# Identification of Potential Brackish Groundwater Production Areas -Nacatoch Aquifer

## TWDB Contract Number 1600011952

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# TABLE OF CONTENTS

# List of Figures

# List of Tables



# List of Appendices

# 1 Executive Summary

House Bill 30 was passed in 2015 by the 84th Texas Legislature with a goal to identify and designate local or regional brackish groundwater production zones in areas of the state with moderate to high availability of brackish groundwater that can be used to reduce the use of fresh groundwater. The goal of these studies is to identify potential production areas that can provide brackish water over a 30 to 50-year time period using the Nacatoch Aquifer Groundwater Availability Model and the application of best available science.

Potential production area may only exist in locations that meet the criteria of House Bill 30. House Bill 30 states that these areas:

- Are separated by hydrogeologic barriers sufficient to prevent significant impacts to water availability or water quality in any area of the same or other aquifers, subdivisions of aquifers, or geologic strata that have an average total dissolved solids level of 1,000 milligrams per liter or less at the time of designation of the zones.
- Are not located in an aquifer, subdivision of an aquifer, or geologic stratum that has an average total dissolved solids level of more than 1,000 milligrams per liter and is serving as a significant source of water supply for municipal, domestic, or agricultural purposes at the time of designation of the zones, or in an area of a geologic stratum that is designated or used for wastewater injection through the use of injection wells or disposal wells permitted under Chapter 27.
- Are not located in an area of the Edwards Aquifer subject to the jurisdiction of the Edwards Aquifer Authority; the boundaries of the Barton Springs-Edwards Aquifer Conservation District; the Harris-Galveston Subsidence District; or the Fort Bend Subsidence District.

Using the exclusion criteria stated in House Bill 30, four potential production areas were delineated in areas outlying the excluded areas. Pumping impacts from the potential production areas were estimated using low, medium and high-volume pumping scenarios of 100, 200 and 500 acre-feet per year assuming both 30 and 50 years of production. Theis drawdown analysis was performed to characterize the effect pumping in these areas would have on existing exclusion wells. Numerous well fields were modeled for each potential production area. The well fields selected for each potential production area are those wellfields which have the least extensive amount of up-dip drawdown. The approximate minimum drawdowns are based on the 100 acre-feet 30-year scenarios, and maximums are based on the 500 acre-feet 50-year scenarios. Potential production areas 2 and 4 appear to have the least impact to up-dip exclusion wells with 0 to 20 feet of drawdown. Volume estimates were not calculated for the potential production areas.

To monitor pumping volumes from wells completed in brackish production areas, it is recommended that 1) meters be installed on each well to track pumping volumes, 2) metered volumes are recorded monthly, and 3) monitoring wells are designated to track water level changes resulting from brackish production. Monitoring wells should be located between existing users excluded by House Bill 30 criteria and brackish production wells. The number of

monitoring wells located peripheral to brackish pumping that are necessary to characterize the impacts of pumping upon existing users will be driven by several site-specific factors, including (but not limited to) distance to nearest exclusion well, monitoring well candidate locations, as well as landowner and property access issues.

The modeling results indicate that there are approximately 5,445,315 acre-feet of in-place groundwater within the Nacatoch Aquifer in the project area. An estimated 574,761 acre-feet, or eleven percent, of the available groundwater is within the fresh water zone. Slightly saline and moderately saline water estimated volumes are 1,768,713 acre-feet (32 percent) and 1,637,529 acre-feet (30 percent), respectively. The very saline estimated volume within the project area is estimated to be 1,464,312 acre-feet (27 percent) of the total estimated volume.

# 2 Introduction

House Bill 30 was passed in 2015 by the 84$^{th}$ Texas Legislature with a goal to identify and designate local or regional brackish groundwater production zones in areas of the state with moderate to high availability of brackish groundwater that can be used to reduce the use of fresh groundwater. This legislation was driven by the recent severe drought coupled with continuous population growth in Texas.

The first four aquifers to be evaluated include: the Carrizo-Wilcox Aquifer within GMA-13 (between the Colorado River and the Rio Grande), the Blaine, Rustler, and Gulf Coast Aquifers. These aquifer studies were finalized in August 2016. Three additional aquifers - the Blossom, Nacatoch and Trinity Aquifers – evaluations must be completed by August 2017. Any other aquifers with potential brackish production zones need to be evaluated by December 1, 2022.

The Nacatoch Aquifer of northeast Texas occurs in a narrow band that extends from near the Navarro-Limestone County line northward through the communities of Kaufman and Commerce, and then eastward through Bowie County and beyond into Arkansas (George, Mace, & Petrossian, 2011) (Figure 2-1). The project area for the Nacatoch Aquifer includes the downdip portion of the Nacatoch Formation that is estimated to have a total dissolved solids concentration up to 10,000 milligrams per liter. This area incorporates all of the geophysical log locations that were analyzed for water quality estimates. The project area encompasses 8,118 square miles as shown in Figure 2-1.

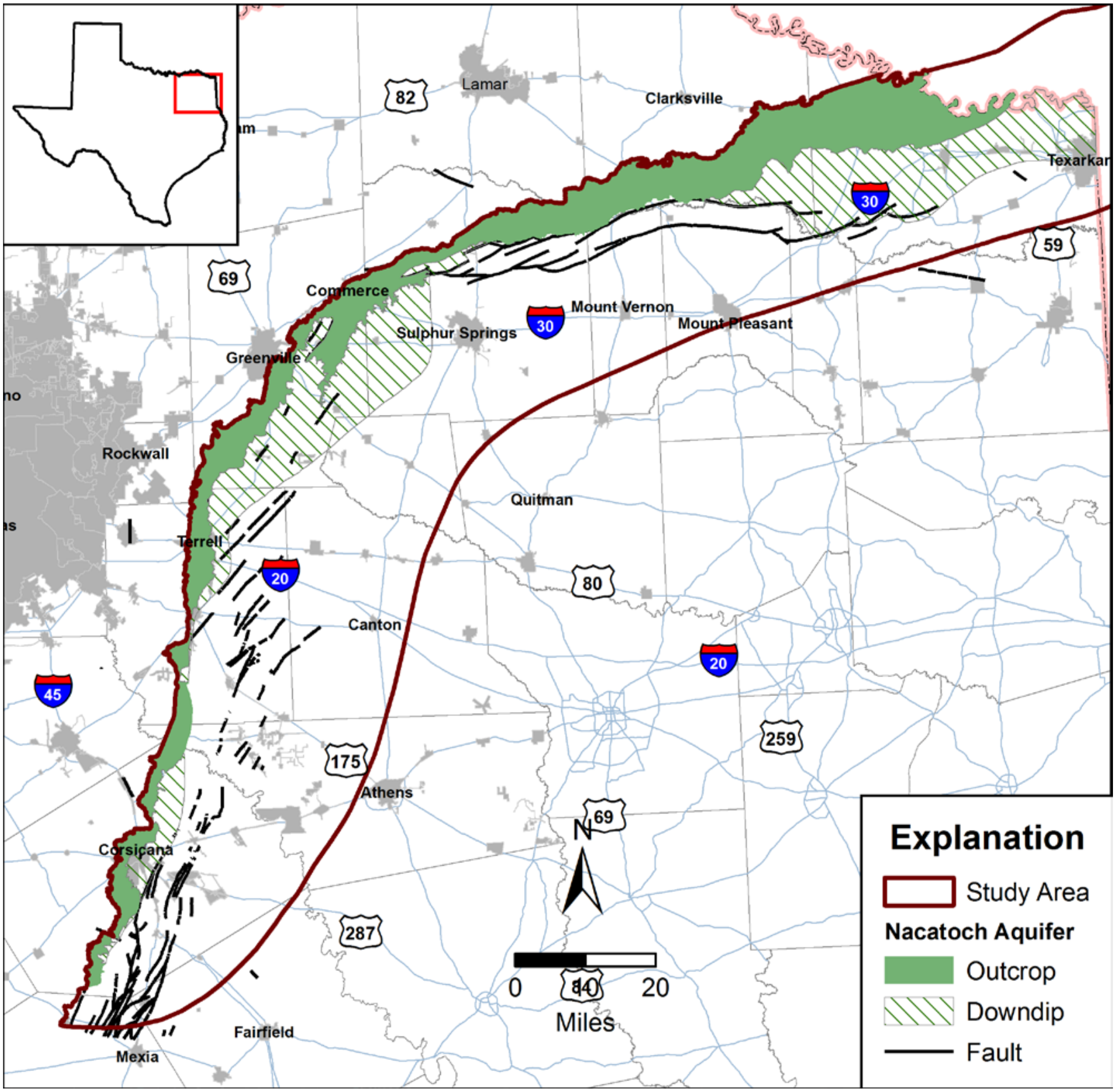


**Figure 2-1.** **Project area.**

# 3 Project Deliverables

Project deliverables include: this report, an ArcGIS geodatabase, and geophysical log metadata to be uploaded to the BRACS database. Data used for the completion of this project includes: water quality analytical data, geophysical logs, and water well reports from multiple sources. No geophysical logs or water quality results were used for this project from sources other than TWDB, therefore none are provided with this project as a deliverable.

Metadata from geophysical log analyses have been provided in the BRACS database format that is structurally identical to Meyer (2014). The applicable source data has been integrated within an ESRI geodatabase format consistent with TWDB standard data model framework for delivery.

The results and evaluation of these data are discussed in this report. Any data that was incorporated into the results of this study have been provided to the TWDB with this report. Volumetric analyses were performed using the Nacatoch Groundwater Availability Model and best available science.

# 4 Project Area

The Nacatoch Aquifer of northeast Texas occurs in a narrow band that extends from near the Navarro-Limestone County line northward through the communities of Kaufman and Commerce, and then eastward through Bowie County and beyond into Arkansas. Geologic mapping of the Nacatoch Sand extends further southward through Limestone and Falls Counties; however, the Nacatoch Sand in this area is recognized as non-water bearing and is therefore not included in the aquifer delineation. The project area includes the Nacatoch Aquifer outcrop, local alluvium and terrace deposits, and its downdip/subsurface extent for a distance from zero to approximately 15 miles. Due to faulting, very little outcrop occurs in the central portion of the aquifer extent in the general area of the City of Commerce (Figure 2-1). Significant areas of the lateral outcrop are covered by silt and sand floodplain deposits (mapped as alluvium and terrace deposits).

The project area is contained within two water planning regions, Region C in the southwestern half and Regions D (North East Texas) in the northern half (Figure 4-1). Only the western Henderson County portion of the Neches and Trinity Valleys Groundwater Conservation District is impacted significantly by the study area, although Freestone County of the Mid-East Texas Groundwater Conservation District lies only slightly outside the area (Figure 4-2). The downdip limit of the Nacatoch Aquifer generally occurs at the eastern border of Groundwater Management Area 8, while Groundwater Management Area 11 lies immediately to the east (Figure 4-3).

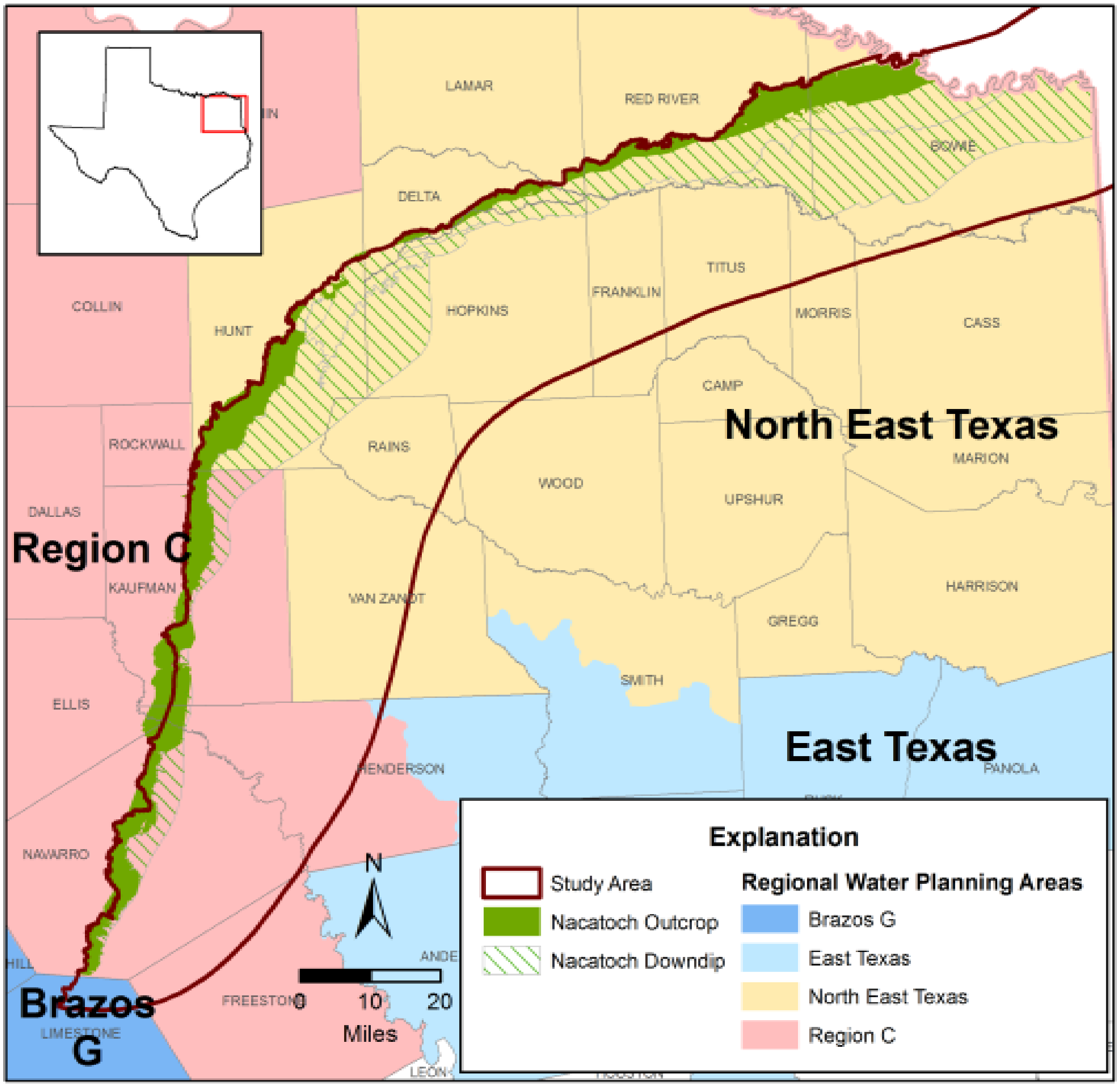


**Figure 4-1.** **Regional water planning areas.**

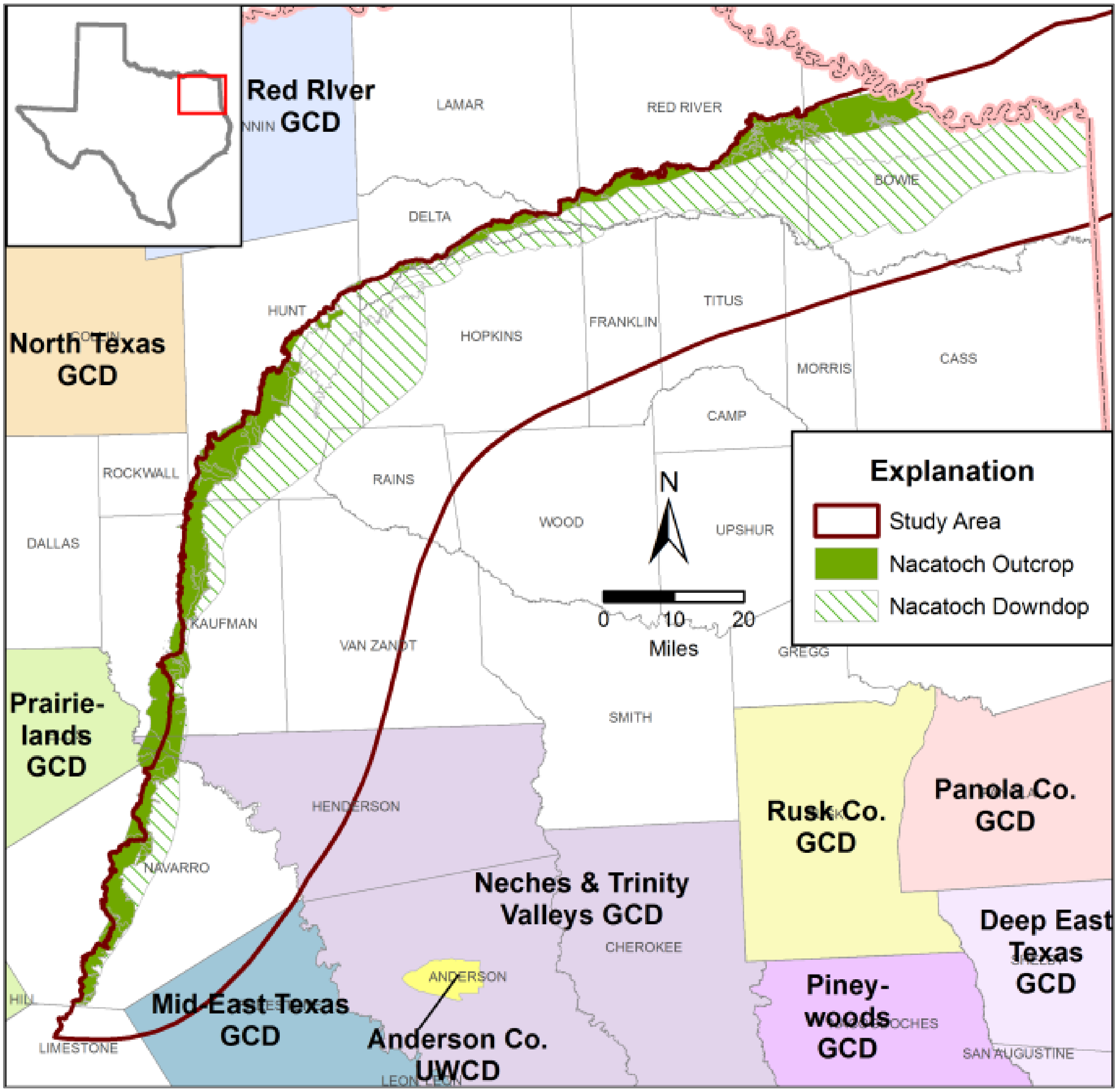


**Figure 4-2.** **Groundwater conservation districts.**

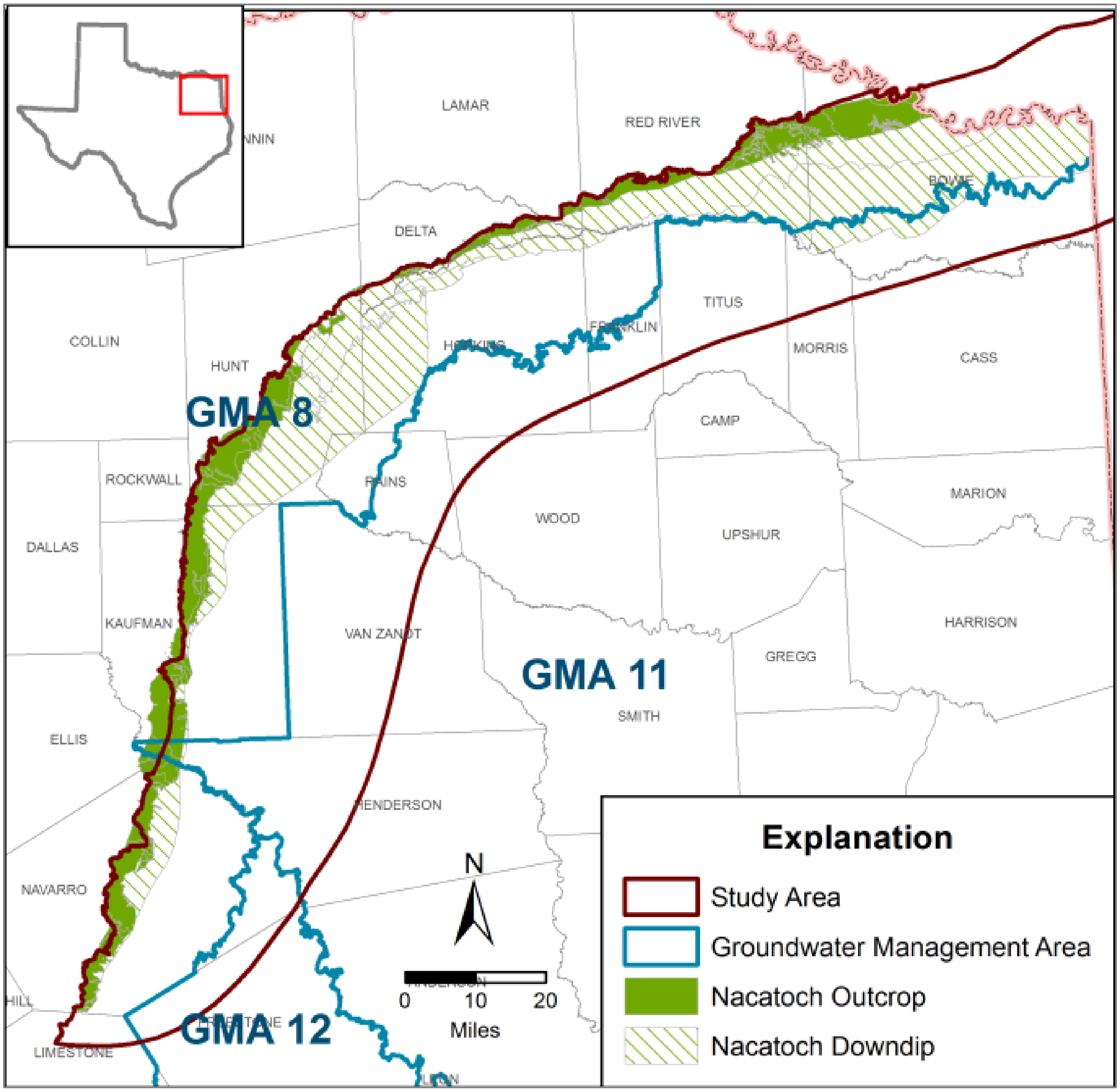


**Figure 4-3.** **Groundwater management areas.**

# 5 Hydrogeologic Setting

## 5.1 Geology

The generalized stratigraphic chart showing the Nacatoch Sand and adjacent formations is shown in Table 5-1. The Nacatoch outcrop and subcrop have an overall northeast to southwest trend in the northern part of the basin, changing to a north-south trend in the western part. Cretaceous sediments of the older Taylor Group lie west of the Nacatoch Sand outcrops. To the east lie younger sands and clays of the Midway Group. Alluvium along the major drainages in the area, as seen in Figure 5-1, also form a part of the Nacatoch Aquifer system.

The structural framework of the Nacatoch Aquifer can base its configuration on three principal components: deposition into the East Texas Basin, deltaic sedimentation processes, and stratigraphic off sets resulting from the Mexia-Talco Fault Zone.

Net sand thickness is greatest within the Pittsburg syncline where it straddles the state line in eastern Bowie and Cass Counties. Elsewhere, increased sand thickness over 100 feet occur in southern Red River and northern Titus Counties, eastern Hunt and western Delta Counties, and in southern Hunt County. These areas of greater thickness indicate focal points of original sediment input into the East Texas Basin. Net sand thickness decreases to 100 feet or less between these sediment input areas, and from central Kaufman County southward, net sand thickness is reduced to approximately 20 feet.

The Mexia-Talco fault zone consisting primarily of strike-oriented normal faults that often formed grabens disrupts the basinward dip of the Nacatoch Aquifer layers. The faulting generally causes the normal downdip flow of groundwater to be halted or diverted, thus limiting the downdip extent of fresh water in the aquifer (Ashworth, 1988).

There are two grabens adjacent to the Nacatoch outcrop (Figure 5-1). One is located in northern Hopkins, Franklin, Titus, and Morris Counties. The other is located to the south in Navarro, Freestone and Limestone counties.

The Nacatoch Aquifer is composed of sand sequences of the Nacatoch Sand interbedded with impermeable layers of mudstone or clay, the latter acting as aquitards that prevent mixing of waters from the different producing zones (LBG-Guyton Associates; NRS Consulting Engineers, 2003). These well-sorted, very fine to fine grained marine sandstones are coarsening upwards, calcitic to unconsolidated, glauconitic, and commonly contain shell fragments (McGowen & Lopez, 1983).

A geologic cross section location map is included on Figure 5-2. Sand distribution within the Navarro is shown in the stratigraphic section (X-X’) along formation strike in Figure 5-3. Dip sections A-A’ (Figure 5-4), B-B’ (Figure 5-5), and C-C’ (Figure 5-6) show the south-easterly dipping formations, and the Nacatoch and lower Navarro sands.

**Table 5-1. Generalized stratigraphic chart for the Nacatoch Aquifer (in gray) and adjacent geologic units.**

| Era | System | Series | Group | Formation | |
|---|---|---|---|---|---|
| Cenozoic | Tertiary | Paleocene | Wilcox | Calvert Bluff Formation | |
| | | | | Simsboro Formation | |
| | | | | Hooper Formation | |
| | | | Midway | Undifferentiated | |
| Mesozoic | Cretaceous | Gulfian | Navarro | Kemp Clay | |
| | | | | Corsicana Marl | |
| | | | | Nacatoch Sand | |
| | | | | Lower Navarro/Neylandville Marl | |
| | | | Taylor | Upper part Taylor Marl | |
| | | | | Pecan Gap Chalk | Annona Chalk |
| | | | | Wolfe City Sand | |
| | | | | Lower Taylor | |
| | | | Austin | Gober Chalk | |
| | | | | Brownstown Marl | |
| | | | | Blossom Sand | |
| | | | | Bonham Marl | |
| | | | | Ector Tongue | |
| | | | Eagle Ford | Eagleford Shale (Sub-Clarksville Member) | |

Source: Baker, 1995.

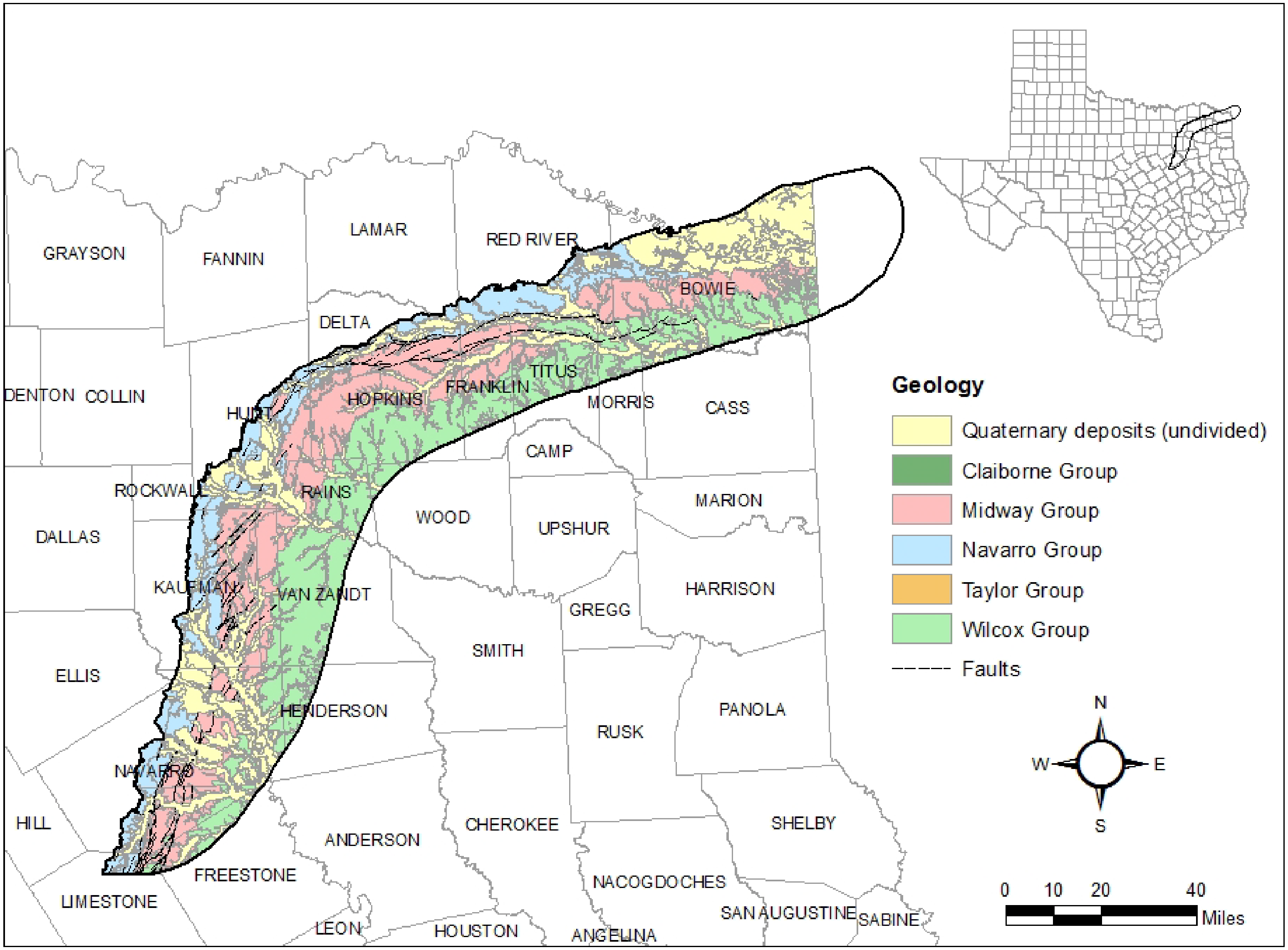


**Figure 5-1.** **Geologic map of project area.**

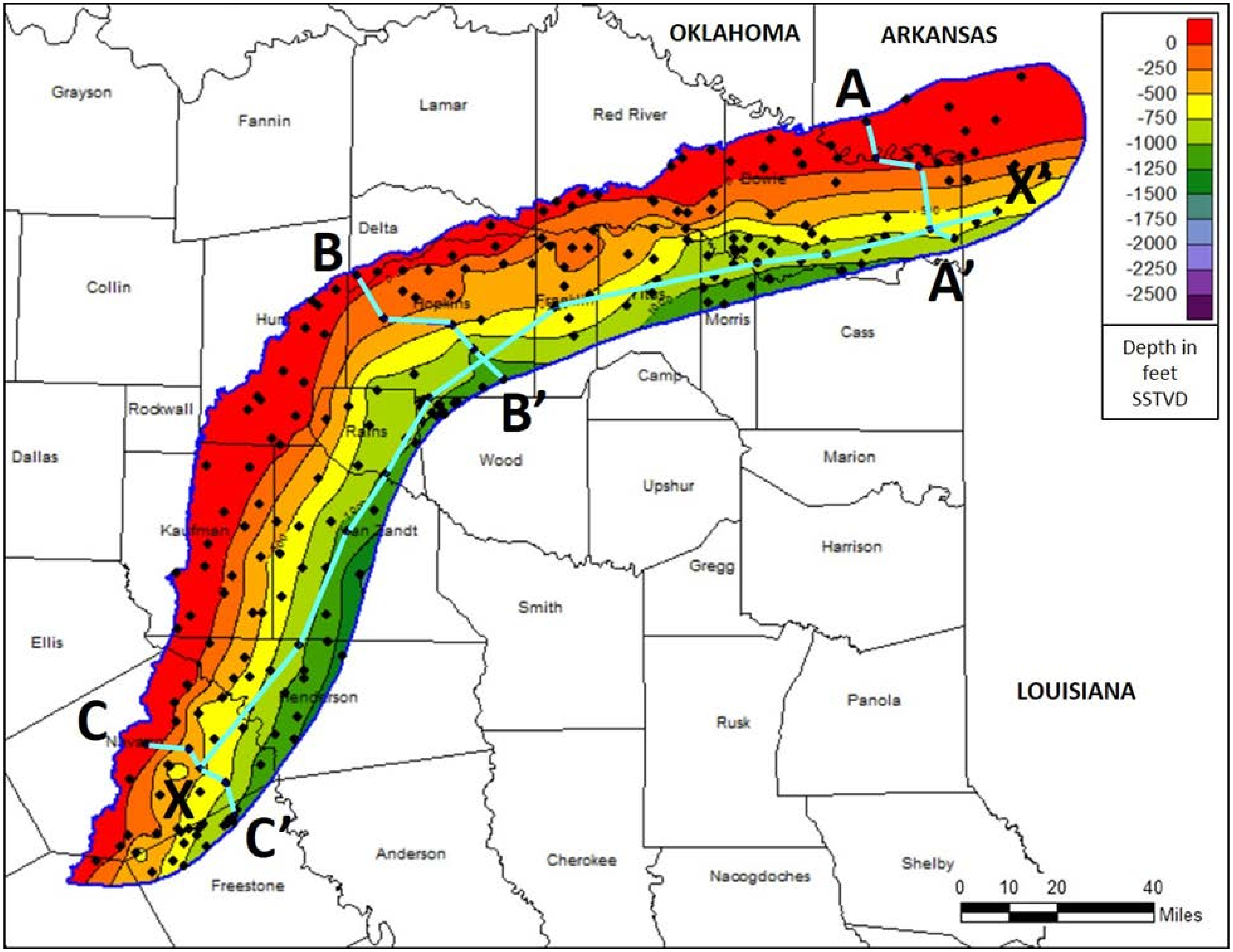


**Figure 5-2.** **Location of cross sections on top of Nacatoch structure map.**

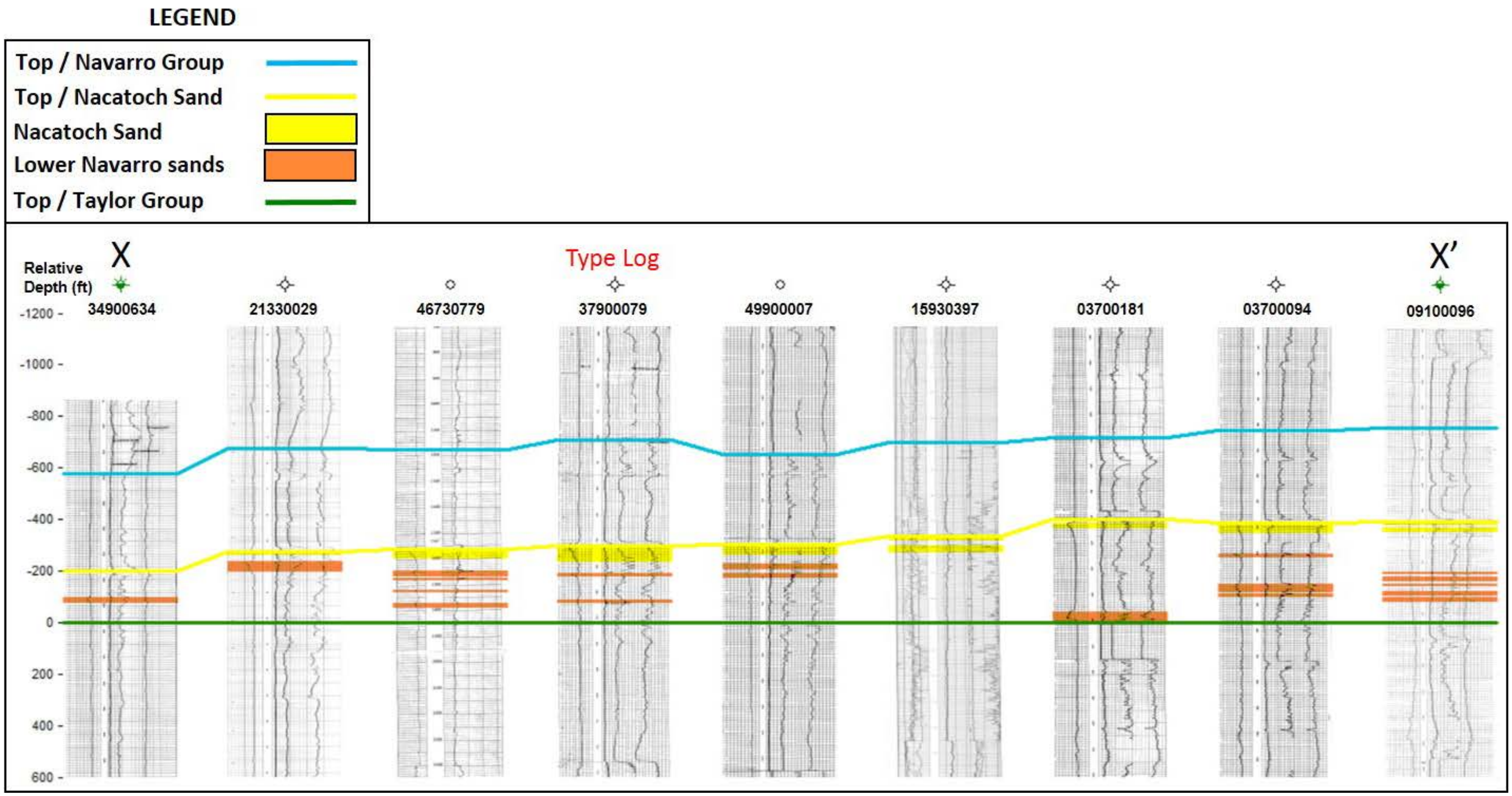


**Figure 5-3. Stratigraphic section X-X' along strike (top of Taylor Group).**

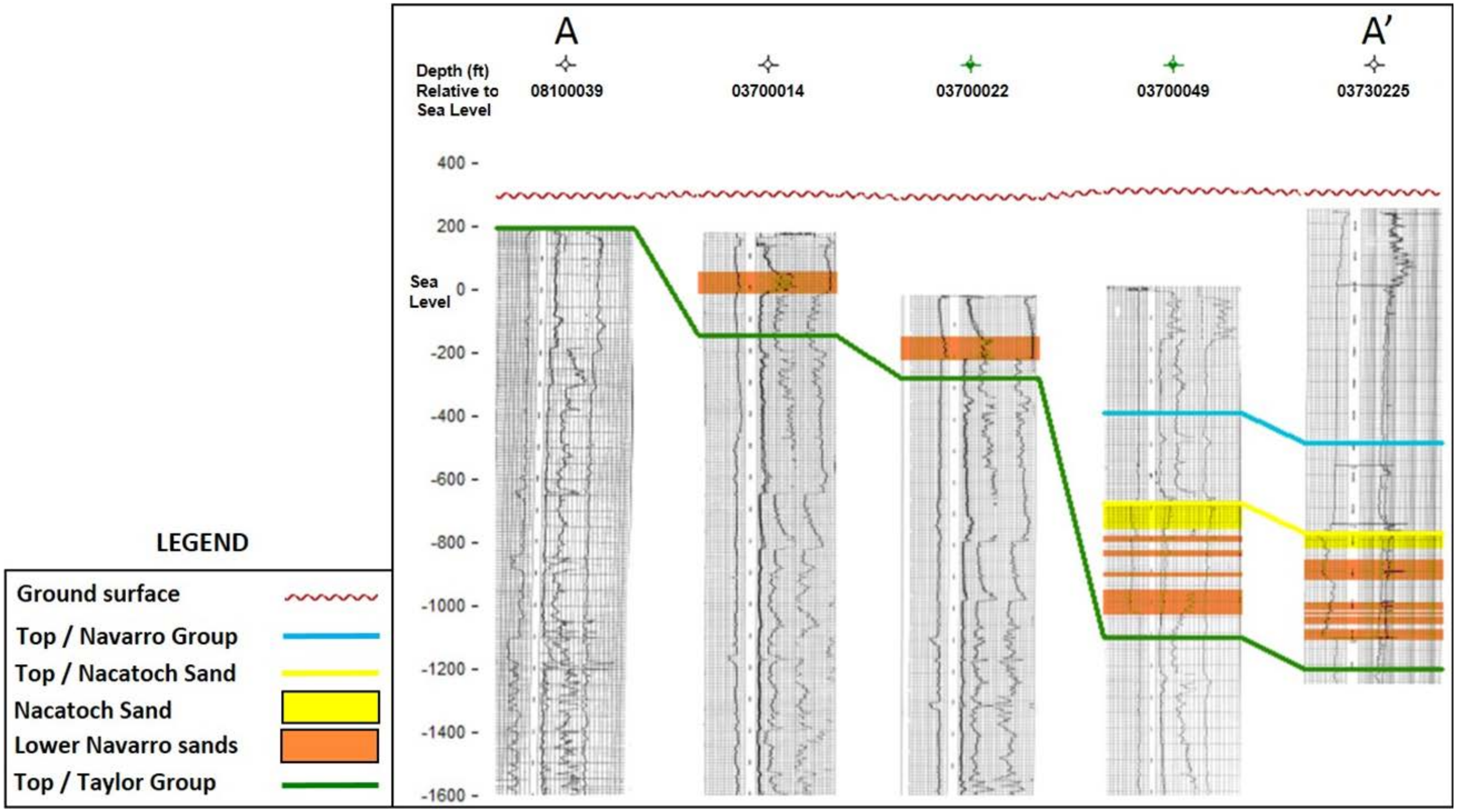


**Figure 5-4.** **Structural section A-A' along formation dip direction.**

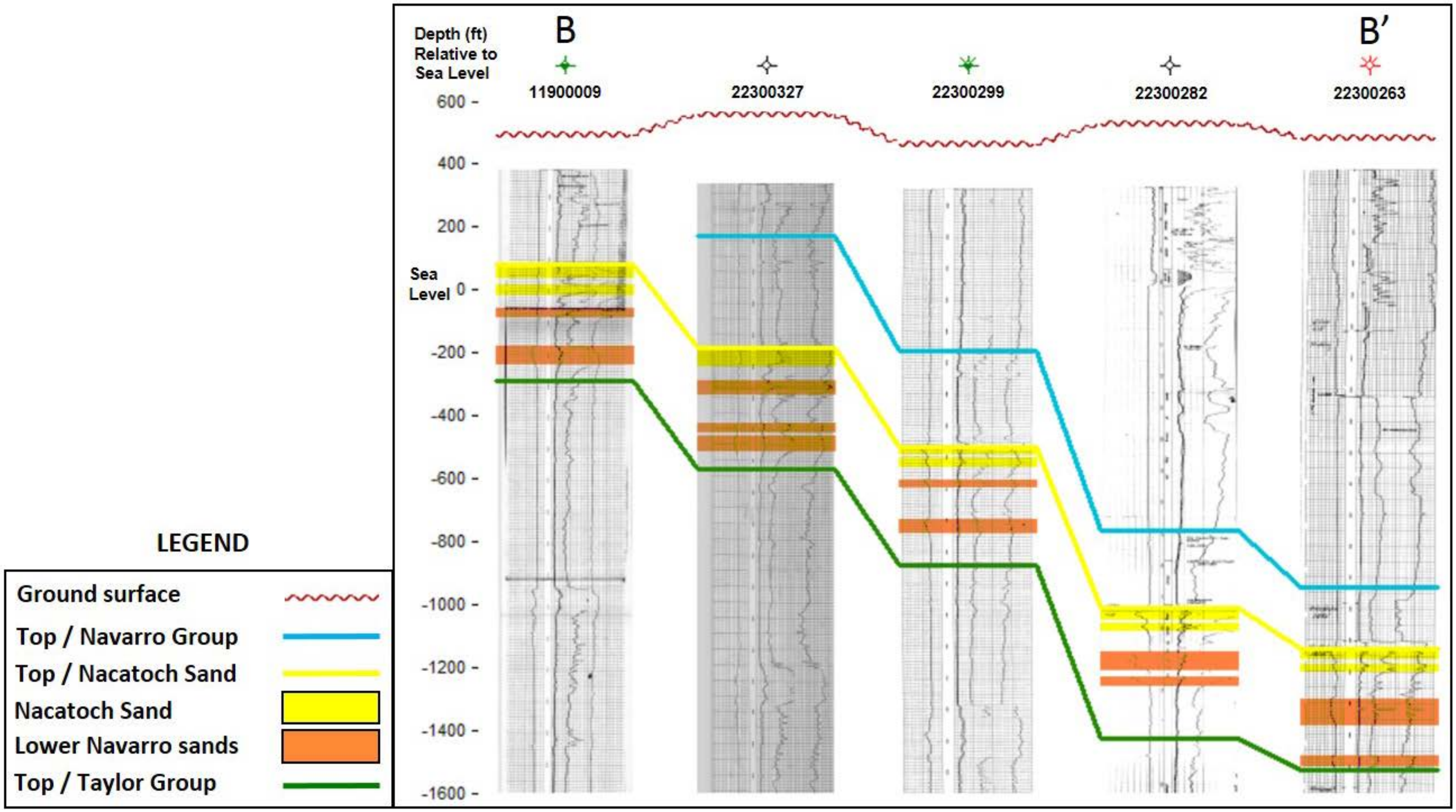


**Figure 5-5.** **Structural section B-B' along formation dip direction.**

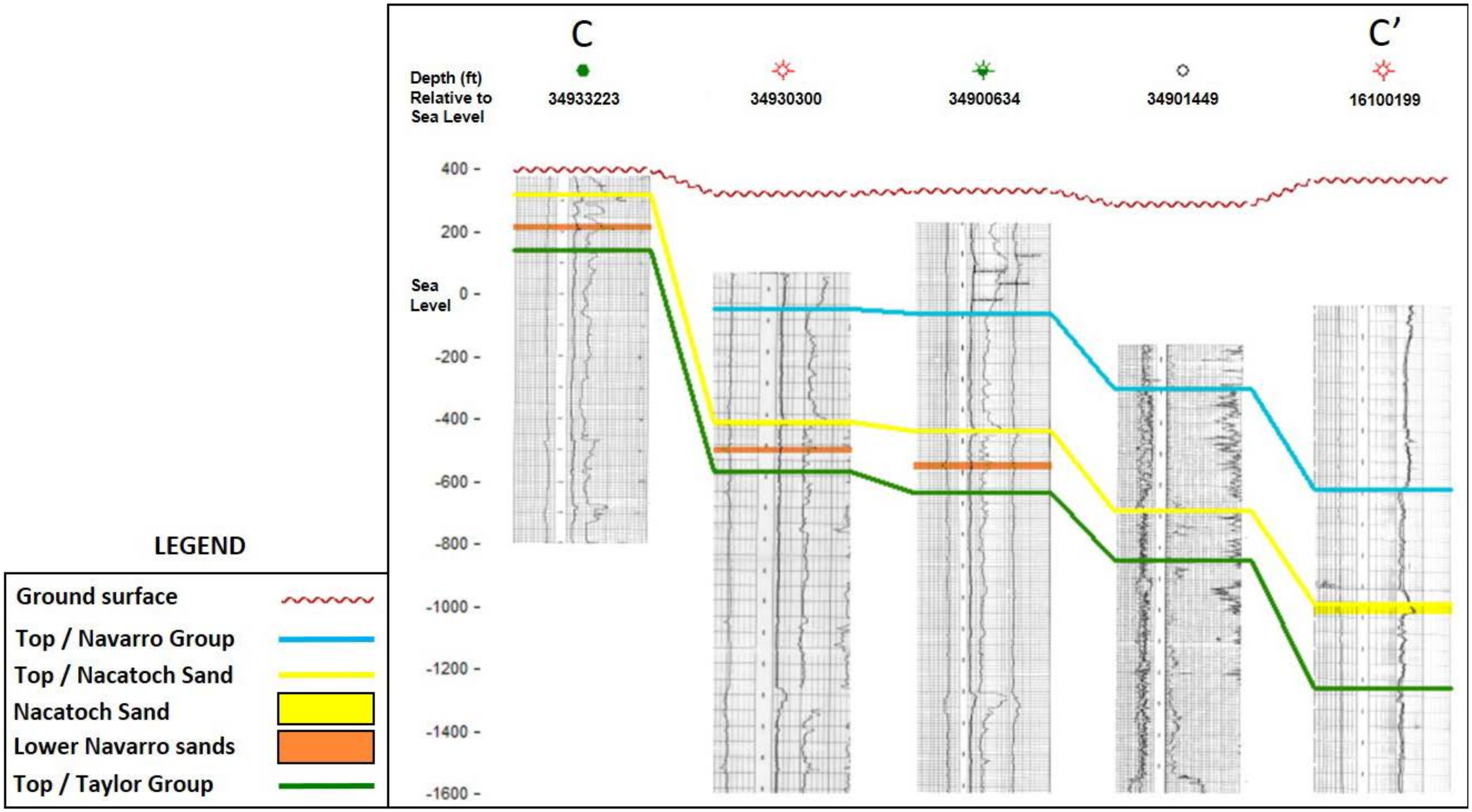


**Figure 5-6. Structural section C-C' along formation dip direction.**

## 5.2 Groundwater

The Nacatoch Aquifer (designated as a minor aquifer) occurs between other major and minor aquifers. Older aquifer formations in the area include the Woodbine and Blossom minor aquifers, which both underlie the Nacatoch Aquifer. Separated primarily by the Midway formation, the Carrizo-Wilcox major aquifer overlies the Nacatoch Aquifer further downdip. The extents of the major and minor aquifers as defined by the TWDB are shown in Figure 5-7 and Figure 5-8, respectively.

The TWDB reports freshwater saturated aquifer thickness of 50 feet on average (George, Mace, & Petrossian, 2011). Approximately 80 feet of alluvium occurs along major drainages that is hydraulically connected to the Nacatoch Sand, and is part of the aquifer system. Groundwater in this aquifer is usually under artesian conditions. An exception occurs in shallow wells where water table conditions exist due to outcropping of the aquifer. The Mexia-Talco Fault Zone interrupts the normal down-dip flow of groundwater, and generally delineates the subsurface limit of the aquifer (George, Mace, & Petrossian, 2011) (LBG-Guyton Associates; NRS Consulting Engineers, 2003).

Major rivers intersecting the model area include the Trinity, Sabine, Sulphur, and Red. The major rivers in the model area tend to flow year around, and are typically considered to be gaining (i.e. groundwater flows into the rivers most of the time). Under predevelopment conditions, groundwater flow in the Nacatoch Aquifer is elevation-driven from the higher elevation outcrops to the lower elevation stream valleys and, in areas where faulting does not disturb aquifer continuity, to the confined sections of the aquifers. Prior to significant resource development, recharge occurring as a result of infiltration and stream loss was balanced by discharge to streams and springs in the outcrop, and through cross-formational flow (Beach, et al., 2009).

Water level data includes data from both the TWDB groundwater database and the State Driller Report database between years 2008 and 2016. Generally, direction of groundwater flows radially away from the topographically-higher land elevations between the river basins towards the river channels (Figure 5-9). For example, groundwater flows to the northeast (Sabine River) and to the south (Trinity River) away from the higher elevations in northern Kaufman County. Similarly, groundwater flows to the southwest, south and southeast towards the Sulphur River radially away the from the data point shown in southern Red River County. Figure 5-10 shows the same data presented as depth to water measurements.

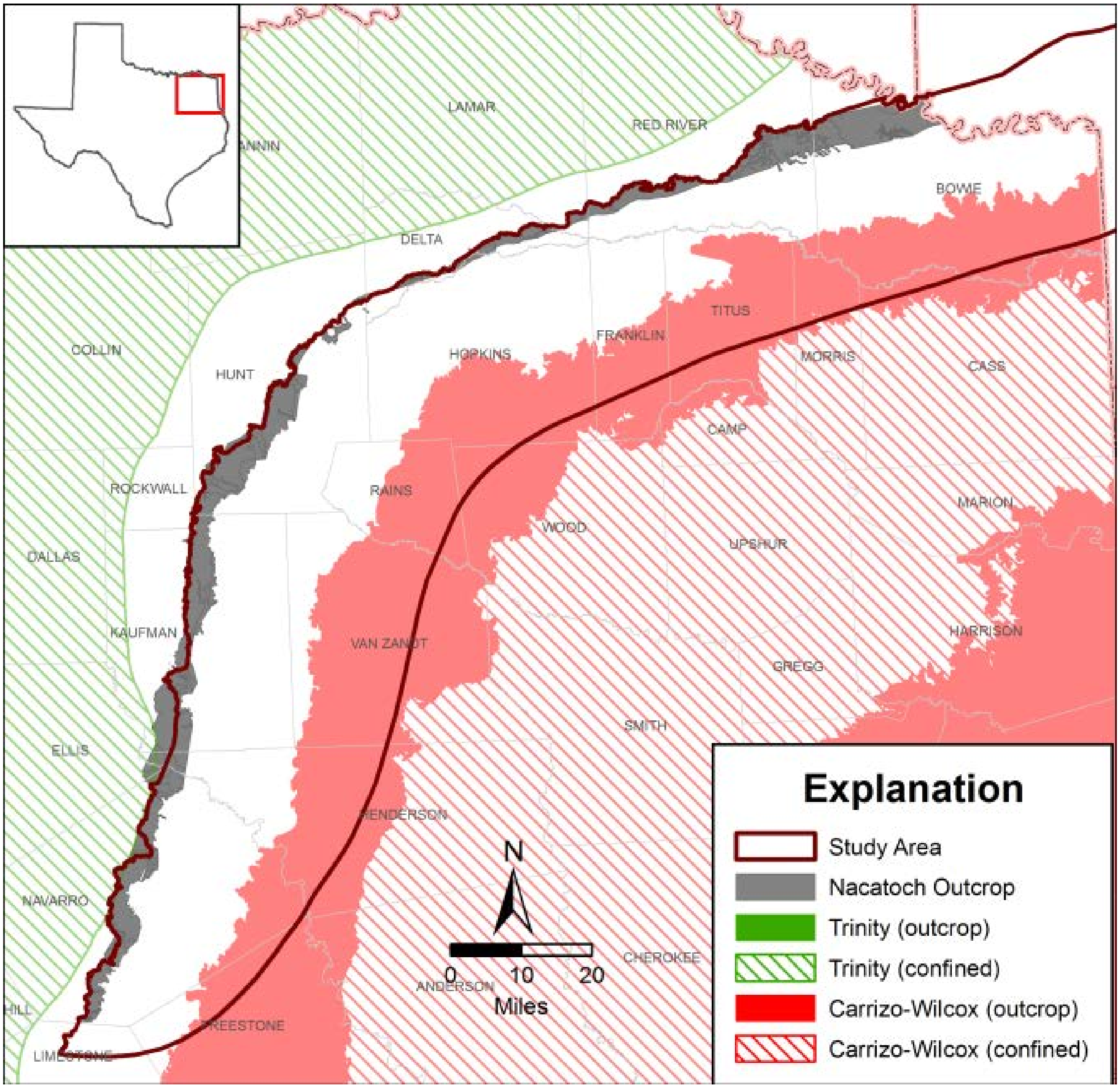


**Figure 5-7. Major aquifers.**

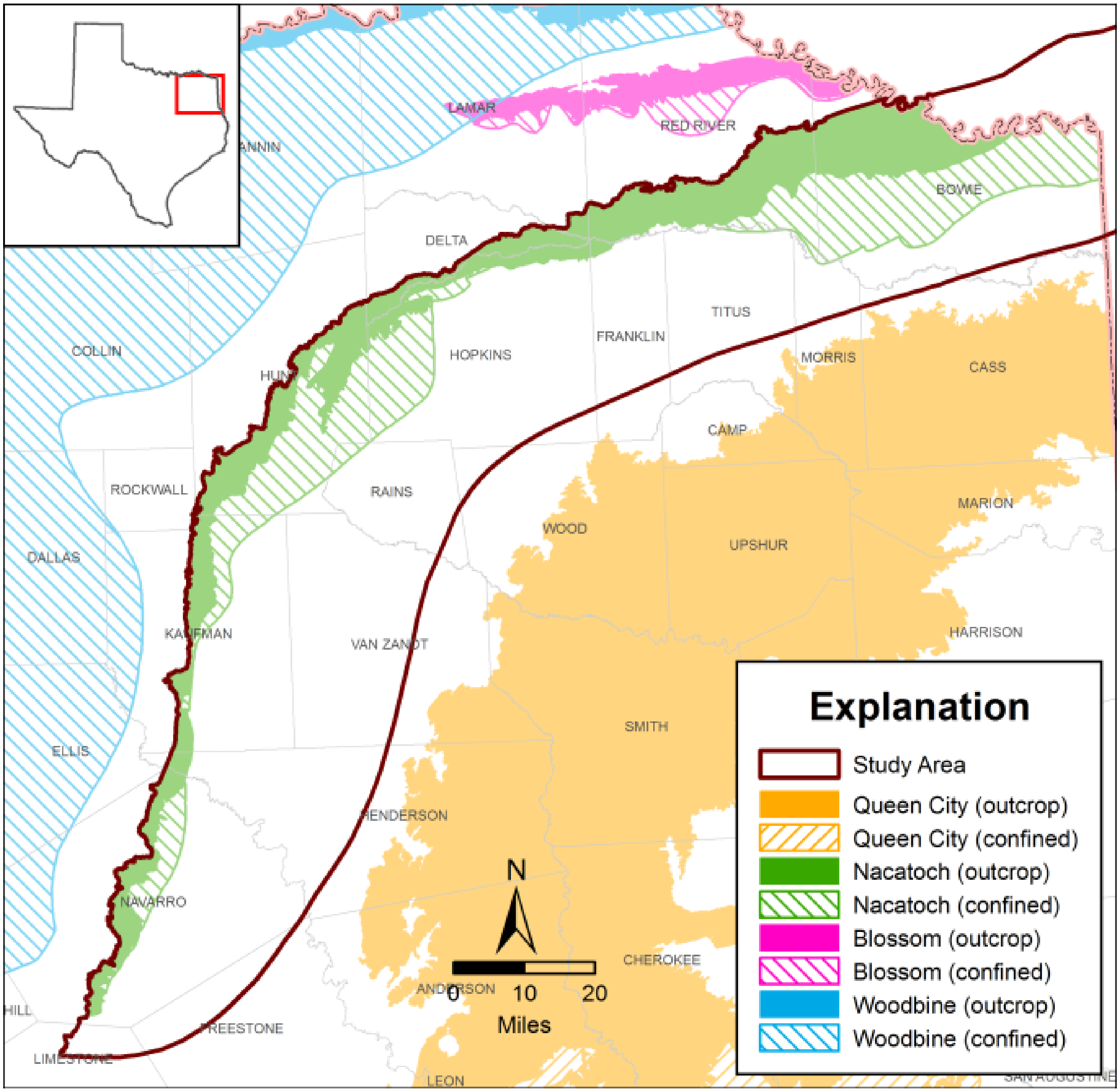


**Figure 5-8.** **Minor aquifers.**

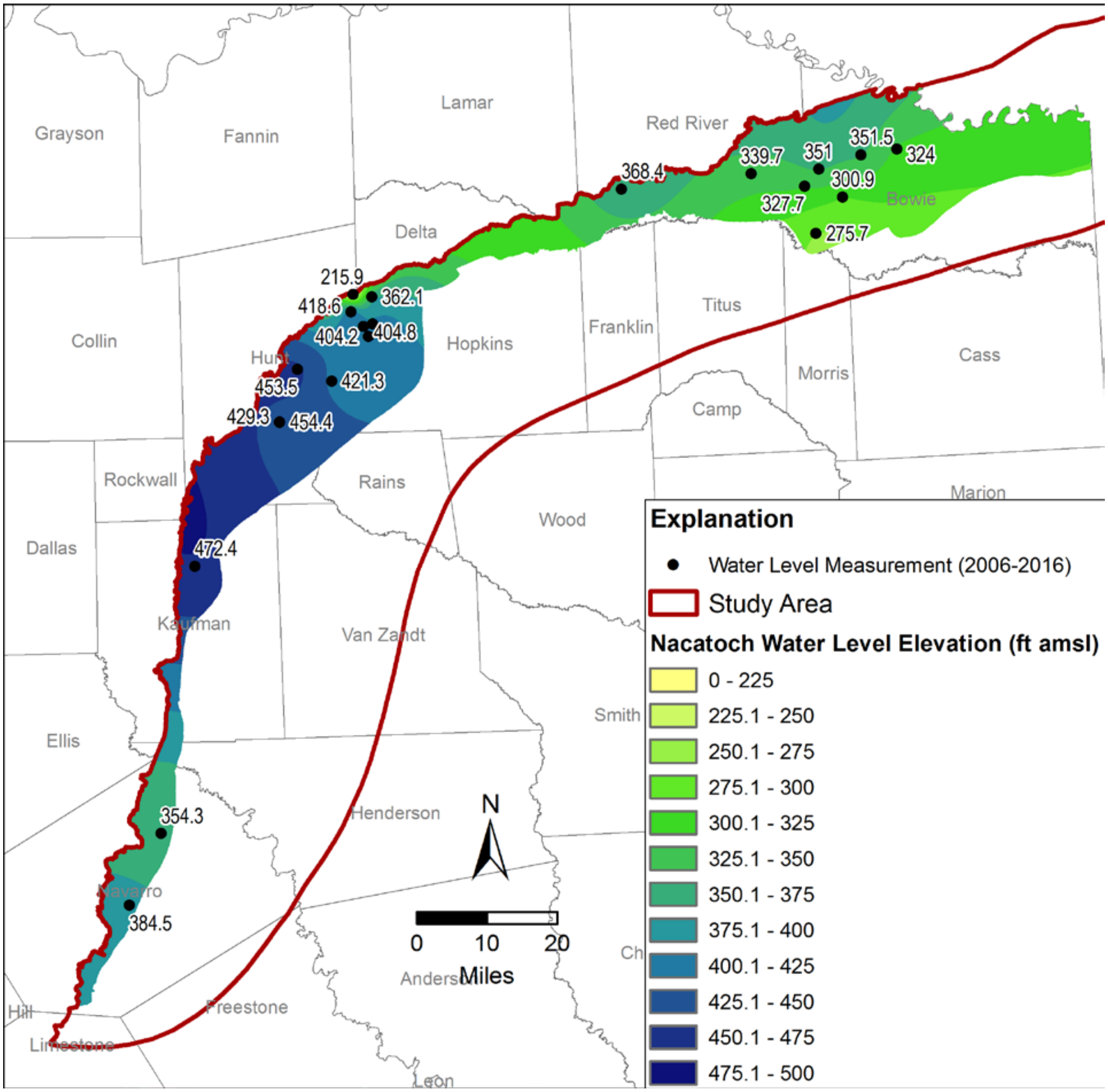


**Figure 5-9.** **2006 to 2016 groundwater elevations.**

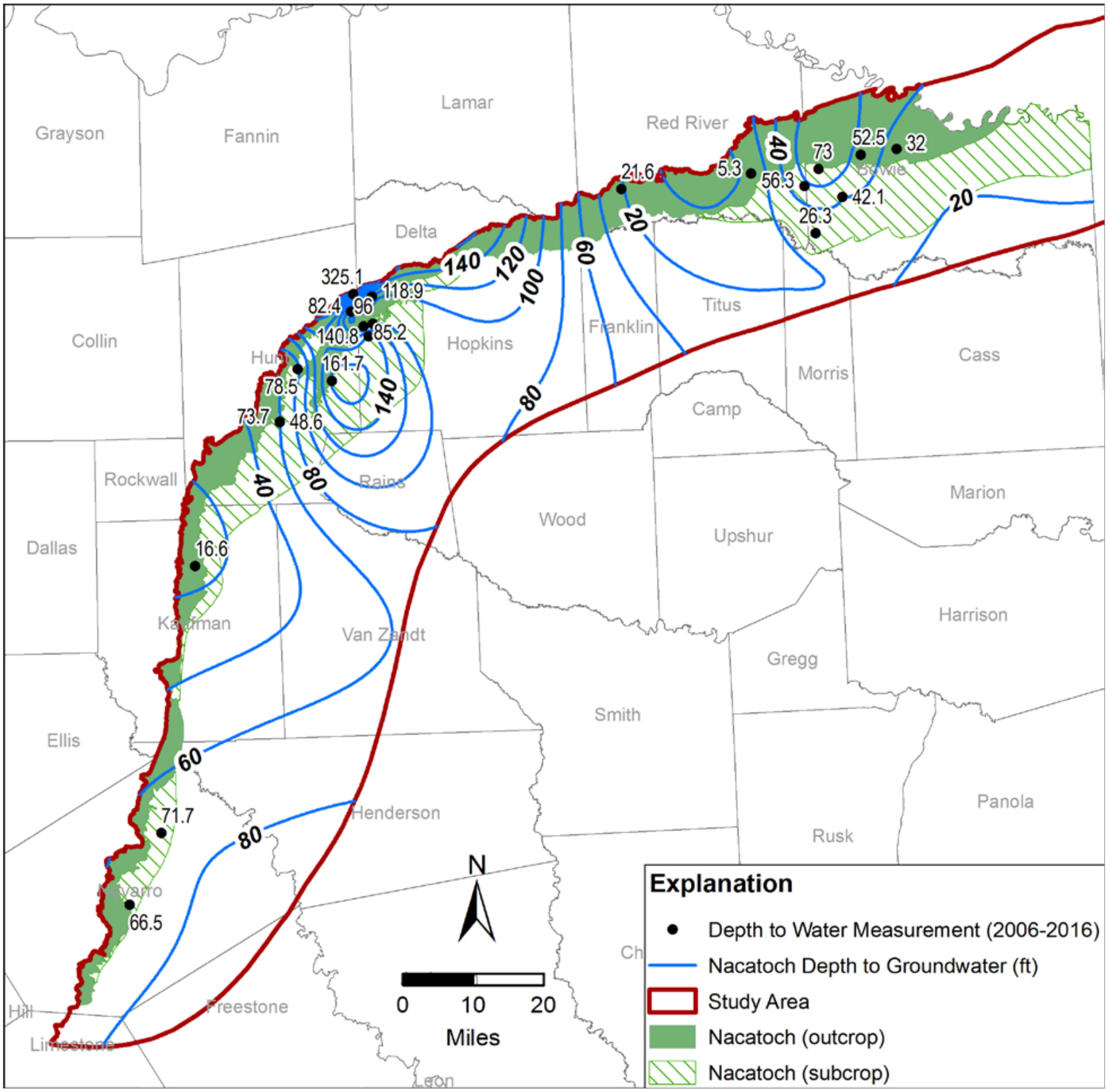


**Figure 5-10.** **2006 to 2016 depths to groundwater.**

# 6 Groundwater Salinity Zones

Groundwater salinity zones are listed in Table 6-1. This report has delineated groundwater salinity zone boundaries in the Nacatoch up to 10,000 milligrams per liter total dissolved solids.

Salinity zones have been defined using existing water quality analytical data (measured total dissolved solids) from wells completed in the Nacatoch Formation, stratigraphic units determined from geophysical logs for which reasonable total dissolved solids estimates were calculated, and the total dissolved solids estimates from geophysical logs. Figure 6-1 shows the distribution of the analytical sample data total dissolved solids concentrations and Figure 6-2 maps the estimates derived from geophysical logs.

Fresh water occurs primarily in the outcrop, or within short distances downdip. Slightly saline groundwater is found frequently in the outcrop, but it dominates the downdip extent of the aquifer. An interesting feature of total dissolved solids distribution in Nacatoch Aquifer is the close proximity of wells with considerable differences in salinity, both in the outcrop and in the confined aquifer. In Bowie County, a moderately saline well with a total dissolved solids of 3,035 milligrams per liter occurs near a fresh water well with a total dissolved solids concentration of about 600 milligrams per liter.

**Table 6-1. Groundwater salinity classification summary.**

| Groundwater Salinity classification | Range in TDS[a] (mg/L)[b] |
|---|---|
| Fresh | Less than 1,000 |
| Slightly saline | 1,001 to 3,000 |
| Moderately saline | 3,001 to 10,000 |
| Very saline | 10,000 to 35,000 |
| Brine | Over 35,000 |

[a] TDS = total dissolved solids.
[b] mg/L = milligrams per liter.
*Source:* Modified from (Winslow & Kister, 1956).

## 6.1 Slightly Saline Zones

The findings of this report align with the current delineation of both the 1,000 and 3,000 milligrams per liter total dissolved solids extents. The delineation of the slightly saline zone is based on water quality sample data as shown in Figure 6-1. The water quality estimates from geophysical logs do not significantly modify the current downdip extent.

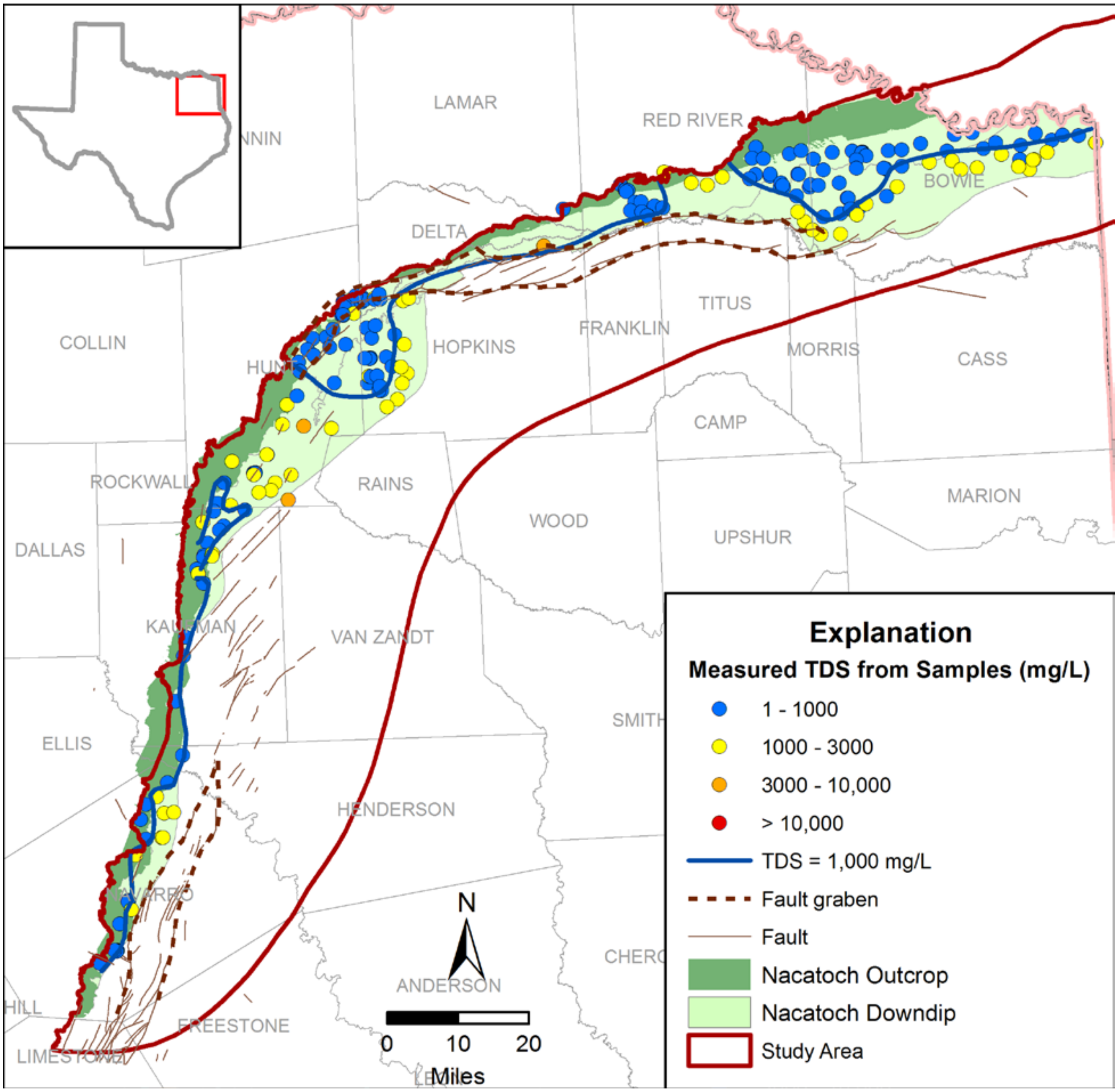


**Figure 6-1. Distribution of measured total dissolved solids values.**

## 6.2 Moderately Saline Zones

Moderately saline zones are those zones with total dissolved solids concentrations between 3,000 and 10,000 milligrams per liter. The findings of this report suggest that the fault grabens control the downdip extent of moderately saline waters where they exist, however, in other portions of the aquifer, it appears that the fault zone does not impact salinity distribution as significantly as it does near the grabens.

## 6.3 Very Saline and Brine Zones

House Bill 30 only requires that the groundwater salinity zones in the Nacatoch Aquifer be delineated up to 10,000 milligrams per liter; therefore, very saline zones (10,000 to 35,000 milligrams per liter) and brine zones (greater than 35,000 milligrams per liter total dissolved solids) are not within the scope of this project.

## 6.4 Cross sections

A total of five geophysical log cross-sections were created that show estimated total dissolved solids values derived from the logs at their respective depth intervals. Figure 6-3 shows the locations of the cross-sections and the cross-sections are presented in Figure 6-4 through Figure 6-8. The top and bottom depths of the Nacatoch Sand formation (Nacatoch Aquifer) are depicted on each cross-section using stratigraphic information developed by the Bureau of Economic Geology. Faults are represented diagrammatically on the cross-sections according to their mapped locations in the Geologic Atlas of Texas Geodatabase (1:250,000 scale). The distance between each well in units of feet is shown at the top of each cross-section. The BRACS ID and log image filename are also provided above each log.

Cross-section A-A' (Figure 6-4) extends from the outcrop area to outside the mapped extent of the aquifer in Hunt County. The up-dip half of cross-section A shows fresh water total dissolved solids estimates in the upper portions of the aquifer that ranged from 50 milligrams per liter to 920 milligrams per liter. A zone of moderately saline water was observed in sand layers below the fresh water zone on the first three logs of the cross-section (BRACS IDs 24559, 22004, 22007). BRACS well 24562 in the central portion of cross-section A-Aˈ provided a total dissolved solids estimate in the slightly saline range at 1,610 milligrams per liter. The next log on the cross-section, BRACS well 21978, displays a transition to moderately saline groundwater across the entire thickness of the aquifer. This log has four sand intervals with total dissolved solids estimates of 3,530 milligrams per liter, 4,230 milligrams per liter, 6,160 milligrams per liter, and 6,650 milligrams per liter. This moderately saline groundwater zone extends through the two logs in the downdip direction, BRACS wells 24549 and 21991, which display total dissolved solids values ranging from 3,160 milligrams per liter to 4,940 milligrams per liter.

Cross-section B-Bˈ (Figure 6-5) begins in the outcrop area and continues past the mapped extent of the aquifer in Hopkins County. The northernmost log on this cross-section, BRACS well 23587, is located in the outcrop area and exhibits total dissolved solids estimates that change from fresh groundwater in the upper part of the aquifer to slightly saline in the middle and moderately saline near the base. The total dissolved solids values vary from 980 milligrams per liter to 1,210 milligrams per liter and 5,370 milligrams per liter. Total dissolved solids estimates from BRACS well 23556, which is adjacent to BRACS 23587, are in the fresh range in the shallow part of the aquifer at 930 milligrams per liter and 950 milligrams per liter, and in the slightly saline range in the middle at 1,320 milligrams per liter. The deeper portion of the aquifer on this log has a moderately saline total dissolved solids value of 5,140 milligrams per liter. The other four logs on cross-section B-Bˈ extend across the downdip area of the aquifer. These logs exhibit increasing total dissolved solids values in the downdip direction. BRACS well 25974 is located within 100 feet of the mapped boundary of the aquifer and provided a total dissolved solids estimate of 3,310 milligrams per liter. BRACS wells 25992 and 20037 had higher total dissolved solids values that were also in the moderately saline range. Groundwater quality transitions into the very saline range between BRACS wells 20037 and 34616. The total dissolved solids estimates from well 34616 are 10,750 milligrams per liter and 11,420 milligrams per liter.

Cross-section C-Cˈ (Figure 6-6) presents six geophysical logs with three logs located in the aquifer outcrop area in Red River County, two logs in Franklin County, and one in Titus County. The first three logs exhibit variability in water quality across the aquifer outcrop area. BRACS well 36027 has fresh groundwater total dissolved solids estimates and the deeper estimate is lower at 590 milligrams per liter than the shallow one at 830 milligrams per liter. The next well, BRACS 15006, provided total dissolved solids values at shallow depths of about 200 feet that are in the slightly saline range at 1,370 milligrams per liter and 1,230 milligrams per liter. BRACS well 35971 displays another fresh groundwater area with a total dissolved solids estimate of 510 milligrams per liter. BRACS well 21230 on cross-section C-Cˈ, located within a graben, has a total dissolved solids value of 9,900 milligrams per liter. The other two logs on this cross-section, BRACS wells 21245 and 21470, have total dissolved solids estimates in the very saline range. The aquifer salinity level in well 21245 is 10,950 milligrams per liter and in well 21470 it is 11,280 milligrams per liter.

Cross-section D-Dˈ (Figure 6-7) extends from the aquifer outcrop area in Red River County into the downdip area of the aquifer in Bowie County. BRACS wells 17831 and 25922, located in the outcrop area and positioned on the left side of the cross-section, exhibit higher salinity levels than the adjacent log in the figure, BRACS well 17826. Well 17831 has a slightly saline aquifer total dissolved solids value of 2,310 milligrams per liter, well 25922 has a moderately saline aquifer total dissolved solids value of 5,970 milligrams per liter, and well 17826 has a slightly saline aquifer total dissolved solids of 1,830 milligrams per liter. Decreasing aquifer salinity levels continue across the next two logs on cross-section D-Dˈ; BRACS wells 17840 and 17837. Well 17840 has a slightly saline total dissolved solids estimate of 1,510 milligrams per liter in the lower portion of the aquifer and well 17837 has a slightly saline total dissolved solids estimate of 1,290 milligrams per liter in the upper section. A moderately saline total dissolved solids value of 3,950 milligrams per liter was identified in a sand layer situated in the lower half of the aquifer in well 17837. The last three logs on cross-section D-Dˈ exhibit moderately to very saline total dissolved solids estimates. One sand layer near the base of the aquifer was analyzed in BRACS well 26090 and it has a very saline total dissolved solids value of 12,720 milligrams per liter. Salinity levels are relatively lower in the aquifer in the next well, BRACS well 26087, with moderately saline total dissolved solids estimates of 6,130 milligrams per liter and 9,840 milligrams per liter. Very saline total dissolved solids levels are observed in BRACS well 26098 at 11,350 milligrams per liter and 10,530 milligrams per liter.

Cross-section E-Eˈ (Figure 6-8) begins in the outcrop area in Bowie County and extends beyond the mapped extent of the aquifer in Morris County. Water quality deteriorates in the downdip direction on this cross-section. Slightly saline aquifer total dissolved solids levels are present in the updip portion of the cross-section at 1,190 milligrams per liter and 2,360 milligrams per liter in BRACS wells 19413 and 25729, respectively. Moderately saline groundwater is present in the aquifer at BRACS well locations 26087 and 23788. BRACS well 26087 has total dissolved solids estimates of 6,130 milligrams per liter and 9,840 milligrams per liter while well 23788 has total dissolved solids estimates of 5,560 milligrams per liter and 8,090 milligrams per liter. BRACS well 23801 has a very saline aquifer total dissolved solids estimate of 10,730 milligrams per liter and BRACS well 23772 also has a very saline aquifer total dissolved solids estimate of 13,690 milligrams per liter.

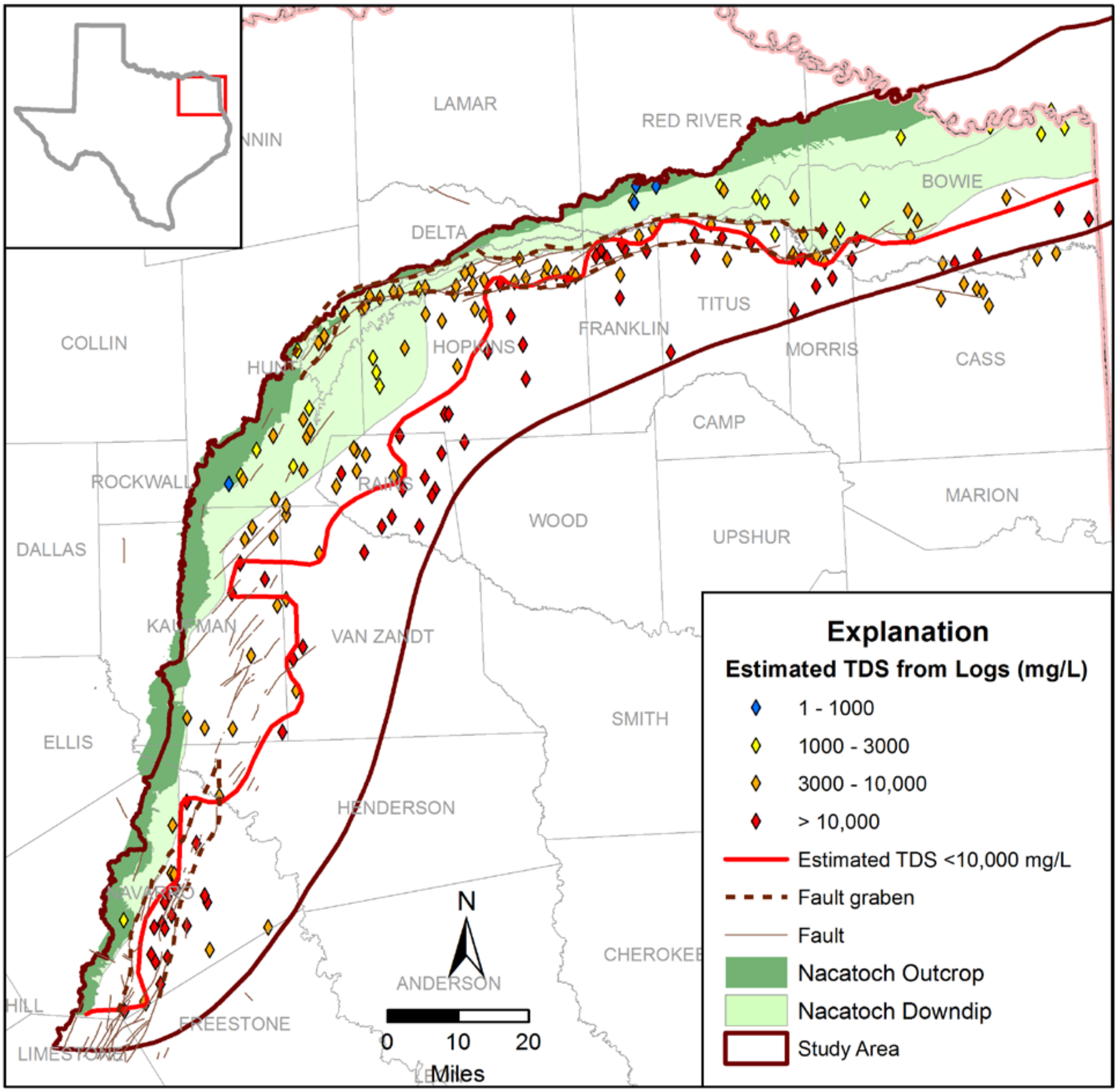


**Figure 6-2. Distribution of estimated total dissolved solids values.**

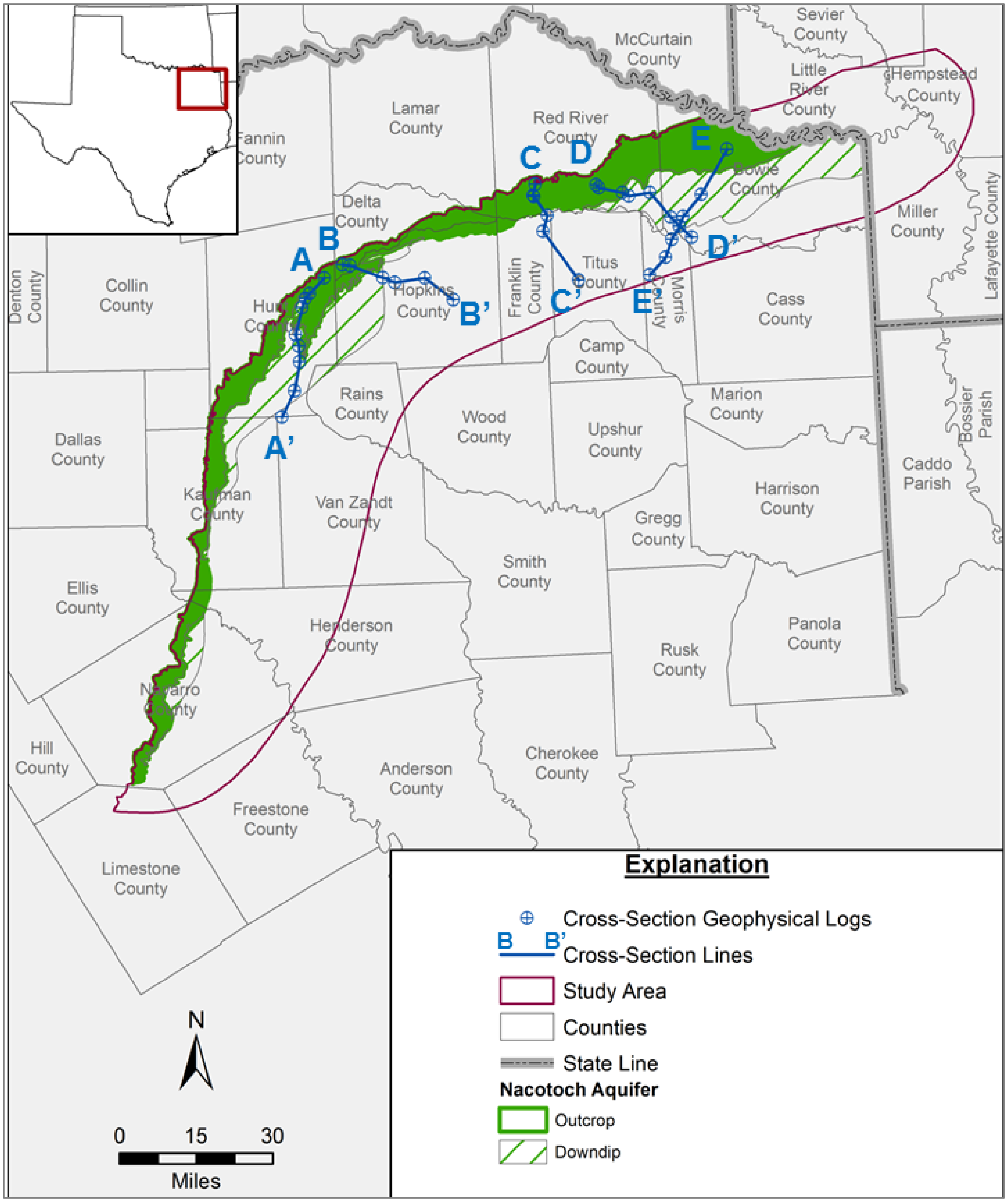


**Figure 6-3.** **Cross section locations.**

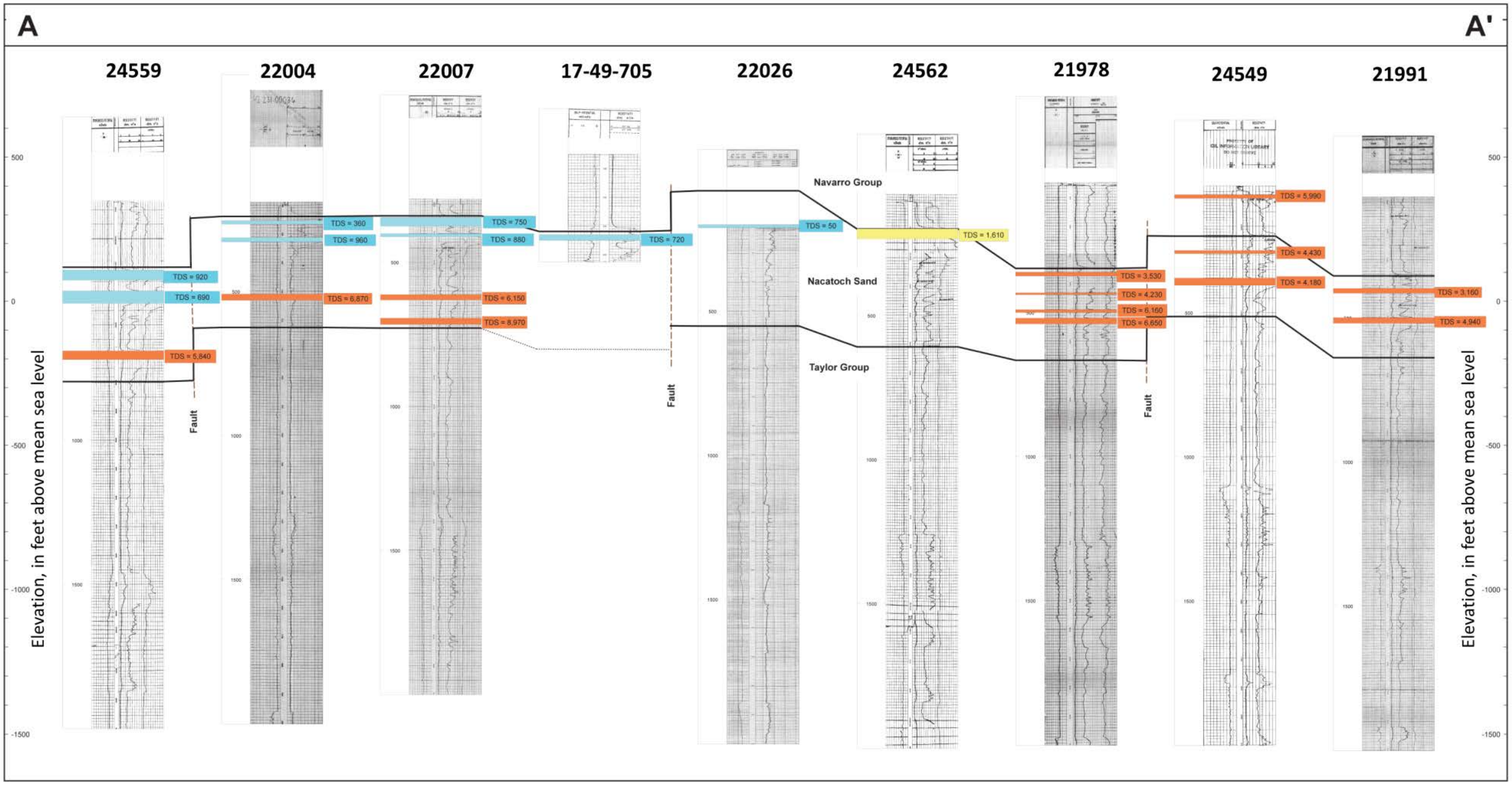


**Figure 6-4. Cross section A-A'.**

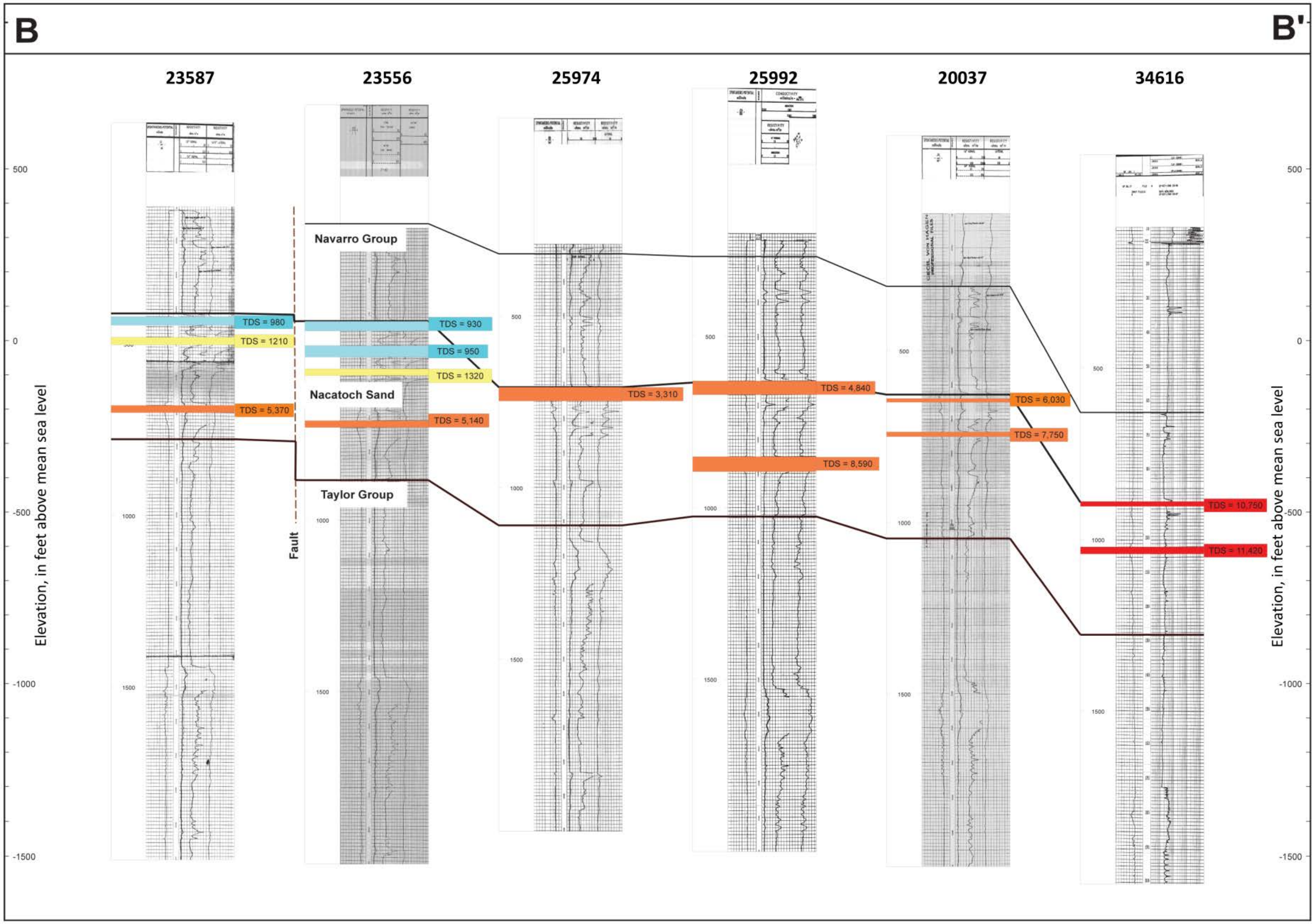


**Figure 6-5.** **Cross section B-B'.**

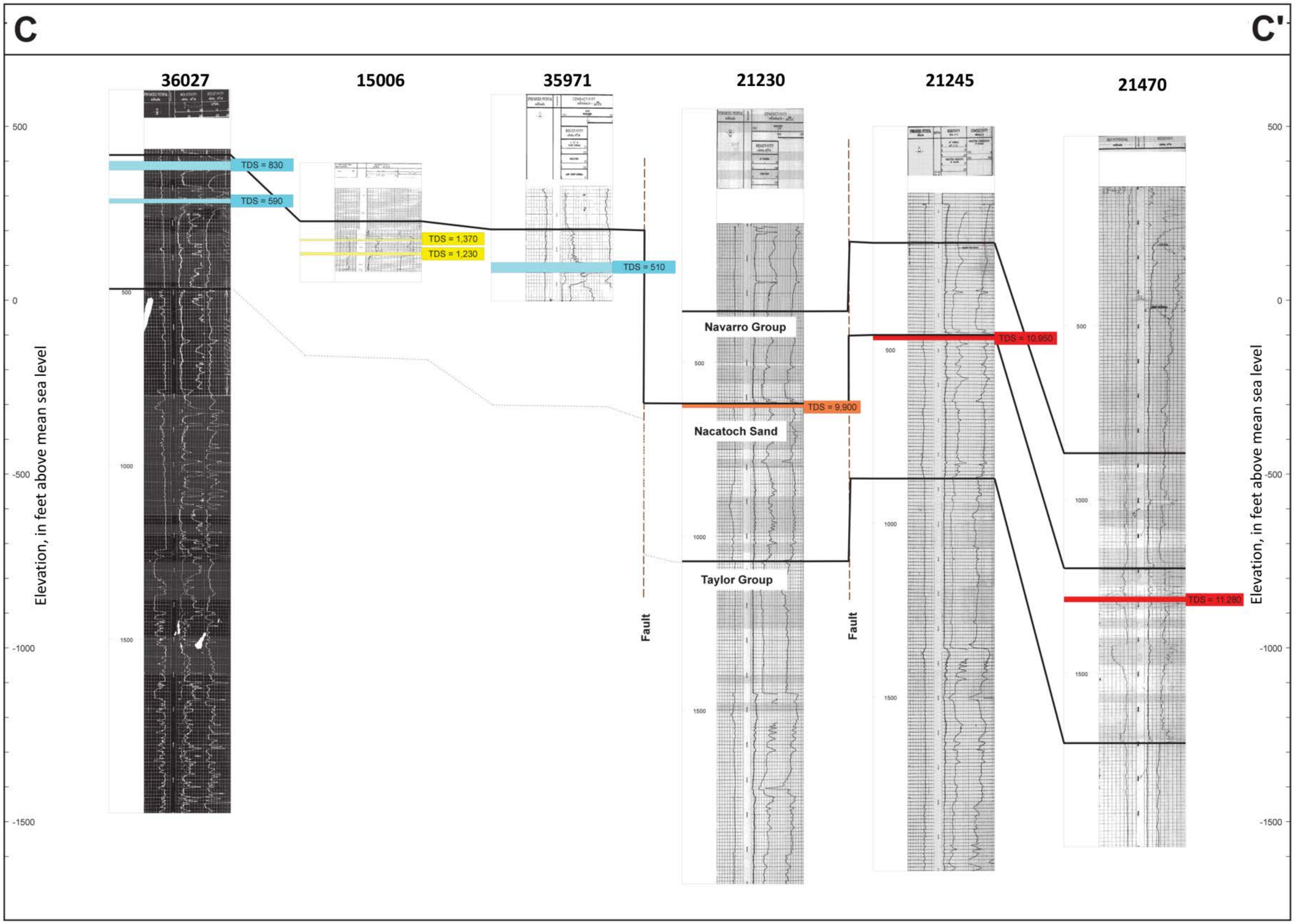


**Figure 6-6. Cross section C-C'.**

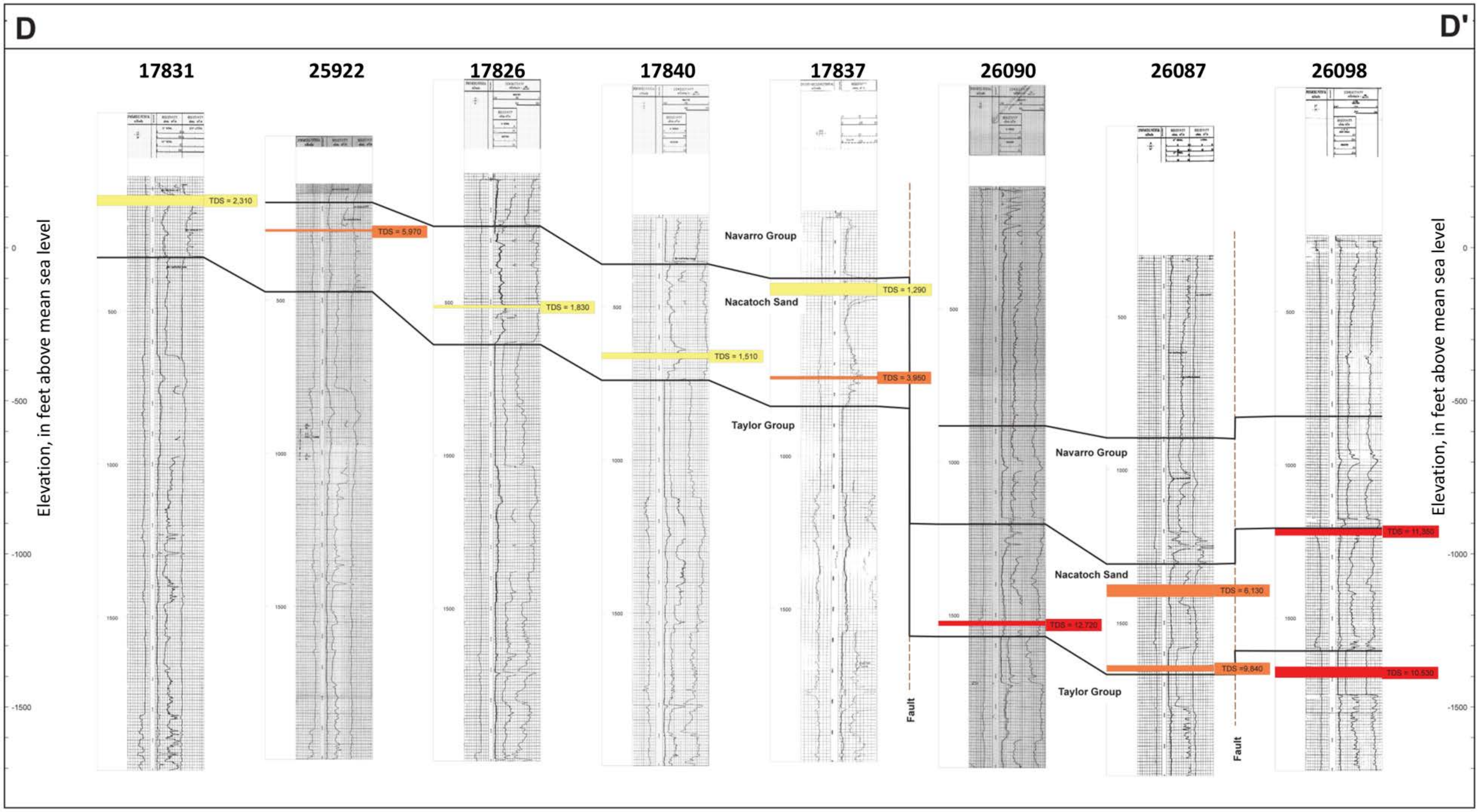


**Figure 6-7. Cross section D-D'.**

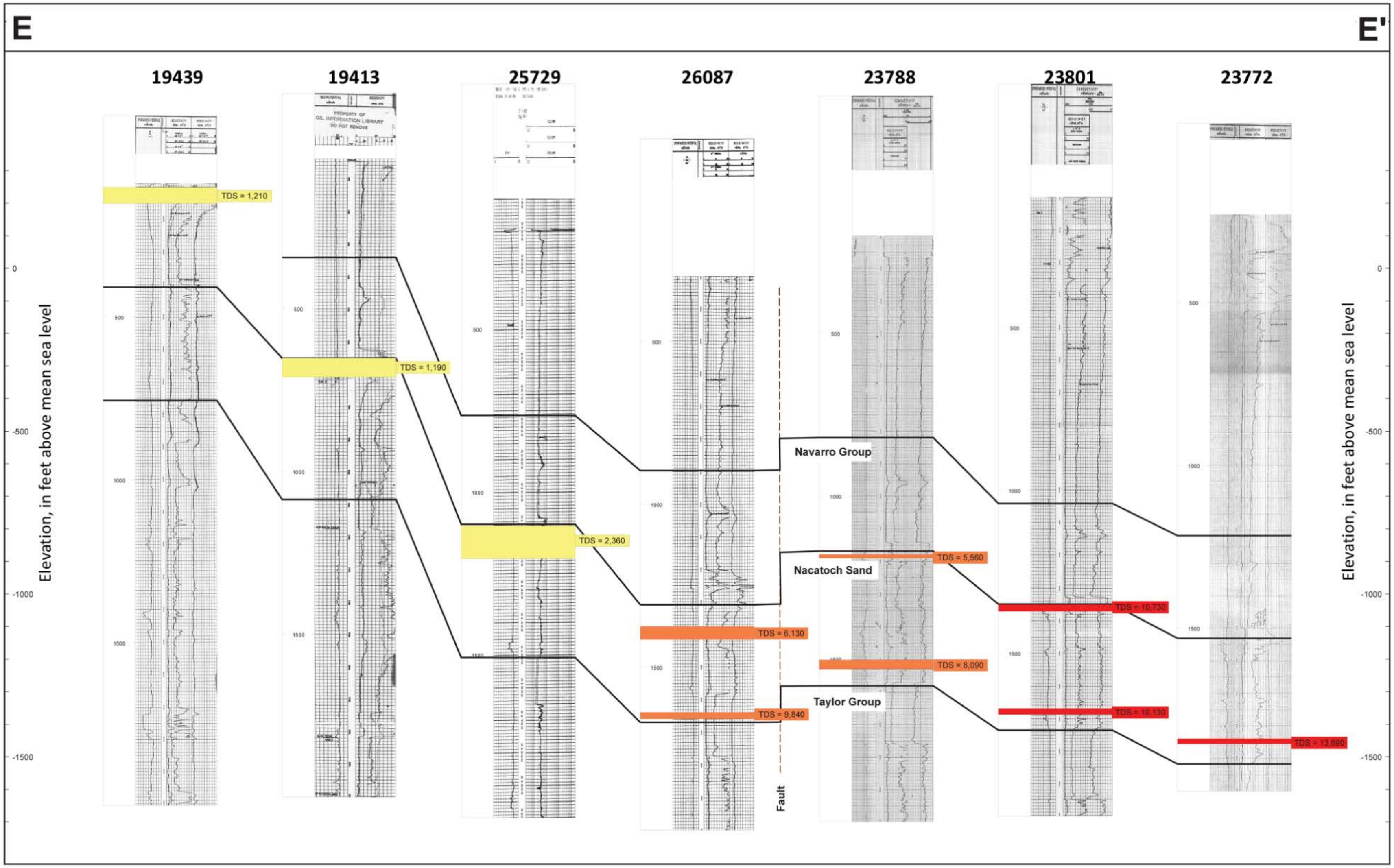


**Figure 6-8.** **Cross section E-E'.**

# 7 Previous Investigations

Cretaceous strata in Texas are divisible into two distinguishable series, the lower Comanche Series and the upper Gulf Series (Sellards, Adkins, & Plummer, 1932). The Navarro Group, which includes the Nacatoch Sand, occurs at the top of this Gulf Series.

Veatch (1906) is credited with introducing the name "Nacatoch Sand". In this report, Veatch provides the following narrative in describing this unit that included both the mid-Navarro sands and underlying Saratoga Chalk:

*Above the Marlbrook Marl is a series of sandy beds* (stratigraphic definition)*, which are of vast economic importance to the strip of country along the Iron Mountain Railway between Arkadelphia and Texarkana, since they are the main water supply source of that region.*

*The outcrop at Nacatoch Bluff, on the Little Missouri River, in Clark County* (Arkansas, the type locality)*, is one of the most complete exposures occurring along this belt and shows the calcareous and quartzitic rocks which, when encountered in wells, are called "water rocks".*

The East Texas Basin is the structural feature that most influenced the depositional environment within which the sands and clays of the Nacatoch were deposited. Numerous reports are listed in the reference section that pertain to the origin, development, and geometry of the East Texas Basin; bordering fault zones and their impacts on oil and gas production; and the Basin's internal salt tectonics. Wood and Guevara (1981) produced regional cross sections across the entire East Texas Basin, followed by McGowen and Lopez (1983) who described the depositional systems of the Nacatoch Sand.

Reports that discuss the hydrologic characterization of the Nacatoch Aquifer at specified locations include the following:

- Baker (1971) – *Occurrence and availability of groundwater in the vicinity of Commerce, Texas.*
- Baker and others (1963) – *Reconnaissance investigation of the groundwater resources of the Sabine River Basin, Texas.*
- Baker and others (1963) – *Reconnaissance investigation of the groundwater resources of the Red River, Sulphur River, and Cypress Creek Basins.*
- Broadhurst (1944) – *Development of groundwater for public supply at Commerce, Hunt County, Texas.*
- Peckham and others (1963) – *Reconnaissance investigation of the groundwater resources of the Trinity River Basin.*
- Rose (1945) – *Groundwater in the Greenville area, Hunt County, Texas.*

The extents of additional selected TWDB and Bureau of Economic Geology report study areas are shown in Figure 7-1.

In 1988, John Ashworth developed the first regional comprehensive assessment of the groundwater availability of the Nacatoch Aquifer in Texas (1988). Five cored test holes drilled for this project provided depositional stratigraphic information that assisted in understanding the lateral connectivity of individual sand beds, as well as yield and water quality characteristics of each sand bed. Ashworth also demonstrated the downdip groundwater flow restriction created by the offset faults of the Mexia-Talco Fault Zone. Working with Ashworth on the Nacatoch

Aquifer project, Knight (1984) described the mineral content of the core and cutting samples, and developed his interpretation of Nacatoch Sand deltaic facies.

In 2009, the Nacatoch Groundwater Availability Model was developed as a tool to better understand the flow system within the aquifer and to support planning efforts (Beach, et al., 2009). The conceptual model divides the aquifer system into two layers. The top layer represents the Midway confining unit except in areas where river alluvium and terrace deposits overlay the Nacatoch Sands. The bottom layer represents the Nacatoch Sands. In areas where the alluvium and terrace deposits are present, they are generally interconnected with the Nacatoch. Underlying the Nacatoch is the Neylandville or Marlbrook unit, which is treated as no flow boundary in the model. The Nacatoch and alluvium deposits receive recharge from precipitation and groundwater discharges to local streams and rivers, of which a portion is lost to evapotranspiration. Recharge into the Nacatoch Aquifer was estimated through baseflow regression analysis and varies with annual precipitation. Evapotranspiration was simulated in the riparian area and a vegetation coefficient was used to adjust potential evapotranspiration for different types of vegetation. Initial estimates of aquifer hydraulic properties were estimated from existing aquifer test data, but the data were limited.

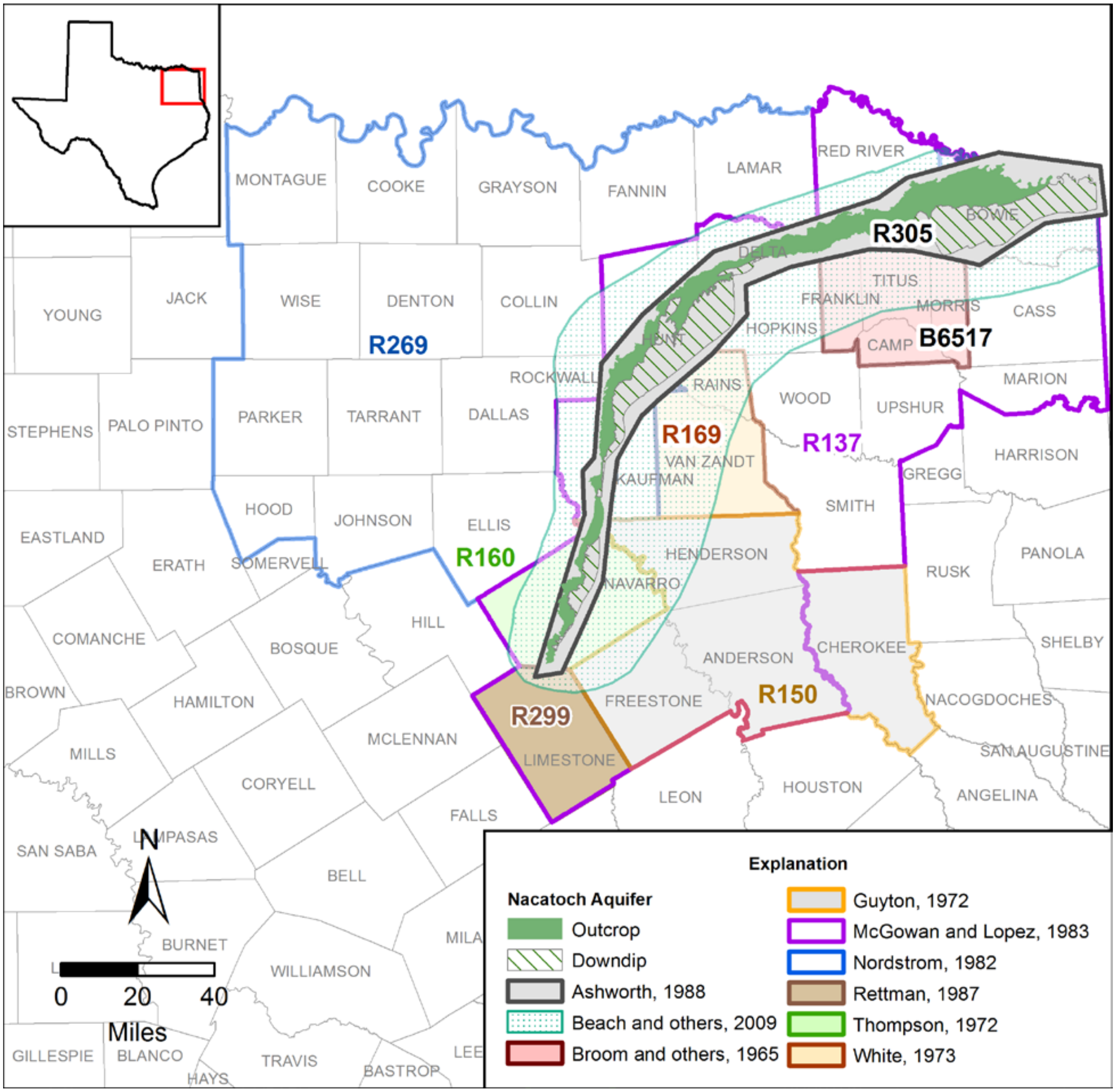


**Figure 7-1. Selected report study areas.**

# 8 Data Collection and Analysis

This section provides an overview of the data collection and analyses undertaken for geologic, hydrologic, and water quality assessments.

## 8.1 Geologic Data for Stratigraphic Analyses

Available information from water wells along with oil and gas wells were used to develop the stratigraphic and hydraulic characteristics of the Nacatoch Aquifer. Data sources include:

- The Bureau of Economic Geology Geophysical Log Facility
- The TWDB BRACS database
- The TWDB Q-log database

Stratigraphic analyses were conducted to estimate tops of the Taylor Group, the Nacatoch Sand (within the Navarro Group), and the Navarro Group. The Taylor/Navarro and Navarro/Midway boundaries cannot be identified without detailed paleontological data. As a result, the tops in this study were estimated based on geophysical and lithologic logs from a Bureau of Economic Geology report (Wood & Guevara, 1981), and extrapolated based on lithologic characteristics of the logs.

## 8.2 Geophysical Log Data for Water Quality Estimates

### *8.2.1 Data Sources and Curve Types*

The primary source of Nacatoch geophysical logs is the TWDB BRACS Database (478 logs). These log data include many of the old paper logs housed at the Railroad Commission of Texas Groundwater Advisory Unit (GAU) (formerly the Texas Commission on Environmental Quality Surface Casing Division). The majority of the log curves available to characterize the Nacatoch are spontaneous potential and resistivity/induction curves as shown in Table 8-1. Groundwater salinity in the Nacatoch Aquifer was estimated at various locations and depths by analyzing geophysical logs. The dataset used for the analysis was obtained from the TWDB BRACS geophysical log collection and consisted of 505 log image files.

Each geophysical log selected for analysis was visually inspected and analyzed using Schlumberger's BlueView software (version 1.0.64). Each log was visually inspected for its suitability to analysis; a spontaneous potential (SP) or deep resistivity log was present that intersected the Nacatoch Aquifer and the image quality was adequate. A spreadsheet was developed to automate the calculations involved in the various geophysical log analyses. A total of 324 salinity estimates were produced using this spreadsheet with well locations shown in Figure 8-1.

The spreadsheet developed for log analysis populates user-input data across multiple worksheets. The spreadsheet corrects depths obtained from the log to true depths using the datum height provided in the log header and includes a field for drilling mud type. Also included are fields for the resistivities of the drilling mud and mud filtrate as well as analyst comments. Water chemistry data is used in the interpretation of geophysical logs to establish a statistical relationship between the total dissolved solids concentration and electrical conductivity and to identify groundwater that is dominated by anions other than chloride.

**Table 8-1. BRACS database Nacatoch log curve types.**

| Curve type | Count |
|---|---|
| Caliper | 3 |
| Density | 1 |
| Dual induction | 25 |
| Dual induction focused | 8 |
| Electric | 56 |
| Gamma ray | 20 |
| High resolution | 1 |
| Induction | 77 |
| Laterolog | 3 |
| Microlog | 1 |
| Neutron | 1 |
| Porosity | 1 |
| Resistivity | 198 |
| Spectral density | 1 |
| Spherically focused | 2 |
| Spontaneous potential | 267 |
| Tension | 1 |

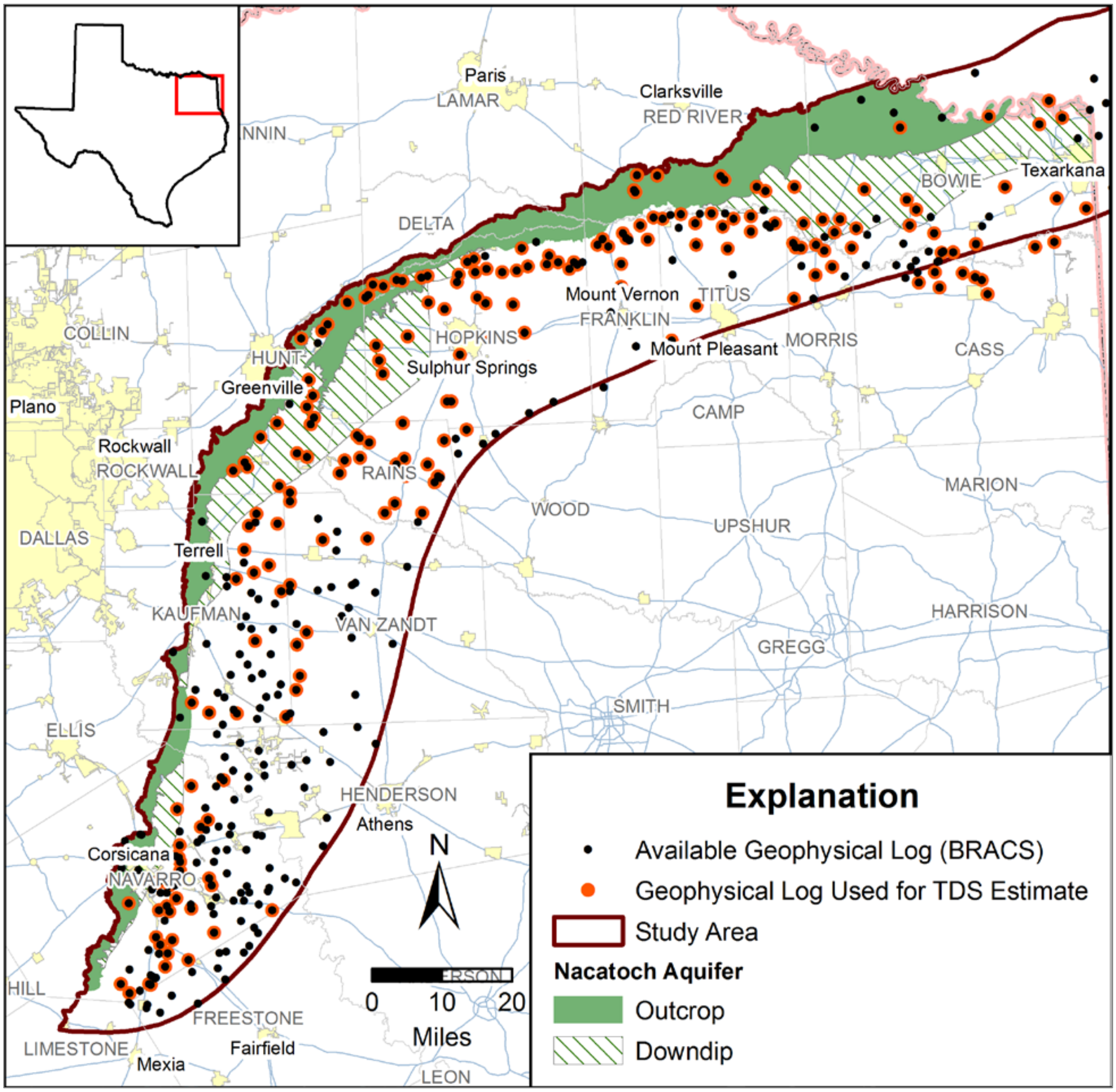


**Figure 8-1. Geophysical logs used for water quality estimates.**

### *8.2.2 Geophysical Well Log Parameter Calibration*

A total of six wells with both water quality data and geophysical well logs were identified in the project area and used to calibrate log interpretation parameters using the Rwa Minimum method (Table 8-2). The Rwa Minimum method provided the most consistent results across a range of total dissolved solids concentrations and various drilling mud types and does not require a mud filtrate resistivity value, which is not always provided in the log header. The calibration procedure consisted of obtaining a deep resistivity value from a log and adjusting the porosity and cementation exponent until satisfactory agreement with the corrected total dissolved solids value was achieved. A freshwater ion correction for bicarbonate was applied as appropriate using the value provide by Estepp (2010). The lithology parameter (a) was assumed to be equal to 1.0 for sand layers.

Cementation exponent values of 1.3, 1.4, or 1.5 were used for each calibration point. These values correspond to the values for fine to medium, slightly cemented sand given by Kwader (1986). Layers deeper than 700 feet were assigned a cementation exponent of 1.5 conforming to the calibration achieved with BRACS well 14850 at target depths of 705 and 727 feet. Porosity values of 0.32, 0.33, and 0.40 were applied in the calibration process. Most sandy layers analyzed for water quality down to 700 feet below ground surface in the project area were assigned a porosity of 0.33 percent and a cementation exponent of 1.4 (which is unitless).

Several other water wells with geophysical logs were not included in the calibration process for various reasons. BRACS wells 15005 and 35971 both have state well number 1739508 assigned to them and have the same geophysical log in files G19400001B_SPR.pdf and Q70_387.tif, respectively. The log from well 35971 was used for calibration because its mapped location is coincident to state well number 1739508. Data from state well number 3307903 is not in the project water quality dataset due to not meeting the charge balance requirement of five percent. State well number 1750706 and BRACS well 14850 are located relatively close to one another at about 1.1 miles and the geophysical log from BRACS well 14850 was selected for calibration instead of state well number 1750706 because well 14850 has brackish groundwater, thicker sand layers, and a better quality geophysical log.

**Table 8-2. Calibration of total dissolved solids calculation using Rwa method.**

| BRACS ID | SWN /Alt. ID | County | Corrected TDS[c] (mg/L)[a] | Rwa Method estimated TDS[c] (mg/L)[a] | Porosity | Cementation exponent | Percent error |
|---|---|---|---|---|---|---|---|
| 14850 | G1120001E | Hopkins | 1,307.5 | 1,320[b] | 0.33 | 1.5 | 1.0 |
| 14862 | 1749316 | Hunt | 745.5 | 735[b] | 0.33 | 1.4 | -1.4 |
| 14866 | G1160081B | Hunt | 891.9 | 880 | 0.33 | 1.4 | -1.3 |
| 15007 | 1739510 | Red River | 482.7 | 510 | 0.40 | 1.3 | -5.4 |
| 35971 | 1739508 | Red River | 456.4 | 510 | 0.40 | 1.3 | 12 |
| None | 1749705 | Hunt | 722.1 | 720 | 0.32 | 1.3 | -0.3 |

[a] Milligrams per liter.
[b] Average value from two sand layers within sample interval.
[c] Total dissolved solids.

### *8.2.3 Specific Conductance and total dissolved solids Relationship*

Estimating the salinity of groundwater from geophysical logs is possible because an approximately linear relationship exists between total dissolved solids and specific conductivity. Linear regression was used to determine the conductivity to total dissolved solids conversion factor, referred to as Ct in Table 8-3, which is slope of the line. The conductivity-to-total dissolved solids conversion factor, referred to as Ct, is the slope of the linear regression line fit to the data. A total of 186 wells had samples with total dissolved solids and specific conductance pairs. The most recent sample was selected in wells having more than one pair.

The regression relationship was examined from several perspectives. First, the regression was defined using all data points across the entire region. This was compared with relationships defined using data with total dissolved solids < 3,000 milligrams per liter and total dissolved solids > 3,000 milligrams per liter. Finally, the relationship was examined geographically by defining separate relationships in the northern, central, and southern part of the study area. The slopes of fitted lines from all relationships varied from 0.47 to 0.56, and correlation coefficients varied from 0.96 to 1.00. Ultimately, it was decided to use geographically defined conductivity-to-total dissolved solids values which are summarized in Table 8-3 below. The plot is shown in Figure 8-2.

**Table 8-3. Specific conductivity – Total dissolved solids conversion factor.**

| Region | Ct[a] | Counties used for determination | Extrapolated counties |
|---|---|---|---|
| North | 0.55 | Bowie, Red River | Cass, Morris, Titus, Franklin |
| Central | 0.50 | Delta, Hopkins, Hunt | Rains, Wood |
| South | 0.55 | Henderson, Kaufman, Navarro | Freestone, Van Zandt |

[a] Conductivity-to-total dissolved solids conversion factor

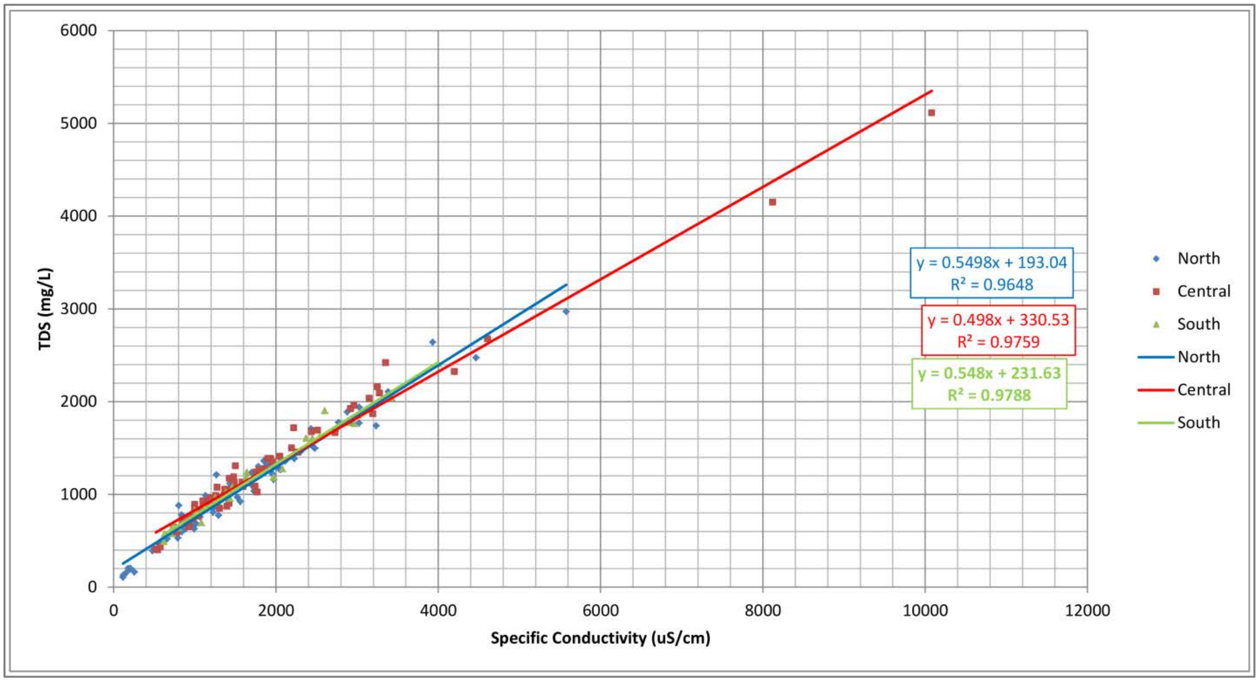


**Figure 8-2. Total dissolved solids vs. specific conductivity.**

## 8.3 Water Quality Data

Groundwater chemistry data were sought from government agency databases and published reports, including the TWDB Groundwater Database, the U.S. Geological Survey National Water Information System and Produced Water Database, and files of the Texas Commission on Environmental Quality. The TWDB has records for 400 water samples from 207 wells completed in the Nacatoch Aquifer and is the primary source for these data. Three Nacatoch analyses were found in the U.S. Geological Survey Produced Water Database, and three usable analyses were obtained from Texas Commission on Environmental Quality records. Data tables in several older TWDB reports (Guyton, 1972), (Nordstrom, 1982), and (Thompson, 1972) were reviewed for analysis records not found in the TWDB Database.

Data were screened using criteria based on Kreitler and others (2013) which focus on known well production depth or well depth, locational accuracy, and charge balance. TWDB includes a field in its database for charge balance, which was independently verified. Some sodium concentrations are calculated which results in a sample analysis that is always balanced. Samples with calculated sodium concentrations were also eliminated. This review of the data resulted in a working dataset of 360 analyses from 195 Nacatoch wells.

The following criteria were applied to screen water chemistry data for acceptability:

1. The well must have a known depth or completion interval.
2. The location accuracy must be plus or minus one minute.
3. The aquifer code must be Nacatoch Sand. Wells with multiple aquifers or unknown aquifers were not used.
4. Sodium must be measured, not calculated.
5. Charge balance must be plus or minus five percent.

Most of the data from the TWDB Groundwater Database meet these criteria. The results of screening are shown in Table 8-4.

**Table 8-4. Data failures for screening criteria.**

| Criterion | Failure count |
|---|---|
| 1. Known depth or completion interval? | 1 |
| 2. Location known within +/- one minute? | 3 |
| 3. Aquifer code indicates Nacatoch | 0 |
| 4. Sodium concentration is measured (not “calculated”) | 34 |
| 5. Charge balance within +/- five percent | 19 |

Two samples collected from the Nacatoch Formation are in the U.S. Geological Survey’s Produced Waters Database. One sample is located in Titus County in the Talco field near Talco, Texas, however no precise location information was provided. This sample has a total dissolved solids concentration of 25,165 milligrams per liter. The second sample is from Wood County and is located a couple of miles northeast of Quitman, Texas and has a total dissolved solids of 30,451 milligrams per liter. These wells were included for informational purposes as they represent a very saline water end member for Nacatoch groundwater. Knowing an accurate location was not a critical factor in their use.

The TWDB Database has a field in the Well Table with quantified accuracy entries such as “5 seconds” and “1 minute,” but it also has non-quantified entries such as “Global Positioning System.” Most hand-held Global Positioning System receivers are capable of 30-meter accuracy, assuming that they are set to a datum that is appropriate for North America. Texas Commission on Environmental Quality data tables have undefined field entries of 10 and 30, which appear to represent 10-meter and 30-meter accuracy.

Sodium concentrations are flagged as “calculated” in 34 records from the TWDB Groundwater Database. Calculating sodium concentrations was a common practice in earlier analytical work due to the difficulty of measurement. These samples necessarily balance since sodium was calculated to make up the charge difference between anions and cations. As a result, and as a consequence, the quality of the analyses cannot be assessed. The TWDB Groundwater Database includes a field for charge balance analysis. However, we verified charge balance independently.

Laboratory measured total dissolved solids was compared to calculated total dissolved solids using Collier's (1993) Equation 3-1 which is given as:

$$TDS = total\ of\ ions + SiO_2 - (0.5083) \times HCO_3$$

Units for all constituent concentrations are in milligrams per liter. We eliminated 55 samples for unacceptable quality failures, namely charge balance, absence of depth or completion data, or calculated values of major constituents. A total of 361 samples from 186 well locations were retained. Fifty-five samples were eliminated for unacceptable quality failures.

A few database entries were checked against scanned laboratory reports that are available on the TWDB website. The discrepancies found were minor typographical errors in the tenths or hundredths position of the decimal fraction and did not affect the charge balance.

The TWDB Groundwater Database lists Storet Codes for analyses. The data downloaded on July 1, 2016 indicated that the units for Calcium and Magnesium were "milligrams per liter as CaCO3." However, the analyses balance as is, and converting to milligrams per liter of the cation resulted in unbalanced analyses. This apparent error in the Storet Codes was verified with Ms. Janie Hopkins of the TWDB on August 3, 2016.

Total Dissolved Solids analyses of Nacatoch samples are described in the TWDB database as "Solids, Dissolved, Sum of Constituents" indicating that the total dissolved solids is calculated from the concentrations of measured cations and anions. However, the total dissolved solids concentrations in the database are on average 22 percent lower than the sum of the measured constituents, suggesting that the listed total dissolved solids is from analysis by evaporation to dryness. In the evaporation method, some bicarbonate is lost from the residue by conversion to carbonate. Adjusting the total dissolved solids using the correction given in Collier (1993, p.58-59) gives a total dissolved solids value that generally agrees with true sum of constituents to within about one percent. The corrected total dissolved solids is used in the water quality assessments of this study. This approach compensates for the absence of silica, fluoride, or nitrate analyses in some samples.

Collection and reliability remarks in the TWDB Groundwater Database call attention to field sampling procedures concerning purging, filtering, preservation and holding times. No acceptance standard was developed using these remarks. Charge balance is accepted as an indication of the quality of the analyses, but it is acknowledged that sample representativeness could be questioned due to purging practices or collection location, such as from a pressure tank.

After screening, 360 analyses representing 195 wells were available for use in this study. However, in determining total dissolved solids/conductivity relationships, only the most recent analysis was used from wells with multiple samplings over time.

## 8.4 Water Level Data

Water level data includes data from the TDWB groundwater database between years 2006 and 2016. A total of 226 water level measurements were found for 21 Nacatoch wells. All measurements were averaged for each well location to derive an average water level measurement for the eleven-year period of record. Of the 226 water level measurements, 208 were flagged “P” for publishable and 18 were flagged “Q” for questionable. The measurements flagged “Q” were not outliers and did not affect the average water levels.

# 9 Aquifer Hydraulic Properties

Specific capacity data for 65 wells completed in the Nacatoch Aquifer was compiled from TWDB records. Of these, 10 wells also had transmissivity calculated from pumping tests in Myers (1969), Ashworth (1988), or Christian and Wuerch (2012). A linear relationship was derived from specific capacity and transmissivity data from these 10 wells and used to estimate transmissivity in the remaining wells for which there was only specific capacity data.

Hydraulic conductivity was estimated using screened interval thickness as equivalent to aquifer thickness for all wells, and the locations of the wells with hydraulic conductivity estimates is presented in Figure 9-1. Specific capacity, transmissivity, and hydraulic conductivity data for the Nacatoch Aquifer wells are summarized in Table 9-1. Aquifer properties by well are included as Appendix 9-4.

**Table 9-1. Summary of Nacatoch Aquifer hydraulic properties.**

| | Specific Capacity (gpm/ft)[a] | Transmissivity (gal/day-ft)[b] | Hydraulic Conductivity (ft/day)[c] |
|---|---|---|---|
| **Average** | 1.22 | 1,686 | 4.98 |
| **Maximum** | 13.80 | 13,127 | 56.60 |
| **Minimum** | 0.04 | 206 | 0.49 |
| **Median** | 0.50 | 1,220 | 2.95 |

[a] Gallons per minute per foot.
[b] Gallons per day per foot.
[c] Feet per day.

A much smaller data set (seven wells) was available for wells with specific capacity data completed in alluvium in the project area. All of the alluvium hydraulic property data came from wells completed in the northeastern portion of the model area. Of these seven wells, only one had transmissivity calculated from a pumping test in Myers (Myers, 1969). Therefore, transmissivity for the six wells completed in alluvial deposits with only specific capacity data was estimated using the relationship given in Driscoll (Groundwater and Wells, 1986) for unconfined aquifers:

$$Specific\ capacity\ \left(\frac{gpm}{ft}\right) = Transmissivity\left(\frac{gpm}{ft}\right)\ \div 1{,}500$$

This relationship is approximate because it is based on assumed values in the log term of the modified non-equilibrium equation of Cooper and Jacob (1946). Taking the logarithm of these assumed values tends to mute inaccuracies in the assumptions, leading to the approximation above. Hydraulic conductivity was estimated using screened interval thickness as equivalent to aquifer thickness for these seven wells, and the locations and estimated hydraulic conductivities of the wells are presented in Figure 9-1. Specific capacity, transmissivity, and hydraulic conductivity data for the alluvial wells are summarized in Table 9-2 and Appendix 19-4.

**Table 9-2. Summary of alluvium hydraulic properties.**

| | Specific Capacity (gpm/ft)[a] | Transmissivity (gal/day-ft)[b] | Hydraulic Conductivity (ft/day)[c] |
|---|---|---|---|
| **Average** | 1.76 | 3,528 | 33.58 |
| **Maximum** | 4.63 | 13,127 | 56.61 |
| **Minimum** | 0.50 | 750 | 16.71 |
| **Median** | 0.60 | 900 | 30.99 |

[a] Gallons per minute per foot.
[b] Gallons per day per foot.
[c] Feet per day.

No storativity values calculated from pumping tests were found in the TWDB data or in Myers (1969), or Christian and Wuerch (2012). Freeze and Cherry (1979) indicate that the storativity in confined aquifers usually range in value from 0.005 to 0.00005. The specific yields of unconfined aquifers are much higher than the storativities of confined aquifers, and generally range from 0.01 to 0.30 (Freeze & Cherry, 1979). We found no data regarding the vertical hydraulic conductivity or estimated anisotropy in the hydraulic conductivity tensor. Regional estimates of horizontal to vertical hydraulic conductivity ratios range from 10 to 10000.

*Modified Cooper-Jacob Equation Derivation*

The Cooper-Jacob equation can be derived from a derivation of the Theis Equation which is

$$h - h_0 = \frac{Q}{4\pi T}\int_u^\infty \frac{e^{-u}du}{u} \qquad \text{Eqn. 1}$$

where,

$$u = \frac{r^2 S}{4Tt}. \qquad \text{Eqn. 2}$$

The integral of *u* is known as the Well Function, W(u), which is can be expressed as,

$$h - h_0 = \frac{Q}{4\pi T}W(u). \qquad \text{Eqn. 3}$$

The Well Function can be represented as an infinite series for the semilog method of pump test interpretation. The Theis Equation then becomes,

$$h - h_0 = \frac{Q}{4\pi T}\left(-0.5772 - \ln u + u - \frac{u^2}{2*2!} + \frac{u^3}{3*3!} + \cdots\right) \qquad \text{Eqn. 4}$$

Cooper and Jacob noted that for small *u* the sum of the series beyond ln *u* becomes negligible, so that

$$h - h_0 = \frac{Q}{4\pi T}(-0.5772 - \ln u) \qquad \text{Eqn. 5}$$

Since ln *u* = 2.3log *u*, -ln *u* = ln 1/*u*, ln 1.78 = 0.5772, and substituting Eqn. 2 for *u*, the Modified Cooper-Jacob Equation becomes

$$h - h_0 = \frac{2.303Q}{4\pi T}\log\left(\frac{2.25Tt}{r^2S}\right) \qquad \text{Eqn. 6}$$

$h - h_0$ = drawdown, feet

Q = pump rate, cubic feet per day

T = Transmissivity, square feet per day

t = time, day

S = storativity (dimensionless)

r = radial distance to well, feet

Source: (Freeze & Cherry, 1979).

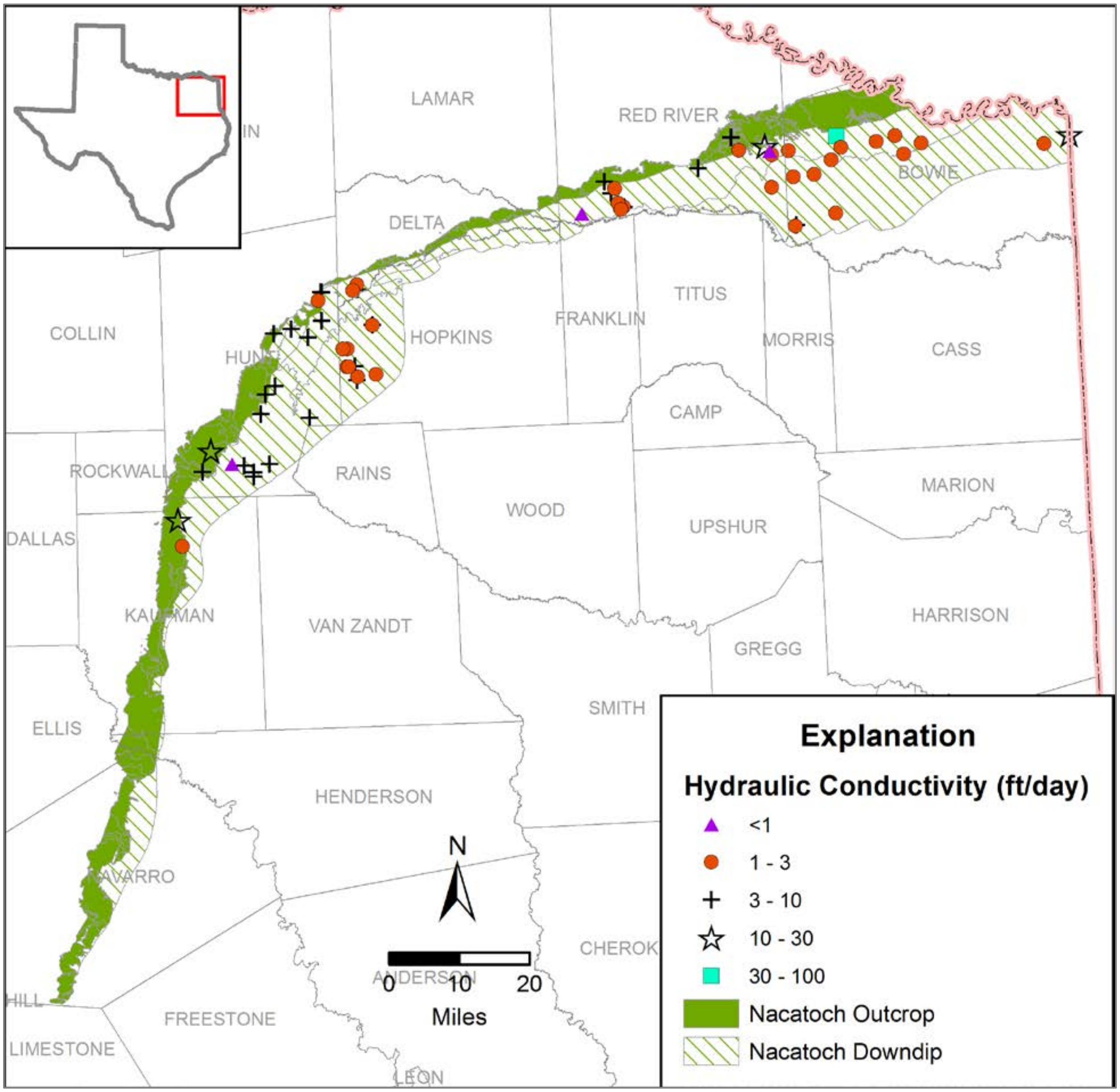


**Figure 9-1. Nacatoch Aquifer hydraulic conductivity estimates.**

# 10 Water Quality Data

## 10.1 Dissolved Minerals

Total dissolved solids is a measure of the dissolved mineral content in water and is a simple indicator of water quality. The United States Environmental Protection Agency has set a secondary drinking water standard of 500 milligrams per liter total dissolved solids while Texas Commission on Environmental Quality has set a secondary standard of 1,000 milligrams per liter (30 TAC §290.118). The concern with total dissolved solids arises from taste, hardness, scale, and staining issues associated with higher concentrations. Distribution of total dissolved solids is mapped in Figure 10-1.

The spatial distribution of anions is shown in Figure 10-2. Sulfate occurs as the dominant or principle anion mainly in wells scattered through the outcrop. Bicarbonate occurs as the dominant anion in the outcrop and in the areas of the subcrop where Nacatoch sands are thicker. Chloride typically occurs as the dominant anion downdip from the bicarbonate-dominated areas. Nacatoch groundwater becomes increasingly chloride-rich as depth and distance from the outcrop increase.

Figure 10-3 and Figure 10-4show the groundwater composition on a Piper diagram for wells in the outcrop and wells in subcrop (confined) parts of the aquifer. Sodium and bicarbonate are the dominant ions in both outcrop and subcrop. However, the proportions of calcium, chloride and sulfate are higher in the outcrop, so that composition is more variable. In downdip parts of the aquifer, calcium and sulfate decrease so that the groundwater composition tends to vary between sodium bicarbonate and sodium chloride.

Recognition of these regional trends is important for estimating groundwater total dissolved solids from geophysical logs. In downdip areas where water wells and water quality analyses are absent, it appears safe to assume that groundwater is chloride-dominated and that corrections are unnecessary. Figure 10-10 and Figure 10-12 show the distribution of bicarbonate and sulfate, respectively, as a percentage of total dissolved solids. Corrections may be necessary in areas where the percentage exceeds 50 percent. Wells exceeding 50 percent bicarbonate are interspersed with wells having less than 50 percent bicarbonate. Wells with greater than 50 percent sulfate are few and widely scattered.

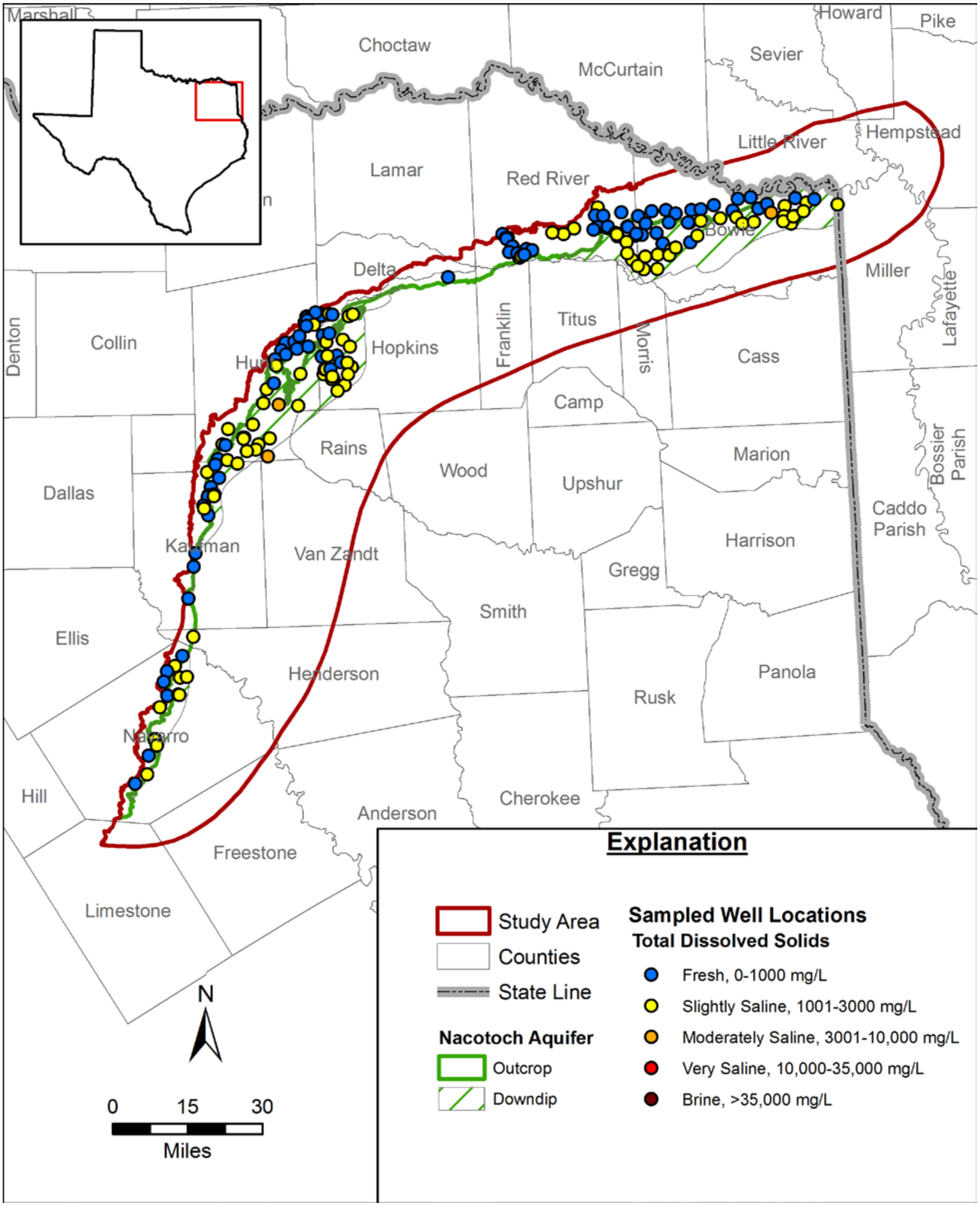


**Figure 10-1.** **Distribution of total dissolved solids concentrations.**

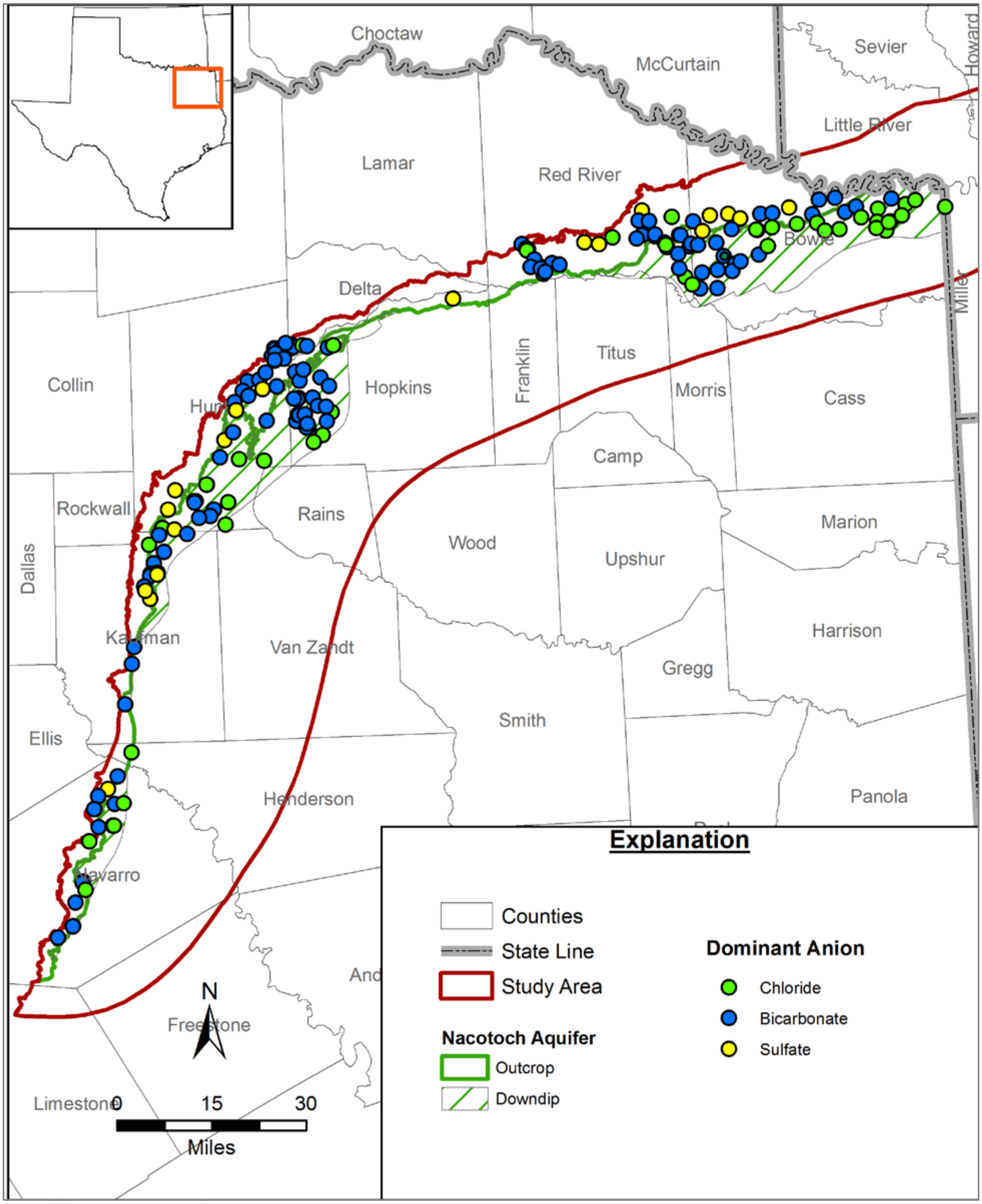


**Figure 10-2. Distribution of dominant anions.**

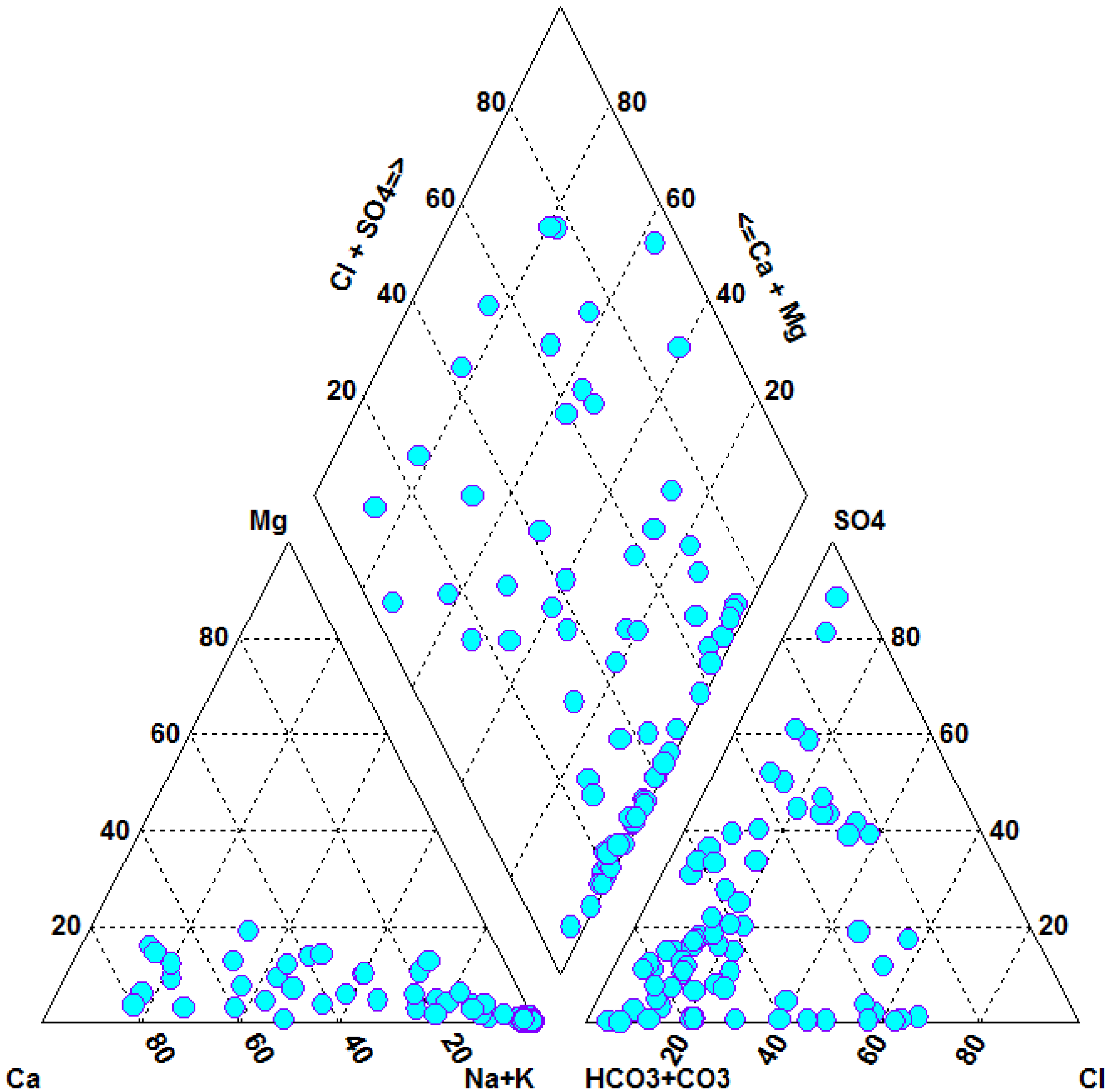


**Figure 10-3. Composition of groundwater in the outcrop.**

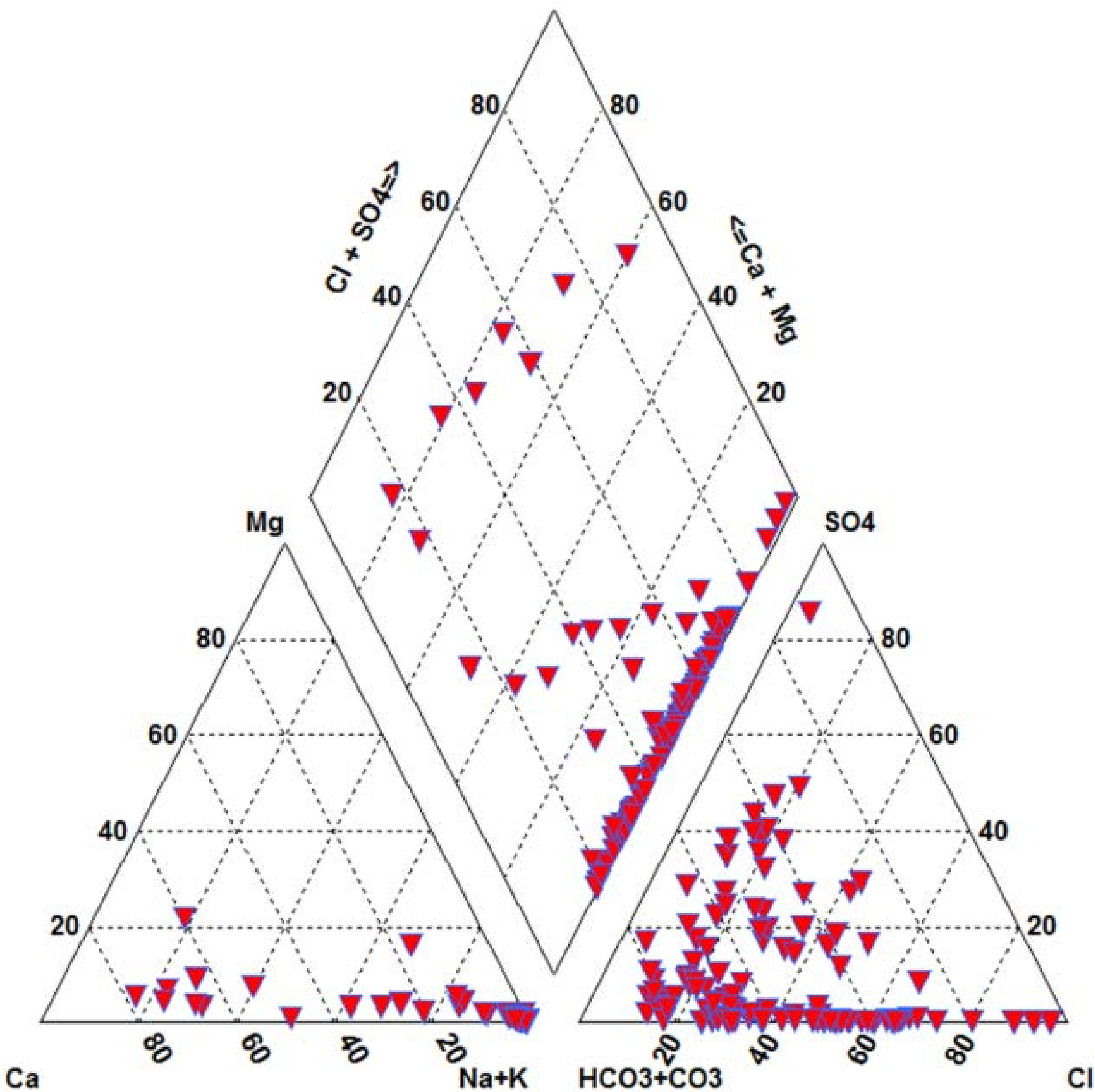


**Figure 10-4. Composition of groundwater in the subcrop (confined).**

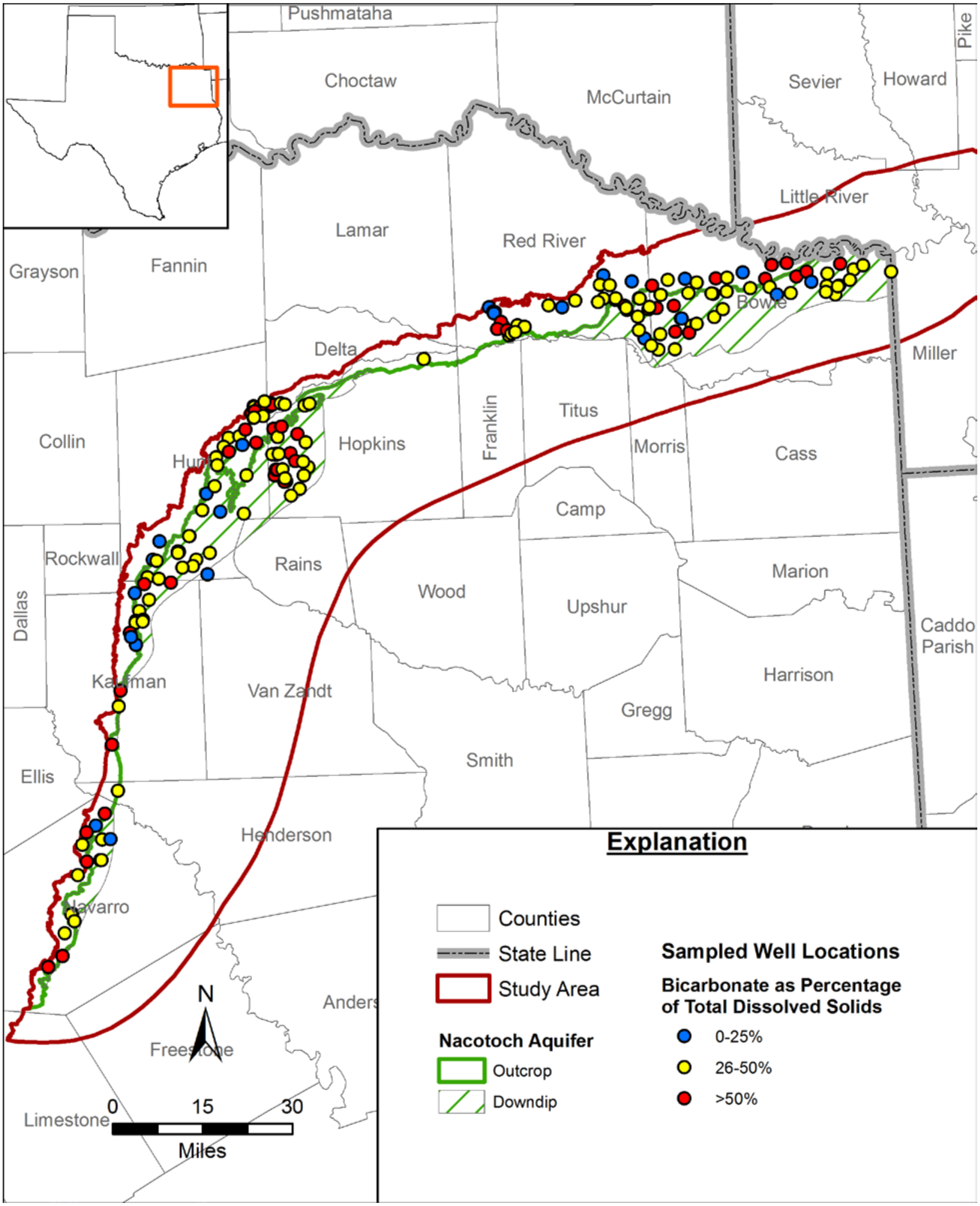


**Figure 10-5. Bicarbonate percentage of total dissolved solids.**

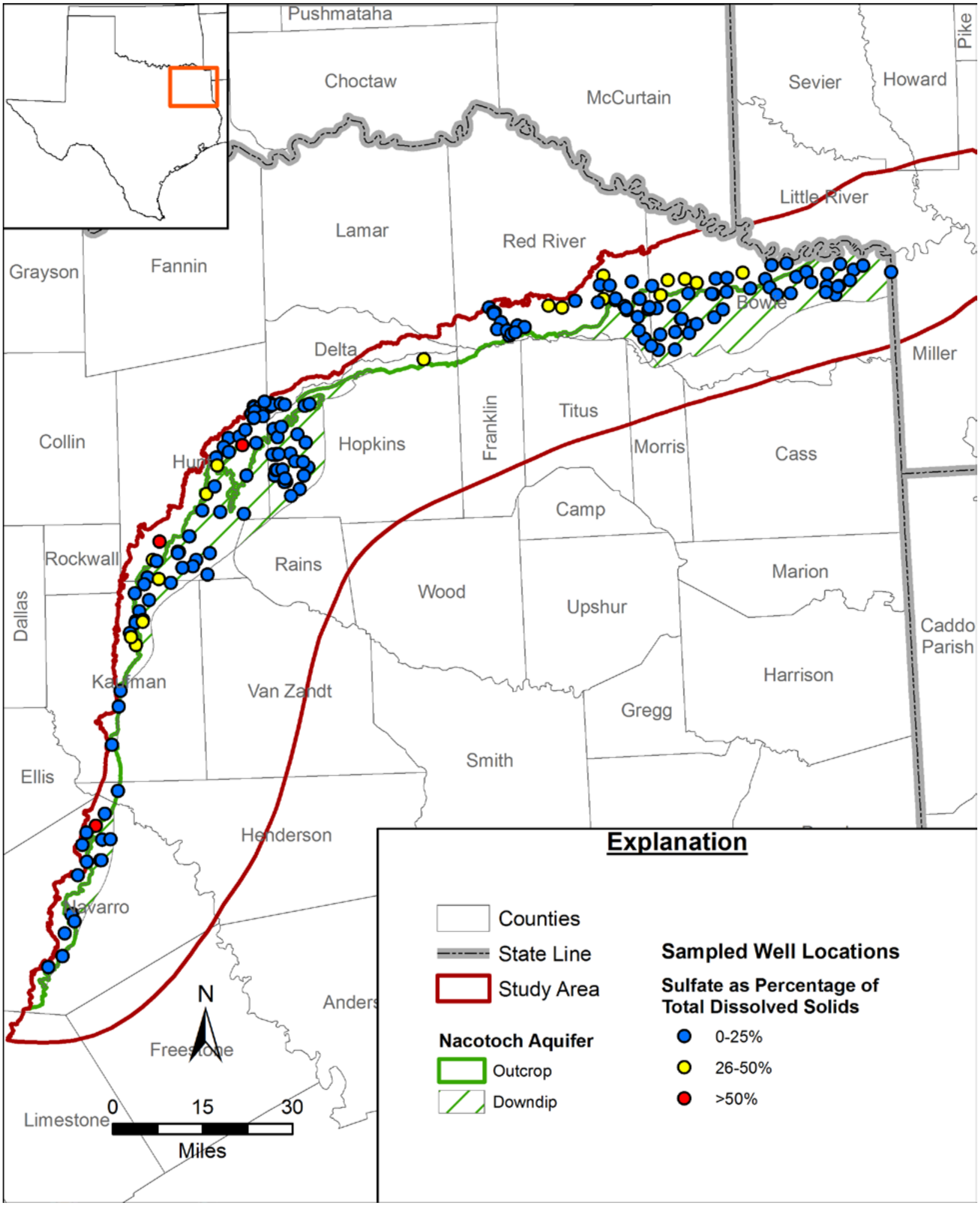


**Figure 10-6.** **Sulfate percentage of total dissolved solids.**

## 10.2 Radionuclides

The U.S. Environmental Protection Agency has established standards for radionuclides in drinking water as follows:

- Alpha radiation, 15 picocuries per liter
- Beta radiation, 4 millirem per year, or 50 picocuries per liter
- $^{226}Ra + ^{228}Ra$, 5 picocuries per liter combined
- Uranium, 30 micrograms per liter

The radionuclide data available in the Texas Water Development Board Groundwater Database are presented in Figure 10-7 through Figure 10-12, and are listed in Table 10-1. Detection of these parameters is restricted to alpha radiation, which in no instance exceeds drinking water standards.

Eight wells sampled for gross alpha and gross beta had concentrations below the maximum concentration level of 15 and 50 picocuries per liter, respectively, for drinking water, as enforced by the Texas Commission on Environmental Quality. Two wells were tested for radium 226 and 228 and were below the maximum concentration level of five picocuries per liter (combined total of both analytes). Four wells were tested for uranium and were found to have concentrations below the maximum concentration level of 30 micrograms per liter per year.

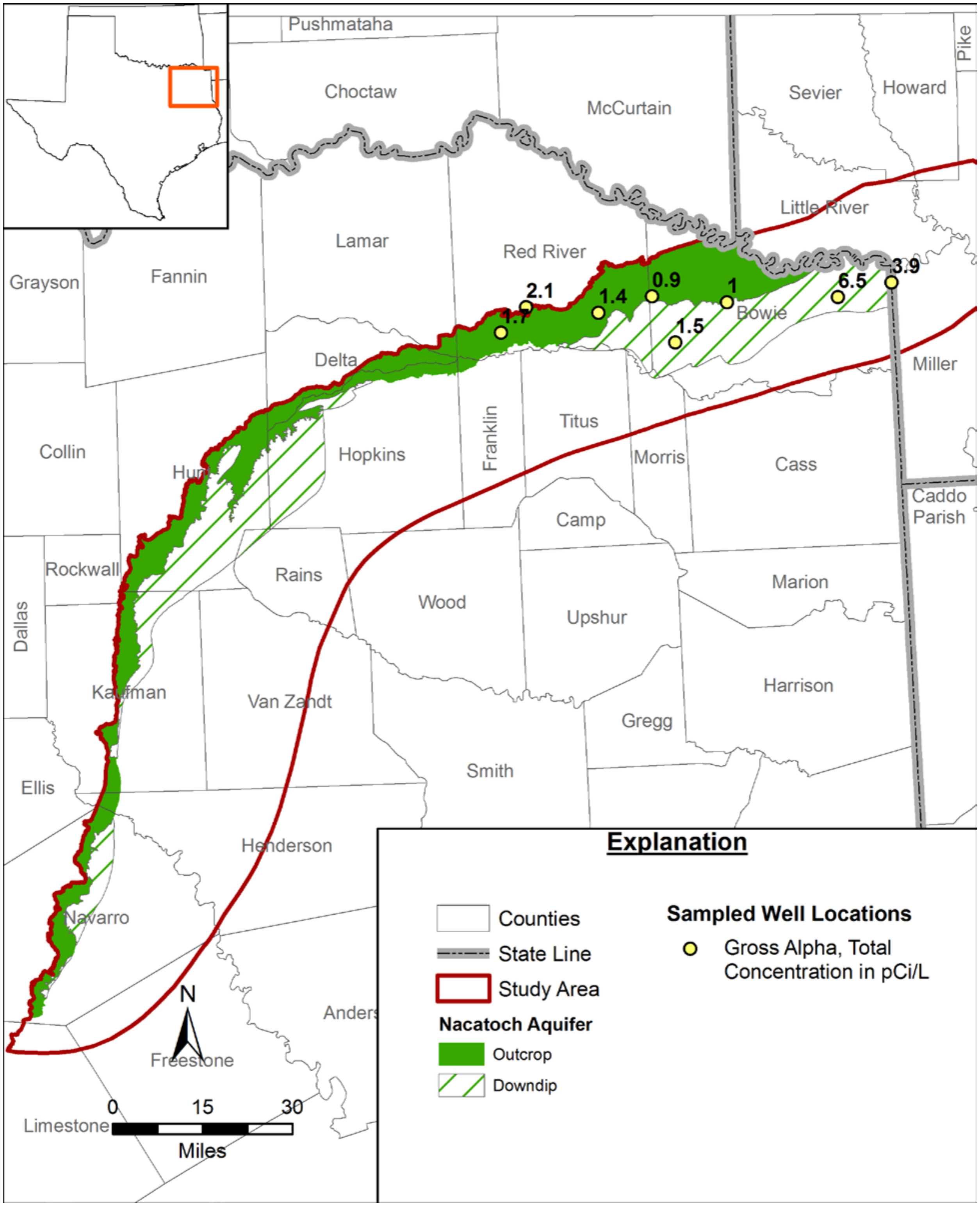


**Figure 10-7. Distribution of gross-alpha radiation.**

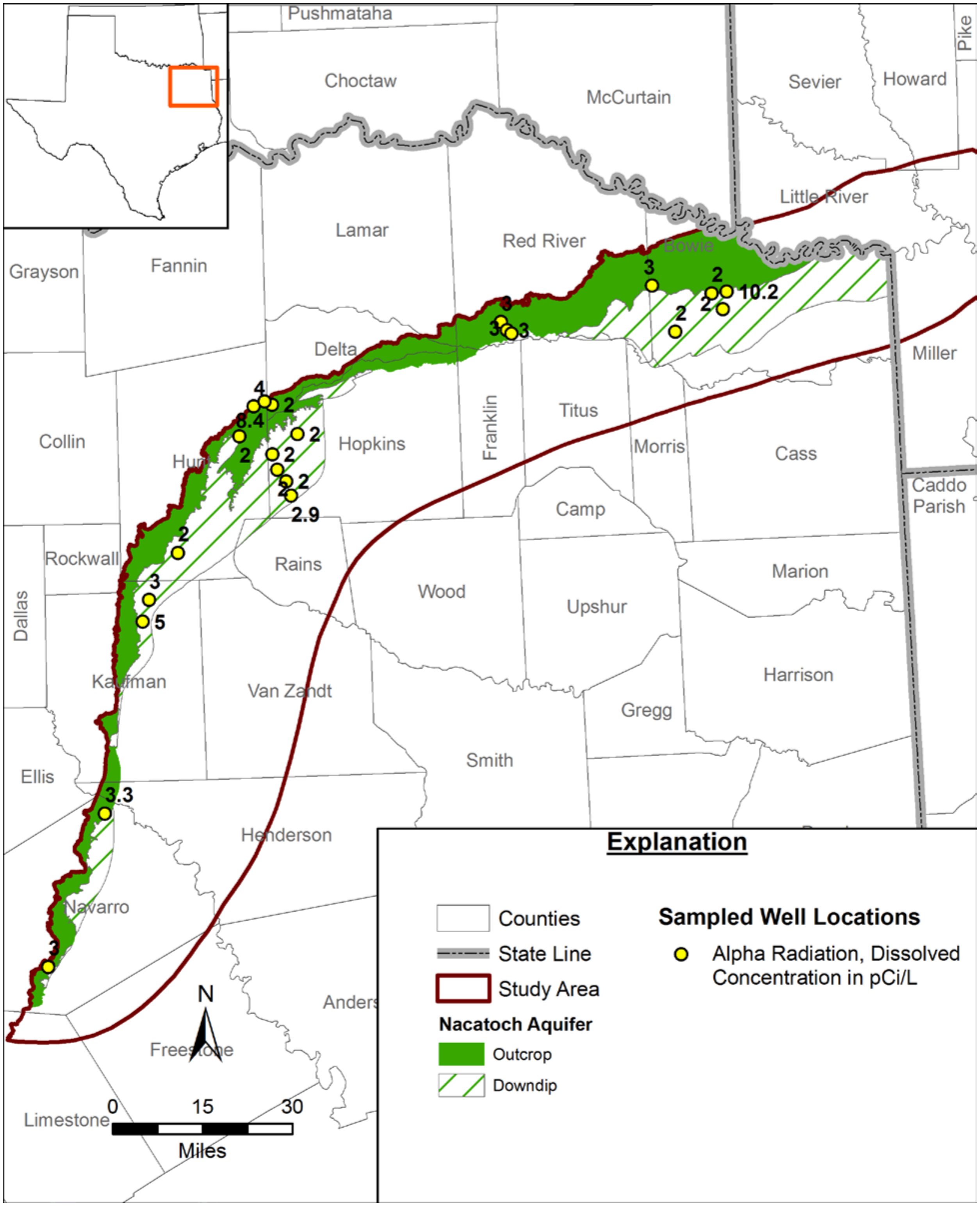


**Figure 10-8.** **Distribution of alpha concentrations.**

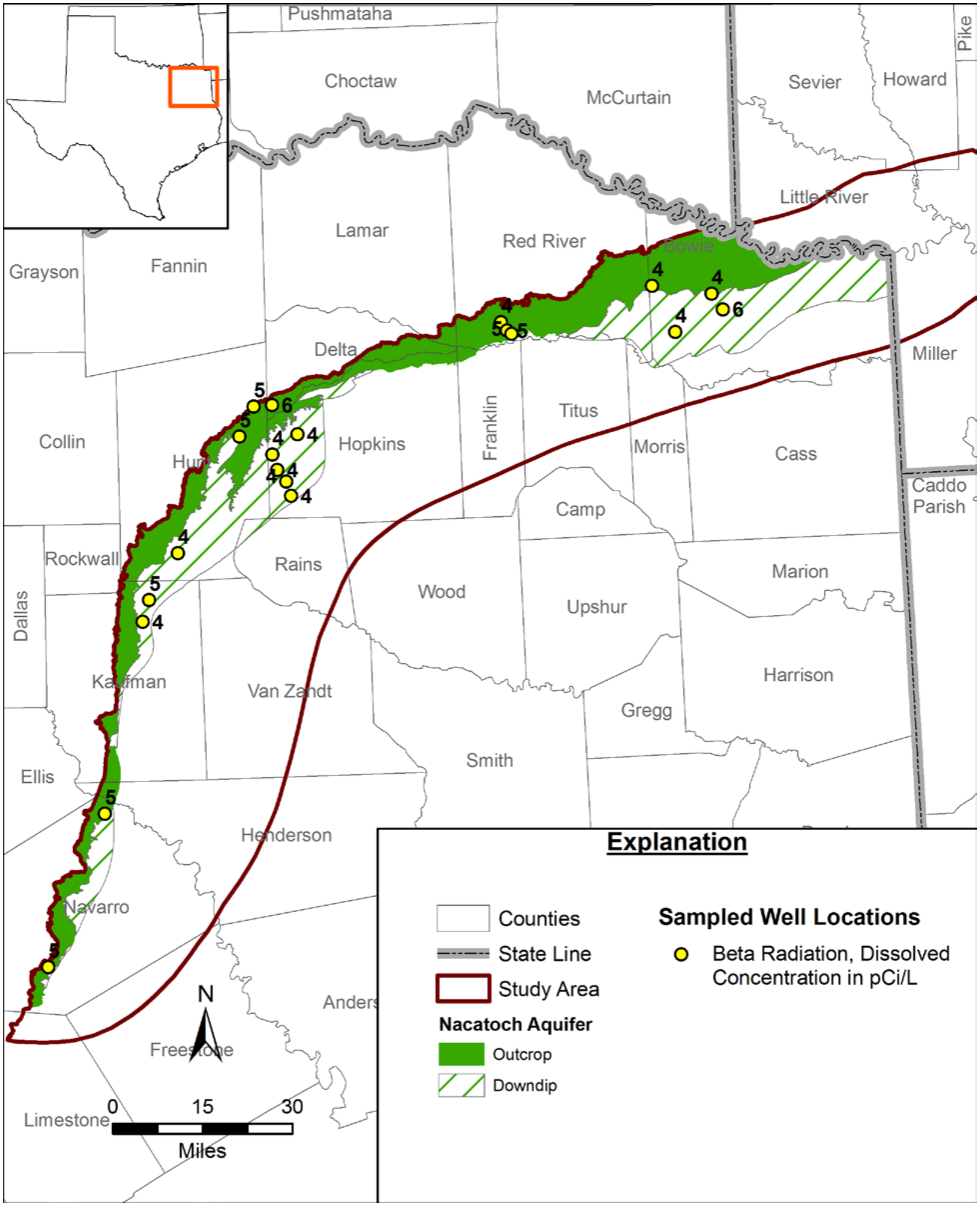


**Figure 10-9. Distribution of beta radiation.**

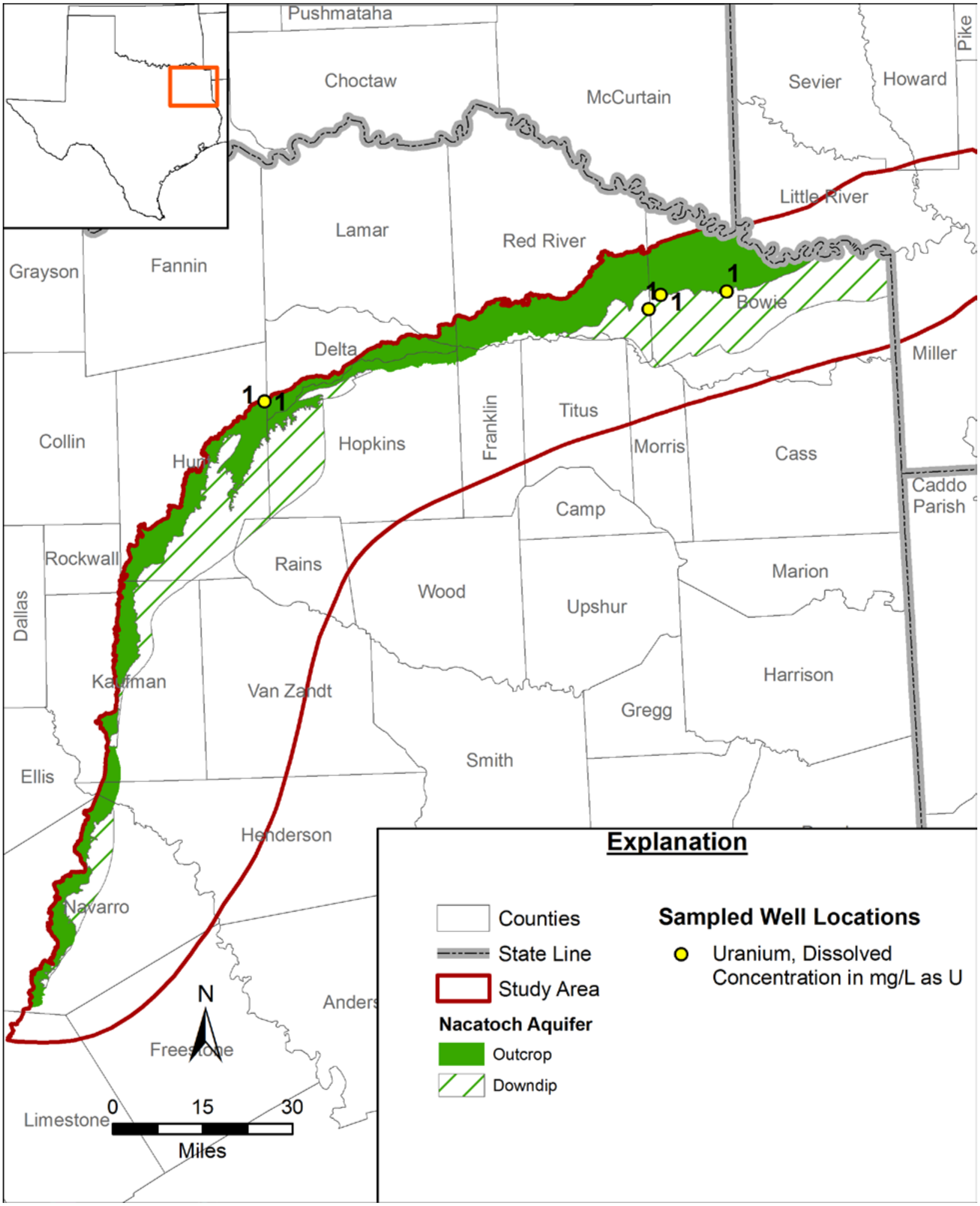


**Figure 10-10. Distribution of uranium concentrations.**

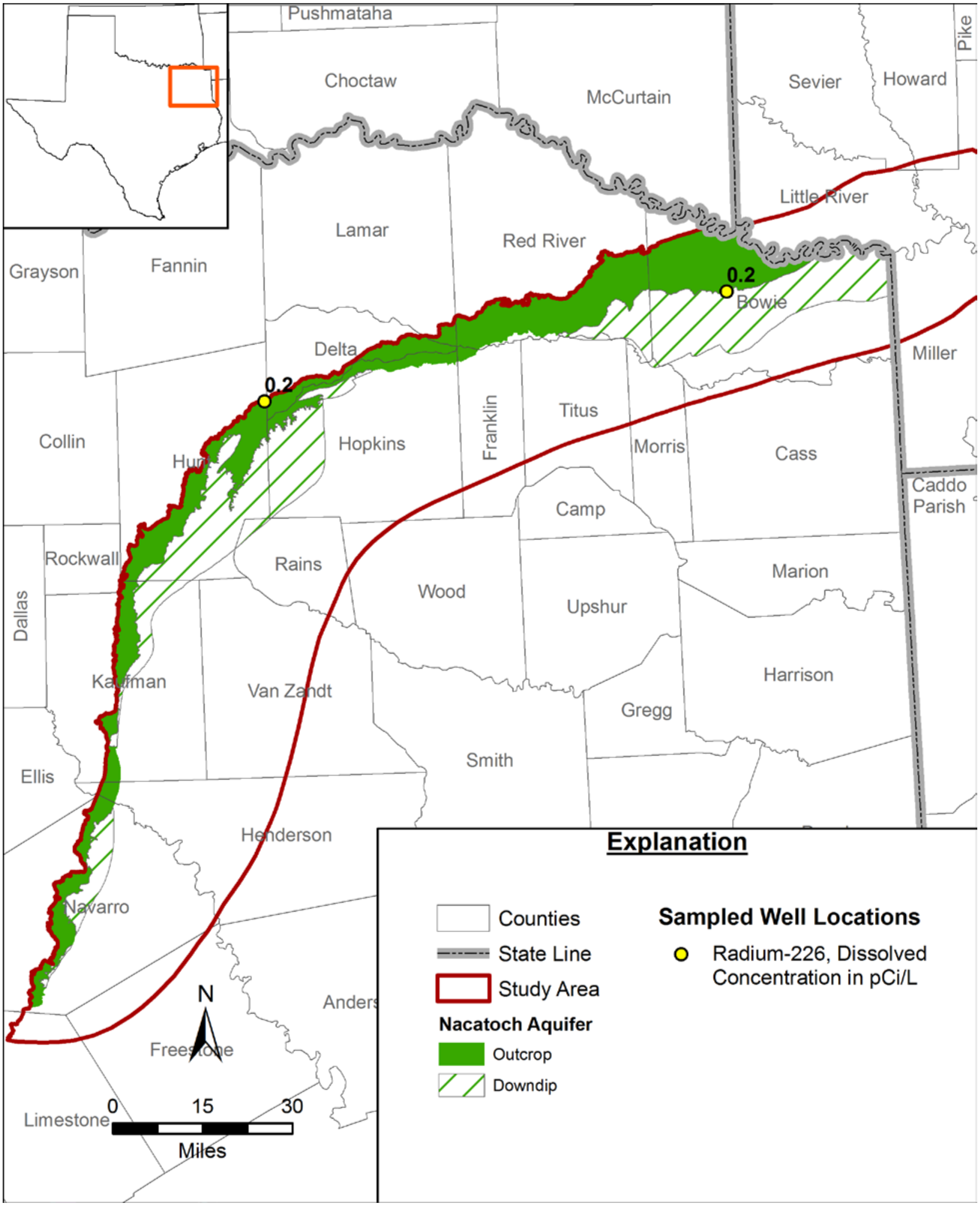


**Figure 10-11. Distribution of Ra-226 concentrations.**

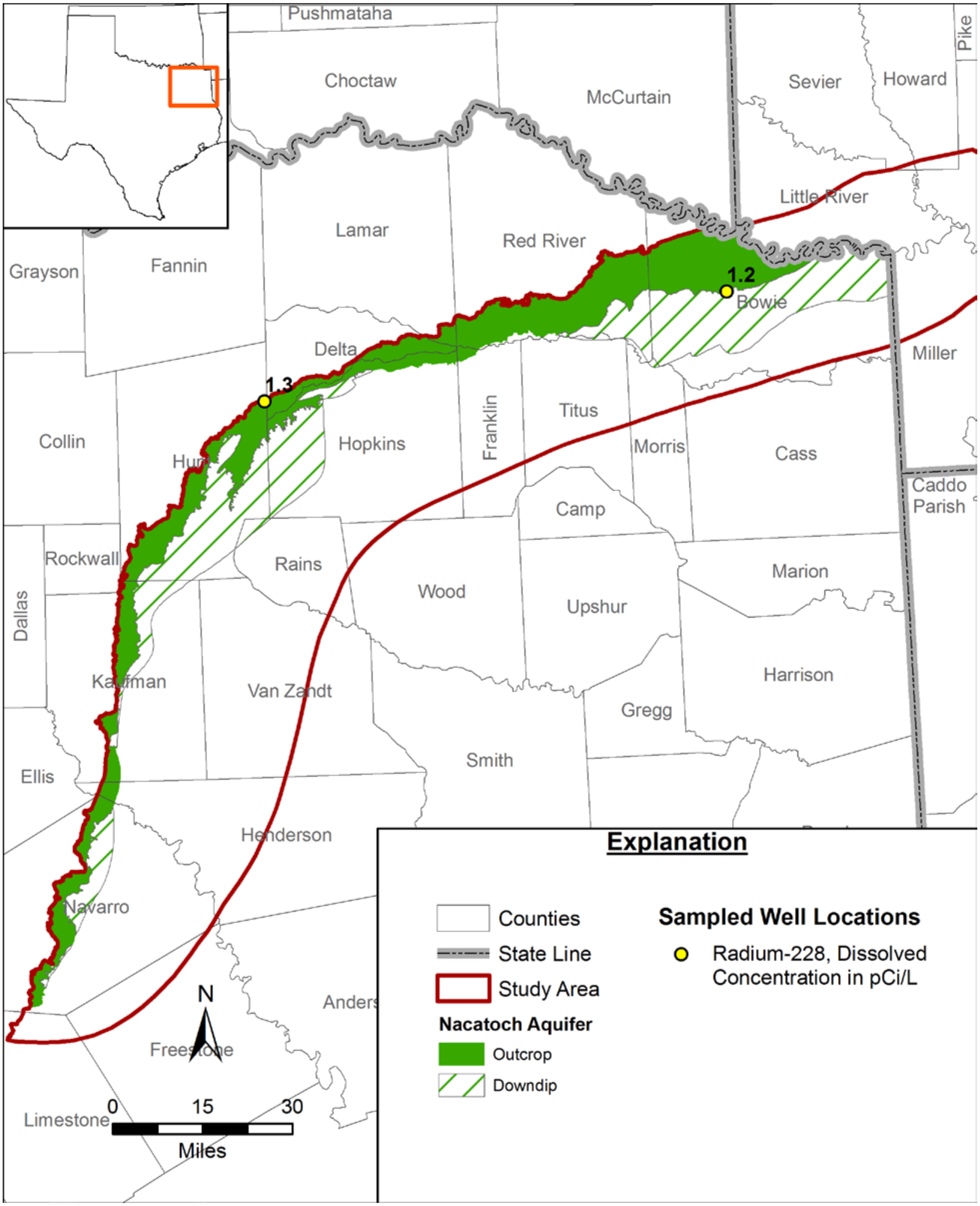


**Figure 10-12. Distribution of Ra-228 concentrations.**

**Table 10-1. Radiological data for the Nacatoch Aquifer.**

| State Well Number | Date | Gross Alpha, Total (pCi/L)[a] | Alpha, Dissolved (pCi/L)[a] | Beta, Dissolved (pCi/L)[a] | $^{226}$Ra, Dissolved (pCi/L)[a] | $^{228}$Ra, Dissolved (pCi/L)[a] | Uranium (ug/L)[b] |
|---|---|---|---|---|---|---|---|
| 1627701 | 9/22/1993 | | <3 | <4 | | | |
| | 9/10/2001 | **0.9** | | | | | |
| 1632813 | 9/11/2001 | **3.9** | | | | | |
| 1633305 | 9/13/2001 | **1.4** | | | | | |
| 1634602 | 5/12/2010 | | | | | | <1 |
| 1635101 | 5/13/2010 | | | | | | <1 |
| 1635803 | 9/21/1993 | | <2 | <4 | | | |
| | 9/11/2001 | **1.5** | | | | | |
| 1636205 | 9/21/1993 | | <2 | <4 | | | |
| 1636306 | 9/11/2001 | **1** | | | | | |
| | 6/7/2011 | | <10.2 | | <0.2 | <1.2 | <1 |
| 1636601 | 9/21/1993 | | <2 | <6 | | | |
| 1639206 | 9/11/2001 | **6.5** | | | | | |
| 1739510 | 9/16/1993 | | <3 | <4 | | | |
| | 9/12/2001 | **1.7** | | | | | |
| 1739906 | 9/16/1993 | | <3 | <5 | | | |
| 1739907 | 9/16/1993 | | <3 | <5 | | | |
| 1740102 | 9/13/2001 | **2.1** | | | | | |
| 1741902 | 9/22/1993 | | <4 | <5 | | | |
| 1742706 | 10/1/1993 | | <2 | <6 | | | |
| 1742707 | 4/26/2010 | | | | | | <1 |
| | 6/9/2011 | | <8.4 | | <0.2 | <1.3 | <1 |
| 1749504 | 9/21/1993 | | <2 | <5 | | | |
| 1750603 | 11/14/1991 | | <2 | <4 | | | |
| 1750706 | 11/14/1991 | | <2 | <4 | | | |
| 1758104 | 11/14/1991 | | <2 | <4 | | | |
| 1758501 | 11/14/1991 | | <2 | <4 | | | |
| 1758801 | 11/14/1991 | | **2.9** | <4 | | | |
| 3307906 | 9/21/1993 | | <2 | <4 | | | |
| 3315402 | 9/22/1993 | | <3 | <5 | | | |
| 3323107 | 9/21/1993 | | <5 | <4 | | | |
| 3346707 | 9/16/1993 | | **3.3** | <5 | | | |
| 3904502 | 9/16/1993 | | <3 | <5 | | | |

[a] Picocuries per liter.
[b] Micrograms per liter.
Source: Texas Water Development Board, Groundwater Database

# 11 Net Sand Analysis

The Nacatoch sand occurs in the middle of the Navarro Group below a marly unit that is identifiable in a number of wells. Sands of the middle and lower Navarro were picked on geophysical logs using SP and resistivity curves, and care was taken to avoid the shaly zones. The net sand thicknesses obtained were then gridded to produce net sand maps as shown in Figure 11-1 and Figure 11-2. Based on the maps, the Nacatoch Sand appears to be the thickest in northeastern Texas stretching into Arkansas, with net thicknesses greater than 150 feet (Figure 11-1); these sands are interpreted to be of tidal origin (McGowen & Lopez, 1983). The central part of the Nacatoch around Hunt County also reaches net sand thickness of almost 100 feet; these sands are interpreted to have been deposited by deltaic systems (McGowen & Lopez, 1983). In most areas, net sand thickness averages 50 feet or more. Multiple lower Navarro sands are also identifiable on most well logs. They appear more thinly bedded at log scale than the Nacatoch, with thick mudstones or clays separating coarsening upwards sand cycles. The lower Navarro net sand thickness varies from less than 25 feet to as high as 125 feet (Figure 11-2).

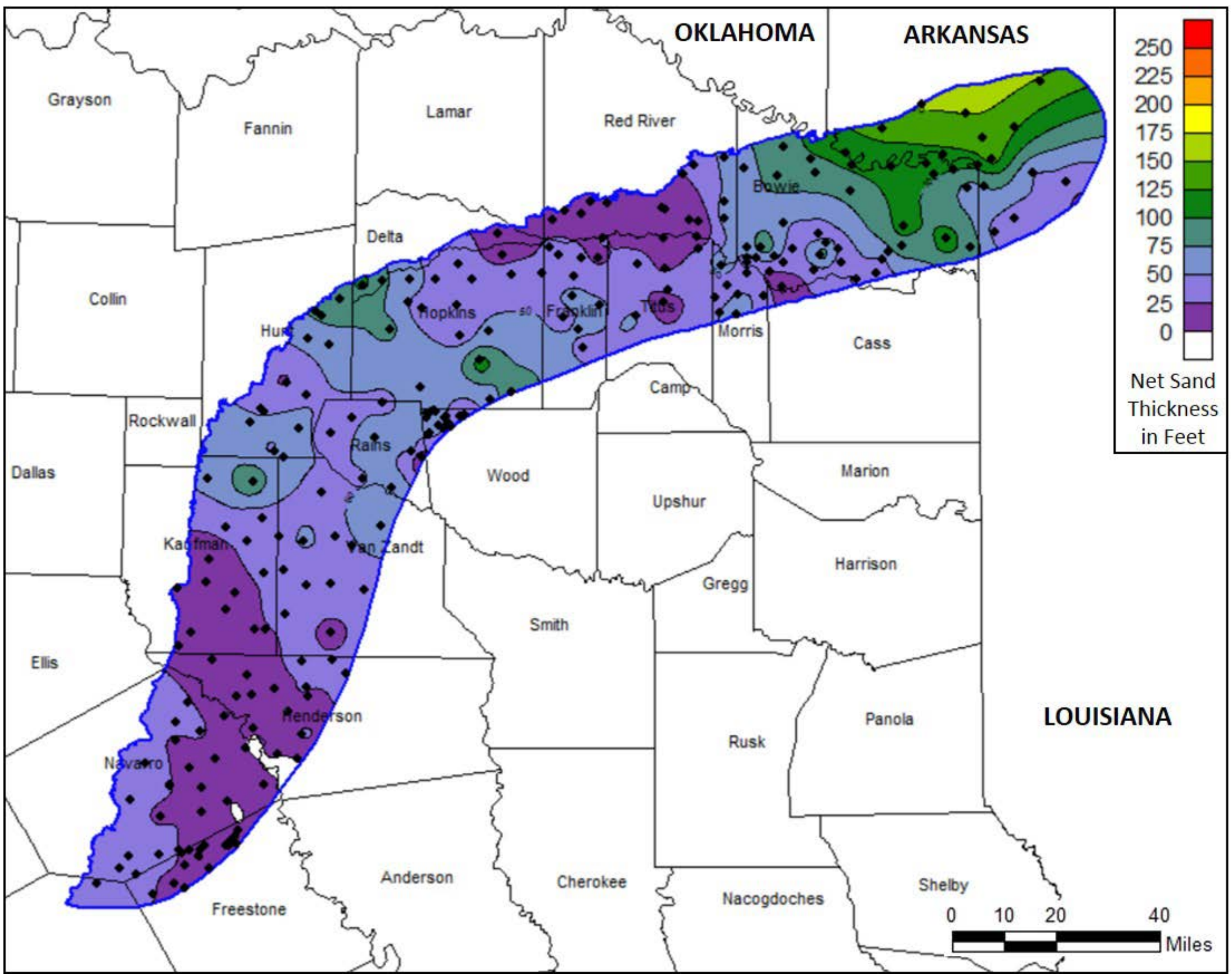


**Figure 11-1. Net sand thickness of Nacatoch sand.**

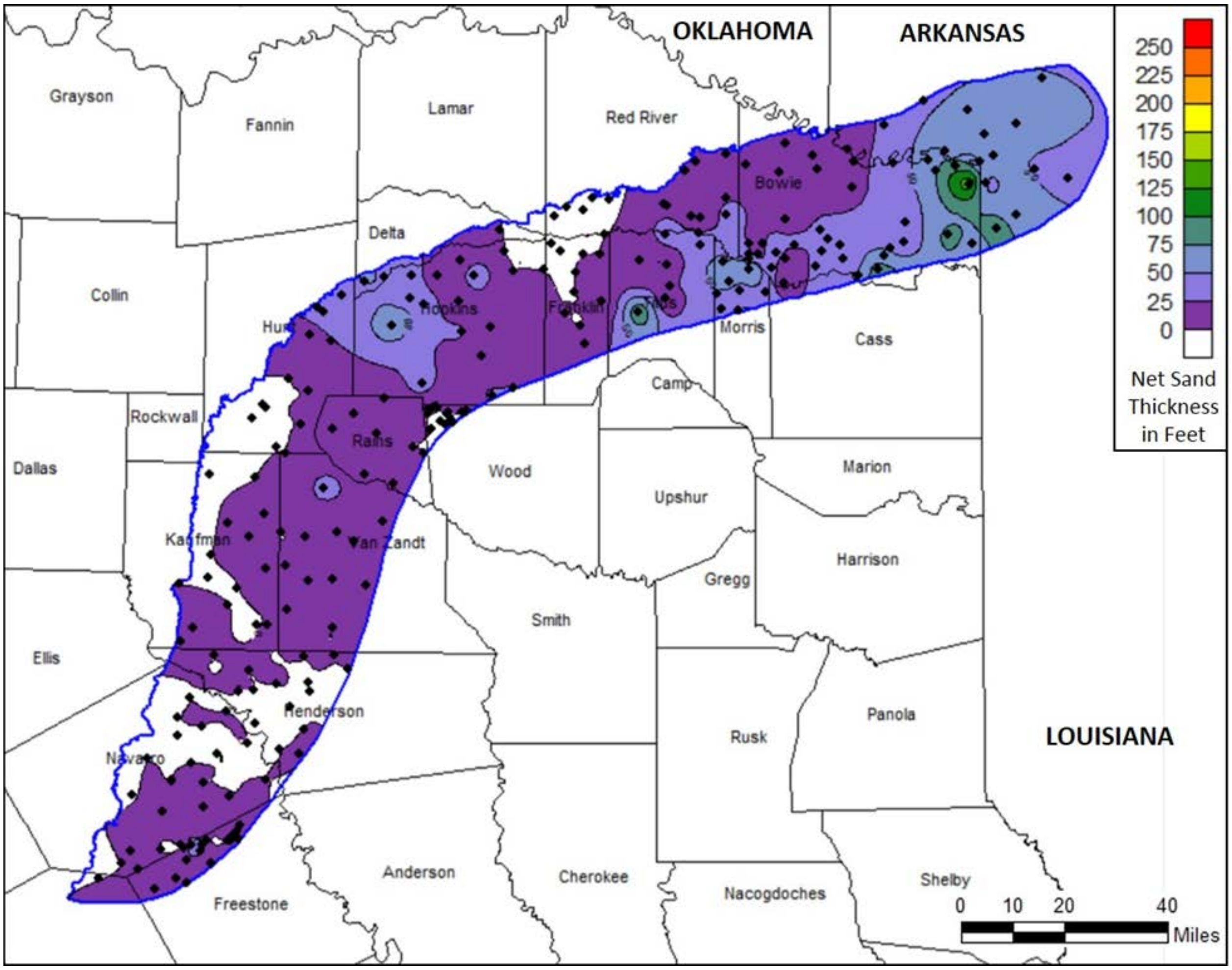


**Figure 11-2. Net sand thickness of lower Navarro sands.**

# 12 Groundwater Volume Methodology

The primary assumption made for the Nacatoch Aquifer was that total dissolved solids values do not vary vertically, and that the only relevant portion of the aquifer is in the basal sand unit.

The Nacatoch Aquifer surfaces were interpolated using ArcGIS Pro's geostatistical analyst package using empirical bayesian kriging. Along with the aquifer itself, the top and bottom of the basal sand unit was also interpolated. The thickness for both the aquifer and the basal sand was determined by the interpolated surfaces. The assumption of no vertical change in total dissolved solids values allowed for the total dissolved solids point values to be interpolated using the same method, but was confined to only to the basal sand unit. The interpolated total dissolved solids values were then zoned into the four salinity categories.

With the total dissolved solids zones defined, the top, bottom, and thickness of each zone could be extracted. With these values, along with water level, specific yield, and specific storage the volumes for each zone could be estimated. The water level data came from the TWDB's groundwater database and was based on 2006 readings, which were interpolated for the entire area of the aquifer. The specific yield and specific storage values were extracted from the draft

Nacatoch Aquifer groundwater availability model, taking the values from the third layer that represented the Basal sand unit. The method used to estimate the volumes is similar to the TERS calculations and was performed for each cell.

Volume Unconfined: Vunconfined =Area * Sy * (Water Level - Bottom)

Volume Confined: Total Volume = Vconfined + Vunconfined

Vconfined = Area * S * (Water level - Top)

Vunconfined = Area * Sy * Thickness

Variables:

| | |
|---|---|
| Vunconfined | = storage volume due to water draining from the formation (Cubic feet) |
| Vconfined | = storage volume due to elastic properties of aquifer and water (Cubic feet) |
| Area | = area of the aquifer (square feet) |
| S | = storativity (unitless) |
| Sy | = specific yield (1/feet) |
| Water Level | = groundwater depth (feet) |
| Top | = top depth of aquifer (feet) |
| Bottom | = bottom depth of aquifer (feet) |

The modeling results indicate that there are approximately 5,445,315 acre-feet of in-place groundwater within the Nacatoch Aquifer in the project area. An estimated 574,761 acre-feet, or eleven percent, of the available groundwater is within the fresh water zone. Slightly saline and moderately saline water estimated volumes are 1,768,713 acre-feet (32 percent) and 1,637,529 acre-feet (30 percent), respectively. The very saline estimated volume within the project area is estimated to be 1,464,312 acre-feet (27 percent) of the total estimated volume. Table 12-1 summarizes volumes by salinity zone.

Tables 12-2 through 12-4 summarize the Nacatoch Aquifer salinity zone volumes within the project area by regional planning group, groundwater conservation district, and county, respectively. The North East Texas region (D) has a total in-place availability of 3,095,797 acre-feet; and Region C has approximately 758,430 acre-feet. The Neches and Trinity Valleys district has an estimated in-place volume of 221,766 acre-feet, mostly within the moderately saline zone. The three counties with the highest total volumes include Bowie (34%), Hopkins (12%), and Van Zandt (12%).

**Table 12-1. Nacatoch salinity zone volumes by zone (in acre-feet).**

| Salinity Zone | Unconfined | Confined | Total (acre-feet) | Percent |
|---|---|---|---|---|
| Fresh | 387,518 | 187,243 | 574,761 | 11% |
| Slightly Saline | 497,987 | 1,270,726 | 1,768,713 | 32% |
| Moderately Saline | 38,689 | 1,598,840 | 1,637,529 | 30% |
| Very Saline | 13,183 | 1,451,129 | 1,464,312 | 27% |
| **Total** | | | **5,445,315** | 100% |

**Table 12-2. Salinity zone volumes by planning region (in acre-feet).**

| Region | Fresh | Slightly saline | Moderately saline | Very saline | Total | Percent |
|---|---|---|---|---|---|---|
| North East Texas (D) | 482,759 | 579,017 | 903,868 | 1,130,153 | 3,095,797 | 80% |
| East Texas (I) | N/A | N/A | 3,529 | N/A | 3,529 | 0% |
| Region C | 52,370 | 67,502 | 364,243 | 274,315 | 758,430 | 20% |
| Brazos G | N/A | N/A | N/A | 19,767 | 19,767 | 1% |
| Total | 535,129 | 646,518 | 1,271,640 | 1,424,235 | 3,877,523 | 100% |
| Percent volume by salinity zone | 14% | 17% | 33% | 37% | 100% | |

**Table 12-3. Salinity zone volumes by groundwater conservation district (in acre-feet).**

| Region | Fresh | Slightly saline | Moderately saline | Very saline | Total | Percent |
|---|---|---|---|---|---|---|
| Neches and Trinity Valleys GCD | 597 | 1,420 | 158,035 | 61,714 | 221,766 | 78% |
| Mid-East Texas GCD | N/A | N/A | 34,122 | 28,181 | 62,303 | 22% |
| Prairielands GCD | N/A | 12 | 1,272 | N/A | 1,284 | 0.4% |
| Total | 597 | 1,432 | 193,429 | 89,895 | 285,352 | |
| Percent volume by salinity zone | 0% | 1% | 68% | 32% | 100% | |

**Table 12-4. Salinity zone volumes by county (in acre-feet).**

| County | Fresh | Slightly saline | Moderately saline | Very saline | Total | Percent volume by county |
|---|---|---|---|---|---|---|
| Red River | 42,773 | 29,535 | 17,538 | 3,922 | 93,768 | 2% |
| Lamar | 1,334 | 780 | 286 | | 2,400 | 0% |
| Bowie | 368,574 | 396,064 | 360,141 | 209,234 | 1,334,013 | 34% |
| Delta | 4,177 | 12,918 | 10,357 | | 27,452 | 1% |
| Hunt | 42,184 | 57,219 | 19,490 | | 118,893 | 3% |
| Titus | | 1,519 | 76,092 | 90,757 | 168,368 | 4% |
| Franklin | | | 28,991 | 60,328 | 89,319 | 2% |
| Hopkins | 25,379 | 83,768 | 181,785 | 175,772 | 466,704 | 12% |
| Morris | | | 27,304 | 71,499 | 98,802 | 3% |
| Cass | | | 31,744 | 2,908 | 34,652 | 1% |
| Wood | | | | 26,449 | 26,449 | 0.7% |
| Rockwall | | 457 | | | 457 | 0.01% |
| Rains | | 270 | 37,143 | 144,942 | 182,356 | 5% |
| Kaufman | 36,418 | 36,775 | 105,564 | 32,359 | 211,116 | 5% |
| Van Zandt | | | 111,717 | 344,489 | 456,206 | 12% |
| Ellis | | 12 | | | 12 | 0.00% |
| Henderson | 597 | 1,374 | 158,744 | 62,135 | 222,849 | 6% |
| Navarro | 15,355 | 29,019 | 70,880 | 152,661 | 267,915 | 7% |
| Freestone | | | 34,014 | 28,181 | 62,194 | 2% |
| Limestone | | | | 19,948 | 19,948 | 0.51% |
| | | | | | | 100% |
| **Total** | 536,791 | 649,709 | 1,271,790 | 1,425,583 | 3,883,874 | |
| **Percent** | 14% | 17% | 33% | 37% | 100% | |

# 13 Geophysical Well Log Analysis and Methodology

## 13.1 Geophysical Log Interpretation

The Nacatoch Sand poses some challenges to total dissolved solids estimation using geophysical logs. In general, log interpretations require sand bodies that are shale free and thick enough to develop true resistivity and spontaneous potential. Nacatoch Aquifer sand bodies, however, are often thin and usually shaly. Spatial coverage of the study area by geophysical logs was fortunately not a problem.

The following guidelines were developed to estimate total dissolved solids concentrations in the Nacatoch Aquifer using geophysical logs:

1. Examine sand beds that:
    a. are at least 10 feet thick,
    b. are shale-free,
    c. have separation between the shallow and deep resistivity curves indicating invasion and therefore porosity, and
    d. have SP development.

2. Select water quality corrections using analyses from nearby water wells. In downdip areas where water wells are not present, water quality should be set to “primarily NaCl” when the Rwa method is yielding an estimate of approximately 2,500 milligrams per liter or more.
3. Attempt to evaluate the majority of geophysical logs in the BRACS database within the project area by selecting at least one log per 2.5-minute grid cell in areas where multiple logs are present and analyzing suitable logs in all other areas to develop sufficient spatial coverage.
4. Attempt to evaluate at least one log on either side of a fault.
5. Continue log interpretation in a downdip direction until a trend of total dissolved solids levels greater than 10,000 milligrams per liter is obtained in the entire thickness of the aquifer or until log characteristics in an area indicate that further assessment is not warranted.

The conditions in the first standard are not perfectly attained in the majority of logs owing to the presence of thin, shaly beds. Bed thickness is a critical element in obtaining reliable measurements of true resistivity (Rt) from the observed resistivity (Ro) and for obtaining the static spontaneous potential (sSP) of a bed, which is its maximum SP value (see Appendix A-5 of this report for the table summarizing the effects of tool geometry on open hole logs from Collier, 1993, p. 139).

Porosity is a necessary input for total dissolved solids estimation. The Nacatoch log suite has many old logs and few have porosity logs through that interval. The available porosity logs in the Nacatoch are of poor quality, chiefly because of borehole rugosity. As a result, local estimates for this parameter are not used. Instead, values of 0.32 to 0.4 were used from the calibration process (Driscoll, 1986).

All total dissolved solids estimation methods were considered for this study, however, the only method that appears geospatially accurate when mapped with the sample data is the Rwa Minimum method. The other methods did not suggest any spatial consistency.

Example geophysical logs with total dissolved solids estimation using the Rwa method are shown in Figure 13-1. A step-by-step overview of the Rwa calculations is included in this section. A tabulation of relevant BRACS variables from the geophysical log on Figure 13-1 is included as Table 13-2.

The 10-foot minimum thickness is based primarily on the SP which needs at least this thickness of clean, shale-free sand to yield an approximation of the sSP (Asquith & Gibson, 1982, p. 28). However, note that the SP tool can only resolve beds 12 feet or more in thickness.

Short and long normal tools measure resistivity in the invaded zone (short normal) and uninvaded zone (long normal). The 16-inch normal requires a bed 60 inches thick and the 64-inch normal requires a bed 20 feet thick to develop a true resistivity under ideal conditions. Induction logs are better, with true resistivity being obtained in beds just slightly thicker than their electrode spacing. However, bed resolution is still a problem on standard-scale logs and expanded-scale logs are not always available in the Nacatoch interval. Most of the logs in the Nacatoch project area are either 16-inch/64-inch normal or 16-inch normal/40-inch induction logs.

Corrections to resistivity readings for environmental conditions are not made. The most obvious choice, given its influence, would be to correct for bed thickness effects. However, correction charts in the literature are developed for specific conditions which may not be met in individual wells (Collier, 1993, p. 159). More importantly, correction charts are not available for all of the various logging systems encountered in the Nacatoch log suite.

Corrections are normally applied in several methods when bicarbonate or sulfate comprises more than 50 percent of the total dissolved solids. Numerous water wells exceed this limit. The difficulty is that such wells are situated near wells with concentrations of less than 50 percent of total dissolved solids so that it is not always clear whether a correction should be applied to a particular log.

Porosity is a necessary input for total dissolved solids estimation. The Nacatoch log suite has many old logs and few have porosity logs through that interval. The available porosity logs in the Nacatoch are of poor quality, chiefly because of borehole rugosity. As a result, local estimates for this parameter are not used. Instead, values of 0.32 to 0.4 were used from the calibration process (Driscoll, 1986).

All total dissolved solids estimation methods were considered for this study, however, the only method that appears geospatially accurate when mapped with the sample data is the $R_{wa}$ Minimum method. The other methods did not suggest any spatial consistency.

A step-by-step overview of the $R_{wa}$ calculations is included in this section. An example geophysical log with total dissolved solids estimation using the $R_{wa}$ method is shown in Figure 13-1. A type log which illustrates log signatures of the Nacatoch and surrounding geological units is included as Figure 13-2. A tabulation of relevant BRACS variables from the geophysical log on Figure 13-1 is included as Table 13-1.

## 13.2 Estimation Using the $R_{wa}$ Total Dissolved Solids Minimum Method

The $R_{wa}$ minimum total dissolved solids method is based upon Archie's water saturation equation applied in a shale free, water-saturated formation (Schlumberger, 2009).

Four parameters are required to use the $R_{wa}$ minimum total dissolved solids method:

- Deep resistivity ($R_t$)
- Porosity ($\phi$)
- Cementation exponent (m) A dimensionless, empirically-derived parameter related to the degree of matrix cementation
- Lithology parameter (a)

Using the four parameters, calculation of the estimated total dissolved solids concentration proceeds using the following process reproduced from Estepp (2010):

1. Select a deep resistivity (~ $R_t$) value from the electric log.
2. Compute total porosity from a neutron-density porosity log. Average the neutron porosity ($\phi_N$) and density porosity ($\phi_D$):
3. $(\phi_{ND}) = \sqrt{\frac{\phi_N^2 + \phi_D^2}{2}}$
4. Determine a value for the cementation exponent (m) from:
   a. Pickett Plot – Plot of porosity ($\phi$) versus $R_o$. An offset well may be acceptable if there is no porosity log on the subject well or
   b. Best estimate – based upon reservoir description form driller's log. Set a = 1, then selecting the proper cementation exponent;
5. Solve for $R_{wa}$ :

   $R_{wa} = \frac{\phi^m \cdot R_t}{a}$
6. Freshwater ion correction for $R_{wa}$

   If high bicarbonates are present, then apply Alger's (1966) equation:

   $R_{wa(cor)} = 1.75 \cdot R_{wa}$

   For sodium bicarbonate groundwater, use:

   $R_{wa(cor)} = 1.33 \cdot R_{wa}$
7. Calculate formation temperature ($T_f$) using the bottom-hole temperature (TBH), which is the temperature in degrees F at the bottom of the hole at the time the well was logged (from the log header), and surface temperature ($T_s$), which is a 30-year climatic normal.

   $$T_f = (TBH - T_s)\frac{formation\ depth}{total\ depth} + T_s$$

8. Convert $R_{wa(cor)}$ at $T_f$ to $R_w$ at 75°F with

   $$R_{w75} = R_{wa(cor)} \left(\frac{T_f}{75}\right)$$

9. Convert formation water resistivity at 75°F ($R_{w75}$) to specific conductance at 75°F ($C_{w75}$) with

   $$C_{w75} = \frac{10{,}000}{R_{w75}}$$

10. Solve for total dissolved solids using the specific conductivity-total dissolved solids conversion factor (ct) in

    total dissolved solids = ct · $C_{w75,}$

    Where ct = $C_w$-total dissolved solids conversion factor and $C_{w75}$ = Specific conductivity at 75°F.

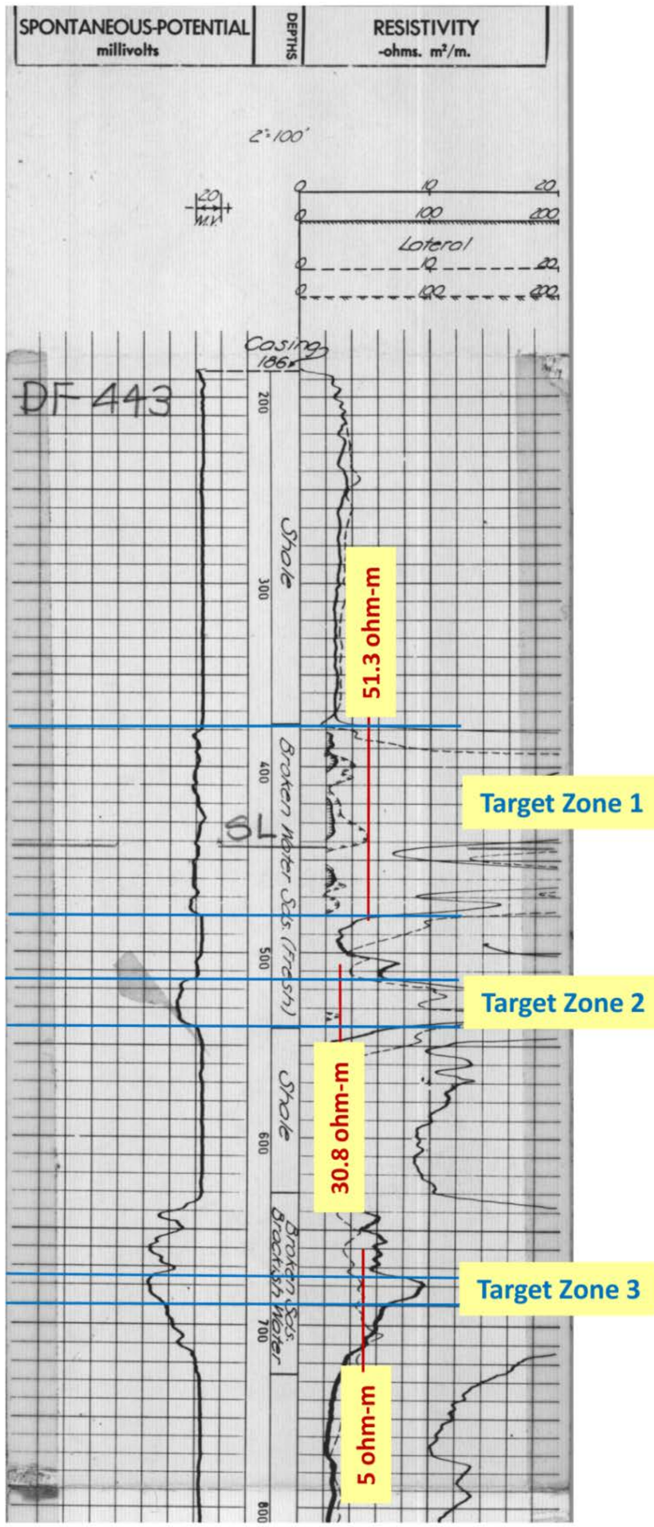


**Figure 13-1.** **BRACS ID# 23582 geophysical log Ro values.**

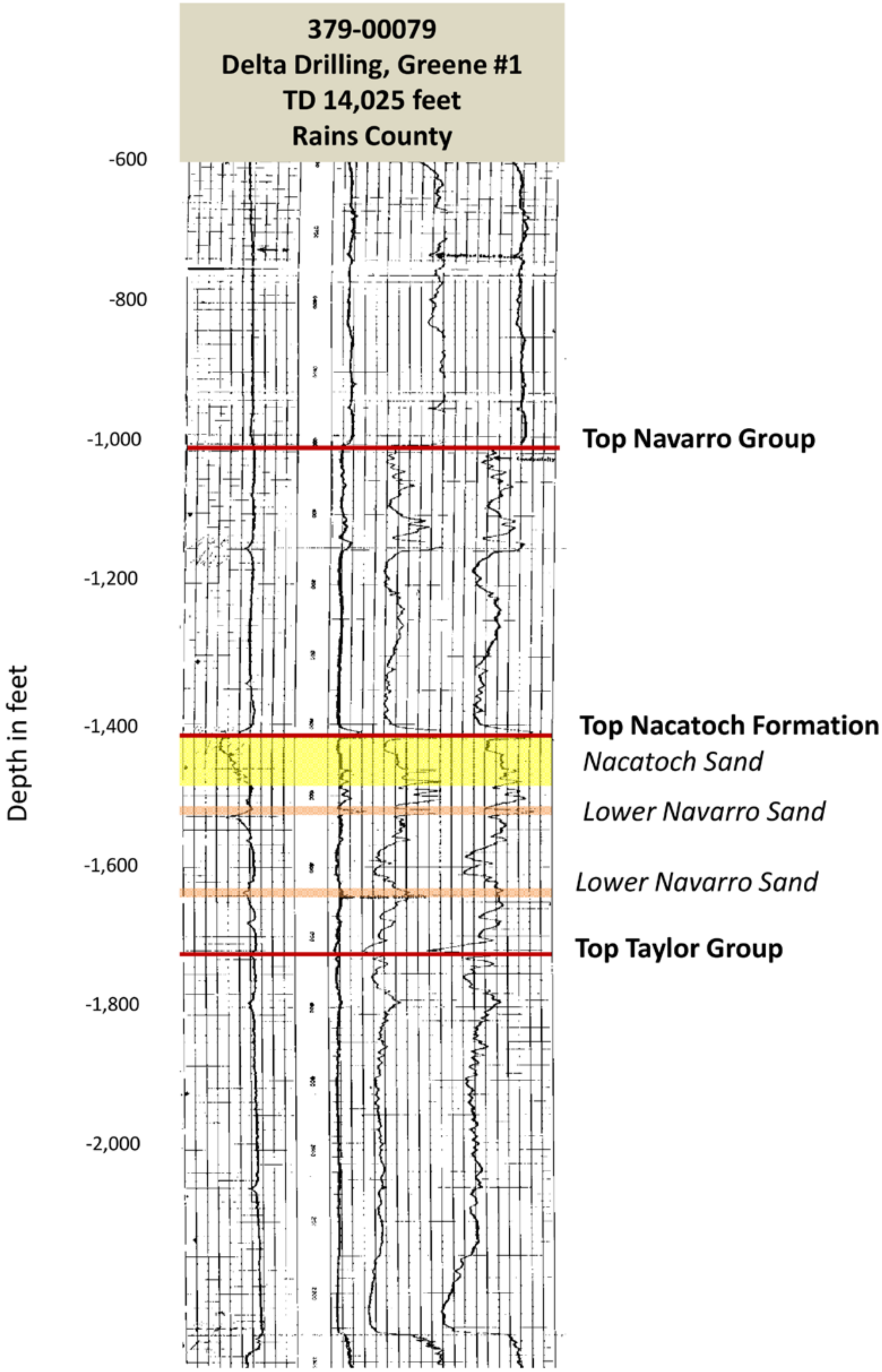


**Figure 13-2. Type log.**

**Table 13-1. Total dissolved solids estimates using Rwa method for log in Figure 13-1.**

| Field description | Target zone 1 | Target zone 2 | Target zone 3 |
|---|---|---|---|
| WELL_ID | 23582 | 23582 | 23582 |
| DF | 435 | 535 | 680 |
| TDS_INTERPRETED | 660 | 1,070 | 4,790 |
| RO | 51.3 | 30.8 | 5.0 |
| A | 1 | 1 | 1 |
| M | 1.4 | 1.4 | 1.4 |
| PHI | 0.33 | 0.33 | 0.33 |
| CT | 0.5 | 0.5 | 0.5 |
| RWE | 10.9 | 6.5 | 1.1 |
| RWE_RW_COR | 1.33 | 1.33 | 1.0 |
| RW_COR | 8.2 | 4.9 | 1.1 |
| RW_75 | 7.6 | 4.7 | 1.0 |
| CW | 1,313 | 2,137 | 9,590 |
| DT | 4,699 | 4,699 | 4,699 |
| TS | 63 | 63 | 63 |
| TBH | 138 | 138 | 138 |
| TF | 69.9 | 71.5 | 73.9 |

WELL_ID: BRACS unique well ID.

DF: Depth of the assessed formation of interest, not corrected for kelly bushing height. Units are feet below ground surface.

TDS_INTERPRETED: Interpreted total dissolved solids (TDS) concentration at the depth of formation. The units of are milligrams per liter total dissolved solids.

RO: Resistivity of the saturated formation in units of ohm-meter. The formation should be 100 percent saturated with water.

A: Lithology of tortuosity factor in Archie's Law.

M: Cementation exponent in Archie's Law.

PHI: Porosity data were not available for the Nacatoch. Assumed a porosity of 0.33 in thick sand with high deep resistivity or prominent negative deflection on SP.

CT: Total dissolved solids divided by specific conductance. The field value is less than one and is dimensionless.

RWE: Resistivity of water equivalent in units of ohm-meter.

RWE_RW_COR: Correction factor for high anion waters using the SP and Rwa minimum method (Estepp, 1998). The value units are dimensionless.

RW_COR: Resistivity of the water as determined by geophysical well log analysis. Units are ohm-meters.

RW75: Resistivity of the water as determined by geophysical well log analysis corrected for 75 degrees Fahrenheit. Units are ohm-meters.

CW: Conductivity of the water as determined by geophysical well log analysis corrected for 75 degrees Fahrenheit. Units are microsiemens per meter.

DT: The total depth of the log (not the total depth of the hole).

RMF_COR: Correction factor for resistivity of the mud filtrate when using the SP method of analysis.

TS: Temperature at the ground surface. Temperature is in units of degrees Fahrenheit.

TBH: Temperature at the bottom of the hole at the time the well was logged. Temperature is in units of degrees Fahrenheit.

TF: The temperature at the depth of formation of interest [DF]. Units are degrees Fahrenheit.

# 14 Potential Brackish Groundwater Production Area Analysis and Modeling Methodology

## 14.1 Exclusion Criteria

Potential production area may only exist in locations that meet the criteria of House Bill 30. House Bill 30 states that these areas:

- *Are separated by hydrogeologic barriers sufficient to prevent significant impacts to water availability or water quality in any area of the same or other aquifers, subdivisions of aquifers, or geologic strata that have an average total dissolved solids level of 1,000 milligrams per liter or less at the time of designation of the zones.*
- *Are not located in an aquifer, subdivision of an aquifer, or geologic stratum that has an average total dissolved solids level of more than 1,000 milligrams per liter and is serving as a significant source of water supply for municipal, domestic, or agricultural purposes at the time of designation of the zones, or in an area of a geologic stratum that is designated or used for wastewater injection through the use of injection wells or disposal wells permitted under Chapter 27.*

Using these criteria for guidance, several public supply, irrigation, domestic, and injection wells were determined to qualify for exclusion. Two-mile buffer zones were applied to all Nacatoch wells. One-mile buffers were applied to wells found in the state driller report database (Figure 14-1). The summary table (Table 14-1) lists the type of well and total count of the wells found. Alluvium wells completed within less than 200 feet of vertical separation from the top of the Nacatoch were excluded. Injection wells with injection zones located within 300 vertical feet of either the top of the Nacatoch Formation or the base of the Taylor Group were excluded. Most of these are located in the southern fault graben, thus the entire graben has been excluded. Tables of all excluded wells are included as Appendix 19-1. Any area between the 1,000 and 10,000 milligrams per liter total dissolved solids extents that were not excluded using these criteria were considered for evaluation as potential production areas (Figure 14-2). Some portions of the potential production areas extend past the estimated 10,000 milligrams per liter limit merely to simplify the modeling task (Figure 14-3 and Figure 14-4).

**Table 14-1. Exclusion wells summary.**

| Source | Well use | Count | Aquifer |
|---|---|---|---|
| Texas Commission on Environmental Quality | Public Supply | 88 | Nacatoch |
| Texas Commission on Environmental Quality | Public Supply | 1 | Alluvium |
| TWDB groundwater database | Domestic | 188 | Nacatoch |
| TWDB groundwater database | Irrigation | 8 | Nacatoch |
| TWDB groundwater database | Public Supply | 74 | Nacatoch |
| State Driller Report database | Domestic | 231 | Nacatoch, Alluvium |
| State Driller Report database | Irrigation | 16 | Nacatoch, Alluvium |
| State Driller Report database | Public Supply | 1 | Nacatoch, Alluvium |
| Railroad Commission Class II wells | Injection, Disposal | 431 | Nacatoch |

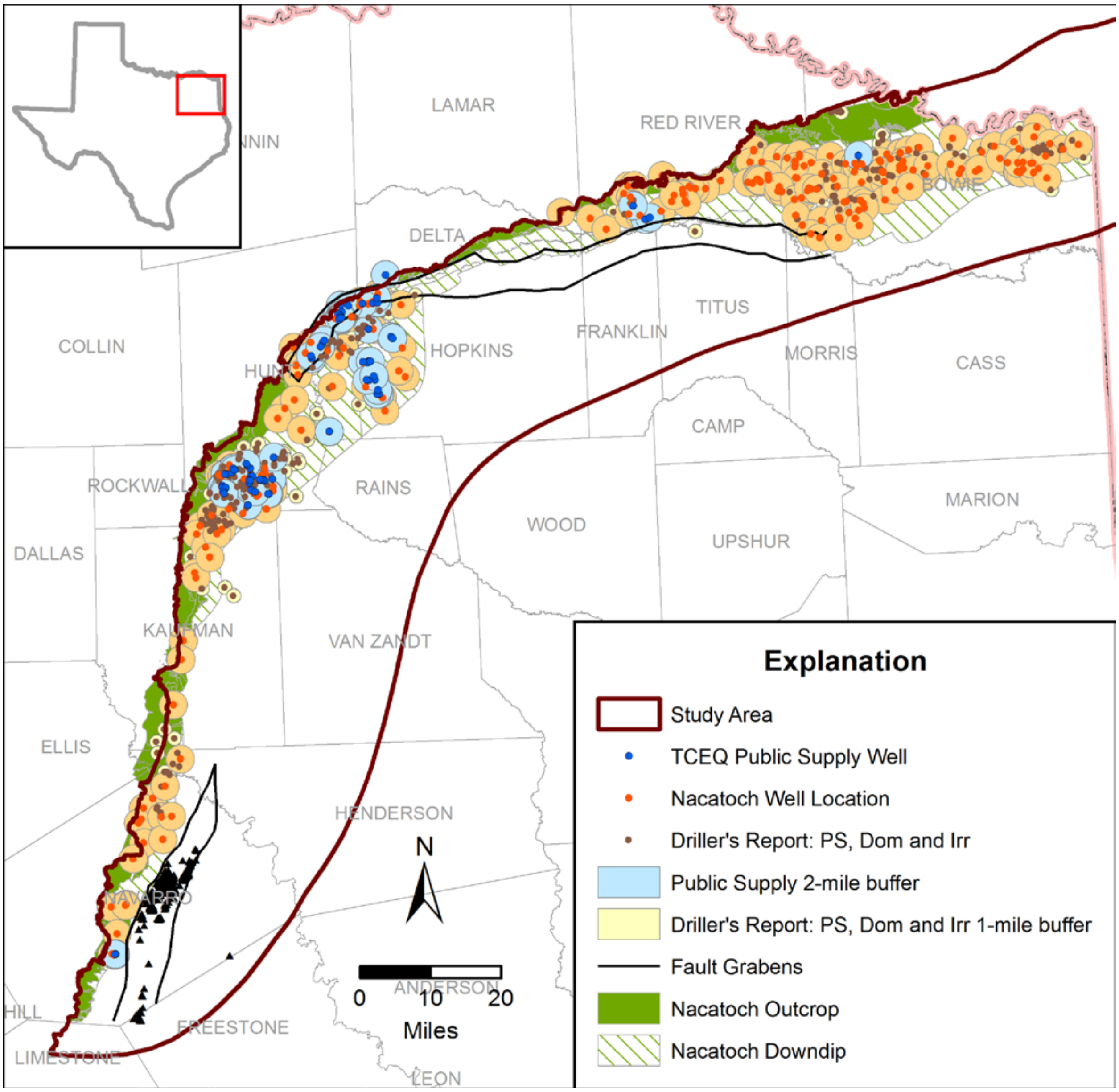


**Figure 14-1.** **Exclusion areas for wells, injection wells and faults.**

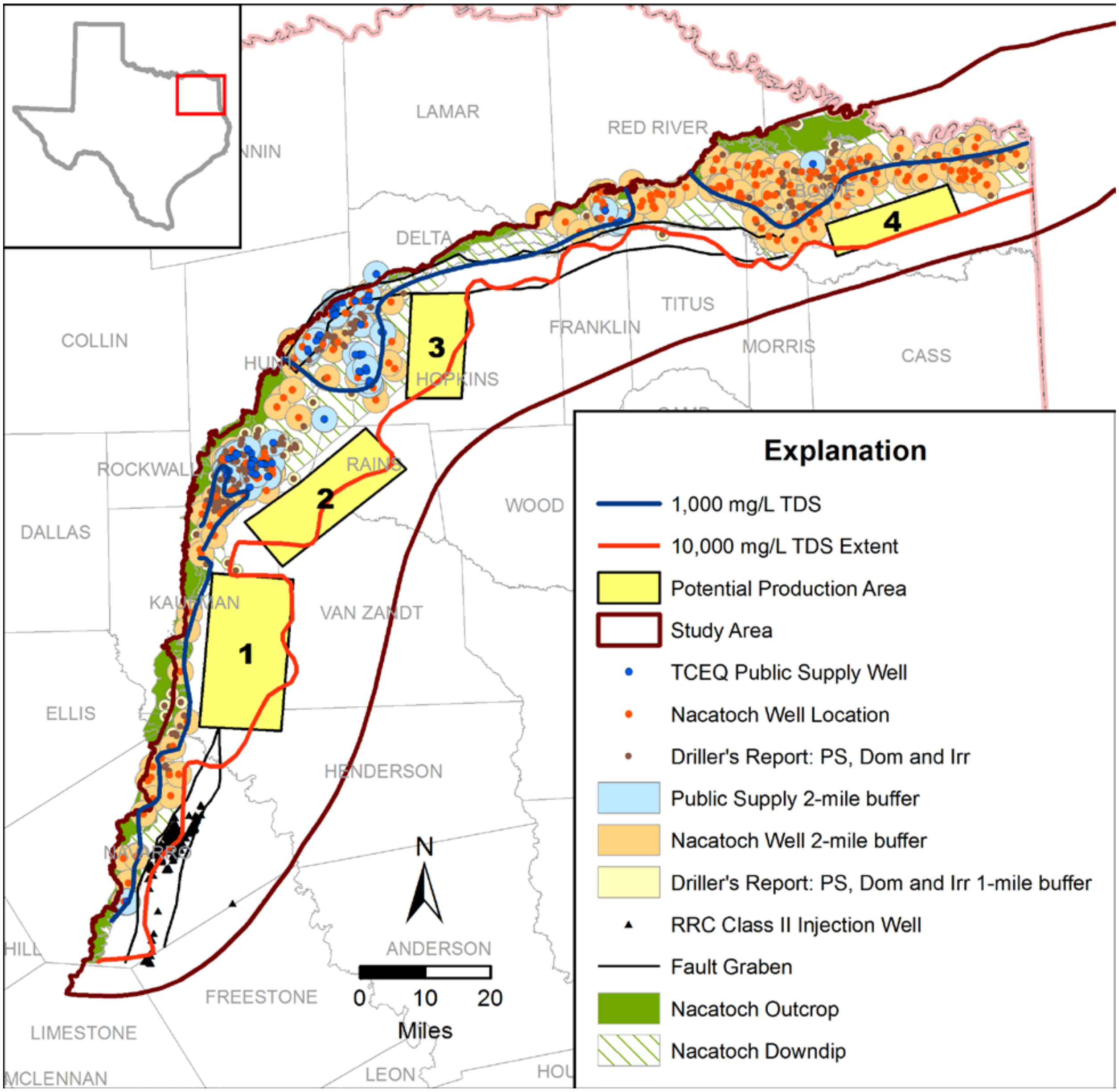


**Figure 14-2.** **Exclusion areas and potential production areas.**

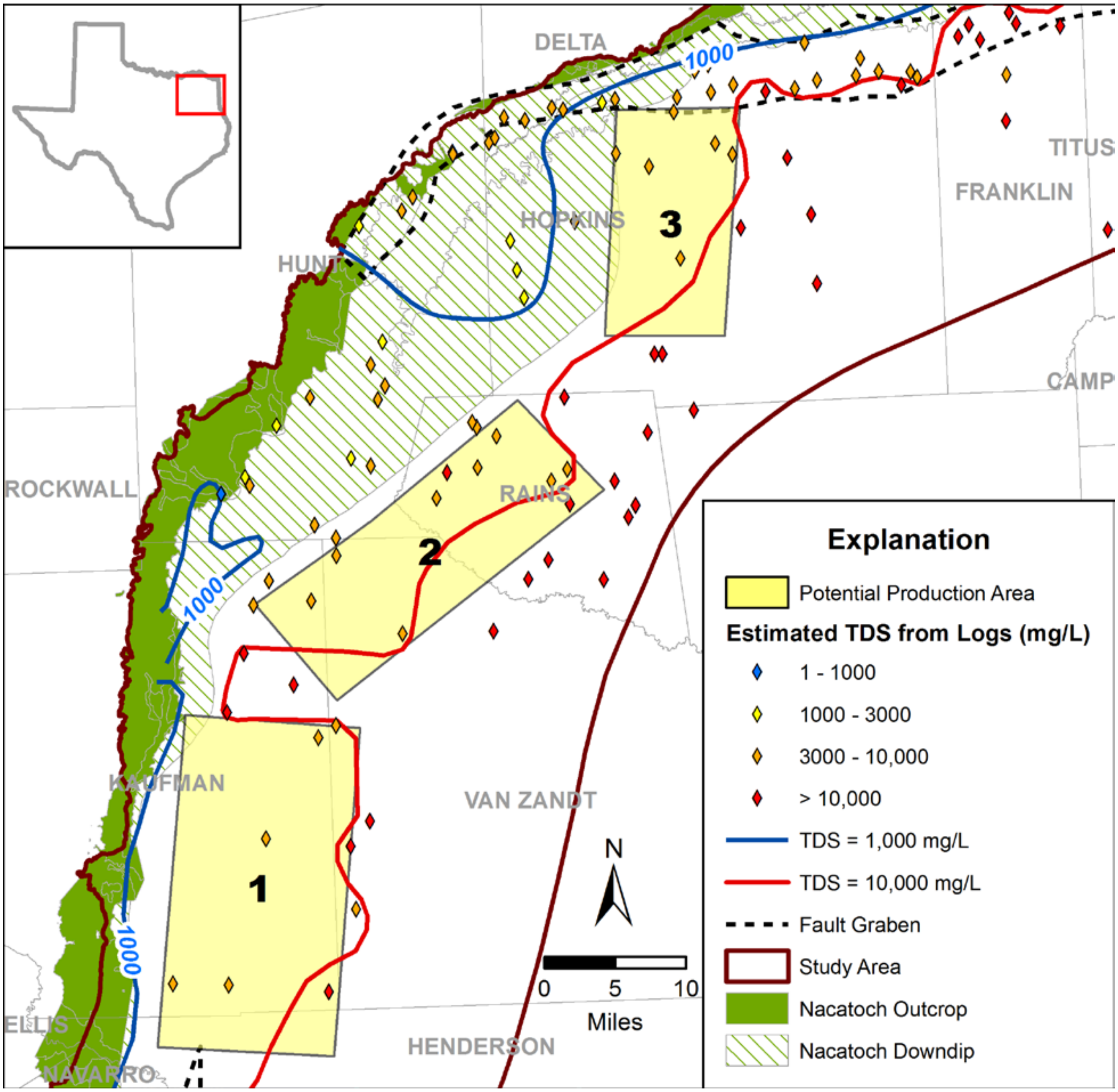


**Figure 14-3.** **Potential production areas 1, 2 and 3.**

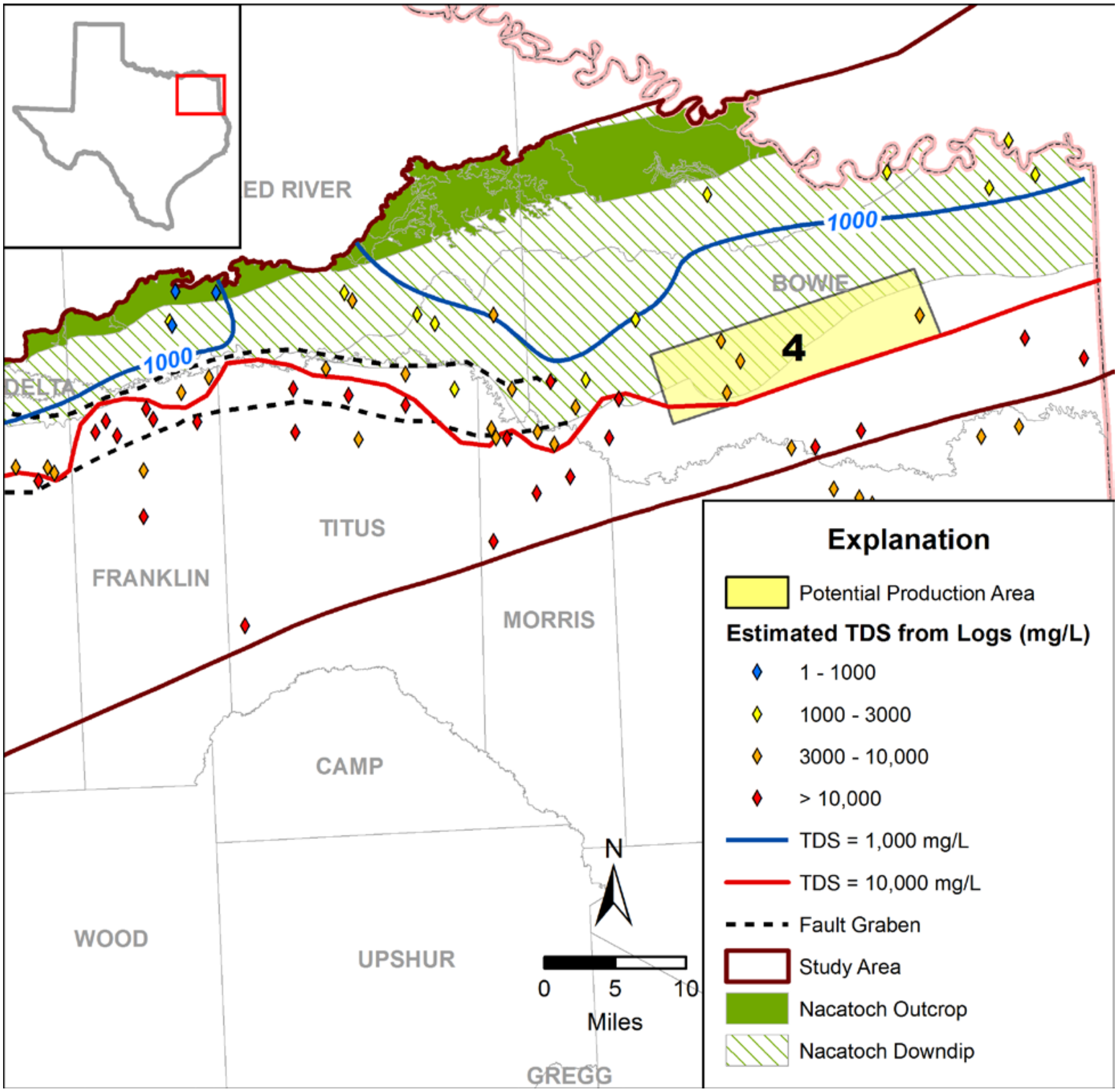


**Figure 14-4. Potential production area 4.**

## 14.2 Pumping Analysis and Results For 30- and 50-Year Periods

Theis drawdown analysis was performed for the four potential production areas to understand the effect pumping in these areas would have on nearby locations. Each potential production area was pumped at a low, medium, and high rate and for a period of 30 and 50 years (Table 14-2).

**Table 14-2. Nacatoch Aquifer simulated pumping volumes.**

| Pumping range | Pumping volume (acre-feet per year) |
|---|---|
| Low | 100 |
| Medium | 200 |
| High | 500 |

The well field set up was the same for each scenario, but placed in different locations throughout the potential production areas to understand the different effects they could have at various locations. The well field set up remained the same as a series of six wells offset by 4,000 feet. It was assumed that the wells fully screened the sand portions of the Nacatoch Aquifer. The properties for each potential production area were taken from the Nacatoch Groundwater Availability Model and averaged over the potential production area. The values used for each potential production area are shown in table 14-3.

Numerous well fields were modeled for each potential production area. The well fields selected for each potential production area are those wellfields which have the least extensive amount of up-dip drawdown. The drawdown contours for each of the selected well fields and associated potential production areas are included as Figure 14-5 through Figure 14-28. The approximate minimum and maximum impact, in feet of drawdown, to the nearest exclusion wells at each of the potential production areas are summarized in Table 14-4. Minimum drawdowns are 100 acre-feet 30-year scenarios, and maximums are from 500 acre-feet 50-year scenarios. Potential production areas 2 and 4 appear to have the least impact to up-dip exclusion wells with 0 to 20 feet of drawdown.

The Theis analysis assumes the standard assumptions such as fully penetrating well screen, constant pumping rate, and homogenous and isotropic confined aquifer. This analysis is limited in that it cannot show changes in pumping through time, recharge, or regional factors that could influence water levels through time.

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**Table 14-3. Nacatoch Aquifer properties for the modeled potential production areas.**

| Potential production area | Average storativity | Average transmissivity (gallons per day per foot) |
|---|---|---|
| 1 | $1.4 \times 10^{-5}$ | 5,850 |
| 2 | $2.7 \times 10^{-5}$ | 11,460 |
| 3 | $3.1 \times 10^{-5}$ | 4,588 |
| 4 | $3.1 \times 10^{-5}$ | 13,935 |

**Table 14-4. Summary of estimated impact on nearest exclusion wells, in feet of drawdown**

| Potential production area | Minimum drawdown (feet) | Maximum drawdown (feet) |
|---|---|---|
| 1 | 7 | 35 |
| 2 | 0 | 20 |
| 3 | 8 | 70 |
| 4 | 0 | 20 |

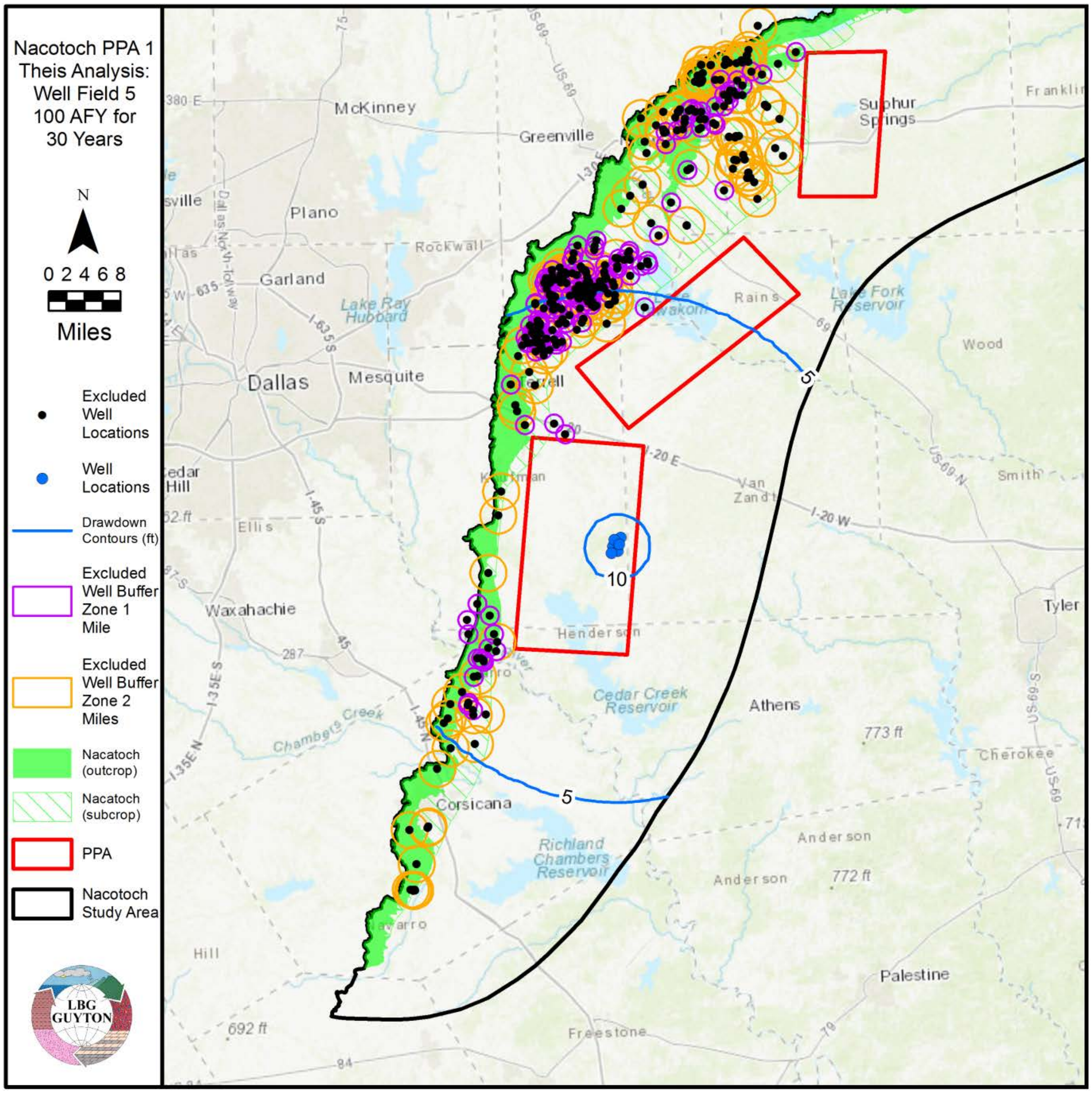


**Figure 14-5. Potential production area 1: 30-year drawdown at 100 acre-feet per year.**

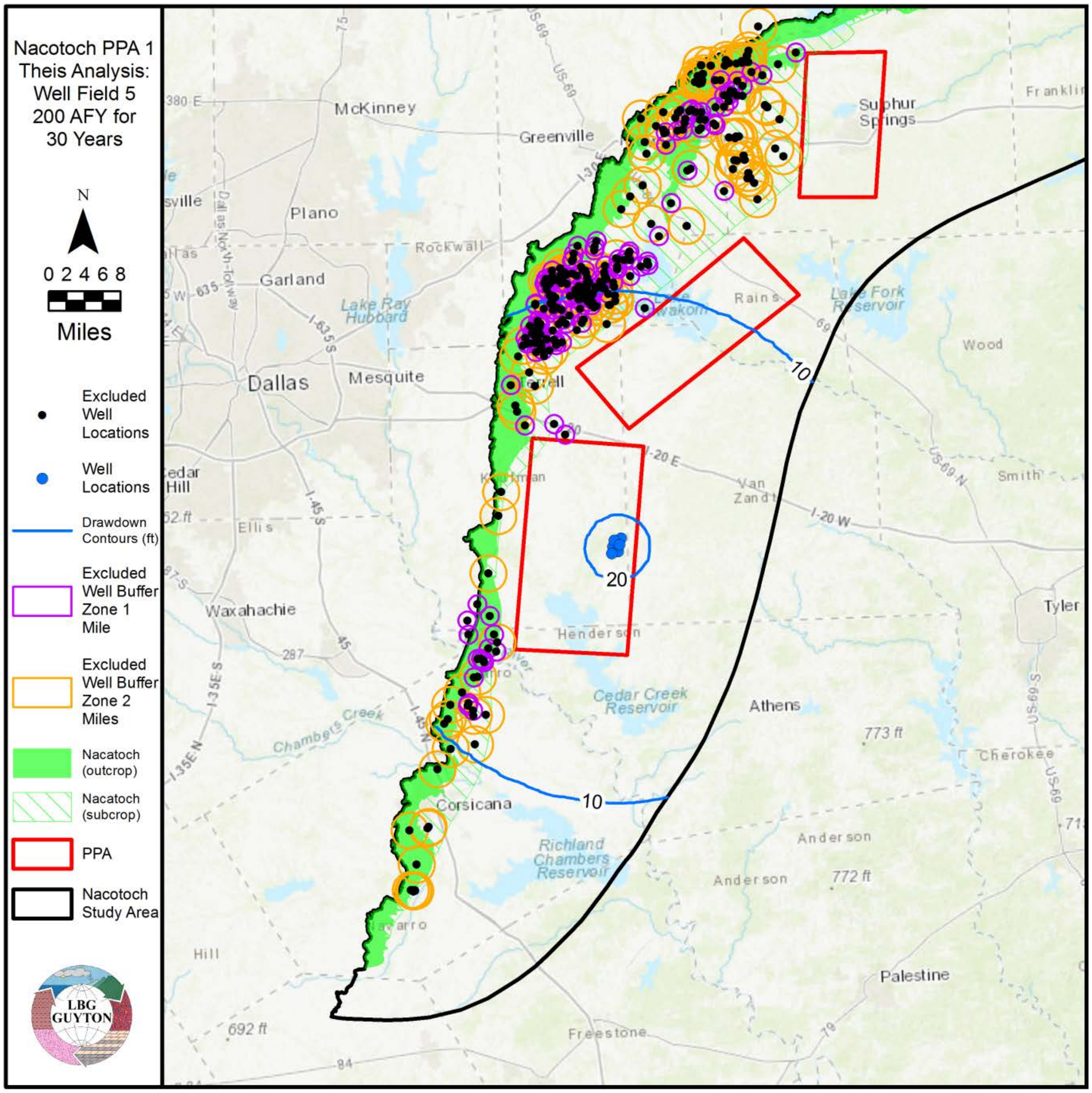


**Figure 14-6.** **Potential production area 1: 30-year drawdown at 200 acre-feet per year.**

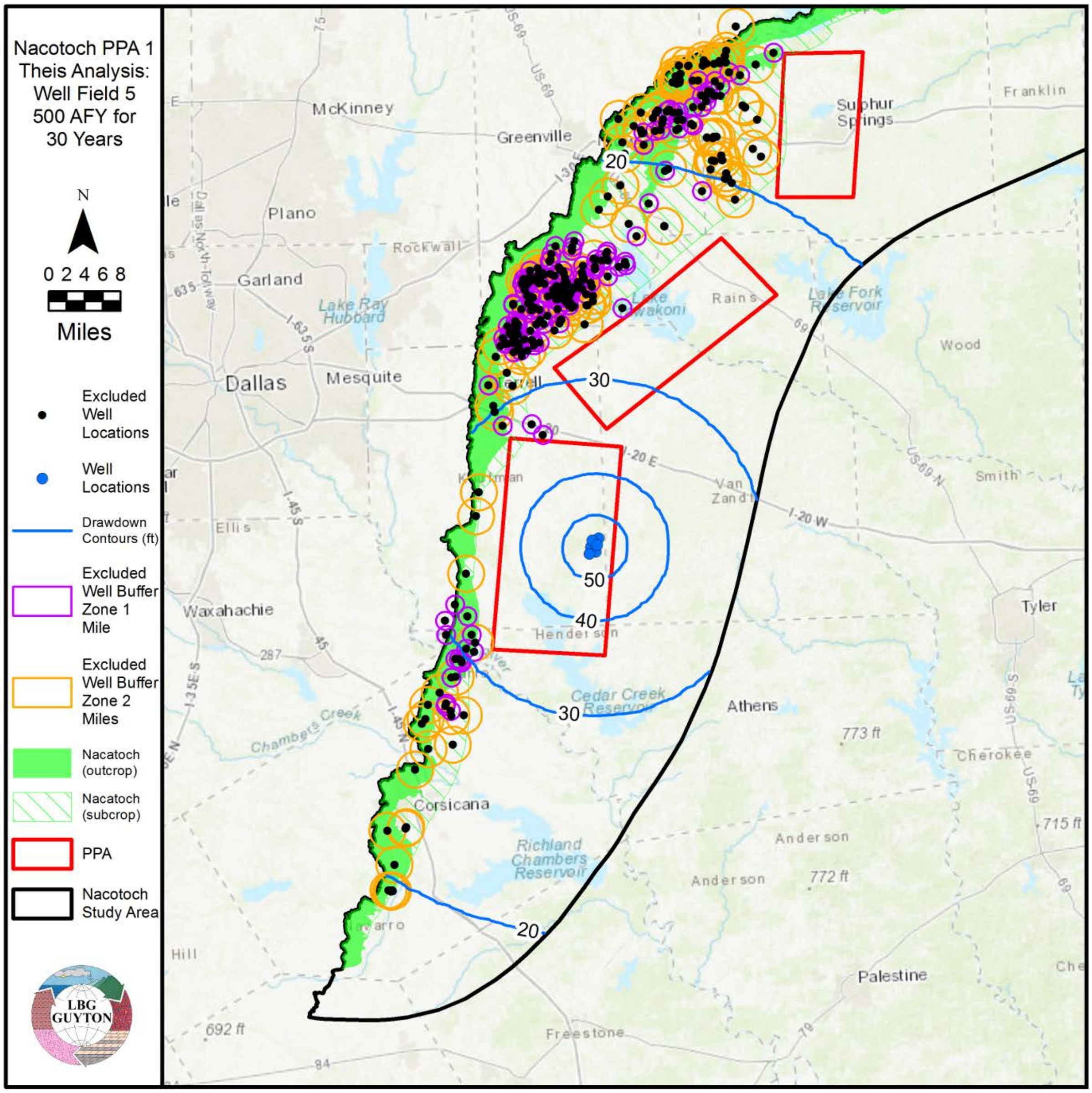


**Figure 14-7. Potential production area 1: 30-year drawdown at 500 acre-feet per year.**

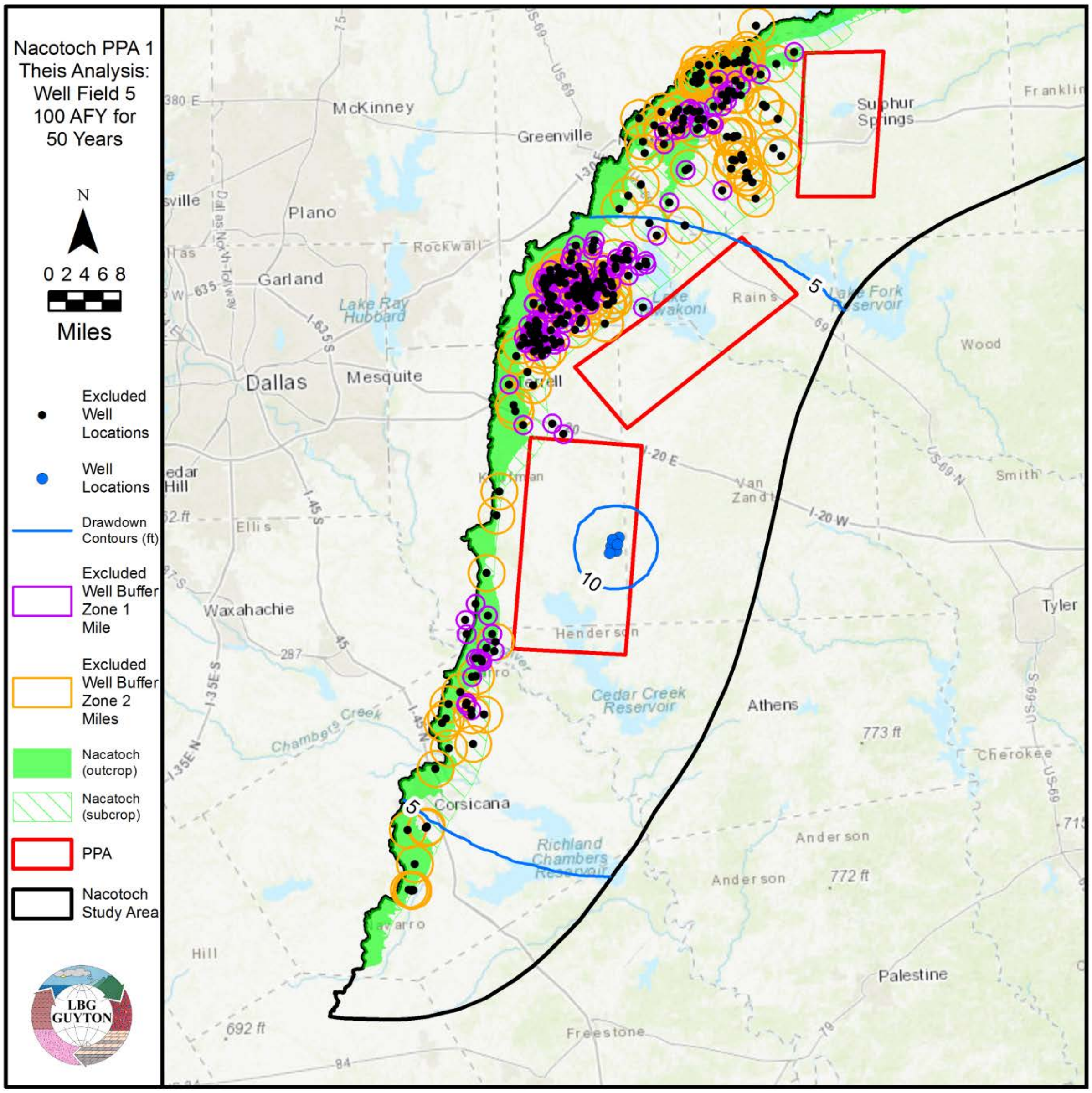


**Figure 14-8.** **Potential production area 1: 50-year drawdown at 100 acre-feet per year.**

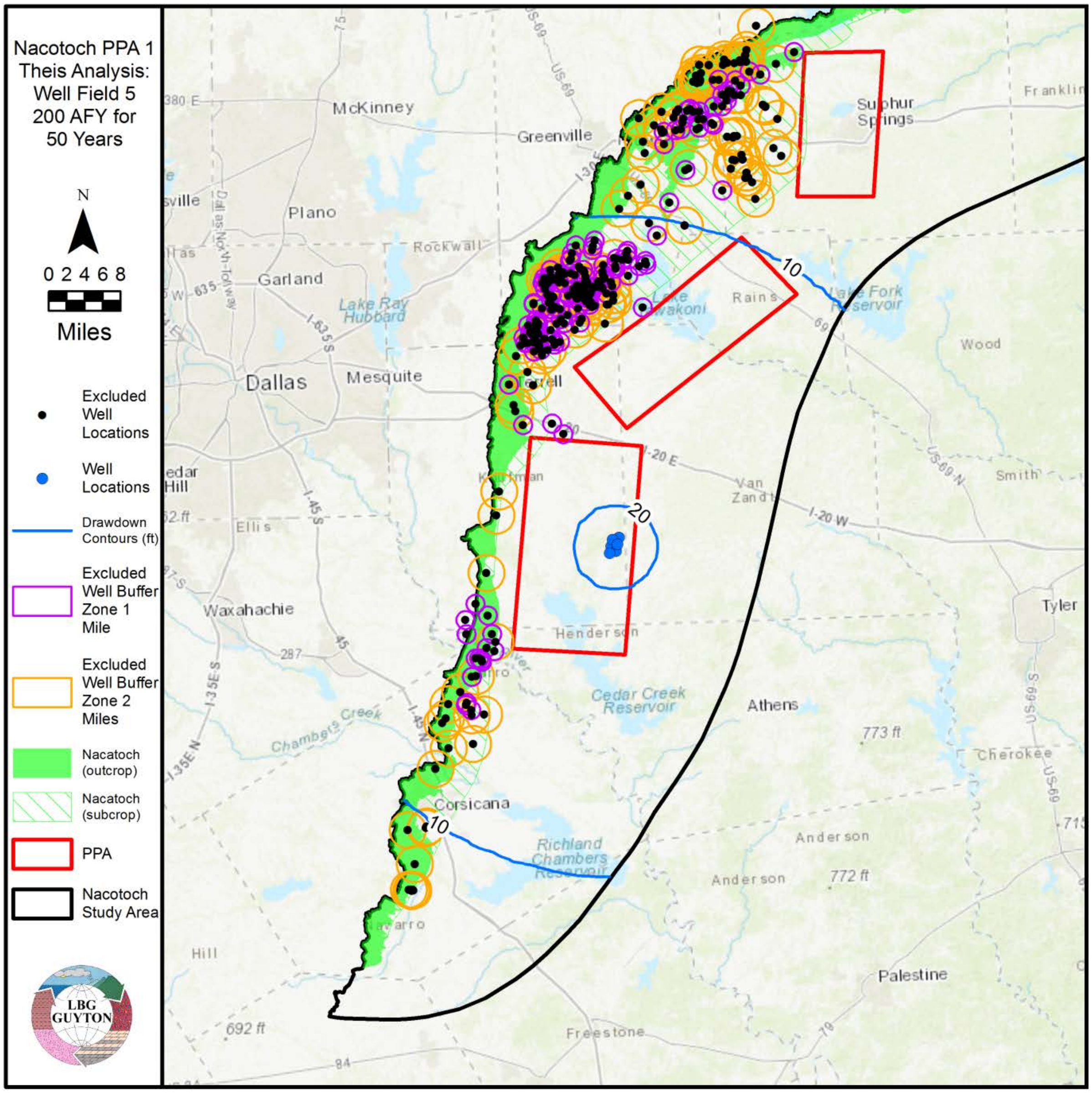


**Figure 14-9.** **Potential production area 1: 50-year drawdown at 200 acre-feet per year.**

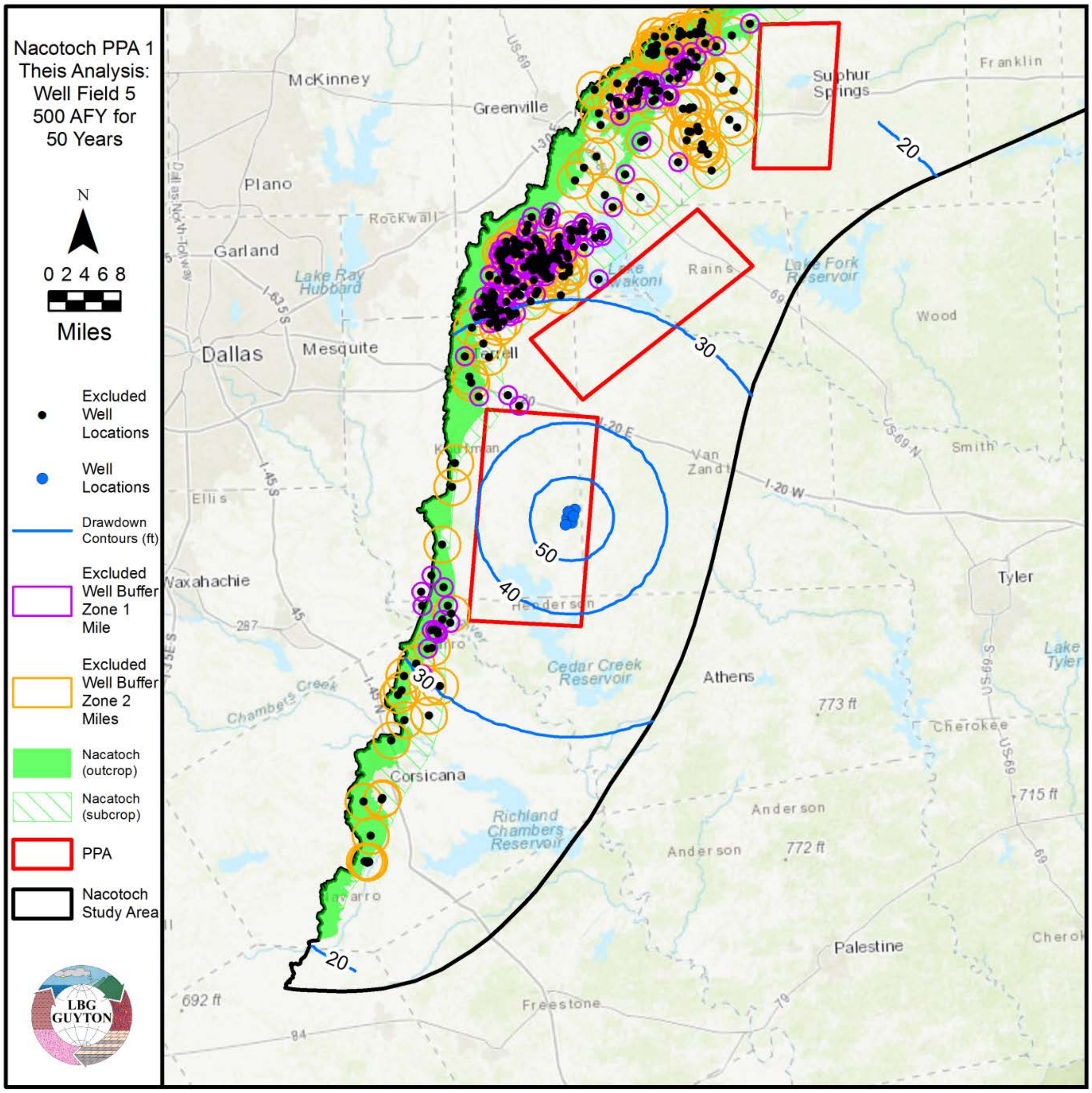


**Figure 14-10.** **Potential production area 1: 50-year drawdown at 500 acre-feet per year.**

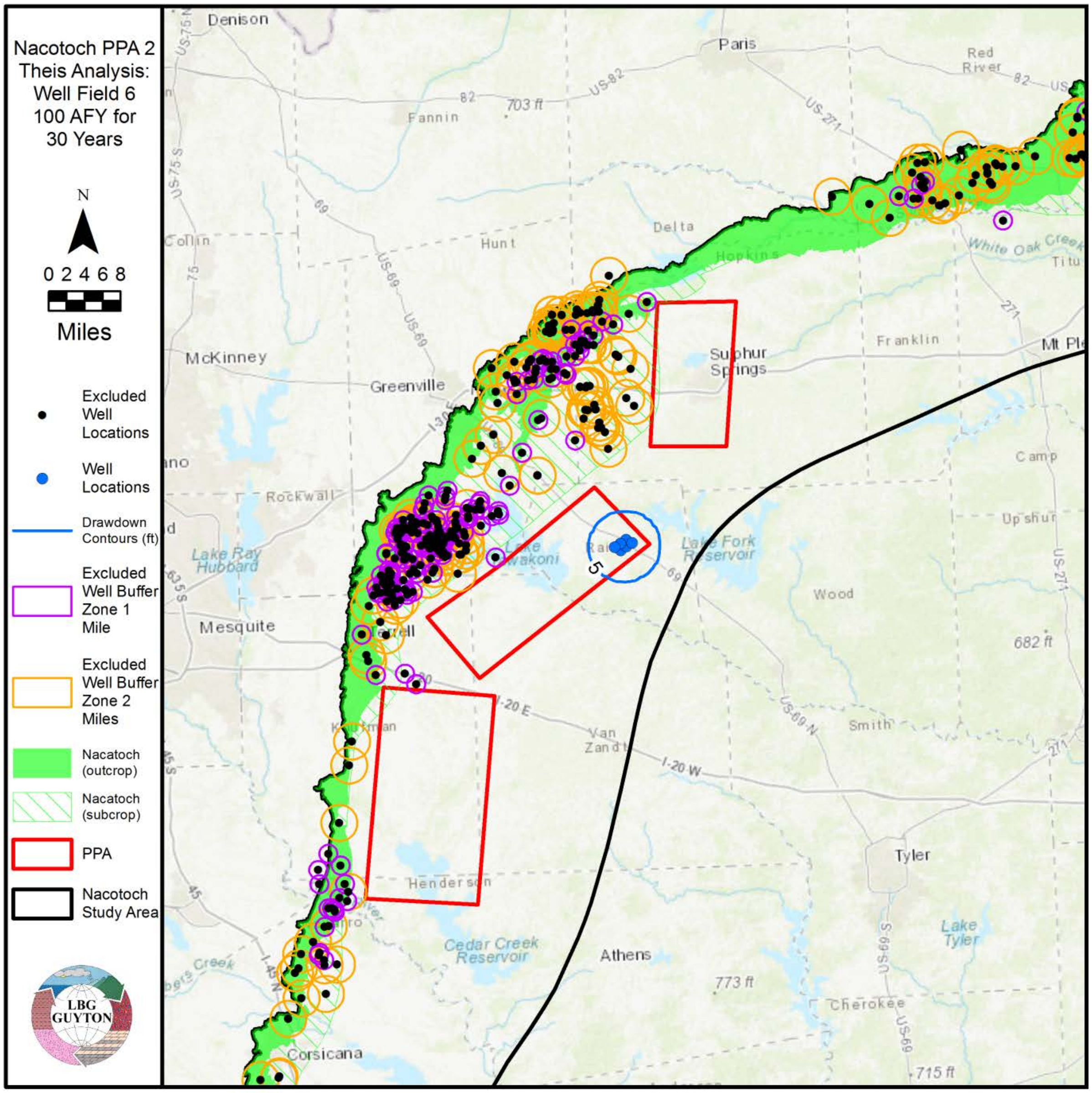


**Figure 14-11. Potential production area 2: 30-year drawdown at 100 acre-feet per year.**

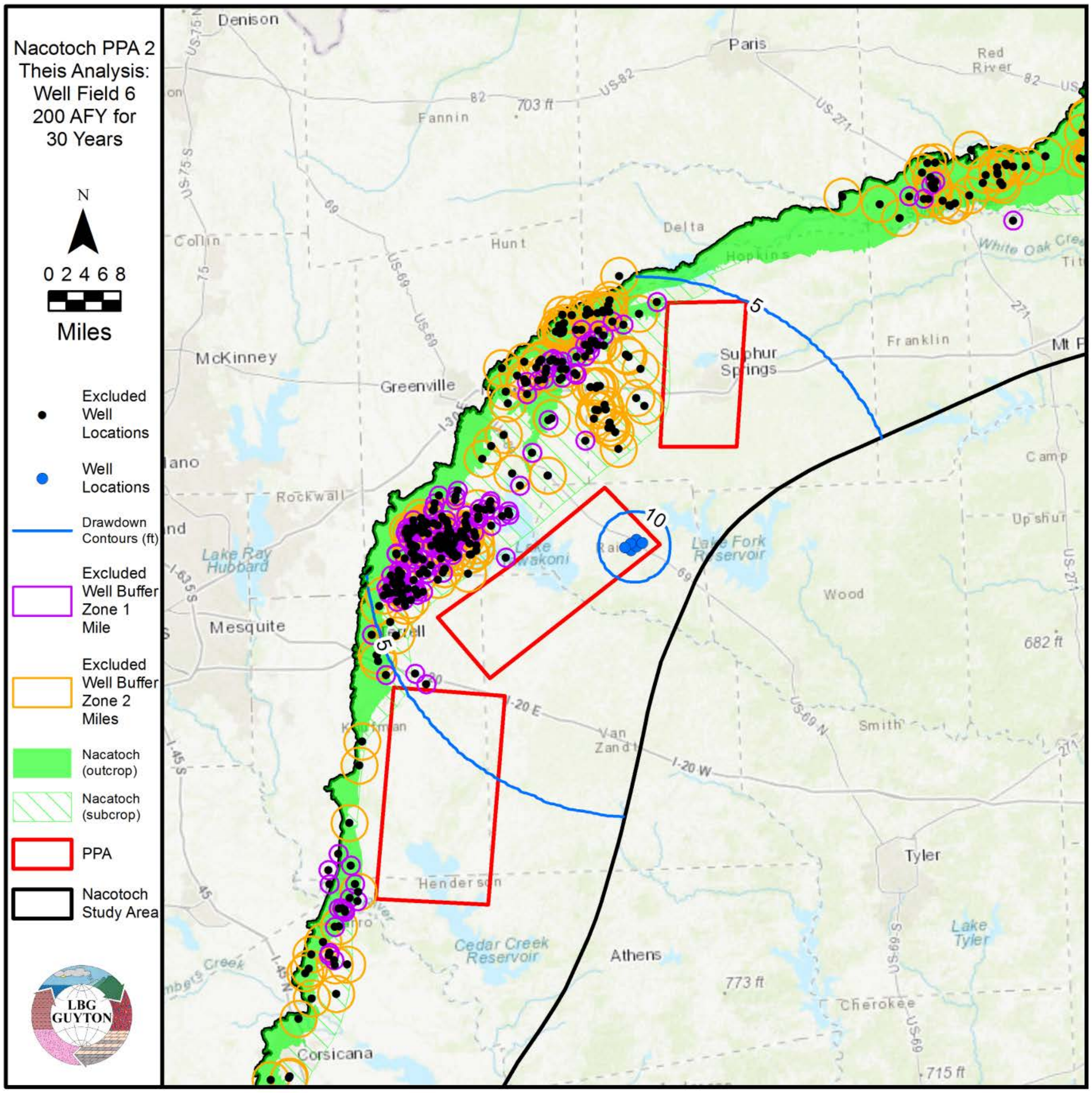


**Figure 14-12.** **Potential production area 2: 30-year drawdown at 200 acre-feet per year.**

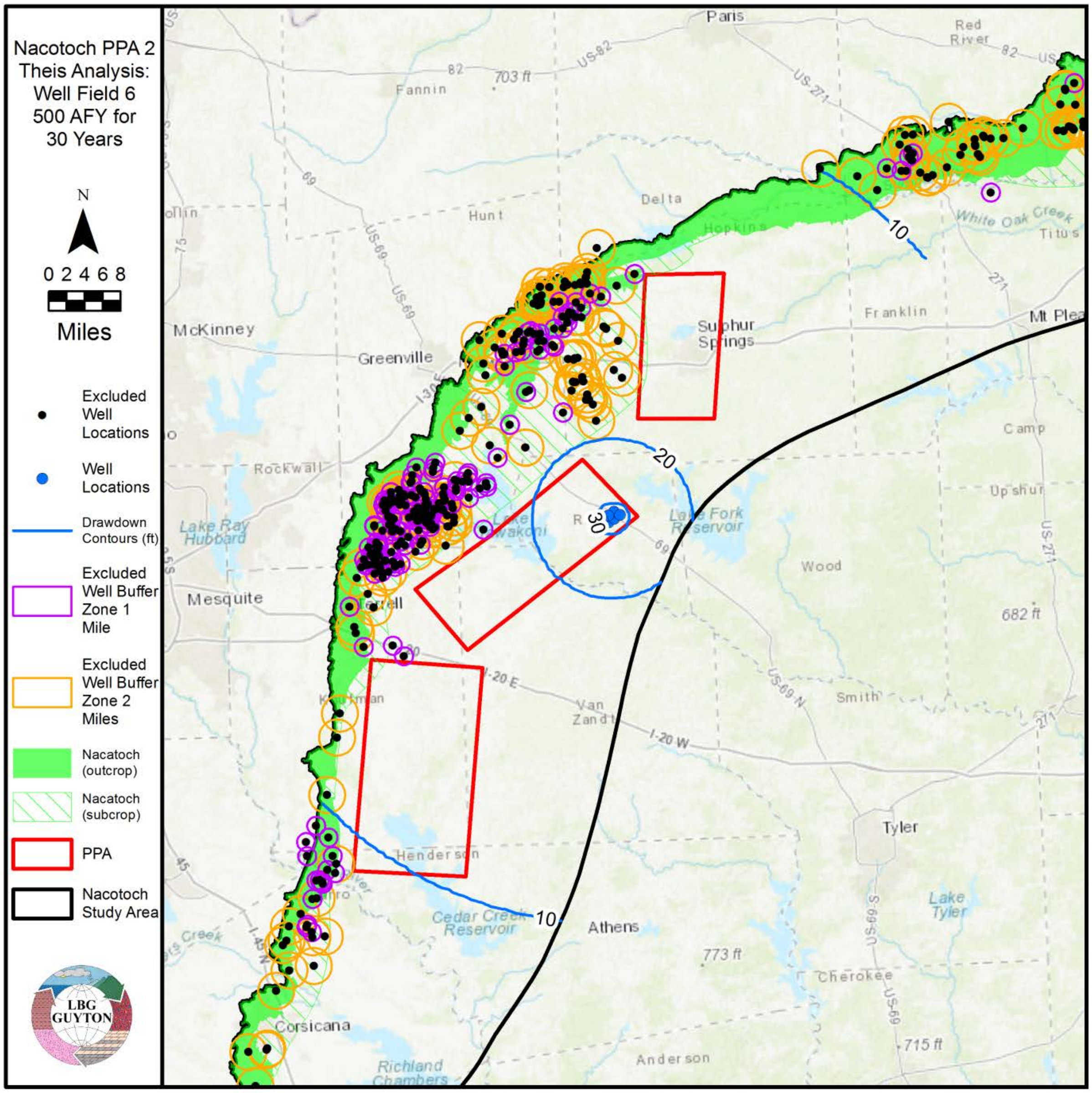


**Figure 14-13. Potential production area 2: 30-year drawdown at 500 acre-feet per year.**

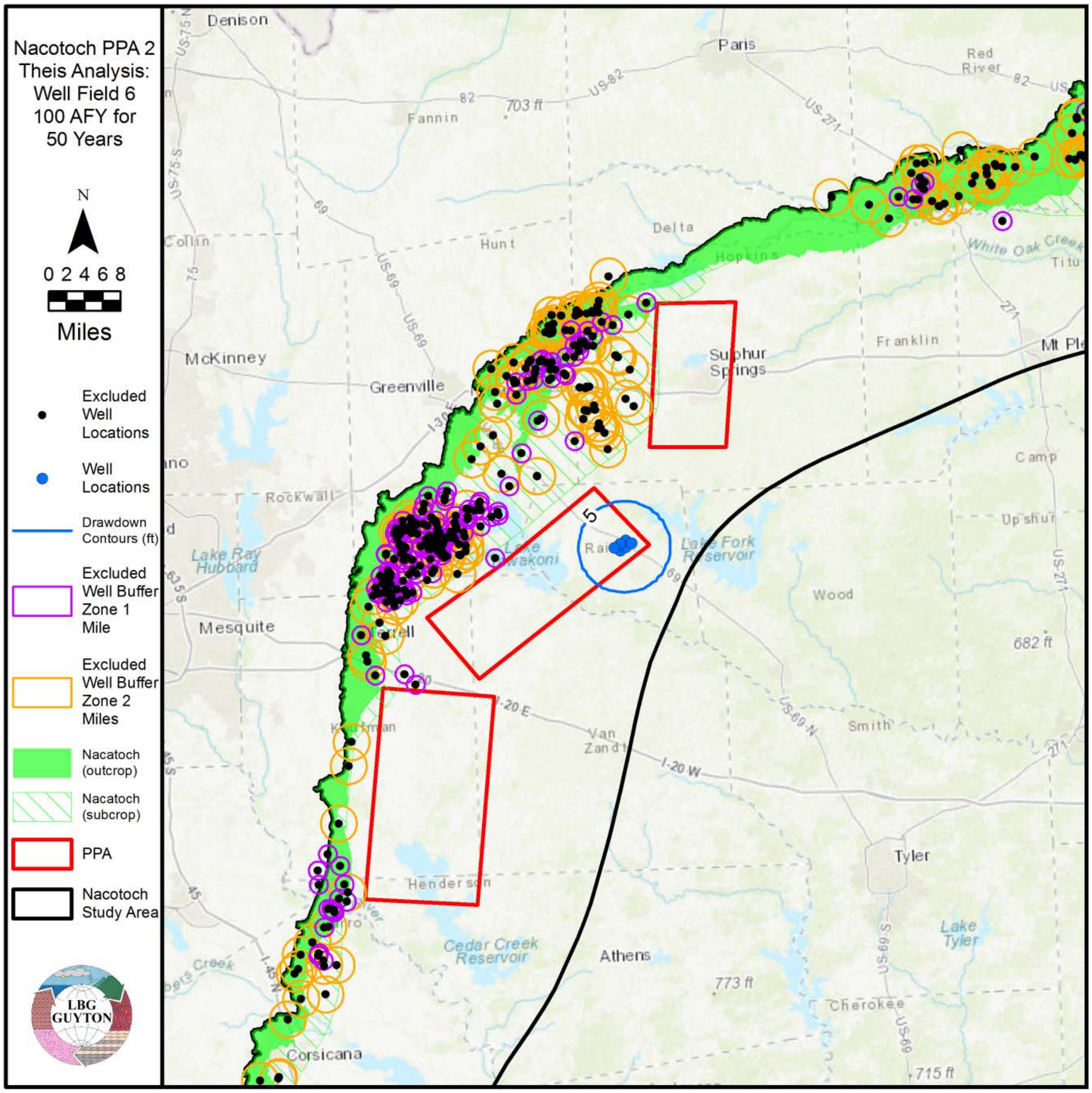


**Figure 14-14. Potential production area 2: 50-year drawdown at 100 acre-feet per year.**

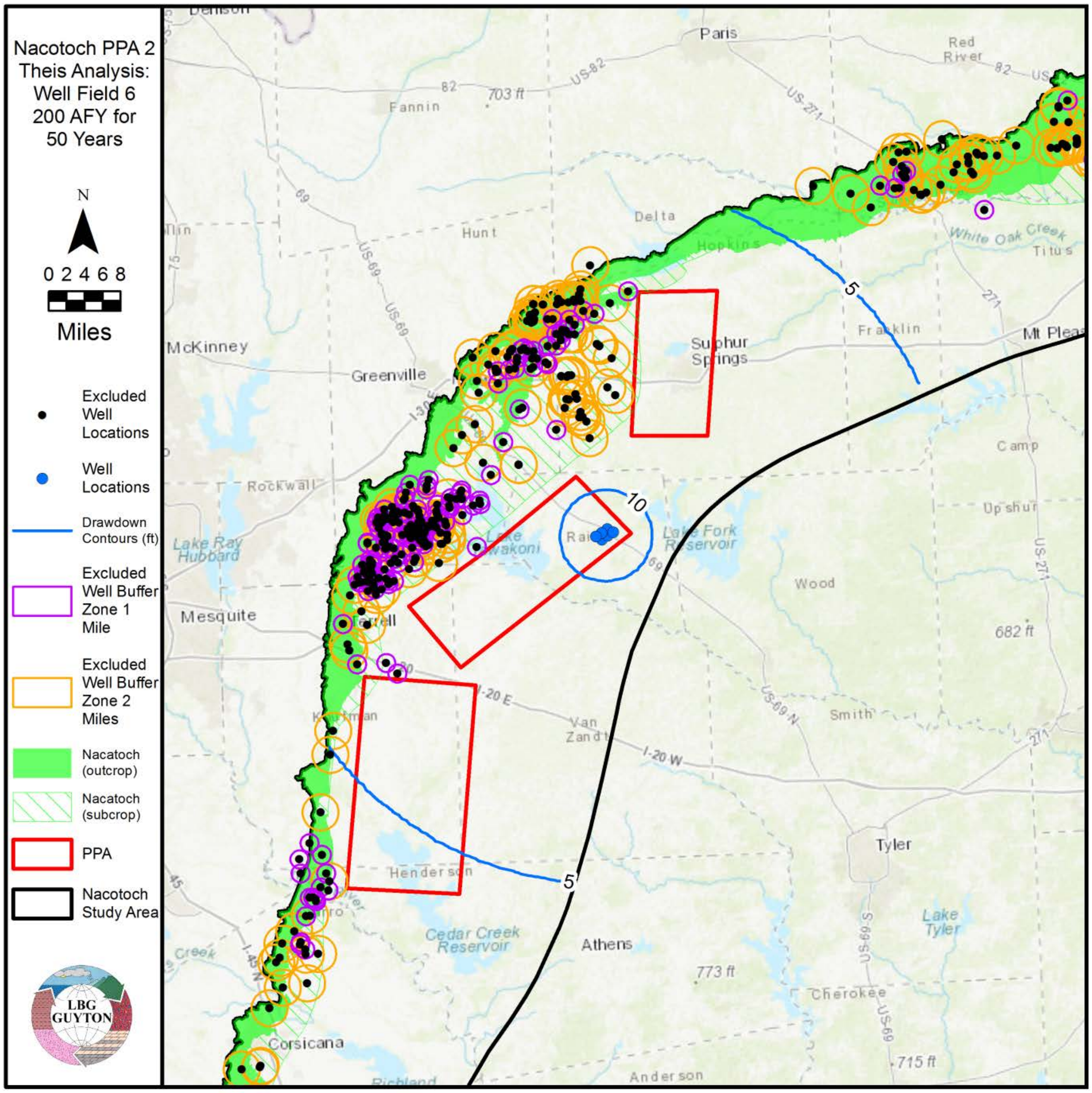


**Figure 14-15.** **Potential production area 2: 50-year drawdown at 200 acre-feet per year.**

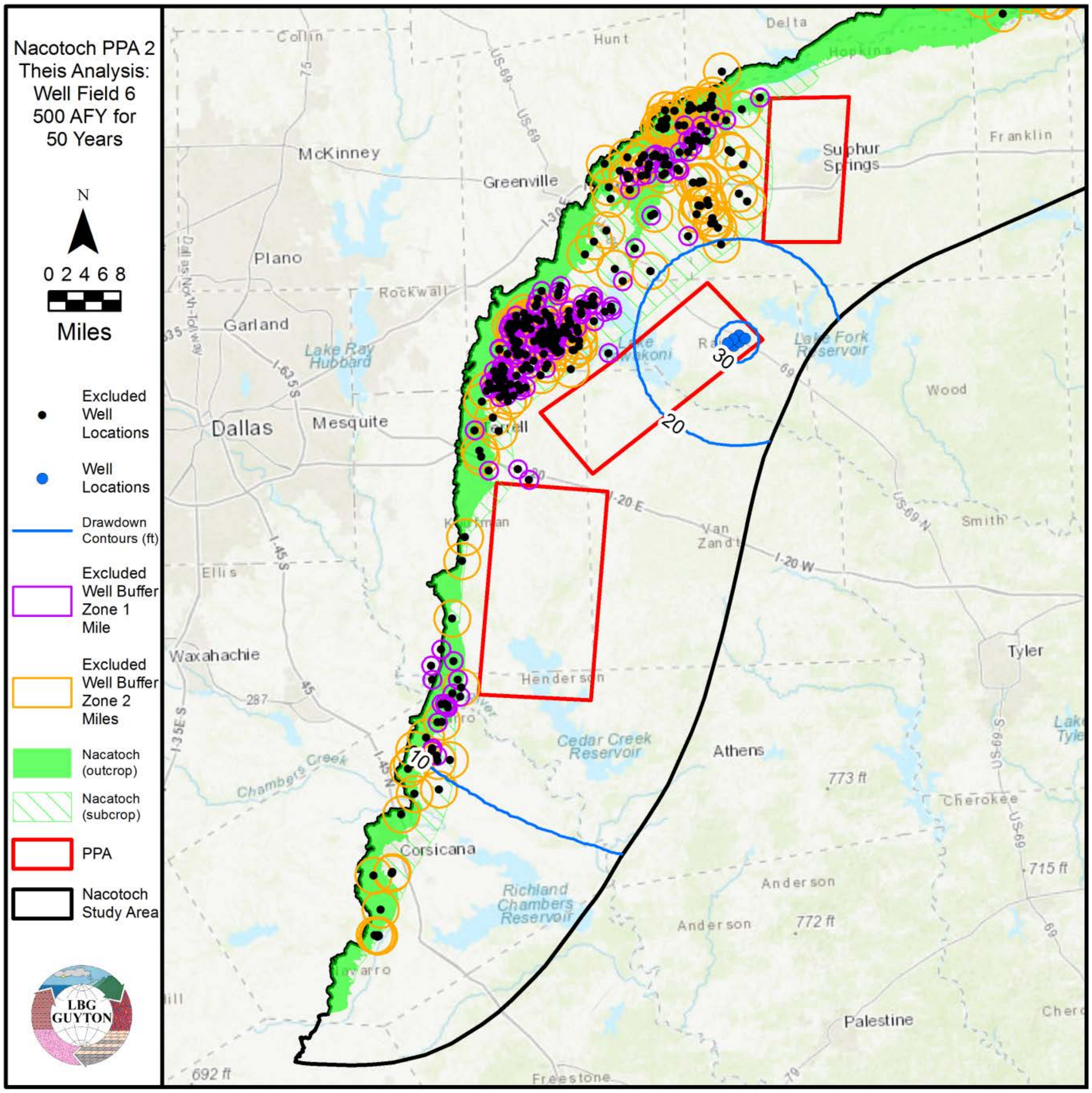


**Figure 14-16.** **Potential production area 2: 50-year drawdown at 500 acre-feet per year.**

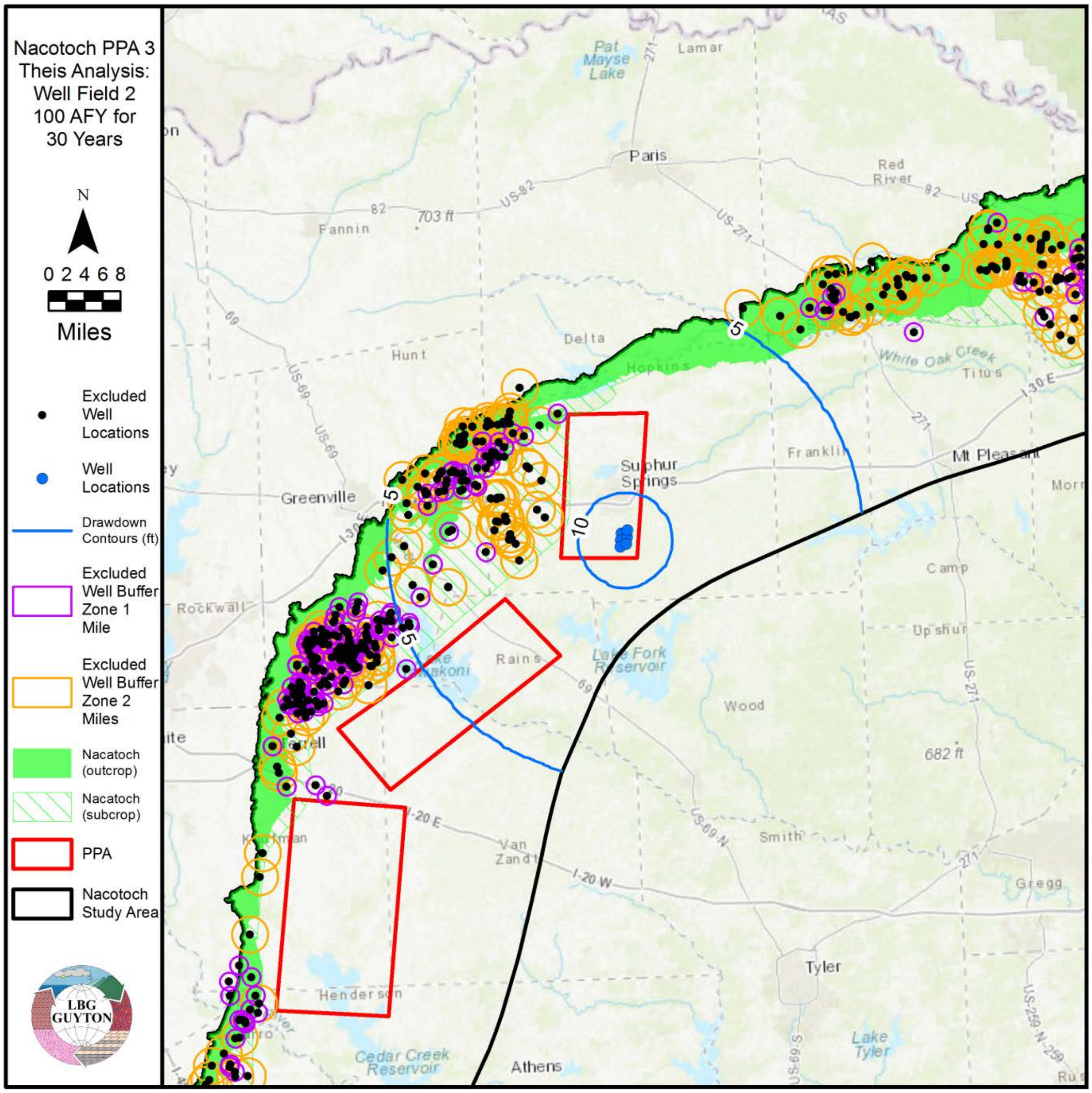


**Figure 14-17.** **Potential production area 3: 30-year drawdown at 100 acre-feet per year.**

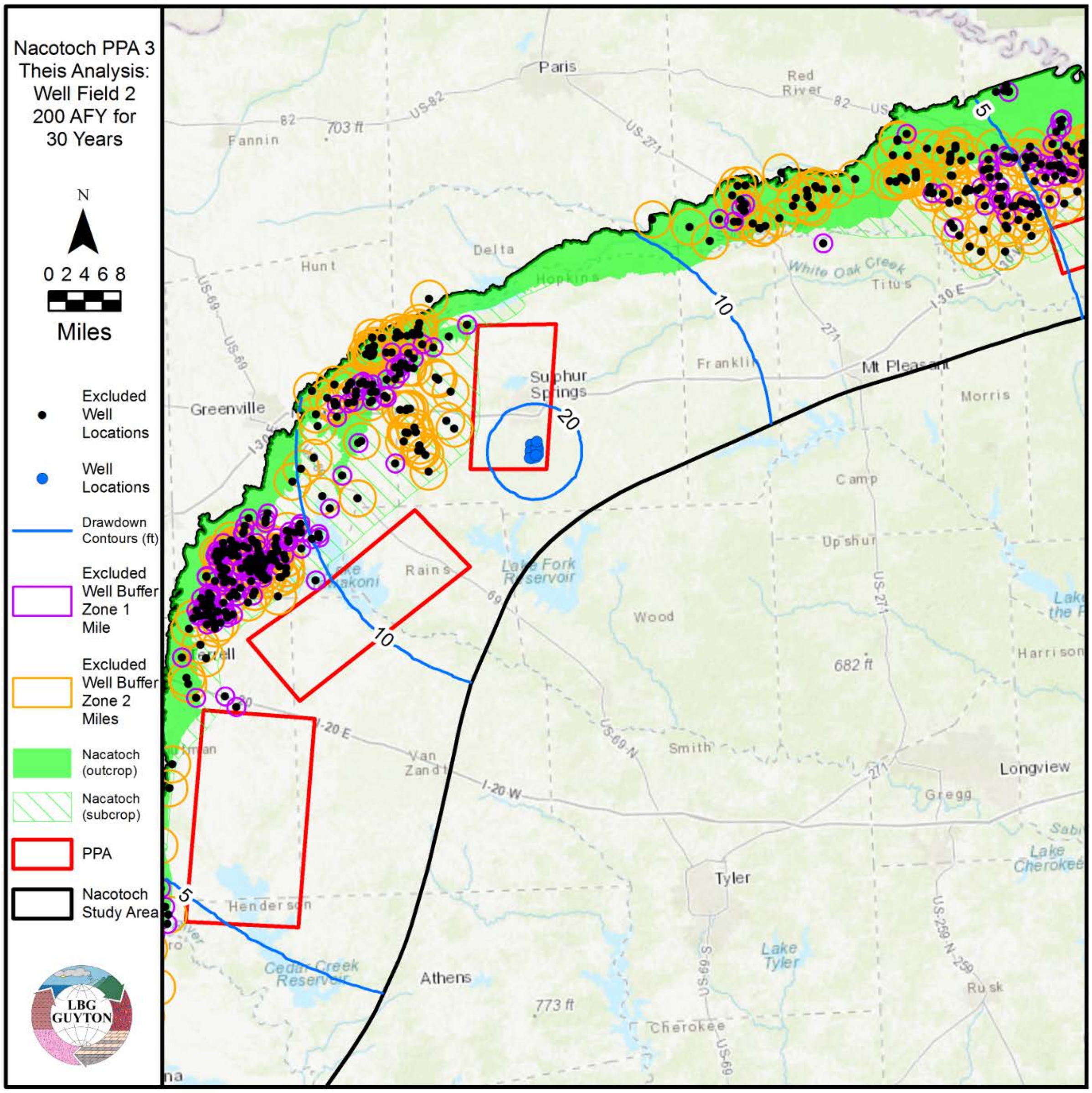


**Figure 14-18.** **Potential production area 3: 30-year drawdown at 200 acre-feet per year.**

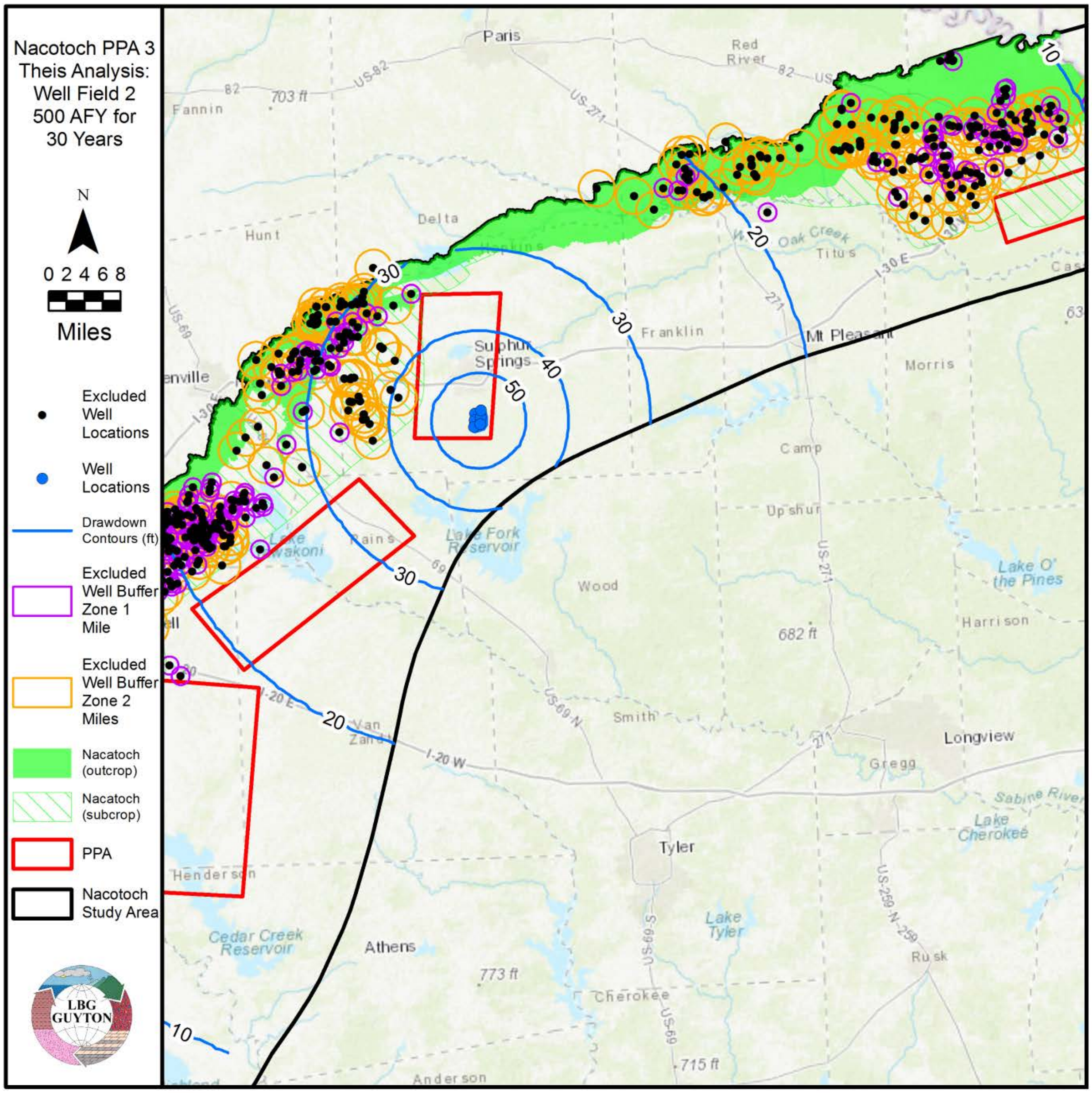


**Figure 14-19. Potential production area 3: 30-year drawdown at 500 acre-feet per year.**

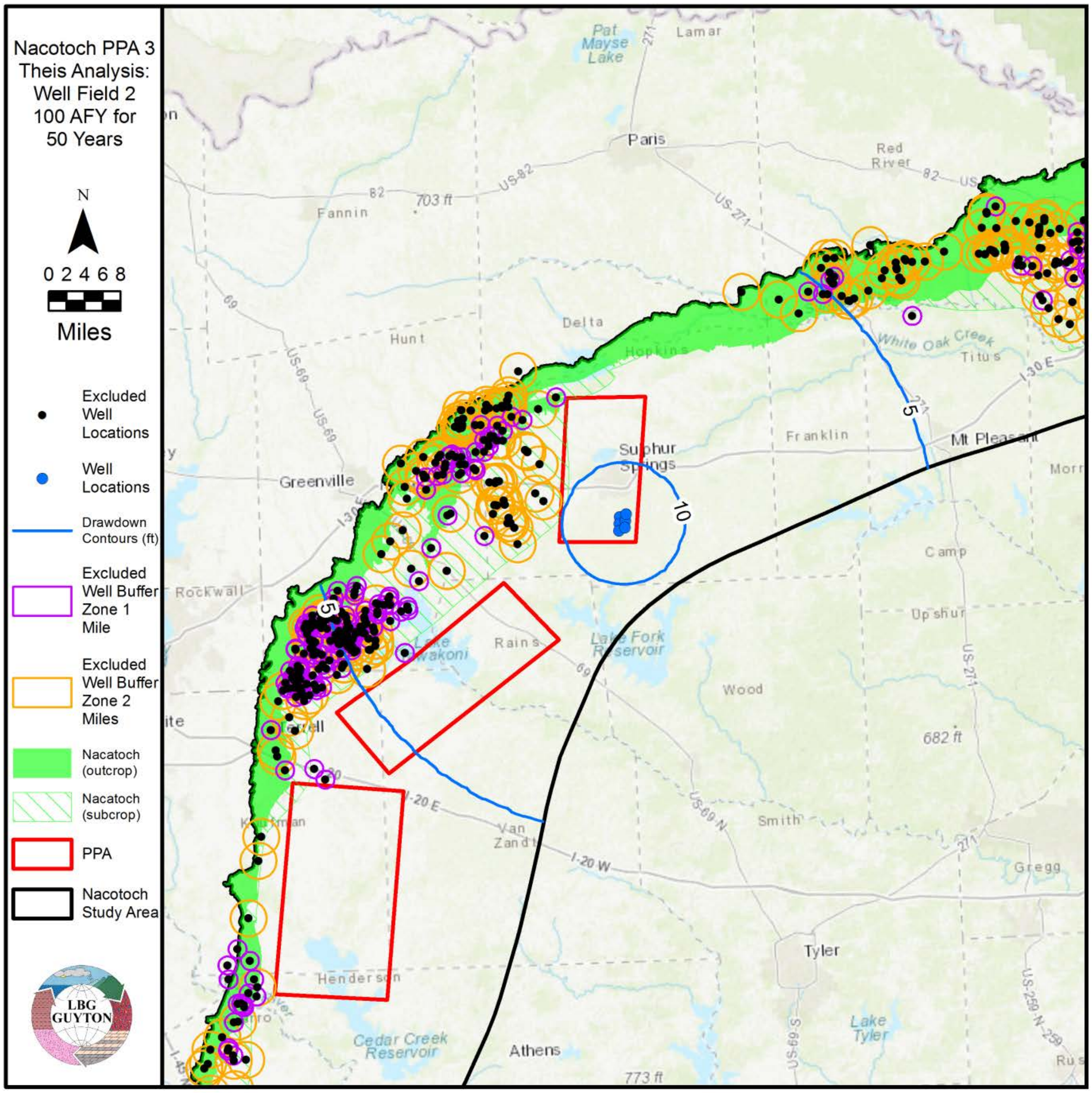


**Figure 14-20. Potential production area 3: 50-year drawdown at 100 acre-feet per year.**

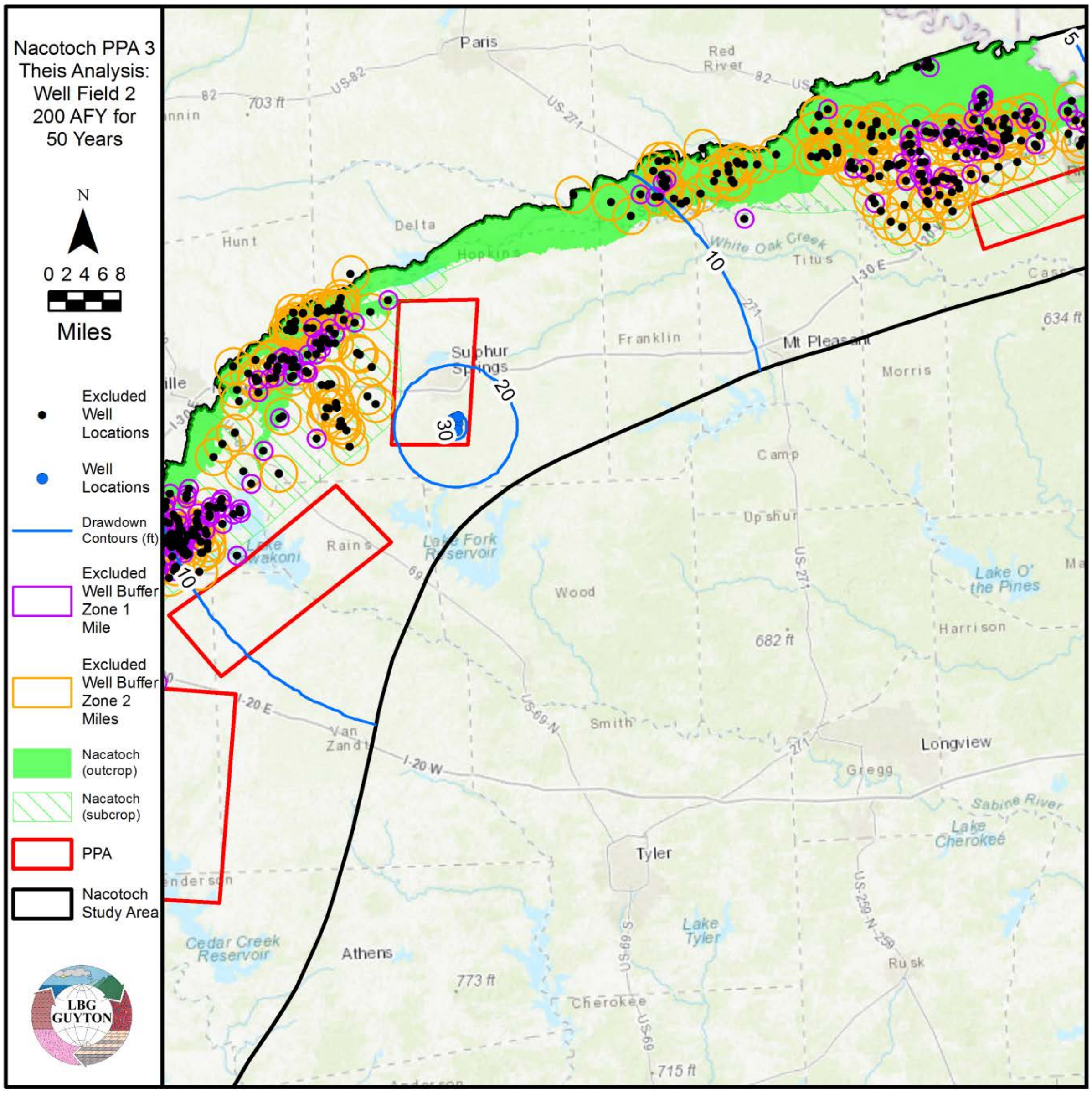


**Figure 14-21. Potential production area 3: 50-year drawdown at 200 acre-feet per year.**

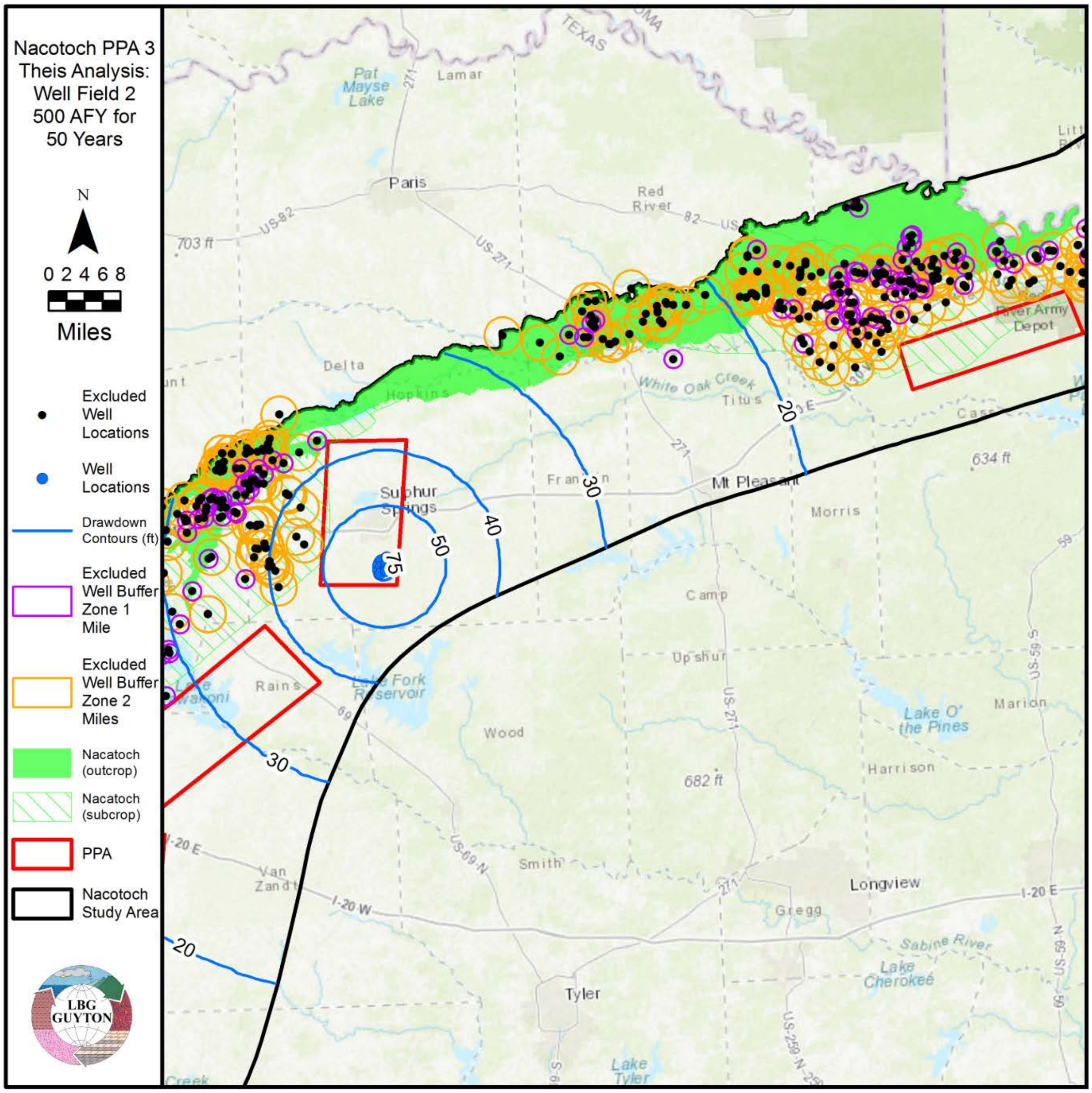


**Figure 14-22. Potential production area 3: 50-year drawdown at 500 acre-feet per year.**

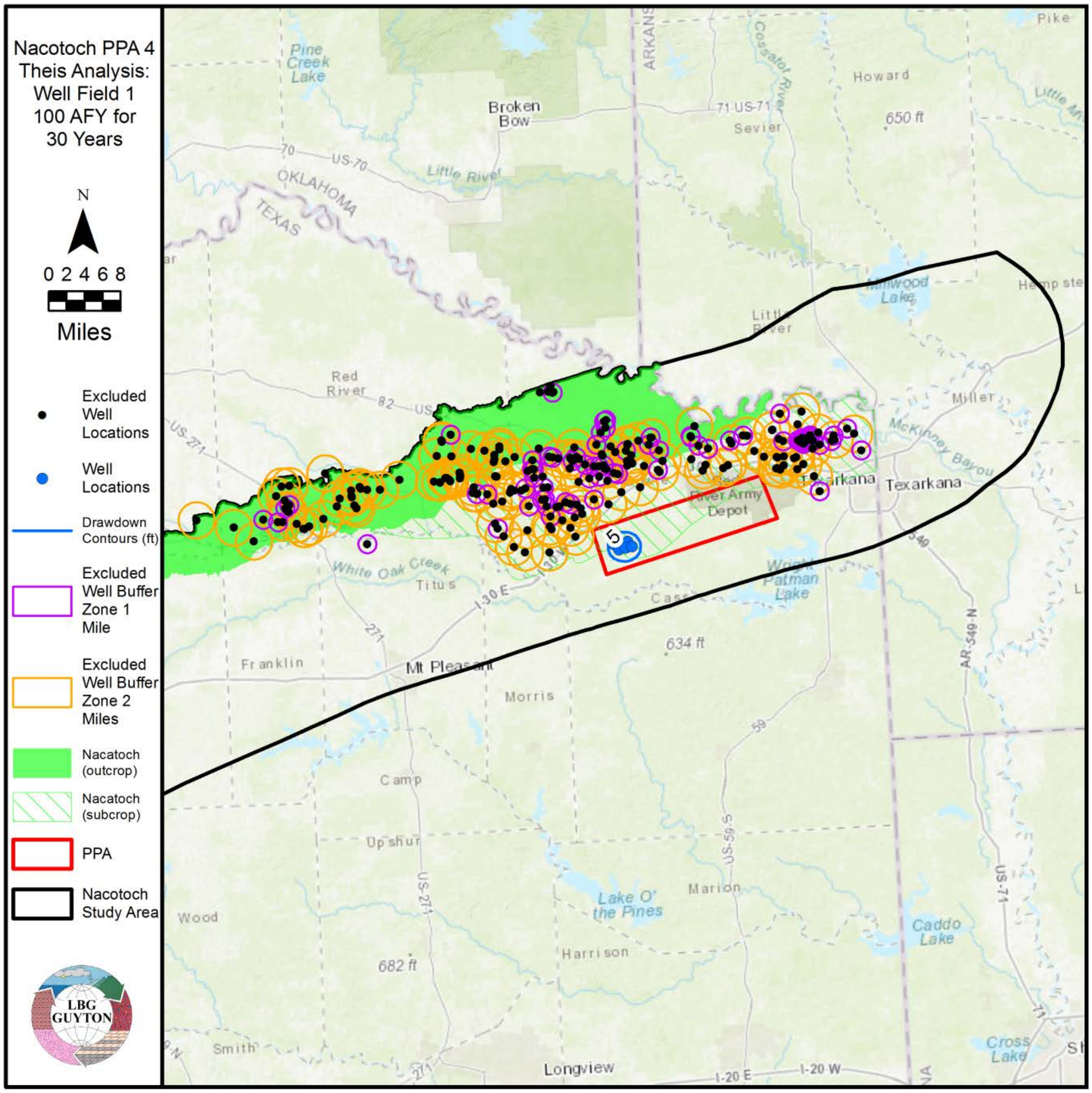


**Figure 14-23. Potential production area 4: 30-year drawdown at 100 acre-feet per year.**

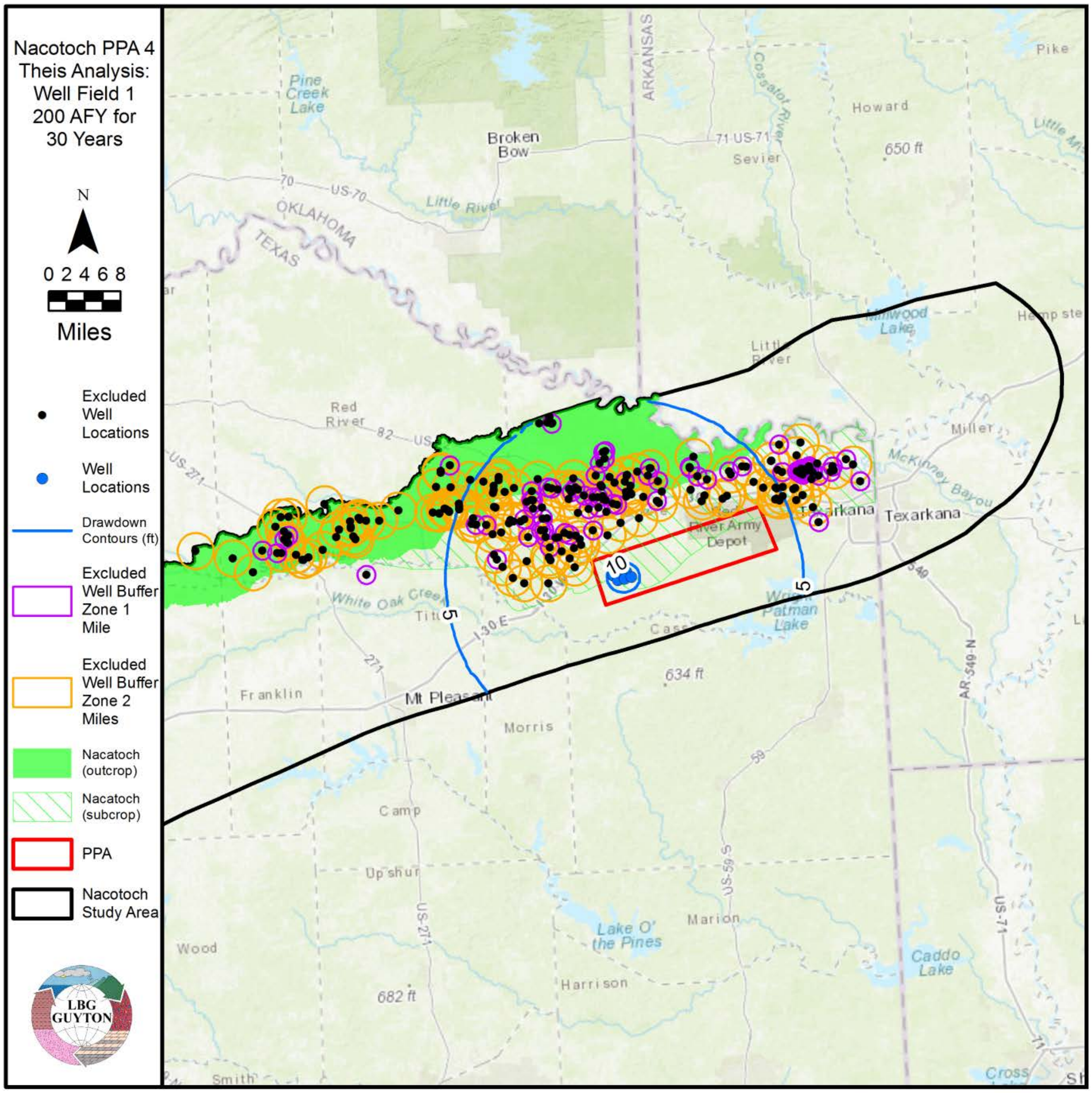


**Figure 14-24.** **Potential production area 4: 30-year drawdown at 200 acre-feet per year.**

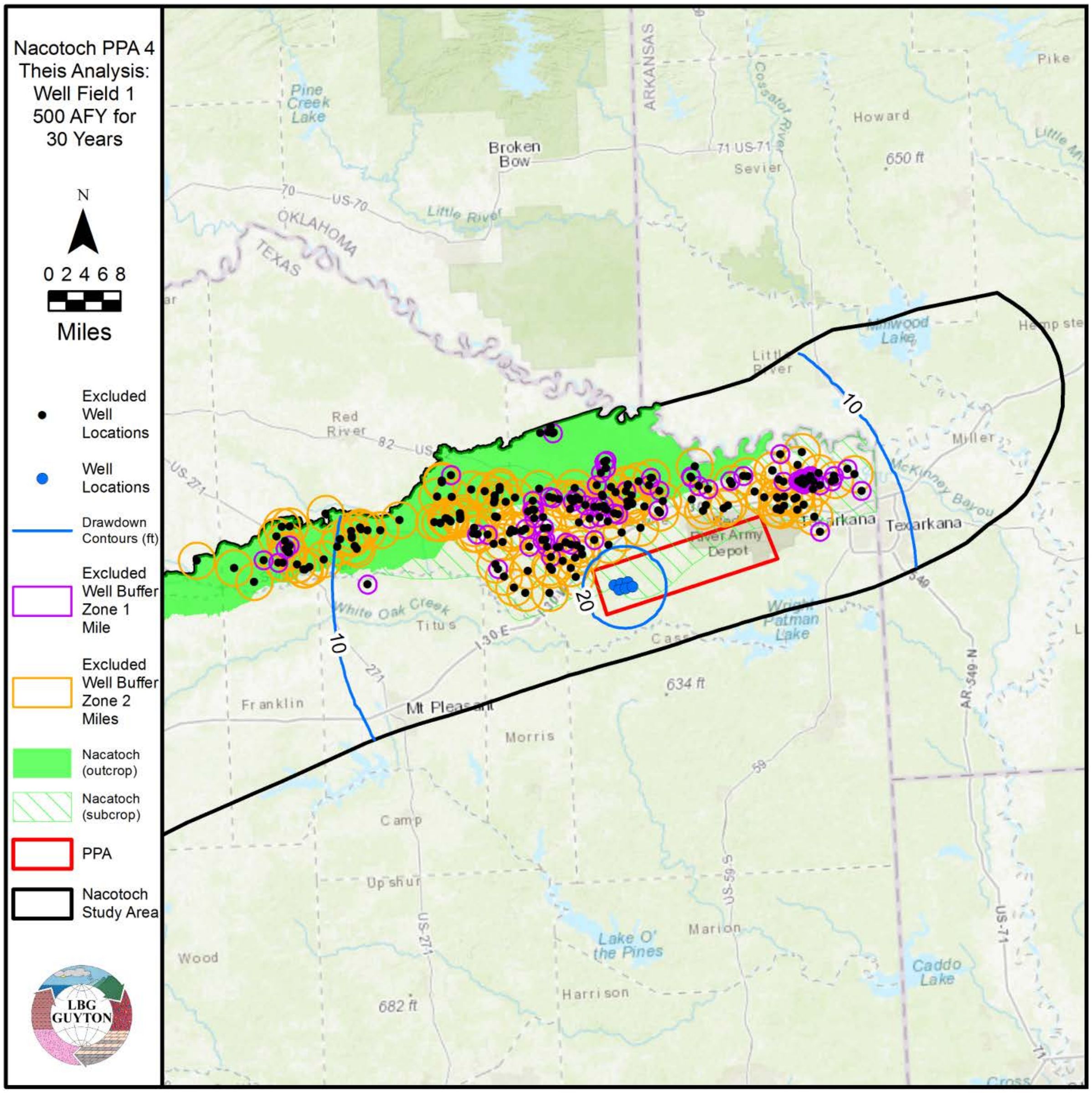


**Figure 14-25. Potential production area 4: 30-year drawdown at 500 acre-feet per year.**

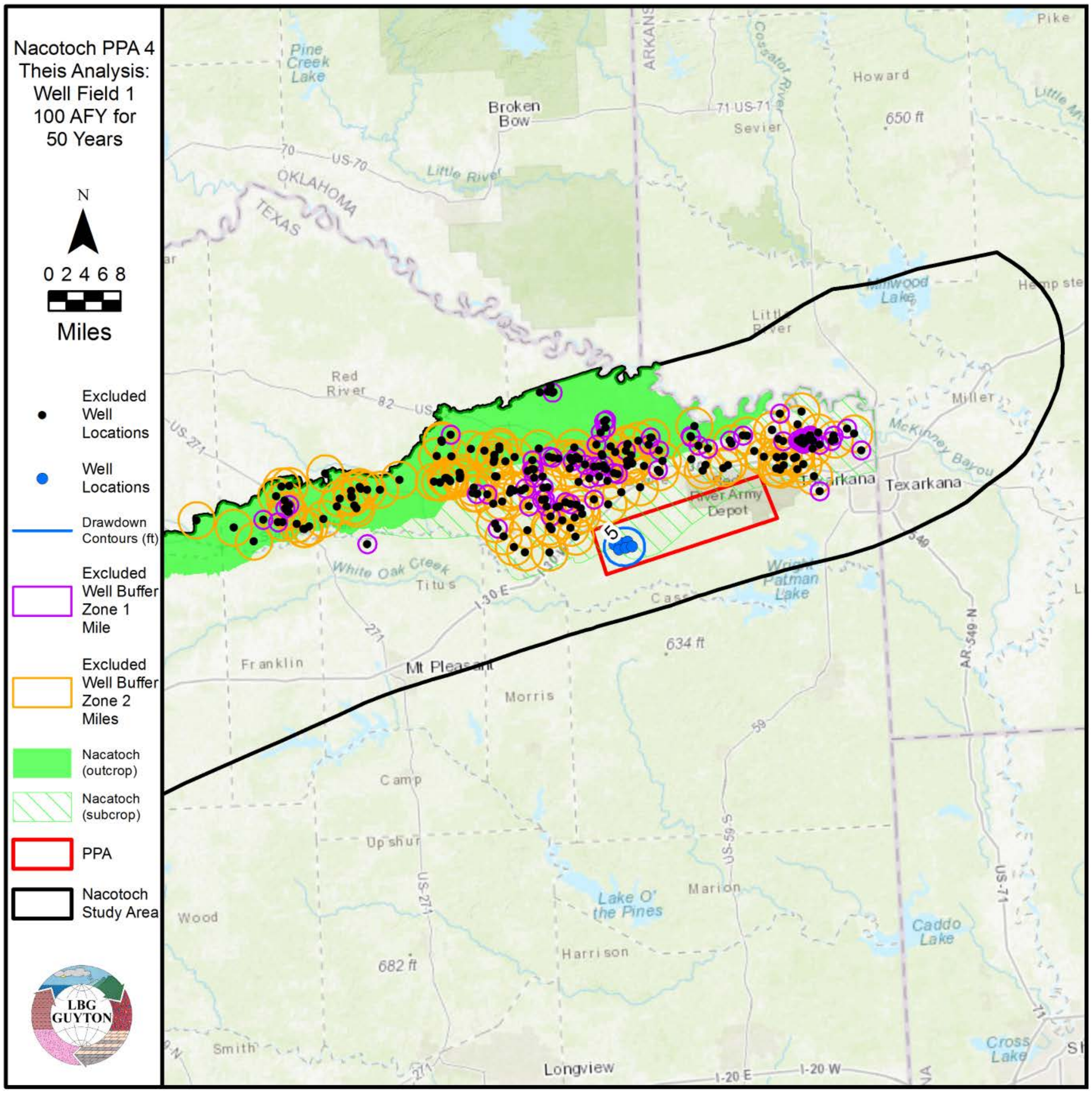


**Figure 14-26.** **Potential production area 4: 50-year drawdown at 100 acre-feet per year.**

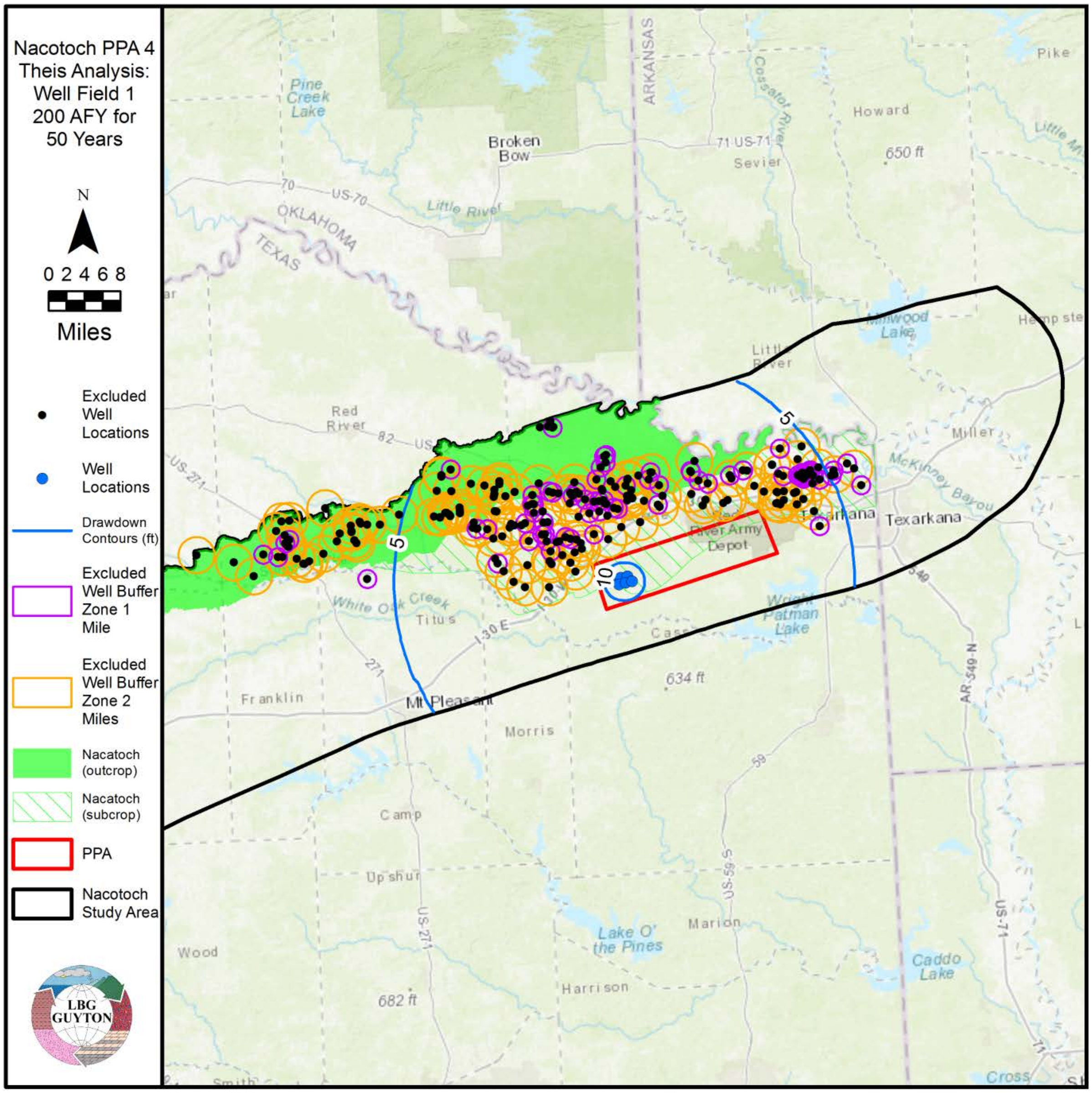


**Figure 14-27. Potential production area 4: 50-year drawdown at 200 acre-feet per year.**

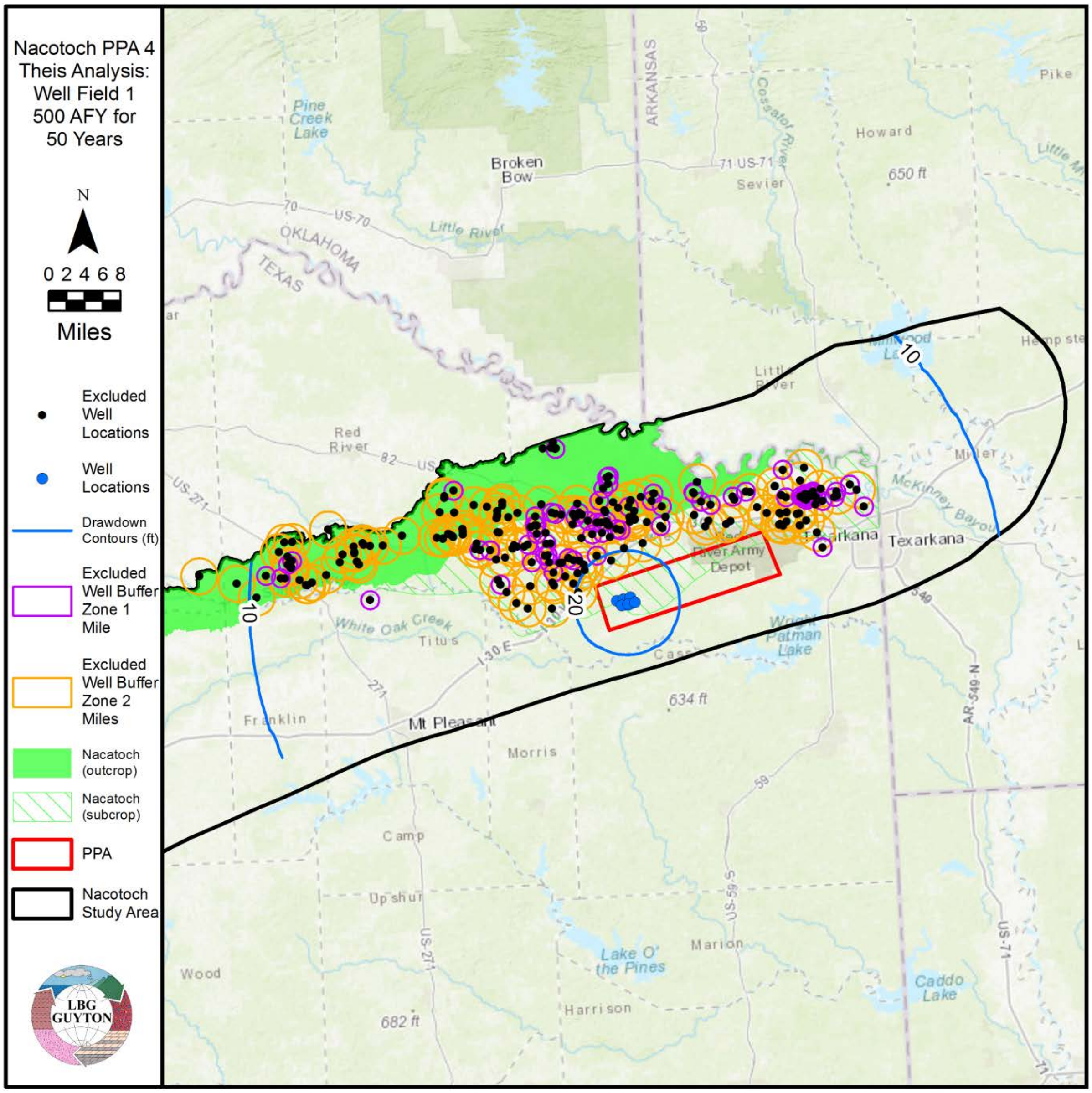


**Figure 14-28. Potential production area 4: 50-year drawdown at 500 acre-feet per year.**

## 14.3 Limitations

One major limitation of this study was the lack of geophysical log data and water sample data that were able to be paired for the calibration of total dissolved solids concentrations. Diligent effort was made to find any and all existing pairs for this purpose; however, resulting matches were limited.

# 15 Future Improvements

Further investigative efforts that would be invaluable for the application of the results of this project would be test hole drilling and aquifer testing within the potential production areas to verify and/or revise the predicted production volumes that have been calculated for this project. Water quality sampling and geophysical logging of any text holes would also be essential to confirming and/or revising expected total dissolved solids concentrations.

# 16 Conclusions

Using the exclusion criteria stated in House Bill 30, four potential production areas were delineated in areas outlying the excluded areas. Pumping impacts from the potential production areas were estimated using low, medium and high-volume pumping scenarios of 100, 200 and 500 acre-feet per year assuming both 30 and 50 years of production. Theis drawdown analysis was performed to characterize the effect pumping in these areas would have on existing exclusion wells. Numerous well fields were modeled for each potential production area. The well fields selected for each potential production area are those wellfields which have the least extensive amount of up-dip drawdown. The approximate minimum drawdowns are based on the 100 acre-feet 30-year scenarios, and maximums are based on the 500 acre-feet 50-year scenarios. Potential production areas 2 and 4 appear to have the least impact to up-dip exclusion wells with 0 to 20 feet of drawdown. Volume estimates were not calculated for the potential production areas.

To monitor pumping volumes from wells completed in brackish production areas, it is recommended that 1) meters be installed on each well to track pumping volumes, 2) metered volumes are recorded monthly, and 3) monitoring wells are designated to track water level changes resulting from brackish production. Monitoring wells should be located between existing users excluded by House Bill 30 criteria and brackish production wells. The number of monitoring wells located peripheral to brackish pumping that are necessary to characterize the impacts of pumping upon existing users will be driven by several site-specific factors, including (but not limited to) distance to nearest exclusion well, monitoring well candidate locations, as well as landowner and property access issues.

The modeling results indicate that there are approximately 5,445,315 acre-feet of in-place groundwater within the Nacatoch Aquifer in the project area. An estimated 574,761 acre-feet, or eleven percent, of the available groundwater is within the fresh water zone. Slightly saline and moderately saline water estimated volumes are 1,768,713 acre-feet (32 percent) and 1,637,529 acre-feet (30 percent), respectively. The very saline estimated volume within the project area is estimated to be 1,464,312 acre-feet (27 percent) of the total estimated volume.

# 17 Acknowledgements

We would like to thank the Innovative Water Technologies staff at TWDB for their guidance and patience during the preparation and completion of this project, specifically: Jean Perez, John Meyer and Erika Mancha. Technical consulting staff which made significant contributions to this project include: Lou Fleischhauer, Matthew Wise, Peter George and Peter Schulmeyer (Collier Consulting, Inc.); Scott Hamlin, Bridget Scanlon, J.P. Nicot and Amy Banerji (The University of Texas Bureau of Economic Geology); and Brant Konetchy (LBG-Guyton Associates). We would also like to acknowledge the Texas State Legislature for providing the funding for this project and making this work possible.

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Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

| State well number | Owner name | Primary water use | Well depth (ft) | County name |
|---|---|---|---|---|
| 1625901 | M. R. Drum | Domestic | 120 | Red River |
| 1625902 | Alton Kenney | Domestic | 120 | Red River |
| 1625903 | Dan King | Domestic | 60 | Red River |
| 1626701 | Buford Ward | Domestic | 195 | Red River |
| 1626801 | M. F. Anderson | Domestic | 200 | Red River |
| 1626802 | M. T. Story | Domestic | 48 | Red River |
| 1626902 | Joe Yates | Domestic | 80 | Red River |
| 1626903 | R. E. Stanley | Domestic | 40 | Red River |
| 1626904 | C. L. Jackson | Domestic | 150 | Red River |
| 1626906 | F. C. Stevens | Domestic | 60 | Red River |
| 1627701 | Ms. A. Brower | Domestic | 160 | Bowie |
| 1627802 | Mable Garland | Domestic | 100 | Bowie |
| 1628802 | Loyd Yates | Domestic | 200 | Bowie |
| 1628803 | Charles Carey | Domestic | 140 | Bowie |
| 1628901 | Paul Goodwin | Domestic | 190 | Bowie |
| 1628902 | Richard LaGwinn | Domestic | 200 | Bowie |
| 1629701 | A.R. Anderson | Domestic | 150 | Bowie |
| 1629702 | John Warren | Domestic | 120 | Bowie |
| 1629903 | Alberta Phillips | Domestic | 143 | Bowie |
| 1630802 | T.L. Sellers | Domestic | 587 | Bowie |
| 1630903 | Jimmie Daniels | Domestic | 164 | Bowie |
| 1631501 | C.M. Gay | Domestic | 320 | Bowie |
| 1631701 | Mrs. Byron Berkman | Domestic | 1100 | Bowie |
| 1631702 | Mrs. Byron Barkman | Domestic | 520 | Bowie |
| 1631802 | Mrs. John Barkman | Domestic | 180 | Bowie |
| 1631901 | Bill Avery | Domestic | 317 | Bowie |
| 1632704 | John Addington | Domestic | 553 | Bowie |
| 1632803 | David Musselman | Domestic | 390 | Bowie |

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

| State well number | Owner name | Primary water use | Well depth (ft) | County name |
|---|---|---|---|---|
| 1633101 | W. S. Hunter | Domestic | 180 | Red River |
| 1633102 | Cross Arrow Ranch | Domestic | 367 | Red River |
| 1633302 | Leon Baird | Domestic | 210 | Red River |
| 1633303 | J. V. Baird | Domestic | 370 | Red River |
| 1633305 | A. B. Baird | Domestic | 180 | Red River |
| 1634101 | A.W. Jackson | Domestic | 170 | Red River |
| 1634102 | U. Humphries | Domestic | 286 | Red River |
| 1634104 | Herb Stanphill | Domestic | 263 | Red River |
| 1634105 | Bobby Lipe | Domestic | 403 | Red River |
| 1634108 | D. Minter | Domestic | 343 | Red River |
| 1634109 | Marvin Sterman | Domestic | 343 | Red River |
| 1634110 | Harold Peek | Domestic | 243 | Red River |
| 1634111 | C. D. Floyd | Domestic | 208 | Red River |
| 1634301 | Sam Hilton | Domestic | 303 | Red River |
| 1634302 | C. E. O'Bier | Domestic | 200 | Red River |
| 1634303 | J. A. Houser | Domestic | 220 | Red River |
| 1634304 | Don Cole | Domestic | 305 | Red River |
| 1634504 | Owen and Keys Well No. 1 | Domestic | 350 | Red River |
| 1634508 | Dick Bench | Domestic | 580 | Red River |
| 1634601 | Paul Megason | Domestic | 536 | Red River |
| 1634602 | Bob Pirkey | Domestic | 456 | Red River |
| 1634603 | Alford York | Domestic | 480 | Red River |
| 1634901 | D. W. Burkhead | Domestic | 1050 | Red River |
| 1634903 | J.H. Raleigh | Domestic | 635 | Red River |
| 1635101 | Mrs. Otto Tidwell | Domestic | 320 | Bowie |
| 1635201 | B.B. Randolph | Domestic | 380 | Bowie |
| 1635301 | Johnnie Fowler | Domestic | 170 | Bowie |
| 1635302 | J. Wood Ranch | Domestic | 400 | Bowie |

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

| State well number | Owner name | Primary water use | Well depth (ft) | County name |
|---|---|---|---|---|
| 1635304 | E.L. Hawkins | Domestic | 280 | Bowie |
| 1635305 | JAMES STURDIVANT | Domestic | 220 | Bowie |
| 1635401 | D.V. Pirkey | Domestic | 500 | Bowie |
| 1635402 | Lawrence Day | Domestic | 467 | Red River |
| 1635403 | Dwight Wood | Domestic | 480 | Bowie |
| 1635501 | Neil Proctor | Domestic | 500 | Bowie |
| 1635601 | R.W. Bass | Domestic | 673 | Bowie |
| 1635603 | Eldon R. Allen | Domestic | 610 | Bowie |
| 1635701 | C.L. Plumlee | Domestic | 900 | Bowie |
| 1635802 | Leon McMillion | Domestic | 924 | Bowie |
| 1635803 | Bill Robinson | Domestic | 906 | Bowie |
| 1635901 | William B. Humphries | Domestic | 780 | Bowie |
| 1635902 | Mr. Rodgers | Domestic | 705 | Bowie |
| 1635903 | Mr. Tucker | Domestic | 940 | Bowie |
| 1636101 | C.B. Barkley | Domestic | 220 | Bowie |
| 1636102 | Frank Soares | Domestic | 500 | Bowie |
| 1636201 | Herman Hudson | Domestic | 200 | Bowie |
| 1636202 | Austin Chapel | Domestic | 350 | Bowie |
| 1636203 | C.V. Holt | Domestic | 380 | Bowie |
| 1636204 | Carl Wittle | Domestic | 300 | Bowie |
| 1636205 | Lillie Beggs | Domestic | 385 | Bowie |
| 1636301 | A.C. Williams | Domestic | 280 | Bowie |
| 1636302 | O.A Estes | Domestic | 360 | Bowie |
| 1636304 | A.R. Anderson | Domestic | 360 | Bowie |
| 1636305 | A.R. Anderson | Domestic | 420 | Bowie |
| 1636306 | Huley Russell | Domestic | 430 | Bowie |
| 1636401 | Mrs. Susie Jackson | Domestic | 580 | Bowie |
| 1636502 | Danny Watson | Domestic | 675 | Bowie |

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

| State well number | Owner name | Primary water use | Well depth (ft) | County name |
|---|---|---|---|---|
| 1636601 | Gary Williams | Domestic | 550 | Bowie |
| 1636701 | Sam Hall Jr. | Domestic | 744 | Bowie |
| 1636702 | W.L. May | Domestic | 734 | Bowie |
| 1637101 | L.R. Atkin | Domestic | 420 | Bowie |
| 1637103 | W.A. Adcock | Domestic | 650 | Bowie |
| 1637202 | Norris Crosby | Domestic | 440 | Bowie |
| 1637301 | J.L. Forrester | Domestic | 500 | Bowie |
| 1637303 | Frank Autrey | Domestic | 737 | Bowie |
| 1637401 | Wilbert Barthel | Domestic | 800 | Bowie |
| 1638101 | Jerry Gildon | Domestic | 655 | Bowie |
| 1638201 | Keith Springer | Domestic | 770 | Bowie |
| 1638302 | A.R. Goodwin | Domestic | 720 | Bowie |
| 1638303 | Ms. James Terral | Domestic | 676 | Bowie |
| 1639101 | A.L. Mize | Domestic | 670 | Bowie |
| 1639102 | W.E. Taylor | Domestic | 600 | Bowie |
| 1639103 | J.K. Austin | Domestic | 780 | Bowie |
| 1639108 | Hignight | Domestic | 575 | Bowie |
| 1639202 | C.C. Goodwin | Domestic | 628 | Bowie |
| 1639203 | T.A. Taylor | Domestic | 630 | Bowie |
| 1639204 | Reymond Kirkman | Domestic | 585 | Bowie |
| 1639206 | Betty Pendley | Domestic | 600 | Bowie |
| 1639301 | Jimmy Clem | Domestic | 375 | Bowie |
| 1639601 | Top Freeman | Domestic | 780 | Bowie |
| 1643102 | C. N. Dalby | Domestic | 1100 | Red River |
| 1643103 | B. D. English | Domestic | 1270 | Bowie |
| 1643202 | J.B. Lesley | Domestic | 1220 | Bowie |
| 1738401 | C. L. Kennedy | Domestic | 20 | Lamar |
| 1738901 | W. O. Woods | Domestic | 32 | Red River |

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

| State well number | Owner name | Primary water use | Well depth (ft) | County name |
|---|---|---|---|---|
| 1739201 | Roy D. Jones | Domestic | 82 | Red River |
| 1739202 | W. C. Mauldin | Domestic | 20 | Red River |
| 1739502 | R.V. Kunkel | Domestic | 60 | Red River |
| 1739504 | F. M. Foster | Domestic | 23 | Red River |
| 1739505 | W.A. Cotton | Domestic | 112 | Red River |
| 1739701 | Homer Scoggins | Domestic | 58 | Red River |
| 1739801 | J. Roberts | Domestic | 310 | Red River |
| 1740101 | Otha White | Domestic | 90 | Red River |
| 1740201 | L. Eudy | Domestic | 50 | Red River |
| 1740301 | A. W. Harvell | Domestic | 340 | Red River |
| 1740303 | Charlie Green | Domestic | 290 | Red River |
| 1740304 | P. L. Brooks | Domestic | 220 | Red River |
| 1740401 | Ray Early | Domestic | 380 | Red River |
| 1740402 | Doyle Brooks | Domestic | 200 | Red River |
| 1740501 | Harmen Belcher | Domestic | 57 | Red River |
| 1740502 | Fred White | Domestic | 27 | Red River |
| 1740503 | Kenneth Brown | Domestic | 385 | Red River |
| 1740504 | W. C. Garmon | Domestic | 23 | Red River |
| 1740505 | C. C. Cannon | Domestic | 303 | Red River |
| 1742703 | George Hoffman | Domestic | 416 | Delta |
| 1742704 | Robert Shipp | Domestic | 460 | Delta |
| 1742705 | E. R. Petty | Domestic | 460 | Delta |
| 1742804 | Harold Collar | Domestic | 460 | Delta |
| 1742805 | O. E. Scott | Domestic | 470 | Delta |
| 1742902 | Howard Mobley | Domestic | 280 | Hopkins |
| 1749317 | McCasland | Domestic | 320 | Hunt |
| 1749401 | Richard George | Domestic | 261 | Hunt |
| 1749704 | Charles Bowen | Domestic | 281 | Hunt |

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

| State well number | Owner name | Primary water use | Well depth (ft) | County name |
|---|---|---|---|---|
| 1749801 | L. E. Holley | Domestic | 105 | Hunt |
| 1749901 | W. Gaudreau | Domestic | 220 | Hunt |
| 1749902 | P. E. Hartline | Domestic | 225 | Hunt |
| 1750501 | Don Smith 14654 Hwy 11 Crumby | Domestic | 370 | Hopkins |
| 1750901 | Doug Jourdan | Domestic | 762 | Hopkins |
| 1757201 | Paul Fry | Domestic | 301 | Hunt |
| 1758101 | B. D. Wells | Domestic | 764 | Hopkins |
| 1758301 | Bill Tate | Domestic | 1027 | Hopkins |
| 1758303 | Cecil Dickens | Domestic | 943 | Hopkins |
| 1758503 | Mrs. T. D. Duke | Domestic | 930 | Hopkins |
| 1758801 | Truman Dickens | Domestic | 1018 | Hopkins |
| 1856602 | Danny Keene | Domestic | 140 | Hunt |
| 1856901 | Jack Wall | Domestic | 268 | Hunt |
| 1864301 | Jerry Nowlin | Domestic | 220 | Hunt |
| 1864501 | J. P. Martin | Domestic | 115 | Hunt |
| 1864602 | L. E. Shrum | Domestic | 160 | Hunt |
| 1864903 | H. A. Conovar | Domestic | 600 | Hunt |
| 3307501 | Larry Roberts | Domestic | 120 | Hunt |
| 3314601 | Lon Akin | Domestic | 85 | Kaufman |
| 3314901 | John Booth | Domestic | 165 | Kaufman |
| 3315102 | Richard Akin | Domestic | 80 | Kaufman |
| 3315201 | Susie Holt | Domestic | 145 | Hunt |
| 3315302 | Travis Stodgill | Domestic | 550 | Kaufman |
| 3315401 | R. L. Wiley | Domestic | 230 | Kaufman |
| 3316104 | Frank Reedy | Domestic | 560 | Hunt |
| 3316106 | W. O. Walls | Domestic | 338 | Hunt |
| 3322305 | Fuller's Towing | Domestic | 100 | Kaufman |
| 3322602 | R. K. Ramsey | Domestic | 57 | Kaufman |

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

| State well number | Owner name | Primary water use | Well depth (ft) | County name |
|---|---|---|---|---|
| 3323101 | Pat Johnson | Domestic | 160 | Kaufman |
| 3330501 | Charles Dykes | Domestic | 100 | Kaufman |
| 3330801 | Lenilu Adams | Domestic | 90 | Kaufman |
| 3338403 | A. L. Potts | Domestic | 54 | Kaufman |
| 3345901 | L. B. Sands | Domestic | 48 | Navarro |
| 3346204 | | Domestic | 60 | Henderson |
| 3346707 | R.W. Thomas | Domestic | 70 | Navarro |
| 3353201 | | Domestic | 44 | Navarro |
| 3353202 | J. Arnett | Domestic | 34 | Navarro |
| 3353204 | | Domestic | 20 | Navarro |
| 3353302 | | Domestic | 150 | Navarro |
| 3353501 | | Domestic | 39 | Navarro |
| 3353601 | Bryant Cotton Co. | Domestic | 200 | Navarro |
| 3353801 | E. T. Denn | Domestic | 29 | Navarro |
| 3354109 | | Domestic | 230 | Navarro |
| 3360901 | Mrs. N. Watts | Domestic | 26 | Navarro |
| 3361401 | J. D. McManus | Domestic | 127 | Navarro |
| 3361402 | B. Carpenter | Domestic | 181 | Navarro |
| 3904609 | | Domestic | 39 | Navarro |
| 3905104 | C. J. Davis | Domestic | 70 | Navarro |
| 1634501 | Owen and Keys, Well No. 1 | Irrigation | 0 | Red River |
| 1638102 | Red River Parts and Equipment Company | Irrigation | 650 | Bowie |
| 1643303 | J.M. Proctor | Irrigation | 1200 | Bowie |
| 1749315 | Jess Buker | Irrigation | 300 | Hunt |
| 1864801 | Herb Williams | Irrigation | 240 | Hunt |
| 3307703 | H. E. Borden | Irrigation | 80 | Hunt |
| 3314602 | Lewis Slaughter | Irrigation | 123 | Kaufman |
| 3315402 | Highland Memorial Gardens | Irrigation | 240 | Kaufman |

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

| State well number | Owner name | Primary water use | Well depth (ft) | County name |
|---|---|---|---|---|
| 1628801 | Jones Crossing School | Public Supply | 250 | Bowie |
| 1631704 | B.G. Butler | Public Supply | 415 | Bowie |
| 1639104 | Plattner's MHP Well #2 (Roosevelt) | Public Supply | 864 | Bowie |
| 1639105 | Plattner's MHP Well #3 (Victory) | Public Supply | 800 | Bowie |
| 1639106 | George Manning | Public Supply | 780 | Bowie |
| 1739206 | City of Bogata, New Well No.1 | Public Supply | 115 | Red River |
| 1739508 | City of Bogata Well No.4 | Public Supply | 351 | Red River |
| 1739509 | City of Bogata Well No.5 | Public Supply | 257 | Red River |
| 1739510 | City of Bogata Well #6 | Public Supply | 300 | Red River |
| 1739901 | City of Talco Well No.1 | Public Supply | 408 | Red River |
| 1739906 | Talco-Bogata Ind. Sch. Dist. | Public Supply | 300 | Red River |
| 1739907 | City of Talco Well No.2 | Public Supply | 430 | Red River |
| 1741902 | City of Commerce Well #2 | Public Supply | 580 | Hunt |
| 1741905 | City of Commerce Horton Well No. 5 | Public Supply | 510 | Hunt |
| 1742706 | City of Commerce Horton Field Well #4 | Public Supply | 510 | Delta |
| 1742806 | City of Commerce Horton Well No. 1 | Public Supply | 540 | Delta |
| 1742807 | City of Commerce Horton Well No. 2 | Public Supply | 635 | Delta |
| 1742808 | City of Commerce Horton Well No. 3 | Public Supply | 538 | Delta |
| 1749306 | City of Commerce New Well No. 5 | Public Supply | 542 | Hunt |
| 1749310 | East Texas State University | Public Supply | 466 | Hunt |
| 1749311 | East Texas State University | Public Supply | 483 | Hunt |
| 1749316 | Maloy WSC | Public Supply | 538 | Hunt |
| 1749504 | Campbell Water Supply Well No. 2 | Public Supply | 388 | Hunt |
| 1749505 | Campbell WSC. Well No. 1 | Public Supply | 0 | Hunt |
| 1749705 | Campbell Water Supply Well No. 3 | Public Supply | 427 | Hunt |
| 1750403 | Gafford Chapel Water Supply Corp. | Public Supply | 640 | Hopkins |
| 1750601 | Gafford Chapel Water Supply Corp. (#2) | Public Supply | 690 | Hopkins |
| 1750603 | Gafford Chapel Water Supply Corp. (#3) | Public Supply | 640 | Hopkins |

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

| State well number | Owner name | Primary water use | Well depth (ft) | County name |
|---|---|---|---|---|
| 1750704 | City of Cumby Well #2 | Public Supply | 750 | Hopkins |
| 1750705 | City of Cumby Well #3 | Public Supply | 845 | Hopkins |
| 1750706 | City of Cumby Well #4 | Public Supply | 752 | Hopkins |
| 1758102 | Miller Grove WSC (Cash Well) | Public Supply | 942 | Hopkins |
| 1758104 | Miller Grove Water Supply Corp. | Public Supply | 854 | Hopkins |
| 1758201 | Miller Grove WSC Well #3 | Public Supply | 950 | Hopkins |
| 1758501 | Miller Grove WSC Well #1 | Public Supply | 909 | Hopkins |
| 1758502 | Miller Grove WSC Well #2 | Public Supply | 875 | Hopkins |
| 1758504 | Miller Grove WSC Well #6 | Public Supply | 946 | Hopkins |
| 3307502 | Country Wood | Public Supply | 275 | Hunt |
| 3307503 | Country Wood | Public Supply | 260 | Hunt |
| 3307504 | Country Wood | Public Supply | 198 | Hunt |
| 3307505 | Country Wood | Public Supply | 306 | Hunt |
| 3307602 | Taylor Water Co. | Public Supply | 235 | Hunt |
| 3307603 | Taylor Water Co. | Public Supply | 235 | Hunt |
| 3307801 | Oak Lake | Public Supply | 80 | Hunt |
| 3307802 | Whispering Oaks | Public Supply | 239 | Hunt |
| 3307803 | Crazy Horse Subd. New well #1 | Public Supply | 180 | Hunt |
| 3307804 | Crazy Horse Subd. New well #2 | Public Supply | 180 | Hunt |
| 3307906 | City of Quinlan Well #4 | Public Supply | 400 | Hunt |
| 3307907 | Taylor Water Co. | Public Supply | 400 | Hunt |
| 3307908 | Taylor Water Co. | Public Supply | 400 | Hunt |
| 3307909 | Shady Oaks | Public Supply | 190 | Hunt |
| 3307910 | Shady Oaks | Public Supply | 185 | Hunt |
| 3307911 | Jimmy Seay | Public Supply | 290 | Hunt |
| 3308405 | Tawakoni Water Utility | Public Supply | 231 | Hunt |
| 3308701 | Tawakoni Water Utility | Public Supply | 362 | Hunt |
| 3308702 | Tawakoni Water Utility | Public Supply | 177 | Hunt |

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

| State well number | Owner name | Primary water use | Well depth (ft) | County name |
|---|---|---|---|---|
| 3308703 | Tawakoni Water Utility | Public Supply | 174 | Hunt |
| 3308704 | Tawakoni Water Utility | Public Supply | 214 | Hunt |
| 3308705 | Tawakoni Water Utility | Public Supply | 212 | Hunt |
| 3308706 | Tawakoni Water Utility | Public Supply | 224 | Hunt |
| 3308707 | Tawakoni Water Utility | Public Supply | 232 | Hunt |
| 3308802 | Taylor Water Co. | Public Supply | 420 | Hunt |
| 3308803 | Taylor Water Co. | Hunt | | |
| 3308805 | Taylor Water Co. | Public Supply | 406 | Hunt |
| 3315303 | Helen Taylor | Public Supply | 575 | Hunt |
| 3315304 | Helen Taylor | Public Supply | 680 | Hunt |
| 3316103 | Mulberry Cove Water Supply Corporation | Public Supply | 480 | Hunt |
| 3316109 | Tawakoni Water Utility | Public Supply | 490 | Hunt |
| 3401201 | City of Lone Oak | Public Supply | 524 | Hunt |
| 3904602 | H. R. Stroube, Richland City, | Public Supply | 120 | Navarro |
| 3904603 | H. R. Stroube, Richland City, | Public Supply | 119 | Navarro |
| 3904604 | H. R. Stroube, Richland City, | Public Supply | 120 | Navarro |
| 3904605 | H. R. Stroube, Richland City, | Public Supply | 119 | Navarro |
| 3904607 | H. R. Stroube, Richland City, | Public Supply | 119 | Navarro |
| 3904608 | H. R. Stroube, Richland City, | Public Supply | 119 | Navarro |

Appendix 19-1. Texas Commission on Environmental Quality wells which meet House Bill 30 exclusion criteria.

| Water source | System name | State well number | Aquifer | Well depth (ft) |
|---|---|---|---|---|
| G0190001A | CITY OF DE KALB | | Alluvium | 91 |
| G2250002A | CITY OF TALCO | 1739901 | Nacatoch | 408 |
| G2250002B | CITY OF TALCO | 1739907 | Nacatoch | 420 |
| G2250002C | CITY OF TALCO | | Nacatoch | 394 |
| G1940001B | CITY OF BOGATA | 1739508 | Nacatoch | 300 |
| G1940001D | CITY OF BOGATA | 1739510 | Nacatoch | 300 |
| G1750020A | CITY OF RICHLAND | 3904602 | Nacatoch | 120 |
| G1750020B | CITY OF RICHLAND | 3904605 | Nacatoch | 120 |
| G1750020C | CITY OF RICHLAND | 3904604 | Nacatoch | 120 |
| G1750020D | CITY OF RICHLAND | 3904607 | Nacatoch | 120 |
| G1750020E | CITY OF RICHLAND | 3904608 | Nacatoch | 120 |
| G0600017A | WEST DELTA WSC | | Nacatoch | 190 |
| G1120001A | CITY OF CUMBY | 1750703 | Nacatoch | 710 |
| G1120001B | CITY OF CUMBY | 1750704 | Nacatoch | 750 |
| G1120001C | CITY OF CUMBY | 1750705 | Nacatoch | 809 |
| G1120001D | CITY OF CUMBY | 1750706 | Nacatoch | 752 |
| G1120001E | CITY OF CUMBY | | Nacatoch | 820 |
| G1120014A | GAFFORD CHAPEL WSC | 1750603 | Nacatoch | 640 |
| G1120014B | GAFFORD CHAPEL WSC | 1750601 | Nacatoch | 690 |
| G1120014C | GAFFORD CHAPEL WSC | 1750403 | Nacatoch | 422 |
| G1120014D | GAFFORD CHAPEL WSC | 1750602 | Nacatoch | 650 |
| G1120016A | MILLER GROVE WSC | | Nacatoch | 909 |
| G1120016B | MILLER GROVE WSC | | Nacatoch | 875 |
| G1120016C | MILLER GROVE WSC | | Nacatoch | 950 |
| G1120016D | MILLER GROVE WSC | | Nacatoch | 845 |

Appendix 19-1. Texas Commission on Environmental Quality wells which meet House Bill 30 exclusion criteria.

| Water source | System name | State well number | Aquifer | Well depth (ft) |
|---|---|---|---|---|
| G1120016E | MILLER GROVE WSC | | Nacatoch | 840 |
| G1120016F | MILLER GROVE WSC | | Nacatoch | 946 |
| G1120016G | MILLER GROVE WSC | | Nacatoch | 900 |
| G1120016H | MILLER GROVE WSC | | Nacatoch | 890 |
| G1160003A | CITY OF COMMERCE | 1741902 | Nacatoch | 580 |
| G1160003B | CITY OF COMMERCE | | Nacatoch | 550 |
| G1160003C | CITY OF COMMERCE | 1742806 | Nacatoch | 540 |
| G1160003D | CITY OF COMMERCE | 1742807 | Nacatoch | 635 |
| G1160003E | CITY OF COMMERCE | 1742808 | Nacatoch | 538 |
| G1160003F | CITY OF COMMERCE | 1742706 | Nacatoch | 510 |
| G1160003G | CITY OF COMMERCE | 1741905 | Nacatoch | 510 |
| G1160006A | CITY OF LONE OAK | | Nacatoch | 510 |
| G1160007A | CITY OF QUINLAN | 3307906 | Nacatoch | 400 |
| G1160007B | CITY OF QUINLAN | | Nacatoch | 432 |
| G1160007C | CITY OF QUINLAN | | Nacatoch | 300 |
| G1160007D | CITY OF QUINLAN | | Nacatoch | 415 |
| G1160008A | TEXAS A&M UNIVERSITY COMMERCE | 1749304 | Nacatoch | 440 |
| G1160008B | TEXAS A&M UNIVERSITY COMMERCE | 1749303 | Nacatoch | 454 |
| G1160008C | TEXAS A&M UNIVERSITY COMMERCE | 1749310 | Nacatoch | 466 |
| G1160008D | TEXAS A&M UNIVERSITY COMMERCE | 1749311 | Nacatoch | 483 |
| G1160011A | ROCKWALL EAST MINI RANCH | | Nacatoch | 186 |
| G1160011B | ROCKWALL EAST MINI RANCH | | Nacatoch | 186 |
| G1160017A | CAMPBELL WSC | 1749505 | Nacatoch | 437 |
| G1160017B | CAMPBELL WSC | 1749504 | Nacatoch | 367 |
| G1160017C | CAMPBELL WSC | 1749705 | Nacatoch | 418 |

Appendix 19-1. Texas Commission on Environmental Quality wells which meet House Bill 30 exclusion criteria.

| Water source | System name | State well number | Aquifer | Well depth (ft) |
|---|---|---|---|---|
| G1160017D | CAMPBELL WSC | | Nacatoch | 414 |
| G1160017E | CAMPBELL WSC | | Nacatoch | 484 |
| G1160034A | MALOY WSC | 1749316 | Nacatoch | 528 |
| G1160034B | MALOY WSC | | Nacatoch | 528 |
| G1160052A | COMBINED CONSUMERS SUD | 3308704 | Nacatoch | 214 |
| G1160052B | COMBINED CONSUMERS SUD | 3308705 | Nacatoch | 212 |
| G1160052C | COMBINED CONSUMERS SUD | 3308706 | Nacatoch | 224 |
| G1160052D | COMBINED CONSUMERS SUD | 3308707 | Nacatoch | 232 |
| G1160052E | COMBINED CONSUMERS SUD | | Nacatoch | 350 |
| G1160052F | COMBINED CONSUMERS SUD | | Nacatoch | 220 |
| G1160052G | COMBINED CONSUMERS SUD | | Nacatoch | 284 |
| G1160052I | COMBINED CONSUMERS SUD | | Nacatoch | 570 |
| G1160052J | COMBINED CONSUMERS SUD | 3316103 | Nacatoch | 480 |
| G1160063A | QUINLAN NORTH SUBDIVISION | 3307602 | Nacatoch | 235 |
| G1160063B | QUINLAN NORTH SUBDIVISION | 3307603 | Nacatoch | 235 |
| G1160064A | QUINLAN SOUTH SUBDIVISION | 3307907 | Nacatoch | 400 |
| G1160064B | QUINLAN SOUTH SUBDIVISION | 3307908 | Nacatoch | 400 |
| G1160064C | QUINLAN SOUTH SUBDIVISION | | Nacatoch | 320 |
| G1160066A | BARROW SUBDIVISION | 3315301 | Nacatoch | 531 |
| G1160066B | BARROW SUBDIVISION | 3315303 | Nacatoch | 557 |
| G1160066C | BARROW SUBDIVISION | 3315304 | Nacatoch | 0 |
| G1160067C | CRAZY HORSE SUBDIVISION | 3307803 | Nacatoch | 180 |
| G1160067D | CRAZY HORSE SUBDIVISION | 3307804 | Nacatoch | 180 |
| G1160067E | CRAZY HORSE SUBDIVISION | | Nacatoch | 175 |
| G1160067F | CRAZY HORSE SUBDIVISION | | Nacatoch | 170 |

Appendix 19-1. Texas Commission on Environmental Quality wells which meet House Bill 30 exclusion criteria.

| Water source | System name | State well number | Aquifer | Well depth (ft) |
|---|---|---|---|---|
| G1160069A | LITTLE CREEK ACRES | | Nacatoch | 172 |
| G1160081A | WHISPERING OAKS WATER COOP | | Nacatoch | 200 |
| G1160081B | WHISPERING OAKS WATER COOP | | Nacatoch | 236 |
| G1160089A | CADDO MESA WSC | | Nacatoch | 287 |
| G1160091A | 4 R RANCH WATER 2 | 3307909 | Nacatoch | 190 |
| G1160091B | 4 R RANCH WATER 2 | 3307910 | Nacatoch | 185 |
| G1160091C | 4 R RANCH WATER 2 | | Nacatoch | 192 |
| G1160093A | COUNTRY WOOD ESTATES | 3307504 | Nacatoch | 198 |
| G1160093B | COUNTRY WOOD ESTATES | 3307503 | Nacatoch | 260 |
| G1160093C | COUNTRY WOOD ESTATES | | Nacatoch | 280 |
| G1160093D | COUNTRY WOOD ESTATES | 3307502 | Nacatoch | 275 |
| G1160093E | COUNTRY WOOD ESTATES | 3307505 | Nacatoch | 306 |
| G1160097A | W OAKS PHOENIX CORP | | Nacatoch | 212 |
| G1160097B | W OAKS PHOENIX CORP | | Nacatoch | 320 |

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

| Tracking number | Owner name | County | City | Date drilled | Total depth (ft) |
|---|---|---|---|---|---|
| 3292 | Jim Elder | Kaufman | Terrell | 11/8/2001 | 155 |
| 3491 | Hugh Arrendondo | Kaufman | Terrell | 11/15/2001 | 167 |
| 4076 | Sonia | Navarro | Chatfiel | 12/28/2001 | 100 |
| 4239 | Allan Hester | Navarro | | 1/11/2002 | 120 |
| 13819 | Delphin Germany | Bowie | Dekalb | 9/13/2002 | 170 |
| 17943 | Bethlehem Baptist Church | Bowie | Dekalb | 2/3/2003 | 72 |
| 17947 | Jeff Flowers Poultry Farm | Bowie | Dekalb | 2/4/2003 | 70 |
| 17949 | Jeff Flowers Poultry Farm | Bowie | Dekalb | 2/5/2003 | 71 |
| 23065 | WALTER DAVIS | Bowie | DEKALB | 6/3/2003 | 148 |
| 25477 | Richard Hall | Kaufman | Kemp | 9/12/2003 | 51 |
| 28385 | WILLIAM WHITSON | Bowie | DEKALB | 10/1/2003 | 300 |
| 28388 | BRUCE WHITSON | Bowie | DEKALB | 10/4/2003 | 310 |
| 28391 | LORI STRAND | Bowie | DEKALB | 10/10/2003 | 650 |
| 34176 | Ken Adams | Hunt | Quinlan | 5/1/2003 | 70 |
| 34182 | Larry Lane | Kaufman | Terrell | 6/15/2003 | 173 |
| 34186 | Gary Dalton | Hunt | Quinlan | 6/25/2003 | 132 |
| 34466 | Tyler Martin | Bowie | Texarkana | 7/15/2003 | 40 |
| 36105 | CAVIN FANNIN POULTRY | Bowie | DEKALB | 3/10/2004 | 438 |
| 37438 | TIM FANNIN | Bowie | DEKALB | 3/26/2004 | 360 |
| 47577 | James Sturidvant | Bowie | Dekalb | 9/10/2004 | 220 |
| 49044 | P.E. Hartline | Hopkins | Cumby | 11/16/2004 | |
| 64265 | RUSTY MARSACK | Bowie | DEKALB | 5/16/2005 | 320 |
| 69739 | Robert Lee | Kaufman | Terrell | 10/26/2005 | 52 |
| 70637 | Robert Rhoads | Red River | Same | 2/4/2004 | 75 |
| 79764 | Hazel Mitchell | Bowie | New Boston | 3/26/2004 | 60 |
| 80622 | STEVE STARRETT | Bowie | DEKALB | 2/18/2006 | 280 |
| 80623 | JASON CULPEPPER | Bowie | DEKALB | 2/21/2006 | 320 |

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

| **Tracking number** | **Owner name** | **County** | **City** | **Date drilled** | **Total depth (ft)** |
|---|---|---|---|---|---|
| 80624 | HELEN WHITTLE | Bowie | DEKALB | 2/24/2006 | 240 |
| 82133 | JOE HOUSE | Bowie | DEKALB | 3/16/2006 | 200 |
| 82988 | MARIO GARCIA | Bowie | NEW | 4/30/2006 | 68 |
| 85341 | Charlie Sparks | Hunt | Terrell | 3/10/2004 | 90 |
| 85335 | Sandra Snyder | Kaufman | Terrell | 3/9/2004 | 84 |
| 85397 | Joe Cannon | Hunt | Quinlan | 3/29/2004 | 220 |
| 85398 | Pat Weatherly | Hunt | Quinlan | 3/23/2004 | 280 |
| 87683 | JOSE GAMINO | Kaufman | KEMP | 7/14/2006 | |
| 88809 | Mike Lee | Hunt | Quinlan | 8/12/2003 | 264 |
| 88770 | Don Seawright | Hunt | Quinlan | 7/21/2003 | 168 |
| 88771 | Thomas McClemme | Kaufman | Terrell | 8/4/2003 | 105 |
| 88772 | Thomas McClemme | Kaufman | Terrell | 8/25/2003 | 105 |
| 88813 | Jason Armstrong | Hunt | Quinlan | 9/3/2003 | 190 |
| 88836 | Arthur Masters | Hunt | Quinlan | 9/17/2003 | 225 |
| 90752 | Barbara Hornick | Navarro | Timothy | 8/18/2006 | 100 |
| 94880 | George Patterson | Hopkins | Sulphur | 3/17/2006 | 262 |
| 98752 | ARMSTRONG RANCH | Red River | AVERY | 10/3/2006 | 300 |
| 98762 | HAROLD TOTTY | Red River | AVERY | 10/11/2006 | 380 |
| 110820 | JIM MILLS | Bowie | DEKALB | 3/20/2007 | 82 |
| 114134 | Carl W Jones | Red River | Bogata | 11/15/2006 | 252 |
| 118003 | Richard Stewart | Kaufman | Terrell | 9/22/2004 | 110 |
| 118581 | Kevin Crockett | Hunt | Campbell | 9/16/2004 | 48 |
| 119771 | dean | Red River | Avery | 5/27/2007 | 140 |
| 120660 | Thomas Meurer | Kaufman | Terrell | 8/22/2007 | 390 |
| 122797 | BENNY HERMAN | Hunt | CUMBY | 10/28/2003 | 300 |
| 123291 | MIKE LILLY | Bowie | SAME | 10/27/2003 | 43 |
| 133149 | Taylor, Tray | Hunt | Quinlan | 11/28/2007 | 171 |

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

| Tracking number | Owner name | County | City | Date drilled | Total depth (ft) |
|---|---|---|---|---|---|
| 133303 | Scott Clarey | Bowie | dekalb | 2/1/2008 | 300 |
| 134243 | David and Connie Rowe | Bowie | Texarkana | 2/4/2008 | 57 |
| 134832 | Robert Trumble | Bowie | Texarkana | 1/11/2008 | 52 |
| 142259 | BARRY AUSTIN | Navarro | CHATFIELD | 4/20/2008 | |
| 146339 | hu sun duke | Bowie | dekalb | 6/6/2008 | 200 |
| 146548 | Hartsbluff Game Ranch | Franklin | Talco | 6/5/2008 | 502 |
| 150052 | bill toten | Bowie | De Kalb | 3/3/2008 | 80 |
| 150054 | David goodwin | Bowie | De Kalb | 7/19/2008 | 70 |
| 150056 | amanda goodwin | Bowie | De Kalb | 5/15/2008 | 75 |
| 150057 | ricks | Bowie | De Kalb | 3/8/2008 | 75 |
| 152597 | Sidney Stone | Hunt | Quinlan | 7/2/2005 | 224 |
| 152603 | Dan Cantrell | Hunt | Quinlan | 7/20/2005 | 224 |
| 152608 | Richard Kennedy | Hunt | Quinlan | 8/1/2005 | 90 |
| 154462 | Scott McCool | Bowie | | 6/7/2005 | 42 |
| 154804 | Monte Randolph | Red River | Bogata | 8/31/2005 | 175 |
| 164800 | J R F Enterprises | Hunt | Quinlan | 8/6/2004 | 185 |
| 164788 | Pat Bellinger | Kaufman | Terrell | 9/13/2004 | 108 |
| 164797 | Kevin Keck | Hunt | Quinlan | 8/10/2004 | 160 |
| 167750 | Darryl Holcomb | Bowie | Dekalb | 12/15/2006 | 575 |
| 173542 | ANGEL JOSE RODRIGUEZ | Navarro | CHATFIELD | 2/10/2009 | |
| 174403 | Joe Robbins | Bowie | Texarkana | 6/6/2006 | 45 |
| 176657 | Thomas Clayton | Red River | Lydia | 3/19/2009 | 720 |
| 177263 | Stace Hayward | Hunt | Terrell | 7/3/2006 | 105 |
| 177265 | Sean Morris | Kaufman | Terrell | 7/5/2006 | 90 |
| 177266 | Tom Cheney | Hunt | Terrell | 7/6/2006 | 130 |
| 177268 | Stanley Ewaniak | Kaufman | Terrell | 7/7/2006 | 91 |
| 177272 | Jerry Hinojosa | Hunt | Terrell | 7/10/2006 | 80 |

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

| Tracking number | Owner name | County | City | Date drilled | Total depth (ft) |
|---|---|---|---|---|---|
| 177273 | Bill Randall | Hunt | Terrell | 7/11/2006 | 74 |
| 177276 | George Dugger | Hunt | Terrell | 7/12/2006 | 70 |
| 177284 | Jeff Adams | Hunt | Quinlan | 7/18/2006 | 70 |
| 177299 | Weathers Concrete | Hunt | Quinlan | 8/14/2006 | 160 |
| 177307 | Shuck Wieland | Kaufman | Terrell | 8/31/2006 | 240 |
| 177334 | Donald Woodruff | Bowie | DeKalb | 2/18/2009 | |
| 181492 | Dan Garrett | Hunt | Quinlan | 11/30/2005 | 96 |
| 181493 | Rocky Johnson | Hunt | Quinlan | 12/1/2005 | 80 |
| 181453 | Dick Tymer | Hunt | Quinlan | 10/22/2005 | 298 |
| 181464 | Helen Ballard | Kaufman | Terrell | 11/4/2005 | 85 |
| 181468 | Walter Dodge | Hunt | Quinlan | 11/5/2005 | 84 |
| 181471 | Walter Dodge | Hunt | Quinlan | 11/7/2005 | 80 |
| 181472 | Walter Dodge | Hunt | Quinlan | 11/10/2005 | 78 |
| 181494 | Christin Neubaur | Hunt | Campbell | 12/6/2005 | 60 |
| 183248 | C.T. Mitchell Const. | Bowie | Texarkana | 5/18/2004 | 369 |
| 190873 | Joe Miller | Hunt | Quinlan | 2/12/2006 | 255 |
| 190875 | Allien Myer | Hunt | Quinlan | 2/14/2006 | 143 |
| 191140 | rolling homes | Bowie | De Kalb | 9/18/2008 | |
| 192330 | Don Zachary | Hunt | Campbell | 7/11/2009 | 200 |
| 192331 | Don Sachary | Hunt | Campbell | 7/10/2009 | 200 |
| 192332 | Alex Cardenas | Hunt | Campbell | 7/18/2009 | 242 |
| 192333 | Shirley Wilson | Hunt | Quinlan | 7/21/2009 | 140 |
| 192334 | Tom White | Hunt | Quinlan | 7/30/2009 | 258 |
| 193055 | David Sevehla | Rockwall | Rockwall | 9/30/2006 | 53 |
| 194538 | Dwight Hawkins | Kaufman | Terrell | 3/7/2006 | 122 |
| 194559 | Arley Sansom | Hunt | Quinlan | 3/15/2006 | 225 |
| 194560 | Trey Griffith | Kaufman | | 3/29/2006 | 122 |

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

| Tracking number | Owner name | County | City | Date drilled | Total depth (ft) |
|---|---|---|---|---|---|
| 194561 | Terry Chambers | Kaufman | Terrell | 3/31/2006 | 105 |
| 196543 | Star Mobile Homes | Bowie | Dekalb | 5/21/2009 | |
| 196576 | Mike Hatfield | Hunt | same | 8/20/2009 | 238 |
| 196578 | Ron Blaske | Hunt | | 8/29/2009 | 230 |
| 196682 | Wallace Watson | Hunt | | 8/24/2009 | 178 |
| 196865 | Lance Simpson | Bowie | Texarkana | 10/19/2009 | 55 |
| 197151 | Aiken, Jimmy | Bowie | Texarkana | 4/12/2008 | |
| 197268 | Palmer, Curtis | Bowie | Wamba | 8/19/2008 | |
| 210543 | Barry Austin | Navarro | Chatfield | 2/21/2010 | |
| 216168 | Evalyne Clements | Bowie | DeKalb | 2/22/2010 | |
| 220061 | Robert Maxwell | Bowie | Texarkana | 8/13/2007 | 55 |
| 221830 | Charles Morse | Hunt | Quinlan | 4/2/2009 | 190 |
| 221833 | Richard Depp | Kaufman | Terrell | 4/6/2009 | 94 |
| 221835 | Lymon Peterman | Hunt | Quinlan | 4/8/2009 | 84 |
| 221840 | Nick Wilton | Hunt | Quinlan | 2/22/2007 | 268 |
| 221845 | Jim L. Raney | Hopkins | Cumby | 3/1/2007 | 280 |
| 221884 | Bruce Hudson | Hunt | Campbell | 5/1/2007 | 123 |
| 221889 | Eddie Williams | Hunt | Quinlan | 5/3/2007 | 84 |
| 221904 | James Sutton | Hunt | Quinlan | 5/19/2007 | 160 |
| 221908 | Fred Wiese | Hunt | Quinlan | 10/3/2007 | 255 |
| 221910 | Larry Jones | Kaufman | Terrell | 10/9/2007 | 118 |
| 221911 | Wesley Patton | Kaufman | Terrell | 10/11/2007 | 118 |
| 221915 | Ron Kifer | Hunt | Quinlan | 11/16/2007 | 96 |
| 221916 | Kyle Shannon | Kaufman | Terrell | 11/19/2007 | 95 |
| 221918 | Dave Cellela | Kaufman | Terrell | 11/20/2007 | 108 |
| 221921 | Stefan Gradanay | Hunt | Quinlan | 4/22/2008 | 226 |
| 221922 | D. Garrett | Hunt | Quinlan | 4/24/2008 | 192 |

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

| Tracking number | Owner name | County | City | Date drilled | Total depth (ft) |
|---|---|---|---|---|---|
| 221924 | Mark Baird | Hunt | Terrell | 5/1/2008 | 144 |
| 221925 | Kenneth Jones | Kaufman | Terrell | 5/19/2008 | 105 |
| 221929 | Septimo Landeverde | Hunt | Quinlan | 7/3/2008 | 140 |
| 221931 | Brad Erwin | Kaufman | Terrell | 7/21/2008 | 110 |
| 221938 | Bonnie Hart | Hunt | Quinlan | 8/7/2008 | 195 |
| 221948 | James Yonker | Hopkins | Cumby | 9/16/2008 | 268 |
| 221954 | Keith Siebolt | Hunt | Quinlan | 11/27/2008 | 165 |
| 221957 | Texas A&M Commerce | Hunt | Commerce | 6/2/2009 | 103 |
| 221958 | Texas A&M Commerce | Hunt | Commerce | 6/2/2009 | 100 |
| 222558 | John Gregory | Bowie | Texarkana | 5/27/2007 | 56 |
| 222873 | John Campbell | Bowie | Dekalb | 9/3/2007 | 630 |
| 222881 | Gary Northam Construction | Bowie | Texarkana | 5/17/2007 | 48 |
| 222912 | Ken Hawkins | Bowie | Texarkana | 9/12/2007 | 38 |
| 224450 | Dave Stotcher | Kaufman | | 6/7/2010 | 136 |
| 226793 | Mike Cole | Kaufman | | 8/14/2007 | 90 |
| 227119 | vivian raymond | Bowie | De Kalb | 11/12/2009 | 65 |
| 228086 | HMW Special Utility District | Harris | Cypress | 8/25/2009 | 398 |
| 229291 | Oscar Smith III | Henderson | Seven Points | 7/24/2010 | 60 |
| 230279 | Brown, John M. | Bowie | Texarkana | 6/22/2010 | |
| 230323 | MLM Construction | Bowie | Texarkana | 6/4/2010 | |
| 231599 | Maria Gutierrez | Kaufman | | 8/4/2010 | 90 |
| 231577 | Jim Nichols | Kaufman | | 8/2/2010 | 105 |
| 231593 | Raymond Delton | Kaufman | | 8/3/2010 | 96 |
| 233180 | McCan, Eugene | Hunt | | 8/29/2010 | 202 |
| 234206 | Bob Gunter | Hopkins | Cumby | 7/20/2007 | 276 |
| 234856 | Stanley Henderson | Hunt | | 9/5/2010 | 180 |
| 234857 | Vincent Rendevez | Hunt | | 9/7/2010 | 195 |

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

| Tracking number | Owner name | County | City | Date drilled | Total depth (ft) |
|---|---|---|---|---|---|
| 234861 | Chuck Adams | Hunt | | 9/20/2010 | 96 |
| 236984 | Eslinger | Hunt | same | 10/12/2010 | 232 |
| 237661 | Vic Cox | Red River | Bogata | 10/12/2010 | 152 |
| 239773 | Ken Parker | Hopkins | | 11/3/2010 | 240 |
| 239774 | Joe Hobbs | Kaufman | | 11/1/2010 | 110 |
| 241121 | Kelly Poole | Hunt | Quinlan | 6/14/2005 | 216 |
| 241461 | David Wallace | Hunt | Campbell | 6/5/2005 | 110 |
| 241466 | Bill Miller | Hunt | Campbell | 5/30/2005 | 230 |
| 241467 | Robert Griffith | Hunt | Quinlan | 5/26/2005 | 156 |
| 241469 | Johnny Calvert | Hunt | Campbell | 5/24/2005 | 205 |
| 243007 | Dr. Howard Morris | Bowie | Texarkana | 9/15/2003 | 70 |
| 254483 | Jake Bell | Hunt | | 4/8/2011 | 188 |
| 254503 | Cesar Renalos | Hunt | | 4/19/2011 | 190 |
| 256012 | Wright, William | Bowie | Texarkana | 12/3/2010 | |
| 256022 | Yarberry, John | Bowie | Texarkana | 11/12/2010 | |
| 256071 | Flanery, John | Bowie | New Boston | 9/9/2010 | |
| 258628 | Clint Hutchins | Hopkins | | 5/6/2011 | 354 |
| 258840 | Mike Featherston | Hunt | | 6/13/2011 | 100 |
| 258847 | Linda Wheatly | Hunt | | 6/18/2011 | 268 |
| 264494 | Doug Lavern | Hunt | | 7/5/2011 | 215 |
| 264663 | Quinlan School District | Hunt | | 8/19/2011 | 322 |
| 269773 | Joe W. Heather | Henderson | Kemp | 9/19/2011 | 26 |
| 270130 | Roy Lorance | Bowie | Hooks | 8/12/2011 | |
| 272864 | Stacey Smith | Hunt | | 10/11/2011 | 175 |
| 272867 | Shelly Smith | Kaufman | | 10/12/2011 | 120 |
| 273138 | Kim Sosebee | Hunt | | 10/19/2011 | 280 |
| 273922 | John Hughes | Henderson | Kemp | 10/4/2011 | 71 |

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

| **Tracking number** | **Owner name** | **County** | **City** | **Date drilled** | **Total depth (ft)** |
|---|---|---|---|---|---|
| 278238 | John Felshiem | Hunt | | 12/13/2011 | 220 |
| 278239 | Alton Folmar | Hunt | | 12/10/2011 | 220 |
| 278240 | Q.I.S.D | Hunt | | 12/16/2011 | 262 |
| 278242 | Mike Wesley | Hunt | | 1/4/2012 | 160 |
| 278243 | Ruby Murphy | Hunt | | 1/6/2012 | 145 |
| 281981 | Don Reneau | Kaufman | Kemp | 3/3/2012 | 52 |
| 290718 | Eddie Bobo | Henderson | Kemp | 5/22/2012 | 70 |
| 291155 | Frank Akenback | Hunt | | 5/4/2012 | 160 |
| 291160 | Bruce Allen | Hunt | | 5/15/2012 | 298 |
| 295451 | Mark Cherry | Bowie | De Kalb | 4/23/2012 | 250 |
| 295454 | David Sealing | Bowie | De Kalb | 7/30/2012 | 480 |
| 297879 | Quinlan school district | Hunt | | 7/23/2012 | 160 |
| 298475 | Becky Lindsey | Red River | Avery | 7/23/2012 | 662 |
| 301227 | Nick Shaffer | Hunt | | 8/13/2012 | 128 |
| 301228 | Kirk Lane | Kaufman | | 8/30/2012 | 212 |
| 305533 | ARNOLD BARFIELD | Bowie | NEW BOSTON | 8/10/2012 | 42 |
| 307810 | Chris Jabin | Hunt | Lone Oak | 11/14/2012 | 315 |
| 308638 | Casey Romans | Hopkins | | 11/16/2012 | 314 |
| 308820 | Bobby Parks | Hunt | | 12/7/2012 | 274 |
| 309165 | Darrel Tucker | Bowie | Dekalb | 12/7/2012 | |
| 311106 | Mark McCrary | Bowie | DeKalb | 1/19/2013 | |
| 321812 | Paul Wiley | Kaufman | | 5/2/2013 | 132 |
| 321815 | Stillwater construction | Hunt | | 5/24/2013 | 120 |
| 331825 | Norvelle Walker | Bowie | De Kalb | 11/10/2010 | 38 |
| 331885 | G.W. Farr | Bowie | New Boston | 10/1/2011 | 73 |
| 331897 | Tommy Baggett | Bowie | New Boston | 8/13/2012 | 166 |
| 331955 | Chris Loveall | Bowie | Texarkana | 3/16/2012 | 725 |

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

| Tracking number | Owner name | County | City | Date drilled | Total depth (ft) |
|---|---|---|---|---|---|
| 331963 | Hal Lovance | Bowie | Hooks | 7/15/2011 | 56 |
| 331987 | Austin Chapel Bap. Ch. | Bowie | De Kalb | 8/16/2012 | 280 |
| 331992 | Danny Rich | Bowie | De Kalb | 3/16/2013 | 350 |
| 332147 | Lone Star Custom Homes | Bowie | Texarkana | 11/2/2011 | 40 |
| 332191 | Trey Fuzy | Bowie | Texarkana | 7/6/2011 | 45 |
| 332209 | Taylor Custom Homes | Bowie | Texarkana | 6/16/2011 | 53 |
| 333435 | MARY LIGHTFOOT | Kaufman | TERRELL | 9/2/2006 | |
| 333485 | J KENNEDY | Hunt | QUINLAN | 9/13/2006 | |
| 333489 | J KENNEDY | Hunt | QUINLAN | 9/12/2006 | |
| 333494 | JAMES DENNIS | Kaufman | TERRELL | 9/11/2006 | |
| 333593 | RAY COX | Hunt | QUINLAN | 6/27/2006 | |
| 333617 | OSCAR STARBUCK | Hunt | QUINLAN | 5/31/2006 | |
| 333632 | JOE KILLIAN | Hopkins | COMMERCE | 5/12/2006 | |
| 333652 | MIKE WARD | Hunt | QUINLAN | 5/10/2006 | |
| 334112 | Ernest Smith | Hunt | Commerce | 9/16/2005 | 288 |
| 336716 | TAFFY JONES | Hunt | QUINLAN | 4/27/2013 | 224 |
| 338317 | Christina Buxton | Bowie | DeKalb | 7/26/2013 | |
| 338351 | Robert Hill | Bowie | Hooks | 10/12/2006 | 65 |
| 338355 | Teresa McKee | Bowie | New Boston | 10/9/2006 | 84 |
| 338362 | J.T. Calhoun | Bowie | DeKalb | 10/4/2006 | 337 |
| 339123 | Kitty Cernock | Hunt | Terrell | 5/25/2006 | 80 |
| 339890 | Alex Bitner | Hunt | | 7/3/2013 | 90 |
| 340275 | TJ Dodge | Hunt | | 7/9/2013 | 80 |
| 340279 | Soloman | Hunt | | 7/17/2013 | 110 |
| 340284 | Fannie Nichols | Hunt | | 8/6/2013 | 340 |
| 342493 | David Dewitter | Navarro | Chatfield | 8/17/2013 | 60 |
| 351701 | Barry Ragle | Hunt | | 11/28/2013 | 0 |

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

| Tracking number | Owner name | County | City | Date drilled | Total depth (ft) |
|---|---|---|---|---|---|
| 351699 | J.L.Morse | Hunt | | 11/20/2013 | 0 |
| 351700 | John Munoz | Hunt | | 11/22/2013 | 0 |
| 354674 | Michael Starcher | Navarro | Chatfield | 1/25/2014 | |
| 361069 | Mark Dunlap | Hunt | Cambell | 4/11/2014 | 0 |

Appendix 19-2. GIS datasets.

GIS dataset descriptions have been included in the report text where applicable.

Appendix 19-3. GIS file names and codes.

| File content | File name | File type |
|---|---|---|
| Available Geophysical Log (BRACS) | BRACS AvailableLogs | Point shapefile |
| Cities and Towns | Cities and Towns | Polyline shapefile |
| Counties in GAM projection | Counties_GAM | Polyline shapefile |
| Faults | Faults_clip | Polyline shapefile |
| Study area in GAM projection | GAMstudyarea | Polyline shapefile |
| Study area geology | GEOL_StudyArea | Polygon shapefile |
| Groundwater Management Area | groundwater_management_areas_01_23_14 | Polygon shapefile |
| Nacatoch Well Location | GWDB_clipped_NCTC2 | Point shapefile |
| Nacatoch Well 2-mile buffer | GWDB_clipped_NCTC2buffer2mi | Polygon shapefile |
| Measured TDS from Samples (mg/L) | GWDB_TDS_211NCTC | Point shapefile |
| Hydraulic Conductivity (ft/day) | hyd_prop_GAM | Point shapefile |
| Major Roads | Major Roads | Polyline shapefile |
| Nacatoch downdip | MinAq_NACATOCH | Polygon shapefile |
| Study Area extents | MOD_Grid_extent | Polygon shapefile |
| Fault Grabens | MTfaultsgrabens | Polyline shapefile |
| Alpha radiation | NAC_Alpha_LF | Point shapefile |
| Beta radiation | NAC_Beta_LF | Point shapefile |
| Gross Alpha | NAC_Gross_Alpha_LF | Point shapefile |
| Groundwater information point locations | NAC_GW_Classes | Point shapefile |
| Geophysical Log Used for TDS Estimate | Nac_Log_TDS_Summary | Point shapefile |
| Radium 226 | NAC_Ra226_LF | Point shapefile |
| Radium 228 | NAC_Ra228_LF | Point shapefile |
| Major Aquifers | new_major_aquifers_dd | Polygon shapefile |
| Minor Aquifers | new_minor_aquifers_dd | Polygon shapefile |
| Nacatoch outcrop | Outcrop_clipped | Polygon shapefile |
| Previous study | Outline_349 | Polygon shapefile |
| Previous study | Outline_B6517 | Polygon shapefile |
| Previous study | Outline_R150 | Polygon shapefile |
| Previous study | Outline_R160 | Polygon shapefile |
| Previous study | Outline_R169 | Polygon shapefile |
| Previous study | Outline_R269 | Polygon shapefile |
| Previous study | Outline_R299 | Polygon shapefile |
| Potential Production Area | PPA3 | Polygon shapefile |
| Public Supply 2-mile buffer | PWS_clipped_buffer2mi2 | Polygon shapefile |
| Previous study | R137_TestMerged | Polygon shapefile |
| Previous study | R305 | Polygon shapefile |
| Regional Water Planning Areas | Regional_Water_Planning_Areas | Polygon shapefile |
| RRC Class II Injection Well - Excluded | RRCclass2_excl2 | Point shapefile |
| Nacatoch sample locations | Sampled_Nacatoch_Wells_no_dups_LF | Point shapefile |
| Driller's Report: PS, Dom and Irr 1-mile buffer | SDRDB_studyarea_PSirrDom_Only_clip_1mi_buffer3 | Polygon shapefile |

Appendix 19-3. GIS file names and codes.

| File content | File name | File type |
|---|---|---|
| Driller's Report: PS, Dom, and Irr | SDRDB_studyarea_PSirrDom_Only_clip3 | Point shapefile |
| StratMap_City_Poly_v4 | StratMap_City_Poly_v4 | Polygon shapefile |
| Estimated TDS <10,000 mg/L Extent | T10K_tds_extent | Polyline shapefile |
| 1,000 TDS | T1Ktds | Polyline shapefile |
| TCEQ Public Supply Well | TCEQ_Pswells_clip2 | Point shapefile |
| Texas_Major_Hwy_NAD_83 | Texas_Major_Hwy_NAD_83 | Polyline shapefile |
| State line | texas_outline_gamcopy | Polyline shapefile |
| Nacatoch depth to groundwater (ft) | twdb_10yr_avg_con_clipped | Polyline shapefile |
| Groundwater Conservation Districts | TWDB_GCDs_082014 | Polygon shapefile |
| Depth to Water (2006-2016) | WL_nac_TWDB_10yr_avg | Point shapefile |

Appendix 19-3. GIS file names and codes.

| Surface description | Surface file |
|---|---|
| Outline of aquifer model | Aquifer_Model_Outline |
| Bottom of Nacatoch Aquifer, ft amsl | Bot_Nac |
| Confined unit of aquifer | Confined_Area |
| Fresh water bottom depth, ft | fr_bot |
| Fresh water percent sand | fr_ps |
| Fresh water thickness, ft | fr_thk |
| Fresh water top depth, ft | fr_top |
| Fresh water volume, ac-ft | fr_vol |
| Moderately saline bottom depth, ft | ms_bot |
| Moderately saline percent sand | ms_ps |
| Moderately saline thickness, ft | ms_thk |
| Moderately saline top depth, ft | ms_top |
| Moderately saline volume, ac-ft | ms_vol |
| Nacatoch Elevation clipped | Nac_elev_clip |
| Snap grid | Snap_Nac |
| Slightly saline bottom depth, ft | ss_bot |
| Slightly saline percent sand | ss_ps |
| Slightly saline thickness, ft | ss_thk |
| Slightly saline top depth, ft | ss_top |
| Slightly saline volume, ac-ft | ss_vol |
| Thickness of Nacatoch Aquifer, feet | Thk_Nac |
| Top of Nacatoch Aquifer ft amsl | Top_Nac |
| Unconfined unit of aquifer | Unconfined_Area |
| Very saline bottom depth, ft | vs_bot |
| Very saline percent sand | vs_ps |
| Very saline thickness, ft | vs_thk |
| Very saline top | vs_top |
| Very saline volume, ac-ft | vs_vol |
| Depth of water level | wl_depths |

Appendix 19-4. Aquifer properties.

| State well number | Aquifer | Test yield (Gpm) | Drawdown (ft) | Specific capacity | Transmissivity (gpd/ft) | Hydraulic conductivity (ft/d) |
|---|---|---|---|---|---|---|
| 1619803 | Alluvium | 65 | 28 | 2.3 | 3,482 | 46.6 |
| 1627101 | Alluvium | 6 | 10 | 0.6 | 900 | 40.1 |
| 1627102 | Alluvium | 6 | 12 | 0.5 | 750 | 16.7 |
| 1627301 | Alluvium | 6 | 10 | 0.6 | 900 | 24.1 |
| 1628602 | Alluvium | 6 | 10 | 0.6 | 900 | 20.1 |
| 1628702 | Alluvium | 162 | 35 | 4.6 | 13,127 | 56.6 |
| 1628709 | Alluvium | 102 | 33 | 3.1 | 4,636 | 31.0 |
| 1640102 | Nacatoch | 107 | 81 | 1.3 | 206 | 3.0 |
| 1625902 | Nacatoch | 10 | 10 | 1 | 1,546 | 3.4 |
| 1626802 | Nacatoch | 5 | 18 | 0.3 | 1,077 | 28.8 |
| 1627701 | Nacatoch | 6 | 20 | 0.3 | 1,090 | 1.8 |
| 1628702 | Nacatoch | 63 | 0 | 13.8 | 13,127 | 56.6 |
| 1629702 | Nacatoch | 6 | 15 | 0.4 | 1,155 | 2.1 |
| 1629901 | Nacatoch | 15 | 70 | 0.2 | 1,025 | 2.1 |
| 1632813 | Nacatoch | 50 | 40 | 1.3 | 1,709 | 11.4 |
| 1633101 | Nacatoch | 10 | 50 | 0.2 | 1,025 | 4 |
| 1637202 | Nacatoch | 10 | 35 | 0.3 | 1,084 | 2.4 |
| 1643101 | Nacatoch | 6 | 30 | 0.2 | 1,025 | 2.2 |
| 1643103 | Nacatoch | 30 | 322 | 0.1 | 953 | 3.5 |
| 1739501 | Nacatoch | 100 | 60 | 1.7 | 2,002 | 5.1 |
| 1739905 | Nacatoch | 172 | 350 | 0.5 | 1,220 | 2.3 |
| 1741901 | Nacatoch | 285 | 0 | 5.1 | 2,670 | 9.4 |
| 1741902 | Nacatoch | 285 | 31 | 9.3 | 2,660 | 5.9 |
| 1742806 | Nacatoch | 200 | 192 | 1 | 2,300 | 3 |
| 1742807 | Nacatoch | 254 | 211 | 1.2 | 2,570 | 3.1 |
| 1742808 | Nacatoch | 183 | 178 | 1 | 2,150 | 3 |
| 1749304 | Nacatoch | 252 | 180 | 1.4 | 2,000 | 3 |
| 1749401 | Nacatoch | 15 | 138 | 0.1 | 960 | 6.4 |
| 1749601 | Nacatoch | 23 | 75 | 0.3 | 1,097 | 7.3 |
| 1749801 | Nacatoch | 8 | 10 | 0.8 | 1,416 | 5.3 |
| 1750705 | Nacatoch | 56 | 194 | 0.3 | 1,090 | 1.9 |
| 1758201 | Nacatoch | 60 | 32 | 1.9 | 2,133 | 4 |

Appendix 19-4. Aquifer properties.

| State well number | Aquifer | Test yield (Gpm) | Drawdown (ft) | Specific capacity | Transmissivity (gpd/ft) | Hydraulic conductivity (ft/d) |
|---|---|---|---|---|---|---|
| 1758504 | Nacatoch | 60 | 150 | 0.4 | 1,155 | 2.3 |
| 1758604 | Nacatoch | 55 | 155 | 0.4 | 1,136 | 3 |
| 1856602 | Nacatoch | 10 | 20 | 0.5 | 1,220 | 7.8 |
| 1864501 | Nacatoch | 7 | 53 | 0.1 | 979 | 4.5 |
| 1864602 | Nacatoch | 14 | 20 | 0.7 | 1,351 | 6.9 |
| 1864803 | Nacatoch | 0 | 0 | 0 | 3,290 | 7.3 |
| 3307501 | Nacatoch | 10 | 70 | 0.1 | 986 | 13.2 |
| 3308707 | Nacatoch | 50 | 50 | 1 | 1,546 | 4.1 |
| 3308801 | Nacatoch | 16 | 80 | 0.2 | 1,025 | 7.2 |
| 3308802 | Nacatoch | 20 | 25 | 0.8 | 1,416 | 6.3 |
| 3308804 | Nacatoch | 20 | 25 | 0.8 | 1,416 | 6.3 |
| 3314602 | Nacatoch | 30 | 30 | 1 | 1,546 | 10.3 |
| 3401201 | Nacatoch | 90 | 81 | 1.1 | 1,611 | 4.7 |

Appendix 19-5. Effects of tool geometry on common open hole logs.

| Logging Tool | Emitter to receiver spacing (inches) | Minimum vertical resolution (inches) | Minimum bed thickness for true log values under ideal conditions (inches) | Approximate depth of investigation (inches) | Circumference of 8-3/4 inch borehole surveyed (%) |
|---|---|---|---|---|---|
| Calipers | | | | | |
| 3-Arm bow spring recorded with: | | | | | |
| Induction electric | | 18 | | 0 | 25 |
| Compensated electric | | 18 | | 0 | 25 |
| 1-Arm | | | | | |
| Compensated density | | 6 | | 0 | 6 |
| Sidewall epithermal neutron | | 6 | | 0 | 6 |
| 2-Arm | | | | | |
| Proximity-microlog | | 12 | | 0 | 36 |
| Microlaterolog | | 12 | | 0 | 36 |
| 4-Arm | | | | | |
| 4-Arm dual caliper | | 1 | | 0 | 4 |
| High resolution 4-arm diplog | | 12 | | 0 | 50 |
| SP | | 12 | | 0 | 100 |
| Gamma ray | | 24 | | 6 | 100 |
| Single point resistance | 2-3 | 2-3 | -- | 6 | 100 |
| Resistivity | | | | | |
| 16" Normal | 16 | 24 | 60 | 32 | 100 |
| 64" Normal | 64 | 96 | 240 | 128 | 100 |
| 18' 8" Lateral | 224 | 240 | 448 | 224 | 100 |
| Dual induction | | | | | |
| SFL | 12 | 12 | 12 | 40 | 100 |
| Medium induction | 40 | 48 | 48 | 70 | 100 |
| Deep induction | 40 | 48 | 48 | 120 | 100 |
| Laterolog 3 | 12 | 12 | 24 | | |
| Laterolog 7 | 32 | 32 | 30 | 120 | |
| Laterolog 8 | 14 | 14 | 24 | | |
| Dual laterolog | | | | | |
| Shallow laterolog | 24 | 24 | 30 | 30 | 100 |
| Deep laterolog | 24 | 24 | 30 | 120 | 100 |
| Micrologs | | | | | |
| Micro inverse | 1 | 2 | | 1 | 7 |
| Micro normal | 2 | 4 | | 2 | 7 |
| Proximity log | 1 | 12 | 4 | 10 | 7 |
| Microlaterolog | 1 | 4 | 4 | 4 | 7 |
| Porosity | | | | | |
| Sidewall sonic | | 6 | | 0 to 4 | 4 |
| Compensated sonic | 12-36 | 12-36 | 24 | 0 to 4 | 100 |
| Compensated density | 18 | 18 | 24 | 4 | 12 |
| Compensated neutron | 24 | 24 | 24 | 8 | 30 |

This table provides average values. Values may vary depending upon the particular brand of logging equipment and the specific borehole conditions.

Appendix 19-6. Comments and Responses.

**General Report Comments**

1. Thank you for working with us to get the report for this project delivered.

    **Response not required**

2. Professional Geologists and Engineers must affix their seals and sign the final report.

    **Complete**

3. Please spell out House Bill 30 in the report to limit variations of abbreviations.

    **Complete**

4. Please refer to Contract Exhibit D for BRACS contract report requirements.

    **Response not required**

5. Please enlarge all figures to cover the full page and make them legible.

    **Complete**

6. Please provide one image per figure.

    **Complete**

7. Please spell out all acronyms except for TWDB and BRACS and spell out all units of measurement.

    **Complete**

8. Please refer to the Brackish Aquifer Characterization System as “BRACS” throughout the report.

    **Complete**

9. Please ensure all figure captions are thorough, correct, and provide one caption per figure (for example: Figure 4 1. a) Regional water planning areas, b) groundwater conservation districts and c) groundwater management areas.)

    **Complete**

10. Please clip the study area polygon and all derivative figures to the western end of the Nacatoch Aquifer outcrop.

    **Complete**

11. Please provide a section on recommendations for monitoring groundwater production in Potential Production Areas.

    **Provided general recommendations**

12. Please define the study area consistently in the report and deliverables. The report figures have differing study areas (for example Figure 6-1 and 6-2).

    **Complete**

Appendix 19-6. Comments and Responses.

**<u>Specific Report Comments</u>**

1. Page 1. Executive Summary: Considering providing volumes of groundwater in acre-feet in addition to the percentage provided in the report.

    **Complete**

2. Page 4. Section 5.1: please elaborate on geological nature of the Nacatoch sand and on faulting, its effects on geological structure (grabens specifically), and groundwater quality.

    **Complete**

3. Page 8 – 10. Figure 5-3, Figure 5-4, Figure 5-5, and Figure 5-5:

    a. Please provide an additional image with cross-section locations.

    b. Please remove structure map from cross-section images.

    c. Please change figure orientation to landscape.

    d. Label the axes correctly in the left and right of each image (the current images state "subsea depth".)

    e. Please correct API numbers on well labels.

    **Complete**

4. Page 14. Table 6-1: color the Brine classification cell according to Wilson and Kister's color ramp.

    **Complete**

5. Page 16. Figure 6-1: Please provide separate figures for measured and estimated salinity.

    **Complete**

6. Page 16. Figure 6-1: Please revise measured TDS values to reflect well control data within the study area.

    **Complete**

7. Page 16. Section 6.3: Please move Figure 6-1 to the end of Section 6.1.

    **Complete**

8. Page 17. Section 6.3: Please move Figure 6-2 to the end of Section 6.3.

    **Complete**

9. Page 18. Fifth sentence: Please move the remainder of this paragraph to a new paragraph.

    **Complete**

10. Page 19 – 23. Figure 6-3, Figure 6-4, Figure 6-5, Figure 6-6, and Figure 6-7:

    a. Please provide clearer labels for well logs presented in cross-sections

    b. Please label the axes on the left and right of each image.

    **Complete**

11. Page 24. Sixth paragraph: Please include report names when listing previous hydrologic characterization work done in the area.

    **Complete**

12. Page 26. Table 8-1: Please move table past the third paragraph and fit the whole table in one page.

    **Complete**

13. Page 26. Section 8.2.1, first paragraph: Please replace “TWDB Brackish Resources Aquifer Characterization System BRACS Team” to “TWDB BRACS Database”.

    **Complete**

14. Page 28. Figure 8-1: Please increase the font size of figure.

    **Complete**

15. Page 28. Section 8.2.2: Please move section to page 29.

    **Complete**

16. Page 30. Figure8-2: Please make figure clearer and please provide a right border.

    **Complete**

17. Page 32. Section8.4: Please move section to the previous page.

    **Complete**

18. Page 33. Last paragraph: Please derive the Cooper and Jacob equation of modified non-equilibrium.

    **Complete**

19. Page 34. Table 9-3: Please move table to an appendix section.

    **Complete**

20. Page 38 through 41. Figure 10-1a, 10-3a, 10-3b, 10-4, 10-5, and 10-6. Please label counties on the figures.

    **Complete**

21. Page 40 and 41. Please remove less than (<) from figures and label counties.

    **Complete**

22. Page 43 and 44. Figures 11-1 and 11-2: Please make the scale in the figures more legible.

    **Complete**

23. Page 46. Figure12-3: Please correct the figure’s color scheme to reflect the color ramp from Winslow and Kister.

    **Figure removed**

24. Page 46. Section 12.2: please include interpolated salinity zone surfaces in the final report.

    **Surfaces have been included**

25. Page 49. Section 13: please provide a type log figure to illustrate and describe the geophysical properties of the Nacatoch formation, there is a type log on cross-section X-X'.

    **Complete**

26. Page 51. Table 13-1: Please move table to an appendix section.

    **Complete**

27. Page 52. Section 13.2: Please define bottom hole temperature (TBH) on point 7.

    **Complete**

28. Page 56. Section 14.1: All four potential productions areas are delineated past the 10,000 mg/L TDS extend. Please confirm and provide data points to support the delineations.

    **Complete**

29. Page 58. Please provide a map of Potential Production Areas without exclusion zones in the same figure.

    **Complete**

30. Page 59. Section 14.2: Please provide drawdown tables for the three pumping scenarios for each potential production area, if available.

    **Tables are not available**

31. Page 60. Figure 14-4 to 14-10: Please provide additional figures that show exclusion wells and their buffers to determine the drawdown effects nearby wells.

    **Complete**

32. Page 64. Section 16: Please elaborate on salinity calculation methodology, PPA designation methodology.

    **Complete**

33. Page 64. Section 17: Please change "Ericka" to "Erika".

    **Complete**

34. Page 64. Section 16, second paragraph, last sentence: Please clarify "Fresh and slightly saline water represent 16 and 26 percent of all available Blossom groundwater and moderately saline groundwater contributes about 15 percent of the estimated storage volume located in the project area."

    **Complete**

35. Page A-27. Appendix 19.3: Please reposition tables so that they appear below the title of the appendix section they are under, instead of the following page.

    **Complete**

<u>**Data Comments**</u>

1. Please refer to Contract Exhibit G for BRACS contract data requirements.

    **Response not required**

2. Table tblGeophysicalLog_Header is missing data from the following fields and needs to be incorporated into the table. Fields include TS, DT, TBH, RM, RM_TEMP, RMF, and RMF_TEMP.

**Fields have been included**

3. Table tblWell_Geology has 130 records containing a value in the field [hydrochemical_tds_zone] indicating a salinity analysis was performed (confirmed with records in the table tblGeophysicalLog_WQ). However, these 130 records do not have a corresponding record in the following tables:

    a. table tblWell_Geology indicating the stratigraphic name, top and bottom depths

    b. table tblGeophysicalLog_Header

    c. table tblWell_Location

**Records have been added**

4. Please provide the digital geophysical well logs for these 130 wells

**Logs have been provided**

5. Please add these records to the appropriate tables with complete attributes. Adding these records to the table tblGeophysicalLog_Header will ensure there is a complete record of information including TS and TBH for wells used for salinity analysis. The records are listed in the following table:

| Well ID | Well ID | Well ID | Well ID | Well ID |
|---|---|---|---|---|
| 1592 | 20107 | 21530 | 23577 | 26044 |
| 1594 | 20112 | 21532 | 23579 | 26046 |
| 1944 | 20137 | 21663 | 23582 | 26349 |
| 1947 | 20139 | 21678 | 23775 | 26485 |
| 1952 | 20164 | 21969 | 23789 | 27814 |
| 2309 | 20167 | 21986 | 23794 | 29038 |
| 14850 | 20184 | 21988 | 23799 | 29196 |
| 14858 | 20310 | 21995 | 24552 | 30060 |
| 14859 | 20322 | 22004 | 24562 | 30861 |
| 14862 | 20334 | 22007 | 24718 | 31489 |
| 14866 | 20351 | 22017 | 24723 | 31704 |
| 15006 | 20353 | 22026 | 24731 | 32425 |
| 15007 | 20356 | 22034 | 24751 | 33277 |
| 17826 | 21173 | 22699 | 24814 | 33494 |
| 17831 | 21175 | 22709 | 24817 | 33496 |
| 17848 | 21206 | 22711 | 24947 | 33857 |
| 18567 | 21246 | 22715 | 24956 | 35024 |
| 19119 | 21255 | 22724 | 25935 | 35905 |
| 19129 | 21469 | 22729 | 25977 | 35971 |
| 19153 | 21472 | 22732 | 25980 | 36027 |
| 19156 | 21496 | 22736 | 25986 | 36892 |
| 19434 | 21497 | 22780 | 25988 | 37519 |
| 20034 | 21499 | 22784 | 25990 | 37529 |
| 20084 | 21501 | 22797 | 25995 | 37690 |
| 20087 | 21504 | 23107 | 26027 | 50287 |
| 20102 | 21519 | 23556 | 26031 | 50288 |

**Records have been added**

6. Each of the 195 wells in the table tblWell_Geology that contains a value in the field [hydrochemical_tds_zone] will need to have a corresponding record added to this table with the field [geologic_pick] = Hydrochemical, the field [stratigraphic_name] = Nacatoch Formation, and corresponding values in the fields [depth_top] and [depth_bottom] that reflect the top and bottom of the salinity zone. Many wells contain multiple salinity zones within the Nacatoch Formation, so this vertical salinity must be reflected in the geology table.

**Records have been added**

7. The table tblWell_Geology has multiple records with incorrect top and bottom depths since the thickness is negative. These lithologic records are in wells: 21978, 25974, 22007, 21678, 26098, 26090, and 21530.

**Records have been revised**

8. The table tblWell_Geology design contains two key fields: the Well_ID and the Record_Number. The record number must be a unique integer, sequentially increasing numbers, from top to bottom depth. Many records with both lithology and stratigraphic data have the same record numbers. For example, well 17837 has lithology records with record numbers 1 through 5 and stratigraphic records with record numbers 1 through 3. Please correct these problems.

**Record numbers have been revised**

9. The table tblWell_Geology contains lithologic, stratigraphic, and hydrochemical records. Please ensure that the top and bottom depth values for the stratigraphic records are consistent with the lithologic and hydrochemical records. For example, well 19441 indicates the Nacatoch Formation stratigraphic record has a top depth of 1288 and a bottom depth of 1749. The lithologic record with hydrochemical analysis indicates the Nacatoch Formation sand has a top depth of 1270.

**Records have been revised**

10. The table tblWell_Geology contains lithologic records. The lithology provided for the Nacatoch Formation must describe the entire formation. Many wells are incomplete and 130 wells have no corresponding stratigraphic record (a previous comment) so the analysis for completeness cannot be made. Please check each well and add new lithology records as appropriate.

**Records have been added**

11. The table tblGeophysicalLog_WQ is missing the Tf (Temperature of formation) for 145 of the 309 records. These wells were used to determine an interpreted total dissolved solids concentration. Please provide this required information.

**Records have been added**

12. The table tblGeophysicalLog_WQ includes the field [source_porosity] with a value of "Driscoll1986". The draft report does not describe the source of porosity data representative of the Nacatoch Formation. Please provide the page number in the Driscoll 1986 reference that contains Nacatoch Formation porosity data.

**Reference has been revised**

13. The table tblGeophysicalLog_WQ_Method contains a record for well 20351. There are no corresponding record(s) for this well in the table tblGeophysicalLog_WQ. Please add this record to table tblGeophysicalLog_WQ or provide an alternative explanation for this missing record.

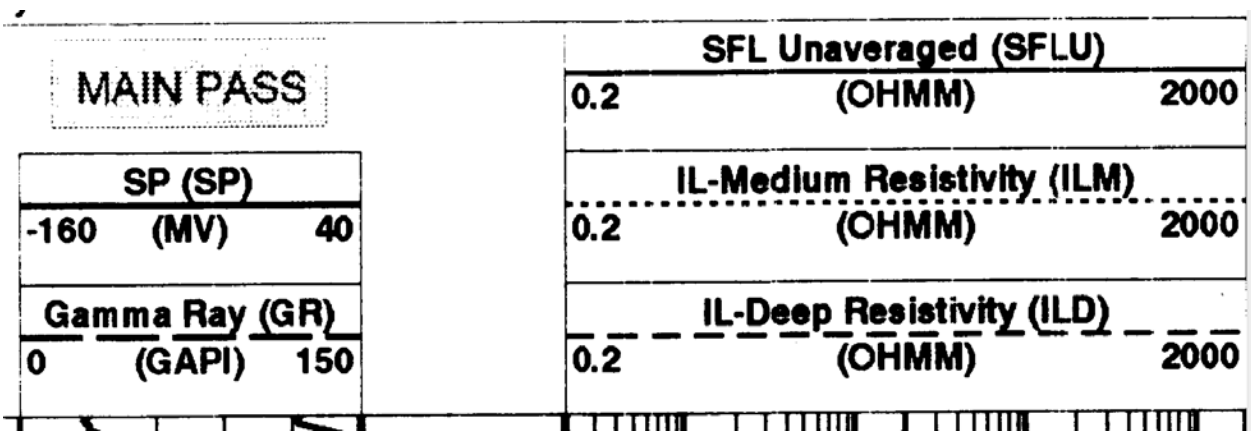
    **Record has been added**

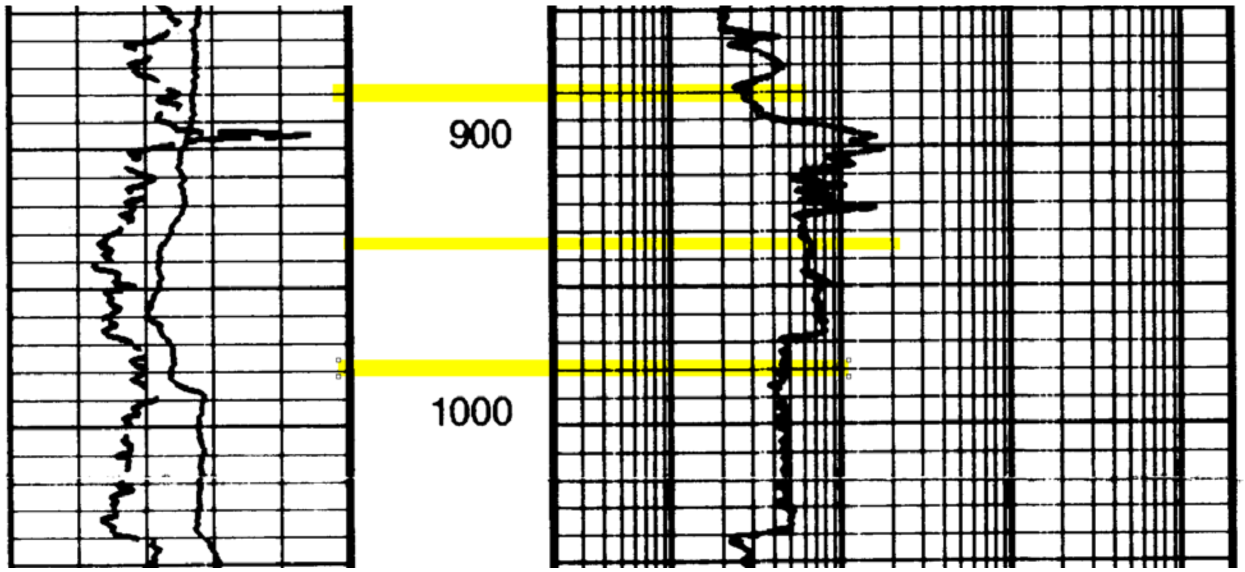
14. The field Df (Depth of formation) in tables tblGeophysicalLog_WQ and tblGeophysicalLog_WQ_Method is defined in the BRACS Database Data Dictionary, second edition, as follows:

    **DF** This is the third key field for this table. This value is based on the depth of the assessed formation of interest. The units are feet below ground surface, and this value is not corrected for kelly bushing height.

    The depth value is that point on the geophysical well log where the tool values are measured. Typically, the point is within a relatively thick and mineralogically uniform lithologic unit where bed boundary effects are minimal.

It appears from analysis of several geophysical well logs that the value Df does not meet this definition and the resistivity values in field Ro do not match the log values at depth Df. The following figure is taken from well 25716:






The following table indicates the differences in resistivity taken from table tblGeophysicalLog_WQ_Method compared with the resistivity read from the geophysical well log:

| Df | CCI Ro | TWDB Ro |
|---|---|---|
| 880 | 14 | 2.7 |
| 935 | 6.9 | 6.5 |
| 980 | 4 | 4.5 |

Clearly the resistivity at depth 880 is completely different. The values at the other two depths are within the margin of error in reading the logs. The values at depths 880 and 980 are probably shales and not sands.

Please provide a discussion of how you determined the Df value and corresponding resistivity values. If necessary, make corrections to tables tblGeophysicalLog_WQ and tblGeophysicalLog_WQ_Method in order to meet the definition of field Df.

**Kelly bushing corrections have been removed**

15. Comparison of the resistivity data in table tblGeophysicalLog_WQ_Method and the geophysical well logs indicates that some logs were misinterpreted. For example, well 22780 at a depth of 1477 has a resistivity value of 1.7 ohm-meters listed in the table. The geophysical well log indicates 6 ohm-meters. In this example, 1.7 ohm-meters would provide a TDS of 13,889, but a value of 6 ohm-meters would provide a TDS of 3,906. This is a significant error, please correct.

**Kelly bushing corrections have been removed**

16. In the course of addressing all of these comments, please double check the depths, resistivity values, lithology, and interpreted total dissolved solids concentrations of every well and correct the tables and derivative products as needed.

**Kelly bushing corrections have been removed**

17. Comparison of the tables tblWell_Geology and tblGeophysicalLog_WQ_Method indicated that three wells (20356, 32425, and 21501) have records where the top and bottom depth of the sand investigated for salinity (in tblWell_Geology) does not match the field Df (depth of formation in table tblGeophysicalLog_WQ_Method. Please correct these discrepancies.

**Kelly bushing corrections have been removed**

Comparison of the tables tblWell_Geology and tblGeophysicalLog_WQ_Method indicated that only 93 of 308 records used to interpret total dissolved solids in table tblGeophysicalLog_WQ_Method matched the corresponding value in the table tblWell_Geology. The following table shows the results of 10 wells where we used the same input parameters to calculate an interpreted total dissolved solids concentration and compared these results to the values provided in the tables. It appears the data in table tblGeophysicalLog_WQ_Method is incorrect.

| Well ID | Df | CCI Hydrochemical Zone tblWell_Geology | CCI TDS tblGeophysicalLog_WQ_Method | TWDB calculated TDS |
|---|---|---|---|---|
| 50287 | 758 | Very saline | 970 | 11702 |
| 50288 | 802 | Very saline | 1760 | 14103 |
| 36892 | 1108 | Very saline | 770 | 12791 |
| 25716 | 880 | Slightly saline | 12900 | 1943 |
| 25716 | 935 | Moderately saline | 19090 | 3901 |
| 21519 | 1282 | Slightly saline | 14630 | 2806 |
| 22004 | 323 | Fresh | 15340 | 975 |
| 22004 | 520 | Moderately saline | 3890 | 6944 |
| 22699 | 1395 | Very saline | 470 | 11364 |
| 25995 | 875 | Moderately saline | 18190 | 8333 |
| 23582 | 435 | Fresh | 2260 | 655 |
| 23582 | 535 | Slightly saline | 6720 | 1064 |
| 23582 | 680 | Moderately saline | 540 | 4762 |

Please verify every record and provide corrected tables for tblWell_Geology and tblGeophysicalLog_WQ_Method. If the impact of these errors has been incorporated into any derivative tables or GIS files, please let us know and provide those corrected files.

**TDS values have been corrected**

18. Evaluation of table tblGeophysicalLog_WQ_Method indicates that the field [geophysical_log] contains some errors. In cases where an induction resistivity tool was used to determine a formation resistivity value, the standard term resistivity was written to the table (for example, well 25716). Please make these corrections as appropriate.

**Appropriate corrections have been made**

19. Please make sure that the following GIS Shapefiles conform to the following requirements:

    a. All GIS files will be compatible with ESRI ArcGIS version 10.2.

b. All GIS files should adhere to the Texas State Mapping System, Albers Equal Area standard.

Projection: Albers

False_Easting: 4921250.0

False_Northing: 19685000.0

Central_Meridian: -100.0

Standard_Parallel_1: 27.5

Standard_Parallel_2: 35.0

Latitude_Of_Origin: 31.25

Linear Unit: Foot_US (0.3048006096012192)

Geographic Coordinate System: GCS_North_American_1983

Angular Unit: Degree (0.0174532925199433)

Prime Meridian: Greenwich (0.0)

Datum: D_North_American_1983

Spheroid: GRS_1980

Semimajor Axis: 6378137.0

Semiminor Axis: 6356752.314140356

Inverse Flattening: 298.257222101

20. Please see Attachment 1 for a complete list of shapefiles that need to adhere to the BRACS contract data requirements.

**Complete**

21. Please provide raster files for the maps in Figure 5-3, Figure 5-4, Figure 5-5, and Figure 5-5.

**These are not GIS files**

22. Please provide complete lithology information for the net sands analysis.

**BEG sand tops and bottoms for net sand maps provided in separate spreadsheet.**

23. Please revise the excel spreadsheet calculator's methodology for the Rwa Minimum method of calculating salinity from geophysical well logs.

a. The freshwater ion correction for Rwa should be:

If high bicarbonates are present, then apply Alger's (1966) equation:

$Rwa(cor) = 1.75 \cdot Rwa$

For sodium bicarbonate groundwater, use:

$Rwa(cor) = 1.33$

The spreadsheet calculator formula states:

☐ =IFERROR ([@Rwe]/[[@[Cf_H2O_Type]], ""), please correct.

**Calculator is correct, no changes were necessary**

b. To solve for TDS using the specific conductivity-TDS conversion factor (ct), the equation is:

TDS = ct · Cw75,

The spreadsheet calculator formula states:

☐ =IFERROR(10000/[@[Rw_Cor_75]],""), please correct.

**Calculator is correct, no changes were necessary**

24. Please re-interpolate all surfaces to reflect well control data within the study area.

a. fr_top
b. fr_bot
c. fr_thk
d. fr_ps
e. fr_vol
f. ss_top
g. ss_bot
h. ss_thk
i. ss_ps
j. ss_vol
k. ms_top
l. ms_bot
m. ms_thk
n. ms_ps
o. ms_vol
p. vs_top
q. vs_bot
r. vs_thk
s. vs_ps
t. vs_vol

**Complete**

25. Please regenerate TDS lines to reflect well control data within the study area.

a. T1Ktds
b. T10K_tds_extent

**TDS lines are correct; no changes were made to contours**

26. Please correct data structure for all MXD figure files, the data structure is broken and does not match the data structure of the associated geodatabase. This problem can be solved by relative linking of the MXD files.

**Complete**

27. Please label MXD figure files to reflect figure names (for example Figure XX-XX Caption.mxd.)

**Complete**

28. Please provide raster image files for net sand images (Figures 11-1 and 11-2).

**These are not GIS files**

29. Please provide MXD files and associated shapefiles for the numerical model result figures. (Figures 14-3 through 14-10).

**Provided shapefiles of drawdown contours and base map template used to make the figures**

**Modeling Comments – Added via email**

1. The Theis model calculations seem correct (for the given property values); however, the storativity values used for the modeling do not seem correct. Table 14-3 of the report lists the storativity values as 1 x 10-5. The specific storage in the Nacatoch GAM is equal to 1 x 10-5 in the model areas which would make the storativity values range from 0.001 to 0.003. In addition, the model calculations actually used storativity of 5 x 10-5 for the drawdown calculations (based on Theis function input file provided with the deliverable). They may need to either recalculate the Theis drawdown maps or make clear in the text that they used a storativity value of 5 x 10-5.

**The range of values for specific storage in layer 2 (Nacatoch) in the Nacatoch GAM is from 1x10-7 to 1x10-5 (see table 8.1.1 in Nacatoch GAM Report). We are using layer 2 data for this analysis from the GAM. The range for storativity after multiplying by the thickness is between 0.01 to 1x10-6 for the entire area of the GAM. (The suggested S value seems large).**

**For the potential production areas, they are as shown here:**

| PPA | Average Storativity |
|---|---|
| 1 | 1.41E-05 |
| 2 | 2.70E-05 |
| 3 | 3.11E-05 |
| 4 | 3.11E-05 |

2. The hydraulic conductivity value for potential production area 3 seems very high compared to the value in the Nacatoch GAM. In the GAM the hydraulic conductivity in that area is less than 1 foot per day; however, the Theis modeling used 3.5 feet per day (7,752 gpd/ft). Is it possible that hydraulic conductivities from Table 9.3 were used for the Theis modeling rather than values from the GAM itself? If this is the case the text should be clear about that.

**Layer 2 of the Nacatoch Aquifer GAM was used for the hydraulic conductivity values, and within the area of potential production area 3 it is split between values between 0.1 and 3.5 feet per day. Initially, only the higher hydraulic conductivity value was used in this area. That has been corrected to take the average hydraulic conductivity over the potential production area, lowering the overall transmissivity (Table 14-3).**

3. I suggest that they add some discussion on the Theis method with assumptions and limitations of the approach.

**Complete.**

4. In the conclusions the report states that the modeling results indicate that ~42,000,000 acre-feet of in-place groundwater exist. This number is probably based on the framework from the GAM; however, the brief write-up may be interpreted to mean that the Theis modeling would suggest this amount is available in the potential production areas. I suggest they make a clear distinction between the Theis modeling results and the volumetric calculation from the GAM.

**Complete**