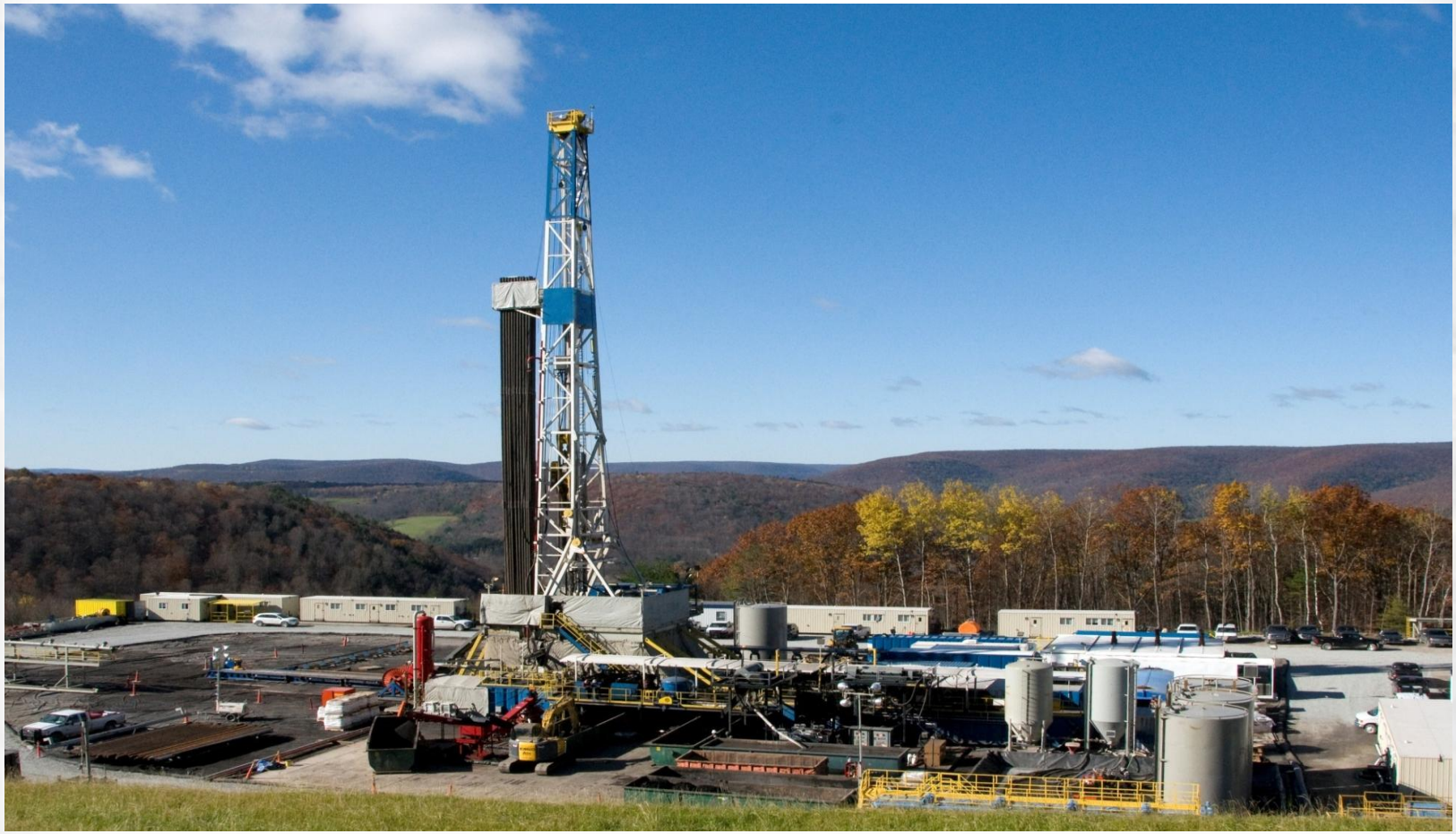
New Natural Gas Production:
Evolving Process, Mitigating Risk, Growing Benefit



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Developing Shale Trends

- Greening of the products and technologies used in the drilling/completion process
  - New chemistry, food grade products
- Emerging technology followed by regulations
  - Closed loop systems w/tanks vs. pits
  - Emerging move to “green completions” -- air emissions
- Evolving hydraulic fracturing technology
  - Less water, fewer chemicals, reduced sand volumes,
- Trained & knowledgeable inspectors
- Public understanding of regulatory process
- Transparency – FracFocus.org

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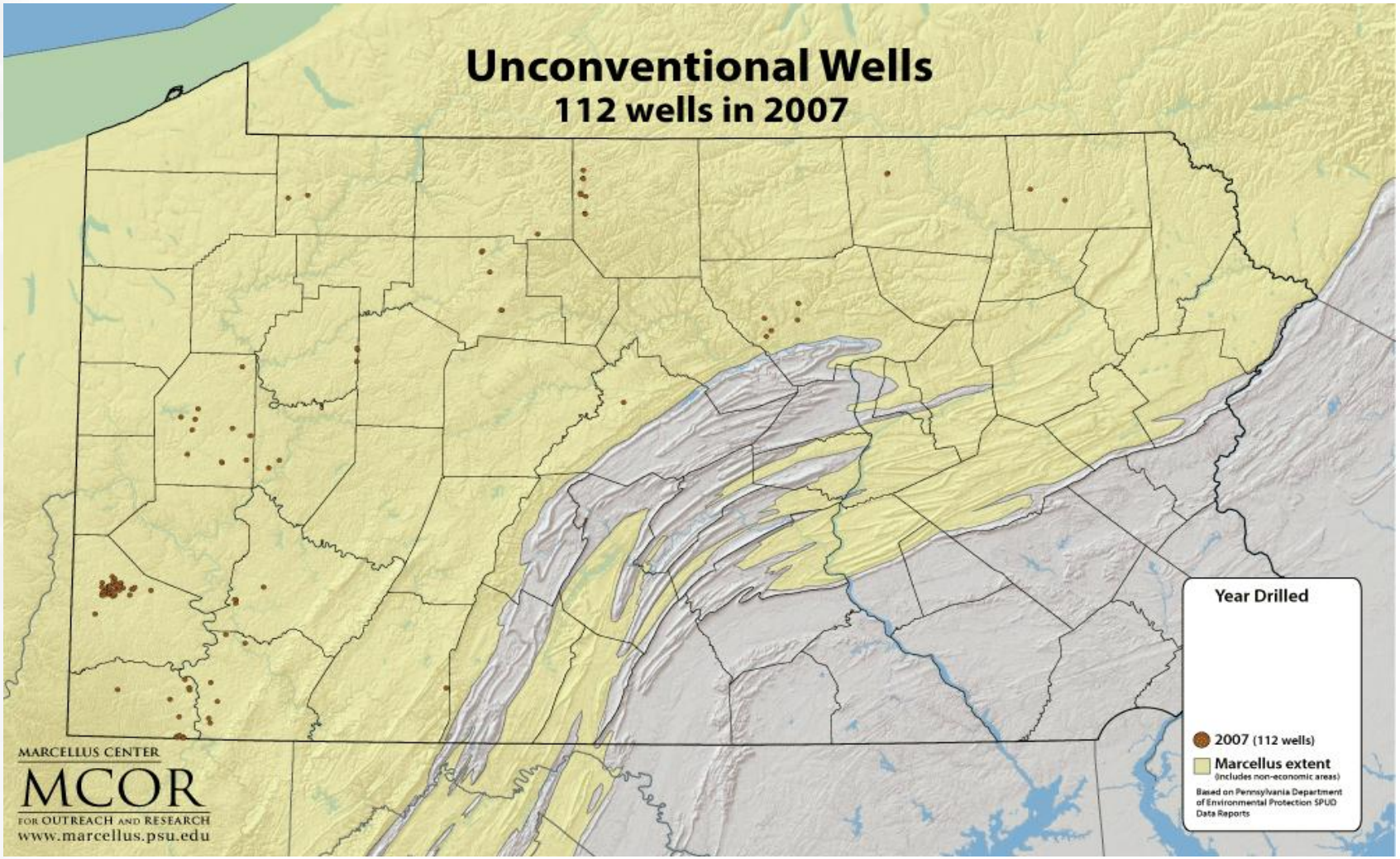
Marcellus Wells Drilled (12/1/12)



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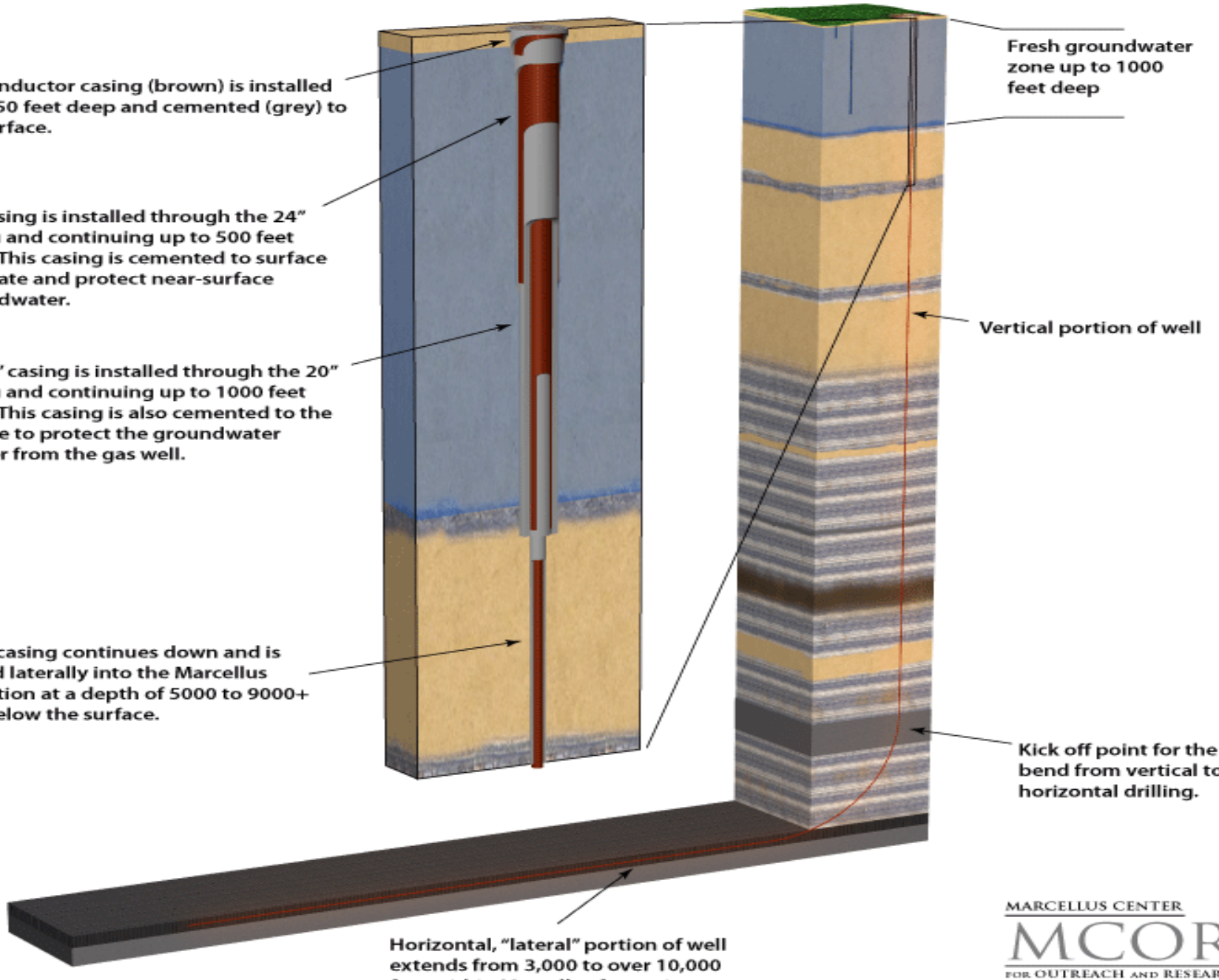
Cross-Section of Typical Horizontal Marcellus Well



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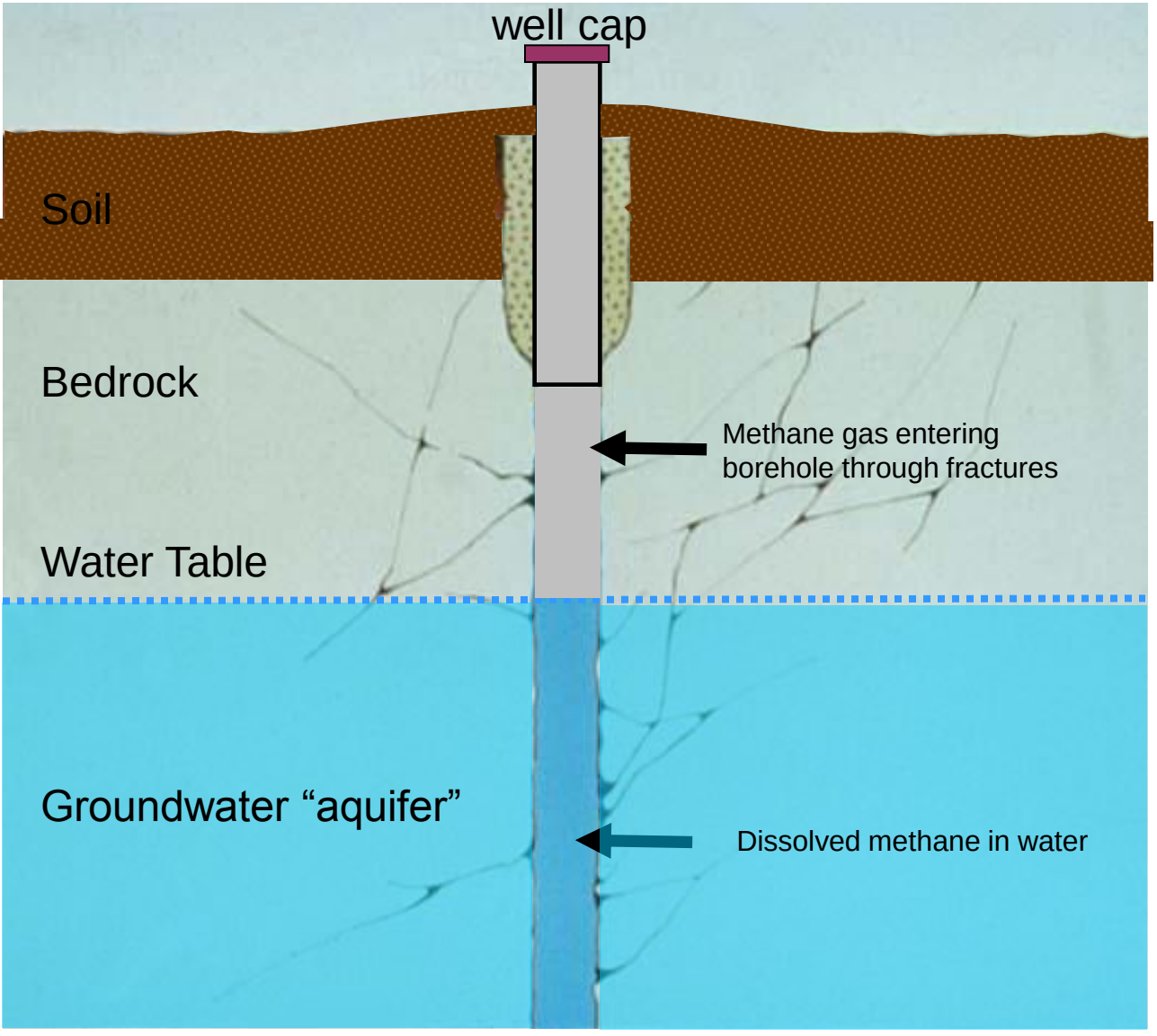
Methane in PA Water Wells



- Can be naturally occurring or from gas drilling
- Pre-existing detectable methane may occur in ~20% of water wells but most are below 1 mg/L.
- Action level when above 28 mg/L.
- New baseline water testing is uncovering pre-existing problems in rural areas

Chapter 78 Well Construction Standards

- Goal – further prevent methane migration and protect water supplies
- Comprehensive update to well construction, casing and cementing standards
- Expanded well completion reporting requirements, including disclosure of hydraulic fracturing chemicals
- Revised well plugging standards
- Evolving technology and regulations greatly mitigating risk
- Transparency

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Increased Groundwater Protection

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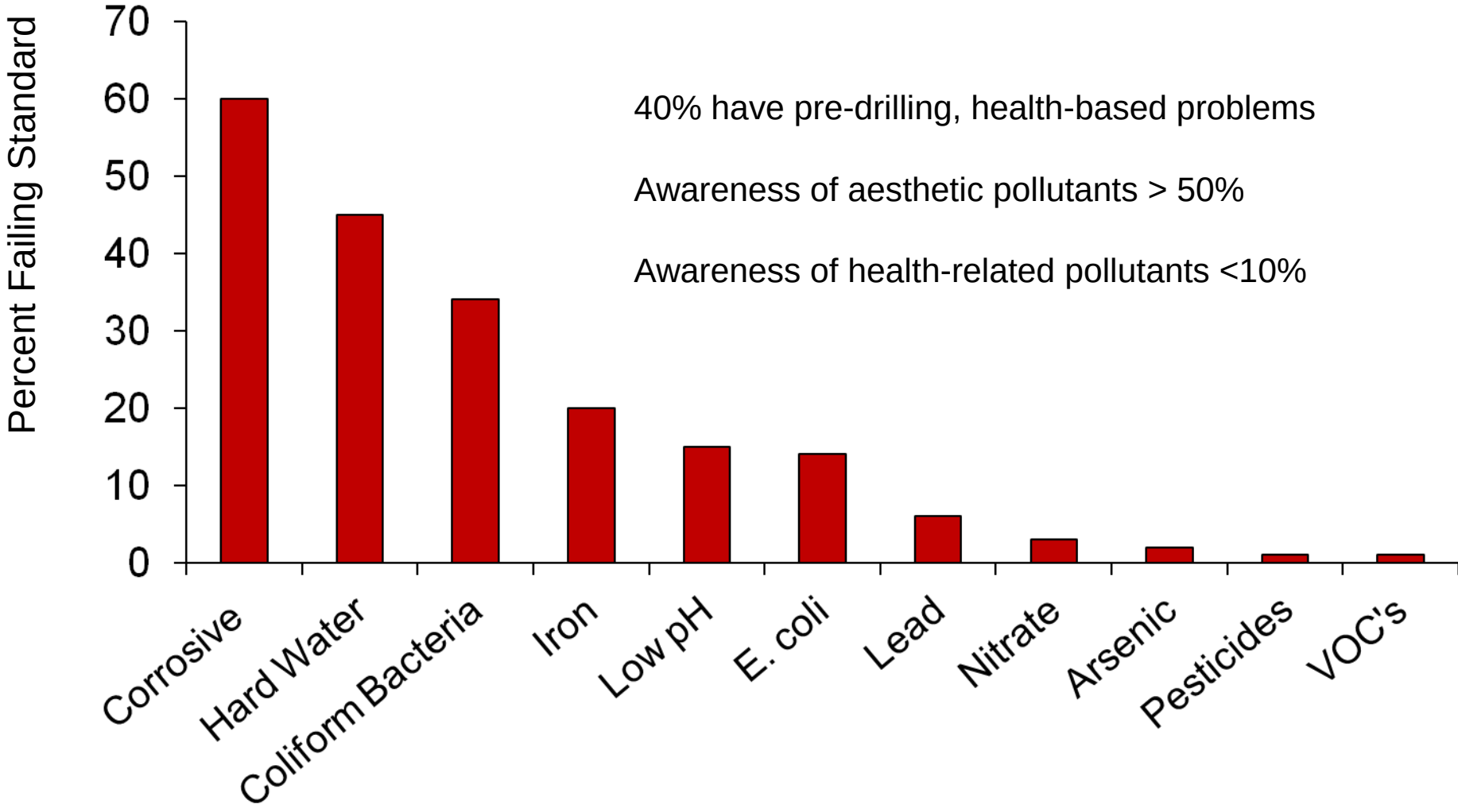
Pre-Drilling Problems are Common

(2006-07 survey of 701 water wells)



Impact of Marcellus Gas Drilling on Rural Drinking Water Supplies

- Five Penn State project coordinators

- Funded by the Center for Rural Pennsylvania (a legislative agency of the Pennsylvania General Assembly) and the Pennsylvania Water Resources Research Center at Penn State University

Objectives:

- Provide an unbiased and large scale study of water quality in private water wells both before and after the drilling of Marcellus gas wells nearby.

- Document both the enforcement of existing regulations and the utilization of voluntary measures by homeowners to protect water supplies.

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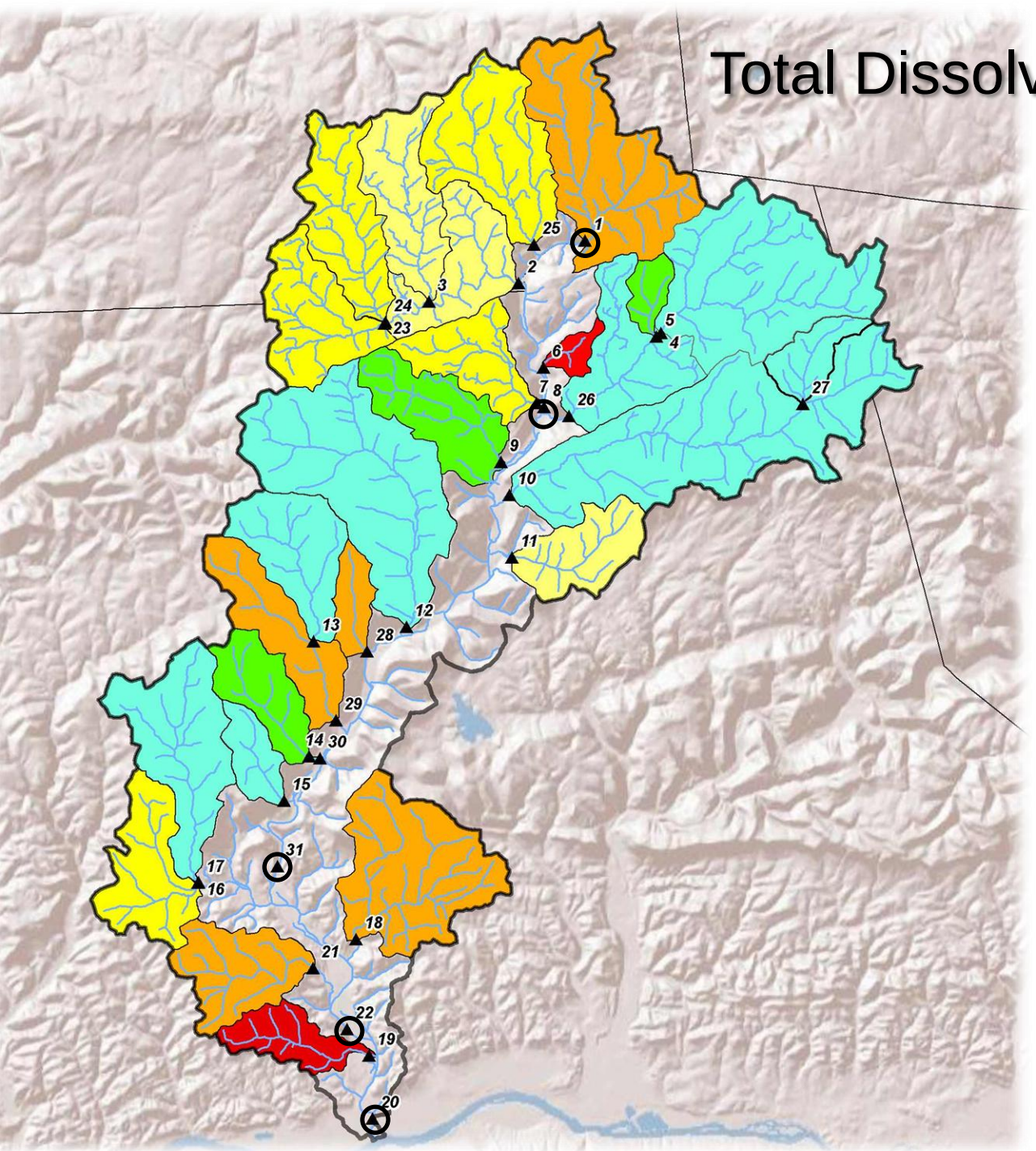
Total Dissolved Solids(TDS)



Site	Trib	ROE
9	Frozen	10
14	Wolf Upper	12
5	Hounds	14
4	Rock Upper	28
15	Daugherty	28
13	Trout Upper	30
12	Grays	32
10	Pleasant	34
16	Hogeland	38
26	Rock Lower	42
27	North Pleasant	44
30	Wolf Lower	44
17	Stoney	59
3	Salt	61
24	Brion	62
11	Slacks	65
23	Roar Head	72
25	Mill (head)	74
7	Red	78
2	Roar Roar	79
28	Hagerman	92
21	Beautys	102
29	Trout Lower	104
18	Mill (mouth)	106
6	Dutchman	191
19	Bottle	202

Chapter 95 Regulation Revisions

- This new rule is the first of its kind in the country
- Limits the discharge of Total Dissolved Solids(TDS) from new or expanded facilities that take oil and gas wastewater – now at drinking water standards.
- Does not allow for new discharges that exceed 250 mg/l for chlorides and also removes radium
- Increases the use of recycled water, promotes the development of alternative forms of disposal
- Promotes the use of alternative sources of water for fracturing fluid

Alternative Water Sourcing

- Acid mine drainage
- Cooling tower water
- Treated waste water

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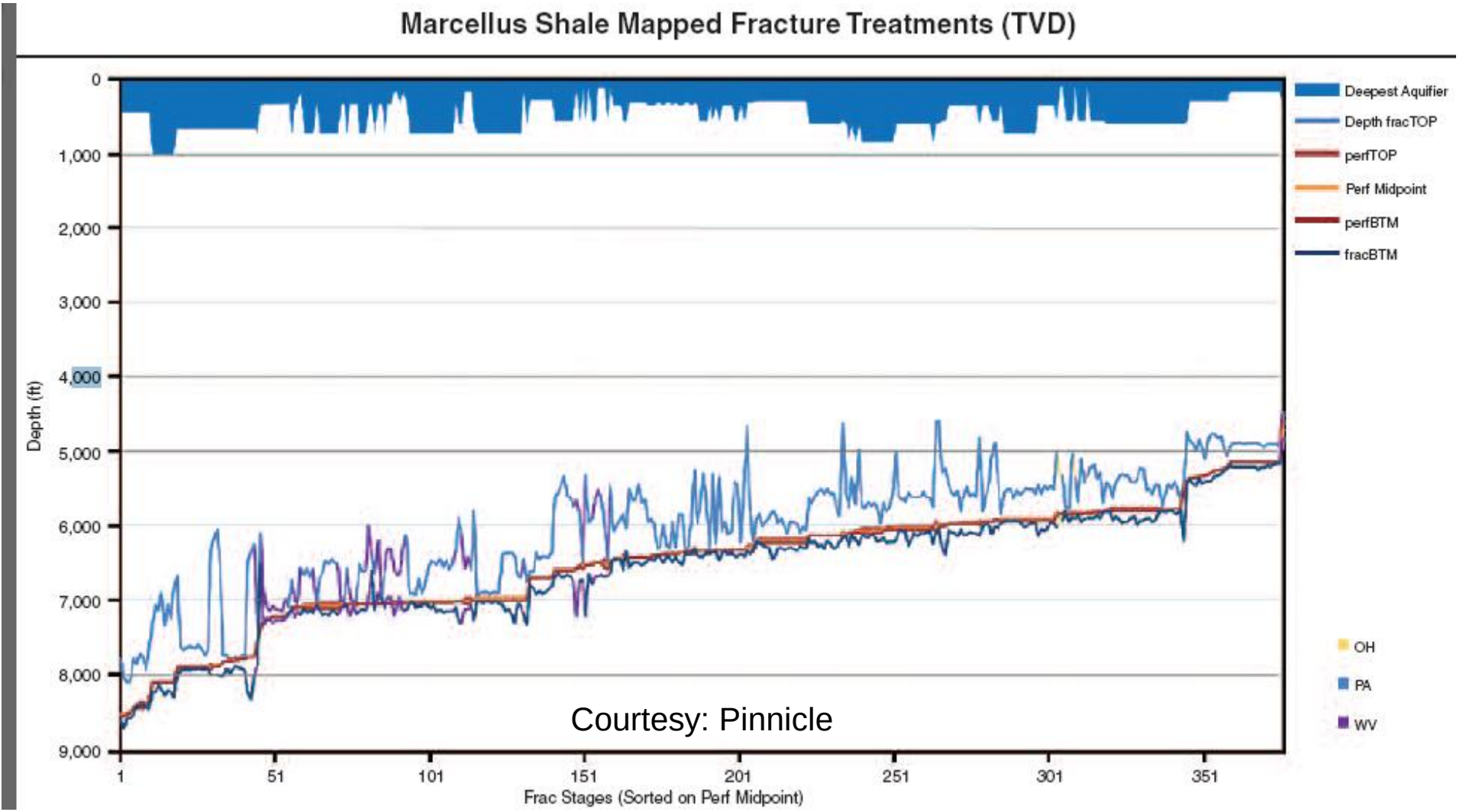
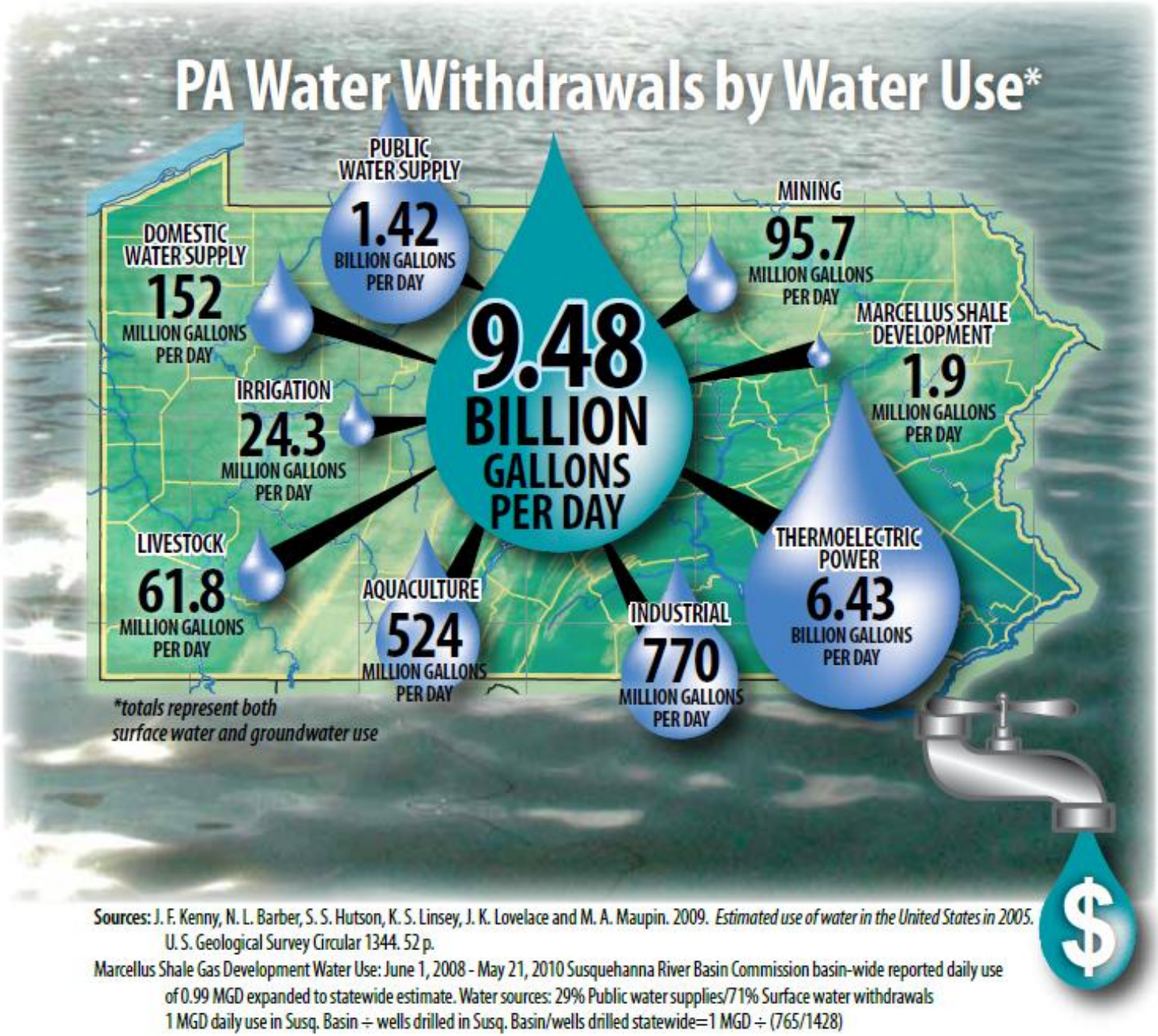
Height-Depth of Fracturing Based on Microseismic Data



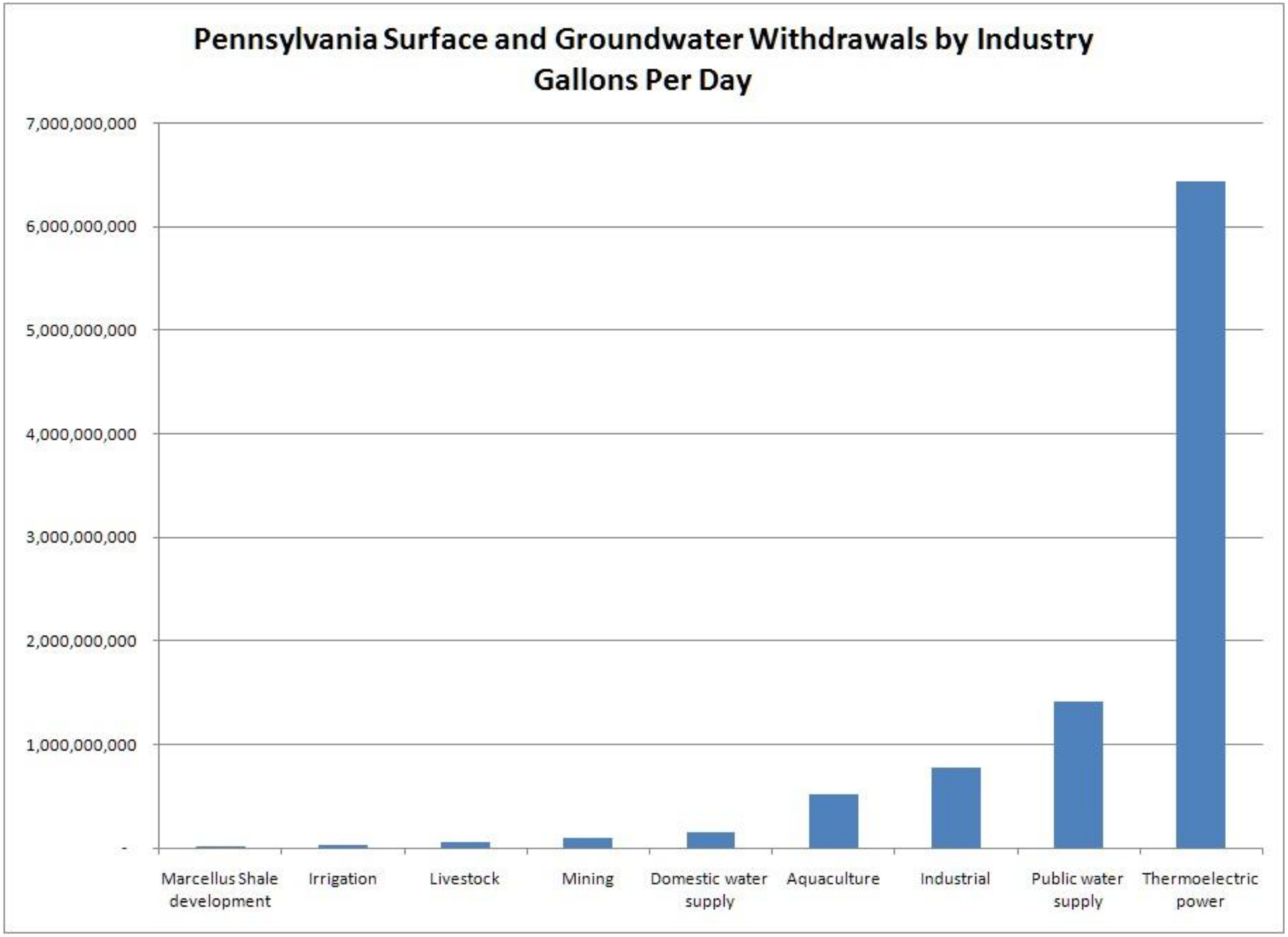
"Frac Barriers" of Onondaga Ls. below & Tully Ls. above. Marcellus Sh. thousands of feet below fresh water aquifers. Induced fractures cannot extend upwards because of overburden stress and horsepower limitations.

Water Usage and Sourcing

- 16.5 million liters per well (ave)
- 40 million liters used in PA per day
  - 0.1% of all water withdrawals in PA daily
    - 40 billion liters/day
- 75% of water used is trucked
  - Trend towards piping water is increasing strongly
- 75% is sourced from surface supply vs. wells
  - Costs from municipal well sources is $5-16/3800L



Source: [PA Fish and Boat Commission]


Pennsylvania Surface and Groundwater Withdrawals by Industry
Gallons Per Day
7,000,000,000
6,000,000,000
5,000,000,000
4,000,000,000
3,000,000,000
2,000,000,000
1,000,000,000
-
Marcellus Shale development
Irrigation
Livestock
Mining
Domestic water supply
Aquaculture
Industrial
Public water supply
Thermoelectric power

Water Storage Trends

- Vertical storage units – more storage, less footprint
- Closed loop systems
- Transportable and can be reused
- Piped to location for hydraulic fracturing
  - Greatly reduces truck traffic
- Redundant systems for spill prevention

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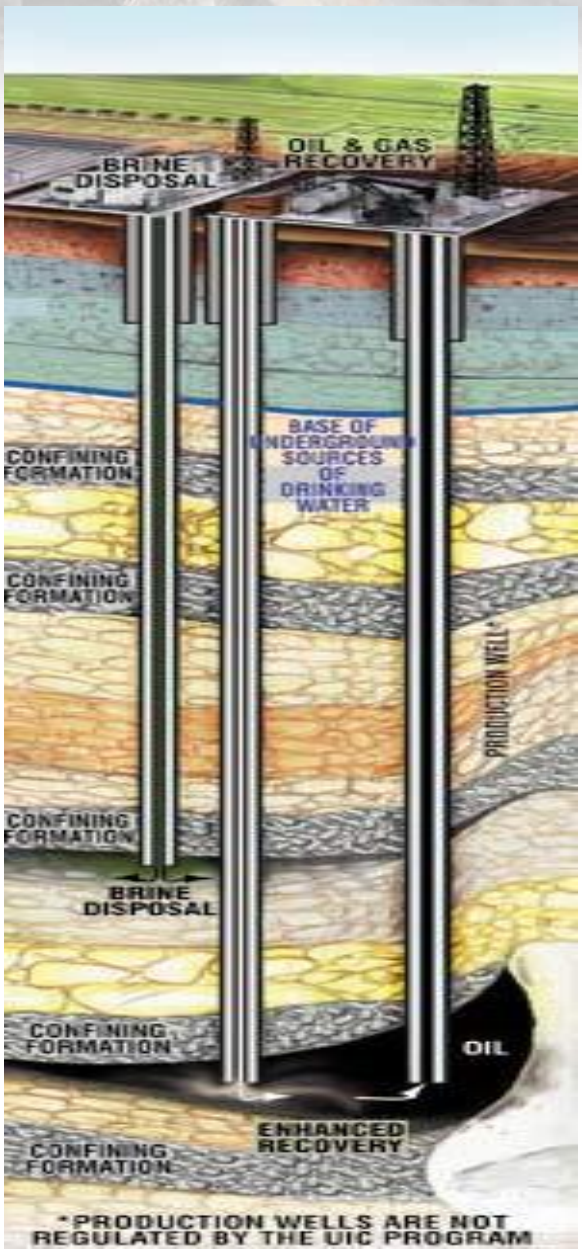
Fluid Remediation/Disposal

- 1.75 billion liters of fluid recovered 1H ’12
- 90% recycling of flowback and produced
- Approx. 10% of fluid returns to surface in Marcellus
- Currently 98% of flowback is recycled
  - 89% infield recycling
  - 9% centralized plant recycling
  - 1.6% stored
  - 0.3% disposal wells

Fluid Management

- Produced fluids – 86% recycled
  - 76% infield recycling
  - 10% centralized plant recycling
  - 14% disposal wells



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Fluid Management

- Total dissolved solids(TDS) of 70K to 100K mg/L in flowback
  - -Surface disposal requirements of 500 mg/L or less
  - -350K+ in produced due to longer contact with shale
- 640 to 800L (4-5 bbls)of produced water/MMCF NG
- 2700 kg (3 tons) of sludge/1.6M liters of fluids (~400gals)

Drill Cuttings Management

- Current common “disposal” is with landfill as cover material
- Looking at beneficial reuse
  - As proppant material
  - Road base
  - Pad stabilization
  - Construction
- Green fields vs. brownfield
- Typically remediated and treated
- Emerging technology

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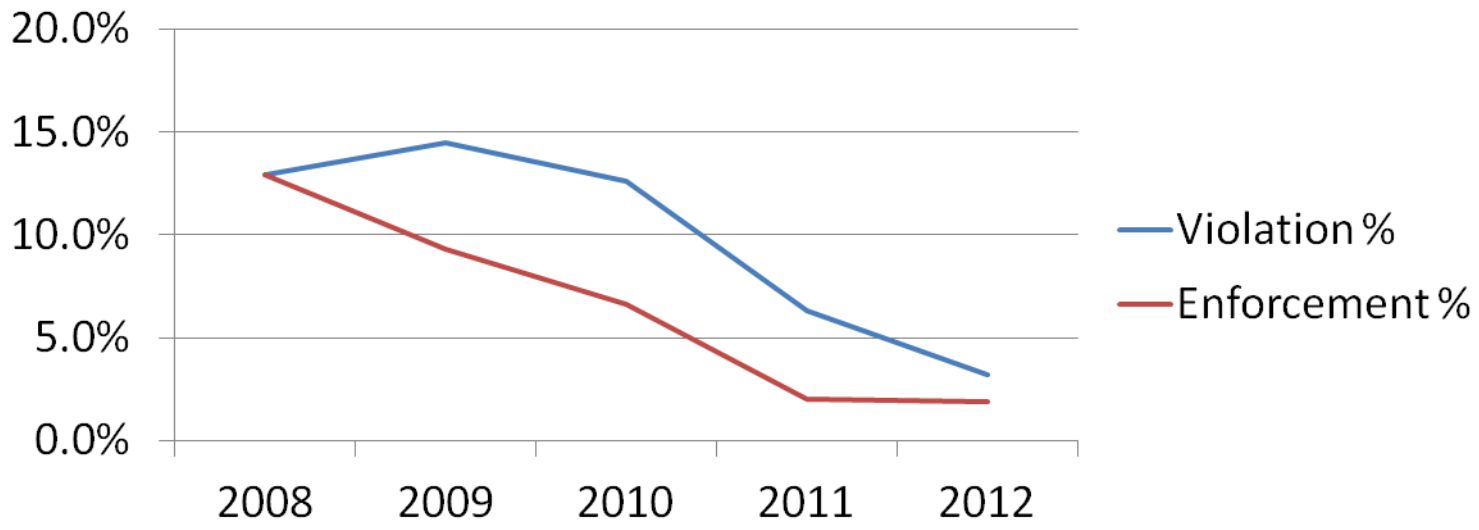
Inspections

Year	Inspections	Inspections with violations	Total Violations	Enforcements	% Inspections with violations	% Inspections with enforcements
2012*	8,467	274	541	162	3.2%	1.9%
2011	10,516	662	1219	235	6.3%	2.2%
2010	5189	655	1273	345	12.6%	6.6%
2009	2308	335	673	214	14.5%	9.3%
2008	1235	159	232	159	12.9%	12.9%



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