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.
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Nathaniel van Oort
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Month 2020
"To provide leadership, information, education, and support for planning, financial assistance, and outreach for the conservation and responsible development of water for Texas"
“Our mission is to educate the water community on the use of nontraditional water supplies.”
Map brackish groundwater!

1. Stratigraphy
2. Lithology
3. Water Quality

http://www.twdb.texas.gov/innovativewater/bracs/studies.asp
What is brackish groundwater?

<table>
<thead>
<tr>
<th>Groundwater Salinity Classification</th>
<th>Salinity Zone Code</th>
<th>Total Dissolved Solids (milligrams per liter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>FR</td>
<td>0 to 1,000</td>
</tr>
<tr>
<td>Slightly Saline</td>
<td>SS</td>
<td>1,000 to 3,000</td>
</tr>
<tr>
<td>Moderately Saline</td>
<td>MS</td>
<td>3,000 to 10,000</td>
</tr>
<tr>
<td>Very Saline</td>
<td>VS</td>
<td>10,000 to 35,000</td>
</tr>
<tr>
<td>Brine</td>
<td>BR</td>
<td>Greater than 35,000</td>
</tr>
</tbody>
</table>

Seawater

Most Texas Major/Minor Aquifer Mapped Limit

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

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)

Study well control

- 8,130 wells total
  - 4,978 water wells
  - 2,941 oil and gas wells
  - 211 “other” wells
Area (Extent) X Saturated Thickness (Net Sand) X Porosity (Specific Yield) = Volume (acre-feet)
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

BRACS Study Iterative Workflow

- Export picks from the DB to GIS
- Interpolate DB points to rasters
- Correct picks in the DB
- 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 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](https://www2.twdb.texas.gov/apps/waterdatainteractive/groundwaterdataviewer)
- Data distribution biased by where wells were drilled
- Aquifer determination
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)
- \(\phi\) = 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
Top of the Queen City Formation at 903 feet below Kelly Bushing

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

<table>
<thead>
<tr>
<th>Value</th>
<th>Parameter</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>7903</td>
<td>Depth total (bottom of borehole), Dt</td>
<td>Feet below Kelly Bushing</td>
</tr>
<tr>
<td>1090</td>
<td>Depth formation, Df</td>
<td>Feet below Kelly Bushing</td>
</tr>
<tr>
<td>69</td>
<td>Temperature surface, Ts</td>
<td>Degrees Fahrenheit</td>
</tr>
<tr>
<td>201</td>
<td>Temperature bottom hole, Tbh</td>
<td>Degrees Fahrenheit</td>
</tr>
<tr>
<td>7.5</td>
<td>Deep resistivity, Ro</td>
<td>Ohm-meter</td>
</tr>
<tr>
<td>0.39</td>
<td>Porosity, Ø</td>
<td>Percent</td>
</tr>
<tr>
<td>0.56</td>
<td>ct conversion factor, ct</td>
<td>Dimensionless</td>
</tr>
<tr>
<td>1.75</td>
<td>Cementation exponent, m</td>
<td>Dimensionless</td>
</tr>
<tr>
<td>1</td>
<td>Water quality correction factor, R_wRw</td>
<td>Dimensionless</td>
</tr>
</tbody>
</table>

\[
TDS = ct \times \frac{10,000}{\phi m \times R_o \times \frac{R_wR_w}{\frac{(Tbh-Ts) \times (Df+Ts)}{Dt} + 6.77} + 6.77}}
\]

8,889 mg/L = 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)
Wilcoxon 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
Structural Cross-section of Dip Line Y

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

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

- 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: