# Brackish Groundwater Production Zone Recommendations for the Nacatoch Aquifer, Texas

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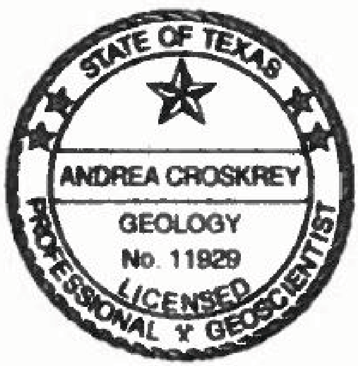


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Ms. Croskrey finalized GIS datasets for geologic surfaces, salinity classes, groundwater volume calculations, and finalized GIS files for publication. The seal appearing on this document was authorized on November 4, 2019, by

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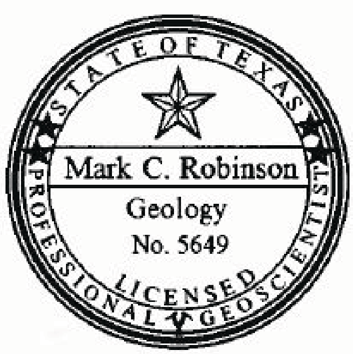


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Mr. Robinson performed stratigraphic analysis of the Nacatoch Sand. The seal appearing on this document was authorized on November 4, 2019, by

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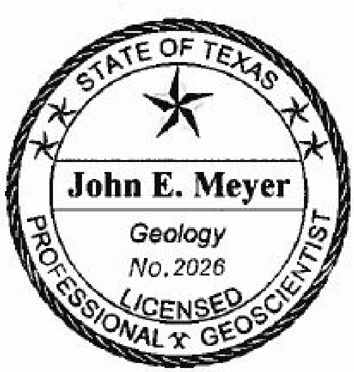


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Mr. Meyer performed geophysical well log analysis to estimate salinity, prepared the master water quality table, performed aquifer determination of well control for the Nacatoch Aquifer study, finalized BRACS Database and documentation, and completed the report. The seal appearing on this document was authorized on November 4, 2019, by

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# Executive summary

The Nacatoch Aquifer, a minor aquifer in northeast Texas, was evaluated for brackish groundwater resources and brackish groundwater production zones as required by Texas Water Code §16.060. In 2015, the 84th Texas Legislature passed House Bill 30, directing the Texas Water Development Board (TWDB) to conduct studies to:

(1) identify and designate brackish groundwater production zones in the state,
(2) determine the volumes of groundwater that a brackish groundwater production zone can produce over 30-year and 50-year periods without causing significant impact to water availability or water quality,
(3) make recommendations on reasonable monitoring to observe the effects of brackish groundwater production within the zone,
(4) work with groundwater conservation districts and stakeholders in general, and
(5) provide a summary of brackish groundwater production zone designations in the biennial report due December 1 of each even-numbered year.

Further, House Bill 30 directed the TWDB to identify and designate brackish groundwater production zones in four aquifers by December 1, 2016, and in the remaining aquifers in the state by December 1, 2022 (Texas, 2015). To assist the TWDB in making designations, the legislature appropriated $2 million for contracts and administrative costs. The TWDB funded seven contracts for eight aquifers.

The TWDB contracted with LBG-Guyton Associates to conduct a brackish resource study for the Nacatoch Aquifer. TWDB staff in the Brackish Resources Aquifer Characterization System (BRACS) program evaluated the data, augmented the data as necessary, and completed calculations for brackish groundwater production zone recommendations. On March 28, 2019, the Board designated five zones in the Nacatoch Aquifer.

These five brackish groundwater production zones contain predominantly moderately saline groundwater with an estimated total volume of 1.8 million acre-feet. Potential production of brackish groundwater from recommended zones at a rate of 165 to 400 acre-feet per year over a 30- and 50-year period was modeled and determined not to have a significant impact to fresh water or existing uses. Evaluation of the entire aquifer within the study area indicates an estimated total volume of 18 million acre-feet of groundwater, which includes 2.1 million acre-feet of fresh, 2.0 million acre-feet of slightly saline, 3.7 million acre-feet of moderately saline, and 8.2 million acre-feet very saline. The remaining 2.0 million acre-feet are in “mixed” classes where a unique salinity class could not be assigned.

# Introduction

The Nacatoch Aquifer is a minor aquifer in northeast Texas (George and others, 2011). The Nacatoch Aquifer and study area boundaries are shown on Figure 1. The Nacatoch Aquifer is composed of the Nacatoch Sand, part of the Cretaceous Navarro Group. The Nacatoch Sand is composed of alternating sequences of fine-grained quartz sand and mudstone with a maximum thickness of 583 feet (McGowen and Lopez, 1983). Two significant accumulations of sand occur in the Bowie-Morris-Red River-Titus and Delta-Hopkins-Hunt county areas. Several cemented layers occur within the geological formation as reported on well driller reports and interpreted on geophysical well logs.

The contractor provided deliverables that included a stratigraphic framework of the Nacatoch Sand, a salinity class map, proposed locations for four potential production areas, and simple Theis modeling to calculate 30- and 50-year production volumes and drawdown without causing significant impact to water availability or quality (LBG-Guyton Associates, 2017). TWDB staff evaluated potential production areas and contract deliverables and augmented the analysis as necessary to make brackish groundwater production zone recommendations.

# Methods

This section describes methods used to augment the analysis for stratigraphy, lithology, salinity, and volumes for the evaluation of potential brackish groundwater production zones.

## Stratigraphy and lithology

TWDB staff used 635 wells to interpolate the stratigraphic framework and 803 wells with 13,360 individual lithologic layers to interpret lithology from the BRACS Database (TWDB, 2019). The net sand map was prepared using 556 lithology wells. The aquifer determination table was created by combining the TWDB BRACS and Groundwater databases with all wells in the study area. There are 3,185 wells in the table, of which 767 have a BRACS well id and no state well number, 2,244 have a state well number and no BRACS well id, and 174 have both a BRACS well id and a state well number.

We used IHS Markit Kingdom® software to make stratigraphic and lithologic picks from geophysical well logs, which greatly improved the reliability and consistency of identifying trackable stratigraphic markers and lithologic units between well logs. The Nacatoch Aquifer is composed of the Nacatoch Sand, part of the Cretaceous Navarro Group (Table 1). There are several places in the outcrop where the Nacatoch Sand is covered by alluvial and terrace deposits, particularly in the eastern counties along the Red River Valley. Estimates of alluvial/terrace thickness were made to control preparation of three-dimensional geological formation surfaces. Lithologic picks were interpreted 100 feet above and below the Nacatoch Sand on geophysical logs, where possible, to ensure complete formation coverage during net sand processing. Additional water well driller reports of lithology were appended to the study to control lithology in and near the outcrop and to provide aquifer hydraulic property data.

**Table 1. Stratigraphy of the Nacatoch Sand and surrounding geologic units in the study area. Geological formations between the Cretaceous and Pleistocene are not listed. Modified from Ashworth (1988).**

| Series | Group | Formation | Maximum thickness (feet) | Lithology |
|---|---|---|---|---|
| Recent | | Alluvium | 93 | Sand, silt, clay, and gravel |
| Pleistocene | | Fluviatile, terrace deposits | | |
| Cretaceous | Navarro | Upper Navarro Clay (Kemp Clay) | 400 | Clay, calcareous, silt, medium-dark gray |
| | | Upper Navarro Marl (Corsicana Marl) | 20 | Mudstone, sandy and hard calcareous sandstone and siltstone |
| | | Nacatoch Sand | 450 | Alternating sequences of fine-grained quartz sand and mudstone |
| | | Lower Navarro Formation (Neylandville Marl) | 125 | Clay, calcareous, silty, sandy, medium-gray |
| | Taylor | Marlbrook Marl<br>Pecan Gap Chalk<br>Wolfe City | 1,500 | Clay, marl, mudstone, and chalk |

## Salinity classes

Comparing stratigraphic surfaces to the well screen interval and total depth of wells, a process called aquifer determination, resulted in identification of 259 Nacatoch Aquifer water quality samples taken at 143 unique wells. Of these samples, 217 included measurements for total dissolved solids. The spatial distribution of measured total dissolved solids data points is in or near the outcrop of the Nacatoch Aquifer (Figure 2).

TWDB staff selected the $R_{wa}$ Minimum Method (Estepp, 1998) to calculate total dissolved solids from geophysical well logs in the Nacatoch Aquifer. The following values were selected for the calculations: 34 percent for porosity, 1.5 for the formation cementation factor (m), 0.50 to 0.56 for the "ct" factor, and 1.00 to 1.35 for the water quality correction factor (NaCl eq cf). Porosity values for the Nacatoch Sand were obtained from Report 157 (TWDB, 1972) and a neutron-density geophysical well log (BRACS well id 1592). Since there were no lab measurements available, the cementation factor was set to a default value for slightly cemented sand (Estepp, 1998). Existing water quality measurements were subdivided into ranges of salinity to provide correction factors for log analysis (Table 2).

We calculated 341 total dissolved solids estimates from 241 wells. These were mostly in the deeper and more saline portions of the study area. The following data were used to map the Nacatoch Aquifer salinity classes: (1) measurements of total dissolved solids from wells, (2) estimates of total dissolved solids from log analysis, (3) geologic faults from the Geologic Atlas of Texas (TWDB, 2007), (4) net sand distribution, and (5) best professional judgement.

**Table 2. Log analysis correction factors based on data from existing water quality measurements. Water quality samples were organized into the TDS low to high bins and averaged.**

| TDS low | TDS high | ct factor | NaCl eq cf | Average TDS | Number of samples |
|---|---|---|---|---|---|
| 0 | 499 | 0.53 | 1.35 | 331 | 37 |
| 500 | 999 | 0.56 | 1.30 | 698 | 107 |
| 1,000 | 1,999 | 0.53 | 1.22 | 1,295 | 52 |
| 2,000 | 2,999 | 0.50 | 1.16 | 2,311 | 4 |
| Greater than 3,000 | ---- | 0.56 | 1.00 | N/A | N/A |

**Notes:**
TDS is total dissolved solids concentration in units of milligrams per liter.
ct is a correction factor = specific conductance / total dissolved solids.
NaCl eq cf is a BRACS water quality correction factor termed the sodium chloride equivalent correction factor.
N/A is none available.

## Volumes

Volumes of total in-place groundwater were calculated by multiplying area by saturated thickness by specific yield. This is also known as the total aquifer storage, which is defined as the total calculated volume of groundwater that an aquifer is capable of producing (Texas Water Code §36.001(24)). In the outcrop, saturated thickness was equal to the interpolated static water level elevation minus the interpolated bottom elevation of the Nacatoch Sand multiplied by the percent sand. The percent sand was calculated by dividing the interpolated net sand by the thickness of the Nacatoch Sand formation. The thickness of the Nacatoch Sand formation was calculated by subtracting the interpolated bottom elevation from the interpolated top elevation. In the subcrop, the saturated thickness was set equal to the interpolated net sand. The geological formation subcrop was assumed to be fully saturated and that any artesian water would be an insignificant volume compared to the regional in-place water volume.

# Results

This section describes results of augmenting the stratigraphy, lithology, salinity, and volume calculations used in the evaluation of potential brackish groundwater production zones.

## Stratigraphy

We used 587 wells, 110,530 outcrop elevation points, 24 alluvial thickness estimate points, and 18 guide points to interpolate the Nacatoch Sand top elevation. We subtracted this raster from the ground surface digital elevation model to create the top depth raster (Figure 3). The minimum top depth of the Nacatoch Sand in the study area is 0 feet, the maximum is 2,065 feet, and the mean is 856 feet.

We used 593 wells, 94 outcrop elevation points, and 22 guide points to interpolate the Nacatoch Sand bottom elevation. We subtracted this raster from the ground surface digital elevation model to create the bottom depth raster (Figure 4). The minimum bottom depth of the Nacatoch Sand in the study area is 1 foot, the maximum is 2,421 feet, and the mean is 1,207 feet.

The isopach thickness raster was created by subtracting the bottom elevation raster from the top elevation raster. Isopach thickness ranges from 0 to 583 feet with a mean of 351 feet (Figure 5). The geological formation is thickest in the Hunt and Hopkins-Franklin-Titus county areas. Extensive quality control checks were run to ensure geological surfaces created using Geographic Information System interpolation met BRACS standards.

Geological formation surfaces within the Mexia-Talco Fault Zone (a series of normal faults, grabens, and horsts) are not well constrained due to the lack of sufficient well control needed to define fault locations and offsets. The geologic faults from the Geologic Atlas of Texas (TWDB, 2007) were used knowing that many synthetic and antithetic faults are not mapped. Quaternary alluvium and terrace deposits obscure fault traces at the surface, further exacerbating the problem. Geological formation rasters in these areas should be used cautiously.

## Lithology

We used 556 wells with lithology records and 182 zero-value outcrop points to interpolate net sand rasters. Net sands ranged from 0 to 264 feet with a mean of 70 feet. The greatest accumulation of sand is in the Delta-Hopkins-Hunt and Bowie-Morris-Red River-Titus county areas (Figure 6).

## Salinity classes

Salinity classes were based on the U.S. Geological Survey groundwater salinity classification system (Winslow and Kister, 1956) that includes fresh water (0 to 999 milligrams per liter [mg/L] of total dissolved solids), slightly saline (1,000 to 2,999 mg/L of total dissolved solids), moderately saline (3,000 to 9,999 mg/L of total dissolved solids), very saline (10,000 to 34,999 mg/L of total dissolved solids), and brine (greater than 35,000 mg/L of total dissolved solids). A total of 503 data points were used to map Nacatoch Aquifer groundwater salinity (Figure 7). The total dissolved solids dataset included 217 measurements (147 fresh, 67 slightly saline, and 3 moderately saline) and 286 calculations (4 fresh, 26 slightly saline, 104 moderately saline, and 152 very saline). We mapped two "mixed" salinity classes where multiple closely-spaced wells had (1) two or more distinct salinity classifications stacked on top of each other in the Nacatoch Sand (43 wells) or (2) wells with different salinity classes too close to each other to parse into separate zones.

Normal geologic faults associated with the Mexia-Talco Fault Zone may be parallel to strike or oblique to strike. The former may act as barriers to groundwater flow, especially where faults are downdip of outcrop and completely offset sand beds. Juxtaposition of fresh water and very saline water in northern Franklin County and fresh and moderately saline water in northeastern Hopkins County (compare Figures 1 and 7) are two examples. Normal faults oblique to strike may inhibit groundwater flow, but not act as barriers, since groundwater could flow around the faults (for example, northern Kaufman and southern Hunt counties).

## Volumes

TWDB staff estimates that the Nacatoch Sand in the 3-million-acre study area contains 18 million acre-feet of total in-place groundwater. This volume includes 2.1 million acre-feet of fresh, 2.0 million acre-feet of slightly saline, 3.7 million acre-feet of moderately saline, and 8.2

million acre-feet of very saline groundwater. The remaining 2 million acre-feet of groundwater are in mixed classes where a unique salinity class could not be assigned. Groundwater volumes were calculated by county and salinity class (Table 3).

**Table 3. Volume of total in-place groundwater in the Nacatoch Aquifer in the study area. Data organized by county and salinity class.**

| County | Volume of groundwater (acre-feet) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Salinity classes | | | | | | Total |
| | Fr | Fr-Ss | Ss | Ms | Ms-Vs | Vs | |
| Bowie | 670,000 | - | 690,000 | 210,000 | 1,850,000 | - | 3,420,000 |
| Delta | 130,000 | 20,000 | - | - | - | - | 150,000 |
| Ellis | - | - | - | - | - | - | - |
| Franklin | 20,000 | - | - | - | - | 810,000 | 830,000 |
| Freestone | - | - | - | - | - | 310,000 | 310,000 |
| Henderson | - | - | 10,000 | 60,000 | - | 520,000 | 590,000 |
| Hopkins | 390,000 | - | 390,000 | 1,040,000 | - | 1,270,000 | 3,090,000 |
| Hunt | 340,000 | 10,000 | 370,000 | 710,000 | - | - | 1,430,000 |
| Kaufman | 90,000 | - | 110,000 | 450,000 | - | 310,000 | 960,000 |
| Lamar | 10,000 | - | - | - | - | - | 10,000 |
| Morris | - | - | - | 70,000 | 40,000 | 160,000 | 270,000 |
| Navarro | 60,000 | - | 150,000 | 170,000 | - | 790,000 | 1,170,000 |
| Rains | - | - | - | 320,000 | - | 470,000 | 790,000 |
| Red River | 410,000 | - | 320,000 | 320,000 | - | 30,000 | 1,080,000 |
| Rockwall* | - | - | - | - | - | - | - |
| Titus | - | - | - | 100,000 | - | 1,410,000 | 1,510,000 |
| Van Zandt | - | - | - | 270,000 | - | 1,450,000 | 1,720,000 |
| Wood | - | - | - | - | - | 660,000 | 660,000 |
| Total | 2,120,000 | 30,000 | 2,040,000 | 3,720,000 | 1,890,000 | 8,190,000 | 17,990,000 |
| Percent | 11.8 | 0.2 | 11.3 | 21 | 10.5 | 45.5 | 100.0 |

**Notes:**
Volumes are rounded to the nearest 10,000-acre-foot.

*Rockwall County contains fresh water, but the outcrop area is so small compared to the study grid cell size that calculations were not made.

Fr (Fresh) = 0 to 999 milligrams per liter total dissolved solids
Fr-Ss = area with a mix of fresh and slightly saline measurements and calculations
Ss (Slightly saline) = 1,000 to 2,999 milligrams per liter total dissolved solids
Ms (Moderately saline) = 3,000 to 9,999 milligrams per liter total dissolved solids
Ms-Vs = area with a mix of moderately and very saline measurements and calculations
Vs (Very saline) = 10,000 to 35,000 milligrams per liter total dissolved solids

# Brackish groundwater production zones

Texas Water Code §16.060 requires that the TWDB identify and designate local or regional brackish groundwater production zones, describe the volumes of brackish groundwater that zones are capable of producing, recommend reasonable monitoring to observe the effects of production in zones, work with stakeholders, and report zones to the governor, lieutenant governor, and speaker of the House of Representatives in the biennial desalination report.

TWDB staff recommends five brackish groundwater production zones in the Nacatoch Aquifer study area: NCTC1, NCTC2, NCTC3, NCTC4, and NCTC5 (Figure 8). The combined area of these brackish groundwater production zones is 326,773 acres. Zone NCTC1 is the only recommended brackish groundwater production zone to overlap with a groundwater conservation district (Figure 9). These zones were approved by the Board on March 28, 2019.

## Designation

Brackish groundwater production zones were recommended in accordance with the criteria outlined in Texas Water Code §16.060 including: aquifer availability and productivity, fresh and brackish groundwater locations, hydrogeologic barriers, administrative jurisdictions, water well existing use, wastewater injection or disposal wells, and potential pumping impacts. The Nacatoch Aquifer in the study area is assumed to be available and productive since active water wells are in the updip portions and oil and gas wells exist in the downdip portions. No public aquifer test data were found in the recommended brackish groundwater production zones, so the aquifer productivity could not be verified. The location of fresh and brackish groundwater was identified during the salinity class mapping. The interbedded sand and clay that overlie and underlie the Nacatoch Sand act as a significant hydrogeologic barrier to isolate fresh groundwater in other aquifers. The distance from a recommended brackish groundwater production zone to existing water wells is referred to as a horizontal distance hydrogeologic barrier. Normal geologic faults exist between portions of a brackish groundwater production zone and updip fresh groundwater and may act as a hydrogeologic barrier.

A three-mile buffer was applied to the state line, downdip of the fresh water line, and 784 existing water wells completed in the Nacatoch Aquifer. Existing water wells include 94 agricultural wells, 572 domestic wells, and 118 municipal wells. Water wells from the following datasets were used: the TWDB Groundwater Database, the TWDB BRACS Database, the Texas Department of Licensing and Regulation Submitted Driller's Report Database, and the Texas Commission on Environmental Quality Public Drinking Water Database. Areas within the three-mile buffers were not considered for brackish groundwater production zones.

TWDB staff evaluated injection wells in the Nacatoch Sand interval within 15 miles of the study area. No Class I or IV injection wells were discovered. There are 532 Class II injection wells within the study area. Three of these Class II injection wells are for liquid petroleum gas, which were not buffered since injection fluid is restricted to reservoir storage. The remaining wells were buffered with a 15-mile radius, and areas within the buffer were removed from brackish groundwater production zone consideration. Five Class III injection wells for brine mining are in a salt dome in Van Zandt County, but these were not buffered since injection fluids are restricted to the mining activity as opposed to waste disposal. Nineteen Class V injection wells for heat flow and shallow aquifer remediation were located, but these were not buffered since they are shallow and do not pose significant risk.

## Production volumes in zones

The total in-place groundwater volumes were calculated for brackish groundwater production zones by salinity class (Table 4). Each of these zones contains moderately saline groundwater (3,000 to 9,999 milligrams per liter total dissolved solids) and a small portion of zone NCTC3 contains slightly saline groundwater (1,000 to 2,999 milligrams per liter of total dissolved solids).

**Table 4. Volume of total in-place groundwater in the recommended brackish groundwater production zones for the Nacatoch Aquifer.**

| Brackish groundwater production zone | Volume of water (acre-feet)* | | |
|---|---|---|---|
| | Slightly saline | Moderately saline | Total |
| NCTC1 | - | 70,000 | 70,000 |
| NCTC2 | - | 20,000 | 20,000 |
| NCTC3 | 10,000 | 1,420,000 | 1,430,000 |
| NCTC4 | - | 140,000 | 140,000 |
| NCTC5 | - | 100,000 | 100,000 |
| Total | 10,000 | 1,750,000 | 1,760,000 |

**Notes:**
* Volume values are rounded to the nearest 10,000-acre-foot.
Slightly saline = 1,000 to 2,999 milligrams per liter total dissolved solids
Moderately saline = 3,000 to 9,999 milligrams per liter total dissolved solids

The contractor (LBG-Guyton Associates, 2017) provided Theis drawdowns based on hypothetical wellfields consisting of six wells spaced 4,000 feet apart using aquifer parameters from the TWDB Nacatoch Aquifer Groundwater Availability Model (Beach and others, 2009). They calculated the effects of pumping 100, 200, and 500 acre-feet per year over a 30- and 50-year period. TWDB staff recalculated the hypothetical drawdowns using aquifer test data from nearby water wells. Transmissivity data was obtained from 16 wells completed in the Nacatoch Aquifer.

Based on a simple Theis drawdown and assuming a wellfield produces approximately 200 acre-feet per year for a 50-year period, we estimated 24 to 43 feet of drawdown at the nearest known water well updip from the brackish groundwater production zones. Therefore, no significant pumping impacts are expected from developing a wellfield in the brackish groundwater production zones. The parameters used for calculations are based on the nearest aquifer transmissivity data to the brackish groundwater production zone (Table 5). The size and production of the wellfields are within the limits of updip well production and are by design conservative. The contractor recommended hypothetical wellfields of six wells spaced 4,000 feet apart. Due to its small area, we used only five wells in zone NCTC2. We assumed at least two wellfields could be sited in zone NCTC3 since its area is large. If a brackish wellfield is planned in the future, actual pumping well tests and monitor well data should provide improved production, well spacing, and drawdown estimates that can be used to refine wellfield design.

**Table 5. Theis drawdown production and parameters for hypothetical brackish groundwater production zone wellfields.**

| Parameters | NCTC1 | NCTC2 | NCTC3 | NCTC4 | NCTC5 |
|---|---|---|---|---|---|
| 50-year cumulative production (acre-feet) | 10,000 | 8,250 | 20,000 | 10,000 | 10,000 |
| 30-year cumulative production (acre-feet) | 6,000 | 4,950 | 12,000 | 6,000 | 6,000 |
| Annual cumulative production (acre-feet) | 200 | 165 | 400 | 200 | 200 |
| Number of wellfields | 1 | 1 | 2 | 1 | 1 |
| Number of wells per wellfield | 6 | 5 | 6 | 6 | 6 |
| Well yield per well (gallons per minute) | 20 | 20 | 20 | 20 | 20 |
| Storage coefficient | 0.000102 | 0.000102 | 0.000102 | 0.000102 | 0.000102 |
| Transmissivity ($feet^2$/day) | 59 | 59 | 59 | 27 | 27 |
| Transmissivity (gallons per day/foot) | 444 | 444 | 444 | 200 | 200 |
| Estimated drawdown 3 miles updip from brackish groundwater production zone (feet) | 24 | 24 | 24 | 43 | 43 |
| Transmissivity source data BRACS well id | 86457 | 86457 | 86457 | 86461 | 86461 |
| Storage coefficient source data BRACS well id | 86451 | 86451 | 86451 | 86451 | 86451 |
| Area of brackish groundwater production zone (acres) | 30,704 | 7,228 | 258,531 | 16,616 | 13,694 |

## Groundwater monitoring in zones

In general, groundwater monitoring is required within the Nacatoch Aquifer and the various aquifers overlying the Nacatoch Aquifer. Monitoring in wells completed in these aquifers would ensure that the marine clay in the upper Navarro Group overlying the Nacatoch Sand provides an adequate hydrologic barrier. Fresh water resources of the Nacatoch Aquifer, updip from the zones, should also be monitored to ensure that significant impact caused by the production of brackish groundwater is prevented. Monitoring is not required below the basal sand unit of the Nacatoch Aquifer because there are no known fresh or brackish aquifers that would be impacted by pumping in these zones. Future wellfields in the brackish zones should include monitor wells to track water levels and water quality during production.

## Stakeholder engagement

A small portion of zone NCTC1 is within the Neches and Trinity Valleys Groundwater Conservation District (Figure 9). Three public stakeholder meetings were held in or near the study area. The first was held on February 8, 2017, in Mount Pleasant, Texas. The second was held on April 18, 2017, in Commerce, Texas. The third was held on October 25, 2017, in Mount Pleasant, Texas. Presentations given at the meetings can be downloaded from the TWDB website: www.twdb.texas.gov/innovativewater/bracs/HB30.asp. A stakeholder email was sent out before the March 28, 2019, public TWDB Board meeting announcing zone designations.

### Biennial desalination report

A summary of the Nacatoch Aquifer Brackish Groundwater Production Zones will be included in the December 1, 2020, biennial desalination report to the governor, lieutenant governor, and speaker of the House of Representatives.

## Limitations

The brackish groundwater production zones were made with the best publicly available data at the time of the analysis. All interpretations and calculations used for the mapping are stored and available in the BRACS Database and Geographic Information System files posted on the TWDB website (www.twdb.texas.gov/innovativewater/bracs/studies.asp). As more wells are drilled and monitored and more data becomes available, recommendations may change.

# References

Ashworth, J.B., 1988, Ground-water resources of the Nacatoch Aquifer: Texas Water Development Board Report 305, 149 p.

Beach, J.A., Huang, Y., Symank, L., Ashworth, J.B., Davidson, T., Vreugdenhil, A.M., and Deeds, N.E., 2009, Nacatoch Aquifer groundwater availability model: LBG-Guyton Associates, contract report to the Texas Water Development Board, variously paginated.

Estepp, J.D., 1998, Evaluation of groundwater quality using geophysical logs: Texas Natural Resource Conservation Commission, unpublished report, variously paginated.

George, P.G., Mace, R.E., and Petrossian, R., 2011, Aquifers of Texas: Texas Water Development Board Report 380, 172 p.

LBG-Guyton Associates, 2017, Identification of Potential Brackish Groundwater Production Areas – Nacatoch Aquifer: LBG-Guyton Associates, contract report (1600011952) to the Texas Water Development Board, variously paginated.

McGowen, M.K., and Lopez, C.M., 1983, Depositional systems in the Nacatoch Formation (Upper Cretaceous), northeast Texas and southwest Arkansas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations 137, 59 p.

Texas, 2015, House Bill 30, 84th Legislature, Regular Session.

TWDB (Texas Water Development Board), 1972, Subsurface Saline Water of Texas, Volume 3 Aquifer Rock Properties: Texas Water Development Board Report 157, 362 p.

TWDB (Texas Water Development Board), 2007, The geologic atlas of Texas: U.S. Geological Survey, contract geodatabase to the Texas Water Development Board, Version 3, one geodatabase.

TWDB (Texas Water Development Board), 2019, BRACS Database: www.twdb.texas.gov/innovativewater/bracs/database.asp.

Winslow, A.G., and Kister, L.R., 1956, Saline-water resources of Texas: U.S. Geological Survey Water-Supply Paper 1365, 105 p.

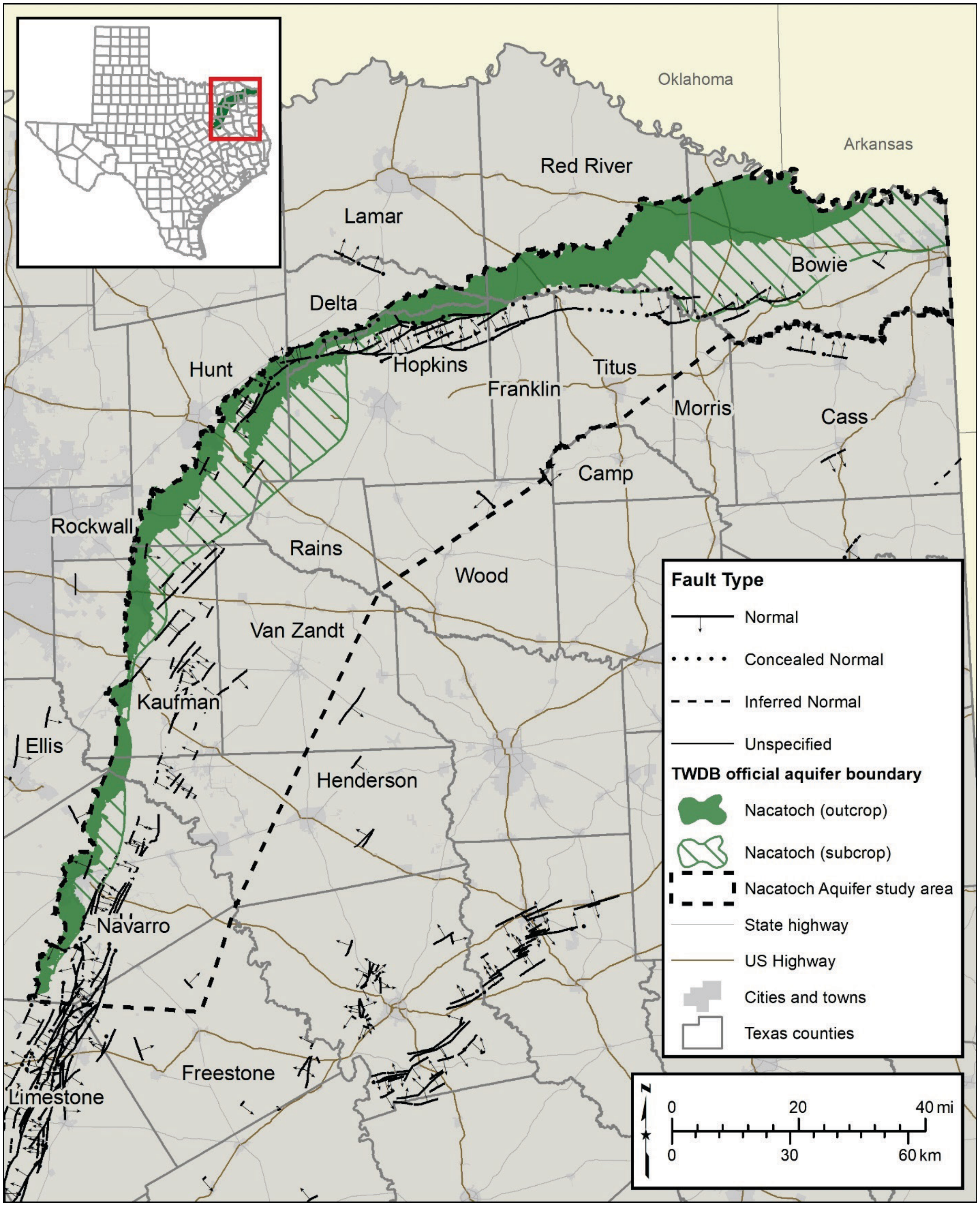


**Figure 1.** **Nacatoch Aquifer study area showing counties, the minor aquifer boundary as defined by the TWDB, and geologic faults from the Geologic Atlas of Texas.**

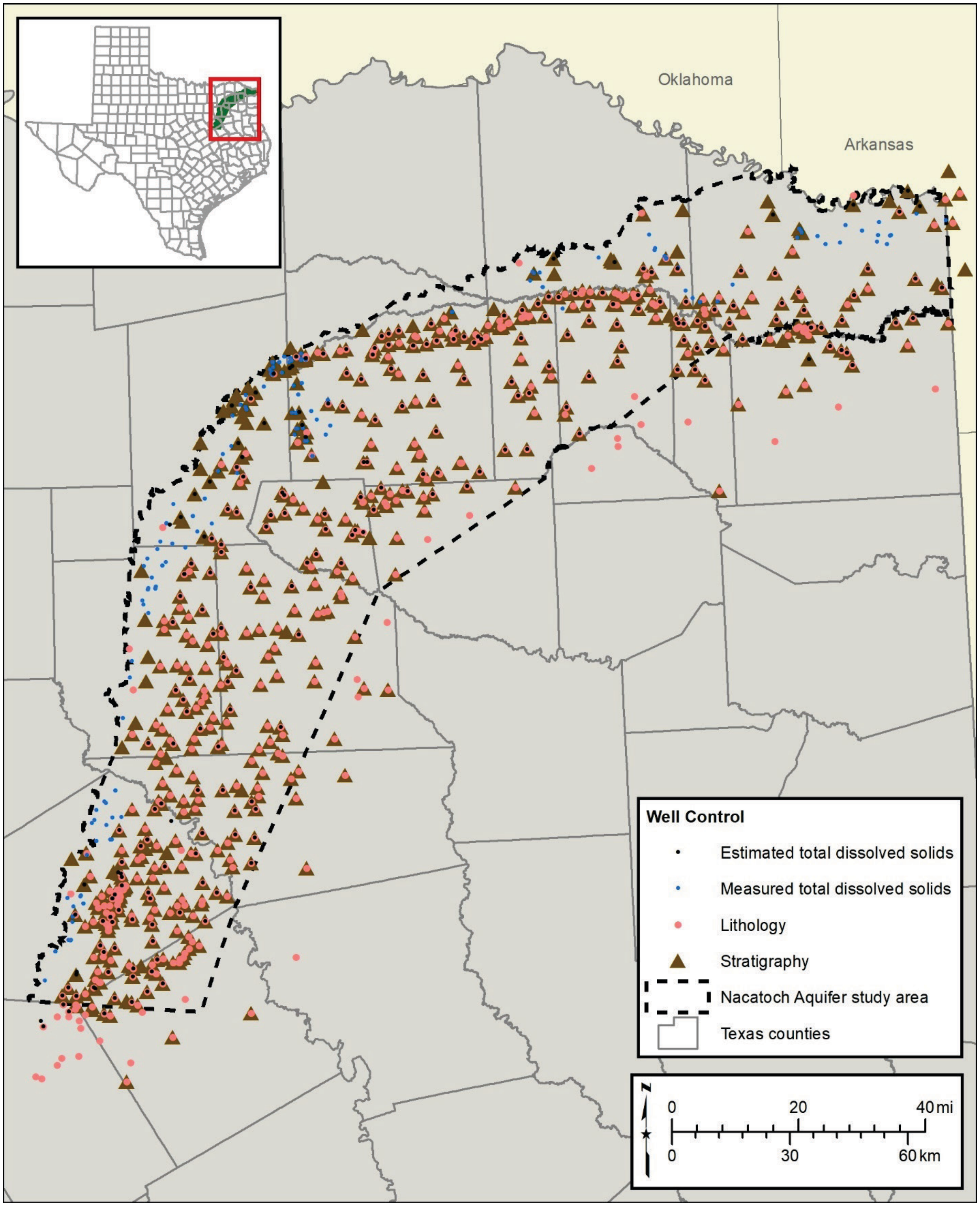


**Figure 2. Well control used to define the lithology, stratigraphy, and measured and estimated total dissolved solids of the Nacatoch Sand. The BRACS Database contains the well control, and most of the measured total dissolved solids samples originated in the TWDB Groundwater Database.**

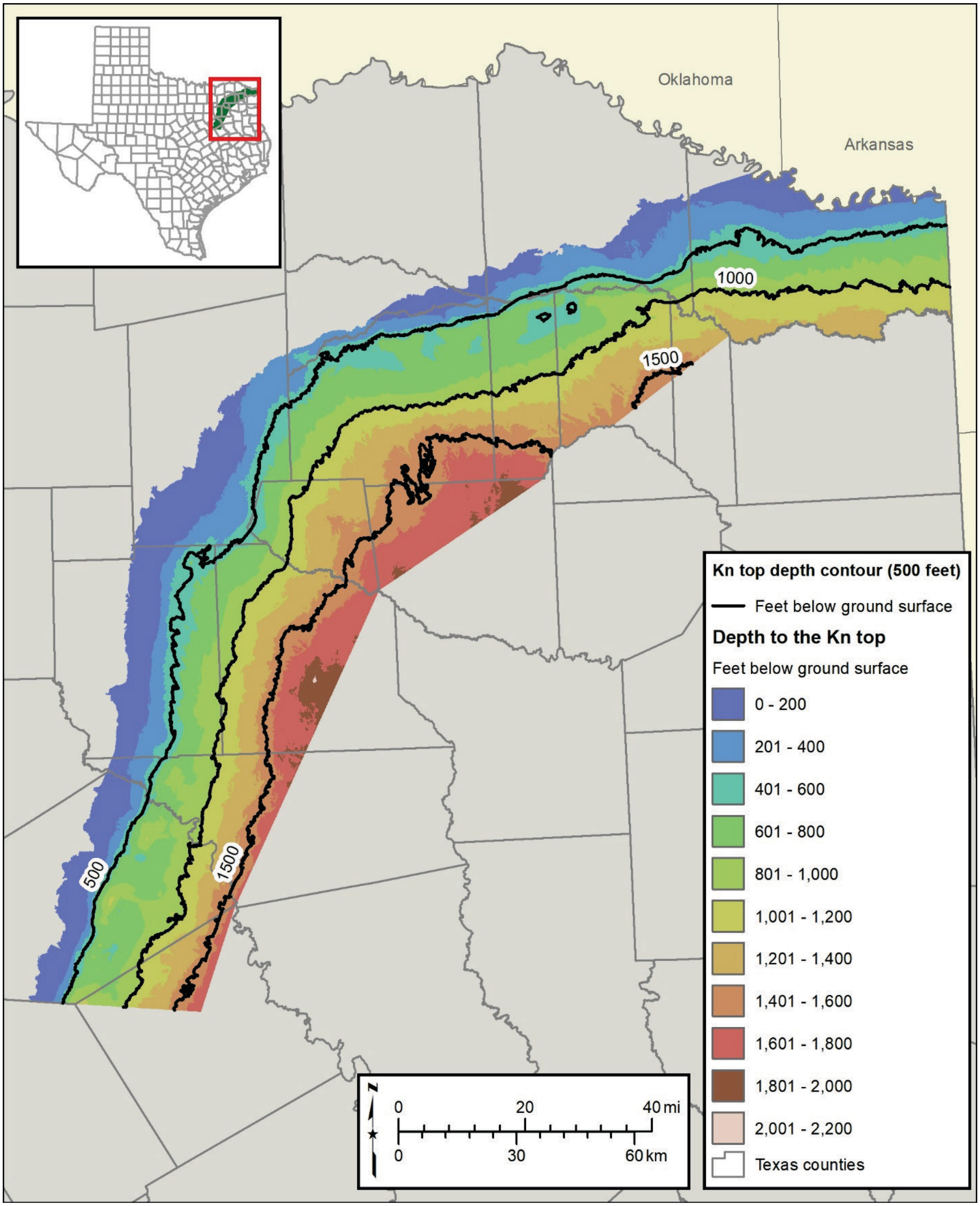


**Figure 3. Top depth of the Nacatoch Sand (Kn) in feet below ground surface.**

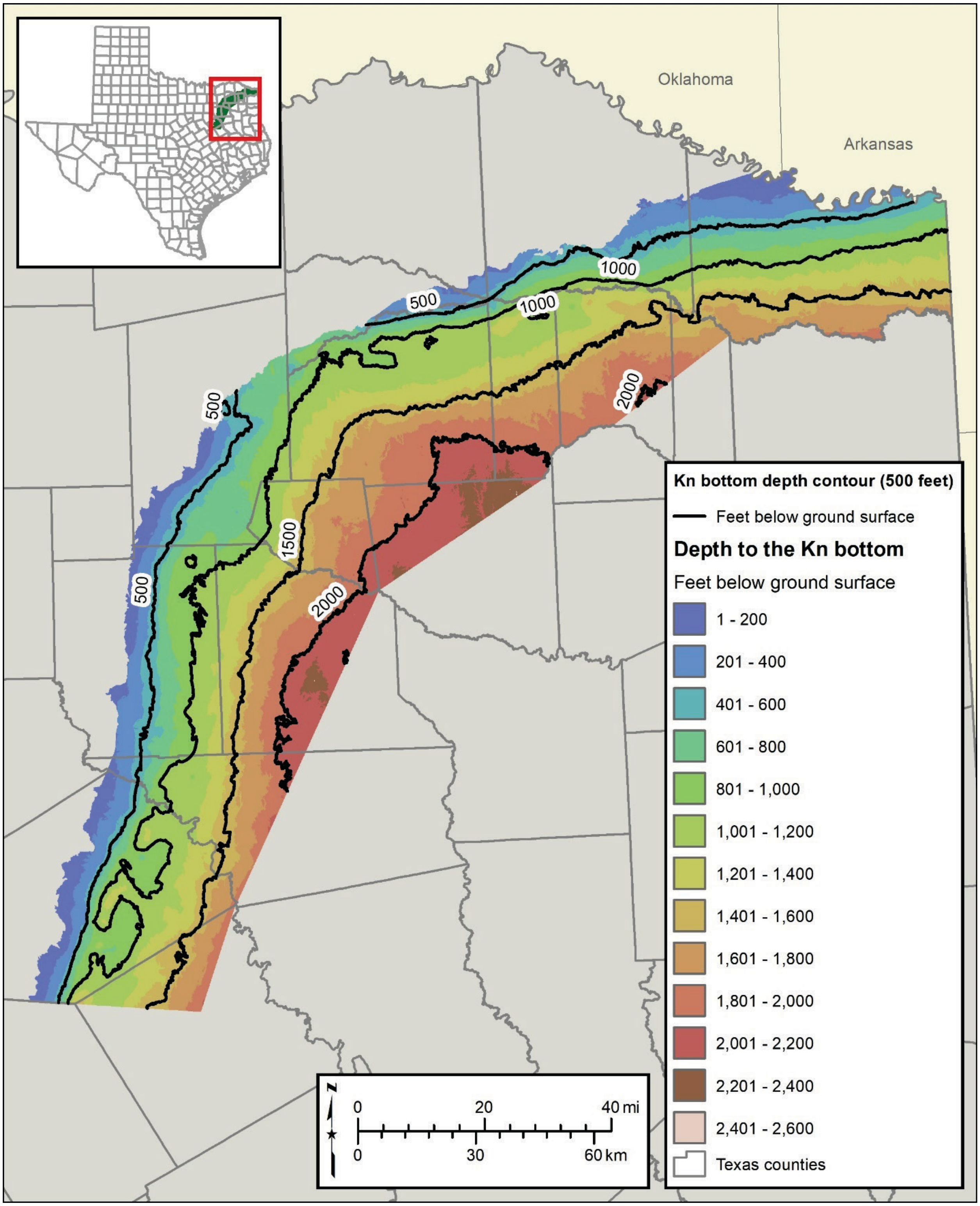


**Figure 4. Bottom depth of the Nacatoch Sand (Kn) in feet below ground surface.**

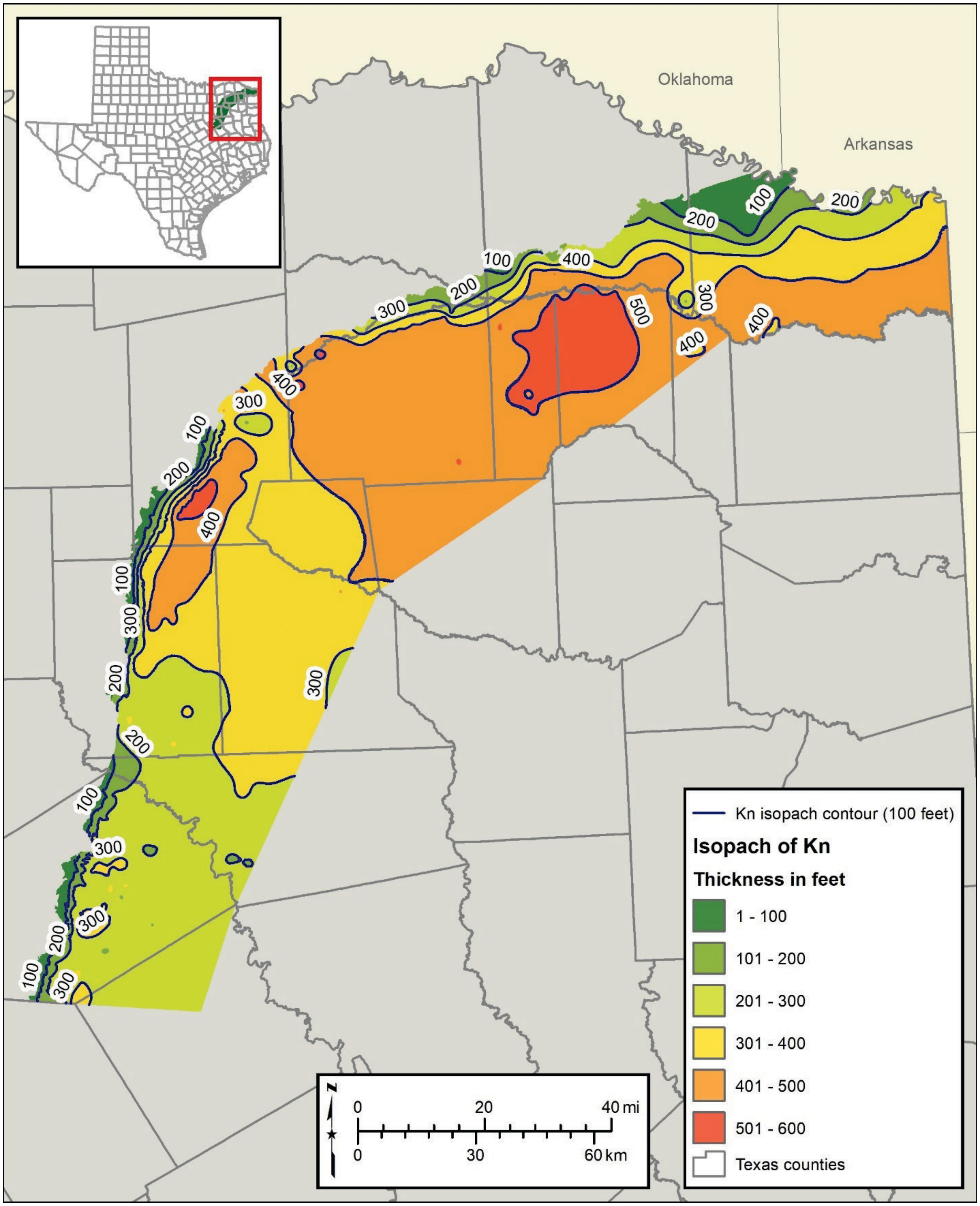


**Figure 5. Isopach of the Nacatoch Sand (Kn).**

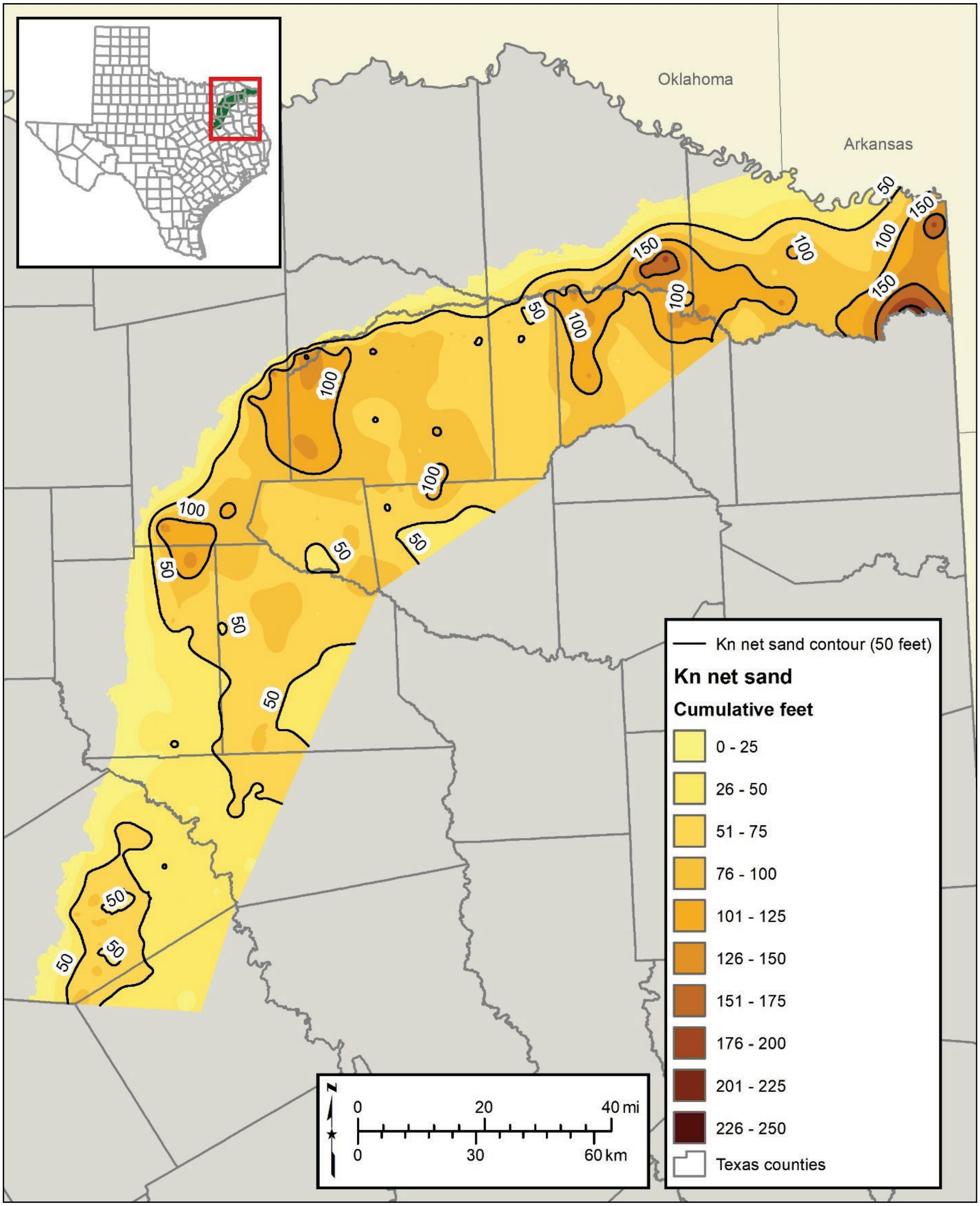


**Figure 6. Net sand of the Nacatoch Sand (Kn) in feet.**

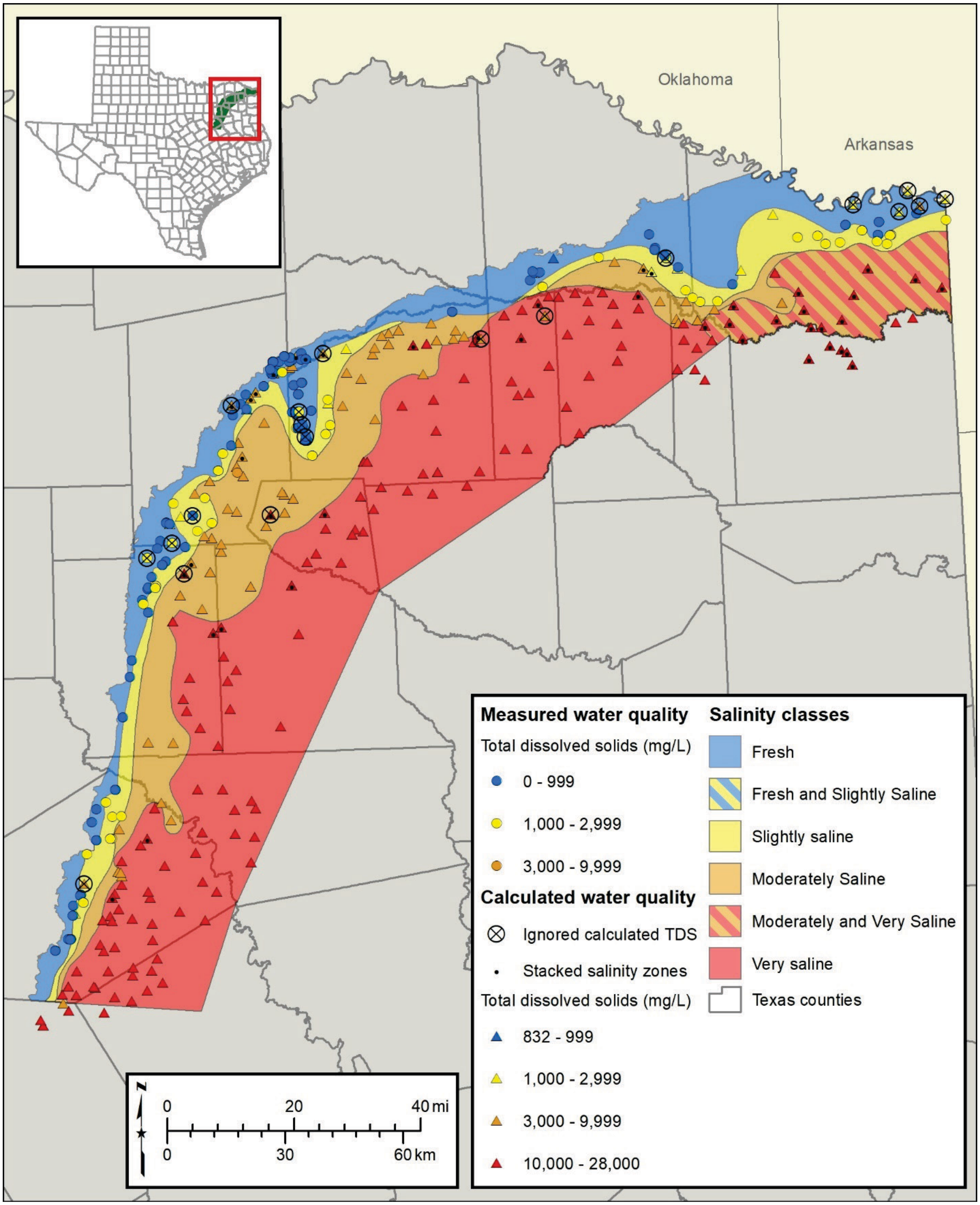


**Figure 7.** **Salinity classes of the Nacatoch Aquifer. Total dissolved solids (TDS) are measured in milligrams per liter (mg/L).**

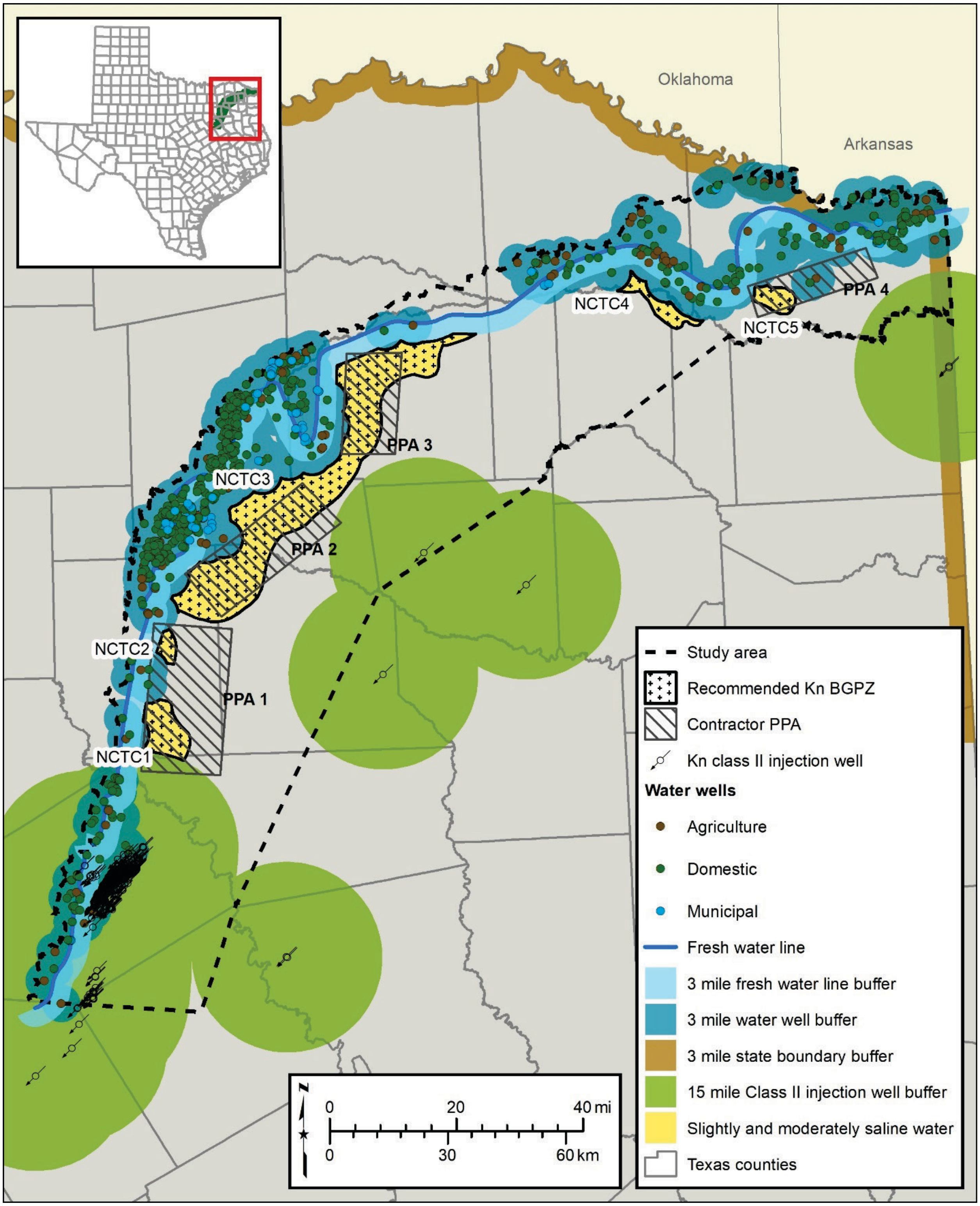


**Figure 8.** **Nacatoch Aquifer (Kn) brackish groundwater production zones (BGPZ). Exclusion wells include water wells and Class II injection wells. Buffers surrounding the wells, state line, and fresh water line were used to define BGPZ limits. Downdip limit of the BGPZ was based on the moderately saline – very saline interface. Potential production areas (PPA) proposed by the contractor are shown for reference.**

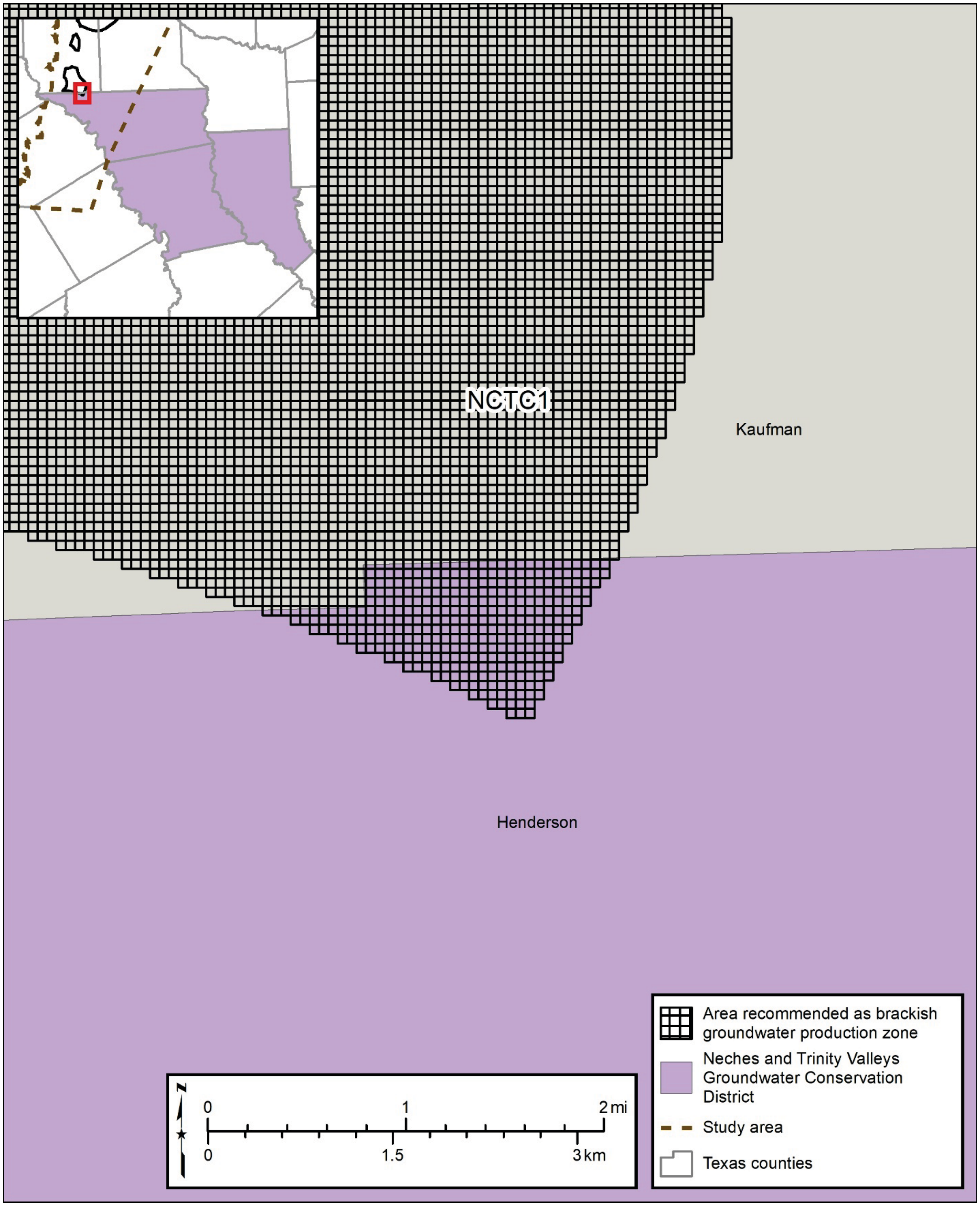


**Figure 9.** **Detail map showing the overlap of the 250-foot grid cells for brackish groundwater production zone NCTC1 and the Neches and Trinity Valleys Groundwater Conservation District.**