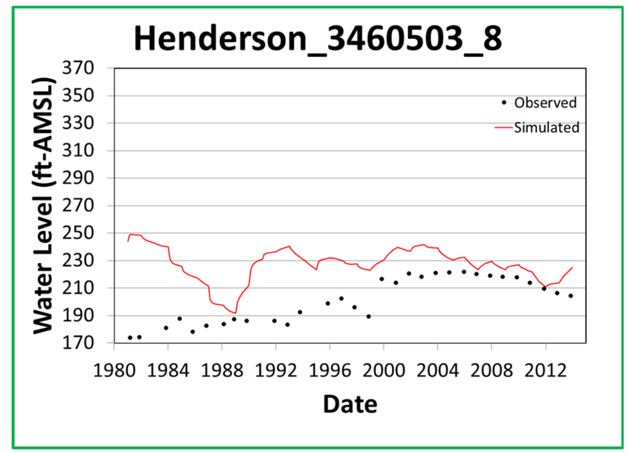












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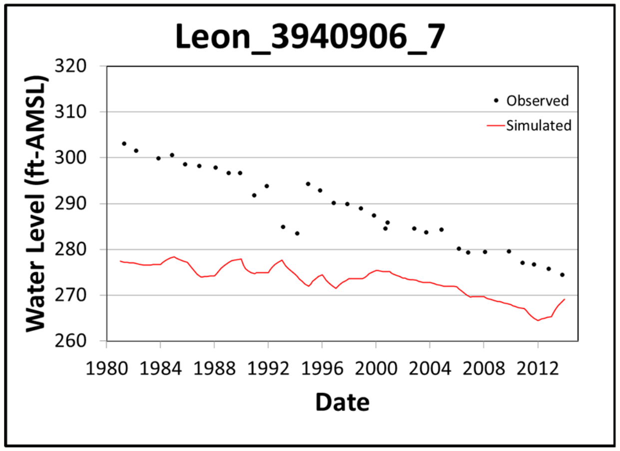
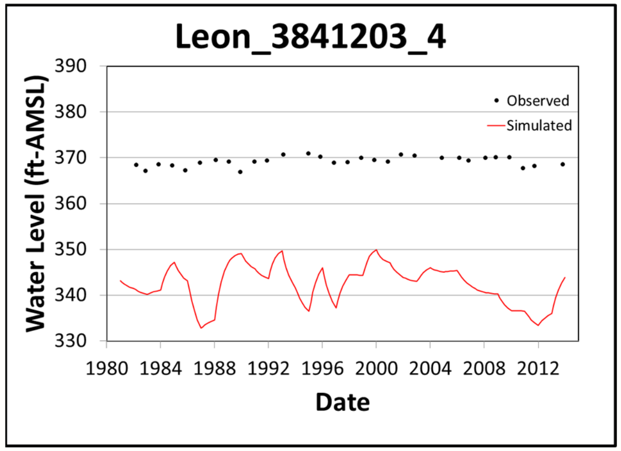
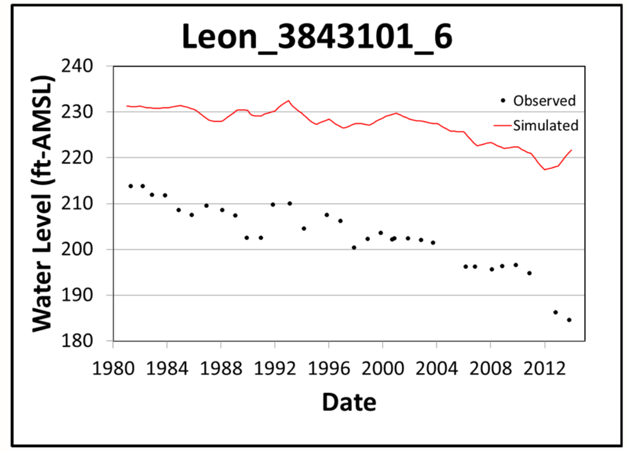
GSI ENVIRONMENTAL

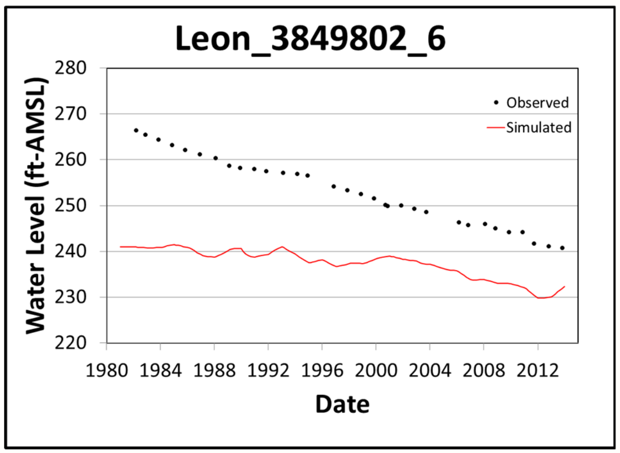
GSI Job No. 4529	Drawn By: HMH
Issued: 2020/07/09	Chk'd By:
Revised:	Aprv'd By:
Scale:	

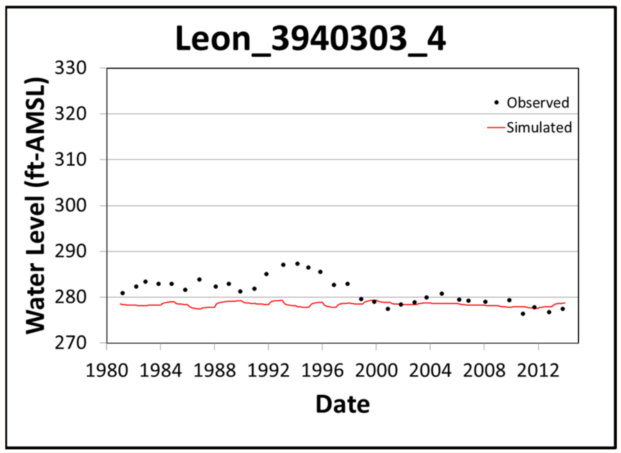
Appendix A – Hydrographs for Select Target Wells

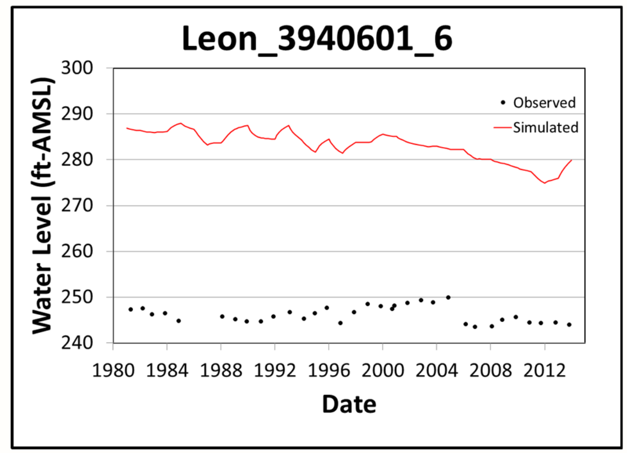












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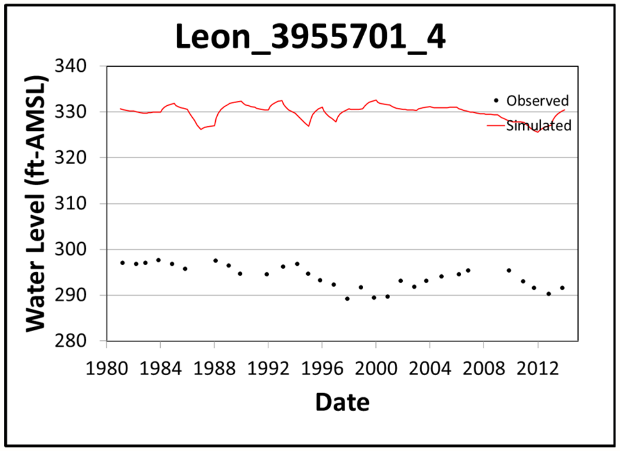
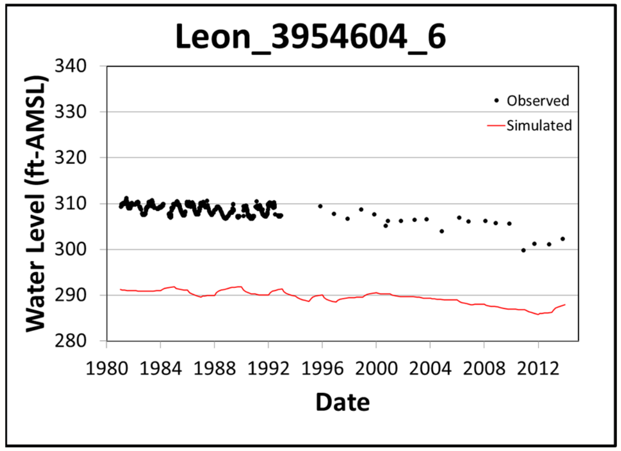
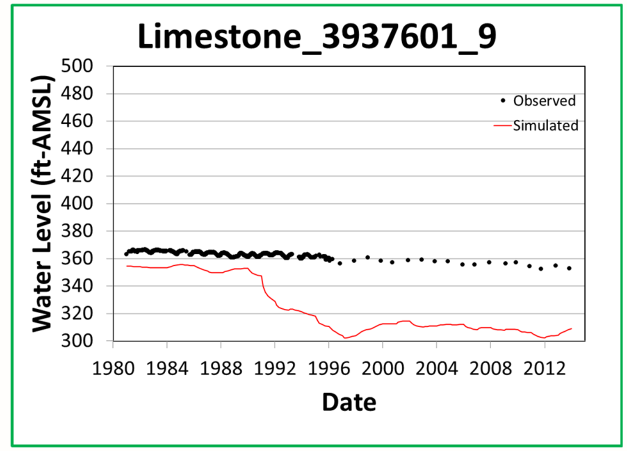
GSI ENVIRONMENTAL

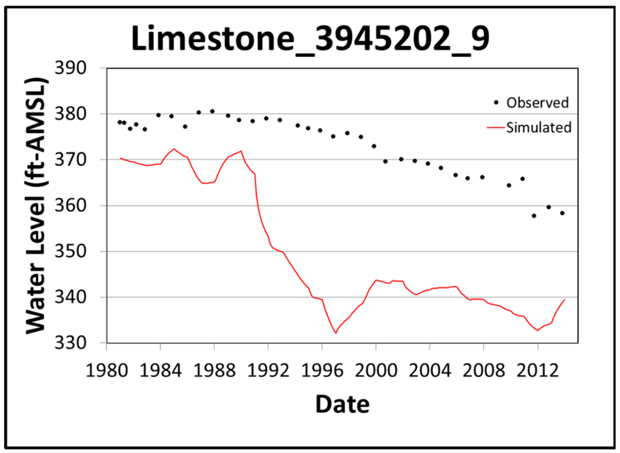
GSI Job No. 4529	Drawn By: HMH
Issued: 2020/07/09	Chk'd By:
Revised:	Aprv'd By:
Scale:	

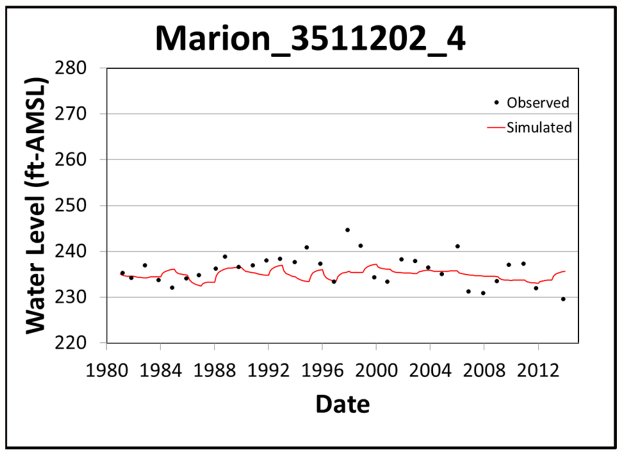
Appendix A – Hydrographs for Select Target Wells

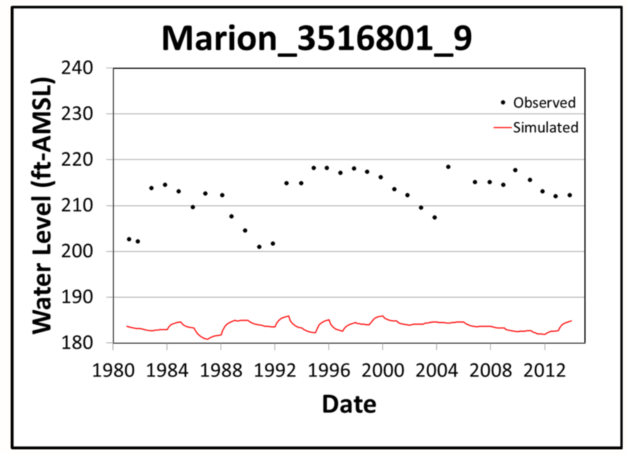












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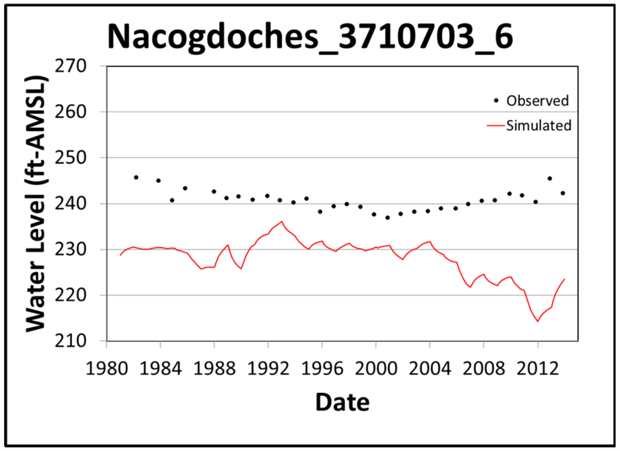
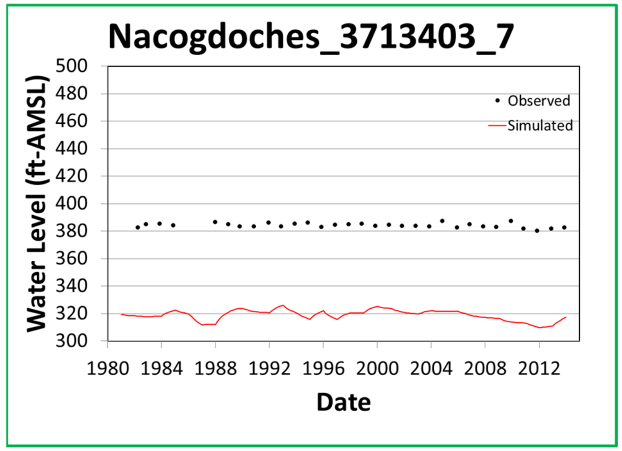
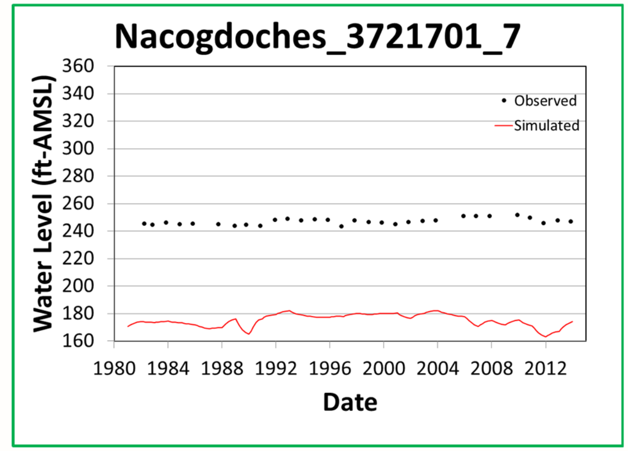
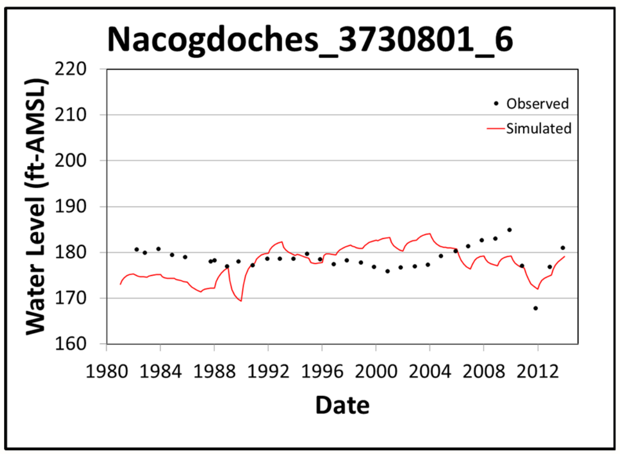
GSI ENVIRONMENTAL

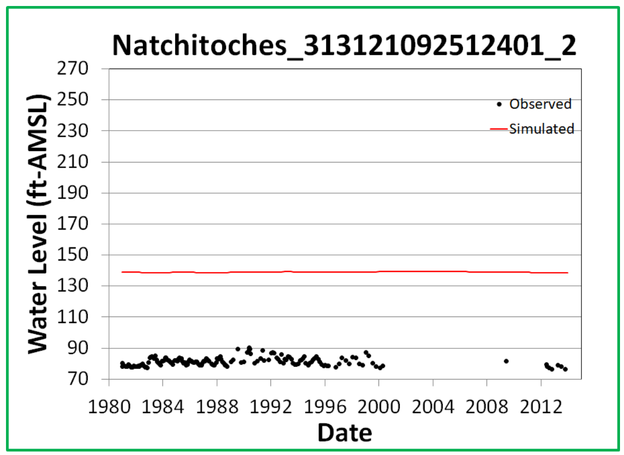
GSI Job No. 4529	Drawn By: HMH	**Appendix A – Hydrographs for Select Target Wells**
Issued: 2020/07/09	Chk'd By:	
Revised:	Aprv'd By:	
Scale:		

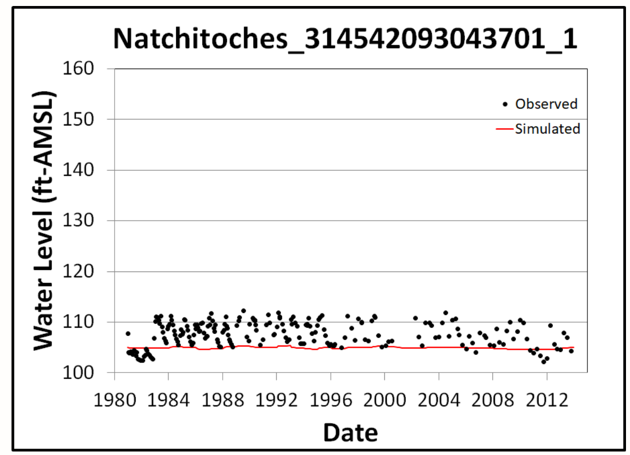












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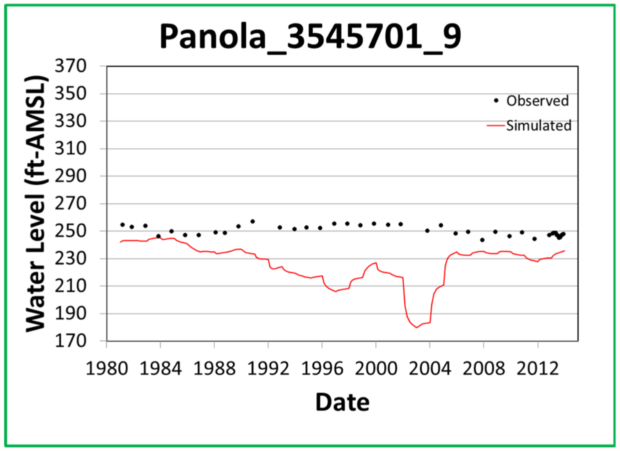
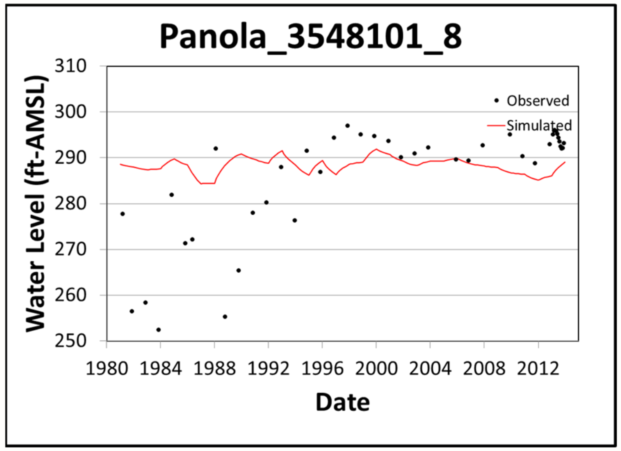
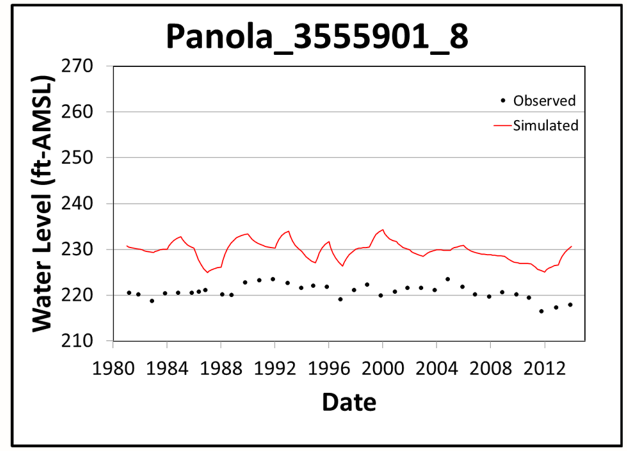
GSI ENVIRONMENTAL

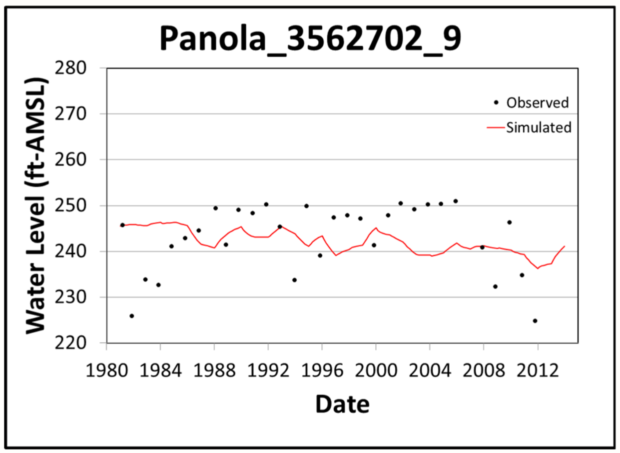
GSI Job No.	4529	Drawn By:	HMH
Issued:	2020/07/09	Chk'd By:	
Revised:		Aprv'd By:	
Scale:			

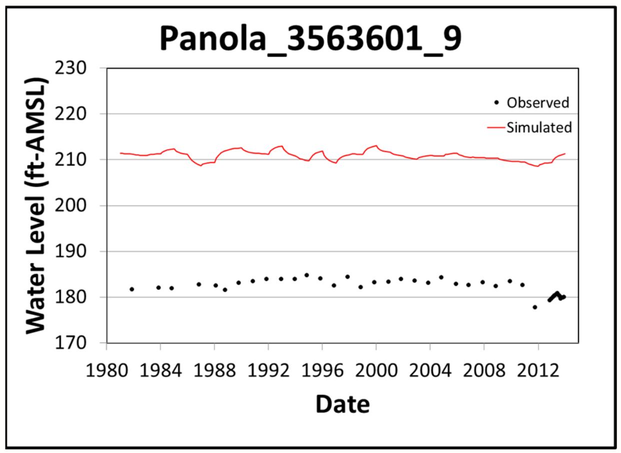
Appendix A – Hydrographs for Select Target Wells

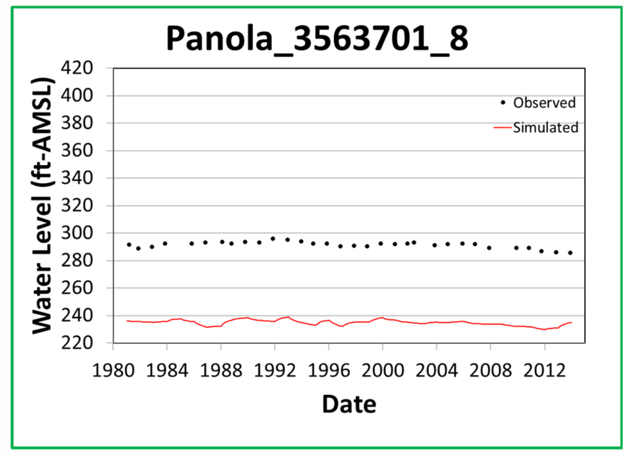












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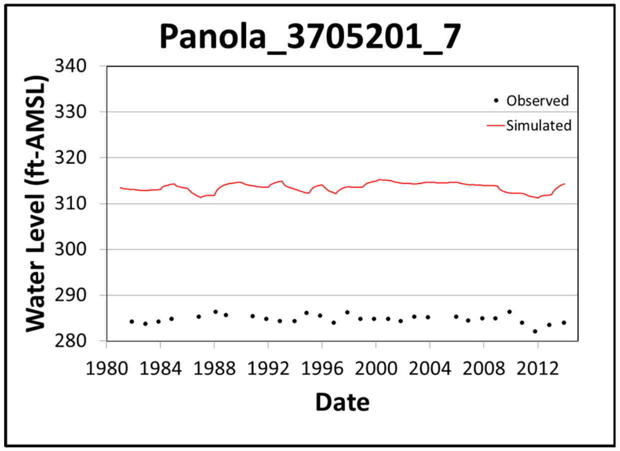
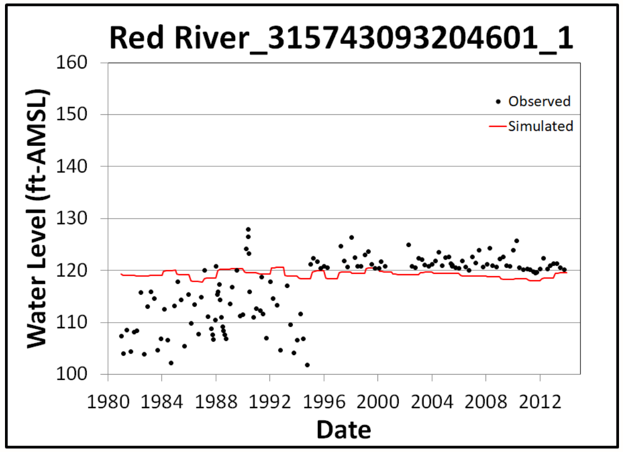
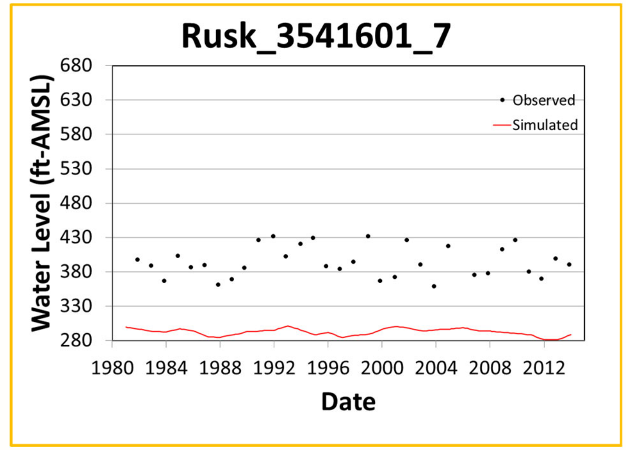
GSI ENVIRONMENTAL

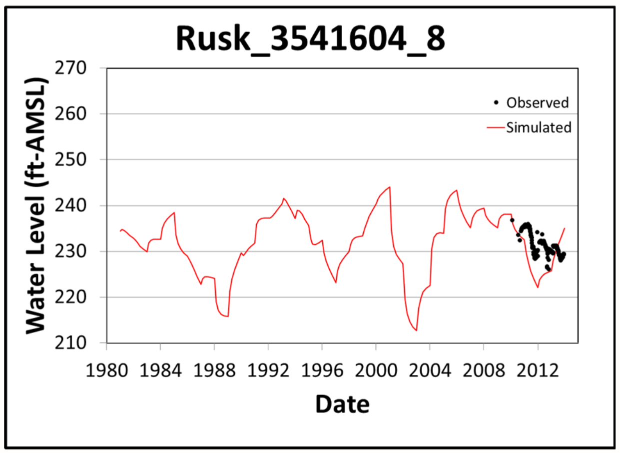
GSI Job No.	4529	Drawn By:	HMH
Issued:	2020/07/09	Chk'd By:	
Revised:		Aprv'd By:	
Scale:			

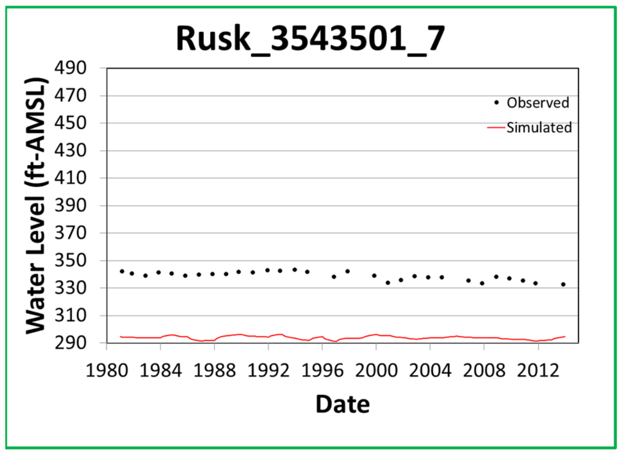
Appendix A – Hydrographs for Select Target Wells

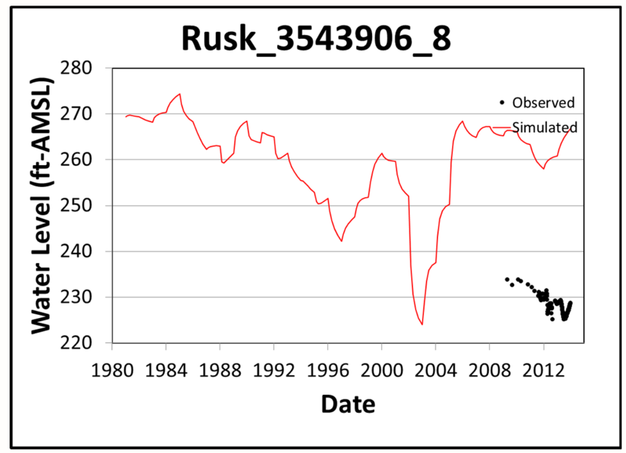












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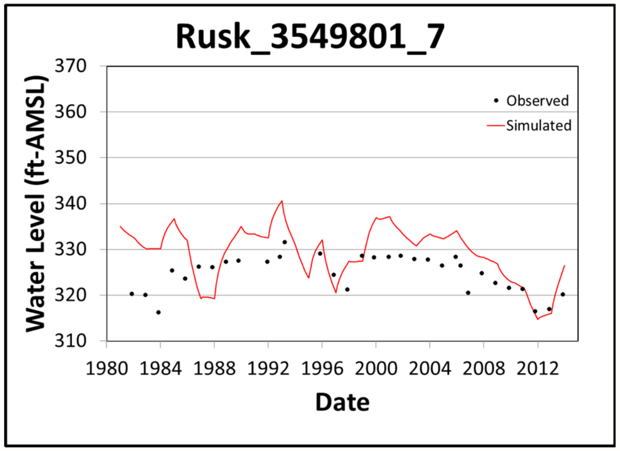
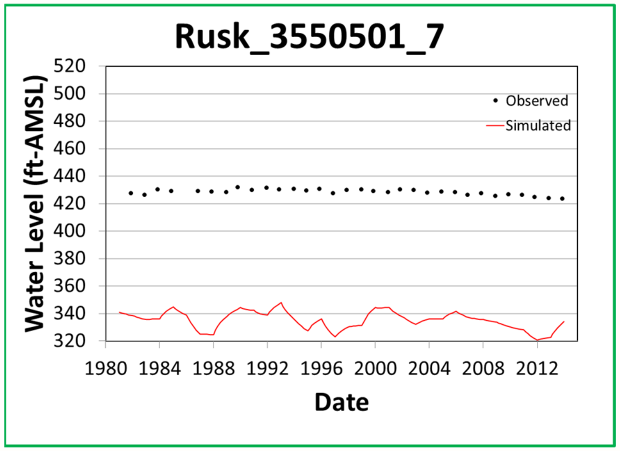
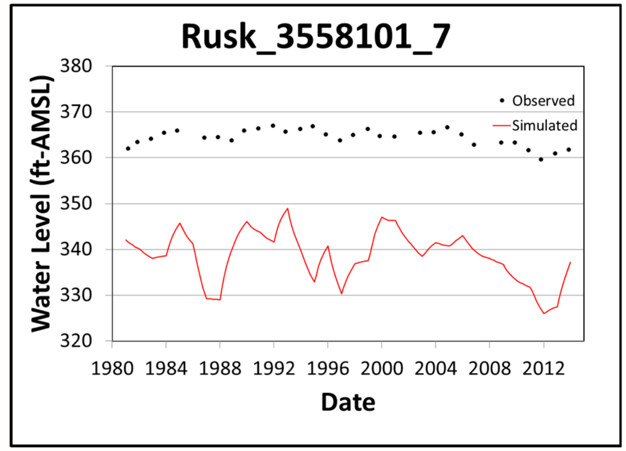
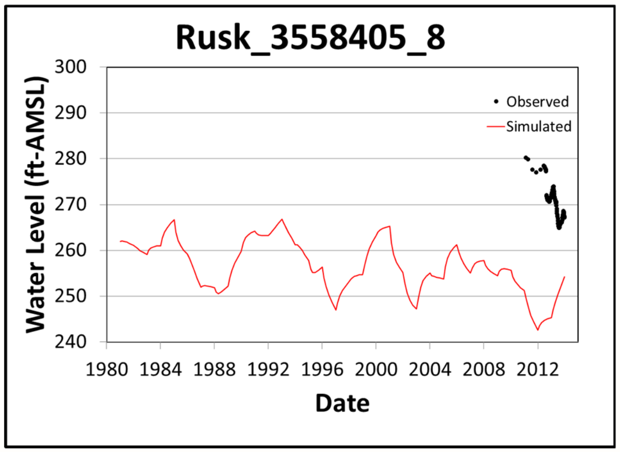
Issued:	2020/07/09	Chk'd By:	
Revised:		Aprv'd By:	
Scale:			

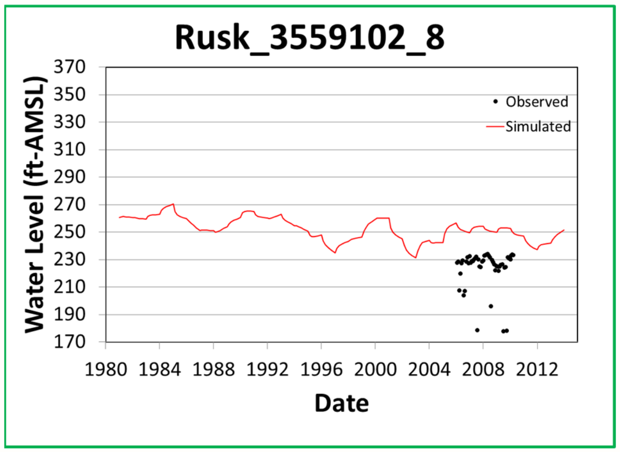
Appendix A – Hydrographs for Select Target Wells

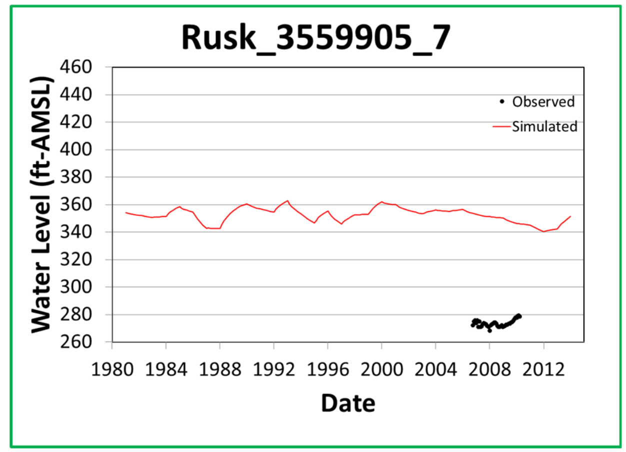












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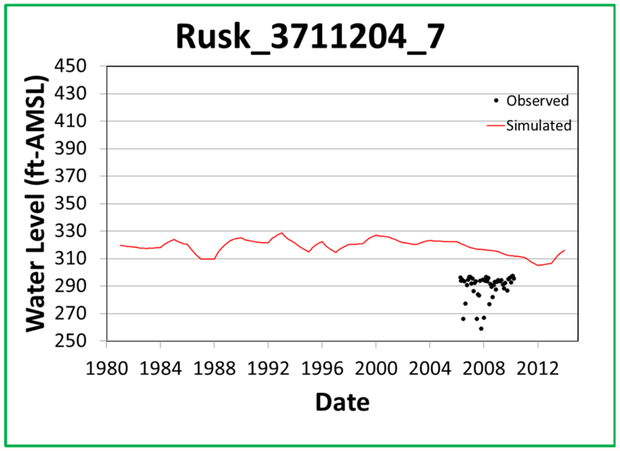

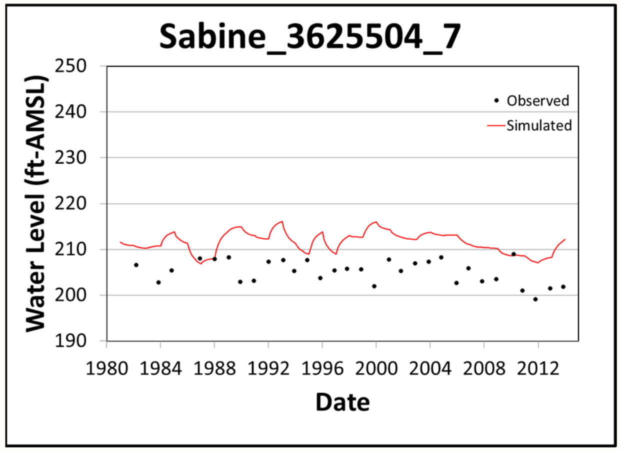

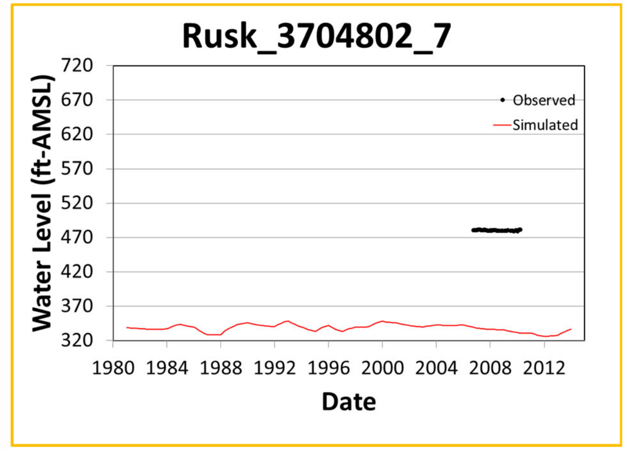

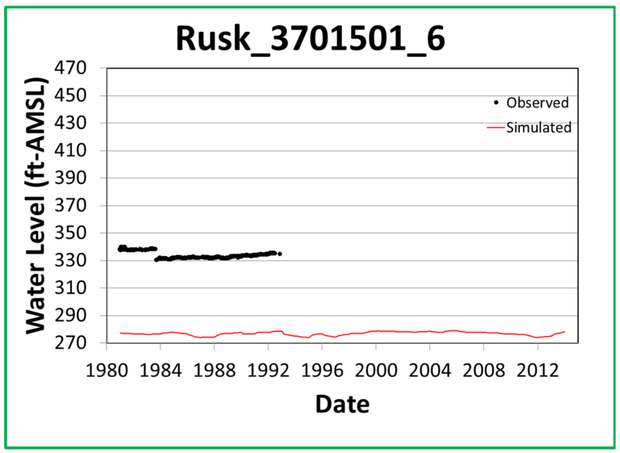

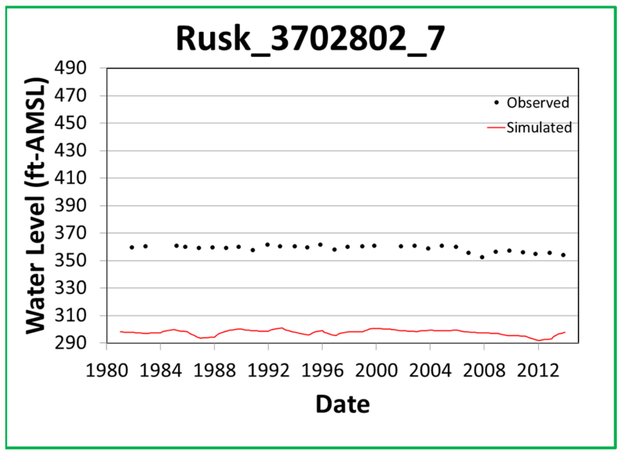

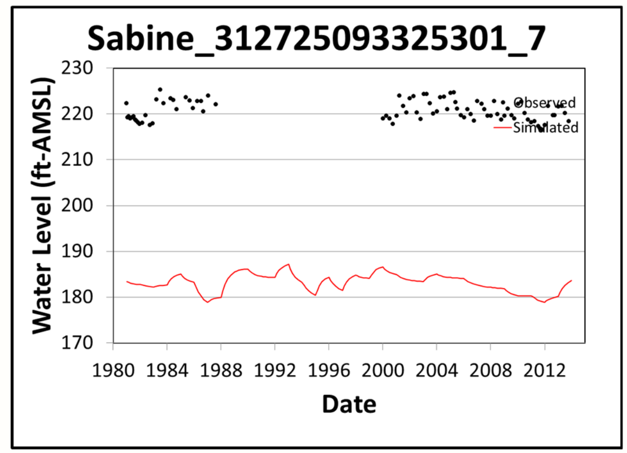

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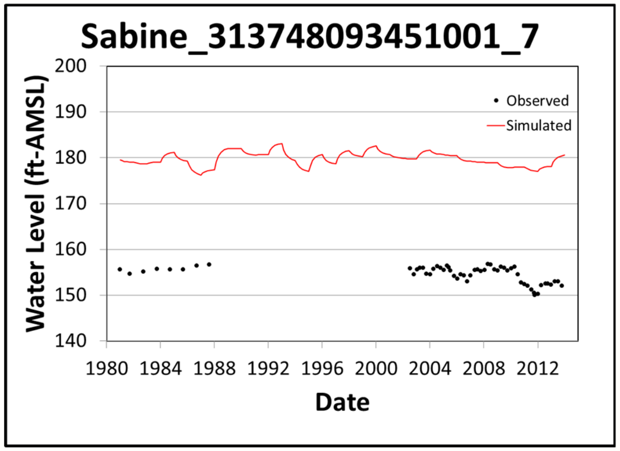

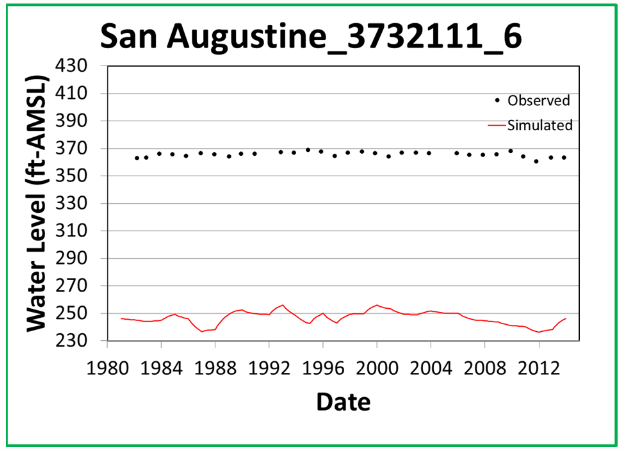

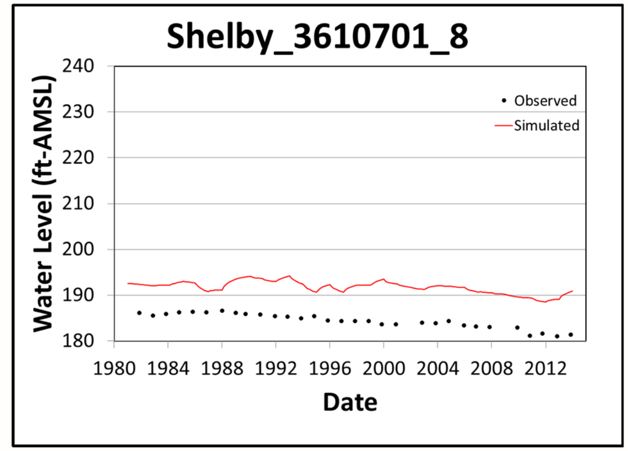

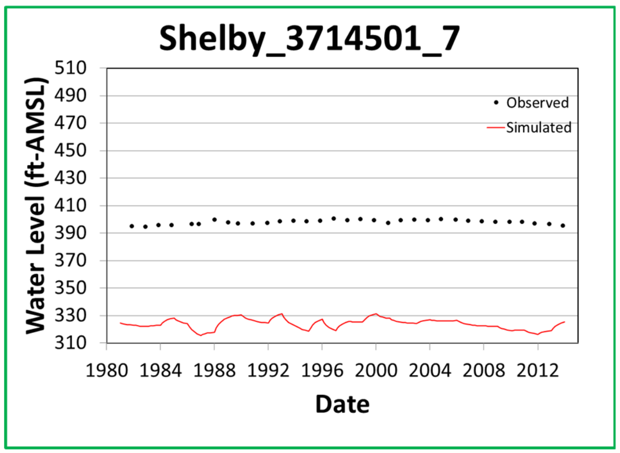

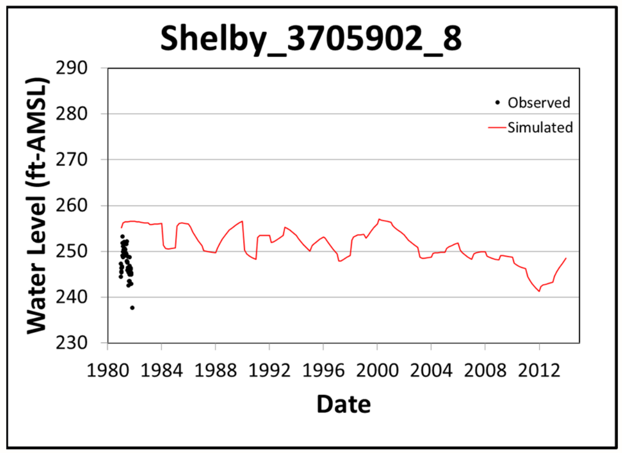

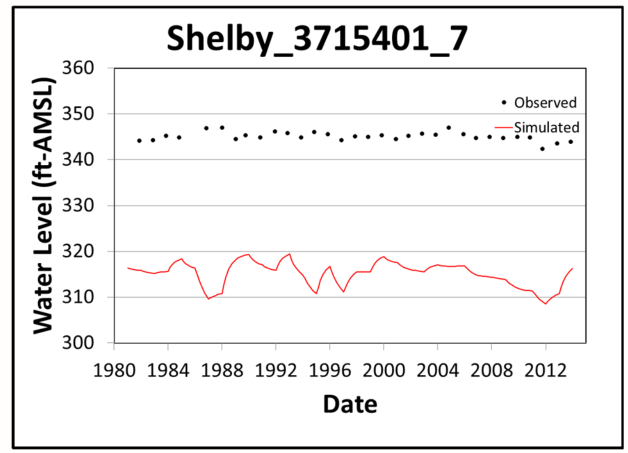

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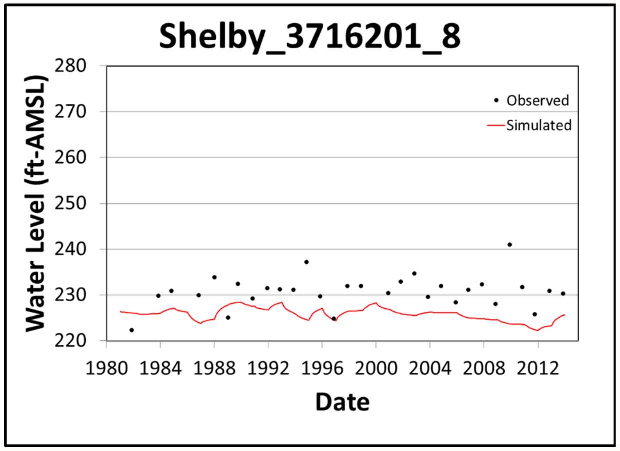

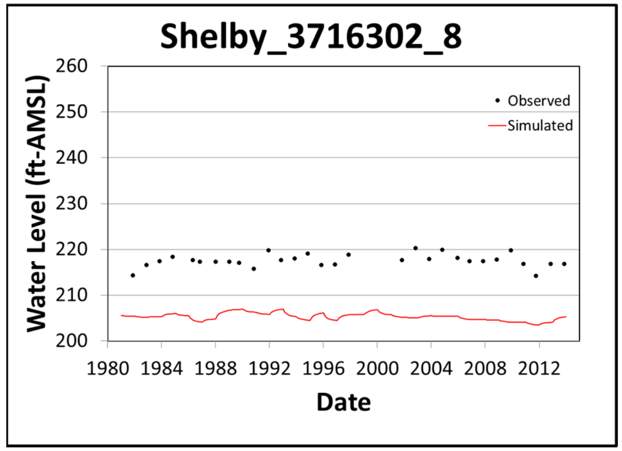

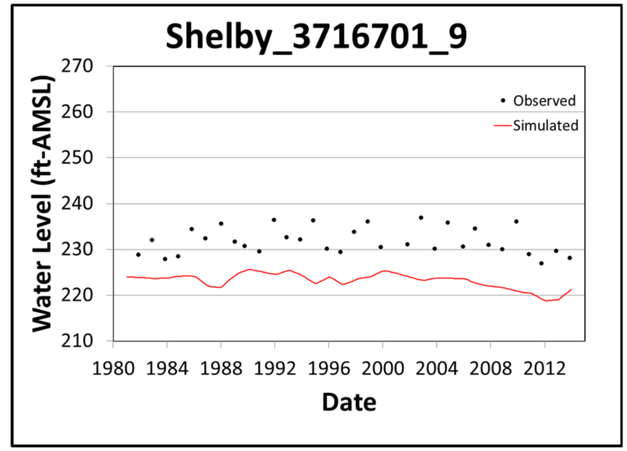

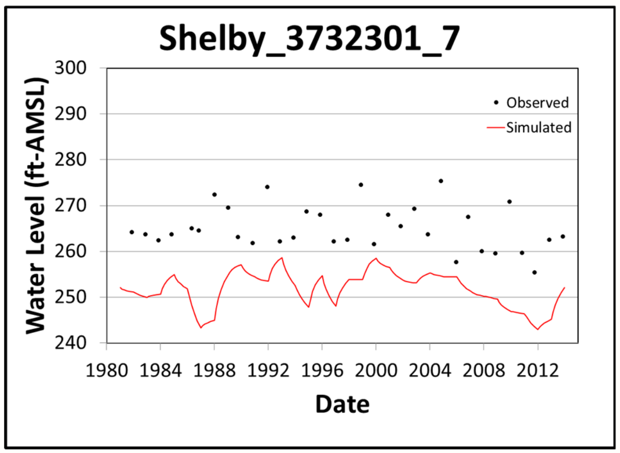

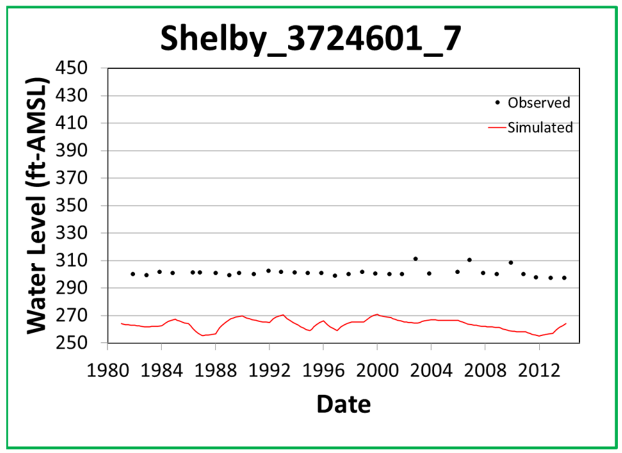

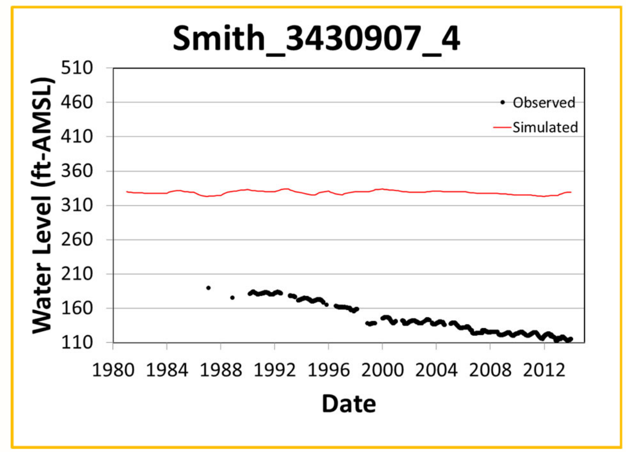

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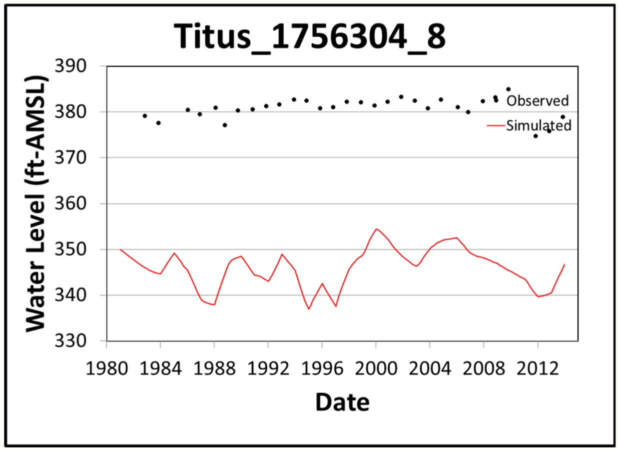

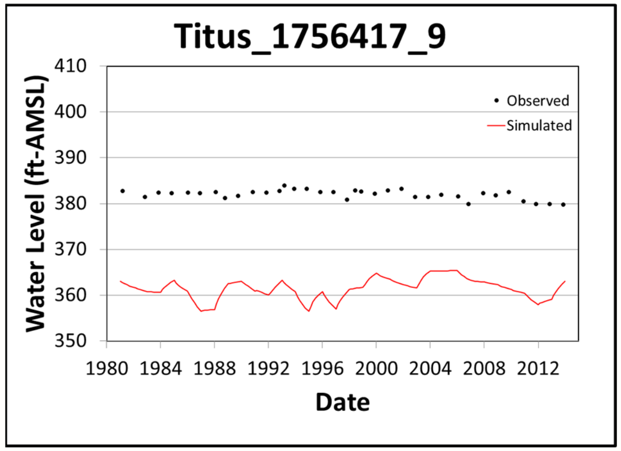

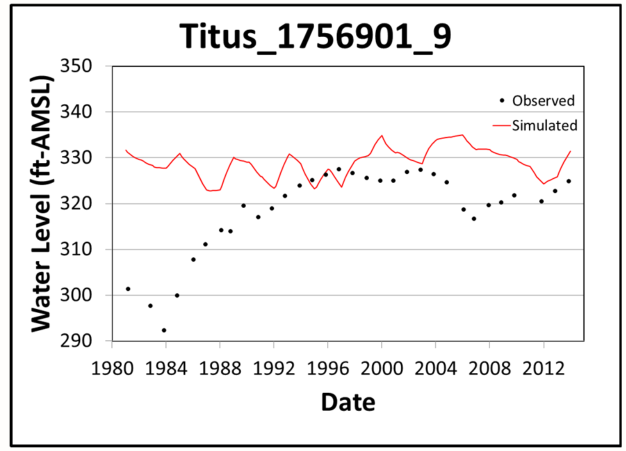

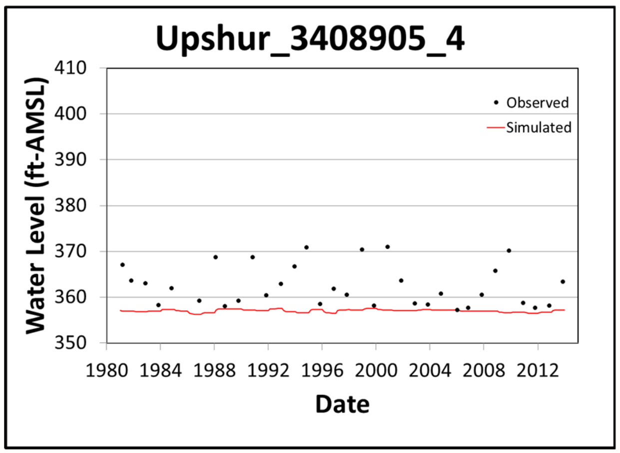

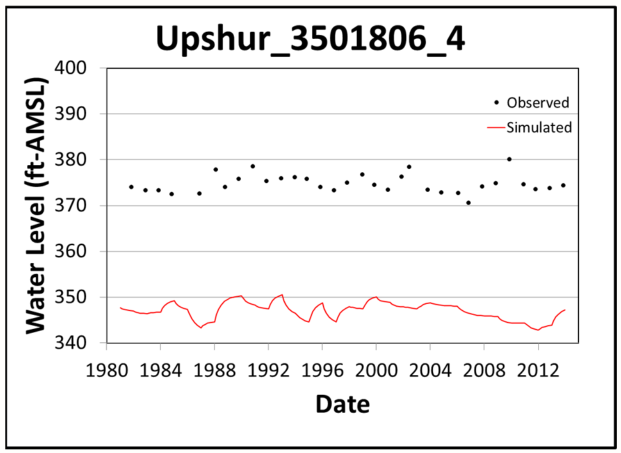

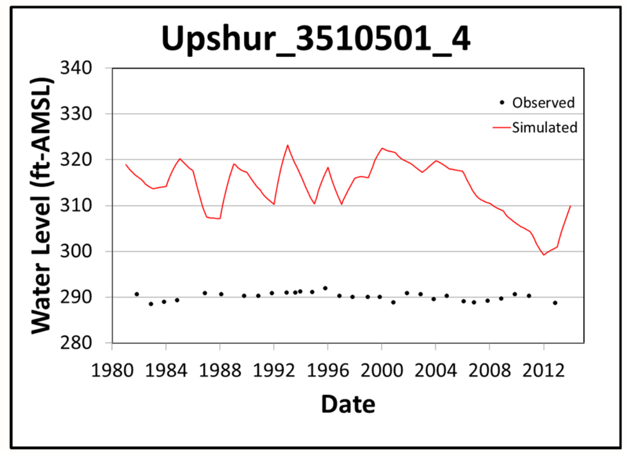

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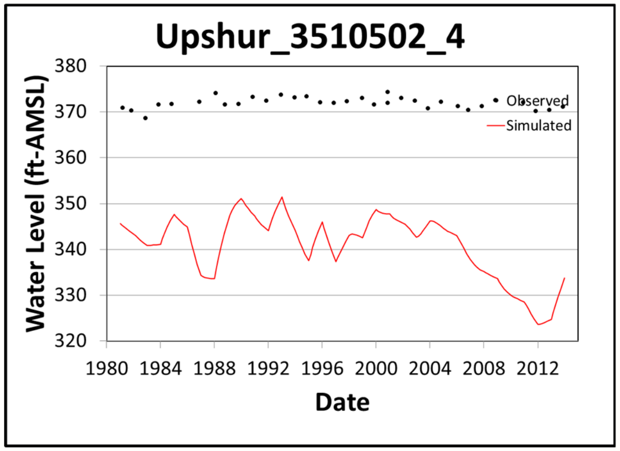

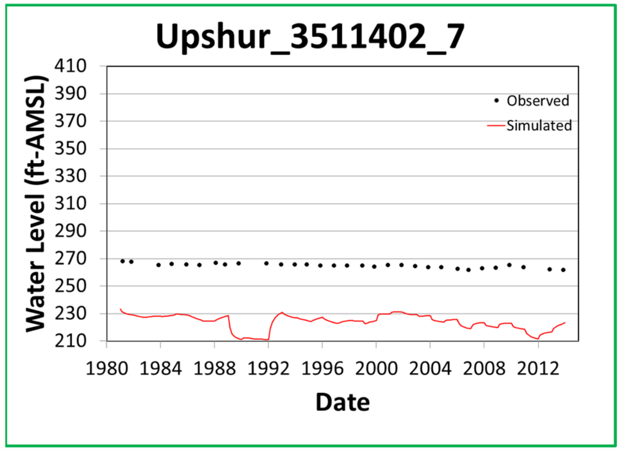

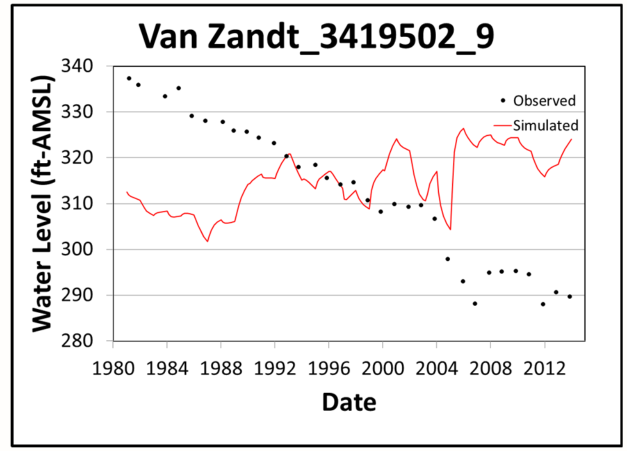

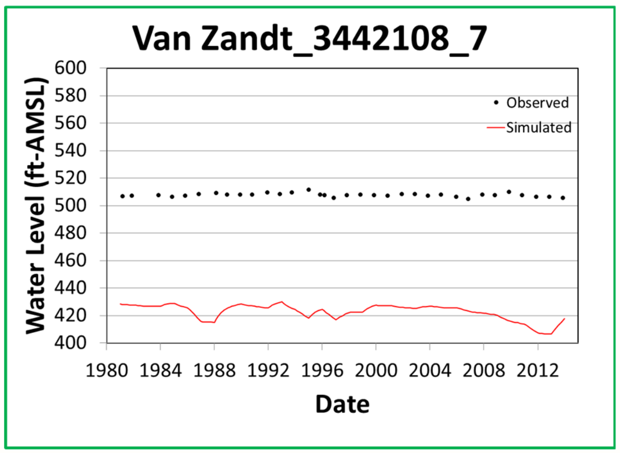

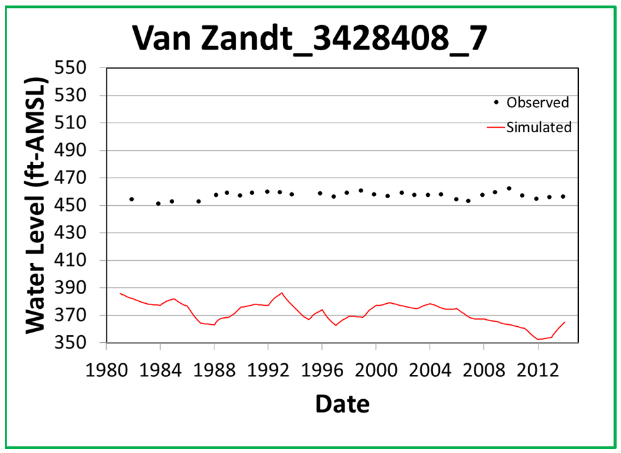

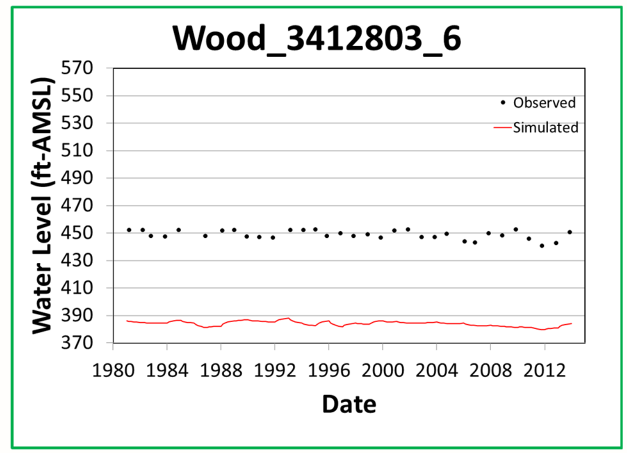

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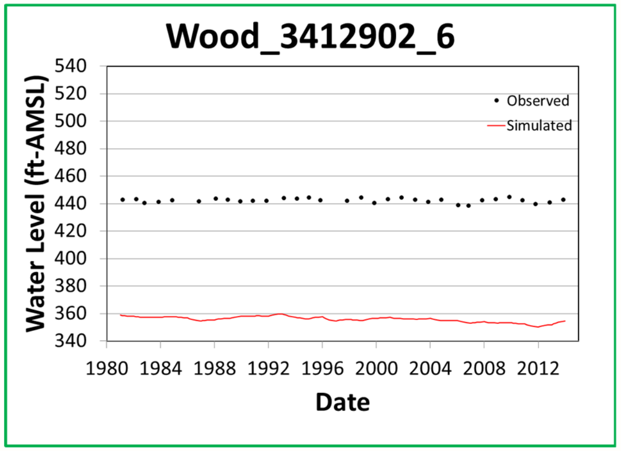

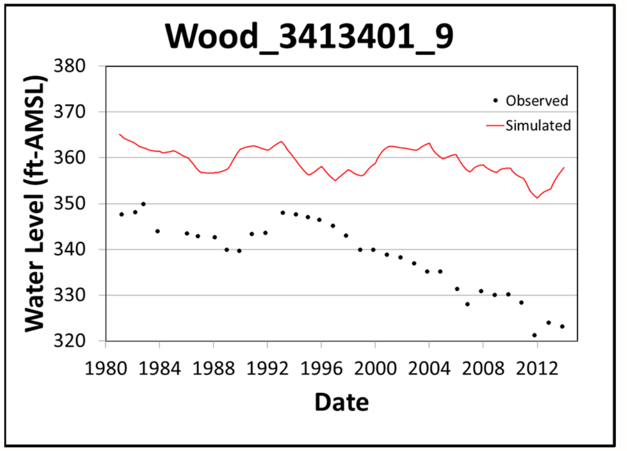

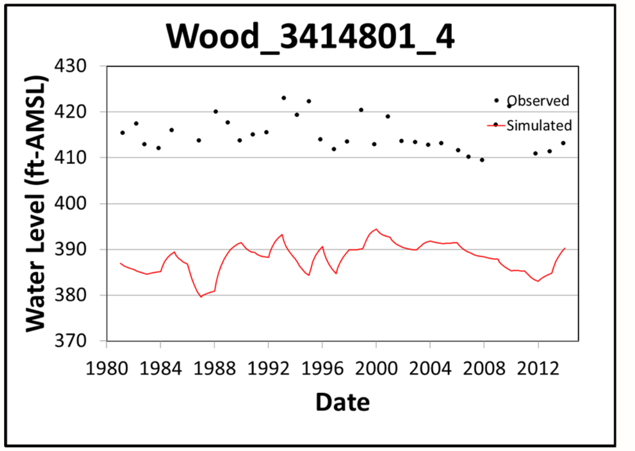

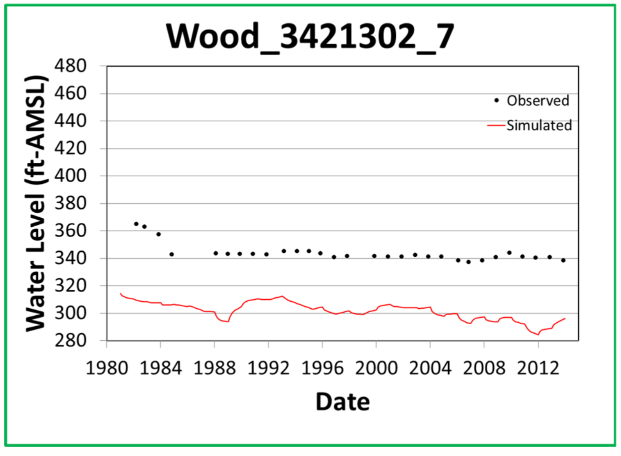

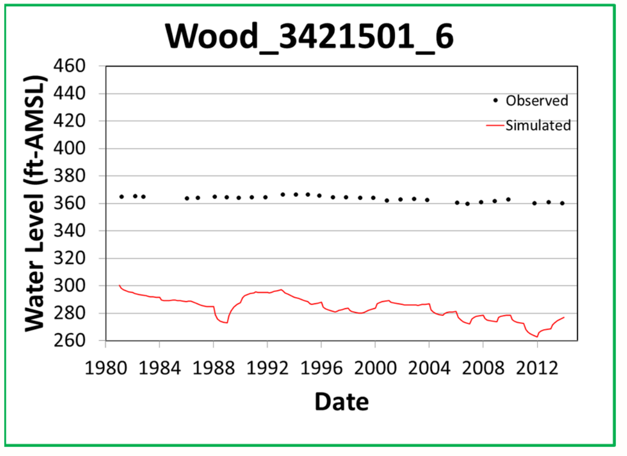

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Appendix A – Hydrographs for Select Target Wells

Draft Technical Memorandum 1

Pumping Sensitivity

Prepared for:

GSI Environmental, Inc.
9600 Great Hills Trail, Suite 350
Austin, TX 78759
512-346-4474

Prepared by:

William R. Hutchison, Ph.D., P.E., P.G.
Independent Groundwater Consultant
9305 Jamaica Beach
Jamaica Beach, TX 77554
512-745-0599
billhutch@texasgw.com

June 22, 2020

Draft Technical Memorandum 1

Professional Engineer and Professional Geoscientist Seals

This report was prepared by William R. Hutchison, Ph.D., P.E., P.G., who is licensed in the State of Texas as follows:

- Professional Engineer (Geological and Civil) No. 96287
- Engineering Firm Registration No. 14526
- Professional Geoscientist (Geology) No. 286

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Appendix

A – Comparison of Maximum Drawdown Difference – Pumping Sensitivity (one graph per model layer, each graph shows 27 counties)

Associated Files

***PumpScenHydrographs.pdf* (213 hydrographs of average drawdown for each county-model layer unit)**

1.0 Executive Summary

Four simulations were run with the updated Groundwater Availability Model to understand the sensitivity of average drawdown due to variation in pumping on a county-model layer basis. For each scenario, pumping was assumed to be constant during the entire predictive period (2014 to 2080). Recharge was assumed equal to steady state conditions (stress period 1 of the calibrated model) and did not vary during the simulation. Other time dependent boundary conditions (general head boundaries, evapotranspiration, and parameters for surface water-groundwater interaction) were also assumed constant and equal to steady state conditions (stress period 1 of the calibrated model).

Results were processed and graphically summarized in 213 hydrographs of average drawdown for each county-model layer unit (saved as a pdf file), and summarized in nine bar graphs that compare the maximum drawdown range during the calibration period and the predictive period for each model layer. Each bar graph shows all 27 counties of Groundwater Management Area 11 that are covered by the Groundwater Availability Model domain.

This analysis demonstrated that the limitations of the previous Groundwater Availability Model related to rising groundwater elevations during the predictive period have been addressed and eliminated. All graphs show an initial response to the change in pumping followed by a period where equilibrium is reached. Achieving an equilibrium condition is present in all 213 hydrographs developed and demonstrates the suitability of the model for the joint planning process.

2.0 Background

The desired future conditions for Groundwater Management Area 11 that were adopted on January 11, 2017 were documented in the Desired Future Condition Explanatory Report (Hutchison, 2017a). As noted in the Explanatory Report, the desired future conditions were based on Groundwater Availability Model (GAM) Scenario 4 as documented in Hutchison (2017b). The selection of Scenario 4 as the basis for the desired future condition was made by the groundwater conservation districts in Groundwater Management Area 11 after the review of the results of seven simulations using the Groundwater Availability Model (Hutchison, 2017c).

In developing the initial seven simulations, a base pumping amount for each county-aquifer unit was developed. This base pumping amount was based on future pumping based on regional water plan data and the proposed Forestar project. The analysis in Hutchison (2017c) included three simulations that sequentially increased the pumping above the base amount and three simulations that sequentially decreased the pumping below the base amount develop a practical analysis of the sensitivity of drawdown to various pumping amounts.

One of the uses of the updated Groundwater Availability Model documented in the main report will be to support the Joint Planning Process that leads to the adoption of desired future conditions by the groundwater conservation districts in Groundwater Management Area 11 and the calculation of the modeled available groundwater by TWDB. As part of the work associated with developing the updated Groundwater Availability Model, three technical memoranda appear in the Appendix of the report:

- Technical Memorandum 1: Pumping Sensitivity
- Technical Memorandum 2: Recharge Sensitivity
- Technical Memorandum 3: Calculation of Drawdown from Existing Modeled Available Groundwater Using Updated Groundwater Availability Model

This technical memorandum compares the average drawdown in each county-model layer unit under alternative assumptions of a base pumping amount. Specifically, the model calibration period is 1980 to 2013. Four alternative base pumping for the period 2014 to 2080 (the simulation period that will be used in simulations to support the joint planning process) were simulated: 2010, 2011, 2012, and 2013.

3.0 Parameters and Assumptions

The updated Groundwater Availability Model was calibrated with data from 1980 to 2013. Pumping by layer is graphically summarized in Figure 1. Please note that pumping in Layer 6 (Carrizo Aquifer) generally increases through the calibration period. Pumping in Layers 7 and 8 (Upper Wilcox and Middle Wilcox, respectively), while lower than the pumping in Layer 6 also increases during the calibration period. Pumping in the other layers is generally low and generally constant during the calibration period.

Figure 2 is a graphical summary of pumping by layer, but only for the years 2010 to 2013 (i.e. the last four years of the calibration period).

Pumping during the final year of the calibration period (2013) in Layers 6, 7, and 8 decreases from the 2012 pumping in each layer. If 2013 is used as the base pumping period and held constant for the entire simulation for predictive simulations through 2080, it is likely that groundwater elevations will initially increase since 2013 pumping is less than immediately previous years. Conversely, if 2011 is used as the base pumping period and held constant for the entire simulation for predictive simulations through 2080, it is likely that groundwater elevations will initially decline since 2011 pumping is more than immediately previous years.

Four simulations were run to evaluate the impact of different base pumping (i.e. constant pumping) on drawdown in each county-layer unit. The model files used for this practical sensitivity analysis are described below.

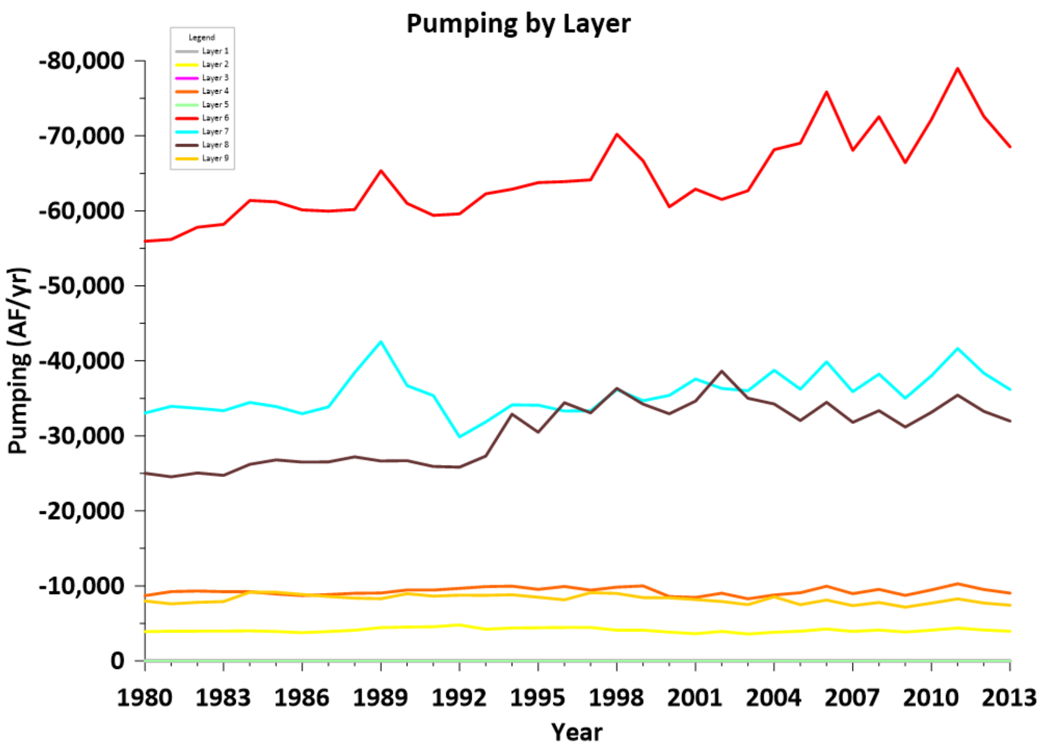


Figure 1. Layer Pumping from Calibrated Model (1980 to 2013)

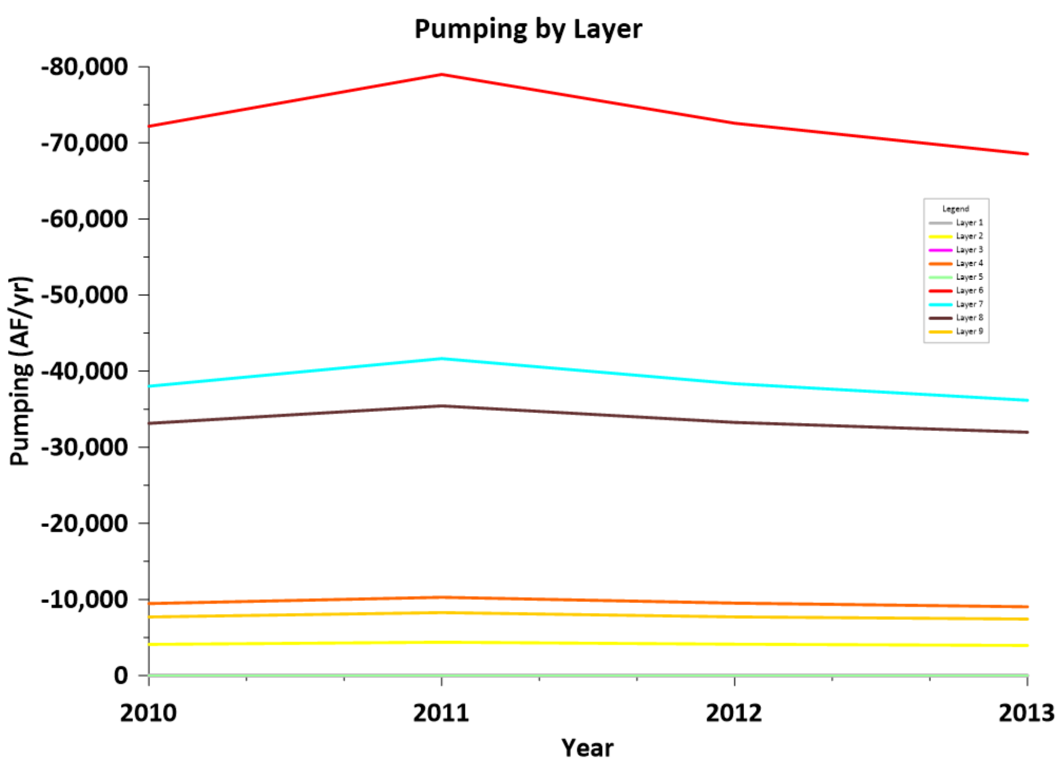


Figure 2. Layer Pumping from Calibrated Model (2010 to 2013)

3.1 Files Unchanged from Calibrated Model

Files that contain model input parameters related to the model grid and aquifer parameters were the same as the files used in the calibrated model as shown in Table 1.

Table 1. Predictive Model Files Unchanged from Calibrated Model

File Name	File Date	Description
findd.disu	4/10/2020	Spatial Discretization
findd.ims	4/10/2020	Solver Parameters
finddd.npf	4/10/2020	Node Property Flow
tr58_g.kx	4/10/2020	Horizontal Hydraulic conductivity
tr58_g.kz	4/10/2020	Vertical Hydraulic Conductivity
tr58_g.ss	4/10/2020	Specific Storage
tr58_g.sy	4/10/2020	Specific Yield

3.2 Time Discretization and Storage

The predictive simulation was run for the period 2014 to 2080, a total of 67 annual stress periods. The calibrated model included a steady-state stress period at the beginning of the simulation. Thus, the DISU file was modified to reflect 67 annual stress periods and named *finddd.tdis*. The specification of steady state or transient stress period in MODFLOW 6 is contained in the STO file. This file was updated and named *finddd.sto.*

3.3 Groundwater Pumping (WEL Package)

This set of predictive simulations included evaluating the effect of alternative base pumping amounts from 2014 to 2080. The FORTRAN program *makebasepump.exe* was written to develop four model input files of pumping. The program reads the calibrated model file *tr58_g.wel*, which contains cell-by-cell pumping amounts from 1980 to 2013. The program then writes four files as follows:

- *pump2010.wel* specifies 2010 pumping for 2014 to 2080
- *pump2011.wel* specifies 2011 pumping for 2014 to 2080
- *pump2012.wel* specifies 2012 pumping for 2014 to 2080
- *pump2013.wel* specifies 2013 pumping for 2014 to 2080

3.4 Evapotranspiration (EVT Package)

The FORTRAN program *makeevt.exe* was written to develop a model input file for evapotranspiration. Inspection of the calibrated model input file for evapotranspiration (*tr58_g.evt*) shows that the same evapotranspiration parameters were used for each stress period of the calibration period (1980 to 2013). The program simply extracts the first stress period of the calibration period and writes it to a new file named *finddd.evt*.

3.5 General Head Boundaries (GHB Package)

The FORTRAN program *makeghb.exe* was written to develop a model input file for the general head boundaries, which were implemented to simulate the effects of overlying formations that are not formally part of the model domain.

Inspection of the calibrated model input file for general head boundaries (*tr58_g.ghb*) shows that the same general head boundary parameters were used for each stress period of the calibration period (1980 to 2013). The program simply extracts the first stress period of the calibration period and writes it to a new file named *finddd.ghb*.

3.6 Recharge (RCH Package)

The recharge input file *tr58_g.rch* contains the cell-by-cell recharge amounts for each stress period of the calibrated model (1980 to 2013). Recharge was implemented by defining a steady-state recharge (applied to stress period 1) and applying a stress period-specific factor to increase or decrease the recharge for each stress period. The first stress period of recharge was extracted from the calibrated model input file using a FORTRAN program named *makerch.exe*. The output file saved as *finddd.rch.*

3.7 River (RIV Package)

The calibrated model simulated surface water-groundwater interactions with the River (RIV) package specified in the file *tr58_g.rch*. Inspection of the input file yielded the conclusion that RIV head values changed slightly for each stress period. River conductance and bottom elevations remained the same in all stress periods.

The FORTRAN program *makeriv.exe* was written to extract the first stress period of RIV parameters for the predictive simulations and hold them constant for all stress periods. The output file from this program is *finddd.riv.*

3.8 Other Input Files

Other files that were developed for these predictive simulations are summarized in Table 2.

Table 2. Other Input Files Summary

File Name	Description	Modification
finddd.ic6	Starting Heads	Specified 2013 heads as starting heads
mfsim.nam	Global Simulation Name File	Updated tdis and ims file names
pumpXXXX.nam	Scenario Name File	Updated scenario file names (XXXX refers to specific scenario)
pumpXXXX.oc6	Output Control	Updated scenario-specific output files and adjusted number of stress periods (XXXX refers to specific scenario)

4.0 Methods and Results

4.1 Model Scenarios

Four scenarios were completed to evaluate the changes in average drawdown in each county-model layer unit due to different levels of constant pumping. Assumed pumping were based on applying 2010, 2011, 2012, and 2013 pumping from 2014 to 2080. The results were summarized for county-model layer units in Groundwater Management Area 11.

4.2 Post-Processing of MODFLOW 6 Results

A FORTRAN program named *getdd.exe* was written to extract groundwater elevation data from the model output files. The program was modified for each scenario to reflect different input and output file names unique to the scenario.

The program reads a list of county names and codes (*countynamelist.dat*) and a grid file of cell number, layer, and county code (*celllayercountyns.csv*). The program counts the number of cells in each county-model layer unit and reports the results in a file named *cellcount.dat.* The 27 counties within Groundwater Management Area 11 and the number of cells in each layer of those counties is presented in Table 3. Based on Table 3, there are 213 county-model layer units with at least one active model cell.

The program then reads the binary output files from the calibrated model (*tr58g.hds*) and the specific scenario of the predictive simulation (*pumpXXXX.hds*). The program then calculates the drawdown for each cell with a starting date of 2013 (the last year of the calibrated model). Drawdowns for each county-model layer unit are then summed, and the average drawdown for each county-model layer unit is calculated as the summed drawdown for that unit divided by the number of cells in that unit.

The program then reads a list of file names for each county-model layer unit for the 27 counties in Groundwater Management Area 11 and writes annual drawdowns for each layer to the county-based output files for the scenario.

4.3 Results

There is a total of 27 output files for each scenario (one for each county). Within each county file, there are average drawdown results for each model layer for each year of the simulation. Where there is no active cells, the drawdown is listed as -9999.00 to designate that there are no active cells. Also included are the county number (1 to 27), the county number of the entire list of counties in the model, the county code from the grid file, and the county name.

The 213 individual hydrographs that plot all scenarios for a county-model layer unit were saved in a pdf file (*PumpSensHydrographsDD.pdf*). The hydrographs are printed one to a page for easy viewing with a pdf reader. An example is shown in Figure 3.

Table 3. Cell Counts for Each County-Model Layer Unit

County	Number of Model Cells in Each County-Model Layer Unit									Number of Active Layers
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8	Layer 9	
Anderson	19,582	106	359	3,276	3,455	1,932	1,639	1,203	1,087	9
Angelina	552	3,828	1,312	865	865	865	865	865	865	9
Bowie	6,382	0	0	0	0	0	1,312	1,034	522	4
Camp	2,674	0	0	392	371	387	451	233	201	7
Cass	12,311	5	61	3,249	1,843	716	1,524	1,221	988	9
Cherokee	14,757	603	676	3,030	2,404	1,885	1,414	1,096	1,059	9
Franklin	2,136	0	0	0	3	177	607	320	170	6
Gregg	4,065	0	0	414	557	928	465	290	274	7
Harrison	10,279	0	2	413	995	621	2,226	1,845	1,311	8
Henderson	11,104	0	9	1,445	1,072	701	1,071	1,471	1,540	8
Hopkins	4,213	0	0	0	1	23	500	634	839	6
Houston	7,210	5,267	2,187	2,455	1,424	1,238	1,237	1,237	1,237	9
Marion	7,315	1	5	899	1,017	336	1,214	694	545	9
Morris	3,694	0	6	484	509	169	344	636	317	8
Nacogdoches	13,147	1,630	1,706	1,456	1,595	1,390	1,787	1,094	983	9
Panola	12,656	0	0	0	1	4	996	3,921	1,269	6
Rains	3,109	0	0	0	0	0	56	246	864	4
Rusk	13,447	7	14	191	760	1,842	3,677	1,311	943	9
Sabine	3,513	2,242	795	398	566	566	1,121	658	577	9
SanAugustine	2,534	1,511	770	385	611	792	836	623	594	9
Shelby	10,606	8	3	1	2	42	2,558	2,546	1,037	9
Smith	12,534	331	837	3,653	2,053	1,234	1,107	964	947	9
Titus	6,547	0	0	32	221	245	1,096	876	559	7
Trinity	0	4,124	1,225	713	713	713	713	713	713	8
Upshur	6,347	20	49	1,905	1,142	928	636	595	595	9
VanZandt	9,253	0	7	268	293	384	1,940	1,013	1,723	8
Wood	9,934	77	215	1,681	1,070	839	1,516	1,046	740	9

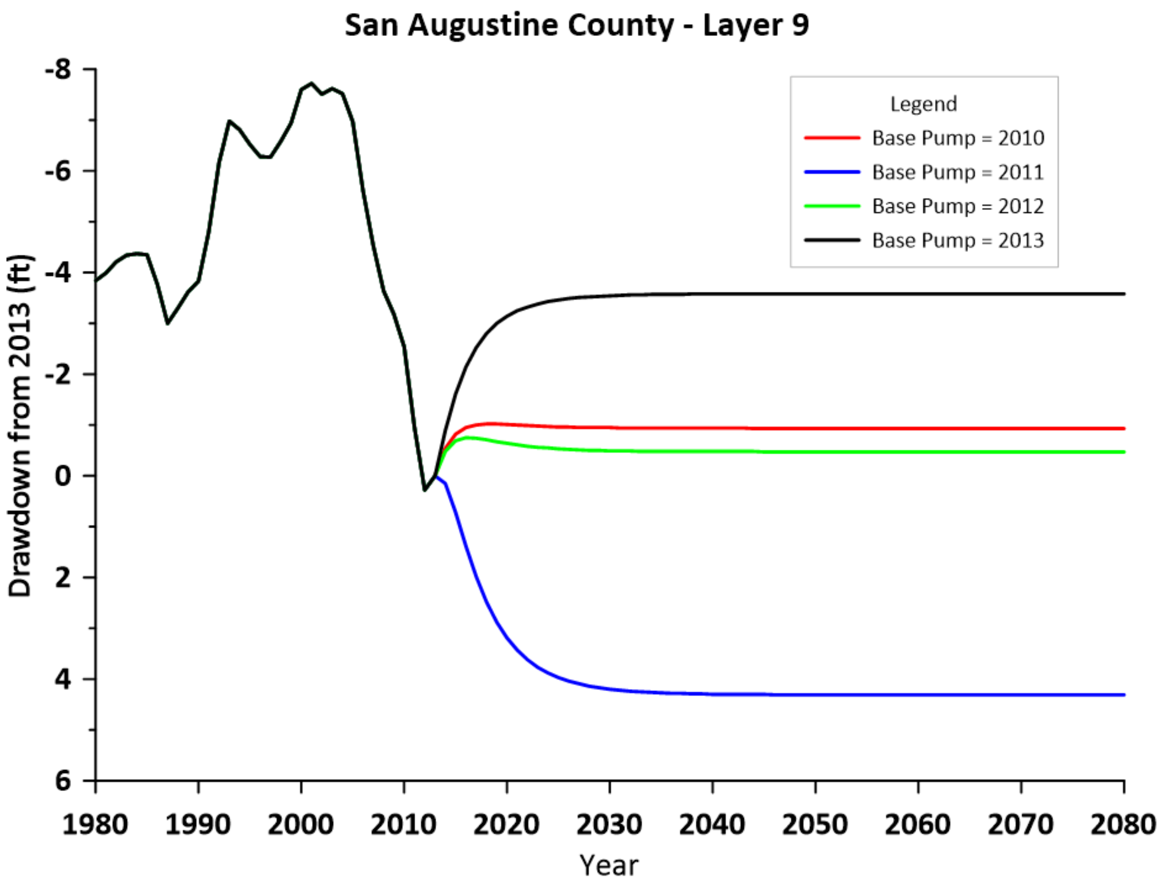


Figure 3. Average Drawdown in San Augustine County - Layer 9

From 1980 to 2013 (the calibration period) average drawdown from 2013 ranges from -7.62 ft in 2003 to 0.28 ft in 2012, a range of about 8 feet. From 2014 to 2080, the range in drawdown is defined by the difference of the 2013 simulation (black line) and the 2011 simulation (the blue line), also a difference of about 8 feet. Thus, the selection of the base pumping year will influence the simulated drawdown. If 2013 is chosen as the base year, the simulation results show an average recovery in groundwater elevation and, thus, a negative drawdown of about 4 feet. If 2011 is chosen as the base year, the simulation shows a decline in groundwater elevation, and, thus, a drawdown of about 4 feet.

Please note that the primary interpretation in Figure 3 is that there is an initial response to the change in pumping starting in 2014 (either a recovery or a decline, depending on the base pumping), and an equilibrium condition is achieved after a few years. Achieving an equilibrium condition is present in all 213 hydrographs developed, and demonstrates the suitability of the model for the joint planning process.

The example in Figure 3 can also be compared to a similar plot from Hutchison (2017b) reproduced below as Figure 4.

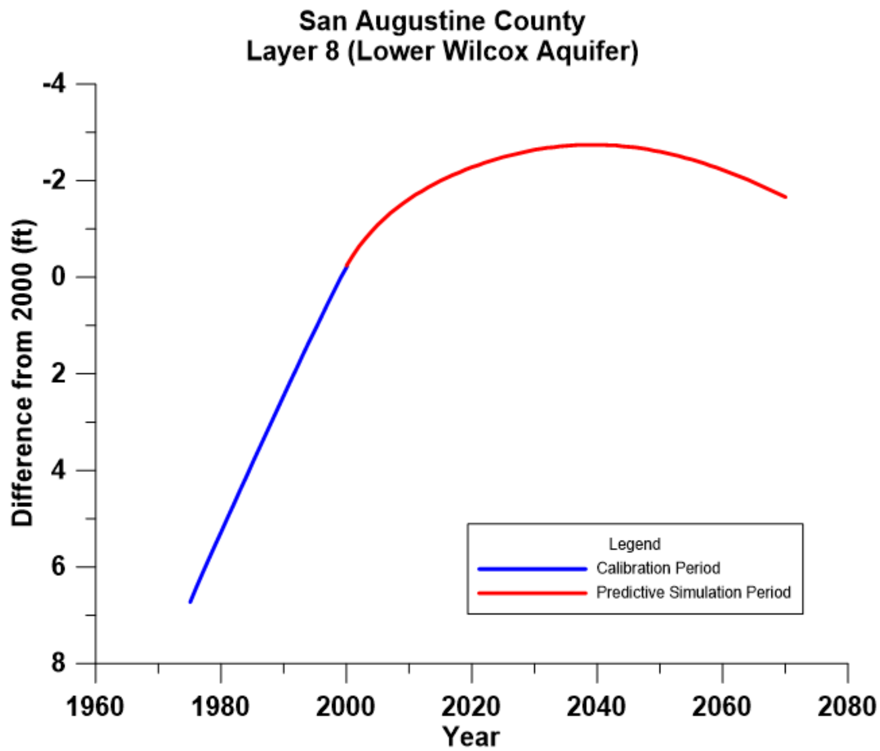


Figure 4. Average Drawdown from Previous Groundwater Availability Model - San Augustine County, Layer 8

Please note that in the previous Groundwater Availability Model, Layer 8 represented the Lower Wilcox Aquifer. This new Groundwater Availability Model has an extra layer to simulate alluvial formations in the areas of streams and rivers, so Layer 9 now represents the Lower Wilcox Aquifer.

As discussed in Hutchison (2017b), during the calibration period, average groundwater levels rose about 7 feet from 1975 to 1999. This suggests that the model is simulating actual conditions well. The model conditions that caused the rise from 1975 to 1999 continue to affect the change in average groundwater levels after 2000 (the simulation period). The rise continues until about 2030, and the model predicts a drop in average groundwater level after this peak. However, the decline from 2030 to 2070 leaves the average groundwater level higher than the average level in 2000 (the start of the simulation period). This was an example of a model limitation that had to considered when using the results of the old model in considering desired future conditions. Based on the hydrograph in Figure 3 and an inspection of all the hydrographs in Appendix A, this limitation has been eliminated in this updated Groundwater Availability Model.

Summary graphs that compare the range in calibration period drawdown and the range in the predictive period drawdown for all scenarios are presented in Appendix A. Each graph plots the range in drawdowns for each county for a specific layer. These plots, and companion plots in Technical Memorandum 2 are useful in interpreting simulation results for the joint planning process.

5.0 Limitations

The objective of these simulations was to provide a practical basis for selecting a base pumping year for simulations focused on joint planning. As a result, there are some limitations to the results given the regional nature of the objective:

- The scenarios considered only increases and decreases in overall pumping to assess general sensitivity of pumping on average drawdown. For this analysis, there were no attempts to understand sensitivity on a finer scale (i.e. varying pumping on an individual county-model layer unit).
- The scenarios did not attempt to distinguish the relative effect of "local" pumping (pumping within the county-model layer unit) versus neighboring pumping in adjacent county-model layer units.
- The results provide some insight on pumping sensitivity but are coupled with a companion analysis of sensitivity to recharge in Technical Memorandum 2.

6.0 References

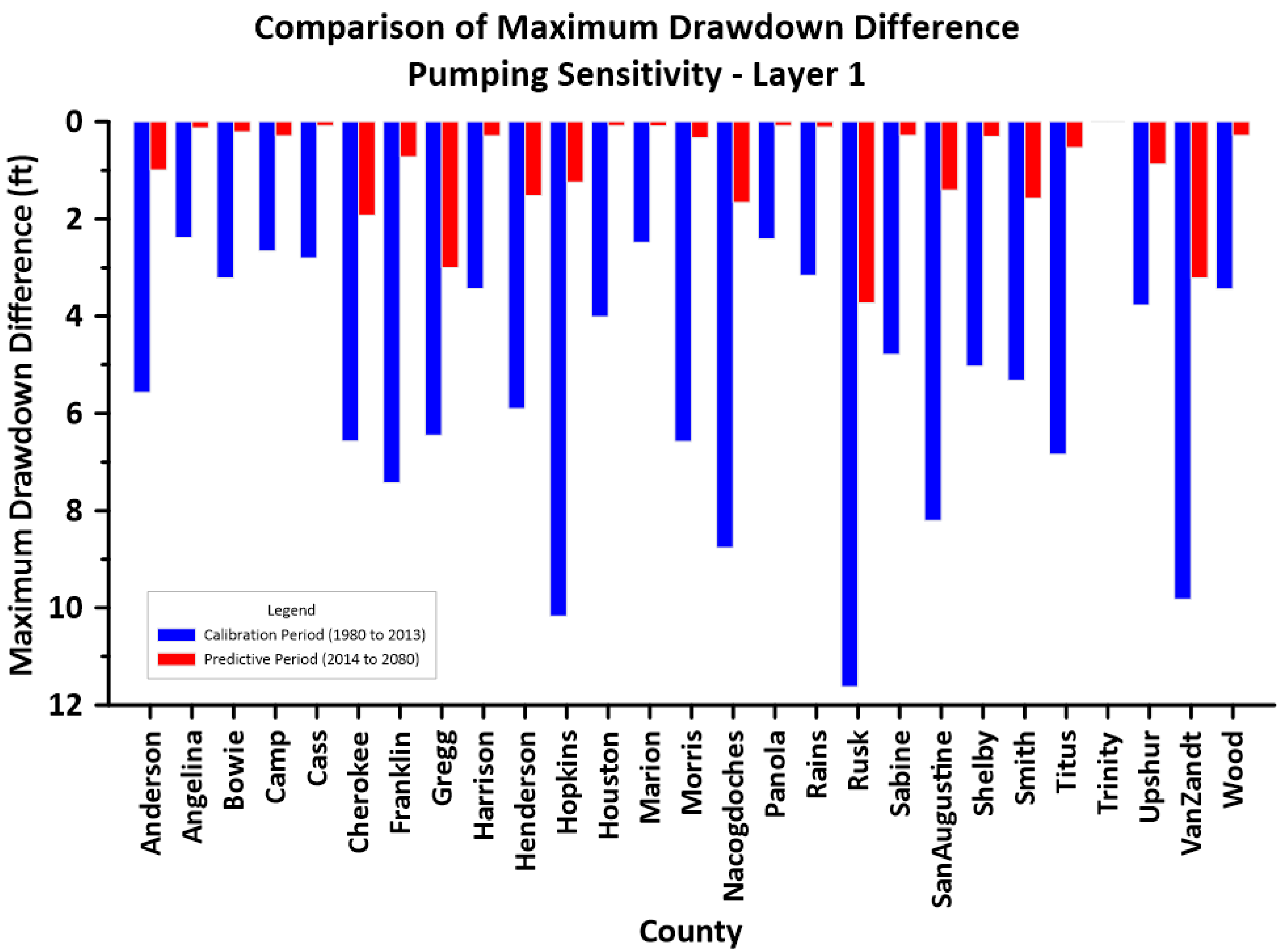
Hutchison, W.R., 2017a. Desired Future Condition Explanatory Report: Carrizo-Wilcox/Queen City/Sparta Aquifers for Groundwater Management Area 11. Report submitted to Texas Water Development Board, January 24, 2017, 445p.

Hutchison, W.R., 2017b. Use of Predictive Simulation Results from Scenario 4 in Desired Future Conditions for Sparta, Queen City, and Carrizo-Wilcox Aquifer. GMA 11 Technical Memorandum 16-02. Report submitted to Groundwater Management Area 11. January 24, 2017, 15p.

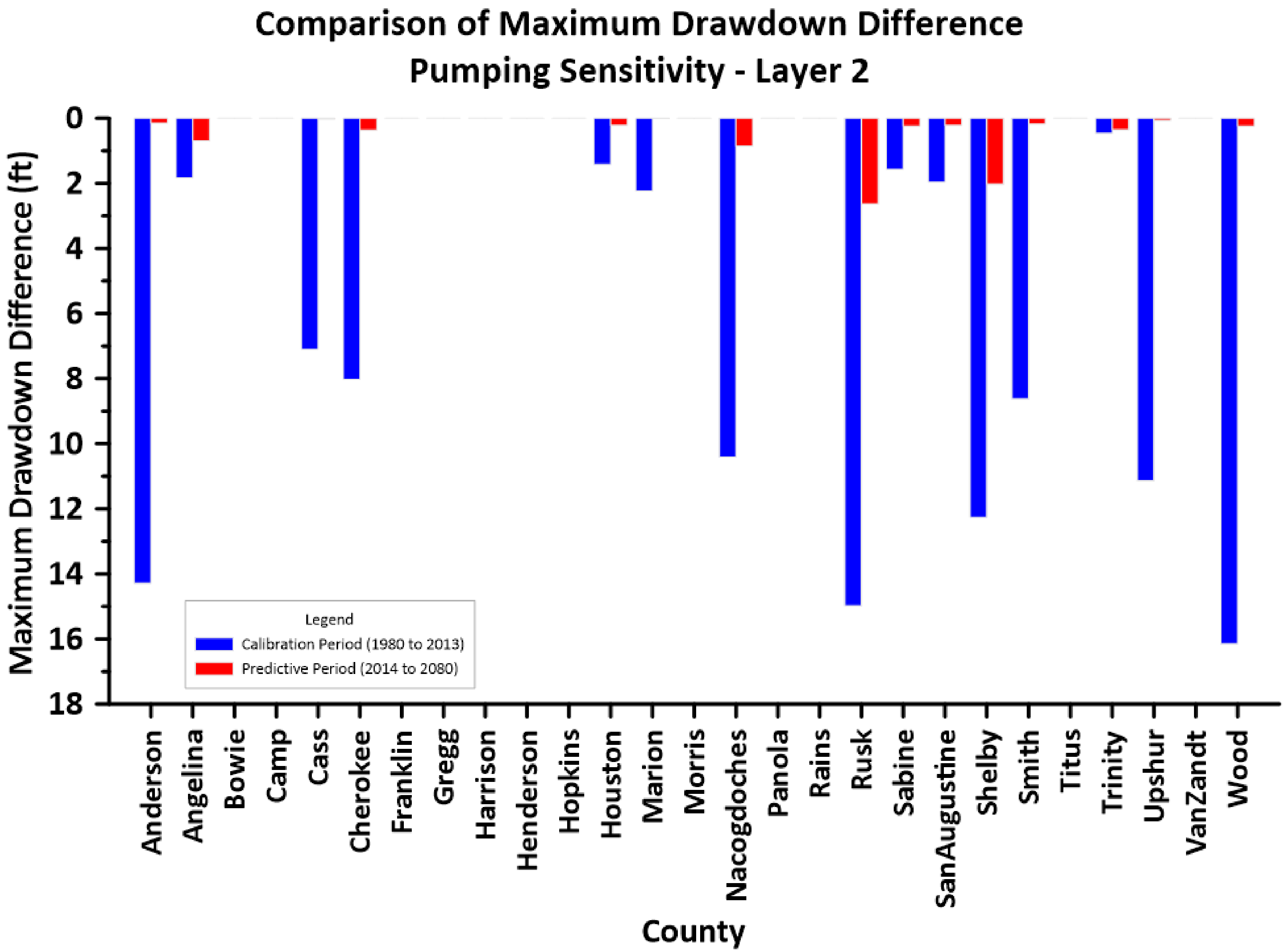
Hutchison, W.R., 2017c. Initial GAM Simulations for Sparta, Queen City and Carrizo-Wilcox Aquifers. GMA 11 Technical Memorandum 15-01. Report submitted to Groundwater Management Area 11. January 21, 2017, 109p.

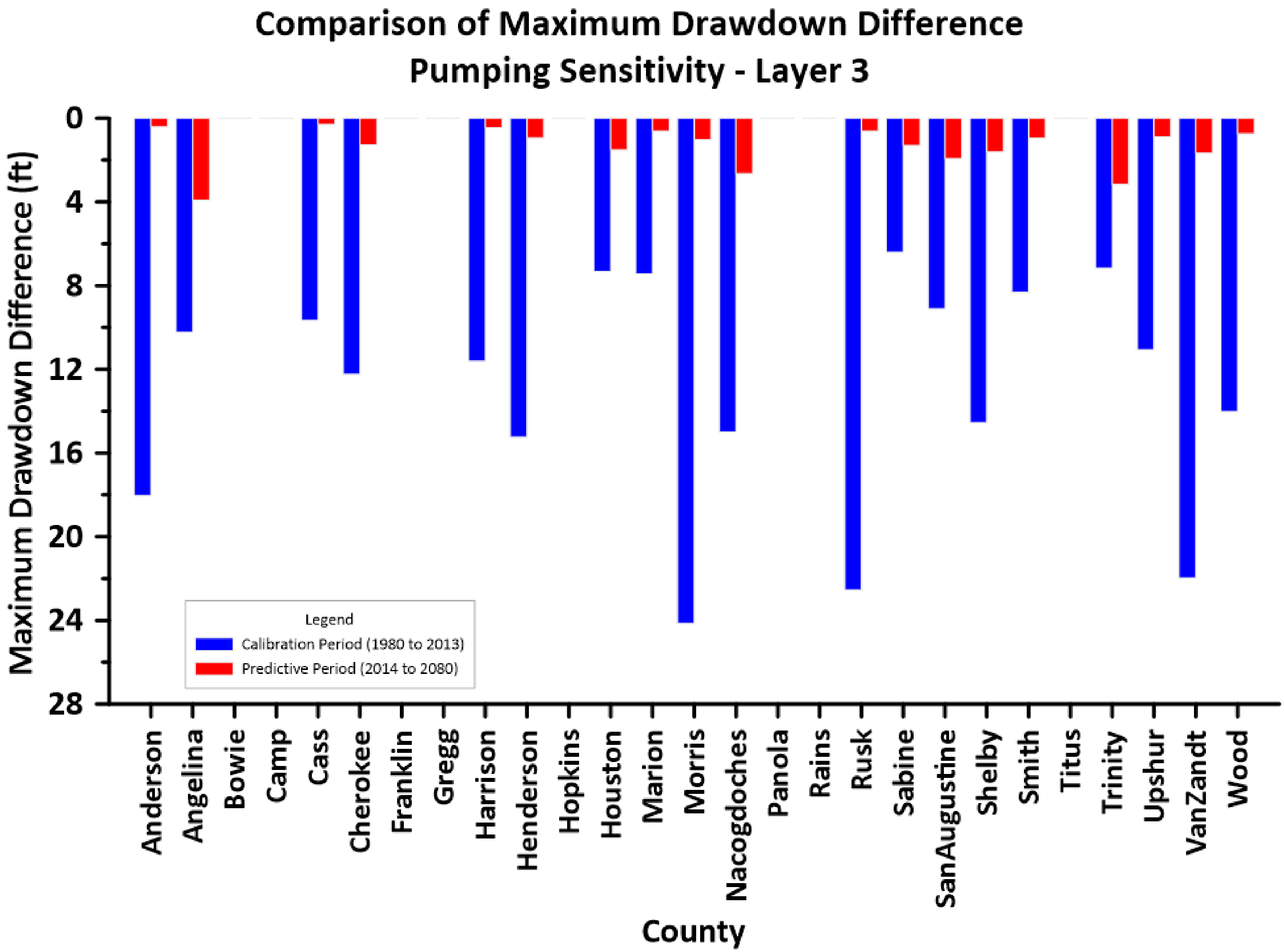
Appendix A

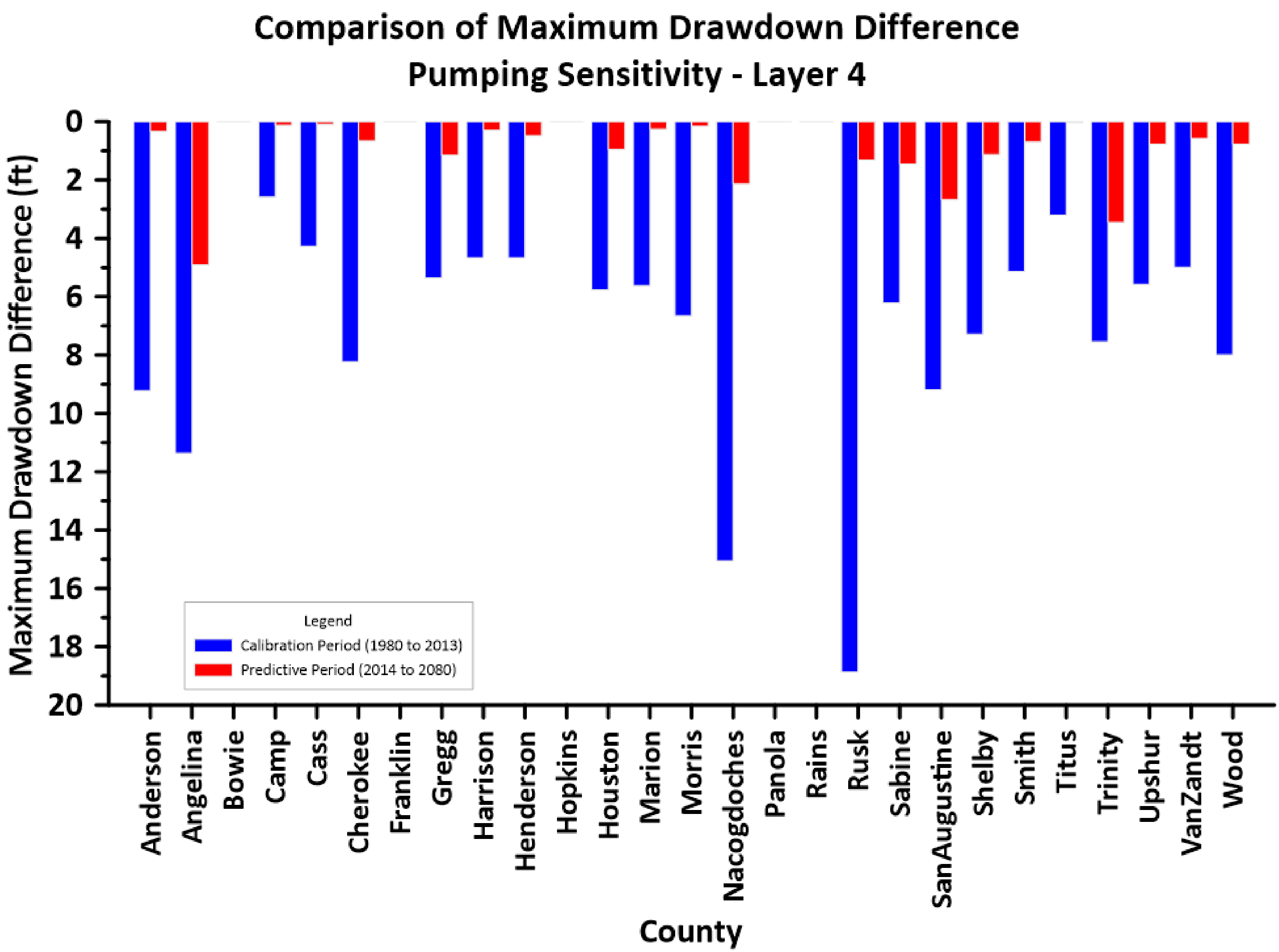
Comparison of Maximum Drawdown Difference – Pumping Sensitivity (one graph per model layer, each graph shows 27 counties)



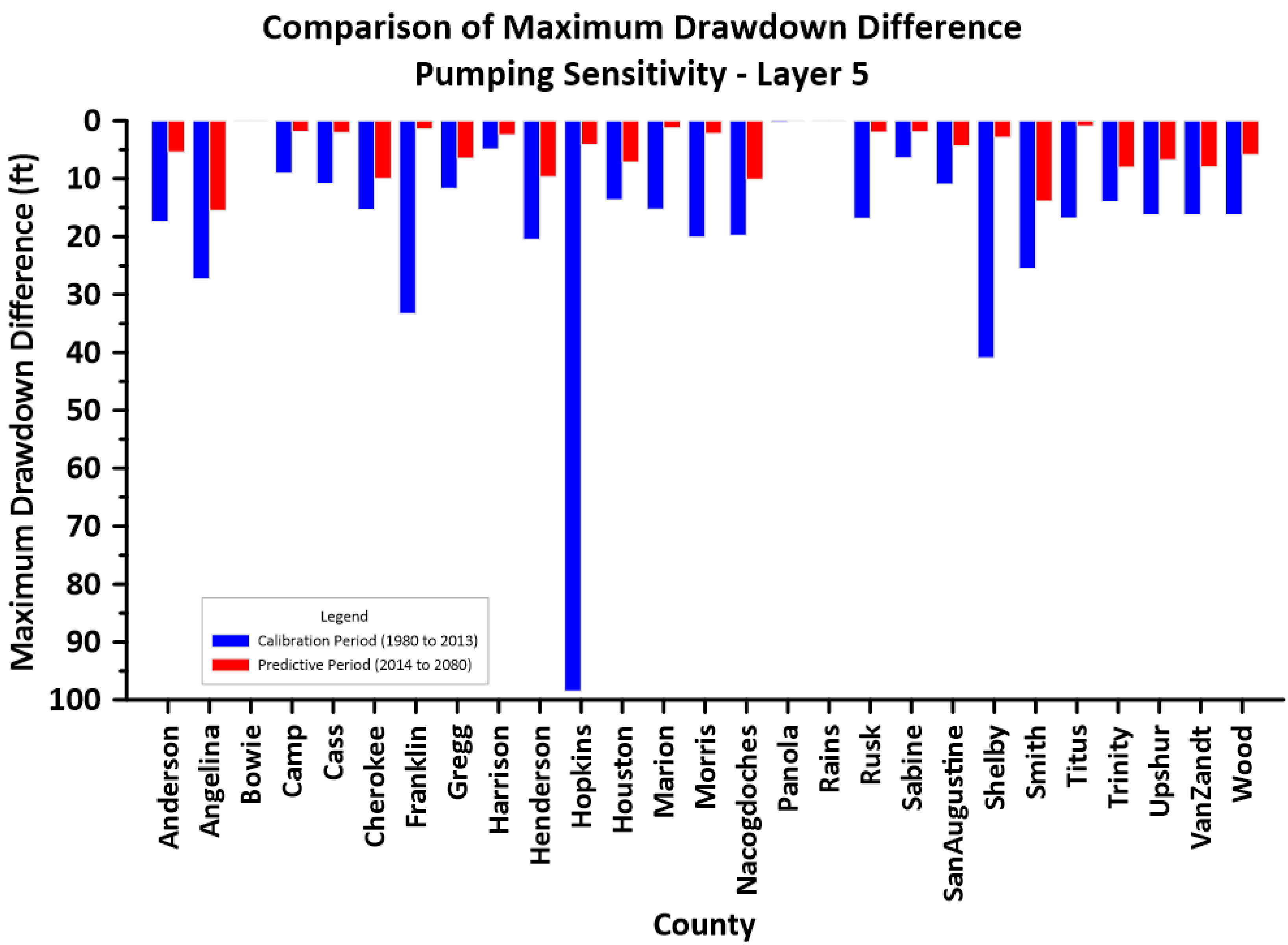
Comparison of Maximum Drawdown Difference
Pumping Sensitivity - Layer 1
Maximum Drawdown Difference (ft)
0
2
4
6
8
10
12
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
Panola
Rains
Rusk
Sabine
SanAugustine
Shelby
Smith
Titus
Trinity
Upshur
VanZandt
Wood
County

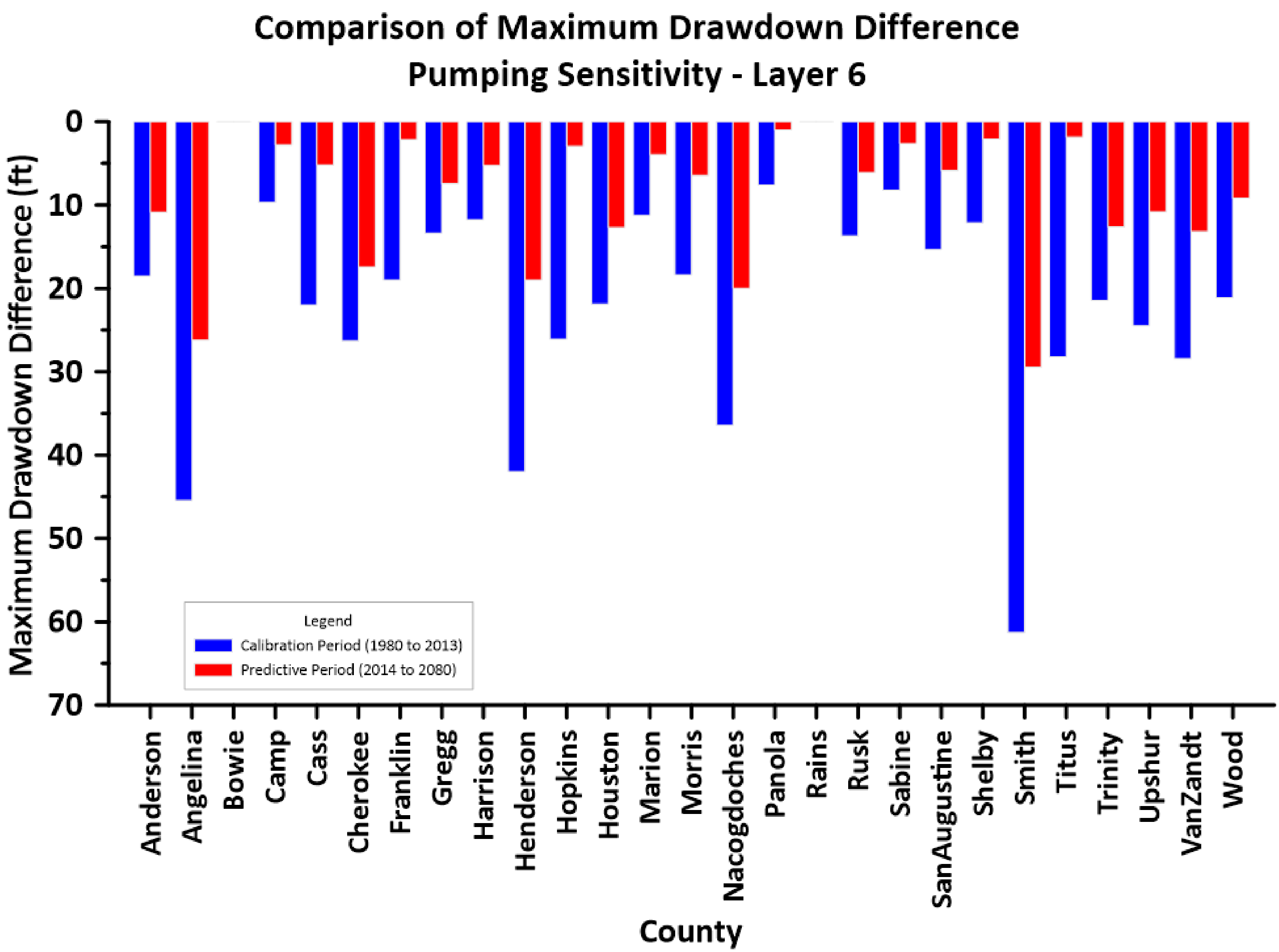

Comparison of Maximum Drawdown Difference
Pumping Sensitivity - Layer 2
Maximum Drawdown Difference (ft)
0
2
4
6
8
10
12
14
16
18
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
Panola
Rains
Rusk
Sabine
SanAugustine
Shelby
Smith
Titus
Trinity
Upshur
VanZandt
Wood
County

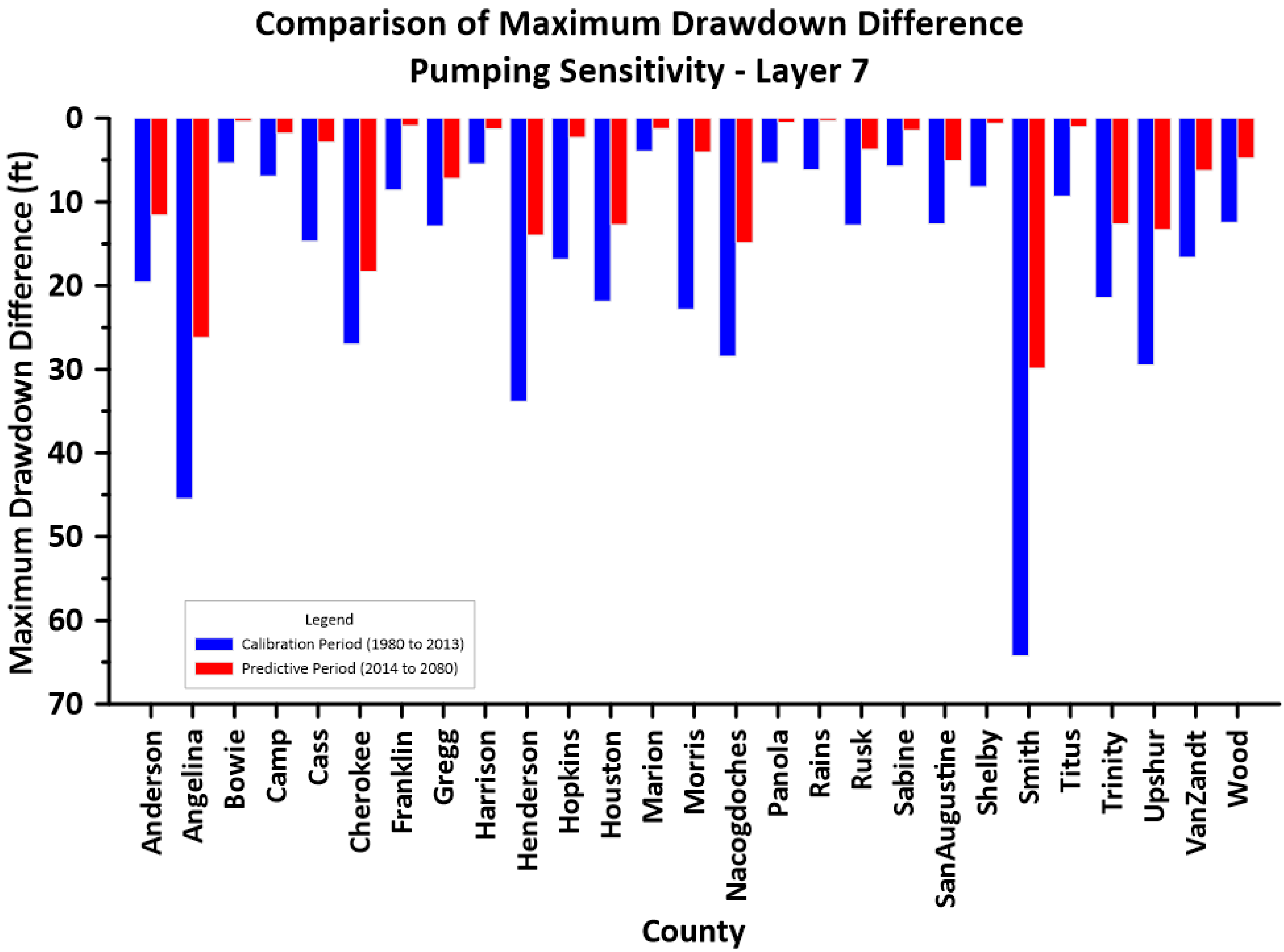

Comparison of Maximum Drawdown Difference
Pumping Sensitivity - Layer 3
Maximum Drawdown Difference (ft)
0
4
8
12
16
20
24
28
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
Panola
Rains
Rusk
Sabine
SanAugustine
Shelby
Smith
Titus
Trinity
Upshur
VanZandt
Wood
County

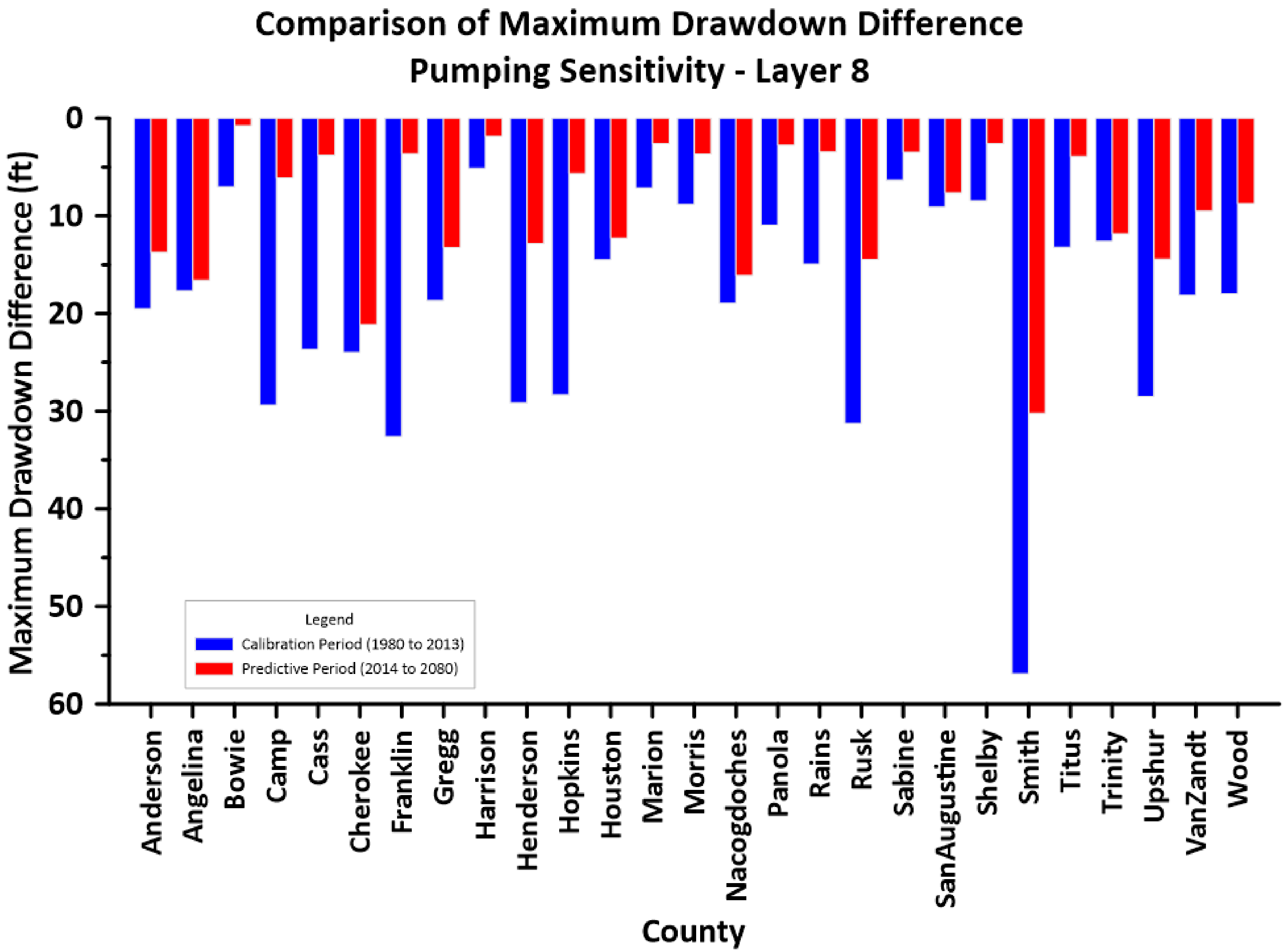


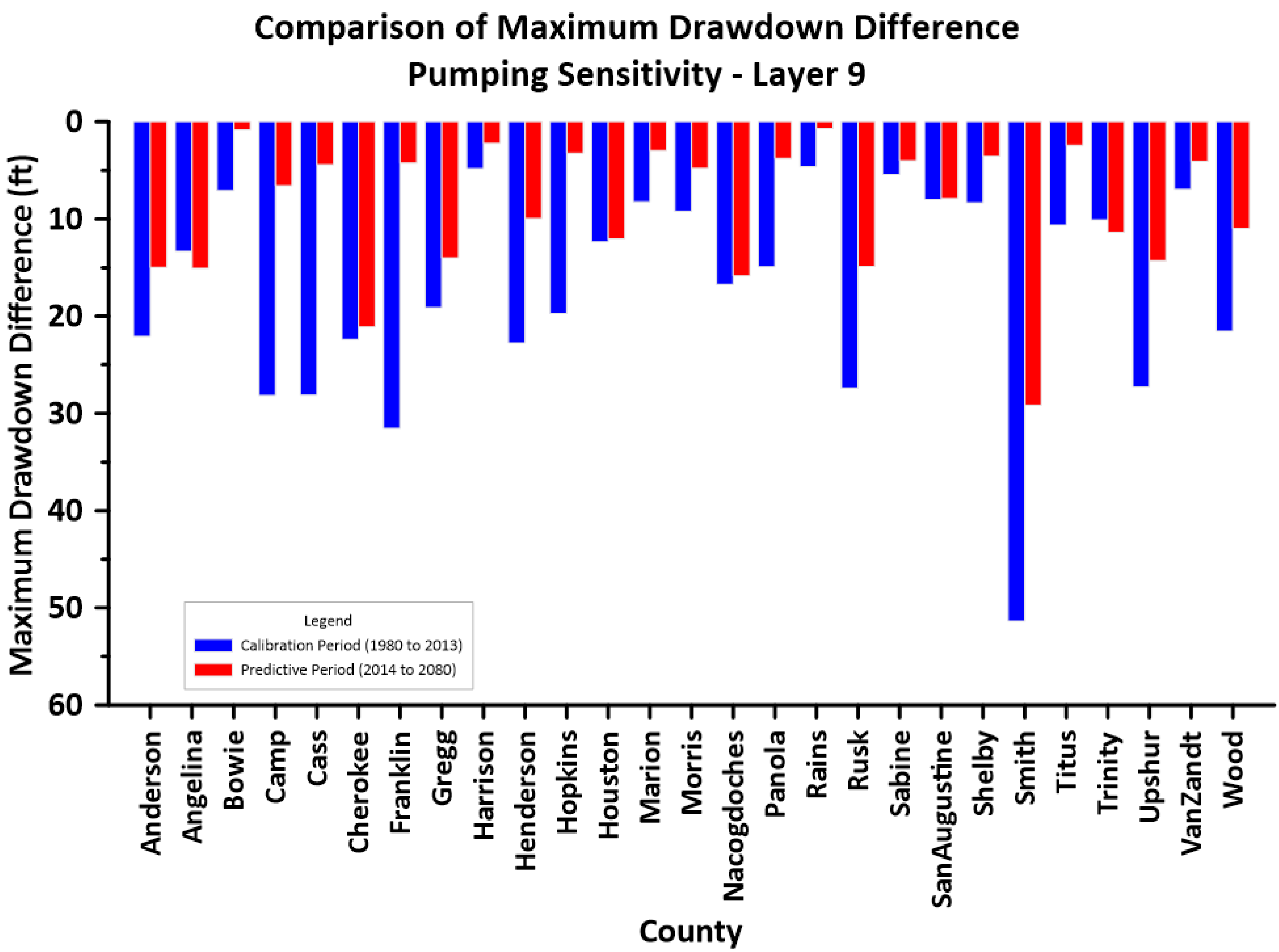
Comparison of Maximum Drawdown Difference
Pumping Sensitivity - Layer 4
Maximum Drawdown Difference (ft)
0
2
4
6
8
10
12
14
16
18
20
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
Panola
Rains
Rusk
Sabine
SanAugustine
Shelby
Smith
Titus
Trinity
Upshur
VanZandt
Wood
County


Comparison of Maximum Drawdown Difference
Pumping Sensitivity - Layer 5
Maximum Drawdown Difference (ft)
0
10
20
30
40
50
60
70
80
90
100
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
Panola
Rains
Rusk
Sabine
SanAugustine
Shelby
Smith
Titus
Trinity
Upshur
VanZandt
Wood
County


Comparison of Maximum Drawdown Difference
Pumping Sensitivity - Layer 6
Maximum Drawdown Difference (ft)
0
10
20
30
40
50
60
70
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
Panola
Rains
Rusk
Sabine
SanAugustine
Shelby
Smith
Titus
Trinity
Upshur
VanZandt
Wood
County


Comparison of Maximum Drawdown Difference
Pumping Sensitivity - Layer 7
Maximum Drawdown Difference (ft)
0
10
20
30
40
50
60
70
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
Panola
Rains
Rusk
Sabine
SanAugustine
Shelby
Smith
Titus
Trinity
Upshur
VanZandt
Wood
County


Comparison of Maximum Drawdown Difference
Pumping Sensitivity - Layer 8
Maximum Drawdown Difference (ft)
0
10
20
30
40
50
60
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
Panola
Rains
Rusk
Sabine
SanAugustine
Shelby
Smith
Titus
Trinity
Upshur
VanZandt
Wood
County


Comparison of Maximum Drawdown Difference
Pumping Sensitivity - Layer 9
Maximum Drawdown Difference (ft)
0
10
20
30
40
50
60
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
Panola
Rains
Rusk
Sabine
SanAugustine
Shelby
Smith
Titus
Trinity
Upshur
VanZandt
Wood
County

Draft Technical Memorandum 2

Recharge Sensitivity

Prepared for:
GSI Environmental, Inc.
9600 Great Hills Trail, Suite 350
Austin, TX 78759
512-346-4474

Prepared by:
William R. Hutchison, Ph.D., P.E., P.G.
Independent Groundwater Consultant
9305 Jamaica Beach
Jamaica Beach, TX 77554
512-745-0599
billhutch@texasgw.com

June 22, 2020

Draft Technical Memorandum 2

Professional Engineer and Professional Geoscientist Seals

This report was prepared by William R. Hutchison, Ph.D., P.E., P.G., who is licensed in the State of Texas as follows:

- Professional Engineer (Geological and Civil) No. 96287
- Engineering Firm Registration No. 14526
- Professional Geoscientist (Geology) No. 286

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Appendices

A – Comparison of Maximum Drawdown Difference – Recharge Sensitivity (one graph per model layer, each graph shows 27 counties)
B – Comparison of Predictive Period Average Drawdown – Recharge and Pumping Sensitivity (one graph per model layer, each graph shows 28 counties)

Associated Files

***RechScenHydrographs.pdf* (213 hydrographs of average drawdown for each county-model layer unit)**

1.0 Executive Summary

Five simulations were run with the updated Groundwater Availability Model to understand the sensitivity of average drawdown due to variation in recharge on a county-model layer basis. Recharge was assumed to be constant during the entire predictive period (2014 to 2080). Pumping was assumed equal to the pumping simulated in 2011 in the calibrated model and did not vary during the simulation. Other time dependent boundary conditions (general head boundaries, evapotranspiration, and parameters for surface water-groundwater interaction) were assumed constant and equal to steady state conditions (stress period 1 of the calibrated model).

Results were processed and graphically summarized in 213 hydrographs of average drawdown for each county-model layer unit (saved as a pdf file), and summarized in nine bar graphs that compare the maximum drawdown range during the calibration period and the predictive period for each model layer. Each bar graph shows all 27 counties of Groundwater Management Area 11 that are covered by the Groundwater Availability Model domain.

This analysis demonstrated that the limitations of the previous Groundwater Availability Model related to rising groundwater elevations during the predictive period have been addressed and eliminated. All graphs show an initial response to the change in pumping followed by a period where equilibrium is reached. Achieving an equilibrium condition is present in all 213 hydrographs developed and demonstrates the suitability of the model for the joint planning process.

2.0 Background

The desired future conditions for Groundwater Management Area 11 that were adopted on January 11, 2017 were documented in the Desired Future Condition Explanatory Report (Hutchison, 2017a). As noted in the Explanatory Report, the desired future conditions were based on Groundwater Availability Model (GAM) Scenario 4 as documented in Hutchison (2017b). The selection of Scenario 4 as the basis for the desired future condition was made by the groundwater conservation districts in Groundwater Management Area 11 after the review of the results of seven simulations using the Groundwater Availability Model (Hutchison, 2017c).

In developing the initial seven simulations, a base pumping amount for each county-aquifer unit was developed. This base pumping amount was based on future pumping based on regional water plan data and the proposed Forestar project. The analysis in Hutchison (2017c) included three simulations that sequentially increased the pumping above the base amount and three simulations that sequentially decreased the pumping below the base amount develop a practical analysis of the sensitivity of drawdown to various pumping amounts.

One of the uses of the updated Groundwater Availability Model documented in the main report will be to support the Joint Planning Process that leads to the adoption of desired future conditions by the groundwater conservation districts in Groundwater Management Area 11 and the calculation of the modeled available groundwater by TWDB. As part of the work associated with developing the updated Groundwater Availability Model, three technical memoranda appear in the Appendix of the report:

- Technical Memorandum 1: Pumping Sensitivity
- Technical Memorandum 2: Recharge Sensitivity
- Technical Memorandum 3: Calculation of Drawdown from Existing Modeled Available Groundwater Using Updated Groundwater Availability Model

This technical memorandum compares the average drawdown in each county-model layer unit under alternative assumptions of recharge. Specifically, the model calibration period is 1980 to 2013, which includes variation of recharge by applying a multiplication factor to the steady state recharge in stress period 1. Five alternative recharge files for the period 2014 to 2080 (the simulation period that will be used in simulations to support the joint planning process) were developed:

- 80 percent of steady state recharge
- 90 percent of steady state recharge
- 100 percent of steady state recharge
- 110 percent of steady state recharge
- 120 percent of steady state recharge

3.0 Parameters and Assumptions

The updated Groundwater Availability Model was calibrated with data from 1980 to 2013. Figure 1 shows the recharge factor that was applied to each stress period of the calibrated model. Please note that the values generally range from slightly over 1.2 to slightly less than 0.8. In order to cover a reasonable range for the sensitivity analysis, five scenarios were developed ranging from a factor of 0.8 (80 percent of steady state recharge) to a factor of 1.20 (120 percent of steady state recharge).

3.1 Files Unchanged from Calibrated Model

Files that contain model input parameters related to the model grid and aquifer parameters were the same as the files used in the calibrated model as shown in Table 1.

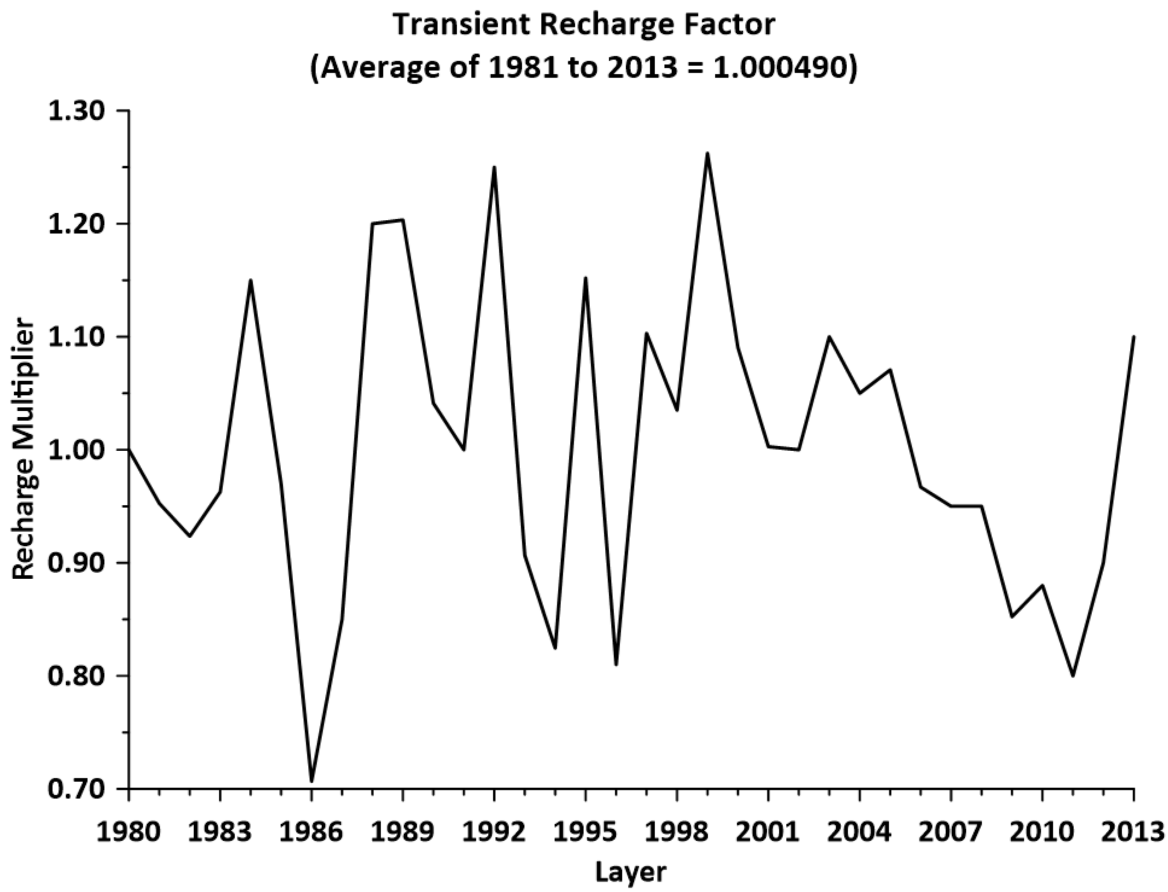


Figure 1. Recharge Factors for Each Stress Period of Calibrated Model

Table 1. Predictive Model Files Unchanged from Calibrated Model

File Name	File Date	Description
findd.disu	4/10/2020	Spatial Discretization
findd.ims	4/10/2020	Solver Parameters
finddd.npf	4/10/2020	Node Property Flow
tr58_g.kx	4/10/2020	Horizontal Hydraulic conductivity
tr58_g.kz	4/10/2020	Vertical Hydraulic Conductivity
tr58_g.ss	4/10/2020	Specific Storage
tr58_g.sy	4/10/2020	Specific Yield

3.2 Time Discretization and Storage

The predictive simulation was run for the period 2014 to 2080, a total of 67 annual stress periods. The calibrated model included a steady-state stress period at the beginning of the simulation. Thus, the DISU file was modified to reflect 67 annual stress periods and named *finddd.tdis*. The specification of steady state or transient stress period in MODFLOW 6 is contained in the STO file. This file was updated and named *finddd.sto.*

3.3 Groundwater Pumping (WEL Package)

After evaluating the results of the companion pumping sensitivity documented in Technical Memorandum 1, the base pumping selected for the recharge sensitivity analysis was 2011. This year was selected since it was the highest pumping in the last four years, and generally resulted in declining groundwater elevations during the predictive period with steady state recharge.

The FORTRAN program *makebasepump.exe* was written to develop four model input files of pumping used in the pumping sensitivity analysis. The program reads the calibrated model file *tr58_g.wel*, which contains cell-by-cell pumping amounts from 1980 to 2013. The program then writes four files as follows:

- *pump2010.wel* specifies 2010 pumping for 2014 to 2080
- *pump2011.wel* specifies 2011 pumping for 2014 to 2080
- *pump2012.wel* specifies 2012 pumping for 2014 to 2080
- *pump2013.wel* specifies 2013 pumping for 2014 to 2080

The file *pump2011.wel* was used for the recharge sensitivity analysis.

3.4 Evapotranspiration (EVT Package)

The FORTRAN program *makeevt.exe* was written to develop a model input file for evapotranspiration. Inspection of the calibrated model input file for evapotranspiration (*tr58_g.evt*) shows that the same evapotranspiration parameters were used for each stress period of the calibration period (1980 to 2013). The program simply extracts the first stress period of the calibration period and writes it to a new file named *finddd.evt*.

3.5 General Head Boundaries (GHB Package)

The FORTRAN program *makeghb.exe* was written to develop a model input file for the general head boundaries, which were implemented to simulate the effects of overlying formations that are not formally part of the model domain.

Inspection of the calibrated model input file for general head boundaries (*tr58_g.ghb*) shows that the same general head boundary parameters were used for each stress period of the calibration period (1980 to 2013). The program simply extracts the first stress period of the calibration period and writes it to a new file named *finddd.ghb*.

3.6 Recharge (RCH Package)

The recharge input file *tr58_g.rch* contains the cell-by-cell recharge amounts for each stress period of the calibrated model (1980 to 2013). The FORTRAN program *makepredrch.exe* was written to develop four additional recharge input files (for 80 percent, 90 percent, 110 percent, and 120 percent of steady state recharge).

The program reads the steady state recharge file used in the pumping sensitivity analysis (renamed *basess.rch* for this program). Factors are applied to each cell-by-cell recharge value in the base file and written to the four new files. Please note that the factor is applied, and the cell value is written if the value is greater than zero. Inspection of the calibrated model recharge input file yields the conclusion that several cells have a zero recharge. Thus, the resulting files for this sensitivity analysis are slightly smaller than the base file.

The four files written by the program are:

- *rech080.rch* (for 80 percent of steady state recharge scenario)
- *rech090.rch* (for 90 percent of steady state recharge scenario)
- *rech110.rch* (for 110 percent of steady state recharge scenario)
- *rech120.rch* (for 120 percent of steady state recharge scenario)

3.7 River (RIV Package)

The calibrated model simulated surface water-groundwater interactions with the River (RIV) package specified in the file *tr58_g.rch*. Inspection of the input file yielded the conclusion that RIV head values changed slightly for each stress period. River conductance and bottom elevations remained the same in all stress periods.

The FORTRAN program *makeriv.exe* was written to extract the first stress period of RIV parameters for the predictive simulations and hold them constant for all stress periods. The output file from this program is *finddd.riv.*

3.8 Other Input Files

Other files that were developed for these predictive simulations are summarized in Table 2.

Table 2. Other Input Files Summary

File Name	Description	Modification
finddd.ic6	Starting Heads	Specified 2013 heads as starting heads
mfsim.nam	Global Simulation Name File	Udated tdis and ims file names
rechXXX.nam	Scenario Name File	Updated scenario file names (XXX refers to specific scenario)
rechXXX.oc6	Output Control	Updated scenario-specific output files and adjusted number of stress periods (XXX refers to specific scenario)

4.0 Methods and Results

4.1 Model Scenarios

Five scenarios were completed to evaluate the changes in average drawdown in each county-model layer unit due to different levels of constant recharge. Assumed recharge values were based on applying alternative multiplication factors of recharge based on the range in the calibrated model. The results were summarized for county-model layer units in Groundwater Management Area 11.

4.2 Post-Processing of MODFLOW 6 Results

A FORTRAN program named *getdd.exe* was written to extract groundwater elevation data from the model output files. The program was modified for each scenario to reflect different input and output file names unique to the scenario.

The program reads a list of county names and codes (*countynamelist.dat*) and a grid file of cell number, layer, and county code (*celllayercountyns.csv*). The program counts the number of cells in each county-model layer unit and reports the results in a file named *cellcount.dat.* The 27 counties within Groundwater Management Area 11 and the number of cells in each layer of those counties is presented in Table 3. Based on Table 3, there are 213 county-model layer units with at least one active model cell.

The program then reads the binary output files from the calibrated model (*tr58g.hds*) and the specific scenario of the predictive simulation (rech*XXX.hds*). The program then calculates the drawdown for each cell with a starting date of 2013 (the last year of the calibrated model). Drawdowns for each county-model layer unit are then summed, and the average drawdown for each county-model layer unit is calculated as the summed drawdown for that unit divided by the number of cells in that unit.

The program then reads a list of file names for each county-model layer unit for the 27 counties in Groundwater Management Area 11 and writes annual drawdowns for each layer to the county-based output files for the scenario.

4.3 Results

There is a total of 27 output files for each scenario (one for each county). Within each county file, there are average drawdown results for each model layer for each year of the simulation. Where there is no active cells, the drawdown is listed as -9999.00 to designate that there are no active cells. Also included are the county number (1 to 27), the county number of the entire list of counties in the model, the county code from the grid file, and the county name.

The 213 individual hydrographs that plot all scenarios for a county-model layer unit were saved in a pdf file (*RechSensHydrographsDD.pdf*). The hydrographs are printed one to a page for easy viewing with a pdf reader. An example is shown in Figure 3.

Table 3. Cell Counts for Each County-Model Layer Unit

County	Number of Model Cells in Each County-Model Layer Unit									Number of Active Layers
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8	Layer 9	
Anderson	19,582	106	359	3,276	3,455	1,932	1,639	1,203	1,087	9
Angelina	552	3,828	1,312	865	865	865	865	865	865	9
Bowie	6,382	0	0	0	0	0	1,312	1,034	522	4
Camp	2,674	0	0	392	371	387	451	233	201	7
Cass	12,311	5	61	3,249	1,843	716	1,524	1,221	988	9
Cherokee	14,757	603	676	3,030	2,404	1,885	1,414	1,096	1,059	9
Franklin	2,136	0	0	0	3	177	607	320	170	6
Gregg	4,065	0	0	414	557	928	465	290	274	7
Harrison	10,279	0	2	413	995	621	2,226	1,845	1,311	8
Henderson	11,104	0	9	1,445	1,072	701	1,071	1,471	1,540	8
Hopkins	4,213	0	0	0	1	23	500	634	839	6
Houston	7,210	5,267	2,187	2,455	1,424	1,238	1,237	1,237	1,237	9
Marion	7,315	1	5	899	1,017	336	1,214	694	545	9
Morris	3,694	0	6	484	509	169	344	636	317	8
Nacogdoches	13,147	1,630	1,706	1,456	1,595	1,390	1,787	1,094	983	9
Panola	12,656	0	0	0	1	4	996	3,921	1,269	6
Rains	3,109	0	0	0	0	0	56	246	864	4
Rusk	13,447	7	14	191	760	1,842	3,677	1,311	943	9
Sabine	3,513	2,242	795	398	566	566	1,121	658	577	9
SanAugustine	2,534	1,511	770	385	611	792	836	623	594	9
Shelby	10,606	8	3	1	2	42	2,558	2,546	1,037	9
Smith	12,534	331	837	3,653	2,053	1,234	1,107	964	947	9
Titus	6,547	0	0	32	221	245	1,096	876	559	7
Trinity	0	4,124	1,225	713	713	713	713	713	713	8
Upshur	6,347	20	49	1,905	1,142	928	636	595	595	9
VanZandt	9,253	0	7	268	293	384	1,940	1,013	1,723	8
Wood	9,934	77	215	1,681	1,070	839	1,516	1,046	740	9

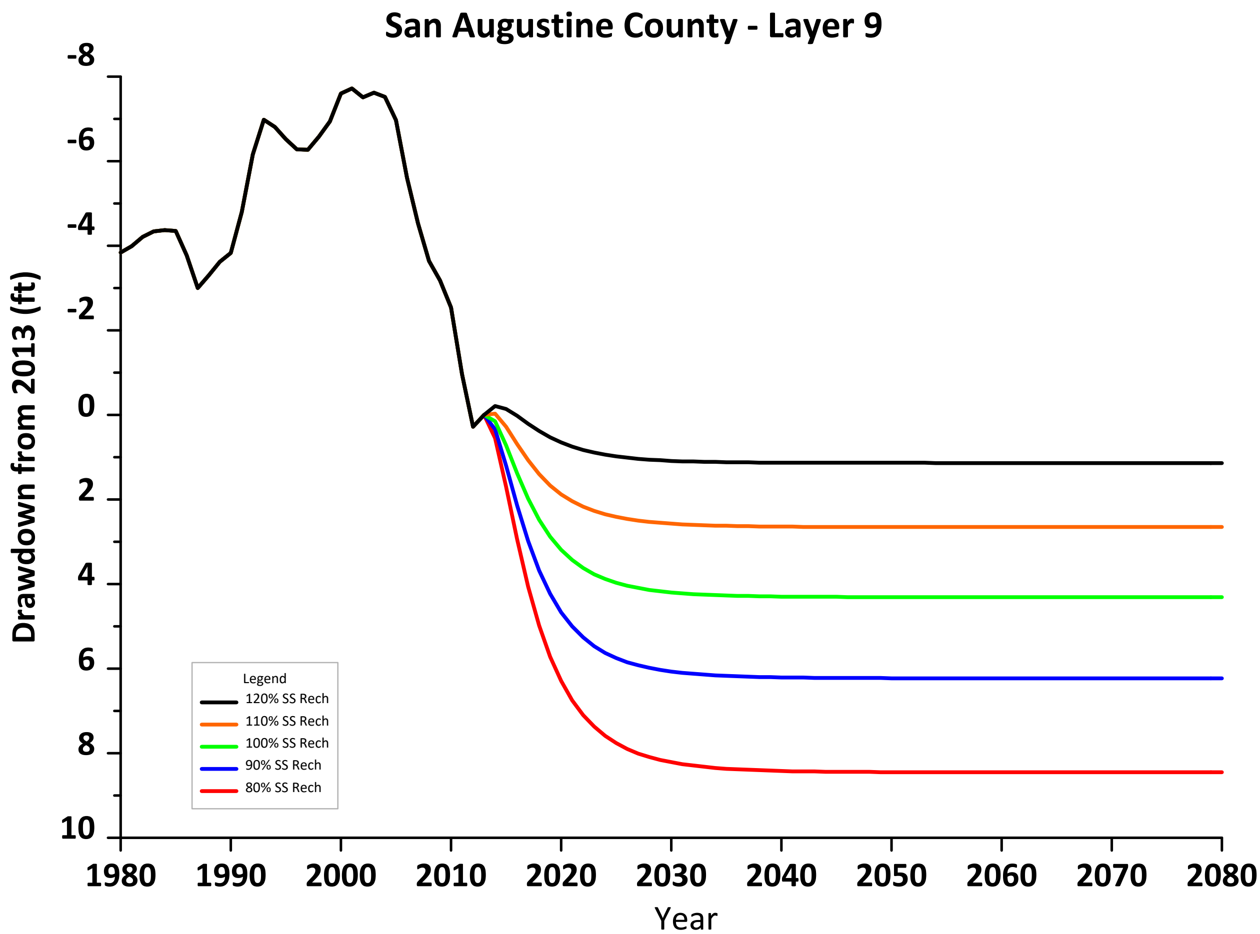


Figure 2. Average Drawdown in San Augustine County - Layer 9

From 1980 to 2013 (the calibration period) average drawdown from 2013 ranges from -7.62 ft in 2003 to 0.28 ft in 2012, a range of about 8 feet. From 2014 to 2080, the range in drawdown is defined by the difference of the 120 percent of steady state recharge (black line) and the 80 percent of steady state recharge (the red line), also a difference of about 8 feet. Thus, the selection of the recharge will influence the simulated drawdown.

Please note that the primary interpretation in Figure 3 is that there is an initial response to the change in recharge starting in 2014, and an equilibrium condition is achieved after a few years. Achieving an equilibrium condition is present in all 213 hydrographs developed and demonstrates the suitability of the model for the joint planning process.

The example in Figure 3 can also be compared to a similar plot from Hutchison (2017b) reproduced below as Figure 4.

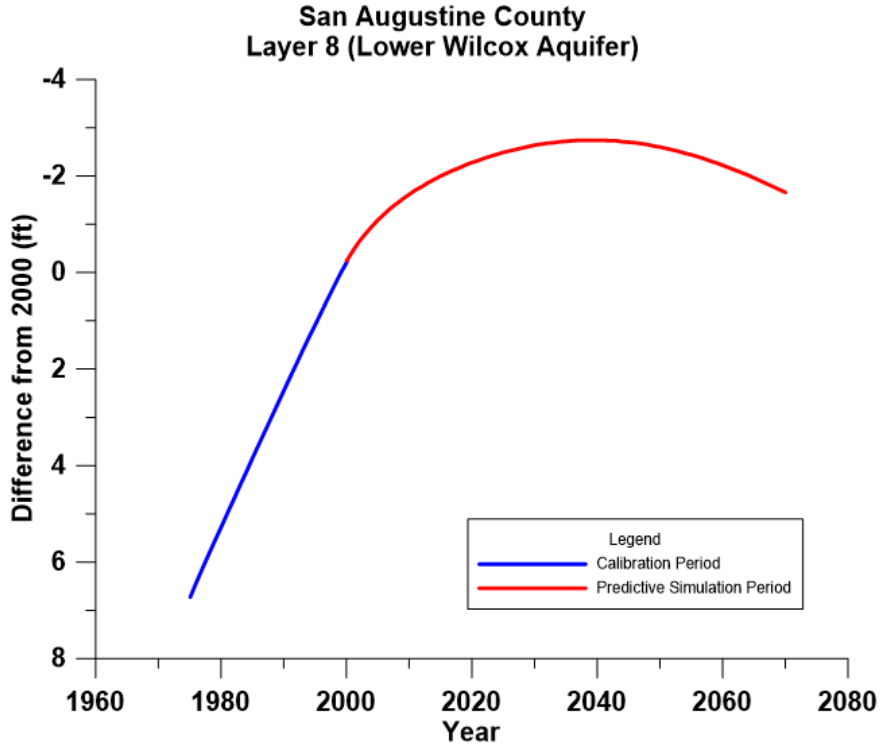


Figure 3. Average Drawdown from Previous Groundwater Availability Model - San Augustine County, Layer 8

Please note that in the previous Groundwater Availability Model, Layer 8 represented the Lower Wilcox Aquifer. This new Groundwater Availability Model has an extra layer to simulate alluvial formations in the areas of streams and rivers, so Layer 9 now represents the Lower Wilcox Aquifer.

As discussed in Hutchison (2017b), during the calibration period, average groundwater levels rose about 7 feet from 1975 to 1999. This suggests that the model is simulating actual conditions well. The model conditions that caused the rise from 1975 to 1999 continue to affect the change in average groundwater levels after 2000 (the simulation period). The rise continues until about 2030, and the model predicts a drop in average groundwater level after this peak. However, the decline from 2030 to 2070 leaves the average groundwater level higher than the average level in 2000 (the start of the simulation period). This was an example of a model limitation that had to considered when using the results of the old model in considering desired future conditions. Based on the hydrograph in Figure 3 and an inspection of all the hydrographs in Appendix A, this limitation has been eliminated in this updated Groundwater Availability Model.

Summary graphs that compare the range in calibration period drawdown and the range in the predictive period drawdown for all scenarios are presented in Appendix A. Each graph plots the range in drawdowns for each county for a specific layer. These plots, and companion plots in Technical Memorandum 1 are useful in interpreting simulation results for the joint planning process. The results in Appendix A were extracted from the individual drawdown files using a FORTRAN program named *sumrechsens.exe*. Please note that in Morris County, the drawdowns in 1989, 1990, and 1991 appeared to be outliers, possibly due to unusually high pumping. These years were discarded when calculating the maximum range of drawdown in Morris County during the calibration period.

A final comparison of the relative sensitivity of pumping and recharge during the predictive period is made with summary graphs in Appendix B, which includes nine plots that compare the predictive range of drawdown under the pumping scenarios documented in Technical Memorandum 1 and the predictive range of drawdowns under the recharge scenarios documented in this Technical Memorandum. Please note that the shallower formations show more sensitivity to recharge than pumping, and the deeper layers show much higher sensitivity to pumping. Although specific conclusions are county dependent, these results will be useful during the joint planning process. It is also consistent with the historic pumping in the area, which has been historically higher in the deeper formations (i.e. Carrizo-Wilcox) as compared with the Sparta and Queen City.

5.0 Limitations

The objective of these simulations was to provide a practical basis for selecting a base recharge amount for simulations focused on joint planning. As a result, there are some limitations to the results given the regional nature of the objective:

- The scenarios considered only increases and decreases in overall recharge pumping to assess general sensitivity of recharge on average drawdown. For this analysis, there were no attempts to vary the recharge year to year, which would occur (i.e. simulate wet periods and dry periods).
- The results provide some insight on recharge sensitivity but are coupled with a companion analysis of sensitivity to pumping contained in Technical Memorandum 2 and the graphs in Appendix B.

6.0 References

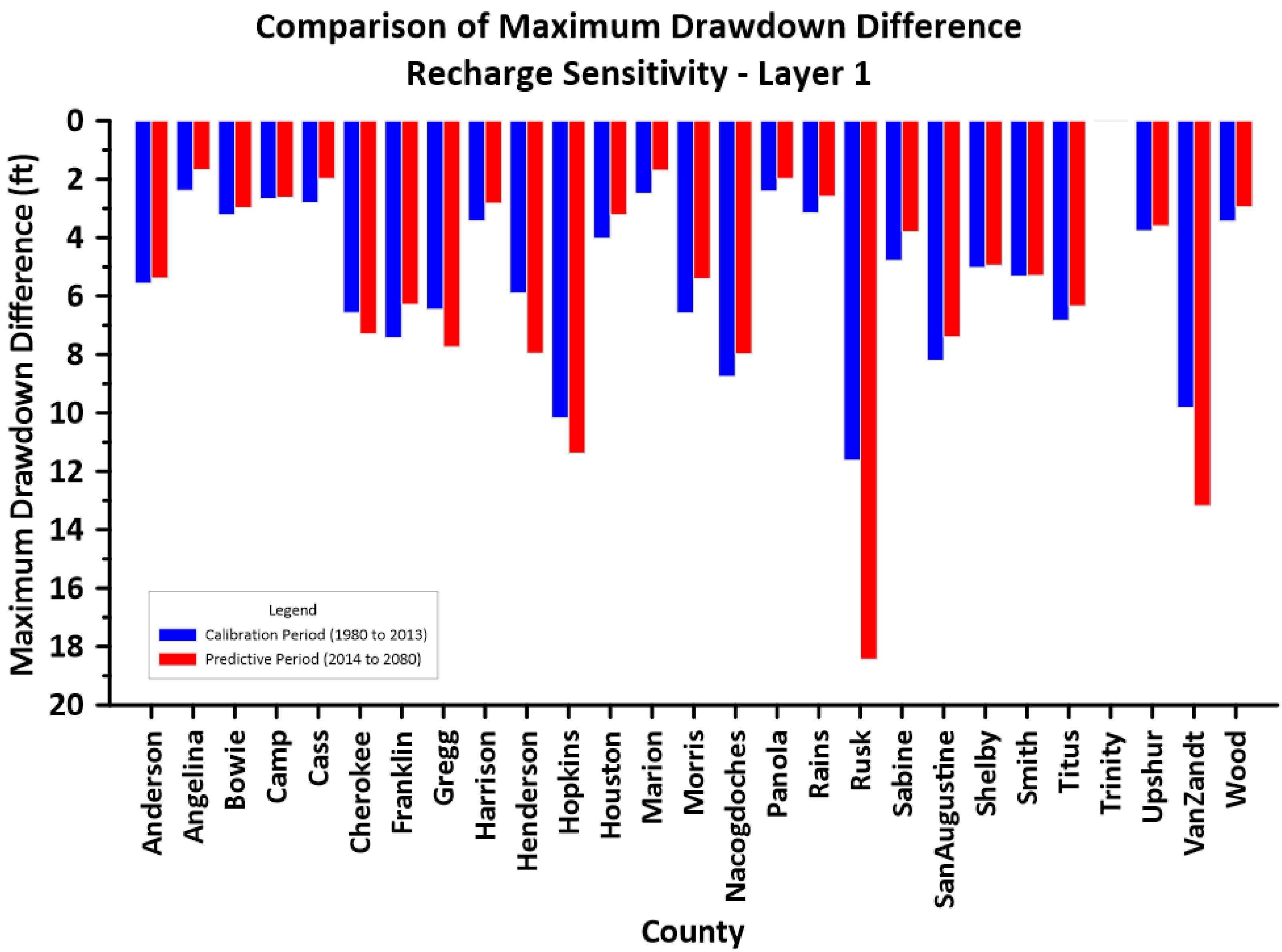
Hutchison, W.R., 2017a. Desired Future Condition Explanatory Report: Carrizo-Wilcox/Queen City/Sparta Aquifers for Groundwater Management Area 11. Report submitted to Texas Water Development Board, January 24, 2017, 445p.

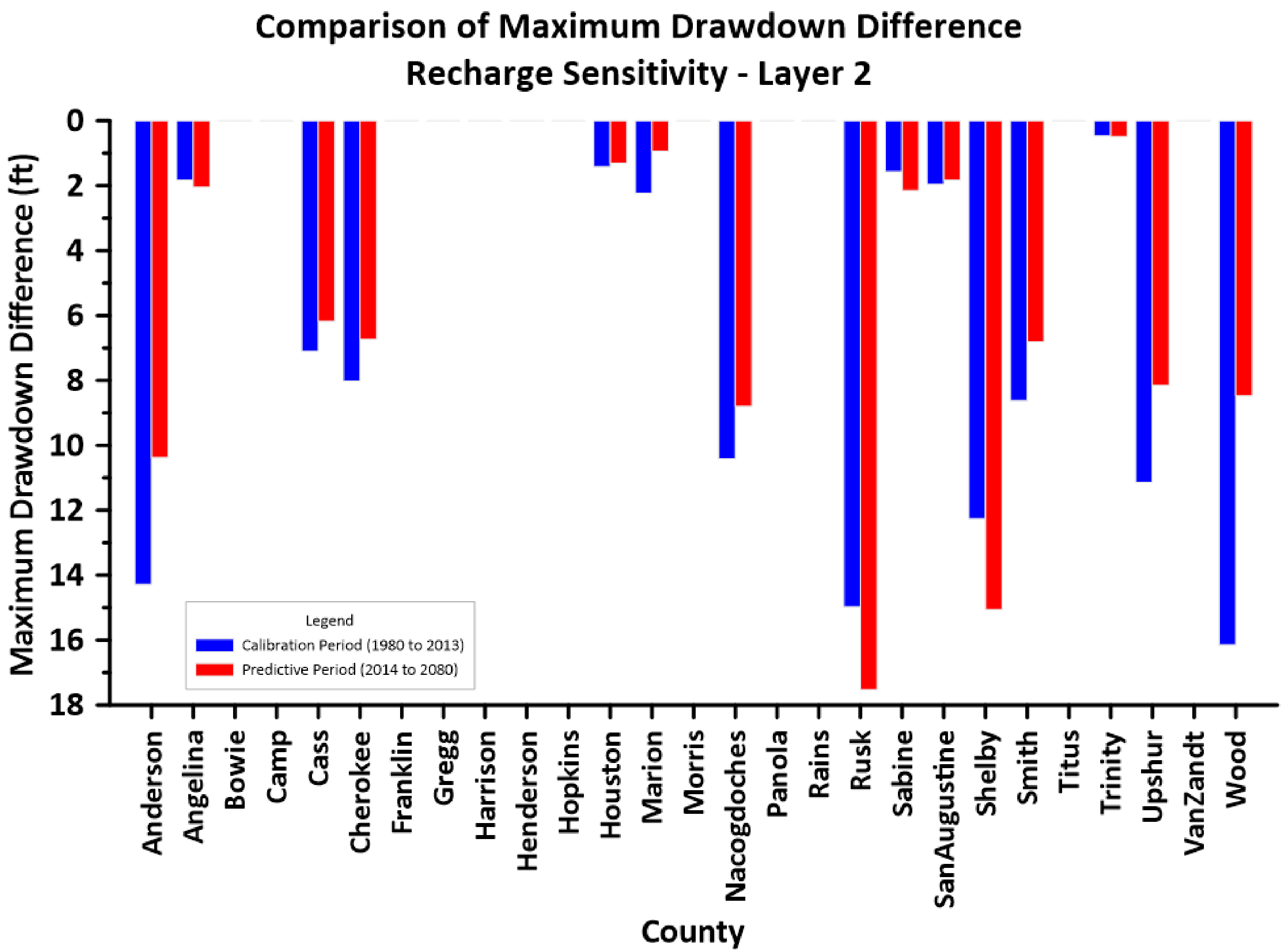
Hutchison, W.R., 2017b. Use of Predictive Simulation Results from Scenario 4 in Desired Future Conditions for Sparta, Queen City, and Carrizo-Wilcox Aquifer. GMA 11 Technical Memorandum 16-02. Report submitted to Groundwater Management Area 11. January 24, 2017, 15p.

Hutchison, W.R., 2017c. Initial GAM Simulations for Sparta, Queen City and Carrizo-Wilcox Aquifers. GMA 11 Technical Memorandum 15-01. Report submitted to Groundwater Management Area 11. January 21, 2017, 109p.

Appendix A

Comparison of Maximum Drawdown Difference – Recharge Sensitivity (one graph per model layer, each graph shows 27 counties)


Comparison of Maximum Drawdown Difference
Recharge Sensitivity - Layer 1
Maximum Drawdown Difference (ft)
0
2
4
6
8
10
12
14
16
18
20
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
Panola
Rains
Rusk
Sabine
SanAugustine
Shelby
Smith
Titus
Trinity
Upshur
VanZandt
Wood
County



Comparison of Maximum Drawdown Difference
Recharge Sensitivity - Layer 2
Maximum Drawdown Difference (ft)
0
2
4
6
8
10
12
14
16
18
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
Panola
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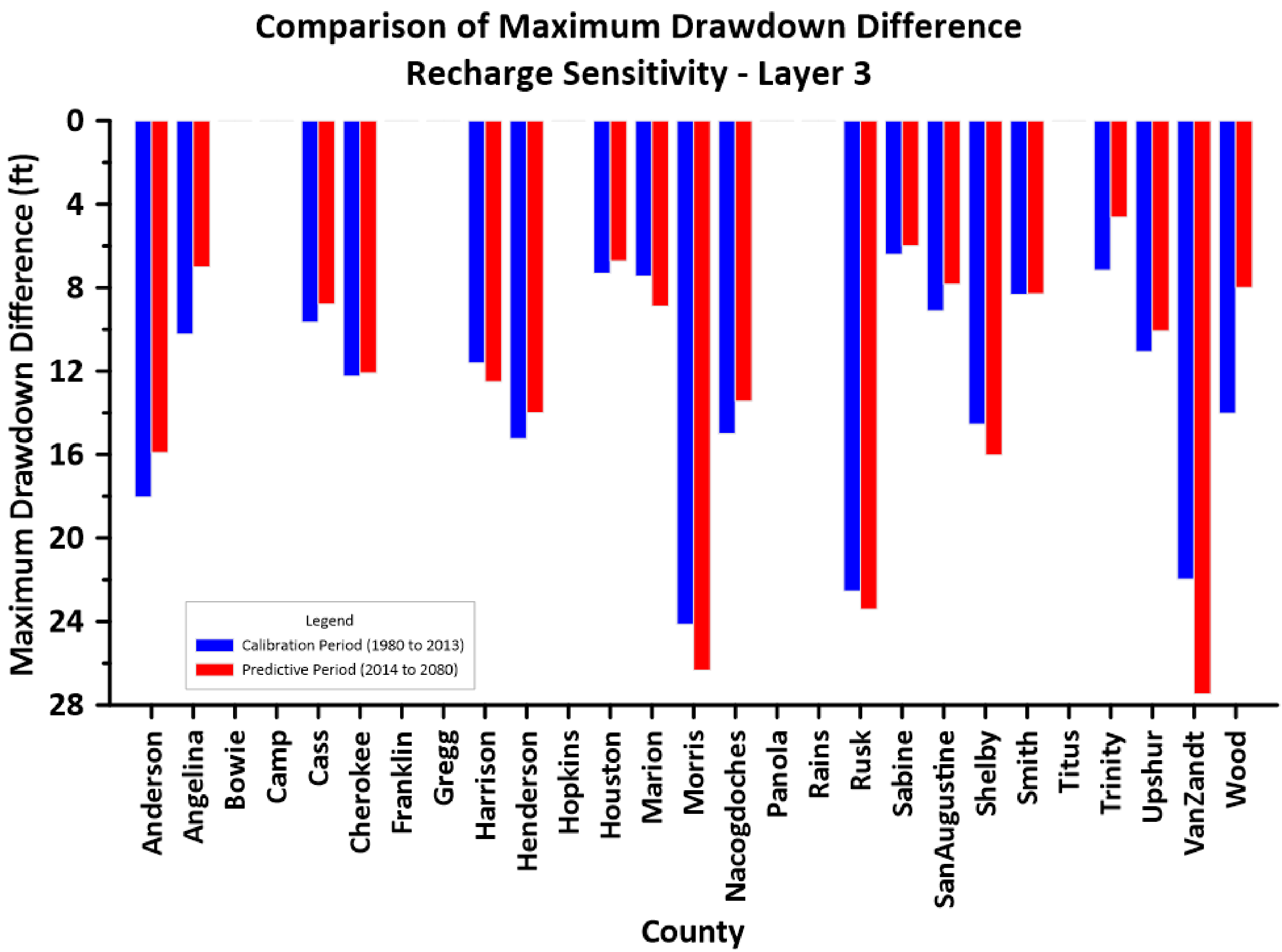
Rusk
Sabine
SanAugustine
Shelby
Smith
Titus
Trinity
Upshur
VanZandt
Wood
County


Comparison of Maximum Drawdown Difference
Recharge Sensitivity - Layer 3
Maximum Drawdown Difference (ft)
0
4
8
12
16
20
24
28
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
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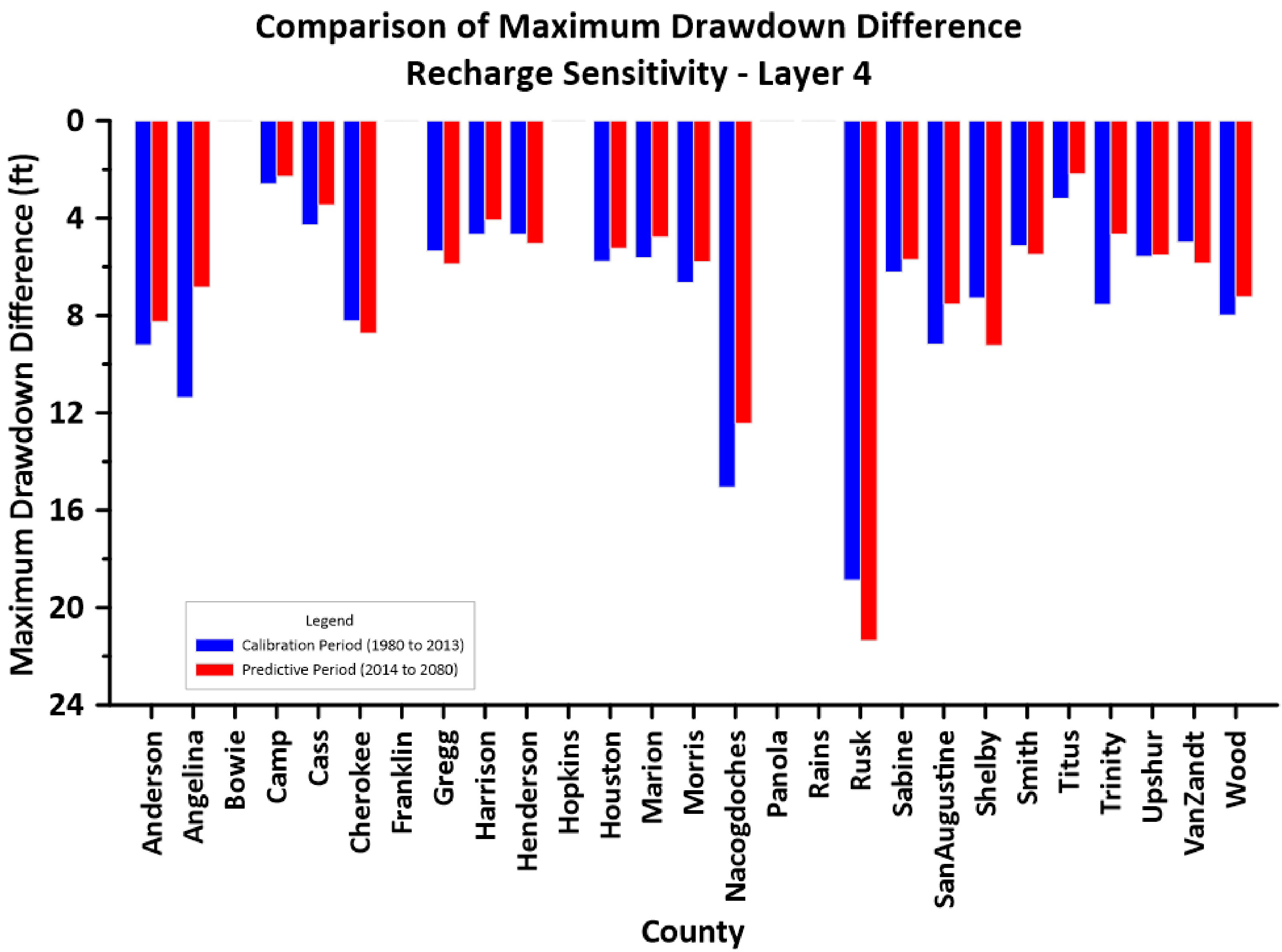
Titus
Trinity
Upshur
VanZandt
Wood
County


Comparison of Maximum Drawdown Difference
Recharge Sensitivity - Layer 4
Maximum Drawdown Difference (ft)
0
4
8
12
16
20
24
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
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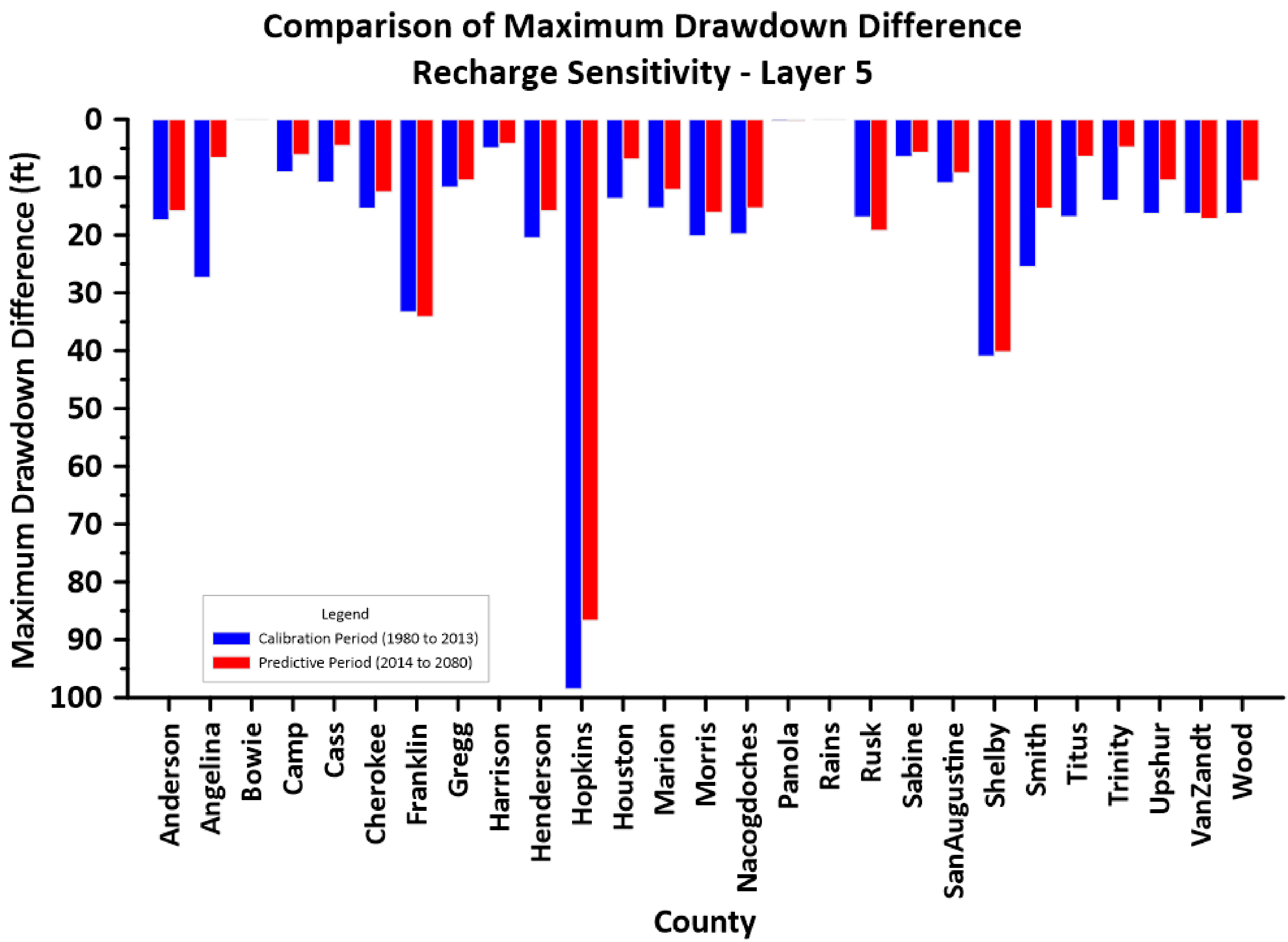
Trinity
Upshur
VanZandt
Wood
County



Comparison of Maximum Drawdown Difference
Recharge Sensitivity - Layer 5
Maximum Drawdown Difference (ft)
0
10
20
30
40
50
60
70
80
90
100
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
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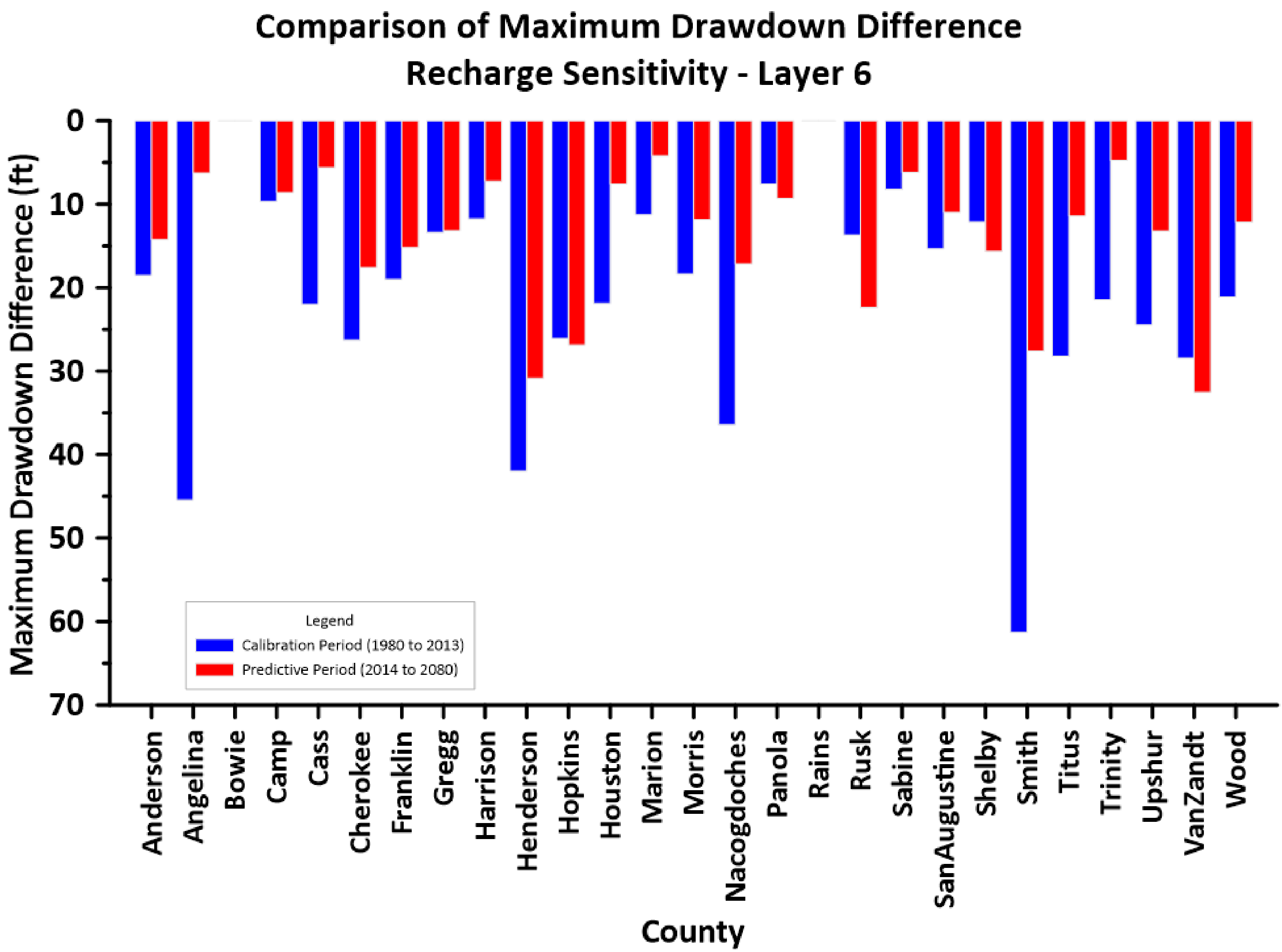
VanZandt
Wood
County


Comparison of Maximum Drawdown Difference
Recharge Sensitivity - Layer 6
Maximum Drawdown Difference (ft)
0
10
20
30
40
50
60
70
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
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Marion
Morris
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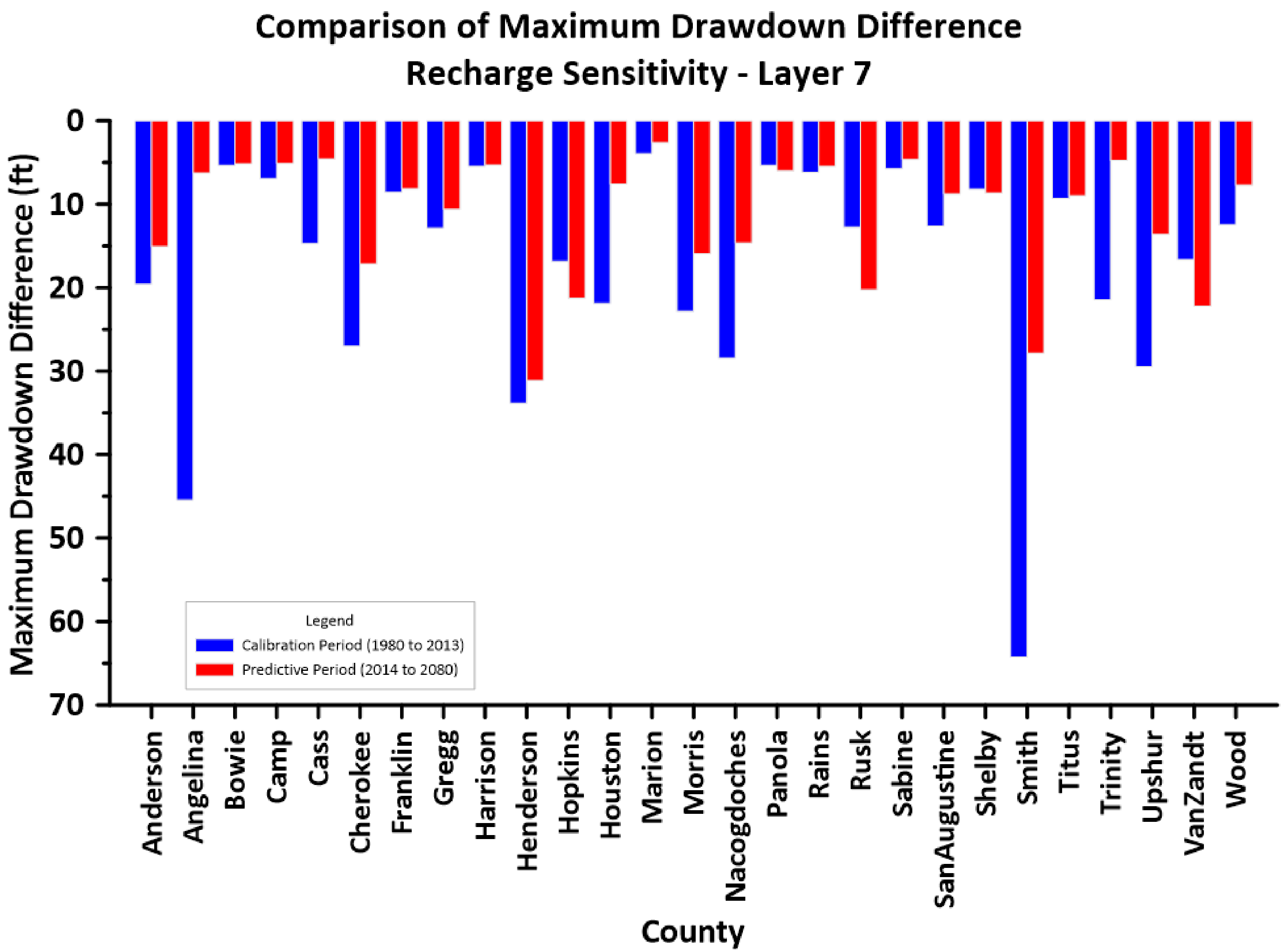
VanZandt
Wood
County



Comparison of Maximum Drawdown Difference
Recharge Sensitivity - Layer 7
Maximum Drawdown Difference (ft)
0
10
20
30
40
50
60
70
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
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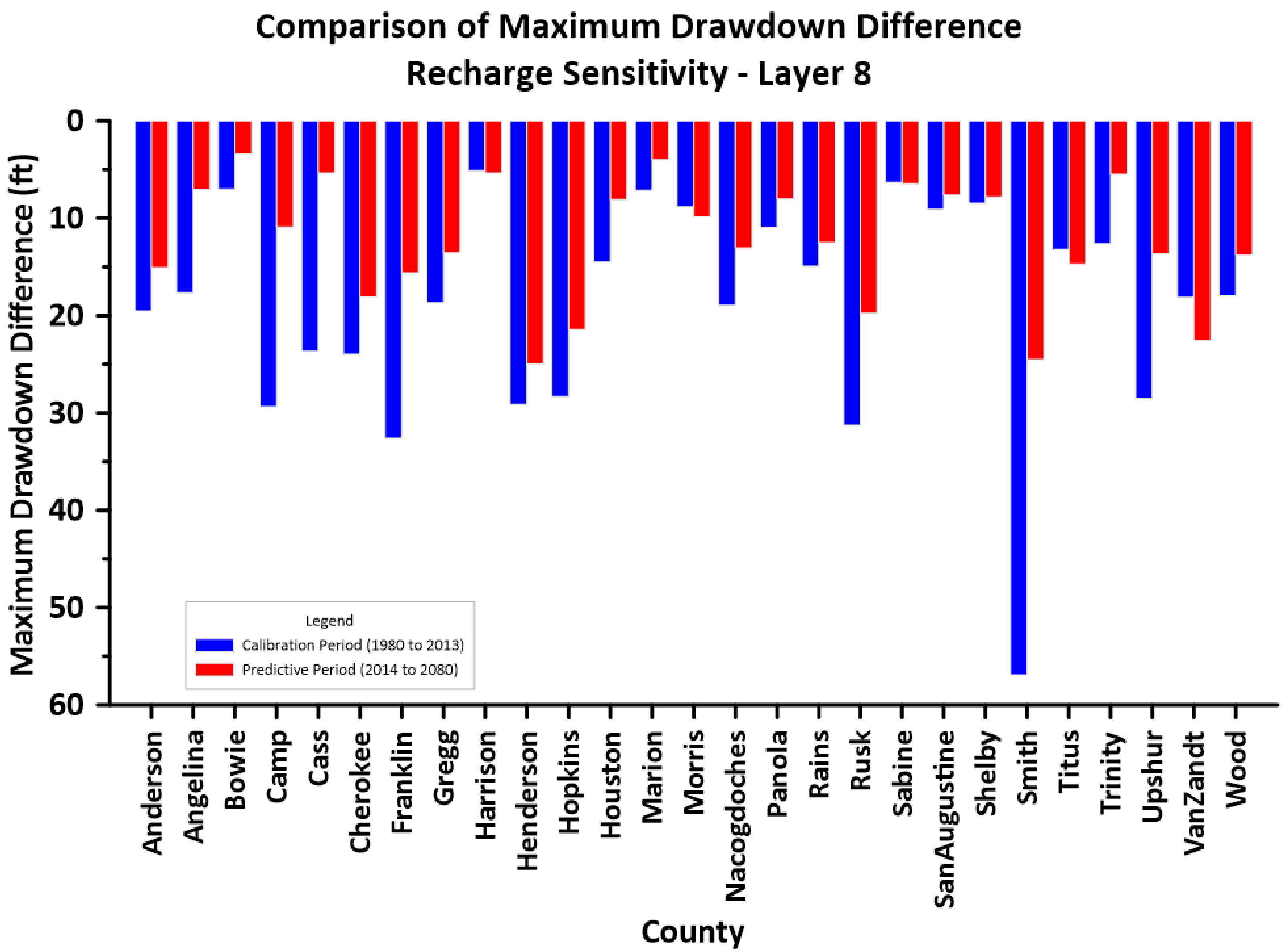
VanZandt
Wood
County


Comparison of Maximum Drawdown Difference
Recharge Sensitivity - Layer 8
Maximum Drawdown Difference (ft)
0
10
20
30
40
50
60
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
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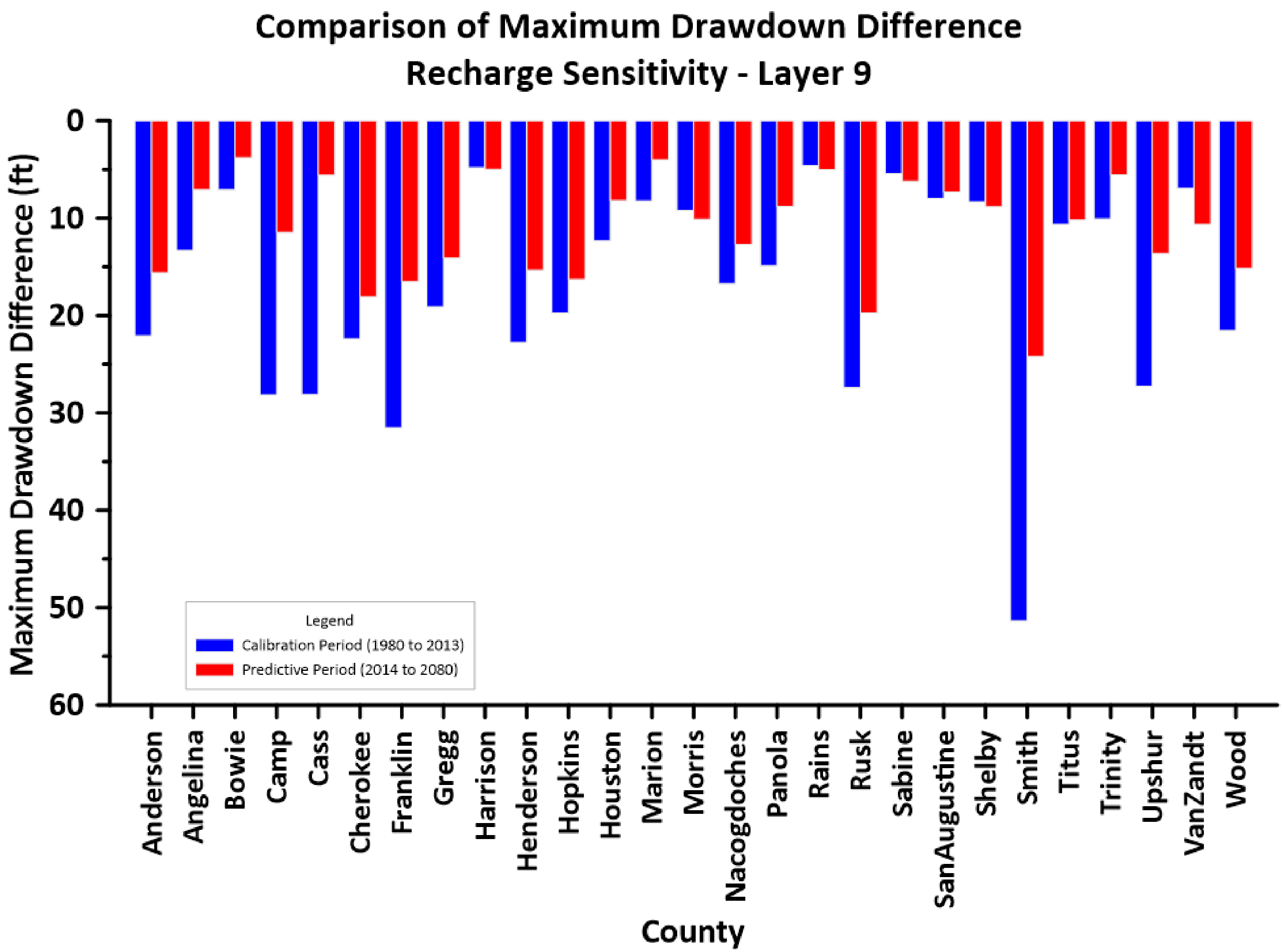

Comparison of Maximum Drawdown Difference
Recharge Sensitivity - Layer 9
Maximum Drawdown Difference (ft)
0
10
20
30
40
50
60
Legend
Calibration Period (1980 to 2013)
Predictive Period (2014 to 2080)
Anderson
Angelina
Bowie
Camp
Cass
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Henderson
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Houston
Marion
Morris
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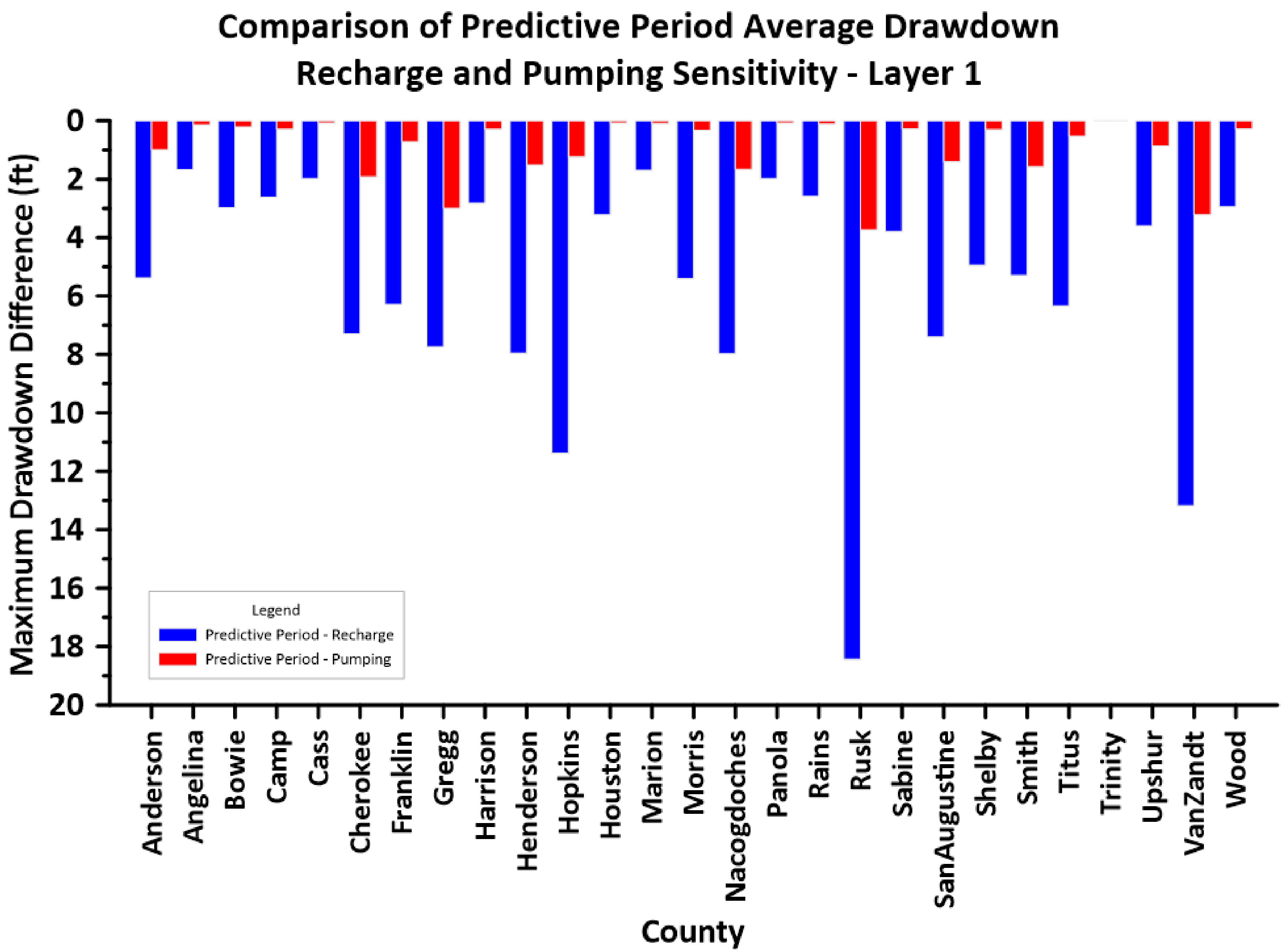
VanZandt
Wood
County

Appendix B

Comparison of Predictive Period Average Drawdown - Recharge and Pumping Sensitivity (one graph per model layer, each graph shows 27 counties)


Comparison of Predictive Period Average Drawdown
Recharge and Pumping Sensitivity - Layer 1
Maximum Drawdown Difference (ft)
0
2
4
6
8
10
12
14
16
18
20
Legend
Predictive Period - Recharge
Predictive Period - Pumping
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
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Henderson
Hopkins
Houston
Marion
Morris
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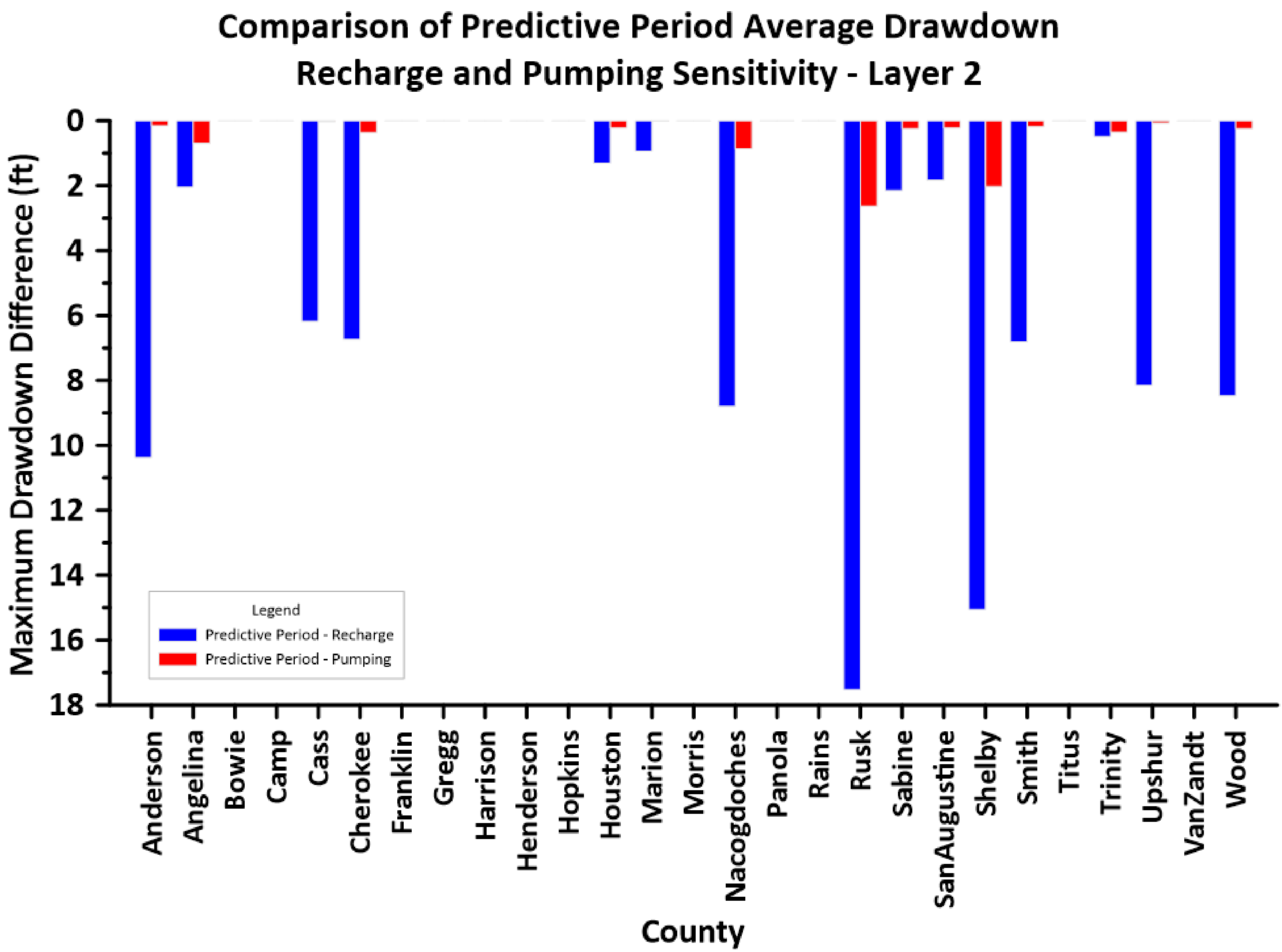
Wood
County


Comparison of Predictive Period Average Drawdown
Recharge and Pumping Sensitivity - Layer 2
Maximum Drawdown Difference (ft)
0
2
4
6
8
10
12
14
16
18
Legend
Predictive Period - Recharge
Predictive Period - Pumping
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
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Marion
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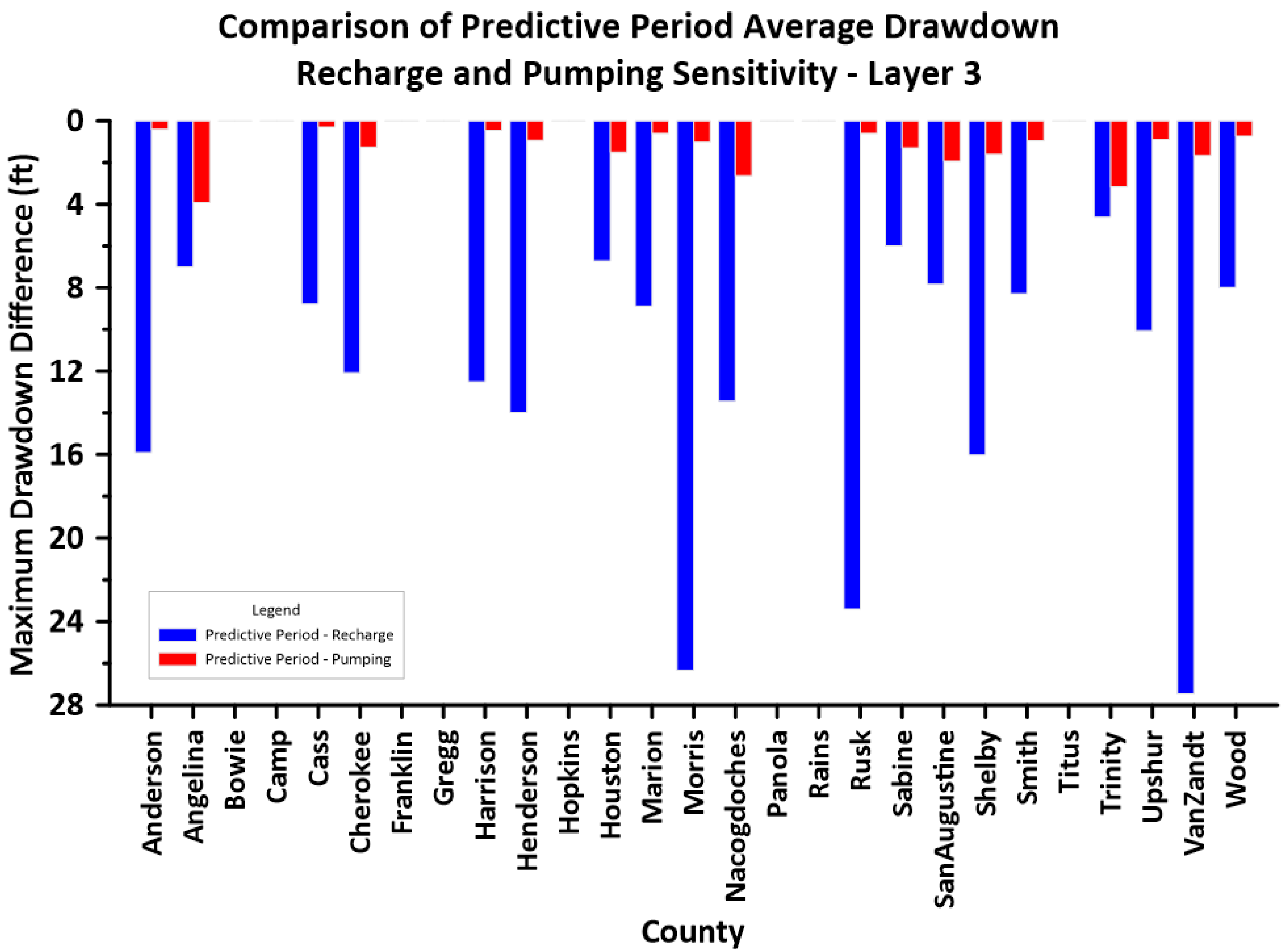
Wood
County



Comparison of Predictive Period Average Drawdown
Recharge and Pumping Sensitivity - Layer 3
Maximum Drawdown Difference (ft)
0
4
8
12
16
20
24
28
Legend
Predictive Period - Recharge
Predictive Period - Pumping
Anderson
Angelina
Bowie
Camp
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Hopkins
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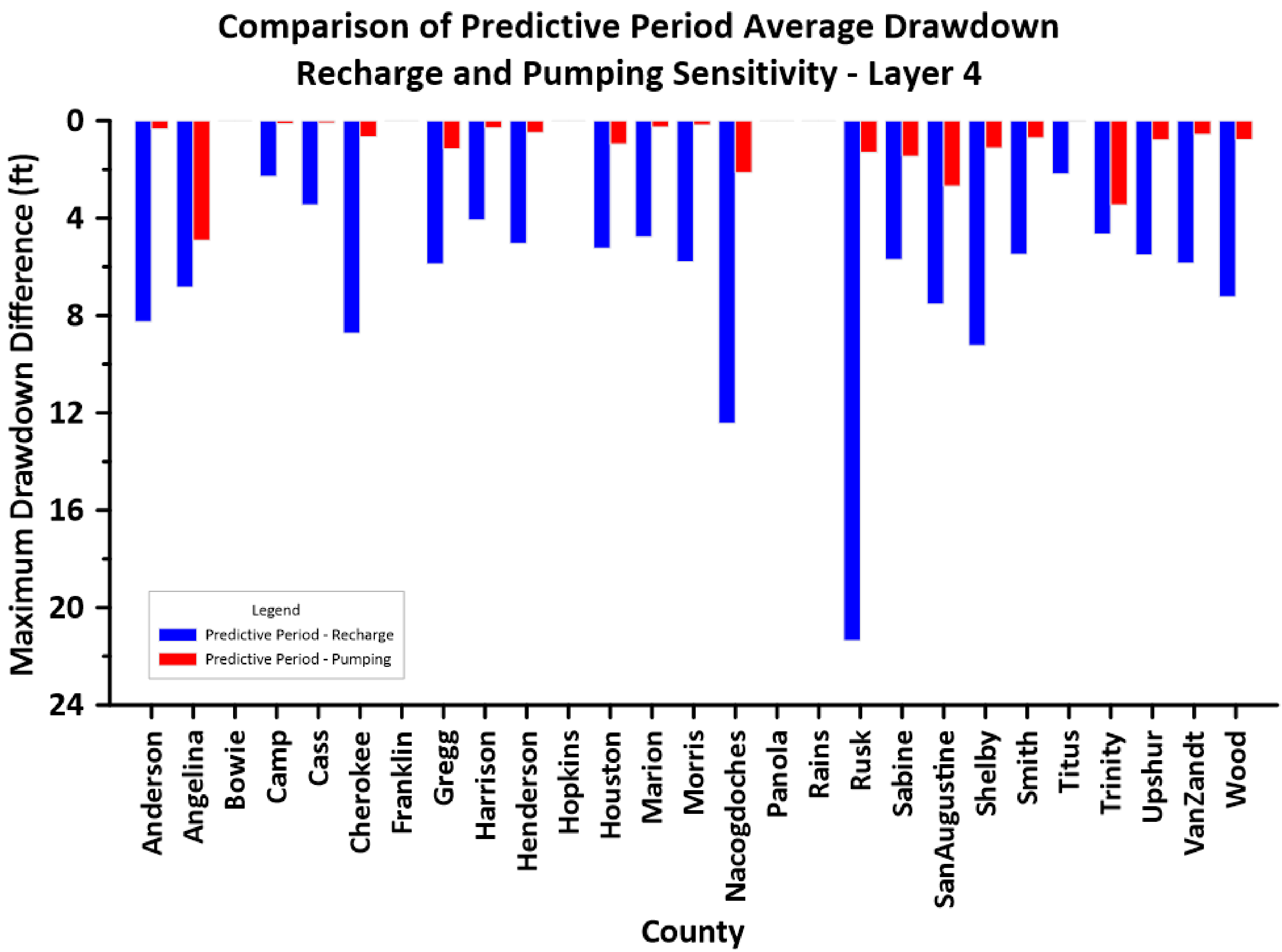

Comparison of Predictive Period Average Drawdown
Recharge and Pumping Sensitivity - Layer 4
Maximum Drawdown Difference (ft)
0
4
8
12
16
20
24
Legend
Predictive Period - Recharge
Predictive Period - Pumping
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
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Marion
Morris
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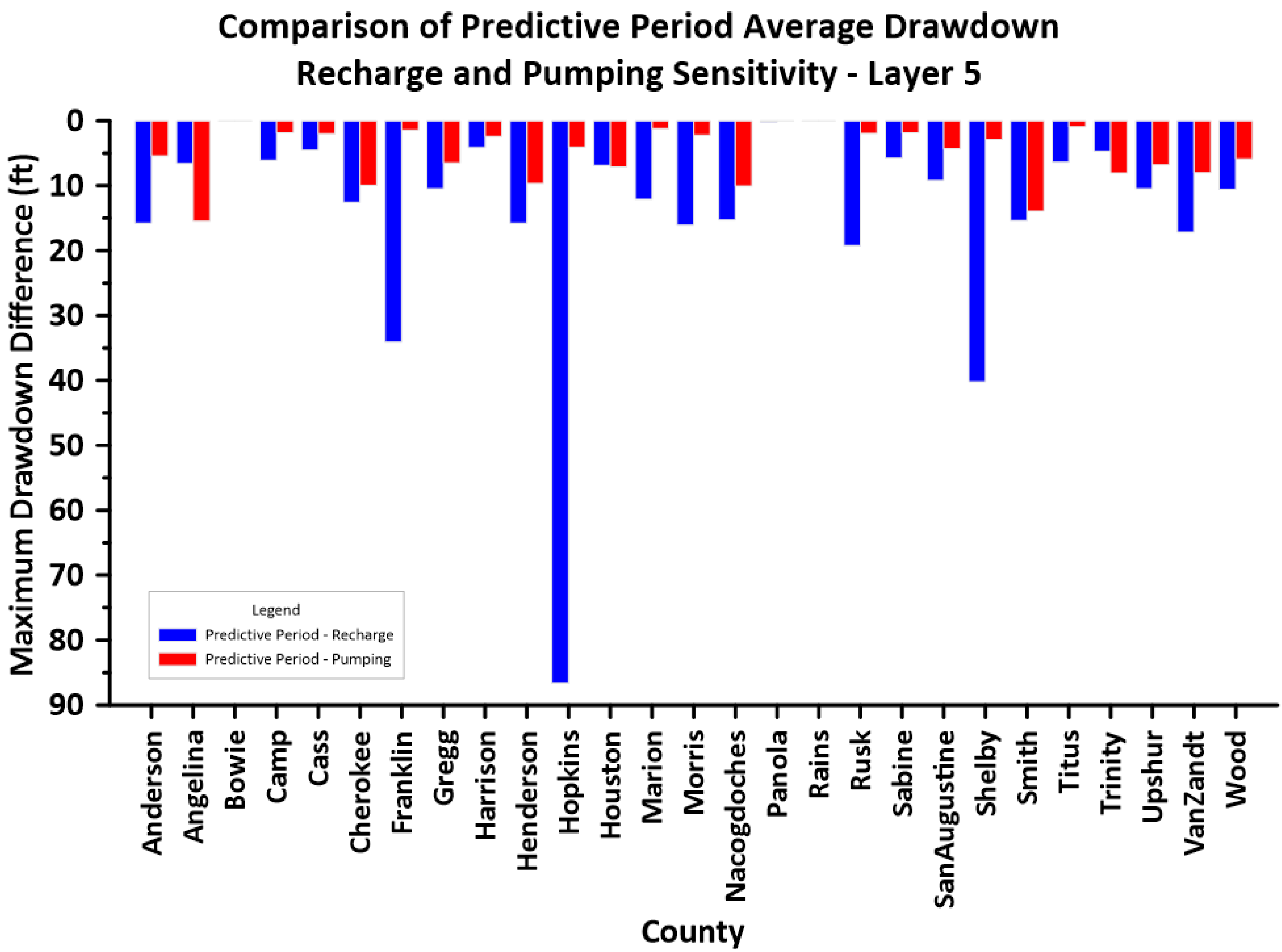
Wood
County


Comparison of Predictive Period Average Drawdown
Recharge and Pumping Sensitivity - Layer 5
Maximum Drawdown Difference (ft)
0
10
20
30
40
50
60
70
80
90
Legend
Predictive Period - Recharge
Predictive Period - Pumping
Anderson
Angelina
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Cherokee
Franklin
Gregg
Harrison
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Hopkins
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Marion
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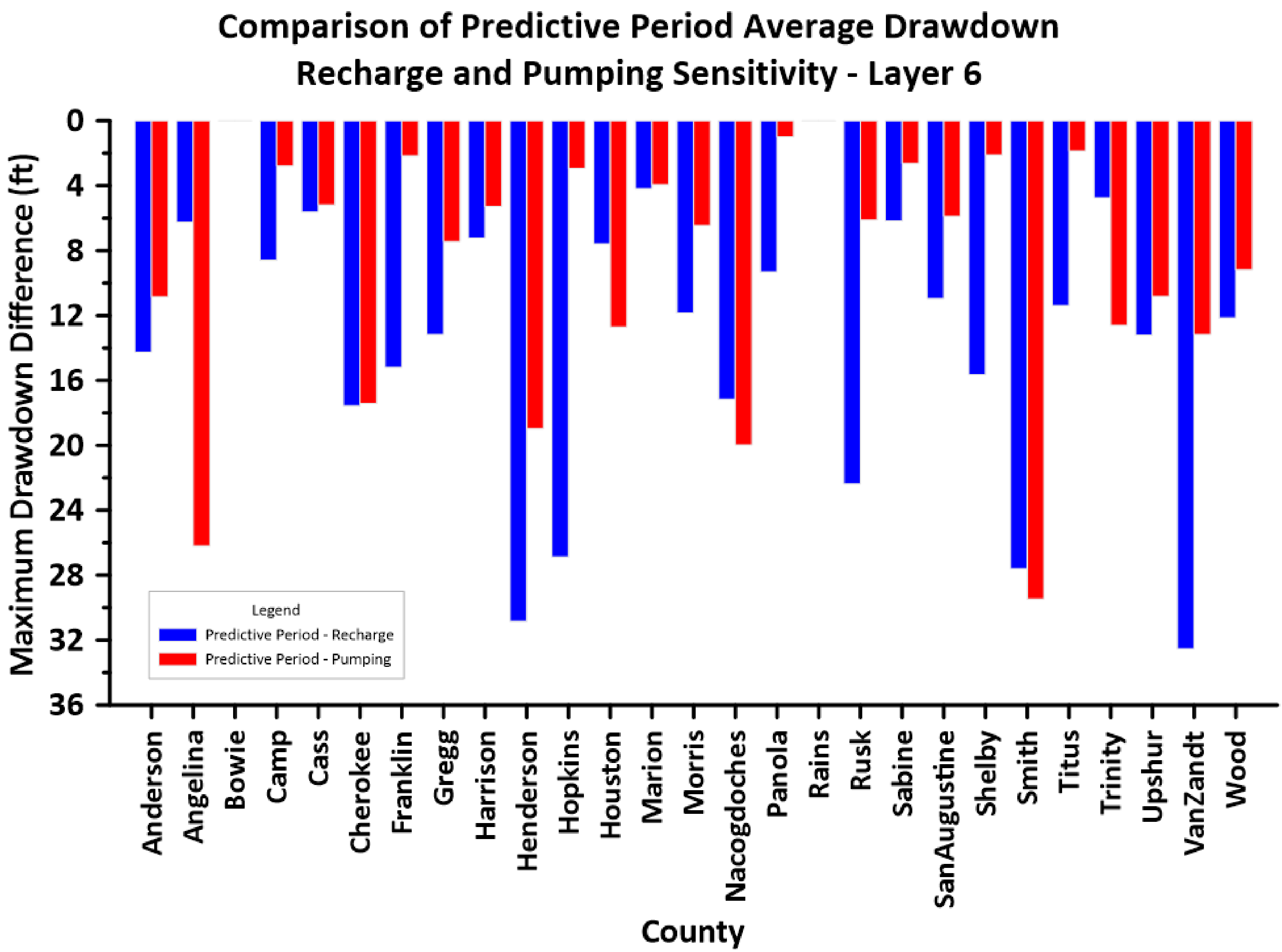
Wood
County


Comparison of Predictive Period Average Drawdown
Recharge and Pumping Sensitivity - Layer 6
Maximum Drawdown Difference (ft)
0
4
8
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28
32
36
Legend
Predictive Period - Recharge
Predictive Period - Pumping
Anderson
Angelina
Bowie
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Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
Panola
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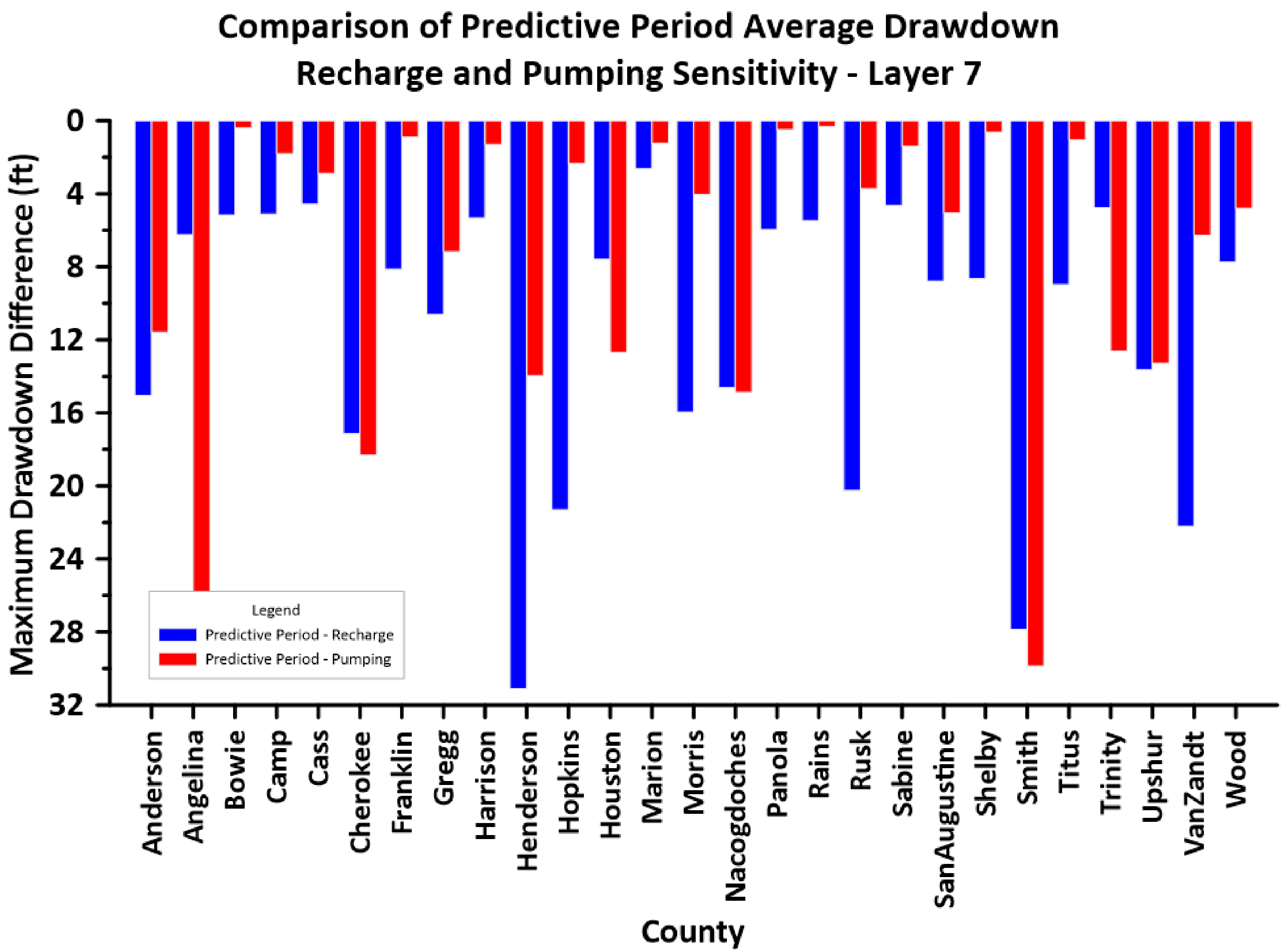
Upshur
VanZandt
Wood
County



Comparison of Predictive Period Average Drawdown
Recharge and Pumping Sensitivity - Layer 7
Maximum Drawdown Difference (ft)
0
4
8
12
16
20
24
28
32
Legend
Predictive Period - Recharge
Predictive Period - Pumping
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
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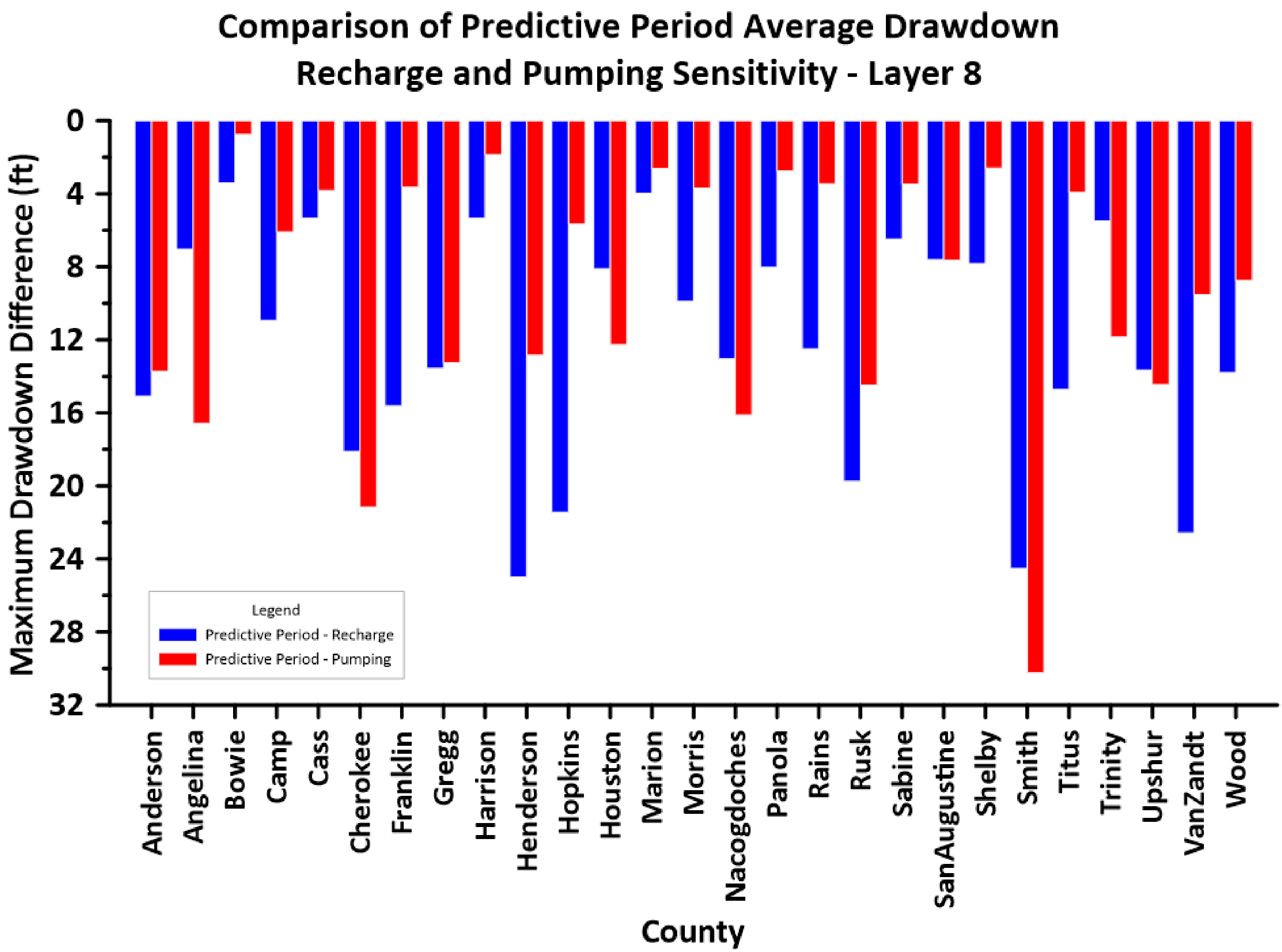
Wood
County


Comparison of Predictive Period Average Drawdown
Recharge and Pumping Sensitivity - Layer 8
Maximum Drawdown Difference (ft)
0
4
8
12
16
20
24
28
32
Legend
Predictive Period - Recharge
Predictive Period - Pumping
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
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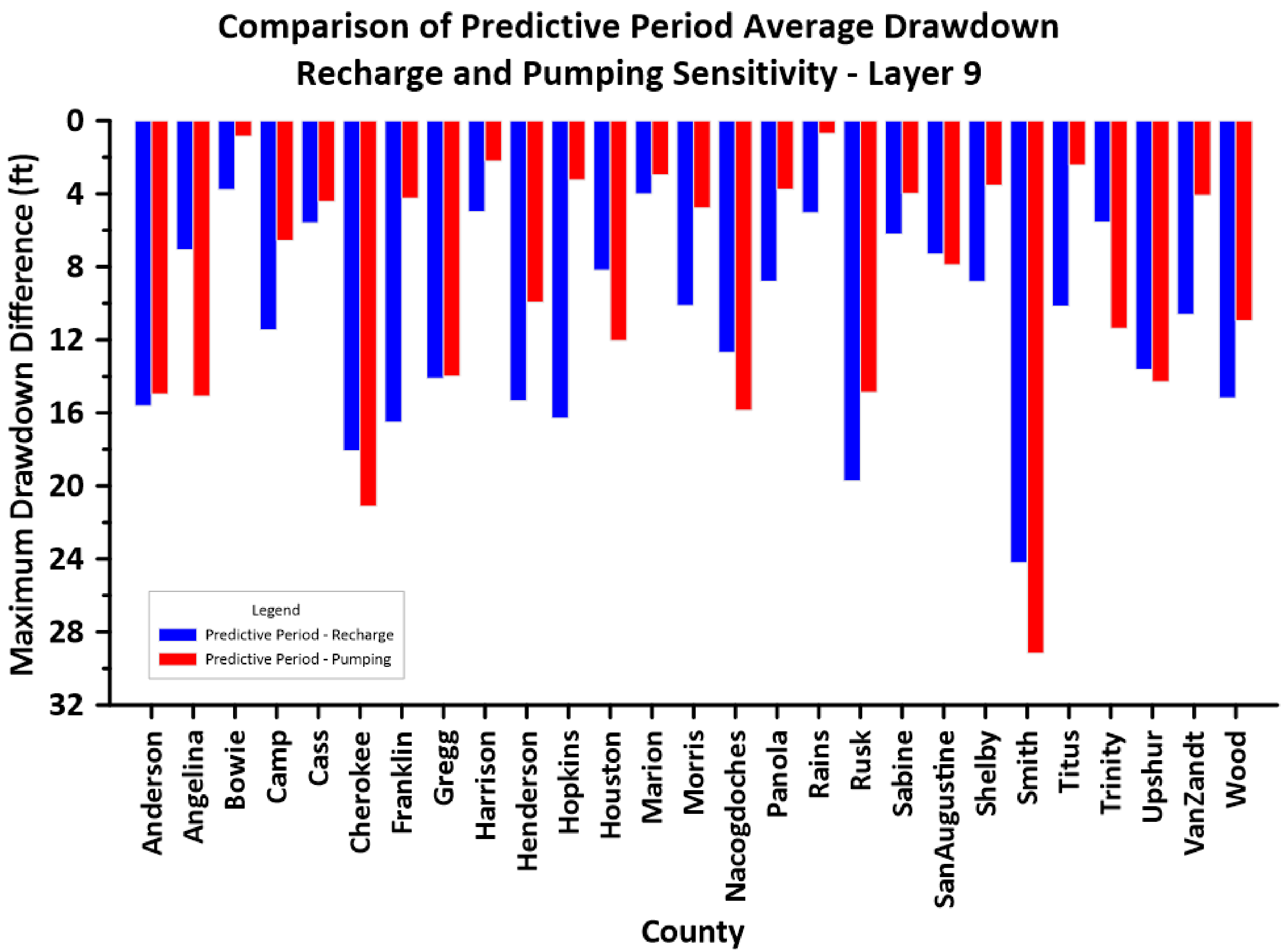
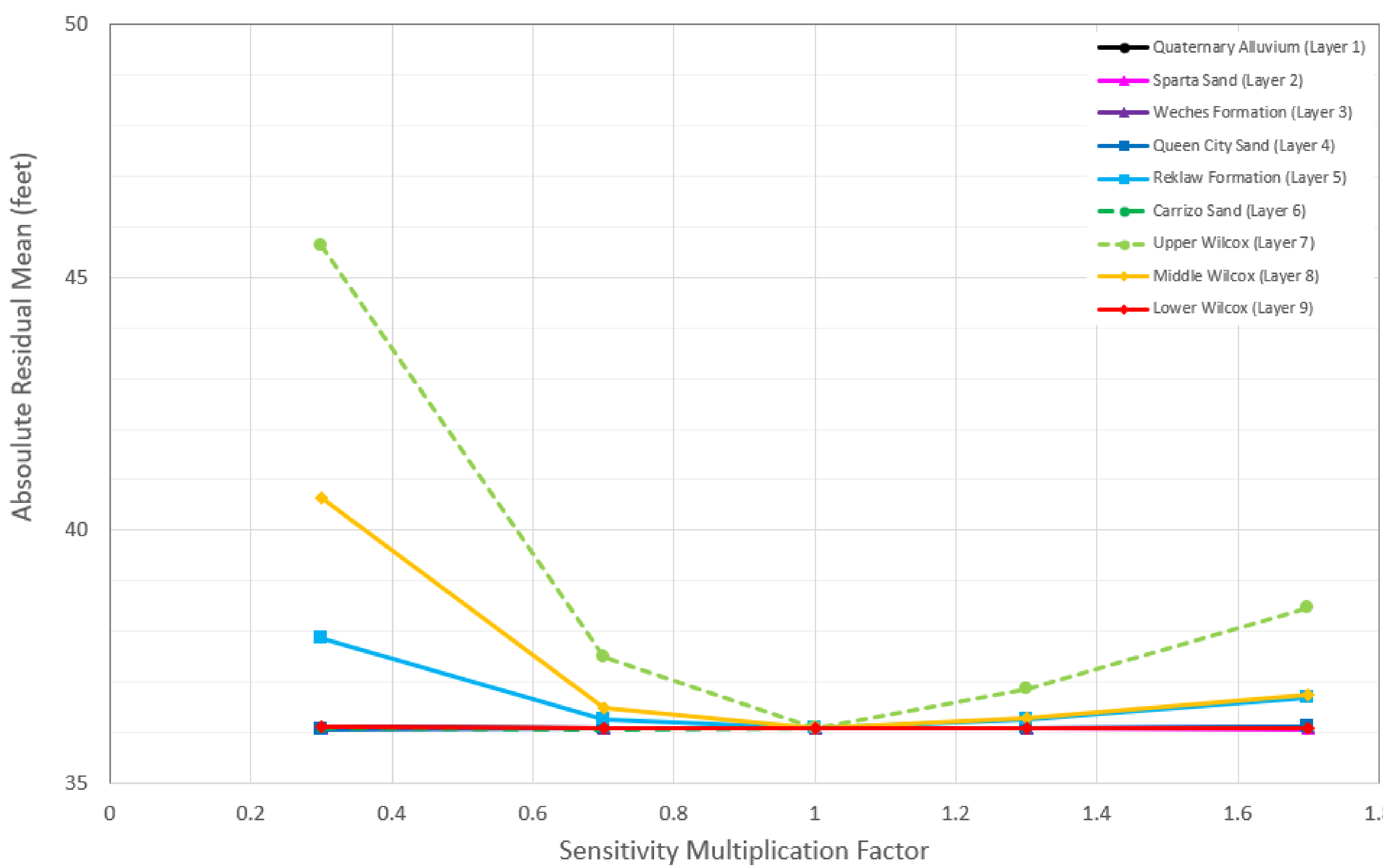
Wood
County


Comparison of Predictive Period Average Drawdown
Recharge and Pumping Sensitivity - Layer 9
Maximum Drawdown Difference (ft)
0
4
8
12
16
20
24
28
32
Legend
Predictive Period - Recharge
Predictive Period - Pumping
Anderson
Angelina
Bowie
Camp
Cass
Cherokee
Franklin
Gregg
Harrison
Henderson
Hopkins
Houston
Marion
Morris
Nacogdoches
Panola
Rains
Rusk
Sabine
SanAugustine
Shelby
Smith
Titus
Trinity
Upshur
VanZandt
Wood
County

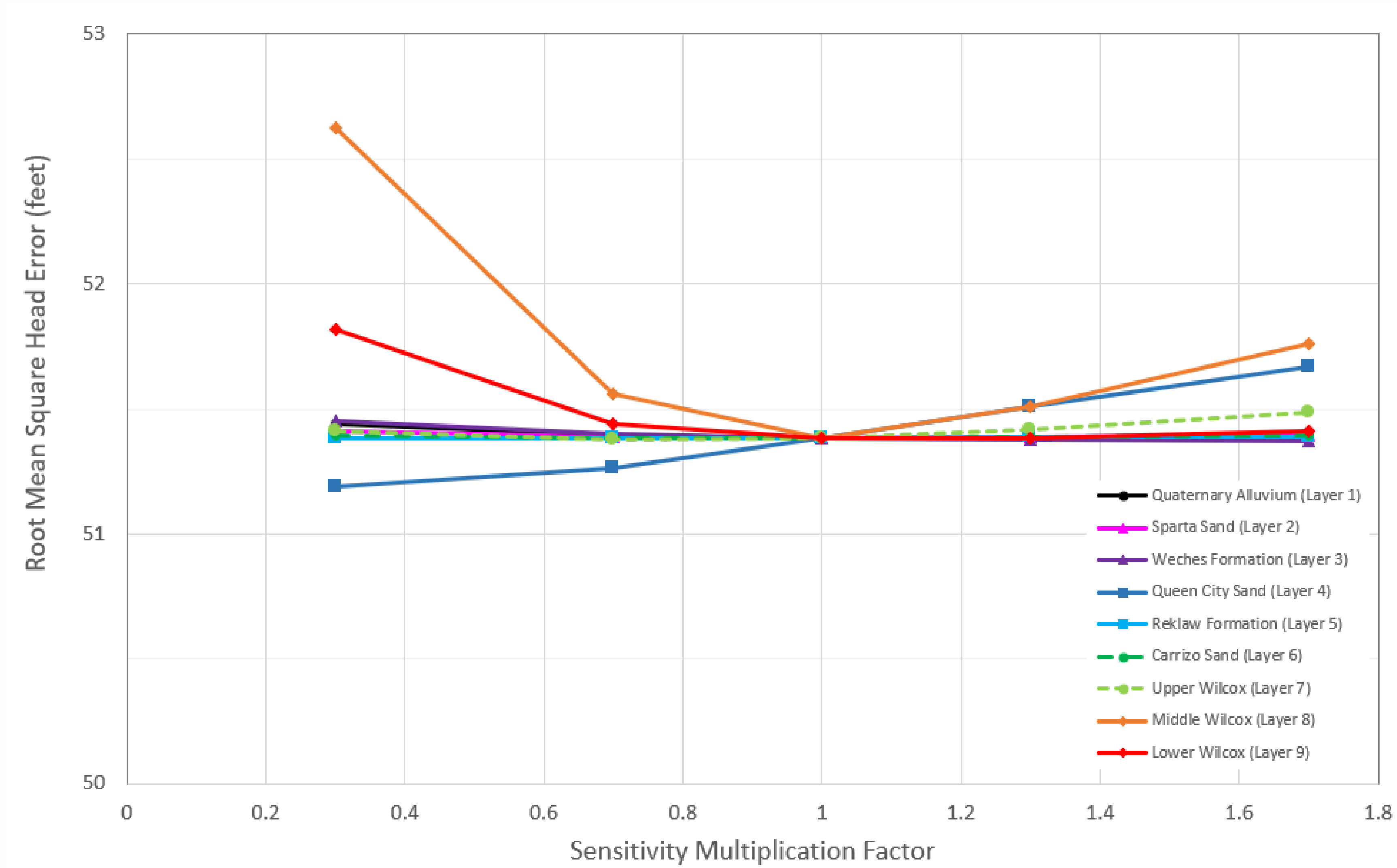


GSI ENVIRONMENTAL

GSI Job No. 4529	Drawn By: GM		
Issued: 12-Jun-2020	Chk'd By:		
Revised:	Aprv'd By: DRAFT		
Scale:	Figure 4.2-2		

SENSITIVITY OF WEIGHTED MEAN HEAD ERROR TO THE CLAY HYDRAULIC CONDUCTIVITY VALUE FOR THE VARIOUS GEOLOGIC UNITS

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers



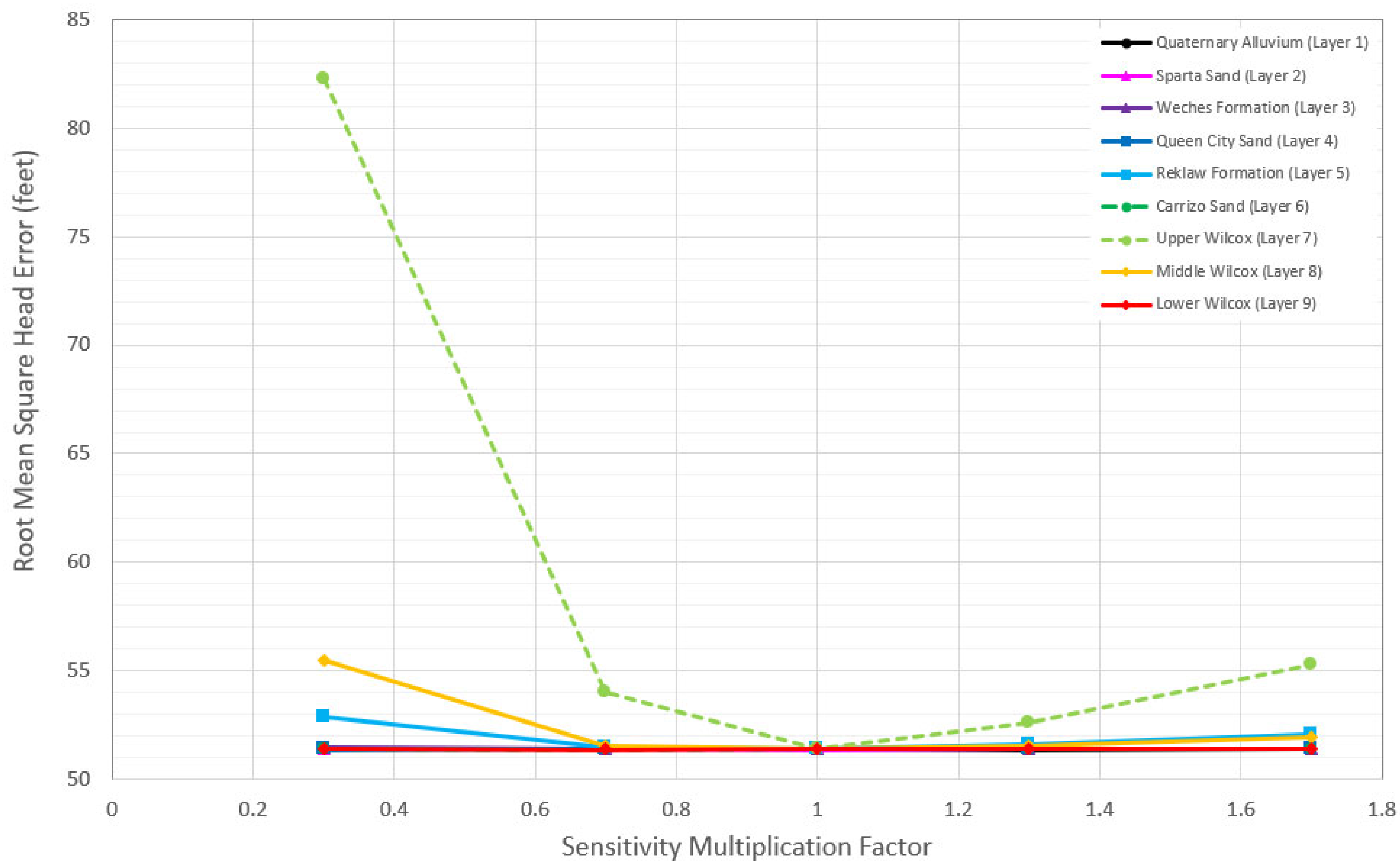
Note: RMS = root mean square

GSI ENVIRONMENTAL

GSI Job No. 4529	Drawn By: BC		
Issued: 12-June-2020	Chk'd By:		
Revised:	Aprv'd By: DRAFT		
Scale:	Figure 4.2-3		

SENSITIVITY OF WEIGHTED RMS HEAD ERROR TO THE SAND HYDRAULIC CONDUCTIVITY VALUE FOR THE VARIOUS GEOLOGIC UNITS

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers



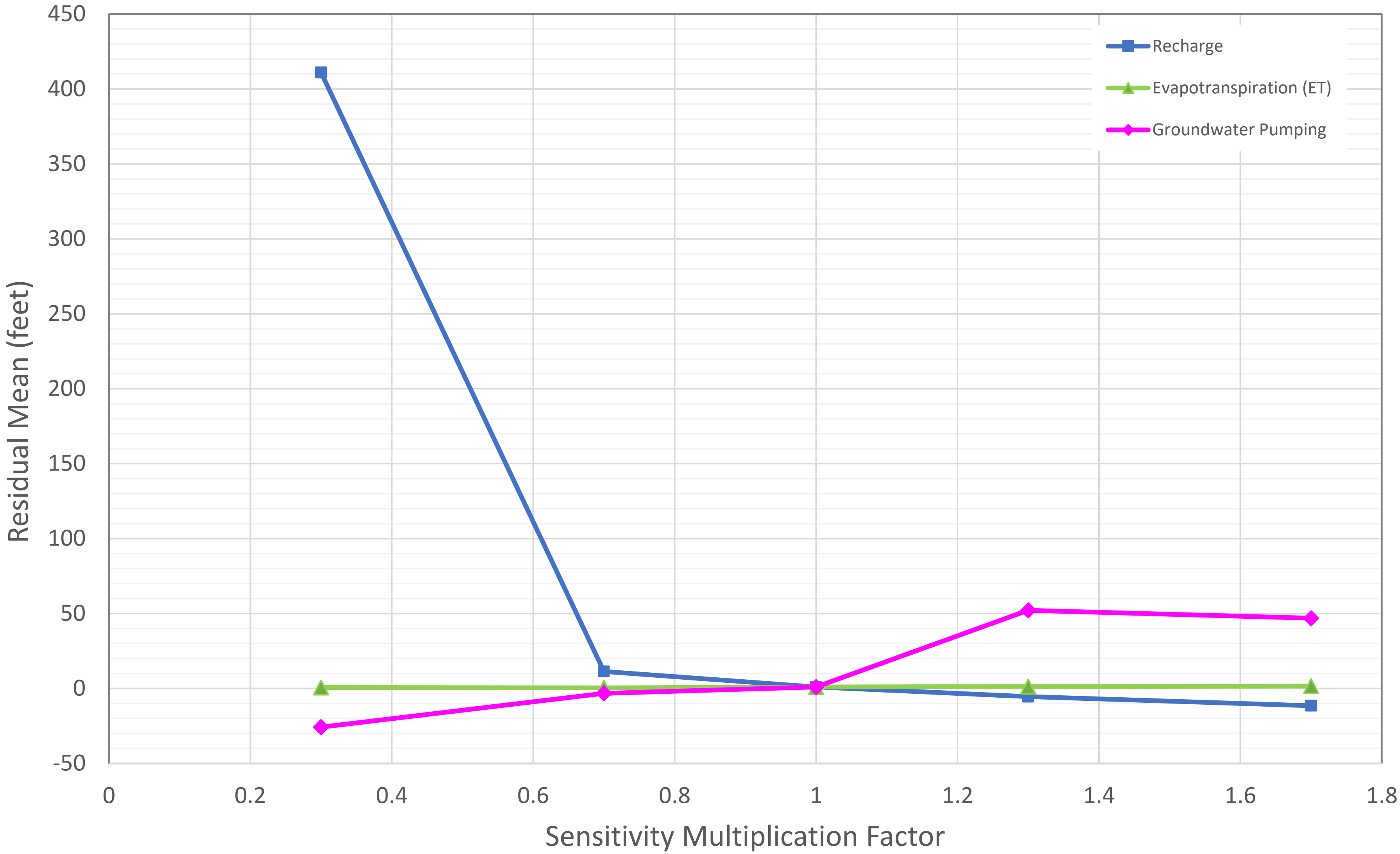
Note: RMS = root mean square

GSI ENVIRONMENTAL

GSI Job No. 4529	Drawn By: BC	
Issued: 12-June-2020	Chk'd By:	
Revised:	Aprv'd By: DRAFT	
Scale:	Figure 4.2-4	

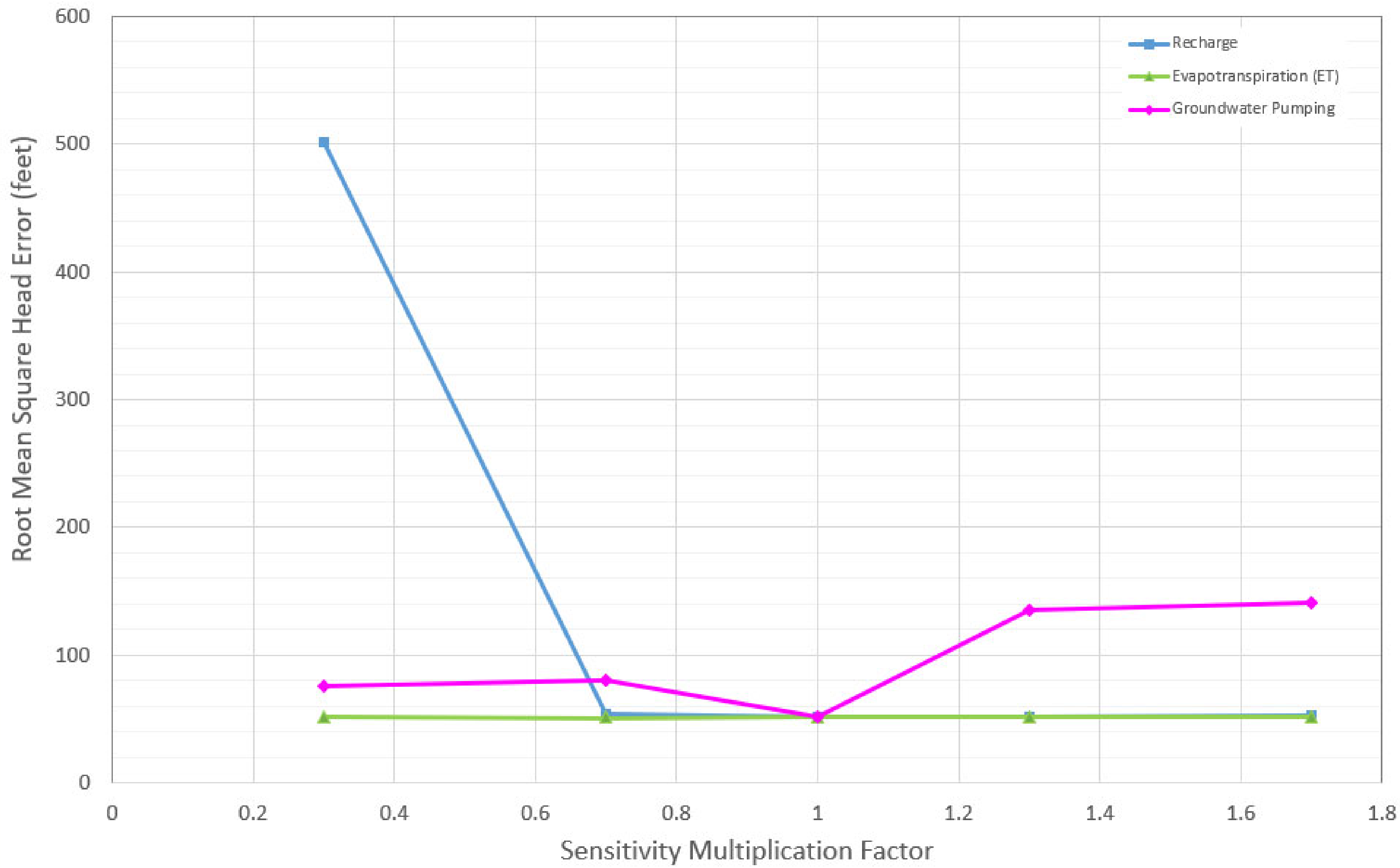
SENSITIVITY OF WEIGHTED RMS HEAD ERROR TO THE CLAY HYDRAULIC CONDUCTIVITY VALUE FOR THE VARIOUS GEOLOGIC UNITS

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers



Note: The 1.3 factor pumping sensitivity used 1,079 instead of 1,081 observation points due to boundary effects at 1 well.

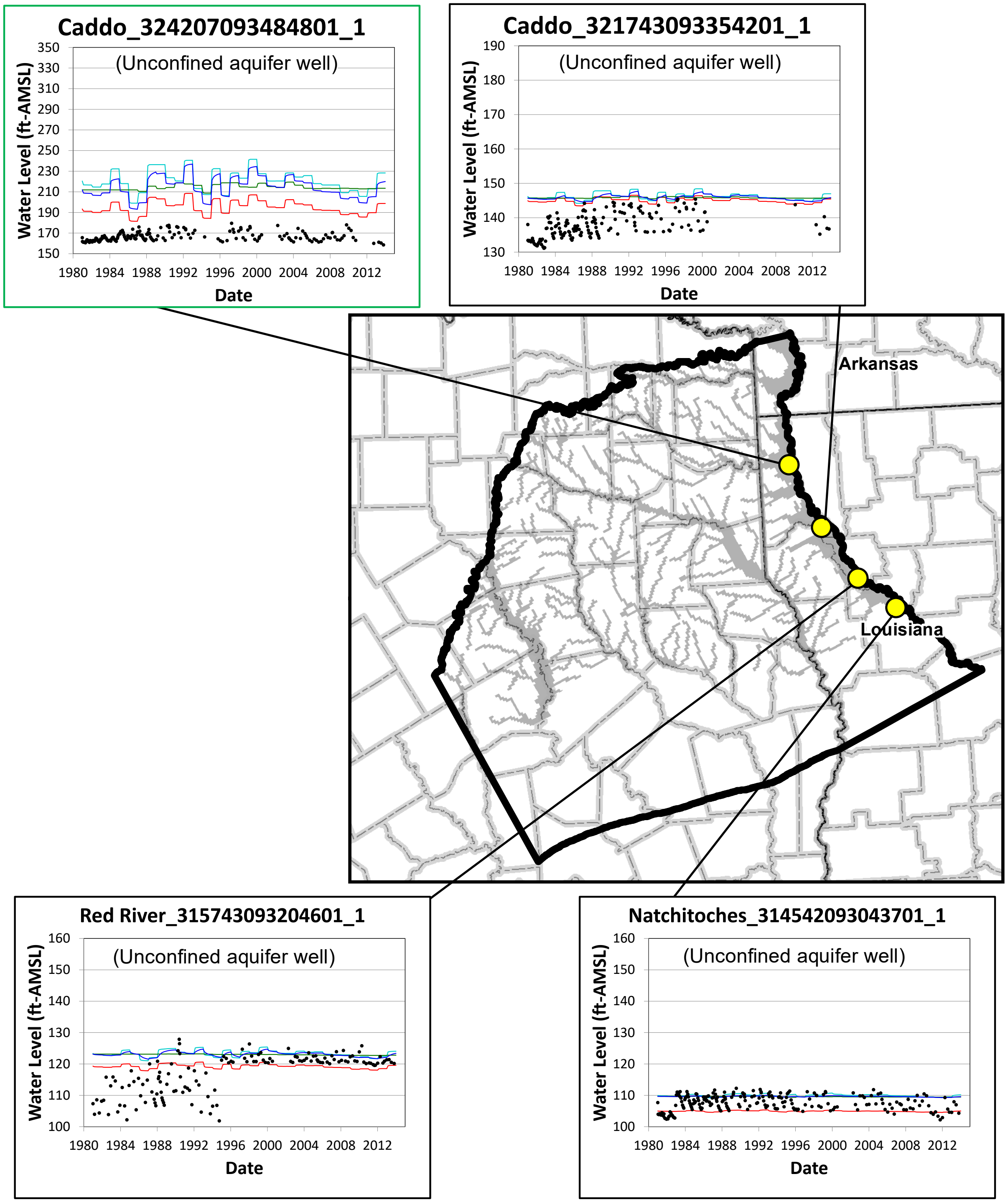
GSI ENVIRONMENTAL	GSI Job No. 4529	Drawn By: BC	**WEIGHTED MEAN ERROR SENSITIVITY GRAPH FOR MODEL PARAMETERS**
	Issued: 12-June-2020	Chk'd By:	
	Revised:	Aprv'd By: DRAFT	Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers
	Scale:	Figure 4.2-5	



Note: The 1.3 factor pumping sensitivity used 1,079 instead of 1,081 observation points due to boundary effects at 1 well.

GSI ENVIRONMENTAL

GSI Job No. 4529	Drawn By: BC	**WEIGHTED ROOT MEAN SQUARED HEAD ERROR SENSITIVITY GRAPH FOR MODEL PARAMETERS**
Issued: 12-June-2020	Chk'd By:	
Revised:	Aprv'd By: DRAFT	Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers
Scale:	Figure 4.2-6	



N

LEGEND

- Model Boundary
- County or Parish Boundary
- Layer 1
- Layer 1 Wells

Chart Name

County, Well Name, Model Layer, Aquifer Type

Chart Legend

- Observed Water Level
- Simulated Water Level
- Sensitivity 1 - No Pumping
- Sensitivity 2 - Recharge
- Sensitivity 3 - Specific Yield

Chart Outline Color for Y-Axis Range

- Y-Axis = 200 feet
- Y-Axis = 60 feet

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 25 50

Projected Coordinate System Datum: GAM

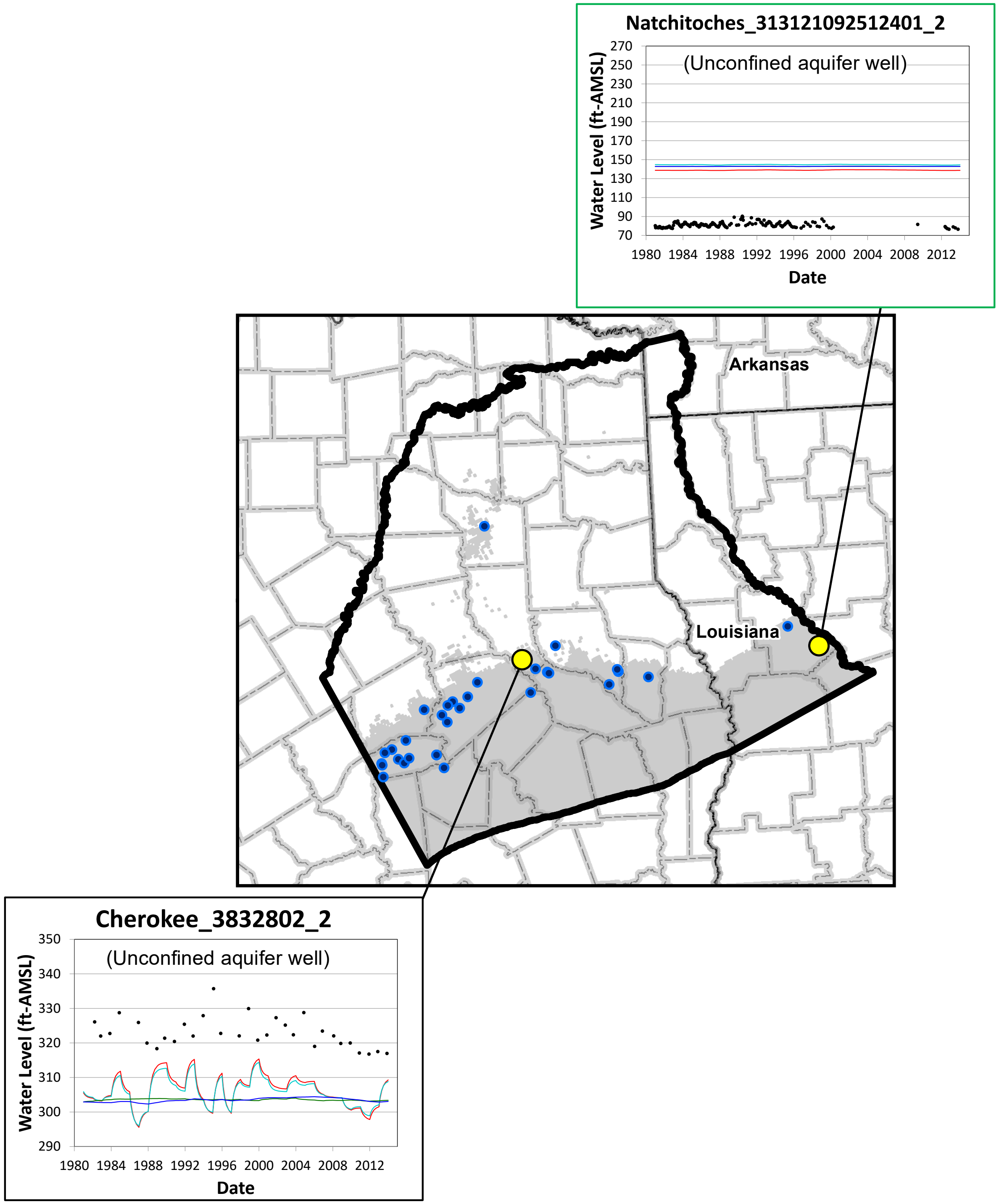
GSI ENVIRONMENTAL

MEASURED AND SIMULATED HYDROGRAPHS AT SELECT WELLS SHOWING MODEL SENSITIVITY QUATERNARY ALLUVIUM (LAYER 1)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 3-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_4_2_7	Appv'd By: DRAFT

FIGURE 4.2-7



N

LEGEND

- Model Boundary
- County or Parish Boundary
- Layer 2
- Select Layer 2 Wells
- Layer 2 Wells

Chart Name

County, Well Name, Model Layer, Aquifer Type

Chart Legend

- Observed Water Level
- Simulated Water Level
- Sensitivity 1 - No Pumping
- Sensitivity 2 - Recharge
- Sensitivity 3 - Specific Yield

Chart Outline Color for Y-Axis Range

- Y-Axis = 200 feet
- Y-Axis = 60 feet

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 25 50

Projected Coordinate System

Datum: GAM

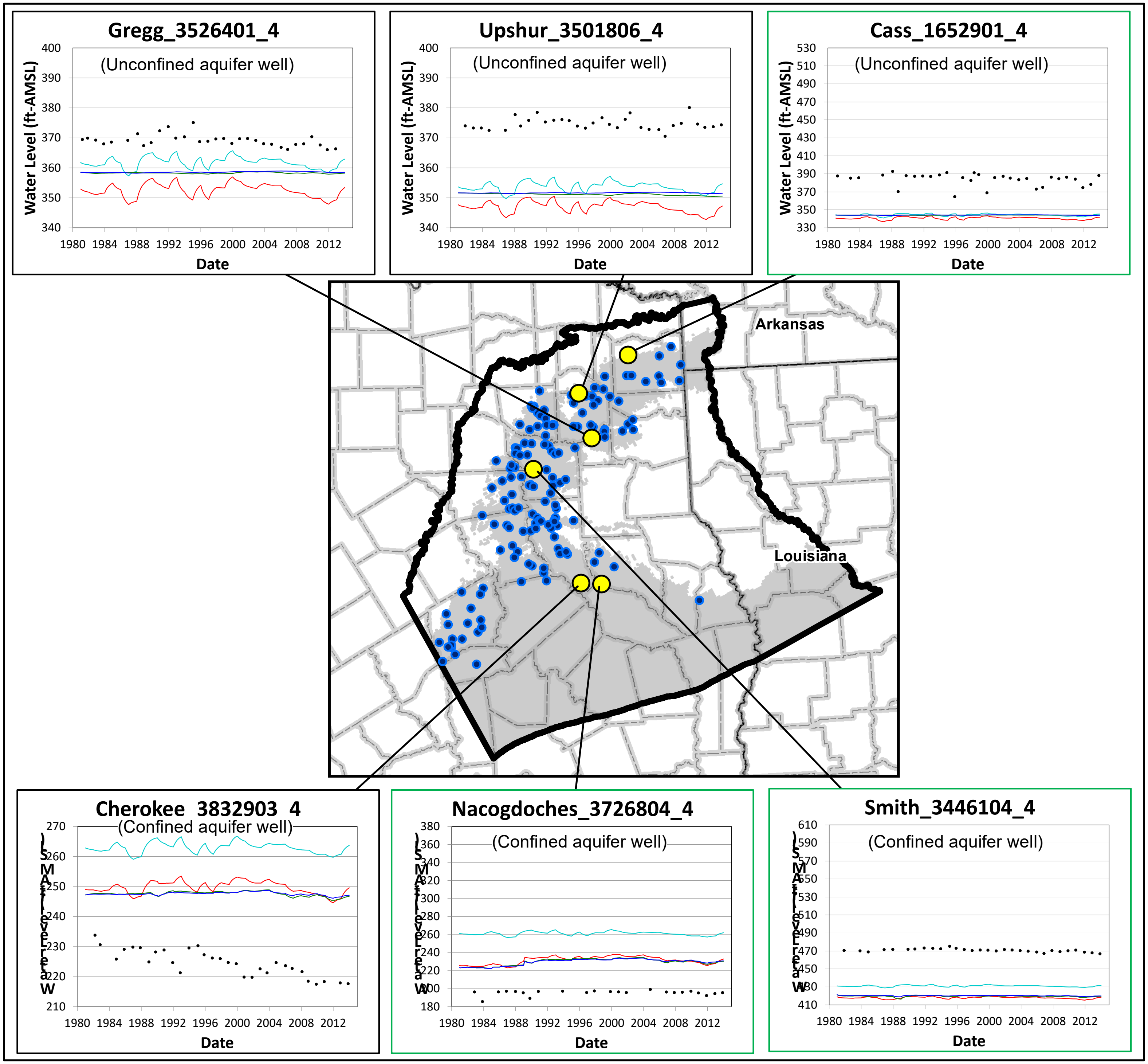
GSI ENVIRONMENTAL

MEASURED AND SIMULATED HYDROGRAPHS AT SELECT WELLS SHOWING MODEL SENSITIVITY SPARTA SAND (LAYER 2)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 3-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_4_2_8	Appv'd By: DRAFT

FIGURE 4.2-8



N

LEGEND

Model Boundary

County or Parish Boundary

Layer 4

Select Layer 4 Wells

Layer 4 Wells

Chart Name

County, Well Name, Model Layer, Aquifer Type

Chart Legend

Observed Water Level

Simulated Water Level

Sensitivity 1 - No Pumping

Sensitivity 2 - Recharge

Sensitivity 3 - Specific Yield

Chart Outline Color for Y-Axis Range

Y-Axis = 200 feet

Y-Axis = 60 feet

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 25 50

Projected Coordinate System Datum: GAM

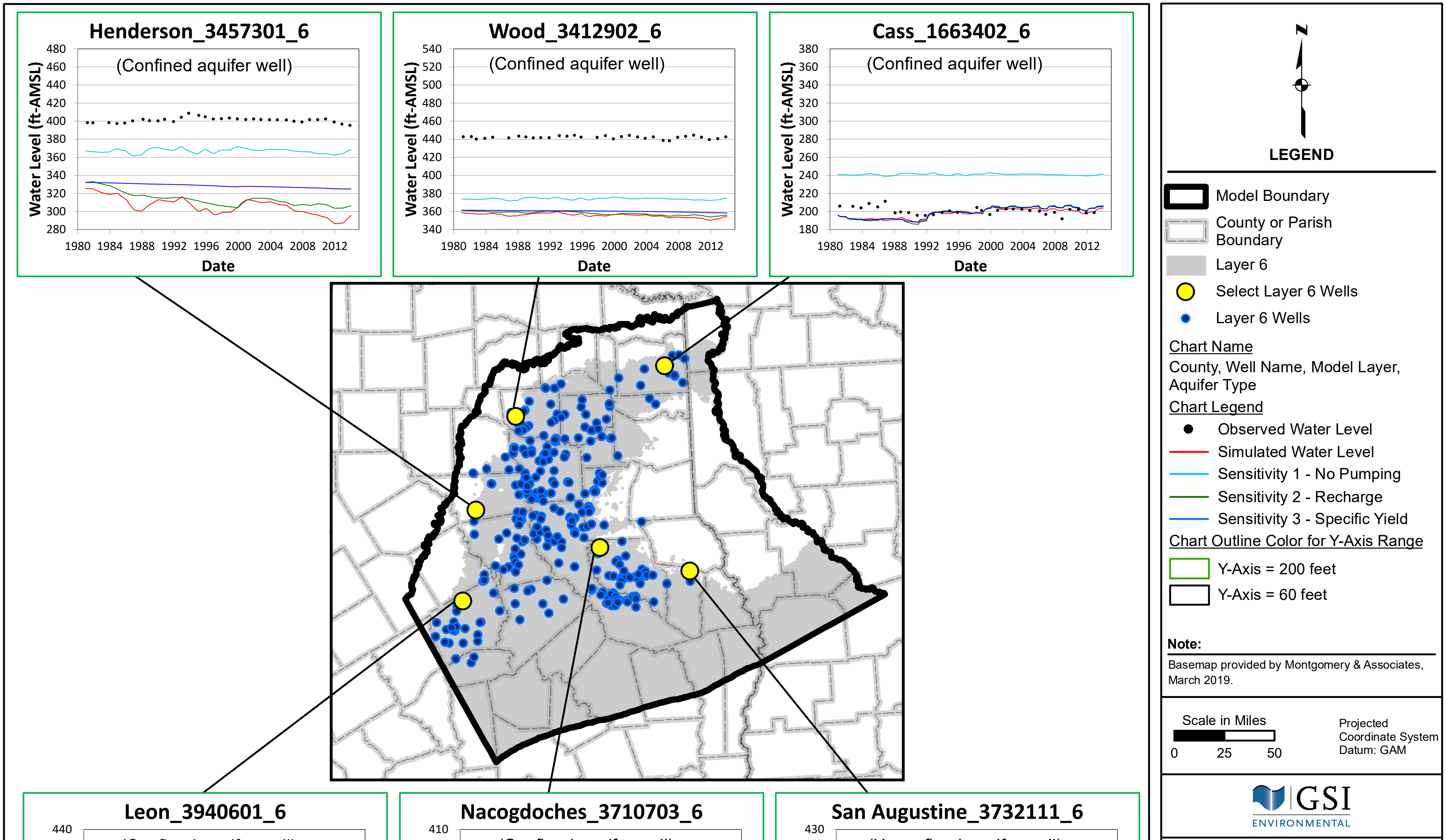
GSI ENVIRONMENTAL

MEASURED AND SIMULATED HYDROGRAPHS AT SELECT WELLS SHOWING MODEL SENSITIVITY QUEEN CITY SAND (LAYER 4)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 3-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_4_2_9	Appv'd By: DRAFT

FIGURE 4.2-9



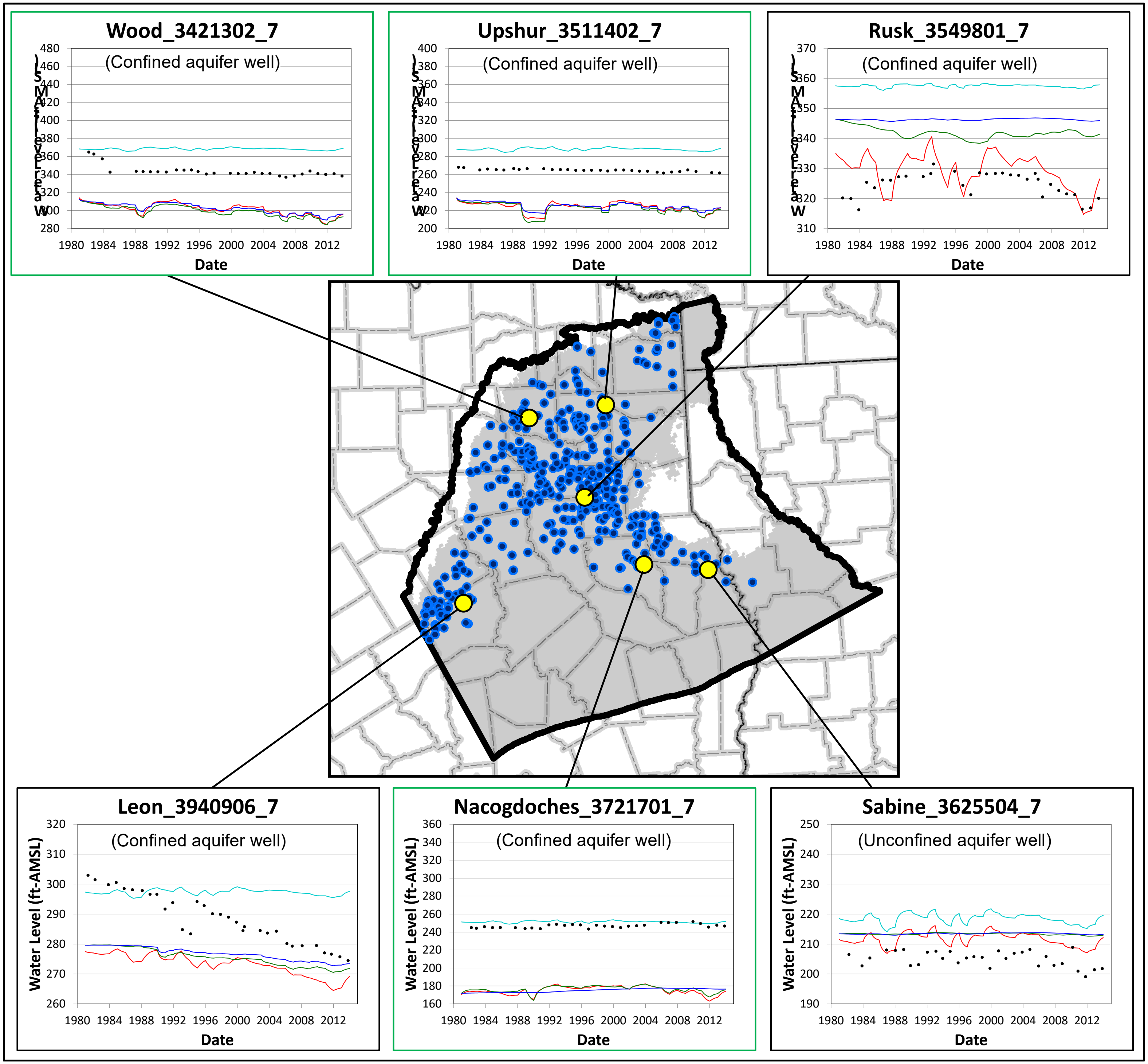
GSI ENVIRONMENTAL

MEASURED AND SIMULATED HYDROGRAPHS AT SELECT WELLS SHOWING MODEL SENSITIVITY CARRIZO SAND (LAYER 6)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 3-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_4_2_10	Appv'd By: DRAFT

FIGURE 4.2-10



N

LEGEND

- Model Boundary
- County or Parish Boundary
- Layer 7
- Select Layer 7 Wells
- Layer 7 Wells

Chart Name

County, Well Name, Model Layer, Aquifer Type

Chart Legend

- Observed Water Level
- Simulated Water Level
- Sensitivity 1 - No Pumping
- Sensitivity 2 - Recharge
- Sensitivity 3 - Specific Yield

Chart Outline Color for Y-Axis Range

- Y-Axis = 200 feet
- Y-Axis = 60 feet

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 25 50

Projected Coordinate System
Datum: GAM

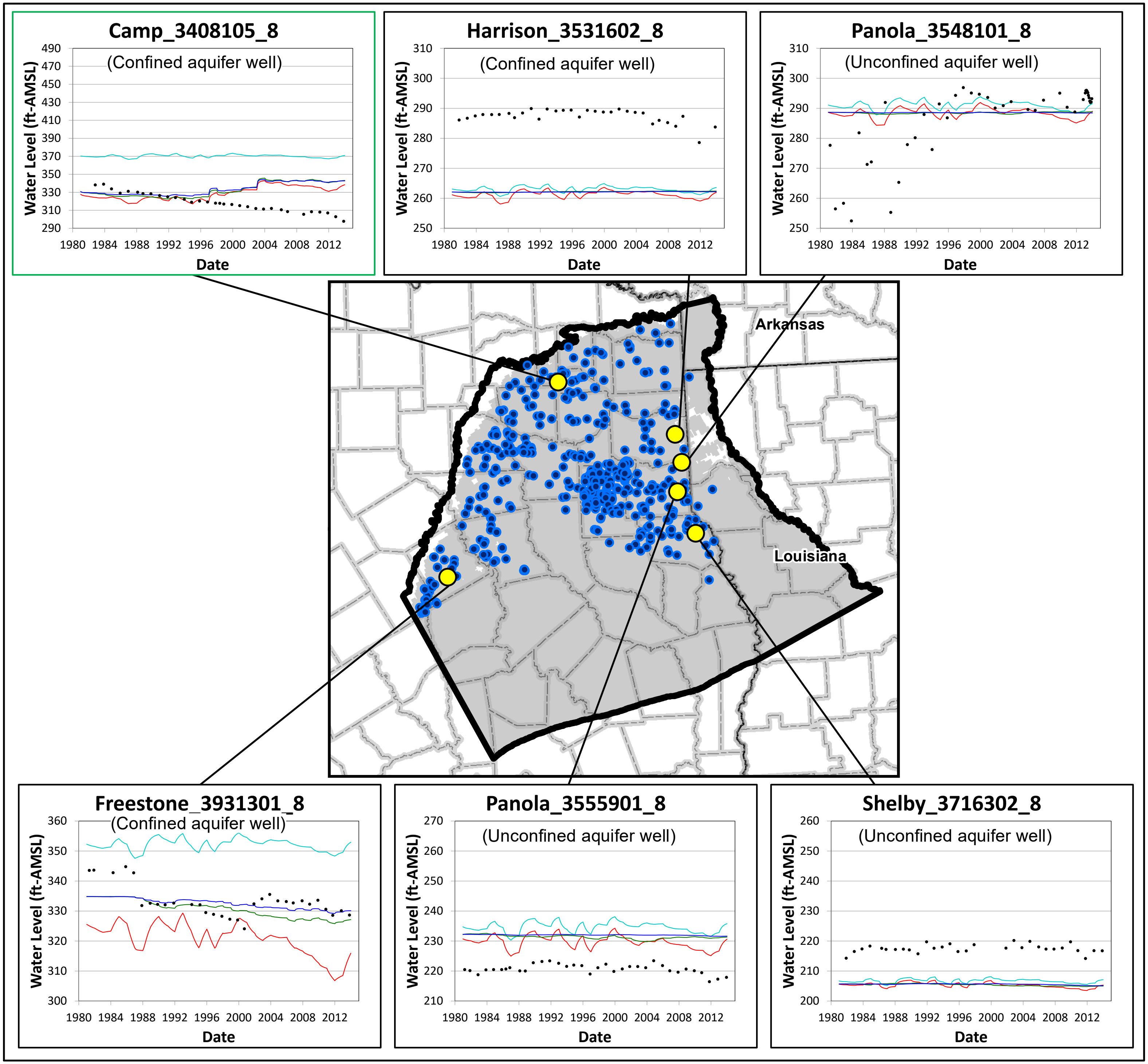
GSI ENVIRONMENTAL

MEASURED AND SIMULATED HYDROGRAPHS AT SELECT WELLS SHOWING MODEL SENSITIVITY UPPER WILCOX (LAYER 7)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 3-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_4_2_11	Appv'd By: DRAFT

FIGURE 4.2-11



N

LEGEND

- Model Boundary
- County or Parish Boundary
- Layer 8
- Select Layer 8 Wells
- Layer 8 Wells

Chart Name

County, Well Name, Model Layer, Aquifer Type

Chart Legend

- Observed Water Level
- Simulated Water Level
- Sensitivity 1 - No Pumping
- Sensitivity 2 - Recharge
- Sensitivity 3 - Specific Yield

Chart Outline Color for Y-Axis Range

- Y-Axis = 200 feet
- Y-Axis = 60 feet

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 25 50

Projected Coordinate System
Datum: GAM

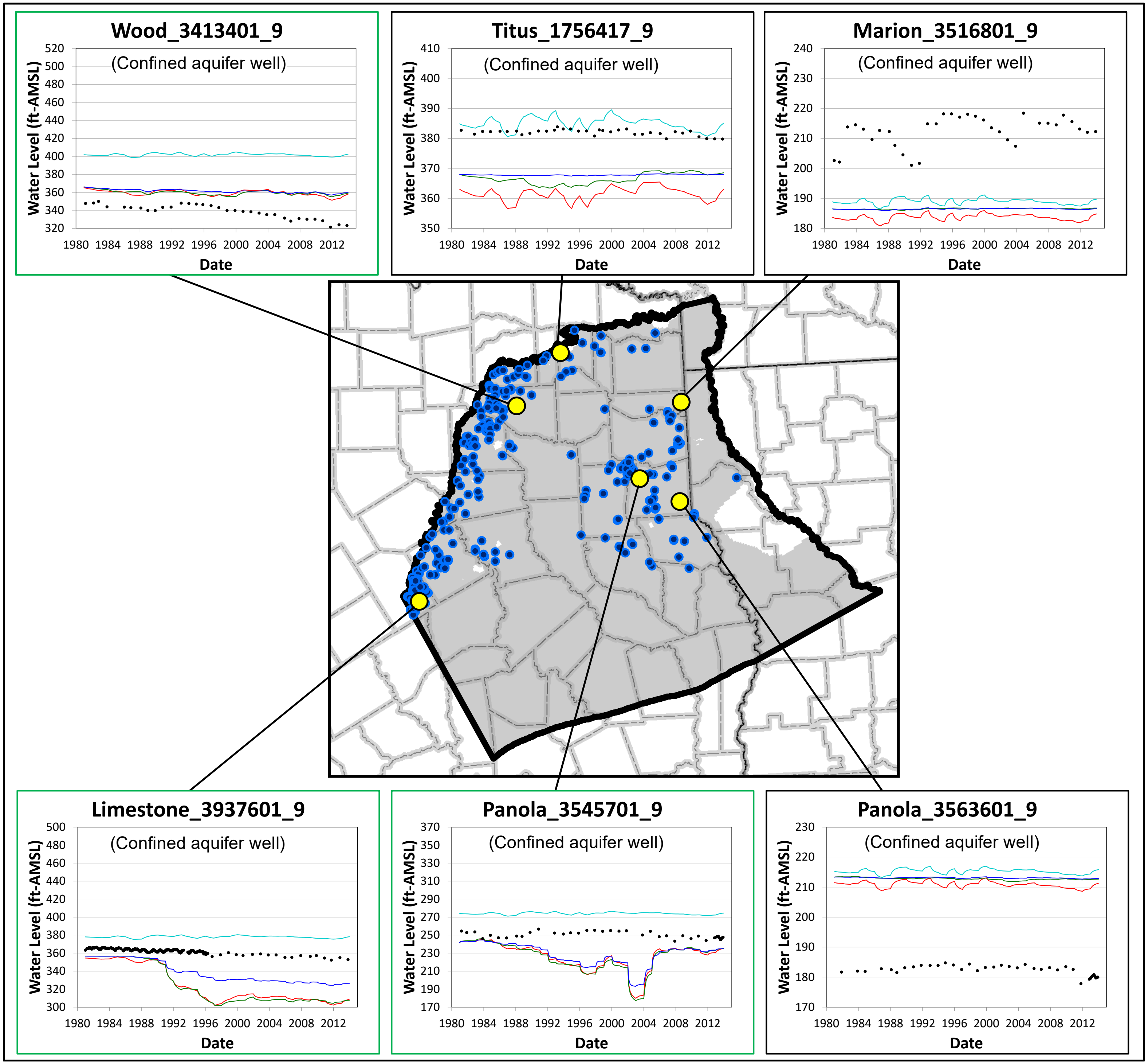
GSI ENVIRONMENTAL

MEASURED AND SIMULATED HYDROGRAPHS AT SELECT WELLS SHOWING MODEL SENSITIVITY MIDDLE WILCOX (LAYER 8)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 3-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_4_2_12	Appv'd By: DRAFT

FIGURE 4.2-12



LEGEND

- Model Boundary
- County or Parish Boundary
- Layer 9
- Select Layer 9 Wells
- Layer 9 Wells

Chart Name

County, Well Name, Model Layer, Aquifer Type

Chart Legend

- Observed Water Level
- Simulated Water Level
- Sensitivity 1 - No Pumping
- Sensitivity 2 - Recharge
- Sensitivity 3 - Specific Yield

Chart Outline Color for Y-Axis Range

- Y-Axis = 200 feet
- Y-Axis = 60 feet

Note:

Basemap provided by Montgomery & Associates, March 2019.

Scale in Miles

0 25 50

Projected Coordinate System
Datum: GAM

GSI ENVIRONMENTAL

MEASURED AND SIMULATED HYDROGRAPHS AT SELECT WELLS SHOWING MODEL SENSITIVITY LOWER WILCOX (LAYER 9)

Northern Portion of the Queen City, Sparta, and Carrizo Wilcox Aquifers

GSI Job No. 4529	Drawn By: GM
Issued: 3-Jul-2020	Chk'd By: KER
Map ID: NCW_Fig_4_2_13	Appv'd By: DRAFT

FIGURE 4.2-13

Draft Technical Memorandum 3

Calculation of Drawdown from Existing Modeled Available Groundwater Using Updated Groundwater Availability Model

Prepared for:

GSI Environmental, Inc.

9600 Great Hills Trail, Suite 350

Austin, TX 78759

512-346-4474

Prepared by:

William R. Hutchison, Ph.D., P.E., P.G.

Independent Groundwater Consultant

9305 Jamaica Beach

Jamaica Beach, TX 77554

512-745-0599

billhutch@texasgw.com

July 13, 2020

Professional Engineer and Professional Geoscientist Seals

This report was prepared by William R. Hutchison, Ph.D., P.E., P.G., who is licensed in the State of Texas as follows:

- Professional Engineer (Geological and Civil) No. 96287
- Engineering Firm Registration No. 14526
- Professional Geoscientist (Geology) No. 286

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1.0 Executive Summary

A simulation was completed that calculates the drawdown based on the existing modeled available groundwater using the updated Groundwater Availability Model. The results are summarized in an accompanying Excel spreadsheet (*ddcompare.xlsx*).

The results show that the new GAM predicts greater drawdown using the same pumping as the old GAM, but that a near-equilibrium condition develops after a few to several years of pumping. The old GAM had numerous instances of negative drawdowns (i.e. groundwater elevation recovery) that appear to have been limitations with the old GAM. These limitations include the role of recharge in the changes in outcrop groundwater elevations and the ability of the old GAM to move water effectively from the outcrop area to the downdip area. These limitations have been corrected in the new GAM. However, the results of the simulation suggest that close attention must be given to the aquifer capabilities and the simulated impacts of future pumping.

2.0 Background

The desired future conditions for Groundwater Management Area 11 that were adopted on January 11, 2017 were documented in the Desired Future Condition Explanatory Report (Hutchison, 2017a). As noted in the Explanatory Report, the desired future conditions were based on Groundwater Availability Model (GAM) Scenario 4 as documented in Hutchison (2017b). The selection of Scenario 4 as the basis for the desired future condition was made by the groundwater conservation districts in Groundwater Management Area 11 after the review of the results of seven simulations using the Groundwater Availability Model (Hutchison, 2017c).

In developing the initial seven simulations, a base pumping amount for each county-aquifer unit was developed. This base pumping amount was based on future pumping based on regional water plan data and the proposed Forestar project. The analysis in Hutchison (2017c) included three simulations that sequentially increased the pumping above the base amount and three simulations that sequentially decreased the pumping below the base amount develop a practical analysis of the sensitivity of drawdown to various pumping amounts.

One of the uses of the updated Groundwater Availability Model documented in the main report will be to support the Joint Planning Process that leads to the adoption of desired future conditions by the groundwater conservation districts in Groundwater Management Area 11 and the calculation of the modeled available groundwater by TWDB. As part of the work associated with developing the updated Groundwater Availability Model, three technical memoranda appear in the Appendix of the report:

- Technical Memorandum 1: Pumping Sensitivity
- Technical Memorandum 2: Recharge Sensitivity
- Technical Memorandum 3: Calculation of Drawdown from Existing Modeled Available Groundwater Using Updated Groundwater Availability Model

This technical memorandum presents the results of a simulation that calculates the drawdown based on the existing modeled available groundwater using the updated Groundwater Availability Model.

3.0 Basis for Pumping Estimates

The simulation to calculate average drawdown for each county-model layer unit in the 27 counties of GMA 11 requires the development of a pumping input file that considers the existing modeled available groundwater, the input pumping from the calibrated model, and the output pumping from the calibrated model.

3.1 Existing Modeled Available Groundwater

The modeled available groundwater values for GMA 11 are documented in Wade (2017). The underlying input and output files for Scenario 4 are documented in Hutchison (2017b). Hutchison (2107b) documented output pumping in a file named *pumpout2070s4.dat* and is shown in Table 1.

Table 1. Summary of Pumping for Scenario 4 (AF/yr)

County	Layer 1 (Sparta)	Layer 2 (Weches confining Unit)	Layer 3 (Queen City)	Layer 4 (Reclaw confining Unit)	Layer 5 (Carrizo)	Layer 6 (Upper Wilcox)	Layer 7 (Middle Wilcox)	Layer 8 (Lower Wilcox)	Overall
Anderson	616	0	20,853	0	9,893	9,748	9,147	281	50,538
Angelina	687	0	1,102	0	28,764	3,486	0	0	34,039
Bowie	0	0	0	0	0	1,468	7,167	358	8,993
Camp	0	0	4,202	0	1,965	1,111	969	2	8,249
Cass	0	0	39,114	0	9,162	4,285	3,350	856	56,767
Cherokee	358	0	23,058	0	6,512	9,683	4,262	0	43,873
Franklin	0	0	0	0	1,894	1,256	6,328	301	9,779
Gregg	0	0	7,568	0	4,363	2,501	1,171	0	15,603
Harrison	0	0	10,323	0	6,378	2,163	2,011	268	21,143
Henderson	0	0	15,838	0	6,303	2,774	2,053	2,444	29,412
Hopkins	0	0	0	0	478	232	3,194	2,484	6,388
Houston	1,492	0	2,321	0	9,142	8,274	9,006	0	30,235
Marion	0	0	15,456	0	1,861	556	303	4	18,180
Morris	0	0	9,355	0	1,188	403	971	5	11,922
Nacogdoches	407	0	4,994	0	12,314	11,094	771	1	29,581
Panola	0	0	0	0	660	770	5,763	869	8,062
Rains	0	0	0	0	0	449	1,000	295	1,744
Rusk	0	0	60	0	6,923	5,153	8,727	0	20,863
Sabine	295	0	0	0	4,212	1,691	469	469	7,136
SanAugustine	204	0	8	0	1,129	651	9	0	2,001
Shelby	0	0	0	0	828	3,314	4,853	104	9,099
Smith	0	0	58,866	0	16,157	14,775	4,933	0	94,731
Titus	0	0	183	0	1,591	1,904	5,938	33	9,649
Trinity	613	0	0	0	2,216	0	0	0	2,829
Upshur	0	0	27,127	0	4,189	2,324	614	0	34,254
VanZandt	0	0	4,877	0	2,203	1,549	4,128	2,084	14,841
Wood	0	0	10,105	0	13,036	5,904	2,279	3	31,327
GMA 11	**4,672**	**0**	**255,410**	**0**	**153,361**	**97,518**	**89,416**	**10,861**	**611,238**

3.2 Updated Model Pumping (Input)

Based on the results of the pumping sensitivity documented in Technical Memorandum 1, the base pumping year is 2011 for the predictive simulations. The input pumping for 2011 organized by county-model layer unites was extracted from the calibrated model input file (*tr58_g.wel*) using the FORTRAN program *welin.exe*.

The program reads the grid file (*celllayercountyns.csv*) and a list of county names, county codes, and output file names. This file also contains a code to identify whether a county is in GMA 11 or not. The input file is read, pumping values are converted to AF/yr, and summed for each year in the county-model layer unit.

The output from the program consists of a summary file for 2011 pumping by county-model layer unit for all counties (*2011wellinAll.dat*) and for the 27 counties in GMA 11 (*2011welinGMA11.dat*). Individual files for each county are also written.

A summary of input pumping for the GMA 11 counties for 2011 is presented in Table 2.

Table 2. Summary of 2011 Input Pumping for GMA 11 Counties (AF/yr)

County	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8	Layer 9
Anderson	0	55	0	733	0	3,811	1,315	233	183
Angelina	0	340	0	97	0	23,221	1,997	0	0
Bowie	0	0	0	0	0	0	2,370	650	142
Camp	0	0	0	178	0	758	386	273	2
Cass	0	0	0	587	0	1,496	807	228	157
Cherokee	0	223	0	1,101	0	4,614	4,979	14	0
Franklin	0	0	0	0	0	155	196	210	150
Gregg	0	0	0	262	0	1,770	1,062	436	0
Harrison	0	0	0	399	0	2,499	841	493	184
Henderson	0	0	0	762	0	4,492	1,813	1,313	1,419
Hopkins	0	0	0	0	0	7	241	905	2,075
Houston	0	799	0	219	0	962	6	0	0
Marion	0	0	0	172	0	918	260	140	3
Morris	0	0	0	142	0	536	213	535	4
Nacogdoches	0	266	0	330	0	11,213	4,766	326	1
Panola	0	0	0	0	0	431	298	2,058	727
Rains	0	0	0	0	0	0	365	159	331
Rusk	0	0	0	26	0	2,199	1,939	3,618	0
Sabine	0	55	0	0	0	522	217	61	61
SanAugustine	0	23	0	0	0	466	387	3	3
Shelby	0	0	0	0	0	711	946	1,847	33
Smith	0	0	0	1,226	0	7,366	6,686	2,163	0
Titus	0	0	0	0	0	533	417	1,226	13
Trinity	0	19	0	1	0	34	0	0	0
Upshur	0	0	0	1,448	0	3,337	1,906	452	0
VanZandt	0	0	0	265	0	1,257	1,027	2,327	972
Wood	0	0	0	1,792	0	3,707	1,649	611	4

3.3 Updated Model Pumping (Output)

During execution of the model, pumping in a cell is reduced if the pumping results in the head of the cell dropping below the bottom of the cell. The output of the model includes a cell-by-cell pumping amount that, therefore, may be different than the input value. The FORTRAN program *welout.exe* was written to extract the cell-by-cell values of pumping from the output file.

The program reads the grid file (*celllayercountyns.csv*) and a list of county names, county codes, and output file names. This file also contains a code to identify whether a county is in GMA 11 or not. The model output file is read, pumping values are converted to AF/yr, and summed for each year in the county-model layer unit.

The output from the program consists of a summary file for 2011 pumping by county-model layer unit for all counties (*2011welloutAll.dat*) and for the 27 counties in GMA 11 (*2011weloutGMA11.dat*). Individual files for each county are also written.

A summary of output pumping for the GMA 11 counties for 2011 is presented in Table 3.

Table 3. Summary of 2011 Output Pumping for GMA 11 Counties (AF/yr)

County	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8	Layer 9
Anderson	0	45	0	733	0	3,733	1,315	233	183
Angelina	0	340	0	97	0	23,221	1,997	0	0
Bowie	0	0	0	0	0	0	2,370	649	142
Camp	0	0	0	53	0	671	386	273	2
Cass	0	0	0	554	0	1,496	807	228	157
Cherokee	0	223	0	1,056	0	4,596	4,979	14	0
Franklin	0	0	0	0	0	102	196	188	147
Gregg	0	0	0	232	0	1,700	1,062	436	0
Harrison	0	0	0	392	0	2,434	841	493	184
Henderson	0	0	0	762	0	2,991	1,794	1,304	1,419
Hopkins	0	0	0	0	0	3	241	828	1,699
Houston	0	795	0	219	0	962	6	0	0
Marion	0	0	0	172	0	918	260	140	3
Morris	0	0	0	119	0	536	213	535	4
Nacogdoches	0	266	0	330	0	10,655	4,766	326	1
Panola	0	0	0	0	0	0	298	2,058	727
Rains	0	0	0	0	0	0	216	154	331
Rusk	0	0	0	23	0	1,791	1,939	3,618	0
Sabine	0	55	0	0	0	498	217	61	61
SanAugustine	0	23	0	0	0	422	387	3	3
Shelby	0	0	0	0	0	147	926	1,847	33
Smith	0	0	0	1,225	0	7,314	6,686	2,163	0
Titus	0	0	0	0	0	313	417	1,199	13
Trinity	0	19	0	1	0	34	0	0	0
Upshur	0	0	0	1,448	0	3,337	1,906	452	0
VanZandt	0	0	0	265	0	872	1,027	2,018	972
Wood	0	0	0	1,643	0	3,644	1,649	611	4

3.4 Comparison of Input and Output Pumping

The difference in input and output pumping (calculated as input minus output) for the 27 GMA 11 counties is presented in Table 3. Table 4 presents the difference calculated as the difference divided by the input pumping times 100 to express the difference as a percentage.

Table 4. Difference Between Input and Output Pumping (AF/yr)

County	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8	Layer 9
Anderson	0	10	0	0	0	78	0	0	0
Angelina	0	0	0	0	0	0	0	0	0
Bowie	0	0	0	0	0	0	0	1	0
Camp	0	0	0	125	0	87	0	0	0
Cass	0	0	0	33	0	0	0	0	0
Cherokee	0	0	0	45	0	18	0	0	0
Franklin	0	0	0	0	0	53	0	22	3
Gregg	0	0	0	30	0	70	0	0	0
Harrison	0	0	0	7	0	65	0	0	0
Henderson	0	0	0	0	0	1501	19	9	0
Hopkins	0	0	0	0	0	4	0	77	376
Houston	0	4	0	0	0	0	0	0	0
Marion	0	0	0	0	0	0	0	0	0
Morris	0	0	0	23	0	0	0	0	0
Nacogdoches	0	0	0	0	0	558	0	0	0
Panola	0	0	0	0	0	431	0	0	0
Rains	0	0	0	0	0	0	149	5	0
Rusk	0	0	0	3	0	408	0	0	0
Sabine	0	0	0	0	0	24	0	0	0
SanAugustine	0	0	0	0	0	44	0	0	0
Shelby	0	0	0	0	0	564	20	0	0
Smith	0	0	0	1	0	52	0	0	0
Titus	0	0	0	0	0	220	0	27	0
Trinity	0	0	0	0	0	0	0	0	0
Upshur	0	0	0	0	0	0	0	0	0
VanZandt	0	0	0	0	0	385	0	309	0
Wood	0	0	0	149	0	63	0	0	0

Please note that this comparison in this table identifies a potential limitation of the model relative to joint planning. Some of the pumping amounts in specific wells were reduced due to limited saturated thickness. If predictive simulations specify pumping amounts above those in the calibrated model, the reduction in pumping will persist. This limitation can be effectively addressed if the specific locations where reductions take place are distinguished from well locations where pumping is not reduced. This should be the practice in any simulations for joint planning.

Table 5. Difference Between Input and Output Pumping (Percent of Input)

County	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8	Layer 9
Anderson	0.00	18.18	0.00	0.00	0.00	2.05	0.00	0.00	0.00
Angelina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bowie	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00
Camp	0.00	0.00	0.00	70.22	0.00	11.48	0.00	0.00	0.00
Cass	0.00	0.00	0.00	5.62	0.00	0.00	0.00	0.00	0.00
Cherokee	0.00	0.00	0.00	4.09	0.00	0.39	0.00	0.00	0.00
Franklin	0.00	0.00	0.00	0.00	0.00	34.19	0.00	10.48	2.00
Gregg	0.00	0.00	0.00	11.45	0.00	3.95	0.00	0.00	0.00
Harrison	0.00	0.00	0.00	1.75	0.00	2.60	0.00	0.00	0.00
Henderson	0.00	0.00	0.00	0.00	0.00	33.41	1.05	0.69	0.00
Hopkins	0.00	0.00	0.00	0.00	0.00	57.14	0.00	8.51	18.12
Houston	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Marion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Morris	0.00	0.00	0.00	16.20	0.00	0.00	0.00	0.00	0.00
Nacogdoches	0.00	0.00	0.00	0.00	0.00	4.98	0.00	0.00	0.00
Panola	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Rains	0.00	0.00	0.00	0.00	0.00	0.00	40.82	3.14	0.00
Rusk	0.00	0.00	0.00	11.54	0.00	18.55	0.00	0.00	0.00
Sabine	0.00	0.00	0.00	0.00	0.00	4.60	0.00	0.00	0.00
SanAugustine	0.00	0.00	0.00	0.00	0.00	9.44	0.00	0.00	0.00
Shelby	0.00	0.00	0.00	0.00	0.00	79.32	2.11	0.00	0.00
Smith	0.00	0.00	0.00	0.08	0.00	0.71	0.00	0.00	0.00
Titus	0.00	0.00	0.00	0.00	0.00	41.28	0.00	2.20	0.00
Trinity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upshur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
VanZandt	0.00	0.00	0.00	0.00	0.00	30.63	0.00	13.28	0.00
Wood	0.00	0.00	0.00	8.31	0.00	1.70	0.00	0.00	0.00

3.5 Factors Applied to 2011 Pumping to Achieve Existing MAG Pumping

The base pumping file for the predictive simulation is based multiplication factors applied to the 2011 pumping from the calibrated model. The MAG pumping (previously presented in Table 1) divided by the output 2011 pumping from the calibrated model (previously presented in Table 3) yields these factors. The Excel spreadsheet *SumPumpFac.xlsx* has five sheets:

- MAG – modeled available groundwater values from Table 1
- ngWelin - 2011 input pumping from the calibrated model from Table 2
- ngWelout – 2011 output pumping from the calibrated model from Table 3
- PredFac(in) – MAG pumping divided by 2011 input pumping
- PredFac(out) – MAG pumping divided by 2011 output pumping

The factors calculated from the input pumping (PredFac(in)) are presented in Table 6.

Table 6. Pumping Adjustment Factors

County	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8	Layer 9
Anderson	1.00	11.20	1.00	28.45	1.00	2.60	7.41	39.26	1.54
Angelina	1.00	2.02	1.00	11.36	1.00	1.24	1.75	1.00	1.00
Bowie	1.00	1.00	1.00	1.00	1.00	1.00	0.62	11.03	2.52
Camp	1.00	1.00	1.00	23.61	1.00	2.59	2.88	3.55	1.00
Cass	1.00	1.00	1.00	66.63	1.00	6.12	5.31	14.69	5.45
Cherokee	1.00	1.61	1.00	20.94	1.00	1.41	1.94	304.43	1.00
Franklin	1.00	1.00	1.00	1.00	1.00	12.22	6.41	30.13	2.01
Gregg	1.00	1.00	1.00	28.89	1.00	2.46	2.35	2.69	1.00
Harrison	1.00	1.00	1.00	25.87	1.00	2.55	2.57	4.08	1.46
Henderson	1.00	1.00	1.00	20.78	1.00	1.40	1.53	1.56	1.72
Hopkins	1.00	1.00	1.00	1.00	1.00	68.29	0.96	3.53	1.20
Houston	1.00	1.87	1.00	10.60	1.00	9.50	1379.00	1.00	1.00
Marion	1.00	1.00	1.00	89.86	1.00	2.03	2.14	2.16	1.33
Morris	1.00	1.00	1.00	65.88	1.00	2.22	1.89	1.81	1.25
Nacogdoches	1.00	1.53	1.00	15.13	1.00	1.10	2.33	2.37	1.00
Panola	1.00	1.00	1.00	1.00	1.00	1.53	2.58	2.80	1.20
Rains	1.00	1.00	1.00	1.00	1.00	1.00	1.23	6.29	0.89
Rusk	1.00	1.00	1.00	2.31	1.00	3.15	2.66	2.41	1.00
Sabine	1.00	5.36	1.00	1.00	1.00	8.07	7.79	7.69	7.69
SanAugustine	1.00	8.87	1.00	1.00	1.00	2.42	1.68	3.00	0.00
Shelby	1.00	1.00	1.00	1.00	1.00	1.16	3.50	2.63	3.15
Smith	1.00	1.00	1.00	48.01	1.00	2.19	2.21	2.28	1.00
Titus	1.00	1.00	1.00	1.00	1.00	2.98	4.57	4.84	2.54
Trinity	1.00	32.26	1.00	0.00	1.00	65.18	1.00	1.00	1.00
Upshur	1.00	1.00	1.00	18.73	1.00	1.26	1.22	1.36	1.00
VanZandt	1.00	1.00	1.00	18.40	1.00	1.75	1.51	1.77	2.14
Wood	1.00	1.00	1.00	5.64	1.00	3.52	3.58	3.73	0.75

4.0 Parameters and Assumptions

4.1 Files Unchanged from Calibrated Model

Files that contain model input parameters related to the model grid and aquifer parameters were the same as the files used in the calibrated model as shown in Table 7.

Table 7. Predictive Model Files Unchanged from Calibrated Model

File Name	File Date	Description
findd.disu	4/10/2020	Spatial Discretization
findd.ims	4/10/2020	Solver Parameters
finddd.npf	4/10/2020	Node Property Flow
tr58_g.kx	4/10/2020	Horizontal Hydraulic conductivity
tr58_g.kz	4/10/2020	Vertical Hydraulic Conductivity
tr58_g.ss	4/10/2020	Specific Storage
tr58_g.sy	4/10/2020	Specific Yield

4.2 Time Discretization and Storage

The predictive simulation was run for the period 2014 to 2080, a total of 67 annual stress periods. The calibrated model included a steady-state stress period at the beginning of the simulation. Thus, the DISU file was modified to reflect 67 annual stress periods and named *finddd.tdis*. The specification of steady state or transient stress period in MODFLOW 6 is contained in the STO file. This file was updated and named *finddd.sto.*

4.3 Groundwater Pumping (WEL Package)

The WEL package for this simulation was developed by the FORTRAN program *makescenwel.exe.* The program reads the grid file (*celllayercountyns.csv*) and the pumping factors previously presented in Table 6 (*ScenPumpFac.csv*). The 2011 pumping file used for the pumping sensitivity analysis documented in Technical Memorandum 1 is opened (*pump2011.wel*). The simulation WEL file is opened (*finddd.wel*). The 2011 file is read line by line, appropriate factors are applied to the pumping amount based on the county-model layer unit, and the results are written to the simulation WEL file.

As a quality control check, the FORTRAN program *welincheck.*exe reads the resulting simulation WEL file (*finddd.wel*) and calculates the total pumping for each county-model layer unit. Results are written in two files, one for all counties (*2011welinAll.dat*) and one for the 27 GMA 11 counties (*2011welinGMA11.dat*). Results were saved to an Excel file (*CrossCheck.xlsx*) and a summary comparison with the existing modeled available groundwater is presented in Figure 1.

Please note that the comparison yields the conclusions that all simulation input values are within rounding error of the existing modeled available groundwater values with two notable exceptions. Titus County (Layer 4) and Houston County (Layer 8) have a modeled available groundwater value greater than zero, but the calibrated model has no wells in these county-model layer units.

The modeled available groundwater value in the Queen City Aquifer in Titus County is small (183 AF/yr), and a well can be added during the joint planning process to accommodate this pumping, if requested.

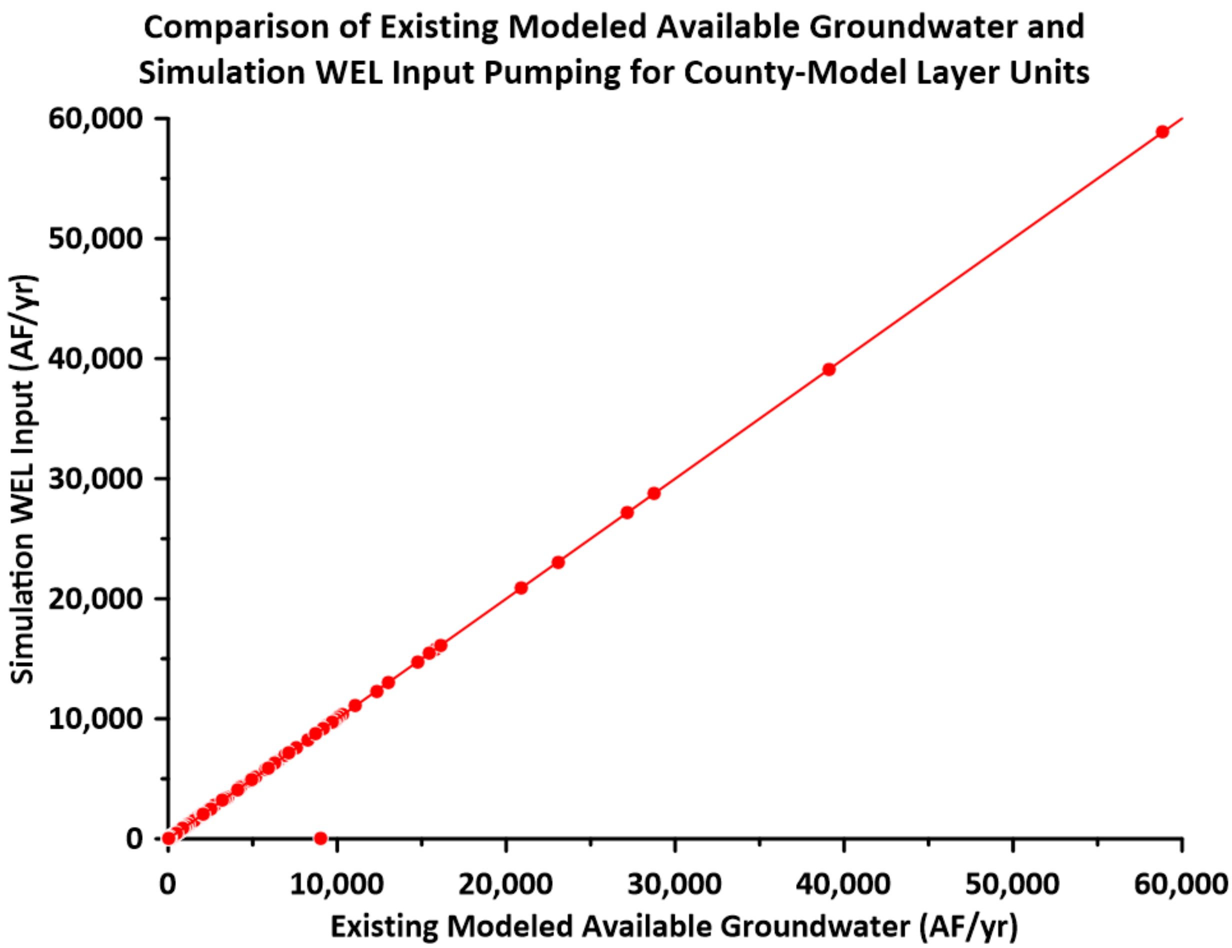

Figure 1. Comparison of MAG and Simulation WEL Input

The modeled available groundwater for the Middle Wilcox Aquifer in Houston County is 9,006 AF/yr and is associated with the proposed Forestar project. This pumping was specifically added in the last round of joint planning. Because these wells do not currently exist, they are not included in the updated calibrated model. During joint planning, the wells associated with the Forestar project will be added and included.

4.4 Evapotranspiration (EVT Package)

The FORTRAN program *makeevt.exe* was written to develop a model input file for evapotranspiration. Inspection of the calibrated model input file for evapotranspiration (*tr58_g.evt*) shows that the same evapotranspiration parameters were used for each stress period of the calibration period (1980 to 2013). The program simply extracts the first stress period of the calibration period and writes it to a new file named *finddd.evt*.

4.5 General Head Boundaries (GHB Package)

The FORTRAN program *makeghb.exe* was written to develop a model input file for the general head boundaries, which were implemented to simulate the effects of overlying formations that are not formally part of the model domain.

Inspection of the calibrated model input file for general head boundaries (*tr58_g.ghb*) shows that the same general head boundary parameters were used for each stress period of the calibration period (1980 to 2013). The program simply extracts the first stress period of the calibration period and writes it to a new file named *finddd.ghb*.

4.6 Recharge (RCH Package)

The recharge input file *tr58_g.rch* contains the cell-by-cell recharge amounts for each stress period of the calibrated model (1980 to 2013). Recharge was implemented by defining a steady-state recharge (applied to stress period 1) and applying a stress period-specific factor to increase or decrease the recharge for each stress period. The first stress period of recharge was extracted from the calibrated model input file using a FORTRAN program named *makerch.exe*. The output file saved as *finddd.rch.*

4.7 River (RIV Package)

The calibrated model simulated surface water-groundwater interactions with the River (RIV) package specified in the file *tr58_g.rch*. Inspection of the input file yielded the conclusion that RIV head values changed slightly for each stress period. River conductance and bottom elevations remained the same in all stress periods.

The FORTRAN program *makeriv.exe* was written to extract the first stress period of RIV parameters for the predictive simulations and hold them constant for all stress periods. The output file from this program is *finddd.riv.*

4.8 Other Input Files

Other files that were developed for these predictive simulations are summarized in Table 8.

Table 8. Other Input Files Summary

File Name	Description	Modification
finddd.ic6	Starting Heads	Specified 2013 heads as starting heads
mfsim.nam	Global Simulation Name File	Udated tdis and ims file names
finddd.nam	Scenario Name File	Updated scenario file names
finddd.oc6	Output Control	Updated scenario-specific output files and adjusted number of stress periods

5.0 Methods and Results

5.1 Post-Processing of MODFLOW 6 Results

A FORTRAN program named *getdd.exe* was written to extract groundwater elevation data from the model output files assuming a base year for the drawdown calculation as 2013 (the last year of the calibrated model). For comparative purposes, the program was modified (*getdd2000.exe)* to extract results with a base year for the drawdown calculations as 2000 to facilitate comparison with the existing desired future conditions.

The program reads a list of county names and codes (*countynamelist.dat*) and a grid file of cell number, layer, and county code (*celllayercountyns.csv*). The program counts the number of cells in each county-model layer unit and reports the results in a file named *cellcount.dat.* The 27 counties within Groundwater Management Area 11 and the number of cells in each layer of those counties is presented in Table 9. Based on Table 9, there are 213 county-model layer units with at least one active model cell.

The program then reads the binary output files from the calibrated model (*tr58g.hds*) and the binary output file of the predictive simulation (*finddd.hds*). The program then calculates the drawdown for each cell with a starting date of 2013 (the last year of the calibrated model), or a starting date of 2000, depending on the version. Drawdowns for each county-model layer unit are then summed, and the average drawdown for each county-model layer unit is calculated as the summed drawdown for that unit divided by the number of cells in that unit.

The program then reads a list of file names for each county-model layer unit for the 27 counties in Groundwater Management Area 11 and writes annual drawdowns for each layer to the county-based output files for the scenario.

Summary results are written for both post-processors report include drawdown results for 2070 (*dd2070.dat*) and 2080 (*dd2080.dat*). The 2070 results are comparable to the last round of desired future conditions, the 2080 results are useful to understand the drawdowns that will be calculated for the next round of desired future conditions.

Table 9. Cell Counts for Each County-Model Layer Unit

County	Number of Model Cells in Each County-Model Layer Unit									Number of Active Layers
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8	Layer 9	
Anderson	19,582	106	359	3,276	3,455	1,932	1,639	1,203	1,087	9
Angelina	552	3,828	1,312	865	865	865	865	865	865	9
Bowie	6,382	0	0	0	0	0	1,312	1,034	522	4
Camp	2,674	0	0	392	371	387	451	233	201	7
Cass	12,311	5	61	3,249	1,843	716	1,524	1,221	988	9
Cherokee	14,757	603	676	3,030	2,404	1,885	1,414	1,096	1,059	9
Franklin	2,136	0	0	0	3	177	607	320	170	6
Gregg	4,065	0	0	414	557	928	465	290	274	7
Harrison	10,279	0	2	413	995	621	2,226	1,845	1,311	8
Henderson	11,104	0	9	1,445	1,072	701	1,071	1,471	1,540	8
Hopkins	4,213	0	0	0	1	23	500	634	839	6
Houston	7,210	5,267	2,187	2,455	1,424	1,238	1,237	1,237	1,237	9
Marion	7,315	1	5	899	1,017	336	1,214	694	545	9
Morris	3,694	0	6	484	509	169	344	636	317	8
Nacogdoches	13,147	1,630	1,706	1,456	1,595	1,390	1,787	1,094	983	9
Panola	12,656	0	0	0	1	4	996	3,921	1,269	6
Rains	3,109	0	0	0	0	0	56	246	864	4
Rusk	13,447	7	14	191	760	1,842	3,677	1,311	943	9
Sabine	3,513	2,242	795	398	566	566	1,121	658	577	9
SanAugustine	2,534	1,511	770	385	611	792	836	623	594	9
Shelby	10,606	8	3	1	2	42	2,558	2,546	1,037	9
Smith	12,534	331	837	3,653	2,053	1,234	1,107	964	947	9
Titus	6,547	0	0	32	221	245	1,096	876	559	7
Trinity	0	4,124	1,225	713	713	713	713	713	713	8
Upshur	6,347	20	49	1,905	1,142	928	636	595	595	9
VanZandt	9,253	0	7	268	293	384	1,940	1,013	1,723	8
Wood	9,934	77	215	1,681	1,070	839	1,516	1,046	740	9

5.2 Results

The summary results from the post-processors were gathered into an Excel spreadsheet named *ddcompare.xlsx*. The first tab (Current DFC) is the drawdown that was the basis of the current desired future condition. The next three tabs represent the following:

- dd2070(2013) are the drawdowns for each county-model layer unit in 2070 with a base year of 2013
- dd2070(2000) are the drawdowns for each county-model layer unit in 2070 with a base year of 2000
- dd2080(2013) are the drawdowns for each county-model layer unit in 2080 with a base year of 2013

The last tab is named CrossCheck and includes the results from the previous four tabs in a format that facilitates plotting. Also, differences between results are included in columns G through K.

Figure 2 presents a comparison of drawdowns in 2070 using 2000 as a base year. The x-axis are the drawdowns associated with the current desired future condition (i.e. based on the old GAM) and the y-axis are the drawdowns calculated from the new GAM using the same modeled available groundwater values (i.e. the pumping from the last round of joint planning). As detailed above, some county-model layer units have slightly different pumping than the modeled available groundwater, but they are isolated cases and do not affect the main conclusions of the comparison

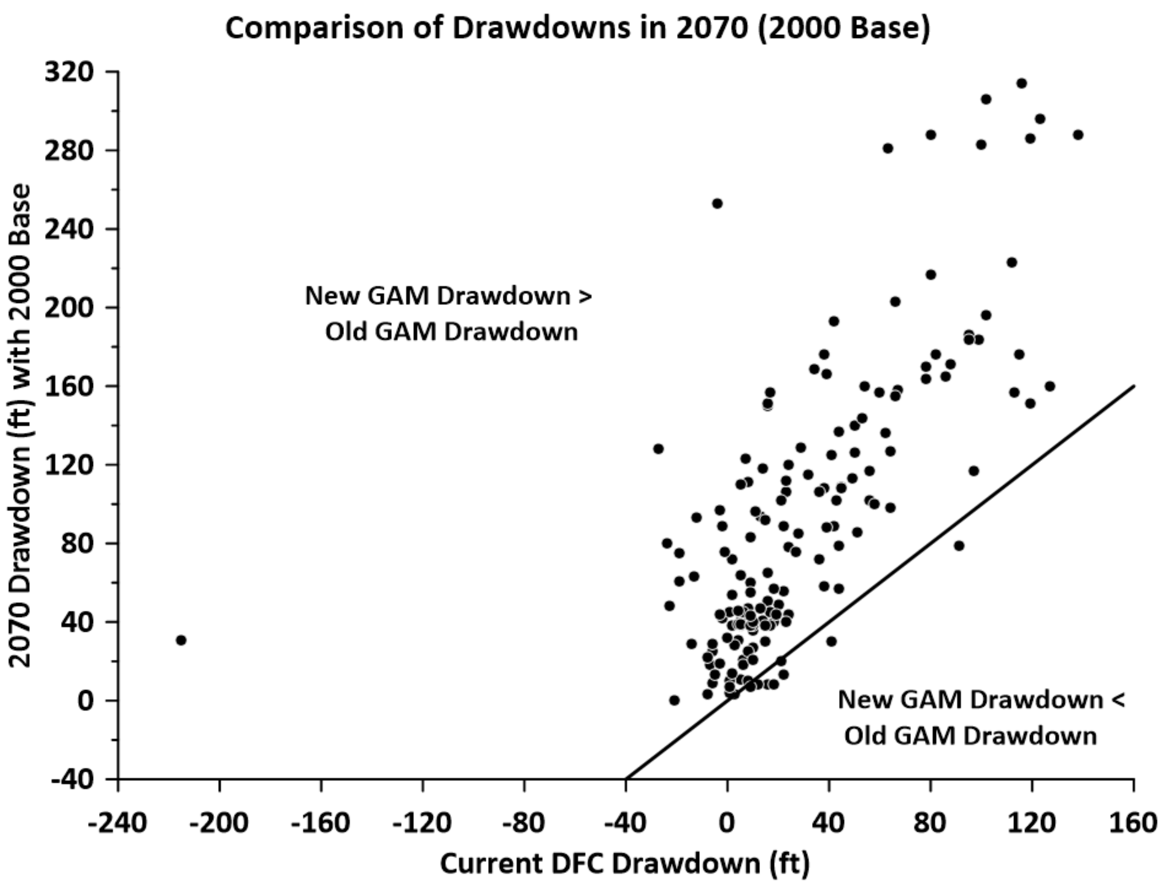

Figure 2. Comparison of Existing DFC Drawdown and Drawdowns from New GAM

Please note that on Figure 2, a one-to-one line of drawdowns is presented. Above and to the left of that line, the new GAM predicts greater drawdown than the old GAM. Below and to the right of that line, the new GAM predicts less drawdown than the old GAM. Based on these results, the new GAM will generally predict greater drawdown than the old GAM. In many cases, the difference is substantial. This will be an important topic of discussion for the groundwater conservation districts in Groundwater Management Area 11.

Please note that the current DFC drawdown includes several county-model layer units with negative drawdowns, or predicted groundwater elevation recoveries, from 2000 to 2070. An extreme example of this is the predicted recovery of 215 feet in Hopkins County in old GAM layer 8 (new GAM layer 9) as documented in Hutchison (2017b, page 5). The underlying issue of the negative drawdowns, as described in Hutchison (2017b), appears to be some combination of high recharge estimates in the old GAM and the inability of groundwater to move from the outcrop areas to the downdip areas. The new GAM effectively addresses those issues as documented in Technical Memoranda 1 and 2.

In the current round of joint planning, TWDB has requested that drawdowns be calculated through the year 2080 to facilitate the use of the modeled available groundwater results for the Regional Planning process. As described in Technical Memoranda 1 and 2, the new GAM results suggest a near-equilibrium state is reached with constant pumping and/or constant recharge. Figure 3 presents a comparison of drawdowns for each county-model layer unit in 2070 and 2080 when 2013 is used as a base year for the drawdown calculation. Based on these results, it appears that there is not significant drawdown from 2070 to 2080, which is the expected result after considering the findings of Technical Memoranda 1 and 2. This conclusion suggests that the new GAM simulates a system that will reach near-equilibrium conditions in a few to several years, even with relatively large increases in future pumping.

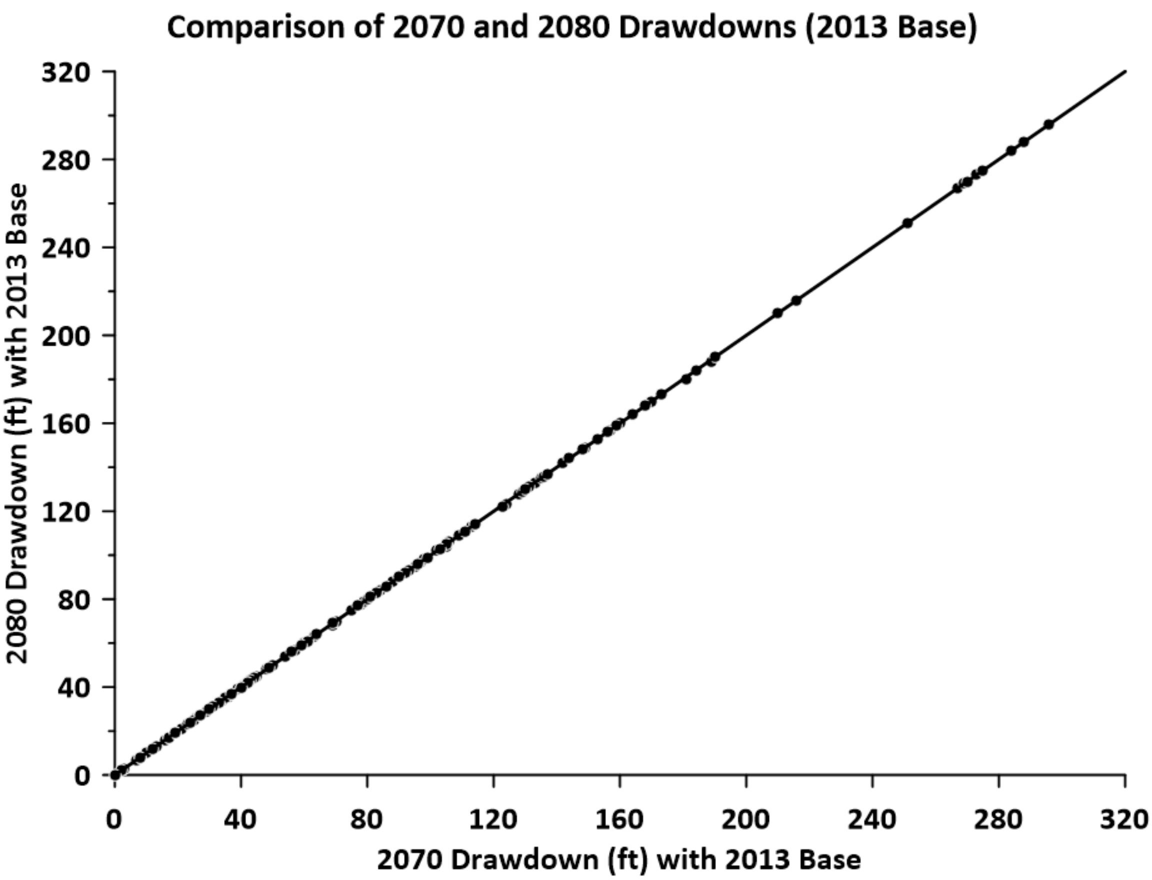

Figure 3. Comparison of 2070 and 2080 Drawdowns (2013 Base)

6.0 Limitations

The objective of these simulations was to provide a practical basis for selecting a base pumping year for simulations focused on joint planning. As a result, there are some limitations to the results given the regional nature of the objective:

- The scenarios considered only increases and decreases in overall pumping to assess general sensitivity of pumping on average drawdown. For this analysis, there were no attempts to understand sensitivity on a finer scale (i.e. varying pumping on an individual county-model layer unit).
- The scenarios did not attempt to distinguish the relative effect of "local" pumping (pumping within the county-model layer unit) versus neighboring pumping in adjacent county-model layer units.
- The simulation failed to converge in stress period 1. The standard output noted that a cell in Titus County in layer 8 consistently had a maximum head change greater than the user-specified tolerance. Convergence was achieved in all other stress periods. To avoid this from occurring in the future, the pumping could be increased over a period of years, or the number of time steps could be increased for the first stress period.
- The old GAM may have been the basis for some of the large pumping increases in the Sparta and Queen City aquifers associated with the first and second round of joint planning. The new GAM shows greater drawdowns than the old GAM. The capability of the Sparta and Queen City aquifers, as well as the various subdivisions of the Carrizo-Wilcox aquifer needs to be reviewed by the groundwater conservation districts of Groundwater Management Area 11. Specific issues related to the impact of recharge on changes in groundwater elevations, the ability of water to move from the outcrop areas to the downdip areas, and the impact of larger drawdowns have always been issues of interest that have been influenced by the limitations of the old GAM. These results from the new GAM may provide additional insight and provide for improved planning and management of the groundwater in the area.

7.0 References

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