Water Issues in the Natural Gas Industry

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The University of Texas at Austin

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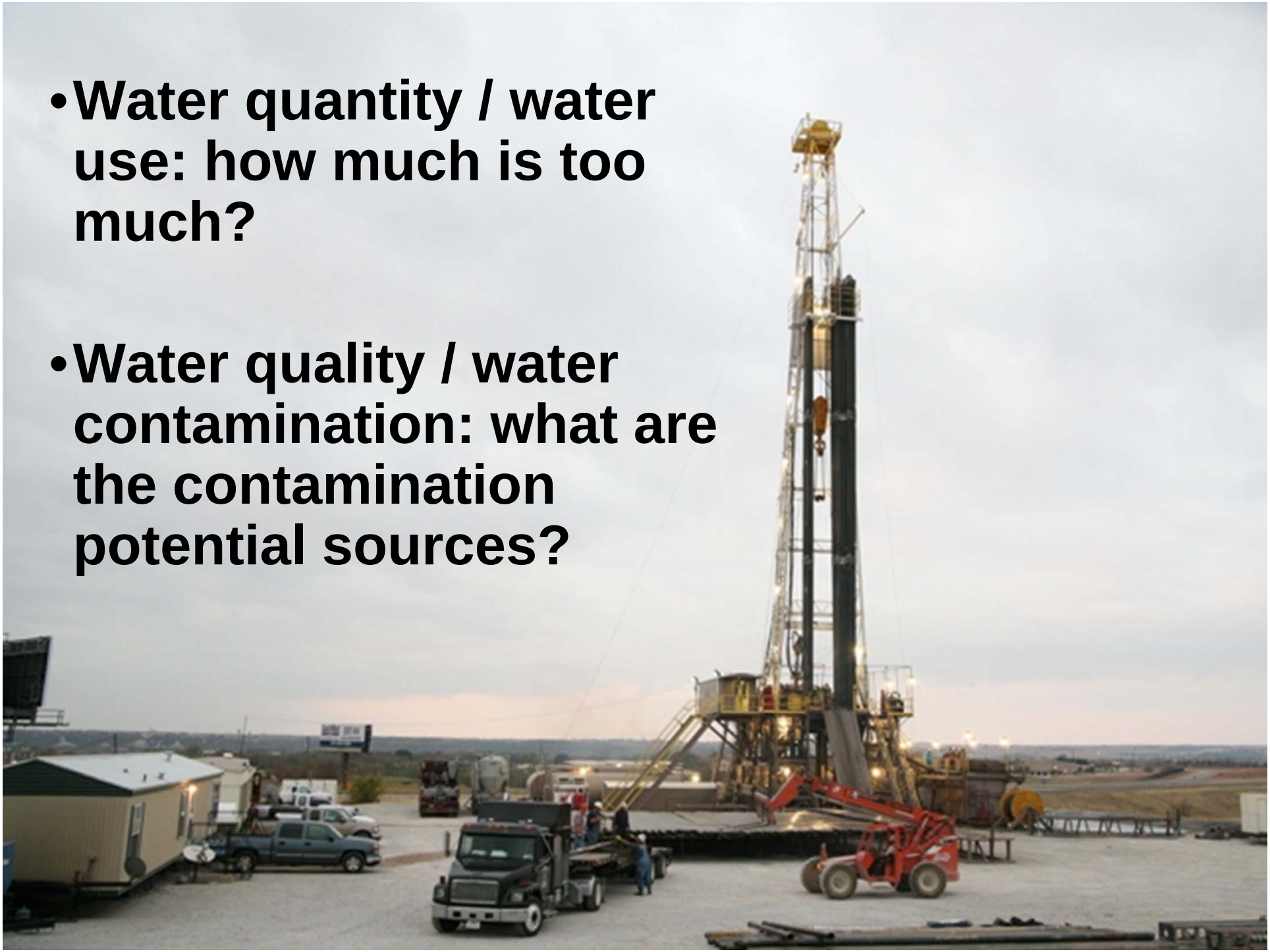
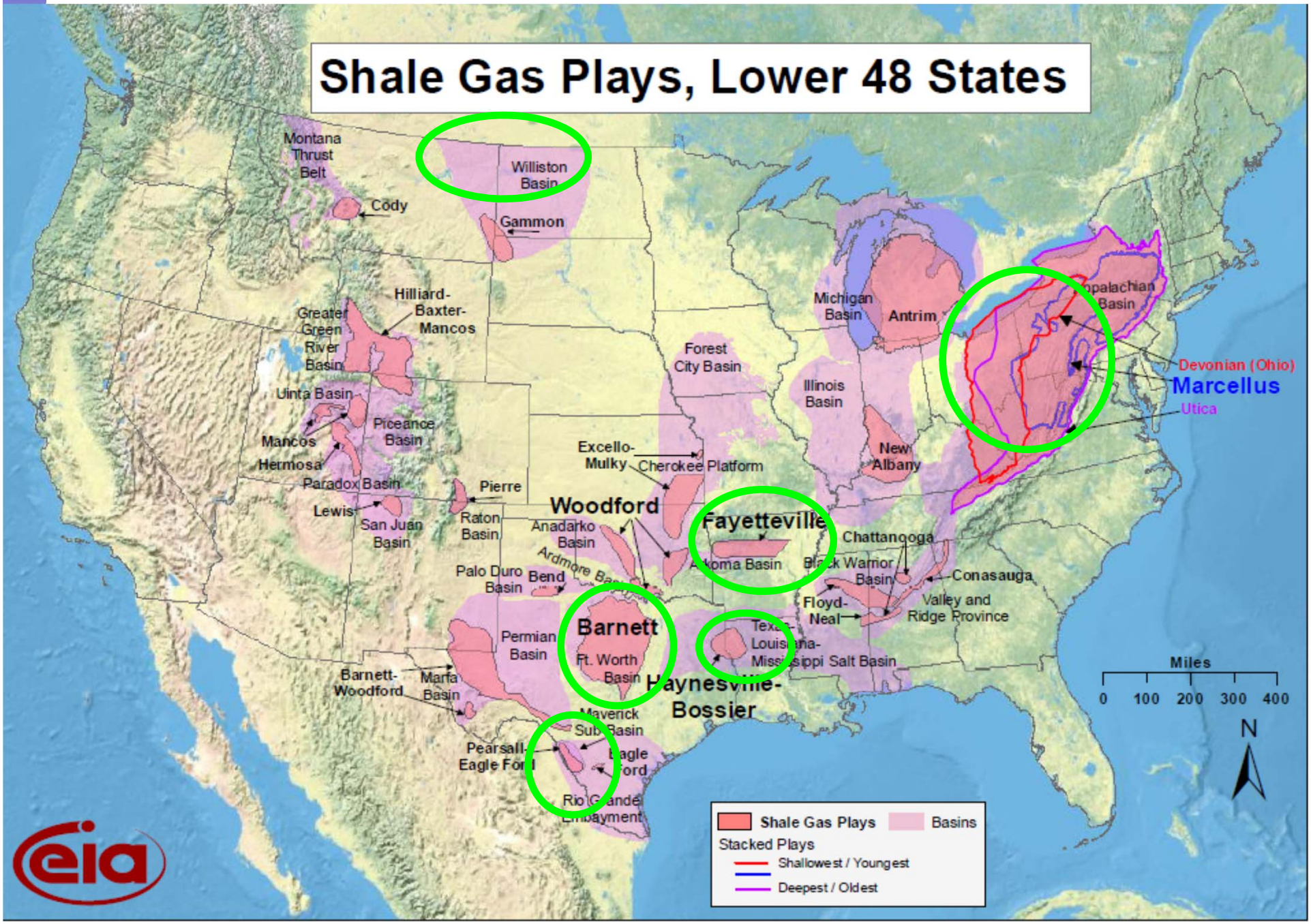
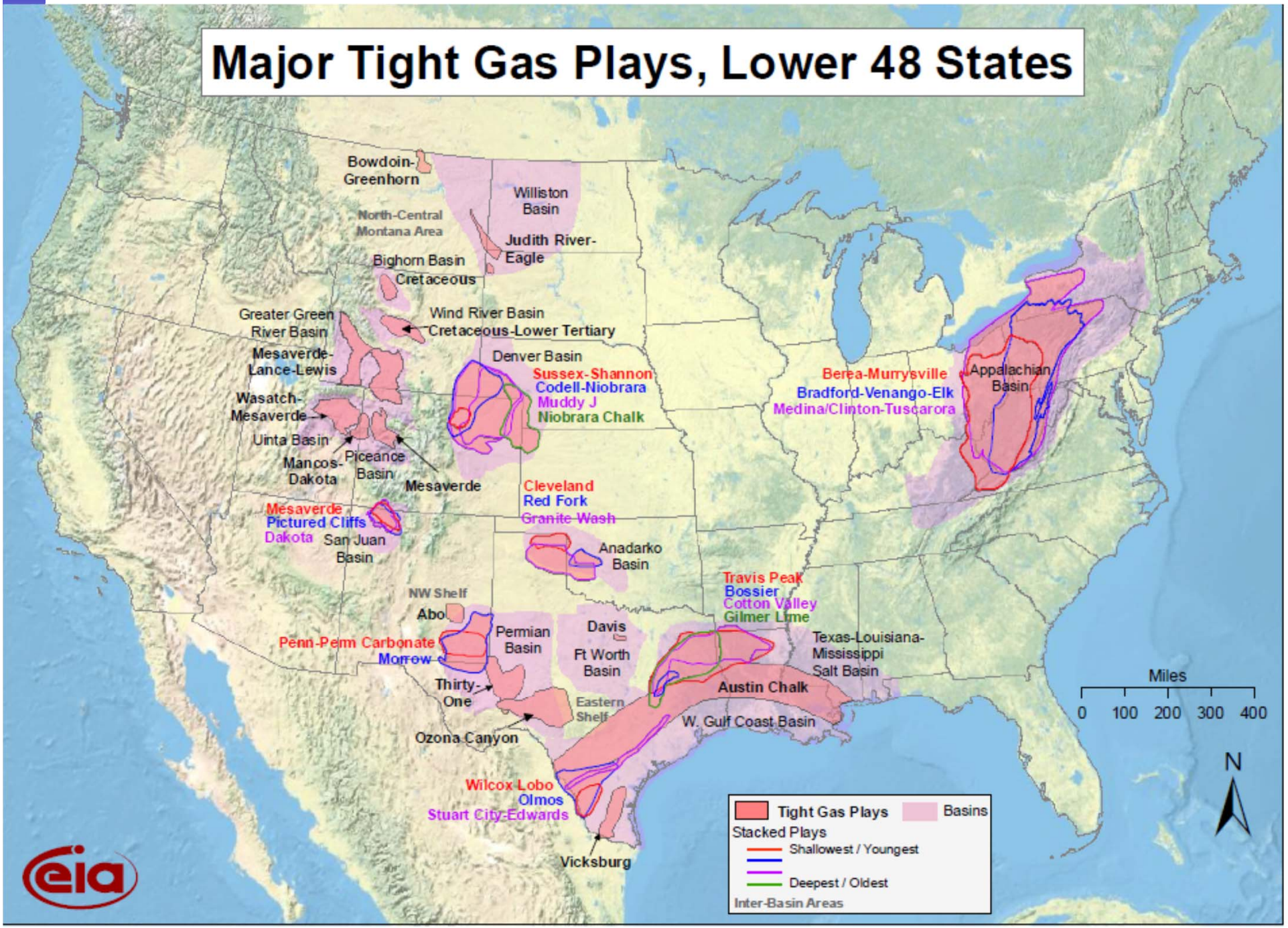
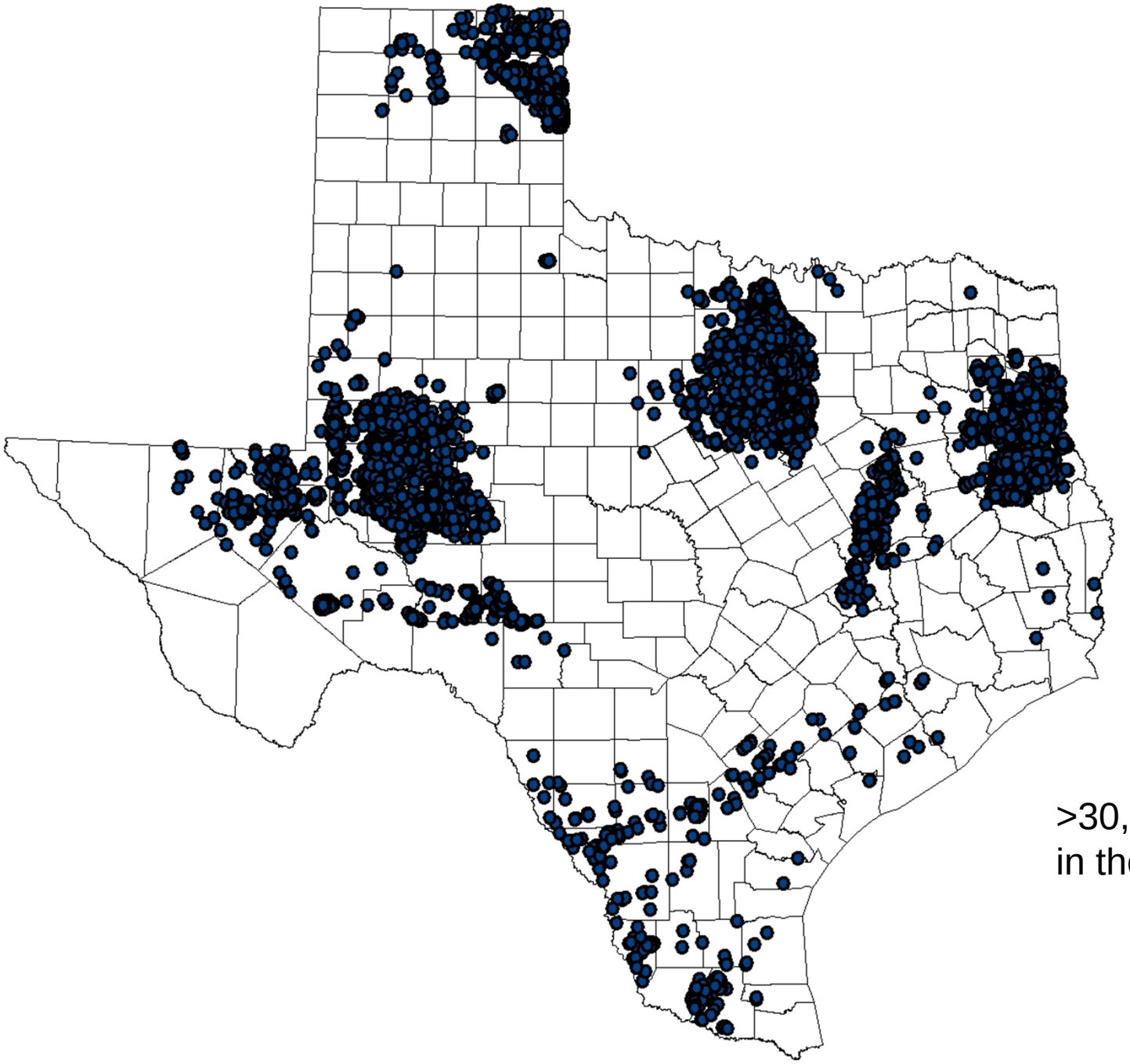


- **Water quantity / water use: how much is too much?**
- **Water quality / water contamination: what are the contamination potential sources?**


Shale Gas Plays, Lower 48 States
Montana Thrust Belt
Williston Basin
Cody
Gammon
Hilliard-Baxter-Mancos
Greater Green River Basin
Uinta Basin
Piceance Basin
Mancos
Hermosa
Paradox Basin
Lewis
San Juan Basin
Pierre
Raton Basin
Forest City Basin
Excello-Mulky
Cherokee Platform
Woodford
Anadarko Basin
Ardmore Basin
Palo Duro Basin
Bend
Permian Basin
Barnett
Ft. Worth Basin
Barnett-Woodford
Marfa Basin
Maverick Sub Basin
Pearsall-Eagle Ford
Rio Grande Embayment
Fayetteville
Arkoma Basin
Haynesville-Bossier
Texas-Louisiana-Mississippi Salt Basin
Michigan Basin
Antrim
Illinois Basin
New Albany
Appalachian Basin
Devonian (Ohio)
Marcellus
Utica
Chattanooga
Black Warrior Basin
Conasauga
Floyd-Neal
Valley and Ridge Province
Miles
0 100 200 300 400
N
Shale Gas Plays
Basins
Stacked Plays
Shallowest / Youngest
Deepest / Oldest
eia


Major Tight Gas Plays, Lower 48 States
Bowdoin-Greenhorn
Williston Basin
North-Central Montana Area
Judith River-Eagle
Bighorn Basin Cretaceous
Greater Green River Basin
Wind River Basin Cretaceous-Lower Tertiary
Mesaverde-Lance-Lewis
Denver Basin
Sussex-Shannon
Codell-Niobrara
Muddy J
Niobrara Chalk
Wasatch-Mesaverde
Uinta Basin
Mancos-Dakota
Piceance Basin
Mesaverde
Cleveland
Red Fork
Granite Wash
Mesaverde
Pictured Cliffs
Dakota
San Juan Basin
Anadarko Basin
NW Shelf
Abo
Permian Basin
Davis
Ft Worth Basin
Penn-Perm Carbonate
Morrow
Thirty-One
Eastern Shelf
Ozona Canyon
Wilcox Lobo
Olmos
Stuart City-Edwards
Vicksburg
Travis Peak
Bossier
Cotton Valley
Gilmer Lime
Texas-Louisiana-Mississippi Salt Basin
Austin Chalk
W. Gulf Coast Basin
Berea-Murrysville
Bradford-Venango-Elk
Medina/Clinton-Tuscarora
Appalachian Basin
Miles
0 100 200 300 400
N
Tight Gas Plays
Basins
Stacked Plays
Shallowest / Youngest
Deepest / Oldest
Inter-Basin Areas
eia



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>30,000 wells fraced
in the past 5 years

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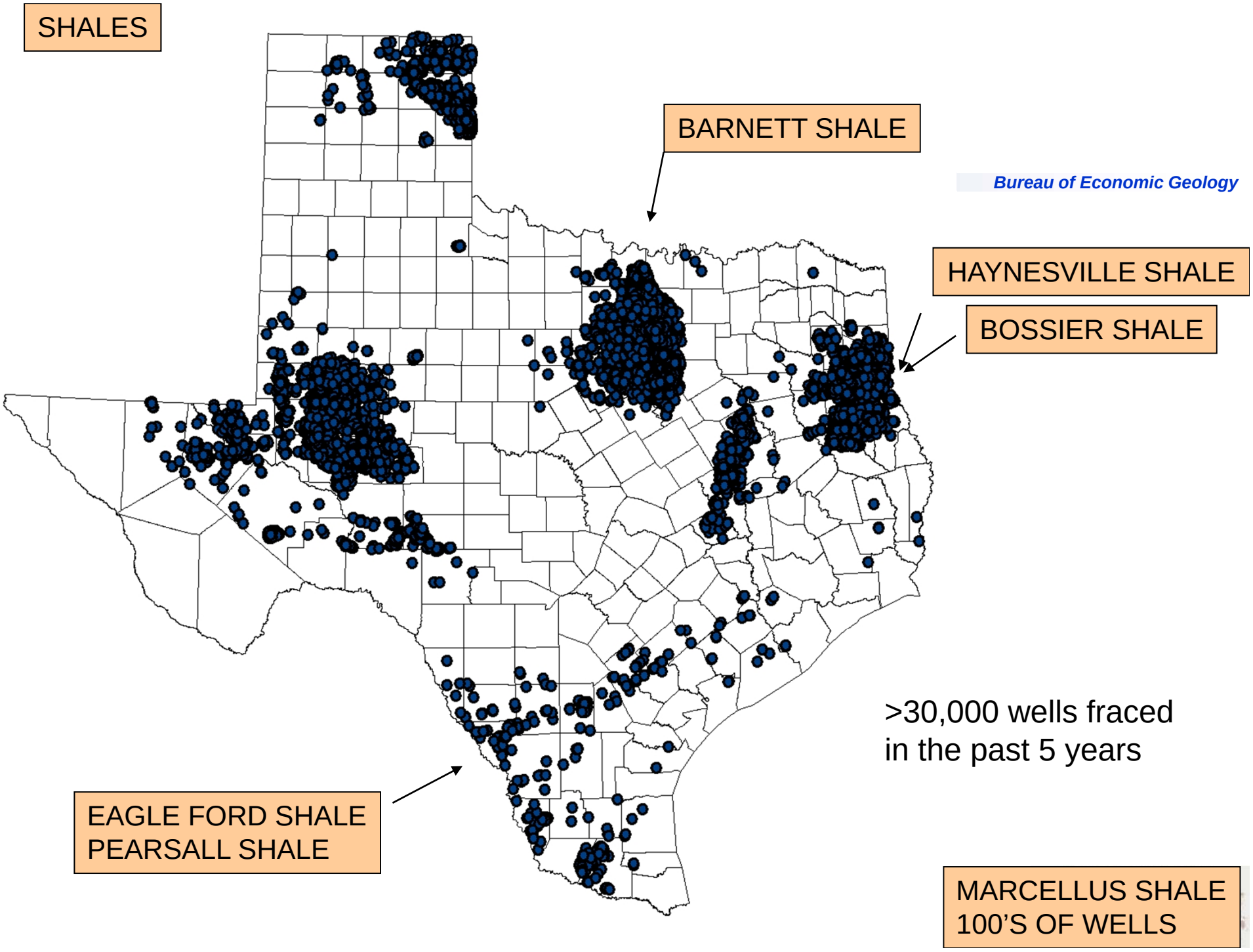
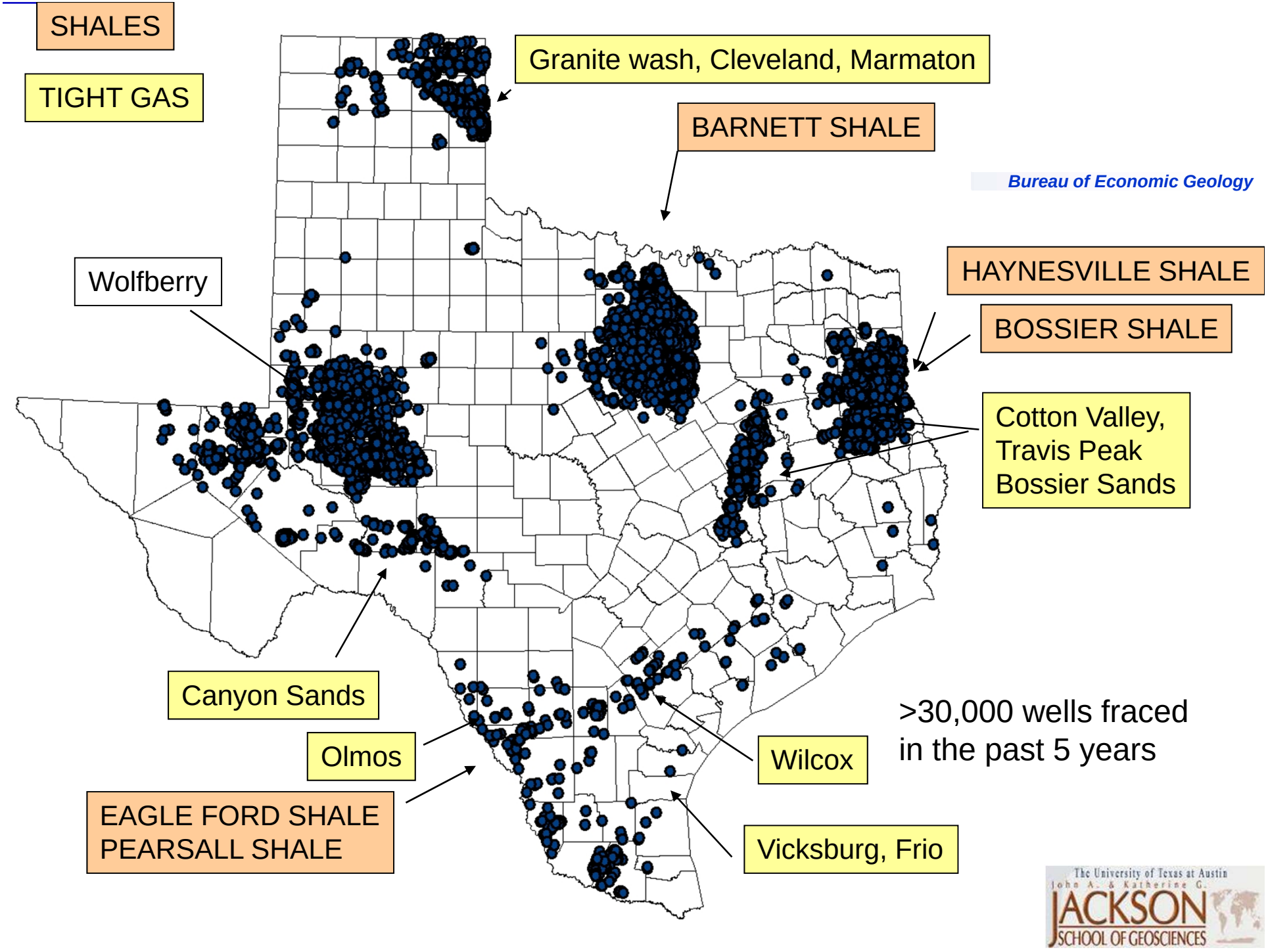

SHALES
BARNETT SHALE
Bureau of Economic Geology
HAYNESVILLE SHALE
BOSSIER SHALE
>30,000 wells fraced
in the past 5 years
EAGLE FORD SHALE
PEARSALL SHALE
MARCELLUS SHALE
100'S OF WELLS


SHALES
TIGHT GAS
Granite wash, Cleveland, Marmaton
BARNETT SHALE
Bureau of Economic Geology
Wolfberry
HAYNESVILLE SHALE
BOSSIER SHALE
Cotton Valley,
Travis Peak
Bossier Sands
Canyon Sands
Olmos
EAGLE FORD SHALE
PEARSALL SHALE
Wilcox
Vicksburg, Frio
>30,000 wells fraced
in the past 5 years
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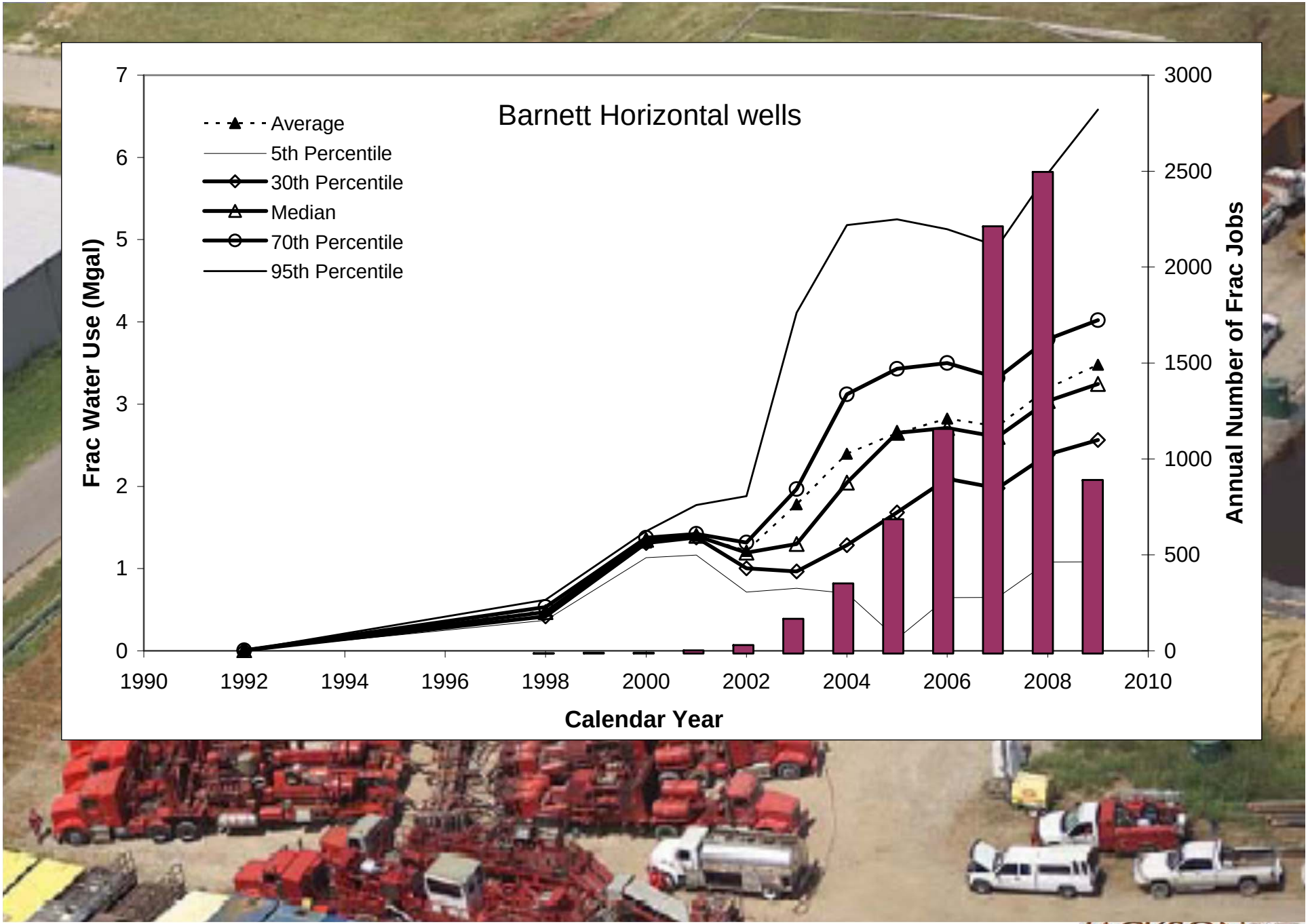
What is a frac job?

- Very low matrix permeability: μd for tight gas sands and nd for gas shale (>1d good aquifer)
- Create a fracture network by injecting large amounts of water at high pressure.
- Add additives to enhance performance
- Add proppant (sand) to keep fractures open after frac job
- Conjunction of horizontal drilling and slick water frac (as opposed to gel, x-linked water fracs)



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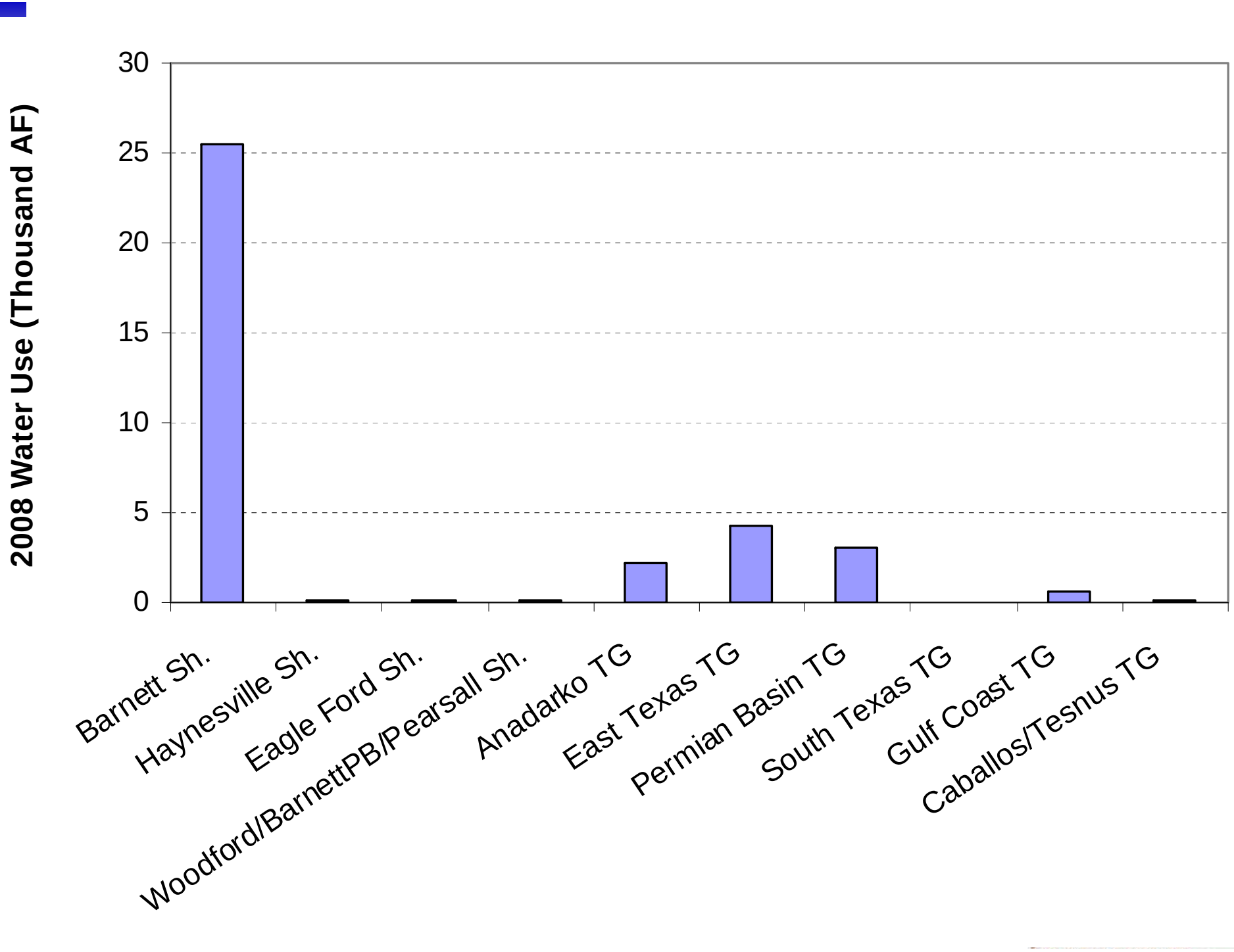
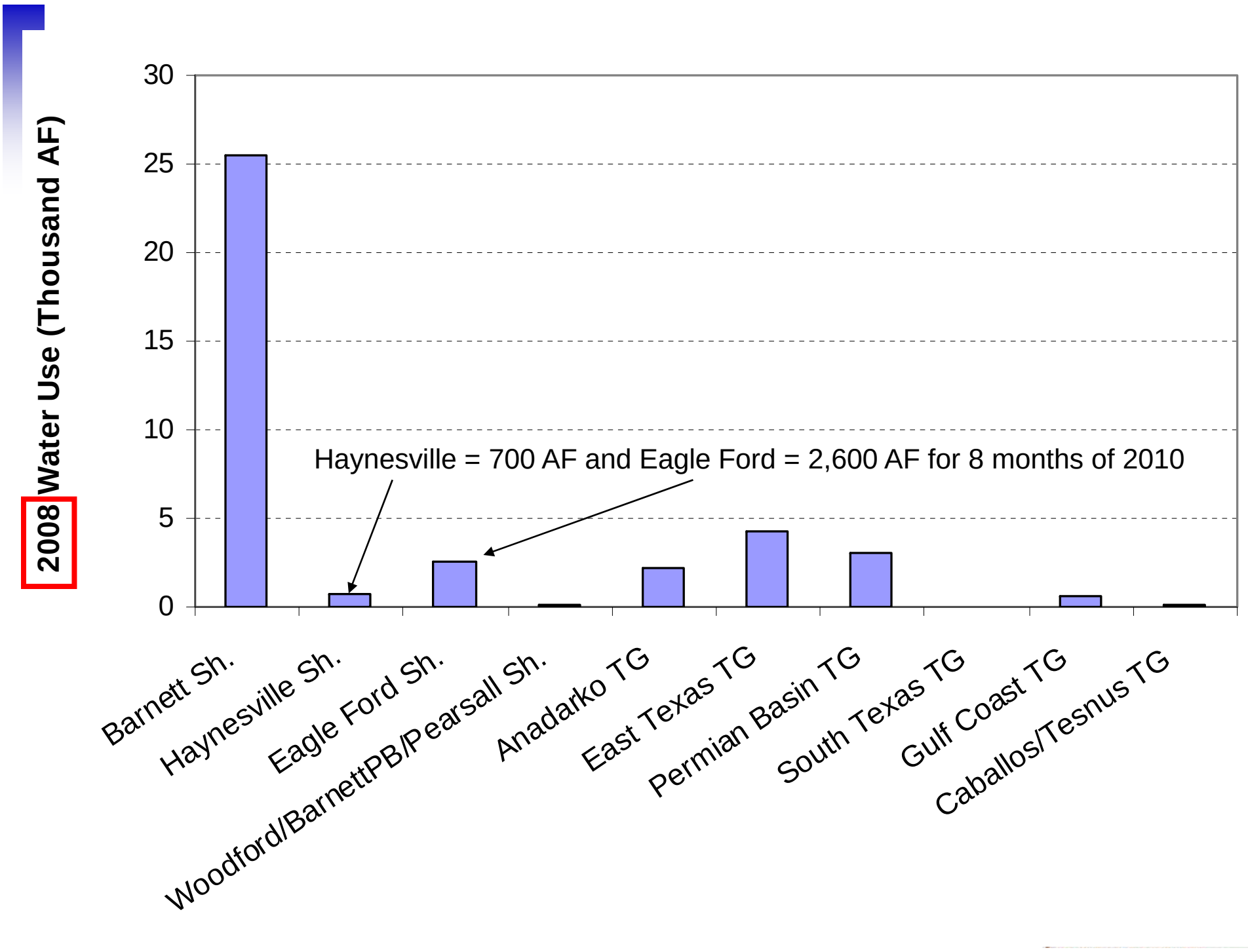

2008 Water Use (Thousand AF)
30
25
20
15
10
5
0
Barnett Sh.
Haynesville Sh.
Eagle Ford Sh.
Woodford/BarnettPB/Pearsall Sh.
Anadarko TG
East Texas TG
Permian Basin TG
South Texas TG
Gulf Coast TG
Caballos/Tesnus TG


2008 Water Use (Thousand AF)
30
25
20
15
10
5
0
Haynesville = 700 AF and Eagle Ford = 2,600 AF for 8 months of 2010
Barnett Sh.
Haynesville Sh.
Eagle Ford Sh.
Woodford/BarnettPB/Pearsall Sh.
Anadarko TG
East Texas TG
Permian Basin TG
South Texas TG
Gulf Coast TG
Caballos/Tesnus TG

How much so far this year?

- 10,268 wells completed
- 7650 wells stimulated
- 3,841 >0.1 Mgal

Total water use of 6,238,000,000 gallons (18.5 MAF)

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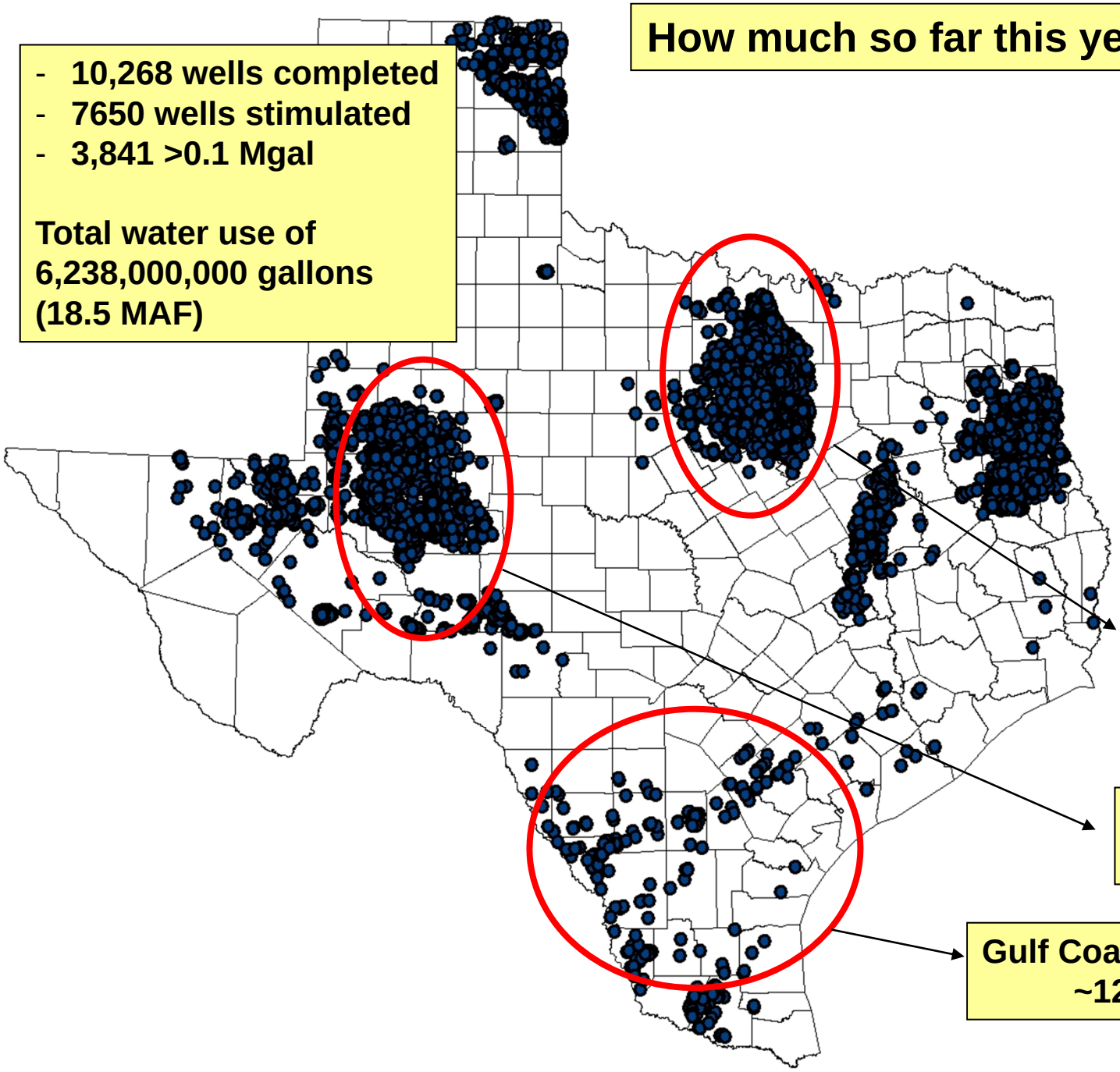

Barnett Shale: ~60% of water use

Permian Basin ~18%

Gulf Coast ~12%

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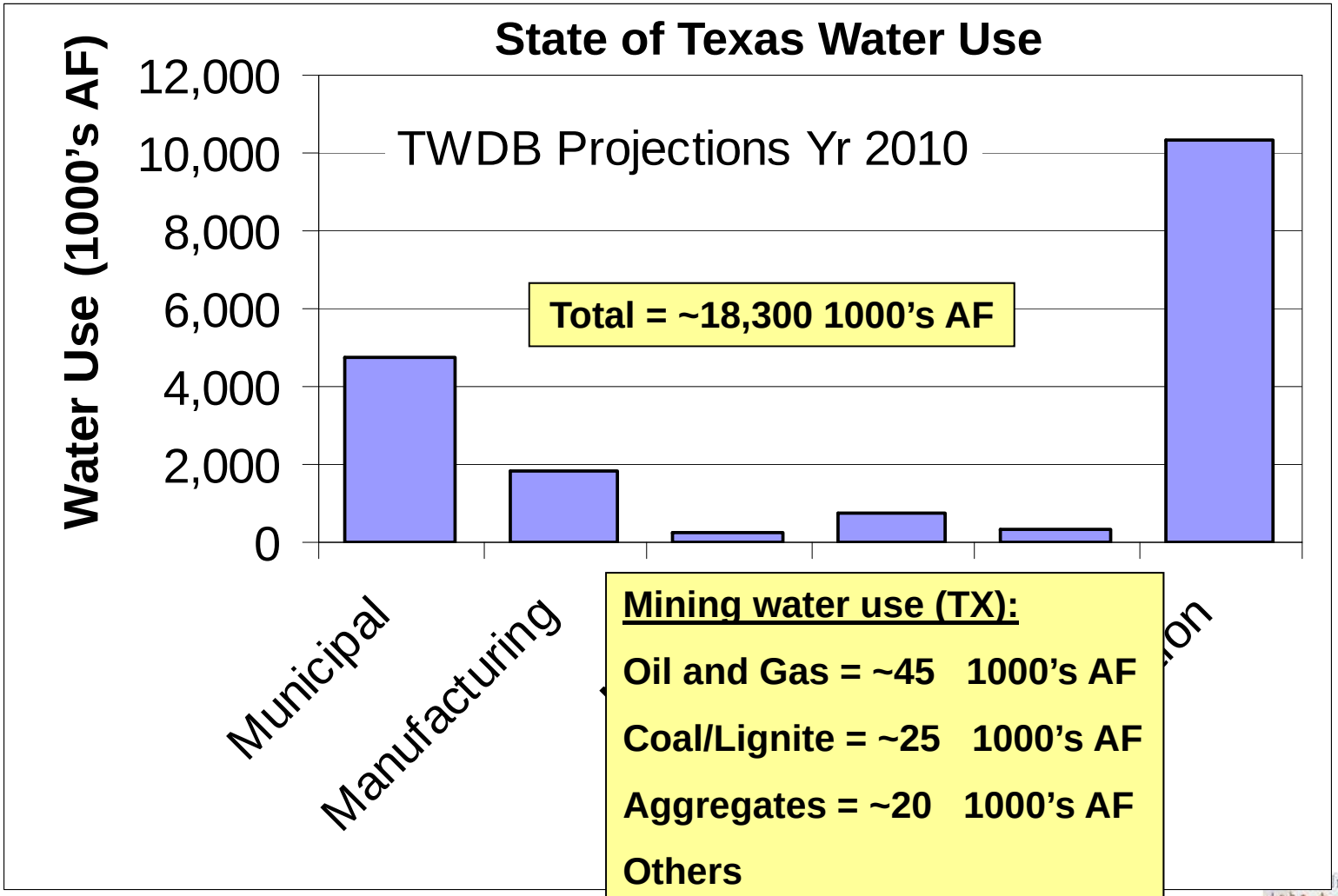
Is that a lot?



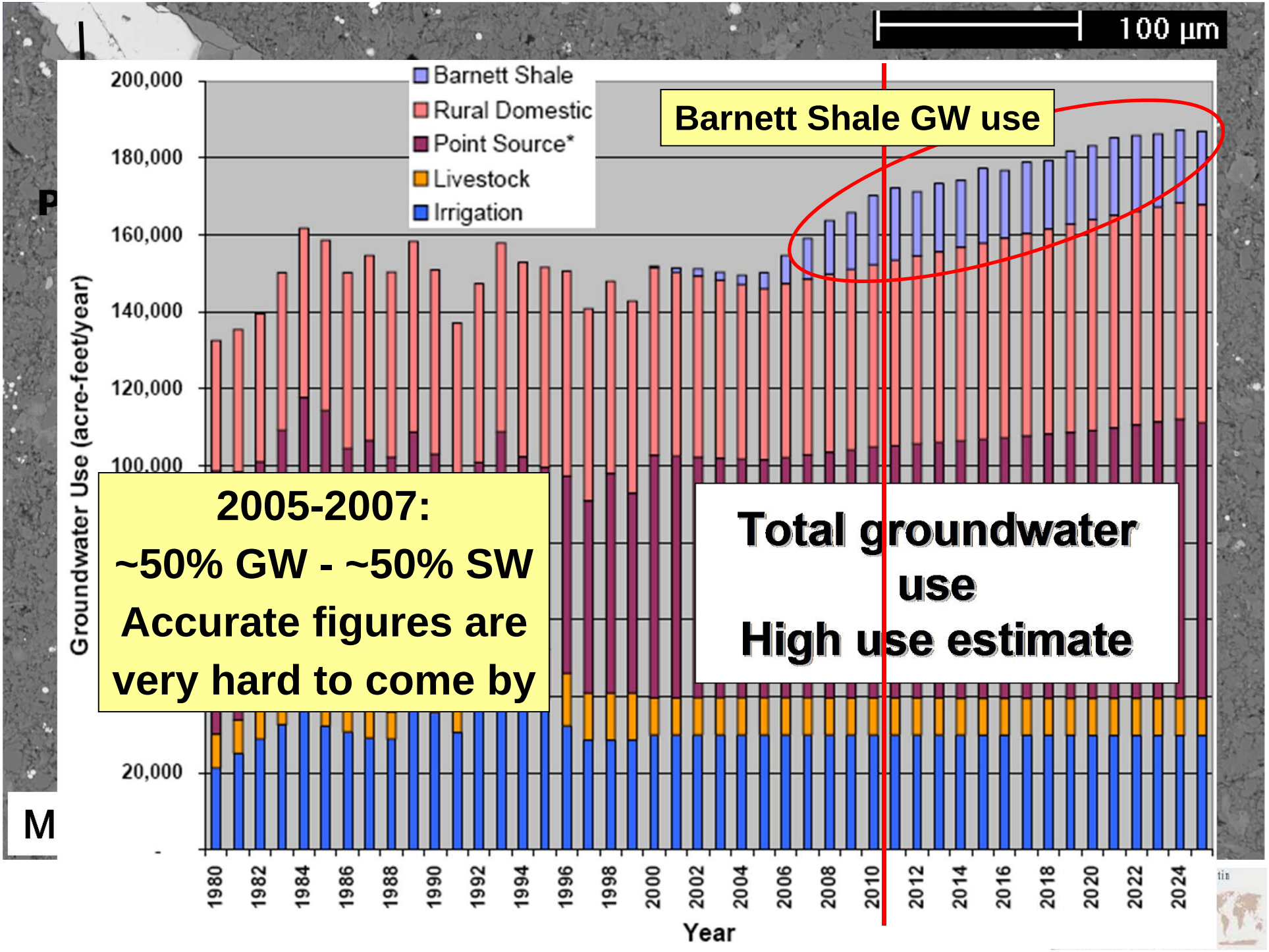
Mining water use (TX):

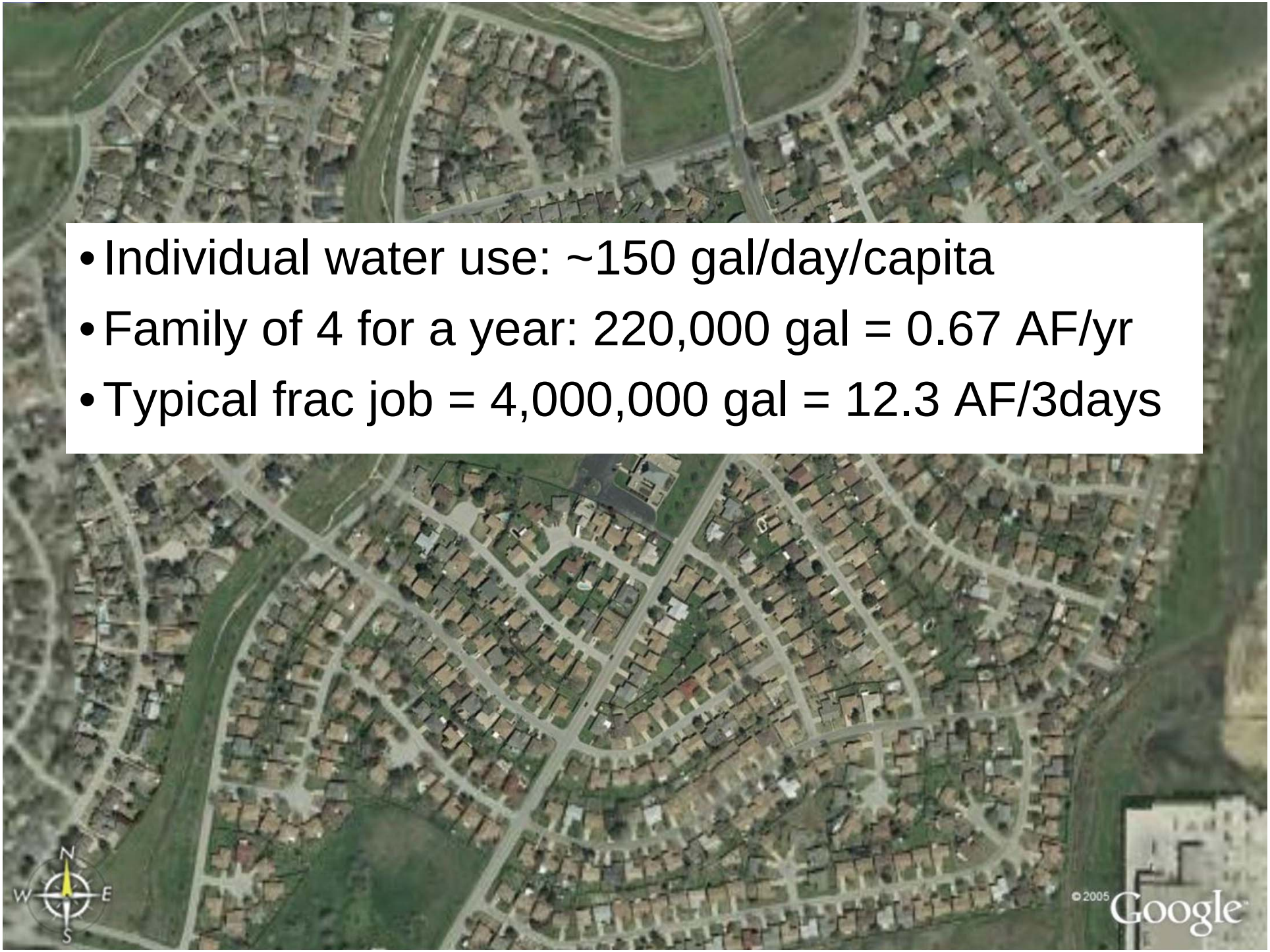
Oil and Gas = ~45 1000's AF

Coal/Lignite = ~25 1000's AF

Aggregates = ~20 1000's AF

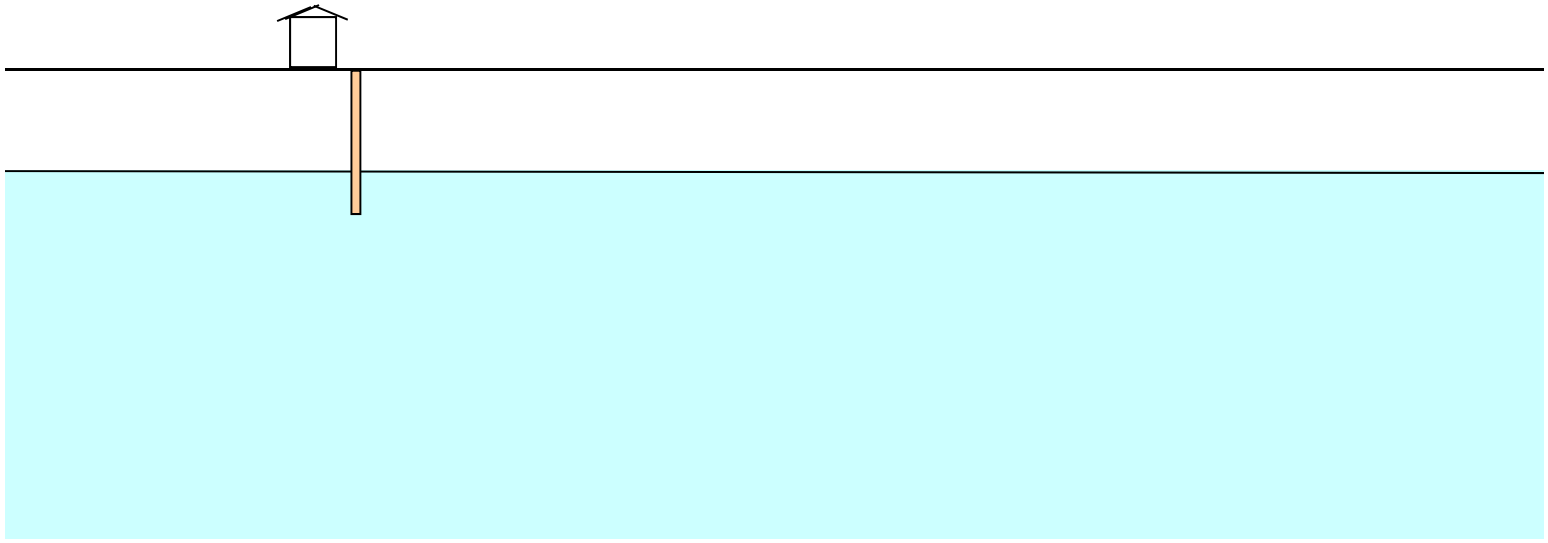
Others


100 µm
Barnett Shale
Rural Domestic
Point Source*
Livestock
Irrigation
Barnett Shale GW use
Groundwater Use (acre-feet/year)
200,000
180,000
160,000
140,000
120,000
100,000
20,000
-
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
2024
Year
2005-2007:
~50% GW - ~50% SW
Accurate figures are very hard to come by
Total groundwater use
High use estimate

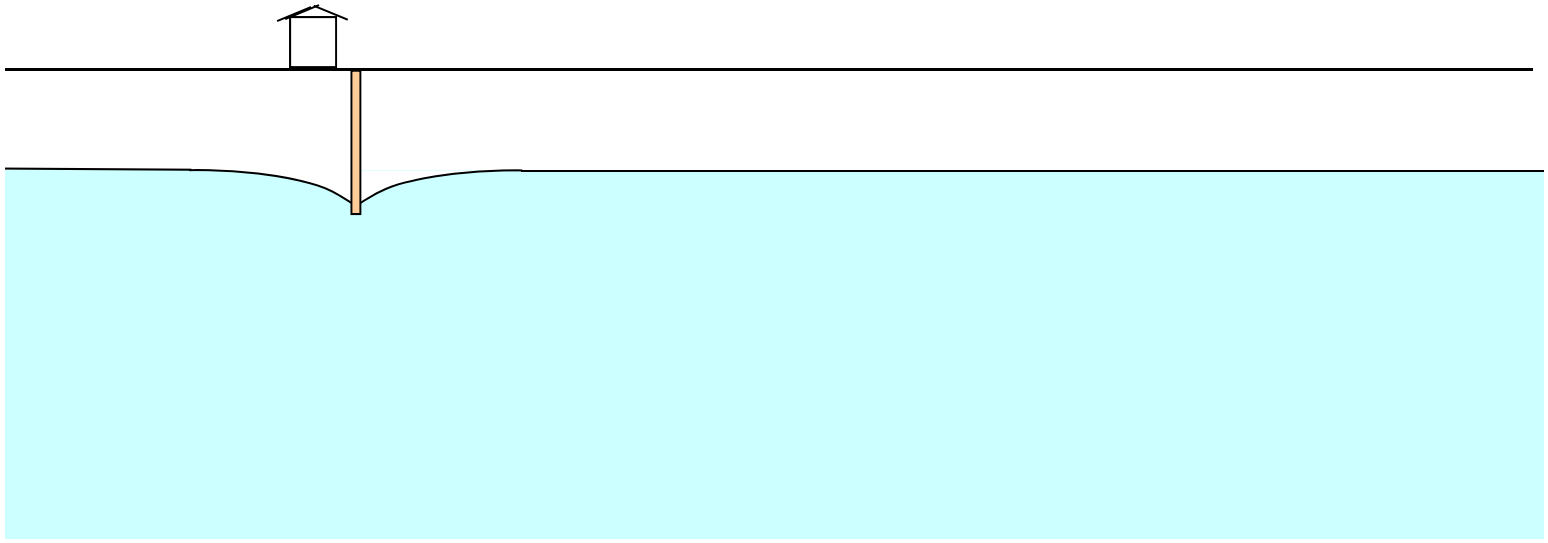


- Individual water use: ~150 gal/day/capita
- Family of 4 for a year: 220,000 gal = 0.67 AF/yr
- Typical frac job = 4,000,000 gal = 12.3 AF/3days

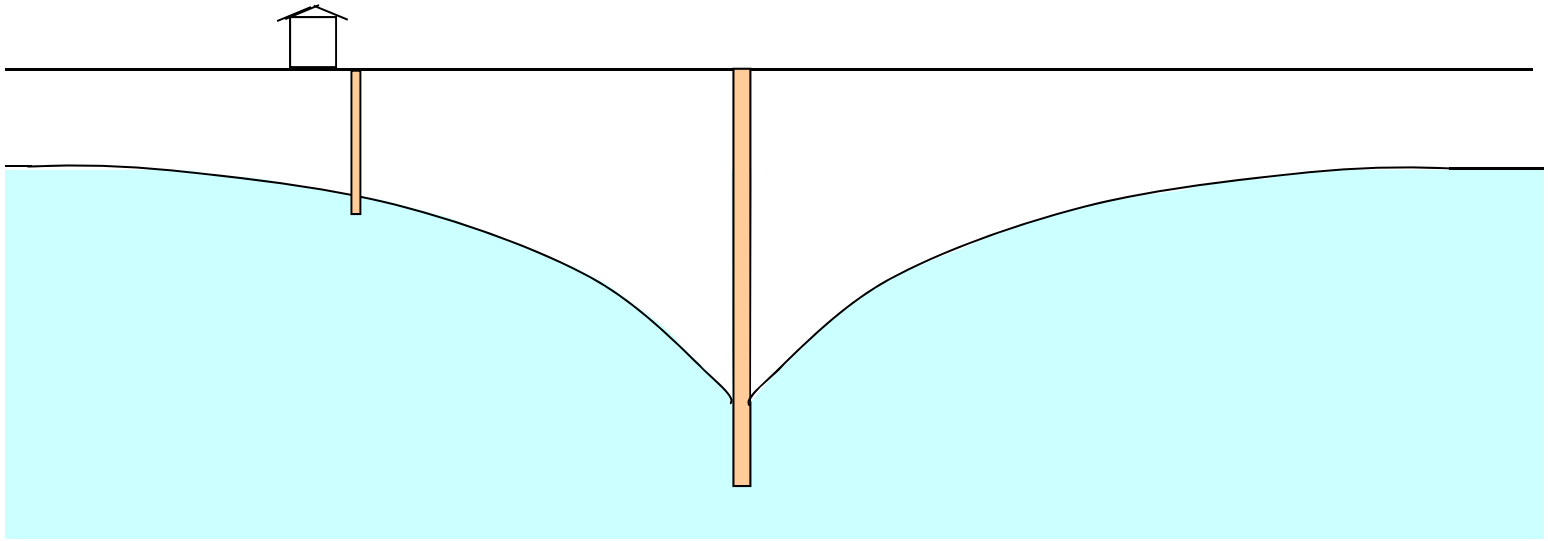
- 0.67 AF/yr vs. 12.3 AF in 2 weeks



- 0.67 AF/yr vs. 12.3 AF in 2 weeks

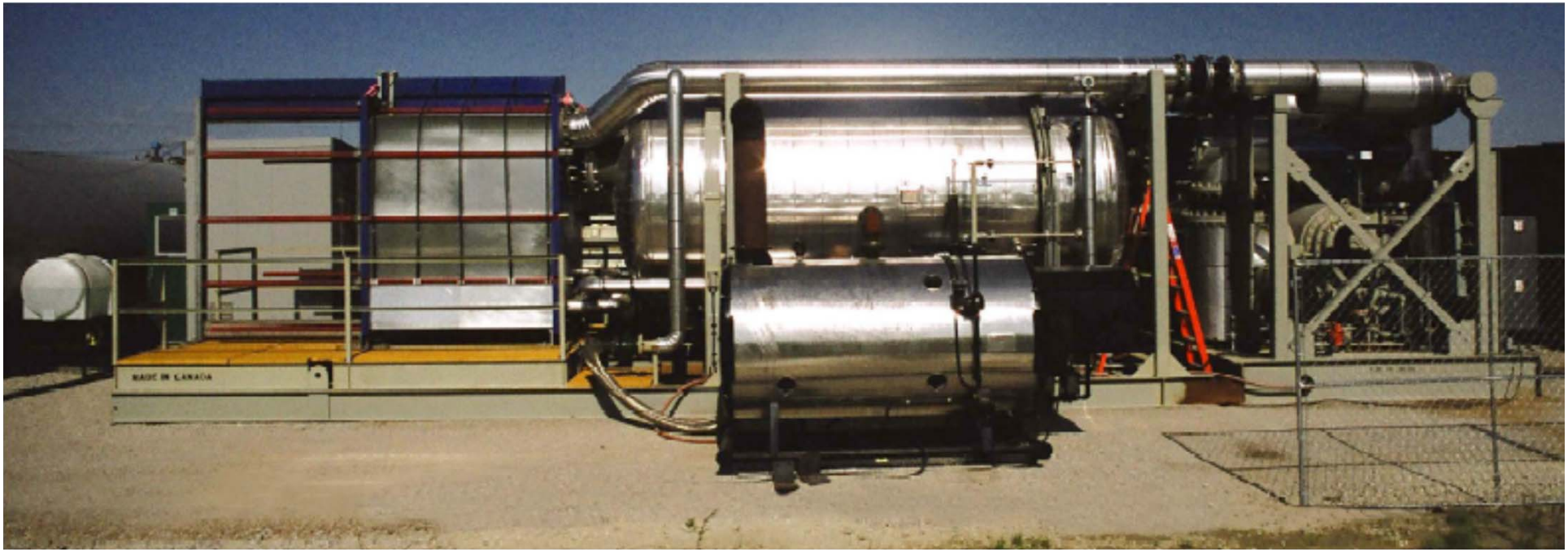


- 0.67 AF/yr vs. 12.3 AF in 2 weeks (several times?)

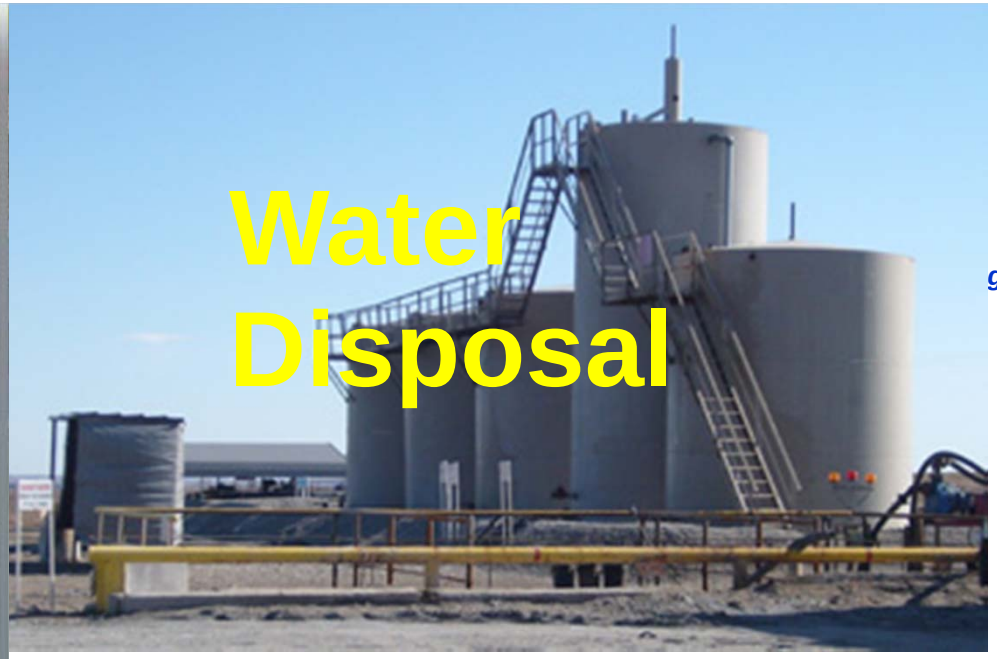


Industry actively working on reducing its water footprint

- Recycling of flow-back water
- Use of brackish water + appropriate additives
- Alternative water sources: WWTP, rain+stock ponds
- Less water-intensive techniques / different fluid




Contamination Issues



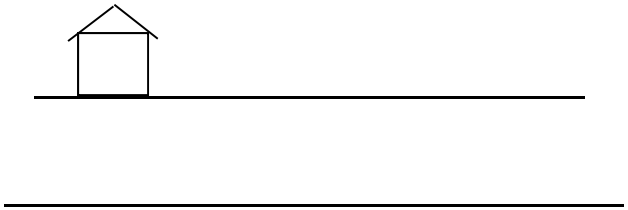
gy

…but all auxiliary activities

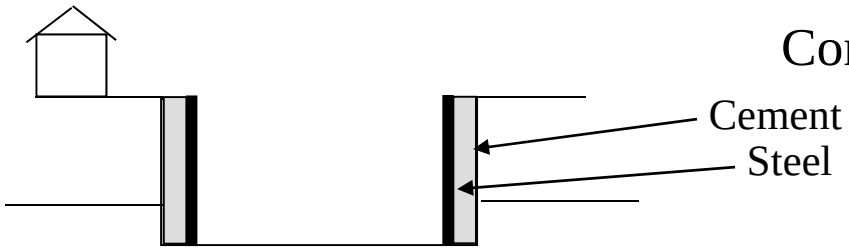
Well casing integrity

- Need to protect USDW (<10,000 mg/L) – surface casing
- Surface injection pressures are high: 3,000-5,000 psi
- Risk for each well is low but there are tens of thousands of wells
- Still, only a few documented cases of defective surface casing: need to review all alleged cases of groundwater contamination

Well construction

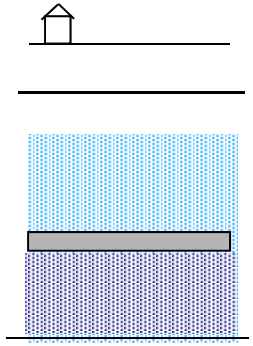


Soil, unconsolidated material

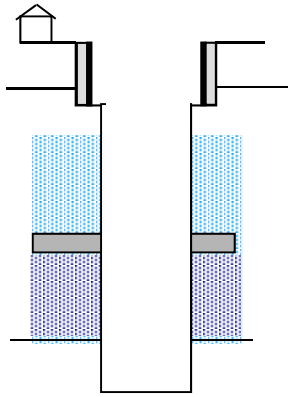


Conductor casing ~20” - ~30”

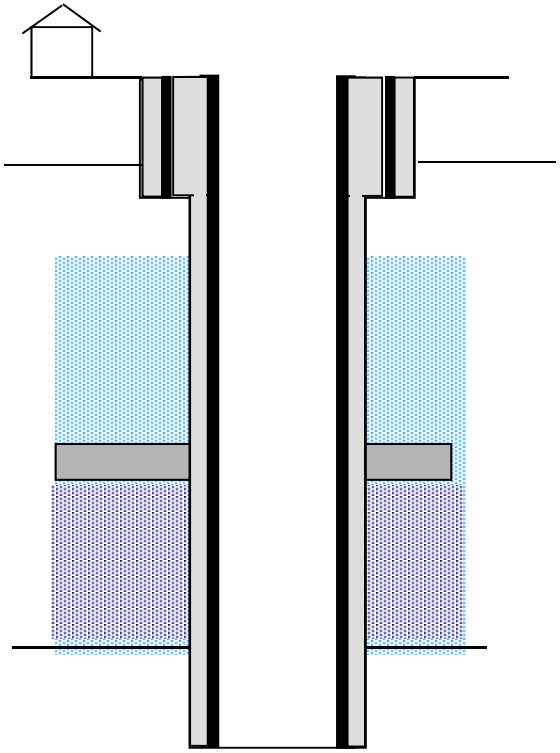
Well construction



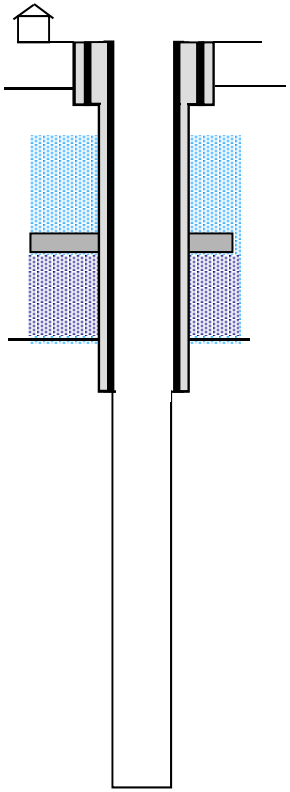
USDW

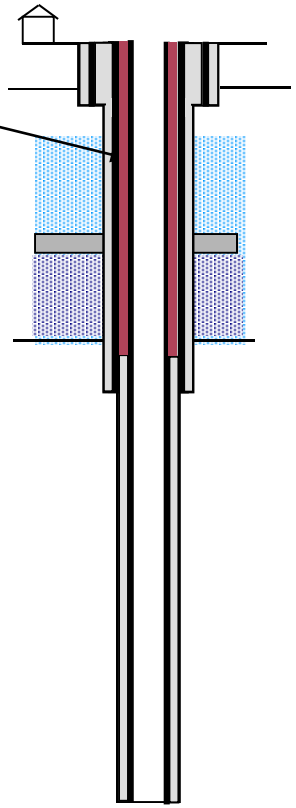


Surface casing - ~13”



Well construction

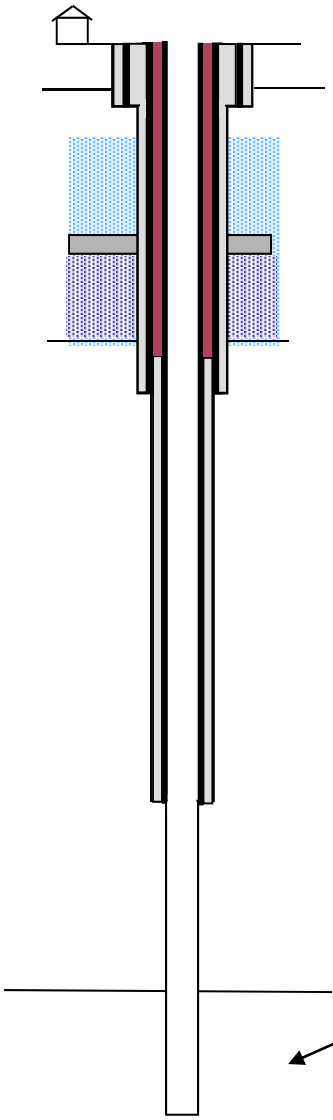




Drilling mud /
Cement

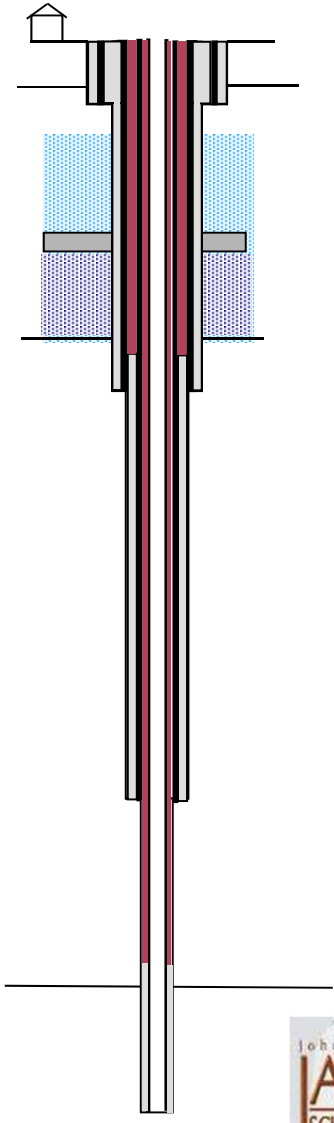
Intermediate Casing – 7” - 9”

Well construction

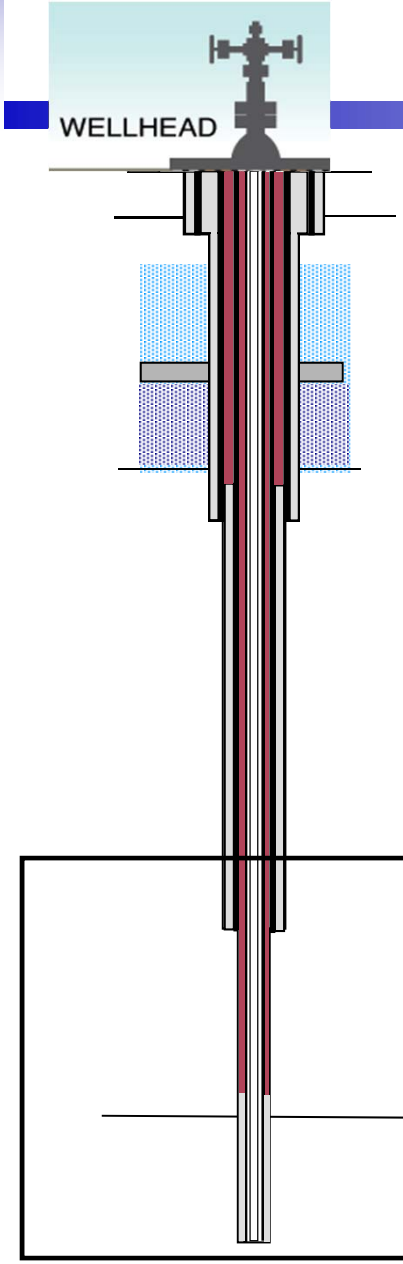


Production casing

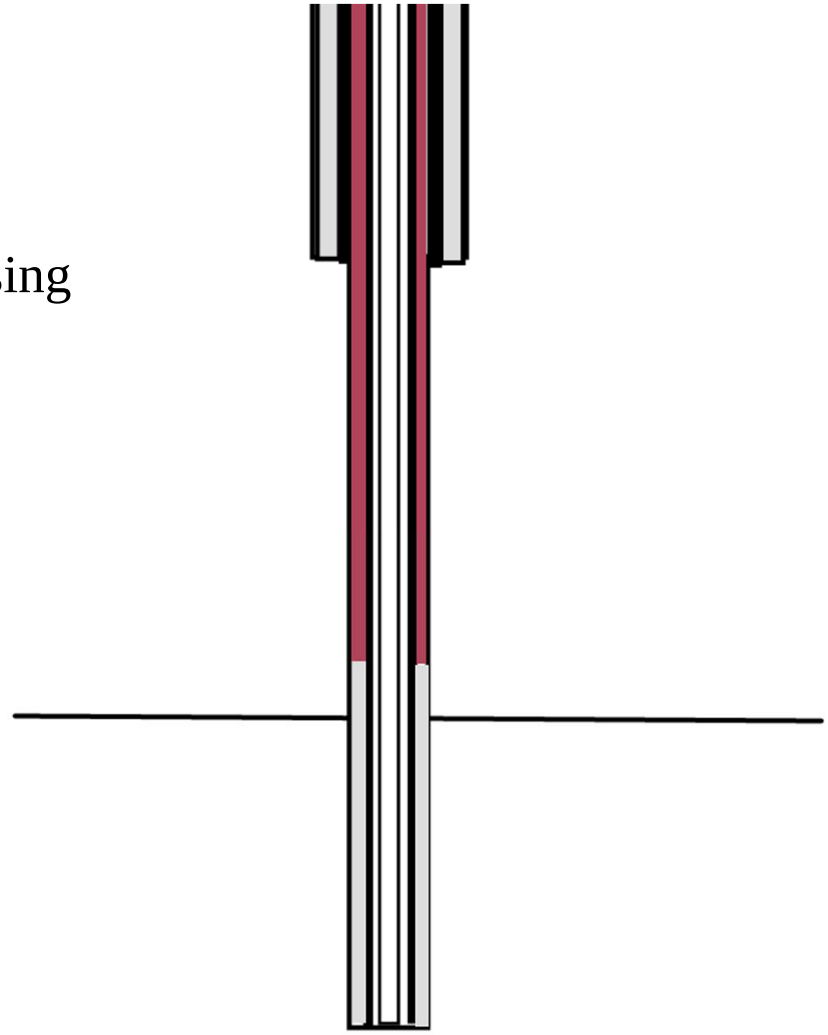
Production interval



Well construction



Production casing
Tubing
Annulus
Liner

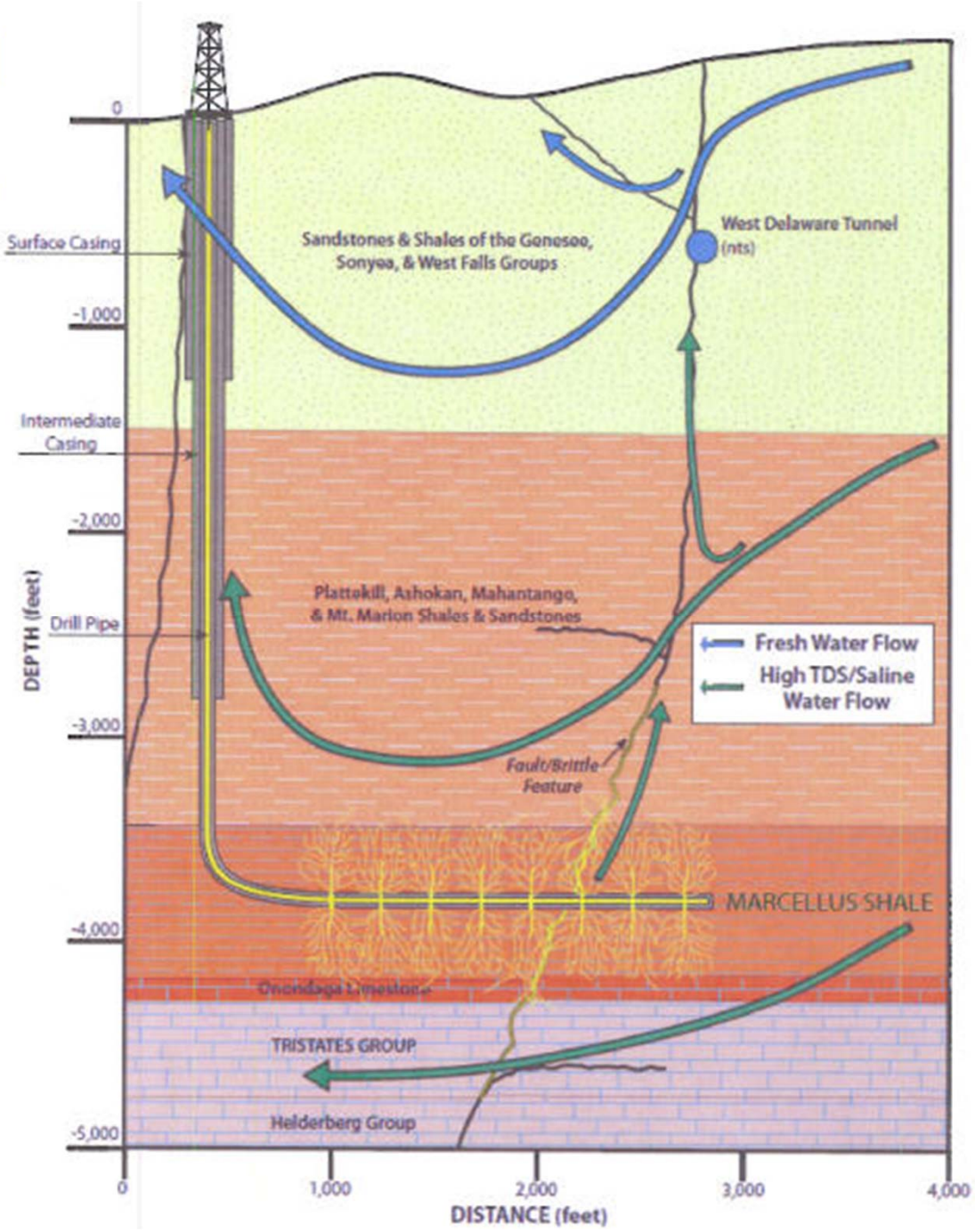


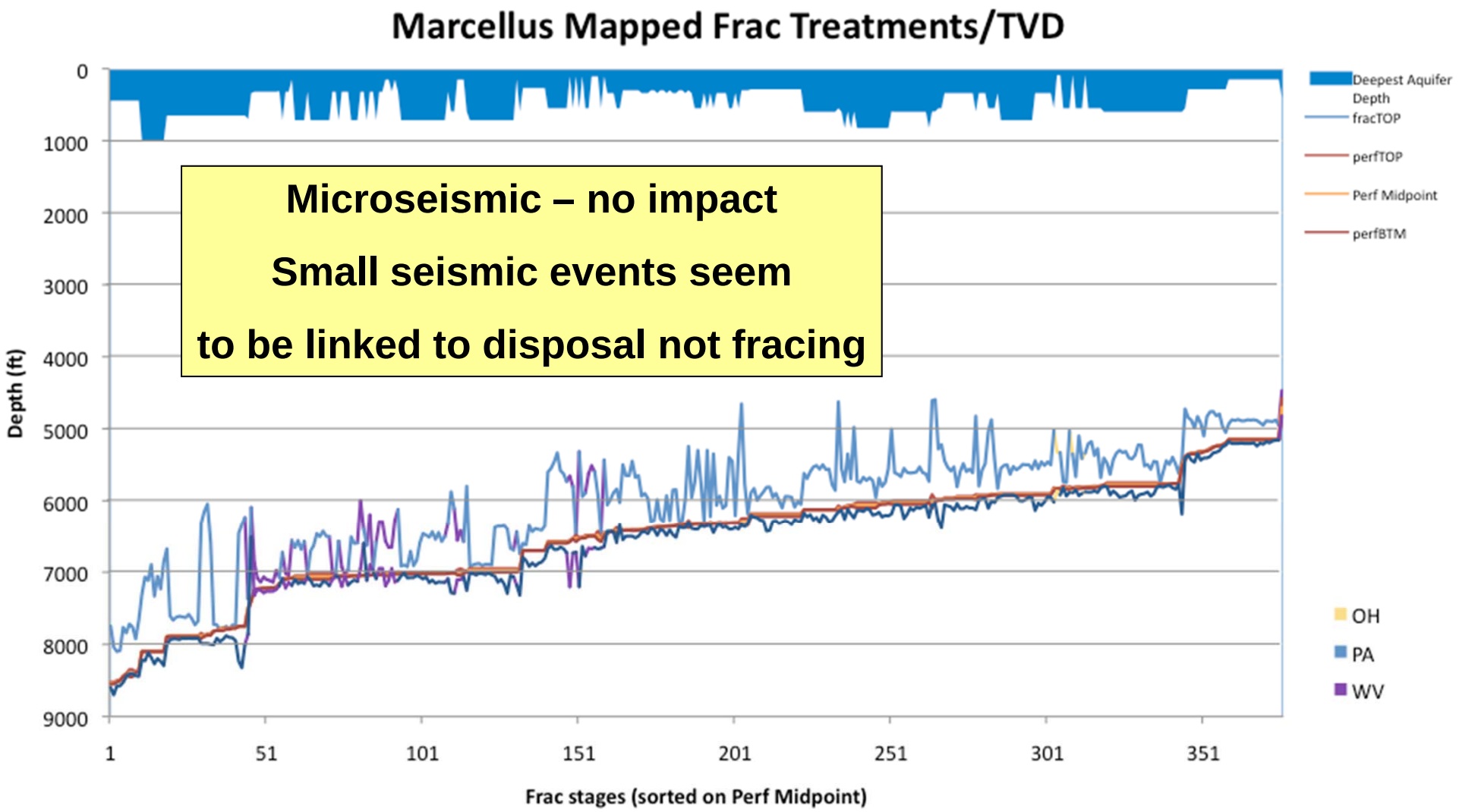
Another Issue: Natural Fractures

- Hazen and Sawyer (2009) is a consultant report that critically evaluates the Environmental Impact Survey of shale gas production produced by the New York state to the New York City Department of Environmental Protection.

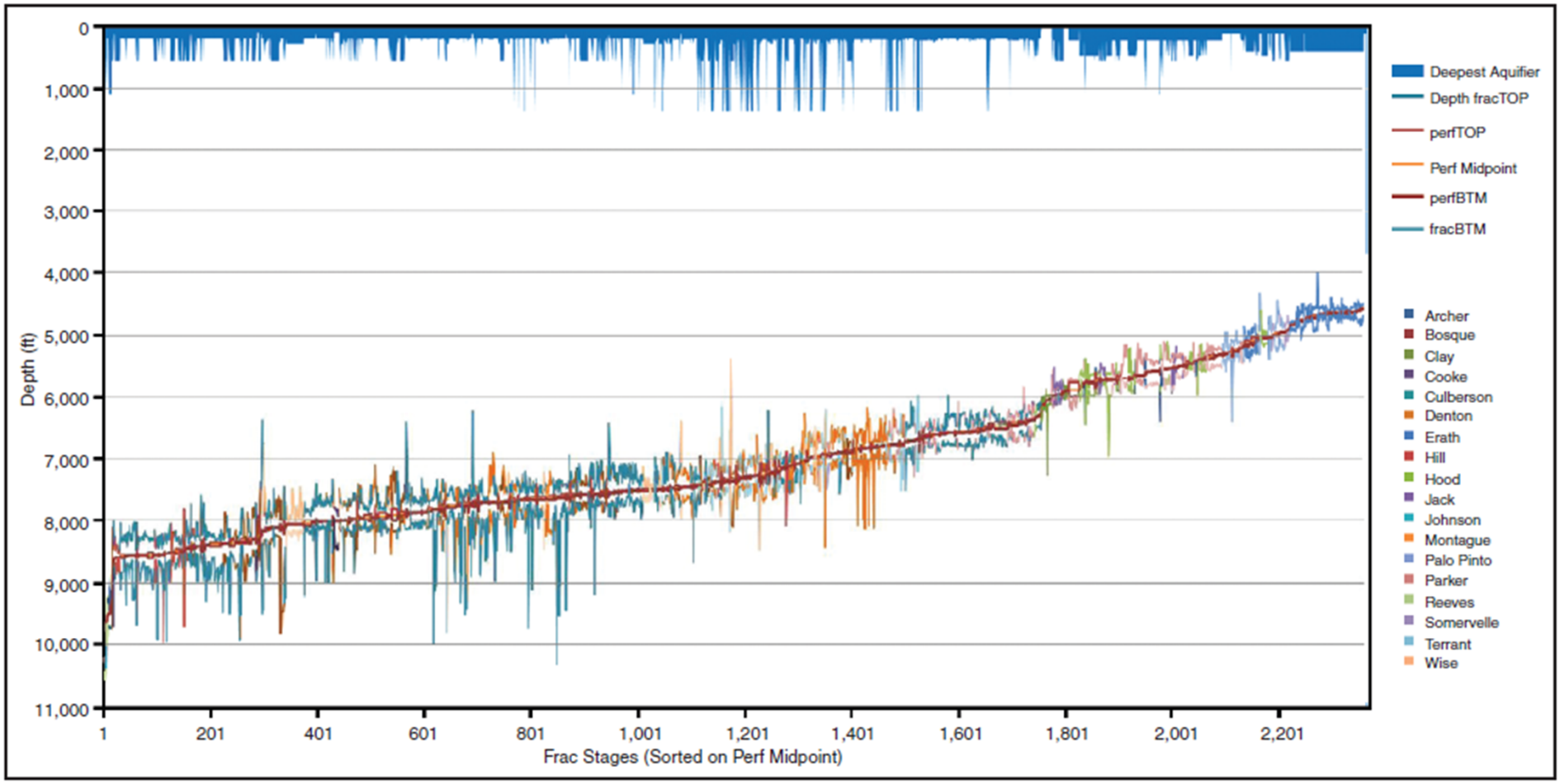
Another

- Hazen an ensive hydraulic contamina aults and fractu





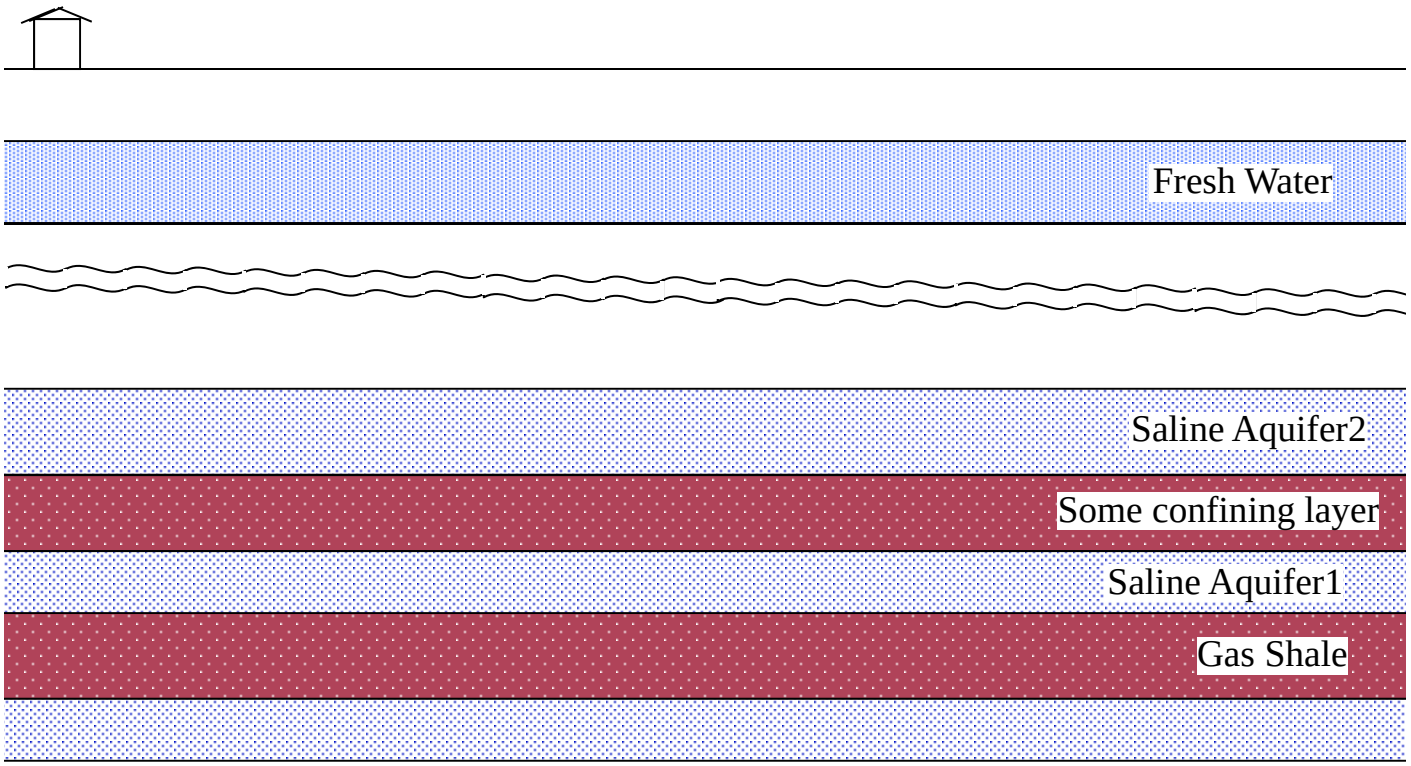
Courtesy Kevin Fisher, Pinnacle

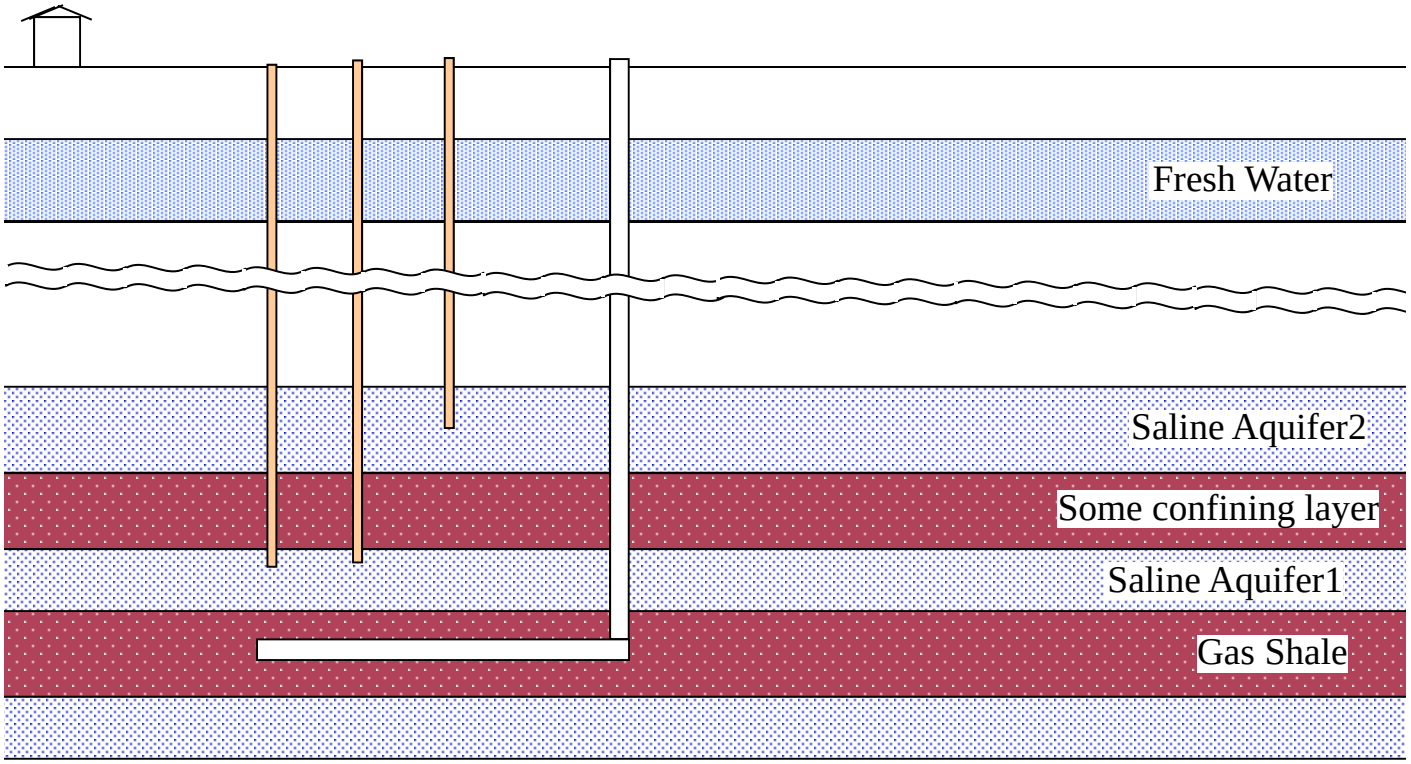


Courtesy Kevin Fisher, Pinnacle

What I'd like to do:

- Obj.: Assess connectivity of induced and natural fracture system potentially leading to fresh water contamination during a frac job
- Approach: sampling of overlying saline aquifers to detect mixing***


Fresh Water
Saline Aquifer2
Some confining layer
Saline Aquifer1
Gas Shale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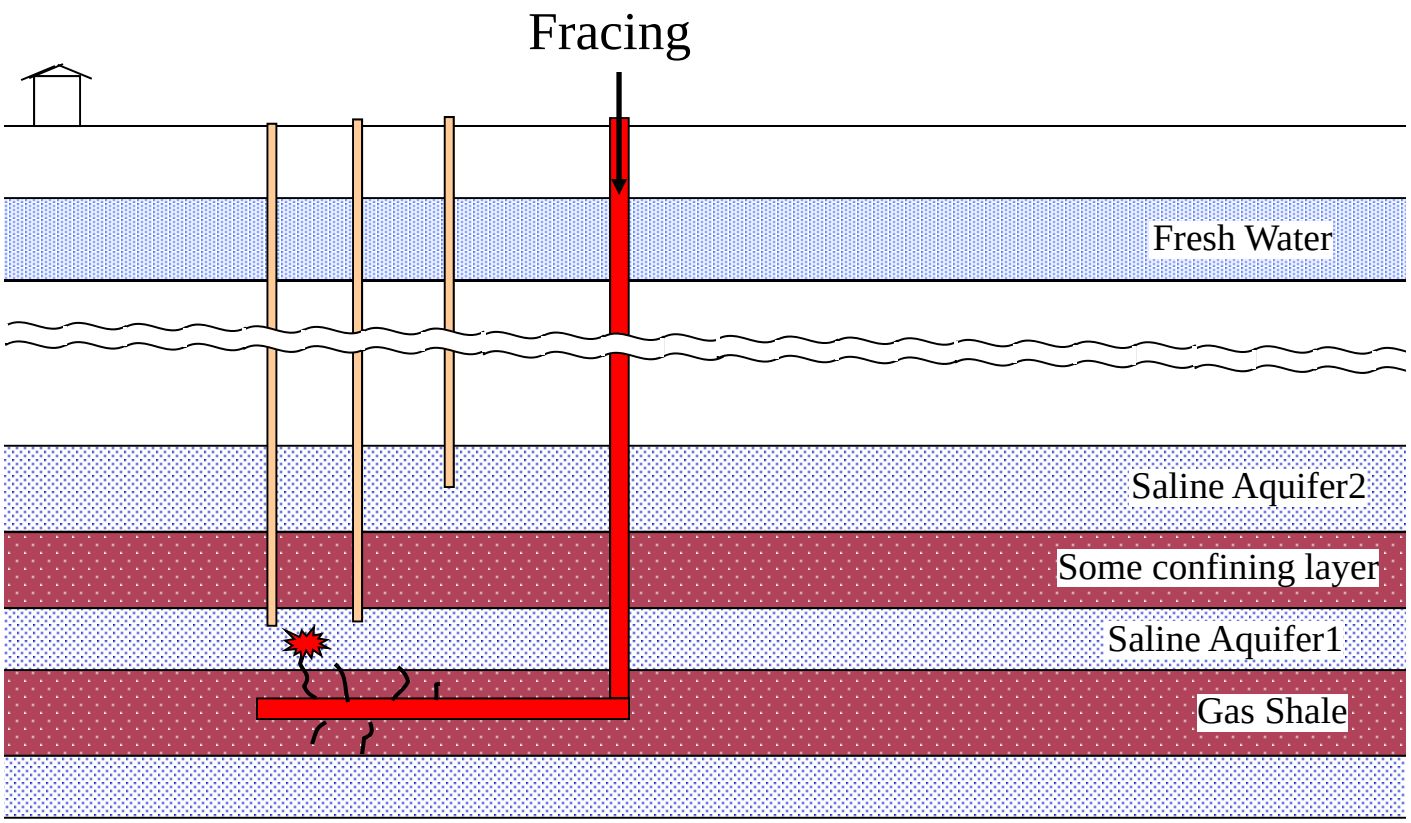
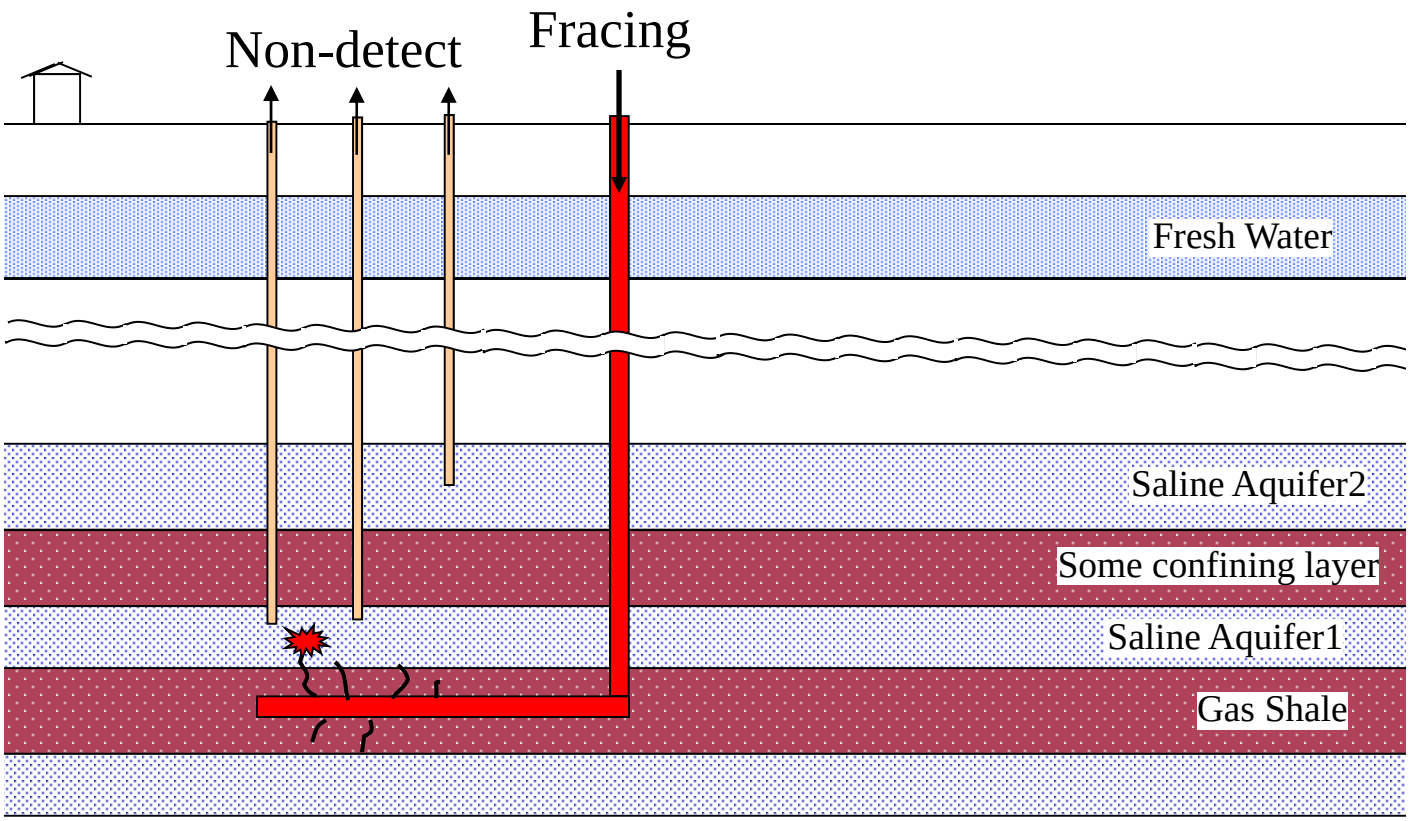
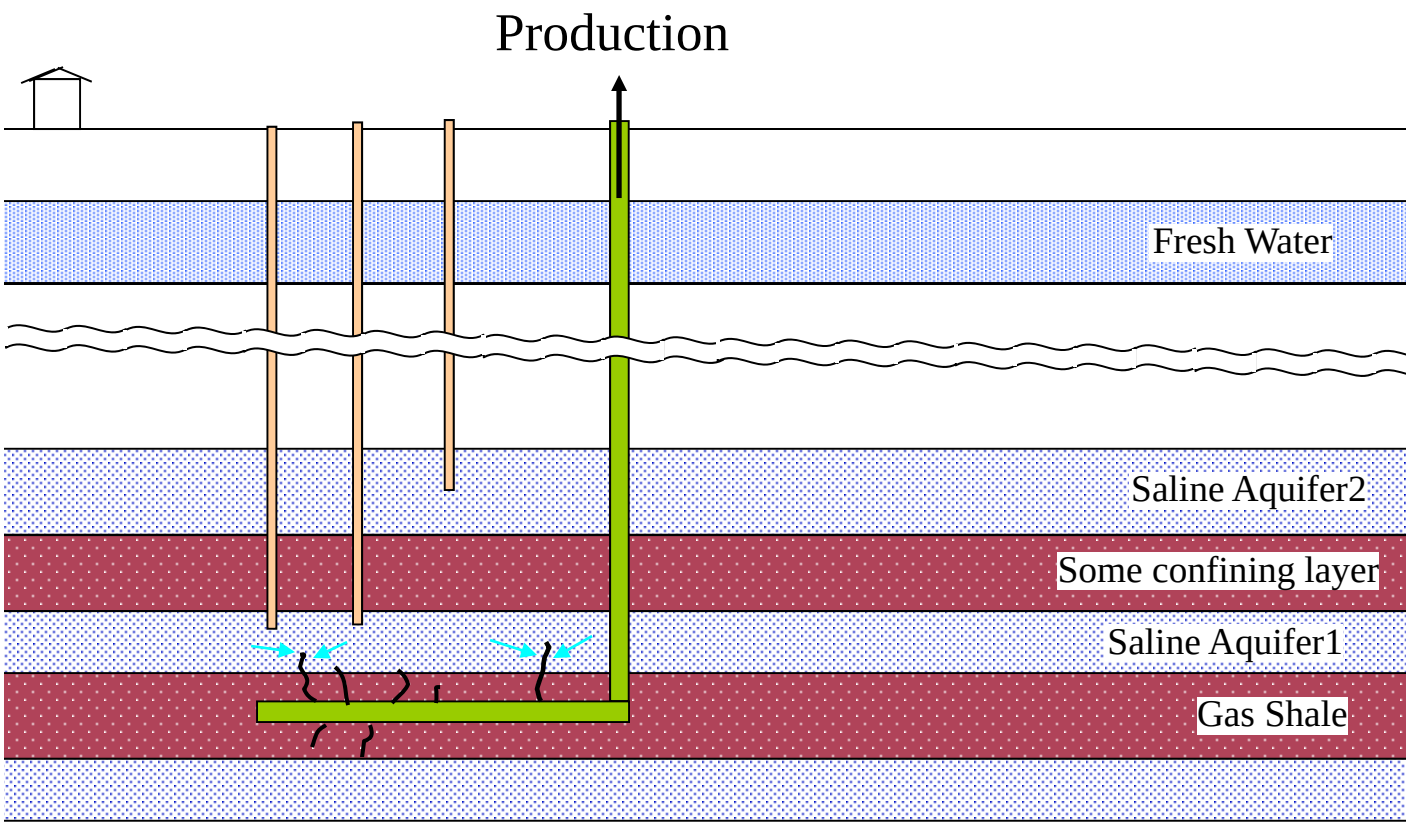
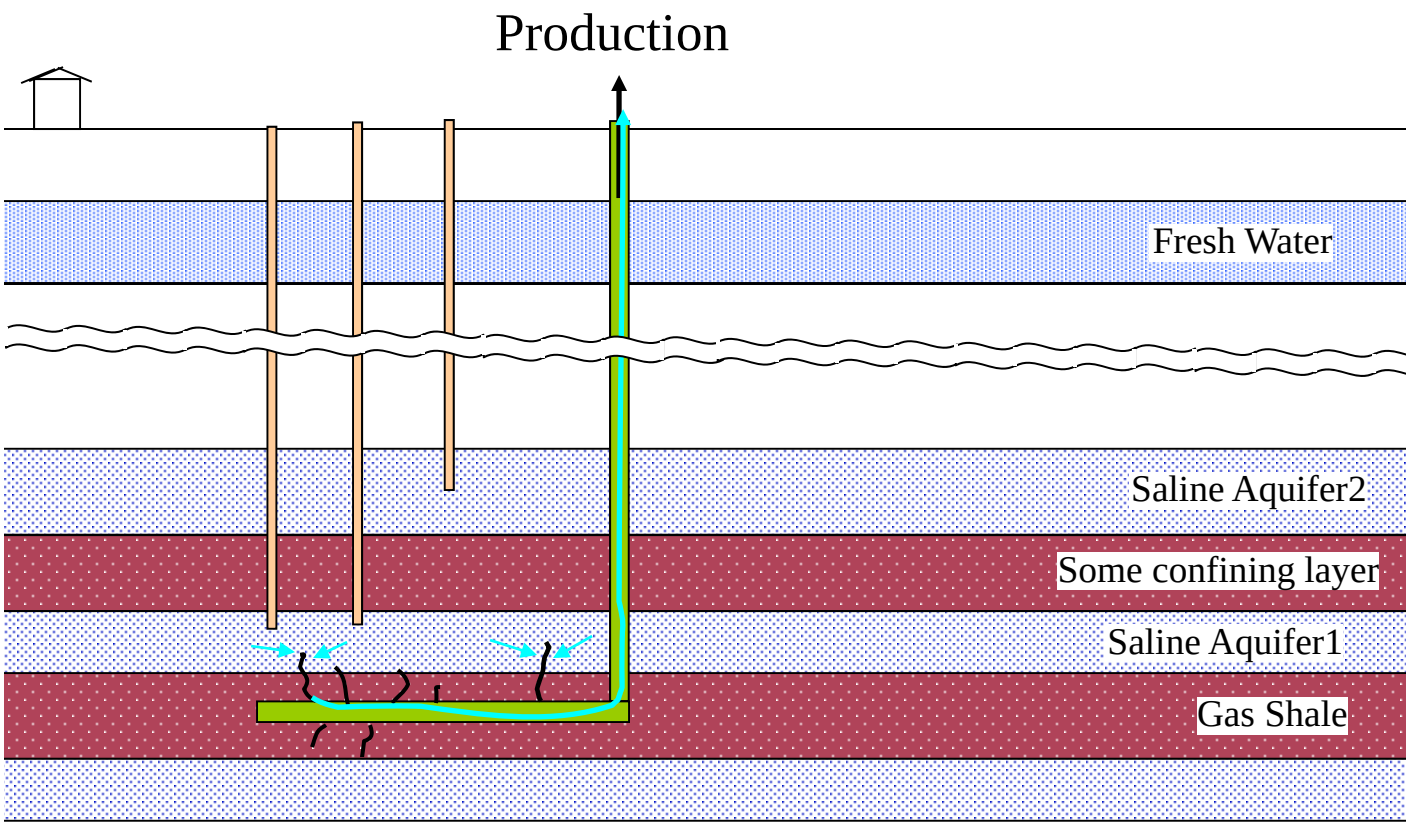

Fracing
Fresh Water
Saline Aquifer2
Some confining layer
Saline Aquifer1
Gas Shale


Non-detect
Fracing
Fresh Water
Saline Aquifer2
Some confining layer
Saline Aquifer1
Gas Shale


Production
Fresh Water
Saline Aquifer2
Some confining layer
Saline Aquifer1
Gas Shale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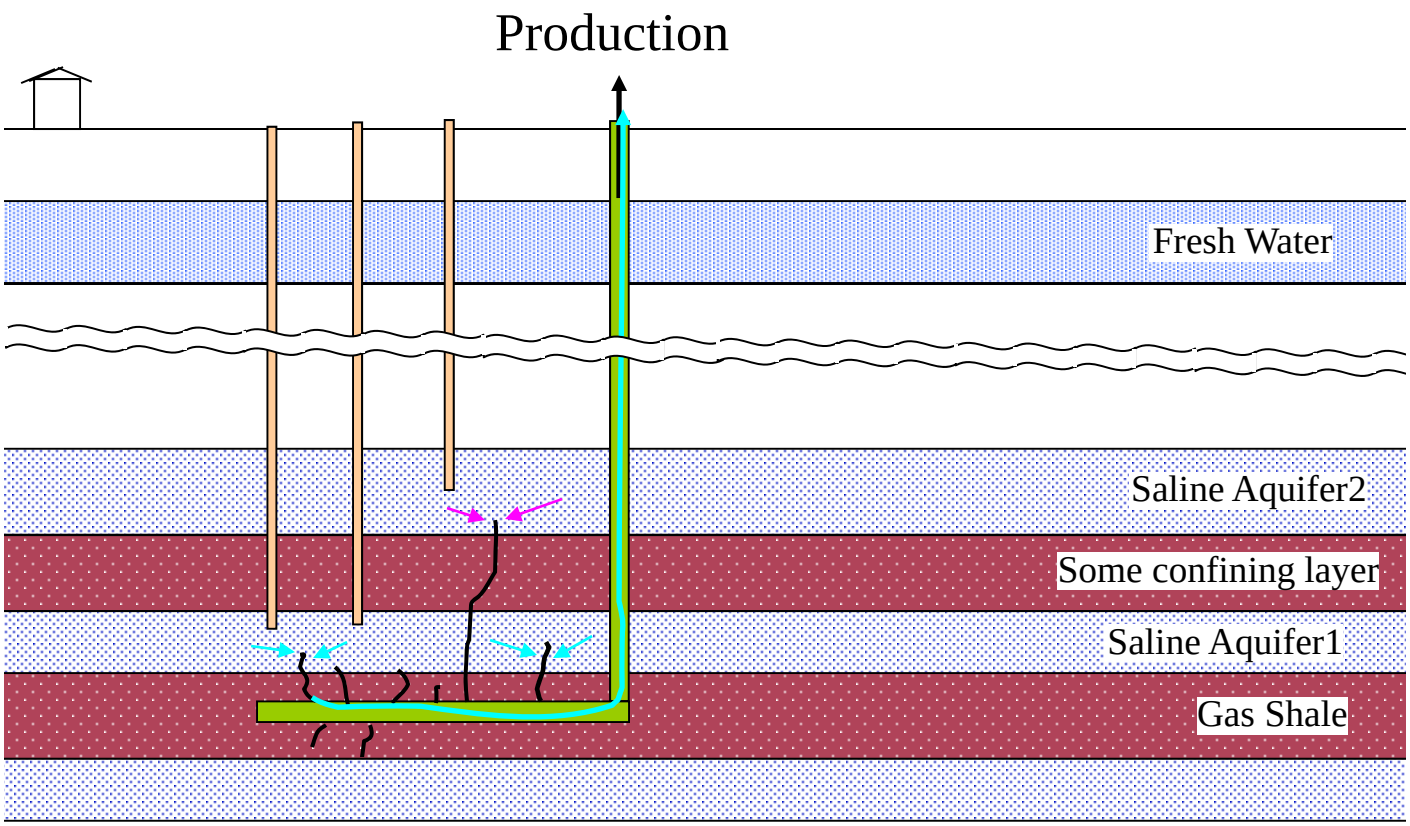
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Fresh Water
Saline Aquifer2
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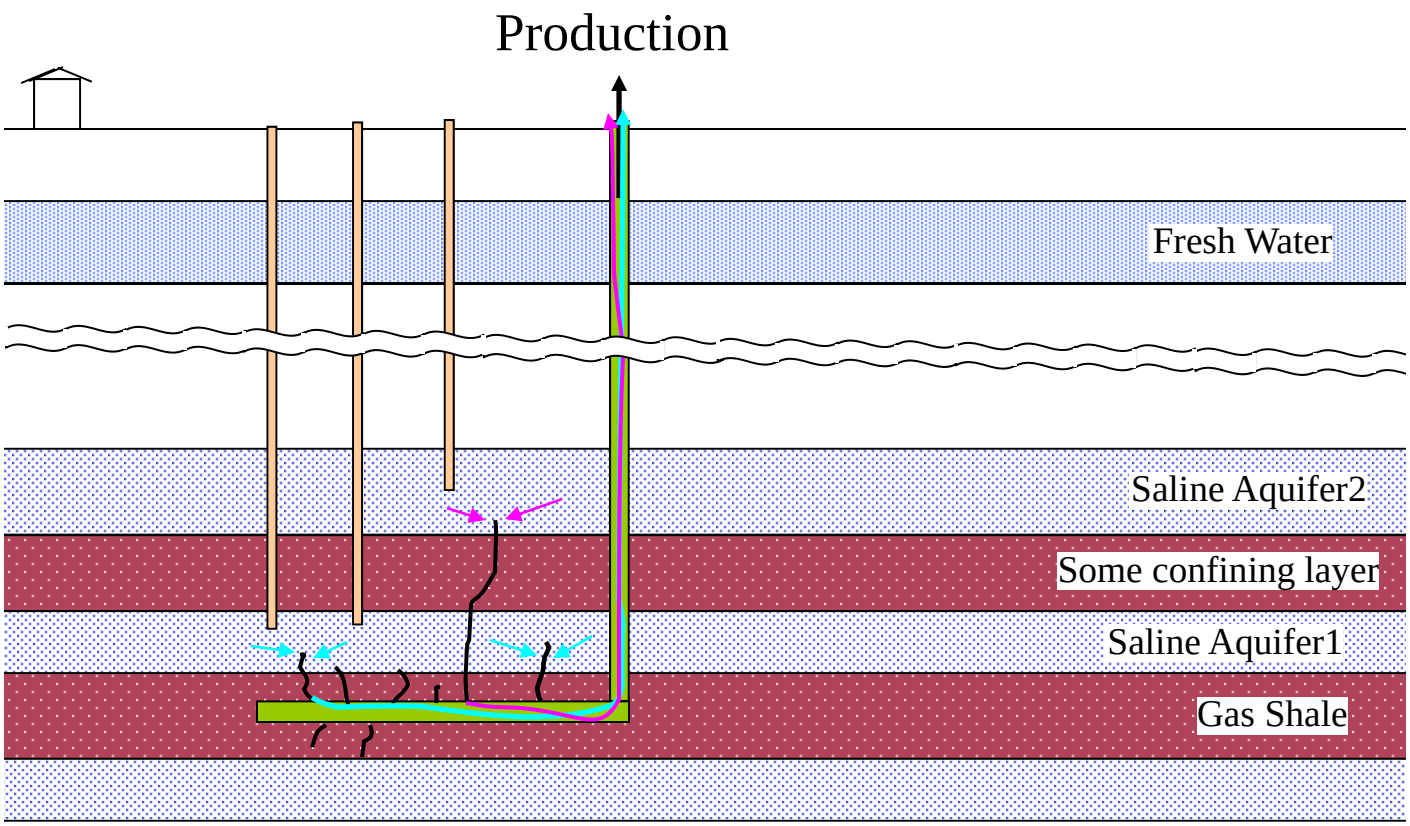
Gas Shale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Fresh Water
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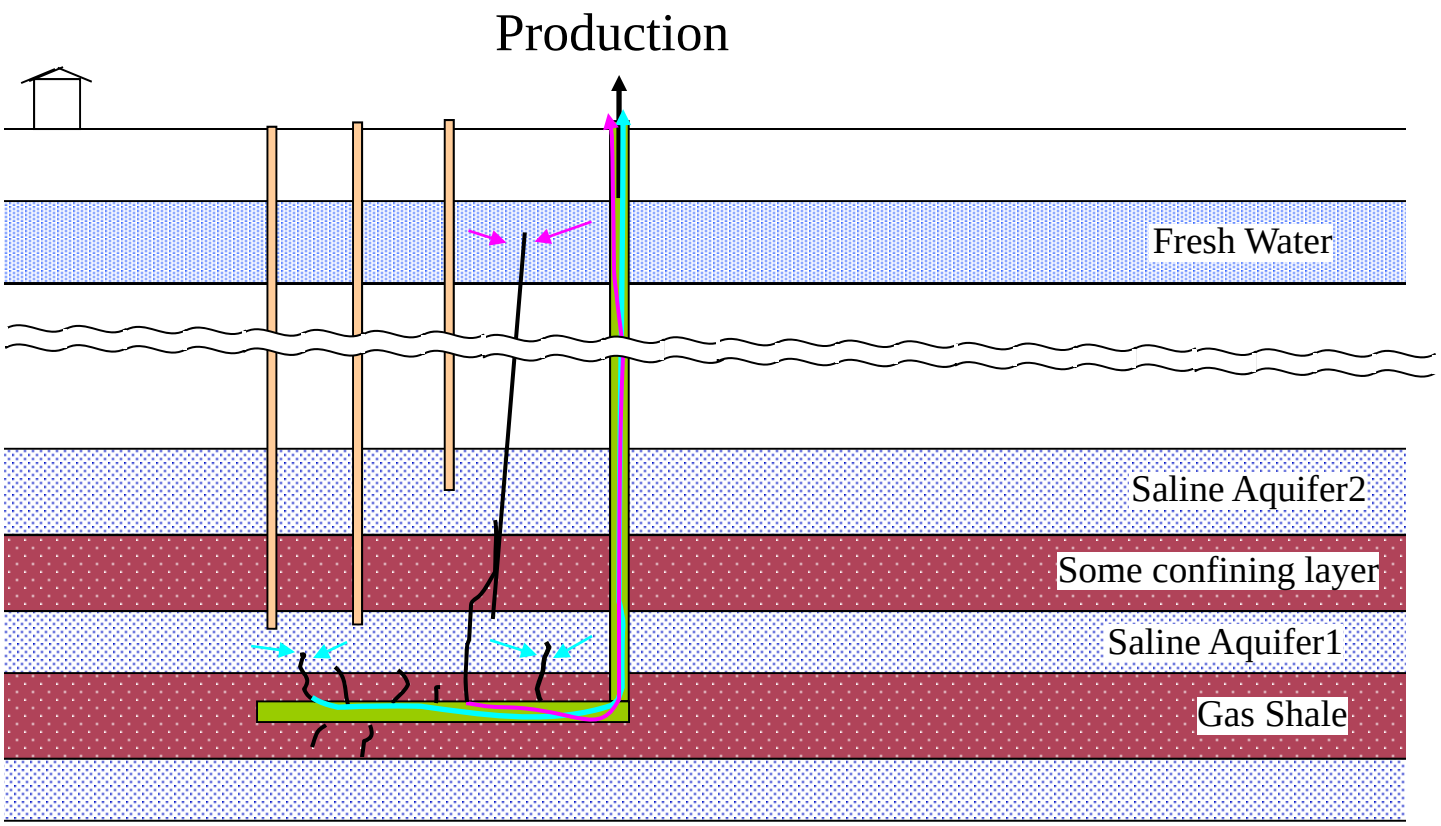
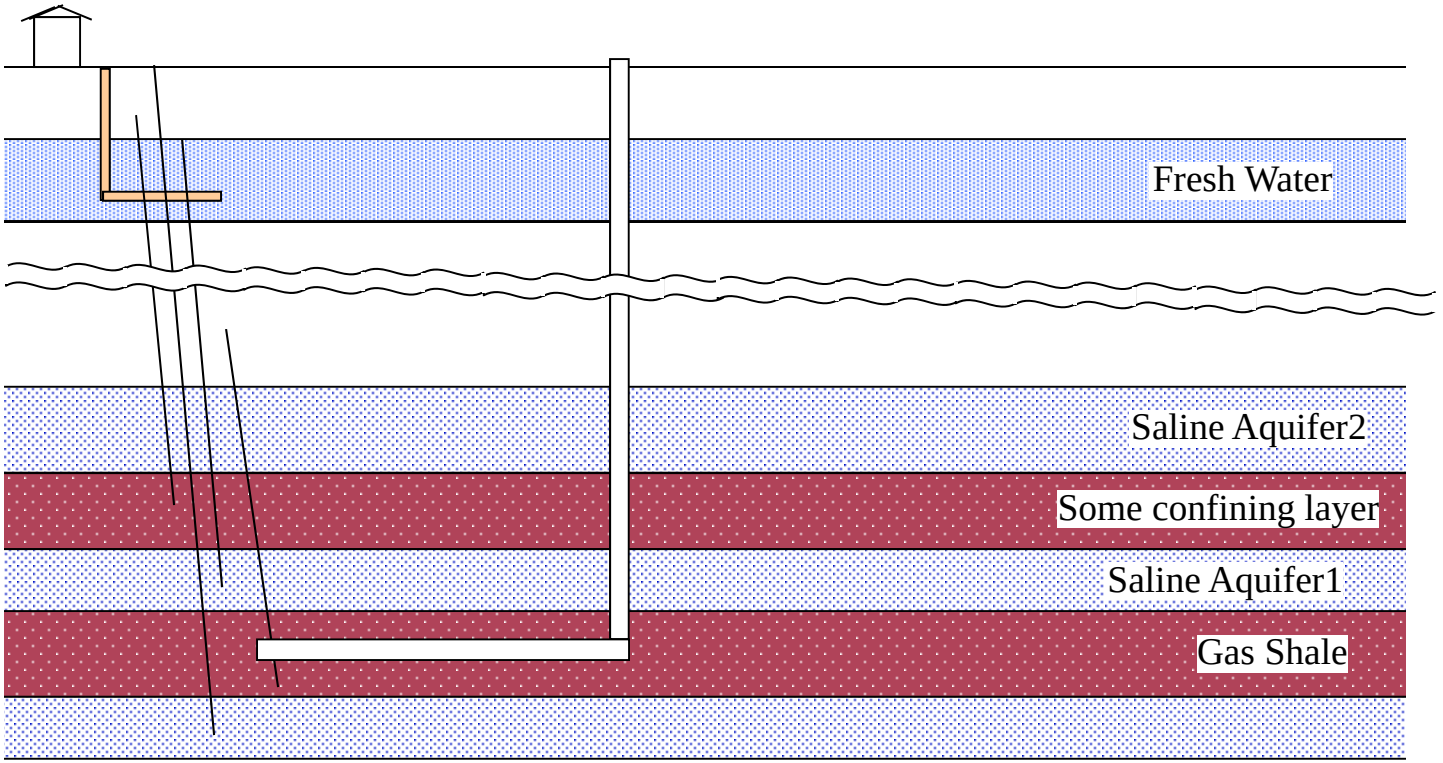

Production
Fresh Water
Saline Aquifer2
Some confining layer
Saline Aquifer1
Gas Shale

- To detect potential leaks before they impact a fresh-water well: direct sampling of overlying aquifers not likely to be useful/successful
- Detection of contribution of overlying aquifers mixed in the flow back / produced water stream. using natural isotopes as natural tracers
- Chemical and isotopic characterization of frac water, produced water, and overlying aquifers:

Sampling along lineamenta



Other ideas for further work

- Shallow horizontal well through a lineament ~above frac job(s)
- Better understanding of the role of natural fractures
- Study of natural attenuation of contaminants / additives (batch, column experiments & field and modeling verification) – Composition of frac fluids
- ……

Questions, comments?