

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

South Texas Geological Society
October 13, 2021

Presenter:

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Our mission: "To lead the state's efforts in ensuring a secure water future for Texas and its citizens"

Texas Water Development Board

1. Funding
2. Outreach
3. Data
4. State Water and Flood Plans



Brackish Resources Aquifer Characterization System (BRACS)

Our studies focus on mapping

1. Stratigraphy
2. Lithology
3. Water Quality

And our data is made publicly available

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

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John E. Meyer, P.G., Andrea D. Croskrey, P.G., Alysa K. Suydam, P.G.,
and Nathaniel van Oort

Report 385
December 2020

Texas Water Development Board
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What is brackish groundwater?

*“saltier than fresh water,
less salty than seawater”*

TCEQ - public water
system threshold →

RRC - Base of useable
quality groundwater →

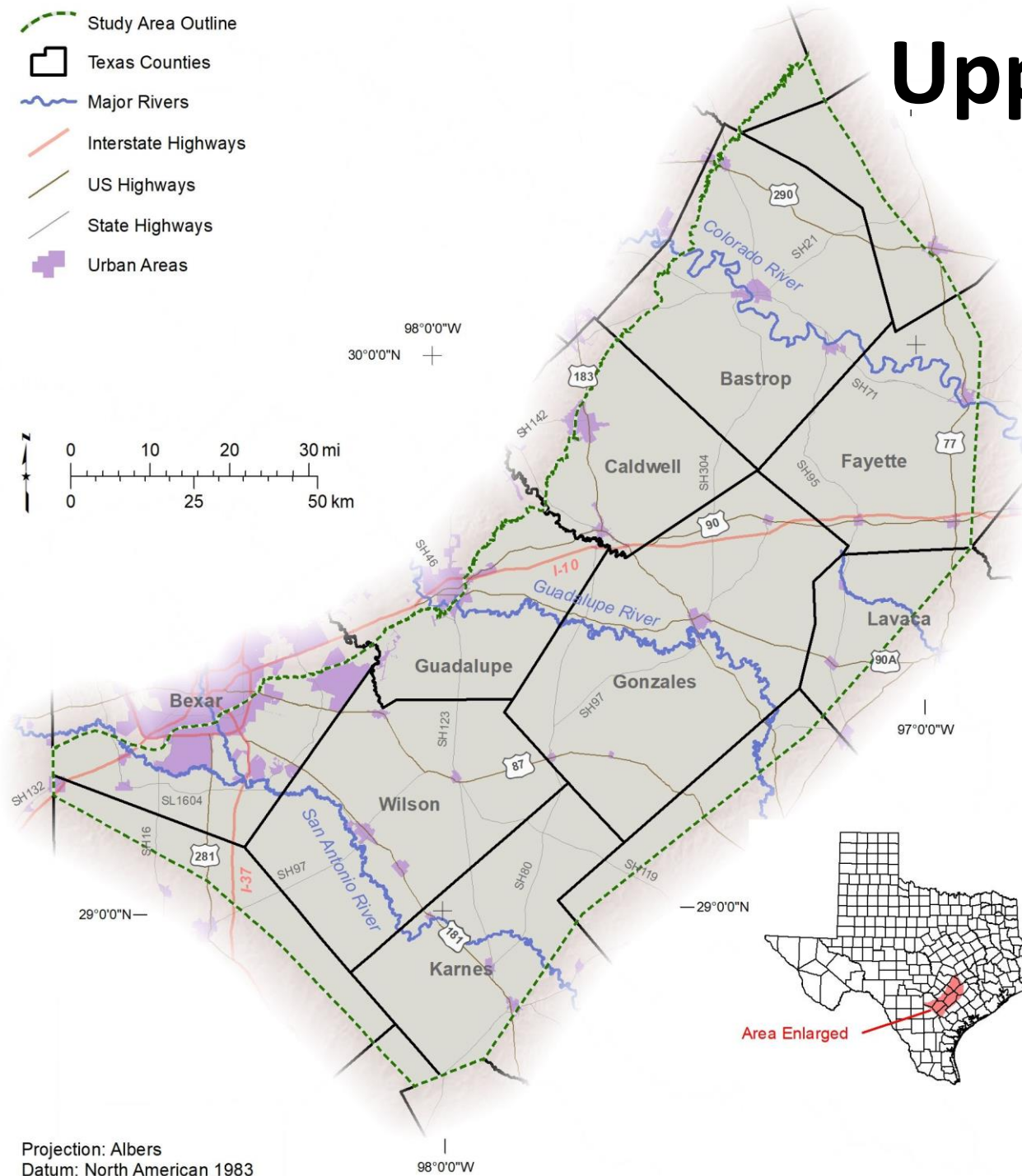
EPA - Underground
source of drinking
water →

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

← Most Texas
Major/Minor
Aquifer
Mapped Limit

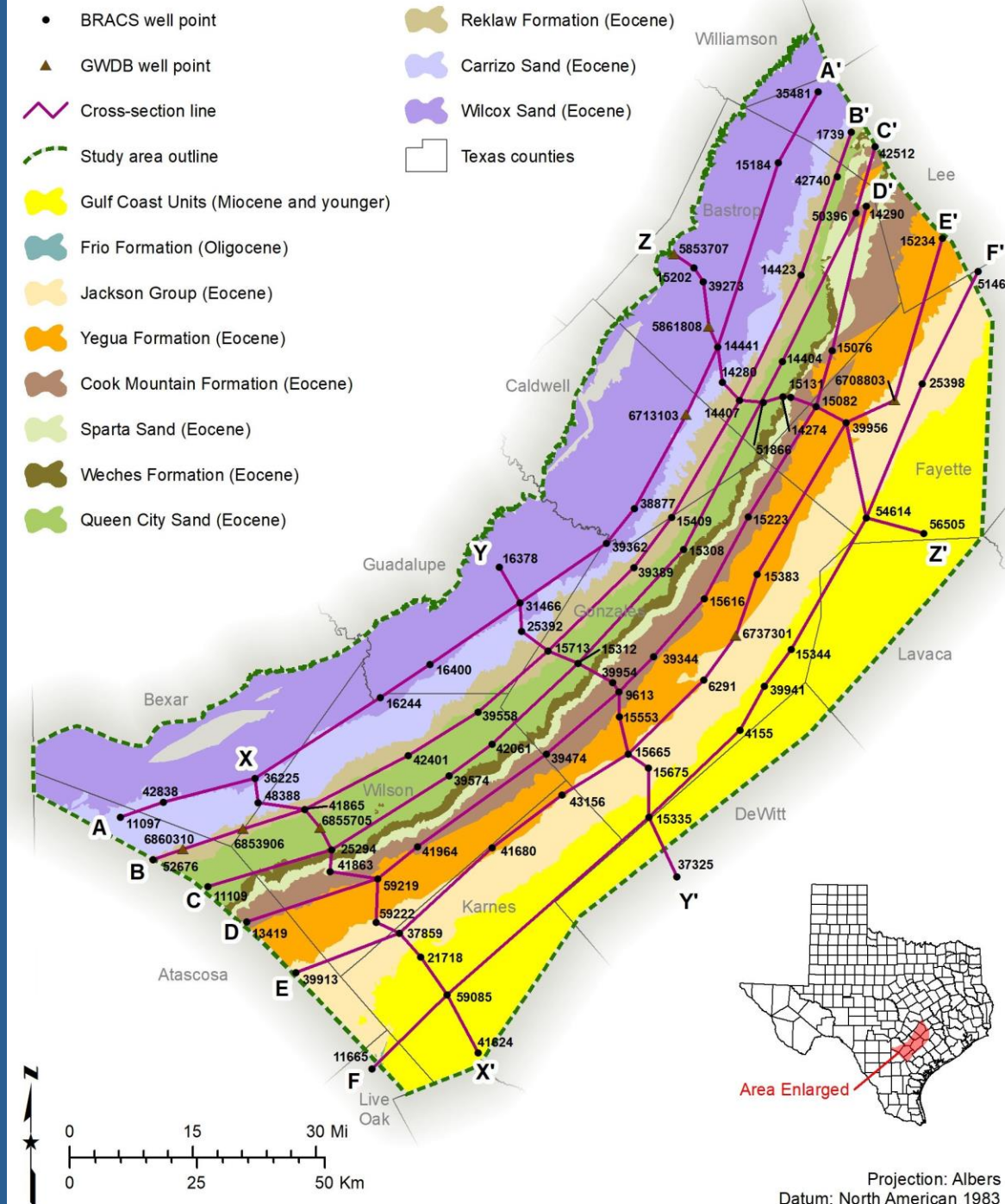
← Seawater

Upper Coastal Plains – Central Study Overview



- Includes parts of 14 counties in central Texas
- We mapped eight Eocene stratigraphic units
 - Yegua
 - Reklaw
 - Cook Mountain
 - Carrizo
 - Sparta
 - Wilcox
 - Weches
 - Queen City

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

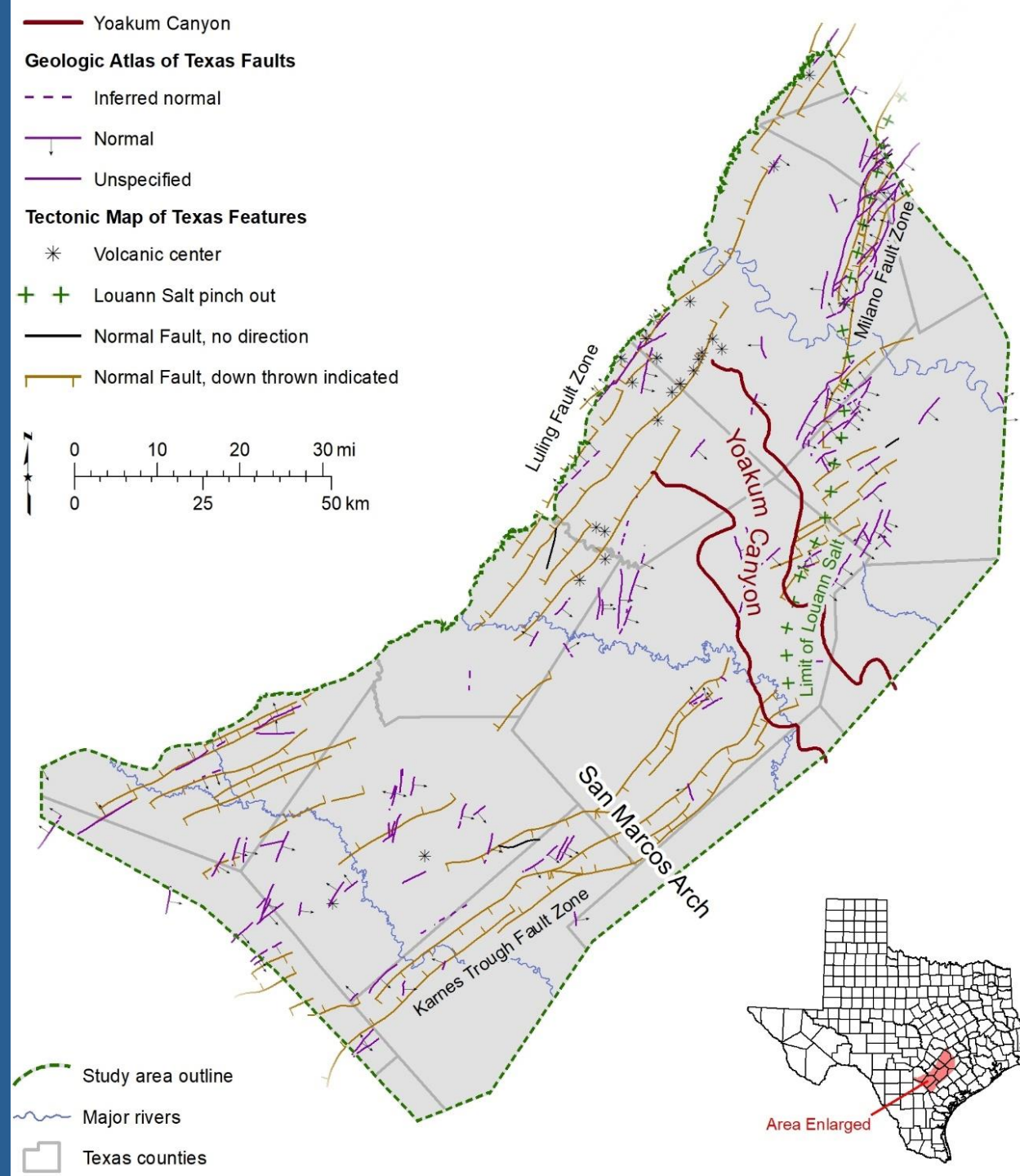


Regional Structures

- Yoakum Canyon
- Faults
- Louann Salt pinch out
- Volcanic centers
- San Marcos Arch

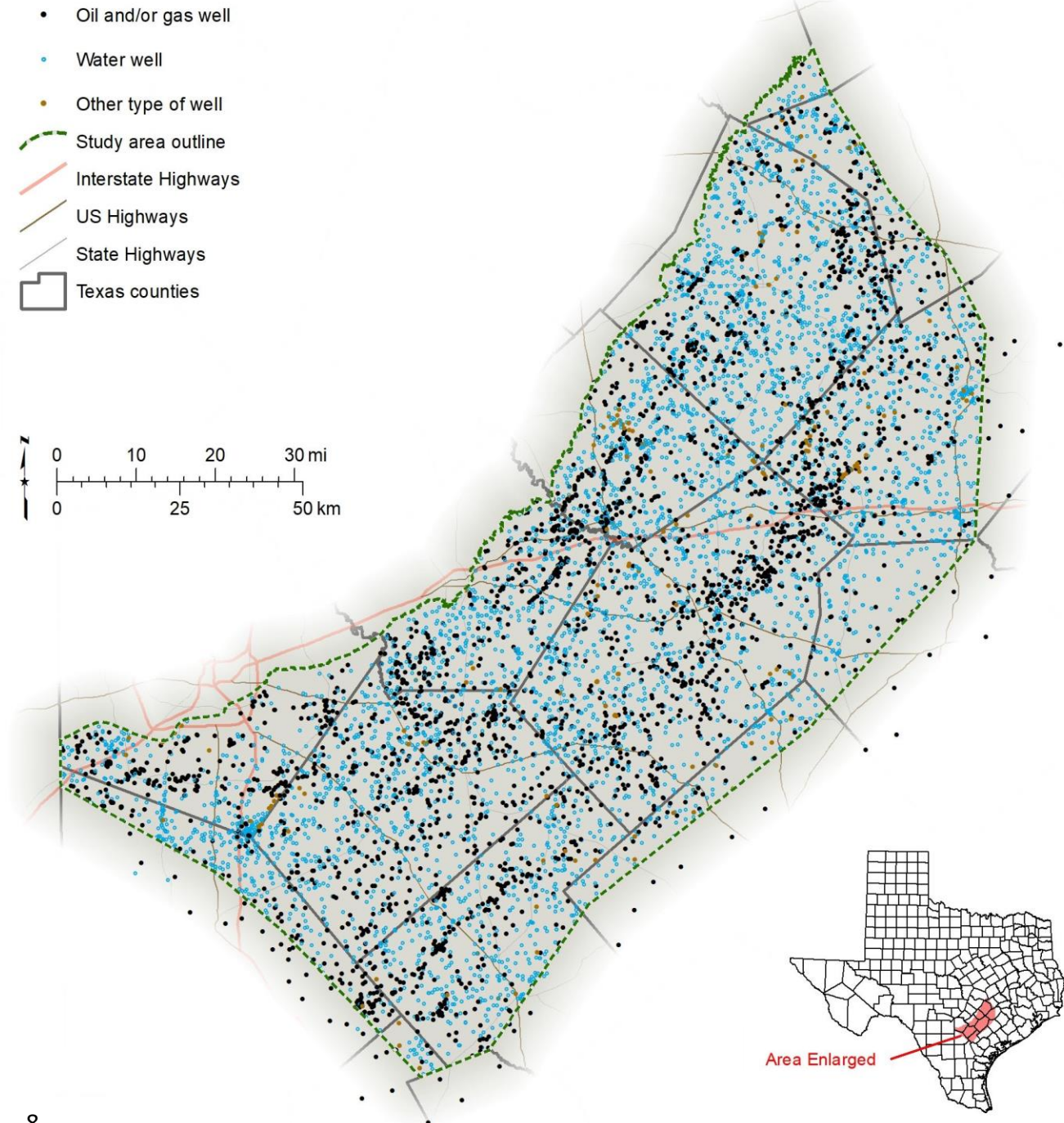
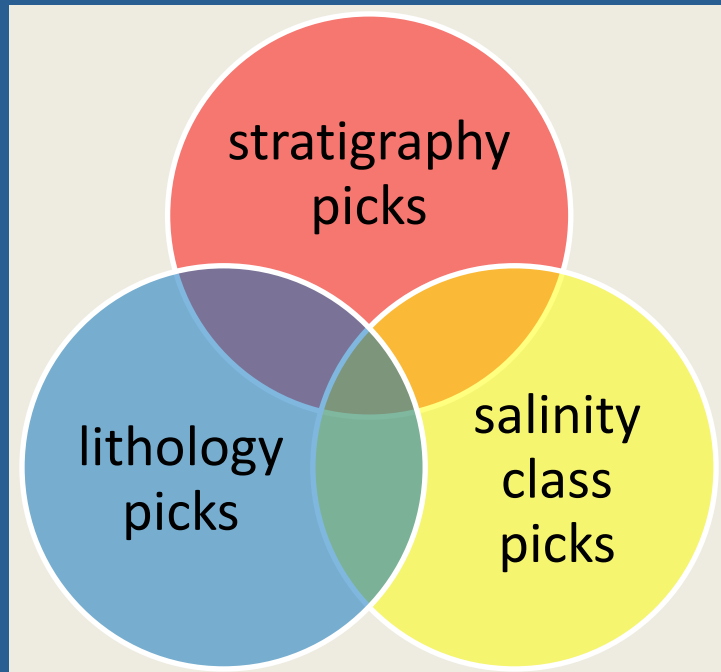
Some sources:

- Dingus and Galloway (1990)
- Digital Geologic Atlas of Texas (TWDB, 2007)
- 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 of Brackish
Groundwater**

$$\begin{aligned} &\text{Volume (acre-feet)} \\ &= \\ &\text{Area} \\ &\times \\ &\text{Saturated net sand} \\ &\times \\ &\text{Effective porosity} \end{aligned}$$

Stratigraphy

- Reviewed cross-sections
- Picked tops from geophysical well logs
- Entered in BRACS Database (MS Access)
- Interpolated to surfaces in ArcGIS

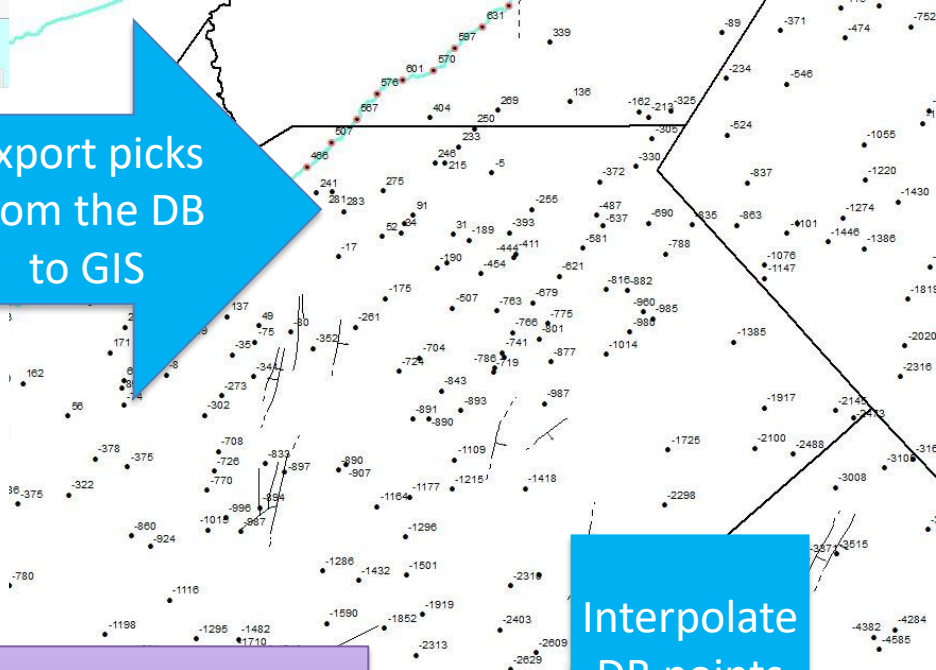
TWDB WSC IWT BRACS Geophysical Log Search Form

BRACS Well ID: 42051

Location and Well IDs | Lithology and Stratigraphy | Digital Well Logs | TDS Analysis using Geophysical Well Logs | Aquifer Test Information | Water Quality | Static Water Level | Well Construction

Lithologic Description					Stratigraphic Description				
Record Number	Geologic Pick	Top Depth Bottom Depth Thickness	Lithologic Description	Source of Data	Record Number	Geologic Pick	Top Depth Bottom Depth Thickness	Stratigraphic Description	Source of Data
6	Lithologic	0 70 70	No Record No Record No Record	Geophysical Well Log	1	Stratigraphic	0 160 160	Queen City Formation	Geophysical Well Log
7	Lithologic	70 90 20	Sand Sand Sand	Geophysical Well Log	2	Stratigraphic	160 270 110	Rekiew Formation	Geophysical Well Log
8	Lithologic	90 125 35	Clay Clay Clay	Geophysical Well Log	3	Stratigraphic	270 992 722	Carizzo Formation	Geophysical Well Log
9	Lithologic	125 130 5	Clay Clay Clay	Geophysical Well Log	4	Stratigraphic	992 2040 1048	Wilcox Group	Geophysical Well Log
10	Lithologic	130 145 15	Sand Sand Sand	Geophysical Well Log	5	Stratigraphic	2040 - - -	Midway Group	Geophysical Well Log
11	Lithologic	145 150 5	Clay with Sand Clay with Sand Clay with Sand	Geophysical Well Log					

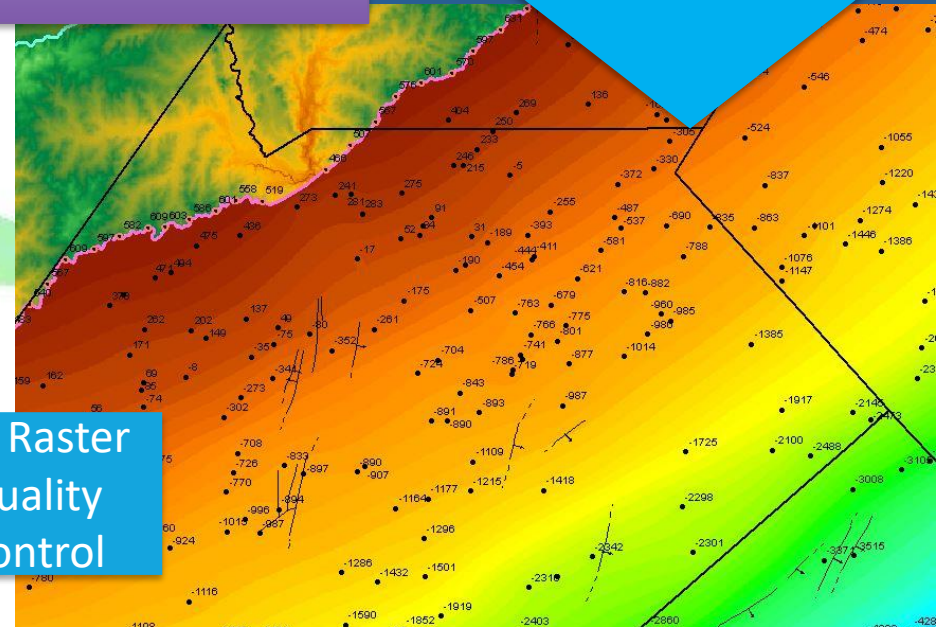
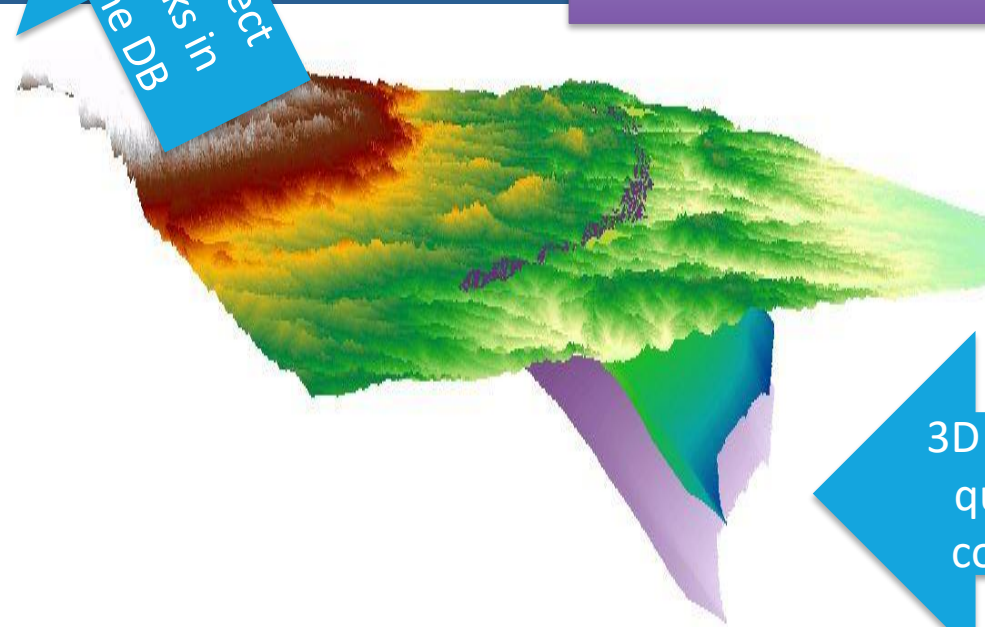
Export picks from the DB to GIS



Interpolate DB points to rasters

BRACS Study Iterative Workflow

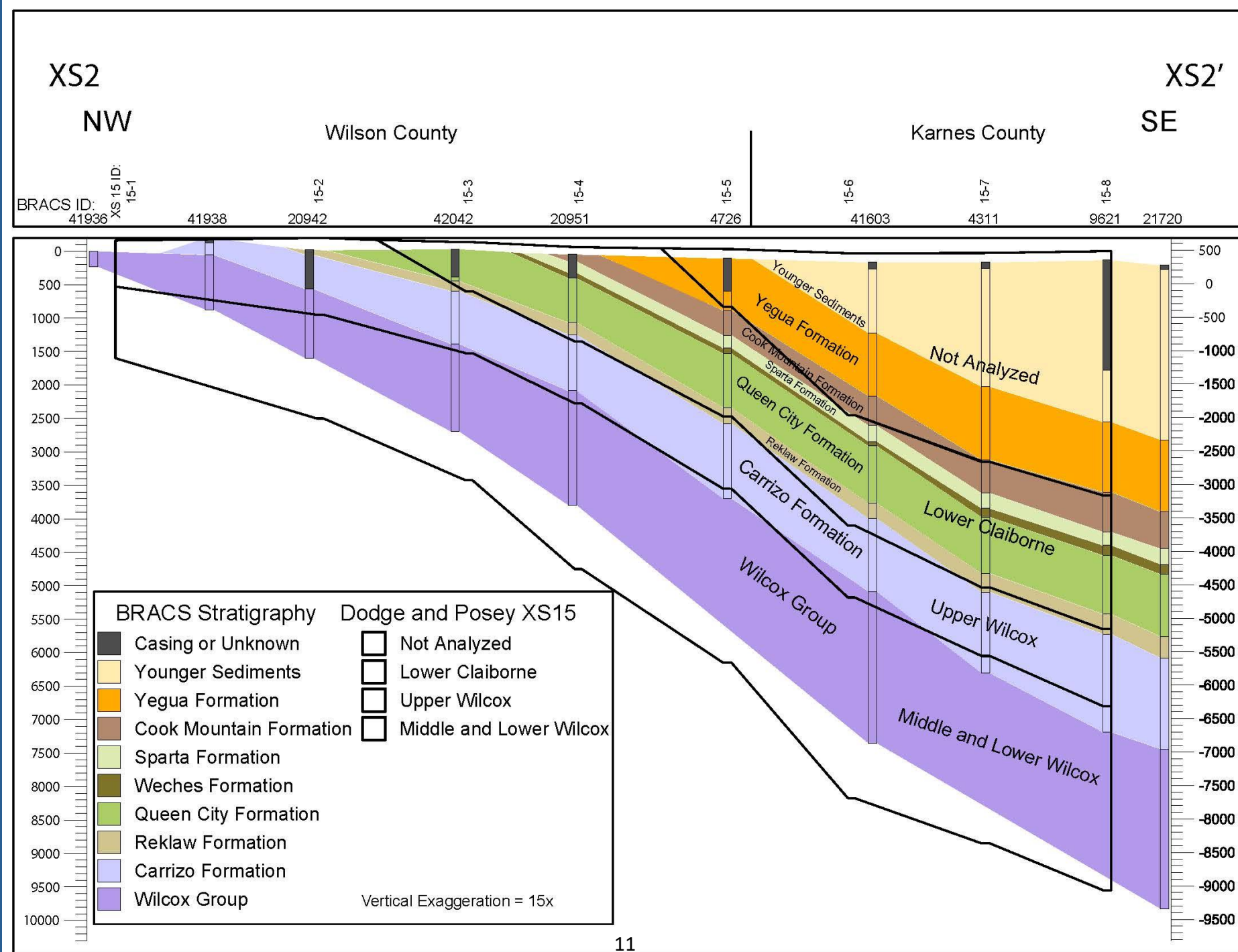
Correct picks in the DB



3D Raster quality control

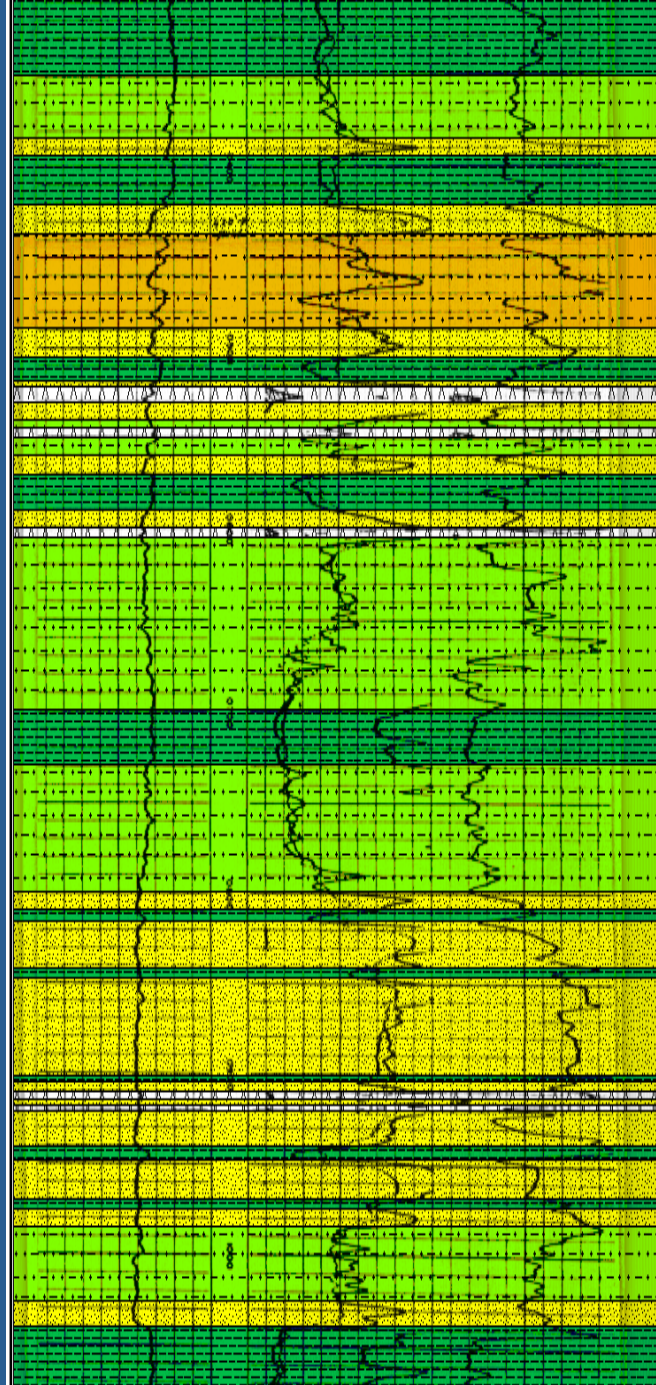
Stratigraphic comparison

This study compared to Dodge and Posey (1981)



Net Sands

- Lithology interpreted from geophysical well logs and driller's reports
- Four categories:
 - Sand
 - Sand with clay
 - Clay with sand
 - Clay
- Interpolated net sand values in ArcGIS



BRACS Well ID 14385

Percent of sand for each interval

Sand (100%)	Sand with clay (65%)
Clay with sand (35%)	Clay (0%)

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

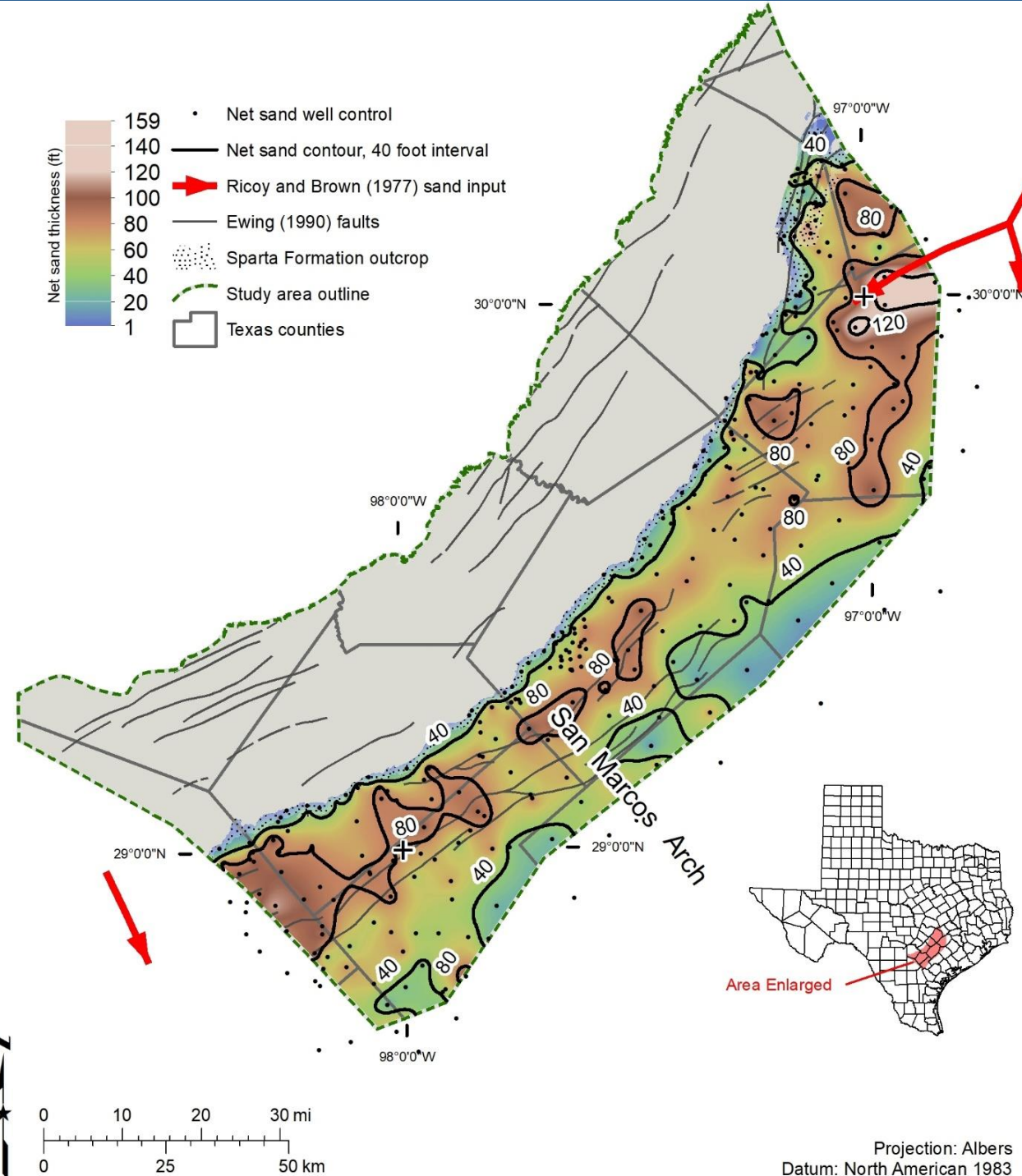
Clay (0%)
Sandy clay (35%)
Sand (100%)
Clay (0%)
Sandy clay (35%)
Clay (0%)
Sand (100%)
Shale (0%)
Unknown (0%)

BRACS Well ID 14271

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

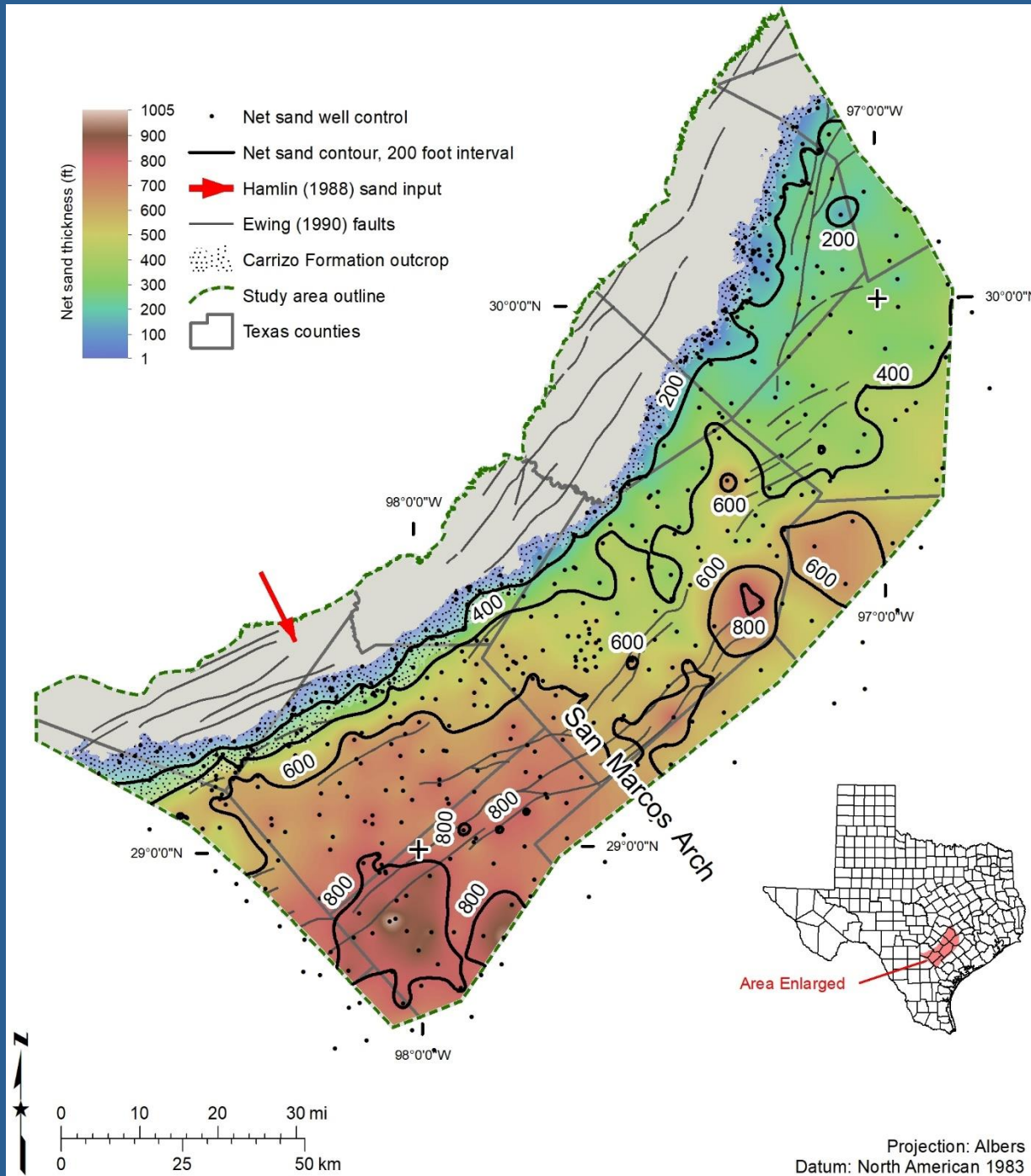
Sparta Aquifer Net Sands

- Up to 140 feet net sand
- Data sources
 - 197 geophysical logs interpreted
 - 138 driller descriptions simplified
- Major sand deposition occurred outside of study area



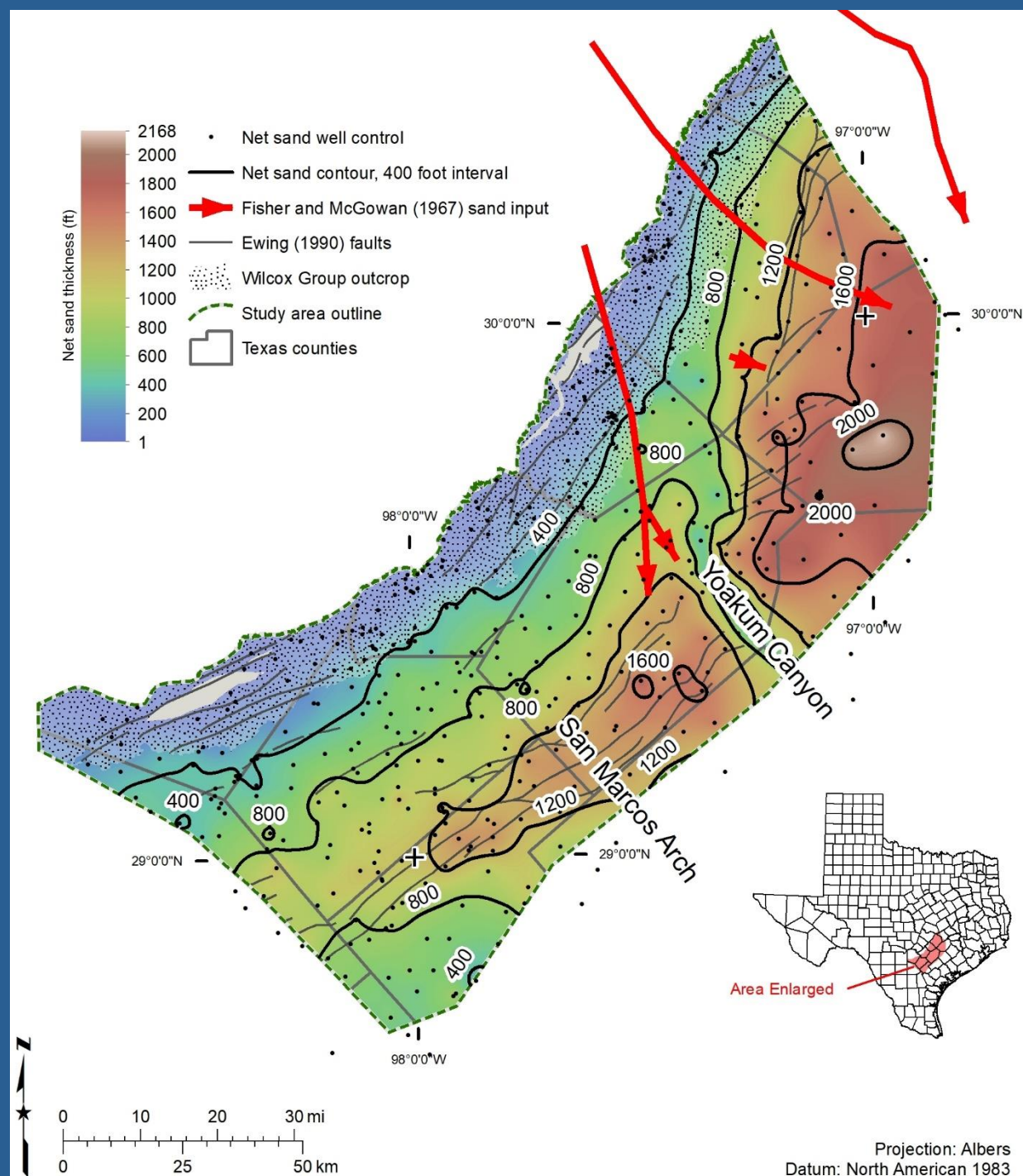
Carrizo Aquifer Net Sands

- Up to 1,000 feet net sand
- Data sources
 - 327 geophysical logs interpreted
 - 199 driller descriptions simplified
- Major sand deposition occurred south of San Marcos Arch
- Increased net sand at Yoakum Canyon



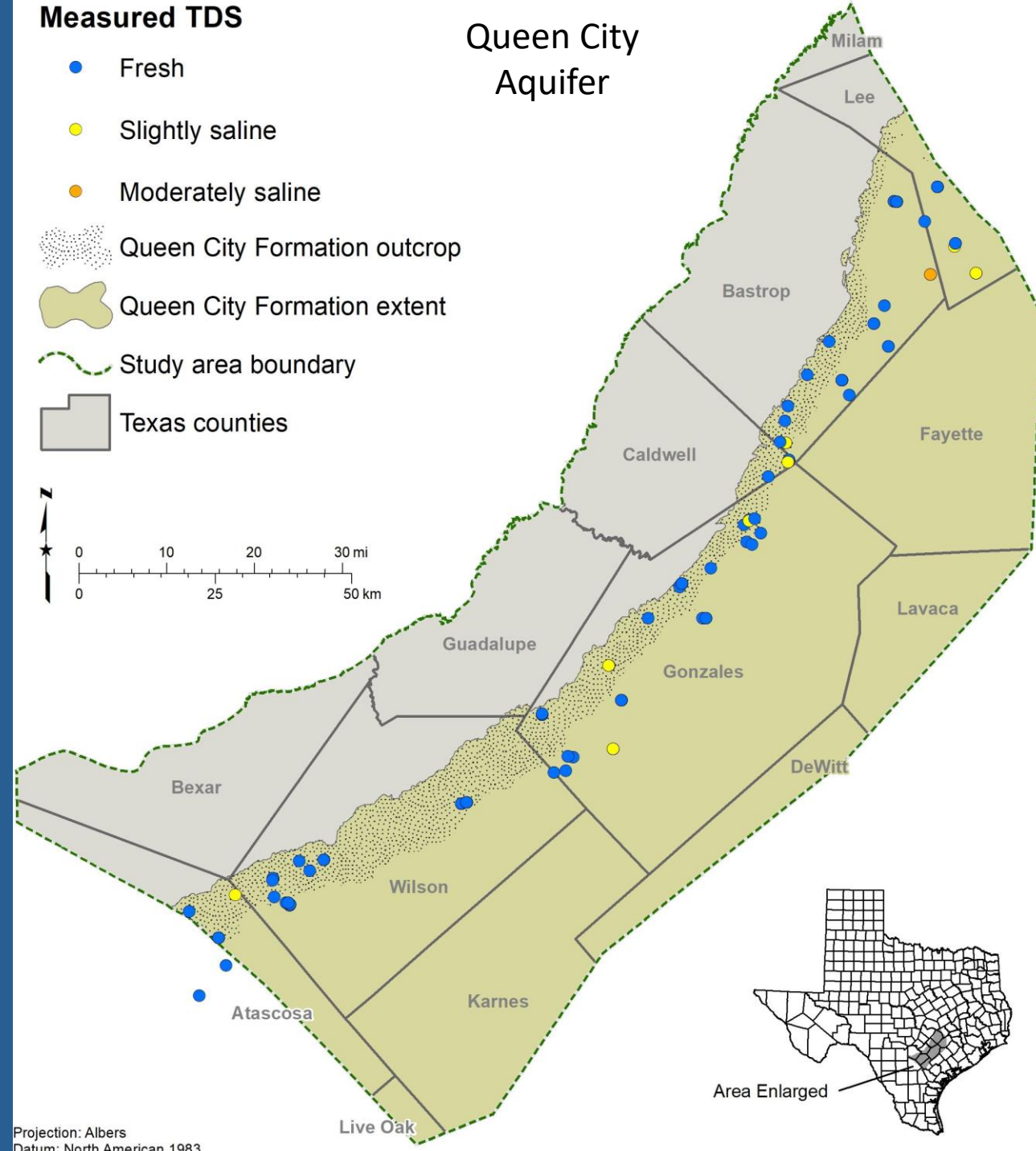
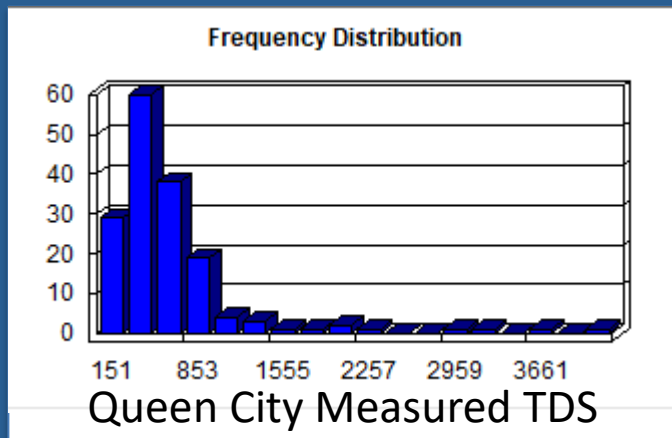
Wilcox Aquifer Net Sands

- Up to 2,000 feet net sand
- Data sources
 - 366 geophysical logs interpreted
 - 133 driller descriptions simplified
- Major sand deposition occurred northeast of San Marcos Arch
 - Bifurcated by Yoakum Canyon



Measured Water Quality

- Primarily from TWDB Groundwater Database
- Can view in Water Data Interactive viewer <https://www2.twdb.texas.gov/apps/waterdatainteractive/groundwaterdataviewer>
- Data distribution biased by where wells were drilled
- Assigned samples to aquifers via “aquifer determination”



Calculated Water Quality

- Calculated 5,139 TDS values from 911 oil and gas wells
- R_{wa} Minimum Method (Resistivity Water Apparent)
 - based on the relationship between water salinity and resistivity.
- From 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 (ohm-meter)
- R_w = resistivity of water (ohm-meter)
- ϕ = porosity (percent)
- m = cementation exponent (dimensionless unit)

- Calculate 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

Example salinity calculation

Measured TDS

- Fresh
- Slightly saline
- Moderately saline

Salinity zone

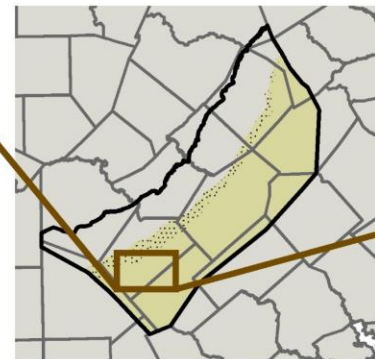
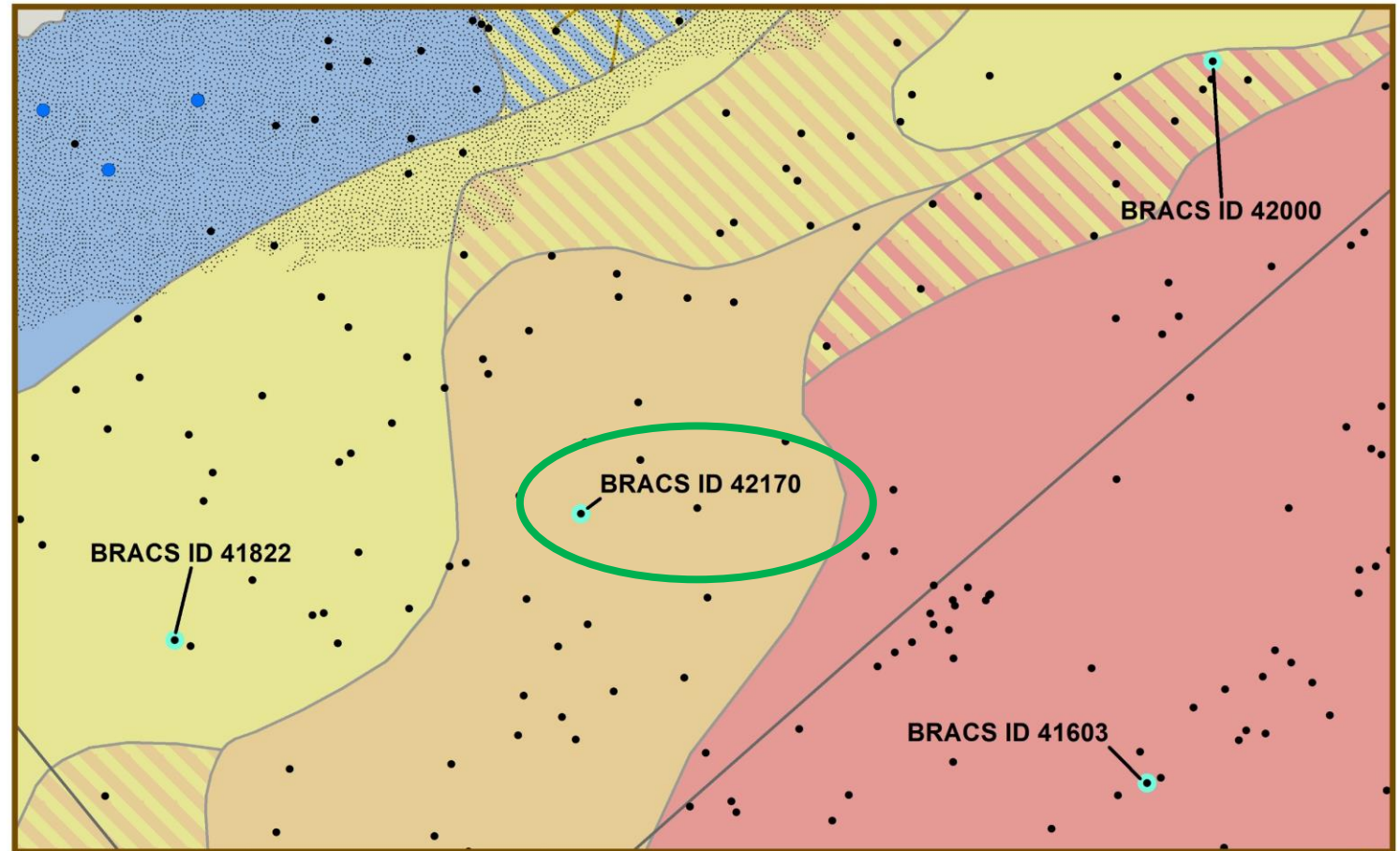
- Fresh
- Fresh and slightly saline mixed zone
- Slightly saline
- Slightly saline and moderately saline mixed zone
- Slightly saline, moderately saline, and very saline mixed zone
- Moderately saline
- Very saline

- Well used in the study with a geophysical well log

- Queen City Formation outcrop

- Queen City Formation extent

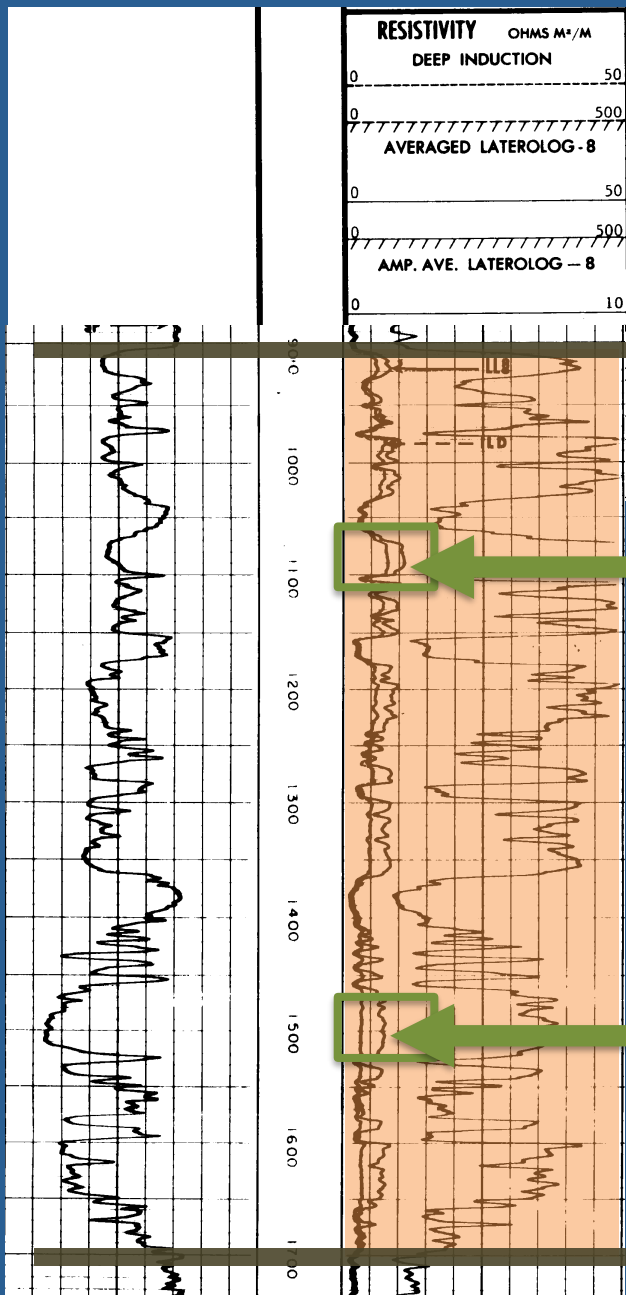
- Texas counties



Projection: Albers
Datum: North American 1983



Example salinity calculation



Top of the Queen City
= 903 feet

Moderately
saline

8,889 mg/L

Bottom of the Queen City =
1,702 feet

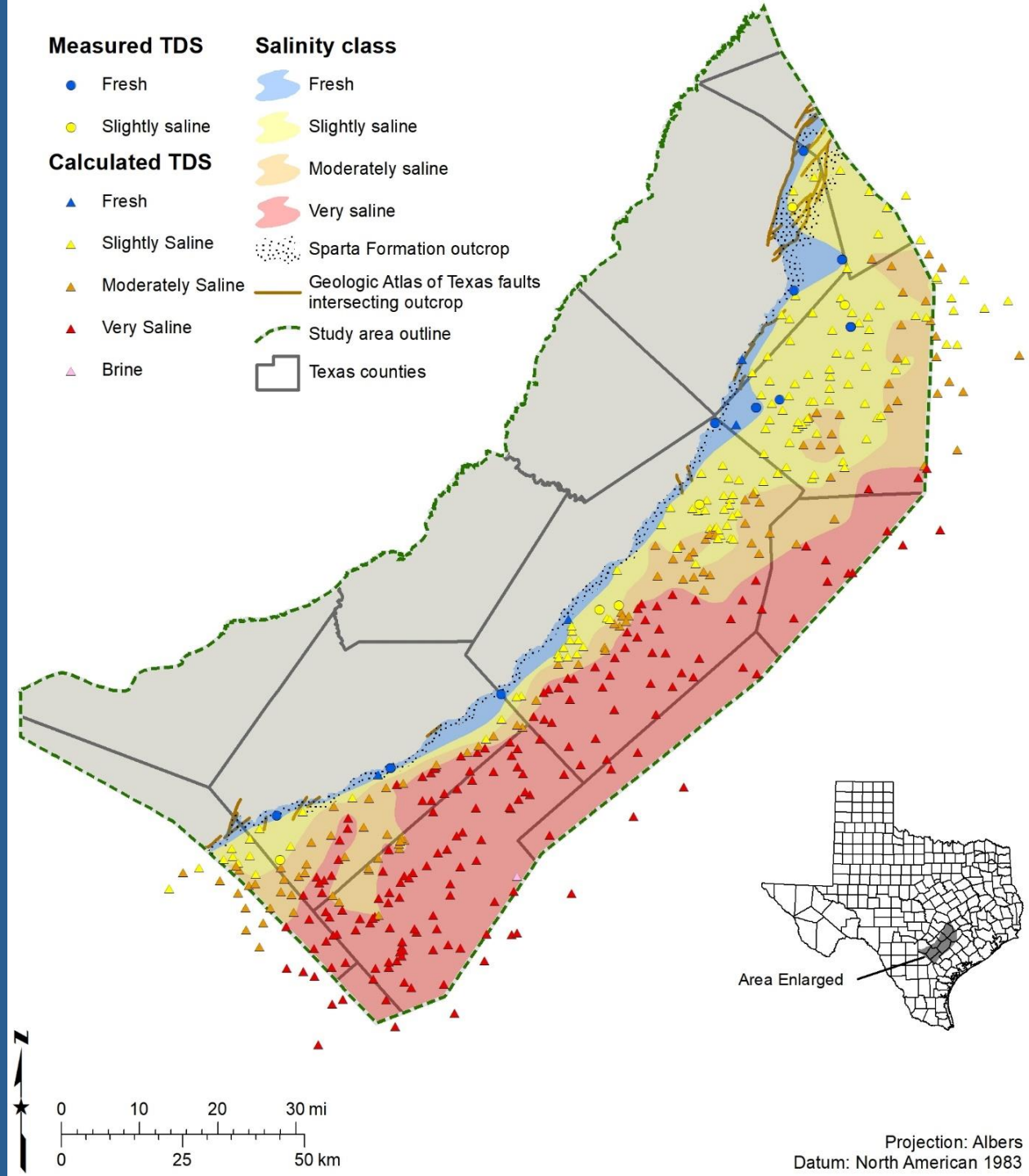
Values	Parameter	Units
7903	Borehole total depth, Dt	Feet
1090	Depth formation, Df	Feet
69	Temperature surface, Ts	Degrees Fahrenheit
201	Temperature bottom hole, Tbh	Degrees Fahrenheit
7.5	Deep resistivity, Ro	Ohm-meter
0.39	Porosity, ϕ	Percent
0.56	ct conversion factor, ct	Dimensionless
1.75	Cementation exponent, m	Dimensionless

$$TDS = ct * \frac{10,000}{R_{wCRW} * \phi^m * R_o} * \frac{\left(\frac{T_{bh} - T_s}{Dt} * Df + T_s\right) + 6.77}{77 + 6.77}$$

$$= 3,478 \text{ mg/L}$$

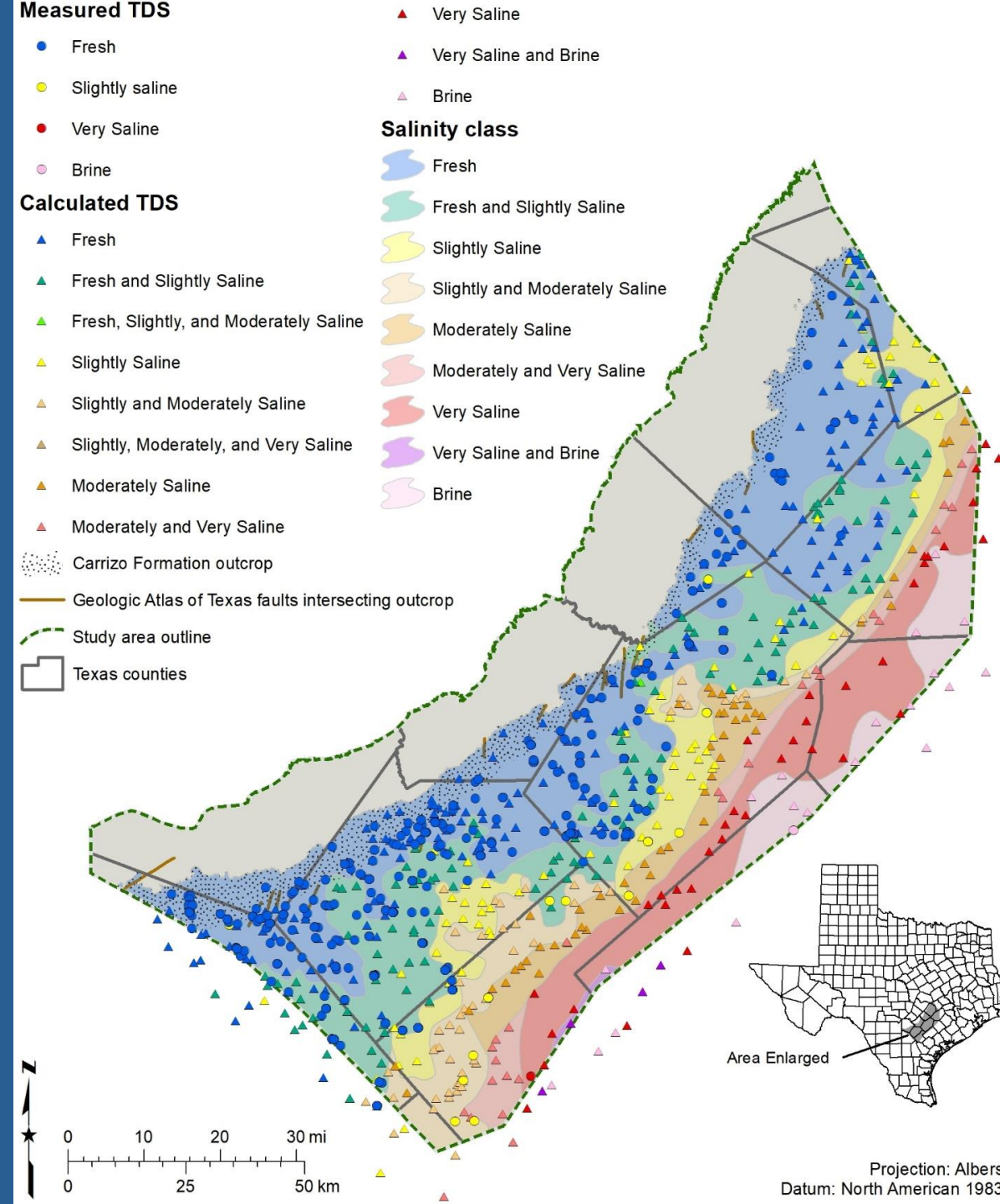
Sparta Aquifer Salinity Classes

- Water quality samples (31 wells)
 - 21 fresh
 - 9 slightly saline
 - 1 moderately saline
- Estimated salinity from 427 geophysical logs
 - 427 calculations
 - 427 assigned salinity class intervals
 - 4 fresh
 - 136 slightly saline
 - 112 moderately saline
 - 174 very saline
 - 1 brine



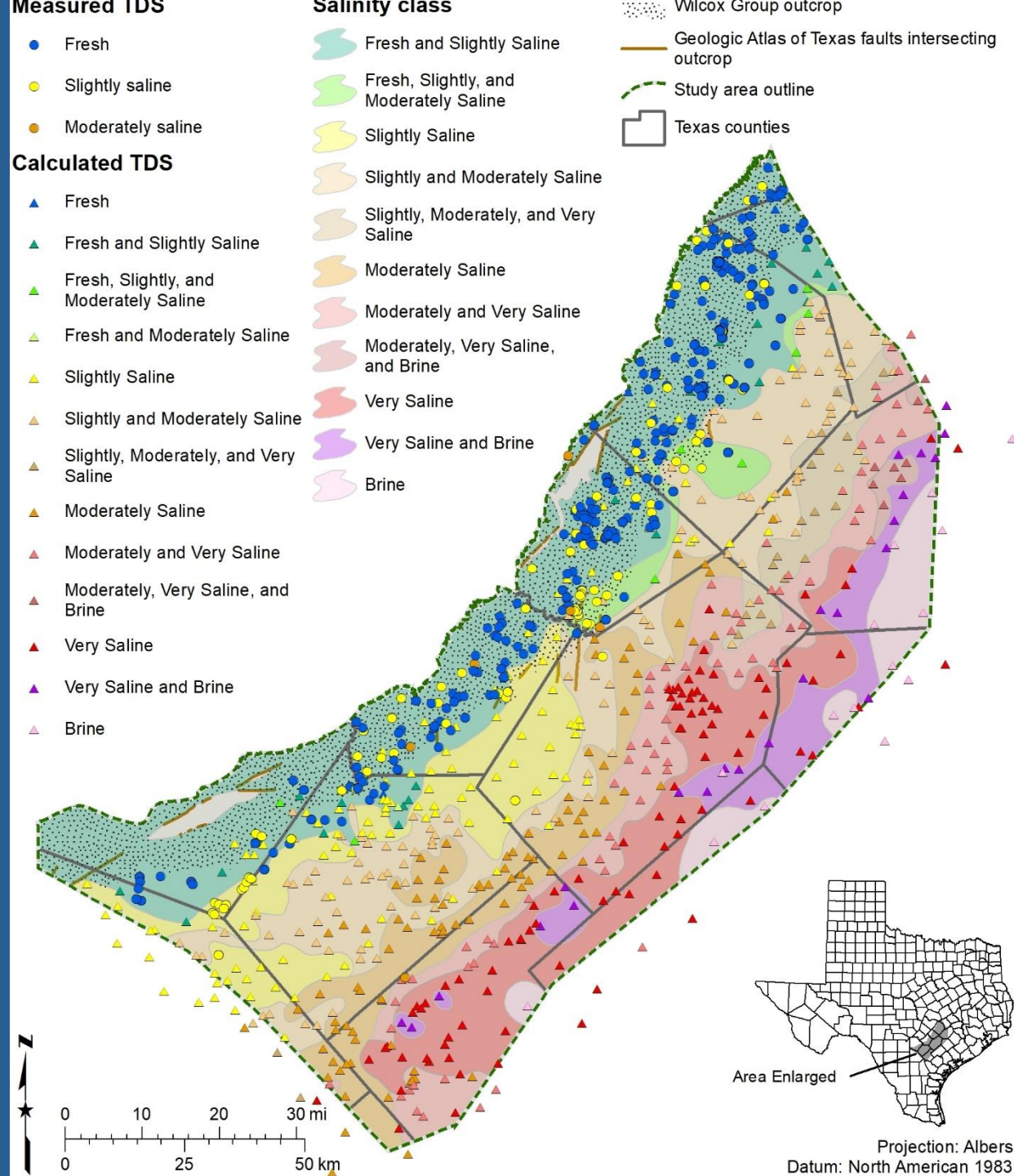
Carrizo Aquifer Salinity Classes

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



Wilcox Aquifer Salinity Classes

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



Structural Cross-section of Dip Line Y

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

NW

SE

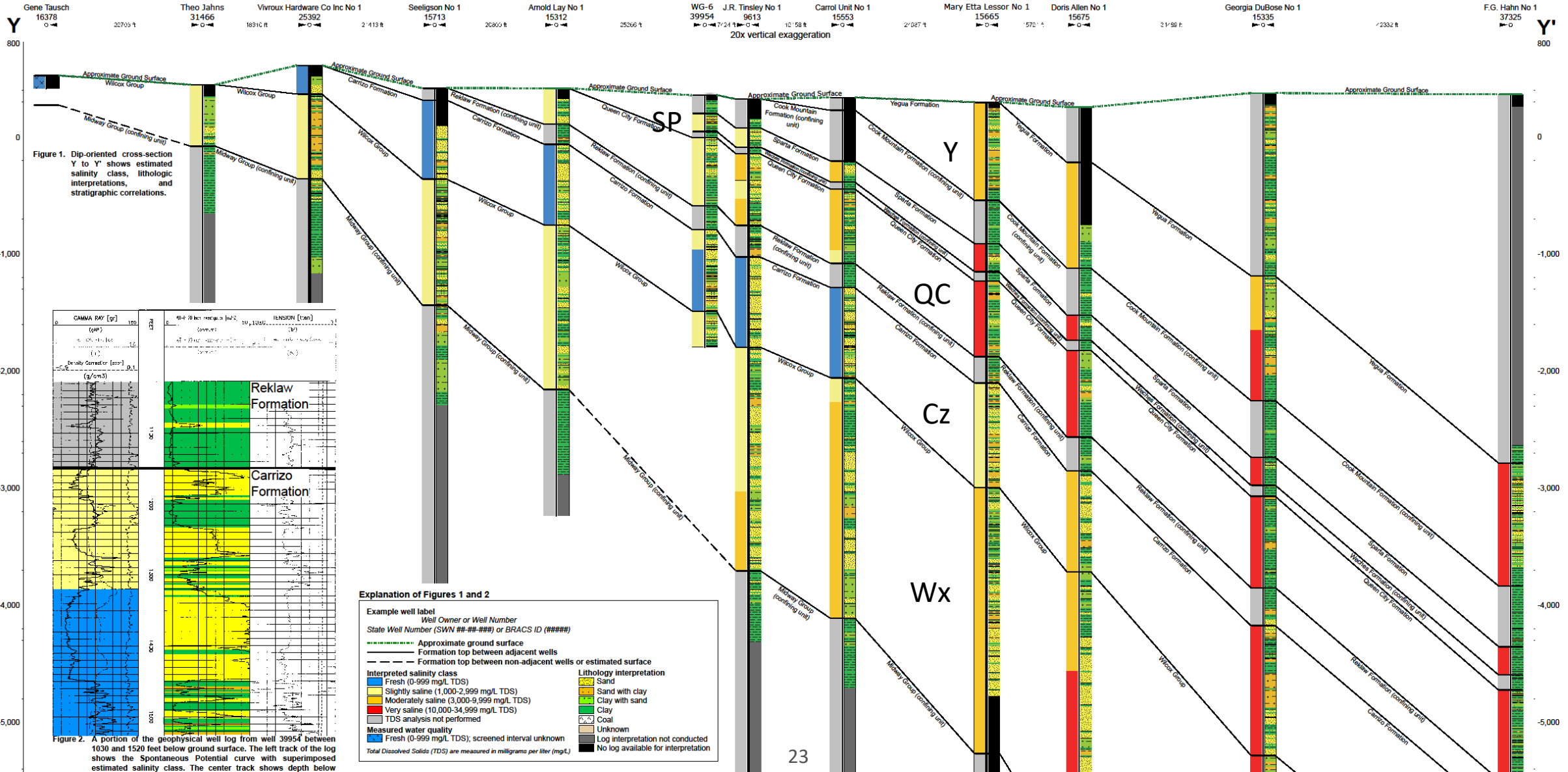


Figure 1. Dip-oriented cross-section Y to Y' shows estimated salinity class, lithologic interpretations, and stratigraphic correlations.

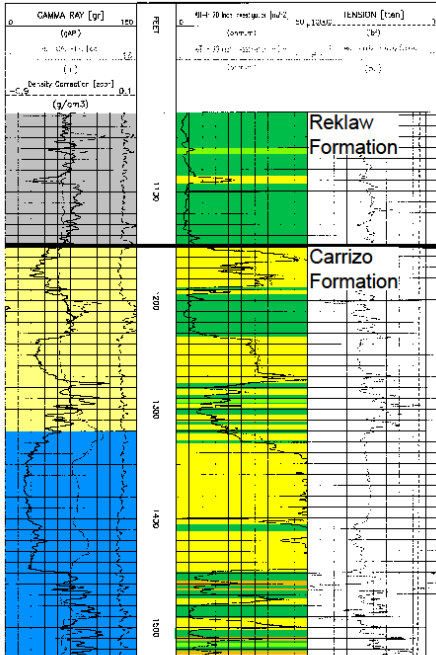


Figure 2. A portion of the geophysical well log from well 39954 between 1030 and 1520 feet below ground surface. The left track of the log shows the Spontaneous Potential curve with superimposed estimated salinity class. The center track shows depth below ground surface. The right track shows lithology interpretation.

Explanation of Figures 1 and 2

Example well label
 Well Owner or Well Number
 State Well Number (SWN ###-###-###) or BRACS ID (#####)

--- Approximate ground surface
 --- Formation top between adjacent wells
 --- Formation top between non-adjacent wells or estimated surface

Interpreted salinity class
 Fresh (0-999 mg/L TDS)
 Slightly saline (1,000-2,999 mg/L TDS)
 Moderately saline (3,000-9,999 mg/L TDS)
 Very saline (10,000-34,999 mg/L TDS)
 TDS analysis not performed

Lithology interpretation
 Sand
 Sand with clay
 Clay with sand
 Clay
 Coal
 Unknown
 Log interpretation not conducted
 No log available for interpretation

Measured water quality
 Fresh (0-999 mg/L TDS); screened interval unknown
 Log interpretation not conducted
 No log available for interpretation

Total Dissolved Solids (TDS) are measured in milligrams per liter (mg/L)

Volumes (millions of acre-feet)

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

Pure brackish = slightly saline, moderately saline, or both

Product Deliverables

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

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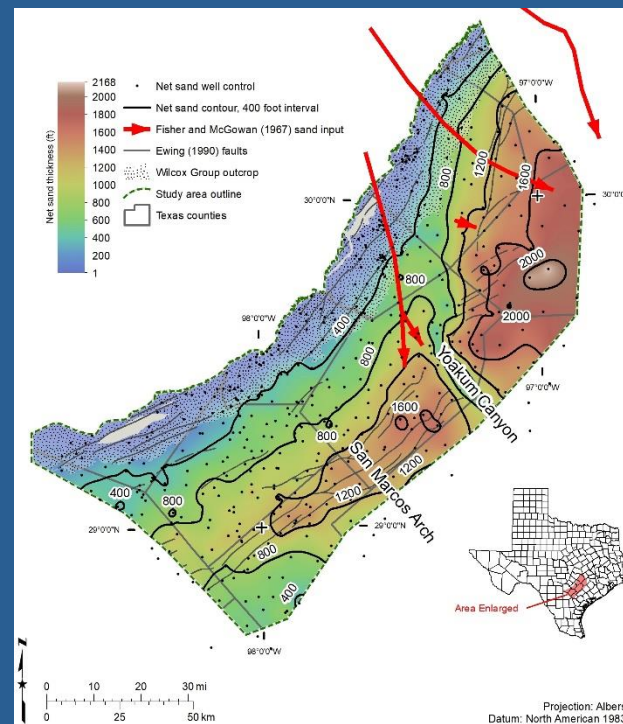
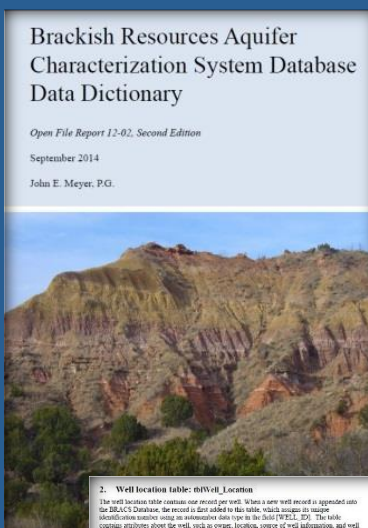
Report 385
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Peer-reviewed report

Relational database



GIS files with metadata



Well data

Field Name	Data Type	Source	Linking Table
WELL_ID	Text	1	WELL_LOC
WELL_NAME	Text	1	WELL_LOC
WELL_DEPTH	Text	1	WELL_LOC
WELL_DEPTH	Text	1	WELL_LOC
WELL_DEPTH	Text	1	WELL_LOC
WELL_DEPTH	Text	1	WELL_LOC

Field Descriptions

WELL_ID Each well record in the database is assigned a unique well ID in this table using the Microsoft Access automatic data type, which is a long integer. This is the key field in the table and serves as the primary key field linking primary BRACKIS Database table.

SOURCE_WELL_DATA Each well record is assigned the source of the well information. In some cases multiple sources exist, in this case, the source of the periodic well logs or water well driller report data, whichever, these field values are used in the linking table.

STATE_NAME The state name based on the well location. This linking table contains state and county Well Test and Adjacent areas. These field values are linked in the linking table WELLS.

COUNTY_NAME The county name based on the well location. This linking table contains state and county Well Test and Adjacent areas. These field values are linked in the linking table WELLS.

DEPTH_FOOT The total depth of the hole in feet below ground surface. This is reported on the water well driller report or header page on a geophysical well log. A value of 0/000 is used if the value is not known.

Future improvements

TDS calculations

1. Higher salinity water quality samples to calibrate our log analyses
2. Determine more accurate cementation exponents
3. Incorporate well log simulation techniques
4. Determine techniques for carbonate rock analysis

Brackish Groundwater

1. Productivity
2. Impact of development
3. Sustainability

Conclusions

- Resistivity logs allow for reproducible estimations of water quality
- Mixed/stacked water quality regions in most of the aquifers
- Millions of acre-feet of brackish groundwater
- This study provides a regional understanding of sand and salinity distribution

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BRACS Website:

<https://www.twdb.texas.gov/groundwater/bracs/index.asp>

2022 State Water Plan:

<https://www.twdb.texas.gov/waterplanning/swp/2022/index.asp>

Scan to open
Report 385 webpage



ASR study in progress

Carrizo-Wilcox Aquifer Characterization for Aquifer Storage and Recovery, Eastern Gonzales and Southern Caldwell Counties, Texas

- TWDB Aquifer Storage and Recovery study
- Supporting the Guadalupe-Blanco River Authority's (GBRA) Mid-basin Water Supply Project (MBWSP)

