A grayscale background image of an oil rig or drilling platform, showing a tall lattice tower structure against a light sky. The rig is positioned in the center of the frame, with some lower-level structures and equipment visible at the base.

Groundwater And Unconventional Natural Gas Development: Lessons From The Barnett and Haynesville Shales

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Role of Unconventional Reservoirs

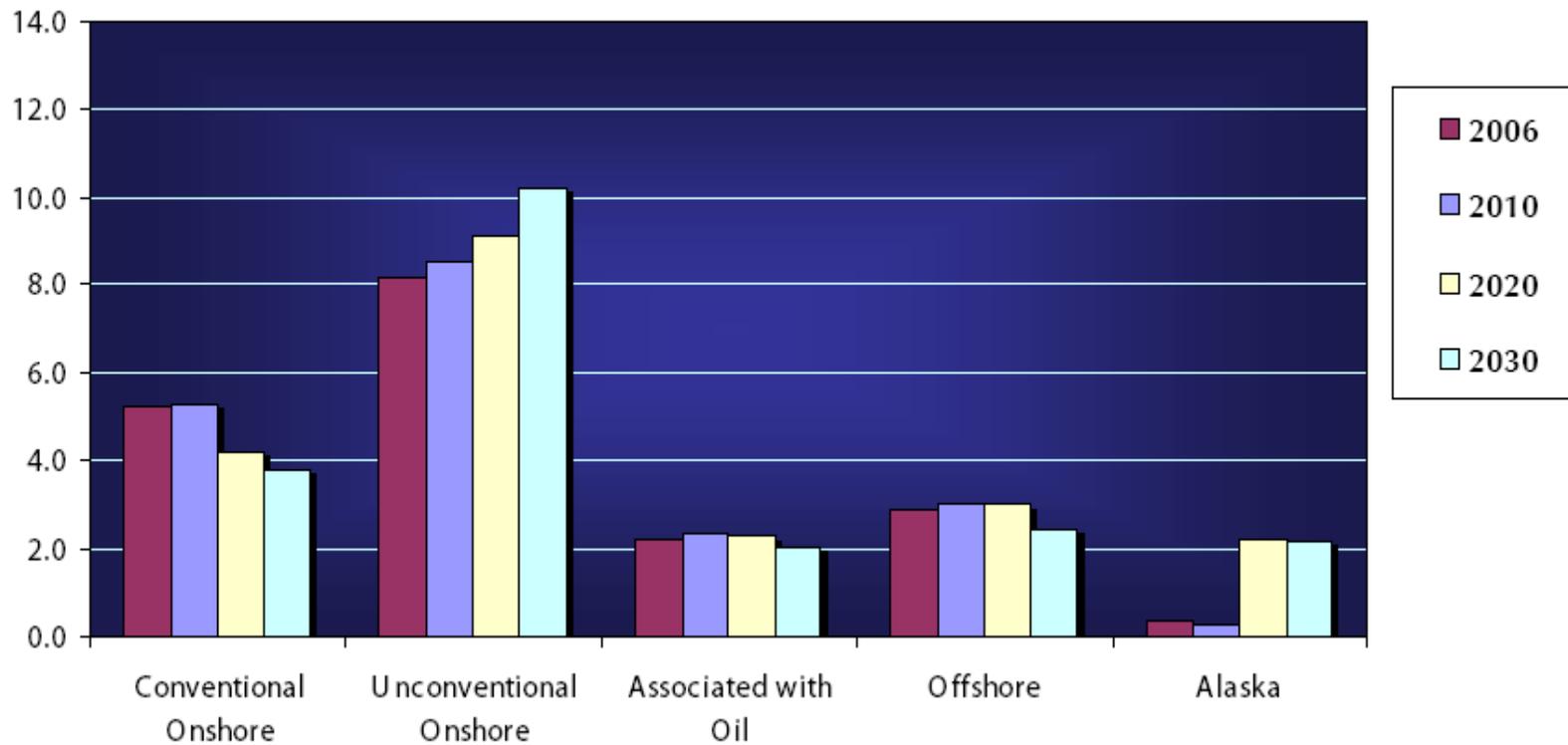
- Increasing volumes of natural gas and oil are coming from unconventional reservoirs:
 - Natural gas
 - Coal beds – western U.S. basins
 - Shale – Barnett in Texas
 - Oil
 - Oil sands – western Canada
 - Shale – Baakin in Montana, North Dakota
- 44% of U.S. gas production was from unconventional reservoirs in 2006 (8 tcf)

Shale Gas and Water

- Shales generally considered source beds in the petroleum cycle – not reservoirs
 - Oil and gas generated there moves to conventional sandstone or limestone reservoirs
- Similarly, shales generally act as aquicludes, not aquifers – impede groundwater movement
 - Groundwater wells go through or to shale beds – don't produce water from the shales

Annual U.S. Natural Gas Production

TCE



Source: EIA Annual Energy Overview 2007

Coalbed Methane Production

(Source: Schlumberger)

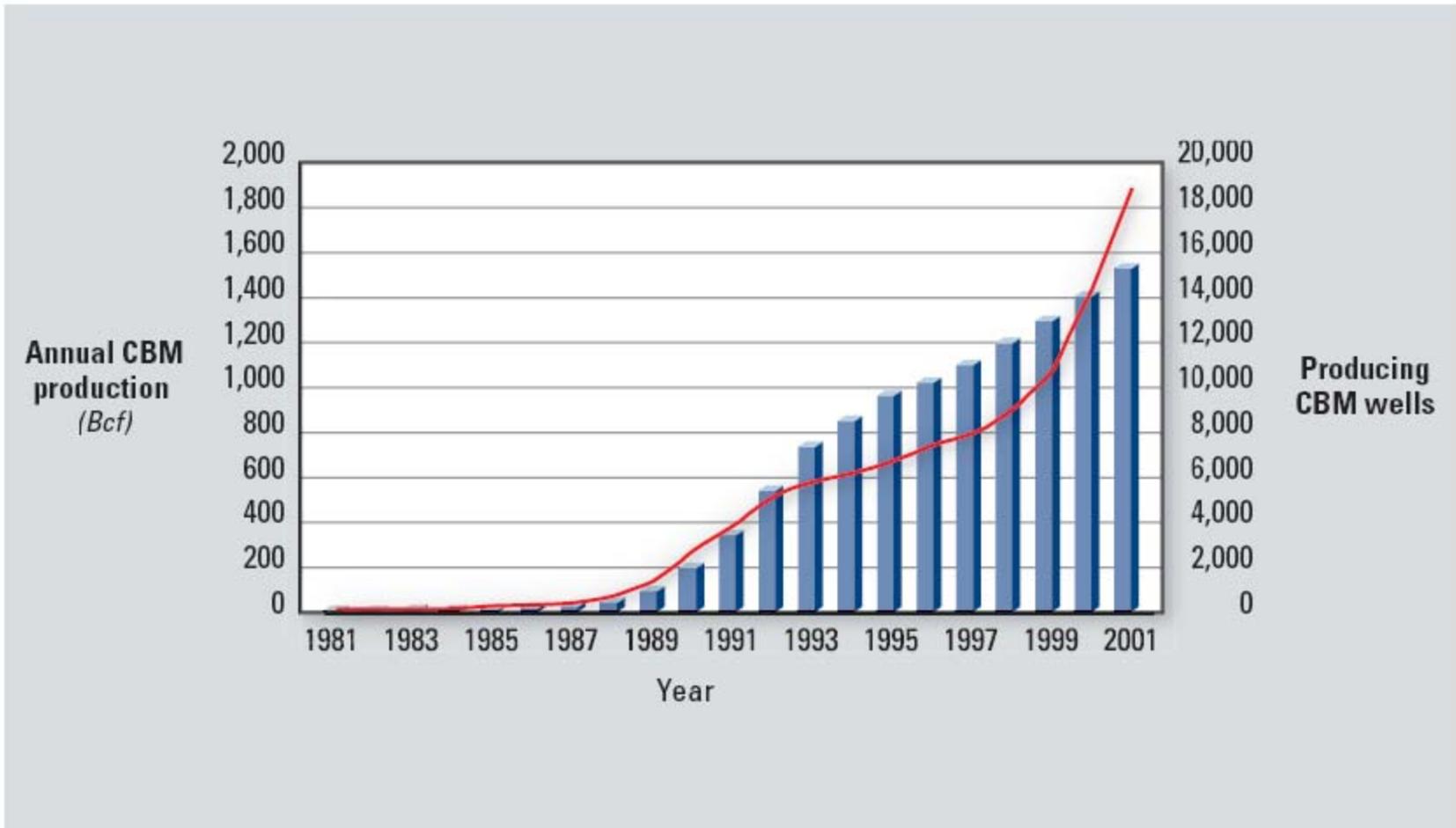


Fig. 2. U.S. CBM production (blue) and number of producing wells (red).

Water Resource Impacts of Unconventional Gas Development

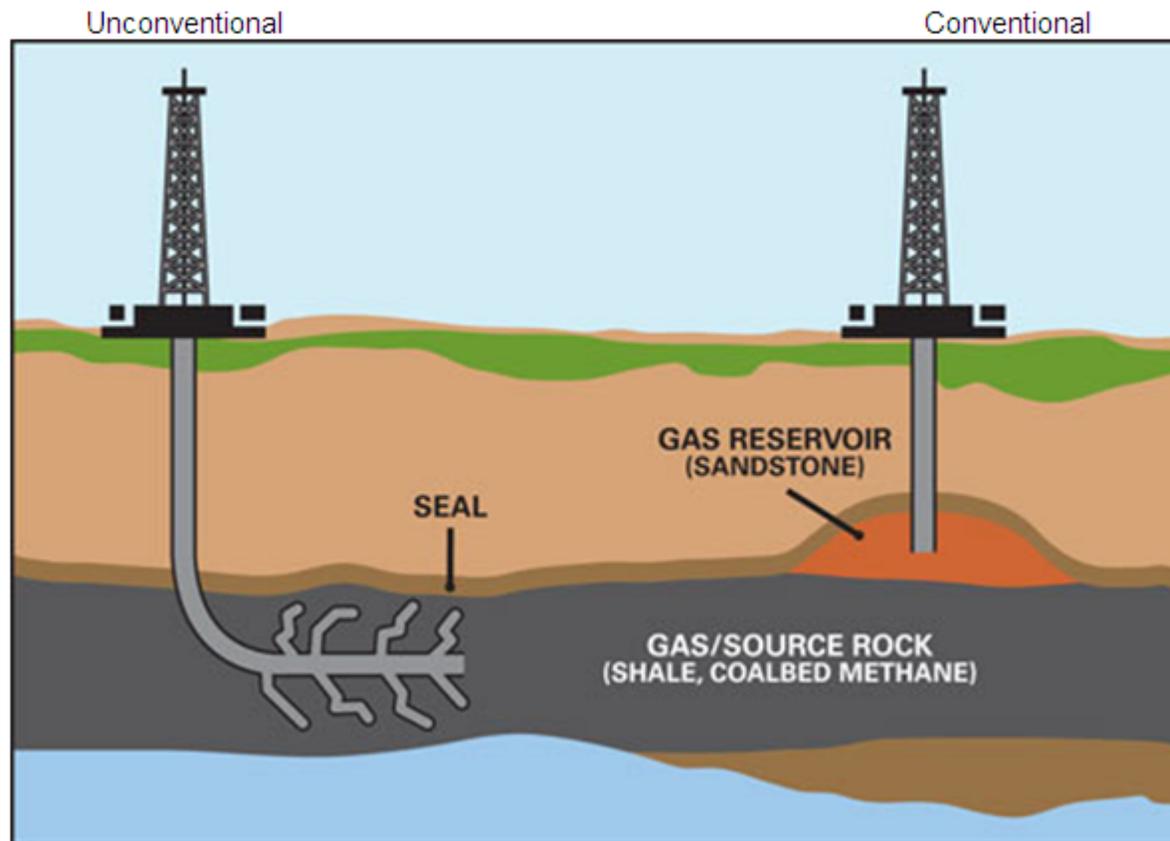
- Coalbed methane production produces large amounts of groundwater as a byproduct
 - Quality varies – some suitable for irrigation, other is not (TDS, SAR issues)
 - Has become a significant landowner issue in the Rocky Mountain CBM producing areas
- Shale gas development uses groundwater for hydraulic fracturing
 - Has raised quantity and quality issues in Barnett and Haynesville Shale areas

Gas Production From Shale

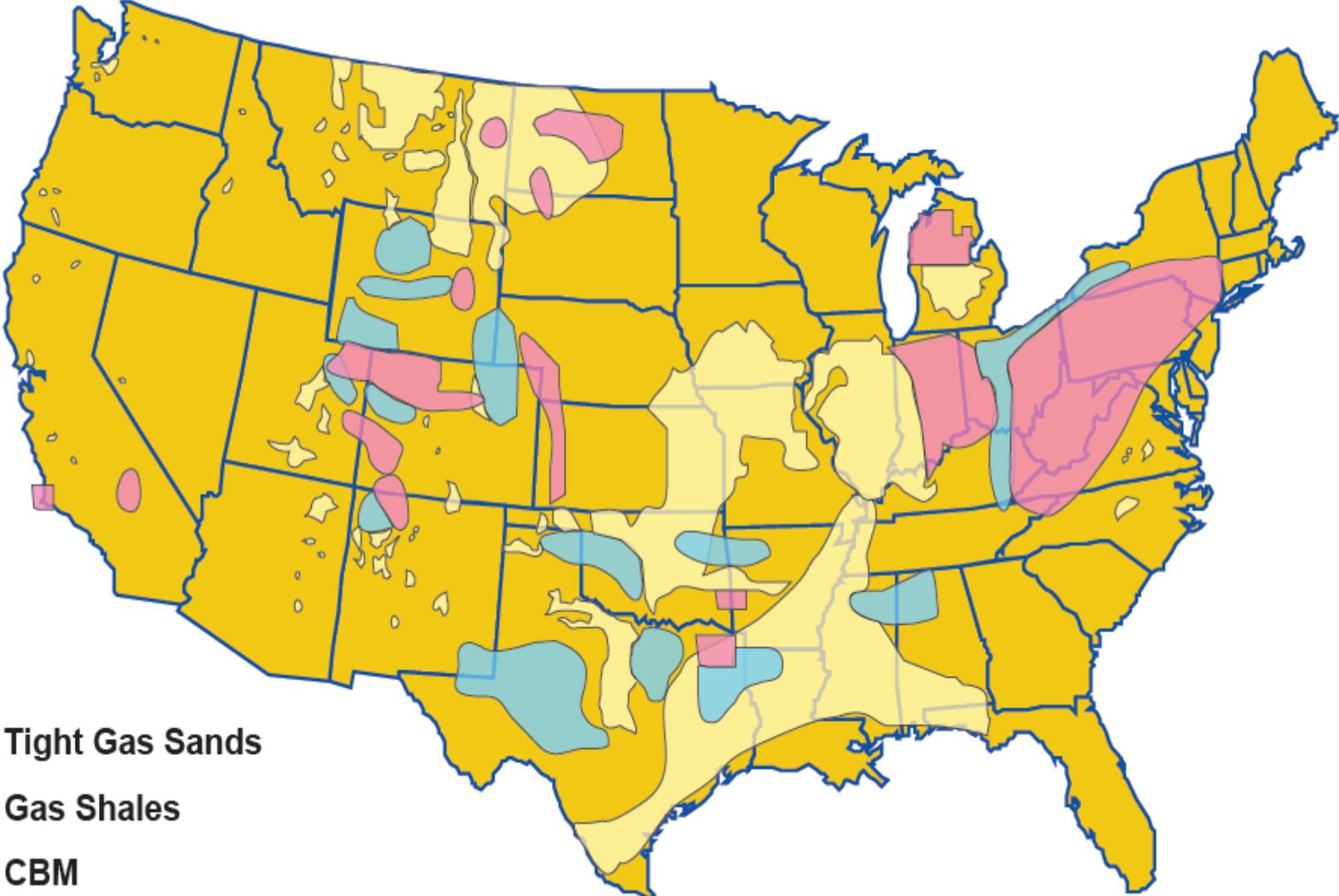
- Horizontal drilling is the rule
- The gas is accessed using a hydraulic fracturing method that injects proppants (sand or manufactured) and water into the rock to free the gas (“fracking”)
- Companies active in shale development: Chesapeake, Anadarko, Range, XTO and Devon
- New **gas fields** are located in Texas, Louisiana, Arkansas, New York, Pennsylvania and other places

Unconventional and Conventional Reservoirs

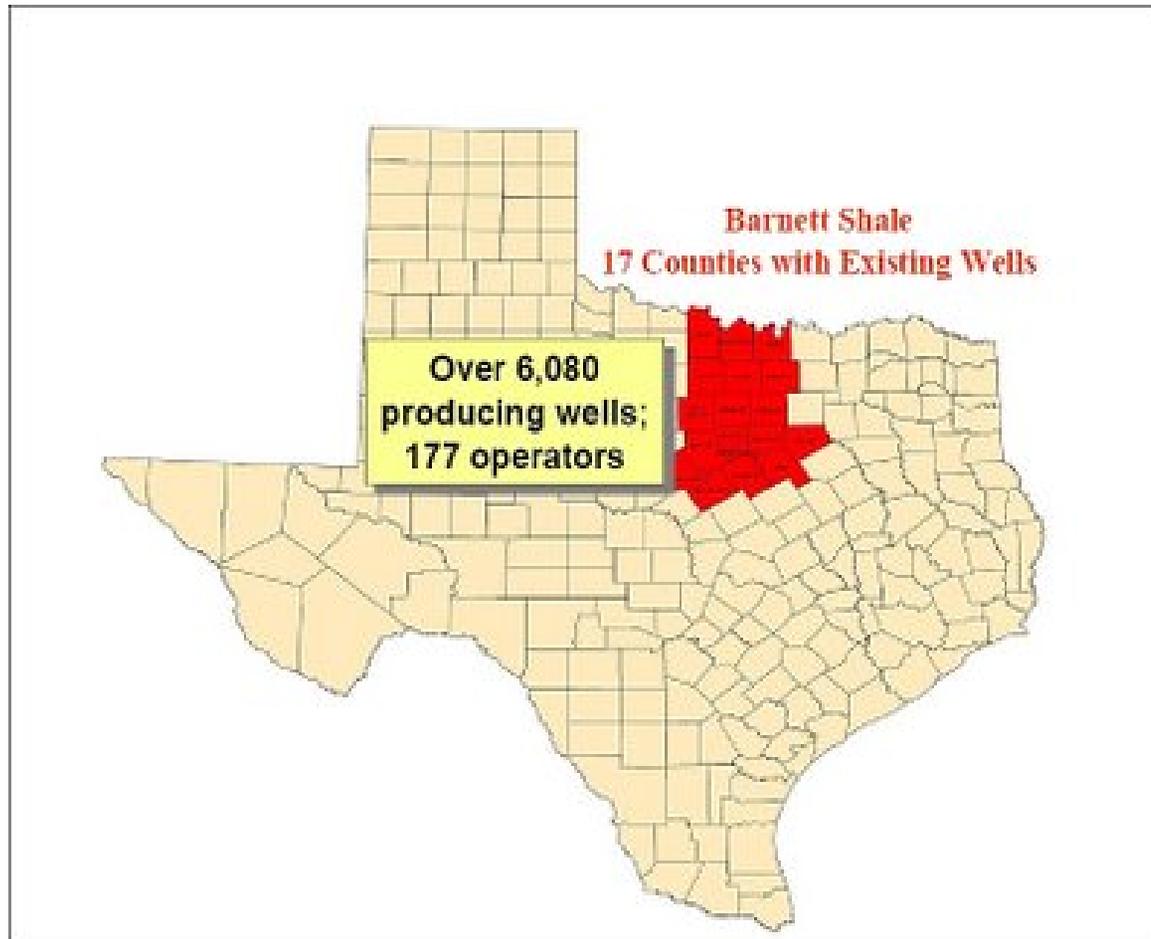
(Source: DTE Energy)



U.S. Unconventional Natural Gas Resources



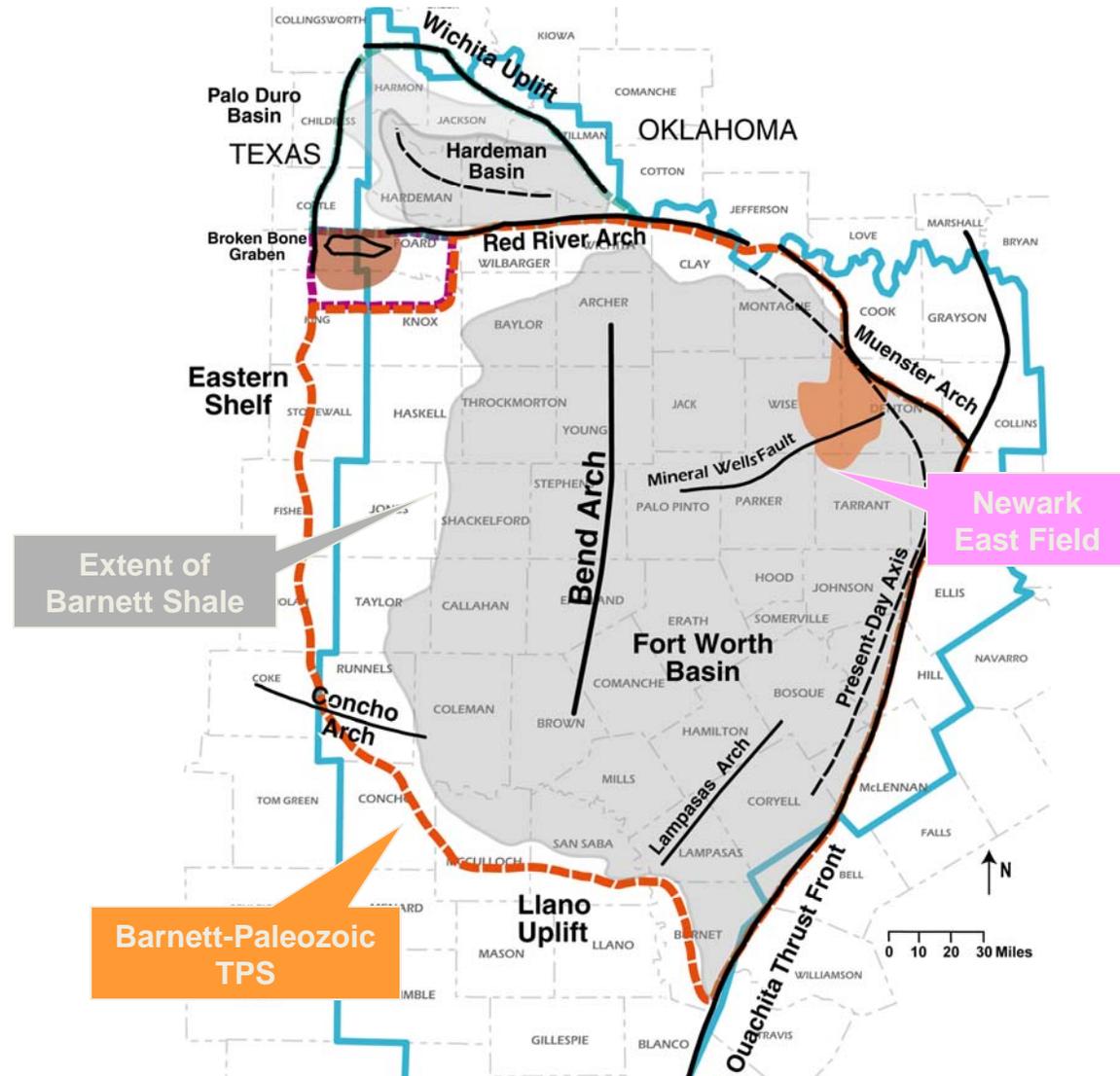
Barnett Shale in Texas



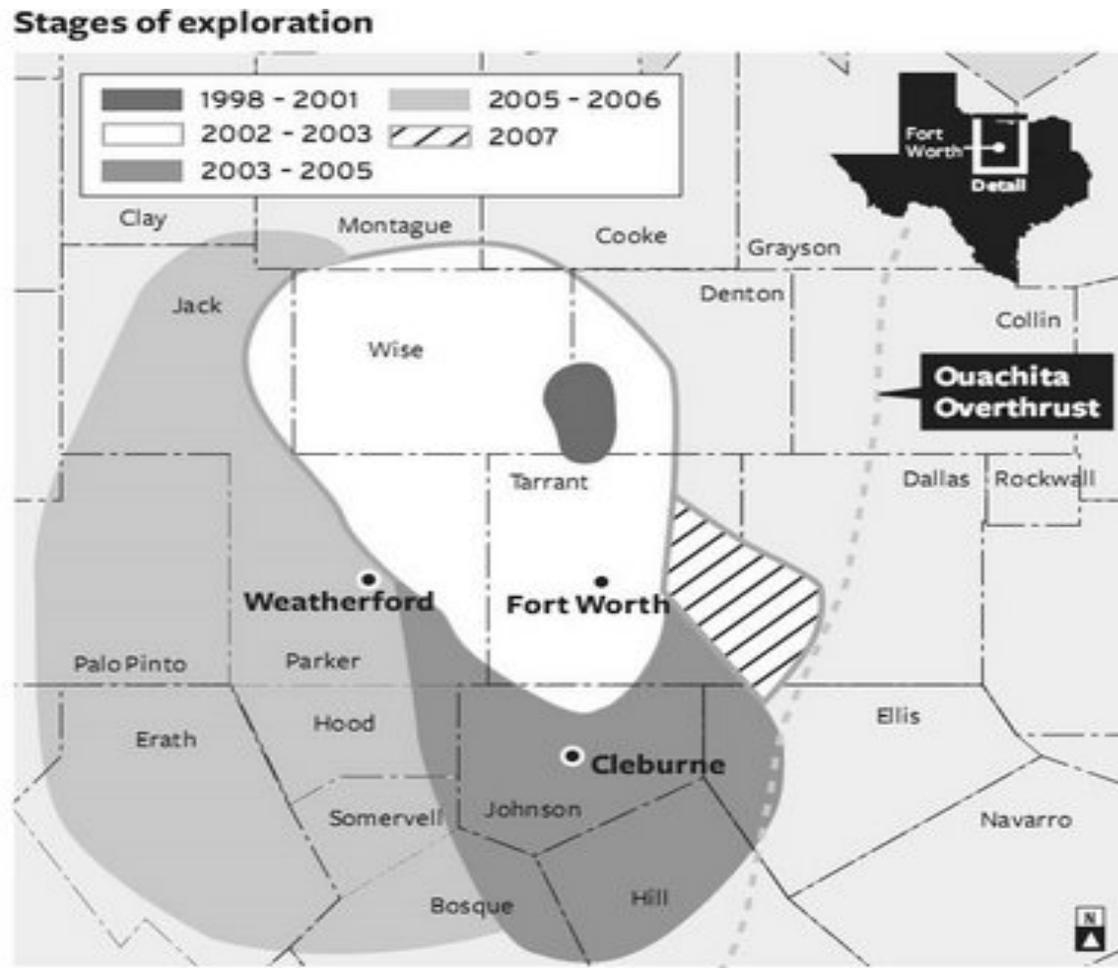
Barnett Shale And Barnett-Paleozoic Total Petroleum System (TPS)

Thermally mature Barnett Shale is present over most of the Fort Worth Basin and Bend Arch is the primary source rock that has produced >2 BBO and >7 TCFG from Paleozoic conventional reservoirs.

Most production from the Barnett Shale is at Newark East field.



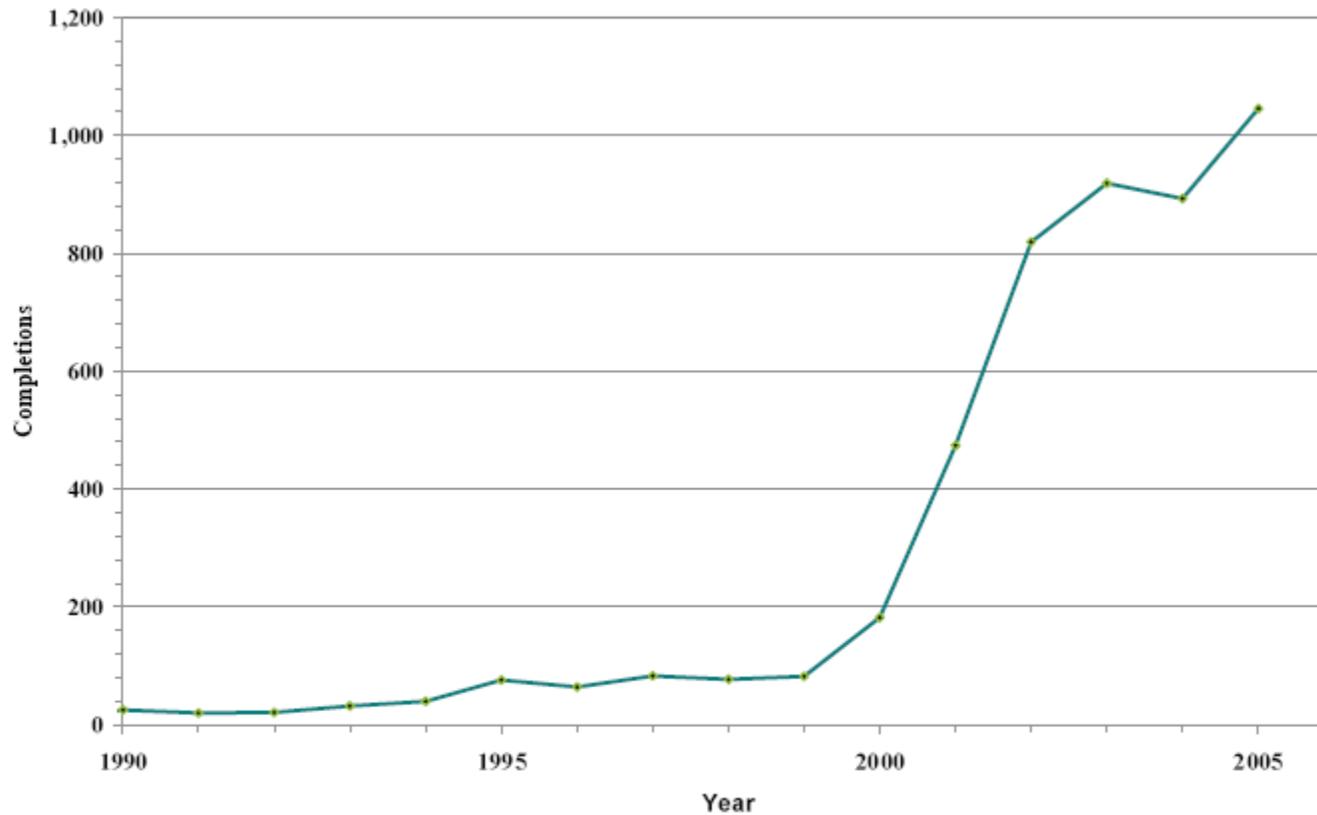
Barnett Exploration History



SOURCE: Stan-Telegram research.

Barnett Shale Well Completions

(Source: TWDB)



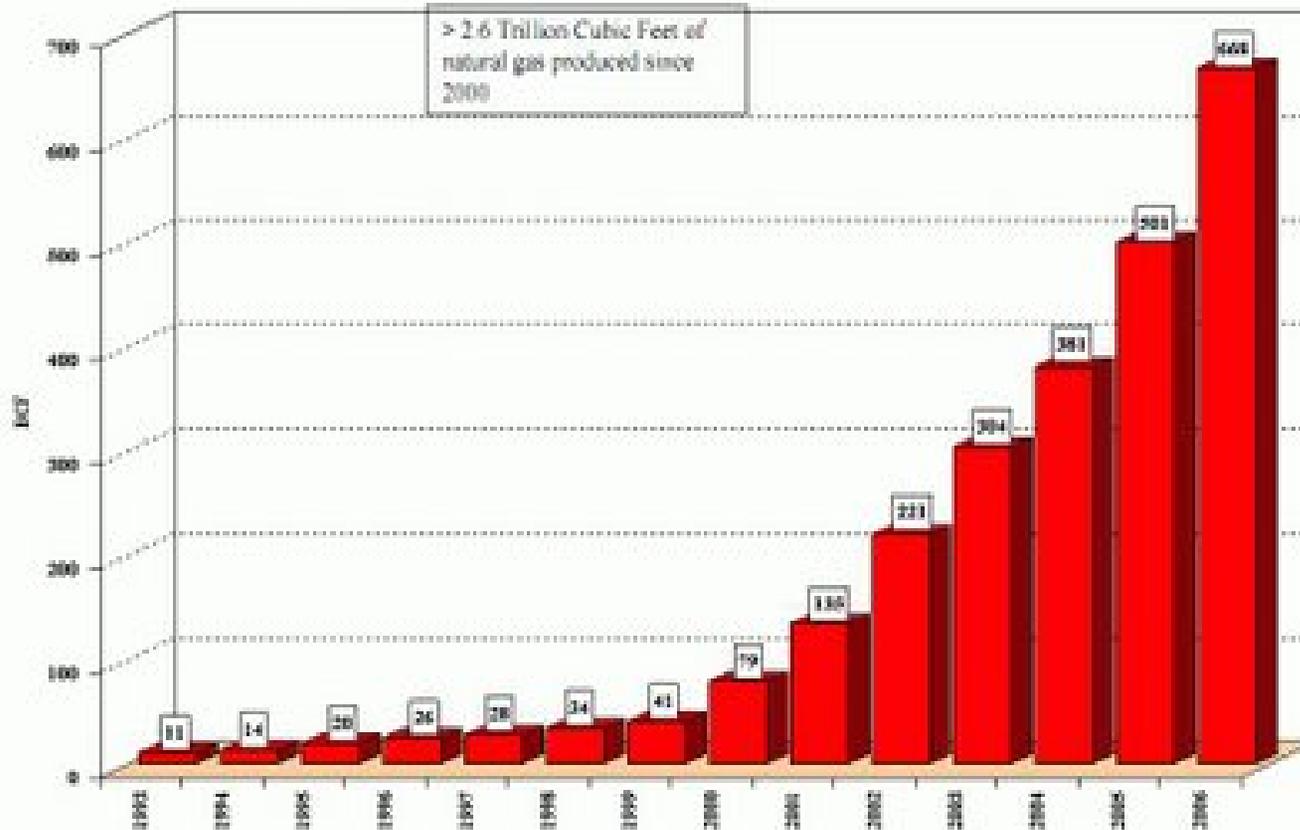
Note: Incomplete reporting of 2006 completions was omitted from the graph

Figure 2. Annual Gas Well Completions in Barnett Shale

Barnett Shale Gas Production From Newark, East Field

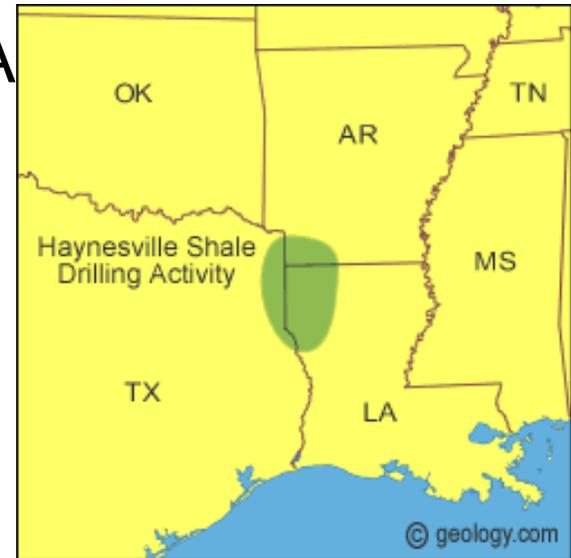
Texas Gas Well Gas Production in the Newark, East (Barnett Shale) Field
1993 through 2006

From Texas RRC

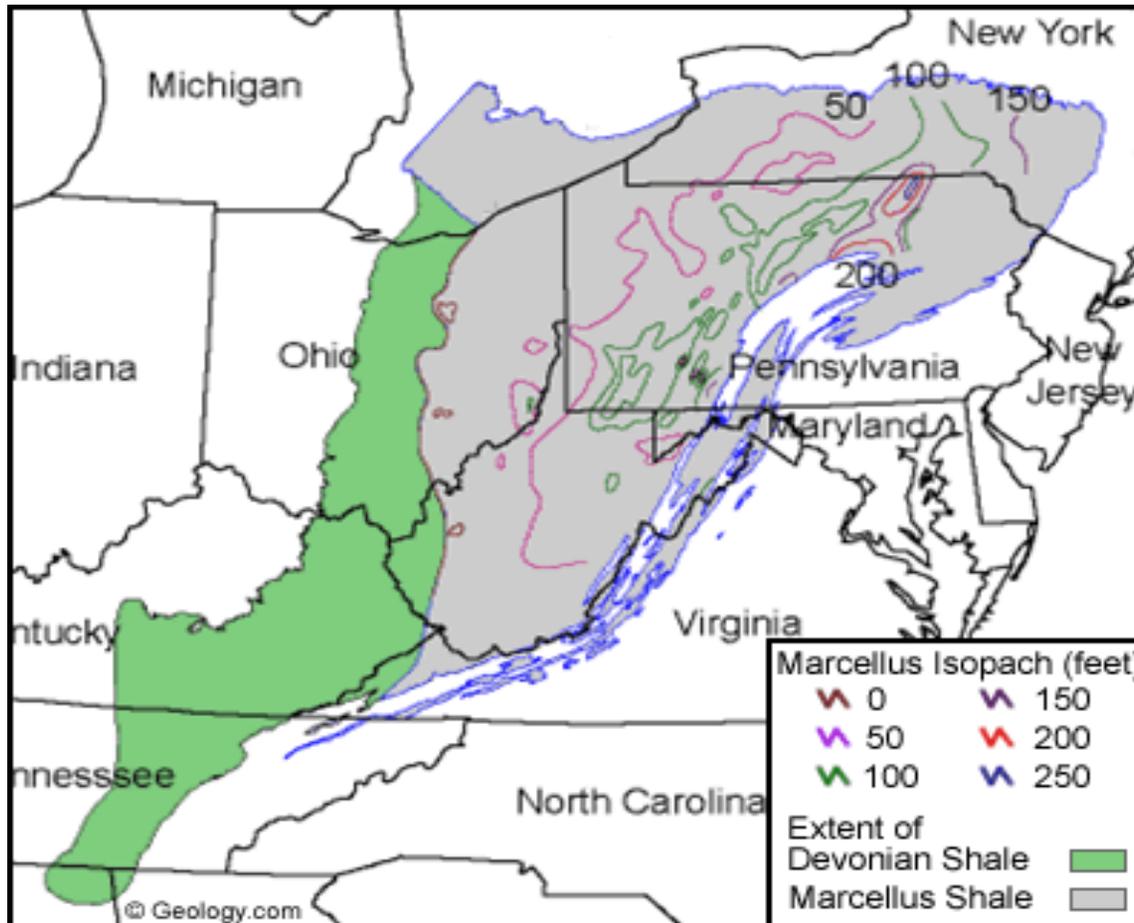


Haynesville Shale

- Organic-rich shale of Upper Jurassic Age
- Very low permeability
- About 10,000 ft below the surface
- Drilling underway
- Drilling is managed by the LA Department of Natural Resources
 - Strict regulations for production
- Lies near the **Red River Alluvial Aquifer** system, a high yield aquifer system
- Lies under the **Carrizo-Wilcox Aquifer**, a low yield aquifer with a slow recharge rate



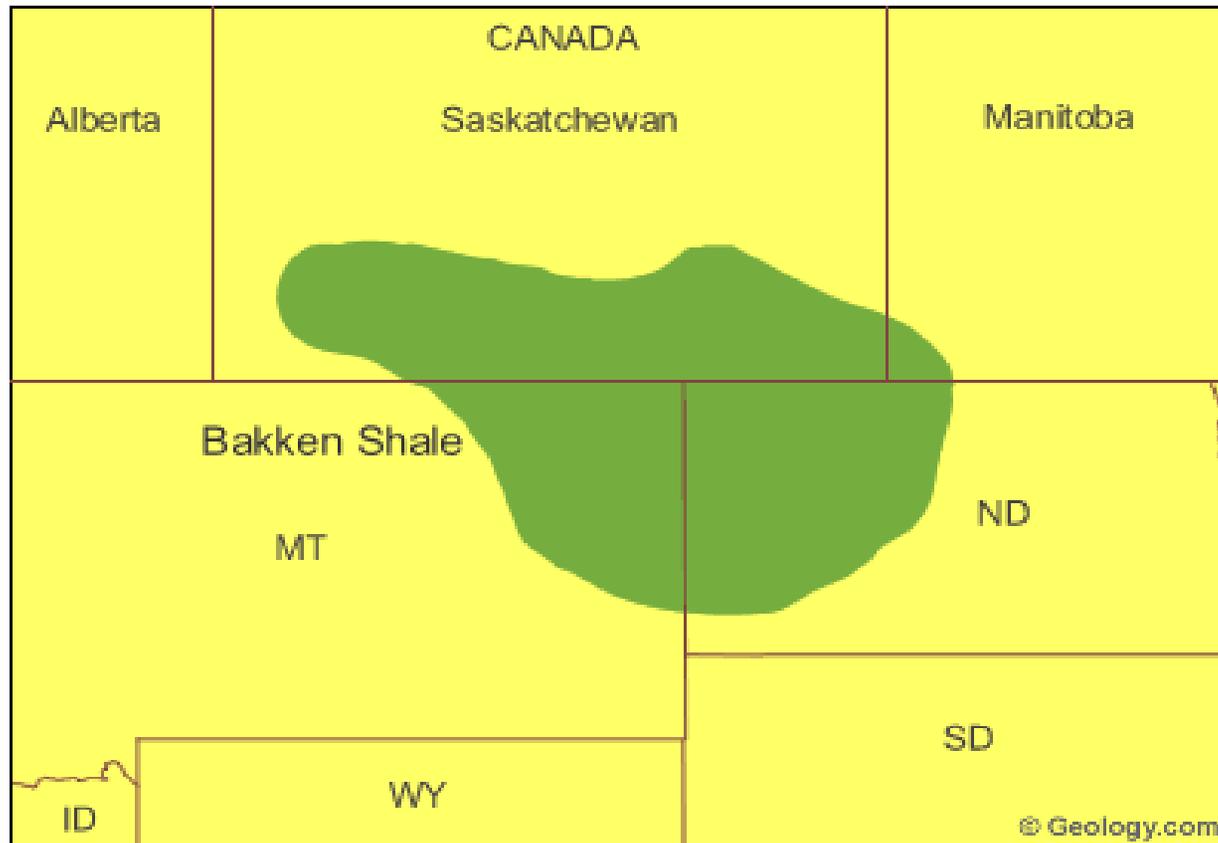
Marcellus Shale



Marcellus Shale

System	Ohio	N. Virginia & West Virginia	Western Maryland	Western Pennsylvania	Northwestern New York		
U. Dev.		Harrell Shale	Harrell Shale	Harrell Shale	Genesee Fm.		
Middle Devonian	Olentangy Shale	Lully Limestone	Mahantango Formation	Lully Limestone	Lully Limestone		
	?	Mahantango Formation		Millboro Shale	Moscow Shale	Hamilton Group	
	Prout Limestone				Hamilton Group		Hamilton Group
	Plum Brook Shale				Hamilton Group		Hamilton Group
	Delaware Limestone				Marcellus Shale		Marcellus Shale
	Columbus Limestone	Huntersville Chert		Needmore Shale	Selinsgrove Limestone	Onondaga Limestone	
	Dois Blanc Limestone	Huntersville Chert		Needmore Shale	Needmore Shale	Bois Blanc Fm.	
Lower Dev.							

Bakken Shale – Oil Play



Water Quality and Shale Gas Production

- Water and drilling
 - Hydraulic fracturing is used to collect the gases
 - One well may use 2-4 millions of gallons of water
 - 8000 acre feet of groundwater used for fracking Barnett Shale wells in 2005 (1.6% of Trinity Aquifer use)
- Contaminated water by-product
 - The well by-product water often contains salt, hydrocarbons and fracturing fluids
 - By product and produced water is commonly stored in holding ponds, then injected through wells to below fresh water

Congress investigates possible water contamination caused by gas well drilling

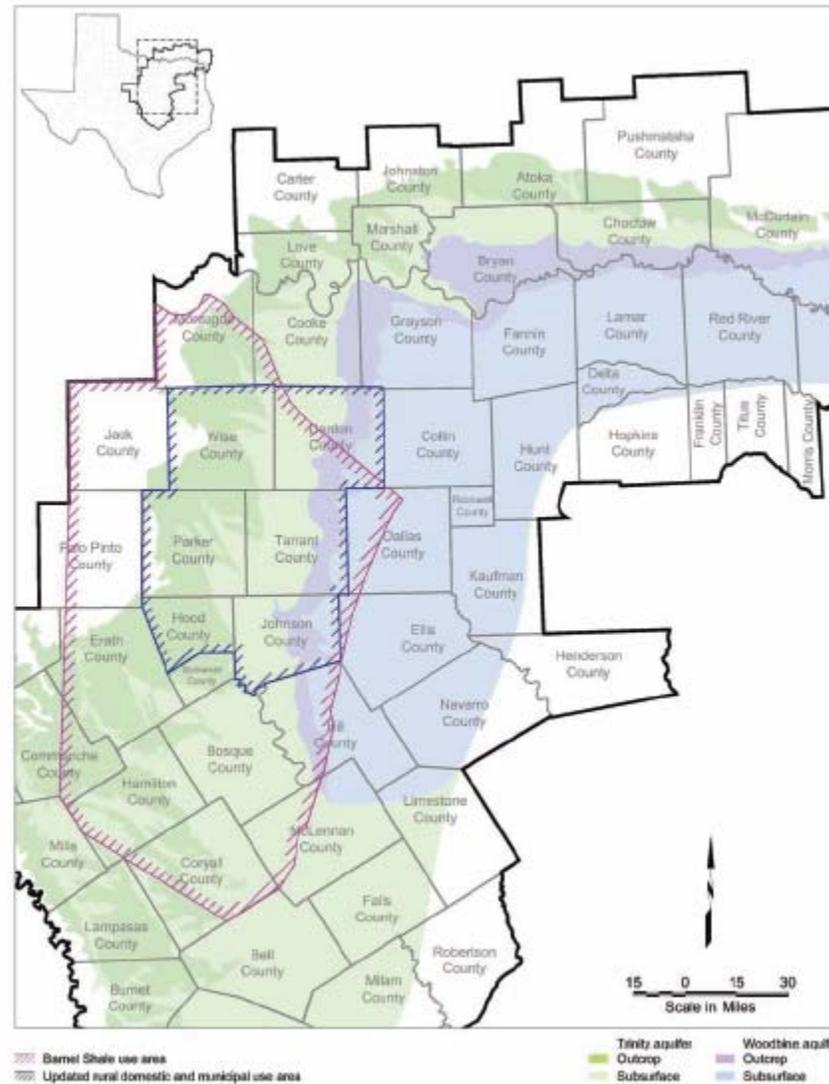
Local group considers legal action

[By TOM KANE](#)

UNITED STATES — Gas drilling companies in the nation are being accused of injecting toxic chemicals into the ground without government or industry oversight.

- Energy Policy Act of 2005
 - Hydraulic fracturing exempt from Safe Drinking Water Act provisions
 - Industry reporting of quantities used is not required

Barnett Shale and Local Aquifers



Water Use

- The Texas Water Development Board (TWDB) worked with Hardin & Assoc., Freese and Nickels, and the University of Texas to estimate the water use impact of mining
- The Groundwater Availability Model (GAM) was used
- The production will likely not have a major regional impact on the aquifers – could be local issues
- High and low estimates of water use are shown on the graphs in the next slides.

Barnett Shale Groundwater Demand

(Source: TWDB)

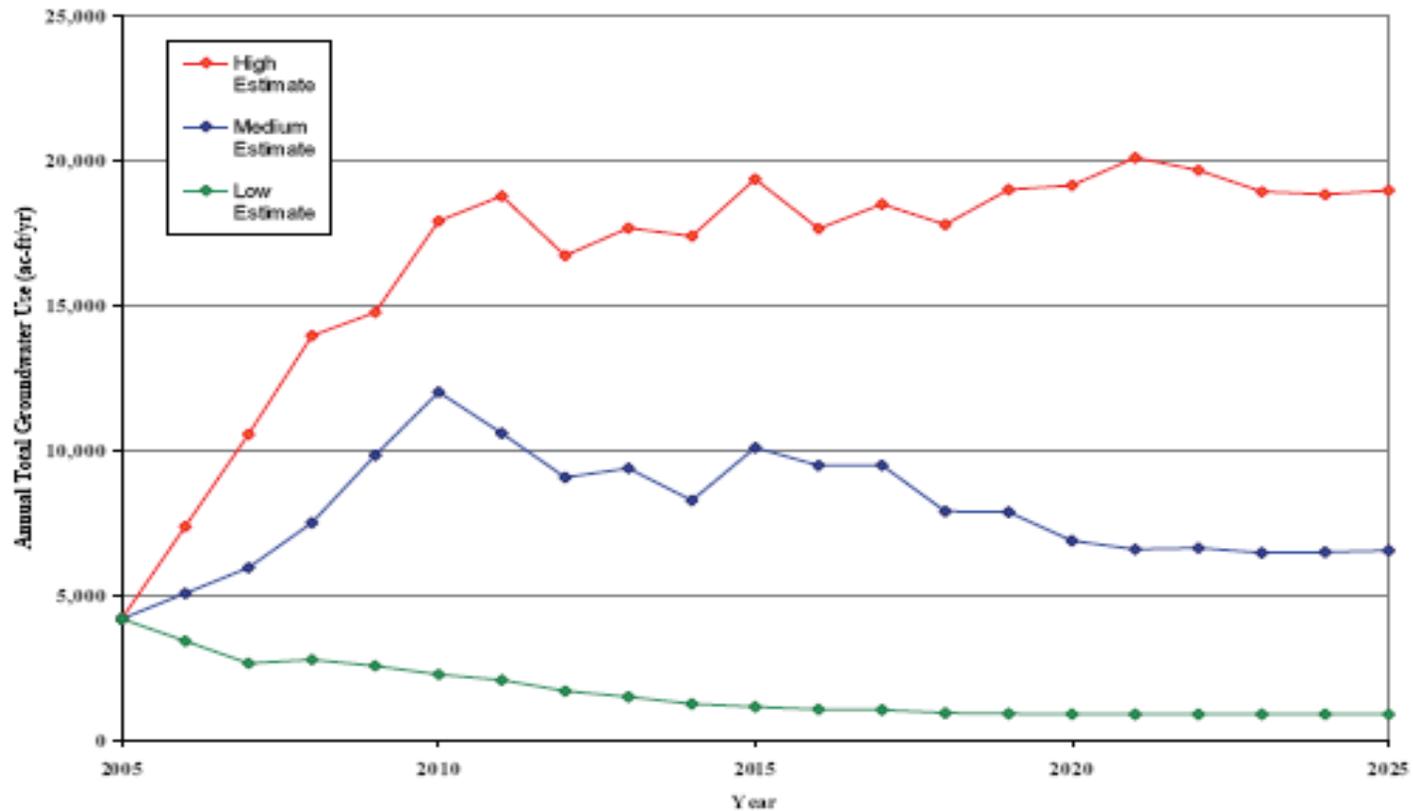
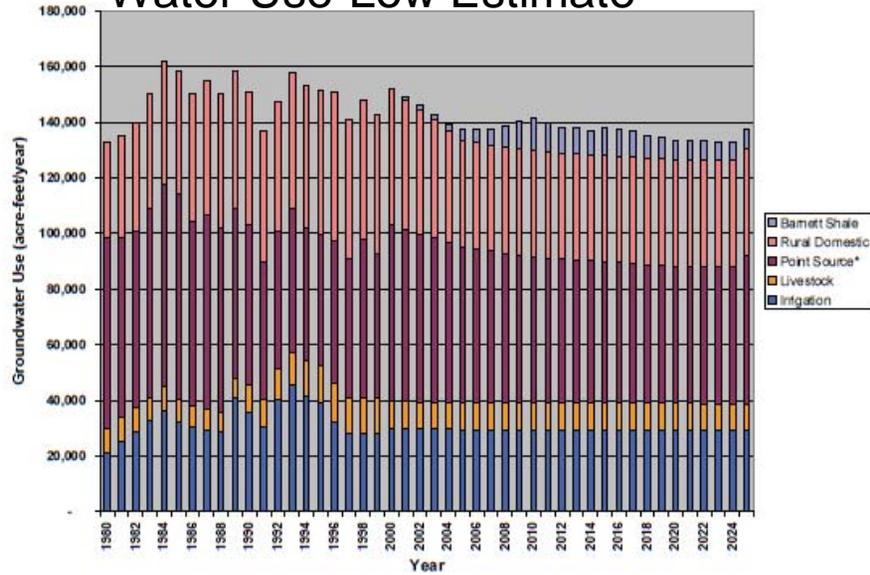


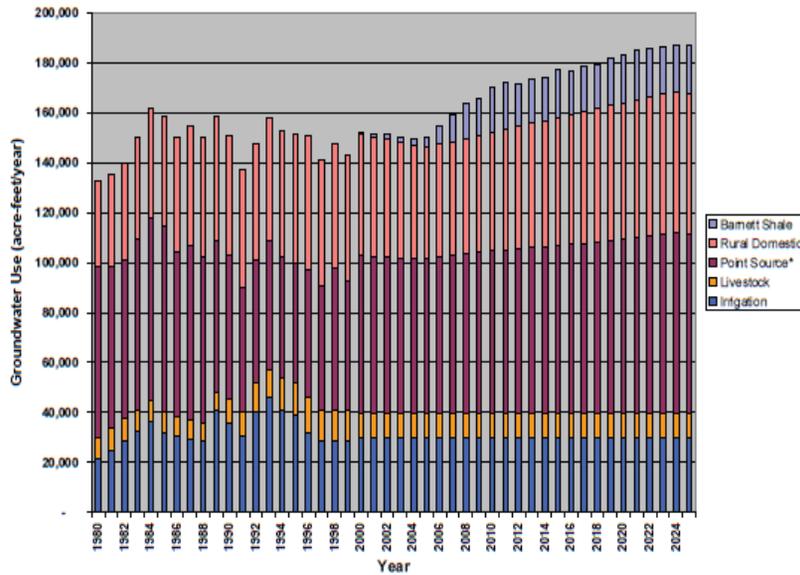
Figure 3. Total Annual Barnett Shale Groundwater Demand Projections

Water Use-Low Estimate



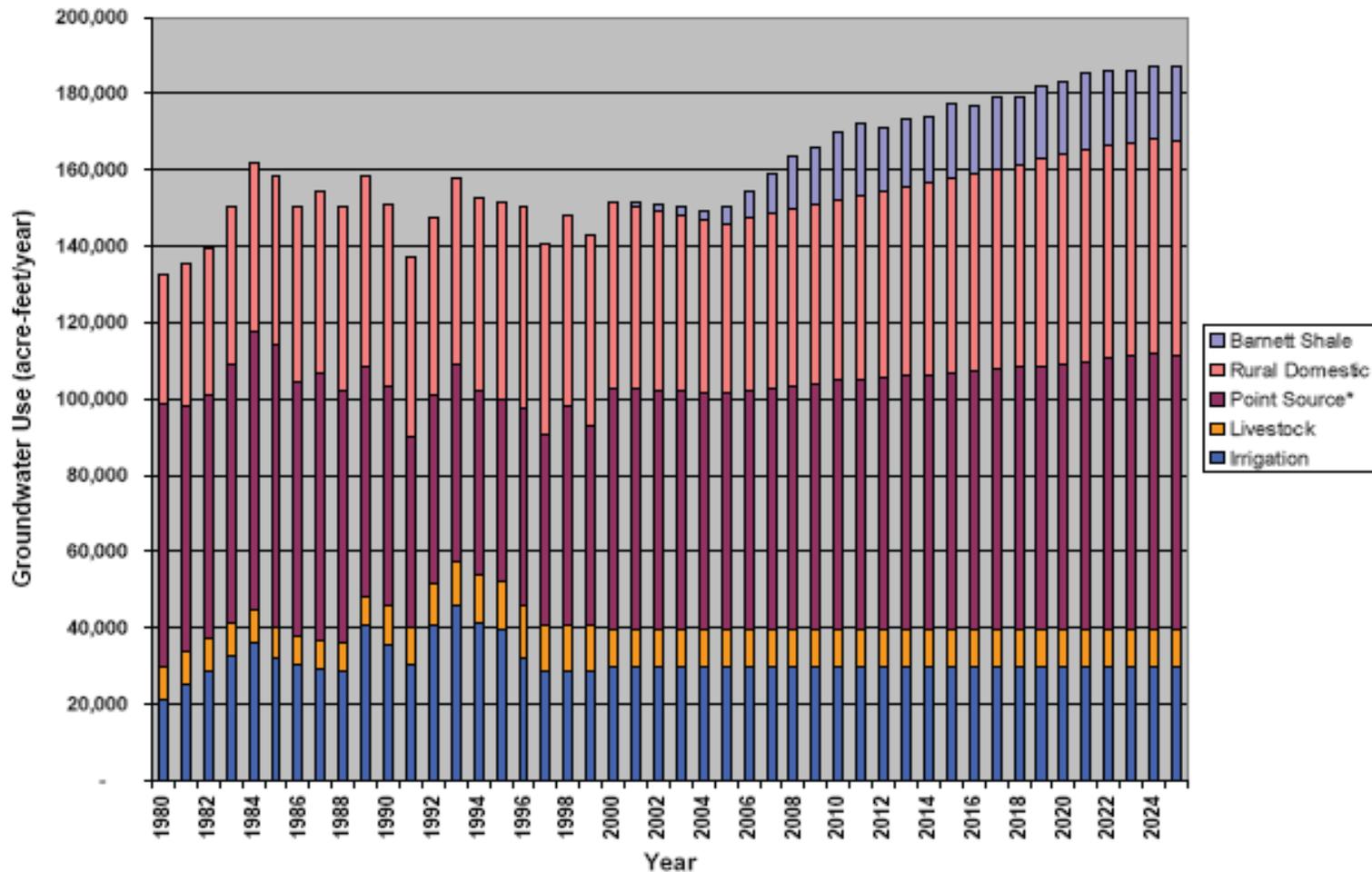
*Note: Includes total groundwater use for Bosque, Comanche, Cooke, Coryell, Dallas, Denton, Ellis, Erath, Hamilton, Hill, Hood, Jack, Johnson, McLennan, Montague, Palo Pinto, Parker, Somervell, Tarrant and Wise Counties. Point source represents municipal, industrial, mining other than Barnett Shale, and power generation uses.

Water Use-High Estimate



*Note: Includes total groundwater use for Bosque, Comanche, Cooke, Coryell, Dallas, Denton, Ellis, Erath, Hamilton, Hill, Hood, Jack, Johnson, McLennan, Montague, Palo Pinto, Parker, Somervell, Tarrant and Wise Counties. Point source represents municipal, industrial, mining other than Barnett Shale, and power generation uses.

Total Groundwater Use – Barnett Shale Development Area – High Demand Projections(TWDB)



The RRC Pollution Rules

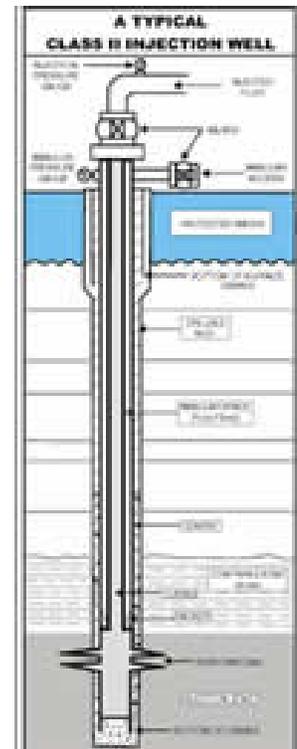
- The Commission's current rules define "pollution of surface or subsurface water" broadly: "The alteration of the physical, thermal, chemical, or biological quality of, or the contamination of, any surface or subsurface water in the state that renders the water harmful, detrimental, or injurious to humans, animal life, vegetation, or property, or to public health, safety, or welfare, or impairs the usefulness or the public enjoyment of the water for any lawful or reasonable purpose."

Barnett Water Contamination Prevention

- The Railroad Commission (RRC) of Texas regulates the exploration and production of oil and gas in Texas
- Recycled water is processed at Fountain Quail Water Management of Jacksboro
- Some of the companies drilling are now attempting onsite recycling methods
- All contaminated water holding pits must be lined with plastic
- Water is also disposed of through injection wells

Injection and Disposal Wells

- The RRC issues permits all wells to insure that they are constructed according to the RRC standard
- Well development also requires a notice to the public, hearing opportunities, a review of area geology, and review of nearby wells
- Wells are inspected at least once a year



Current Haynesville Water Concerns

- Currently water dependant drilling uses water from the Carrizo-Wilcox Aquifer
- Drawdown has began as drilling proceeds
- August, 2008: Caddo Parish officials asked the USGS to do another investigation of the long-term effects of drilling on the Wilcox Aquifer
- Alternative water resources are being investigated
 - The Red River Alluvial Aquifer
 - Toledo Bend Reservoir
 - Water Recycling

Summary

- Two prominent issues in shale natural gas development are groundwater use and quality
 - Consumptive use (shale gas) - water production (CBM)
 - Except in dry climates or in local areas, quantity used for shale gas development is not large in comparison with traditional uses
- Groundwater issues are being managed or regulated by state organizations
 - Federal provisions can be a factor (Energy Policy Act 2005)
- Water quality problems related to produced water disposal have occurred or been perceived

Recommendations

- Modeling and monitoring should be prominent tools in dealing with groundwater quantity and quality
 - Areas in early stages of shale gas development should employ these tools well in advance of major development
 - Regional groundwater models important
 - Possibly led or facilitated by USGS
 - Requires cooperation among states
- Consider water use in broader energy/water context
 - Quantity considerations in evaluating unconventional resources, alternative resources (biologic), and developing technologies