Brackish Groundwater Production Zone Recommendations for the Blossom Aquifer, Texas

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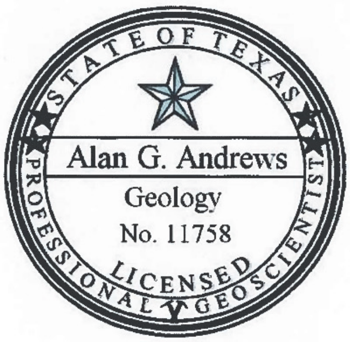
Brackish Resources Aquifer Characterization System Program
Innovative Water Technologies Department

Texas Water Development Board

Geoscientist Seals



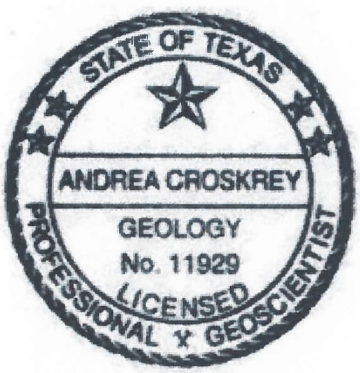
Brackish Resources Aquifer Characterization System Program (BRACS)

The contents of this report (including figures and tables) document the work of the following licensed Texas geoscientists:

Alan G. Andrews, P.G. No. 11758

Mr. Andrews identified and gathered data for analysis, made stratigraphic and lithologic interpretations using geophysical logs, created raster interpolations for stratigraphy and lithology, calculated total dissolved solids from geophysical logs, mapped salinity zones, created GIS files, and provided content for this report. The seal appearing on this document was authorized on March 5, 2019, by

Alan G. Andrews



The contents of this report (including figures and tables) document the work of the following licensed Texas geoscientist:

Andrea Croskrey, P.G. No. 11929

Ms. Croskrey finalized datasets and completed groundwater volume calculations, finalized GIS files for publication, and completed the report. The seal appearing on this document was authorized on March 5, 2019, by

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Executive summary

The Blossom Aquifer, a minor aquifer in northeast Texas, was evaluated for brackish groundwater resources and brackish groundwater production zones as required by Texas Water Code (TWC) §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 Blossom 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 three zones in the Blossom Aquifer.

These three brackish groundwater production zones include slightly and moderately saline in-place groundwater with an estimated total volume of 780,000 acre-feet. Potential production of brackish groundwater from recommended zones at a rate of 100 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 approximately 10 million acre-feet of total in-place groundwater.

Introduction

The Blossom Aquifer is a minor aquifer in northeast Texas (George and others, 2011). The Blossom Aquifer is composed of the Blossom Sand geological formation, part of the Cretaceous Austin Group. The Blossom Sand is composed of fine to medium sand interbedded with marl and chalky marl with a maximum thickness of 360 feet (McLaurin, 1988).

The contractor provided deliverables that included a stratigraphic framework of the Blossom Aquifer, a salinity class map, proposed locations for three potential production areas, and simple Theis modeling to calculate 30- and 50-year production volumes without causing significant impact to water availability or water quality and to determine the effect of pumping on surrounding water resources. TWDB staff evaluated the potential production areas and augmented the analysis as necessary to make brackish groundwater production zone recommendations.

Methods

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

Stratigraphy and lithology

The contractor used 52 wells to determine a stratigraphic framework, interpret lithology, and calculate salinity (LBG-Guyton Associates, 2017). Of the 52 wells, 43 wells came from the TWDB BRACS Database (TWDB, 2018). TWDB staff added 136 wells from the BRACS unprocessed geophysical logs collection, Texas Railroad Commission Q-log Collection, and Texas Commission on Environmental Quality Public Drinking Water Database. This increased the total well control to 188 wells (Figure 1). All 188 wells were used to determine the stratigraphic framework and interpret lithology. Due to log parameter standards, salinity calculations could only be performed on 120 of the 188 wells. The contractor made 242 lithologic picks on their 52 wells, and an additional 1,605 lithologic picks were added for a total of 1,847.

We used IHS Markit Kingdom® software to make stratigraphic and lithologic picks, which greatly improved the reliability and consistency of identifying trackable stratigraphic markers and lithologic units between well logs. Key regional stratigraphic markers used to constrain the Blossom Sand included the top of the Pecan Gap Formation of the Taylor Group and the top of the Ector Chalk Formation of the Austin Group (Table 1). To improve interpolation of subsurface elevation values as they approach the outcrop, the Blossom Aquifer outcrop used for this study takes into consideration the Tokio Formation outcrop in Arkansas, which is stratigraphically equivalent to the Blossom Sand. The outcrop differs from the official TWDB minor aquifer extent (George and others, 2011) in the eastern part of the study area, where the formation is covered by Red River valley alluvium. Lithologic picks were expanded from the basal sand in the Blossom Sand to the entire geological formation.

Table 1. Stratigraphy of the Blossom Sand and surrounding geologic units.

Era	System	Series	Group	Formation	Maximum thickness (feet)	Lithology
Cenozoic	Quaternary	Recent		Alluvium	75	Sand, silt, clay, and gravel
		Pleistocene		Fluviatile, terrace deposits		
Mesozoic	Cretaceous	Gulf	Taylor	Marlbrook Marl, Pecan Gap Chalk, Wolfe City – Ozan Formation	1,500	Clay, marl, shale, chalk, mudstone, and sandstone, very fine-grained
			Austin	Gober Chalk	300	Chalk, discontinuous
				Brownstown	220	Clay or shale
				Blossom Sand	360	Fine to medium sand interbedded with marl and chalky marl
				Bonham	530	Clay or shale
				Ector	80	Chalk
			Eagle Ford		650	Shale with thin beds of sandstone and limestone

Source: Modified from McLaurin (1988)

Salinity classes

Salinity classes were delineated using hand contouring of total dissolved solids samples and calculations. Comparing stratigraphic mapping to the well screen interval and total depth of wells, a process called aquifer determination, resulted in identifying 115 water quality samples taken at 56 unique wells. Since we limited the samples to wells solely screened in the Blossom Aquifer, there were 25 fewer samples and 17 fewer wells than the 140 samples in 73 wells used by the contractor. The resulting spatial distribution of sampled water quality data points was either in or near the outcrop of the Blossom Aquifer. Of the 56 well locations with water quality measurements discretely from the Blossom Aquifer, six locations had nearby geophysical well logs to validate total dissolved solids calculations based on resistivity readings.

The contractor calculated total dissolved solids using the Spontaneous Potential and Alger-Harrison methods (LBG-Guyton Associates, 2017). To implement a consistent methodology, TWDB staff selected to use the Rwa Minimum Method to calculate total dissolved solids (Estepp, 1998). The following values were selected for the total dissolved solids calculations in the Blossom Aquifer: 34 percent for porosity, 1.5 for the formation cementation factor (m), 0.51 to 0.57 for the "ct" factor, and 1 to 1.37 for the water quality correction factor (NaCL eq cf). Porosity values for the Blossom Sand were obtained from a Red River County test well drilled in 1982 (McLaurin, 1988) and a Marion County well drilled prior to 1971 downdip and south of the study area (TWDB, 1972). Since no lab-derived values were available, the formation 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). The "NaCL eq cf" correction factor values are also specific to a range of total dissolved solids and were used to determine the sodium chloride equivalent of total dissolved solids. This approach corrects for the changes in specific conductance of total dissolved solids dependent on variations in the species that make up the solution. The "ct" and

"NaCl eg cf" are unique to this aquifer and water quality measurements acquired for this study. The "NaCl eg cf" is also referred to as the "Rwe to Rw Conversion" correction factor in the BRACS Database (TWDB, 2018). All total dissolved solids calculations are saved in the BRACS Database.

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	0.55	1.37	243	17
500	999	0.54	1.28	830	28
1,000	1,999	0.57	1.28	1,080	32
2,000	2,999	0.53	1.23	2,416	3
3,000	3,999	0.52	1.25	3,460	2
4,000	4,999	0.51	1.23	4,214	1
Greater than 5,000		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.
NcCl eq cf is a BRACS water quality correction factor termed the sodium chloride equivalent correction factor.

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 Blossom Sand multiplied by the percent sand. The percent sand was calculated by dividing the interpolated net sand by the thickness of the Blossom Sand. The thickness of the Blossom Sand 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 sands. The formation subcrop was assumed to be fully saturated and that any artesian waters would be insignificant volumes compared to the regional in-place water volume.

Results

This section describes results of augmenting the contracted analysis of stratigraphy, lithology, salinity, and volumes used for the evaluation of potential brackish groundwater production zones.

Stratigraphy

We used 176 wells and 134 outcrop elevation points to interpolate the Blossom Sand top elevation. A raster dipping from the north-northwest to south-southeast was created. We subtracted this raster from the ground surface digital elevation model to create the top depth raster (Figure 2). The minimum top depth of the Blossom Sand in the study area is 0 feet, the maximum is 2,343 feet, and the mean is 863 feet.

We used 187 wells and 131 outcrop elevation points to interpolate the Blossom Sand bottom elevation. A raster dipping from the north-northwest to south-southeast was created. Subtracting this raster from the digital elevation model for the study area resulted in Blossom Sand bottom depths that ranged from 1 to 2,687 feet below ground surface with a mean of 1,119 feet (Figure 3).

Subtracting the Blossom Sand bottom elevation raster from the top elevation raster resulted in an isopach raster for the Blossom Sand. The isopach generally thickens to the east and thins to the west. Thickness ranges from 1 to 403 feet with the mean thickness of 256 feet in the study area (Figure 4).

Lithology

Data to interpolate net sand values for the study area included 188 wells with lithology records and 131 guide points with a value of zero along the outcrop line. Net sands ranged from 0 to 274 feet with a mean of 133 feet in the Blossom Sand (Figure 5). The greatest accumulation of sand in the geological formation is in the eastern portion of the study area and diminishes to the west. While the net sand mapping provided by the contractor also identified a thickening of net sand from west to east, their net sand analysis was based only the basal sand of the Blossom Sand geological formation and ranged from 0 to 42 feet. TWDB staff mapped all sand belonging to the formation, which included an additional 16 million acre-feet of sand in the study area.

Salinity classes

There were 129 measured water quality samples limited to the shallower and fresher portions of the study area. We used the Rwa Minimum Method (Estepp, 1998) to calculate 211 total dissolved solids estimates for the deeper and more saline portions of the study area. This method resulted in shallower brackish and saline water that is closer to the outcrop than those mapped by the contractor.

After delineating the extent of salinity classes by hand based on the location of water quality measurements and geophysical log calculations for total dissolved solids, the contractor calculated that 23 percent of the total in-place groundwater volume is very saline and TWDB staff calculated 69 percent is very saline. This discrepancy is in part due to differences in methodology and how geophysical logs were interpreted. “Mixed” salinity classes were delineated where (1) a well had two distinct salinity classifications stacked on top of each other in the Blossom Sand, (2) wells with distinct salinity classifications were too close to each other to parse out into separate classes, or (3) the total dissolved solids calculations were just on the cusp of transitioning from one salinity class to the next (e.g., an area with a well with a calculated total dissolved solids of 9,900 milligrams per liter near a well with a calculated total dissolved solids of 10,500 milligrams per liter).

Salinity calculations were grouped by U.S. Geological Survey groundwater salinity classes (Winslow and Kister, 1956). Calculations resulted in the following values: zero fresh, 17 slightly saline, 67 moderately saline, 122 very saline, and 5 brine (Figure 6). No total dissolved solids calculations resulted in fresh water classification because (1) these areas were dominated by measured water quality values and few calculations were needed in those areas, (2) it was rare to find geophysical logs shallow enough to make calculations in the fresh salinity class, and (3) the estimated totals dissolved solids calculations maybe slightly biased toward more saline calculations.

Volumes

Mapping the stratigraphy and lithology of the Blossom Sand in the 1-million-acre study area resulted in calculating 10 million acre-feet of total in-place groundwater. The contractor estimated a total of 3 million acre-feet of in-place groundwater for the same area. The difference in the groundwater volumes is because the contractor mapped only the basal sand of the Blossom Sand geological formation and TWDB staff mapped all sands belonging to the geological formation. Groundwater volumes were calculated for the aquifer by county and salinity class (Table 3). A specific yield of 0.10 in the outcrop and 0.07 in the subcrop was used in this recent calculation. The subcrop specific yield value for this study was based on the core test for State Well Number 1617602 (TWDB, 2018; McLaurin, 1988).

Table 3. **Volume of total in-place groundwater in the Blossom Aquifer in the study area.**

County	Volume of groundwater (acre-feet)*									
	Salinity classes									Total
	Fresh	Fr-Ss	Ss	Ss-Ms	Ms	Ms-Vs	Vs	Vs-Br	Brine	
Bowie	-	10,000	40,000	-	130,000	150,000	2,220,000	30,000	-	2,580,000
Delta	-	-	-	-	-	-	920,000	-	-	920,000
Franklin	-	-	-	-	-	-	120,000	-	-	120,000
Hopkins	-	-	-	-	-	-	200,000	-	-	200,000
Lamar	40,000	-	110,000	-	430,000	150,000	800,000	-	-	1,530,000
Red River	200,000	180,000	200,000	-	970,000	490,000	2,450,000	290,000	-	4,780,000
Titus	-	-	-	-	-	-	130,000	-	-	130,000
Total	240,000	190,000	350,000	-	1,530,000	790,000	6,840,000	320,000	-	10,260,000
Percent	2.3	1.9	3.4	0.0	15.0	7.7	67.0	3.1	0.0	100.0

Notes:
* Volume values are rounded to two significant digits; this results in a 2.9 percent rounding error.

Fr (Fresh)	=	0 to 999 milligrams per liter total dissolved solids
Fr-Ss	=	areas 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
Ss-Ms	=	areas with a mix of slightly and moderately saline measurements and calculations
Ms (Moderately saline)	=	3,000 to 9,999 milligrams per liter total dissolved solids
Ms-Vs	=	areas 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
Vs-Br	=	areas with a mix of very saline and brine measurements and calculations
Br (Brine)	=	greater than 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 three brackish groundwater production zones in the Blossom Aquifer study area: BLSM1, BLSM2, and BLSM3 (Figure 7). The combined area of these zones is 82,187 acres. For each recommended zone, the minimum, maximum, and average top surface depth and thickness were calculated (Table 4). 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, existing use, waste injection, and potential pumping impacts. The Blossom Sand is assumed to be an available and productive aquifer since water wells are in use 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 estimated productivity could not be verified in these specific areas. The location of fresh and brackish groundwater was identified by salinity mapping. The interbedded sands, shales, and clays that overlie and underlie the Blossom Sand act as significant vertical hydrogeologic barriers to protect fresh groundwater resources.

To act as a horizontal distance hydrogeologic barrier to fresh water, jurisdictions, and existing use, a three-mile buffer was applied to the fresh water line, state line, and 86 known municipal, domestic, and agricultural water wells completed in the Blossom Aquifer. Areas in the three-mile buffer were not considered for brackish groundwater production zones. No Class I, III, IV, or V Blossom Sand injection wells were found within 15 miles of the study area. Thirteen Class II Blossom Sand injection wells were found less than 15 miles downdip of the recommended zones. These wells were determined to have hydrogeologic separation from the aquifer by the Mexia-Talco Fault Zone and therefore were not used to exclude areas from brackish groundwater production zone consideration.

The contractor provided drawdowns at hypothetical wellfields in the Blossom Aquifer. Based on their modeling of pumping 100 acre-feet per year for 50 years, the drawdown expected at the nearest receptor well was between 5 and 15 feet. This was determined to not be a significant drawdown after such a long period of pumping. Therefore, no significant pumping impacts are expected from developing wellfields in the recommended brackish groundwater production zones.

Table 4. Parameters of brackish groundwater production zones in the Blossom Aquifer.

Zone name	Measured in feet					
	Minimum top depth	Maximum top depth	Average depth	Minimum thickness	Maximum thickness	Average thickness
BLSM1	115	370	234	98	180	129
BLSM2	0	746	381	224	385	288
BLSM3	339	666	488	268	345	289

Production volumes

The amounts of brackish groundwater in zones were calculated as total in-place groundwater volumes by salinity class (Table 5). Zones BLSM1 and BLSM3 contain moderately saline groundwater (3,000 to 9,999 milligrams per liter total dissolved solids). Zone BLSM2 contains a small amount of slightly saline groundwater (1,000 to 2,999 milligrams per liter of total dissolved solids), but the majority is moderately saline groundwater. The amounts of brackish groundwater that could potentially be produced from BLSM1, BLSM2, and BLSM3 over 30- and 50-year periods were also calculated based on the contractor's modeling (Table 6).

Table 5. Volume of total in-place groundwater in the recommended brackish groundwater production zones for the Blossom Aquifer.

Brackish groundwater production zone	Volume of water (acre-feet)*		
	Slightly saline	Moderately saline	Total
BLSM1	-	30,000	30,000
BLSM2	300	590,000	590,000
BLSM3	-	160,000	160,000
Total	300	780,000	780,000

Notes:
* Volume values are rounded to two significant digits.
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

Table 6: Volumes of brackish groundwater that a zone can produce over 30- and 50-year periods without causing significant impact.

Zone name	Annual pumpage (acre-feet/year)	30-year cumulative (acre-feet)	50-year cumulative (acre-feet)
BLSM1	100	3,000	5,000
BLSM2	100	3,000	5,000
BLSM3	100	3,000	5,000

Groundwater monitoring

In general, groundwater monitoring is required within the Blossom Aquifer brackish groundwater production zones and aquifers overlying the Blossom Aquifer. Monitoring in wells completed in these aquifers would ensure that the interlayered clays, marls, and chalk overlying the Blossom Sand provide an adequate hydrogeologic barrier. Fresh water resources of the

Blossom Aquifer should also be monitored updip of the zones to ensure that significant impact from production of brackish groundwater is prevented. Monitoring is not required below the Blossom Sand geological formation because there are no known fresh or brackish aquifers that would be impacted by pumping in the zones. Future wellfields in the brackish zones should include monitor wells to track water levels and water quality during production.

Stakeholder engagement

No brackish groundwater production zones were designated in existing groundwater conservation districts. Three public stakeholder meetings were held at locations in or near the study area. The first was held on Friday, February 8, 2017, in Mount Pleasant, Texas. The second was held on Tuesday, April 18, 2017, in Commerce, Texas. The third was held on Wednesday, October 25, 2017, in Mount Pleasant, Texas. Presentations from these meetings can be downloaded from 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 Blossom Sand 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 BRACS website (www.twdb.texas.gov/innovativewater/bracs/index.asp). As more wells are drilled and monitored and more data becomes available, recommendations may change.

References

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.R., and Petrossian, R., 2011, Aquifers of Texas: Texas Water Development Board Report 390, 172 p.

LBG-Guyton Associates, 2017, Identification of Potential Brackish Groundwater Production Areas – Blossom Aquifer: LBG-Guyton Associates, contract report (1600011951) to the Texas Water Development Board, 82 p.

McLaurin, C., 1988, Occurrence, availability, and chemical quality of ground water in the Blossom Sand Aquifer: Texas Water Development Board Report 307, 32 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), 2018, BRACS Database, http://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.

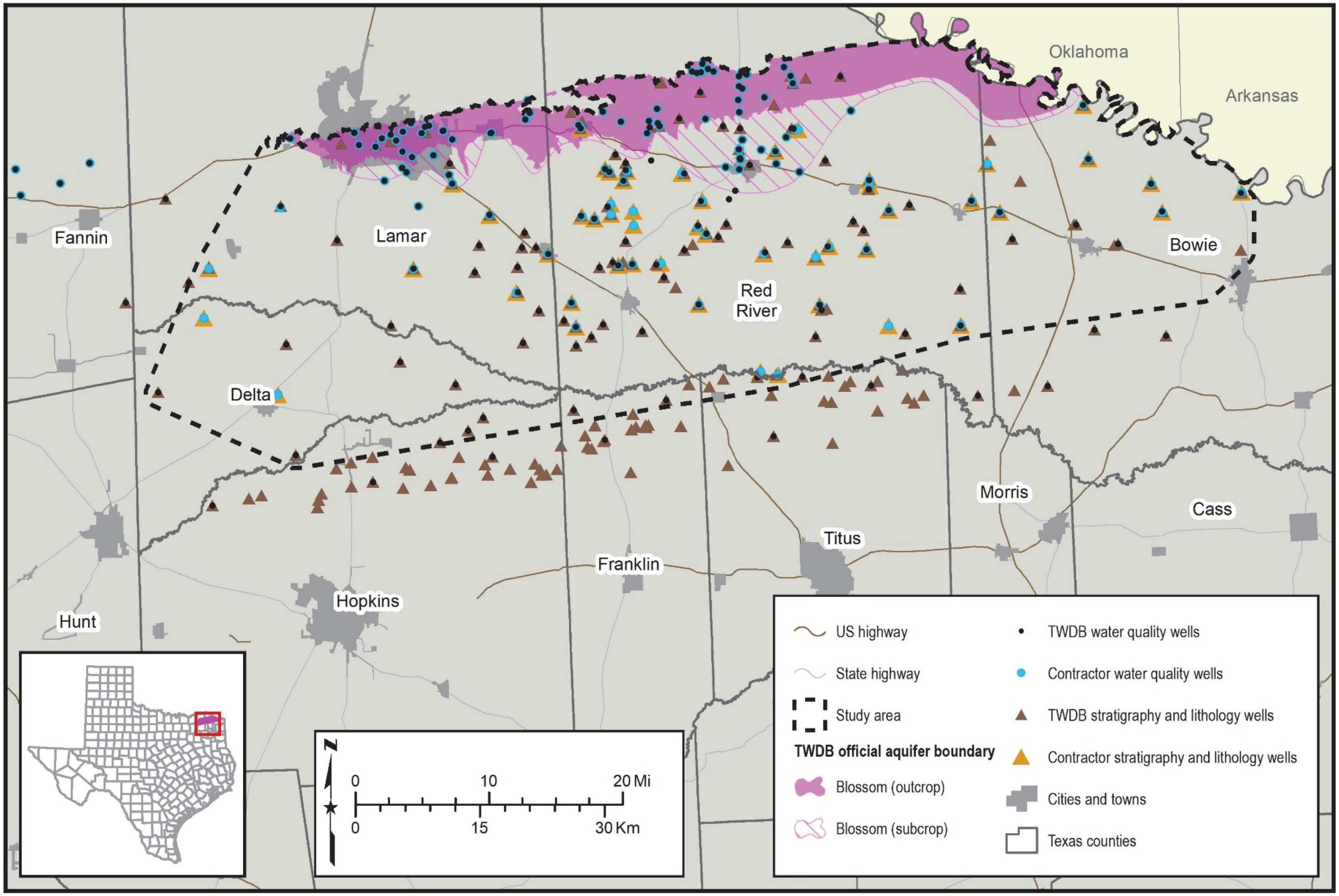

Figure 1. **Study area and well control in the Blossom Aquifer. Water quality wells include total dissolved solids measurements and calculations.**

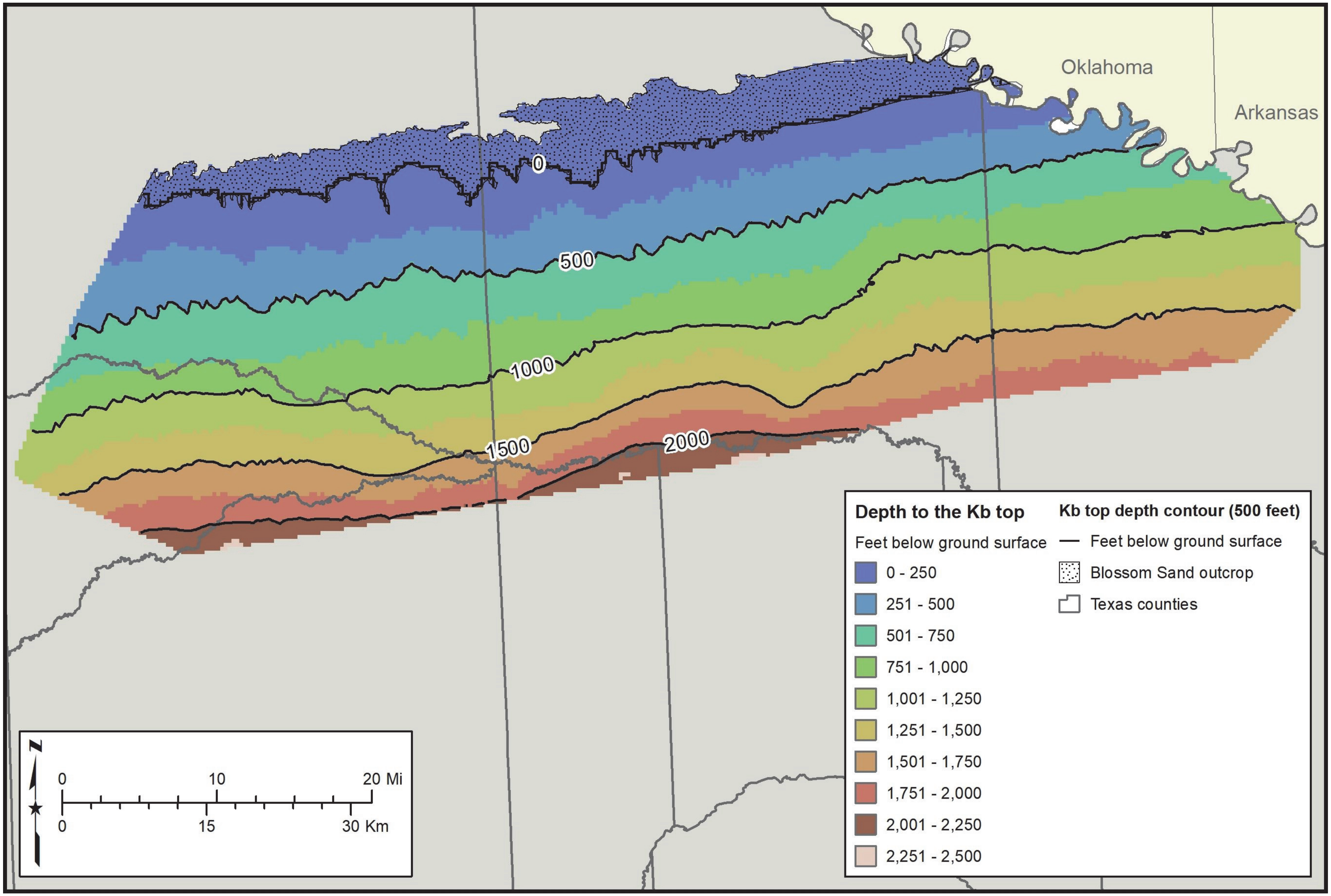

Figure 2. Top depth of the Blossom Sand (Kb).

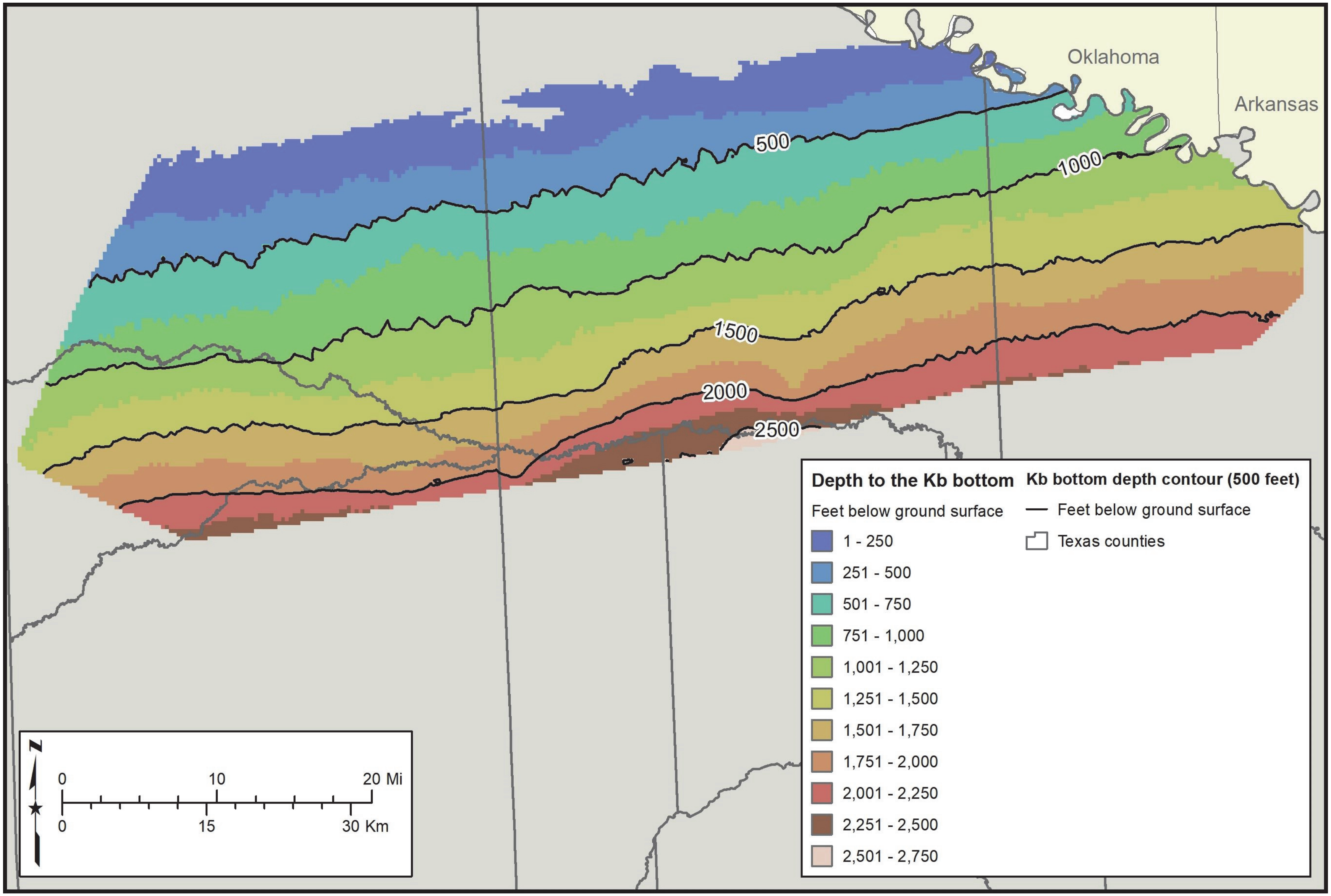

Figure 3. **Bottom depth of the Blossom Sand (Kb).**

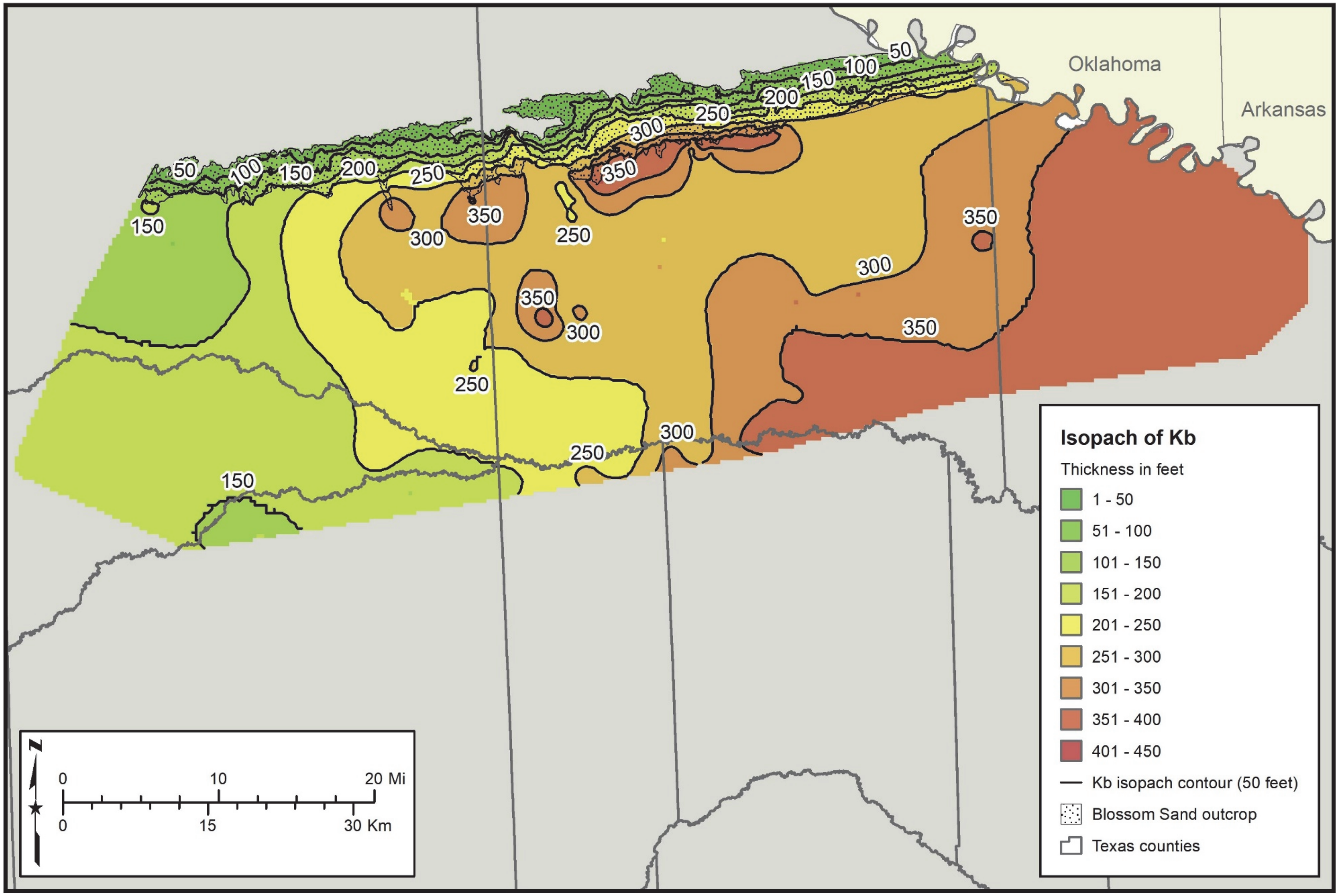

Figure 4. **Isopach of the Blossom Sand (Kb).**

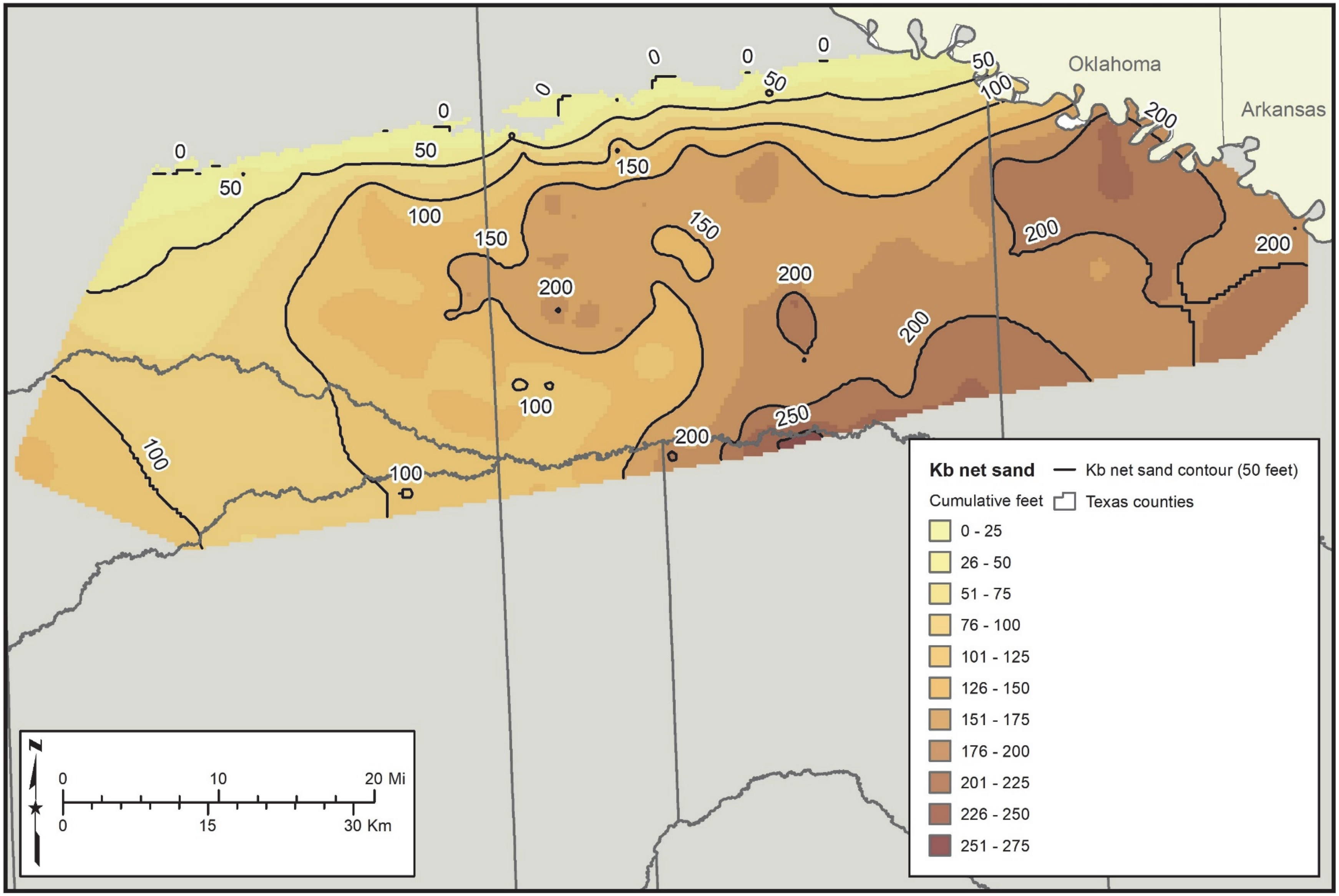

Figure 5. **Net sand of the Blossom Sand (Kb).**

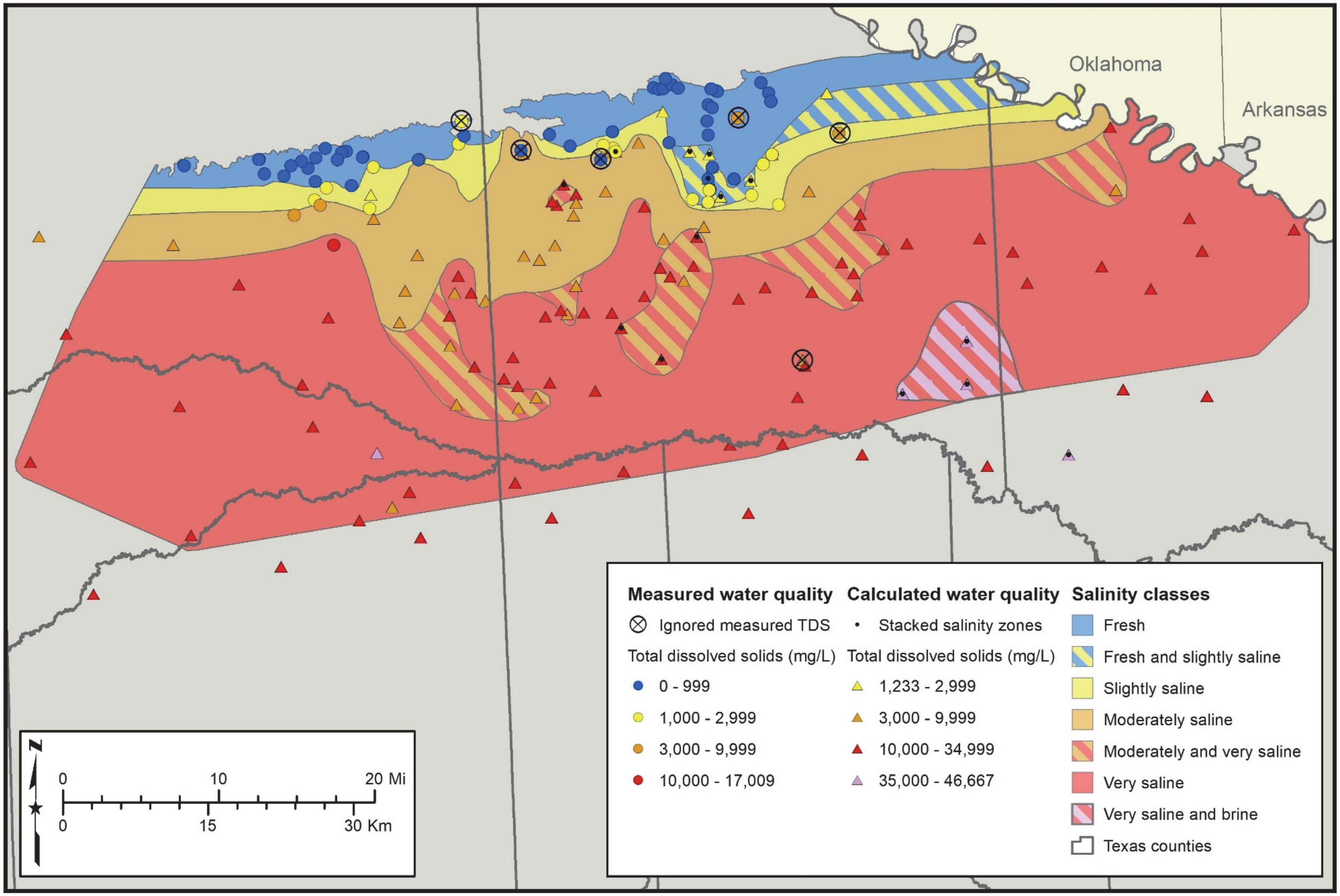

Figure 6. Salinity classes of the Blossom Aquifer. Total dissolved solids (TDS) are measured in milligrams per liter (mg/L).

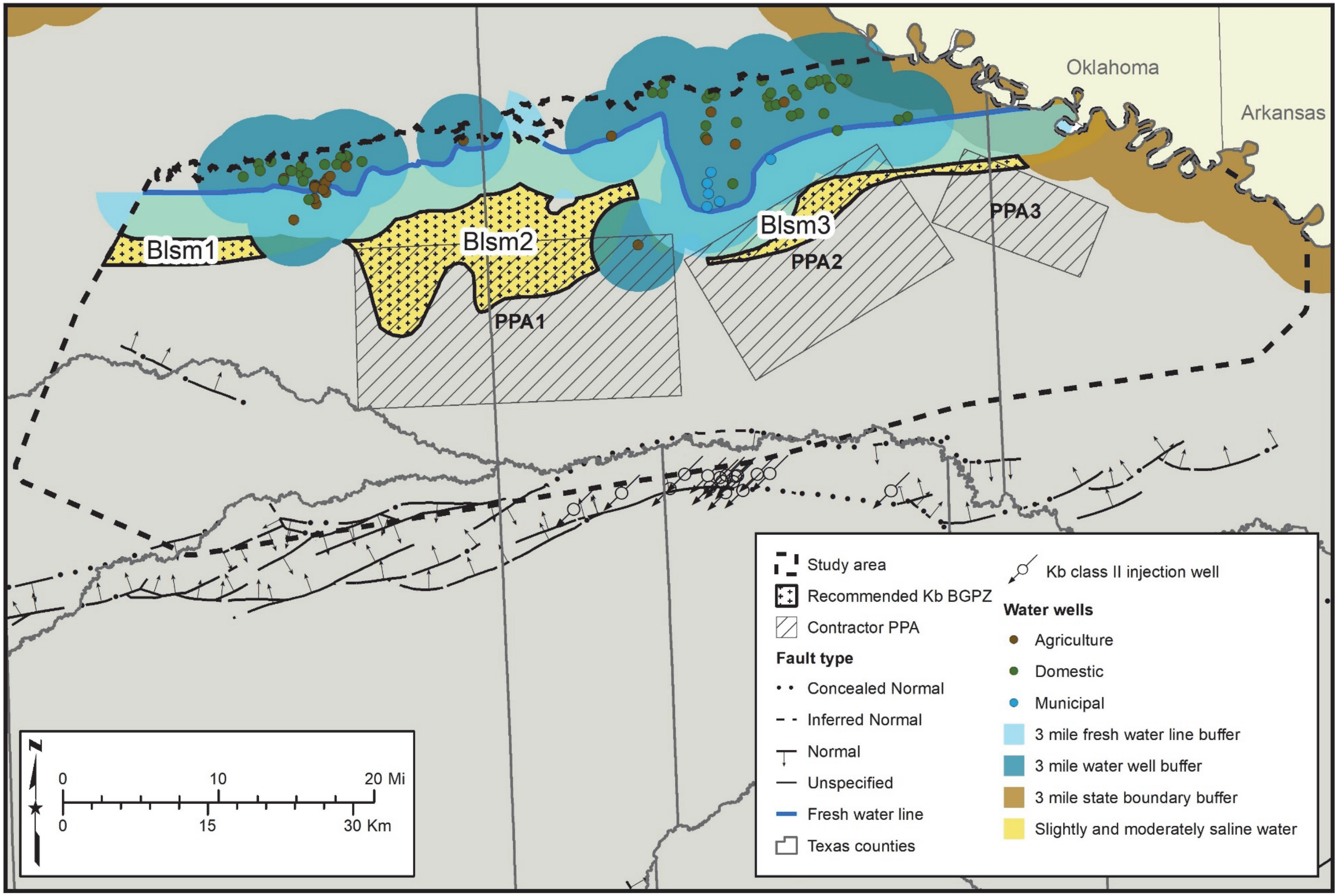

Figure 7. **Recommended brackish groundwater production zones (BGPZ) for the Blossom Sand (Kb).**