Protecting Groundwater During Natural Gas Development

AAEE WORKSHOP

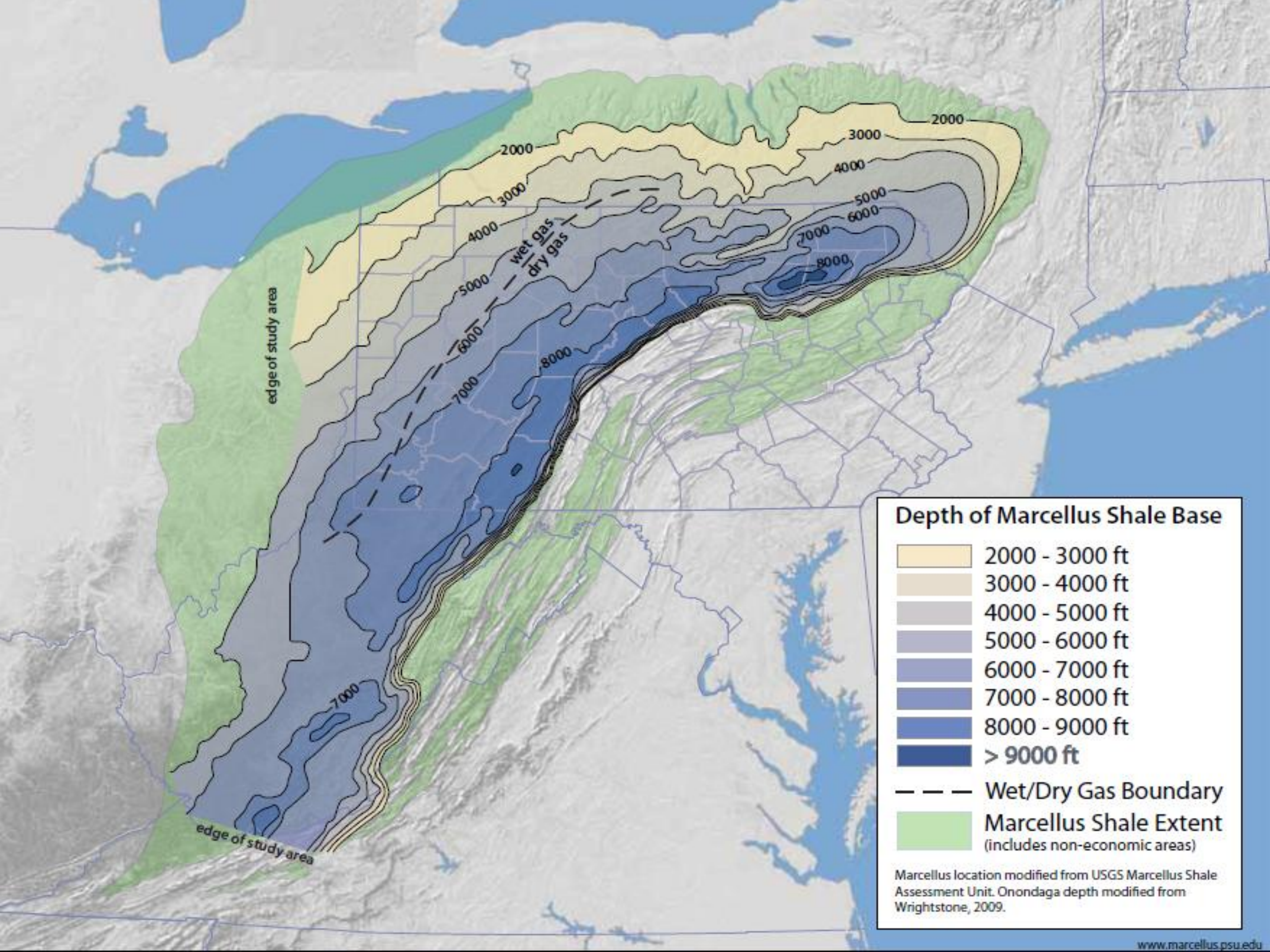
Appalachian Shale Gas Environmental Policy, Development Activities, and Management Practices

May 14, 2012

Presented by David Yoxtheimer, P.G.

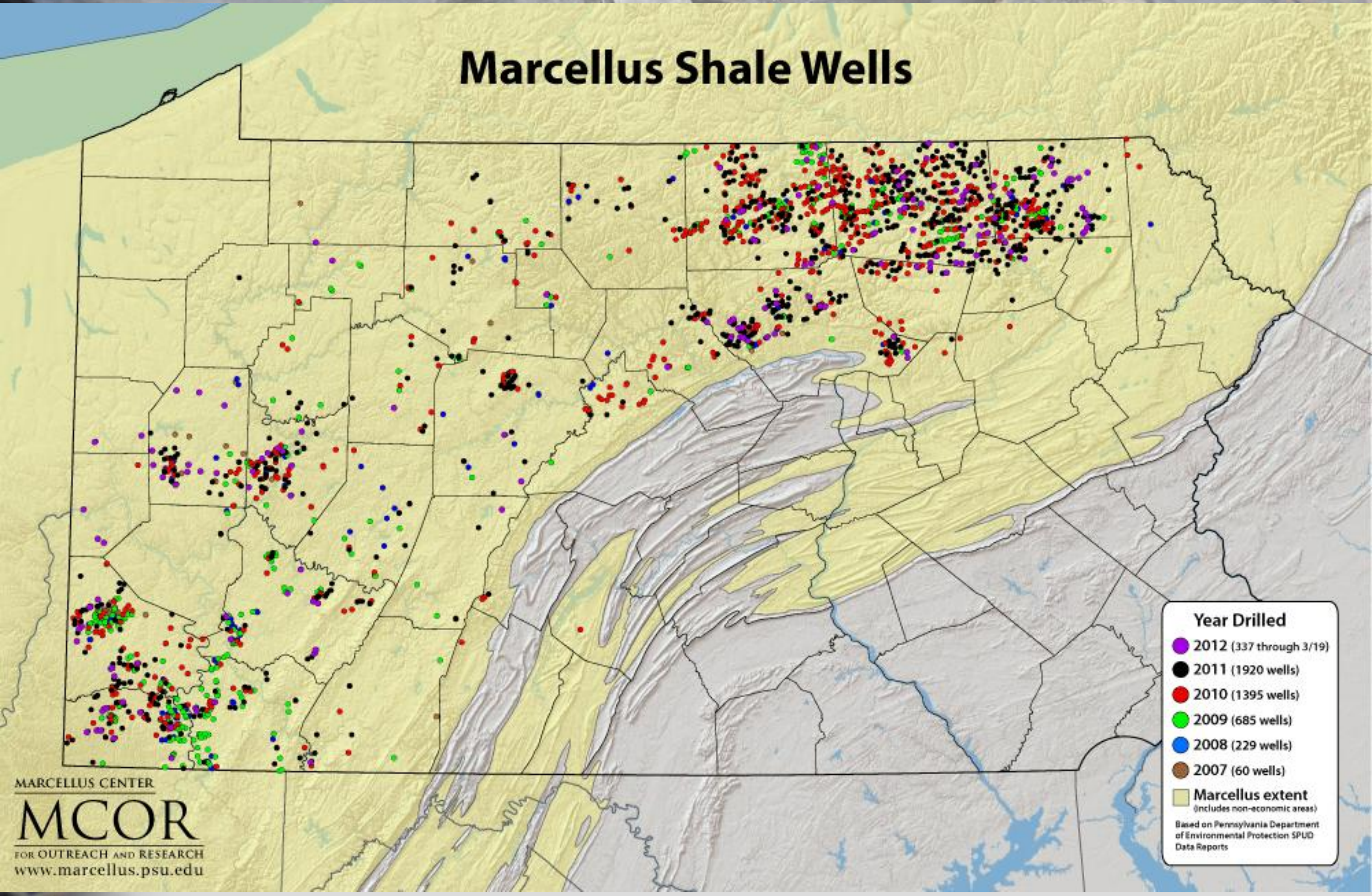
PENNSTATE

MARCELLUS CENTER for OUTREACH & RESEARCH (M-COR)

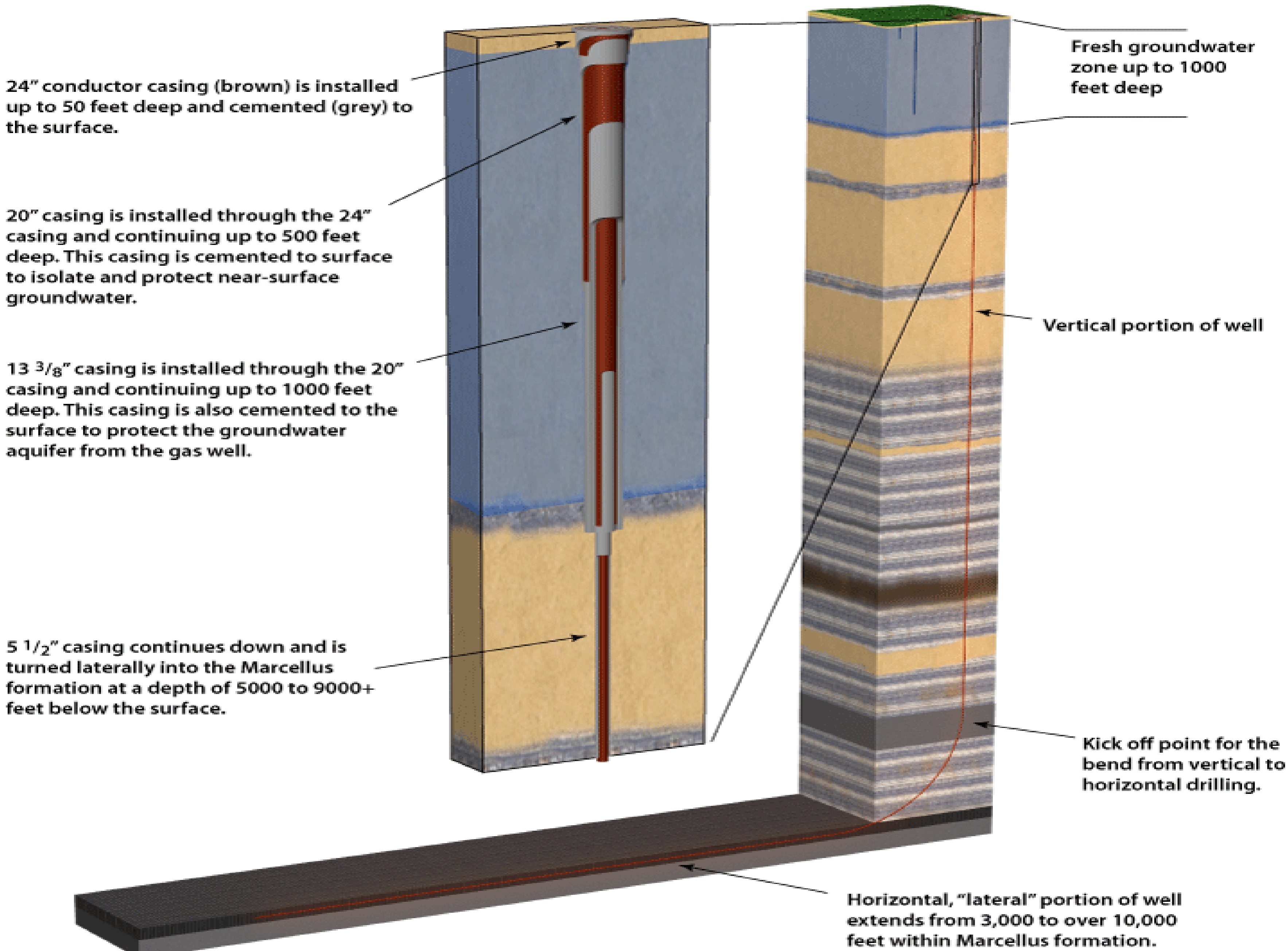


Depth of Marcellus Shale Base
2000 - 3000 ft
3000 - 4000 ft
4000 - 5000 ft
5000 - 6000 ft
6000 - 7000 ft
7000 - 8000 ft
8000 - 9000 ft
> 9000 ft
Wet/Dry Gas Boundary
Marcellus Shale Extent
(includes non-economic areas)
Marcellus location modified from USGS Marcellus Shale Assessment Unit. Onondaga depth modified from Wrightstone, 2009.
wet gas
dry gas
edge of study area
edge of study area
2000
3000
4000
5000
6000
7000
8000
www.marcellus.psu.edu

Well Drilling Locations



Well Site in Operation

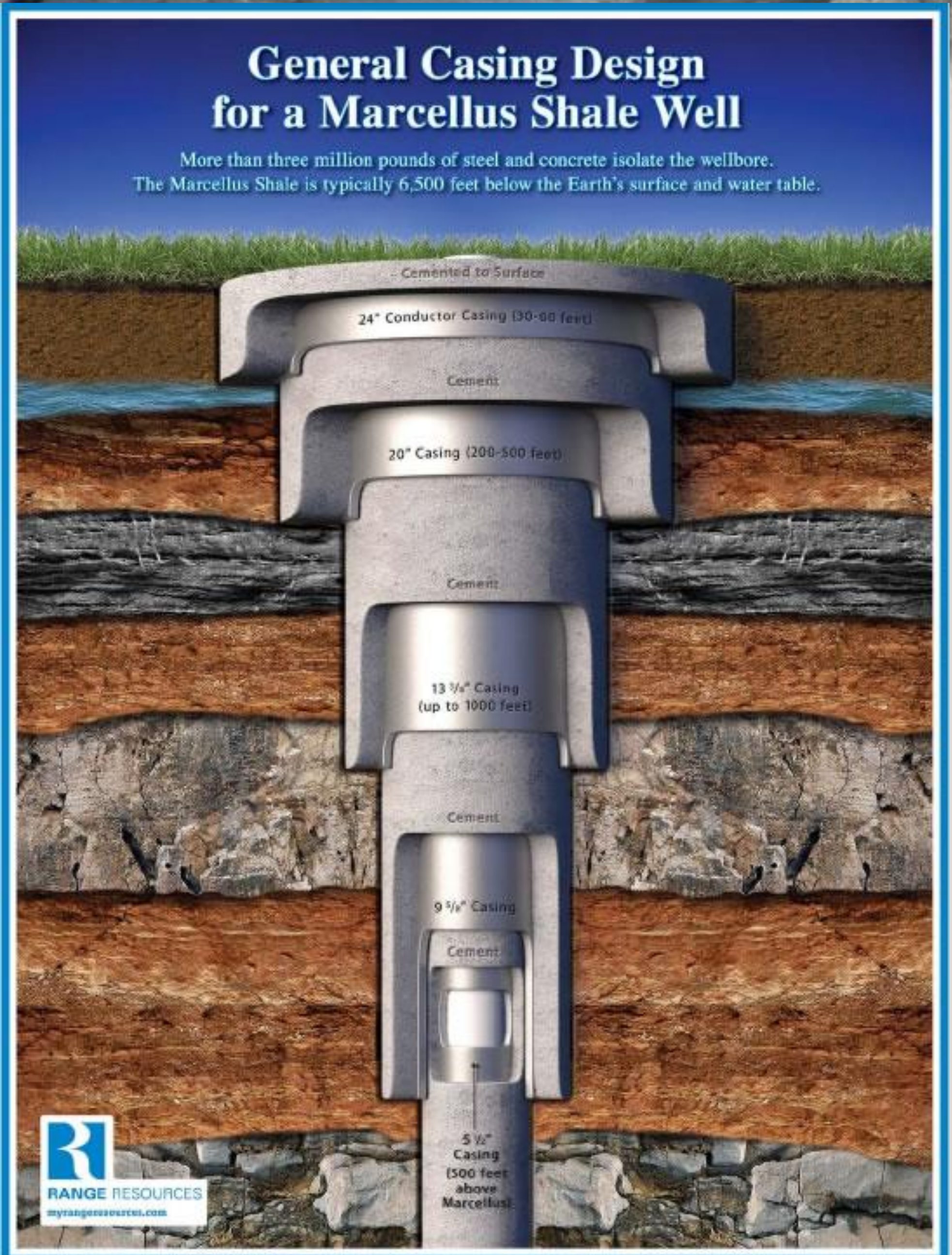


Marcellus Center for Outreach and Research, Penn State - www.marcellus.psu.edu

Potential Groundwater Impact Pathways

- Faulty well construction
  - Allow methane or other hydrocarbons to migrate upwards into an aquifer
  - Possible fracturing fluid migration pathway
- Surface spills seep into aquifer
  - Well blowouts
  - Tear in flowback storage impoundment liner
  - Leaking valve in tanks
  - Spill of fracturing fluids
  - Fuel spills

Well Construction-A Key Step

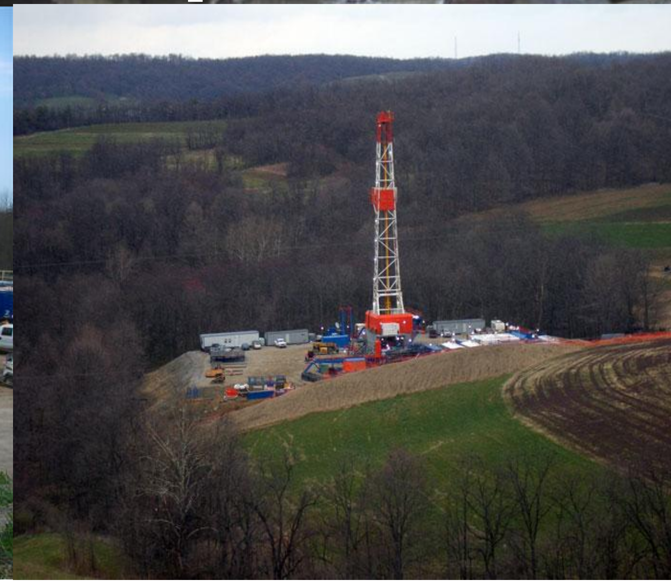


- Marcellus Shale wells are cased and grouted (using special cements) to prevent migration of natural gas and fluid from the producing zone up the well bore into fresh-water aquifers.
- This is a critical operation. Mistakes here could cause aquifer contamination.
- Entire sequence should be cased and cemented, or, if an interval left uncemented, this should be vented to prevent pressure buildup in the well annulus.

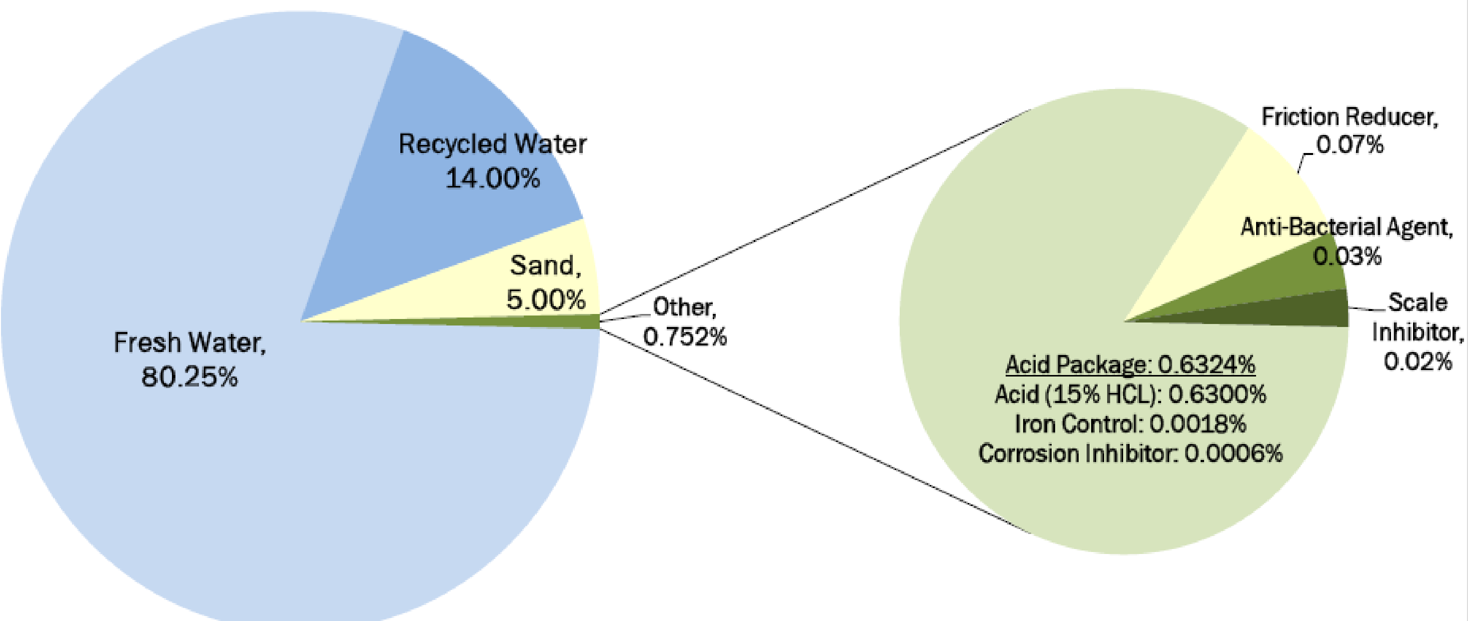
PaDEP Regulations

- In February 2011 PaDEP adopted strengthened well construction regulations (Ch. 78) to prevent methane migration:
  - Where gas pressure is >80% of hydrostatic pressure of casing depth (0.433 psi x casing depth) then intermediate casing shall be installed to prevent gas migration (Ch. 78.73)
  - Casing and cementing plan for each well to:
    - Condition the well to ensure cement bond with formation
    - Use of centralizers on casing
    - Positive cement displacement method using gas block or low flow cement to ensure no annular gas flow
    - Install cement 500 feet above true vertical depth or at least 200 feet above the uppermost perforations in production string, whichever is greater.

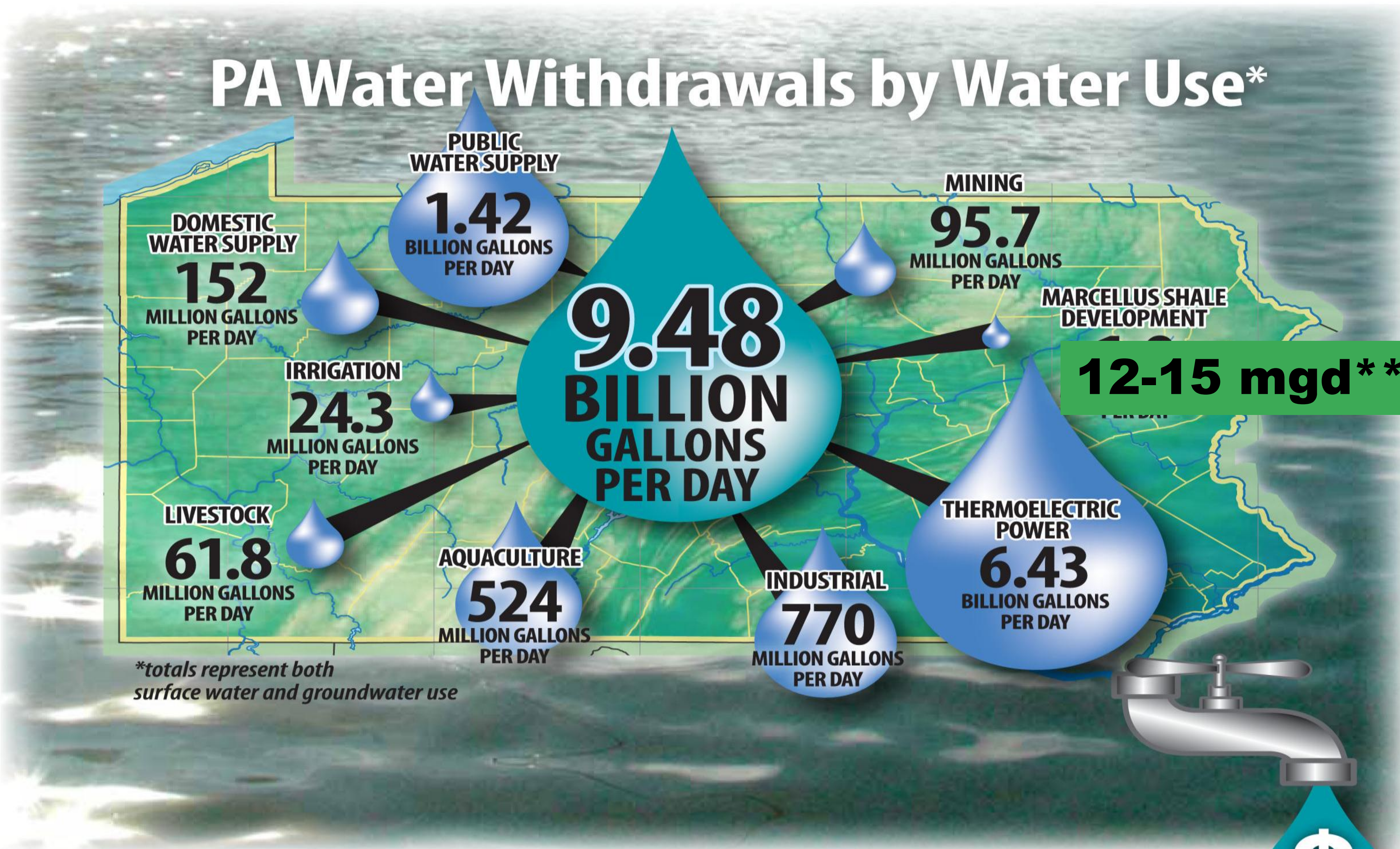
Shale Gas Development Water Use



- **80,000 to 100,000 gallons of water used during drilling**
- **3 to 7 million gallons of water used during hydraulic fracturing**
- **Approximately 8-10% of the injected fluids return as flowback water**



Source: Chesapeake Energy



Sources: J. F. Kenny, N. L. Barber, S. S. Hutson, K. S. Linsey, J. K. Lovelace and M. A. Maupin. 2009. *Estimated use of water in the United States in 2005.* U. S. Geological Survey Circular 1344. 52 p.

Marcellus Shale Gas Development Water Use: June 1, 2008 - May 21, 2010 Susquehanna River Basin Commission basin-wide reported daily use of 0.99 MGD expanded to statewide estimate. Water sources: 29% Public water supplies/71% Surface water withdrawals
1 MGD daily use in Susq. Basin ÷ wells drilled in Susq. Basin/wells drilled statewide=1 MGD ÷ (765/1428)

Source: Pa. Fish and Boat Commission

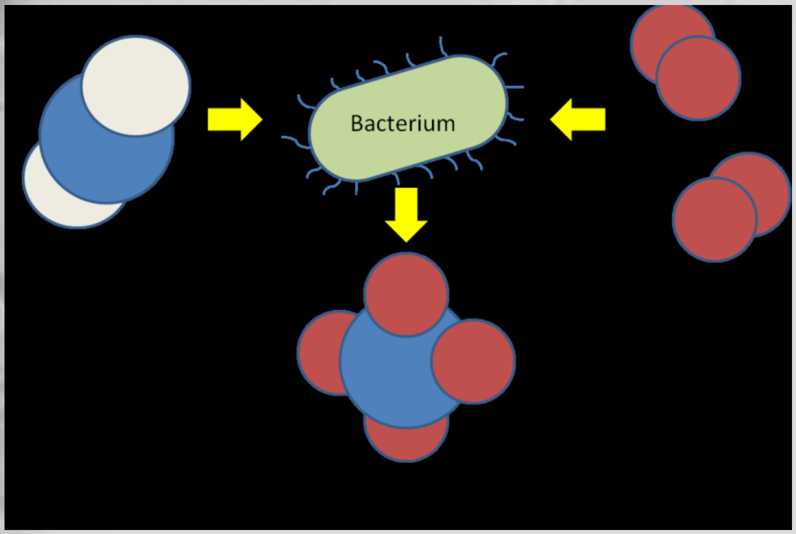
**Estimated based on current SRBC/DEP data

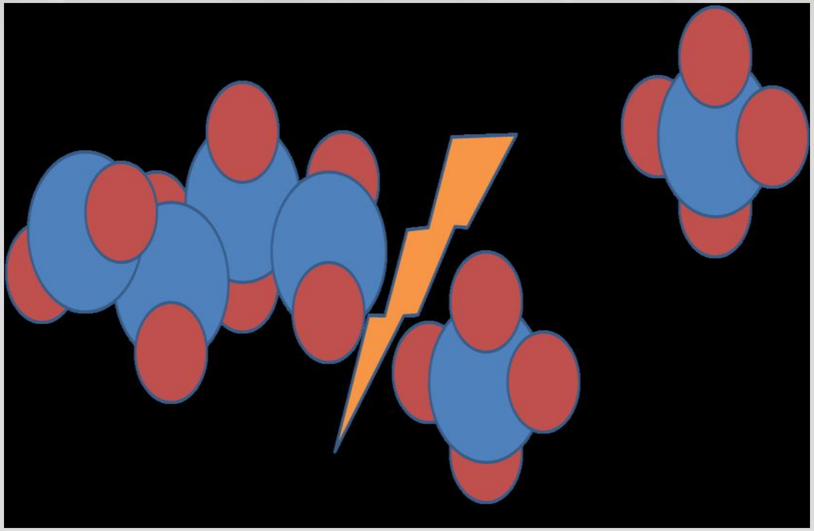
Groundwater/Pad Protections

Methane Migration

- Methane detected in shallow groundwater often occurs naturally prior to any natural gas drilling
  - ~25% of private wells have detectable methane statewide where ~80% of private wells in areas of NE PA have pre-existing methane
- Increased levels of methane have been detected in water wells after gas well drilling primarily in NE PA
  - Inadequate gas well construction (ie bad cement seal) allowed methane to migrate upward into aquifers
  - Approximately ten cases of methane migration attributable to Marcellus drilling operations
- Need to distinguish between pre-existing methane and its source (thermogenic vs. biogenic)

Not All Methane is Created Equally!





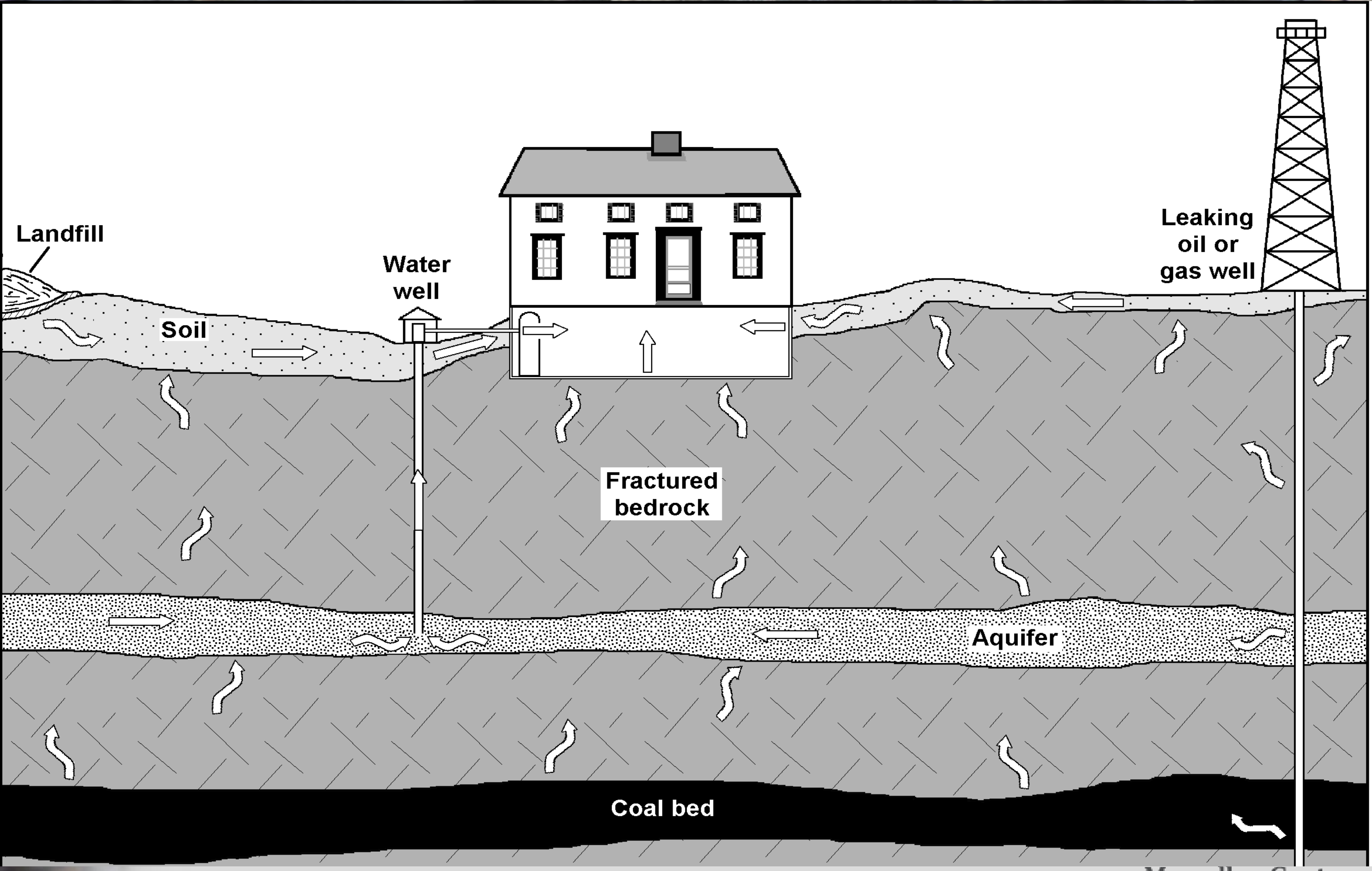
Biogenic methane is formed by methanogens breaking down organic material

Thermogenic methane formed when organic matter in a geological formation is subjected to heat and pressure

Both types of methane have characteristic C and H isotope fractions where lighter isotopes are preferentially selected during transformation processes and heavy isotopes get left behind during the process of methane formation.

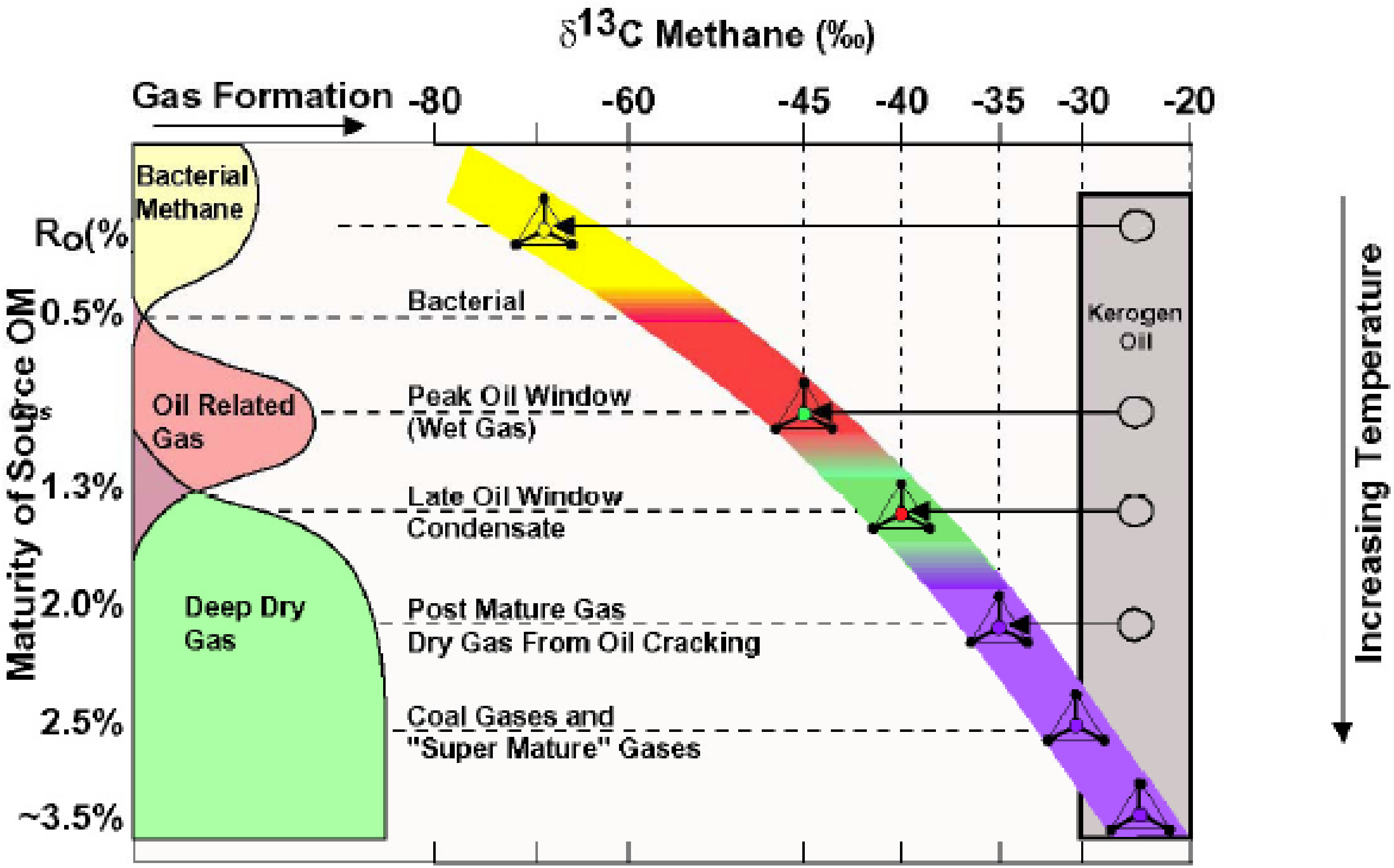
Graphic from NYS Water Resources Institute

Sources of Methane in Groundwater



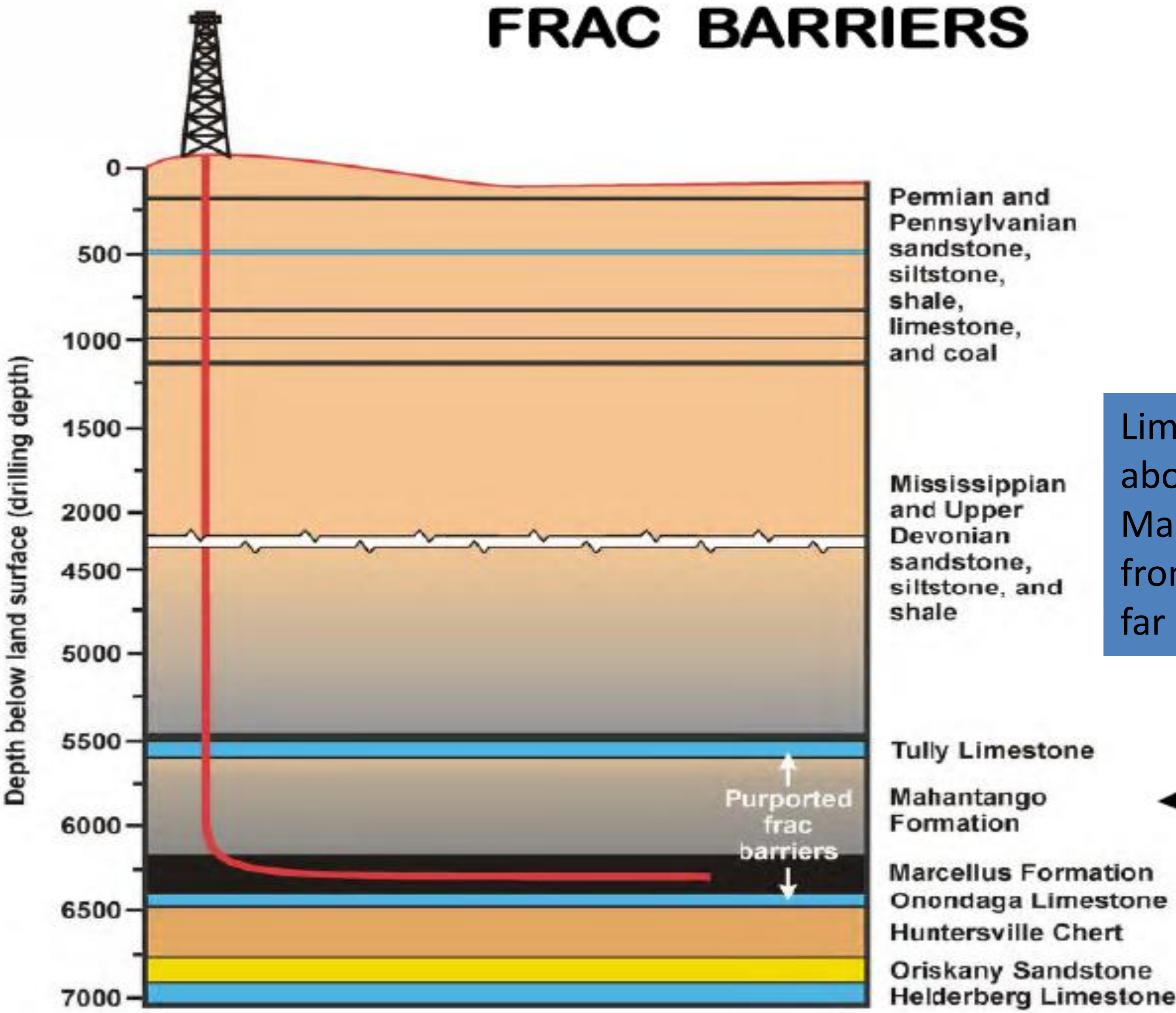
Graphic from Pittsburgh Area Geologic Society, Gas Migration in W. Pa.

Tracing sources of methane through isotope values



after M. Schoell

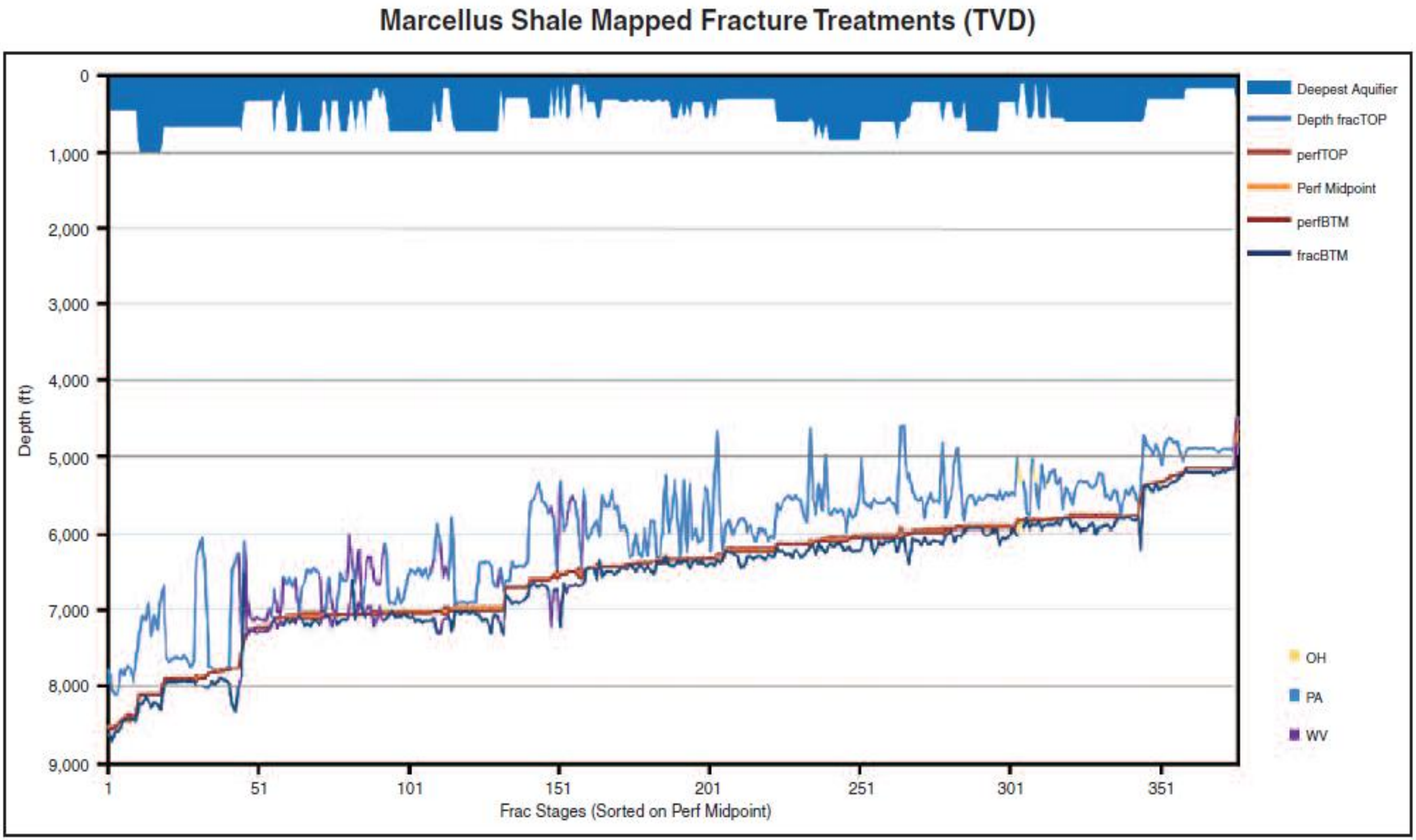
How Geology Plays into Fracturing Safety



Limestone frac barriers above and below the Marcellus keep fractures from growing too far out of the pay zone.

Graphic from Pa DCNR

Hydraulic Fracture Vertical Growth



Graphic from Fisher, 2010, Data Confirm Safety Of Well Fracturing, American Oil and Gas Reporter.


NATURAL FRACTURES IN SHALE
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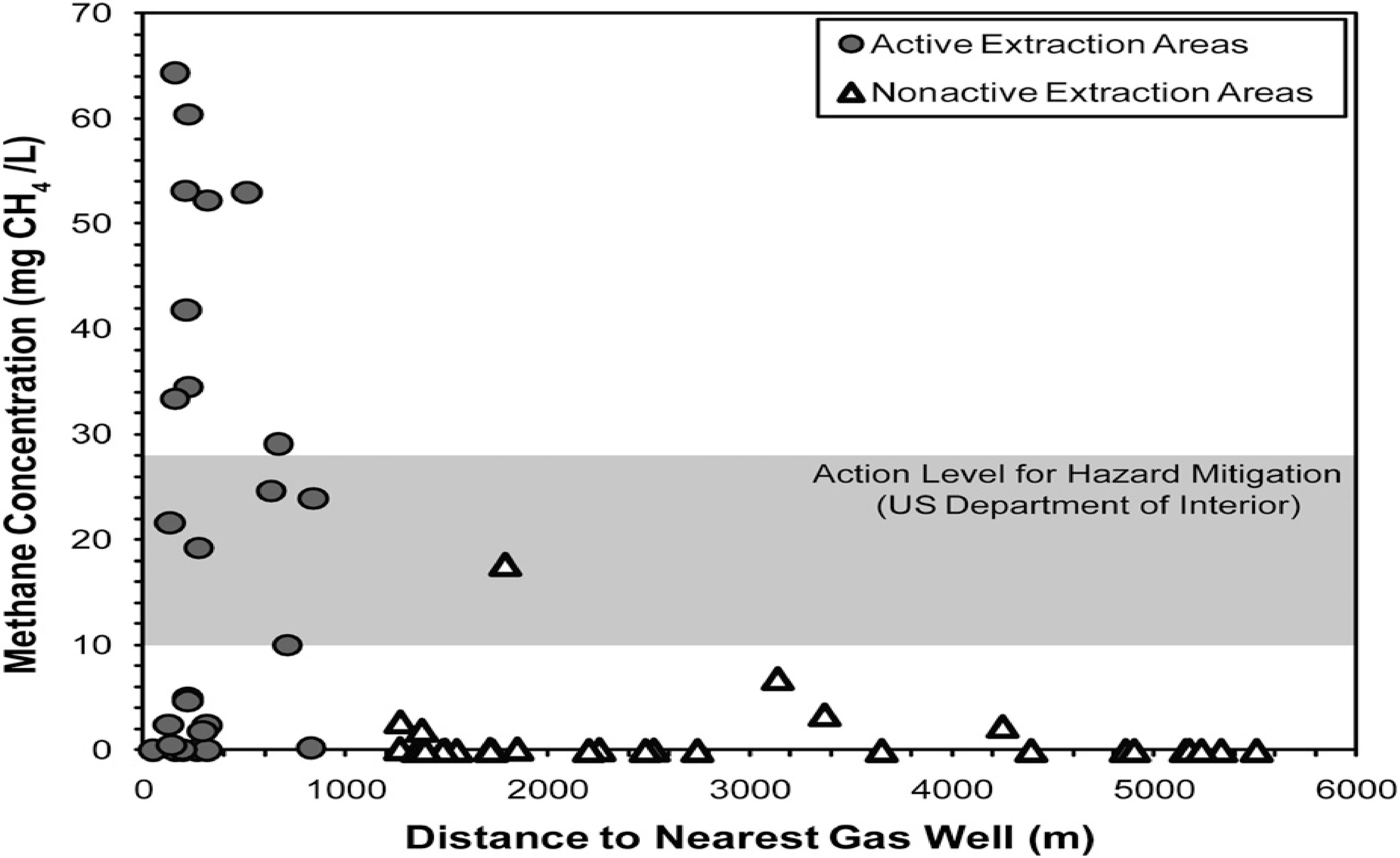
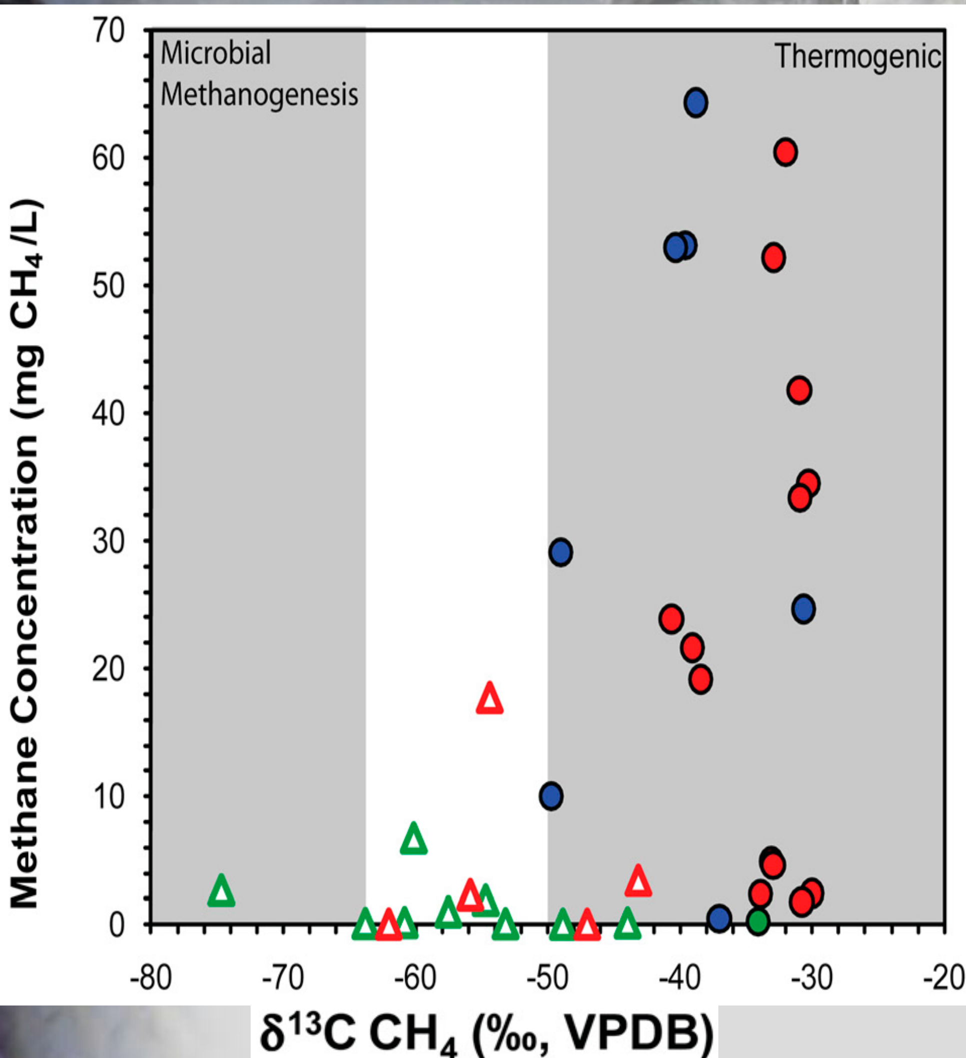
Photo courtesy of Gary Lash

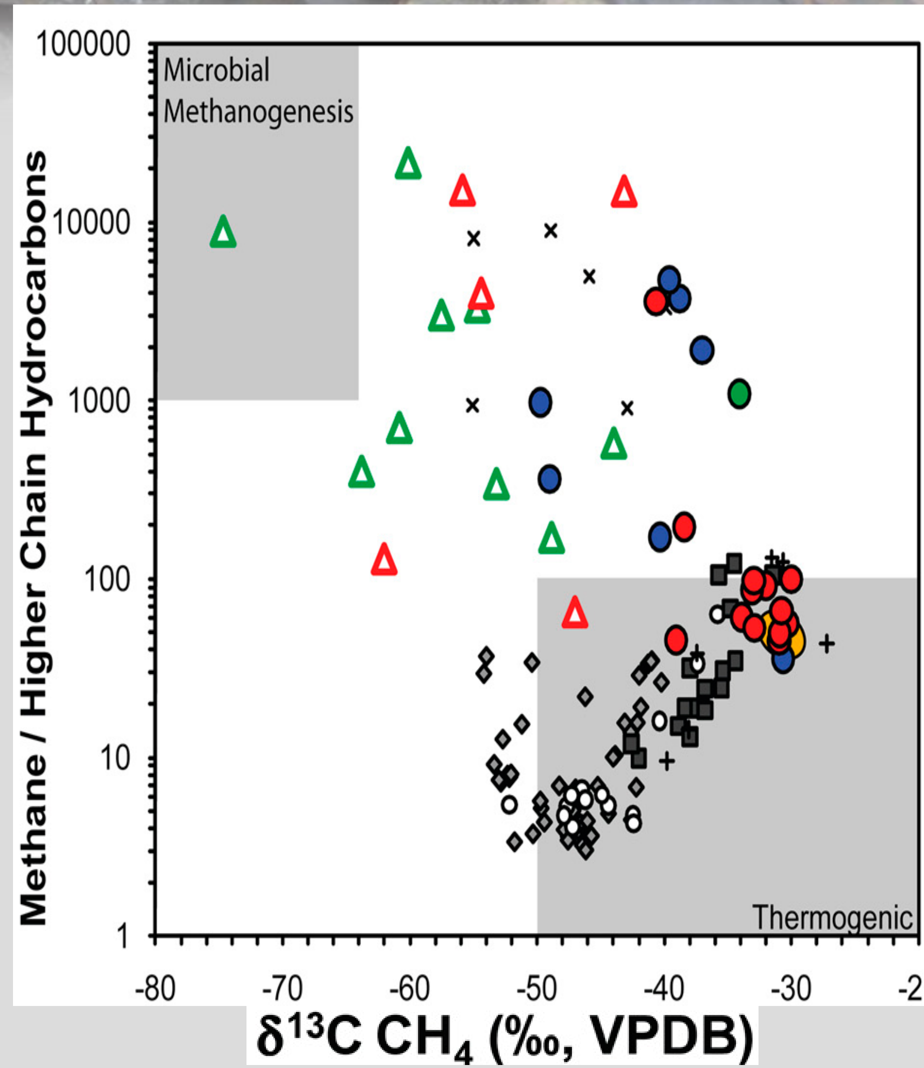
Methane in Groundwater-NE PA



Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing, Osborne et al, 2011

Methane Composition in Water-NE PA





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Methane Migration Mitigation

- Geologic and geophysical characterization of shallow geology to determine depth of aquifer vs. shallower gas-bearing sandstones
- Pre-determine potential problem areas via remote sensing and fracture analysis
- Collection of pre-drilling water samples!!
- Installation of intermediate casing string WITH ADEQUATE CEMENT SEAL to seal off shallow gas where present
- Characterizing methane found in water wells
  - Isotopic characterization of methane in water wells vs. in gas wells
  - Comparing ratio of methane and C2+ hydrocarbons
- Where stray methane has been problematic gas wells have been either remediated (squeeze job), abandoned, or water wells vented.

Study of Groundwater Quality Before and After Drilling

- PSU Researchers received funding from *The Center for Rural PA* to collect pre- and post-drilling water sample from private wells
- Collected and analyzed nearly 230 samples within 1,000 feet and within 1 mile of Marcellus wells
- No significant before/after changes in water quality
  - ~40% of wells fail at least one drinking water standard and background methane found in ~24% of the wells.
- Recommends sufficient setbacks from private wells and pre-drilling water sampling

Groundwater Quality in PA

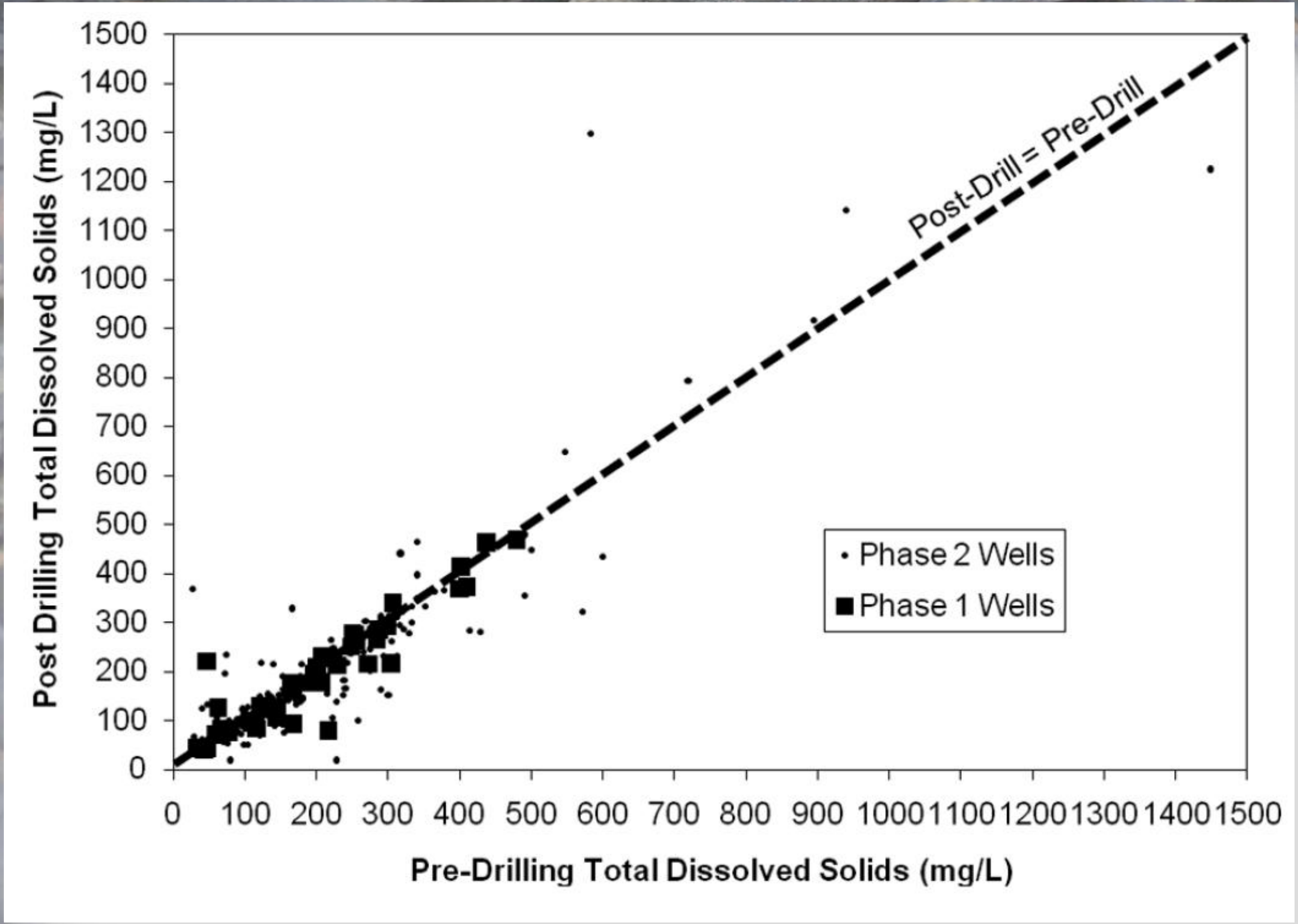
Table 1. Water quality parameters measured in Phase 1 water wells in comparison to Pennsylvania drinking water standards and to typical concentrations in Pennsylvania water wells and Marcellus wastewaters. All concentrations are reported in units of mg/L except pH.

Parameter	Drinking Water Standard[1]	Approximate Median Concentration in Typical Pennsylvania Groundwater[2]	Approximate Median Concentration in Typical Marcellus Wastewater[3]
pH	6.5 to 8.5	7.50	6.60
Total Dissolved Solids	< 500	163.0	67,300
Total Suspended Solids	-	1.0	99.0
Barium	< 2.0	0.070	686
Iron	< 0.30	0.20	39
Manganese	< 0.05	0.01	2.63
Sodium	-	6.87	18,000
Hardness	-	86.1	17,700
Strontium	-	0.26	1,080
Chloride	< 250	5.3	41,850
Sulfate	< 250	18.0	2.4 to 106
Nitrate-Nitrogen	< 10	0.50	0.1 to 1.2
Bromide	-	0.016	445
Dissolved Organic Carbon	-	<1.0	62.8
Dissolved Methane		No data available	No data available
Oil & Grease	-	<5.0	6.3

[1] Pennsylvania Department of Environmental Protection, 2006. [2] Pennsylvania State University, 2011; Davis et al., 2004; and Thurman, 1985. [3] Hayes, 2009.

The Impact of Marcellus Gas Drilling on Rural Drinking Water Supplies, Center for Rural PA, October 2011

Private Well TDS Pre- and Post-Drilling



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Flowback and Fluids Storage

Storage options:

- Centralized impoundment
- Frac tanks

-Liner and tank valve leaks have occurred in several instances and have impacted groundwater locally.

-Impoundments now require leak detection systems and monitoring wells.

Lined Well Pads

Potential for soil or groundwater contamination is minimized with lined well pads.

Closed Loop Drilling Systems

Potential for spills or releases is minimized with closed loop drilling systems.

Conclusions

- Pre-drilling water quality is essential to establish background conditions,
- PSU pre- and post-drilling/fracturing groundwater quality survey found no significant changes in water quality,
- Understanding the geology is a key element proper well design,
- Sufficiently deep casing and high-integrity cement seals per are critical to minimize potential for methane or fluid migration per state regulations,
- More regulators w/more inspections occurring-some well construction issues noted, no verified cases of groundwater impacts in 2012,
- Fluids management at surface requires use of best management practices such as lined pads and secondary containment,
- Hydraulic fracturing itself does not pose a significant threat to groundwater in deep shale formations.

Thank you!

Questions?

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