Produced Water Accounting and Characteristics: the Case of Hydraulic Fracturing in Texas

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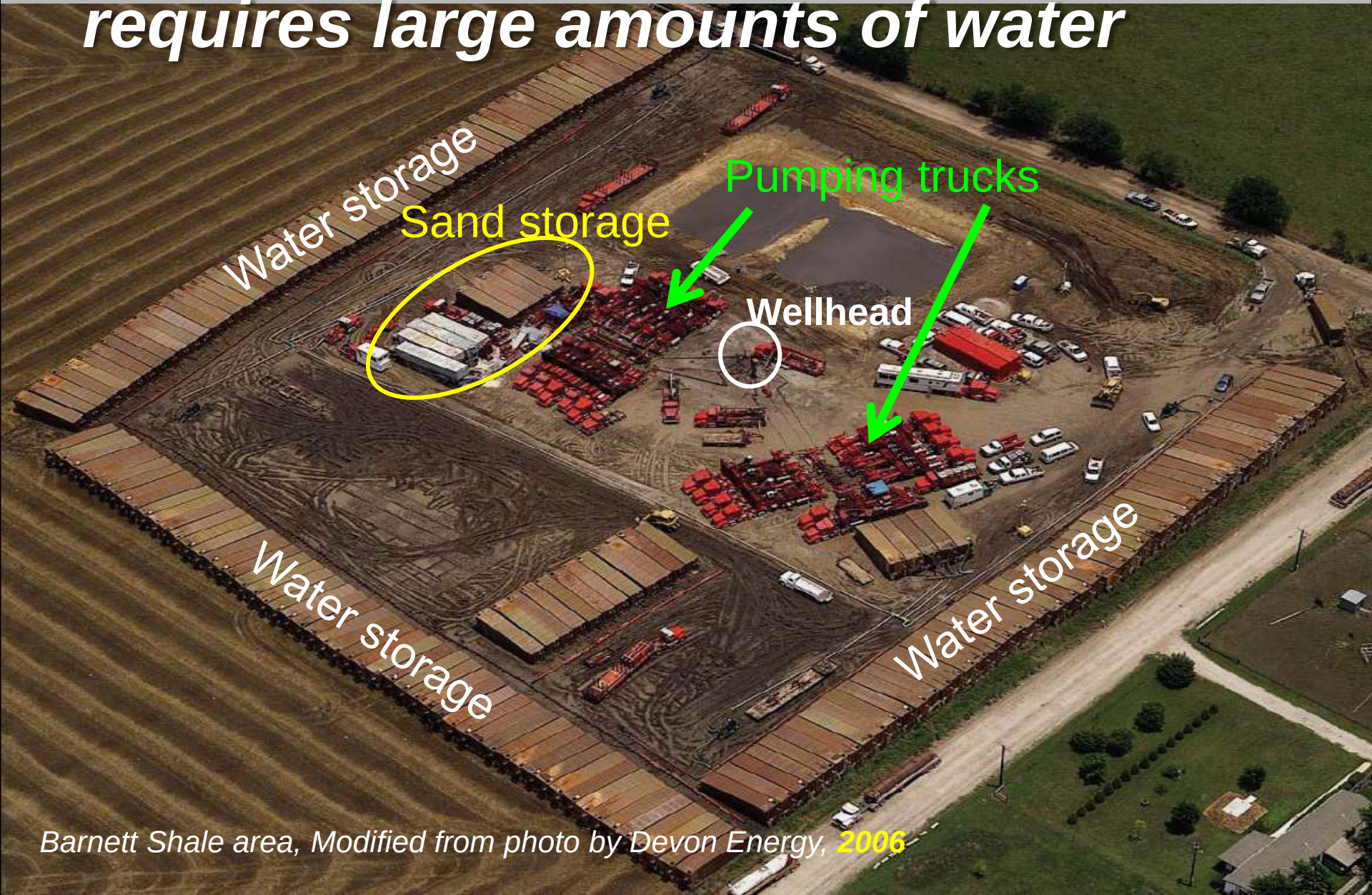
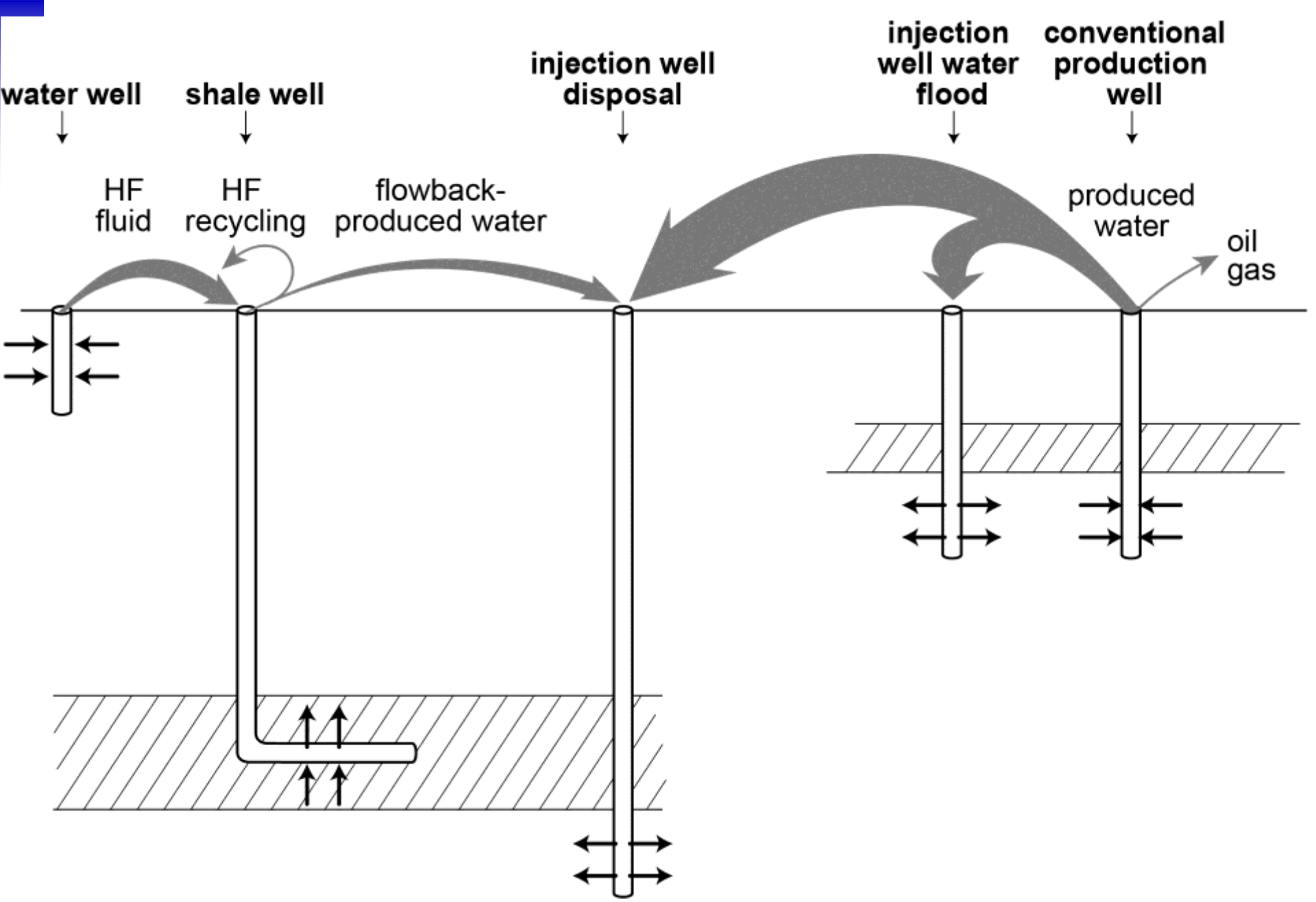
Hydraulic fracturing (HF) of a well requires large amounts of water



*Barnett Shale area, Modified from photo by Devon Energy, **2006***

but only some of it flows back to the surface

*Marcellus Shale area, photo by NETL, **2011***



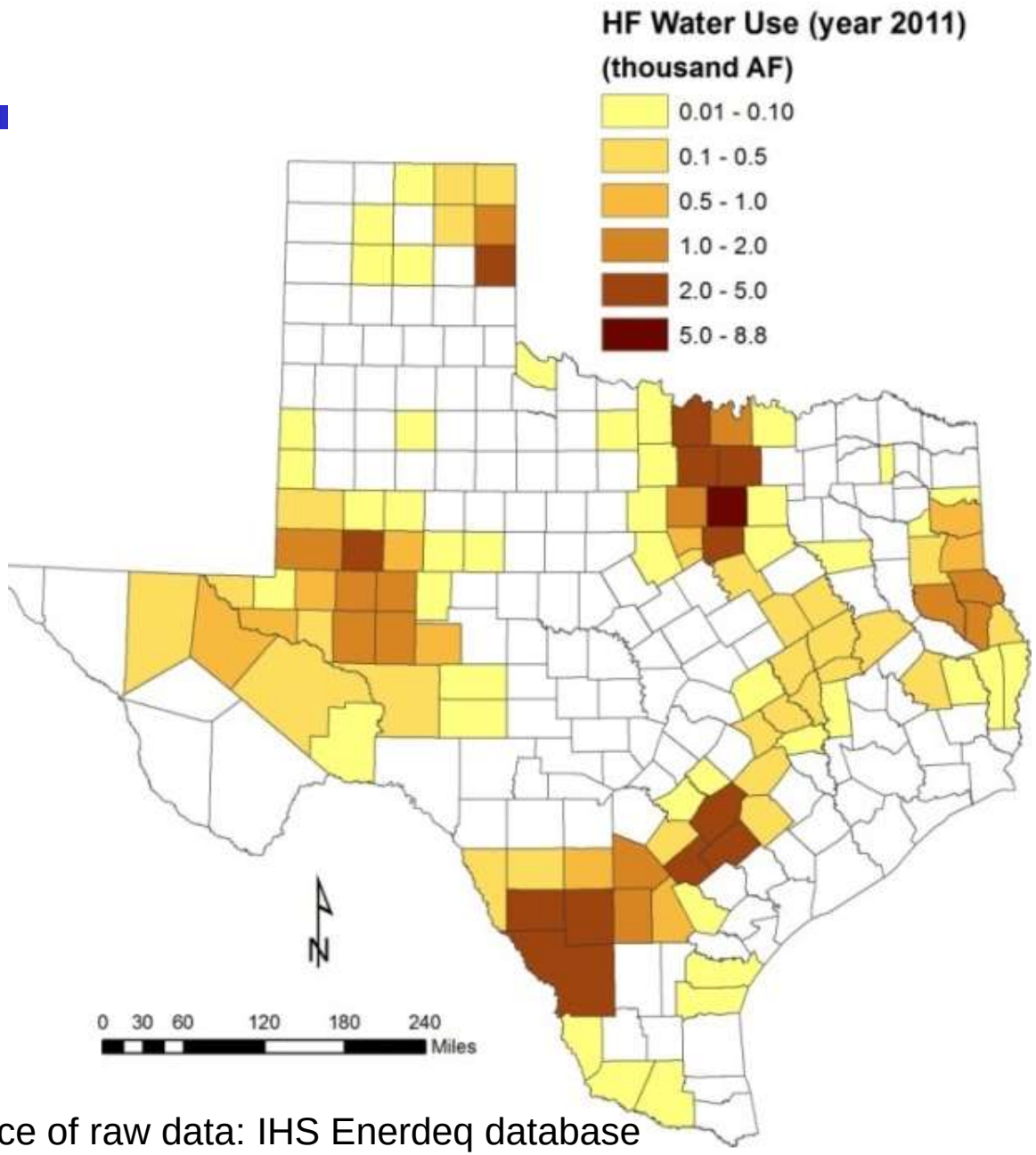
From Nicot, Scanlon, Reedy, and Costley, Source and Fate of Hydraulic Fracturing Water in the Barnett Shale: A Historical Perspective, in review ES&T

Hydraulic Fracturing Water Use

1 AF = 325,851 gallons

1 kAF = 0.775 million bbl

1kAF = 1.23×10^6 m^3



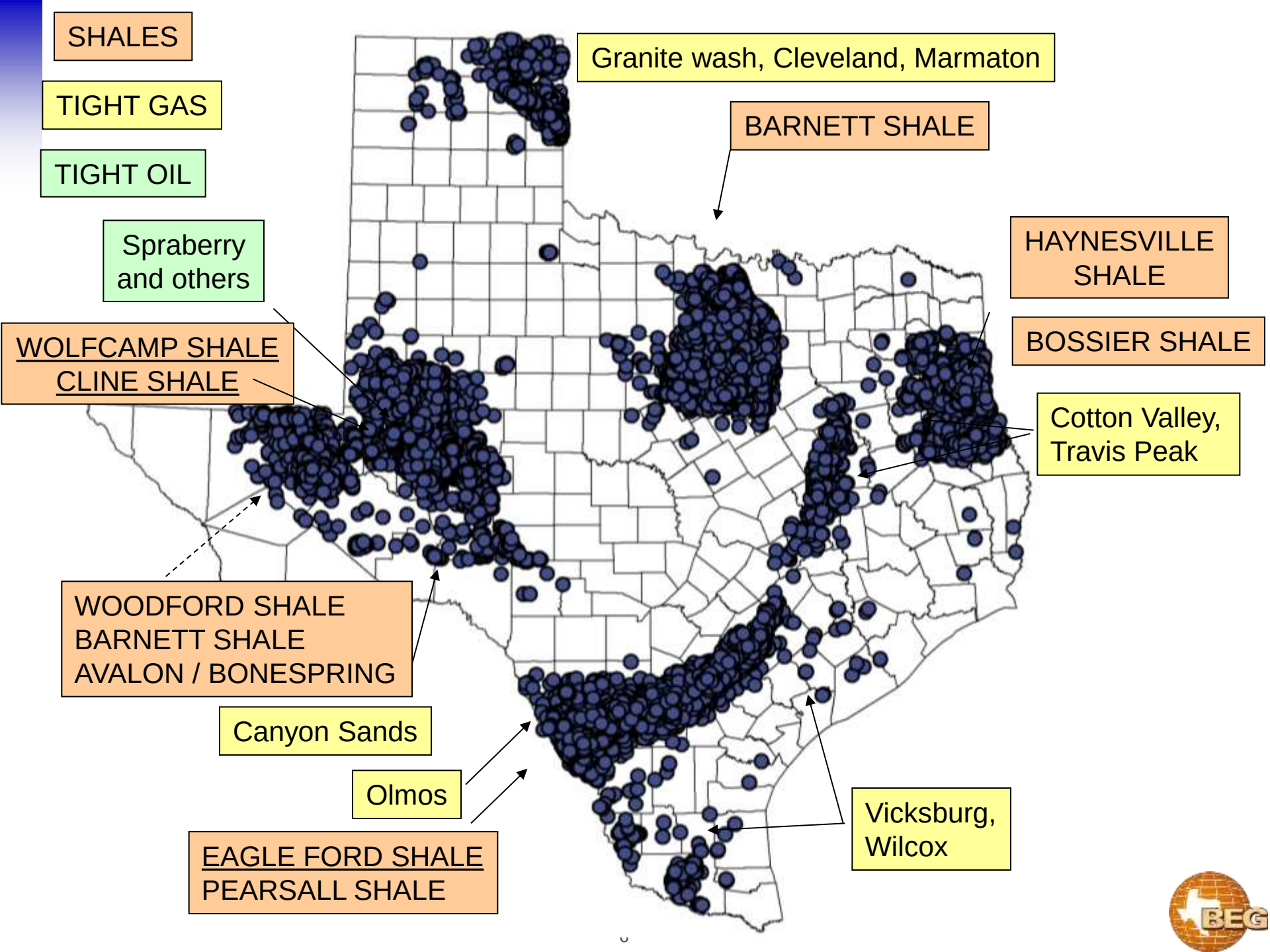
2011: 81.5 kAF

~0.5% of state water use

2013: >100 kAF

IHS, FracFocus, Skytruth

Source of raw data: IHS Enerdeq database


SHALES
TIGHT GAS
TIGHT OIL
Granite wash, Cleveland, Marmaton
BARNETT SHALE
HAYNESVILLE SHALE
Spraberry and others
BOSSIER SHALE
WOLFCAMP SHALE
CLINE SHALE
Cotton Valley, Travis Peak
WOODFORD SHALE
BARNETT SHALE
AVALON / BONESPRING
Canyon Sands
Olmos
Vicksburg, Wilcox
EAGLE FORD SHALE
PEARSALL SHALE

Water use in other states

- Large volumes, 10's of thousands of HF wells in the US, generally small % of total water use (~2013)
  - ND (Bakken): ~22 kAF (27 Mm^3)
  - PA (Marcellus): >20 kAF (>25 Mm^3)
  - CO: ~20 kAF (25 Mm^3)
  - OK: ~15 kAF (18 Mm^3)
  - TX: ~100 kAF (123 Mm^3)

*Bakken area, ND, **2013***

Vern Whitten Photography

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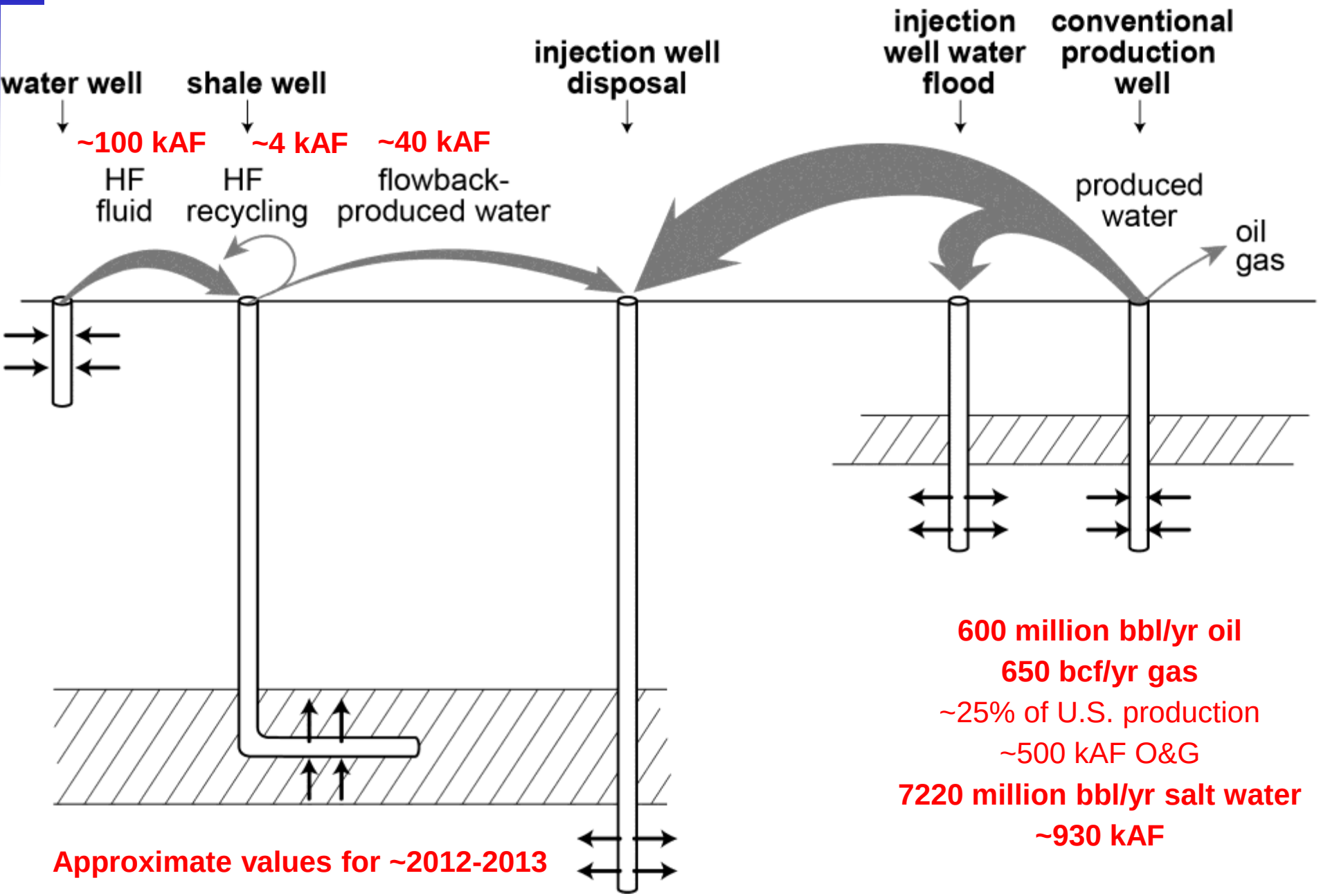

600 million bbl/yr oil

650 bcf/yr gas

~25% of U.S. production

~500 kAF O&G

7220 million bbl/yr salt water

~930 kAF

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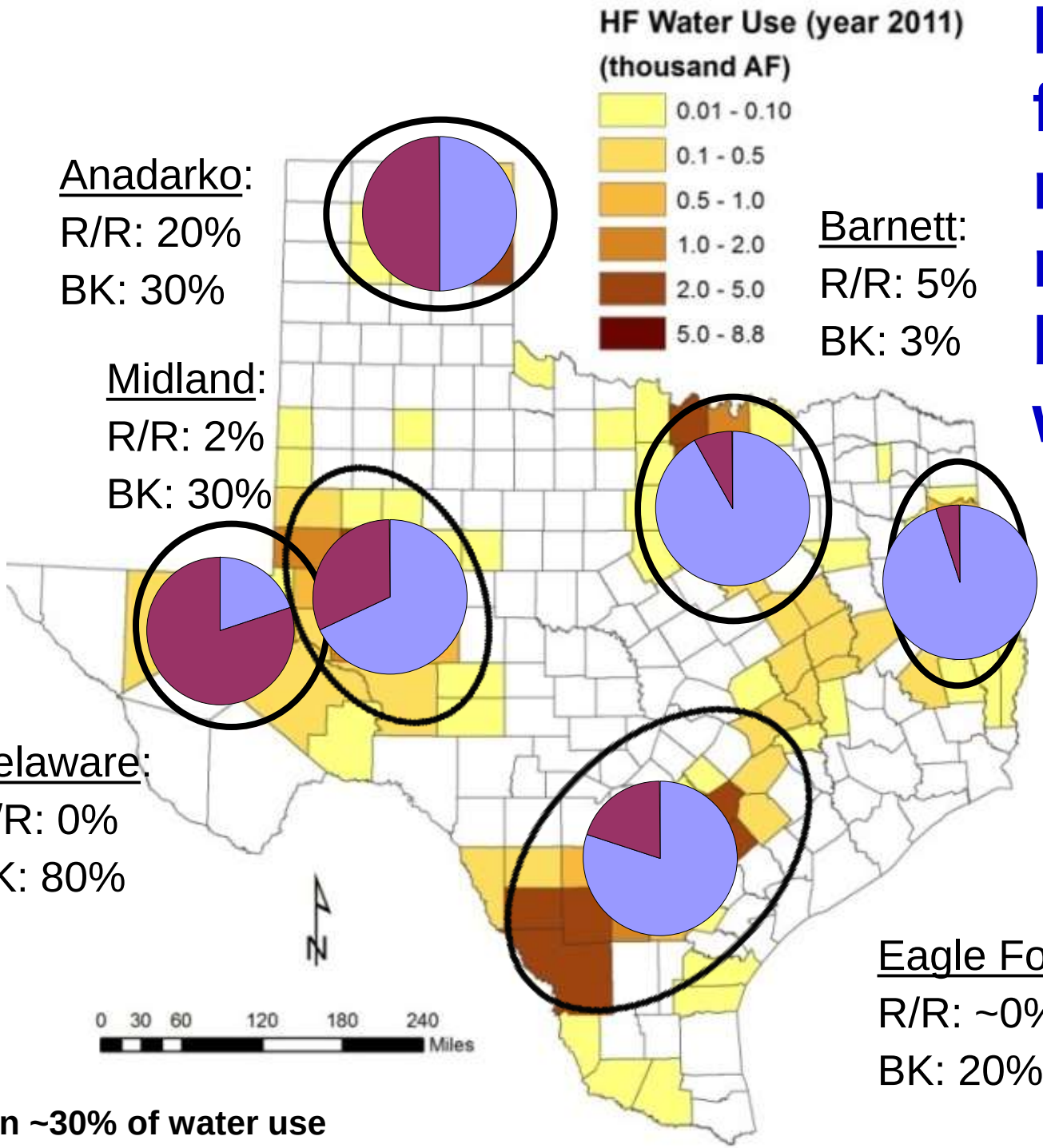
Fraction from recycling / reuse and brackish water



Anadarko:
R/R: 20%
BK: 30%

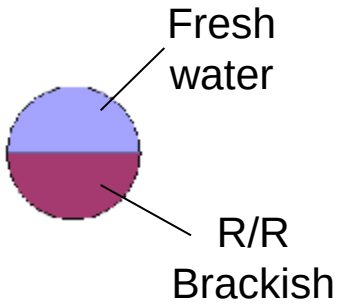
Barnett:
R/R: 5%
BK: 3%

Midland:
R/R: 2%
BK: 30%

East Texas:
R/R: 5%
BK: ~0%

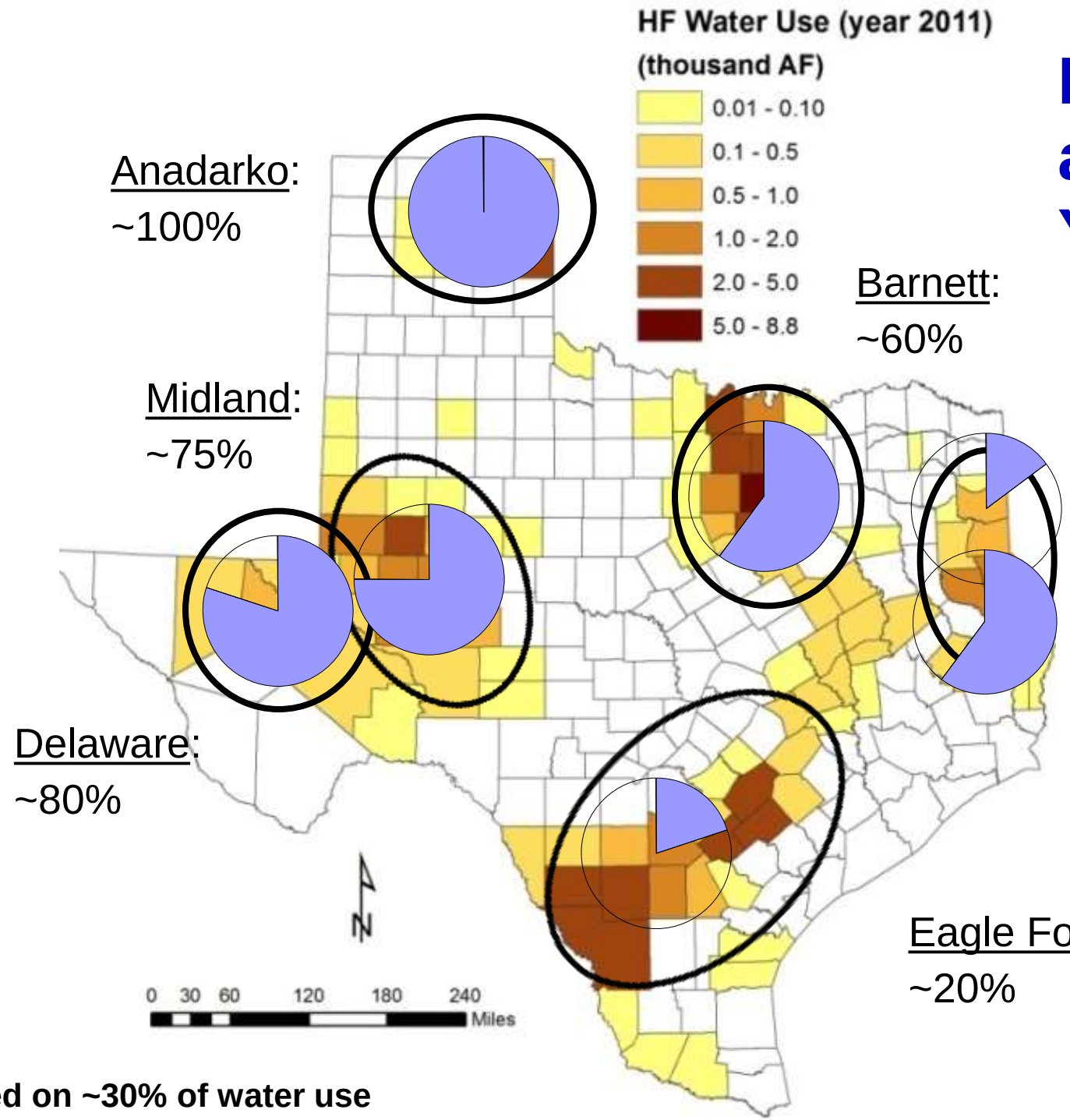
Delaware:
R/R: 0%
BK: 80%

Eagle Ford:
R/R: ~0%
BK: 20%



Based on ~30% of water use

Flowback at end of Year1



Anadarko:
~100%

Barnett:
~60%

Midland:
~75%

Haynesville:
~15%

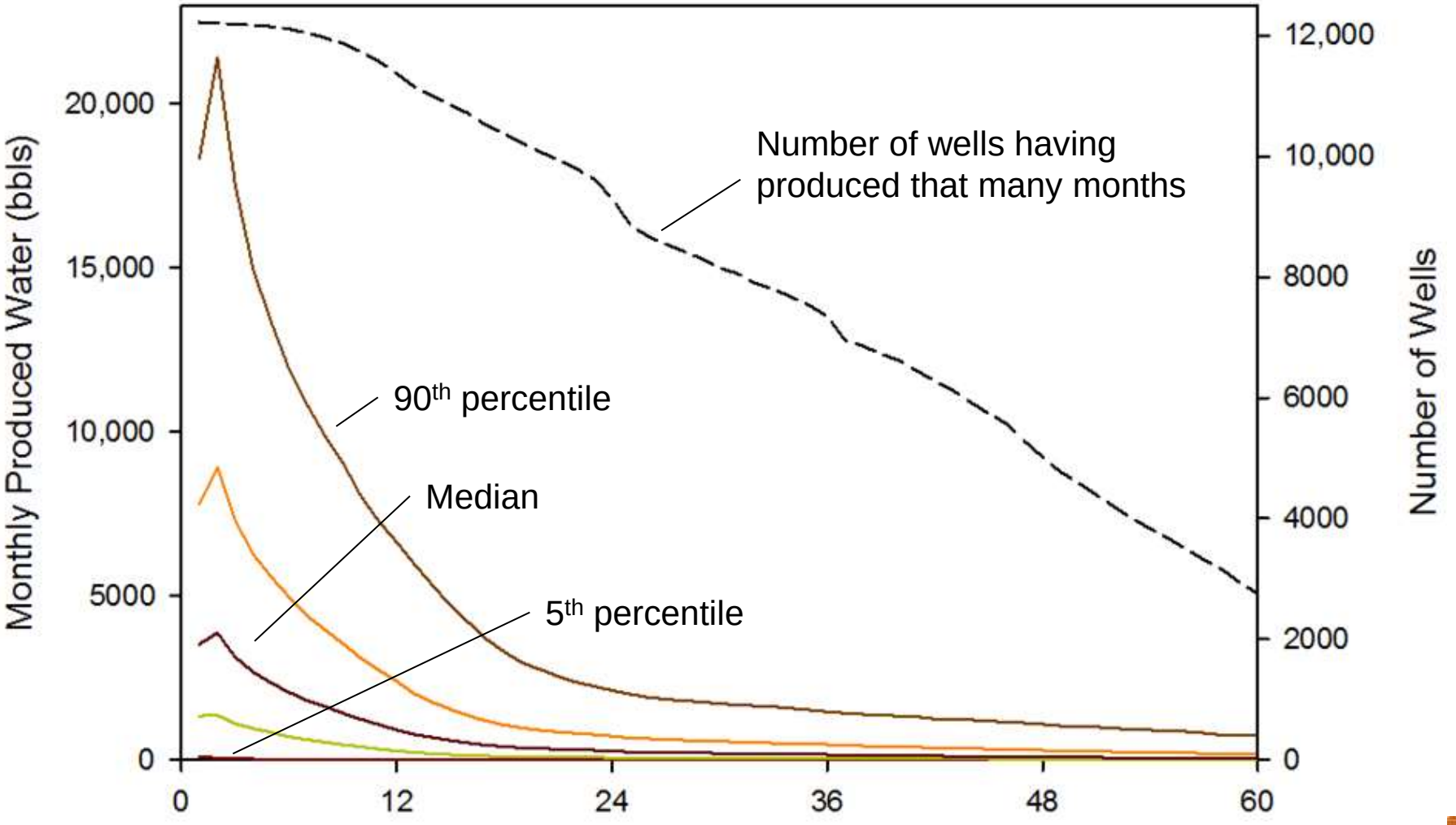
Cotton Valley:
~60%

Delaware:
~80%

Eagle Ford:
~20%

Based on ~30% of water use

Monthly produced water percentiles – Barnett Shale



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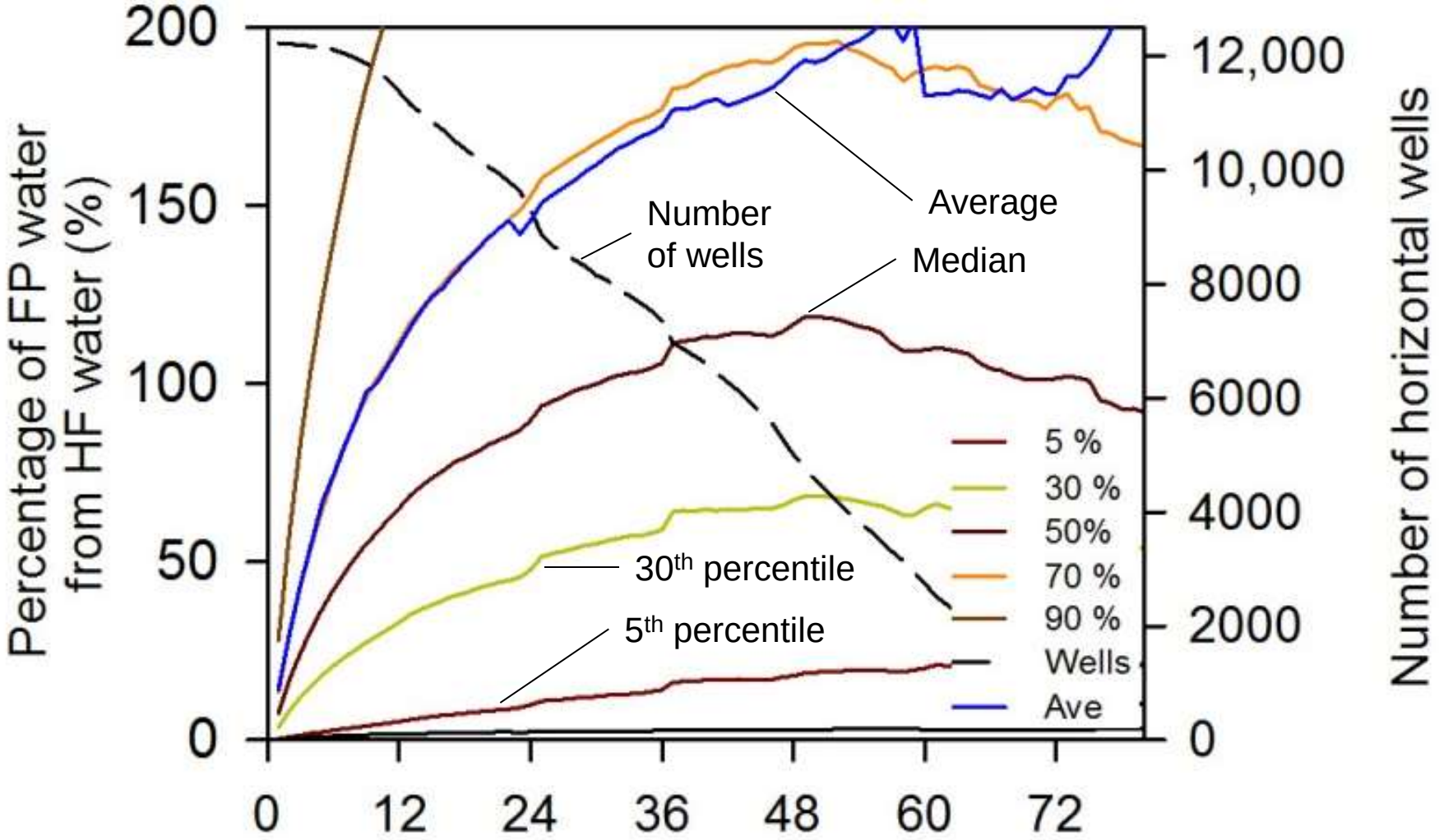
Cumulative produced water percentiles – Barnett Shale



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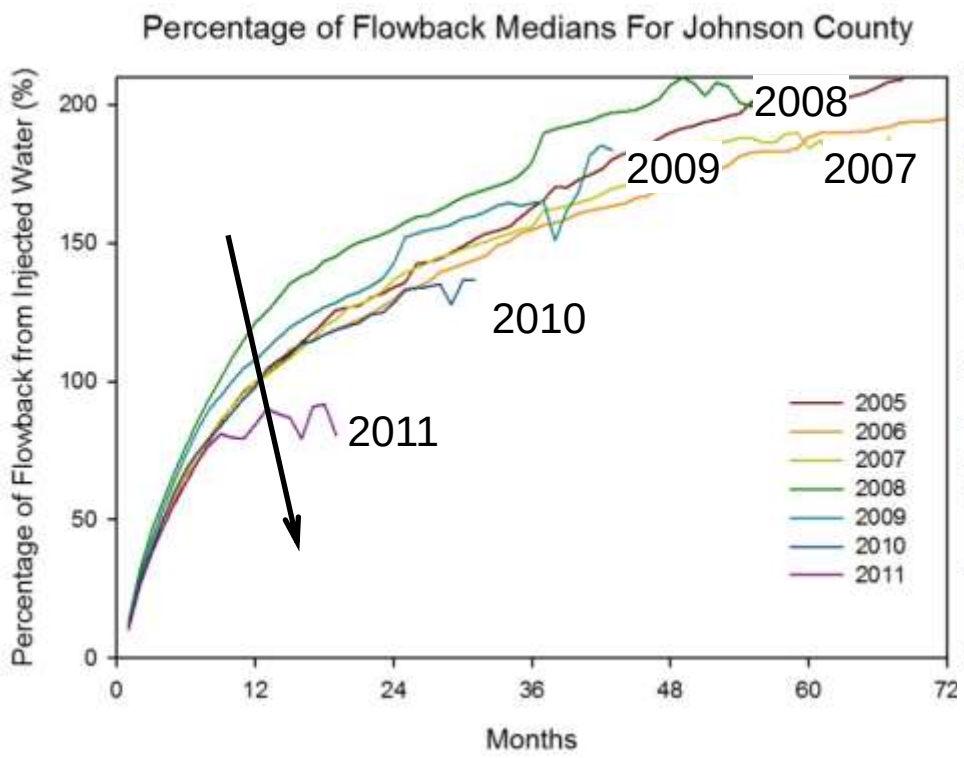
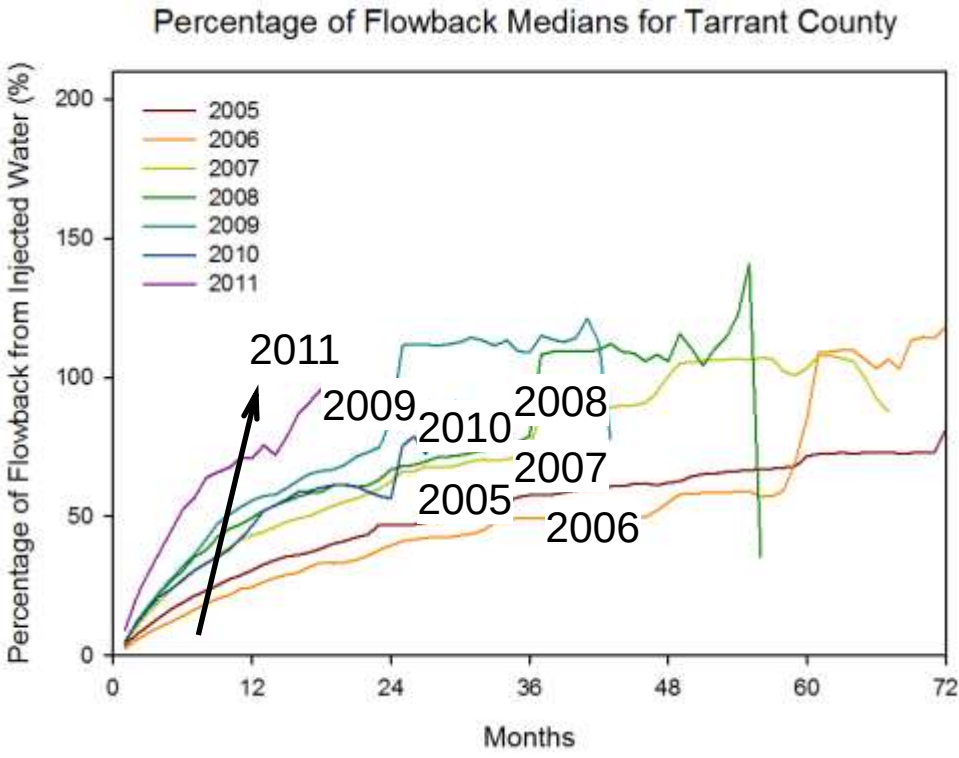
Time variability of produced water fraction





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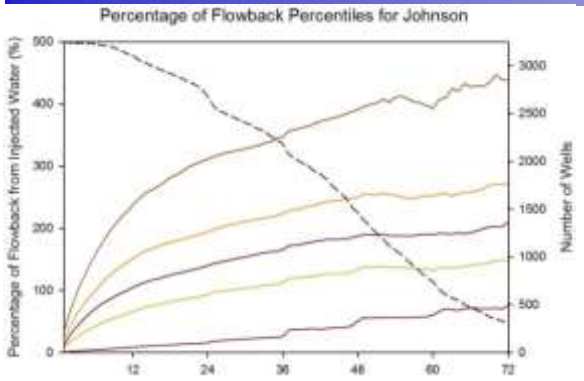
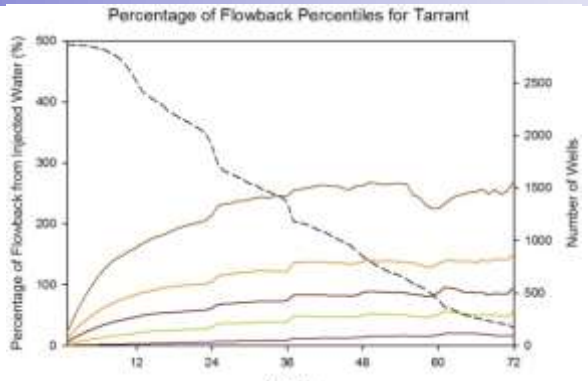
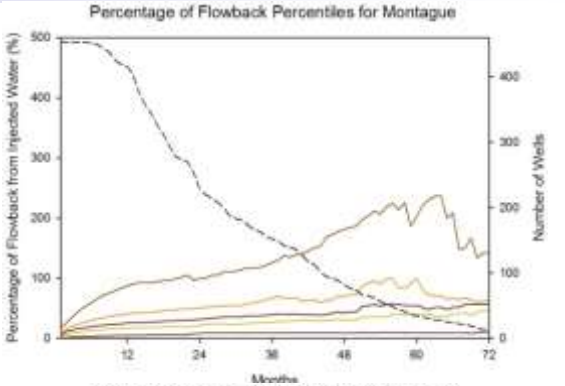
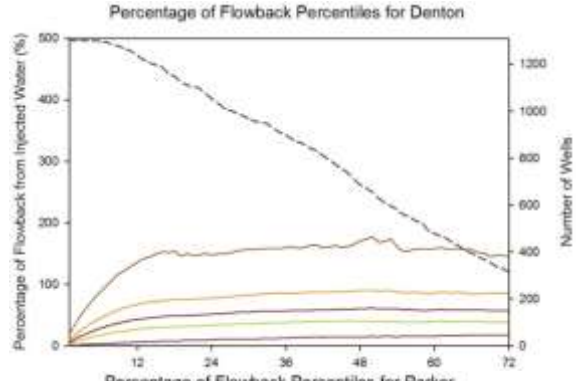
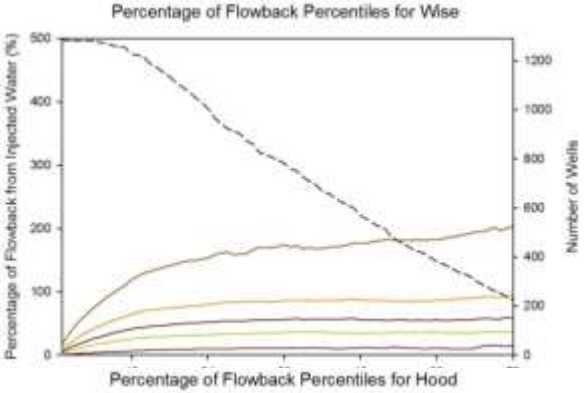
County-level produced water fraction

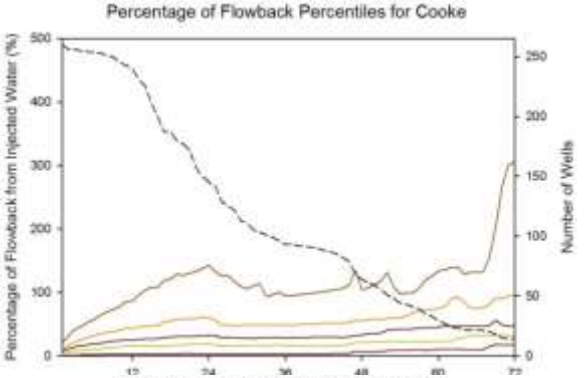


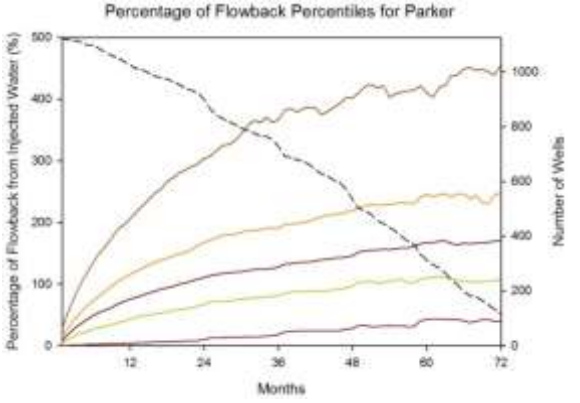


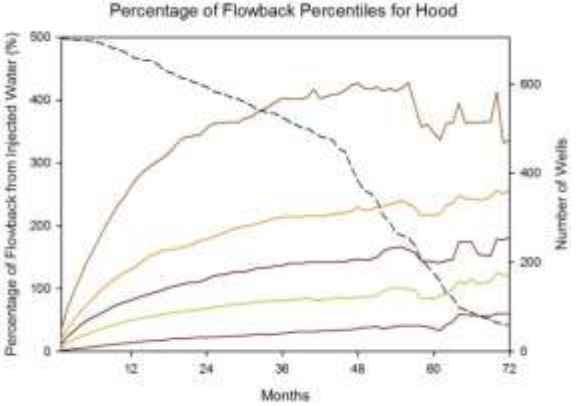


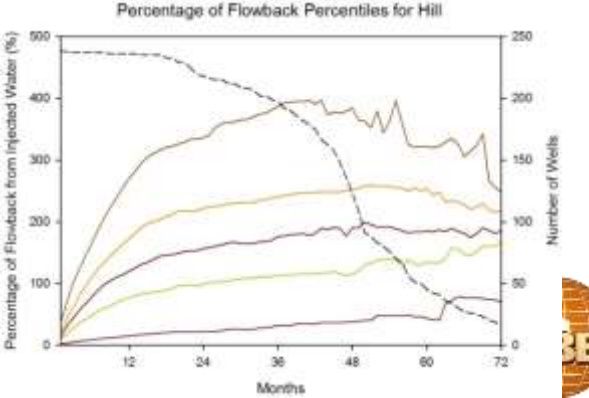




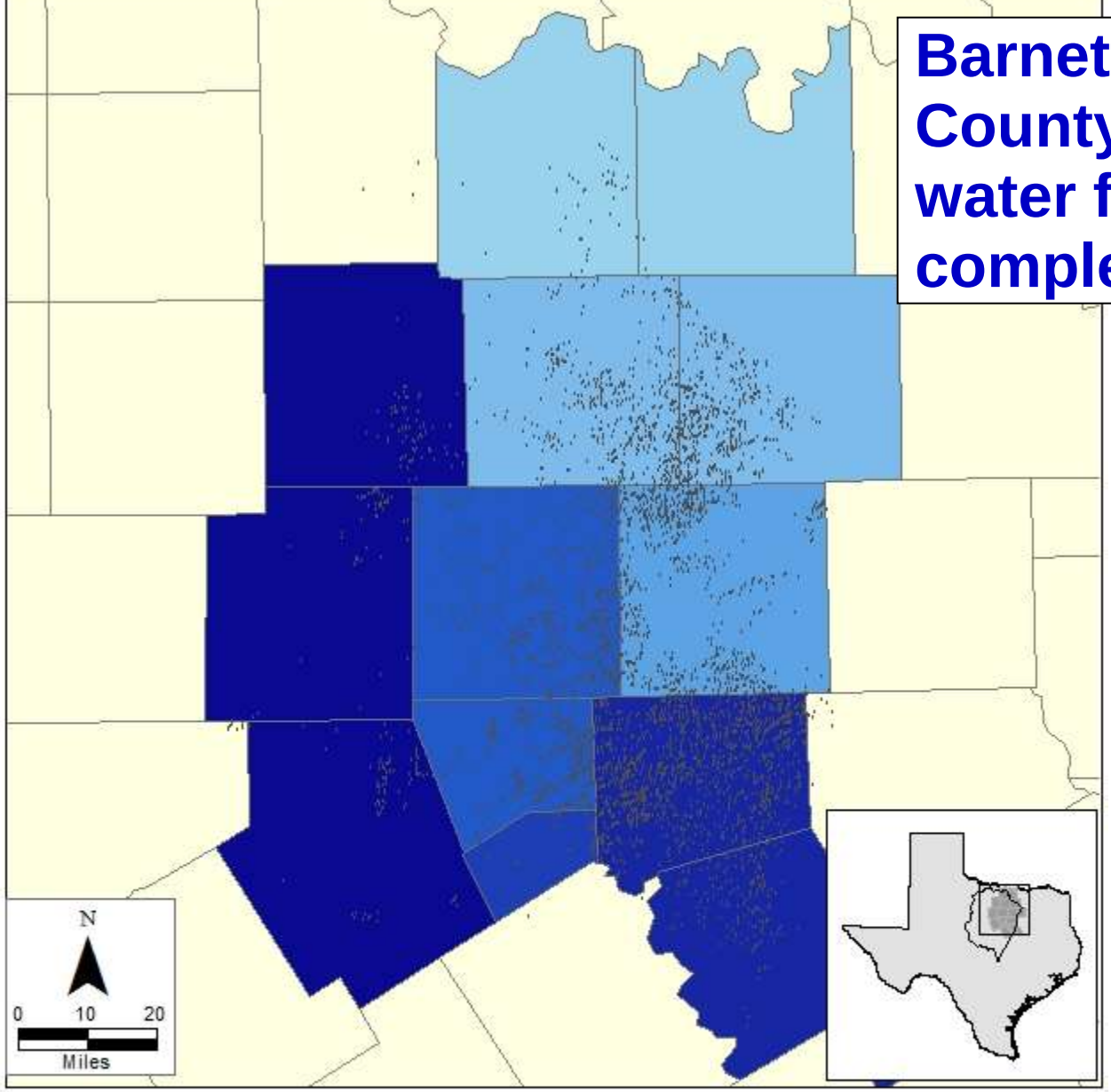








Barnett Shale: County-level produced water fraction from well completion



- 1 month
- 2 months
- 3 months
- 6 months
- 1 year
- 2 years
- 3 years

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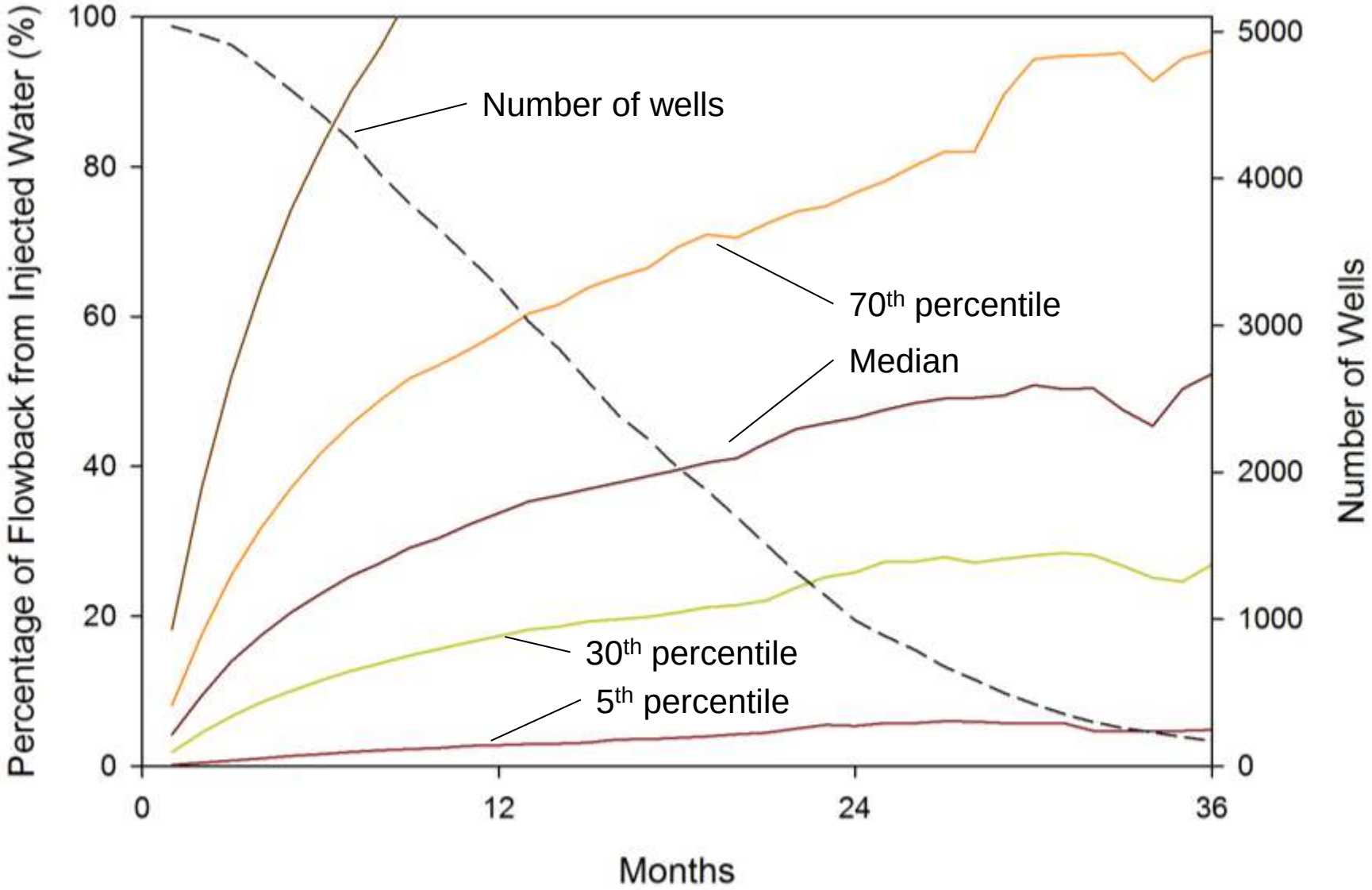
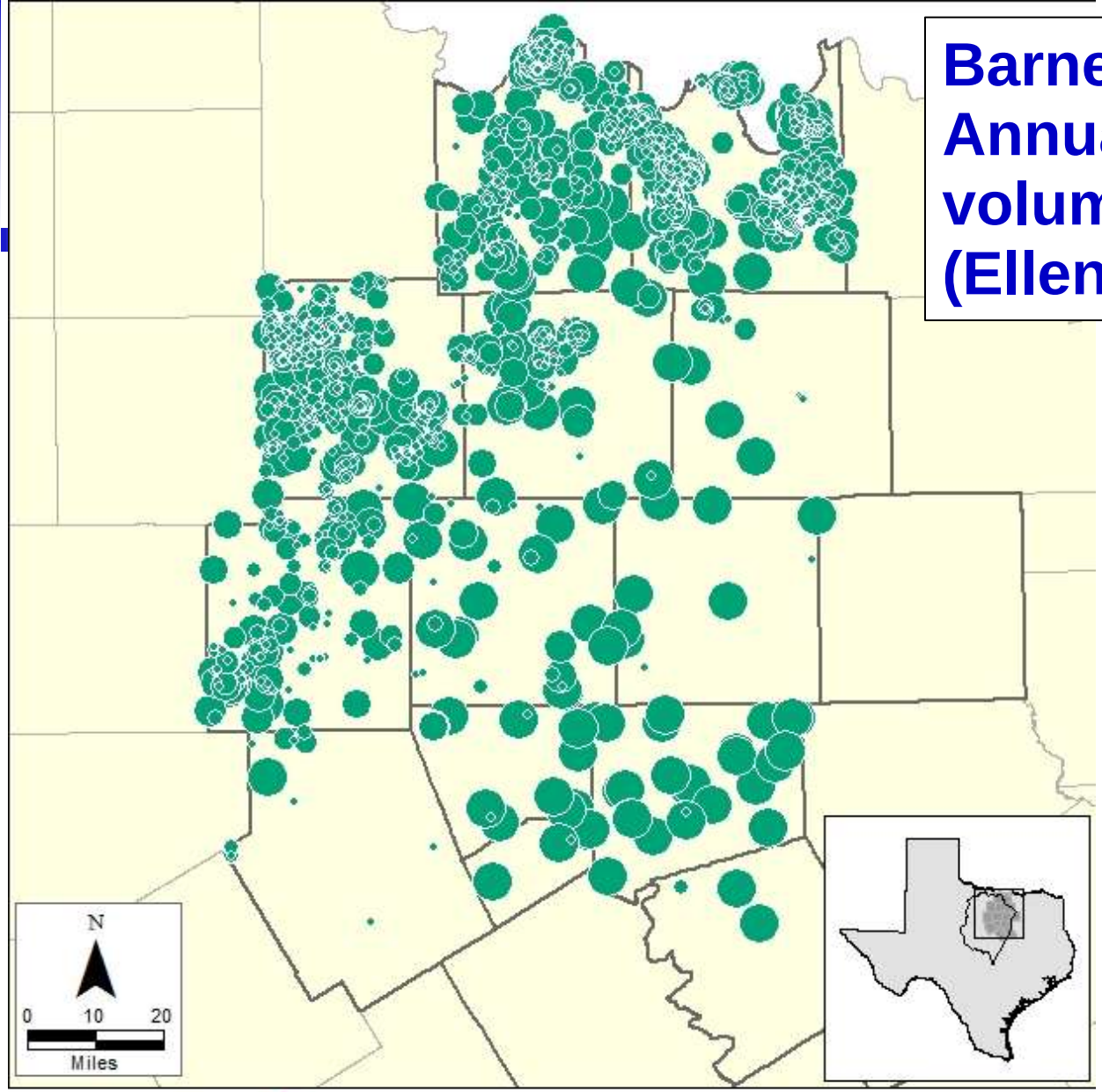
Cumulative produced water percentiles – Eagle Ford



Barnett Shale: Annual injection well volumes through time (Ellenburger Fm.)



- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011

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Summary

- Amount of flowback / produced (FP) water is very variable; higher for tight formations
- Water production decline is similar to that of oil and gas
- Only a small and early fraction of the FP water is recycled
- Deep-well injection of FP water is the norm in Texas but overall FP volumes are small relative to other sources
- Amount of FP water is negatively correlated with well productivity (shales)