Past and Projected Produced Water Volumes in the Permian Basin and Related Management Options

Bridget Scanlon, Robert Reedy, JP Nicot, and Qian Yang

Bureau of Economic Geology, Jackson School of Geosciences
University of Texas at Austin

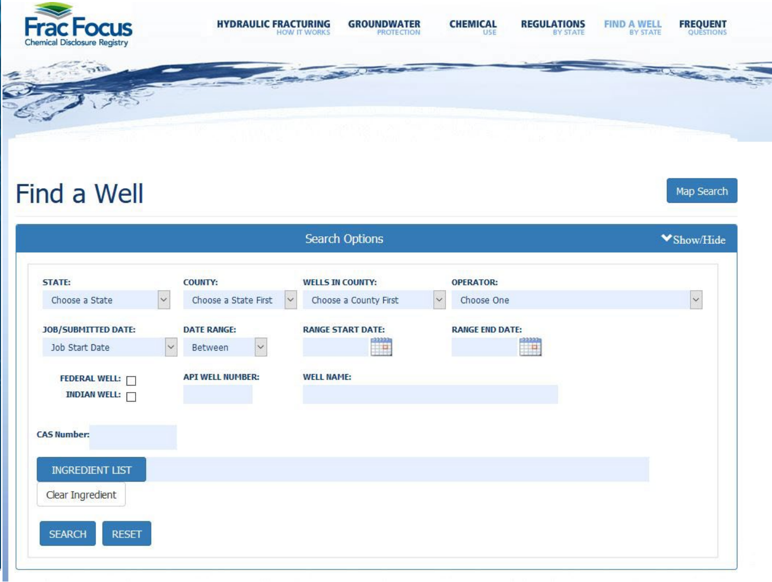
Background

- TCEQ primacy to administer the NPDES program for discharge of produced water in Texas (HB 2771)
- Senator Perry, Interim report from Senate Committee on Water and Rural Affairs, Produced Water:
  - **9.9 Billion bbl** (0.6 maf, ~4% of state water use) produced water (2017), 47% enhanced oil recovery, 54% saltwater disposal (Veil, 2020).
  - **Earthquakes** linked to subsurface disposal.
  - **State Water Plan**: 400,000 af/yr deficit (2070), Region F considering treated PW as a water source.
  - Transportation to and from treatment facilities and to beneficial use locations … missing infrastructure….promote **aquifer storage and recovery**
  - Data gaps: supply, predictability, and condition of PW
  - **TWDB BRACS** program: salt-water disposal could impact brackish groundwater resources (15 mi buffer, new study reevaluating this)

New Mexico Produced Water Research Consortium

- New Mexico State University MOU with NM Environment Dept.
- Objective: fill science and technology gaps for off-field reuse of treated produced water https://nmpwrc.nmsu.edu
- Research questions:
  - What contaminants are in PW generated in NM?
  - How can PW be treated to be safe
  - What changes are needed to our state water quality standards to protect water resources and human health?
- NPDES Plus:
  - Group focuses on requirements to meet NPDES, including constituents such as NORM, BTEX, TPH and other chemicals in HF fluids

Data Sources



Development of Water Use Estimates and Projections in the Texas Mining and Oil and Gas Industries (FY2020)

UT BEG Project

Project Timeline: Dec. 2020 – Mar. 2022

Funding from TWDB through USGS Water Use Data and Research Program Grant

TWBD Project Manager: Katie Dahlberg, Yun Cho

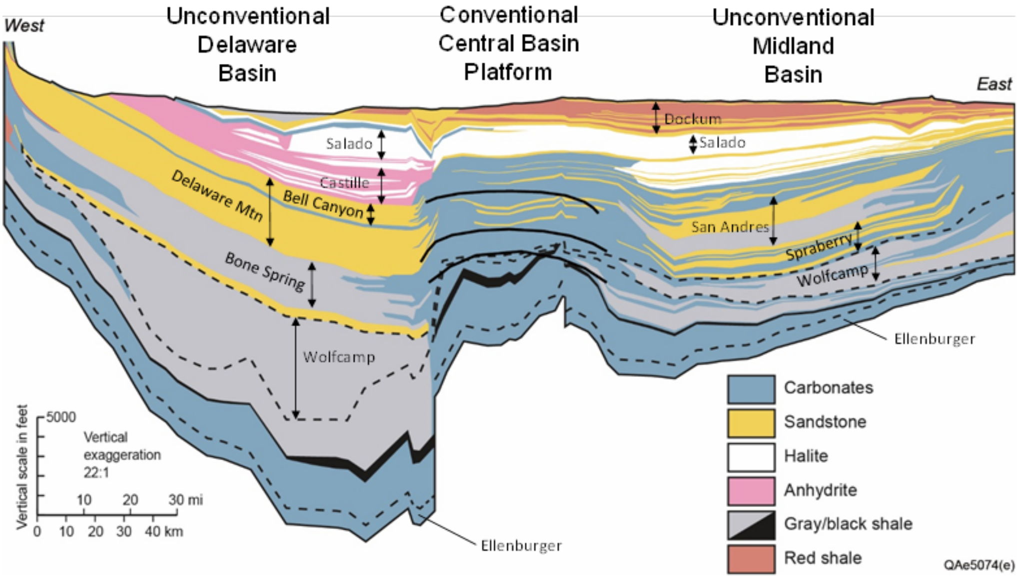
Oil and Gas

- Task 1. Quantify current and historical water use for **hydraulic fracturing and produced water** volumes
- Task 2. Identify the **sources of water** for hydraulic fracturing
- Task 3. Develop **projections** of future water demand for hydraulic fracturing for oil & gas (2030–2080)

Permian Basin
Basic Questions

1. Produced water
   - **How much** produced water is available for reuse?
   - How does produced water availability compare with **water deficits** (State Water Plan, 2070)
   - What is the **quality** of the produced water?
2. Induced seismicity issues
3. Alternative management strategies:
   - Reuse for hydraulic fracturing
   - Discharge to Pecos River
   - Managed aquifer recharge/Aquifer storage and recovery

Cross Section of the Permian Basin

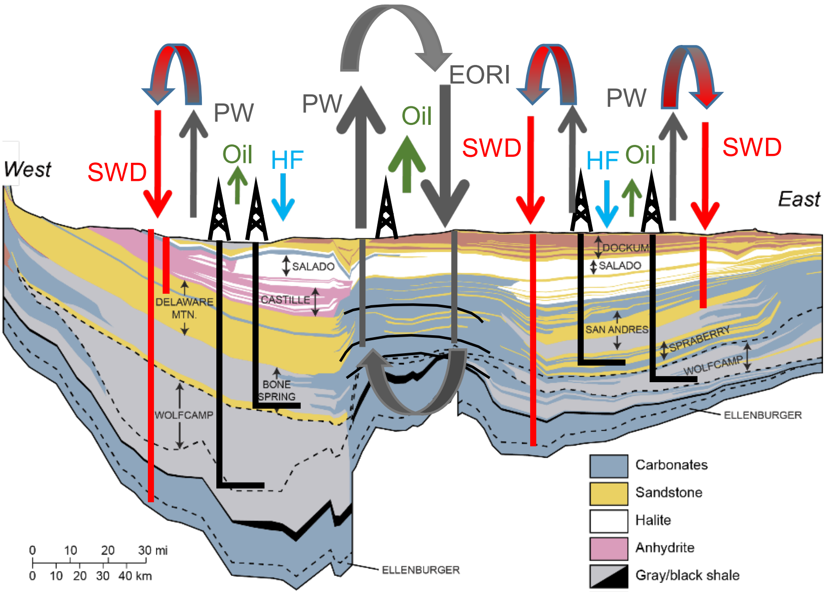


Modified from W. Texas Geol. Soc.

Permian basin

Conventional Reservoirs: PW/Oil ratio = 15

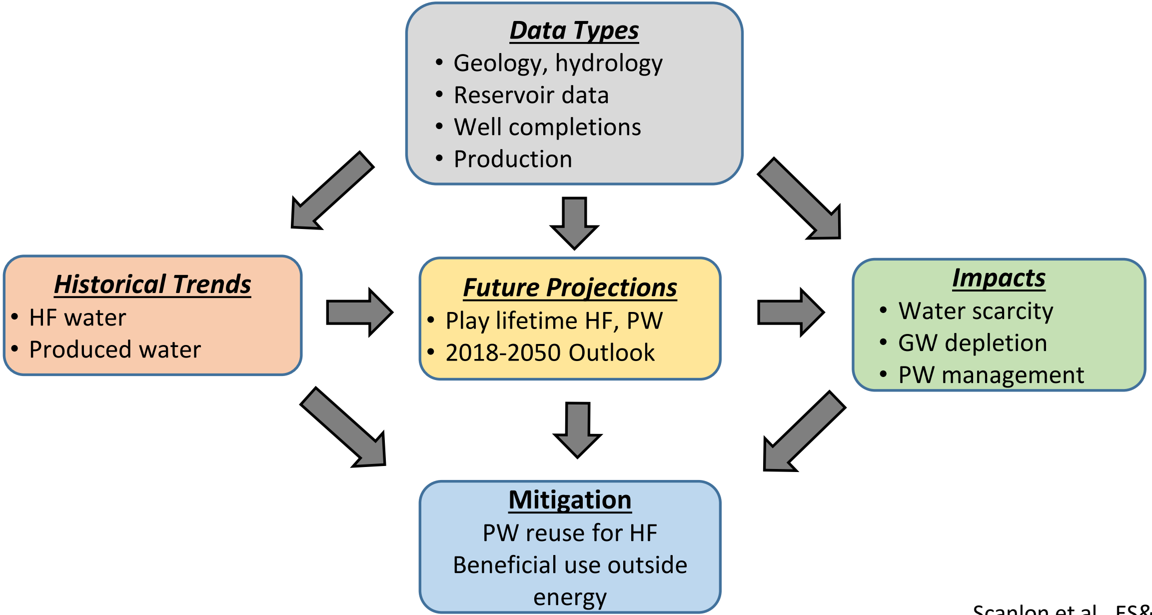
Unconventional Reservoirs: PW/Oil ratio = 3



Conventional reservoir
Big recycle loop

Scanlon et al., ES&T, 2017

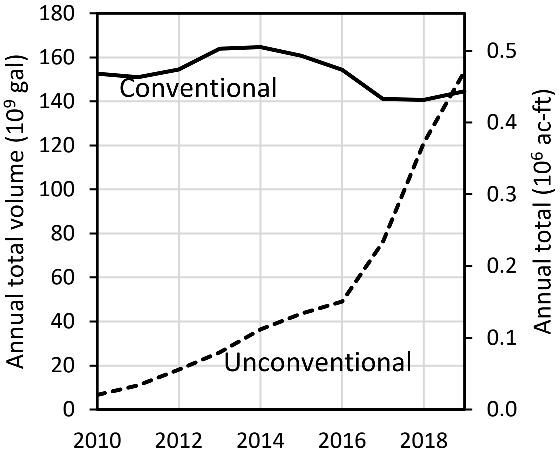
Work Flow



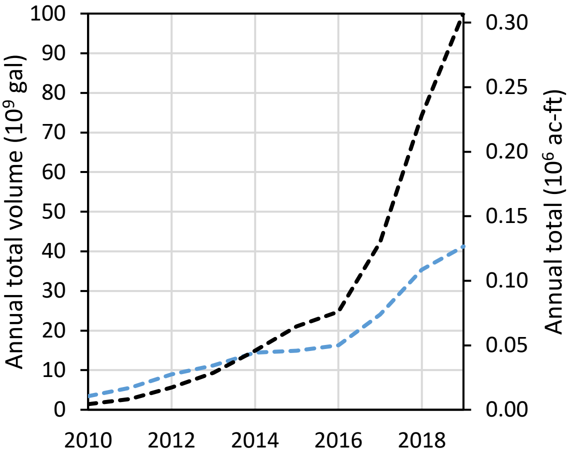
Scanlon et al., ES&T, 2020

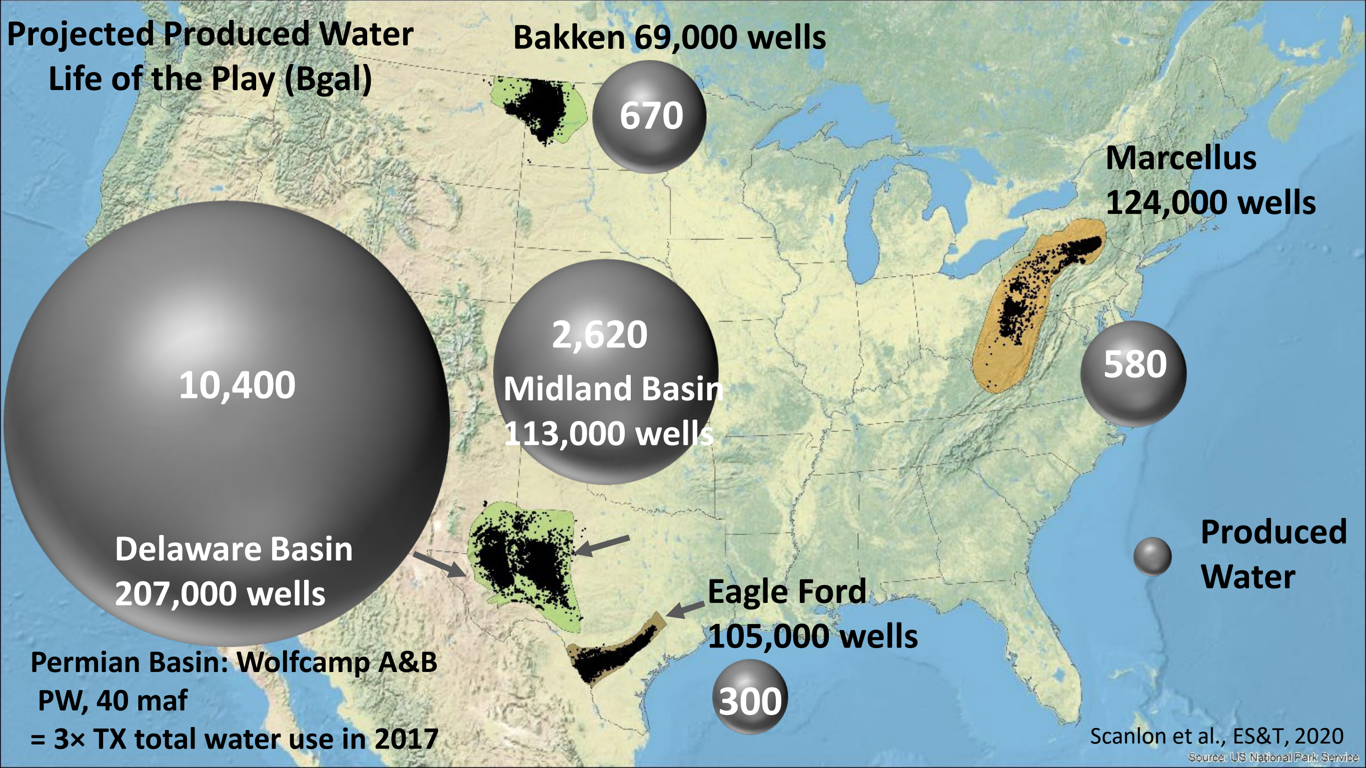
Produced Water

Permian Basin



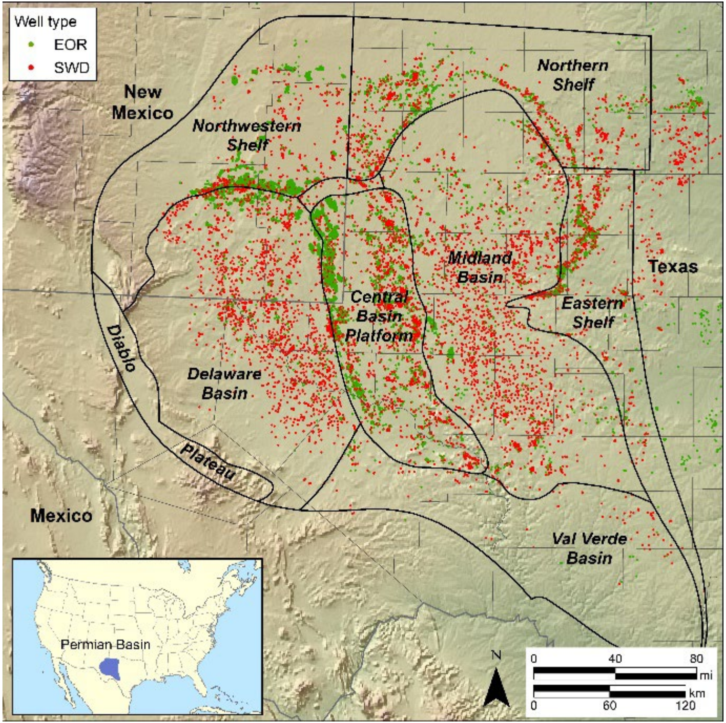
Delaware/Midland





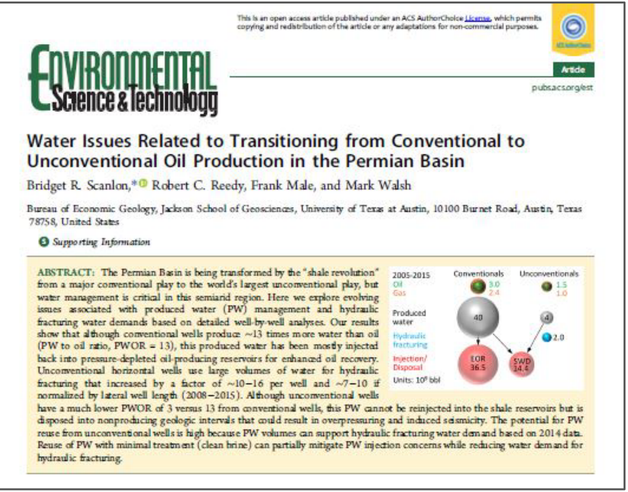
Projected Produced Water
Life of the Play (Bgal)
Bakken 69,000 wells
670
Marcellus
124,000 wells
580
10,400
2,620
Midland Basin
113,000 wells
Delaware Basin
207,000 wells
Eagle Ford
105,000 wells
300
Produced
Water
Permian Basin: Wolfcamp A&B
PW, 40 maf
= 3× TX total water use in 2017
Scanlon et al., ES&T, 2020
Source: US National Park Service

Distribution of Enhanced Oil Recovery (EOR, green) and Salt Water Dipsosal (SWD, red) Wells



EOR wells mostly along basin margins and in Central Basin Platform

SWD also in unconventional basins (Delaware and Midland basins)



Environmental Science & Technology
Article
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Water Issues Related to Transitioning from Conventional to Unconventional Oil Production in the Permian Basin

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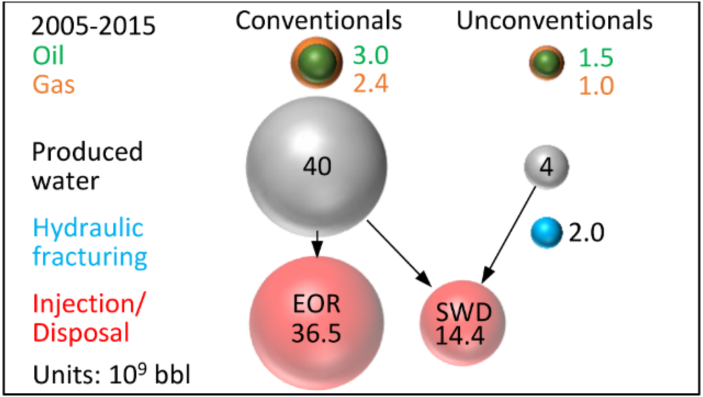
Supporting Information

ABSTRACT: The Permian Basin is being transformed by the "shale revolution" from a major conventional play to the world's largest unconventional play, but water management is critical in this semiarid region. Here we explore evolving issues associated with produced water (PW) management and hydraulic fracturing water demands based on detailed well-by-well analyses. Our results show that although conventional wells produce ~13 times more water than oil (PW to oil ratio, PWOR = 13), this produced water has been mostly injected back into pressure-depleted oil-producing reservoirs for enhanced oil recovery. Unconventional horizontal wells use large volumes of water for hydraulic fracturing that increased by a factor of ~10−16 per well and ~7−10 if normalized by lateral well length (2008−2015). Although unconventional wells have a much lower PWOR of 3 versus 13 from conventional wells, this PW cannot be reinjected into the shale reservoirs but is disposed into nonproducing geologic intervals that could result in overpressuring and induced seismicity. The potential for PW reuse from unconventional wells is high because PW volumes can support hydraulic fracturing water demand based on 2014 data. Reuse of PW with minimal treatment (clean brine) can partially mitigate PW injection concerns while reducing water demand for hydraulic fracturing.



2005 - 2015

Produced Water to Oil Ratio (PWOR)

Conventional:
40 Bbbl PW/3 Bbbl oil = 13 PWOR
Water cut: PW/PW+Oil = 93%

Unconventional:
4 Bbbl PW/1.5 Bbbl oil = ~3 PWOR
Water cut: 73%

Scanlon et al., ES&T, 2017
https://pubs.acs.org/doi/10.1021/acs.est.7b02185

Permian Basin 2019

Conventional

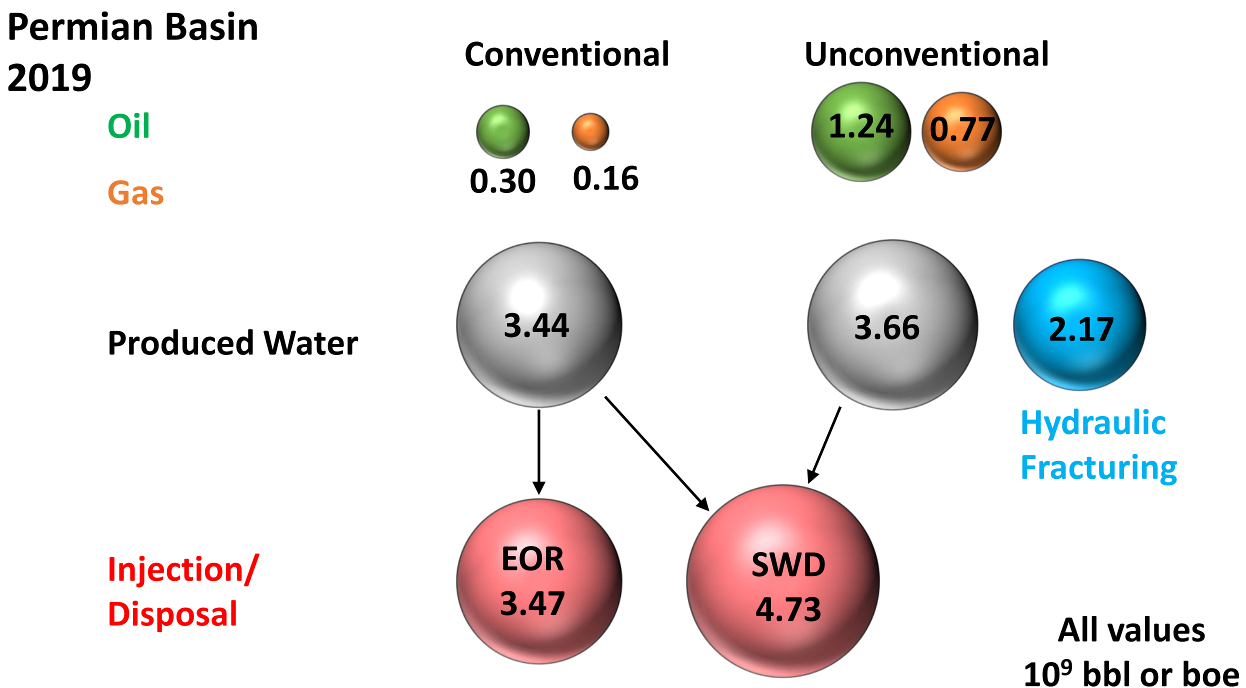
Oil

Gas

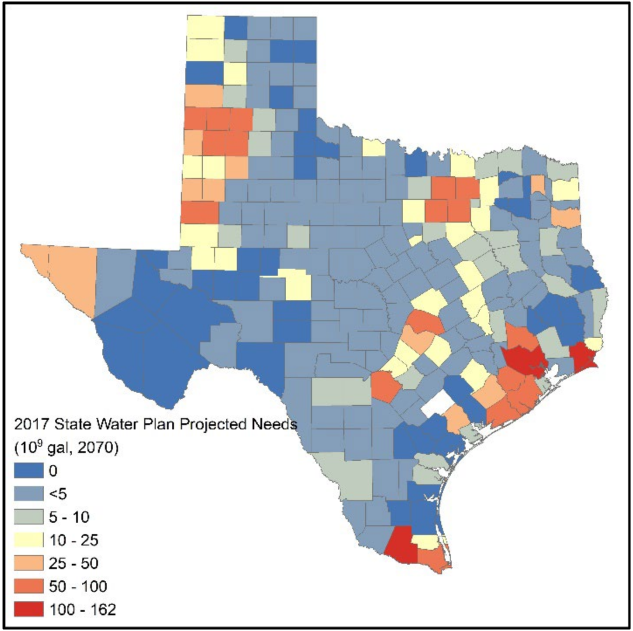
Produced Water

Injection/ Disposal

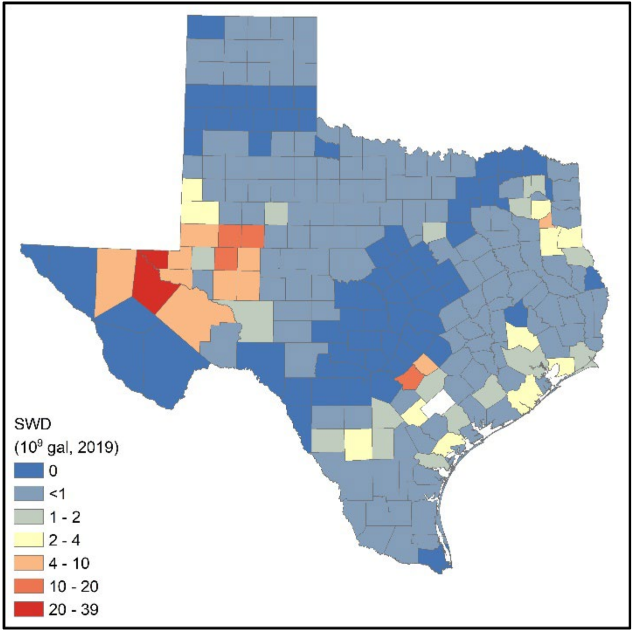
All values 10^9 bbl or boe


Permian Basin
2019
Oil
Gas
Conventional
Unconventional
0.30
0.16
1.24
0.77
Produced Water
3.44
3.66
2.17
Hydraulic
Fracturing
Injection/
Disposal
EOR
3.47
SWD
4.73
All values
10^9 bbl or boe

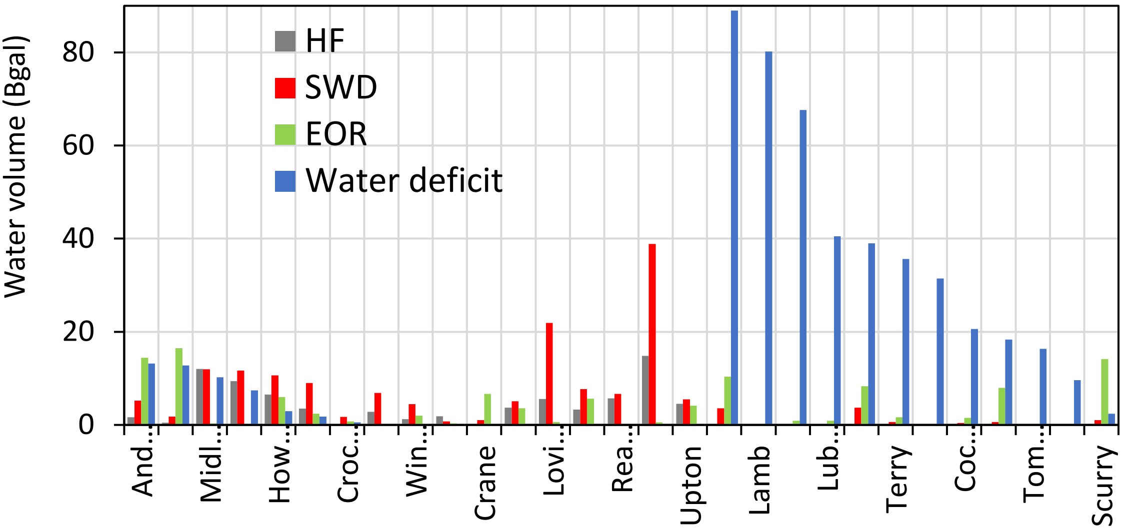
2017 State Water Plan (Needs) Bgal, 2070



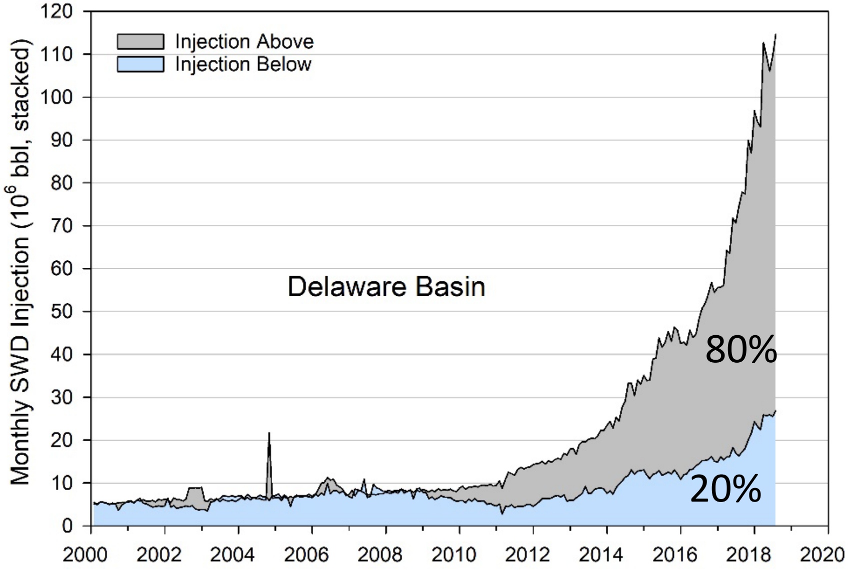
Saltwater Disposal, 2019



Comparison of Water Supply versus Demand in the Permian Basin

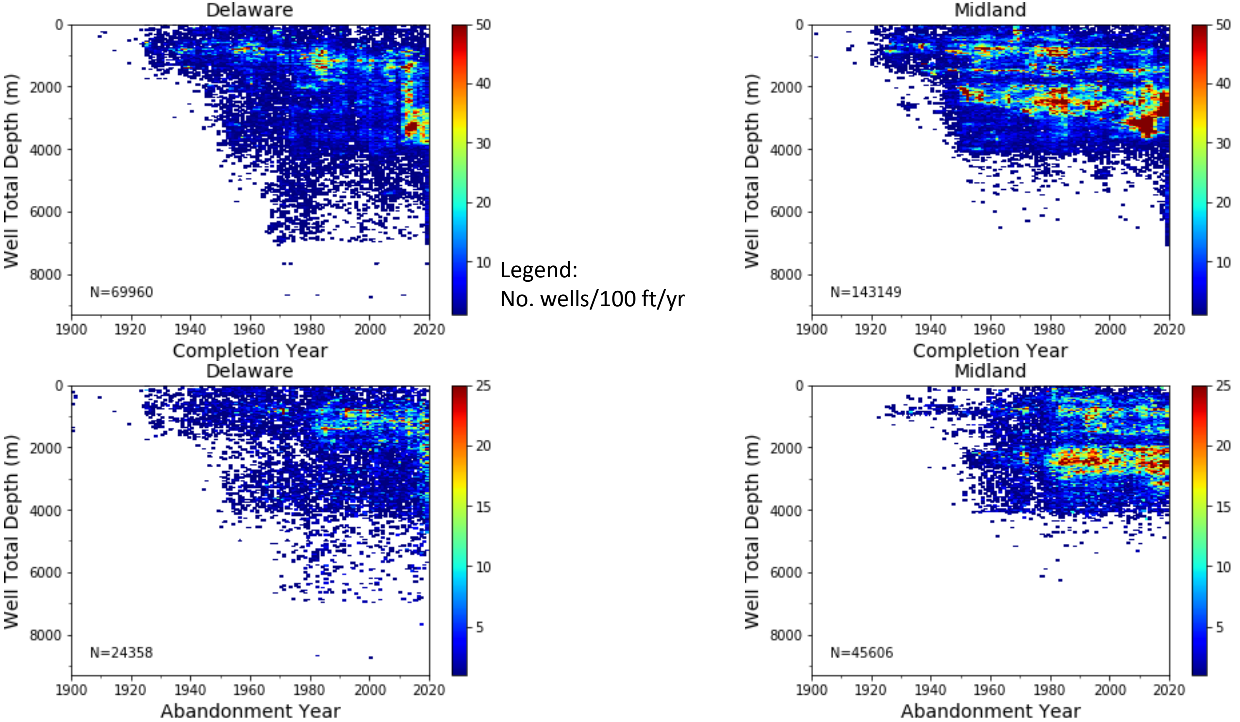


Saltwater Water Disposal, Delaware Basin
Shallow (80%, above reservoir), Deep (20%, below reservoir)

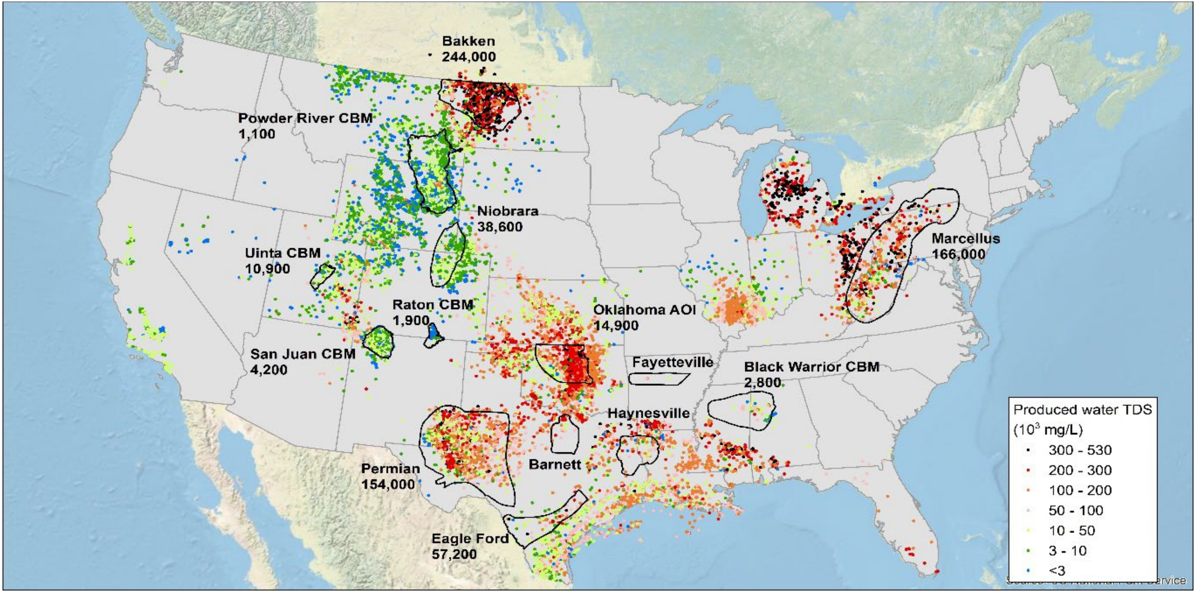


Similar trends in Midland Basin, 70% shallow, 20% deep
Predominance of shallow disposal should minimize induced seismicity but could result in GW contamination from overpressuring

Oil and Gas Wells in the Permian (Drilled and Abandoned)

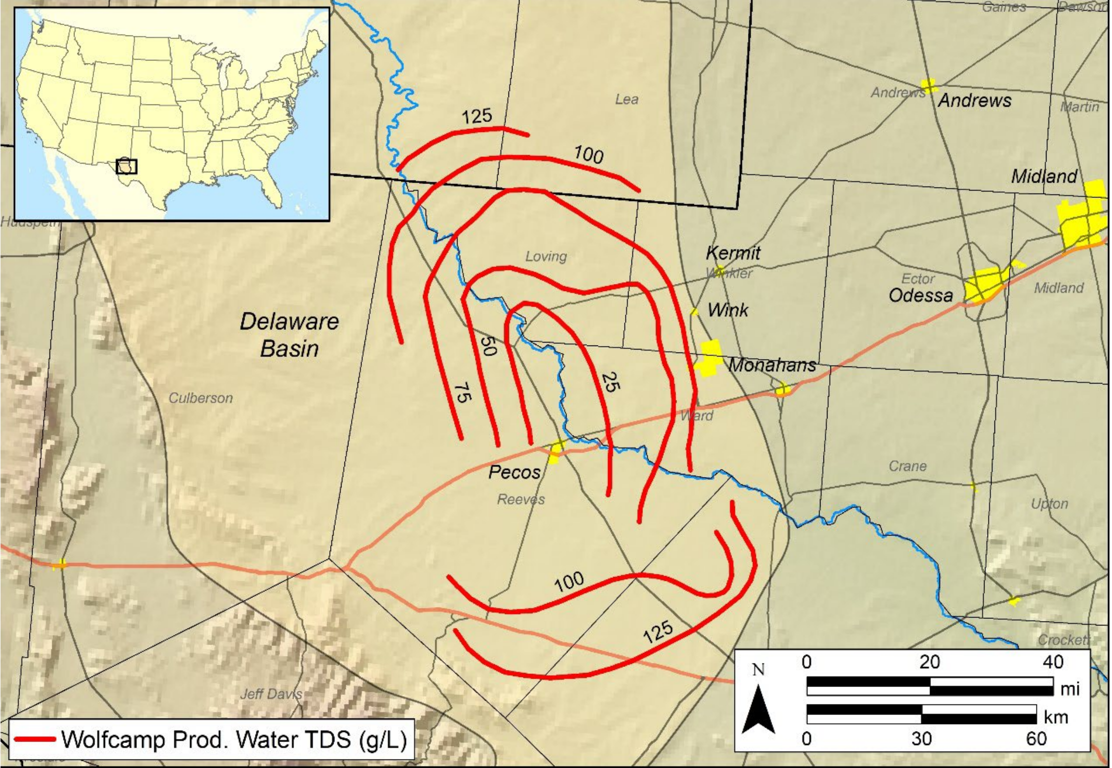


Produced Water Quality: Total Dissolved Solids



USGS: Produced Waters Database

Scanlon et al., STOTEN, 2020



Produced Water Quality

Wolfcamp Resevoir

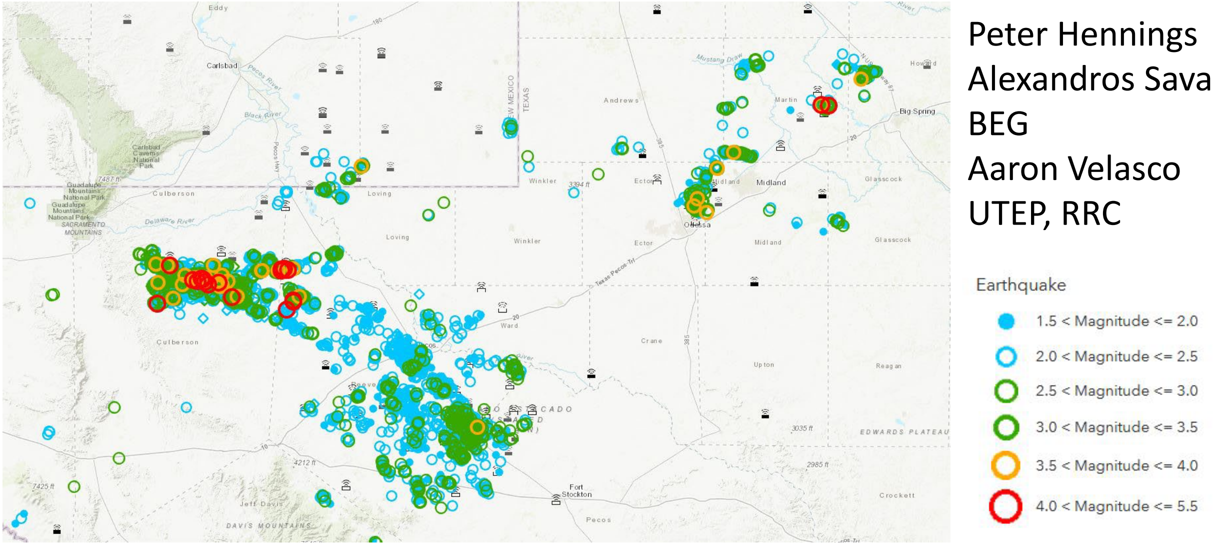
~200 points

Nicot et al., 2020

Permian Basin
Basic Questions

1. Produced water
   - Quantity, SWD, EOR
   - Comparison with water deficits (2070)
   - Quality
2. Induced seismicity issues
3. Alternative management strategies:
   - Reuse for hydraulic fracturing
   - Discharge to Pecos River
   - Managed aquifer recharge/Aquifer storage and recovery

TexNet Seismic Network
Events Jan 2017 – Apr 12, 2022



Peter Hennings
Alexandros Savaiidis
BEG
Aaron Velasco
UTEP, RRC

https://www.beg.utexas.edu/texnet-cisr/texnet/earthquake-catalog

Table of Seismic Events

EventID	Origin Date	Magnitude
texnet2022fvwu	3/25/2022	4.6
texnet2022futk	3/24/2022	4.0
texnet2022elfg	3/5/2022	4.3
texnet2022dbkm	2/13/2022	4.2
texnet2021zjsk	12/28/2021	4.6
texnet2021yope	12/16/2021	4.4
texnet2021ygfk	12/11/2021	4.0
texnet2021tiop	10/3/2021	4.0
texnet2021tbrx	9/29/2021	4.2
texnet2021sqtx	9/23/2021	4.3
texnet2021sitf	9/18/2021	4.1
texnet2021rqlj	9/8/2021	4.3
texnet2021rgbn	9/3/2021	4.3
texnet2021orfg	7/28/2021	4.3
texnet2021oalq	7/19/2021	4.0
texnet2021milw	6/25/2021	4.4
texnet2021iflj	4/27/2021	4.0
texnet2021fhjh	3/17/2021	4.5
texnet2021ctzd	2/9/2021	4.0
texnet2020zslr	12/31/2020	4.2
texnet2020vfxf	10/29/2020	4.0
texnet2020galz	3/26/2020	4.9
texnet2020fzzi	3/26/2020	4.1
texnet2020dksu	2/18/2020	4.1
texnet2019tfir	10/1/2019	4.1
texnet2019tepy	9/30/2019	4.2
texnet2018jsey	5/19/2018	4.0

Induced Seismicity Issues

- Earthquakes in the Permian Basin increased with unconventional reservoir development since ~2010
- **Delaware Basin**: earthquakes are linked to both HF and SWD activities and occur on shallow faults and deep, basement-rooted fault systems
- **Midland Basin**: new earthquake sequences on deep, basement-rooted faults that are evolving rapidly including sequences of concern near Midland and Odessa
- Stratigraphic intervals targeted for SWD are having their dynamic **storage capacity exceeded**

Permian Basin
Basic Questions

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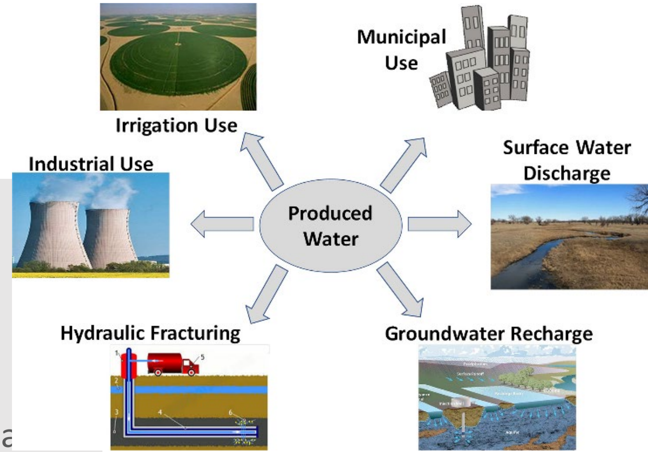
Science of The Total Environment
Available online 3 February 2020, 137085
In Press, Journal Pre-proof

Can we beneficially reuse produced water from oil and gas extraction in the U.S.?

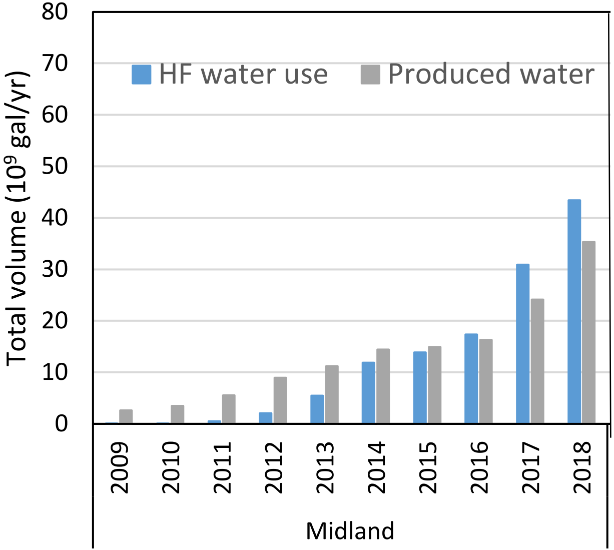
Highlights

- Irrigation demand exceeds produced water (PW) volumes from UOG by 5× in the U.S.
- **PW volumes would not substantially alleviate overall water scarcity**
- PW quality is variable with salinity up to 7 tha
  seawater
- Intensive treatment is required for PW use outside of energy
- Economics, knowledge gaps in PW quality, and regulatory limitations are major barriers to reuse of PW outside of energy



Scanlon, B. R. *et al.* Can we beneficially reuse produced water from oil and gas extraction in the U.S.? *Science of the Total Environment*
https://www.sciencedirect.com/science/article/pii/S0048969720305957

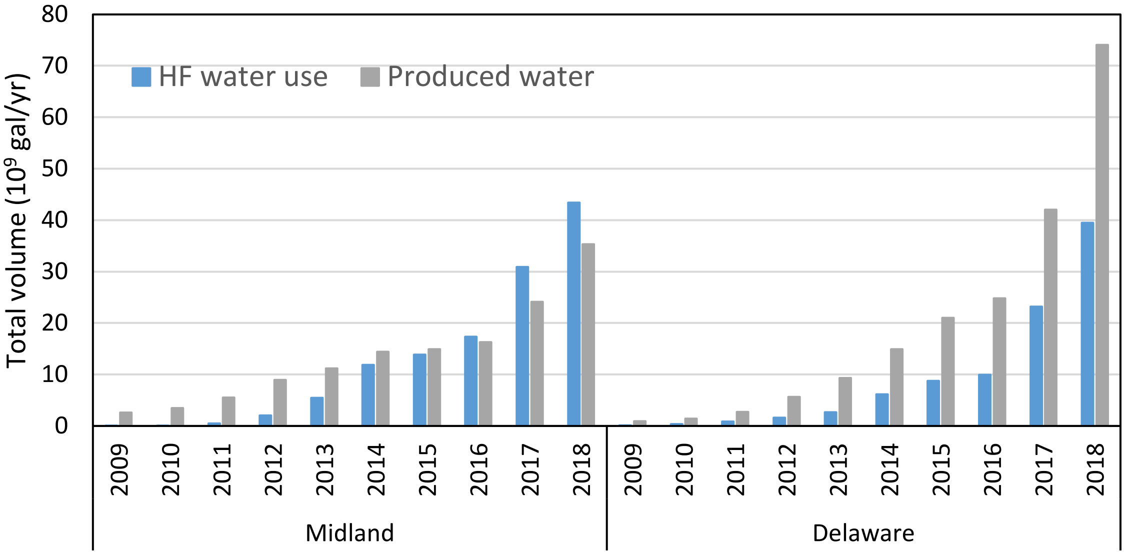
3a. Potential for Reusing Produced Water for Hydraulic Fracturing



PW and HF volumes are similar in Midland

Scanlon et al., ES&T, 2020

3a. Potential for Reusing Produced Water for Hydraulic Fracturing



PW and HF volumes are similar in Midland

PW ~ 2×HF in Delaware Basin in 2018

Excess PW

Scanlon et al., ES&T, 2020

Environmental Science & Technology
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Maximize reuse of PW for HF

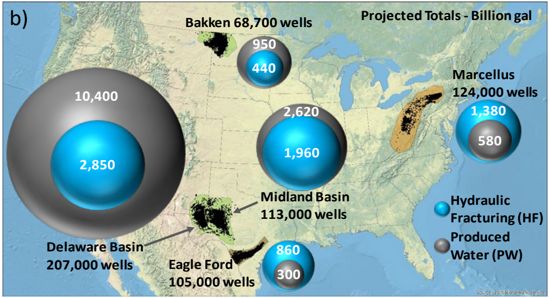
Will Water Issues Constrain Oil and Gas Production in the U.S.?

Bridget R. Scanlon*, Svetlana Ikonnikova, Qian Yang, and Robert C. Reedy

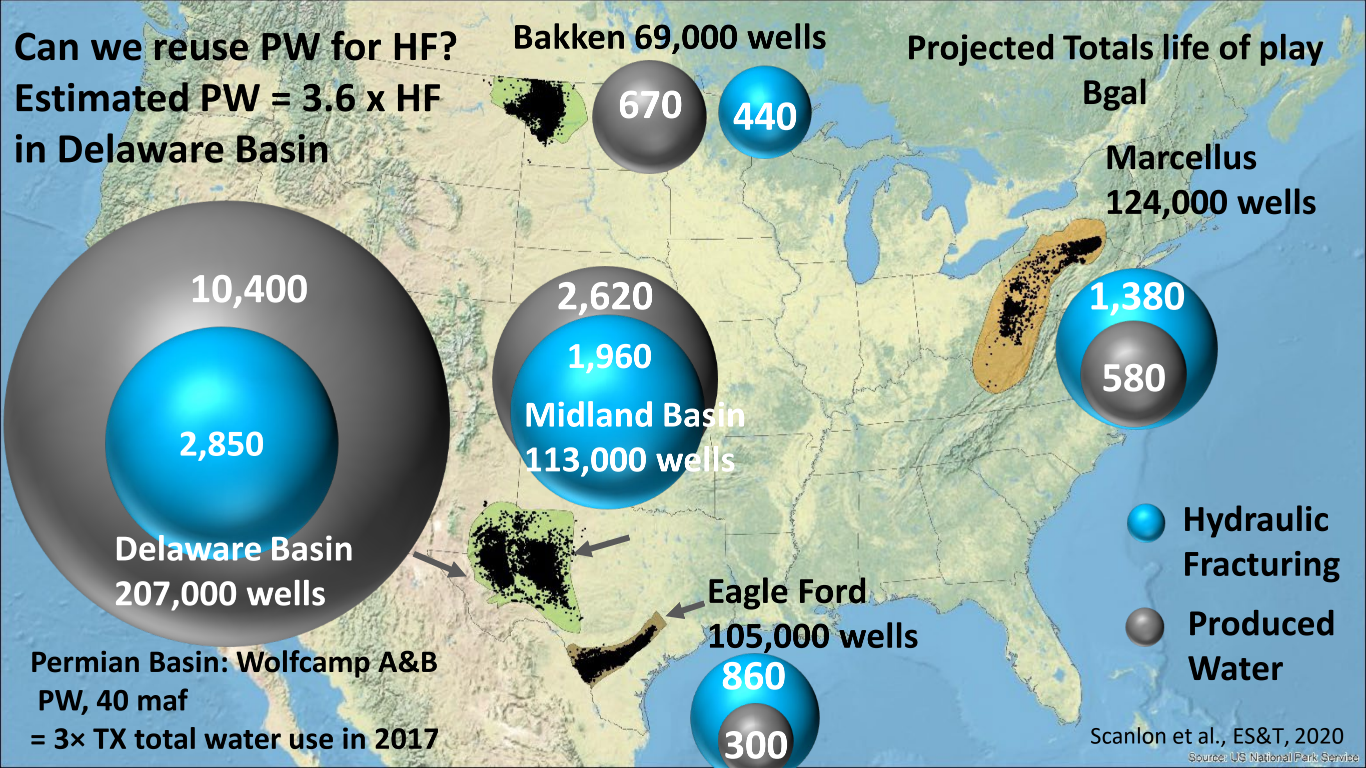
Bureau of Economic Geology, Jackson School of Geosciences, University of Texas at Austin, Austin, Texas

- Oil plays in semiarid W U.S.; gas plays in humid east
- PW from oil reservoirs >> than that from gas reservoirs

  Permian PW = 50× Marcellus PW
- **Partially mitigate water sourcing and disposal issues by reusing PW for HF**
- Projected PW volumes = ~ 4× HF water demand in the Delaware



Scanlon, B. R., Ikonnikova, S., Yang, Q. & Reedy, R. C. , Will water issues constrain oil and gas production in the U.S.? *Env. Sci. & Technol.* https://pubs.acs.org/doi/10.1021/acs.est.9b06390


Can we reuse PW for HF?
Estimated PW = 3.6 x HF
in Delaware Basin
Bakken 69,000 wells
670
440
Projected Totals life of play
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207,000 wells
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Midland Basin
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580
Hydraulic
Fracturing
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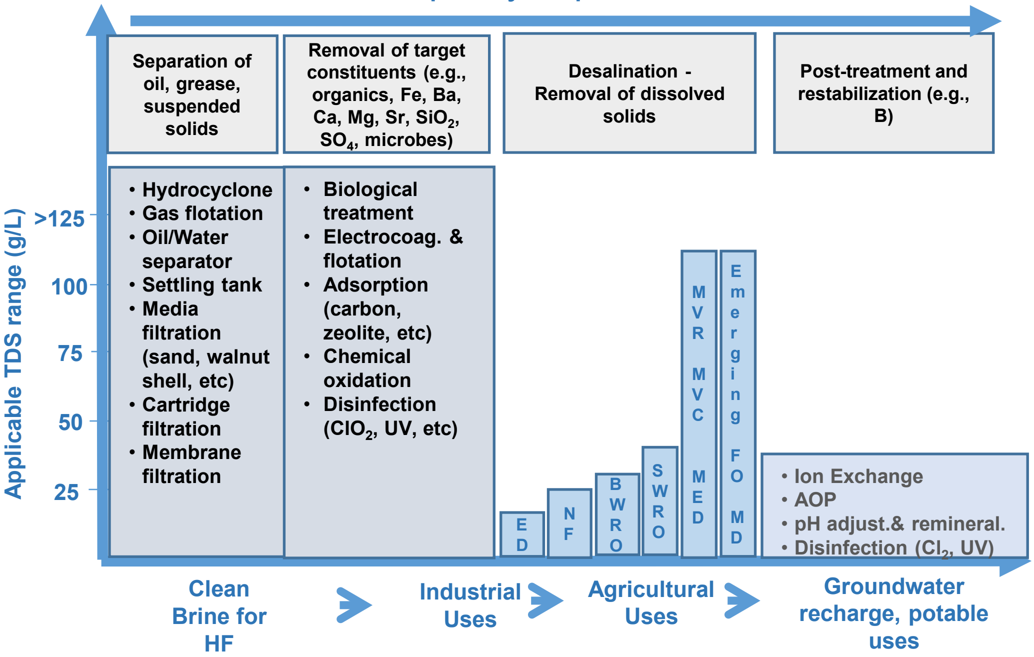
Water
Eagle Ford
105,000 wells
860
300
Permian Basin: Wolfcamp A&B
PW, 40 maf
= 3× TX total water use in 2017
Scanlon et al., ES&T, 2020
Source: US National Park Service

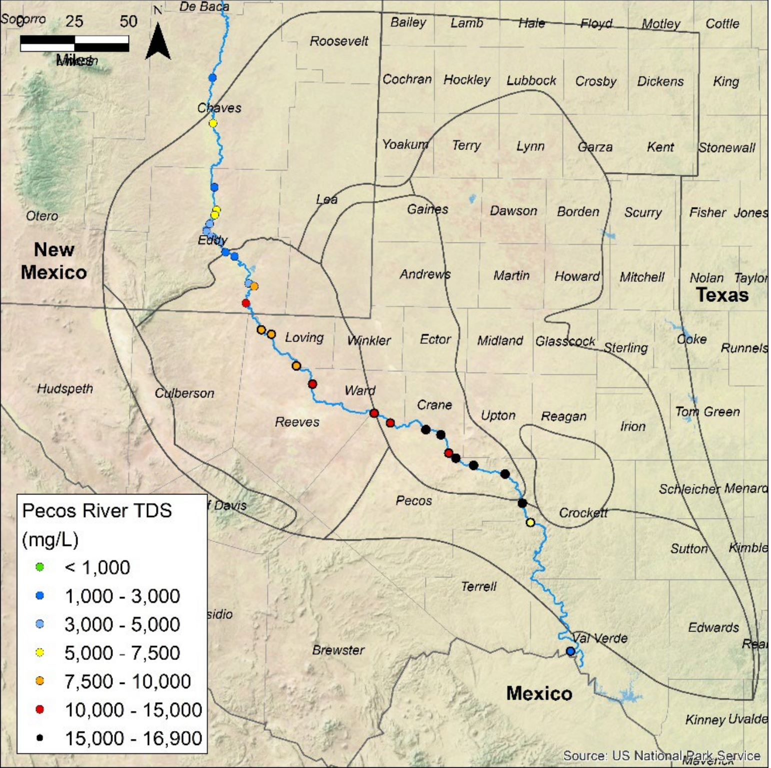
PW treatment costs increase with higher salinity in PW and product water quality improvement



Treatment and Salinity Issues

- We don’t have **standards** for produced water for use **outside of oil and gas sector**
- Produced water contains salts, complex organics (oil, grease, BTEX, PAHs, biopolymers, and humic substances)
- EDF database, 1300 chemical constituents in produced water (Danforth et al., 2020, EDF)
- Low recoveries thermal distillation, 80% concentrate, injected into saltwater disposal wells
- Crystallizer, solid concentrate, zero liquid discharge, salts marketed or disposed in landfills
- Produced water volume in Delaware Basin, 43 Bgal (160 BL)
- 160 BL × 100 g/L (10% salt) = 16 × 10^9 kg of salt = 16 million tons
- Salt density 2 kg/L; salt volume 7.7 BL
- Olympic swimming pool (50 × 25 × 2 = 2.5x10^6 L)
- Salt no porosity = 3,000 Olympic swimming pools of salt

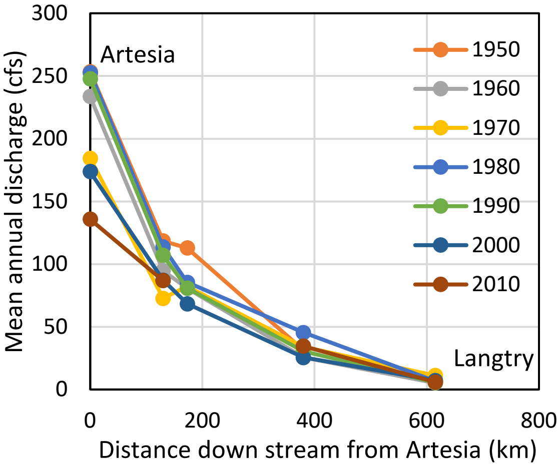
Pecos River Water Quality



Pecos River salinity increases downstream from fresh in New Mexico to 17,000 mg/L TDS in Texas

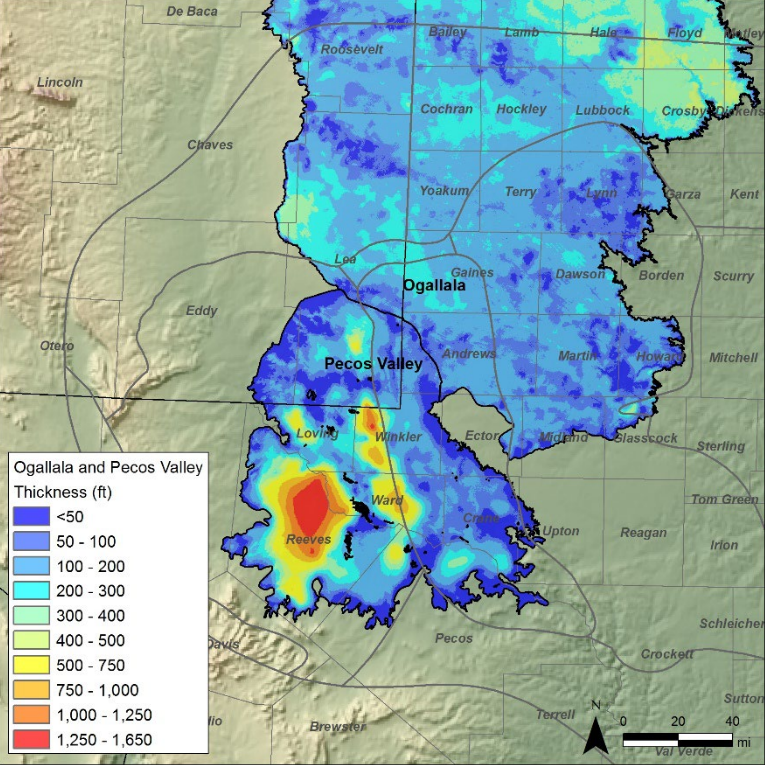
Groundwater Contribution to Pecos River Flow

increasingly important as you go toward the center of the Delaware Basin



Total streamflow decreases down stream
Artesia > Red Bluff > Orla > Girvin > Langtry

- Pecos River flow decreases downstream. Produced water would greatly exceed Pecos River flows during low flow periods.
- Little or no dilution as occurs in Pennsylvania

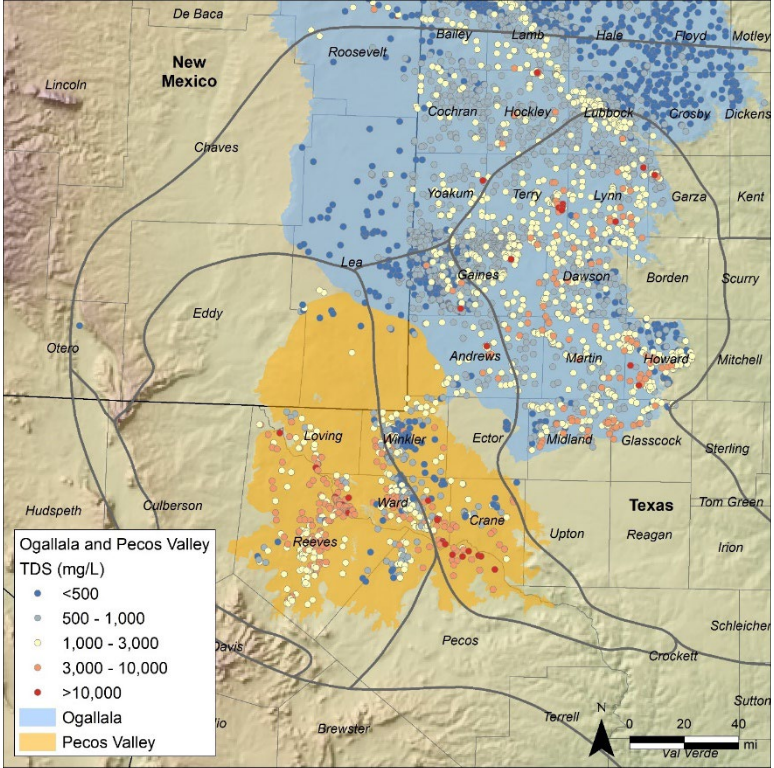


Thickness of Ogallala and Pecos Valley Aquifer

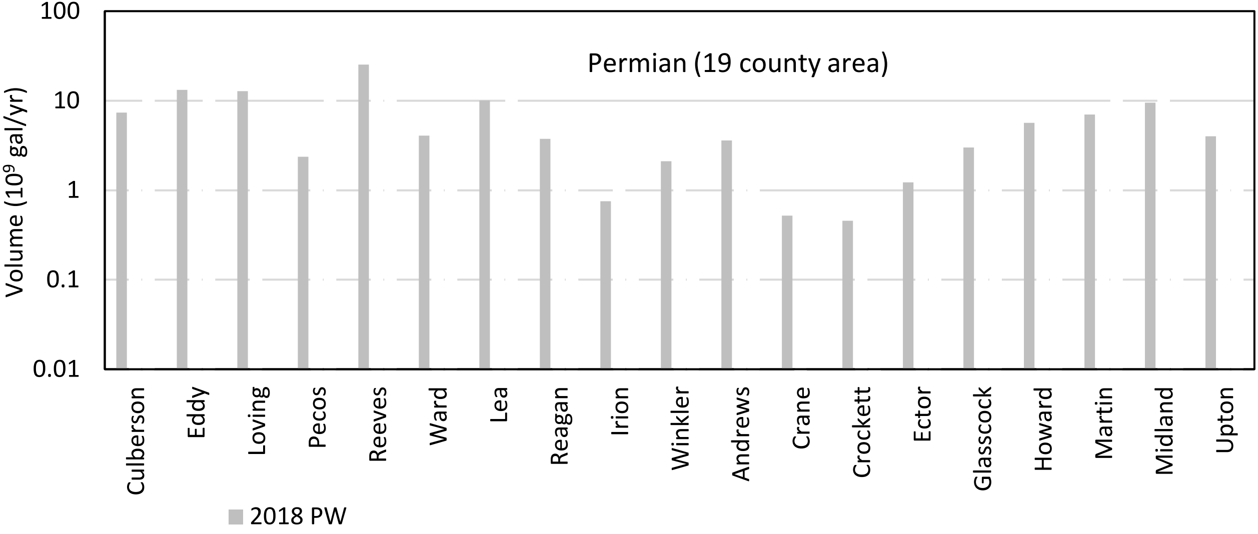
If use treated produced water to recharge the depleted aquifers, need to understand the storage space in these aquifers

TWDB GAM data

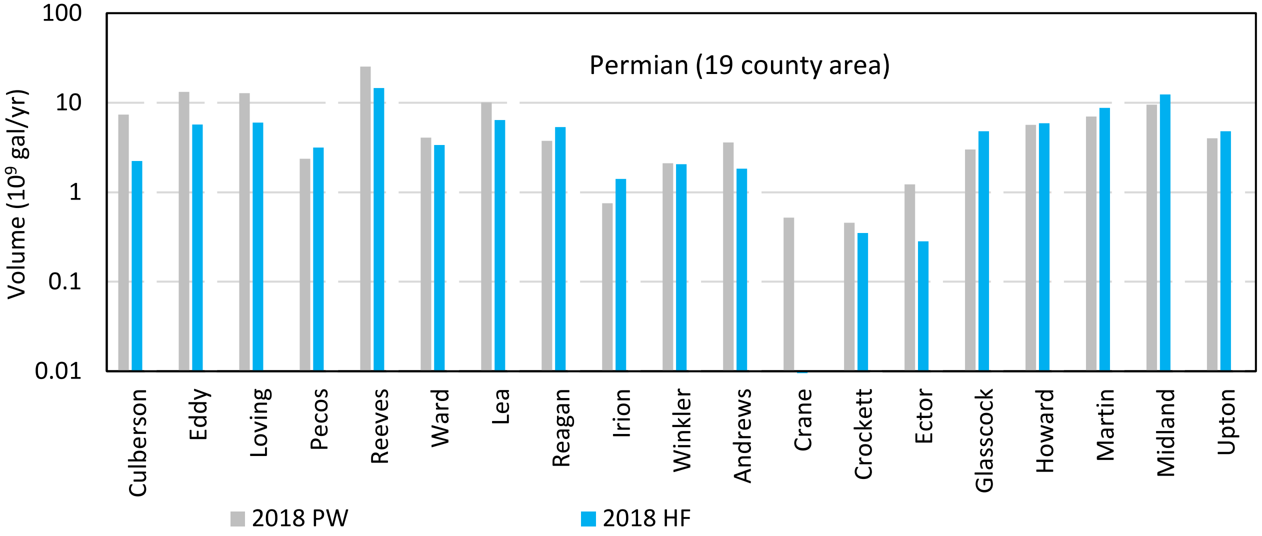
Groundwater Quality Ogallala and Pecos Valley aquifers



3b. Potential for Beneficial Use of Produced Water in Permian outside of the Oil and Gas Sector by County

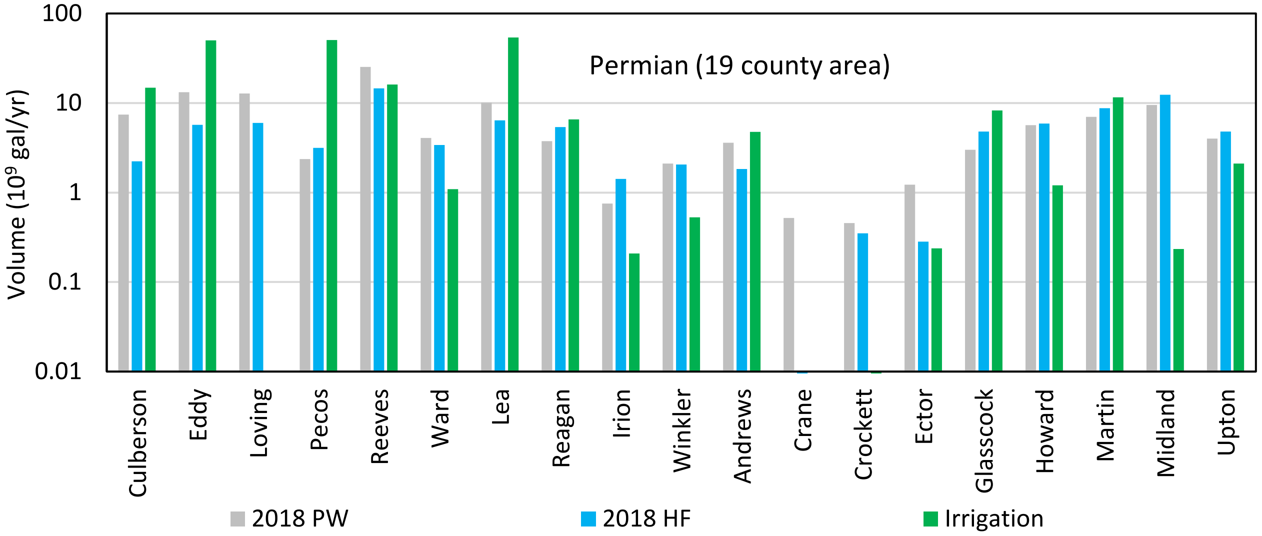


3b. Potential for Beneficial Use of Produced Water in Permian outside of the Oil and Gas Sector



If reuse PW for HF in each county, then limited volume of PW available for irrigation

3b. Potential for Beneficial Use of Produced Water in Permian outside of the Oil and Gas Sector



Counties with high levels of irrigation (Eddy, Pecos, and Lea), excess PW would represent < 10% of irrigation demand

Data Gaps

- Reporting of produced water volumes
- Extent of produced water recycling for hydraulic fracturing (FracFocus)
- Chemical makeup of Texas produced water (spatial and temporal variability)
- Standards for discharge, treatment, land application, irrigation or other fit for purpose standards for produced water chemicals of concern to ensure safe beneficial reuse outside of oil and gas sector
- Risk assessment and toxicity of treated produced water to assess reliability of treatment process and safety of the treated water for humans and the environment
- Lab or field tests to support aquifer recharge of treated produced water

Conclusions

1. Produced water quantity: ~ 50% conventional and 50% unconventional sources, EOR and SWD management
2. Produced water quality highly variable, little information
3. Produced water generally not collocated with projected highest water deficits int eh state
4. Induced seismicity linked to hydraulic fracturing and saltwater disposal
5. Optimal management approach: reuse produced water for hydraulic fracturing (clean brine, minimal treatment)
6. Reuse outside of oil and gas sector: discharge to Pecos River, regulations not established for produced water NPDES, cannot rely on dilution as in NE US
7. Reuse in other sectors outside of oil and gas, treatment requirements, risk assessment on treated produced water, optimal treatment options

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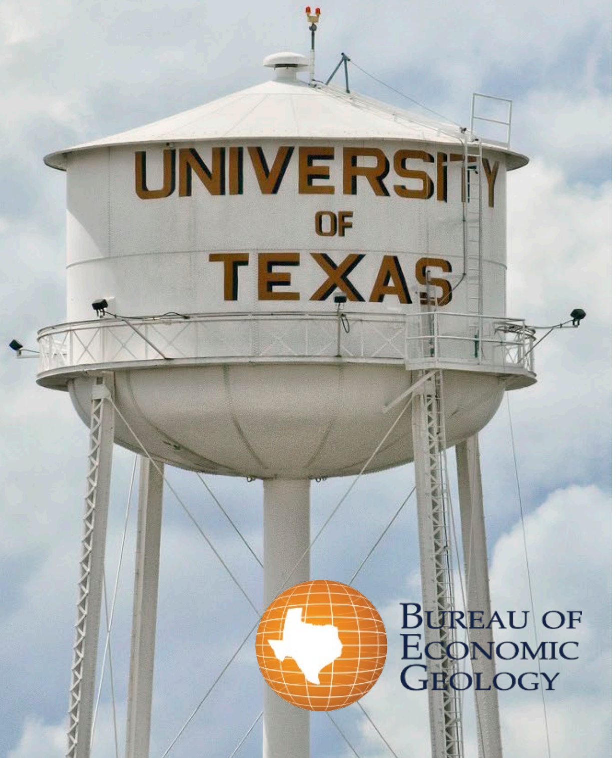

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