Mapping Brackish Groundwater in Aquifers of the Upper Coastal Plains, Central Texas

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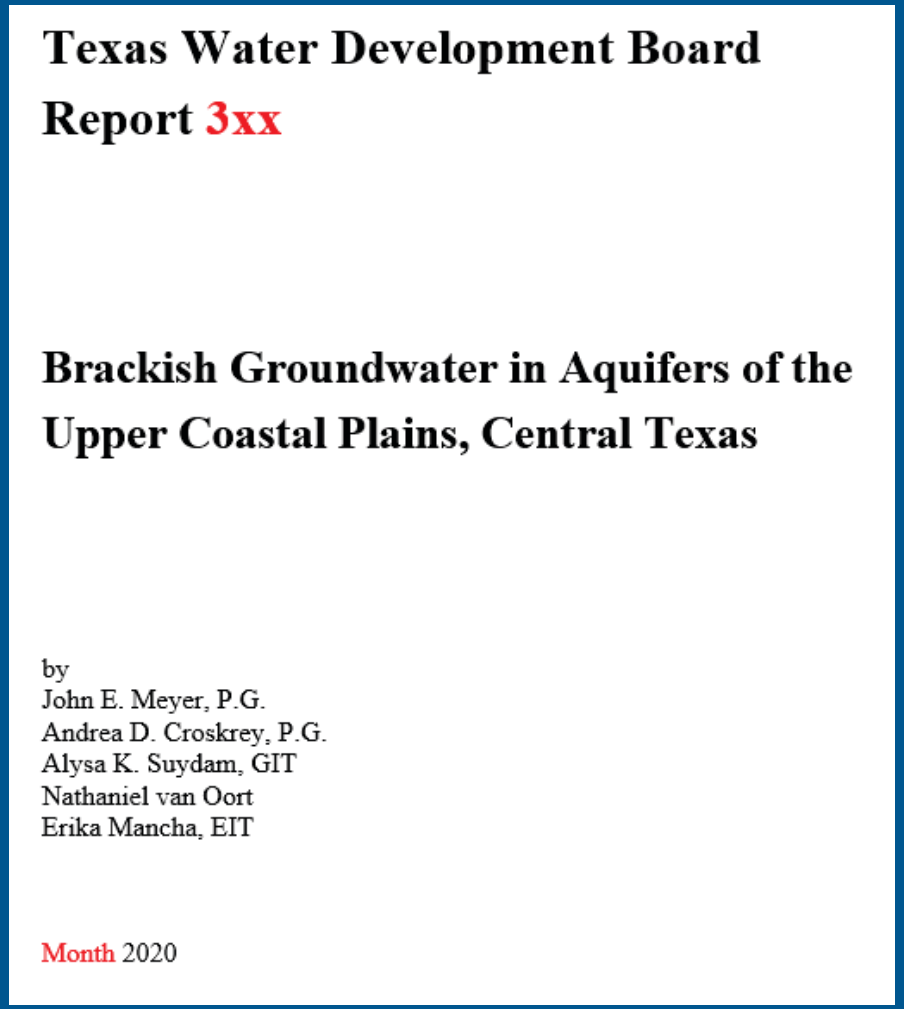
Authors:
John E. Meyer, P.G., Andrea D. Croskrey, P.G., Alysa K. Suydam, GIT, Nathaniel Van Oort, and Erika Mancha, EIT

Summary Slide

- Introduction to TWDB and BRACS
- Study area overview
- Methods
- Mapping results
- Future improvements and conclusions



Texas Water Development Board

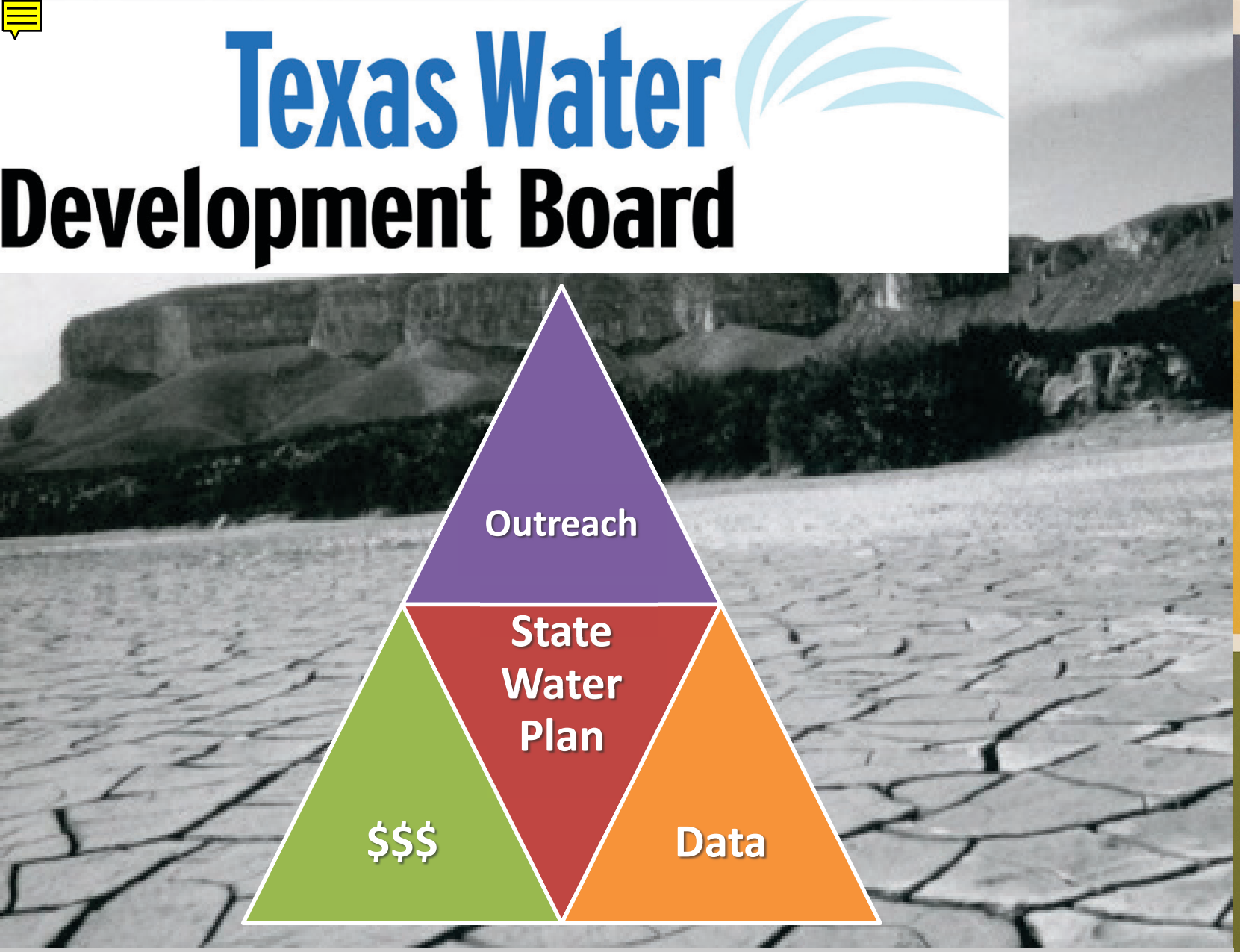
Report 3xx

Brackish Groundwater in Aquifers of the Upper Coastal Plains, Central Texas

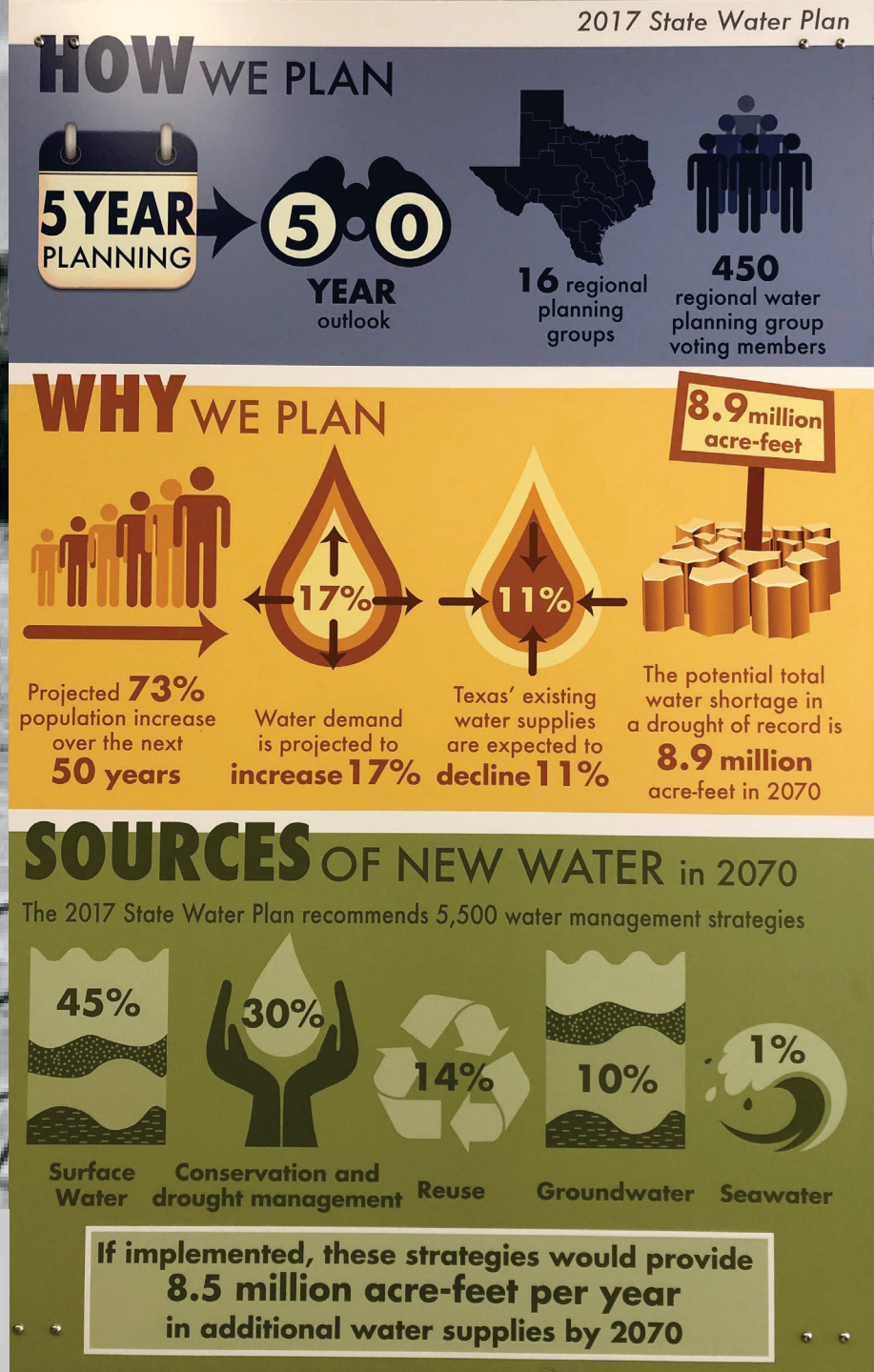
by
John E. Meyer, P.G.
Andrea D. Croskrey, P.G.
Alysa K. Suydam, GIT
Nathaniel van Oort
Erika Mancha, EIT

Month 2020

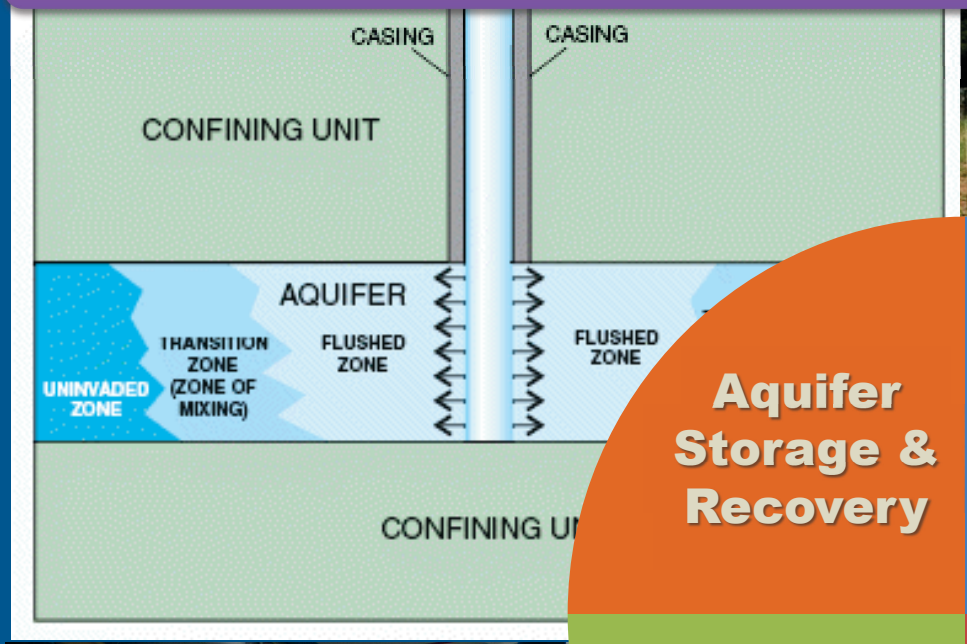
Texas Water Development Board



"To provide leadership, information, education, and support for planning, financial assistance, and outreach for the conservation and responsible development of water for Texas"



Innovative Water Technologies

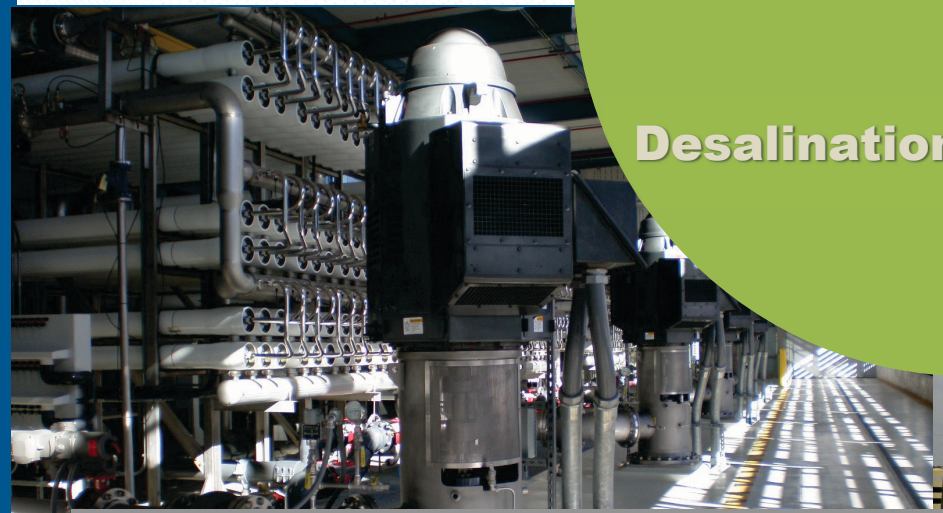


Aquifer Storage & Recovery

Water Reuse

Desalination

Brackish Groundwater



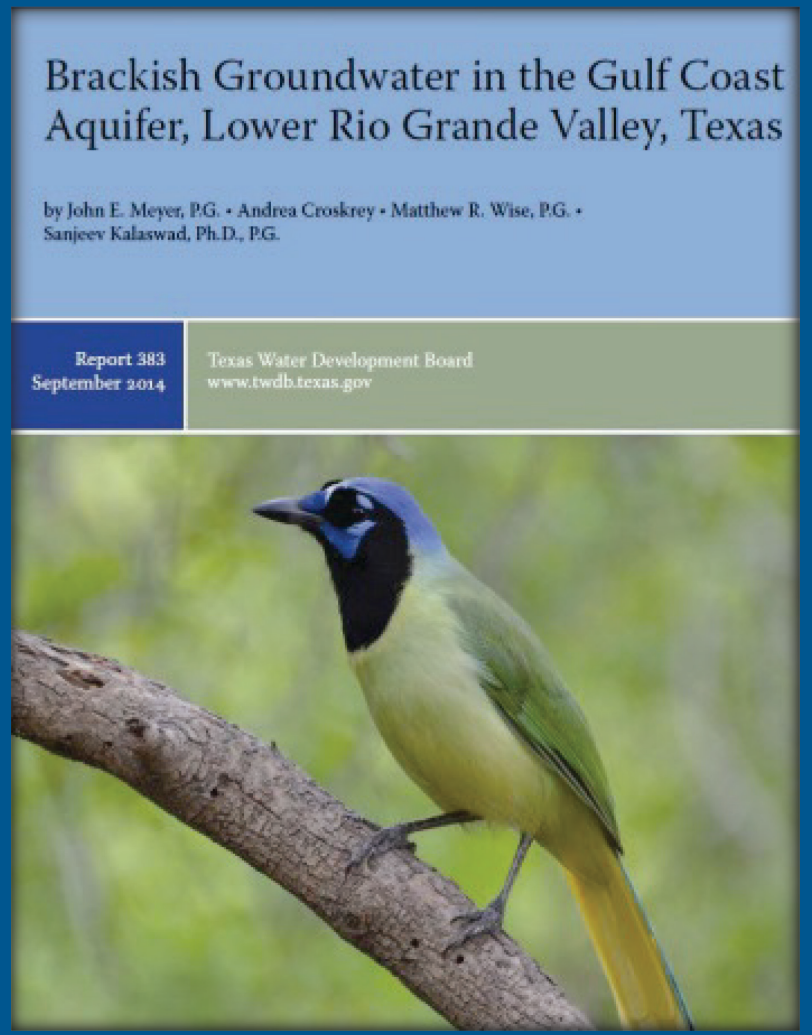
"Our mission is to educate the water community on the use of nontraditional water supplies."

4

Brackish Resources Aquifer Characterization System (BRACS)

Map brackish groundwater!

1. Stratigraphy
2. Lithology
3. Water Quality



http://www.twdb.texas.gov/innovativewater/bracs/studies.asp

What is brackish groundwater?

"saltier than fresh water, less salty than seawater"
or
1,000-10,000 mg/L Total Dissolved Solids

Groundwater Salinity Classification	Salinity Zone Code	Total Dissolved Solids (milligrams per liter)
Fresh	FR	0 to 1,000
Slightly Saline	SS	1,000 to 3,000
Moderately Saline	MS	3,000 to 10,000
Very Saline	VS	10,000 to 35,000
Brine	BR	Greater than 35,000

BRACKISH

PWS →

BUQ →

USDW →

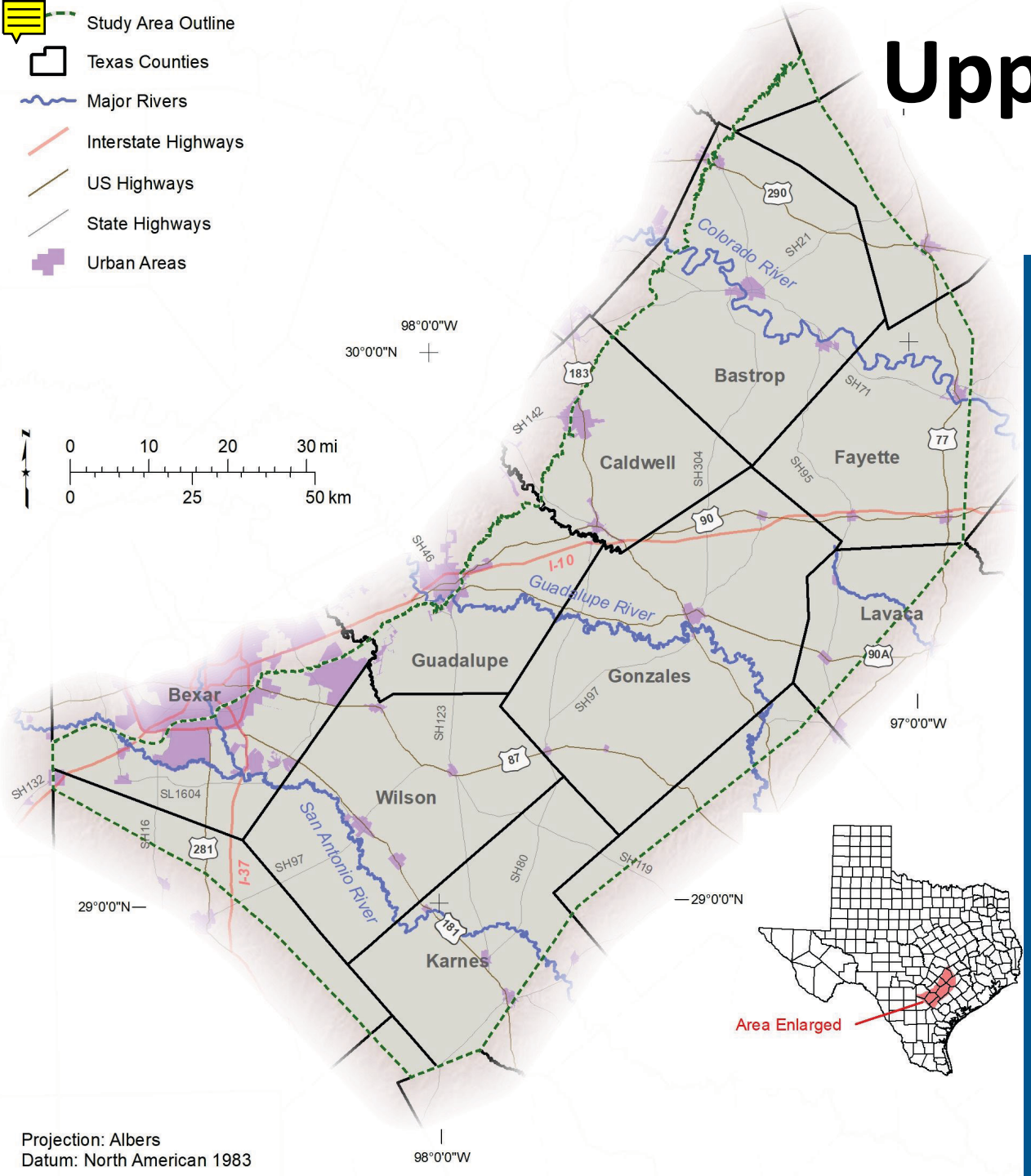
← Most Texas Major/Minor Aquifer Mapped Limit

← Seawater

PWS: Public Water System threshold for fresh water, TX Commission on Environmental Quality
BUQ: Base Useable Quality water, TX Railroad Commission
USDW: Underground Source Drinking Water, US Environmental Protection Agency

modified from Winslow and Kister (1956) USGS WSP 1365

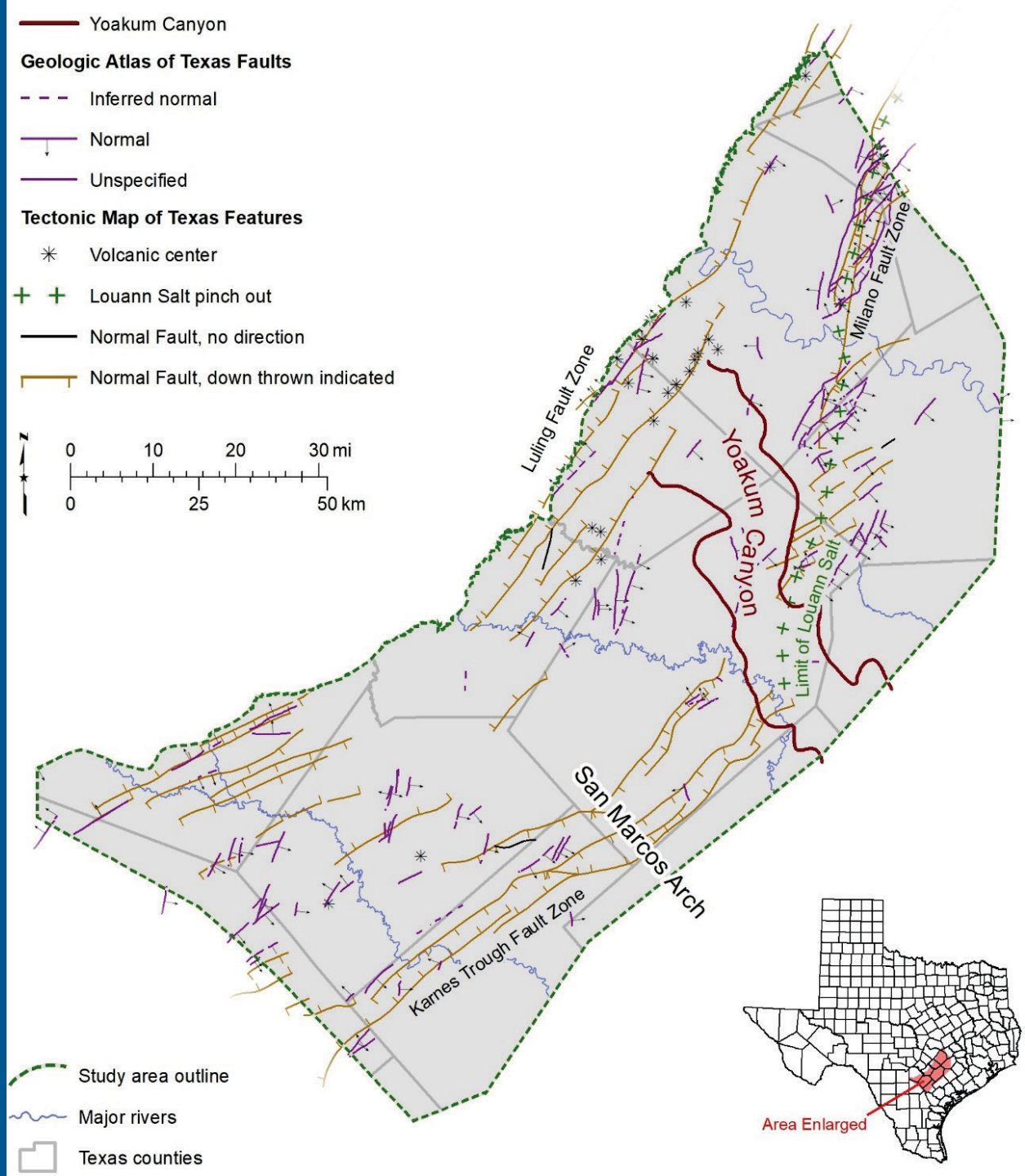
Upper Coastal Plains – Central Study Overview



- Parts of 14 counties in central Texas
- 8 Eocene stratigraphic units mapped
  - (Yegua, Cook Mountain, Sparta, Weches, Queen City, Reklaw, Carrizo, Wilcox)
- 5 aquifers
  - (Yegua, Sparta, Queen City, Carrizo, Wilcox)

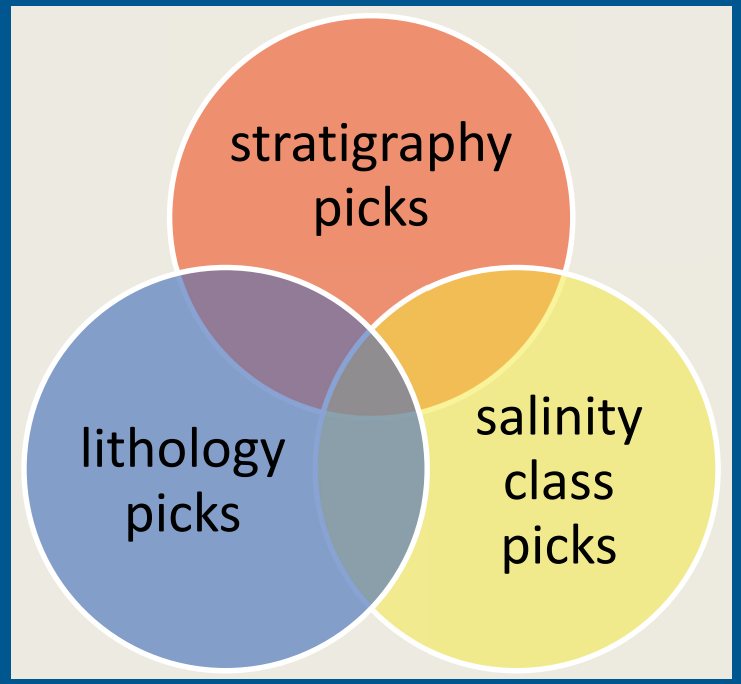
Regional Geologic Structures

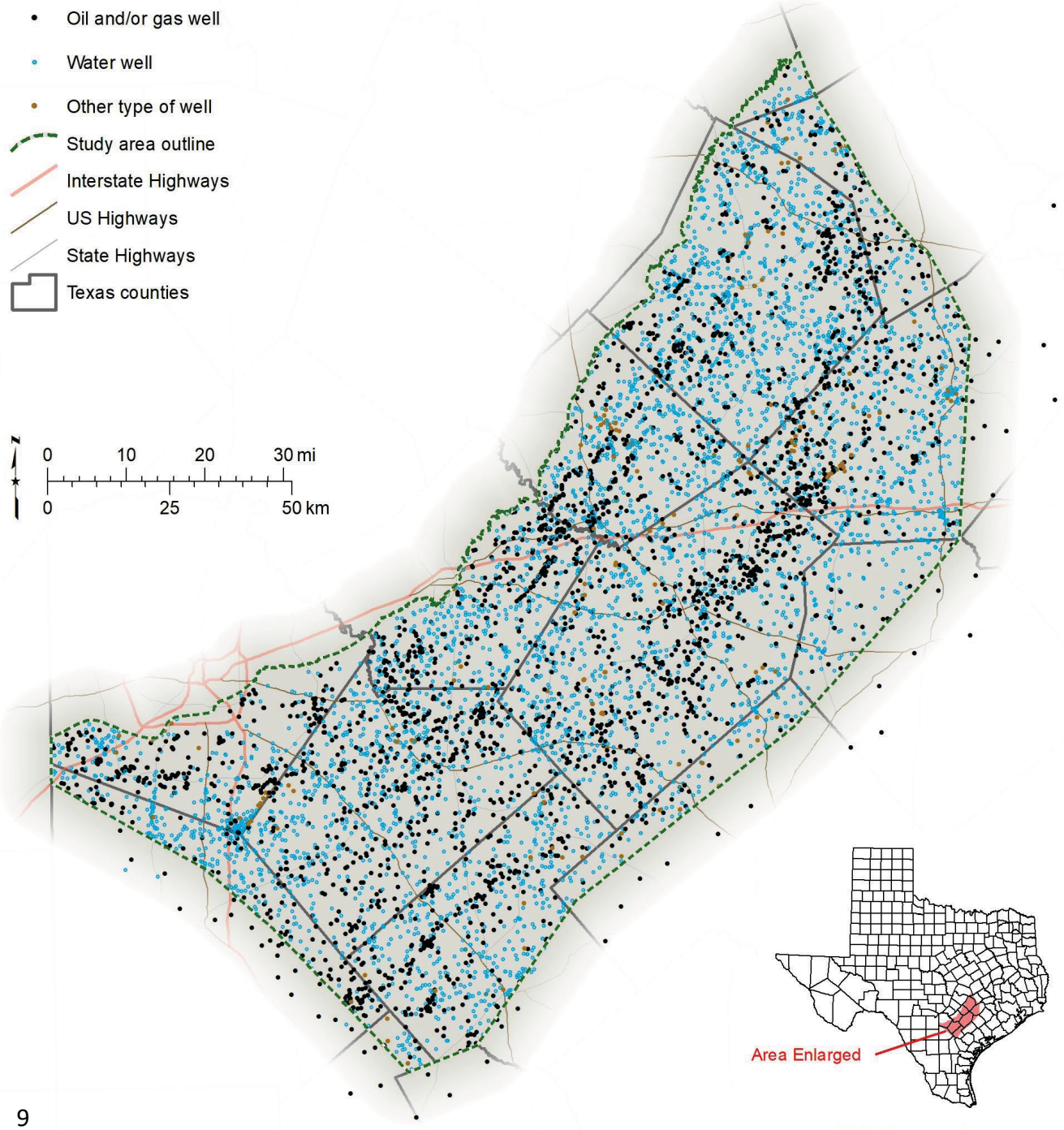
- Yoakum Canyon, based on our mapping and Dingus and Galloway (1990).
- Faults, digital Geologic Atlas of Texas (TWDB, 2007)
- More faults, volcanic centers, and Louann Salt pinch out, Tectonic Map of Texas (Breton, 2013; Ewing, 1991).



Study well control

- 8,130 wells total
  - 4,978 water wells
  - 2,941 oil and gas wells
  - 211 “other” wells



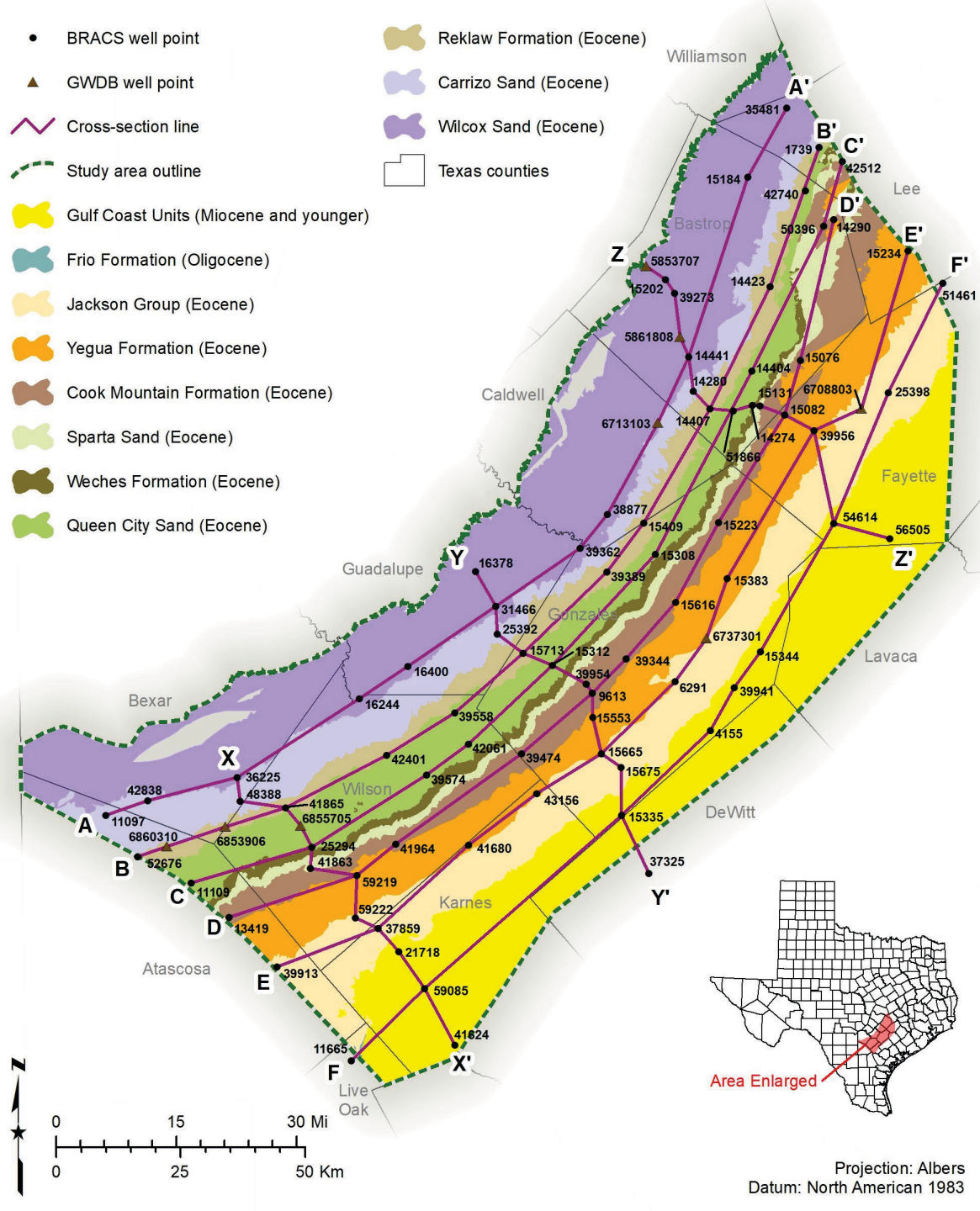


Volume and Quality of Brackish Groundwater

Area (Extent)
X
Saturated Thickness (Net Sand)
X
Porosity (Specific Yield)
=
Volume (acre-feet)

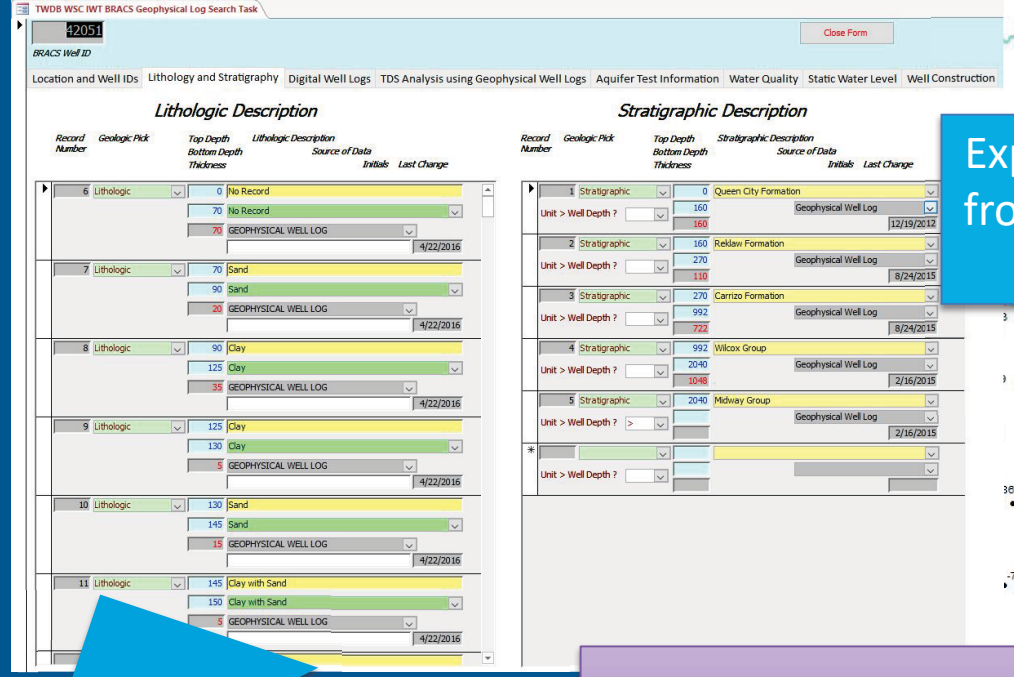
Epoch	Group	Formation	USGS nomenclature	Texas Hydrogeologic unit
Eocene	Jackson	Caddell	Vicksburg-Jackson confining unit	Yegua-Jackson Aquifer
		Moodys Branch		
	Claiborne	Yegua	Upper Claiborne Aquifer	
		Cook Mountain	Middle Claiborne Confining unit	Confining unit
		Hiatus		
		Sparta	Middle Claiborne Aquifer	Sparta Aquifer
		Weches		Confining unit
		Hiatus		
		Queen City		Queen City Aquifer
		Reklaw	Lower Claiborne confining unit	Confining unit
		Hiatus		
	Wilcox	Carrizo	Lower Claiborne – upper Wilcox Aquifer	Carrizo-Wilcox Aquifer
		Hiatus		
		Sabinetown		
		Rockdale	Middle Wilcox Aquifer	
Paleocene		Seguin		
	Midway	Wills Point	Midway confining unit	Confining unit

Stratigraphic column showing relationship between the epochs, formations, and hydrogeologic units. The United States Geological Survey (USGS) nomenclature is based on Ryder (1996). Texas hydrogeologic units are based on TWDB (2007a) and George and others (2011). This table does not reflect the entire Jackson or Midway group stratigraphy. This table is not scaled vertically in uniform units of time.

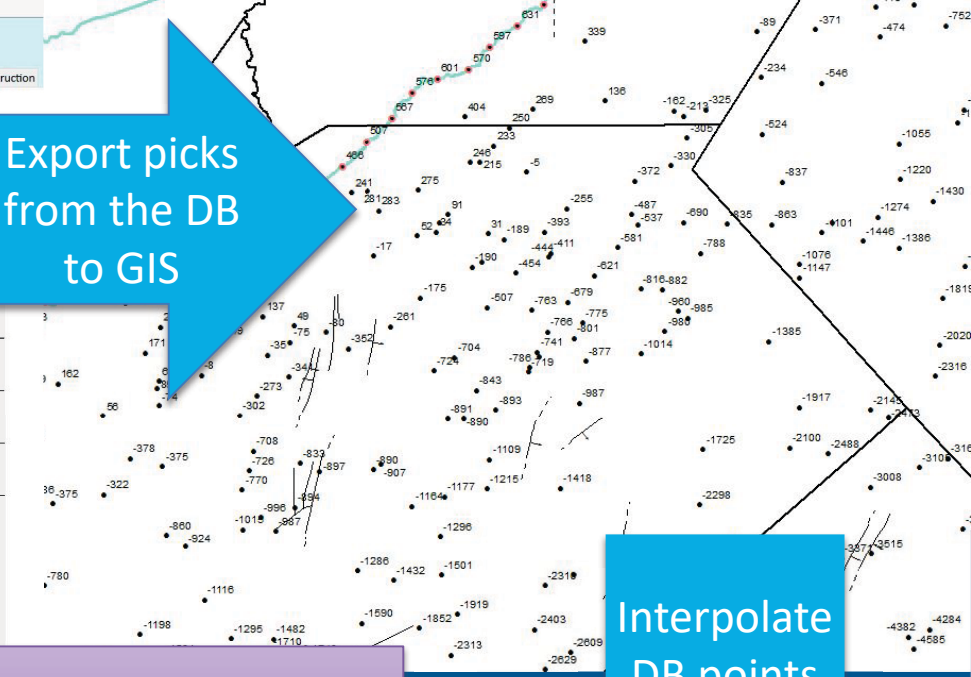


Stratigraphy

- Studied cross-sections
- Picks from geophysical well logs
- Stored in BRACS Database (MS Access)
- Interpolated to surfaces in ArcGIS



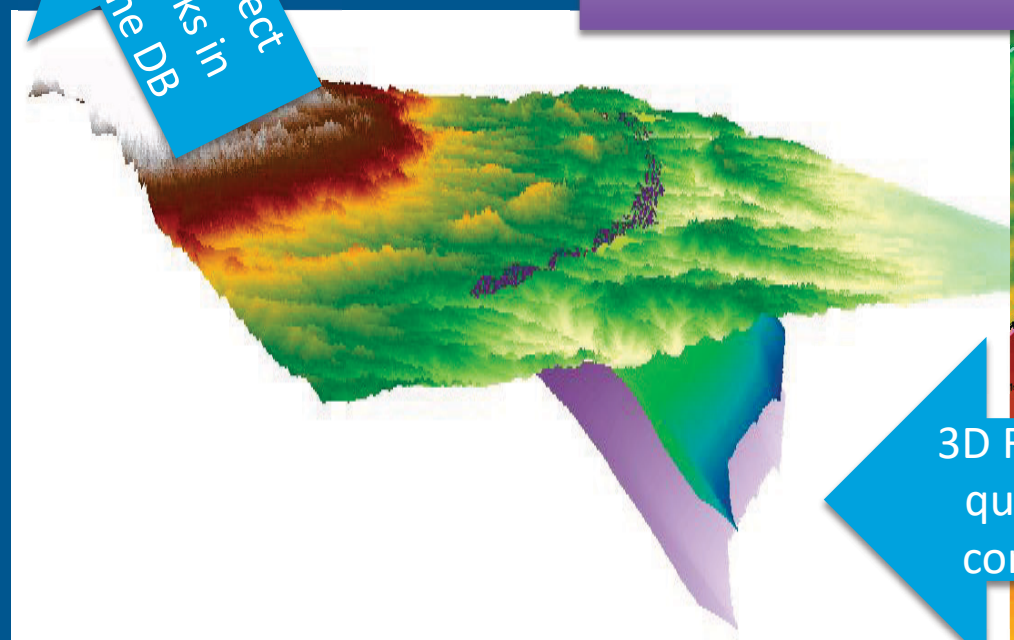
Export picks from the DB to GIS

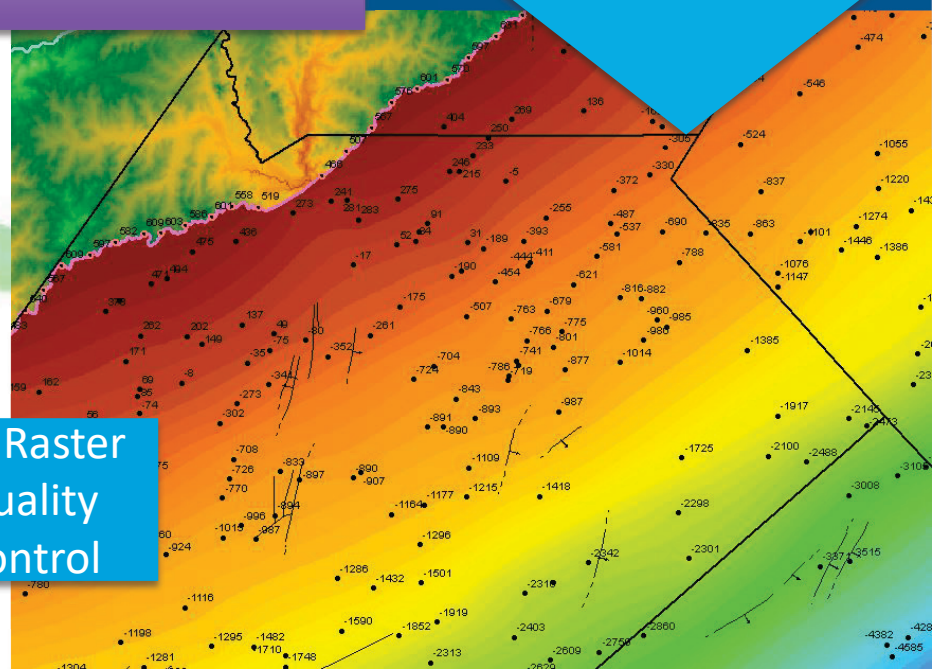


Correct picks in the DB

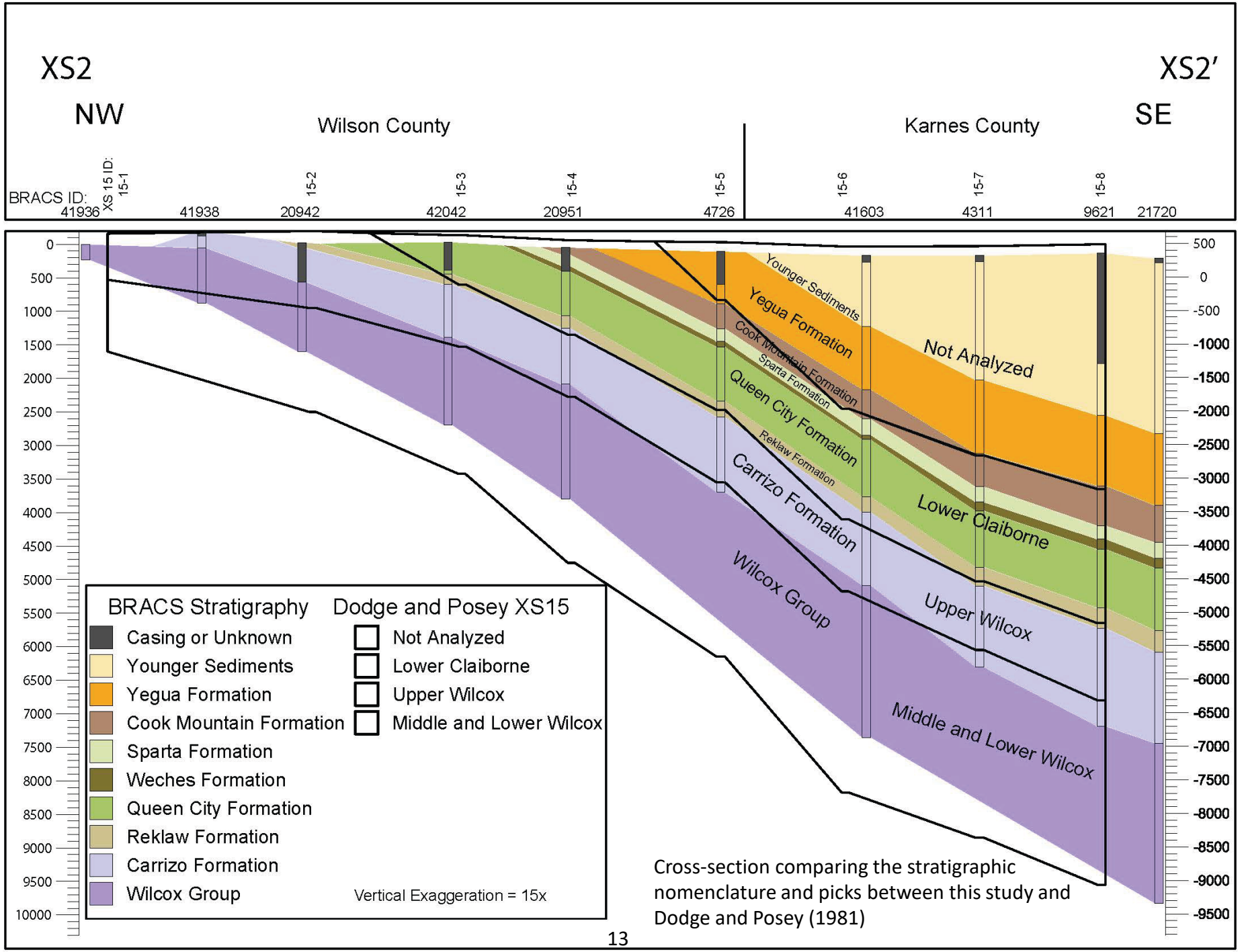
BRACS Study Iterative Workflow

Interpolate DB points to rasters





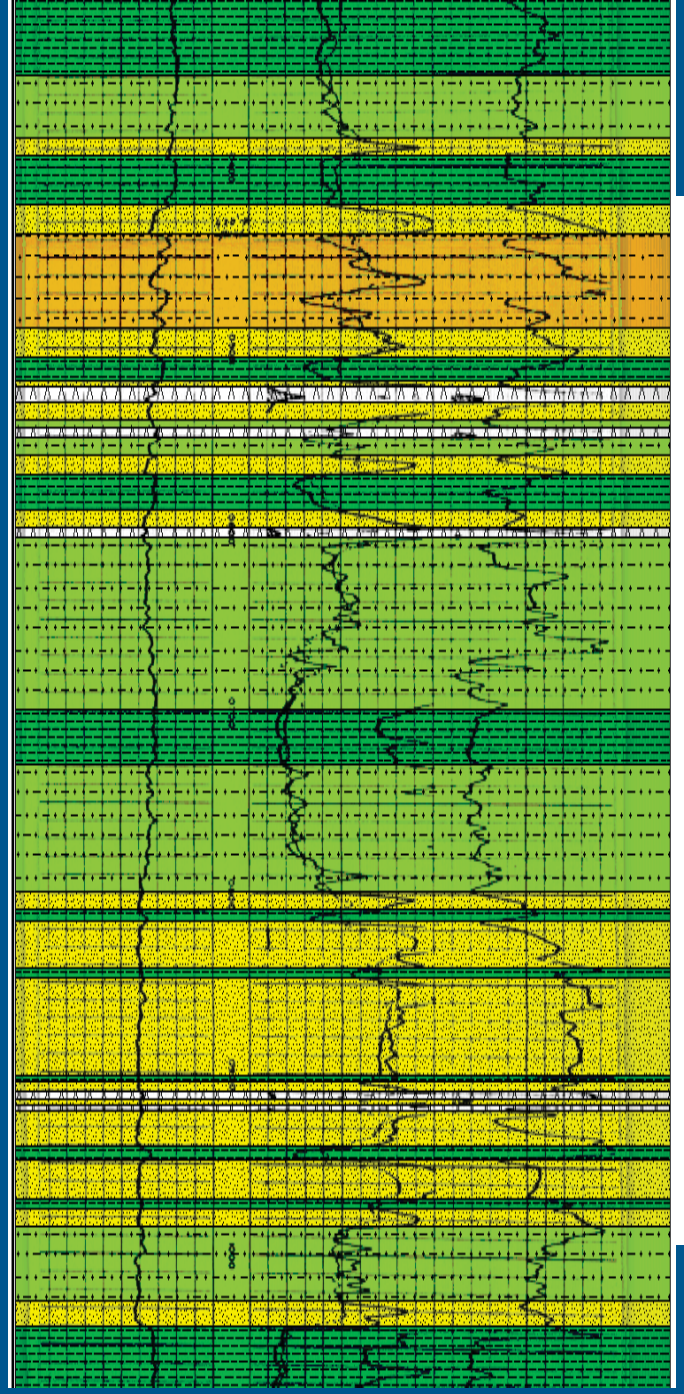
3D Raster quality control



Cross-section comparing the stratigraphic nomenclature and picks between this study and Dodge and Posey (1981)

Net Sands

- Lithology interpreted from geophysical well logs and from driller's reports from the TDLR and GWDB
- Categorized as sand, sand with clay, clay with sand, or clay
- Data distribution varied by source
- Interpolated to surfaces in ArcGIS



BRACS Well ID 14385

Lithology:
DESCRIPTION & COLOR OF FORMATION MATERIAL

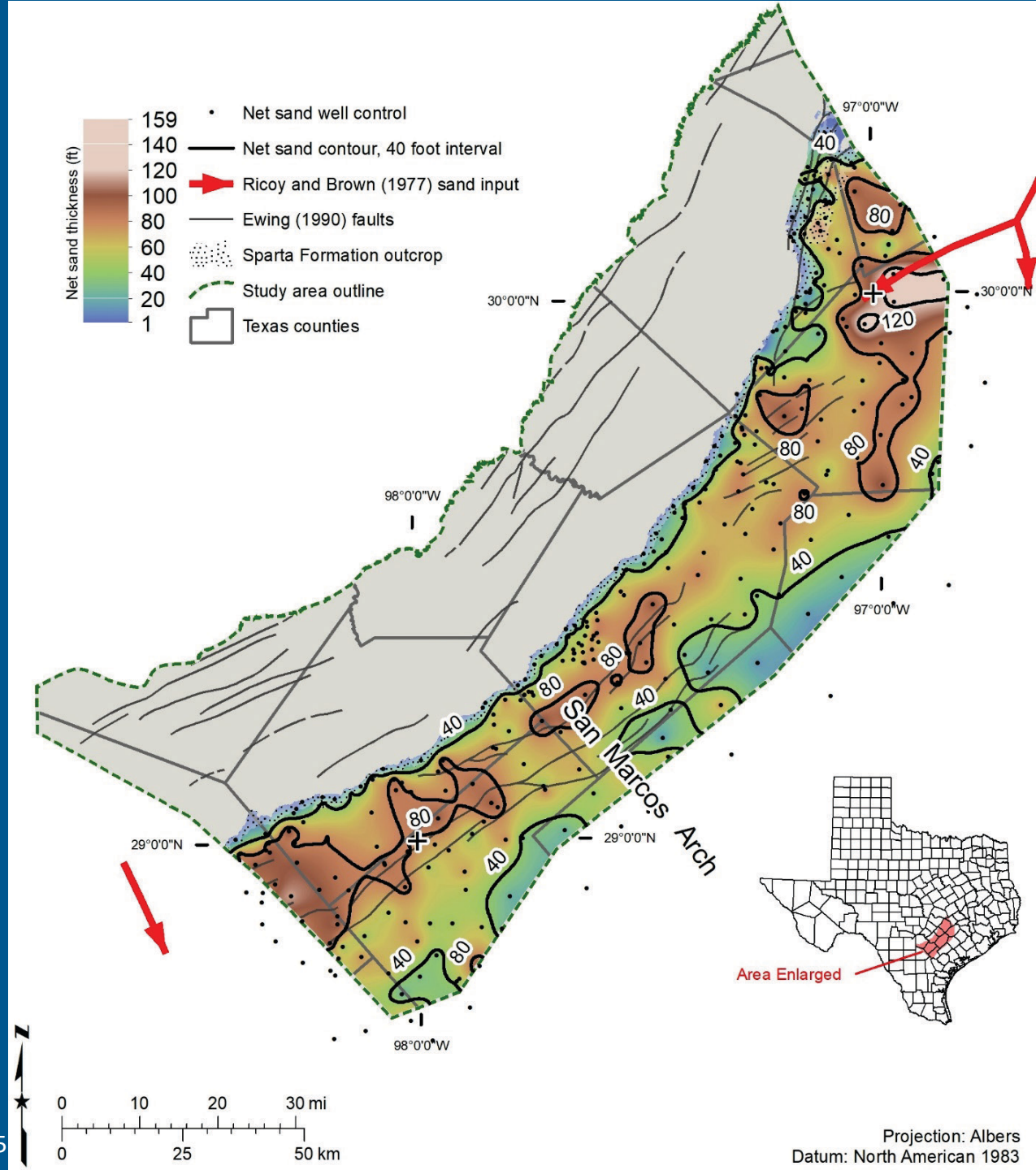
Top (ft.)	Bottom (ft.)	Description
0	4	BROWN CLAY
4	9	RED CLAY
9	46	WHITE-YELLOW CLAY/IRON ROCK
46	60	SANDY GRAY SHALE/IRON ROCK
60	95	BLACK-GRAY SAND/IRON ROCK
95	170	SWAMPY GREEN-GRAY SHALE
170	198	SANDY BROWN SHALE/SAND
198	230	GRAY SHALE/SMALL ROCKS/LIGNITE
230	267	SANDY GRAY SHALE/LIGNITE/SAND
267	304	FINE TO MEDIUM GRAY SAND/ROCKS
304	358	CRUMBLY GRAY-BROWN SHALE
358	370	ROCKY/CRUMBLY GRAY-BROWN SHALE
370	371	ROCK

Simplified Lithology
Clay (0%)
Sandy clay (35%)
Sand (100%)
Clay (0%)
Sandy clay (35%)
Clay (0%)
Sand (100%)
Shale (0%)
Unknown (0%)

BRACS Well ID 14271
https://www2.twdb.texas.gov/apps/waterdatainteractive/GetReports.aspx?Num=42017&Type=SDR-Well

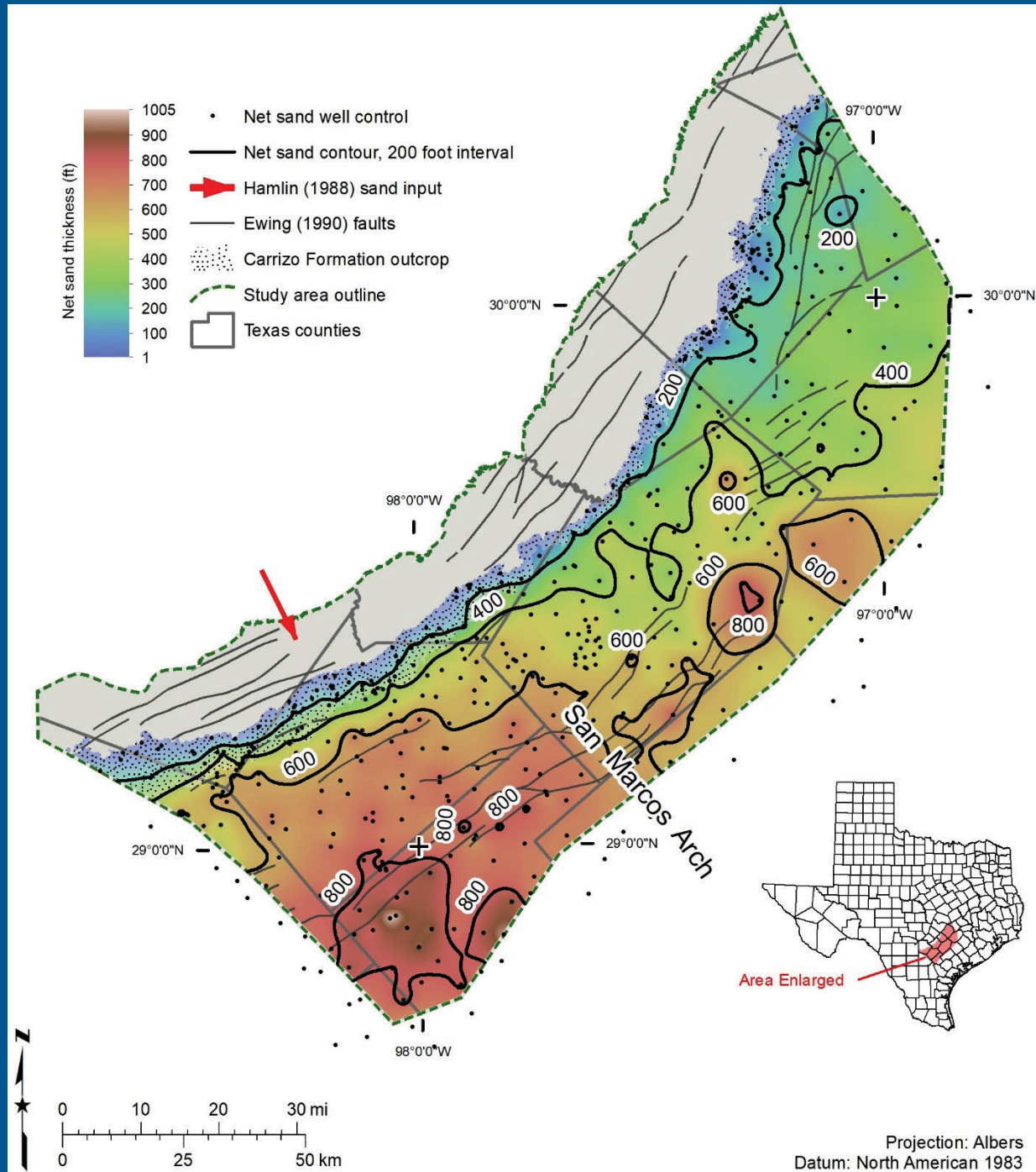
Sparta Aquifer Net Sands

- 0 to >140 feet
- 335 wells
  - Well types
    - 155 water wells
    - 175 oil and gas
    - 5 “other” wells
  - Data Sources
    - 197 geophysical logs interpreted
    - 138 drillers’ descriptions simplified
- Sand inputs outside the study area



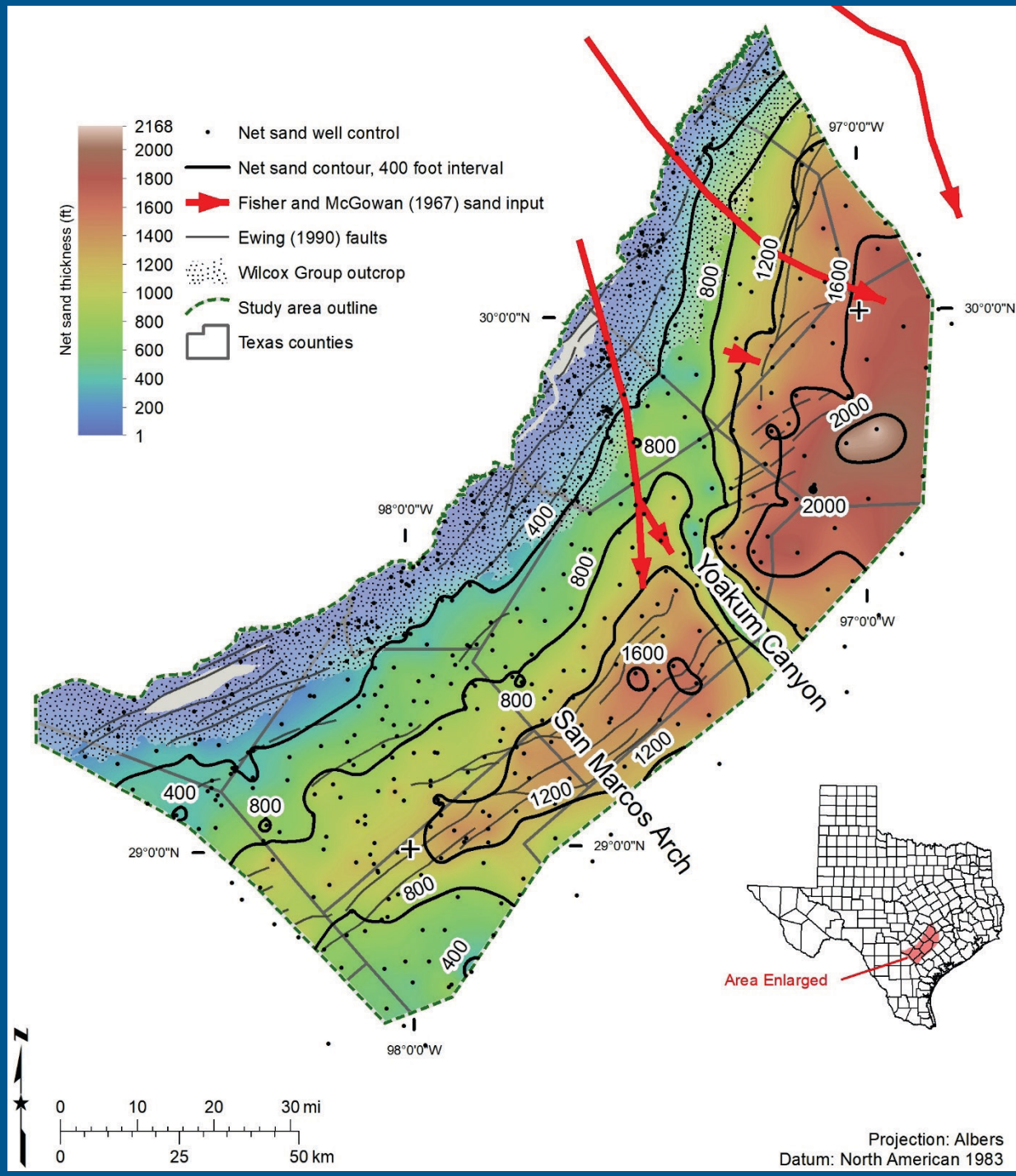
Carrizo Aquifer Net Sands

- 0 to >1,000 feet
- 526 wells
  - Well types
    - 202 water wells
    - 302 oil and gas
    - 22 “other” wells
  - Data Sources
    - 327 geophysical logs interpreted
    - 199 drillers’ descriptions simplified
- Sand input south of San Marcos Arch
- Yoakum Canyon thickening?



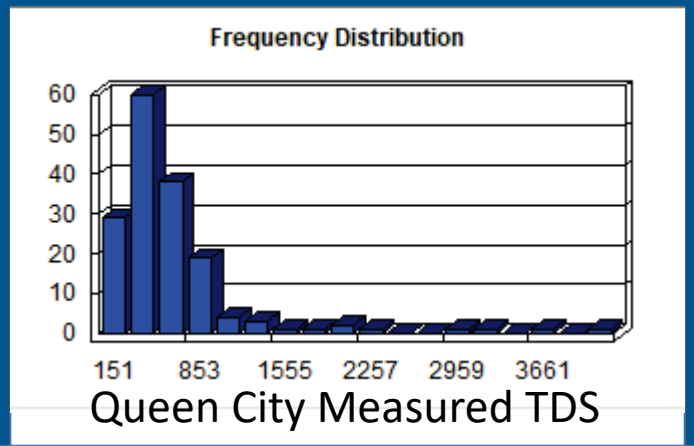
Wilcox Aquifer Net Sands

- 0 to >2,000 feet
- 499 wells
  - Well Types
    - 136 water wells
    - 356 oil and gas
    - 7 “other” wells
  - Data source
    - 366 geophysical logs interpreted
    - 133 drillers’ descriptions simplified
- Sand input south of San Marcos Arch
- Bifurcated by Yoakum Canyon

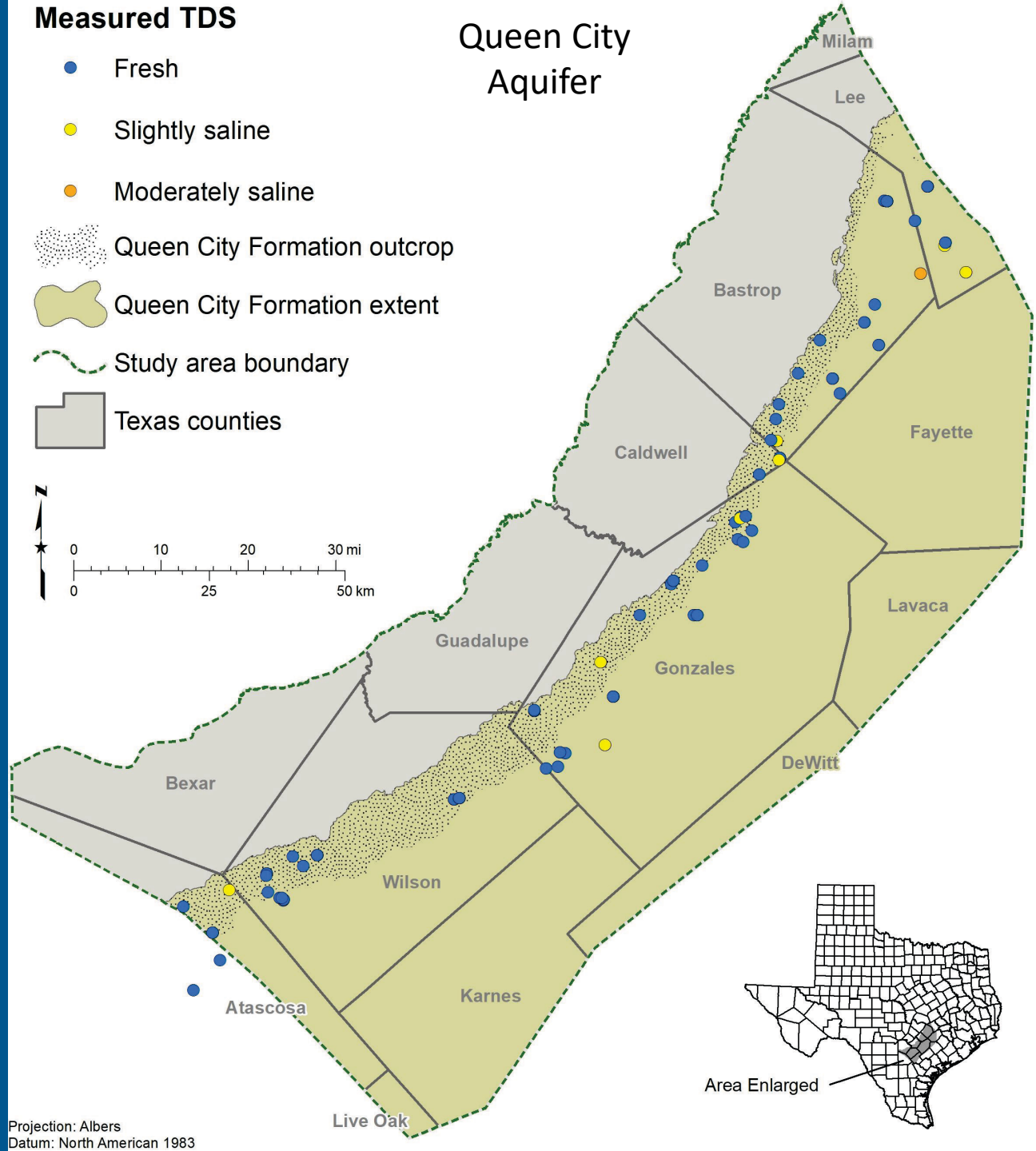


Water Quality, measured

- Groundwater Database
- Water Data Interactive Viewer
- https://www2.twdb.texas.gov/apps/waterdatainteractive/groundwaterdataviewer
- Data distribution biased by where wells were drilled
- Aquifer determination



Queen City Measured TDS



Water Quality, calculated (TDS_{calc})

- 911 oil & gas wells with 5,139 TDS_{calc} values
- The R_{wa} Minimum Method (Resistivity Water Apparent) is based on the relationship between water salinity and resistivity.
- A simplified version of Archie's equation (1942) assumes 100% water saturation and Winsauer factor = 1 :

$$R_w = R_o \cdot \phi^m$$

where:
- R_o = resistivity of the formation (units: ohm-meter)
- R_w = resistivity of water (units: ohm-meter)
- ϕ = porosity (units: percent)
- m = cementation exponent (units: dimensionless)

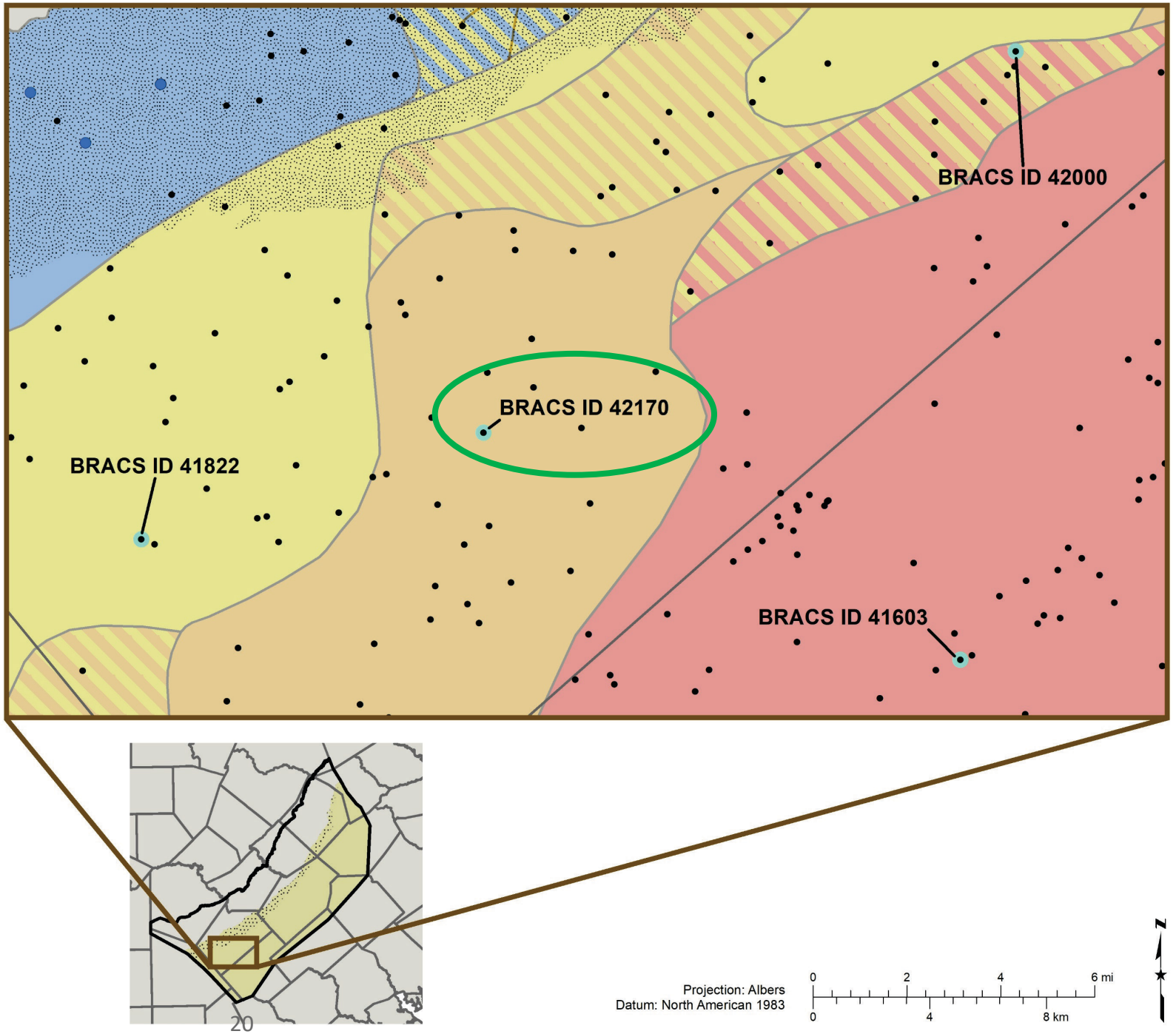
- **Resistivity → specific conductance → total dissolved solids**
- Presentation with all the math and parameters: http://www.twdb.texas.gov/innovativewater/bracs/doc/PowerPoints/4-1_Croskrey_Utilizing_Resistivity_Logs_QC_Fm_TDS_20190325.pdf

Measured TDS

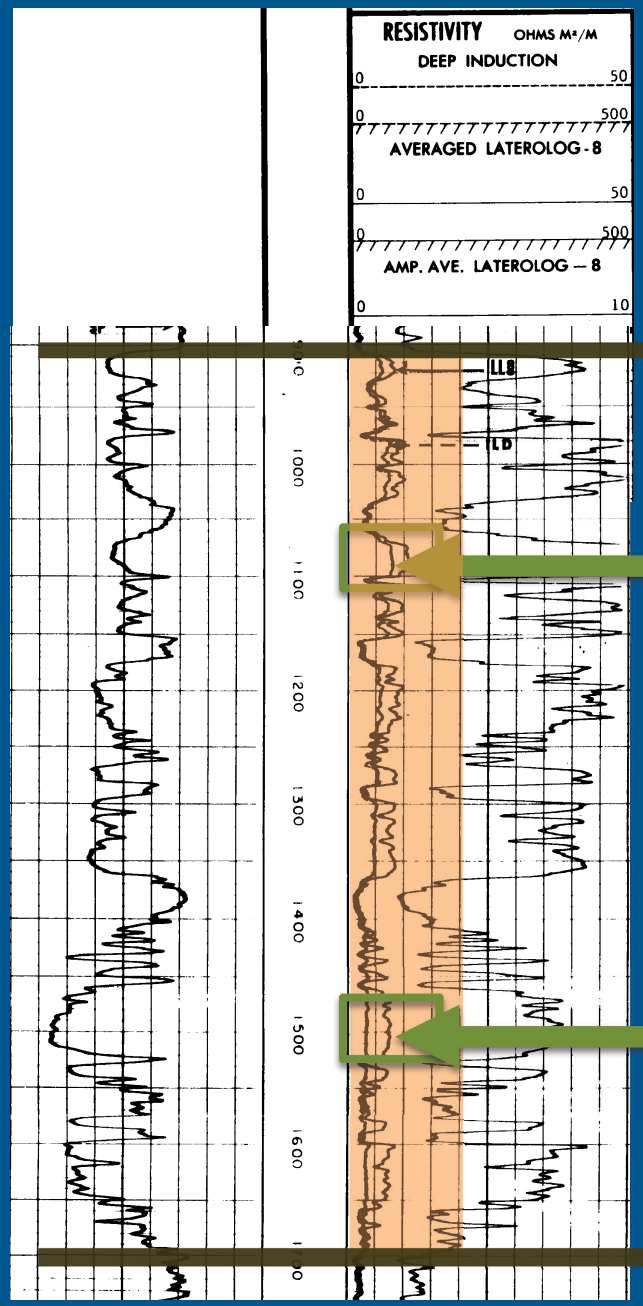
- Fresh
- Slightly saline
- Moderately saline

Salinity zone

- Fresh
- Fresh and slightly saline mixed zone
- Slightly saline
- Slightly saline and moderately saline mixed zone
- Slightly saline, moderately saline, and very saline mixed zone
- Moderately saline
- Very saline
- Well used in the study with a geophysical well log
- Queen City Formation outcrop
- Queen City Formation extent
- Texas counties



Moderately saline well 42170



Top of the Queen City Formation at 903 feet below Kelly Bushing

8,889 mg/L

Bottom of the Queen City Formation at 1,702 feet below Kelly Bushing

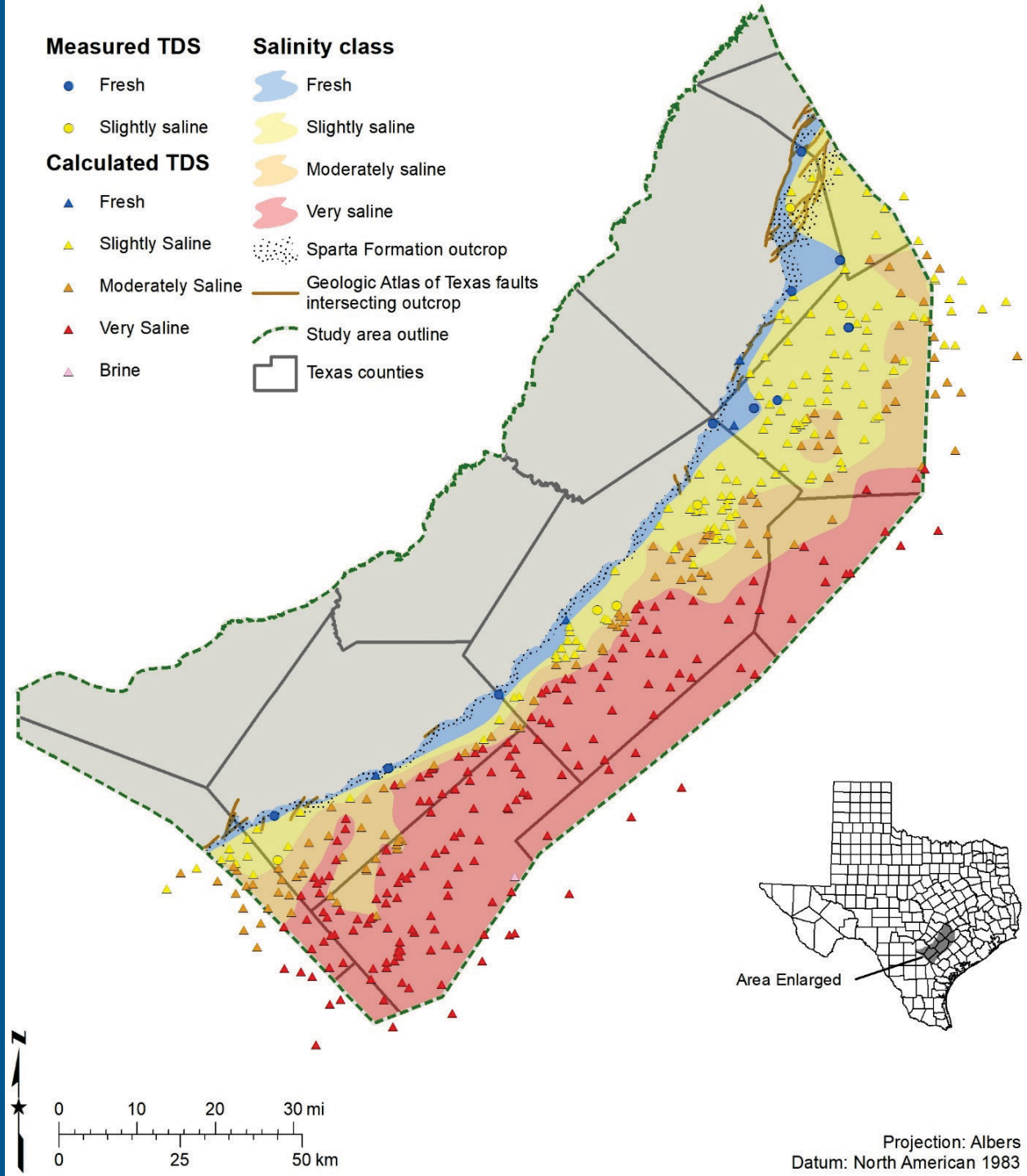
Value	Parameter	Units
7903	Depth total (bottom of borehole), Dt	Feet below Kelly Bushing
1090	Depth formation, Df	Feet below Kelly Bushing
69	Temperature surface, Ts	Degrees Fahrenheit
201	Temperature bottom hole, Tbh	Degrees Fahrenheit
7.5	Deep resistivity, Ro	Ohm-meter
0.39	Porosity, Ø	Percent
0.56	ct conversion factor, ct	Dimensionless
1.75	Cementation exponent, m	Dimensionless
1	Water quality correction factor, R_{wcRw}	Dimensionless

$$TDS = ct * \frac{10{,}000}{\frac{\emptyset^{m} * Ro}{R_{wcRw}} * \frac{\left(\frac{Tbh - Ts}{Dt} * Df + Ts\right) + 6.77}{77 + 6.77}}$$

= 3,478 mg/L

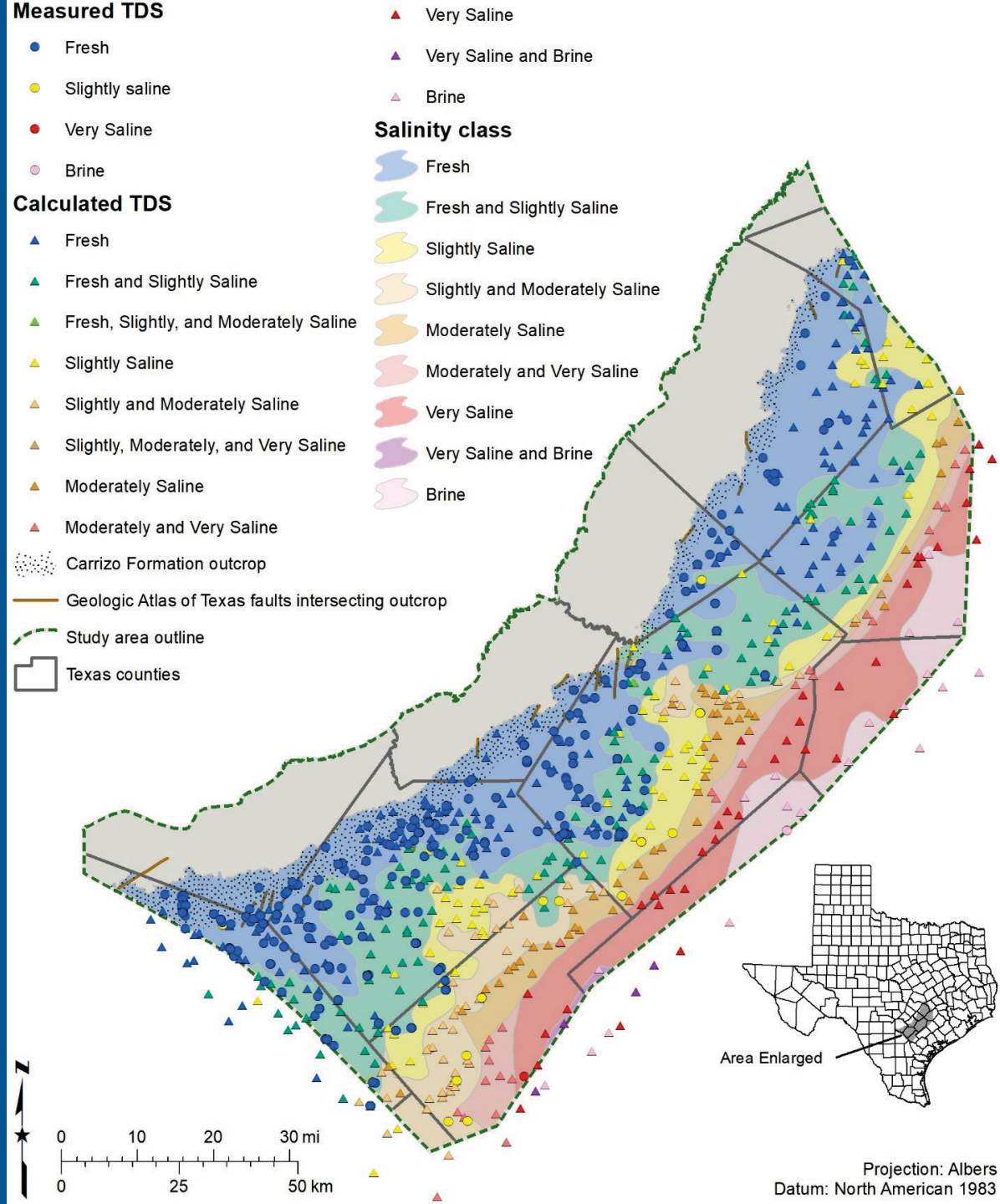
Sparta Aquifer Salinity Classes

- water quality samples
  - 31 wells (21 fresh, 9 slightly saline, and 1 moderately saline)
- Estimated salinity geophysical well logs
  - 427 wells with 427 calculations
  - 427 wells with 427 salinity class intervals: 4 fresh, 136 slightly saline, 112 moderately saline, 174 very saline, and 1 brine)



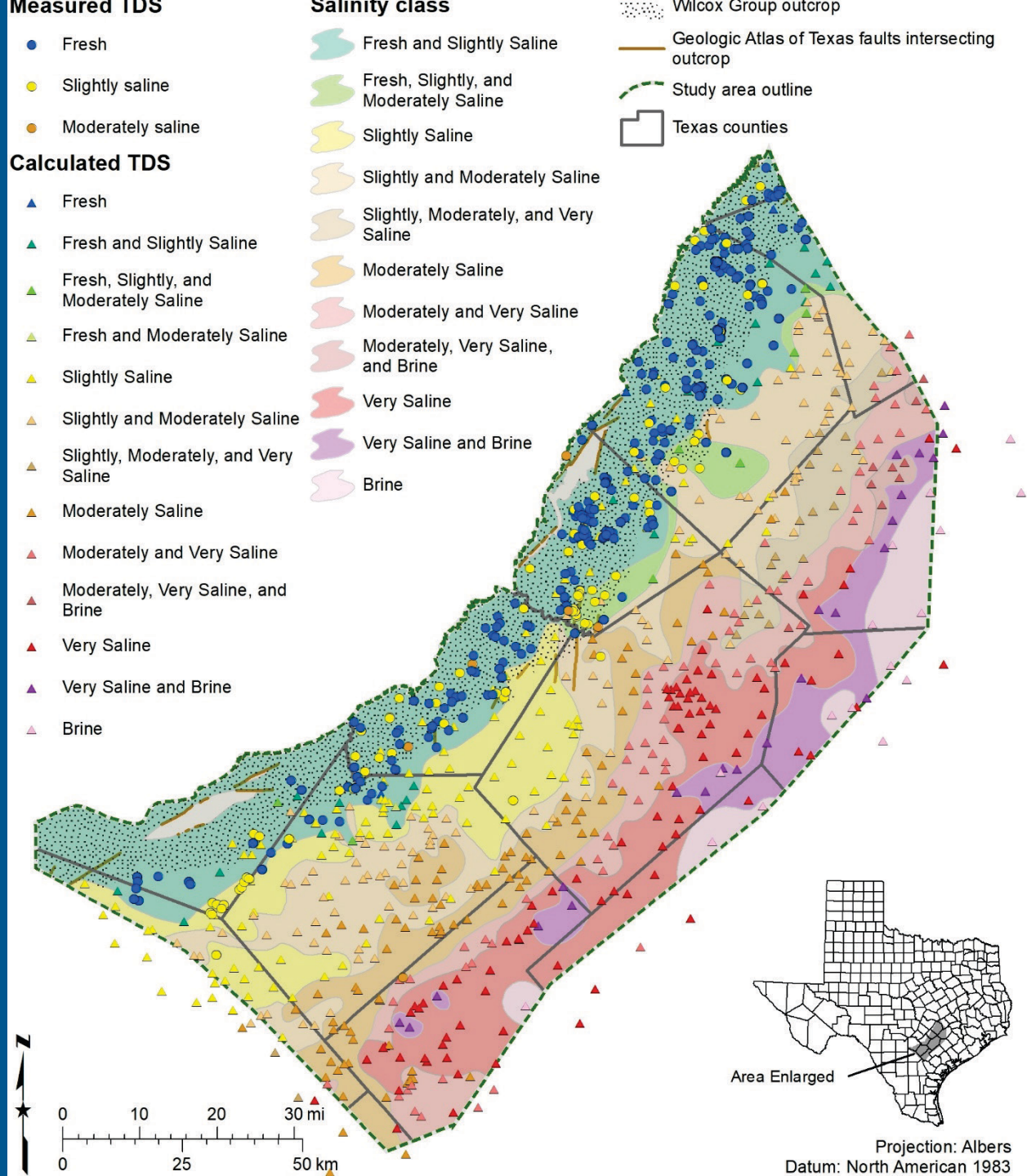
Carrizo Aquifer Salinity Classes

- Water quality samples
  - 250 wells (229 fresh, 16 slightly saline, 1 very saline, and 1 brine)
- Estimated salinity geophysical well logs
  - 590 wells with 1,283 calculations
  - 587 wells with 870 salinity class intervals: 306 fresh, 297 slightly saline, 170 moderately saline, 72 very saline, and 25 brine)



Wilcox Aquifer Salinity Classes

- Water quality samples
  - 384 wells (286 fresh, 92 slightly saline, and 6 moderately saline)
- Estimated salinity geophysical well logs
  - 618 wells with 1,867 calculations
  - 612 wells with 952 salinity class intervals: 36 fresh, 302 slightly saline, 345 moderately saline, 222 very saline, and 47 brine)



Texas Water Development Board Report Plate 8

Structural Cross-section of Dip Line Y

Salinity class and lithology interpretations for the Yegua, Sparta, Queen City, Carrizo, and Wilcox aquifers, Central Texas

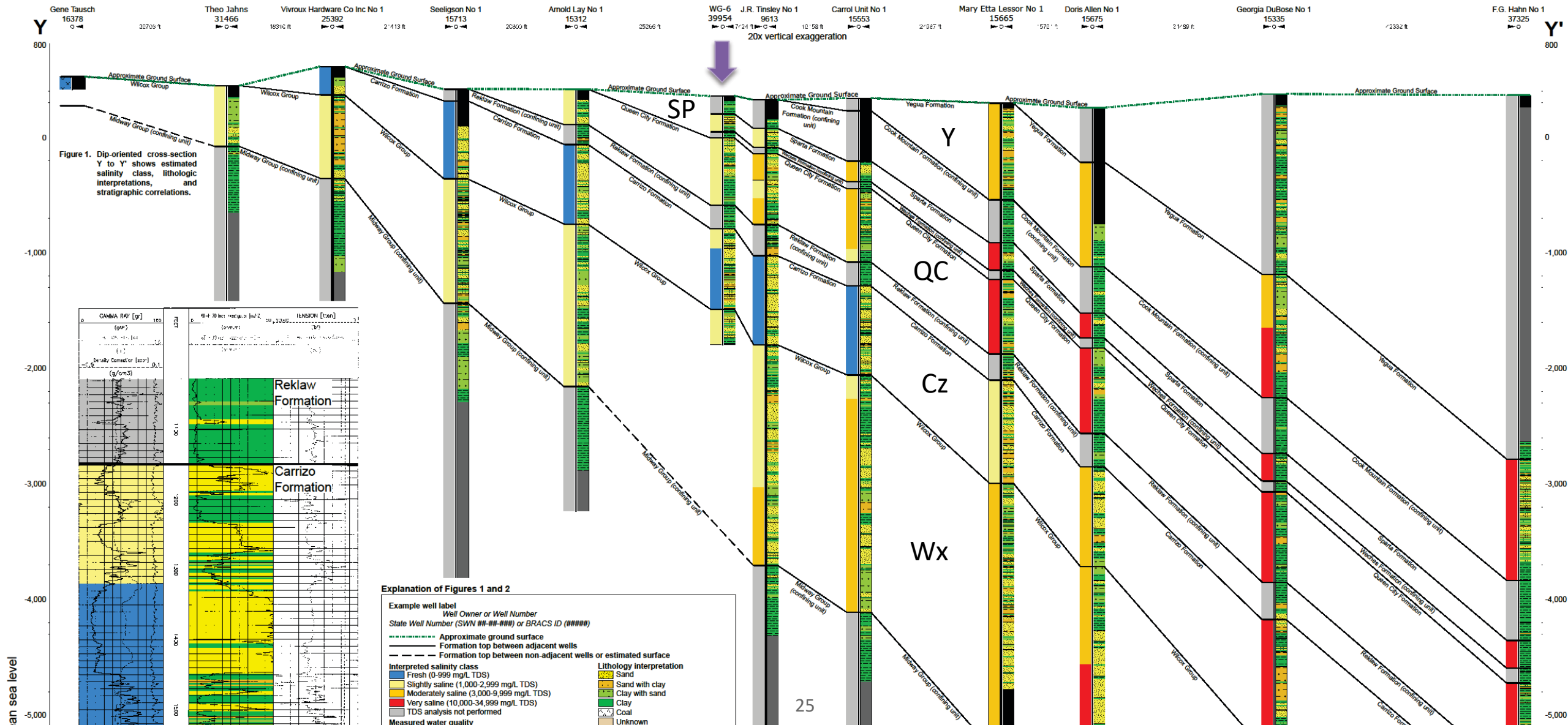


Figure 1. Dip-oriented cross-section Y to Y' shows estimated salinity class, lithologic interpretations, and stratigraphic correlations.

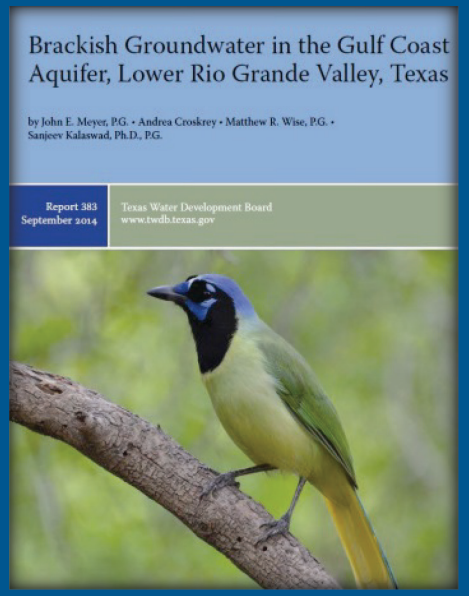
an sea level

Volumes

Aquifer	Pure brackish (1,000-10,000 mg/L TDS)	Total groundwater
Yegua	42	78
Sparta	6	11
Queen City	20	52
Carrizo	57	204
Wilcox	112	321

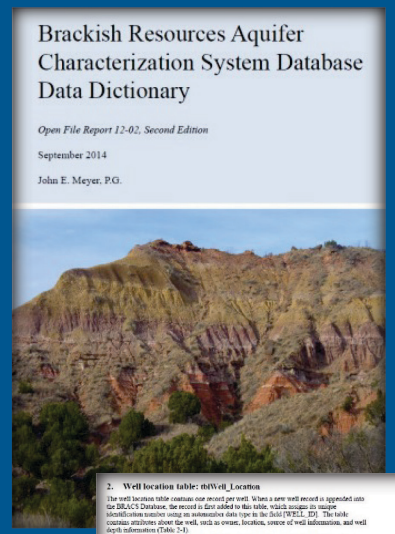
- Units are millions of acre-feet
- In-place water, all this water is NOT recoverable
- Brackish groundwater volume doesn't include areas were brackish groundwater is mixed or stacked with fresh, very saline, or brine groundwater

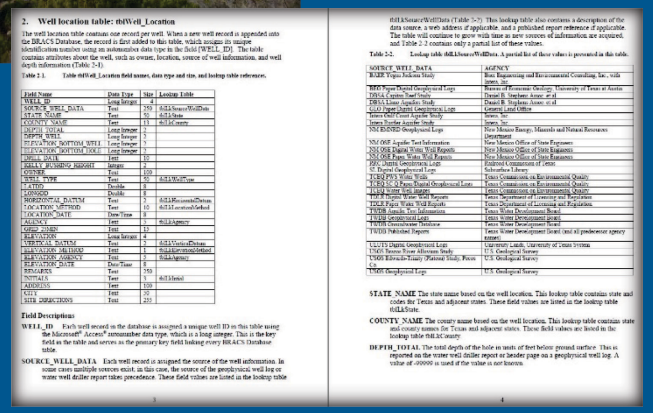
Product Deliverables



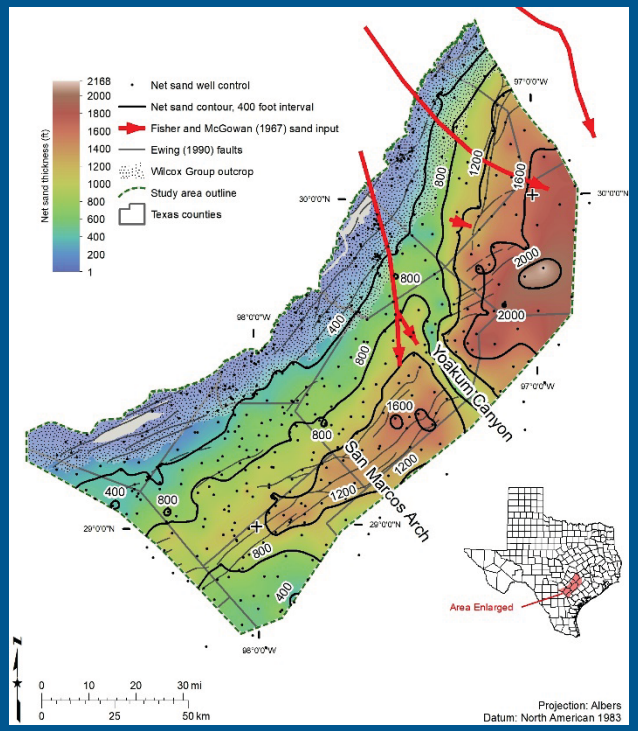
Peer-reviewed report

Relational database





Well data



GIS files with metadata

Future improvements

TDS calculations

1. higher salinity water quality samples to support calibrating log analysis,
2. evaluate correction factors for mixed ion groundwater,
3. determining proper cementation factors,
4. evaluate the effect and presence of grain-coating (pore-filling) clay, and
5. determining techniques of carbonate rock analysis.

Brackish Groundwater Research

1. Productivity
2. Impact of development
3. Sustainability
4. Site specific drilling and monitoring will be required

Conclusions

- Resistivity logs can be used to estimate water quality
- Quality of the calculations depends on:
  - Correlations, parameters, water quality type, complete log headers
- Mixed/stacked water quality regions in most of the aquifers
- All 5 aquifers in the study area have millions of acre-feet of brackish groundwater
- Regional understanding of sand and salinity distribution

JOB VACANCY NOTICE COMING SOON!

Groundwater Modeler

http://www.twdb.texas.gov/jobs/index.asp

Andrea Croskrey, M.S., P.G.

Geologist

Innovative Water Technologies

Texas Water Development Board

andrea.croskrey@twdb.texas.gov

(512) 463-2865

http://www.twdb.texas.gov/innovativewater/index.asp

2017 Water Plan:

http://www.twdb.texas.gov/waterplanning/swp/2017/index.asp